Objects with extreme UV emission in modern sky surveys

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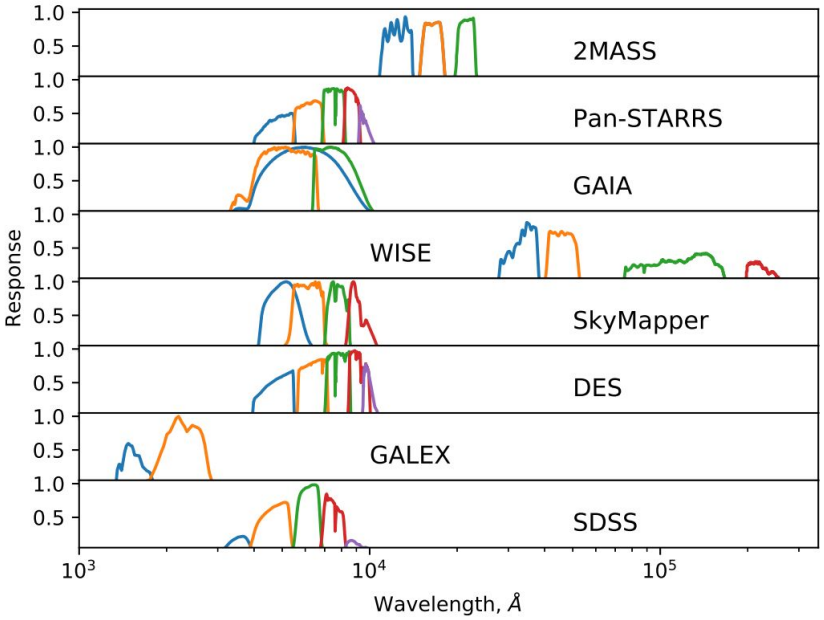
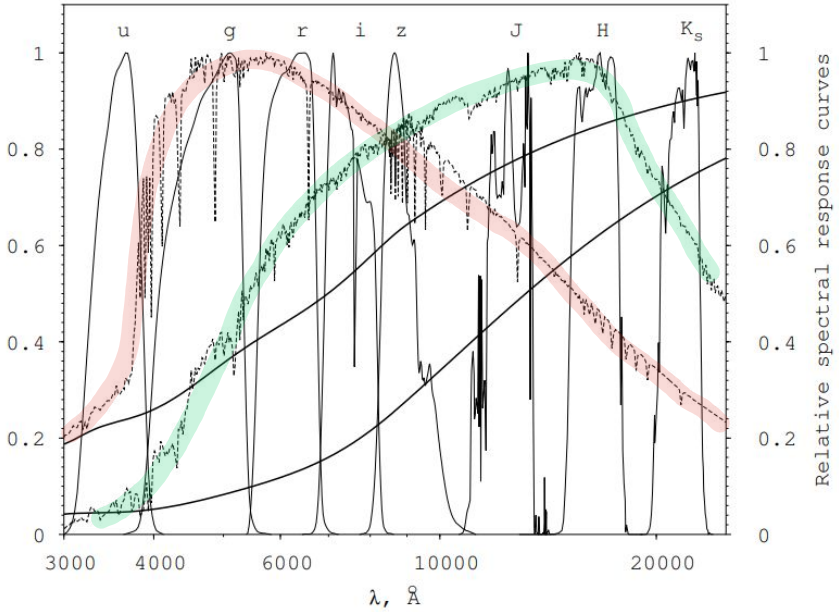
Introduction

- Modern multi-wavelength sky surveys
  - SDSS, Fermi, GALEX, Pan-STARRS, DES, WISE, 2MASS
- Large surveys offer multicolored photometric data for millions of objects

