# The INT Photometric Hα Survey (IPHAS)
## *Second Data Release*

*A seminar by Geert Barentsen for the ING in La Palma on 25 October 2013*

*IPHAS is a 1800 deg$^2$* ***INT/WFC survey*** *of the entire* ***northern Galactic plane*** *in* ***r, i, Hα*** *down to ~20th magnitude.*

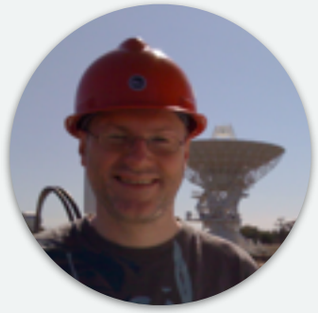

I will tell you about:

1. Survey design and aims
2. The new data release
   - quality control
   - re-calibration
   - catalogue building
3. Outstanding challenges and future opportunities

# I am a postdoc in the galactic plane surveys group at the University of Hertfordshire (UK)

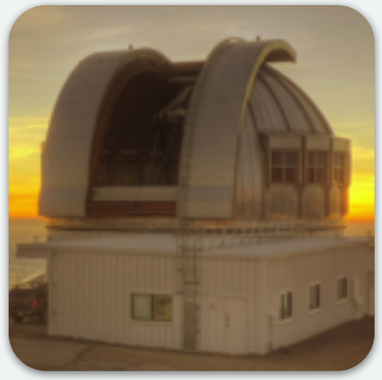
Prof Janet Drew

Dr Phil Lucas



Dr Mark Thompson

INT/IPHAS & UVEX



UKIDSS/GPS

SCUBA-2/JPS & SASSy

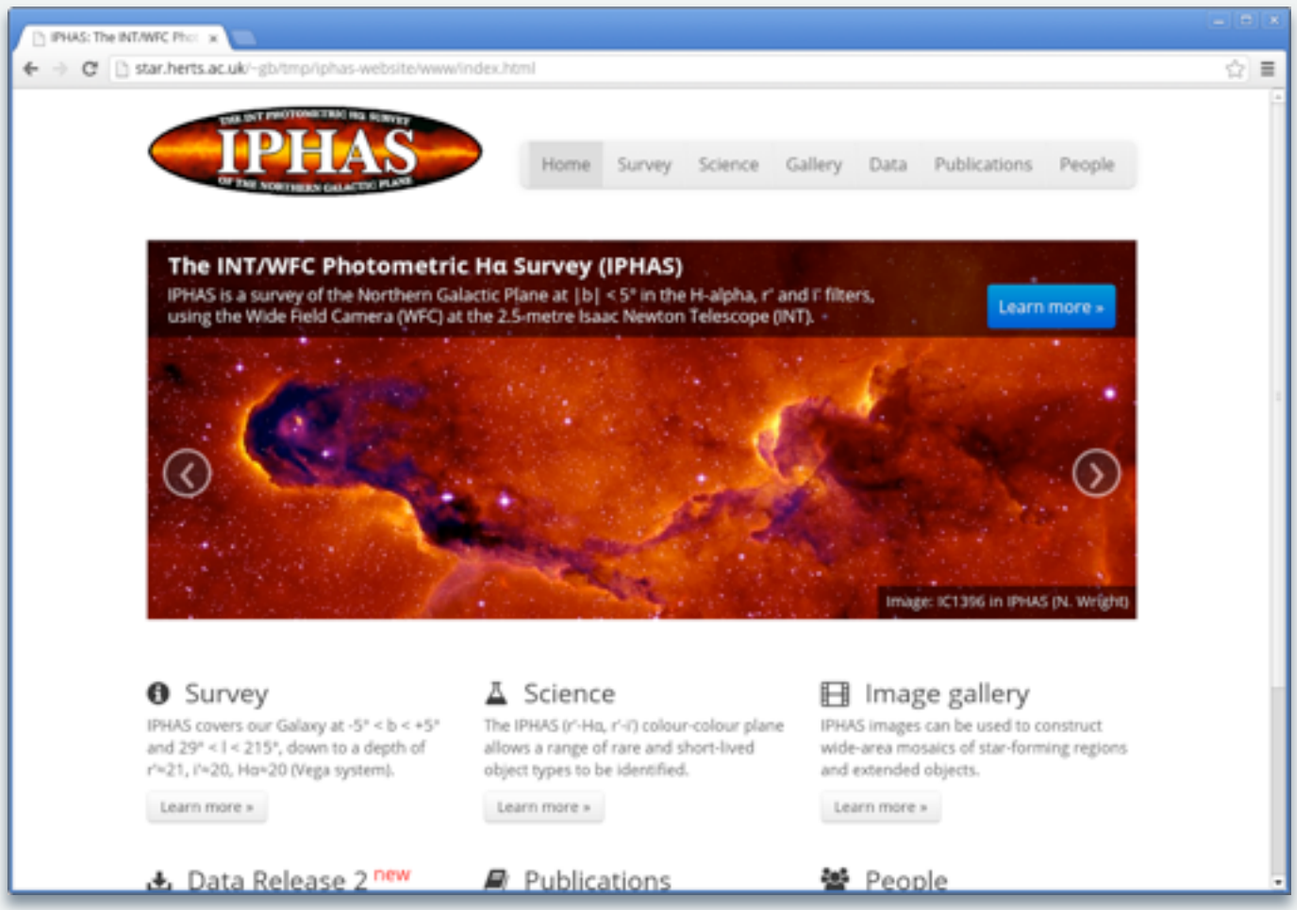
VST/VPHAS

VISTA/VVV

Herschel/Hi-GAL

# In the past six months, we have created a new public data release called “IPHAS DR2”

- 67 047 WFC exposures checked for quality.
- Photometry re-calibrated using exposure overlaps.
- Catalogue generated for 220 million unique sources.

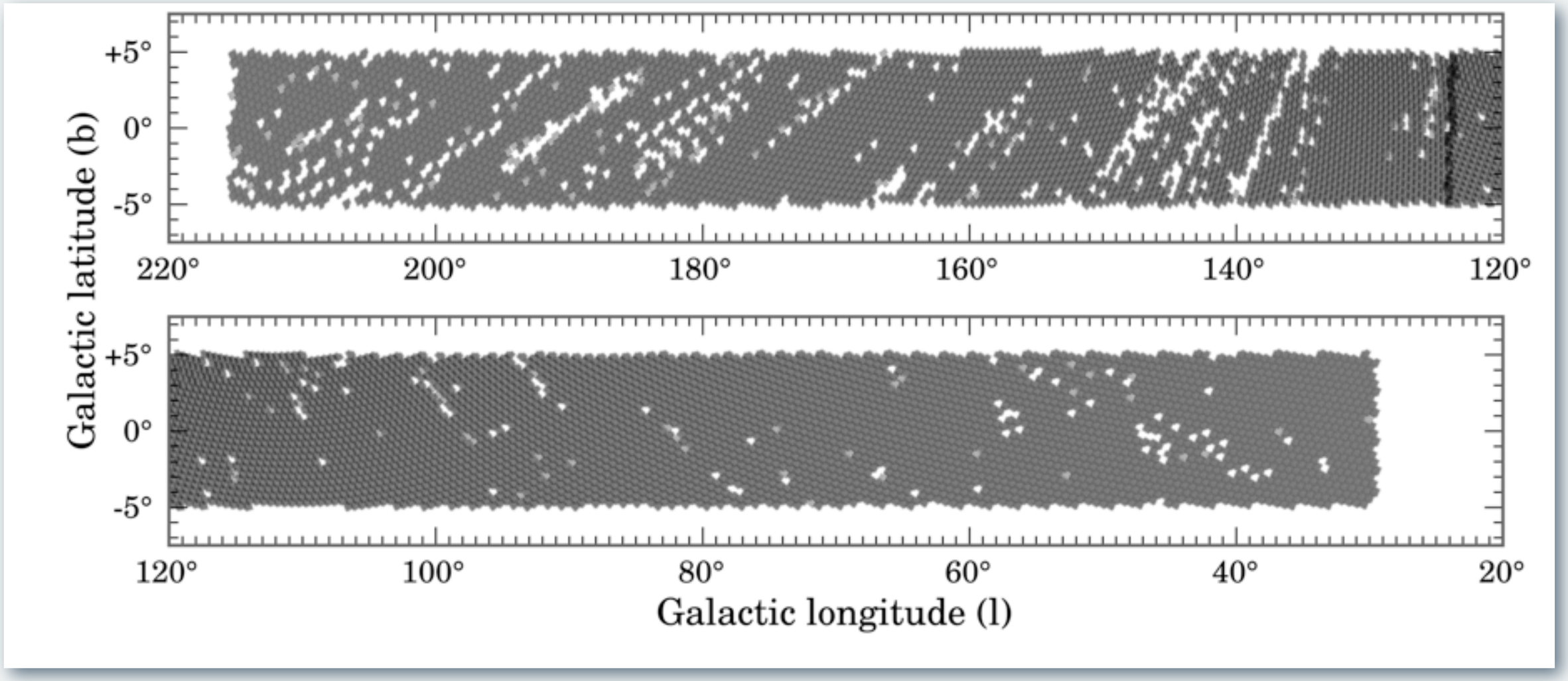



New website: www.iphas.org

# 1. Survey design and aims

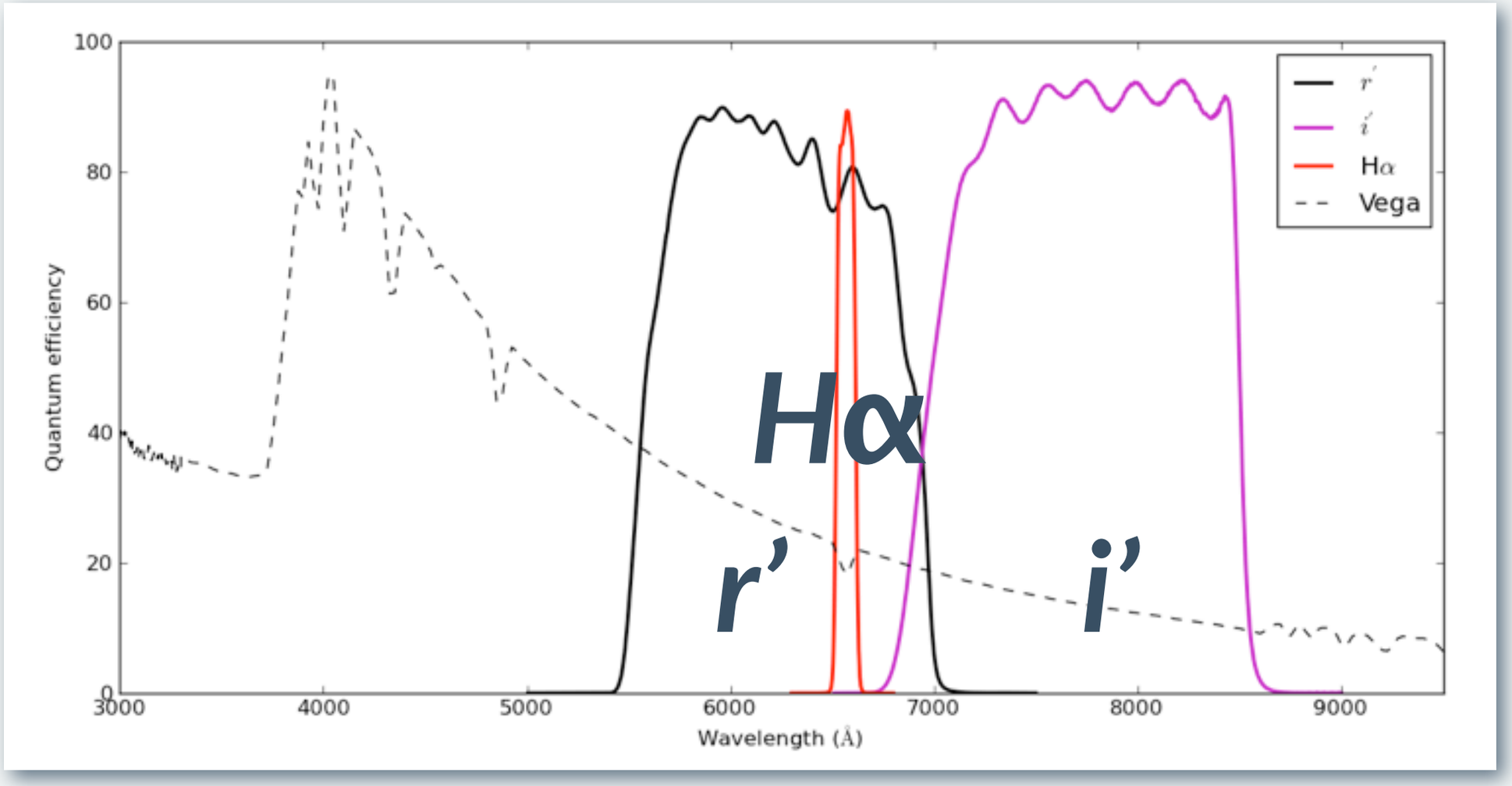
# IPHAS is the first ~arcsecond-resolution digital Hα survey of the Galactic plane

- Footprint covers the entire northern plane, 180 by 10 $deg^2$.
- Taking data since 2003, DR2 is now 93% complete.
- Biggest program in the history of the INT (300+ nights)



