



Photometry for the people



Sergey Karpov / FZU AV ČR



EVROPSKÁ UNIE
Evropské strukturální a investiční fondy
Operační program Výzkum, vývoj a vzdělávání



STDPipe - Simple Transient Detection Pipeline

STDPipe is a set of Python routines for astrometry, photometry and transient detection related tasks, intended for quick and easy **implementation of custom pipelines**, as well as for interactive data analysis.

Design principles:

- implemented as a library of routines covering most common tasks
- operates on standard Python objects: NumPy arrays for images, AstroPy Tables for catalogs and object lists, ...
- conveniently wraps external codes that do not have their own Python interfaces (SExtractor, SCAMP, PSFEx, HOTPANTS, Astrometry.Net, ...)

GitHub repository - <https://github.com/karpov-sv/stdpipe>

Documentation - <https://stdpipe.readthedocs.io/>

STDPipe - Simple Transient Detection Pipeline

- ~~pre-processing~~ - should be handled before in an instrument-specific way
 - bias/dark subtraction, flatfielding, masking
- object detection and photometry
 - **SExtractor** or **SEP** for detection, **photutils** for forced photometry
- astrometric calibration
 - **Astrometry.Net** for blind WCS solving, both local and online
 - **SCAMP** or **Astropy**-based code for refinement
- photometric calibration
 - **Vizier** catalogues, passband conversion (PS1 to Johnson, Gaia to Johnson, ...)
 - spatial polynomial + color term + additive term + intrinsic scatter
- image subtraction
 - **Pan-STARRS** or **DESI Legacy Survey** images, or **HiPS** templates
 - **HOTPANTS** + custom noise model, or **ZOGY**
- transient detection and photometry
 - noise-weighted detection, cutout adjustment, ...
- auxiliary functions
 - PSF estimation with PSFEx, simulated stars, FITS header utilities, image splitting, plotting, ...

From the library to the Web

- Pipelines are good but people are lazy
- Data are heterogeneous, sometimes unexpectedly so
- Easy control and interactive quality checking at every step is desirable
- Most common corner cases should be handled automatically
- Everything that may be guessed should be guessed automatically
- Everything should be kept for further re-processing or examination

- Hey, **Astrometry.Net** succeeded so why not do the same for photometry?..

STDWeb

STDPipe for the Web

STDWeb Files Tasks SkyPortal Upload User: karpov

Simple Transient Detection for the Web

This is a simple web-based tool for a quick-look photometry and transient detection in astronomical images. It is based on [STDPipe](#) library and tries to implement a self-consistent and mostly automatic data analysis workflow from its routines.

It currently allows you to:

- Upload your own FITS files, or analyze some files already on the server
- Do basic pre-processing and masking
- Detect objects in the image and do astrometric calibration, either by blind matching or refining existing solution
- Photometrically calibrate the image using one of supported reference catalogues
- Subtract either user-provided or automatically downloaded template images
- Do forced photometry for a specified target in either original or difference image
- Do (experimental) transient detection in difference image

If you want to better understand the routines used for it, please consult STDPipe [documentation](#) and [example notebooks](#), as well as the [actual source code](#) behind this website.

Image upload

FITS file*

Choose File no file selected

Optional title or comment

Upload

<http://grandma-stdpipe.ijclab.in2p3.fr>

STDWeb Files Tasks SkyPortal Upload User: karpov

File browser

Files / Candidates / GRB / GRB230812B_Fermi / IMAGES / STACK

File Name	Size
GRB230812B_Abulwfa_KAO_2023-08-13T18-00-11_SDSSg_STACK_10X180s_249-1311789_47-858962.fits	7.6 MiB
GRB230812B_Abulwfa_KAO_2023-08-13T18-41-01_SDSSr_STACK_10X180s_249-1311789_47-858962.fits	7.6 MiB
GRB230812B_Abulwfa_KAO_2023-08-13T19-28-23_SDSSi_STACK_20X150s_249-1311789_47-858962.fits	7.6 MiB
GRB230812B_Abulwfa_KAO_2023-09-02T18-26-12_sdssr_STACK_31x180s_249-1311789_47-858962.fits	7.6 MiB
GRB230812B_Abulwfa_KAO_2023-09-02T18-26-12_sdssr_STACK_61x180s_249-1311789_47-858962.fits	7.6 MiB
GRB230812B_Antier_C2PU_2023-08-22T21-10-00_sdssr_STACK_15x300s_249-1311789_47-858962.fits	58.9 MiB
GRB230812B_Antier_CFHT-Megacam_2023-09-12T06-24-15_sdssi_STACK_3x60s_249-152490679_47-8507597516.fits	74.9 MiB
GRB230812B_Antier_CFHT-Megacam_2023-09-12T06-31-48_sdssr_STACKED_3x40s_249-152493728_47-8507588322.fits	74.9 MiB
GRB230812B_Antier_CFHT-Megacam_2023-09-12T06-38-16_sdssg_STACK_10x30s_249-133026889_47-8510499307.fits	74.9 MiB
GRB230812B_Antier_UBAI-AZT-22_2023-08-21T17-56-54_R_STACK_6x300s_249-1311789_47-858962.fits	128.5 MiB
GRB230812B_Azzam_KAO_2023-08-28T17-45-24_sdssi_STACK_26x180s_249-1311789_47-858962.fits	7.6 MiB
GRB230812B_Azzam_KAO_2023-08-28T19-20-25_sdssr_STACK_21x180s_249-1311789_47-858962.fits	7.6 MiB
GRB230812B_Burkhnov_UBAI-AZT-22_2023-08-21T17-56-54_R_STACK_6x300s_249-1311789_47-858962.fits	5.5 MiB

STDWeb Files Tasks SkyPortal Upload User: karpov

Tasks

Filter: Search tasks by filenames or titles or usernames Show all

ID	Task Name	Status
1982	J2151-0220_Kaeouach-Aziz_ASO_2024-04-30T01-00-00_L_Stack_17x180s.fits	subtracted
1979	J2151-0220_Corradini-W_OPD_2024-05-01T07:31:08_R_Stack_12x250s.fits	subtracted
1949	EP240426a_Freeberg_T30_2024-04-26T12-52-02_Rc_Stack_7x180sec.fits	photometrized
1948	image.fits	photometrized
1925	z20240117000169.fit	photometrized
1793	image.fits	photometrized
1559	EP20240331A_Masek-Karpov_FRAM-CTA-N_2024-04-02-T00-00-23_V_STACK_59X60s_169_414-20_042.fit	subtracted

or

<http://stdweb.favor2.info>

STDWeb Files Tasks SkyPortal Upload User: karpov

File browser

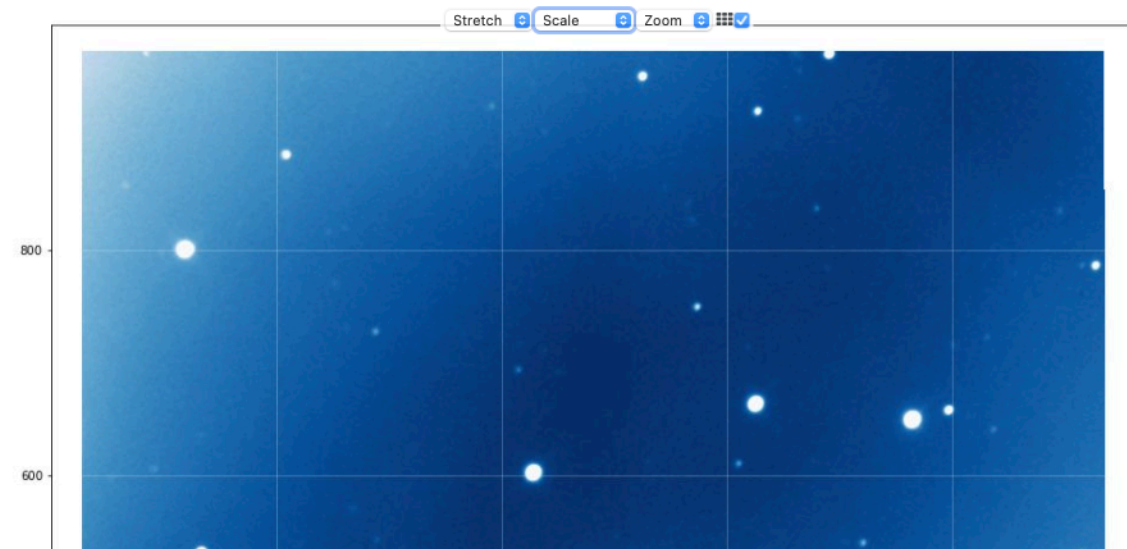
Files / Candidates / GRB / GRB230812B_Fermi / IMAGES / STACK