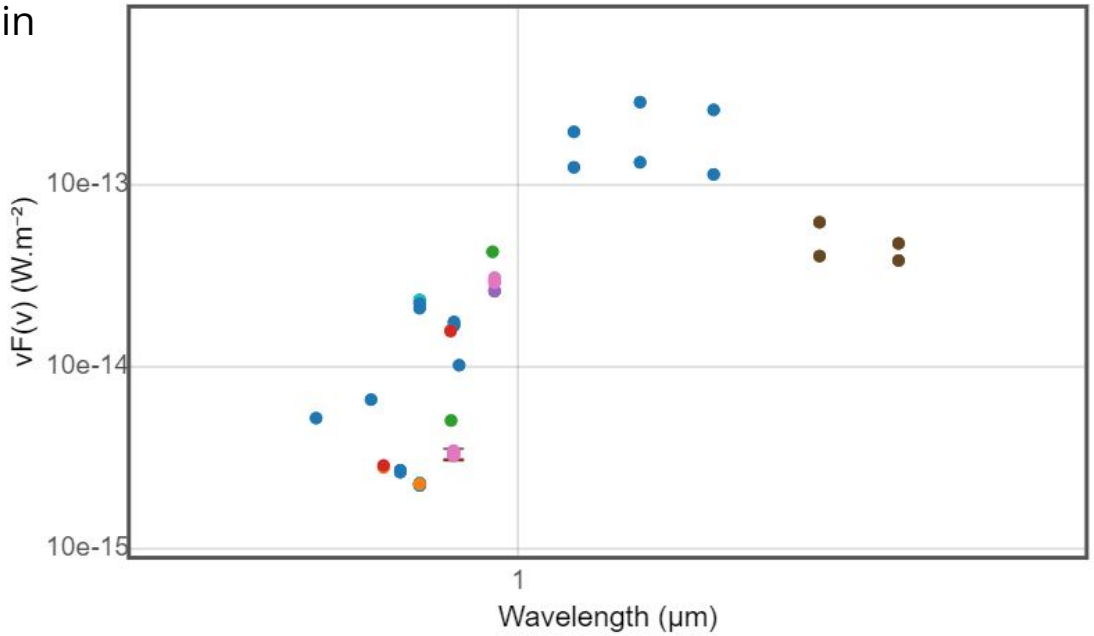




Credit: Sichevsky, 2019

- Objects detected in multiple surveys are the most favorable for the research

- But! Objects that are found only in one of the surveys may offer intriguing prospects for new discoveries
- This work is a continuation of Karpov et al. (2021) arXiv: 2105.01027
- We are looking for the GALEX objects that have no counterparts in two major optical sky surveys: Pan-STARRS and Dark Energy Survey (DES)

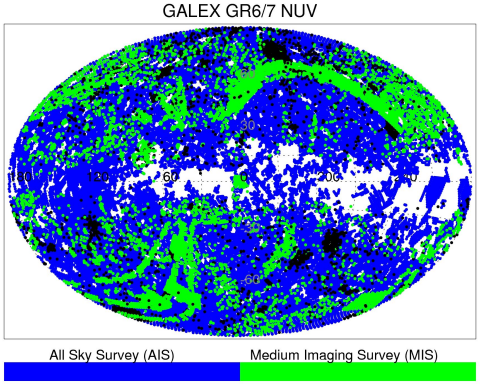


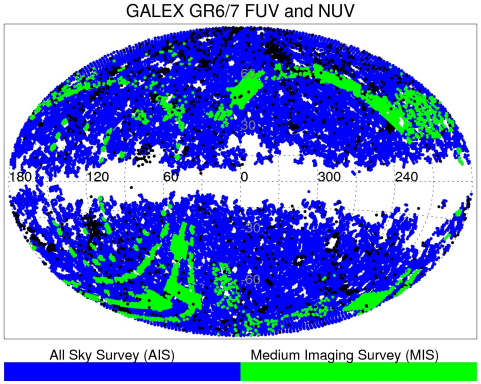
GALEX satellite and its legacy

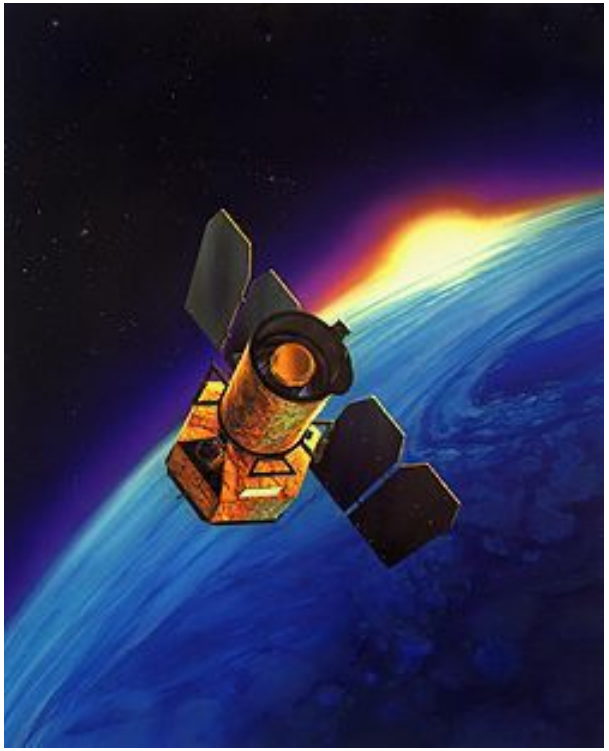
Nearby Galaxy Survey (NGS), Deep (DIS), Medium (MIS), and **All Sky Imaging Survey** (AIS)
(nearly all sky, multiple visits, ~100 s exposures)

Final catalogue of GALEX-detected objects - GUVcat_AIS, **82,992,086** objects
Bianchi et al. (2017), re-processing of all AIS data of the mission

GPhoton - (slow) API for accessing all photons acquired by GALEX (time, position, ...)
Allows reconstruction of both images and light curves (including intra-visit ones)







Launch: April 28, 2003
Observing: July 7, 2003 - February 7, 2012
FUV inactive since 2009