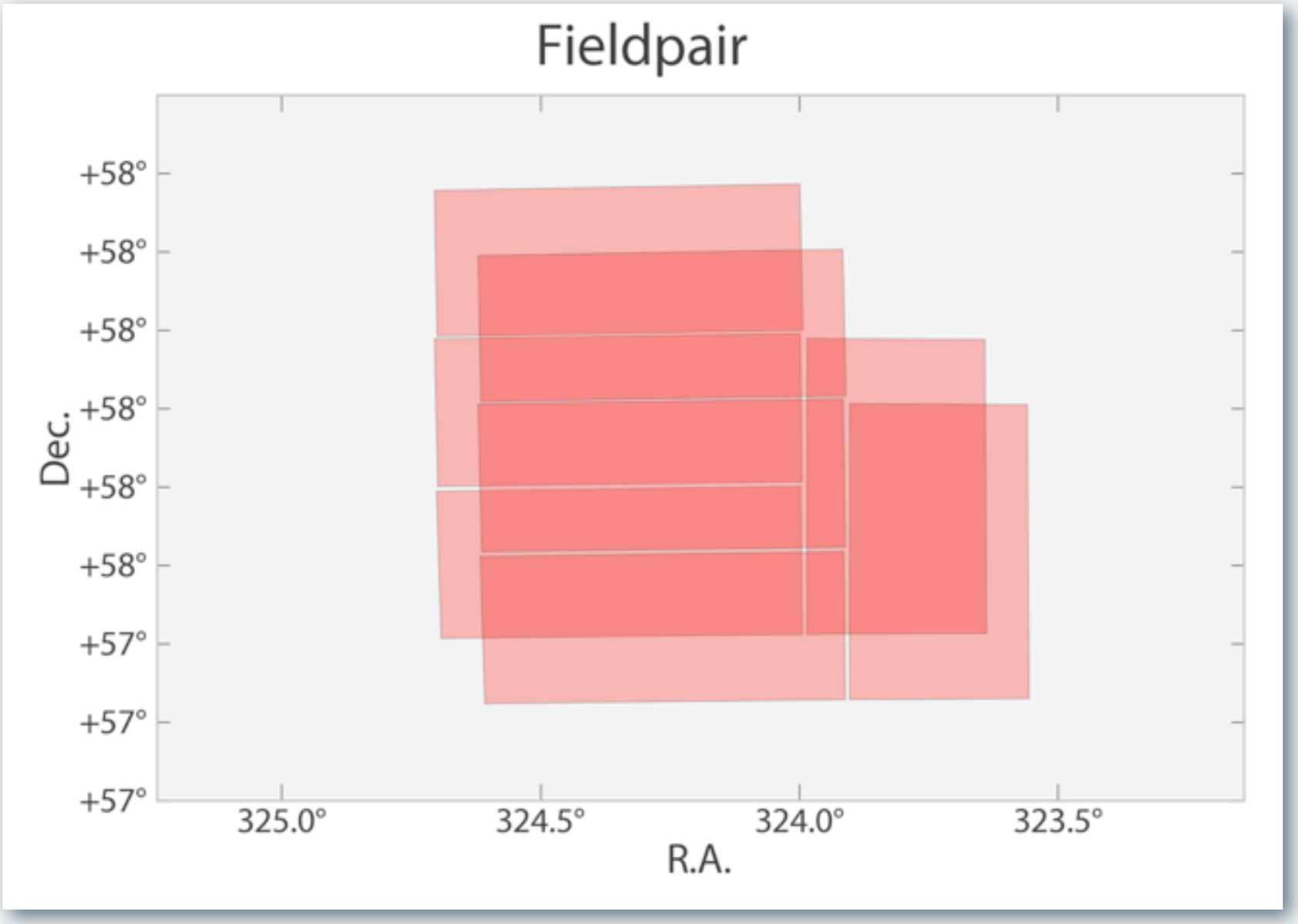
# IPHAS collects r, i, Hα photometry down to ~20th magnitude

- About 1000 times (7 magnitudes) deeper than previous northern plate surveys.
- Exposure times are 120 s (Hα), 30 s (r), 10 s (i).
- r, i, Hα images taken ~simultaneously at each pointing.

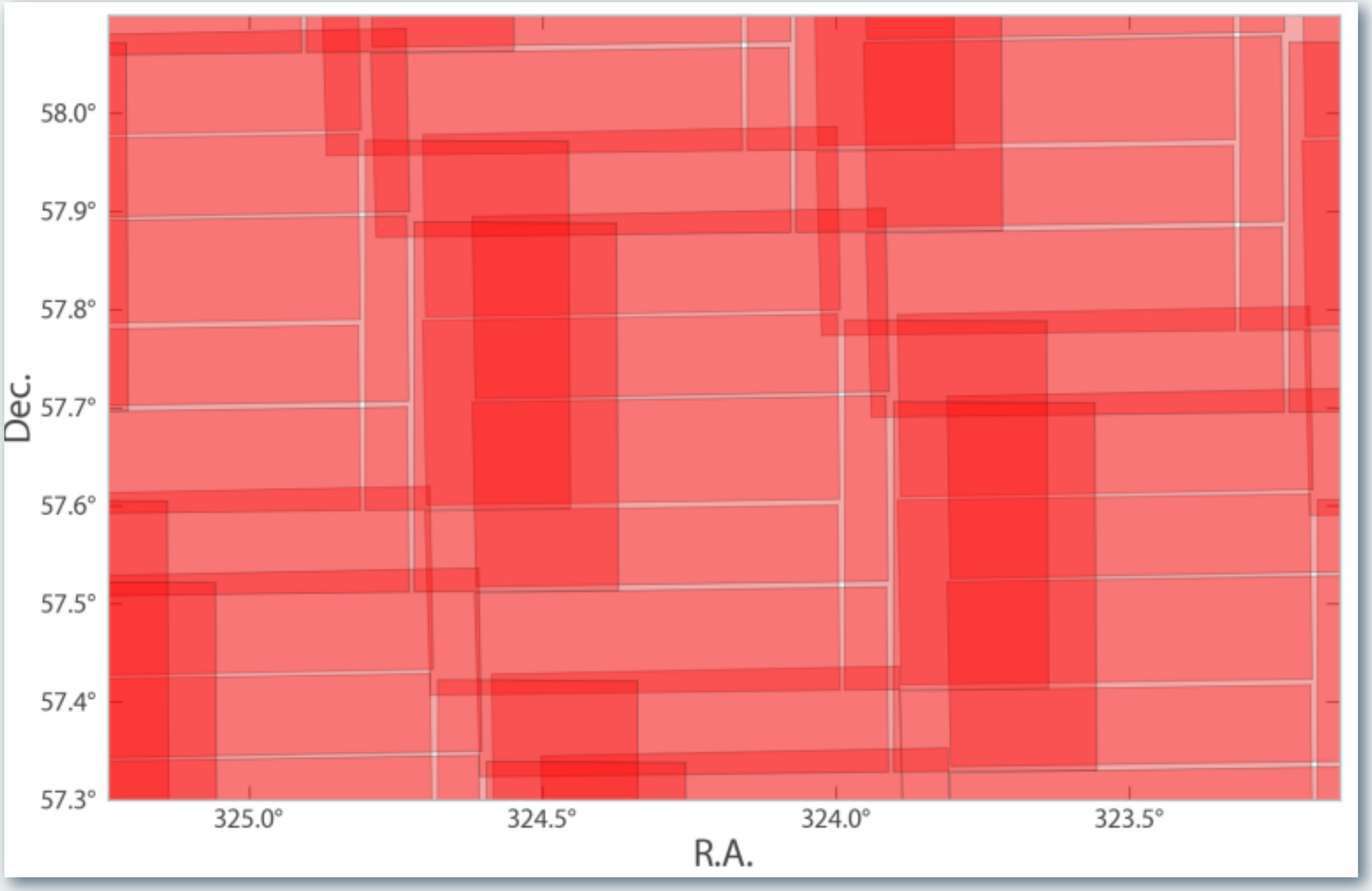


# Data is taken in “fieldpairs” to account for gaps and defects in the WFC

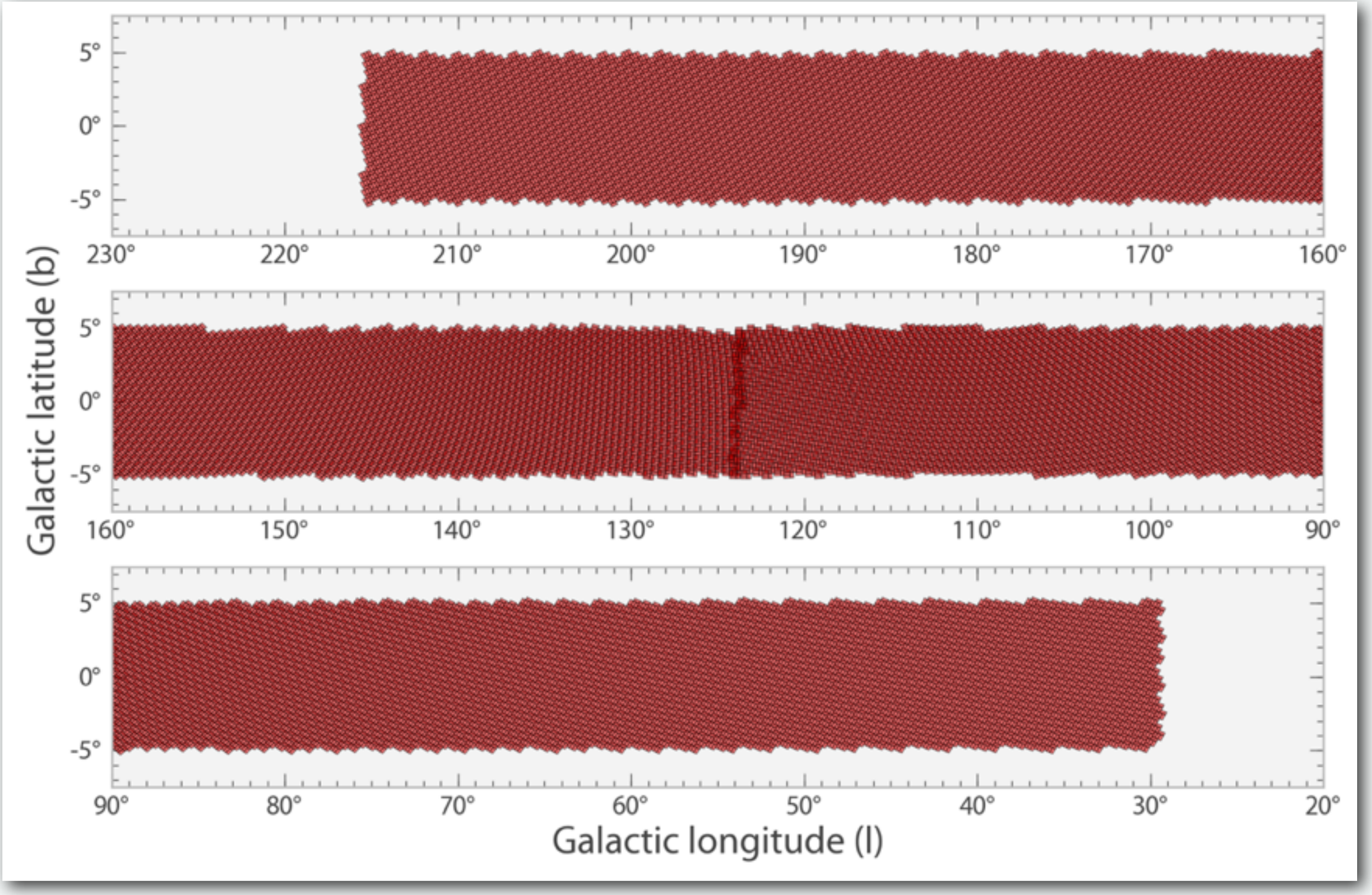
- Each pointing is paired with an offset at 5 arcmin S/W.
- “Simultaneous” observing sequence: Hα, r, i, <slew>, Hα, r, i.
- Low overheads because filter changes and slews are performed during readout (*until recently*).



# Area coverage is efficient, only 0.3% is lost in gaps



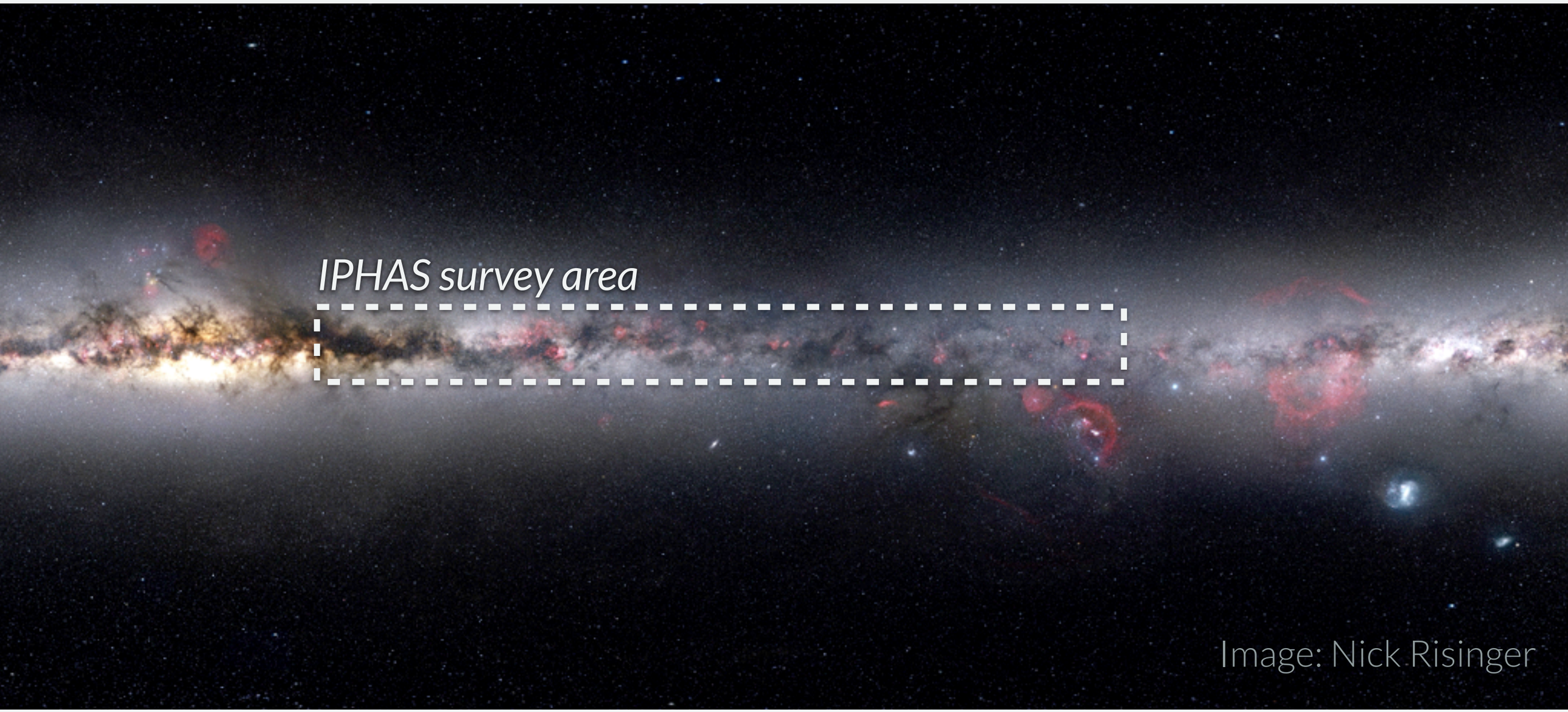
The survey area requires 7635 fieldpairs
= 45810 single-band exposures



So **why** are we doing this?