Path: Candidates/GRB/GRB230812B_Fermi/IMAGES/STACK/GRB230812B_Abulwfa_KAO_2023-09-02T18-26-12_sdssr_STACK_31x180s_249-1311789_47-858962.fits

- Size: 8009280 bytes / 7.6 MiB
- Last modified: 2023-09-06 10:44:58.000
- application/octet-stream: FITS image data, 64-bit, floating point, double precision

Process this file

PRIMARY



STDWeb Files Tasks SkyPortal Upload User: karpov

Photometry and astrometry

S/N Ratio: 5 Initial aperture, pixels: 3 Smoothing kernel, pixels: 0 Background mesh size: 256 Minimal object area: 5

Relative aperture, FWHM: 1 Sky inner annulus, FWHM: 5 Outer annulus, FWHM: 7 FWHM override, pixels: Matching radius, arcsec: 5

Filter: Johnson-Cousins V Reference catalog: Pan-STARRS DR1 Catalog limiting mag: 22.0 Zeropoint spatial order: 2 Use color term

Run photometry

Object detection

```
Will run SExtractor like that:
/pdisk/home/grandmadm/miniconda3/envs/stdpipe/bin/sex
/tmp/sexdgt14/image.fits -c /tmp/sexdgt14/empty.conf -
VERBOSE_TYPE QUIET -DETECT_MINAREA 5 -GAIN 100000.0 -
DETECT_THRESH 2.0 -WEIGHT_TYPE BACKGROUND -MASK_TYPE NONE -
SATUR_LEVEL 1.958649023869893 -FLAG_IMAGE
/tmp/sexdgt14/flags.fits -PHOT_APERTURES 6 -PARAMETERS_NAME
/tmp/sexdgt14/cfg.param -CATALOG_NAME
/tmp/sexdgt14/out.cat -CATALOG_TYPE FITS_LDAC -FILTER N -
BACK_SIZE 256
SExtractor run succeeded
2498 objects found
```

Object measurement

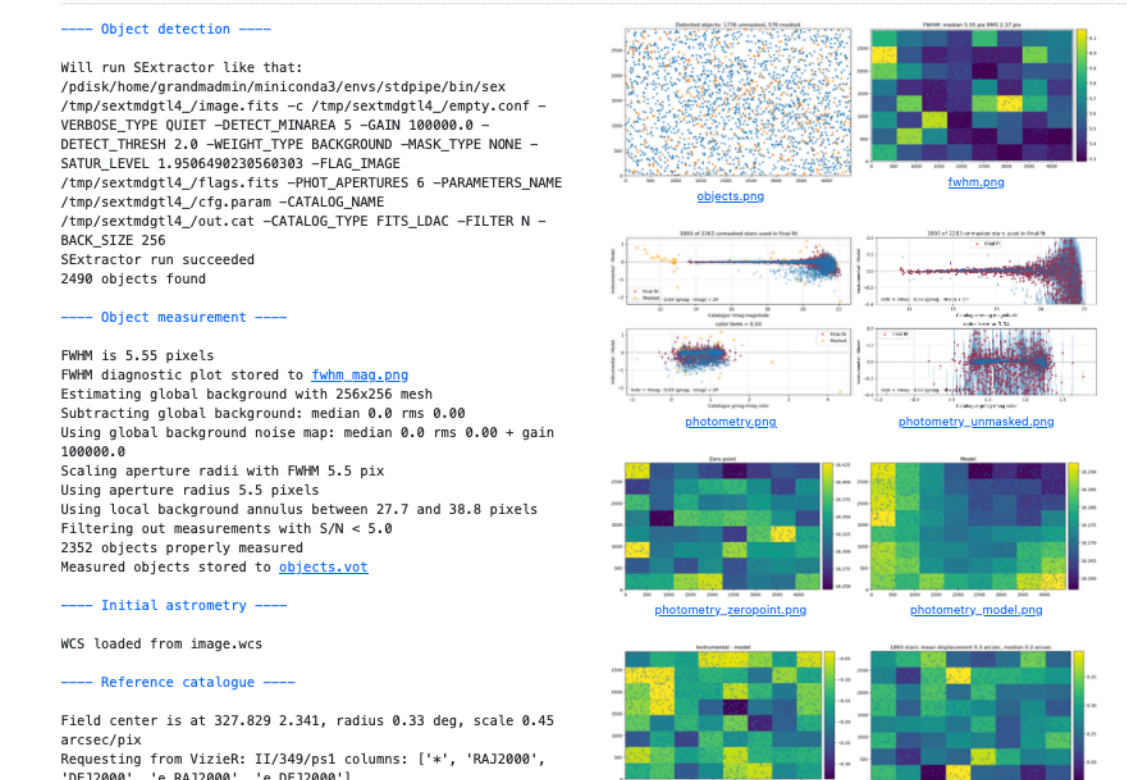
FWHM is 5.55 pixels
FWHM diagnostic plot stored to fwhm_maa.png
Estimating global background with 256x256 mesh
Subtracting global background: median 0.0 rms 0.00
Using global background noise map: median 0.0 rms 0.00 + gain 100000.0
Scaling aperture radii with FWHM 5.5 pix
Using aperture radius 5.5 pixels
Using local background annulus between 27.7 and 38.8 pixels
Filtering out measurements with S/N < 5.0
2352 objects properly measured
Measured objects stored to objects.vot

Initial astrometry

WCS loaded from image.wcs

Reference catalogue

Field center is at 327.829 2.341, radius 0.33 deg, scale 0.45 arcsec/pix
Requesting from Vizier: II/349/ps1 columns: ["*", "RAJ2000", "DECJ2000", "e_RAJ2000", "e_DECJ2000"]
Center: 327.829 2.341 radius: 0.334



STDWeb - technical details

- Django (+minor JS) as web framework, Celery as runner for processing tasks
- Code on GitHub - <https://github.com/karpov-sv/stdweb>
- Highly opinionated processing pipeline based on STDPipe
 - Optimized for most common use cases of follow-up observations
 - Uses a lot of heuristics for guessing various parameters
 - Does not handle wide-field images too well (yet, but we are working on it!)
 - May be used (with little effort) locally without web interface

STDWeb - workflow

- Initial inspection
- Object detection and measurement
- Astrometric refinement
- Photometric calibration
- Forced photometry at target' position
- Transient detection
 - **Simple catalogue-based transient detection**
 - Template subtraction and detection on difference image

STDWeb - workflow

- Initial inspection
 - Object detection and measurement
 - Astrometric refinement
 - Photometric calibration
 - Forced photometry at target' position
- Transient detection
 - **Simple catalogue-based transient detection**
 - Template subtraction and detection on difference image

Hands-on session on Tuesday

Simple catalogue-based transient detection

- Compare detected objects with catalogue and see what's new
 - Uncatalogued objects or significant change of brightness
- What catalogue?
 - Gaia for everything bright enough
 - Pan-STARRS DR1 for northern sky
 - SkyMapper DR4 for southern sky
- Blended objects?
- Extended objects?
- Cosmic rays and artefacts?

