Use of Infrarred Neon lines in the study of the components present in SEDs of Radio Quiet AGNs

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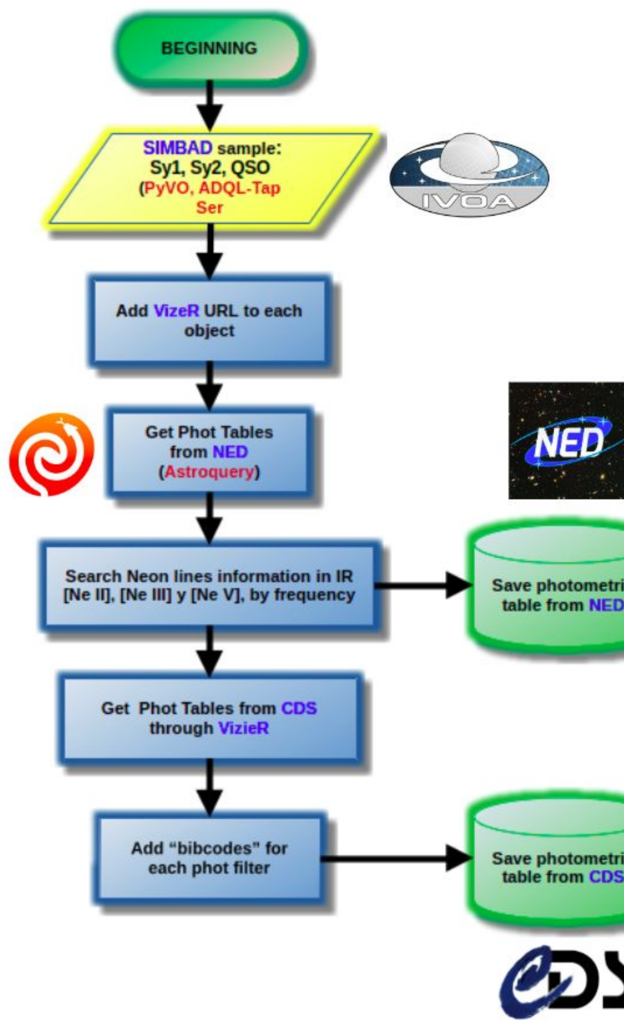
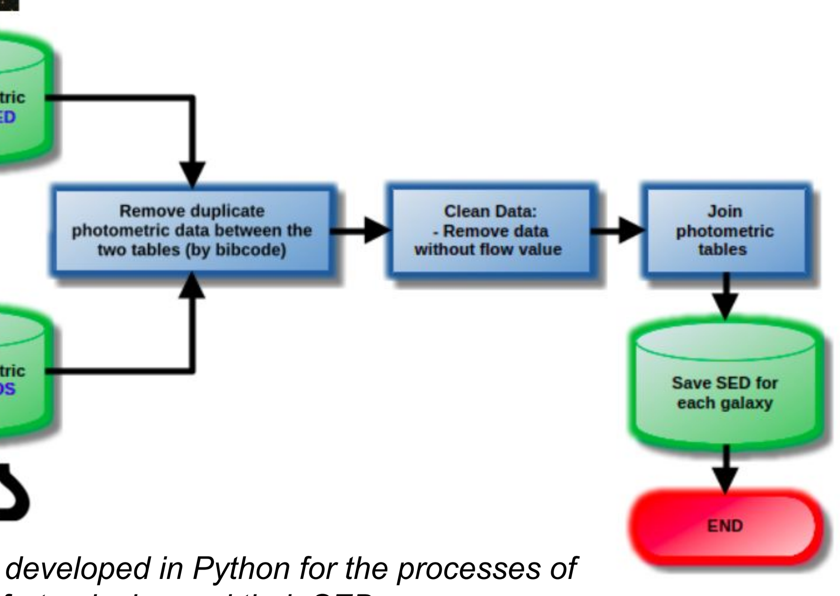
Abstract:

The emission line of [Ne V], in infrared, has proven to be a relevant indicator of the activity of an AGN due to its high ionization potential. Likewise, the analysis of the ratio [Ne V]/[Ne II], has allowed to distinguish between stellar environments and AGNs. Based on the above, this work sought to verify from a sample of Seyfert galaxies taken from the CDS-SIMBAD database, that the estimates of the AGN fraction (f_{AGN}) coming from a spectral energy distribution (SED) modeling tool (CIGALE), coincide with the Neon line tracers in the infrared. From NED tables, galaxies containing data on the lines [Ne II]12.8µm, [Ne V]14.3µm, and [Ne III]15.5µm were filtered from the initial sample. [Ne V]/[Ne II], [Ne V]/[Ne III], and [Ne III]/[Ne II] ratios were compared with the different physical properties estimated from the best SED model of each galaxy.

I. Sample selection and obtaining the SED:

One of the main objectives in the task of obtaining and filtering the sample of galaxies is to allow access and manipulation of data efficiently and automatically. For this purpose, a set of algorithms or codes written in Python were developed, integrating the use of different computational tools. On the one hand, *VO tools* are used to obtain the main sample of galaxies from the **SIMBAD database**. On the other hand, *Astroquery* is used to obtain the photometric tables from the **NED database** (Fig. 1).

In addition, the code automates the tasks of selecting galaxies with information on Neon lines in the IR, obtaining photometric tables from the **CDS database**, cleaning and unifying photometric data from both databases to finally obtain a more complete SED for each galaxy (Fig. 2).

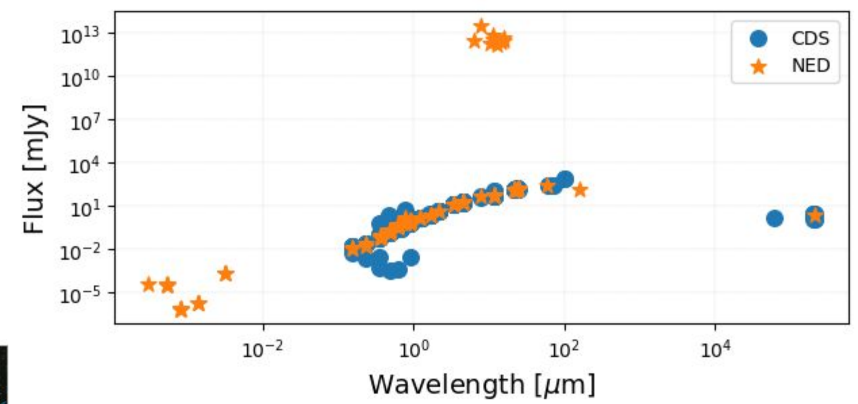


Fig 2. Photometric data for LEDA 3096524

Fig 1. General Flowchart of the algorithms developed in Python for the processes of obtaining the sample of Seyfert galaxies and their SED

The SEDs obtained were constructed from photometric data of 31 bands selected from the GALEX, SDSS, 2MASS, Spitzer, WISE, IRAS and Herschel missions, where it was available, covering wavelengths from UV to FIR.