# Hα in emission is a tracer for diffuse ionised nebulae

- new star-forming regions
- new planetary nebulae
- new supernova remnants



Discovery of the "Príncipes de Asturias" nebula
*(Mampaso et al. 2006)*

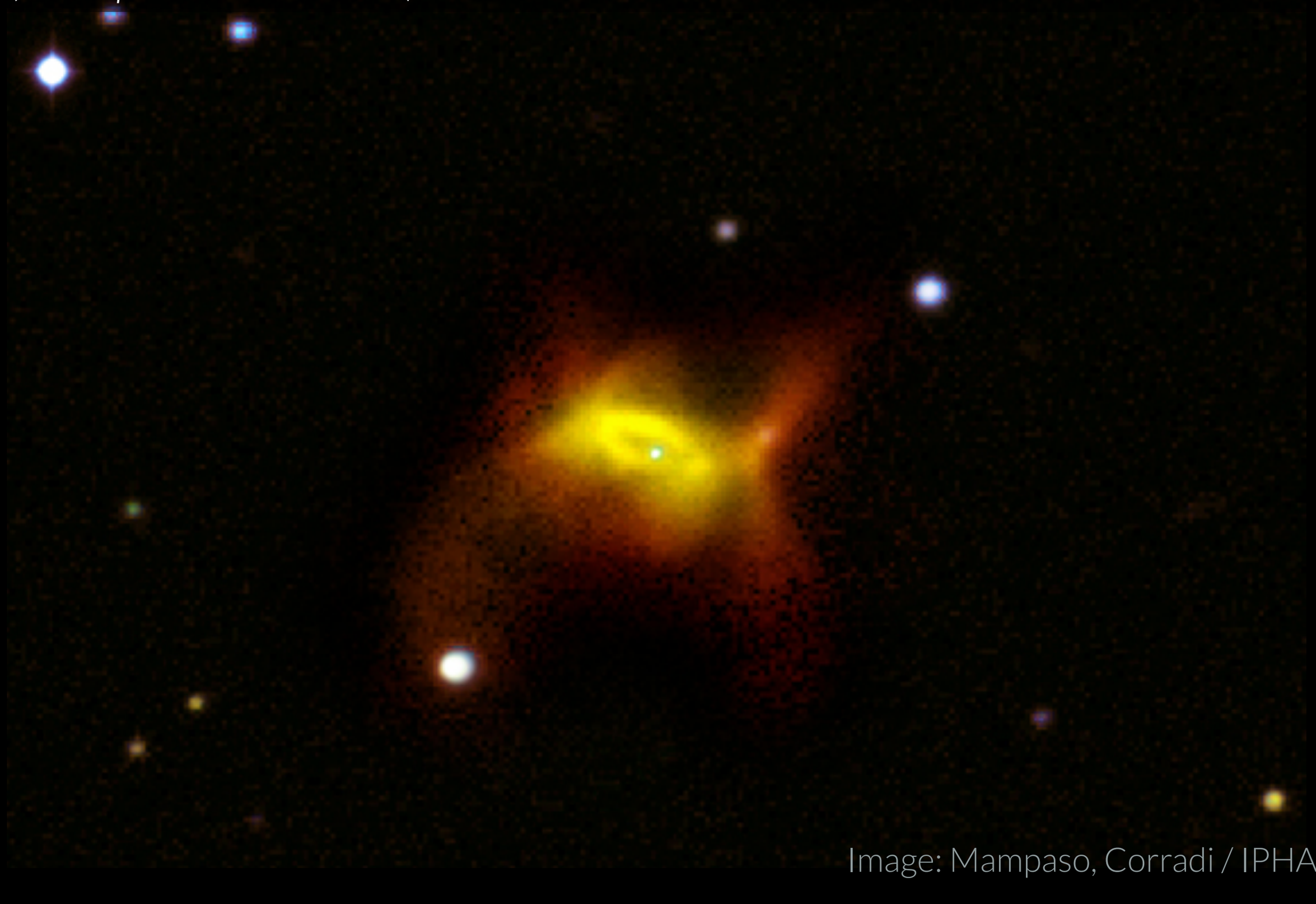


Image: Mampaso, Corradi / IPHAS

# Discovery of the Ear Nebula
*(Sabin et al. 2009)*

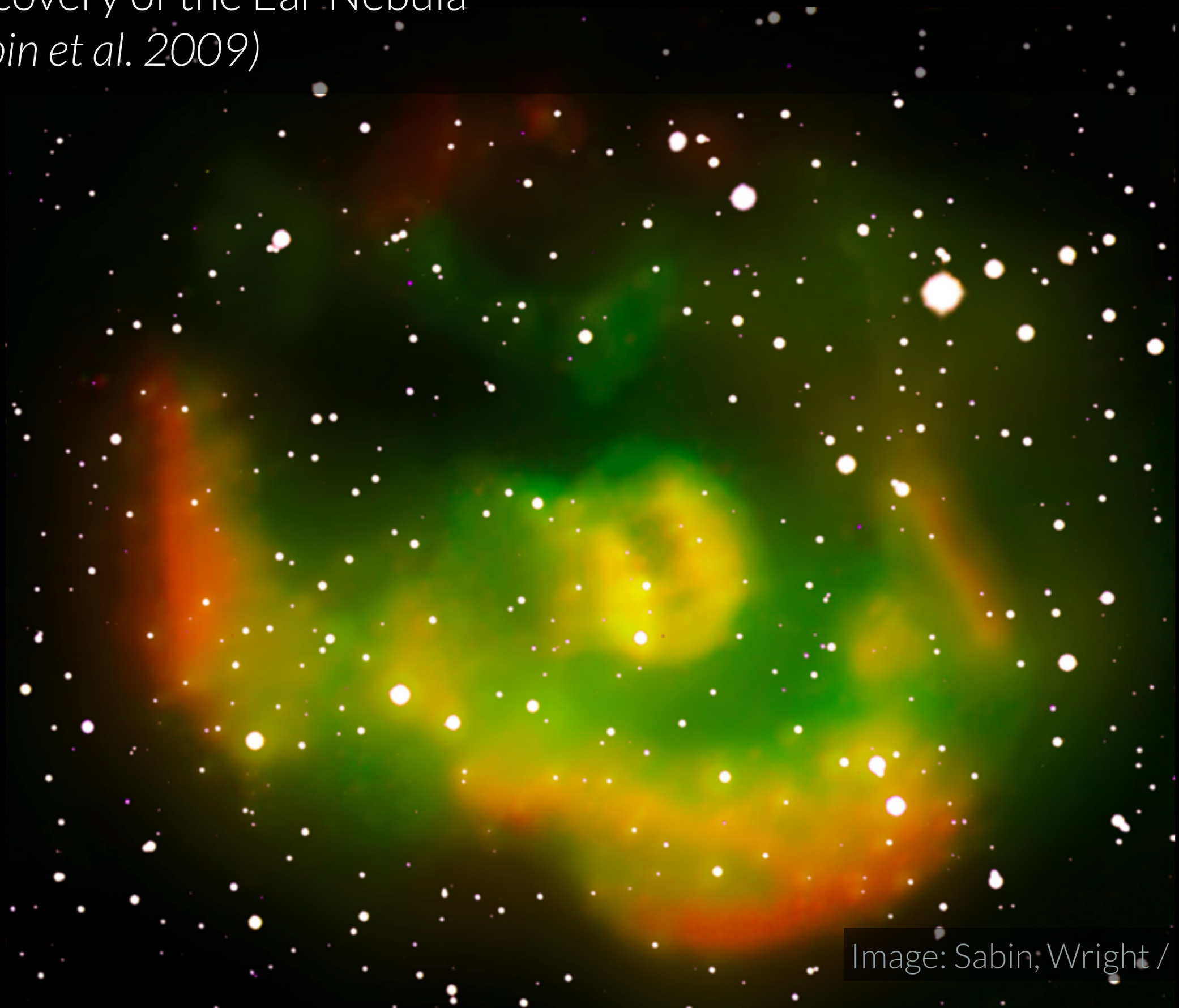
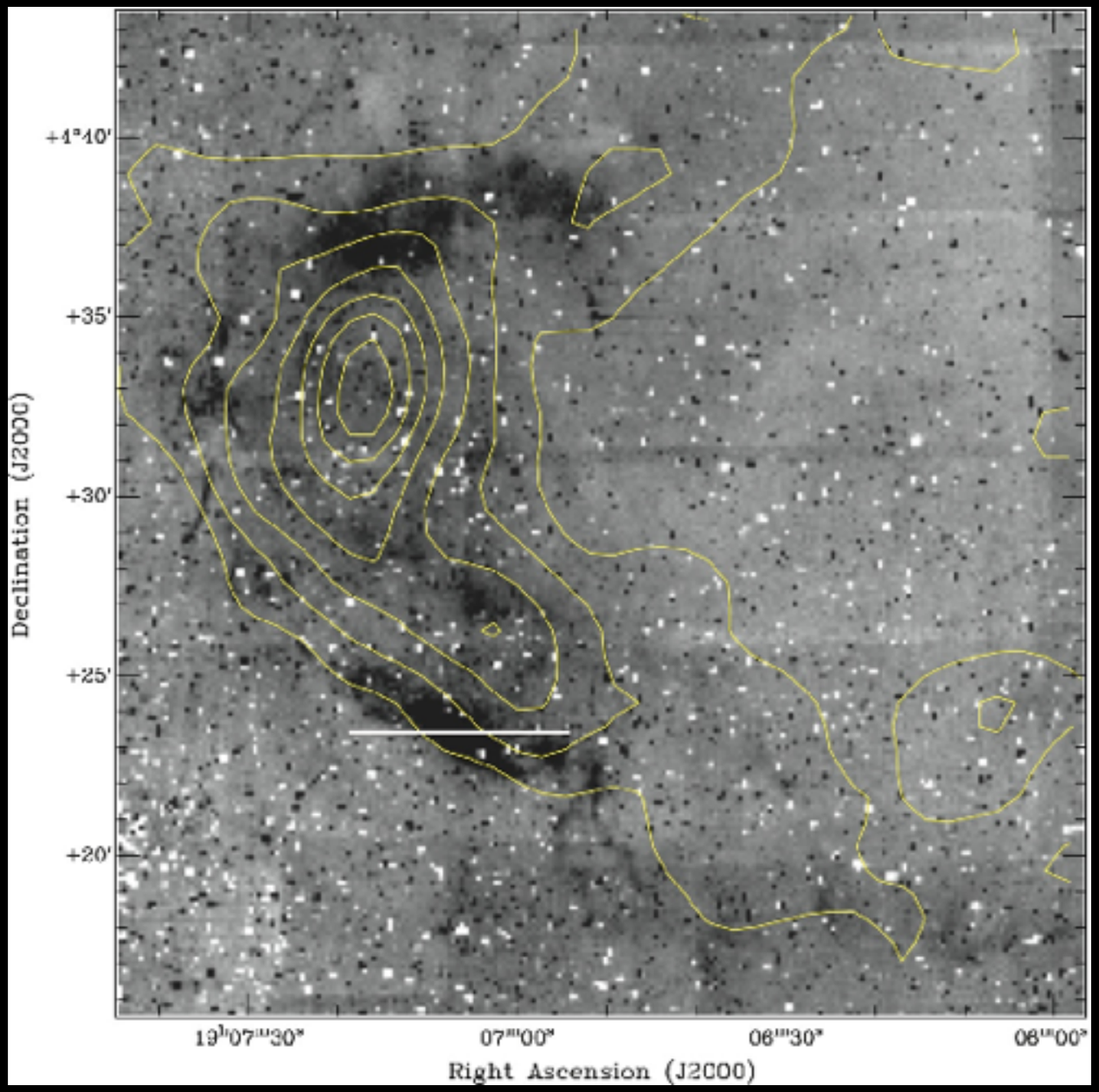