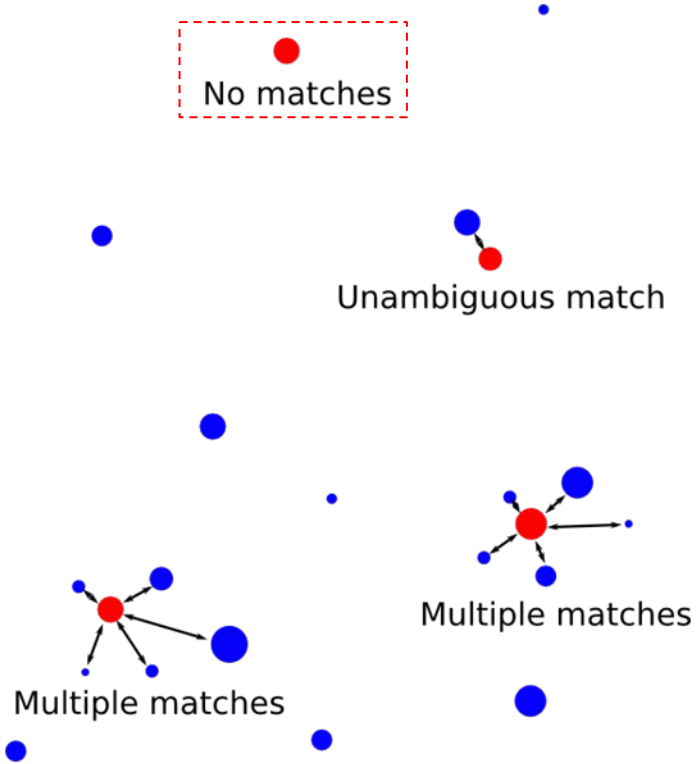
Image scale: 1.5" per pixel
Image FWHM: ~4.2" (FUV)
~5.3" (NUV)

Cross-matching of catalogues

To cross-match is to find the emergence of the same astrophysical object in different catalogues and to link this information.

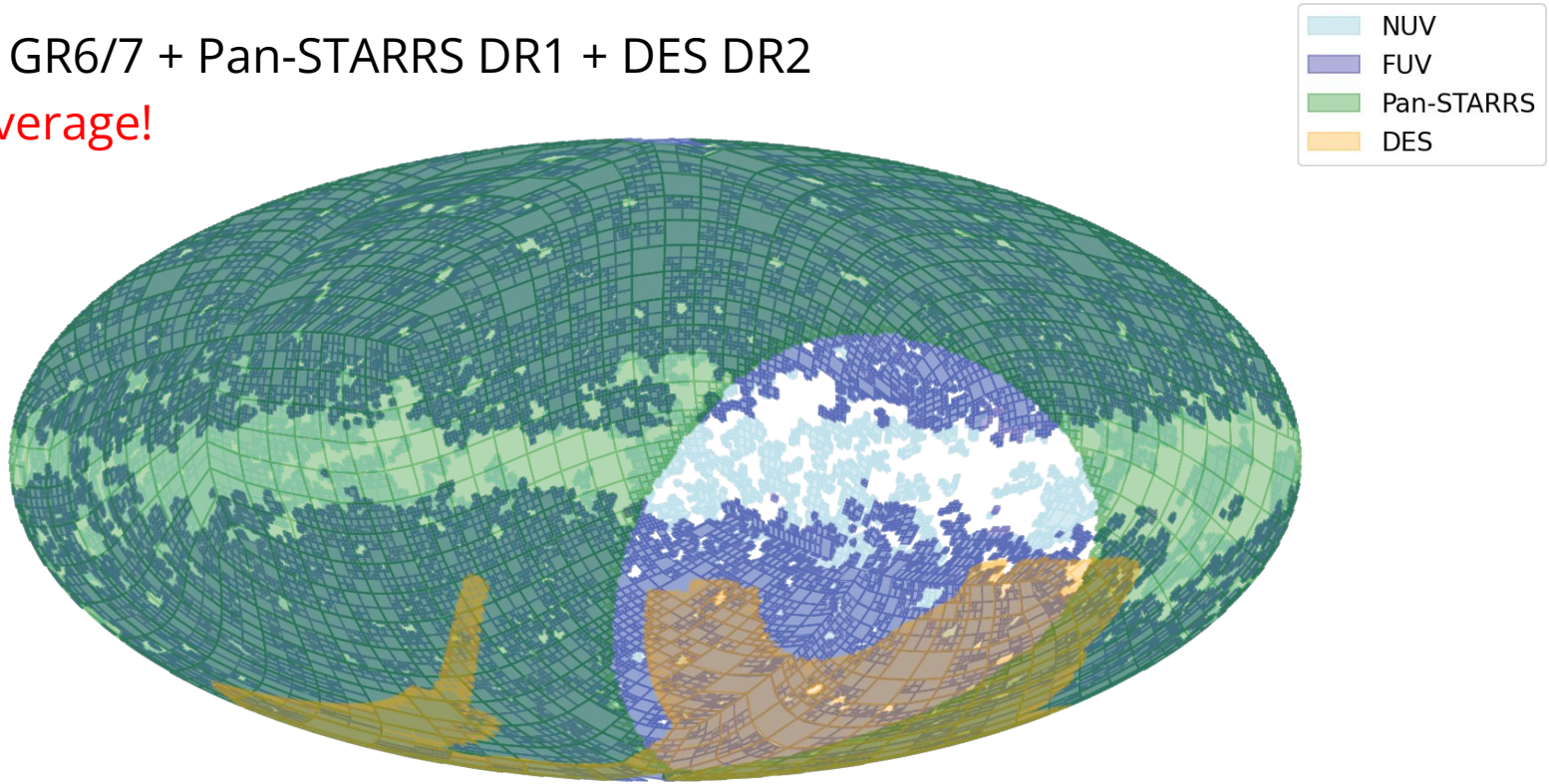
Due to proper motion, different astrometric accuracy between catalogues and different ranges of the spectra, the position of the same object in other catalogue could be different.