Simple catalogue-based transient detection

Simple transient detection



Task IDs to cross-check

Center position to limit the search

Radius, deg

Minimal mag difference

- Check SkyBoT
- Reject blends
- Reject prefiltered

Simple catalogue-based transient detection

Candidates will be rejected if they are not detected in other image(s)

Multi-image mode

Candidates outside this region will be rejected

Positional constraints

Help

Simple transient detection

Task IDs to cross-check

Center position to limit the search

Radius, deg

Minimal mag difference

Check SkyBoT Reject blends Reject prefiltered



Solar System objects

Blend filtering

Simple shape classifier

Brightness threshold

Candidates are rejected if there is known Solar System object within 10" at this time

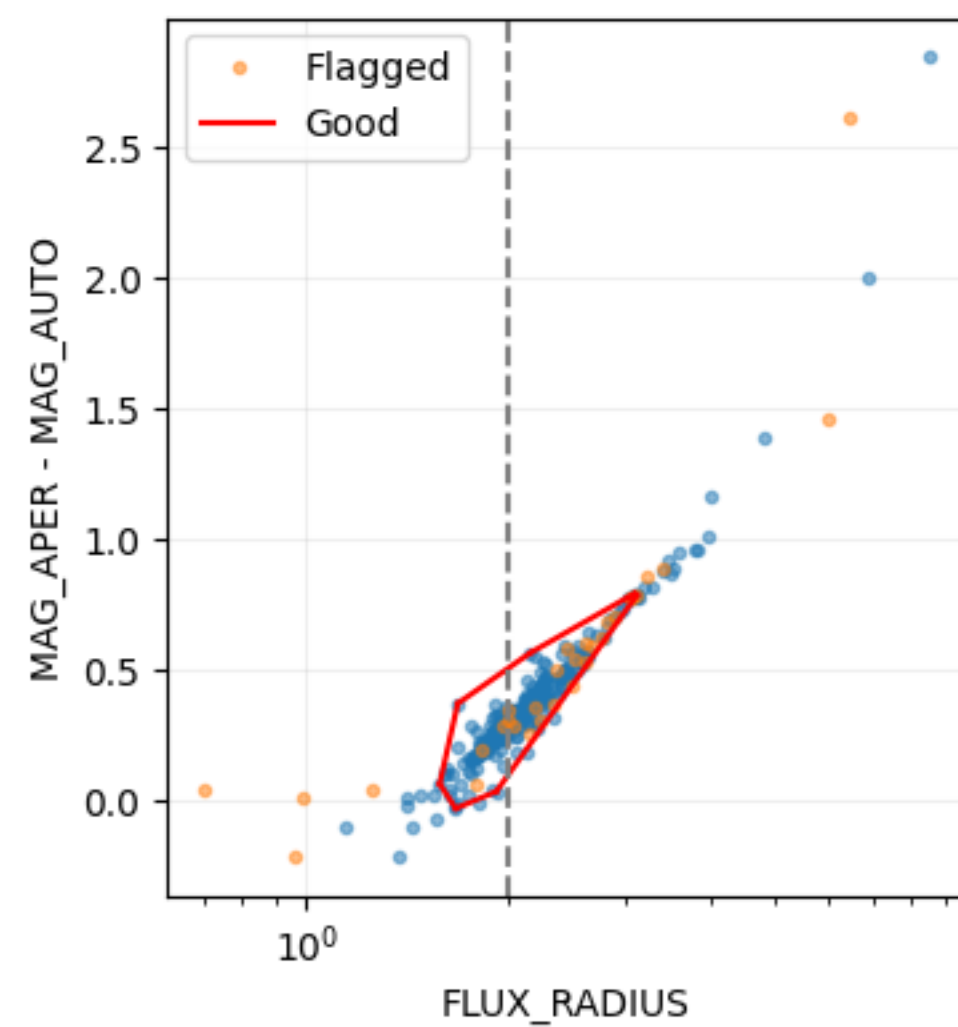
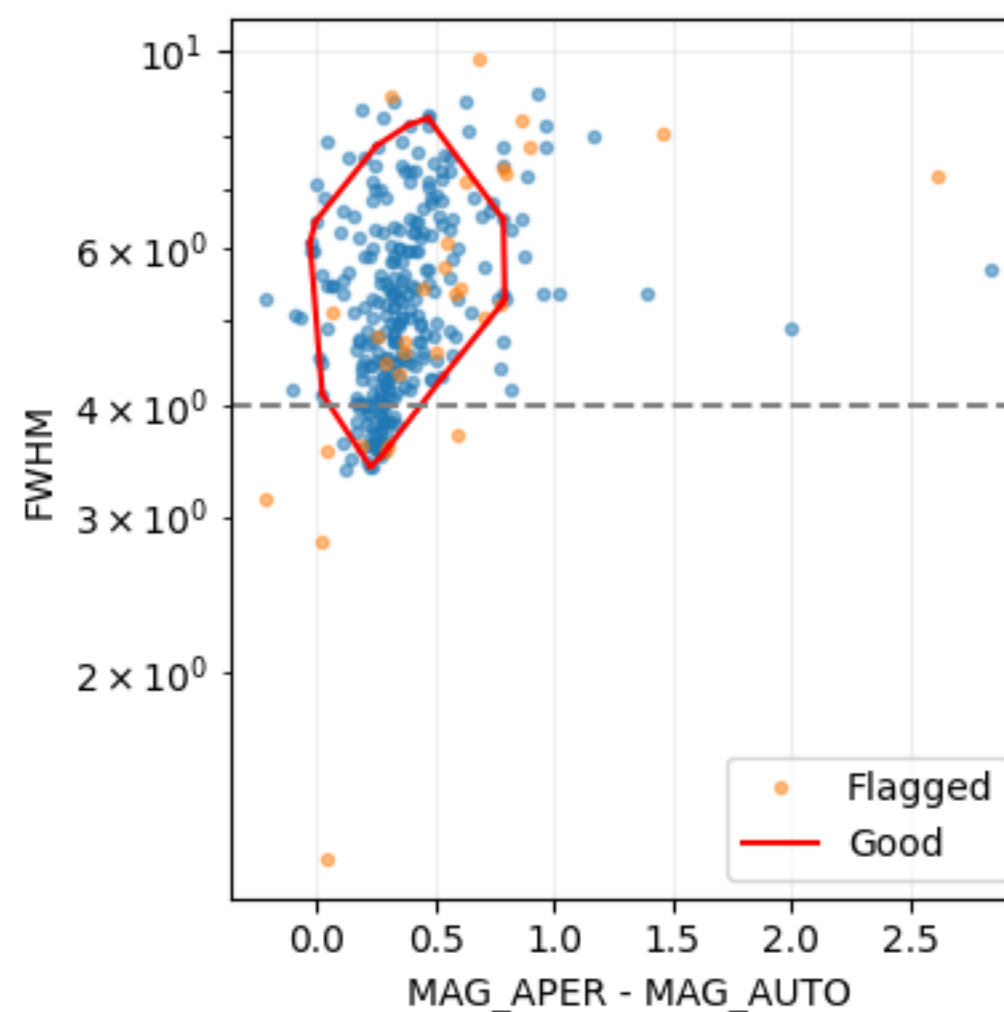
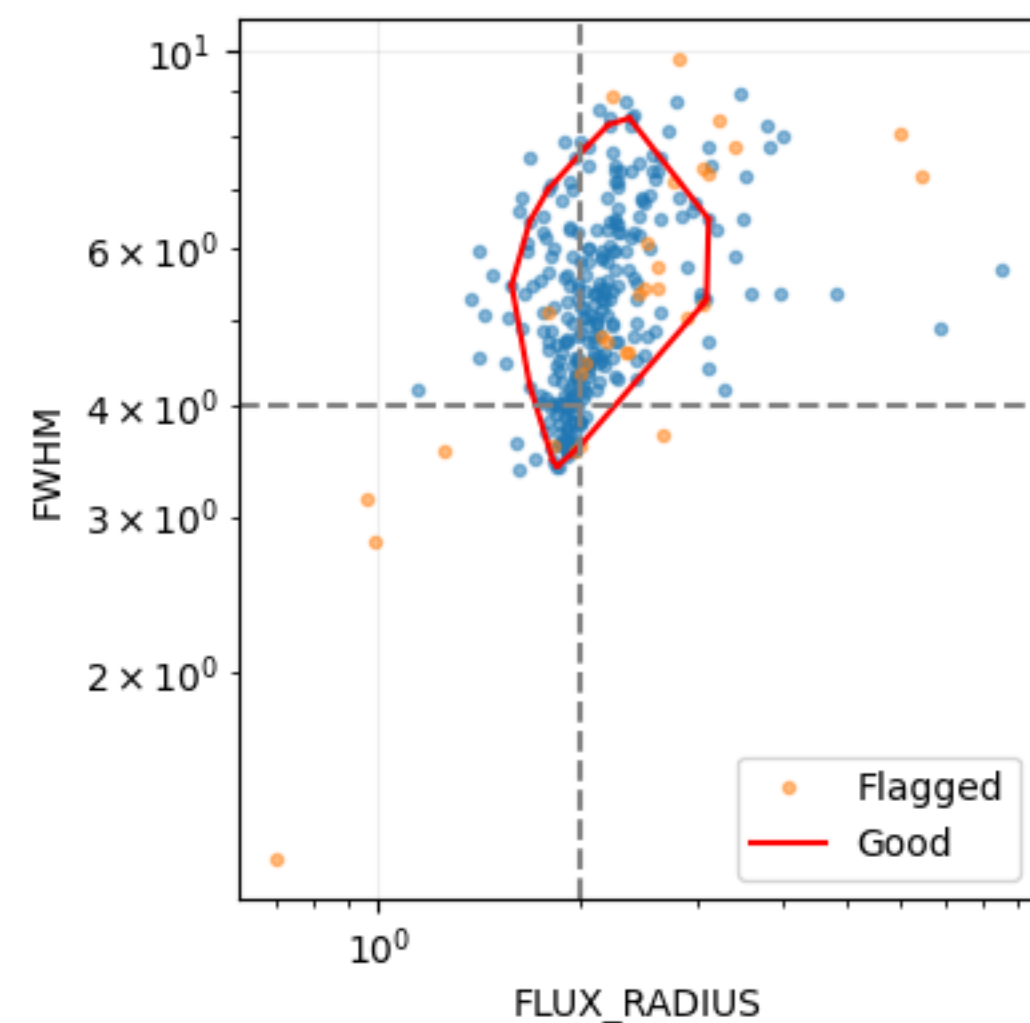
Catalogue stars closer than **2*FWHM** are merged
Centroids are positionally matched with candidates within **0.5*FWHM**

