The First *Swift*/UVOT Serendipitous Source Catalogue

R. P. Mignani

On behalf of the UVOT team:

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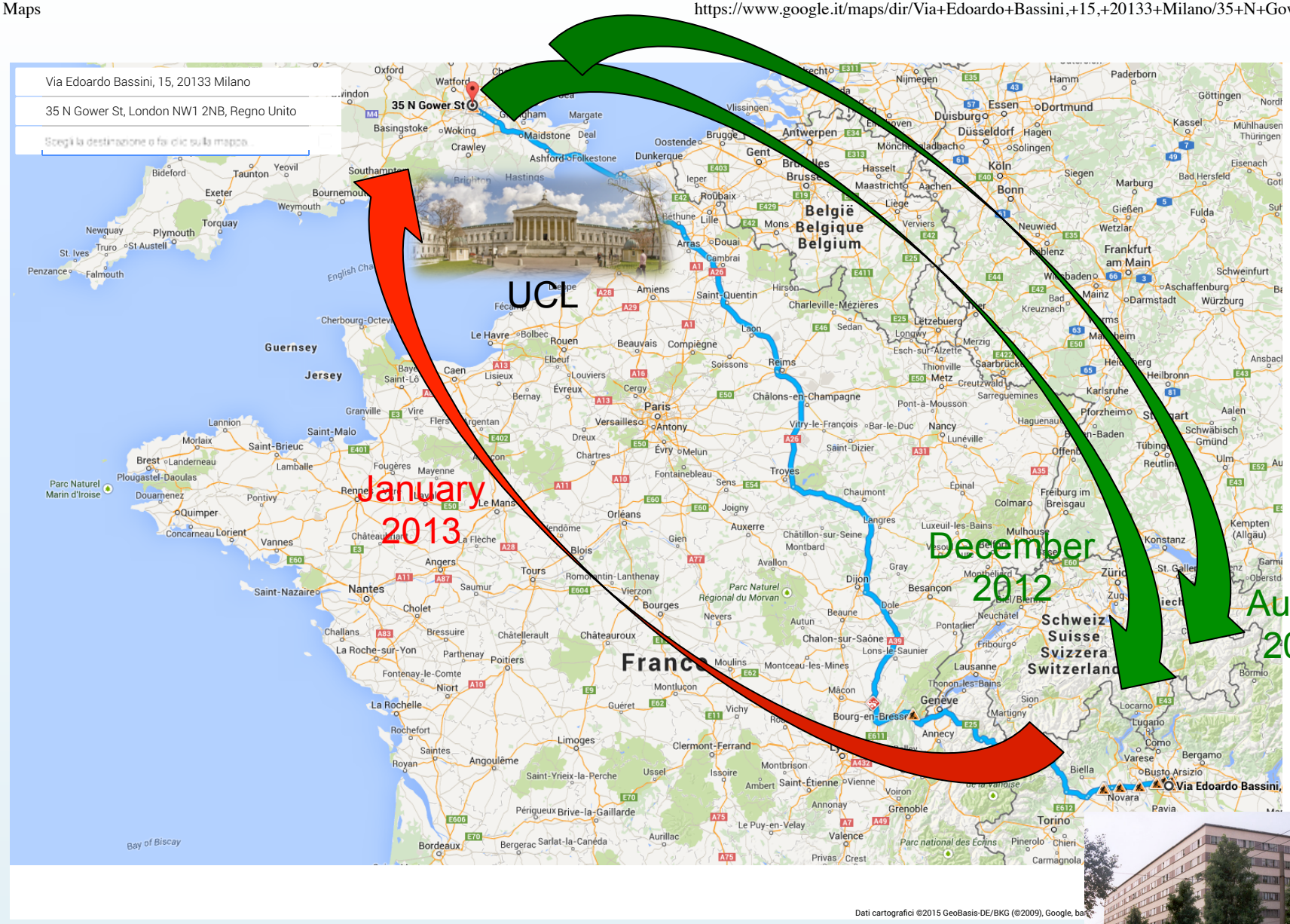
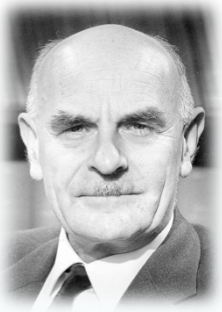
MNRAS 2013, 434, 1955


Via Edoardo Bassini, 15, 20133 Milano
35 N Gower St, London NW1 2NB, Regno Unito
Scegli la destinazione o fai clic sulla mappa
UCL
January 2013
December 2012
August 2013
Via Edoardo Bassini,
Dati cartografici ©2015 GeoBasis-DE/BKG (©2009), Google, ba

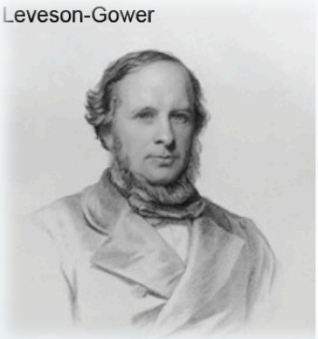
INAF/IASF

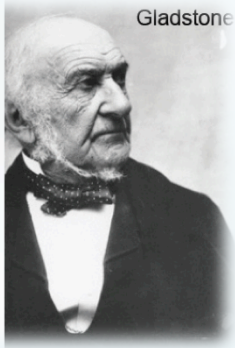
Mullard Space Science Laboratory
University College London



Sir Harrie Massey
(1908-1983)

- Established 1966 in Holmbury St. Mary (Surrey) in the Holmbury House grounds (30 acres) on Holmbury Hill – 857 feet (4th highest point in Surrey)
- First settlement dates back to Iron age (1000-500 BC)





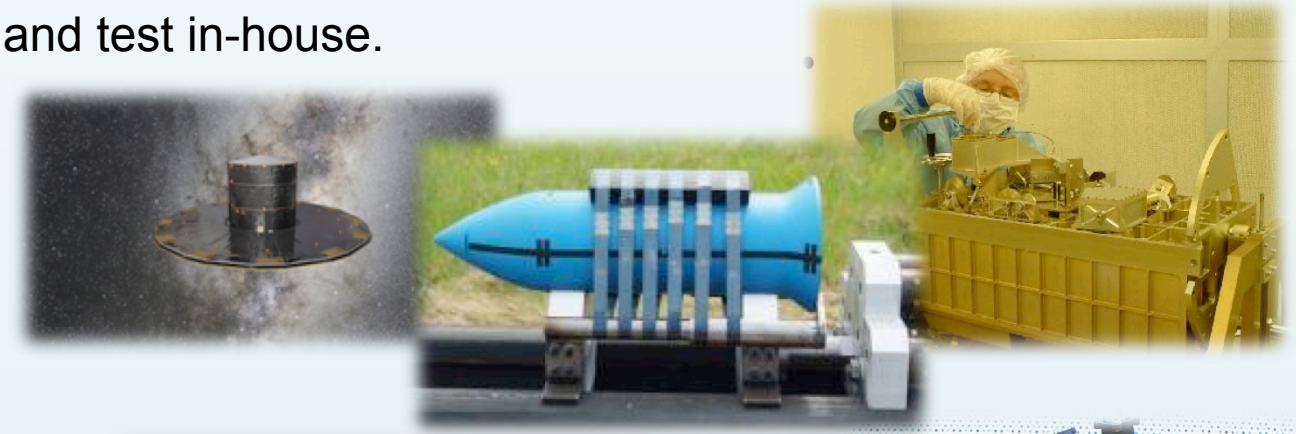
- Built on 1870 for Hon. Fredrick Leveson-Gower on the remains of an old farm house (“The Deacon” 1367)
- Sold to Sir. James Stevenson in 1919 – joint manager director of Johnnie Walker
- Sold to Arthur Ernest Guinnes
- 1940-1950: 13th Maharaja of Boroda
- 1950-1965: Salmon’s Cross School
- 1965: Donated to UCL by Mullard Ltd

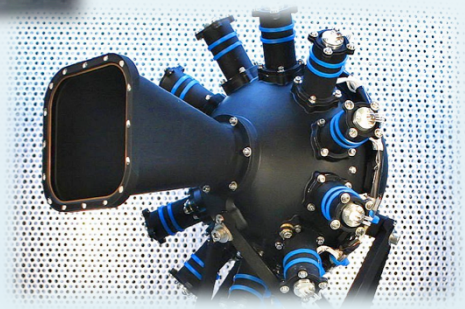
Mullard Space Science Laboratory
University College London

- UK's largest university space group.
- Over **35** satellite missions. Over **200** rocket experiments.
- Gaia, Euclid Plato, Herschel, XMM, Swift …..
- Scientists, mechanical and electronic designers, engineers, technicians.
- Capability to design, build and test in-house.