We here are focused on finding the objects in GALEX that have no counterparts, which could sound like an easier problem, if not ...



Un-matching of catalogues

- GALEX GR6/7 + Pan-STARRS DR1 + DES DR2
- Sky coverage!



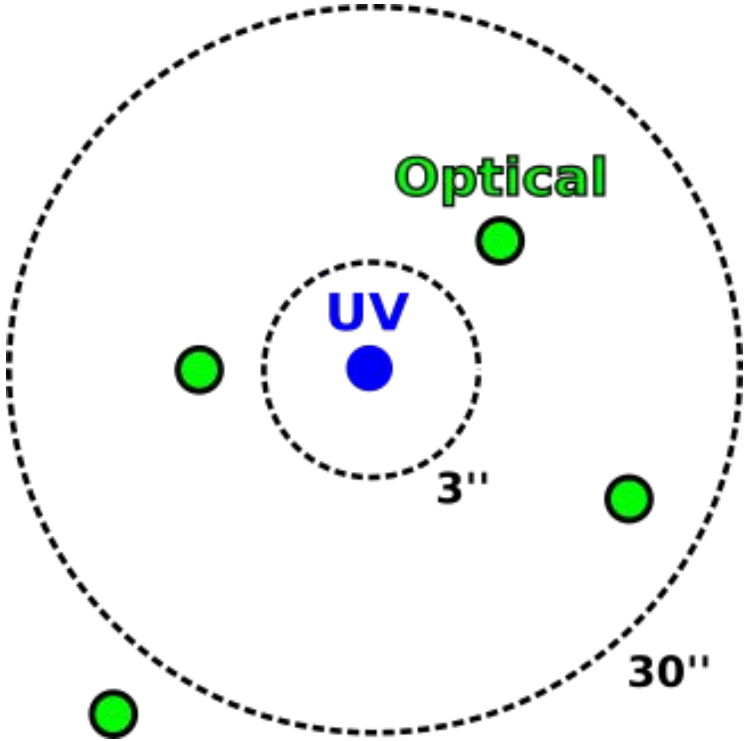
Un-matching catalogues - poor man' solution

- GALEX GR6/7 + Pan-STARRS DR1 + DES DR2
- Sky coverage!

- **CDS XMatch**
  - Split into sky segments using HEALPix
  - Match with **30"** to ensure sky coverage

    -
  - Match with **3"** to get matched objects

    =
  - Keep only non-matched objects



3" is the optimal matching radius according to Bianchi et al. (2020)