Outliers in shape parameter space are rejected, to exclude cosmic rays, hot pixels, extended objects, etc

Only candidates brighter than catalogue stars by this level will be kept.
If not set, all positional matches will be rejected.

Also, everything flagged (saturated / truncated / masked out) is rejected

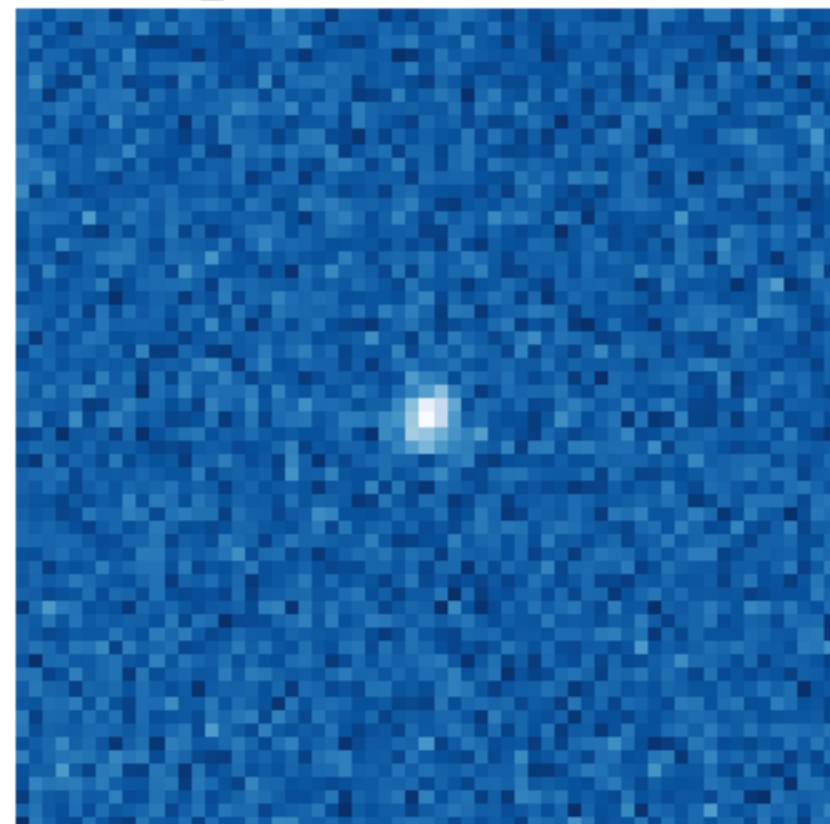
Simple shape classifier



Isolation forest outlier detection
314 objects
31 masked
259 good 55 outliers

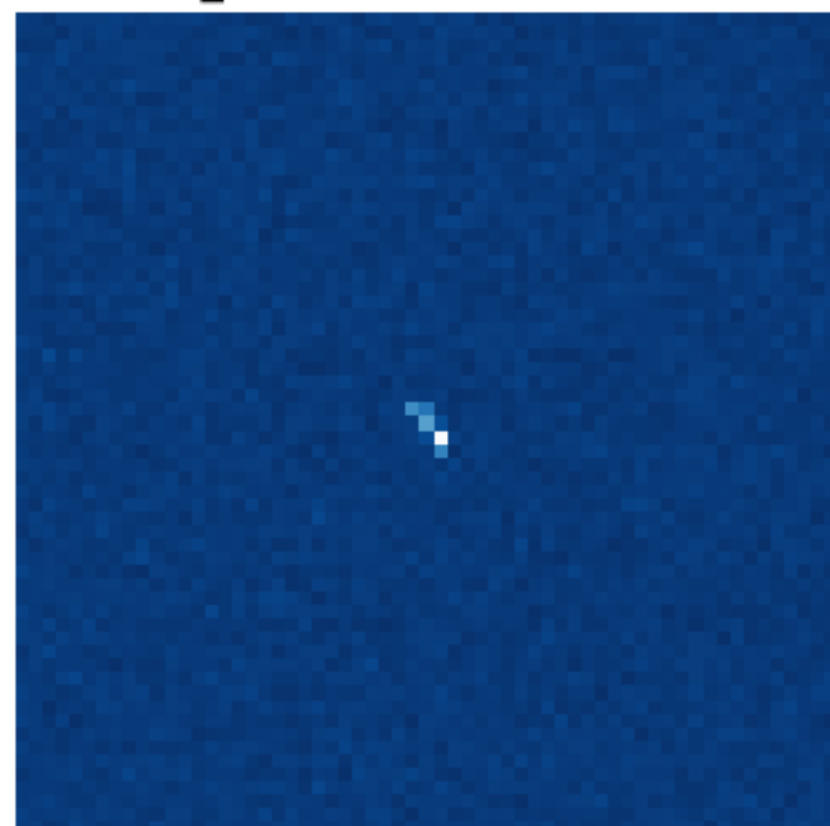
Simple shape classifier

FLUX_RADIUS=1.5 FWHM=3.3

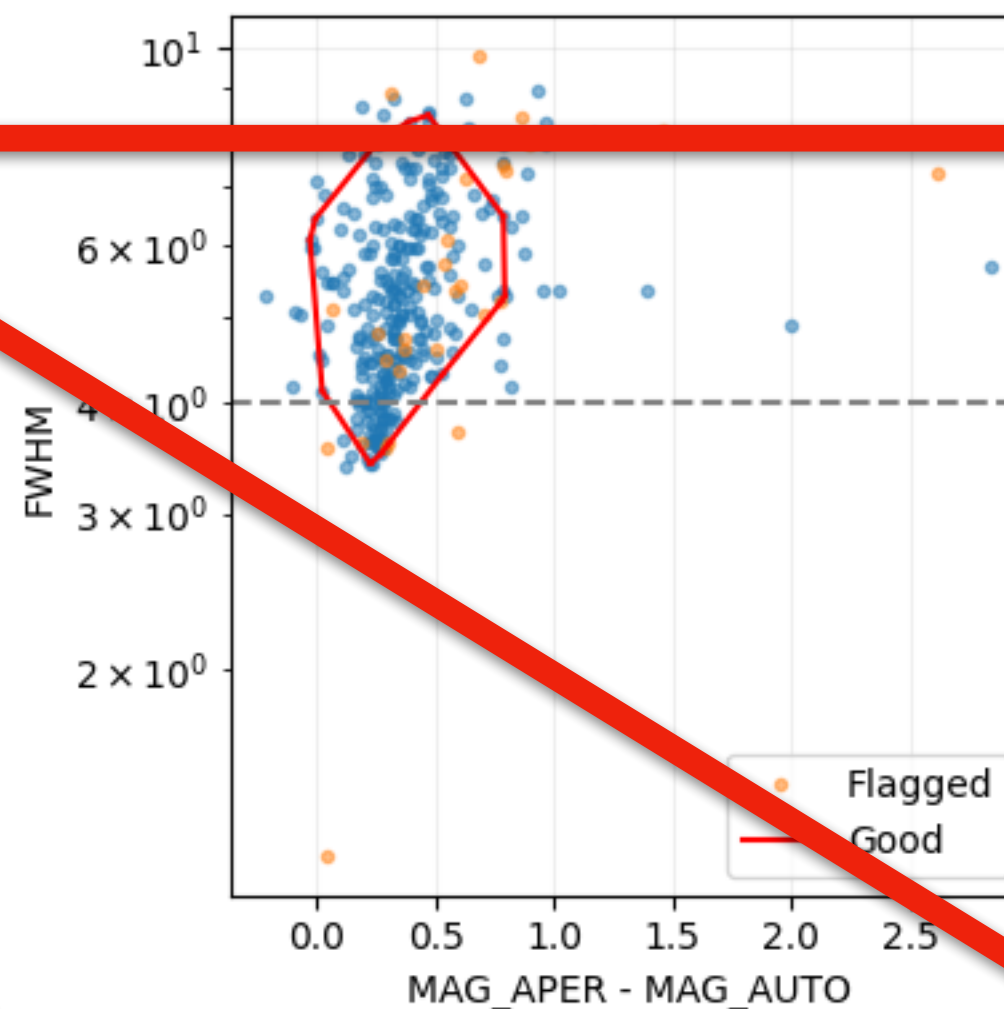
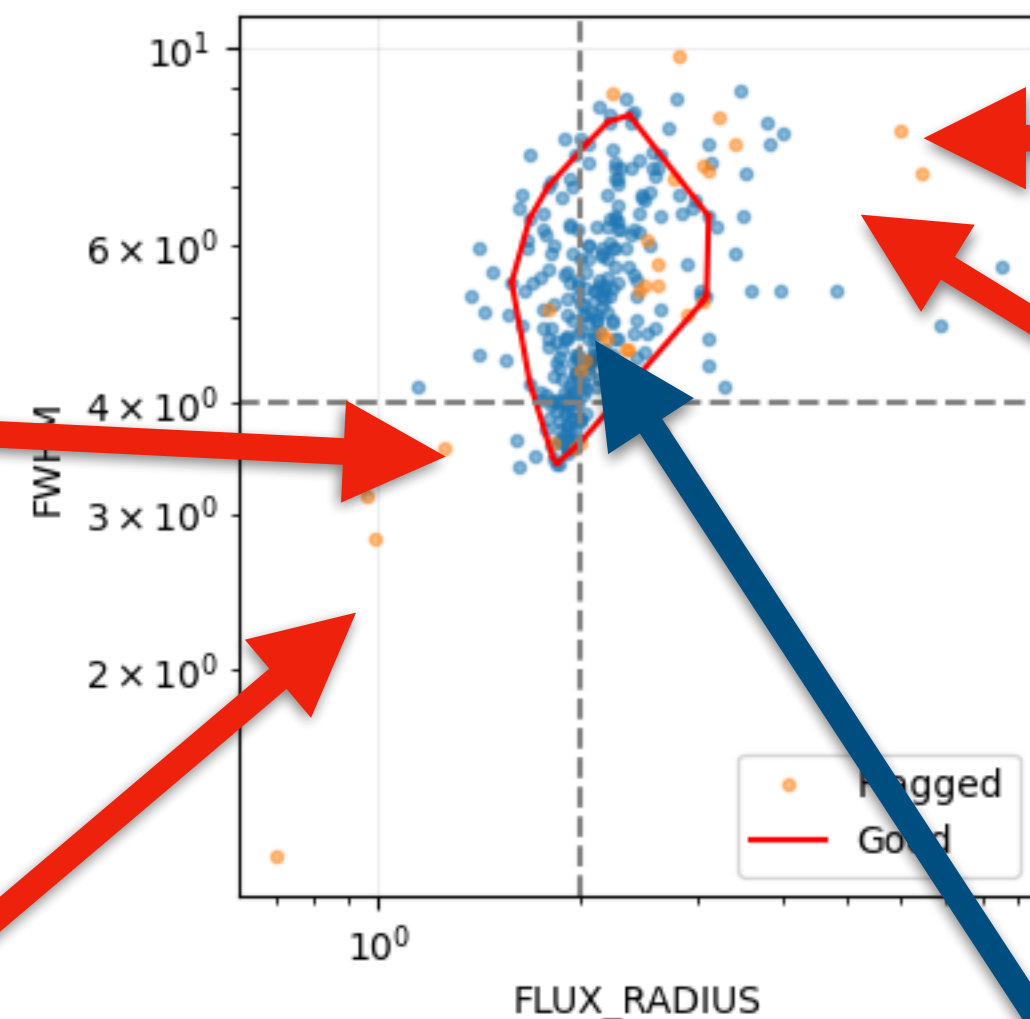