Science areas:

- Astrophysics
- Solar Physics
- Space Plasmas
- Planetary Science
- Earth observations
- Instrument/Detector Science

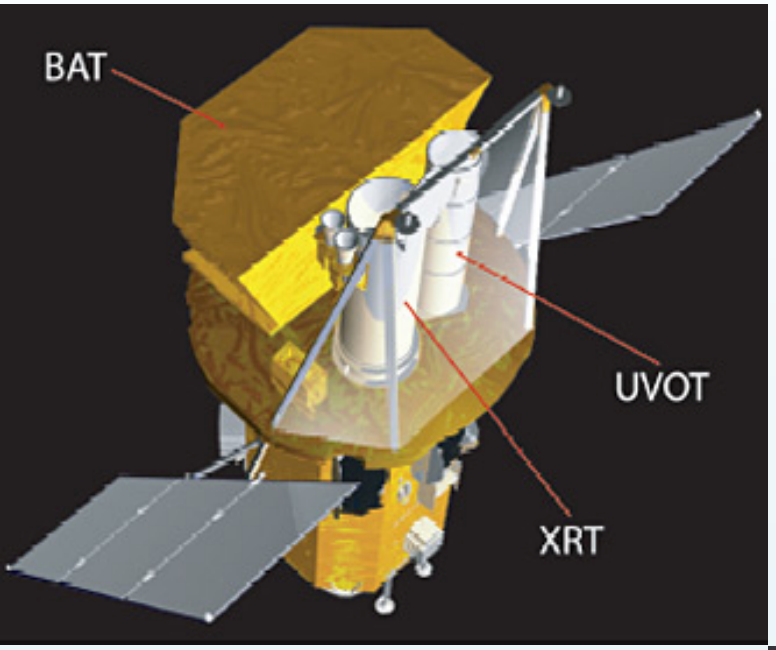


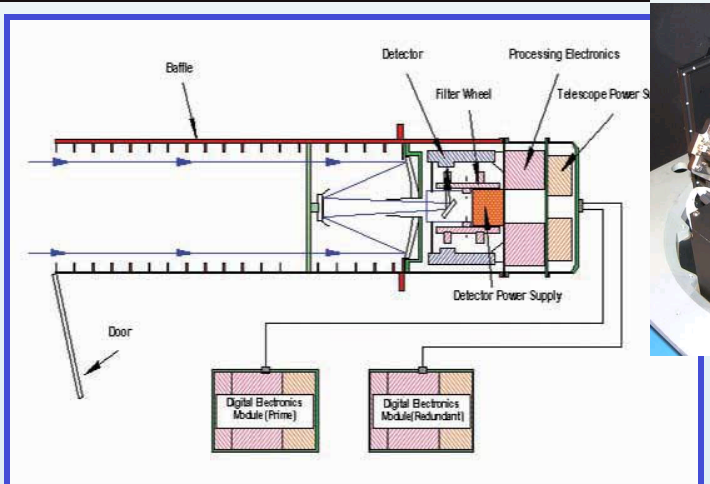


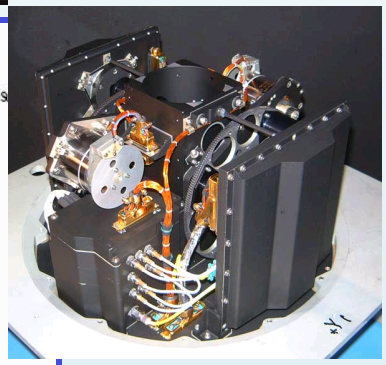
In-house engineering and electronic capabilities

Swift/UV-Optical Telescope (UVOT) (2004-)

But also **Optical Monitor Camera** (OMC) on Integral and **Optical Monitor** (OM) on XMM



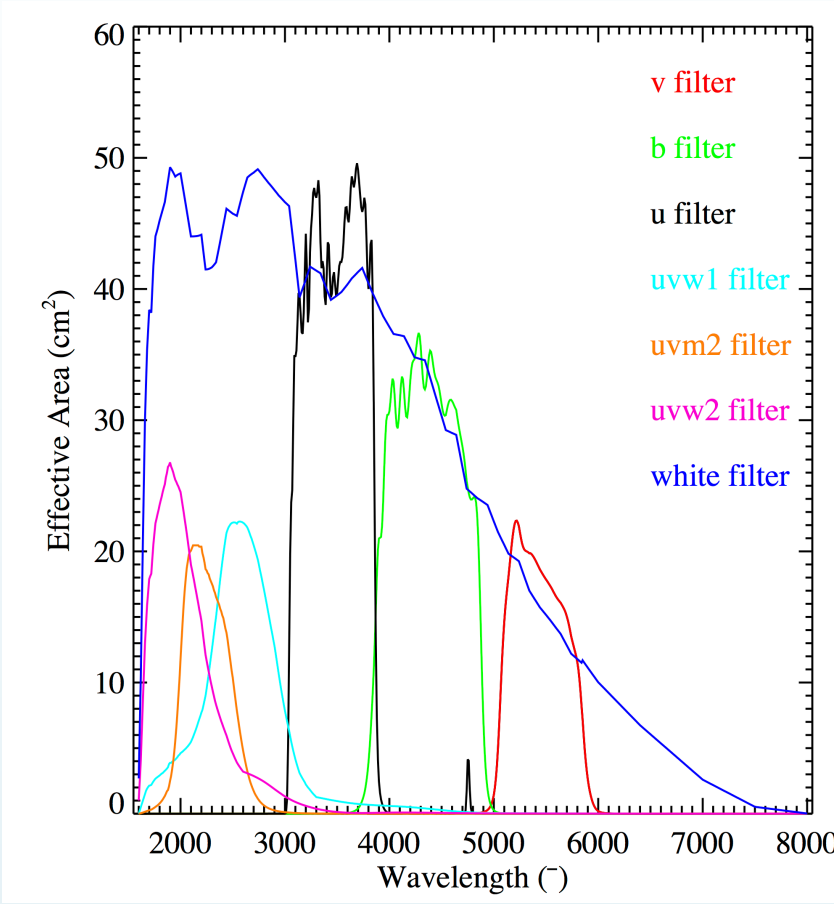




- diam: **30 cm**
- f/12.7 --> 3.8m focal length
- **170-650nm** (optical-UV)
- U, B, V, UVW1, UVM2, UVW2
- UV and optical grisms
- field of view: **17x17 arcmin**
- pixel size: **0.5 arcsec**
- sensitivity: **B=24.7** (1 hr, 5σ)
- ~4m ground-based telescope

The UVOT Serendipitous Source Catalogue

- A catalogue of UV sources observed serendipitously* during UVOT images
- A 5-year project led by MSSL on behalf of the UVOT team.
- A uniform product in terms of astrometry, photometry, and morphological properties.
- An easy route for astronomers to obtain UVOT-derived source parameters without having to analyse UVOT data.



*Strictly speaking, not all of the sources are serendipitous, because the targets of the observations are included in the catalogue.

- GSC2 – Guide Star Catalogue 2 (1998-2000)
  Lasker et al., 2008 AJ, 136,735

- ESO Imaging Survey (2000-2002)
  Momany et al., 2001, A&A, 379, 436
  Arnouts et al., 2001, A&A, 379, 740
  Vandame et al., 2001, arXiv:0102300
  Hatziminaoglou et al., 2002, A&A, 384, 81
  Groenewegen et al., 2002, A&A, 392, 741

- XMM-Serendipitous Ultraviolet Source Survey Catalogue (2010-2012)
  Page et al., 2012, MNRAS, 426, 903

- FORS Instrument Operation Scientist (2002-2006)

How was it made?

- We took all the UVOT images taken by Swift between 2005 and 2010.
- A complete processing pipeline was constructed:
  - Running from raw data to the complete catalogue.
  - Drawing on our experience with the XMM-OM Serendipitous Ultraviolet Source Survey (XMM-SUSS*).
  - Based around the standard UVOT ftools available in HEASOFT.
  - Using the latest calibration data currently available.

