Identification of Active Galactic Nuclei through optical variability selection in the GOODS South field

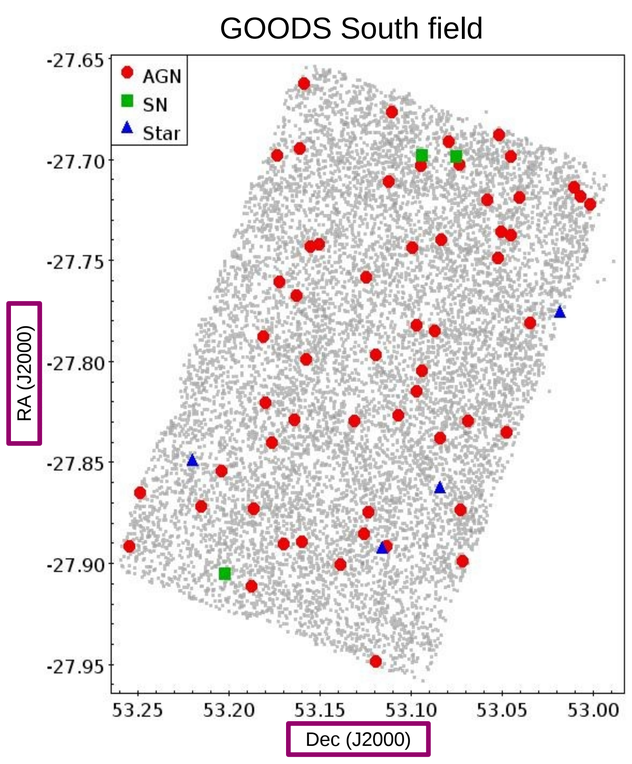
Ektoras Pouliasis[1,2], I. Georgantopoulos[1], A. Bonanos[1], D. Hatzidimitriou[1,2], K. Sokolovsky[1,3,4], M. Yang[1], I. Bellas-Vellidis[1], P. Gavras[1], Z. T. Spetsieri[1,2], G. Mountrichas[1], A. Akylas[1], M. I. Moretti[1,5]

[1] IAASARS, National Observatory of Athens, 15236 Penteli, Greece; [2] Section of Astrophysics, Astronomy and Mechanics, Faculty of Physics, University of Athens, Panepistimiopolis, 15784 Zografos, Athens, Greece; [3]Sternberg Astronomical Institute, Moscow State University, Universitetskii pr. 13, 119992 Moscow, Russia; [4]Astro Space Center of Lebedev Physical Institute, Profsoyuznaya Str. 84/32, 117997 Moscow, Russia; [5]INAF, Osservatorio Astronomico di Capodimonte, via Moiariello 16, Naples, 80131, Italy

Summary

We used z-band (F850LP filter) images taken over 5 epochs spanning 6 months and performed aperture photometry using SExtractor to derive the light curves of the sources. The standard deviation was employed for variability search, resulting in a sample of 63 variable sources. After removing variable stars and known supernovae, the final sample of AGN candidates consisted of 49 extended and 7 point-like sources. The most reliable method to validate the AGN candidates is the presence of X-ray emission, hence we cross-matched our sources with the published Chandra X-ray catalogue in the CDF-S (7 Ms). All the point-like sources emit in X-rays and have been reported as Quasars in the literature. The extension of the remaining sources in addition to the variability indicates that our sources are galaxies hosting an AGN. Out of those, 17 sources have an X-ray counterpart (30%) , while we derived X-ray flux upper limits for 39 sources. The AGN without X-ray counterparts are optically fainter than the detected X-ray AGN and they have higher redshifts. The average of the X-ray luminosity 3–σ upper limits in the [2-10 keV] band for the sources not detected in X-rays is 10^{41} $ergs^{-1}$, suggesting that these are associated with low-luminosity AGN. The 39 AGN candidates of our catalogue not recovered in X-rays represent ~10% of the AGN population classified through the X-ray selection. Our work emphasises the importance of optical variability surveys for finding AGN, which remain undetected even by the deepest X-ray surveys.

Introduction



This work is part of the validation of the "Hubble Catalogue of Variables" (HCV), a project of the European Space Agency that has been launched at the National Observatory of Athens and aims to identify variable sources (extended and point-like) in the Hubble Source Catalogue (Whitmore et al. 2016) through different variability indices.