Atypical shapes

FLUX_RADIUS=1.0 FWHM=2.7

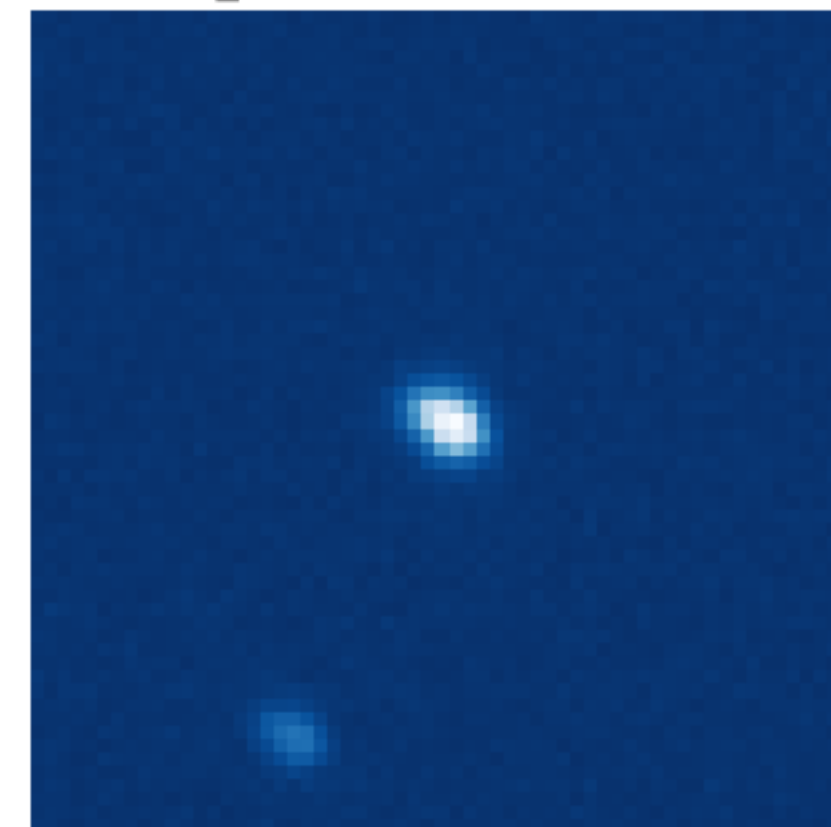


Cosmic rays



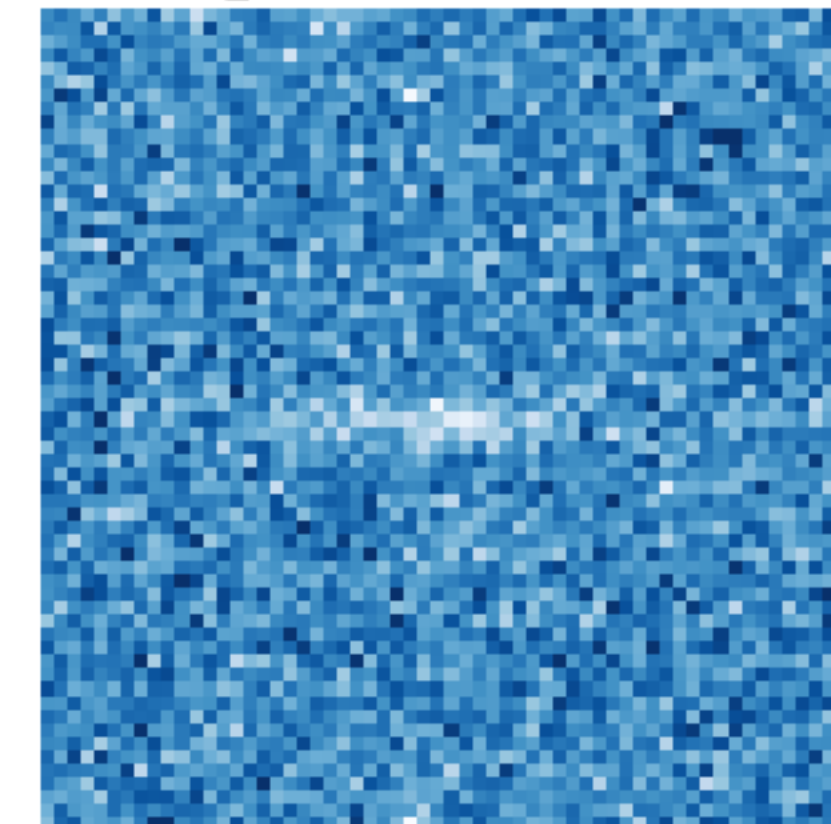
Isolation forest outlier detection
314 objects
31 masked
259 good 55 outliers

