UCL

# The XMM-OM and Swift UVOT source catalogues

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Especially
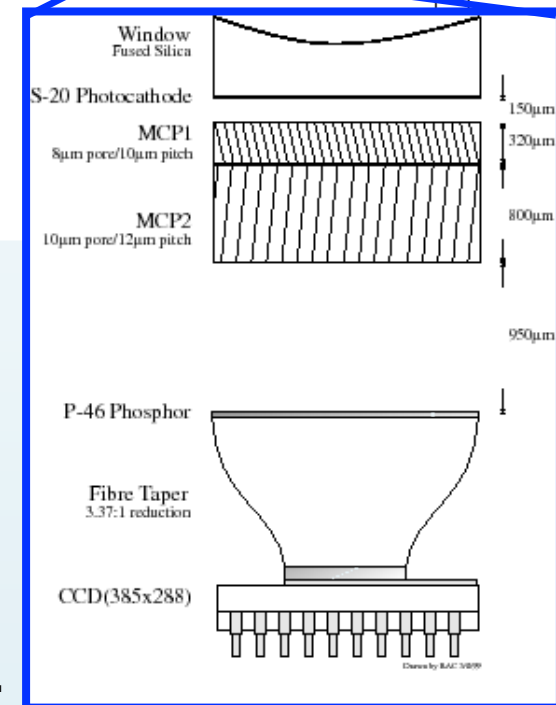Vladimir Yershov

On behalf of the XMM-OM and Swift UVOT teams, with particular contributions from:

V.N. Yershov, A.A. Breeveld, N. P. M. Kuin, A. Talavera.

MNRAS 2013, 434, 1955

Outline

❖ Intro: XMM-OM and UVOT

❖ What the Serendipitous Catalogues are

❖ How they were made

❖ What they contains

❖ How they can be used
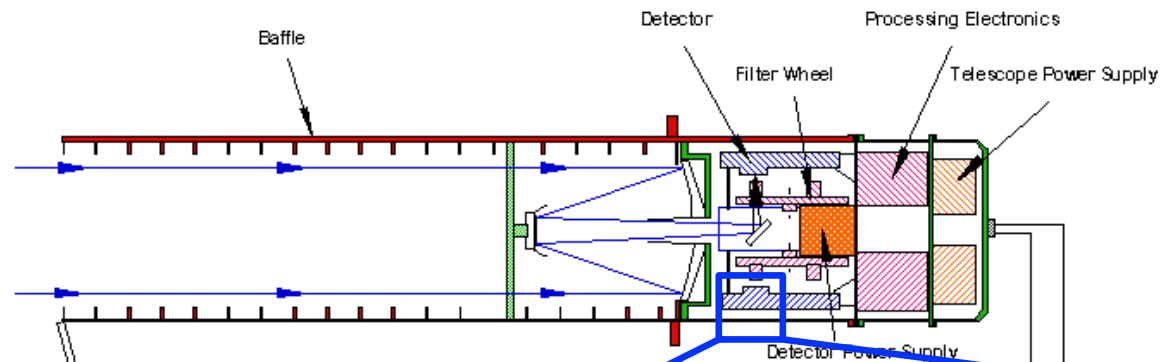
XMM-OM and Swift UVOT:

30 cm diameter Ritchey-Chretien UV/optical telescopes.
Filters: UVW2, UVM2, UVW1, U, B, V (+White, grisms).
Long baffle to permit deep-sky observations.
Detector: microchannel-plate intensified CCD (MIC).
Photon counting, zero read noise, very low dark current.
Field of view: 17' x 17'
Extremely good instruments for UV sky survey work.
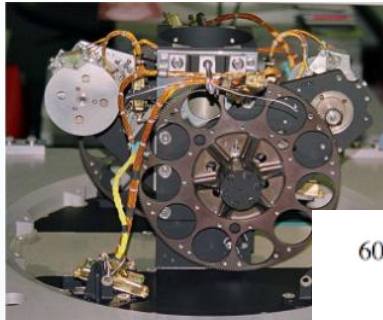
XMM-OM and UVOT passbands
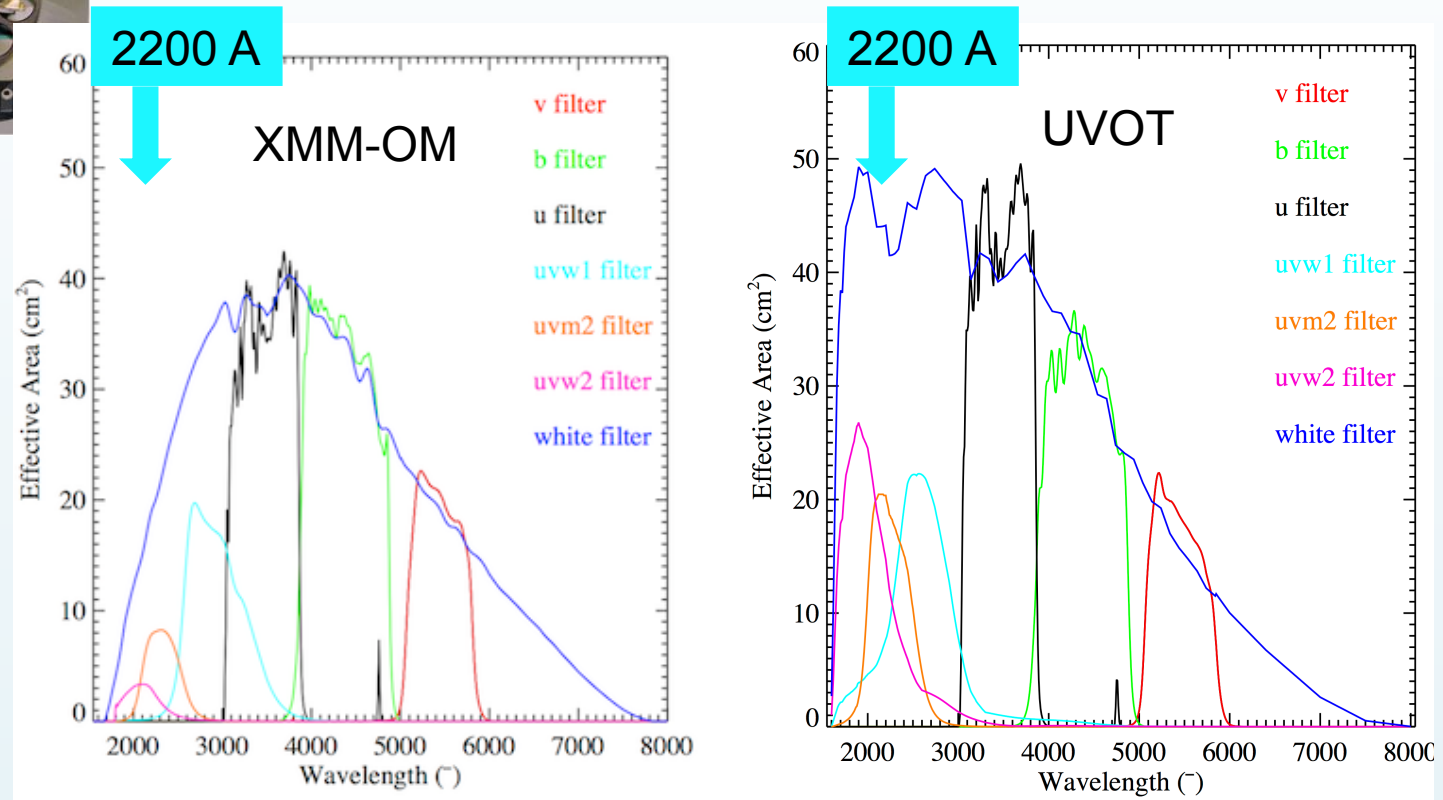
- The UV filters cover very nicely the 2200A extinction bump, so these instruments can disentangle the extinction curve from the underlying spectral shape.