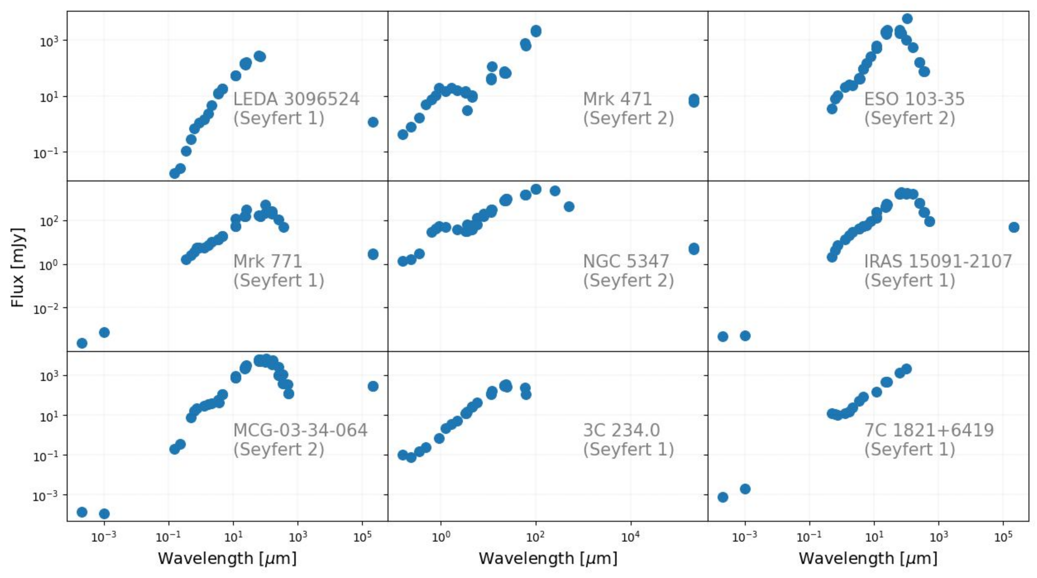


Fig 3. SED of 9 galaxies from the final sample, obtained from photometric data from the NED and CDS databases

II. Modeling and adjustment of SED with CIGALE:

The main tool used in this work is CIGALE (Boquien et al. 2019, Yang et al. 2020 and Yang et al. 2022), a code developed in Python to model the SEDs of galaxies and estimate their physical properties, with the aim of studying the evolution of galaxies.