* Page et al. 2012, MNRAS, 426, 903

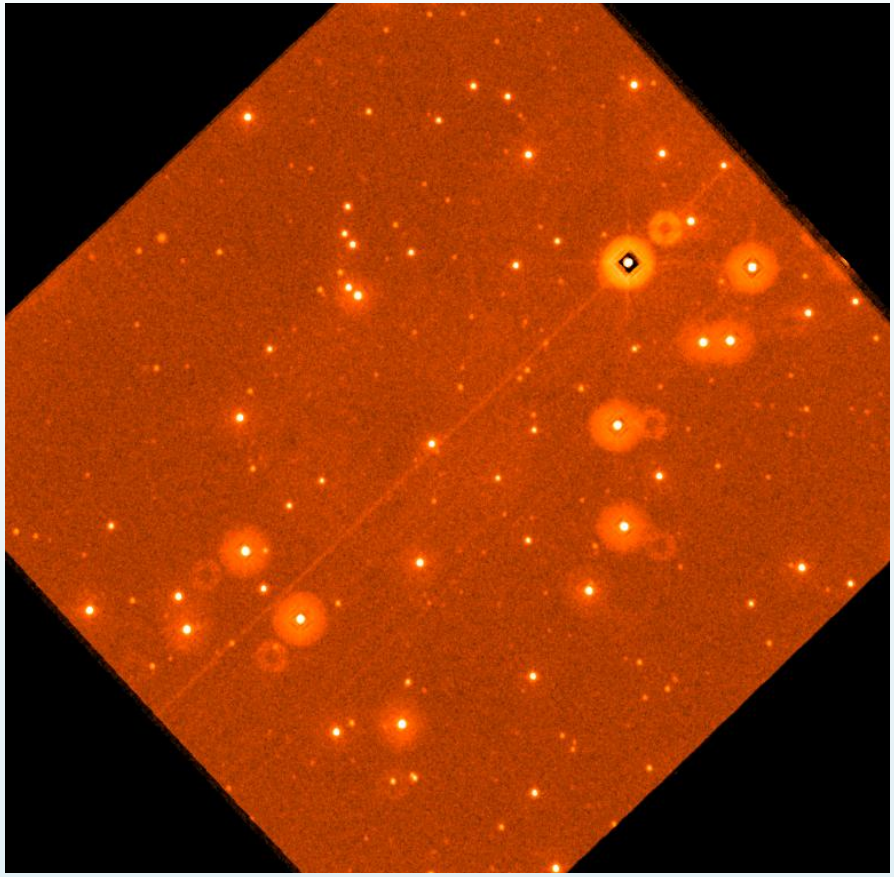
Challenges

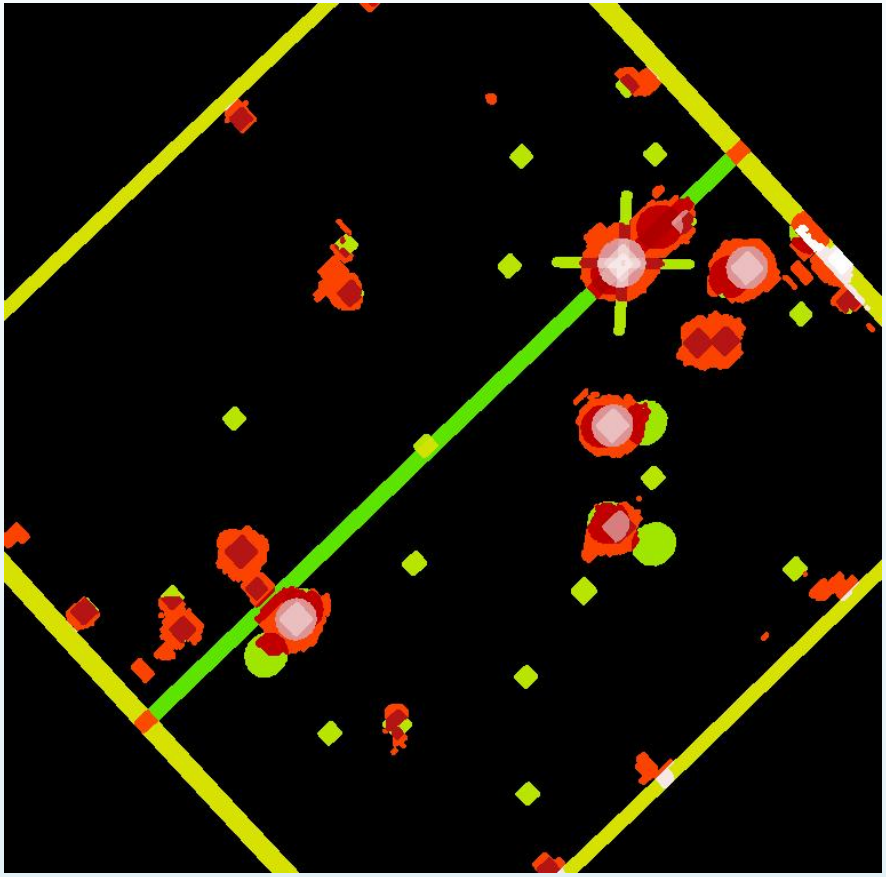
- Terabytes of data to process.
- Large dynamic range of the images:
  - images with almost zero background to images with thousands of counts per pixel in the background.
- Complex, structured backgrounds around nebulae and galaxies.
- Millions of sources.
- Non-linearity of the detector (co-incidence loss) in bright sources.
- Artefacts related to bright sources.

Reduction Steps

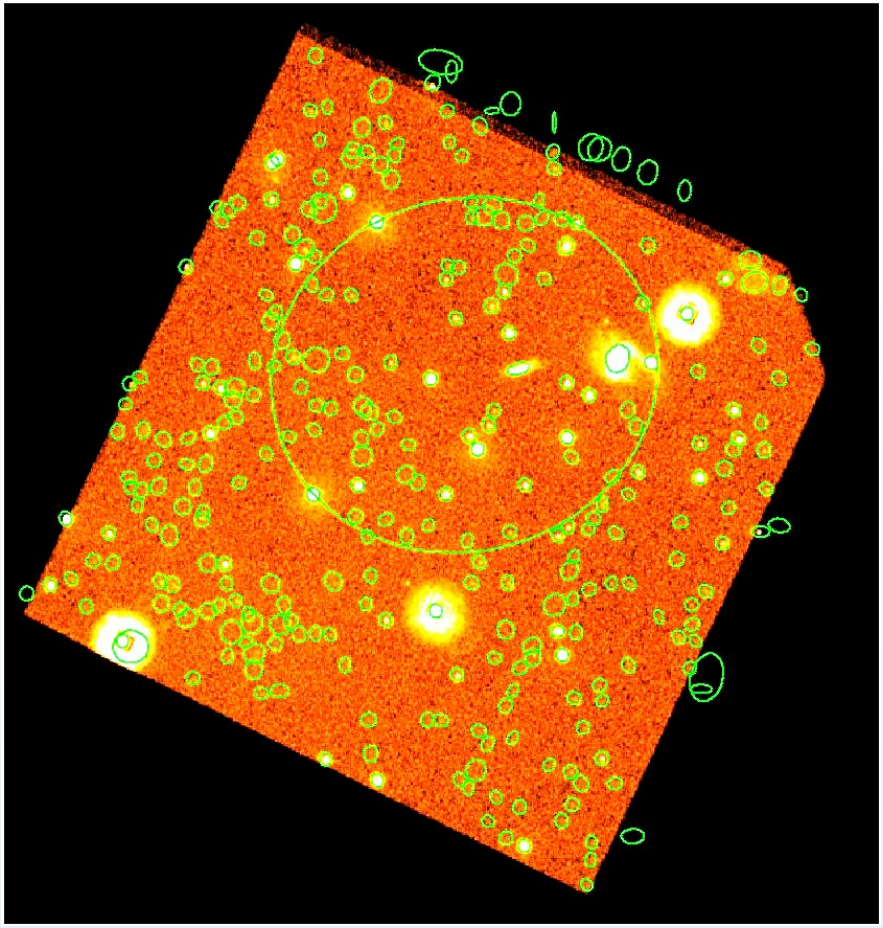
- Stage-1: Reduce the Mod-8 noise pattern; generate a quality map
- Stage-2: Sky-rotation and aspect correction
- Stage-3: Stack different exposure images to a single image
- Stage-4: Source detection (main task: customised *uvotdetect*)
- Stage-5: Build individual source catalogues for different observations
- Stage-6: Merge individual catalogues into a single catalogue
- Stage-7: Sort the catalogue by RA
- Stage-8: Remove low-significance sources
- Stage-9: Identify repeated sources and assign individual source numbers

- Algorithms were written to identify and/or predict read-out streaks, smoke rings, wings of bright sources, sources with large co-I loss, diffraction spikes, etc.
- Artefacts are tracked through to detected sources using “quality maps”.
- Propagate to “quality flags” in final catalogue so you know how reliable each source is.