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The XMM Serendipitous UV Source Survey (XMM-SUSS)

- Based on a pipeline and XMM-SAS software developed at MSSL.

- SUSS 1.0 first released in 2009.

- Detailed description in Page et al. 2012, MNRAS 426, 903

- Now on its third generation: SUSS-3.0

- Production line moved to ESAC from SUSS 2.0 onwards.

- Documentation at http://www.ucl.ac.uk/mssl/astro/space_missions/ xmm-newton/xmm-suss3

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The UVOT Serendipitous Source Catalogue (UVOTSSC)

- All UVOT images taken by Swift between 2005 and 2010.
- A complete processing pipeline was constructed at MSSL.
- Based around the standard UVOT ftools available in HEASOFT.
- Version 1.1 of the UVOTSSC released in 2014.
- Built on all UVOT images taken between 2005 and 2010.
- Described in Page et al. 2014 POS, (arXiv:1503.06597)
- Documentation at: http://www.ucl.ac.uk/mssl/astro/ space_missions/swift/uvotssc
- Version 2 now under development.

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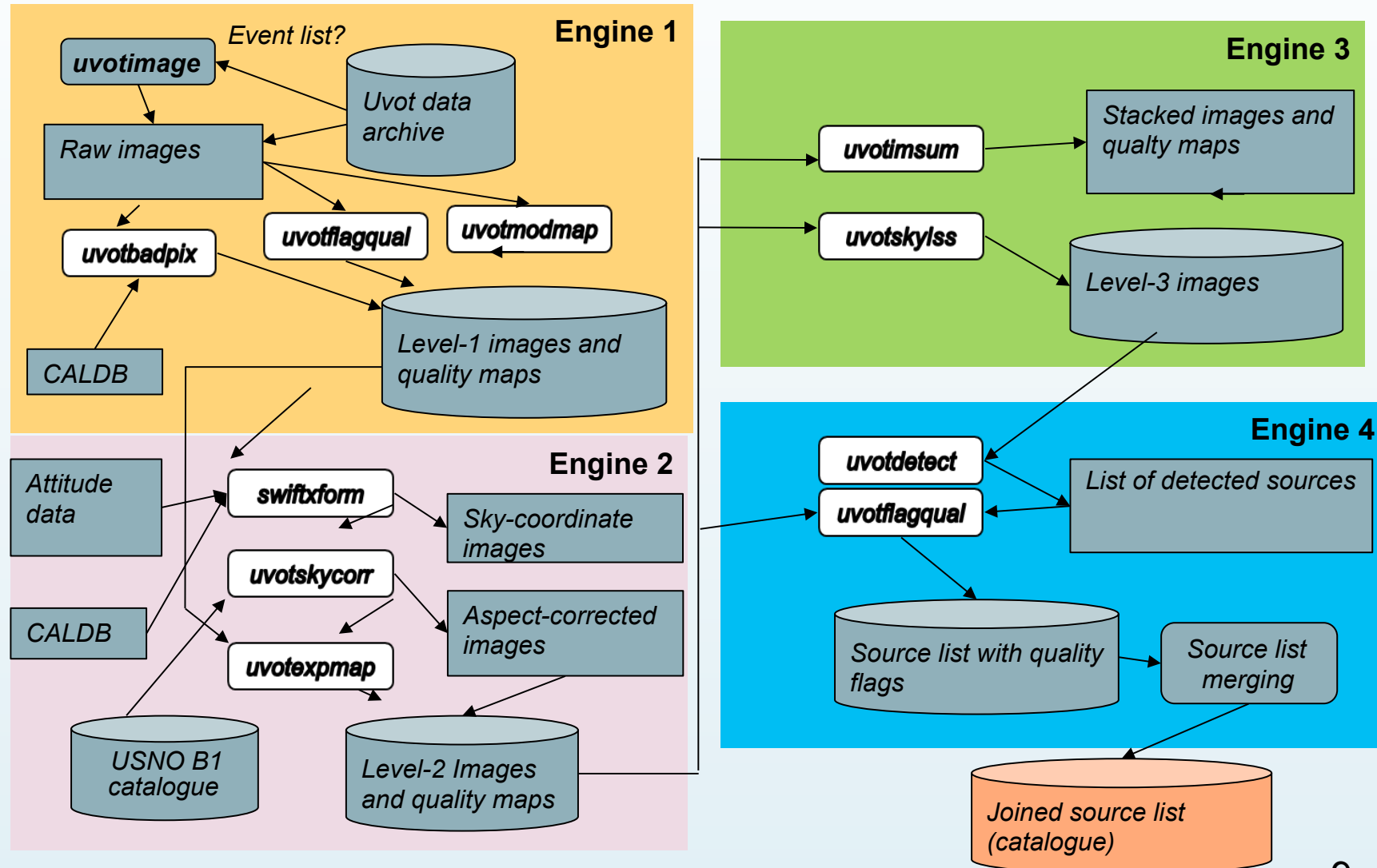
So similar yet so different