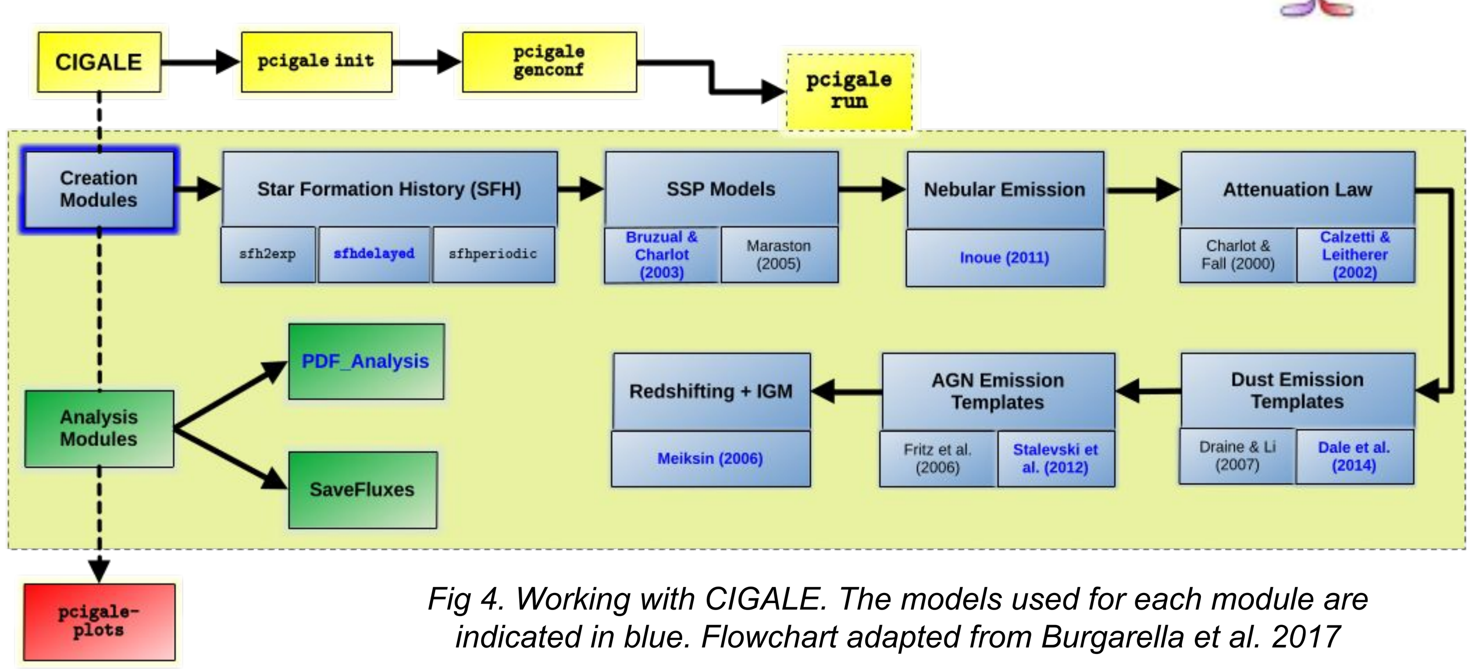


Fig 4. Working with CIGALE. The models used for each module are indicated in blue. Flowchart adapted from Burgarella et al. 2017

We selected 6 models, one for each CIGALE's modules for calculating the different components emissions, that contribute to the SED (Fig. 4). From the modeling and adjustment, physical properties, such as Star Formation Rate, Stellar Mass, AGN Disc Luminosity, AGN Viewing Angle and the AGN Fraction, were estimated, to use in our analysis.