Additional GALEX quality cuts

No extraction flags

Nexf = 0 Fexf = 0

No dichroic or window reflection artifact flags

(Nexf & 6) = 0 (Fexf & 6) = 0

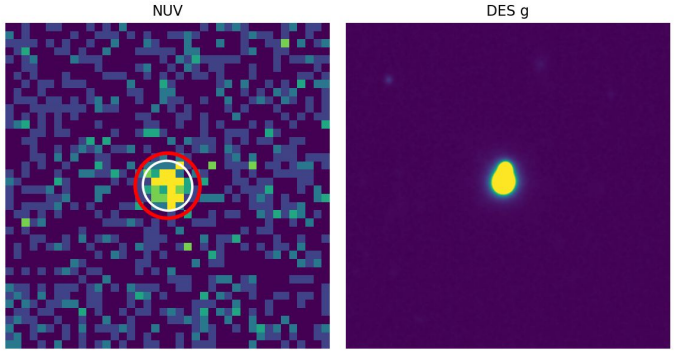
Signal/Noise > 5

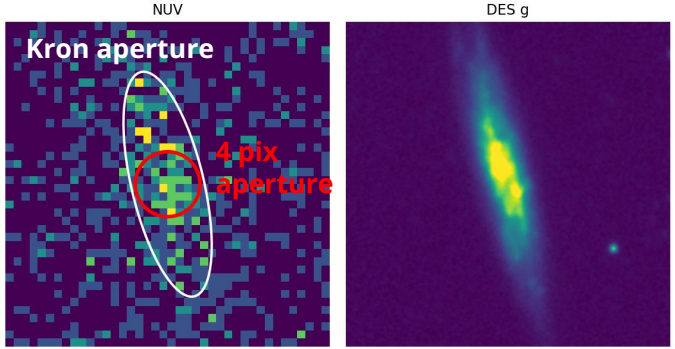
e_NUV < 0.2 e_FUV < 0.2

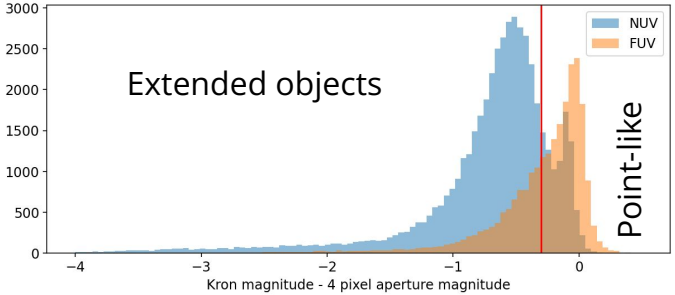
No extendedness

NUV.a - NUV.4 > -0.3 FUV.a - FUV.4 > -0.3

(difference between Kron and 4 pixel wide apertures)







Filtering in optical images

Get Pan-STARRS / DES cutouts from CDS hips2fits service, 60” x 60”

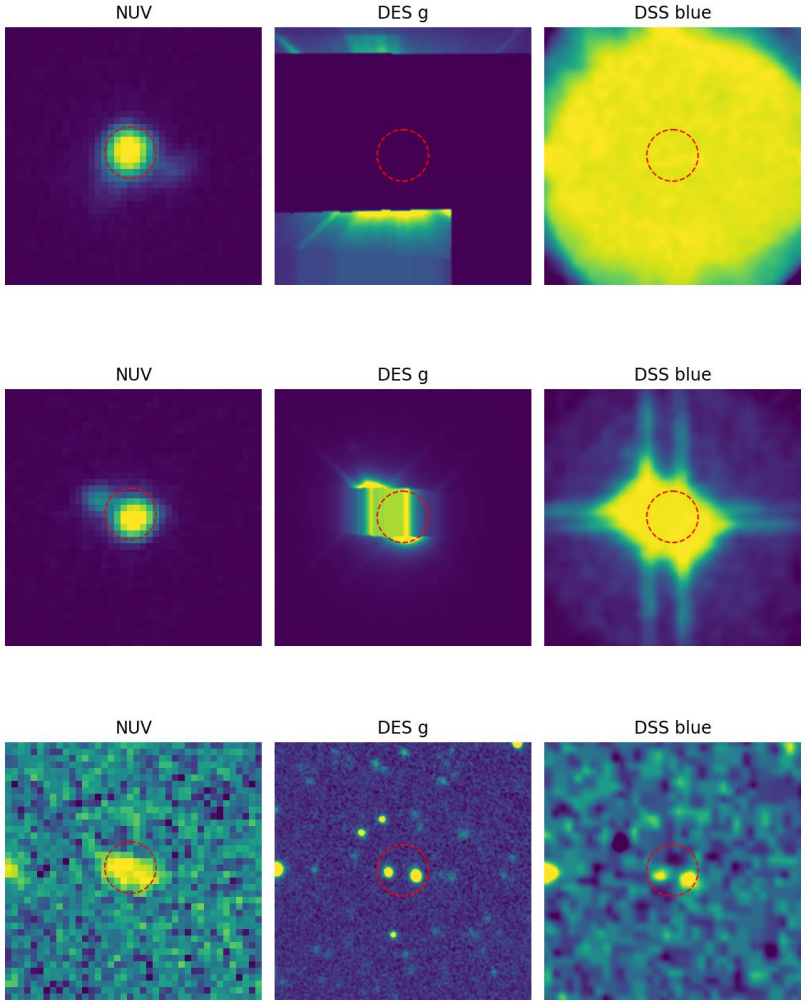
Check masked / zeroed regions

Check footprints of bright objects

Check visible but not catalogued objects

Check for blended objects

1. Detect peaks in the cutout around object position
2. Randomize their flux ratio, compute centroid positions
3. Compare centroid positions with object position