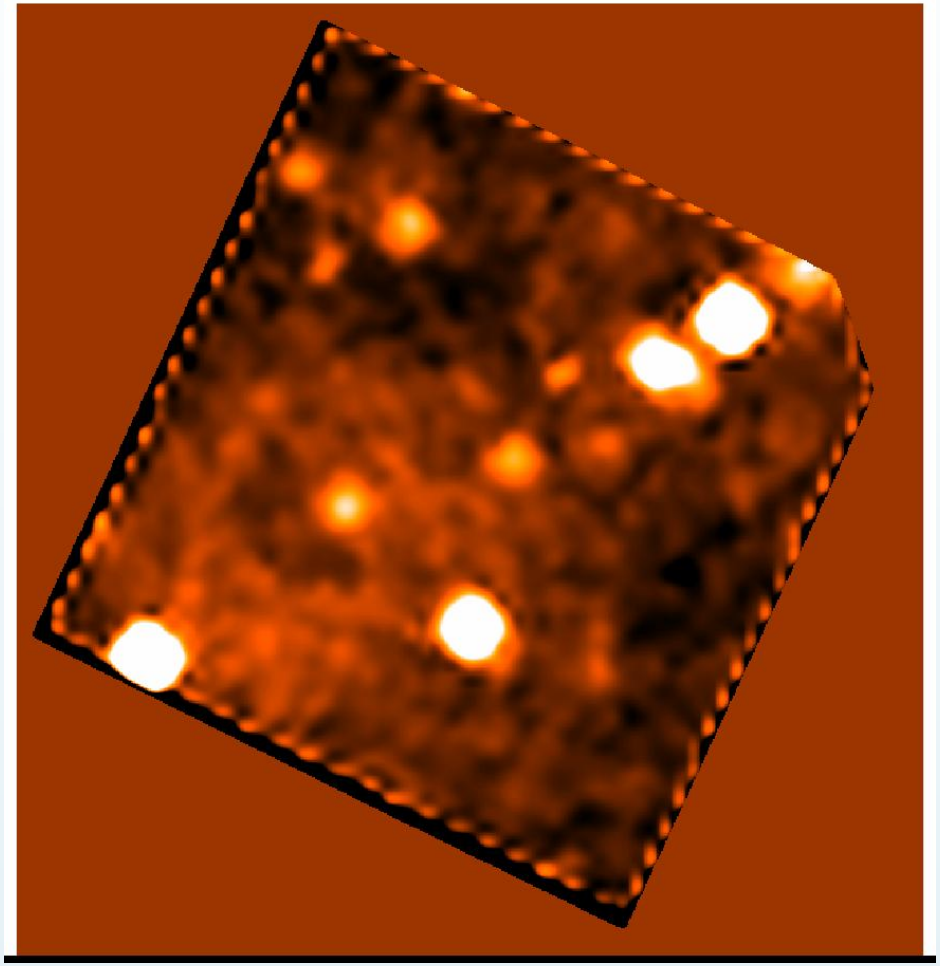


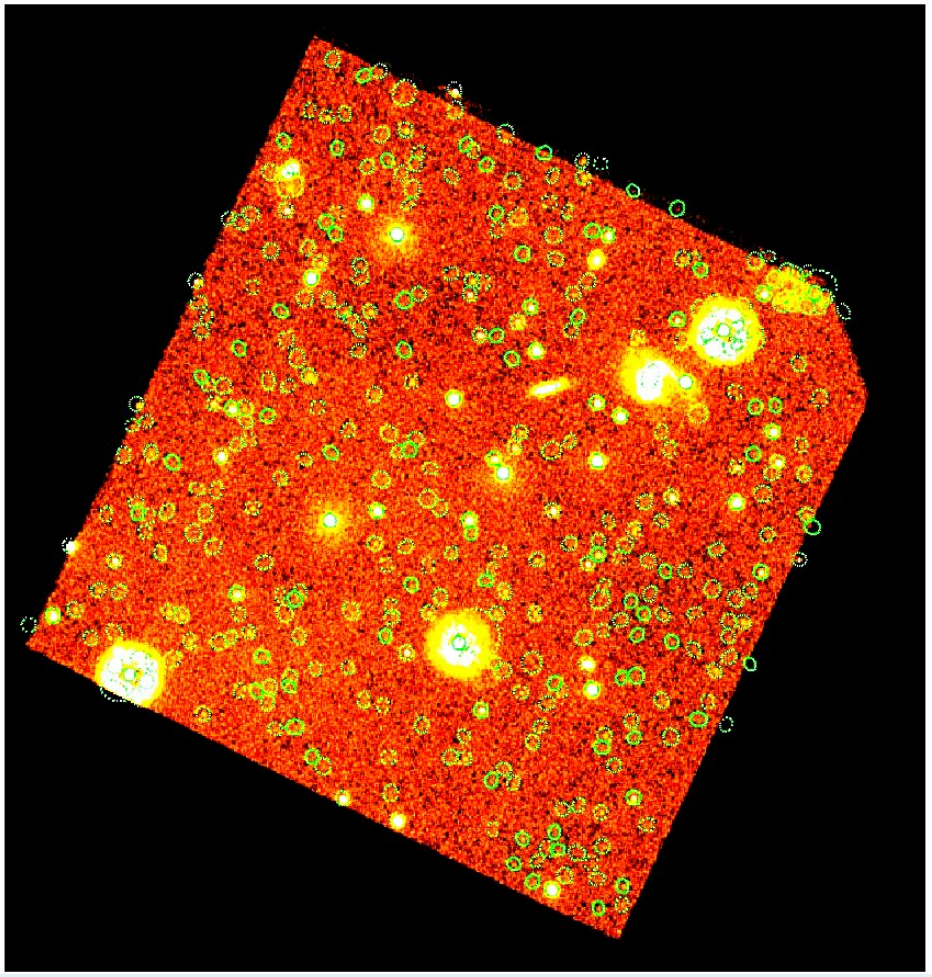
Customisation of the source detection routine



SExtractor in uvotdetect extrapolates the background and background-sigma maps outside of the limits of the sky-rotated image

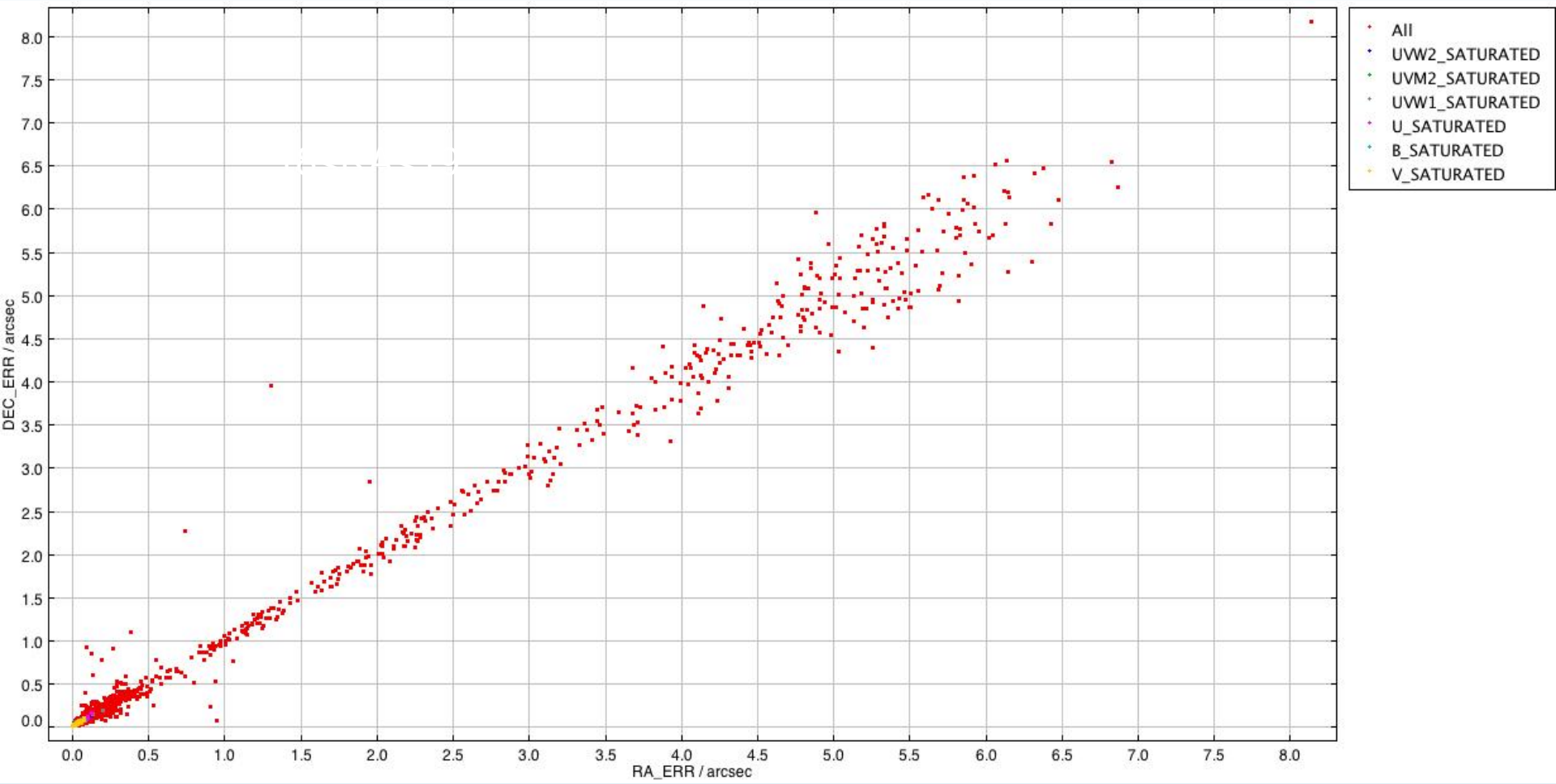
Customisation of the source detection routine