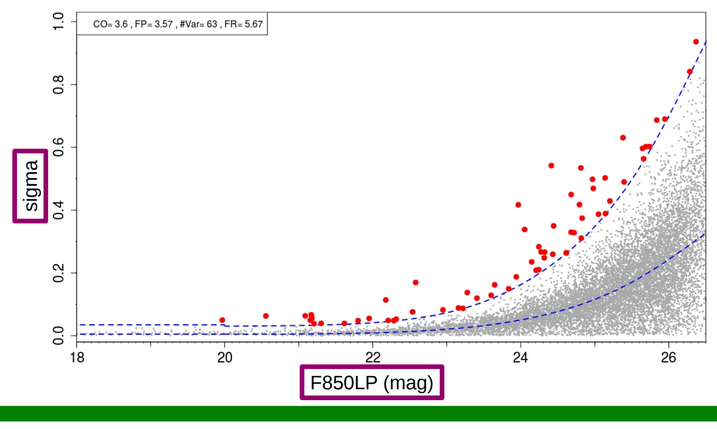
Over the last years, evidence is accumulating, suggesting that there is a strong correlation between the supermassive black holes of the galaxies and the properties of their hosts. Furthermore, the AGN activity seems to play an important role in the star formation and, in general, the galaxy evolution. To better understand this mechanism, it is necessary to study the full range of the different types of AGN (different redshifts, obscuration, low/high luminosity etc.). The variability selection criterion is able to identify low-luminosity AGN, while the other traditional methods are not sensitive to this type of AGN.

Previously, Sarajedini et al. (2003, 2012) used multi-epoch data to assemble a sample of variable sources in the GOODS fields, followed by Trevese et al. (2008) and Villforth et al. (2010). This study goes a step further by identifying fainter objects with higher redshifts that are compared with a deeper X-ray image from Chandra.

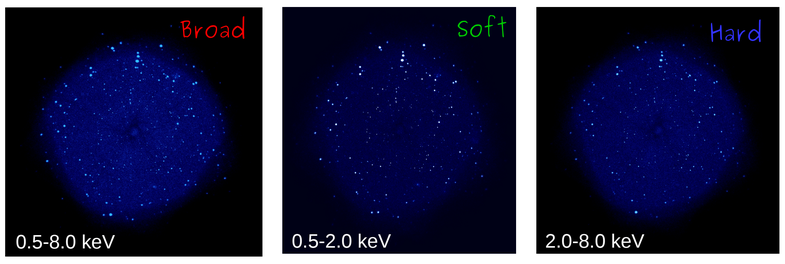
Data Reduction & Methodology

Observations:
We have retrieved HST ACS/WFC z-band (filter F850LP) images of the GOODS-South field from the Hubble Legacy Archive. We used 5 epochs separated by ~45 days and obtained photometry with SExtractor using an aperture radius of 0.36". To identify the variable sources, we selected 11232 sources (10825 extended + 407 point-like) that were detected in at least 3 epochs and have S/N>20.

Variability Index:
We used the standard deviation as the statistical method to characterize the scatter of the measurements in a lightcurve and identify the variability of the sources:

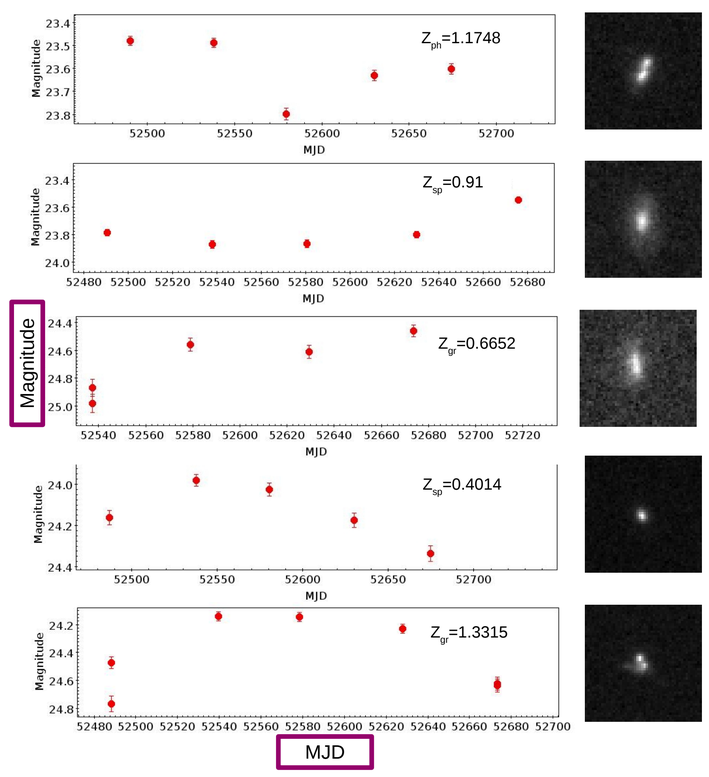


Variable Candidates:
We identified 63 variable sources using a 3.6-σ cut-off. Out of those sources, 4 are variable stars and 3 are known supernovae, resulting to 56 AGN candidates (7 point-like + 49 extended). The finder chart above illustrates their positions.



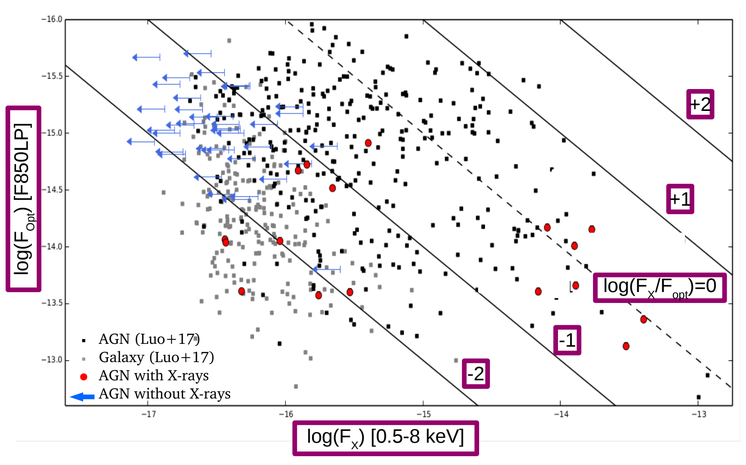
X-ray counterparts:
We cross-matched our AGN catalogue with the 2, 4 and 7 Ms Chandra X-ray catalogues (Luo+08, Xue+11, Luo+17). 17 optical AGN candidates have an X-ray counterpart (30%). All the point-like AGN candidates are confirmed QSO's and have an X-ray counterpart. In order to derive the flux upper limits for the 39 sources without X-ray counterparts, we created the 7 Ms X-ray images by using 99 observations of the Chandra X-ray Observatory from 2000 to 2015. The X-ray images in three bands are shown above.

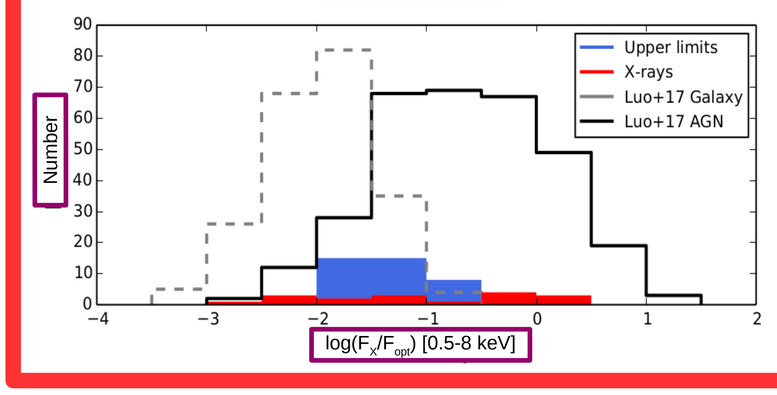
Lightcurves: Examples of lightcurves and thumbnails of 6 extended variable sources, not detected in the X-rays.