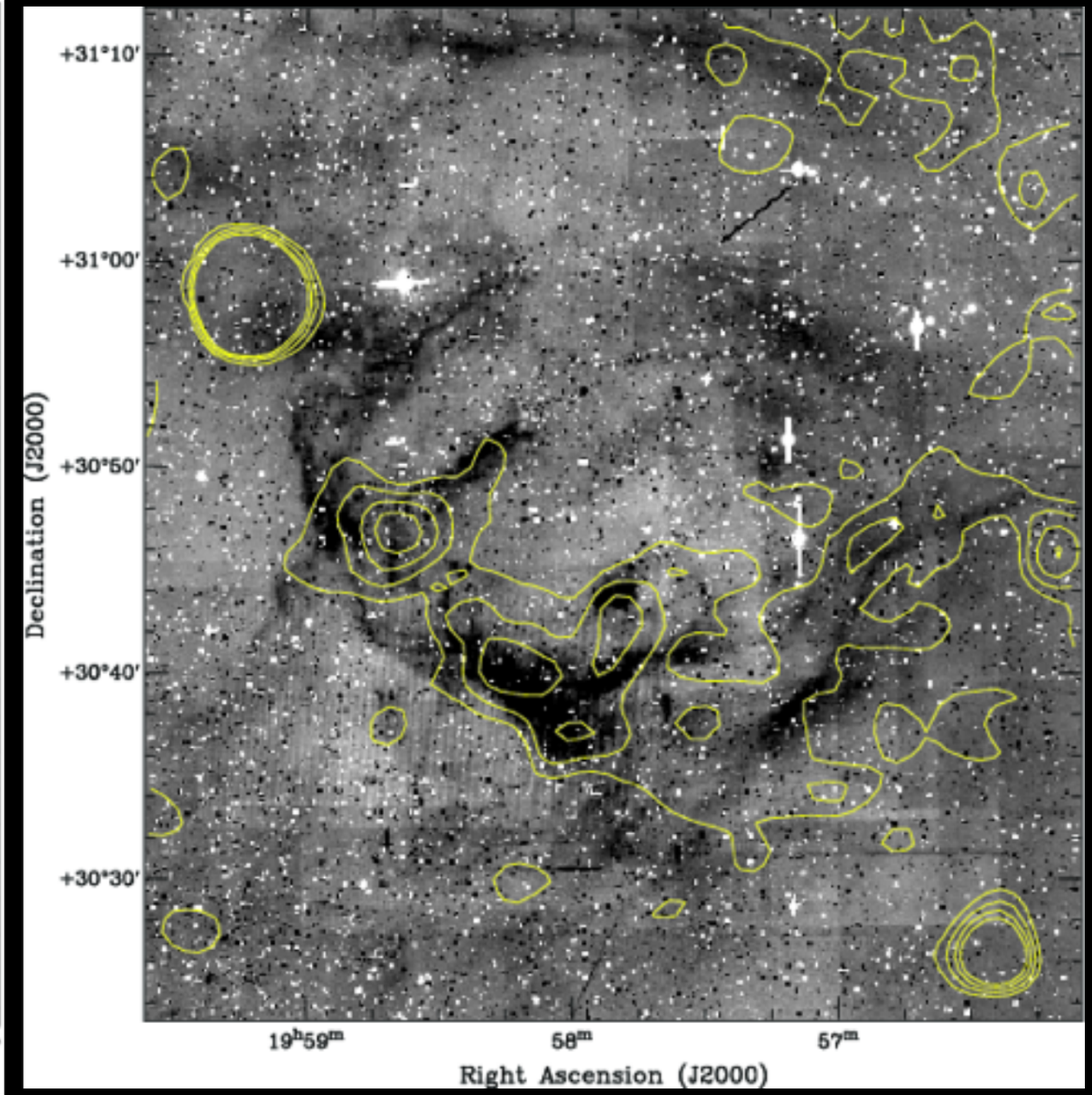
Image: Sabin, Wright / IPHAS

Discovery of the Necklace Nebula
*(Corradi et al. 2011)*

Image: Wright / IPHAS

# Discovery of new supernova remnants
*(Sabin et al. 2013)*



# Discovery of photo-evaporating objects in the Cygnus OB2 star-forming region *(Wright et al. 2012)*

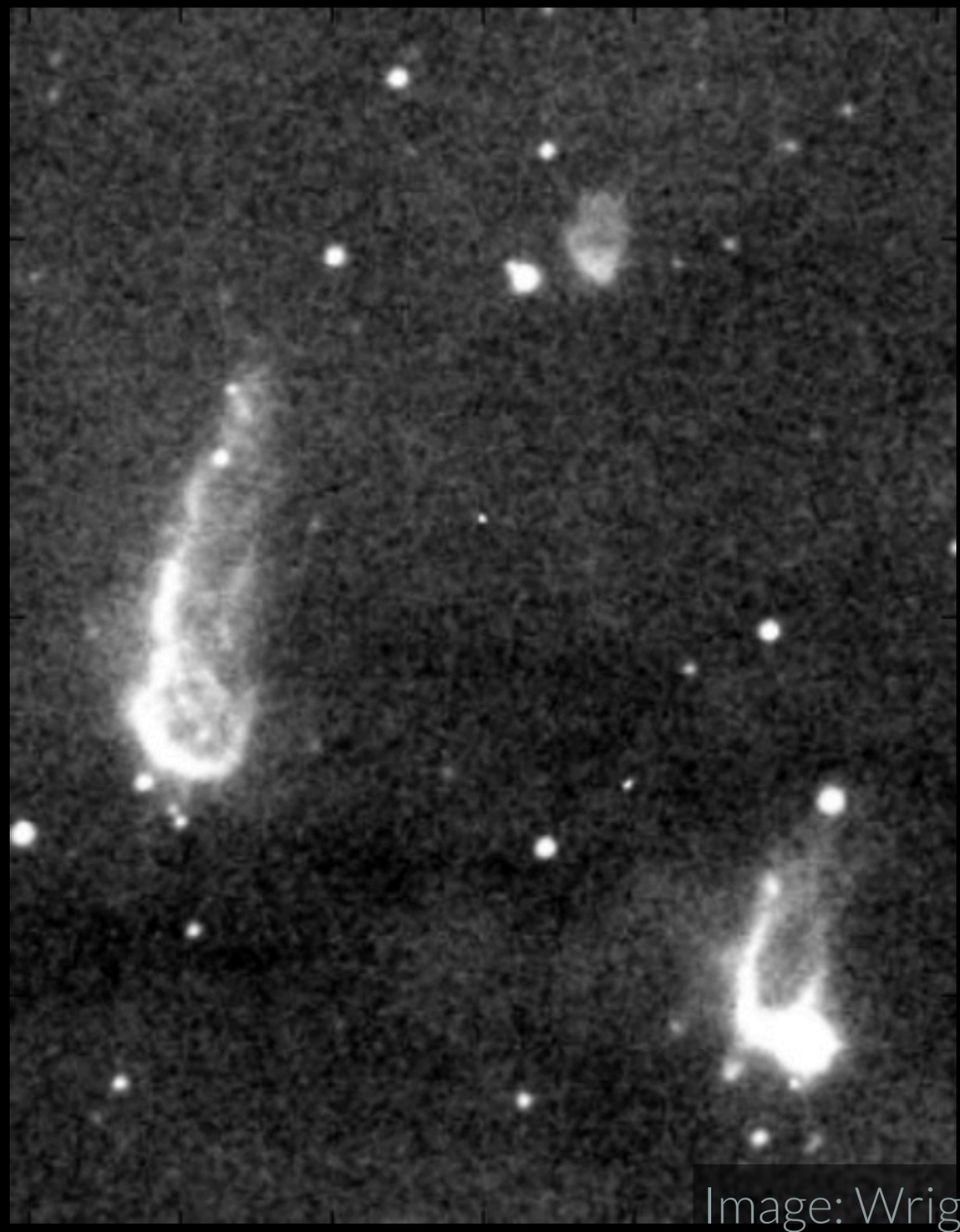
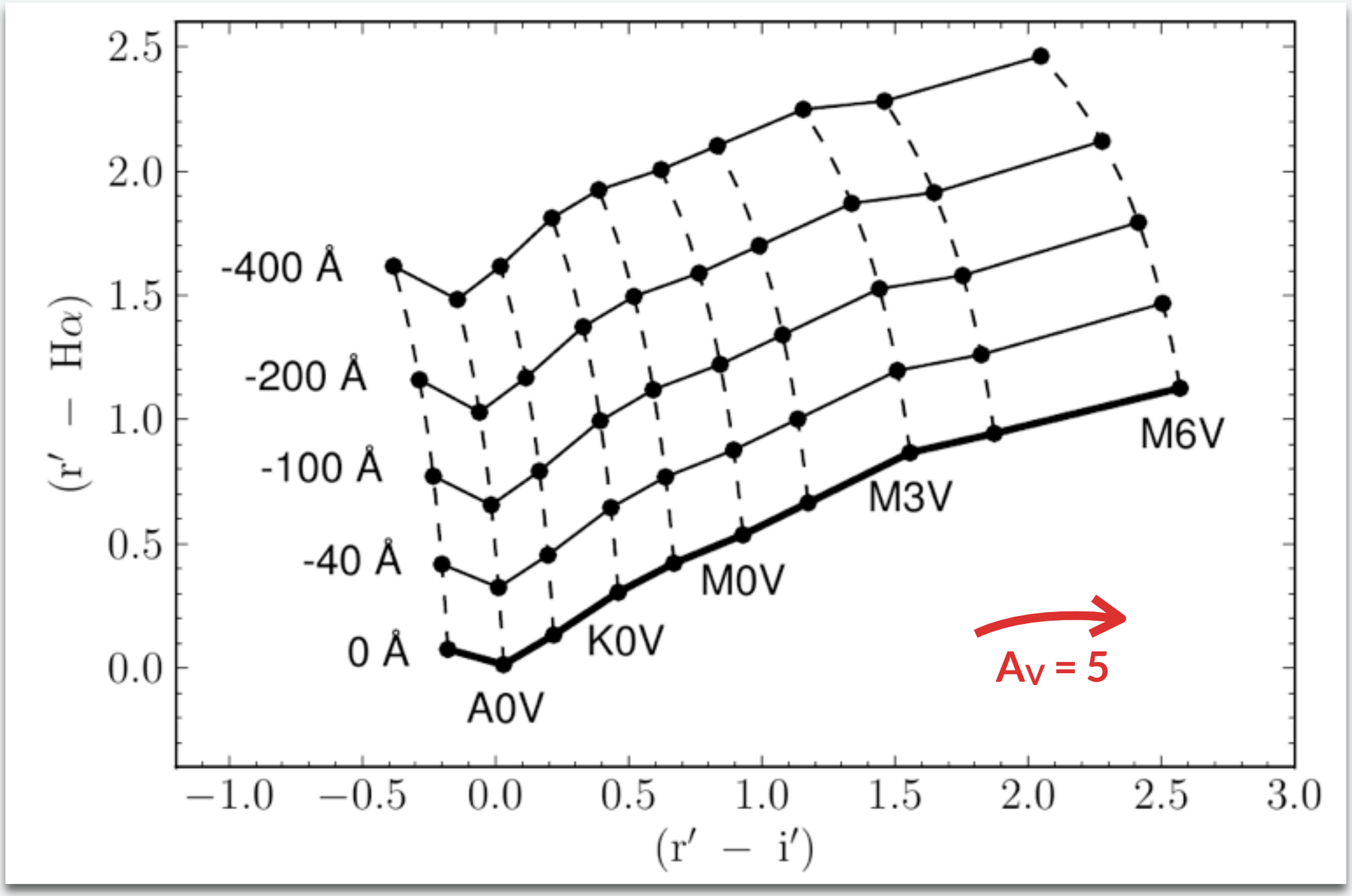


Image: Wright / IPHAS

Dust lanes and globules in the Rosette star-forming region

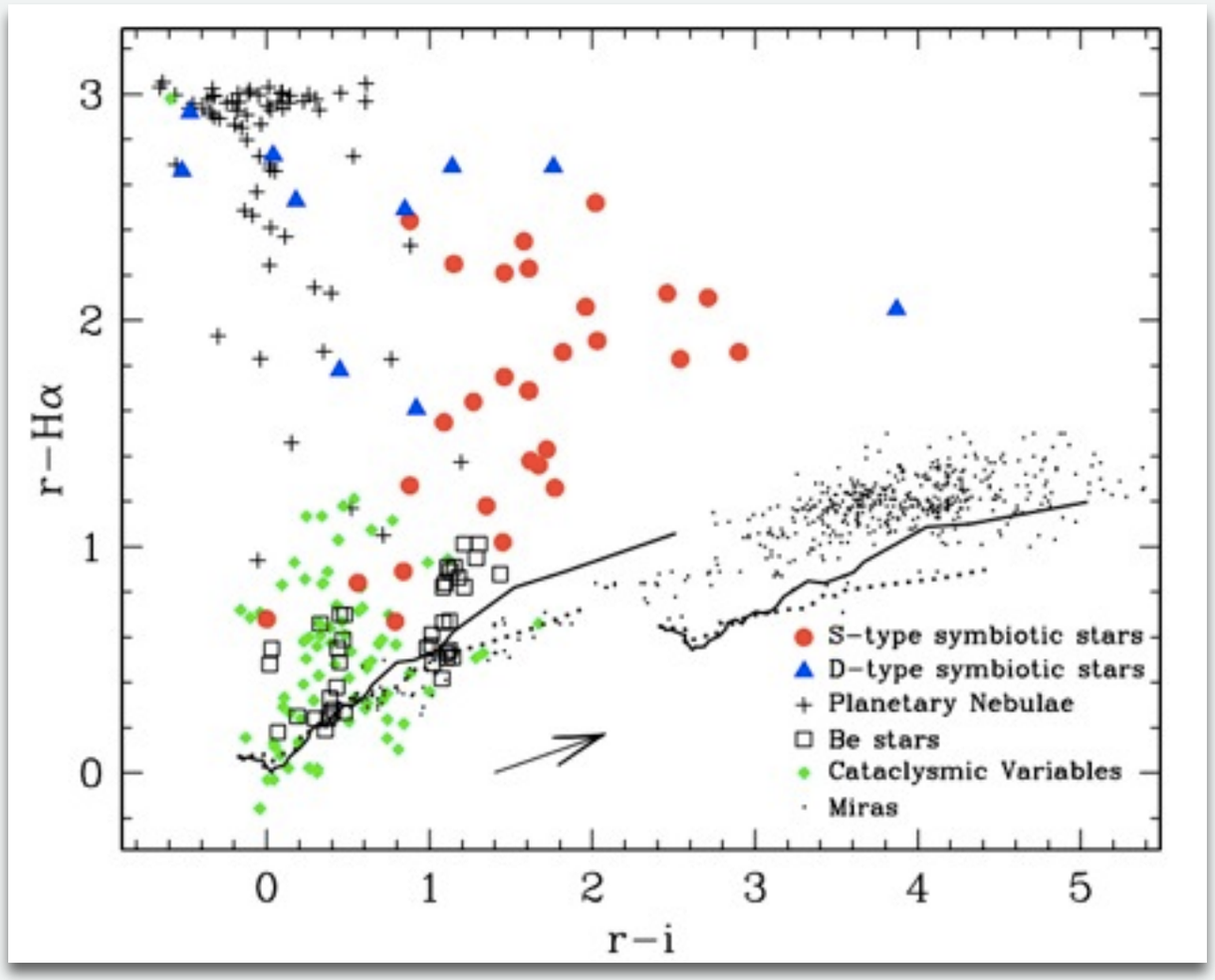
Image: Wright / IPHAS

# IPHAS also reveals spatially unresolved point sources with Hα in emission



# Hence IPHAS enables the discovery of large samples of stars in the crucial stages of stellar evolution

- Pre-main sequence stars
  *e.g. T Tauri,Herbig Ae/Be objects*
- Post-main sequence stars
  *e.g. some AGBs, compact PNs, LBVs, classical Be's*
- Interacting binaries
  *e.g. symbiotic stars, cataclysmic variables*




(Corradi et al. 2008)