- The pipelines were constructed by the same team, so the end products have a similar look, feel, form.
- But there are some fundamental differences in the instruments (UV passbands) and the way the two catalogues are constructed:
  - XMM-SUSS is primarily based on sources detected in individual images, in raw coordinate system, with stacked and sky-coordinate images searched as a second step from SUSS 2.0 onwards.
  - XMM-SUSS source detection uses SAS task omdetect, which was written from scratch for XMM-OM.
  - UVOTSSC based entirely on per-observation stacked, sky-coordinate images.
  - UVOTSSC source detection uses ftool uvotdetect which is based on generic sextractor software.

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Challenges

- Terrabytes 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.

UVOT SSC

SUSS

Catalogue data processing flow chart for UVOTSSC

Engine 1
- Event list?
- uvotimage
- Uvot data archive
- Raw images
- uvotbadpix
- uvotflagqual
- uvotmodmap
- CALDB
- Level-1 images and quality maps

Engine 2
- Attitude data
- swiftxform
- Sky-coordinate images
- uvotskycorr
- CALDB
- Aspect-corrected images
- uvotexpmap
- USNO B1 catalogue
- Level-2 Images and quality maps

Engine 3
- uvotimsum
- Stacked images and qualty maps
- uvotskylss
- Level-3 images

Engine 4
- uvotdetect
- uvotflagqual
- List of detected sources
- Source list with quality flags
- Source list merging
- Joined source list (catalogue)