The background-sigma map is truncated by using the exposure map and is passed as an input file to the second call of SExtractor in the customised uvotdetect task

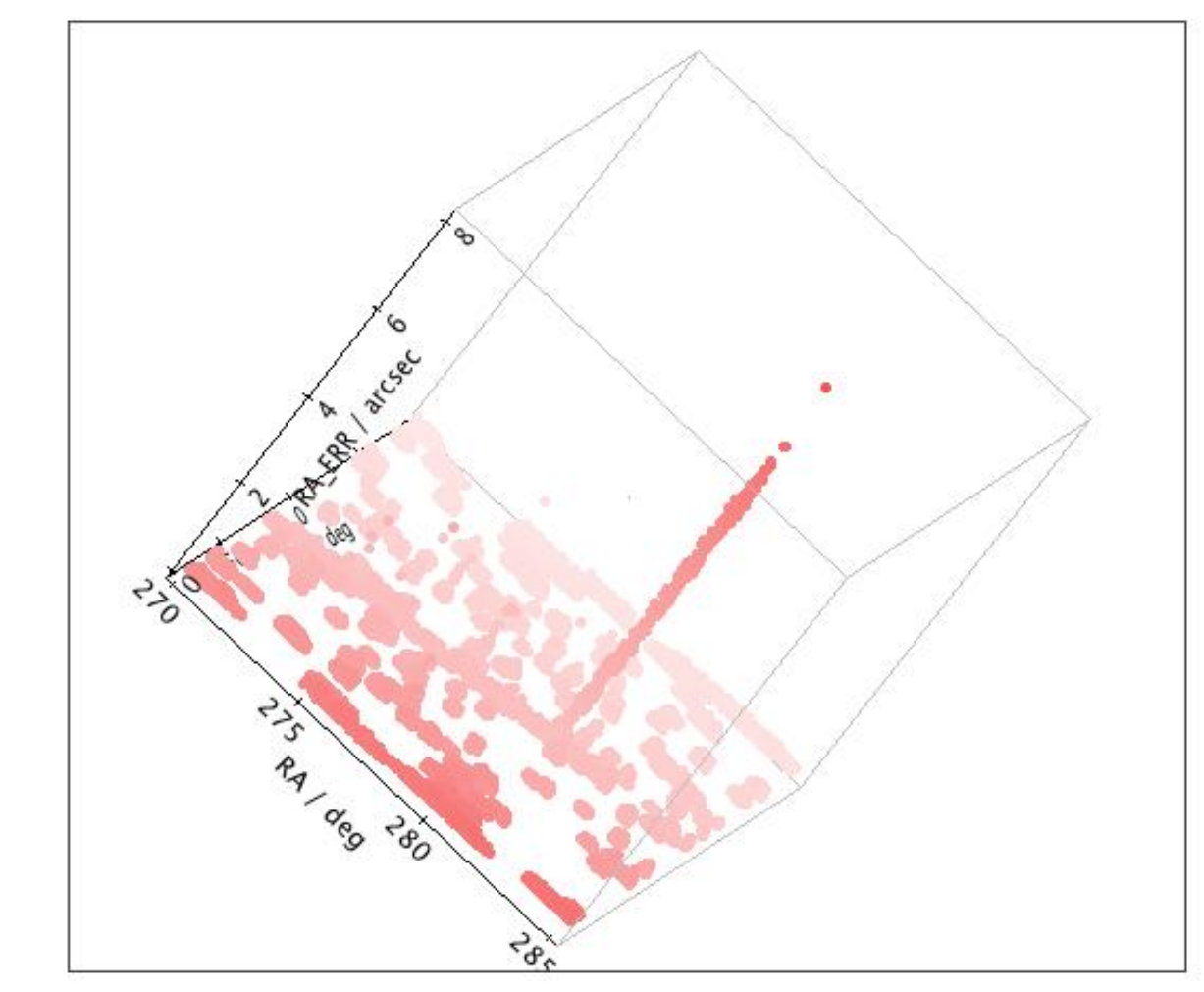
Astrometry: dec_err vs ra_err



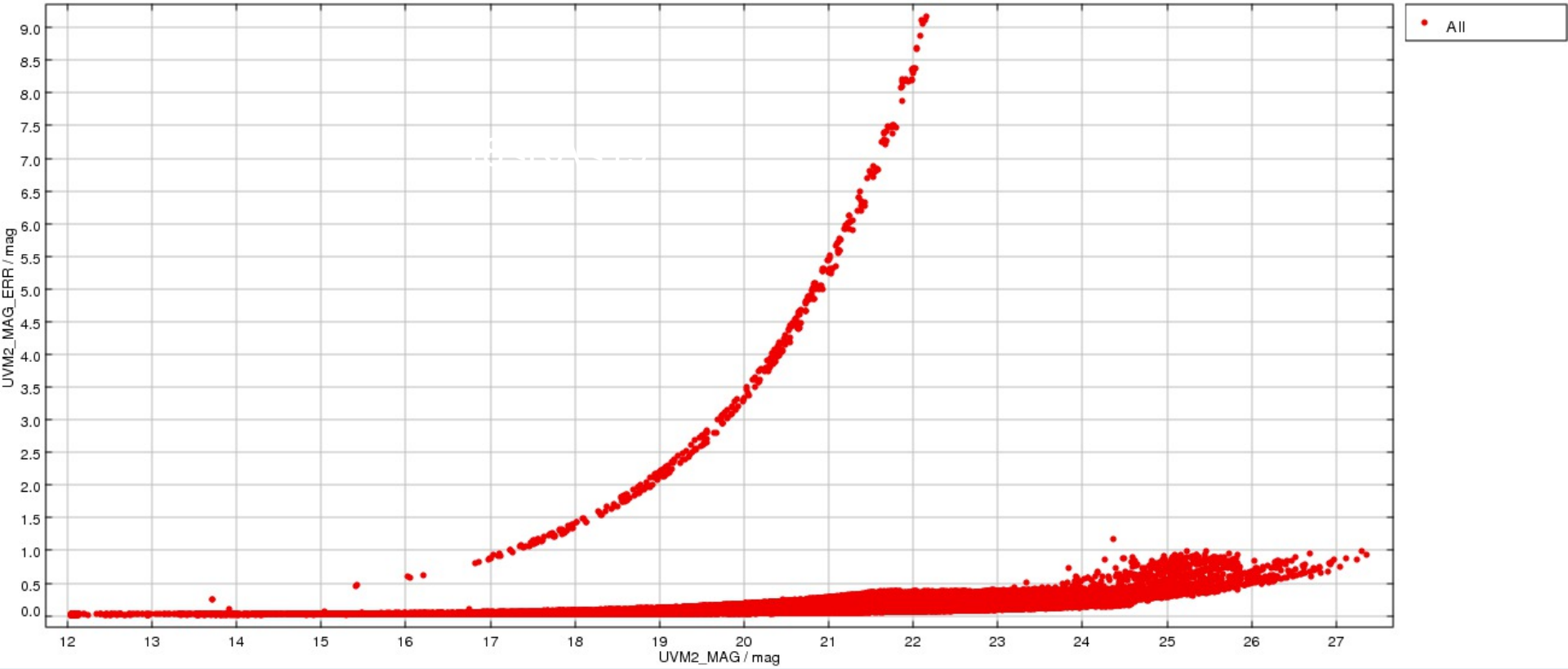
Astrometry: ra_err vs ra dec

OBSID

00030988074
00030988061

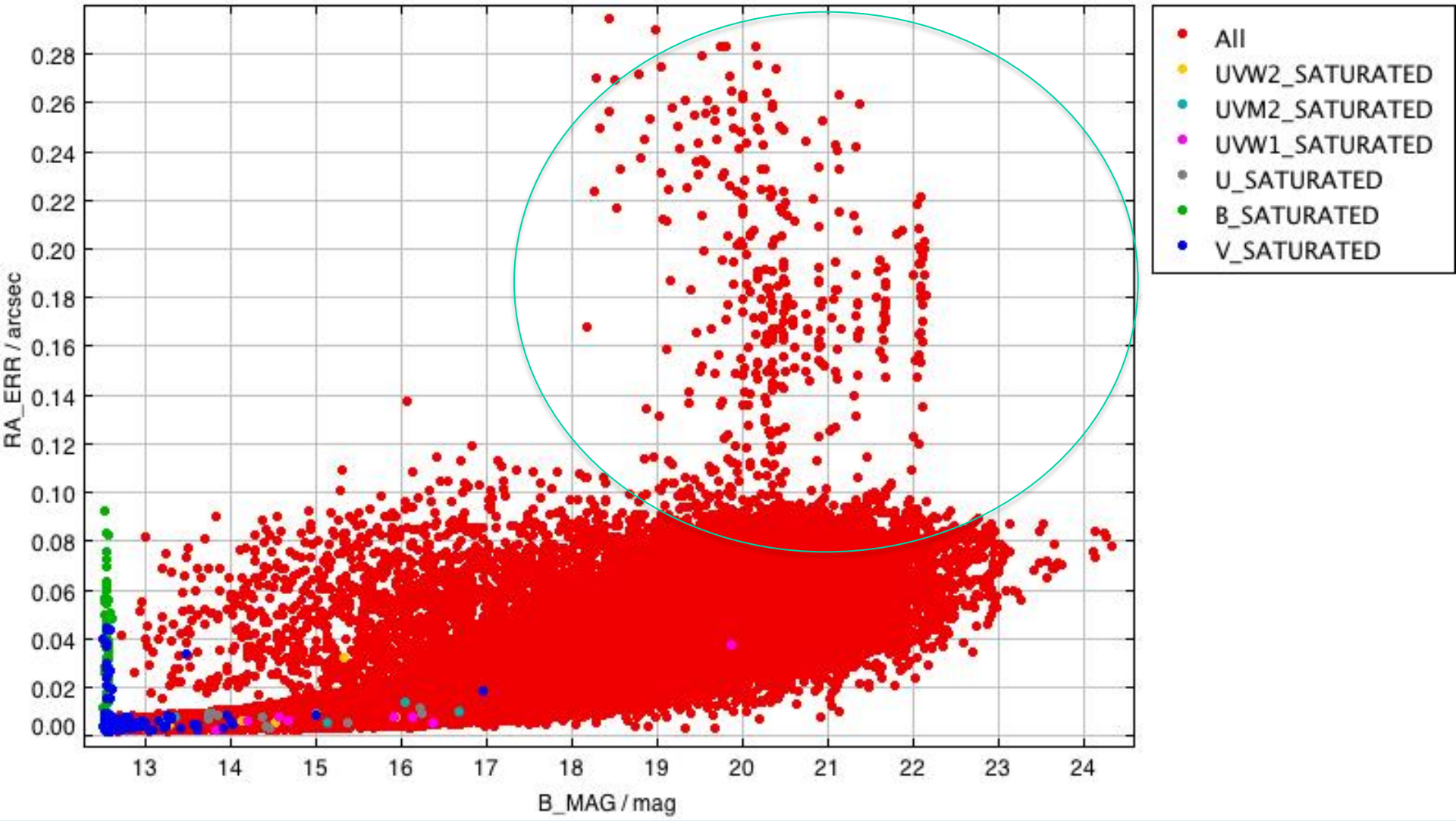


Photometry: mag_err vs mag