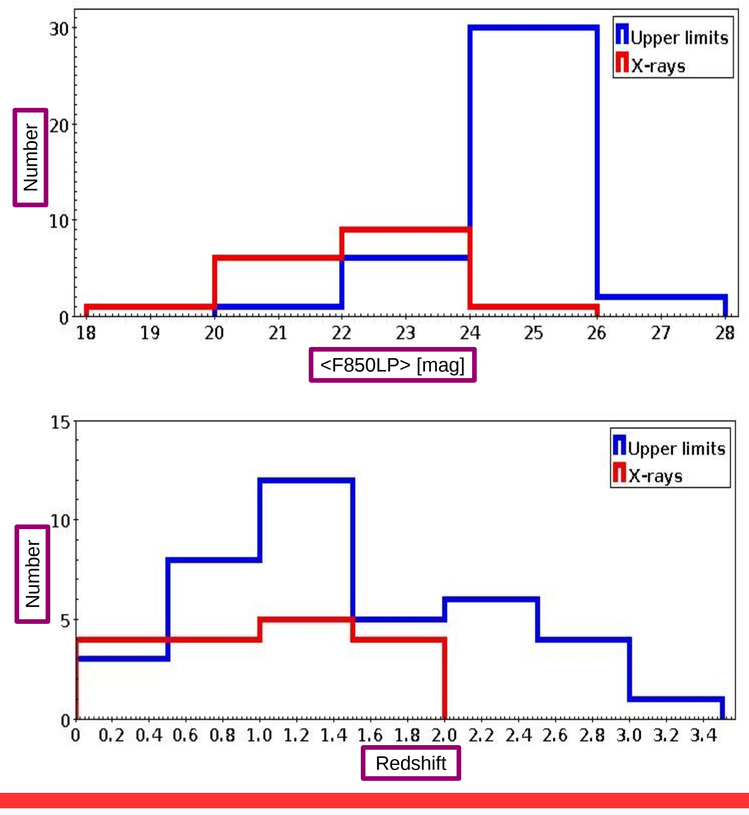
Results

F_X/F_{opt} diagnostic: The majority of the AGN candidates lie within the AGN area. All the sources near and below $\log(F_X/F_{opt})<2$ are confirmed AGN.

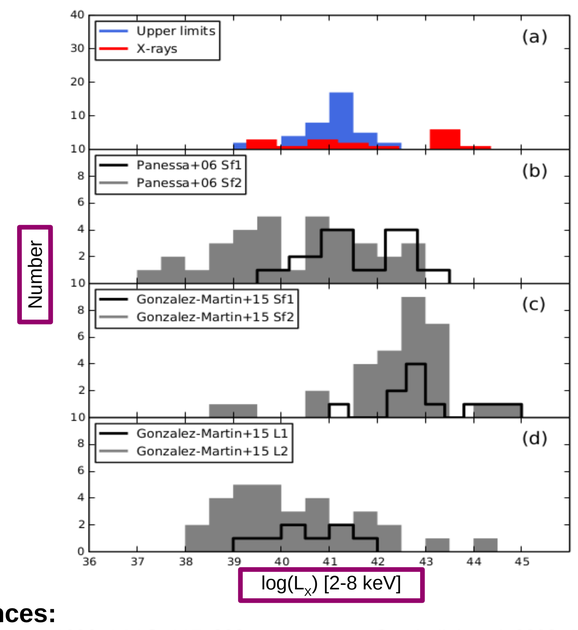




Redshifts/Magnitudes: ~80% of the AGN candidates have spectroscopic redshifts (Momcheva et al. 2015). The sources without X-ray counterparts are optical fainter, while they have higher redshift than those with X-rays.



X-ray Luminosities: The luminosities of our AGN lie at similar ranges as low-luminosity AGN in the Local Universe (LINERS and Seyferts of type I & II).



References:
Bertin & Arnouts 1996, A&AS, 117, 393
Gonzalez-Martin et al. 2015, arXiv:1501.03826
Luo et al. 2008, ApJS, 179, 19
Luo et al. 2017, ApJS, 228, 2
Momcheva et al. 2015, arXiv:151002106
Panessa et al. 2006, A&A, 455, 173
Sarajedini et al. 2003, ApJ, 599, 173
Sarajedini et al. 2011, ApJ, 731, 97
Trevese et al. 2008, A&A, 488, 73
Villforth et al. 2010, ApJ, 723, 737
Xue et al. 2011, ApJS, 195, 10
Whitmore et al. 2016, AJ, 151, 134

Acknowledgments:
This work is funded by the European Space Agency (ESA) project "Hubble Catalogue of Variables".