# Discovery of 124 new pre-main sequence stars in IC 1396 *(Barentsen et al. 2011)*

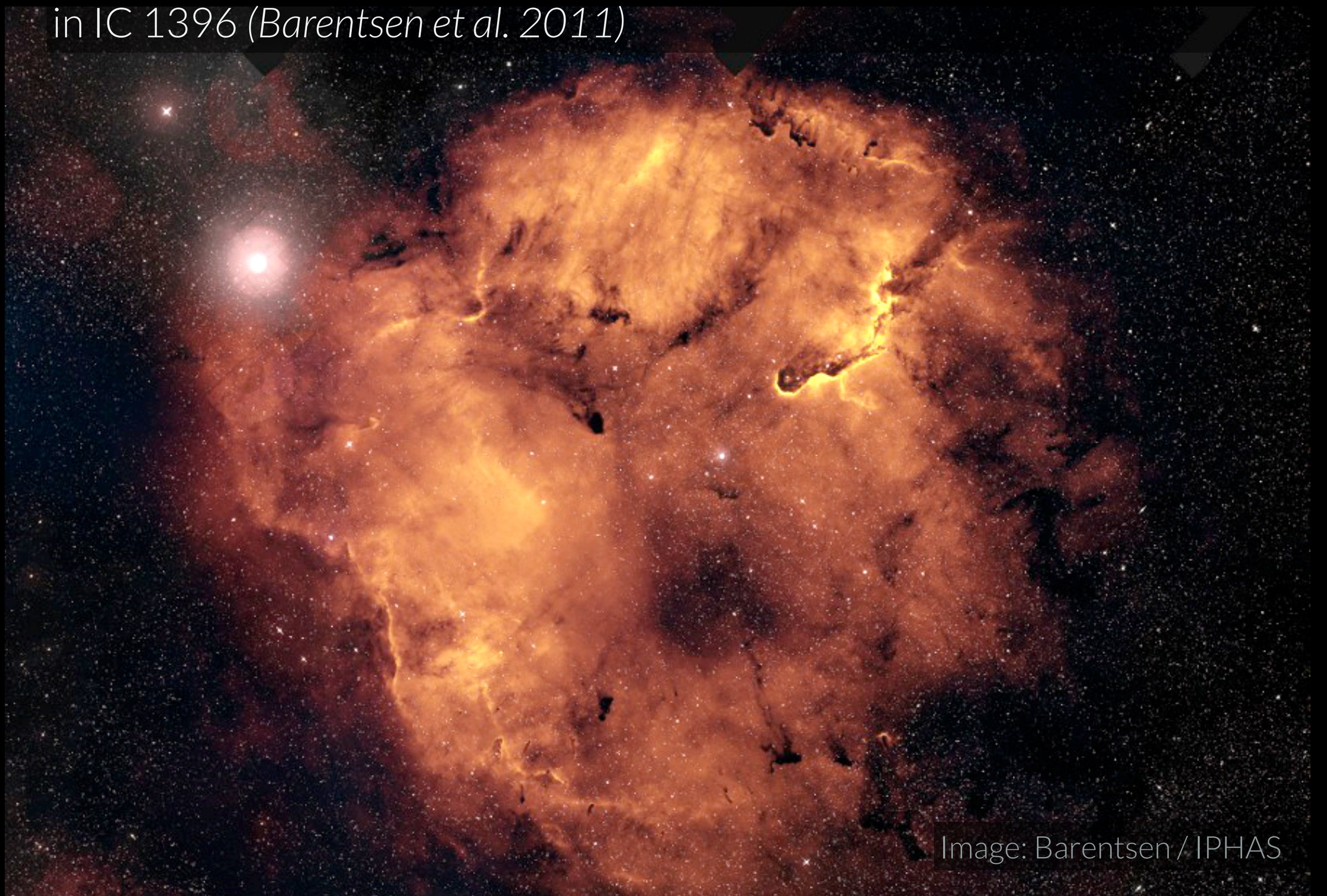
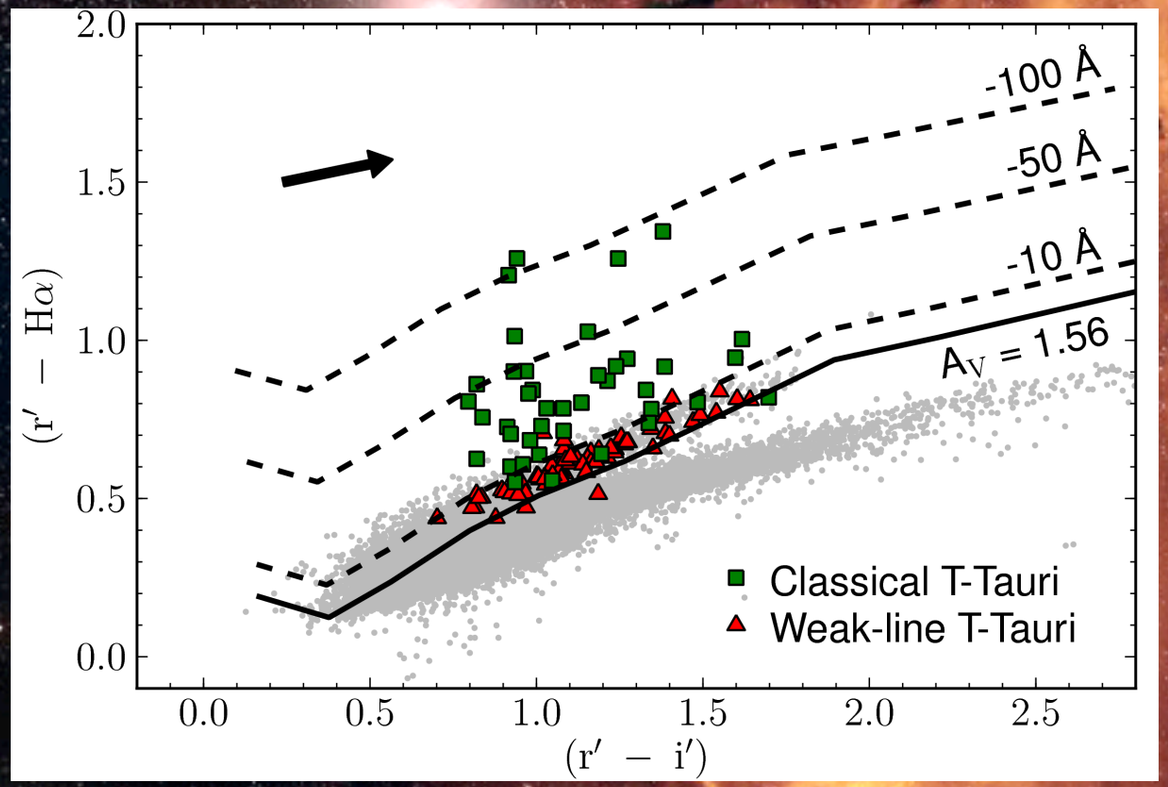


Image: Barentsen / IPHAS

# Discovery of 124 new pre-main sequence stars in IC 1396 (*Barentsen et al. 2011*)



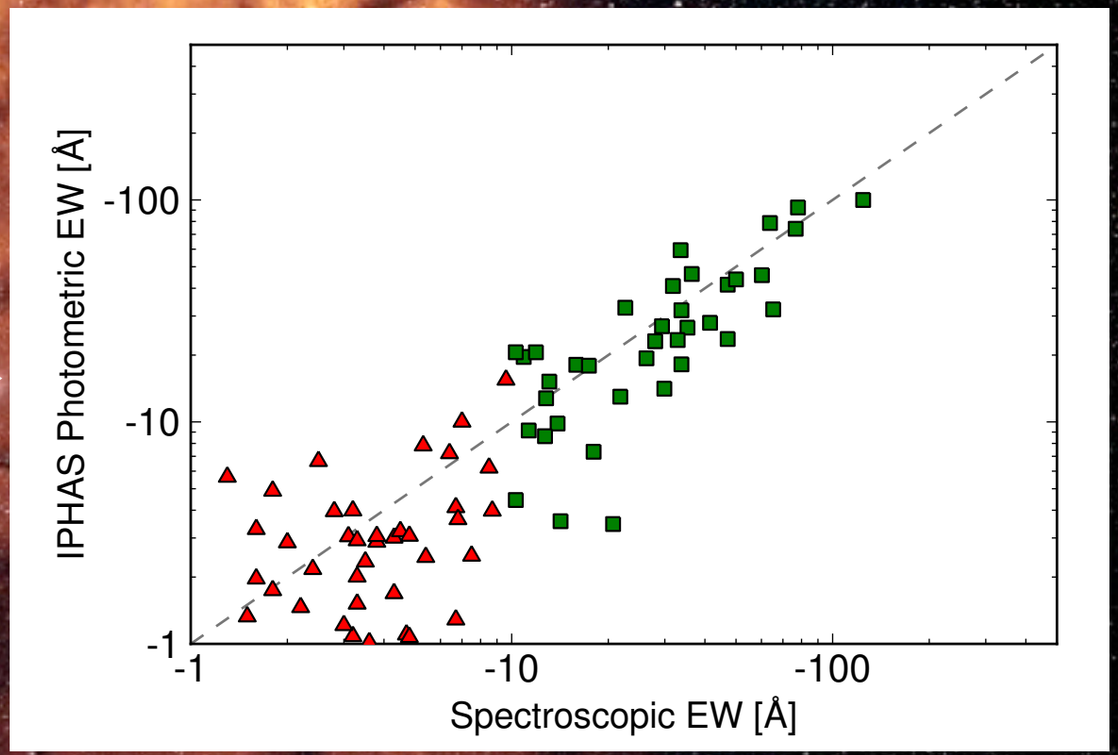
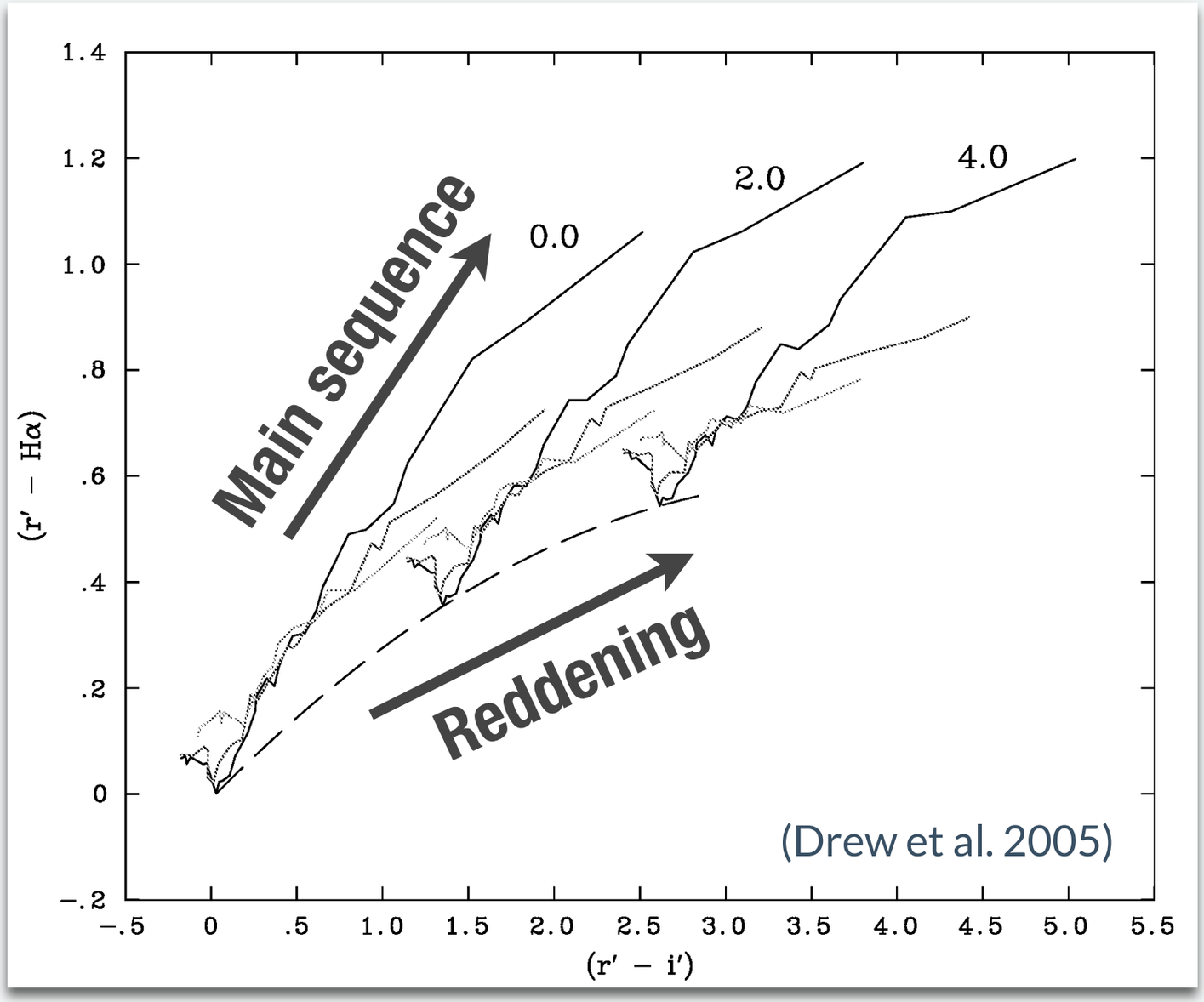