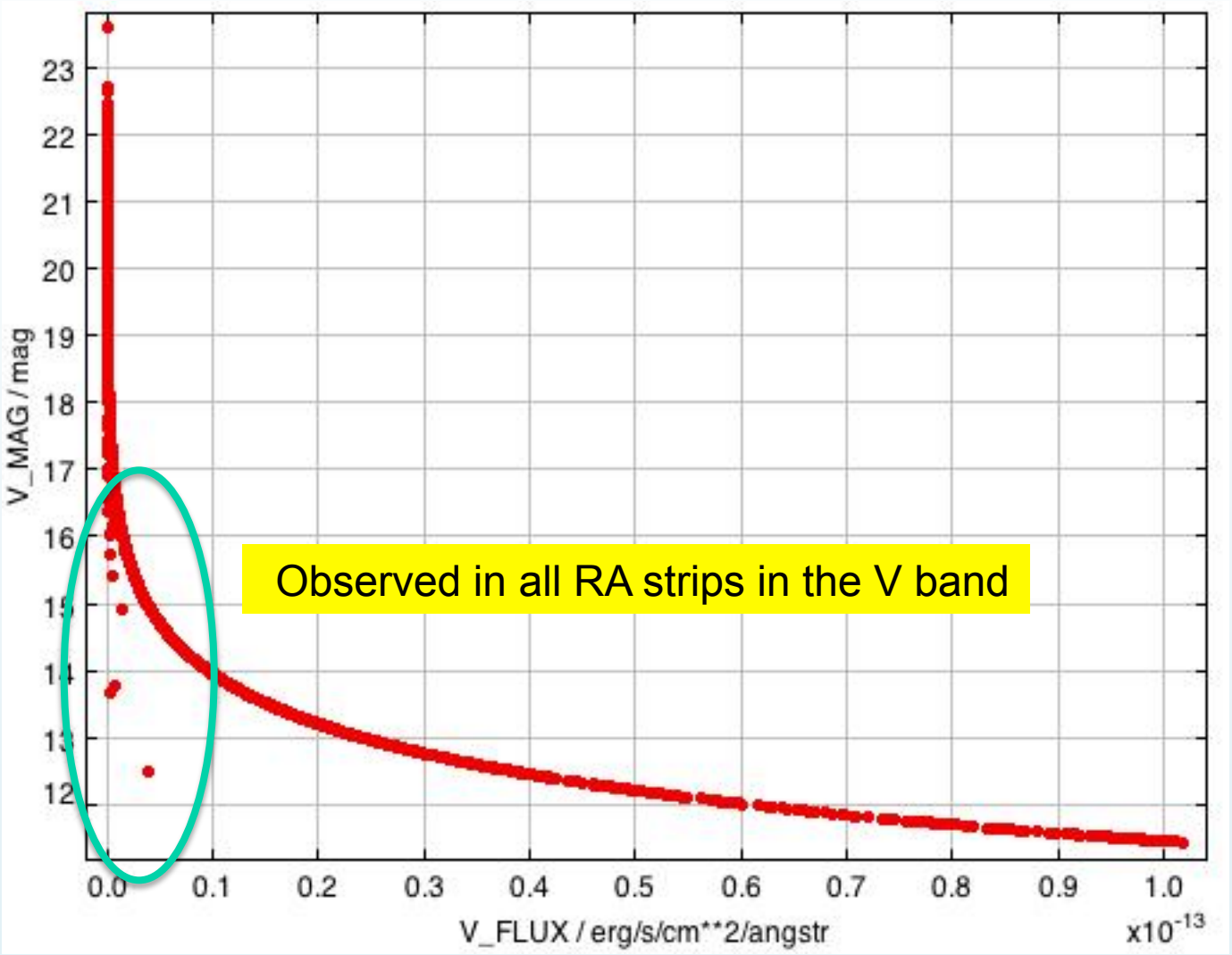


Weird distribution due to astrometry affecting
OBS ID 00030988074, 00030988061

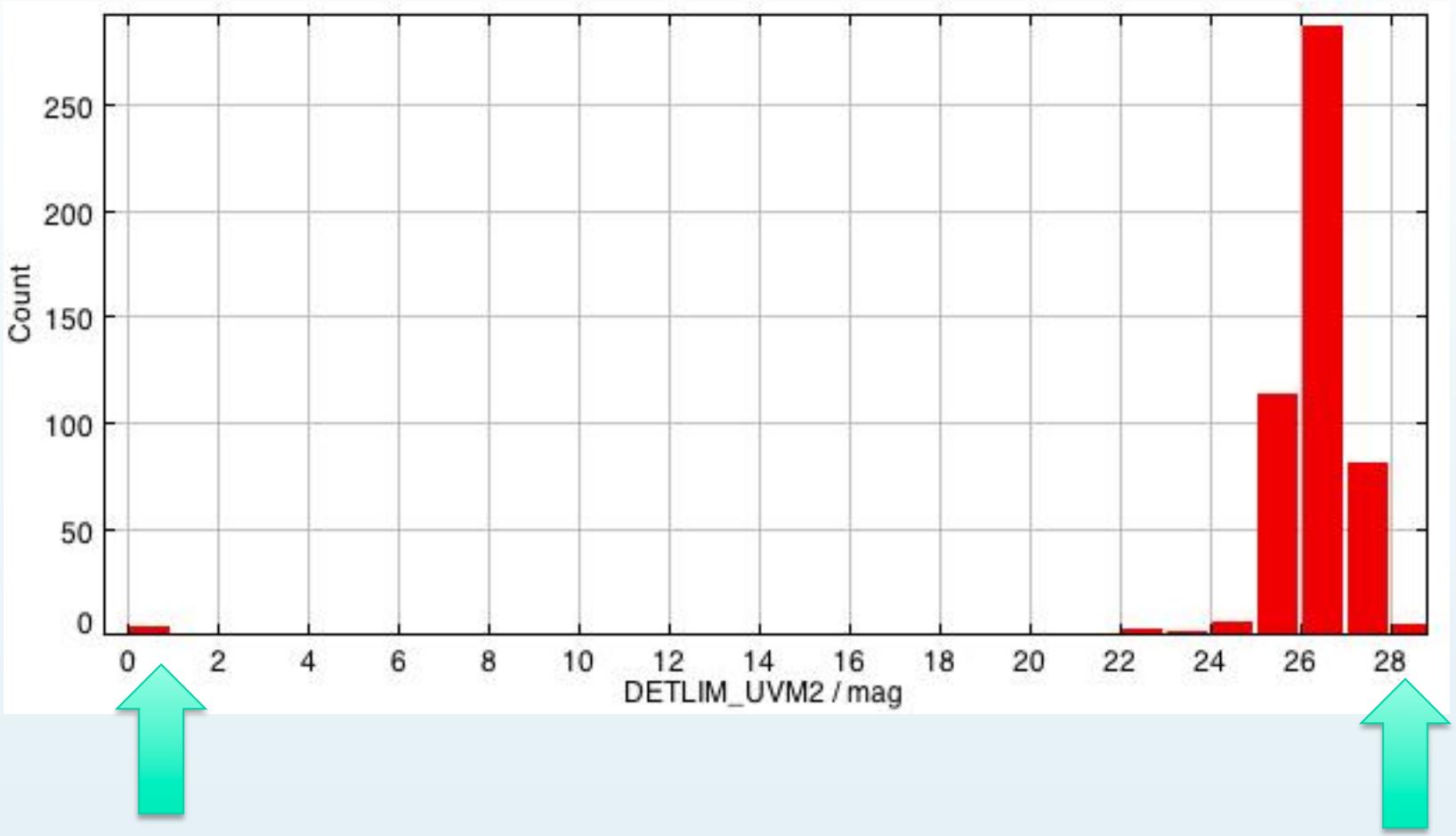
Astrometry: ra_err vs mag



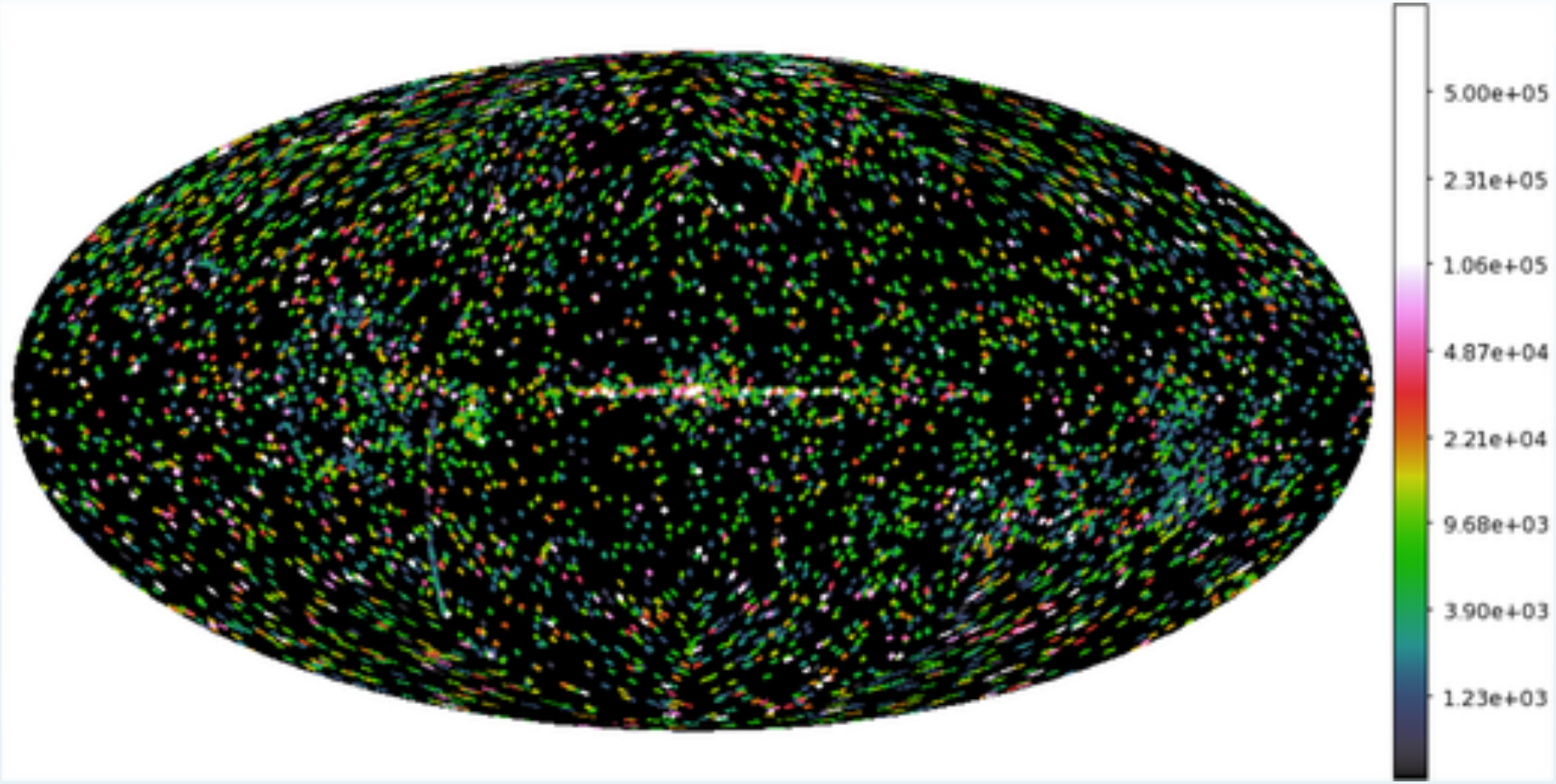
Photometry: mag vs flux



Source detection



Sky coverage



Distribution of the UVOT exposure for 2005-2010 observations in Galactic coordinates.

What's in the UVOTSSC catalogue ?

Each unique source has a unique identifier.
Sources are given an independent entry (i.e. line of parameters) for each Swift observation ID in which they are detected.

Period of observations	2005 - 2010
Total observations	23059
Total sources	6 200 016
Repeated observations	2 027 265
Total entry lines	13 860 569

As there are 82 columns per source entry, the catalogue table contains > 1 billion cells.