III. CIGALE Results:

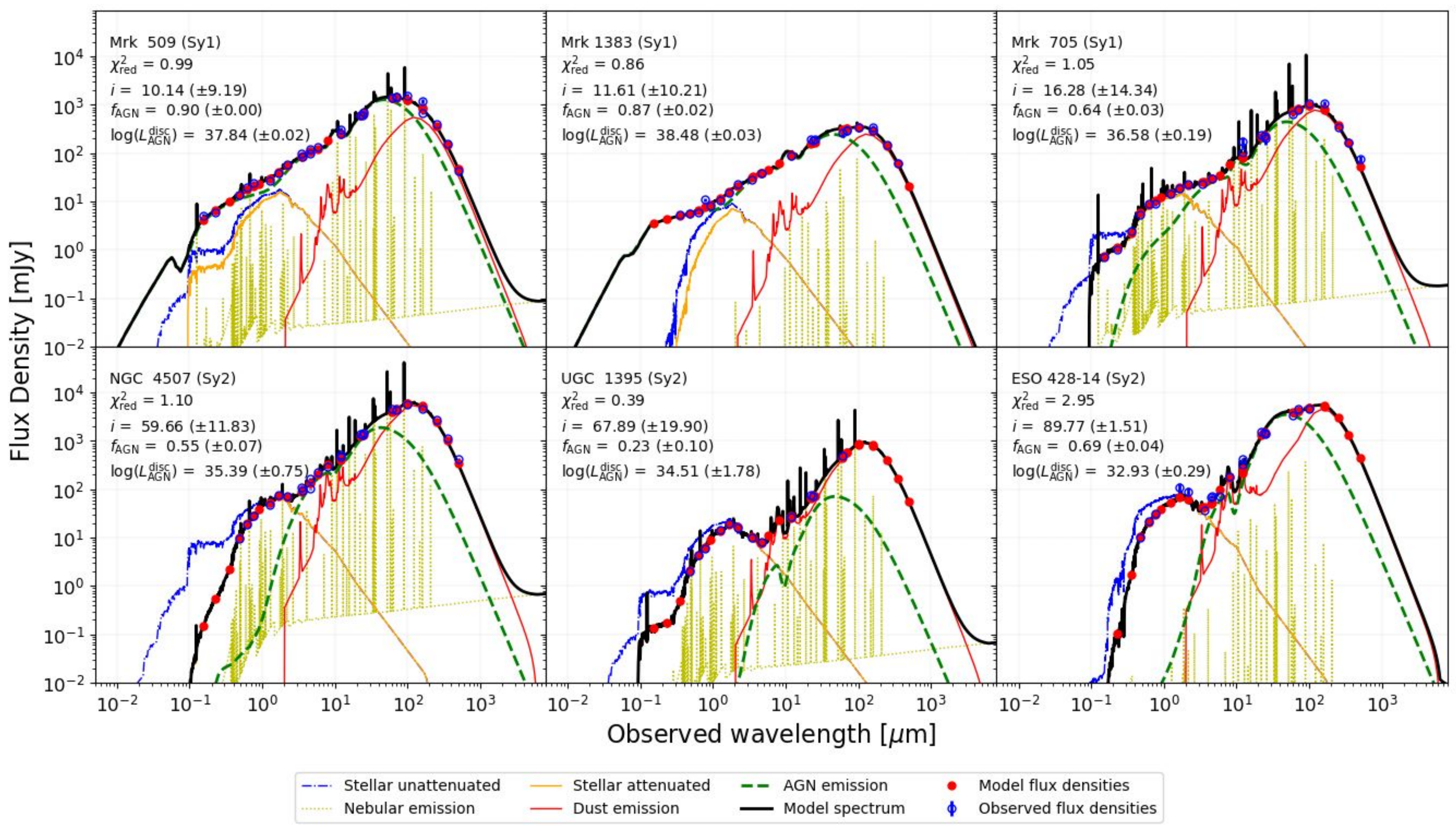


Fig 5. Results of the best modeled spectral energy distribution (SED) for 6 galaxies in our final sample, with the view angle set from 0 to 90 degrees. For each galaxy, the estimated physical properties include the AGN fraction, the viewing angle (i) of the instrument with respect to the AGN axis, and the luminosity of the AGN disk

IV. AGN Fraction vs [Ne V] / [Ne II] ratio:

If we take the entire sample of Seyfert galaxies as a single data set, it shows a moderate positive correlation between the estimated AGN Fraction, and [Ne V]14.3µm/[Ne II]12.8µm line ratio with a Pearson Correlation Coefficient (PCC) of 0.54, statistically significant (p-value = 9.74e-8). Performing a linear regression fit, we obtained the relation:

$$\log_{10}([\text{Ne V}]/[\text{Ne II}]) = (0.96 \pm 0.16) \times f_{AGN} + (-0.76 \pm 0.16), \qquad (1)$$

In the upper-left corner of Fig. 6, we compare our results with those obtained by Feltre et al. 2023 Eq. 4. Their result falls within the 95% confidence interval of ours. Now, if we separate the sample of galaxies, according to their classification, obtained from SIMBAD, between Seyfert 1 (Sy1) and Seyfert 2 (Sy2), we find that the positive correlation between the fraction of the AGN and the Ne line ratio increases for the Seyfert 1 (PCC = 0.66 , p-value = 1.66e-6), but is low for the Seyfert 2 (PCC = 0.28) and is not statistically significant (p-value = 0.083) (upper-center and upper-right of Fig. 6).