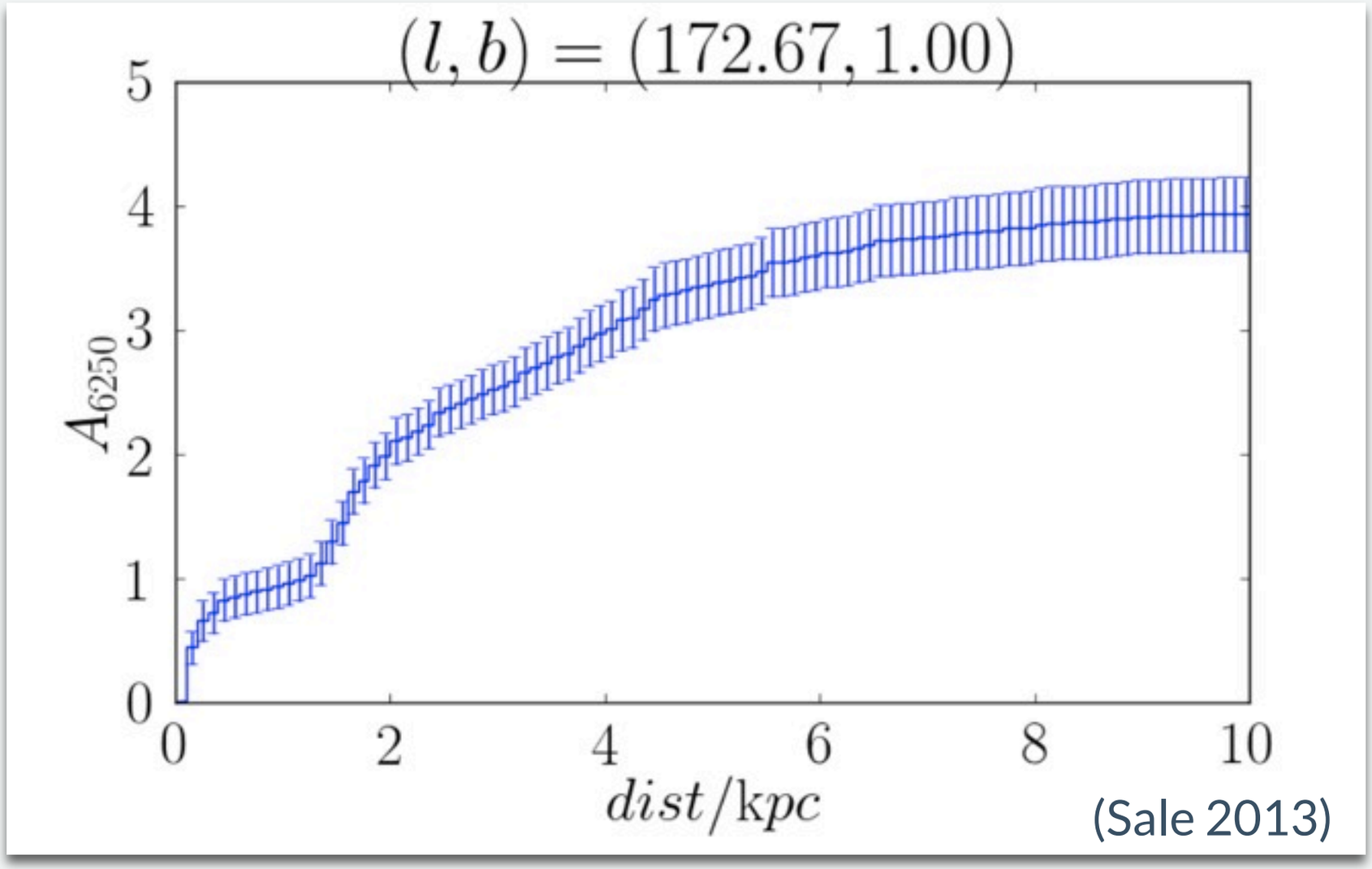

Image: Barentsen / IPHAS

And the legacy of IPHAS is set to extend beyond ‘traditional’ Hα object identification, because the (r - Hα) colour is also a proxy for intrinsic colour.



# IPHAS allows interstellar extinction to be mapped in three dimensions

- Hα, when combined with r/i/J/H/K, offers a first-order spectroscopic parallax and extinction estimate for $10^8$ stars.
- Will aid the upcoming 'Gaia revolution'.



To exploit the survey, it is necessary to build a quality-checked and calibrated catalogue.

**=> DR2 Source Catalogue**

# 2. The new data release

- quality control
- photometric re-calibration
- catalogue building

# IPHAS data flow

ING

↓ Raw images

Cambridge

Irwin, Gonzalez-Solares, Lewis, et al. (CASU)

- bias, non-linearity, dark, flat, fringe correction;
- astrometric calibration;
- nightly zeropoint calibration;
- source detection and measurement.

↓ Calibrated images & detection lists

Hertfordshire

Barentsen, Farnhill, Drew, Greimel, et al.

- quality control;
- homogeneous re-calibration;
- catalogue generation (band-merging, warning flags).

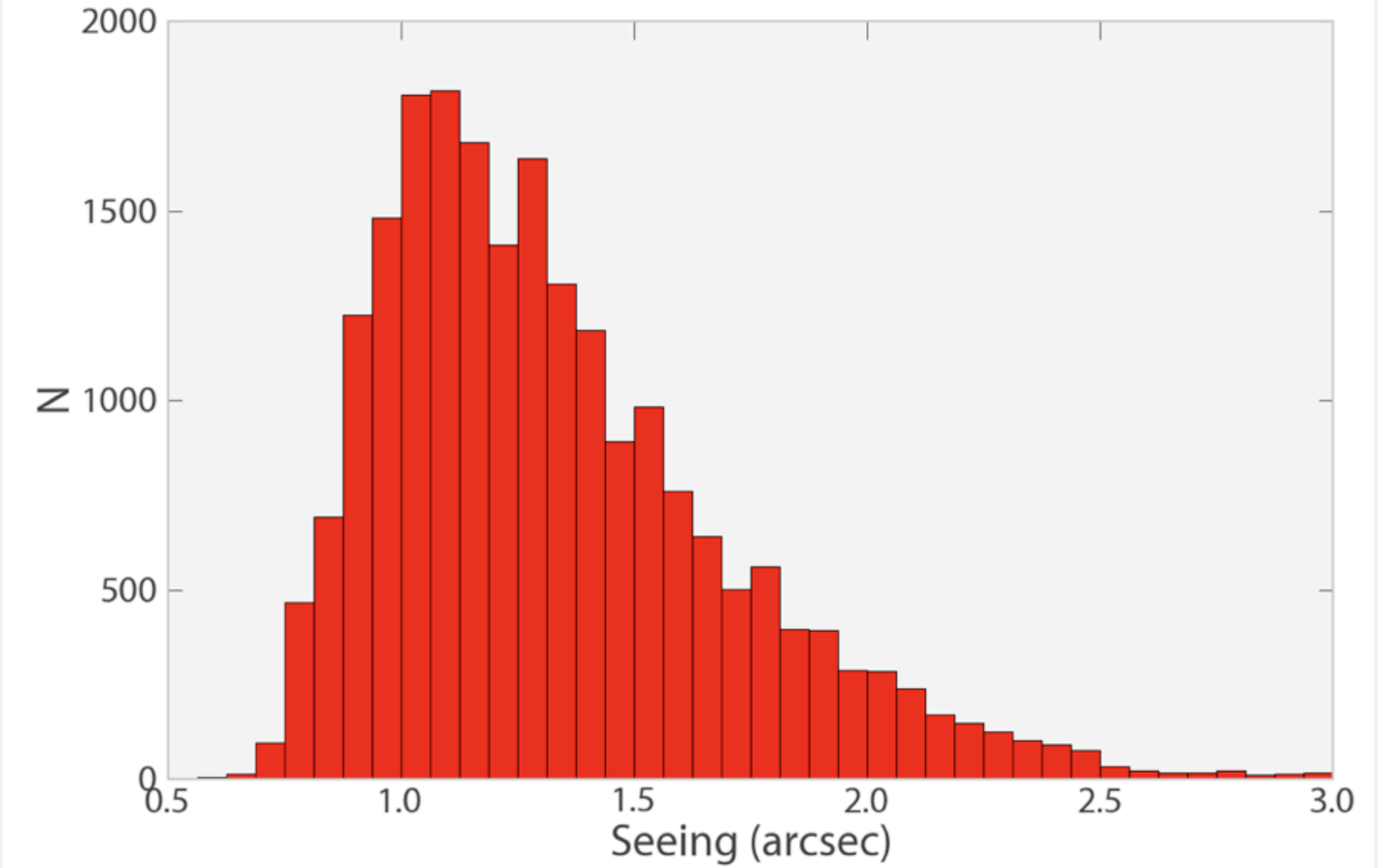
# 2. The new data release

**- quality control**

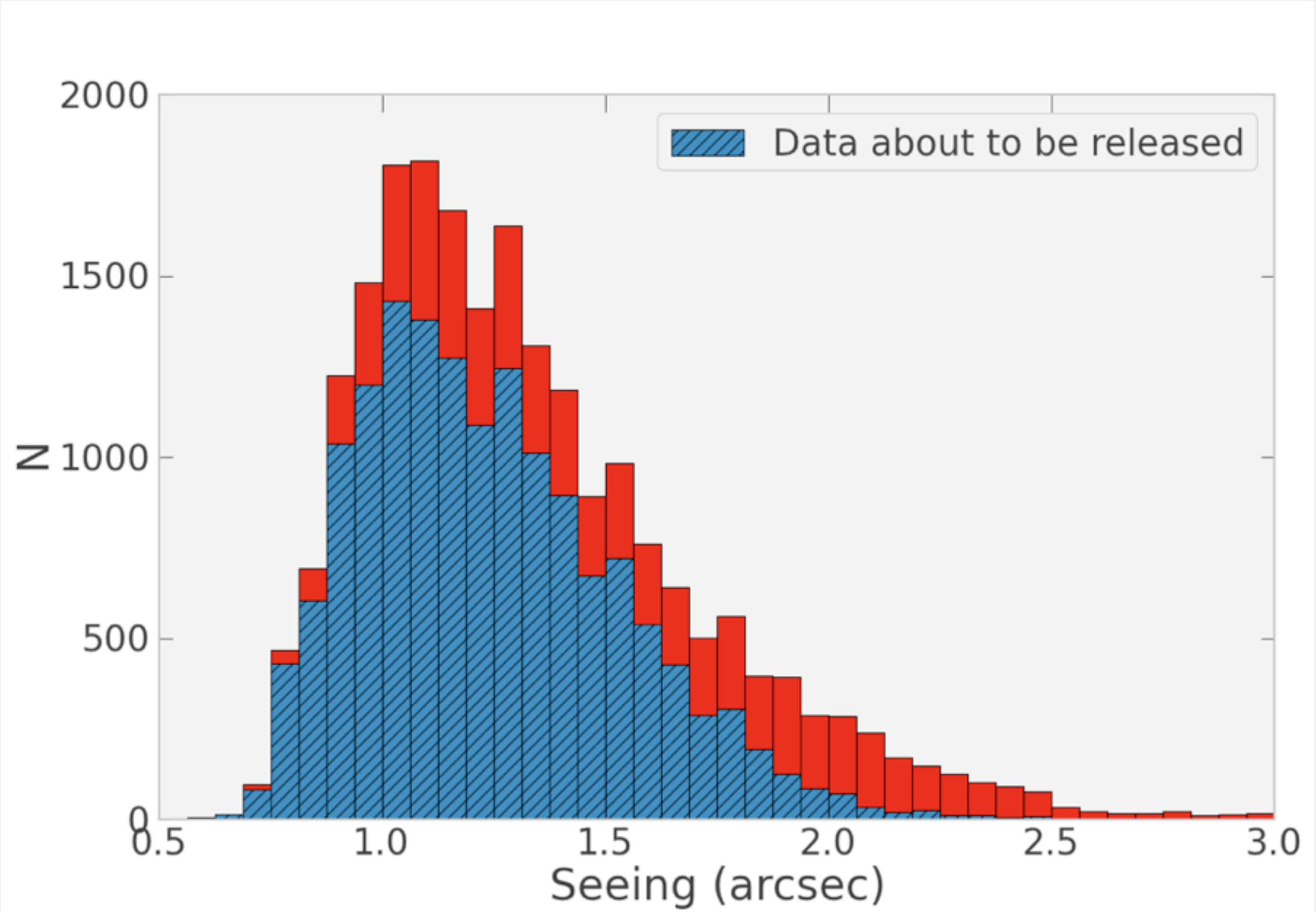
- photometric re-calibration

- catalogue building

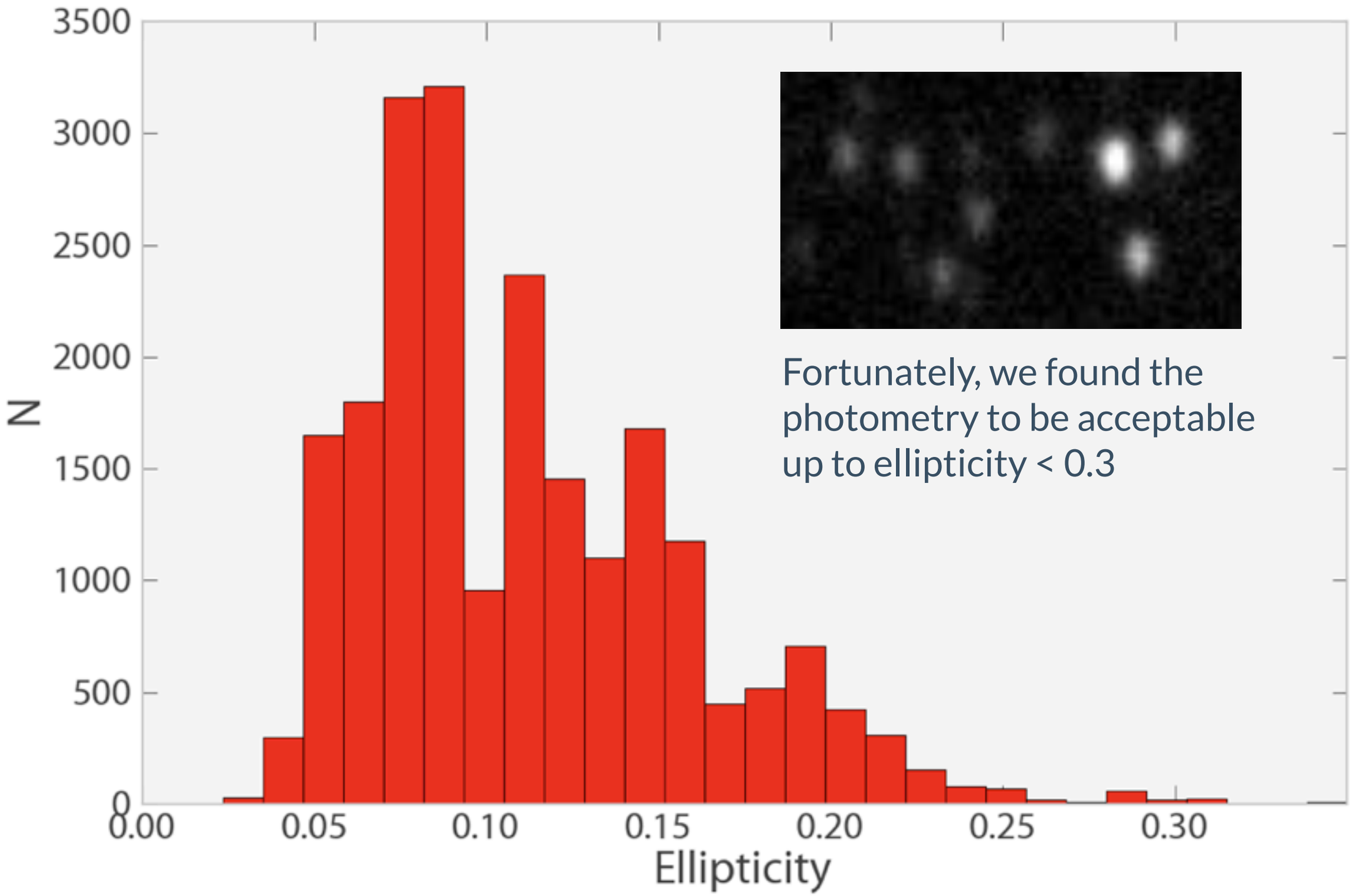
# Median seeing at the INT is 1.2 arcsec (in our red filters)