FLUX_RADIUS=1.9 FWHM=4.2



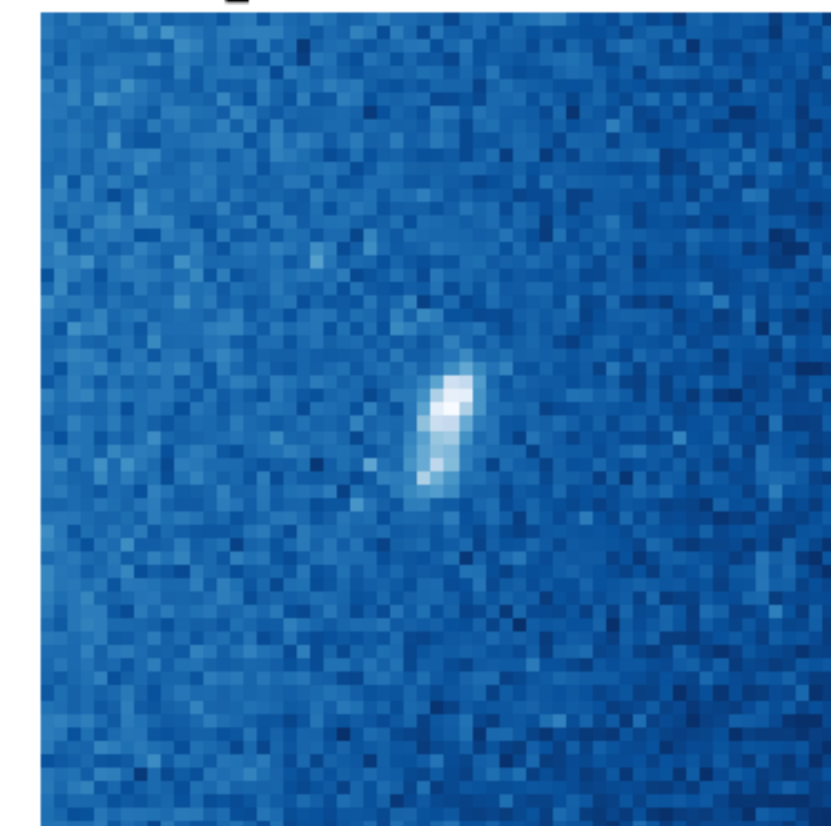
Typical stars

FLUX_RADIUS=7.3 FWHM=9.2



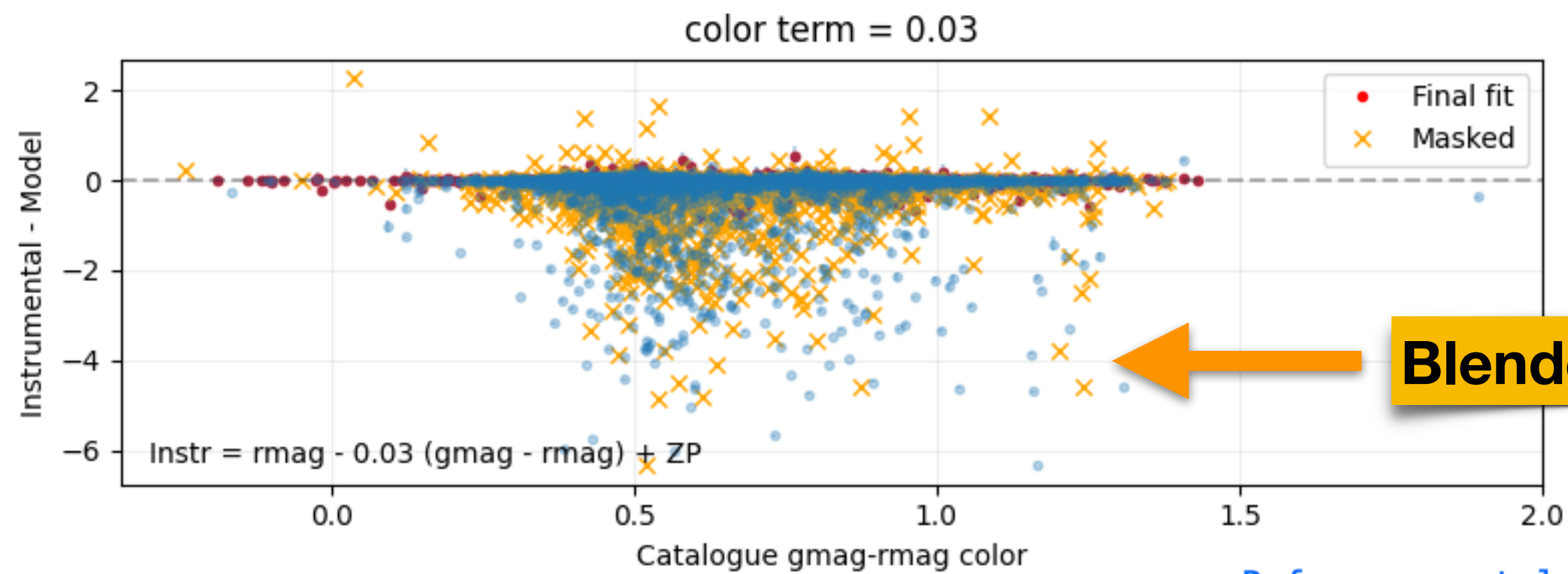