Potential distractors: proper motions of stars

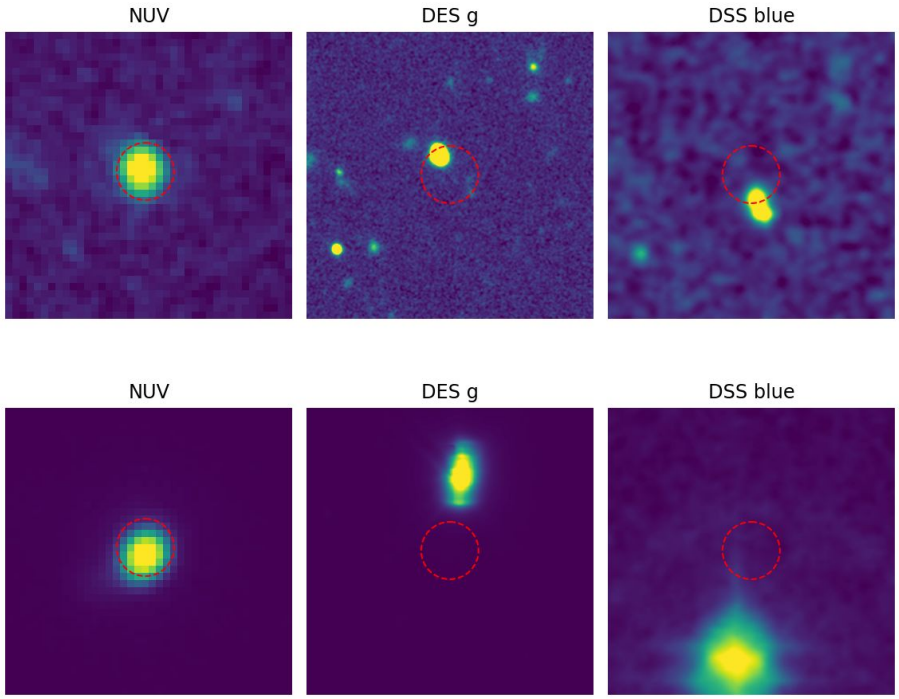
Different epochs of catalogues

- GALEX: 2003-2012
- Pan-STARRS: 2009-2014
- DES: 2013-2019
- DSS2: 1978-1998

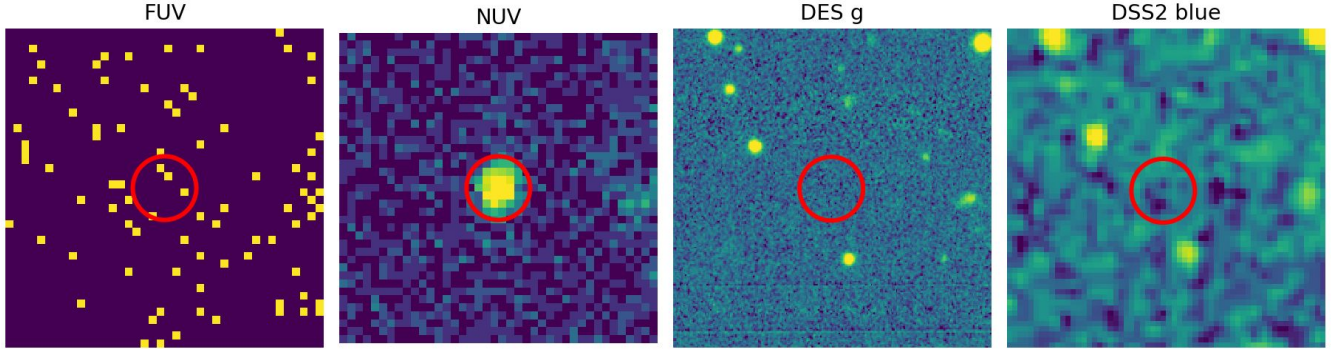
Filtering based on Gaia DR3

Closer than 30”

PM > 0.1”/year

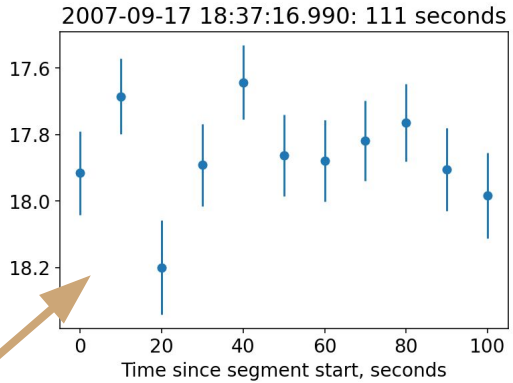


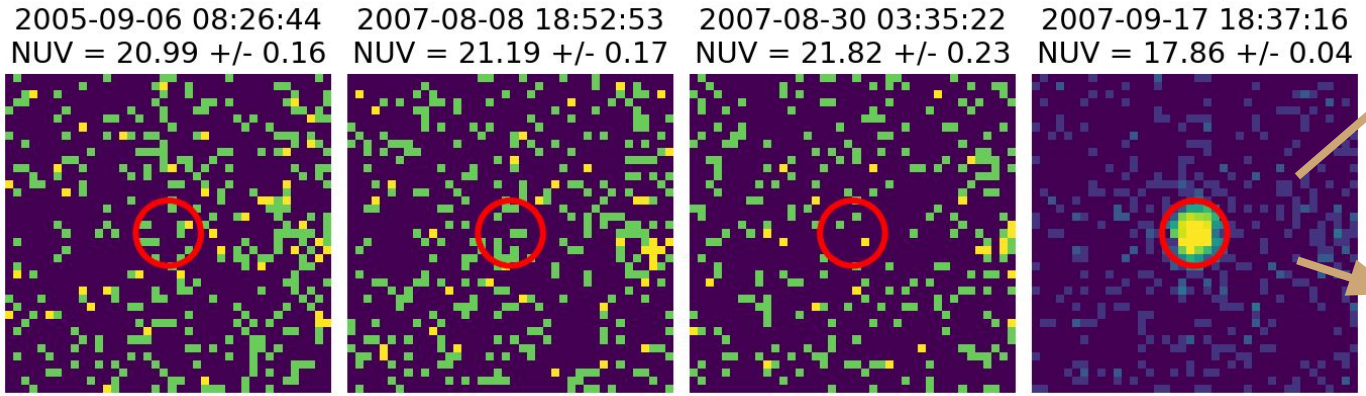
Visit-level analysis and visual checking



