Discovery of a new high-ionization planetary nebula in LAMOST

Luis A. Gutiérrez Soto

November 9, 2022

1 Introduction

Planetary nebulae (PNe) represent the last stage of evolution of low- and intermediate-mass stars ($0.8 M_{\odot}$ - $8.0 M_{\odot}$). The PNe phase begin when gas is ejected from the red giant stars late in their lives and subsequently this gas is ionized by the radiation field coming from the remnant star resulted. An emission nebula expands, a glowing shell of ionized gas until lost in the interstellar medium. Then the dying star core becomes a white dwarf.

The number of the PNe discovered in the galaxy is relatively low ($\sim 3,500$). However, 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 (Frew, 2017). If this is true, there will be a much larger number of PNe in the Galaxy than if a special condition is required. The models of Moe De Marco (2006), for example, predict that there are 46 000 $\pm$ 22 000 for the general case, but only 6600 (De Marco Moe 2005) if close binaries (e.g. common-envelope phase) are required. Miszalski et al. (2009) confirm earlier estimates that the binary fraction of PN central stars is only 10–20% of all PNe, and thus, binarity is not likely to be a major factor in the formation process. If true, there should be many PNe waiting to be found in the Galaxy. This mean that the search for planetary nebulae becoming a important task, that eavery time is more dificult, due to many of the undiscovered PNe are probably the more distant and then the more the weak. And because many of them, probably, are located in nuvens of dust. And note that planetary nebulae only last for about 5,000- 25,000 yr (**?**), making them a very short-lived part of the stellar life cycle. But is import to discovery new planetary nebula? the answer could be very obvious and is related with the idea that PNe provide vital clues for the understanding late-stage stellar evolution and Galactic chemical enrichment. Their strong emission lines allow the determination of abundances, expansion and radial velocities, and CSPN temperatures. The PN phase enriches the ISM with nitrogen, carbon, helium, and dust, important components in the formation of future generations of stars. PNe yield information on the nuclear burning, dredge up, and mass loss in the stellar progenitor (see Kwitter & Henry, 2022 for an excellent recent PN review). Thus, we need to know the number of PNe in the Galaxy in order to develop accurate models of the chemical enrichment rates since the initial burst of Type II supernovae when the Galaxy was young.

PN studies have been hampered by three problems: (i) the previous lack of accurate distances to most Galactic PNe; (ii) obtaining representative PNe samples of the true population diversity (Parker 2022), and (iii) their unknown progenitor masses. The first problem has prospects of resolution via accurate Gaia CSPN distances, though many CSPNe remain too distant and faint for Gaia DR3 and correct CSPN identification remains an issue for some (Parker et al. 2022). The second problem is being addressed by deep, narrow-band, wide-field surveys, e.g., Parker et al. (2005), Drew et al. (2005), and Drew et al. (2014). For the third problem of progenitor masses, these can only be accurately determined for PNe in Galactic globular and open clusters (OCs). These allow precise distance determinations from color–magnitude diagrams (CMD) and Gaia (Fragkou et al., 2022).

2 Surveys

2.1 GAIA EDR3

2.2 Pan-STARRS DR1

2.3 LAMOST DR7

3 Methodology

At the beginning the idea was to identify for new planetary nebula in GAIA. I started to constructed possibles color-color diagrams to separate PNe from other emission lines objects and stars using GAIA only. The separation was not good because PNe and other emission line stars like CVs occupy the same region in the diagram. Then, I decided to move to Pan-STARRS and combining the two surveys Pan-STARRS and GAIA. I found one color diagram that isolate the PNe with, I suppose, strong Hα emission

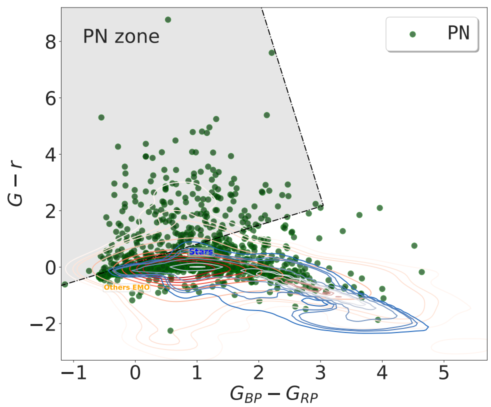

Figure 1:

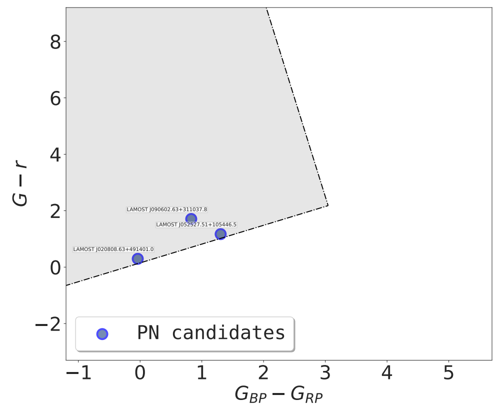

Figure 2:

line. By using the $(G-r)$ versus $(G_{BP}-G_{RP})$ color-color is possible to separate those PNe excess in the in the r-broad-band filter as is possible to see in the Fig 1. Fig 1 shows that the many of the PNe have value in the color $G-r=0$, however several PNe cover the interval in this same color between 0 and 8, and span between -1 and 5. The orange contours represent other emission line objects that includes CV, SySt, YSOs, AeBe stars and SNRs. The contours becoming white at the outside indicating that the number of objects decrease significantly. And the blue contours signify stars from Gaia Collaboration et al. (2021). Where they occupy the region with $(G-r) = 0$.