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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.
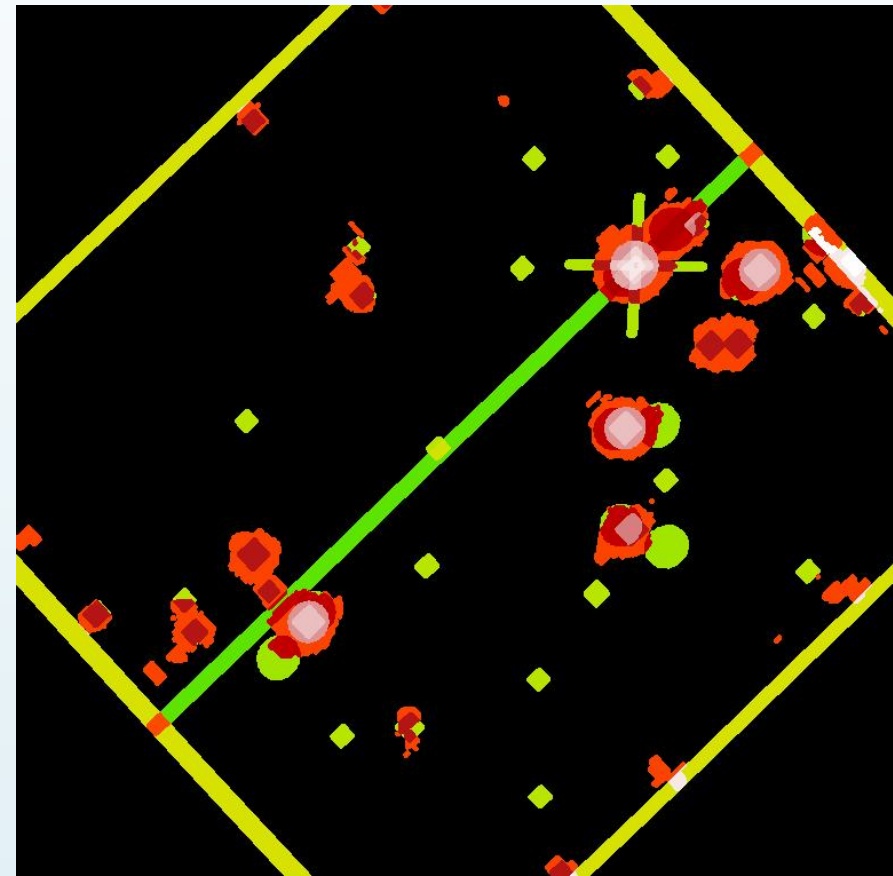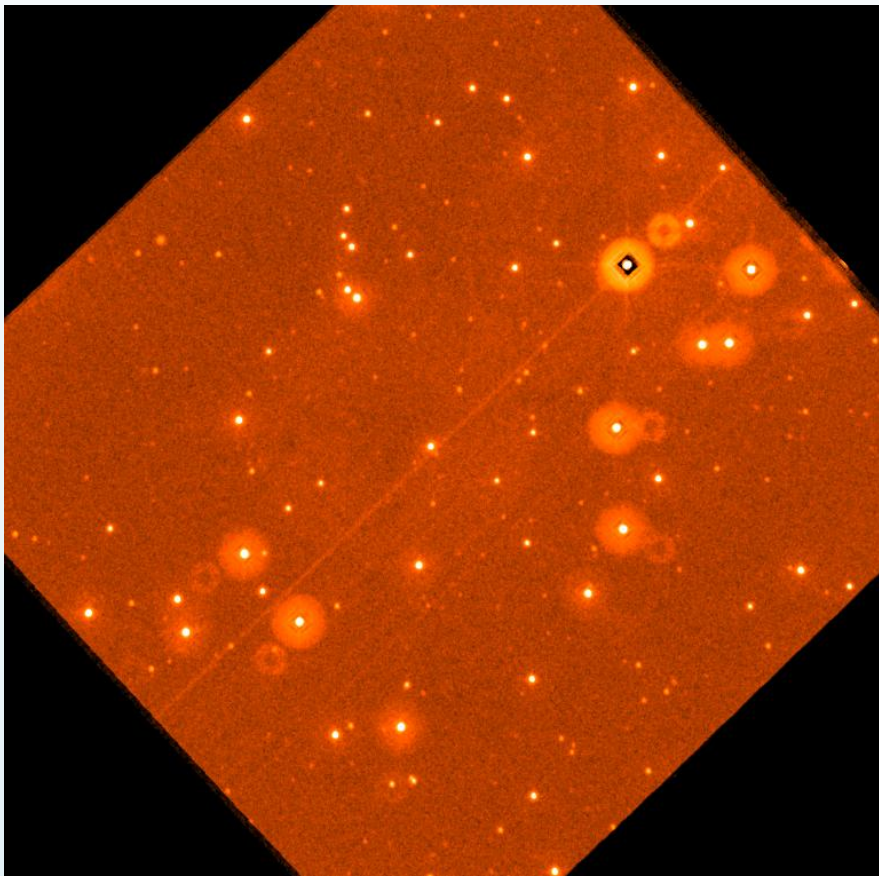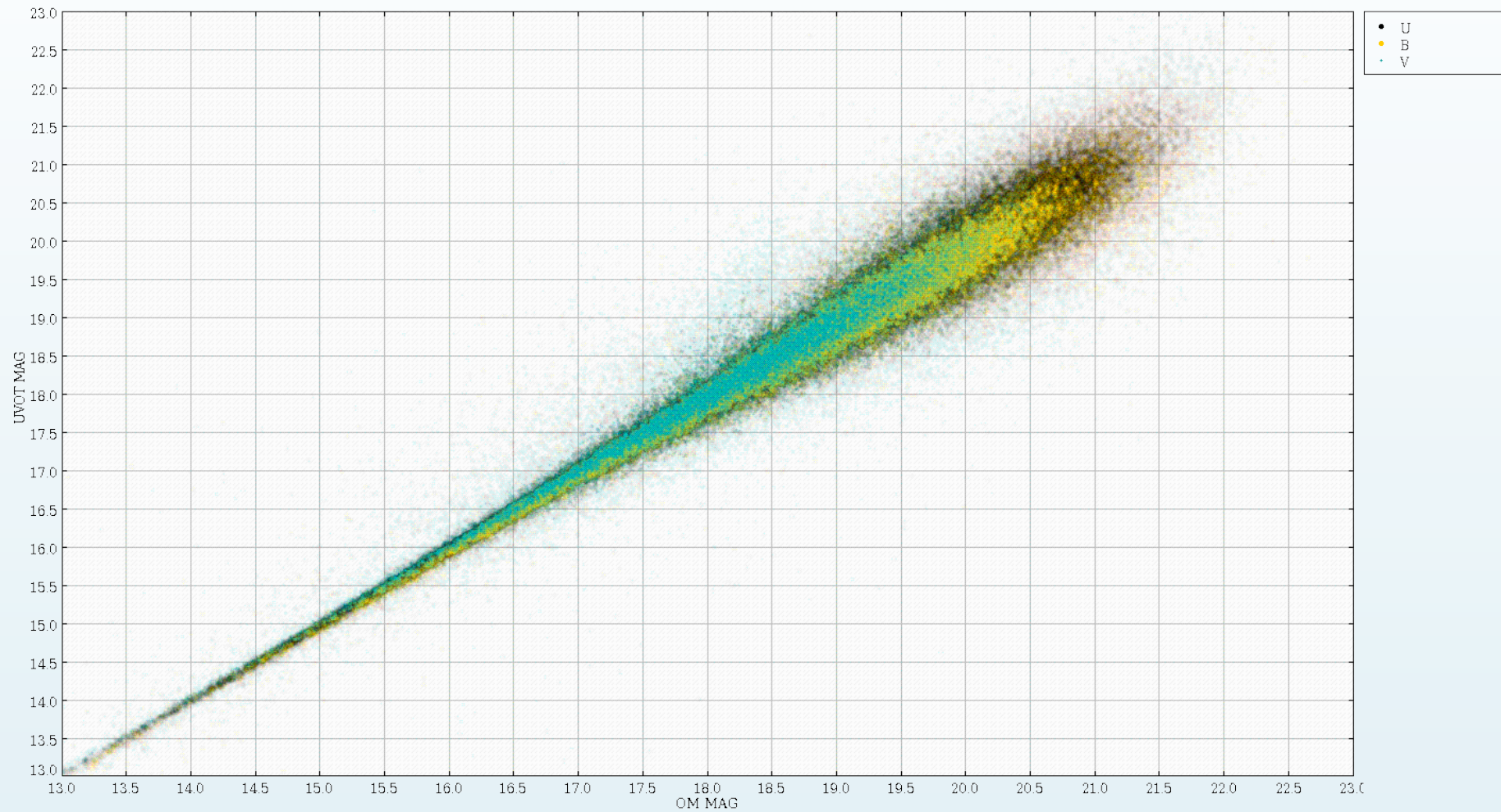