# Due to repeat observations, 65% of DR2 will be based on seeing better than 1.2”



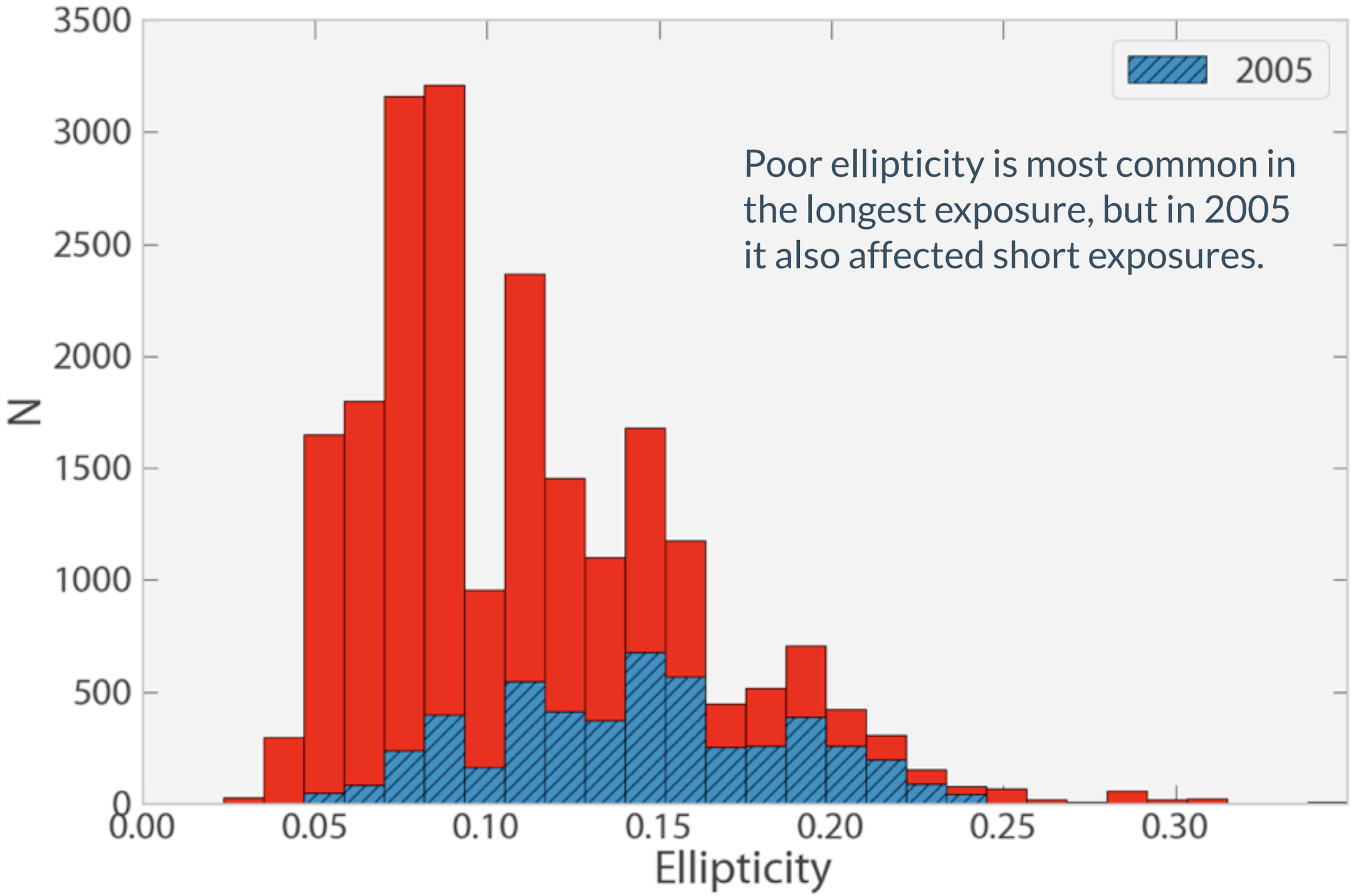
# 6% of our pointings suffered from ellipticity > 0.2 in at least one band