All indicate that the PNe with strong Hα can be selected with this color criteria. Then, to see the possibility of using this color criterion to select these PNe, by testing and using the emission line catalog from Škoda et al. (2020). First, they identify emission line objects from LAMOST DR? implementing a machine learning approach. They divided their final sample of emission line objects in tree subgroups. The `SIMBAD`, Hue and new list. To texting the possibility to find for new PNe with the color criteria explained above, we applied it directly in the new list, which present objects not reported previously in the literature, which is a list with 1000 objects.

Four objects met this condition as is possible to see in the Fig 2. Tree objects of them display strong Hα, but are not display the other emission lines topically of PNe like [O III], He II, [S II], among other. But the three look likes as PNe. Because, it displays He II emission lines, the Balmer ones, [O III], among other. Fig 3 the spectra of the new PNe finding in the list of emission line of Škoda et al. (2020). This PNe seen a very high ionization object, by eye is possible to see that the He II emission line is more strong than the the Hβ line. Given the LAMOST spectra are not calibrated in flux but they are flux relative, then I think that some ratio line can be calculated. Could be?

The images of the PN called LAMOST J020808.63+491401.0 are shows in Fig 4. *Left panel* exhibits the PanSTARRS coloured images [1], which was performed by combining the g, r and i filters in the blue, green and red colour channels, respectively. The image shows clearly a central star surrounding for a nebulae component. *Right panel* shows the WISE RGB image, with the filter W1, W2, and W4 in the blue, green and red channels, respectively.

4 Model

Despite the LAMOST spectra are not in physical flux unity, they have flux relative. This means it is possible compare it with other spectra in physical units. For that, I think, it is pertinent to compare the LAMOST spectra of our PN with models. Fig 5 shows a comparison between LAMOST spectra and a CLOUDY modelled spectra from Gutiérrez-Soto et al. (2020). Note that only is an example for illustrative intentions. This model was taken from a grid o models that reproduce spectra form the Galactic halo. For this, it don't exist a real matches between the two spectra. I will a performed a grid of PN models that better reproduce the LAMOST spectra of our candidate. However, almost all the line are reproduce with this model, that could be interesting, because the temperature effective of this model is 130×10^3K, indicating a very high excitation object. Maybe, it will be good idea estimate ratio lines to confirm that.

[1] This RGB images were made by implementing the python package `aplpy` (Robitaille, 2019)

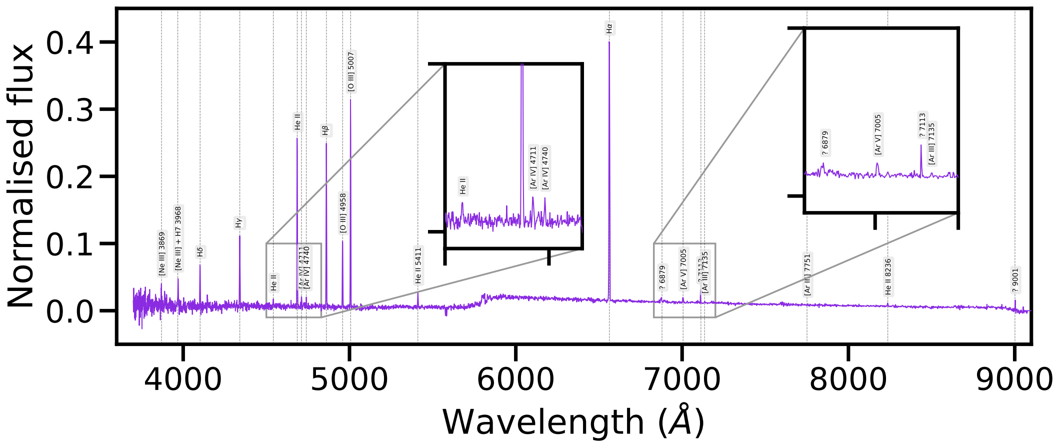

Figure 3:

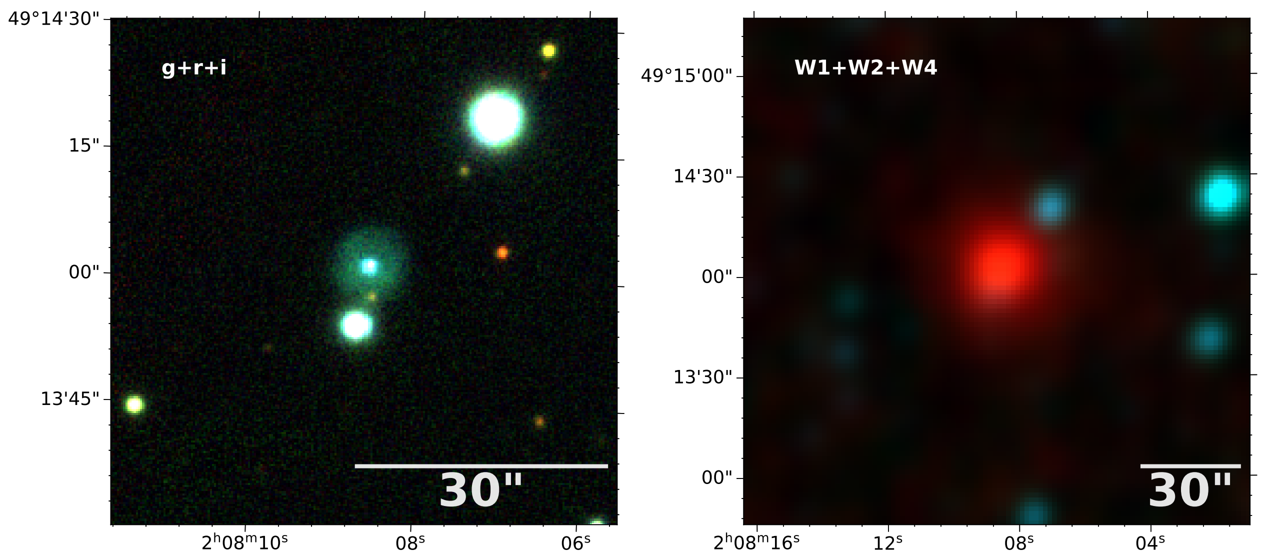

Figure 4:

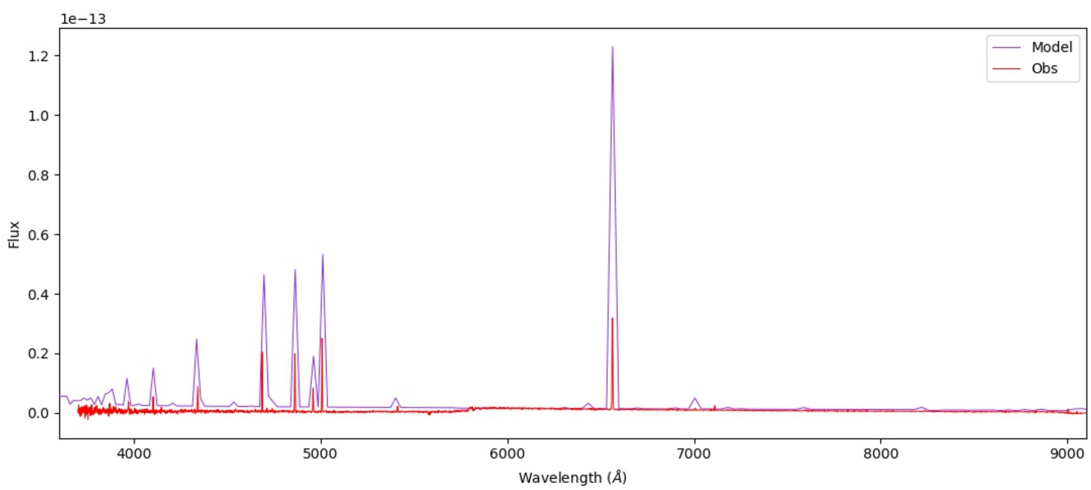

Figure 5:

5 Abundances?

,,

6 Comparing with another PNe

References

Fragkou, V., Parker, Q. A., Zijlstra, A. A., Vázquez, R., Sabin, L., & Rechy-Garcia, J. S. 2022, ApJ, 935, L35

Frew, D. J. 2008, PhD thesis, Department of Physics, Macquarie University, NSW 2109, Australia

Frew, D. J. 2017, in IAU Symposium, Vol. 323, Planetary Nebulae: Multi-Wavelength Probes of Stellar and Galactic Evolution, ed. X. Liu, L. Stanghellini, & A. Karakas, 11–19

Gaia Collaboration et al. 2021, A&A, 649, A6

Gutiérrez-Soto, L. A., et al. 2020, A&A, 633, A123

Jacoby, G. H., et al. 2010, PASA, 27, 156

Kwitter, K. B., & Henry, R. B. C. 2022, PASP, 134, 022001

Robitaille, T. 2019, APLpy v2.0: The Astronomical Plotting Library in Python

Škoda, P., Podsztavek, O., & Tvrdík, P. 2020, A&A, 643, A122

''''