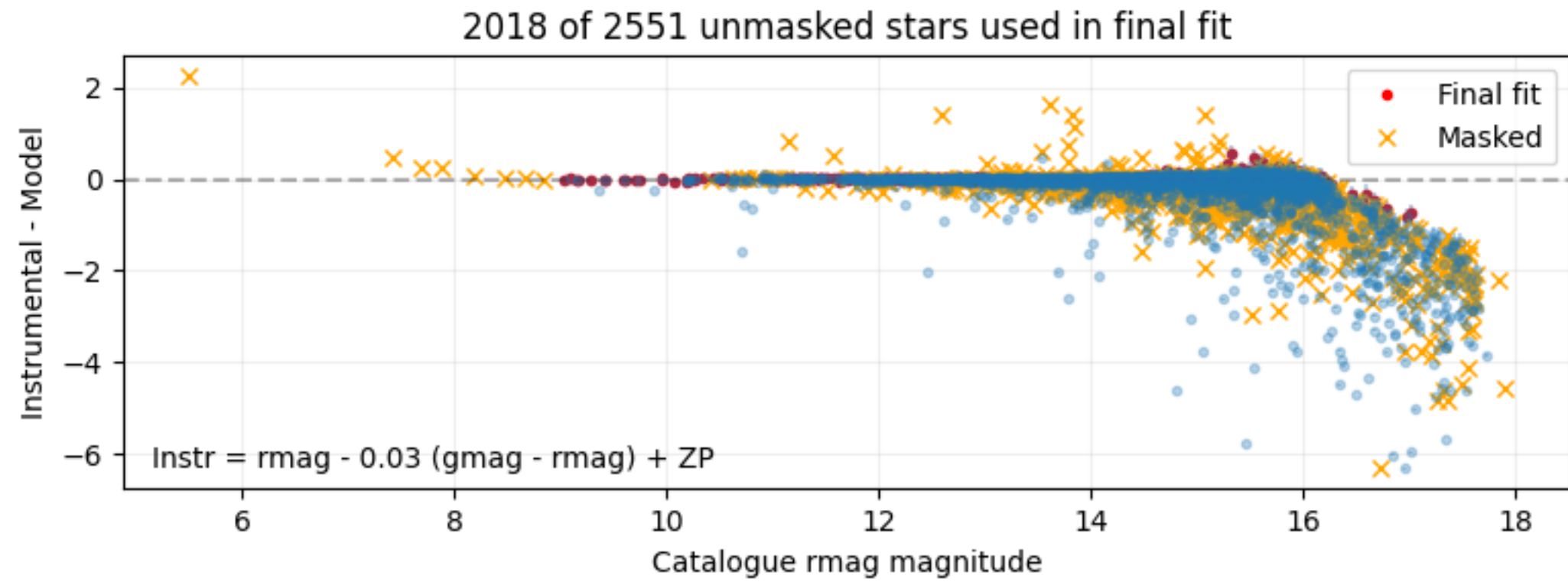
Extended artefacts

FLUX_RADIUS=5.2 FWHM=7.5



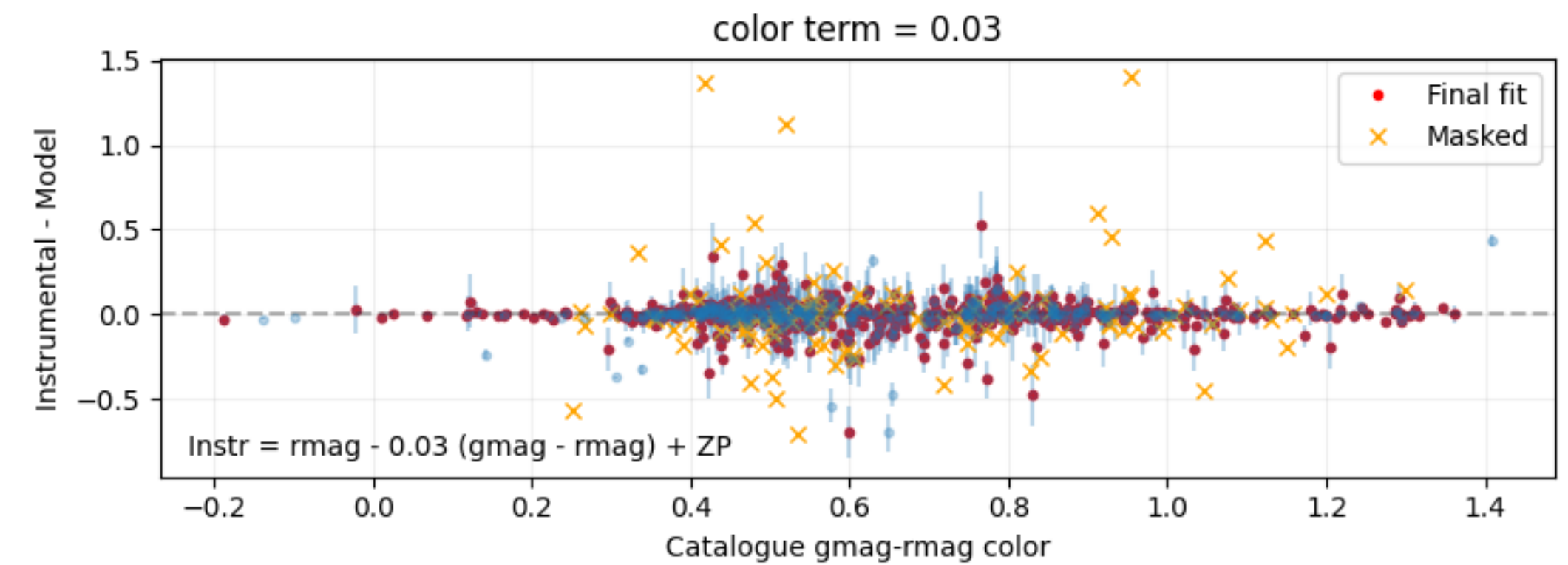
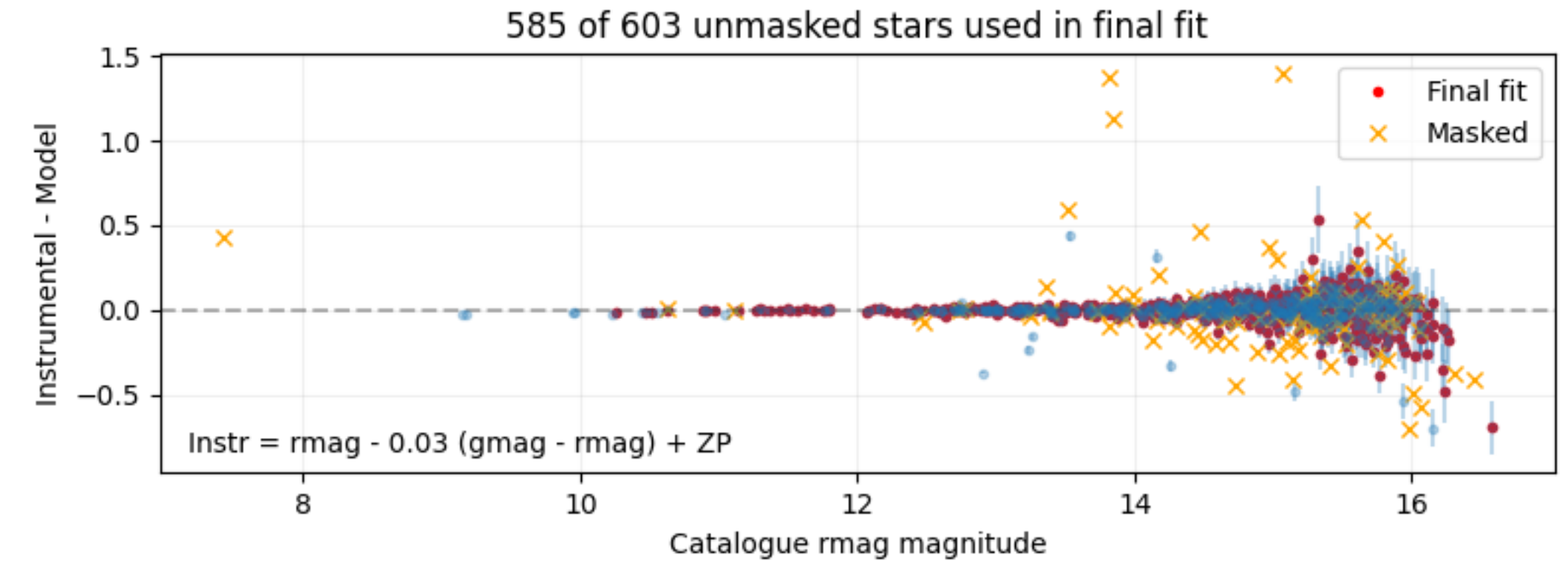
Blends