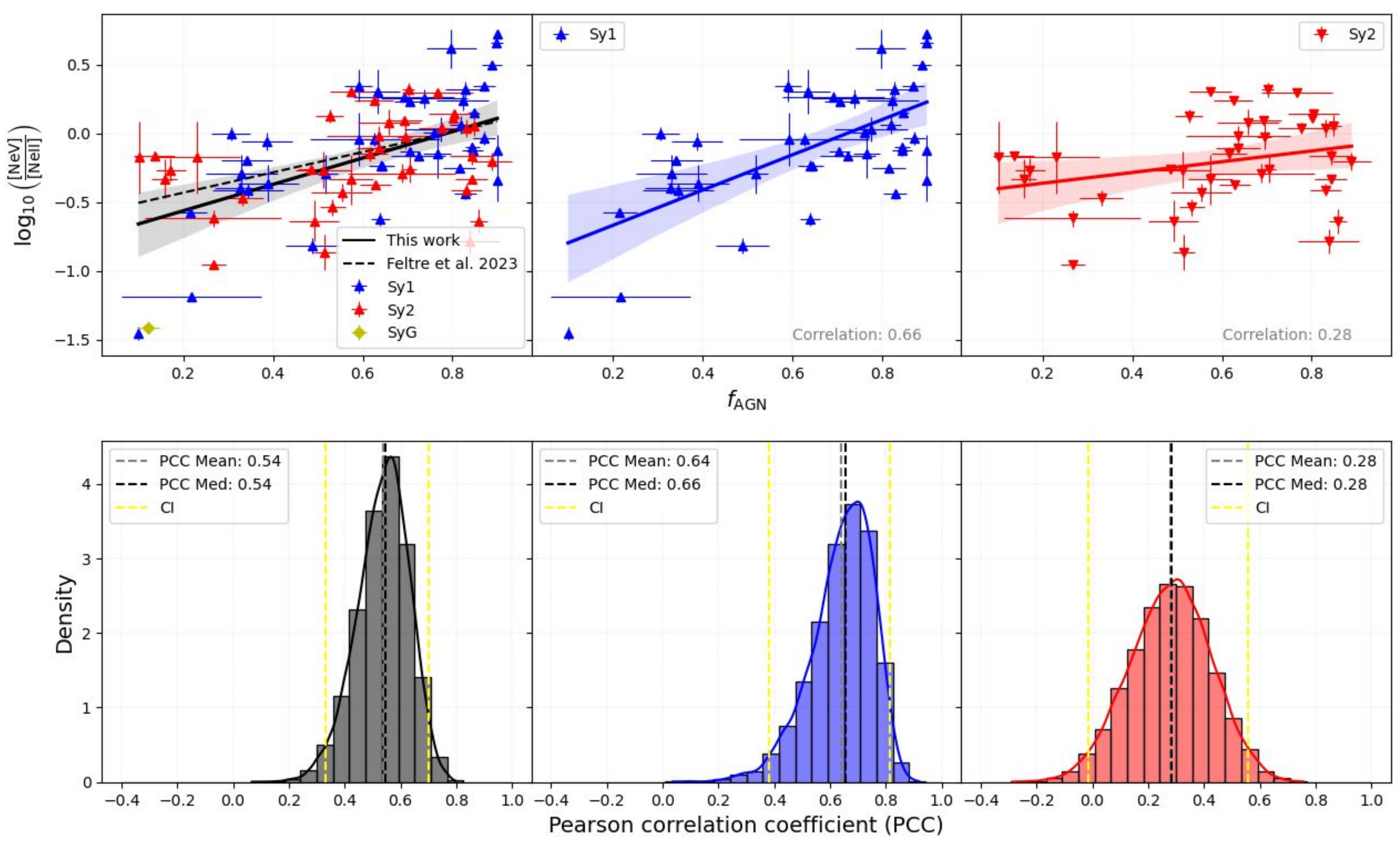


Fig 6. AGN Fraction vs [Ne V]/[Ne II] line ration. Upper-left corner: entire sample of Seyfert galaxies as a single data set. Upper-center: only galaxies from the final sample, classified as Seyfert 1 in SIMBAD. Upper-right corner: only galaxies from the final sample, classified as Seyfert 2 in SIMBAD.
For all the PCC values we performance a bootstrap method with n = 10000. The lower graphics shows it results and the confidence intervals of 95%.