Sky coverage
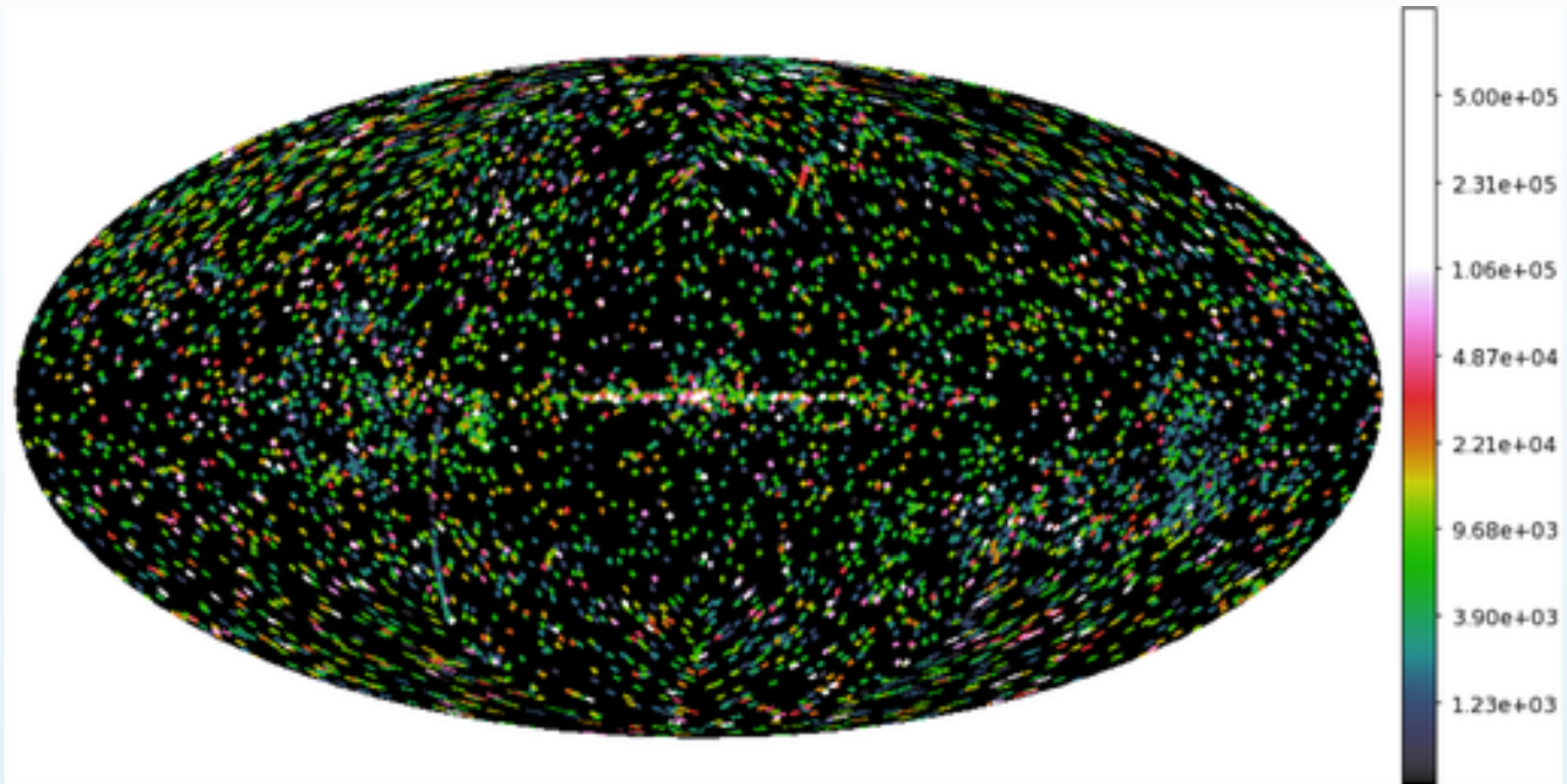
Distribution of the UVOT exposure for 2005-2010 observations in Galactic coordinates. Important to note that pointing locations of <u>both</u> catalogues come with X-ray data.