Blend filtering



Blended stars

----- Reference catalogue -----



Field center is at 286.639 28.756, radius 0.67 deg, scale 3.31 arcsec/pix
 Requesting from Vizier: I/360/syntphot columns: ['*', 'RAJ2000', 'DEJ2000',
 'e_RAJ2000', 'e_DEJ2000', '**', '_RAJ2000', '_DEJ2000']
 Center: 286.633 28.759 radius: 0.687
 Filters: {'rmag': '<18.0'}

Got 20807 entries with 59 columns
 Converting the catalogue Sloan magnitudes to Pan-STARRS ones
 Got 20807 catalogue stars from gaiadr3syn
 Catalogue written to [cat.vot](#)
 4379 catalogue stars after blend filtering with 10.8 arcsec radius
 Will use catalogue column rmag as primary magnitude
 Will use catalogue columns gmag and rmag for color

On photometric calibration stage, catalogue stars closer than **2*FWHM** to each other are excluded from the matching which is done with **0.5*FWHM** radius

Blend filtering

---- Simple catalogue-based transient detection ----

Will check Vizier catalogues: gaiaedr3 ps1
Will only keep matches brighter than catalogue by 2.00 mags
Candidate filtering routine started with 3263 initial candidates and 5.4 arcsec matching radius
3070 of them are unflagged
8 remains after matching with Gaia EDR3
5 remains after matching with PanSTARRS DR1
5 candidates remaining after filtering

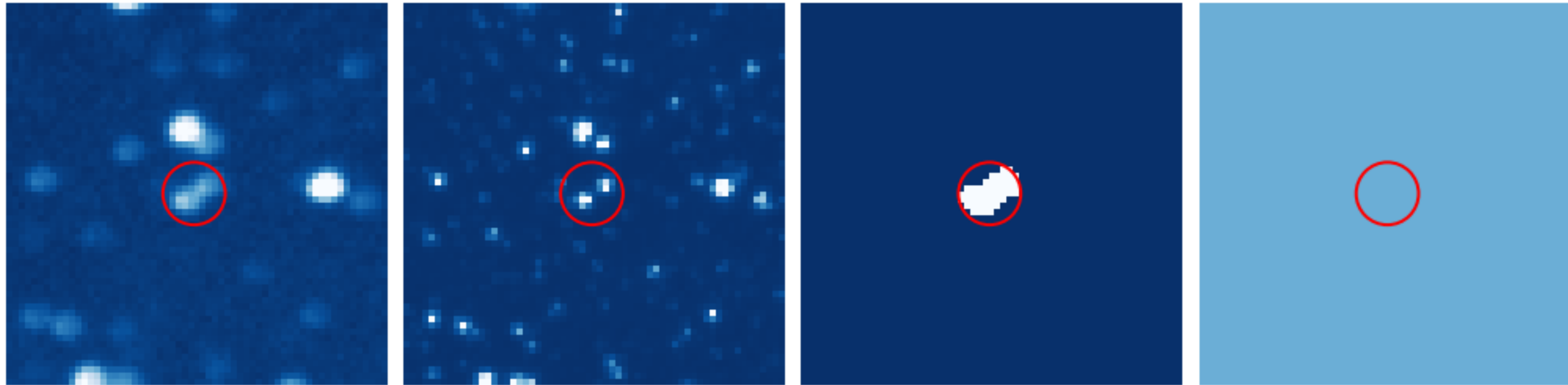
Blend filtering routine started with 5 initial candidates, 21.5 arcsec blending radius and 5.4 arcsec matching radius
0 remains after matching blends with Gaia EDR3

On transient detection stage catalogue stars closer than **2*FWHM** to each other are merged together. Their centroid positions are positionally matched with candidates within **0.5*FWHM**. Candidates matched with these blends are removed if their brightness is not significantly brighter than expected blend magnitude.

IMAGE

J190435.43+285416.6 : mag = 13.65 ± 0.03
TEMPLATE FOOTPRINT

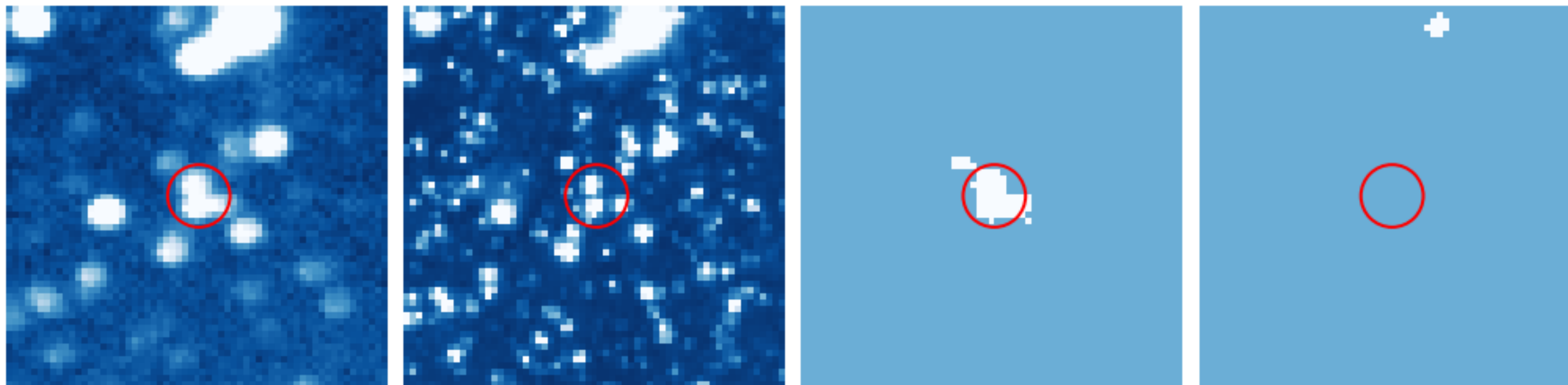
MASK



IMAGE

J190556.34+282655.8 : mag = 13.85 ± 0.03
TEMPLATE FOOTPRINT

MASK



IMAGE

J190606.75+282351.9 : mag = 14.51 ± 0.06
TEMPLATE FOOTPRINT

MASK