According to the unified AGN model (e.g. Urry & Padovani 1995), the classification of Seyfert galaxies, is due to the orientation with respect to the line of sight, in others words, due the physical parameter of viewing angle. However, Ramos Padilla et al. 2021, found that AGN Disc Luminosity is a better parameter for this classification, confirmed with our sample. (Fig. 7)

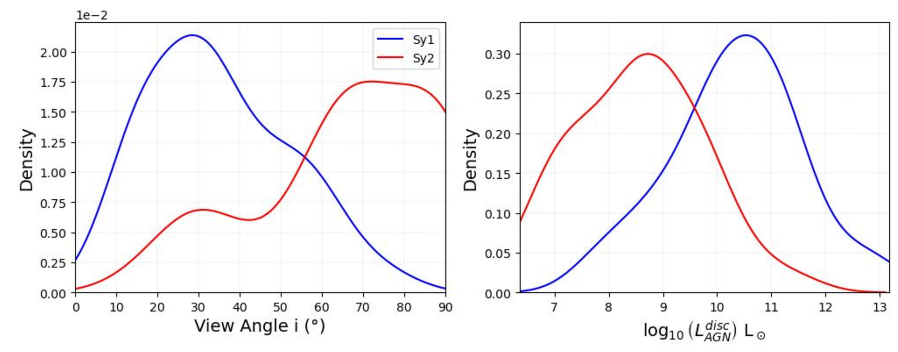


Fig 7. Comparison of the PDF for the estimated parameters view angle and AGN disc luminosity between our Sy1 and Sy2 samples

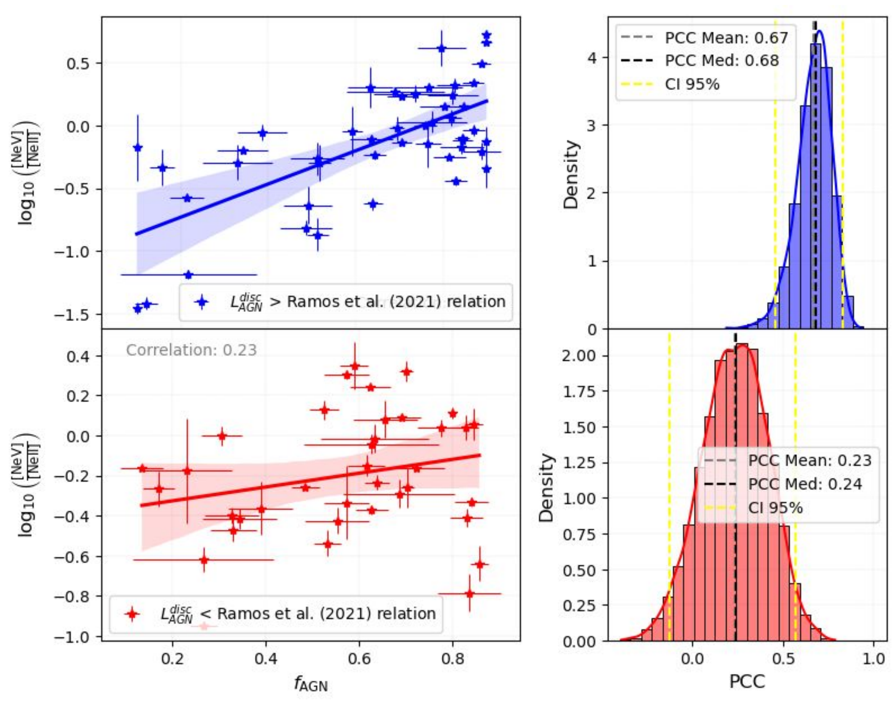


Fig 8. f_{AGN} vs [Ne V]/[Ne II] line ration. Galaxies classified according the estimated AGN disk luminosity

Then, we reclassify our sample, according to the estimated AGN disk luminosity with the criterion of greater (Type 1) and less (Type 2) than the relation of the Eq. 3 of Ramos Padilla et al. 2021 work (Fig. 8). We also made another dataset, but classifying according the estimated view angle "*i*": Greater (Type 1) or less (Type 2) than 45º. In both cases we found that the correlation between the estimated AGN Fraction, and [Ne V]/[Ne II] line ratio has the same pattern of the Sy1-Sy2 classification:

- For Type 1: PCC = 0.68, p-value < 0.05
- For Type 2: PCC = 0.23, p-value > 0.5

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