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Validation: comparison of UVOTSSC optical magnitudes with XMM-SUSS

Comparison of the OM and UVOT source catalogues for three UV filters
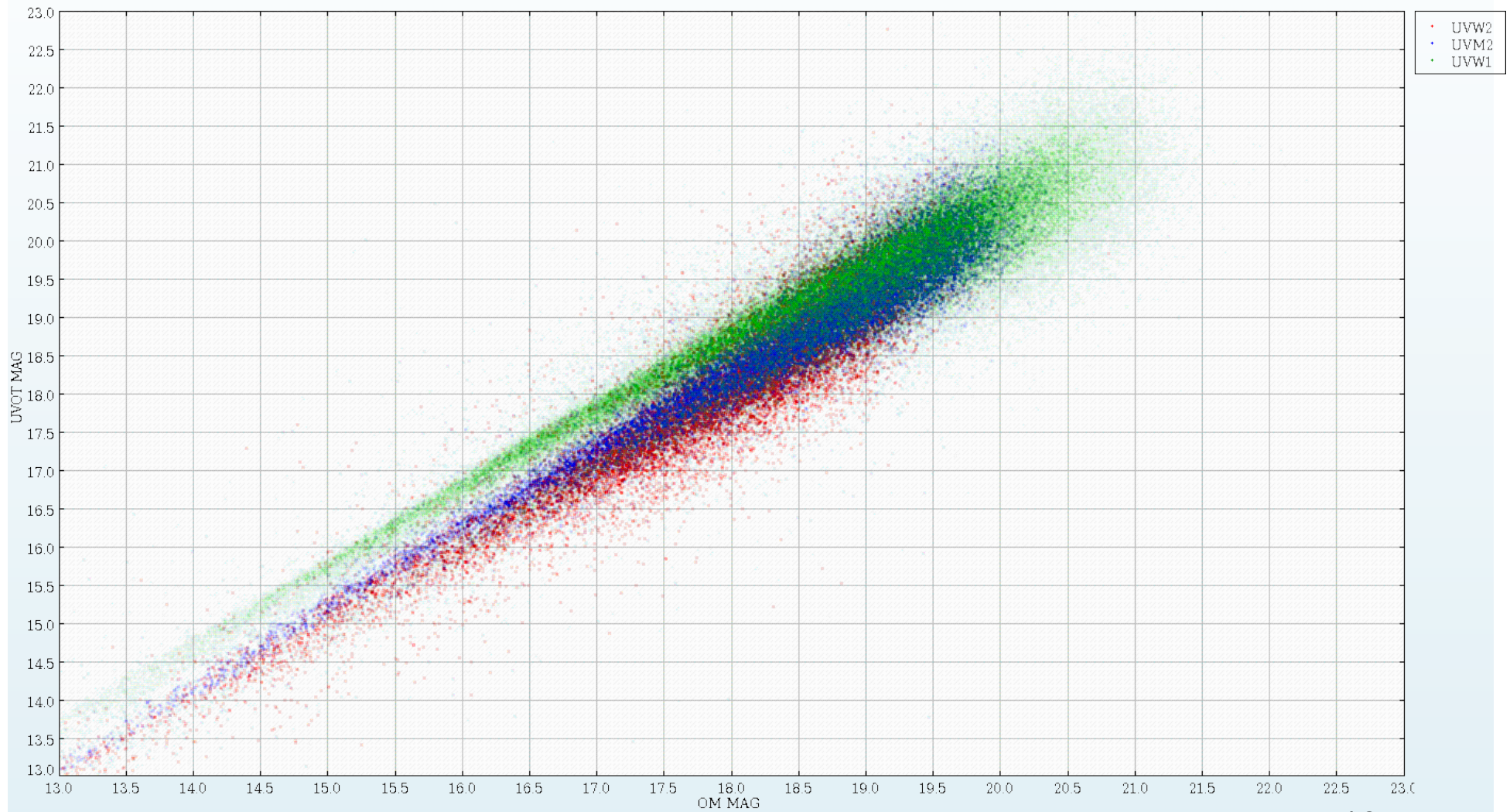
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What's in the catalogues ?

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

	XMM-SUSS3.0	UVOTSSC1.1
Period of observations	2000-2015	2005 - 2010
Total observations	7,886	23,059
Total sources	4,751,889	6,200,016
Repeated observations	867,022	2,027,265
Total entry lines	6,880,116	13,860,569

As there are about 80 columns per source entry, so the catalogue tables each contain ~ 1 billion cells.

Number of sources as a function of source magnitude

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
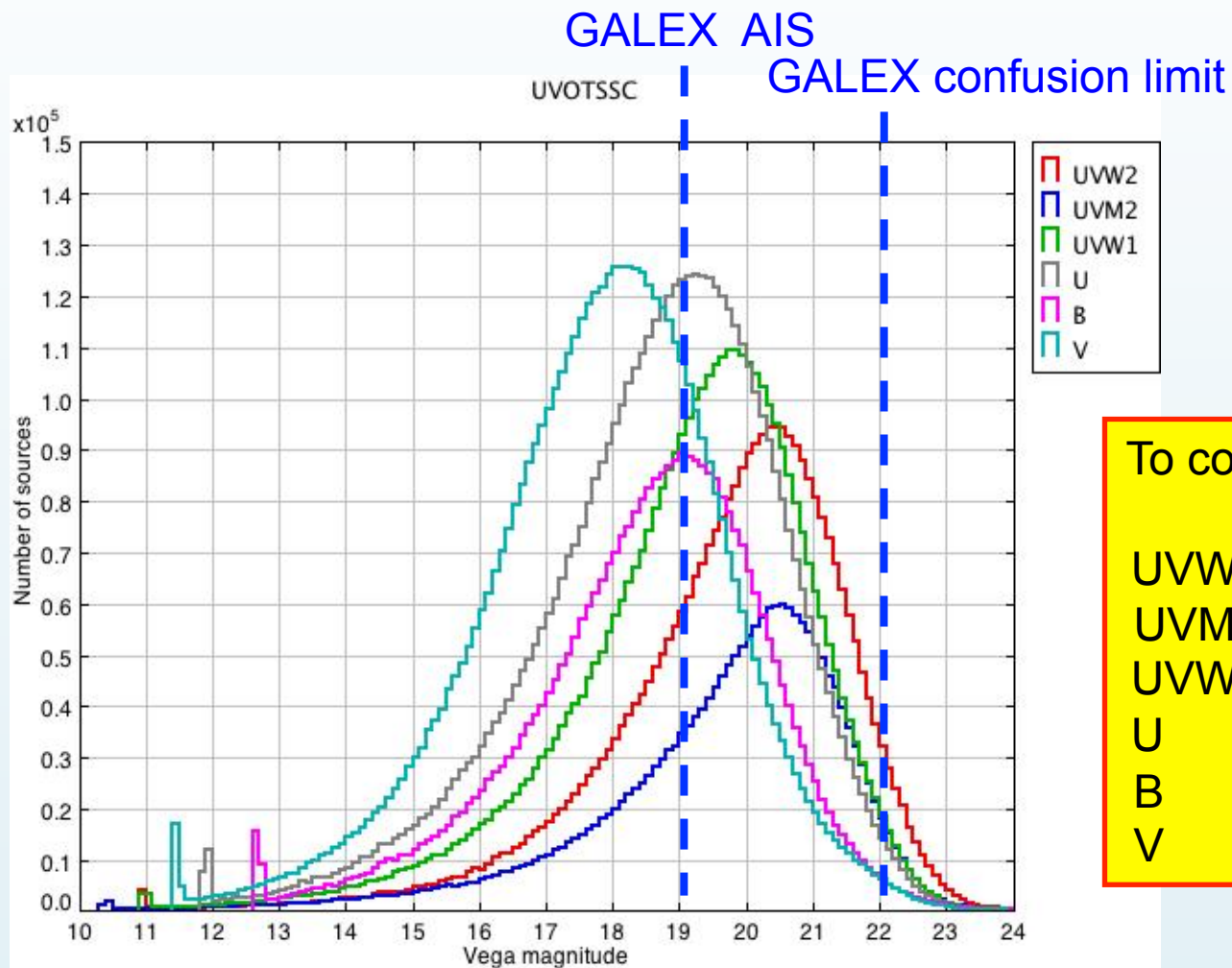
Comparison to GALEX catalogues