gPhoton - Million et al. (2016)

https://github.com/cmillion/gPhoton





SkyBoT check:
Asteroid 776 Berbericia
at 4.3 arcsec

Final candidates

GALEX + DES DR2 = 4786 sq.deg

3,299,100 initial “un-matches”
149,803 after catalogue quality cuts
8,459 point-like with S/N>5
44 after DES cutout checking
28 after proper motion checking

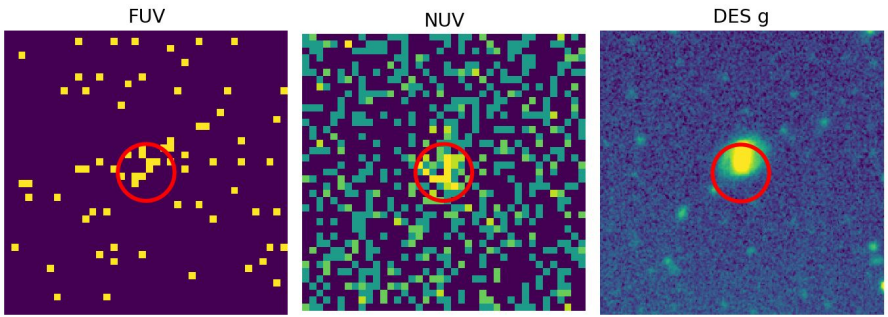
27 asteroids
0 other transients
1 stationary objects

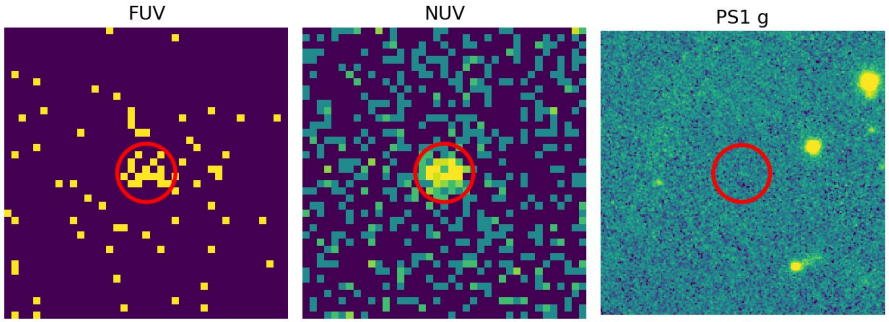
GALEX + PanSTARRS DR1 = 25497 sq.deg

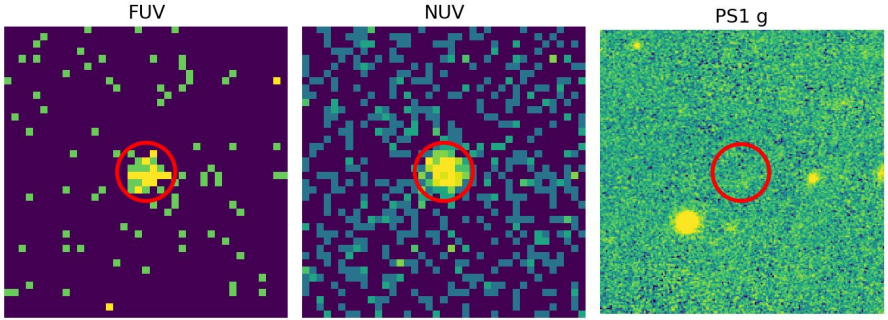
22,679,668 initial “un-matches”
585,423 after catalogue quality cuts
17,434 point-like with S/N>5
778 after PS1 cutout checking
624 after proper motion checking

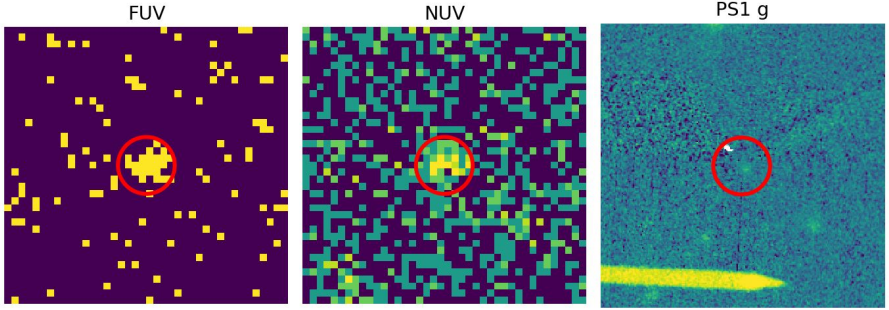
403 asteroids
58 other transients
86 stationary objects
8 single-epoch observations