UVW2<24.3
UVM2<24.1
UVW1<24.3
U<24.1
B<24.3
V<23.8

Source table

- IAUNAME
- N_SUMMARY
- OBSID
- NFILT
- SRCNUM
- RA
- DEC
- RA_ERR
- DEC_ERR
- UVW2_SRCDIST
- UVM2_SRCDIST
- UVW1_SRCDIST
- U_SRCDIST
- B_SRCDIST
- V_SRCDIST
- N_OBSID
- UVW2_SIGNIF
- UVM2_SIGNIF
- UVW1_SIGNIF
- U_SIGNIF
- B_SIGNIF
- V_SIGNIF
- UVW2_VEGAMAG
- UVM2_VEGAMAG
- UVW1_VEGAMAG
- U_VEGAMAG
- B_VEGAMAG
- V_VEGAMAG
- UVW2_ABMAG
- UVM2_ABMAG
- UVW1_ABMAG
- U_ABMAG
- B_ABMAG
- V_ABMAG
- UVW2_MAG_ERR
- UVM2_MAG_ERR
- UVW1_MAG_ERR
- U_MAG_ERR
- B_MAG_ERR
- V_MAG_ERR
- UVW2_FLUX
- UVM2_FLUX
- UVW1_FLUX
- U_FLUX
- B_FLUX
- V_FLUX
- UVW2_FLUX_ERR
- UVM2_FLUX_ERR
- UVW1_FLUX_ERR
- U_FLUX_ERR
- B_FLUX_ERR
- V_FLUX_ERR
- UVW2_MAJOR
- UVM2_MAJOR
- UVW1_MAJOR
- U_MAJOR
- B_MAJOR
- V_MAJOR
- UVW2_MINOR
- UVM2_MINOR
- UVW1_MINOR
- U_MINOR
- B_MINOR
- V_MINOR
- UVW2_POSANG
- UVM2_POSANG
- UVW1_POSANG
- U_POSANG
- B_POSANG
- V_POSANG
- UVW2_EXTENDED
- UVM2_EXTENDED
- UVW1_EXTENDED
- U_EXTENDED
- B_EXTENDED
- V_EXTENDED
- UVW2_QUALITY_FLAG
- UVM2_QUALITY_FLAG
- UVW1_QUALITY_FLAG
- U_QUALITY_FLAG
- B_QUALITY_FLAG
- V_QUALITY_FLAG

To convert to AB

UVW2 add 1.71
UVM2 add 1.64
UVW1 add 1.36
U add 0.93
B sub 0.18
V sub 0.04

Comparison to other UV catalogues

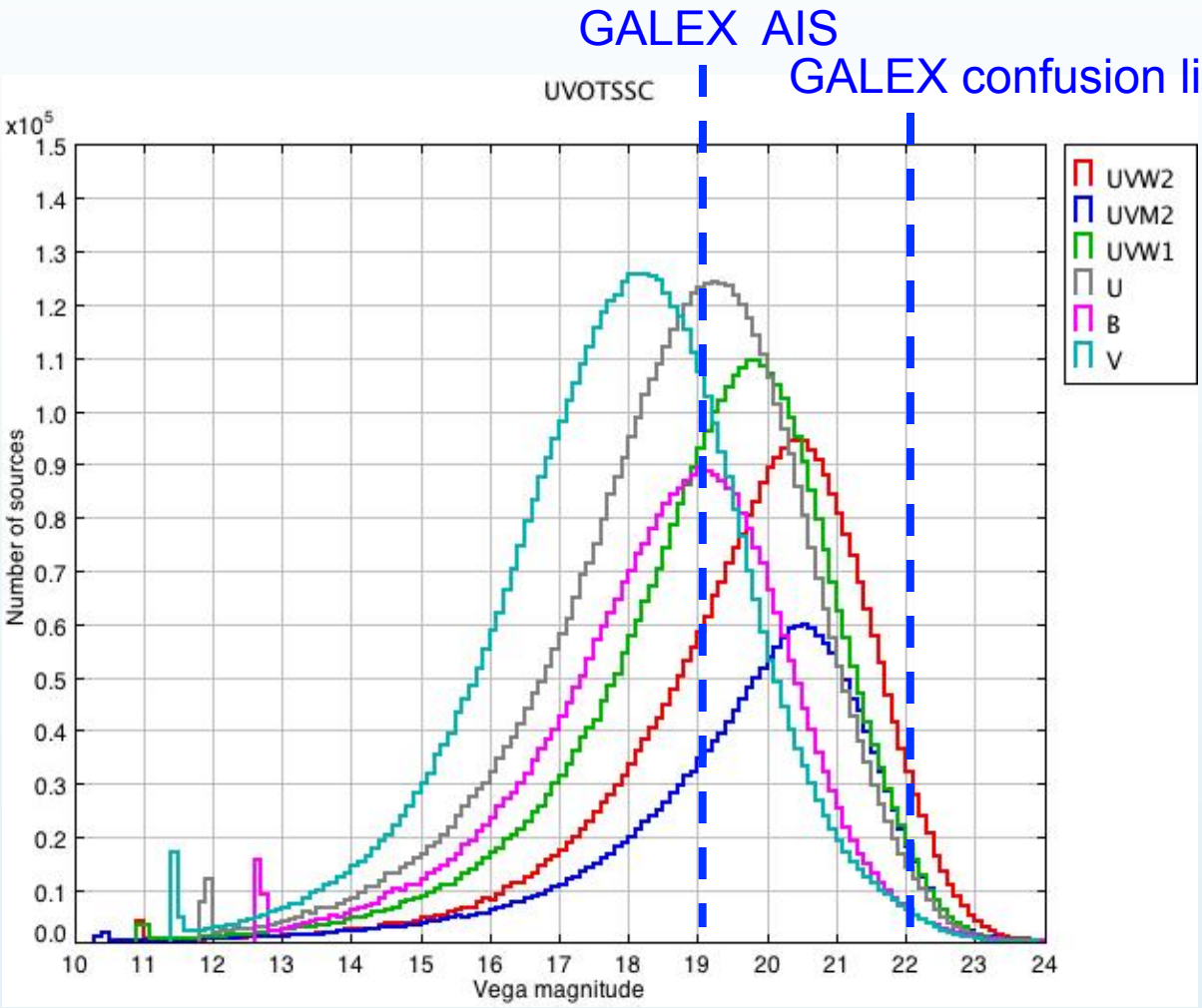
Natural comparison UV catalogues are:

- GALEX surveys (AIS, MIS, DIS)
  - UVOT SSC **reaches 2 mag deeper** than the GALEX confusion limit.
  - UVOT SSC has finer spectral discrimination than GALEX (GALEX NUV = UVW1+UVM2+UVW2).
  - Simpler, more reliable optical counterpart matching in UVOTSSC than GALEX because of UVOT's smaller PSF.

- and the XMM-SUSS v2. (Talavera et al., in prep)
  - UVOT SSC is more than **2 times larger** than XMM-SUSS v2.
  - UVOT SSC **reaches about 2 mag deeper** than XMM-SUSS in UVW2 and 1.5 mag deeper in UVM2.

New parameter space that hasn't been explored before.

Number of sources as a function of source magnitude



What can it be used for?

- Identifying and measuring hot stars, especially in binaries.
- Extinction mapping the Galaxy.
- UV measurements, selection, luminosity functions of galaxies, cosmic star-formation history.
- SEDs and extinction constraints of star-forming galaxies.
- UV measurements of low-redshift quasars for SEDs etc.
- Measuring the intergalactic opacity of the Lyman forest below z=2.
- Classification of X-ray sources, e.g. from the XRT catalogues.
- Identifying the UV or optical counterparts of pulsars in binaries.
- Identifying flare stars.
- Studies of variable stars and novae in quiescence.
- Identifying low-redshift lyman break analogues.
- Plenty of other things besides.
- Select objects with peculiar colours (UV wrt IR)

Binary pulsars studies with multi-wavelength sky surveys. I. Companion star identification

2014, MNRAS, 443, 2223

R. P. Mignani[1,2,3⋆], A. Corongiu[4], C. Pallanca[5], S. R. Oates[3,6], V. N. Yershov[3], A. A. Breeveld[3], M. J. Page[3], F. R. Ferraro[5], A. Possenti[4], A. C. Jackson[7]

Binary pulsar studies with multi-wavelength sky surveys. II. Companion star follow ups

2015, MNRAS, to be submitted

R. P. Mignani[1,2,3⋆], A. Corongiu[4], C. Pallanca[5], S. R. Oates[3,6], V. N. Yershov[3], A. A. Breeveld[3], M. J. Page[3], F. R. Ferraro[5], A. Possenti[4], A. C. Jackson[7]

Is the catalogue available?

YES!

- Beta-release version available now (UVOT SSC V0.99).
- Currently making its way into MAST.
- Get it now in table form from:

  http://www.ucl.ac.uk/mssl/astro/space_missions/swift/uvotssc

- Please start using it.
- Just a few tweaks and some more validation before we release V1.0
- V1.0 should be served to the virtual observatory too.

The FUTURE:

- We've only processed data up to 2010
- Obvious enhancement to UVOTSSC:
- Process the next 5 years data.
- Double the size of the catalogue.