- GALEX surveys (AIS, MIS, DIS)

  - UVOTSSC reaches 2 mag deeper than the GALEX confusion limit.

  - UVOTSSC and XMM-SUSS have finer spectral discrimination than GALEX (GALEX NUV = UVW1+UVM2+UVW2).

  - Simpler, more reliable optical counterpart matching in XMM-SUSS and UVOTSSC than GALEX because of XMM-OM and UVOT's smaller PSF.

What can they 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.

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Stars and galaxies' UV colours

- The UV colours of stars and galaxies split quite nicely.

- Galaxies are the blob at the bottom of the plot. Their colours reflect the stellar population, reddening and redshift. In general, their colours are pretty blue.

- Stars form a precise sequence in UV colour-colour space by spectral type and reddening.

- With distances from Gaia, UV data from XMM-SUSS and UVOTSSC very useful for studying the UV emission and extinction of stars in the Milky Way.
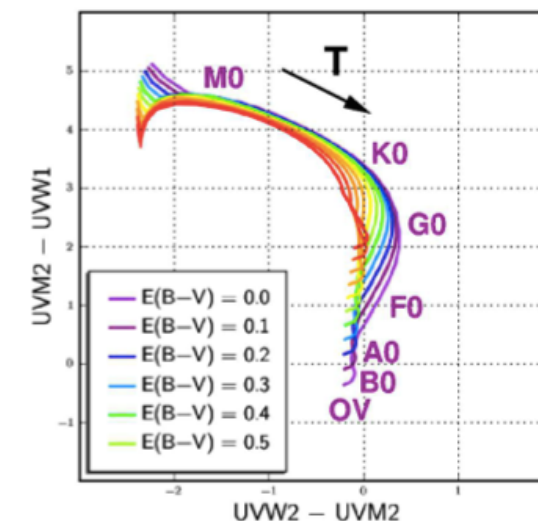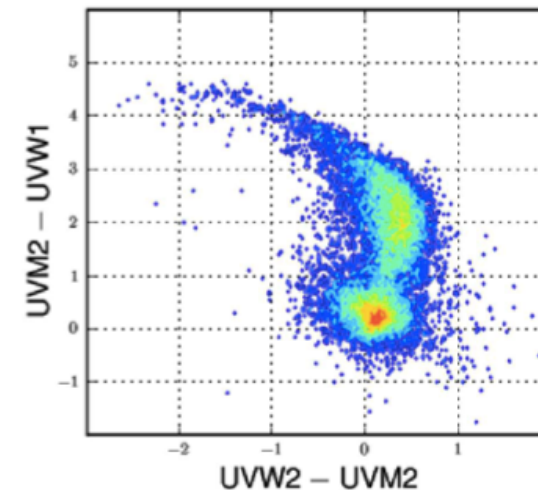
The UV galaxy luminosity function

- Many science areas in which the UV data from UVOT and XMM-OM catalogues have unique value.

- Here is the UV (1500A) luminosity function of galaxies with 0.6<z<1.2 using XMM-OM: a dark patch in our understanding of galaxies.