Final candidates: stationary objects

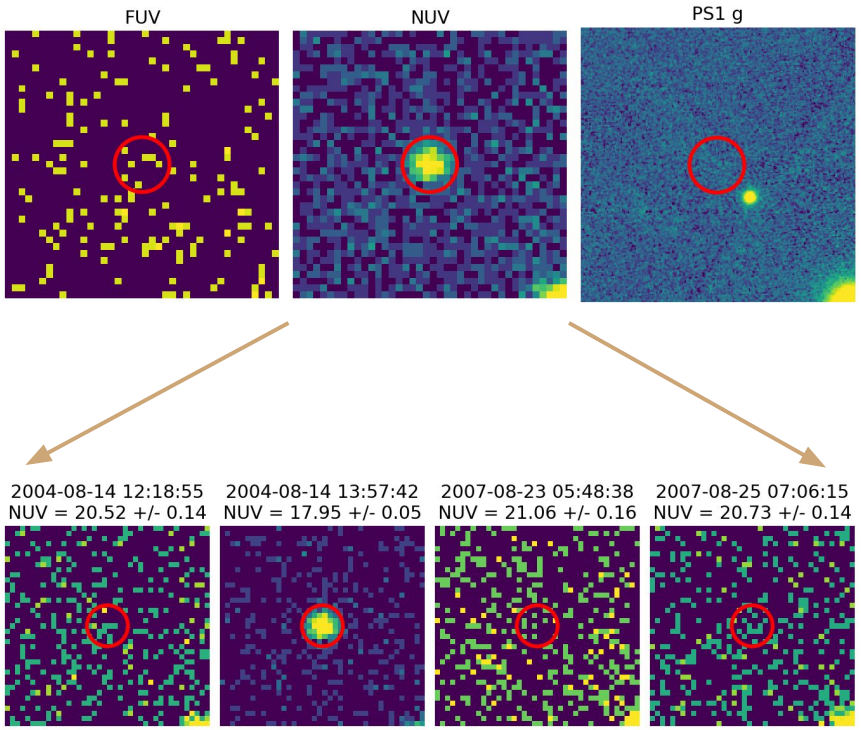


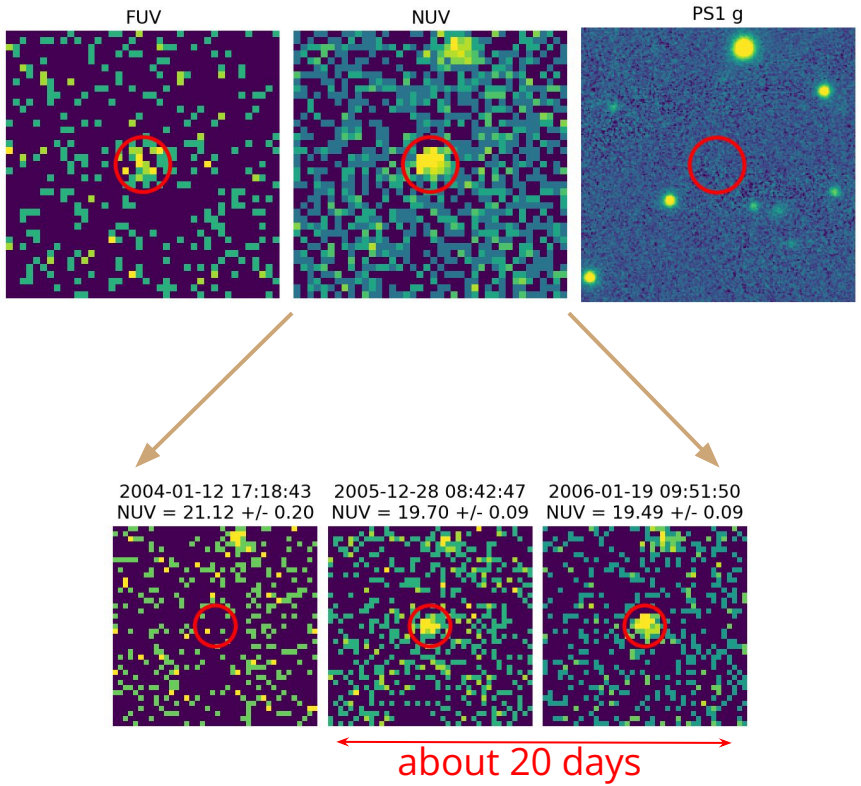






Final candidates: transients





Conclusions

We investigated an approach for detection of unique or transient objects by cross-matching multi-wavelength catalogues and looking for non-matched entries, using GALEX and modern optical sky surveys - Pan-STARRS and DES

We were able to implement it using publicly available online tools and services.

We detected a number of reliable candidates of stable UV object without optical counterparts visible in Pan-STARRS, as well as a number of transients and known asteroids.

The candidates we selected require additional investigation.

Thank you!