Variability Selected Low Luminosity Active Galactic Nuclei from ASAS-SN Survey

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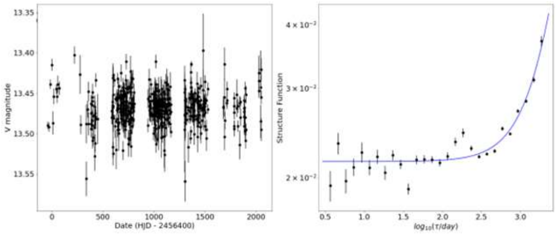
Introduction

- Active galactic nuclei (AGN) have variable nature.
- Structure function, the magnitude difference as a function of time lag, can be used to characterize the AGN variability.
- Simulations and observations show that the structure function of AGN follows a power law.
- We searched for AGN candidates by examining the structure function of galaxies that show variability.
- Photometric data of All-Sky Automated Survey for SuperNovae (ASAS-SN) database is used for this study.

Data & Method

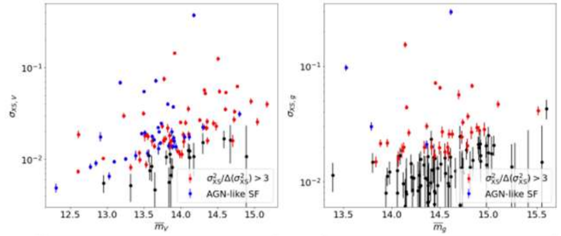
- ASAS-SN light curves of 1218 nearby galaxies with SDSS spectra and magnitude g<14 are analyzed. ASAS-SN surveyed the sky using the V-band filter from 2012 to 2018, and then switched to g-band.
- Excess variance, σ_{XS}^2, is calculated to determine if the target is variable; this is the measurement of the object's intrinsic variability.
- Structure function is calculated to check if the variability is AGN-like, by fitting a power law + constant model.
- SDSS spectra are examined for further



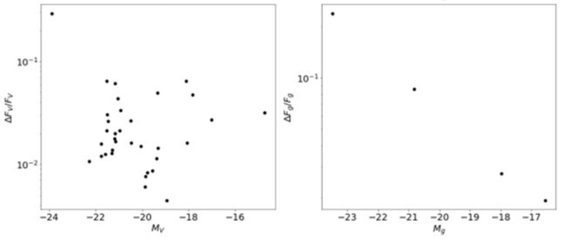
ASAS-SN light curve and structure function of a known AGN, NGC 4158 .

Results

We found that approximately 3% of the sample of galaxies are both variable and have AGN-like structure function.



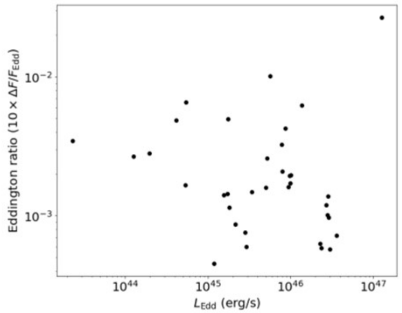
Magnitude variability distribution of the sample. Red data points are the galaxies with significant variability, and the blue data points also have AGN-like structure function.



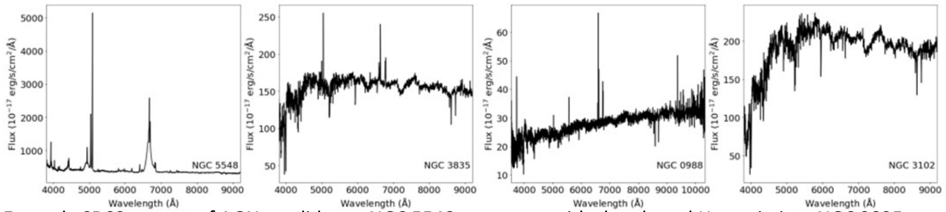
Fractional flux variability distribution of the AGN candidates versus absolute magnitude. There seems to be a trend where brighter objects have greater variability.

- Of the 1218 galaxies, 117 show significant variability (88 in V-band, 39 in g-band, 10 in both). The fractional flux variability is in order of $\sim 10^{-2}$.
- Of the 117 variable targets, 35 have AGN-like structure function (34 in V-band, 4 in g-band, 3 in both).
- The Eddington ratios of the AGN candidates are in order $10^{-4}\sim 10^{-2}$, suggesting that they are mostly low luminosity AGN (LLAGN).
- We estimate the mass of the central supermassive black hole using the spheroid luminosity; they follow a power law relationship.
- Eddington ratio is estimated by scaling the fractional variability:

$$\text{Eddington ratio} = 10 \times \frac{\Delta F}{F_{Edd}}$$

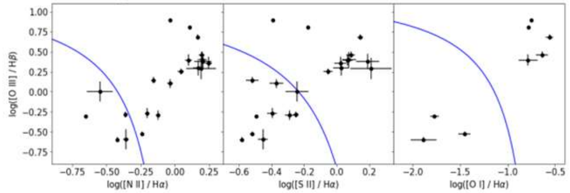


Eddington ratio distribution of the candidates versus Eddington luminosity.



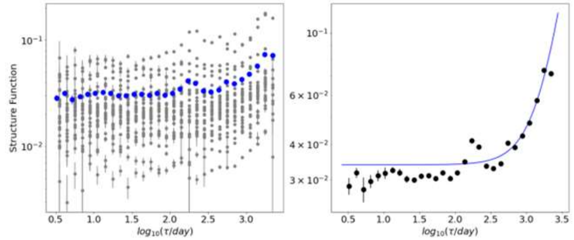
Example SDSS spectra of AGN candidates. NGC 5548: spectrum with clear broad Hα emission. NGC 3835: spectrum with narrow a Hα emission line, classified as AGN by emission line ratios. NGC 0988: spectrum with a narrow Hα emission line, not classified as an AGN given its line ratios. NGC 3102: spectrum with weak or absent Hα emission.

Analysis



BPT diagrams of the AGN candidates. The blue curve represents the classification line dividing star forming (lower right) from AGN (upper right).

BPT diagrams show that $30\%\sim 50\%$ of our AGN candidates are classified as star forming galaxies instead of AGN, by emission line flux ratio method.



Left: Overlapped LLAGN structure functions (grey) and the combined structure function (blue). Right: The combined structure function with the power law + constant model fit.

To examine the general properties of LLAGN as a whole, we combined the structure function of all LLAGN. The combined structure function has the power law index of 1.88 ± 0.05, which is steeper than the expected value from the damped random walk model (~ 0.50).

Conclusion

Using the variability selection method, we found that $\sim 3\%$ of the sample are AGN, where majority of them are LLAGN, with Eddington ratio ranging from 10^{-4} to 10^{-2}. This method is a very useful tool to find AGN that other methods may classify otherwise; for example, BPT diagrams classify $30\%\sim 50\%$ of the AGN candidates as star forming galaxies. With more LLAGN identified, we may be able to understand them better.