- UVW1 is the natural passband for this kind of study; no source confusion, and K-correction is minimal.
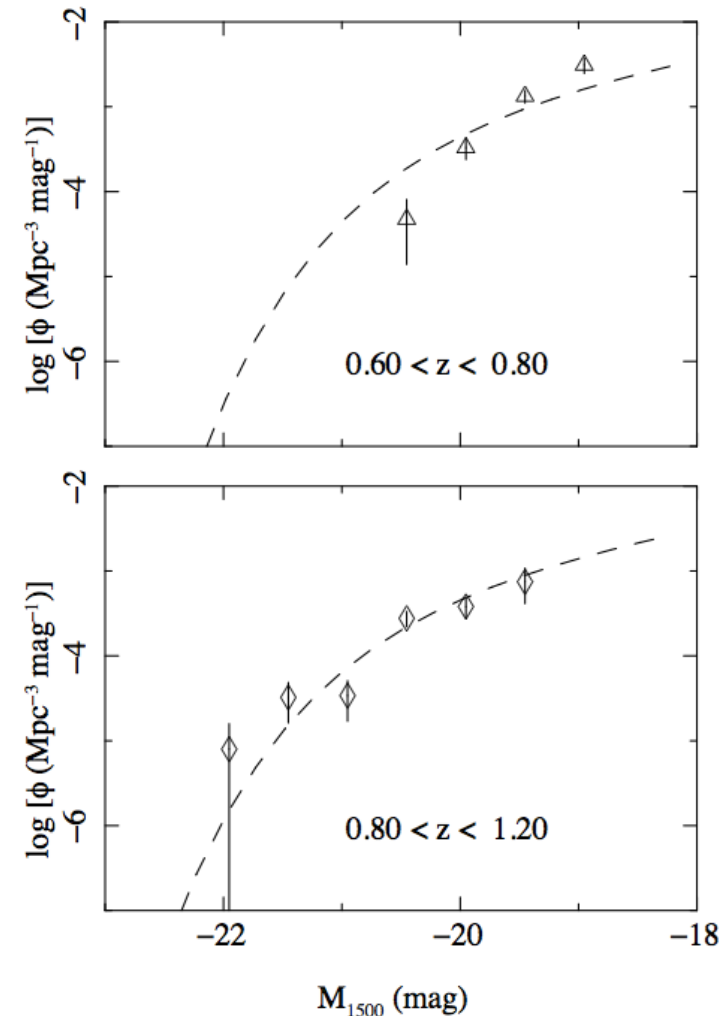
Pushing to brighter magnitudes

- Coincidence loss in detector final stage imposes a bright (i.e. saturation) limit for photometry in XMM-OM and UVOT.

- But photometry can be obtained from the read-out streak formed during frame transfer.

- Pushes bright limit 1.5 (XMM-OM) or 2.4 (UVOT) magnitudes brighter.

- See Page et al. 2013 MNRAS 436, 1684 and Page et al. 2017 MNRAS 466, 1061

- Important in GAIA era to be able to study stars near as well as far.

- Supplementary bright source catalogue for SUSS 3 now available on MSSL and ESA web pages.

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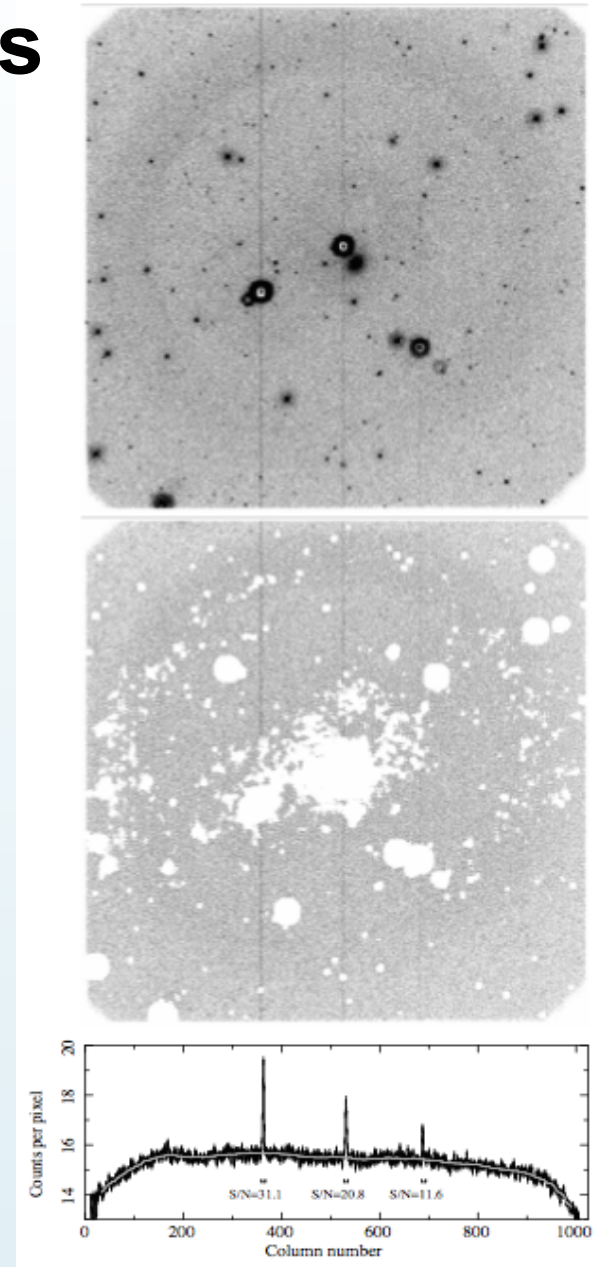
The future

- XMM-SUSS: continuing regular data releases anticipated.

- UVOTSSC:

- The software and pipeline are being improved. E.g. readout streaks are being erased, not just flagged.

- 8 years of data to add to the first five.

- The catalogue will more than double.

UVOT SSC
>twice as big…

Vladimir is lucky he doesn't work for us anymore!

But he visits us regularly anyway and is a big help.

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Conclusions

❖ XMM-OM and Swift UVOT offer large serendipitous source catalogues for UV studies of stars, galaxies and AGN.

❖ About 10 million sources in the two catalogues.

❖ They stretch 2 mag deeper than the GALEX confusion limit

❖ Grab them and use them!

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

❖ http://www.ucl.ac.uk/mssl/astro/space_missions/xmm-newton/xmm-suss3