





Hubble Catalogue of Variables

European Space Agency

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

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National and Kapodistrian UNIVERSITY OF ATHENS



HELLENIC ASTRONOMICAL SOCIETY

July 15, 2016 "Nuclear activity in galaxies"



Outline



- Hubble Catalogue of Variables
- Motivation
- Data Reduction
- Variability Indices
- Results
 - Variable Candidates
 - $^{\circ}$ Validation of Candidates
- Next Steps



Hubble Catalogue of Variables - HCV

- New 3-year project funded by ESA

 → National Observatory of Athens
 (+ ATHENA)
- PI: Prof. K. Tsinganos
 Deputy PI: Dr. A. Bonanos
- Aims to identify and classify variable sources (extended & point-like) from Hubble Source Catalogue through different variability indices
- Master Catalogue → STScI & ESAC databases



Hubble Source Catlogue - HSC



Hubble operating ~26 years
 → many regions + multiple times

STScl

- v.1 (2015) \rightarrow 30 millions sources Whitmore et al. (2016)
- v.2 (fall 2016) → 80 millions sources from 50.000 Hubble images



Motivation



- Validation team: acceptance tests to validate the content & functionality of the HCV
- GOODS South field \rightarrow part of the Control Sample:
 - deepest field
 - multi-wavelength observations
 - Includes part of CDFS & HUDF fields
- Published papers with known variables:
 - Villforth et al. (2010, 2012) ACS/WFC F850LP
 - Trevese et al. (2008) Ground-based
 - Sarajedini et al. (2011) ACS/WFC F606LP
- Improve HSC's versions concerning the extended sources
- Need for photometry \rightarrow check, test & validate!

Data Reduction - Astrometry



- \rightarrow ACS/WFC camera in z-band (F850LP filter)
- \rightarrow 5 epochs separated by ~45 days

The combined images are indicated in the Hubble Legacy Archive (HLA) with proposal ID 9425 (Giavalisco et al. 2004) and datasets named as "HST_9425_*_ACS_WGC_F850LP" with total exposure time of 2120s.

- Initial spatial error up to 2.0"
- GAIA (Starlink)
- Reference Catalog: Giavalisco et al. (2004)
 - ~30 sources cover all image
- Reduced to ~0.20"





ΙΑΑΛΕ

Information Technologie



Data Reduction - Photometry







Data Reduction - Pre-processing



- S/N>20 \rightarrow Limit of (z) magnitude ~28
- Internal Cross-match 0.15"
- Point-like/Extended separation
 - ° CI ~1.24
- $N_{\text{points}} \ge 3$
- Exclude outliers
- 11862 sources





Variability Indices



We used two statistical methods to characterize the scatter of the measurements in a lightcurve and identify the variability of the sources:

Interquartile range (IQR) - Kim et al. (2014)



IQR: reliable variability index for few data points <u>Sokolovsky et al. (2016a, 2016b)</u>

RMS Deviation - <u>Trevese</u> et al. (2008)

sigma² =
$$\frac{1}{N_{epo}} \sum_{i}^{N_{epo}} (m_{k} - \bar{m}_{k})^{2}$$
, where $\bar{m}_{k} = \frac{1}{N_{epo}} \sum_{i}^{N_{epo}} m_{k}^{i}$





Candidates

• 206 Initial candidate variables

 50 False Positives because of: Dispersion
 Diffraction spikes

Misalignment of the center

Too faint sources

- 156 final candidate variables
 - 150 sources with redshift (Momcheva et al. 2015)
 - ° 35 cited → Villforth et al. (2012), Trevese et al. (2008)















40 60 80

60 80

20 40 60





Candidates – New Candidates







Candidates – New Candidates







Validation of Candidates



- **Concentration Index:** We find the majority (93%) of the variable objects to be extended, indicating AGN activity, as illustrated in the histogram in the right.
- Inspection by eye
 - $^{\circ} \rightarrow$ False Positives
 - $^{\circ} \rightarrow$ Nature of variable
- Use X-ray counterparts if available
- \rightarrow AGN
- $^{\circ}$ 2Ms \rightarrow 4Ms \rightarrow 7Ms
 - N of counterparts increases
- ° Optical images much deeper!
- ° Identification of low-luminocity AGN







Next steps



- Comparison with HSC version 2 (~September 2016)
- X-ray non detectable variables
 - X-ray stacking analysis
 - Upper limits of F(X)/F(Opt)
- SED fitting + Spectra analysis of new candidates ???
- The Principal Component Analysis (PCA) ???







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Thank you!!!



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Appendix





Redshift



Redshifts: Histogram of redshifts of the 150 variable sources, which were cross-matched with the <u>Momcheva</u> et al. (2015) catalogue to obtain their photometric, spectroscopic or grism redshifts. Those with and without X-ray counterparts are indicated, in comparison with all X-ray sources from the 4Ms catalogue in the Chandra deep field south.



Candidates – New Candidates













Photometry









26

ATHE

52700

52700

Research & Innovation

Information Technologies