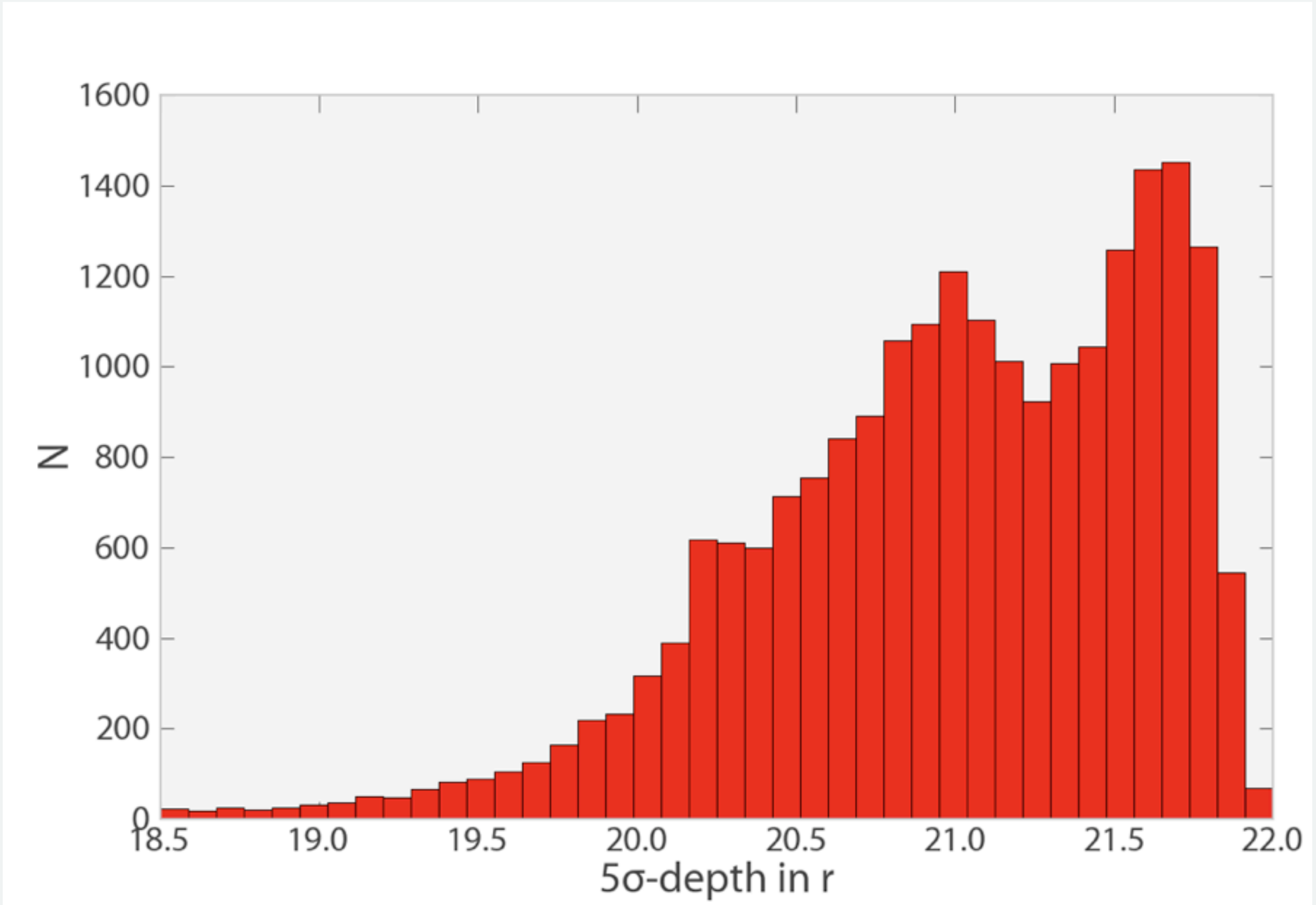



Fortunately, we found the photometry to be acceptable up to ellipticity < 0.3

# In 2005, the INT experienced a stabilisation problem



# Limiting magnitude in the r-band



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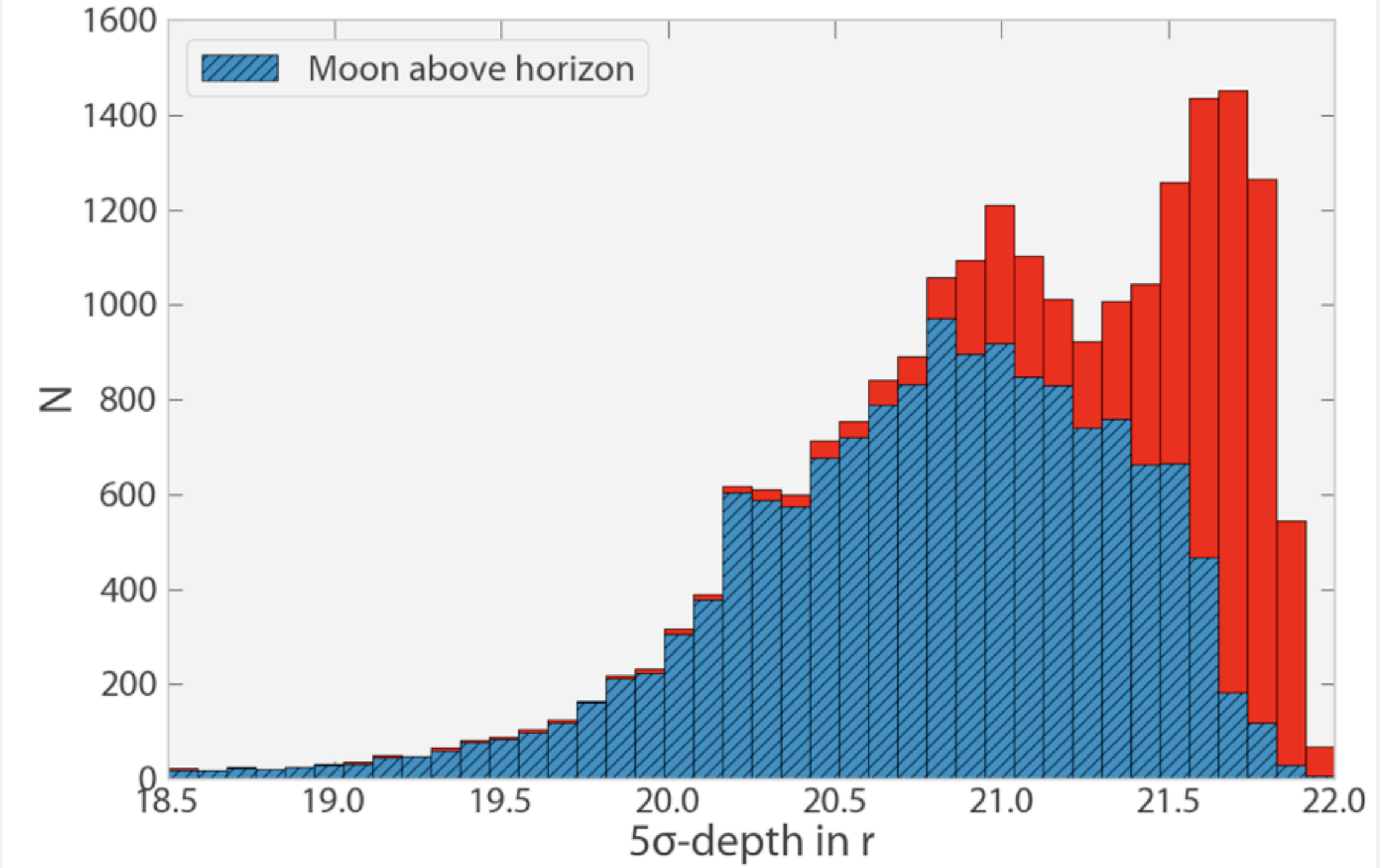
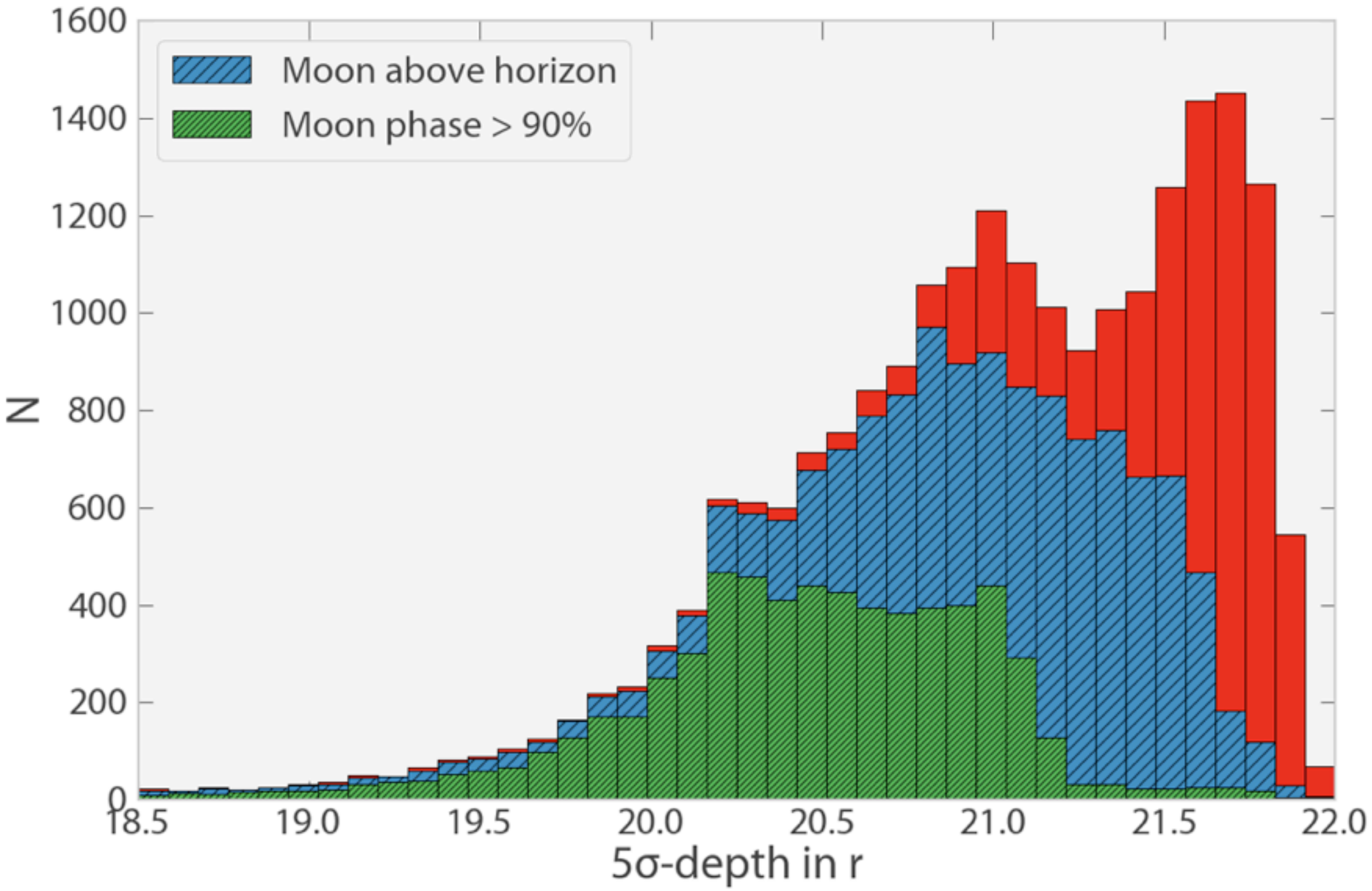
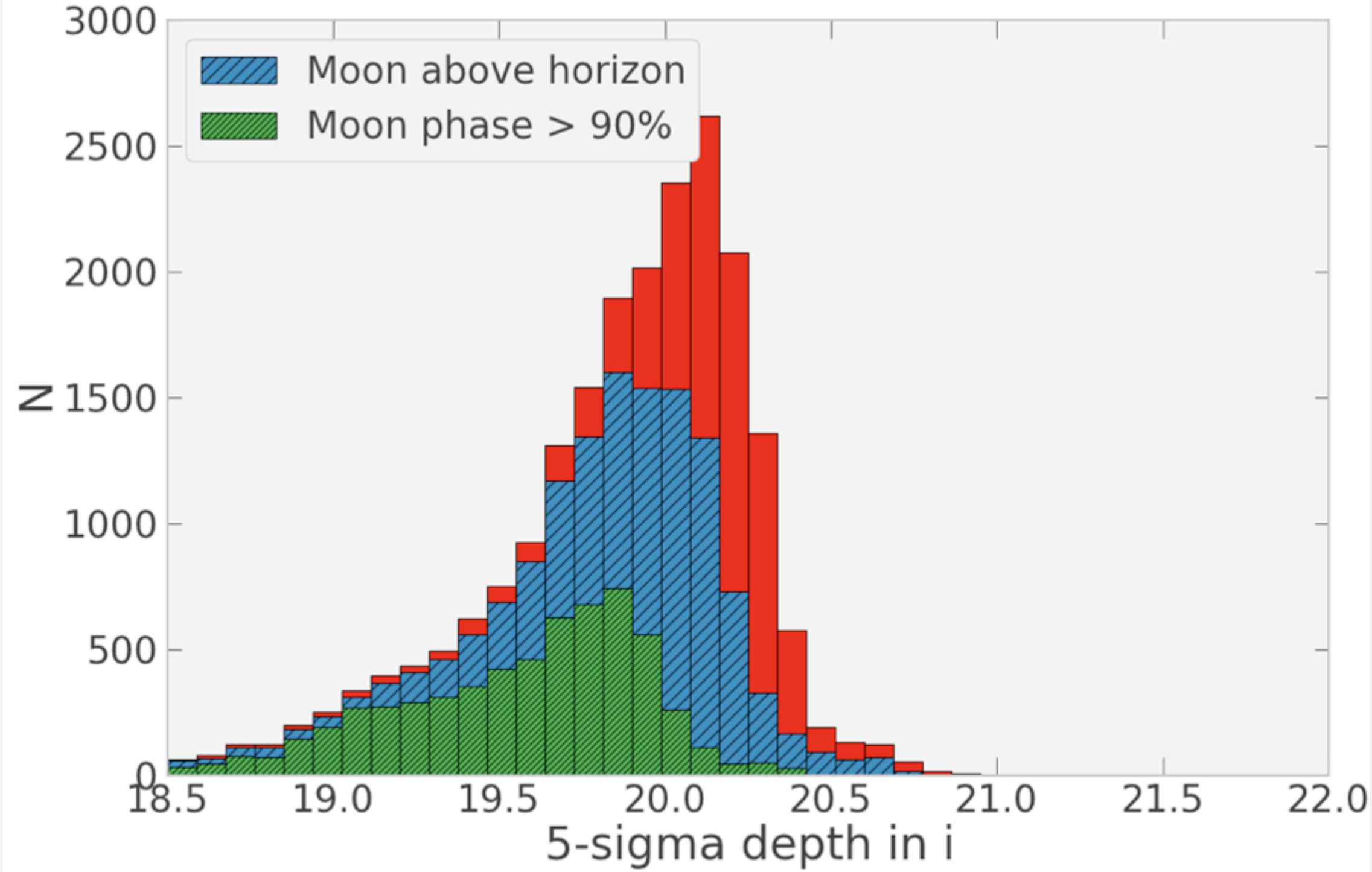


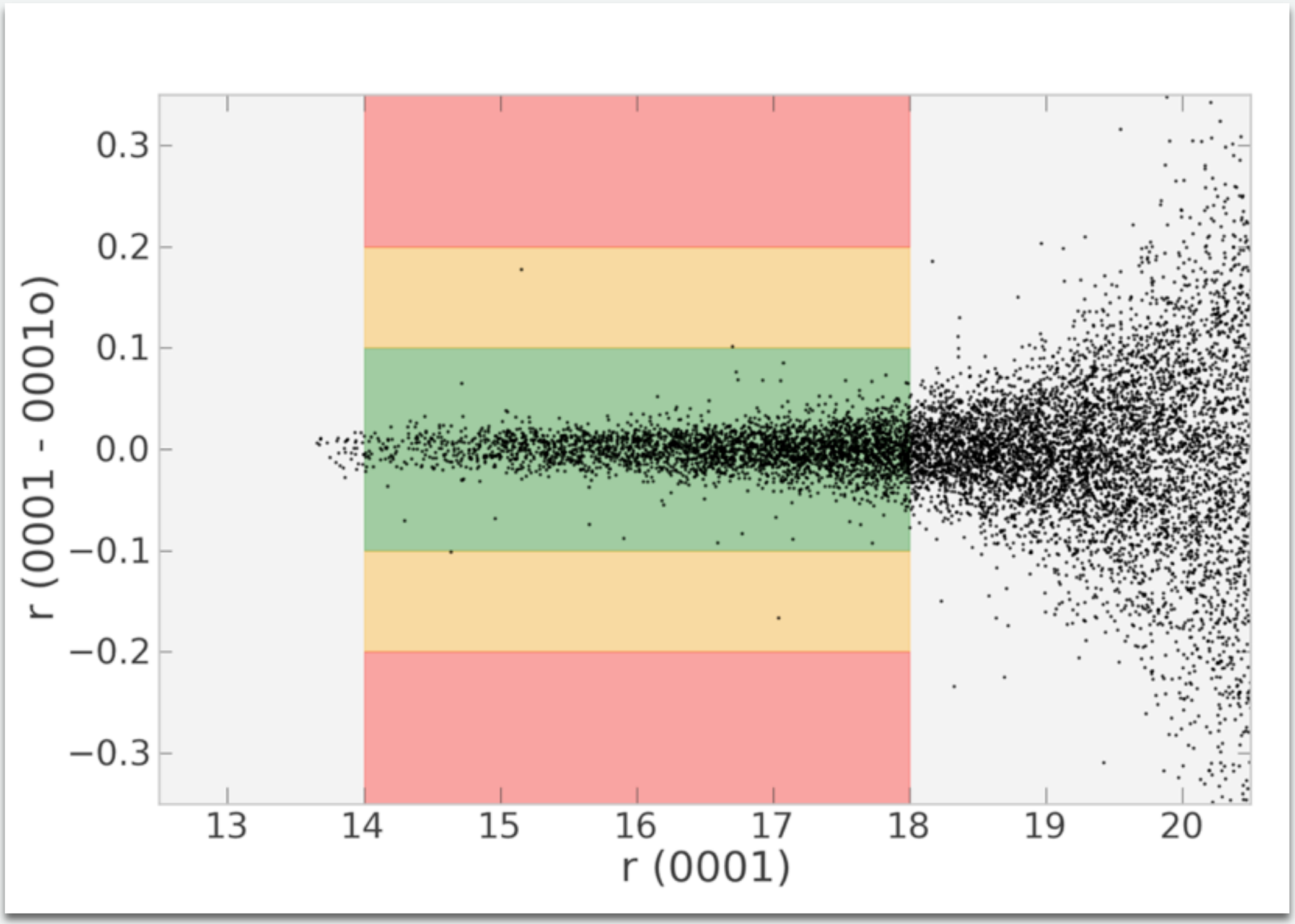
# Limiting magnitude in the r-band



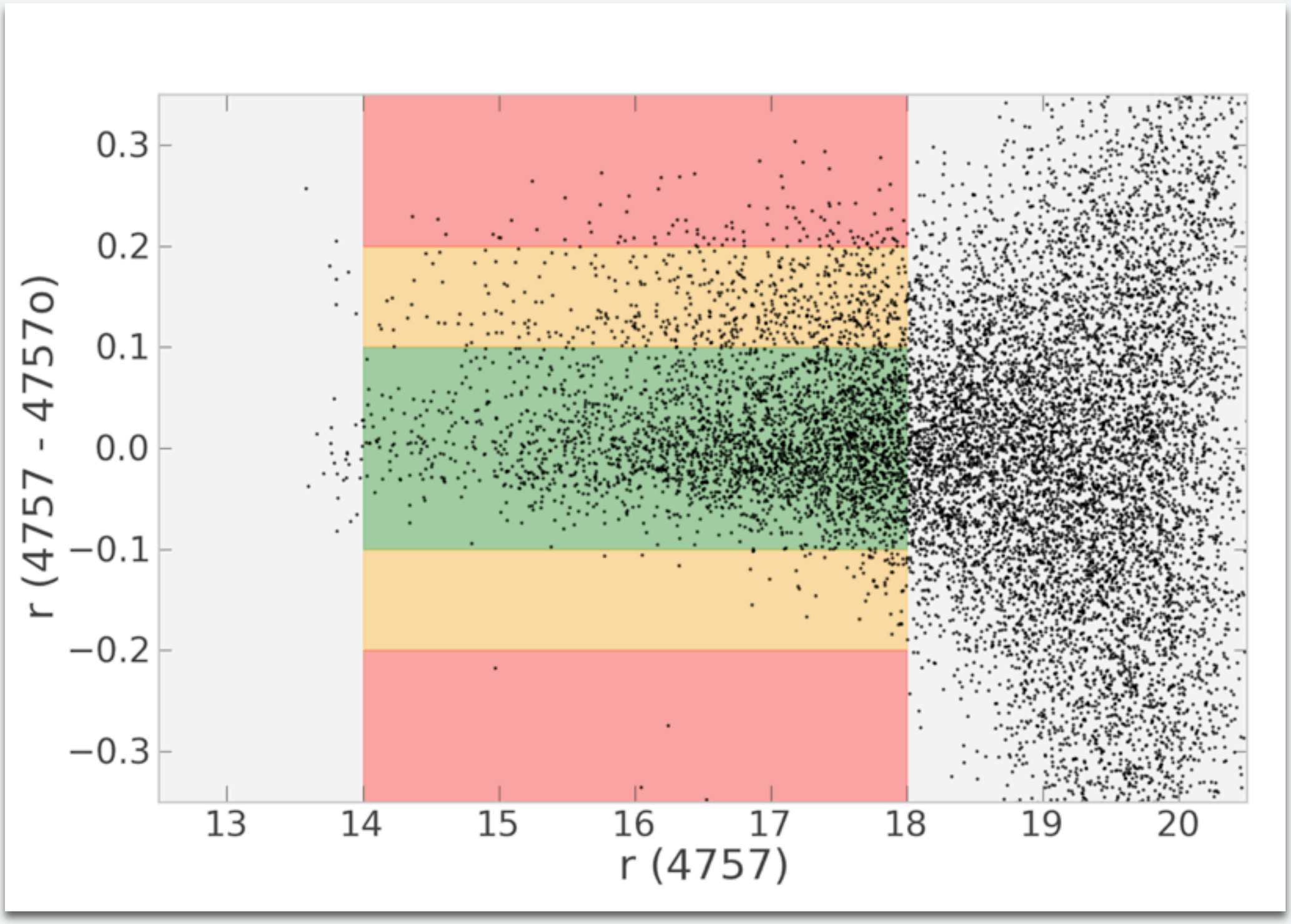
# Limiting magnitude in the i-band



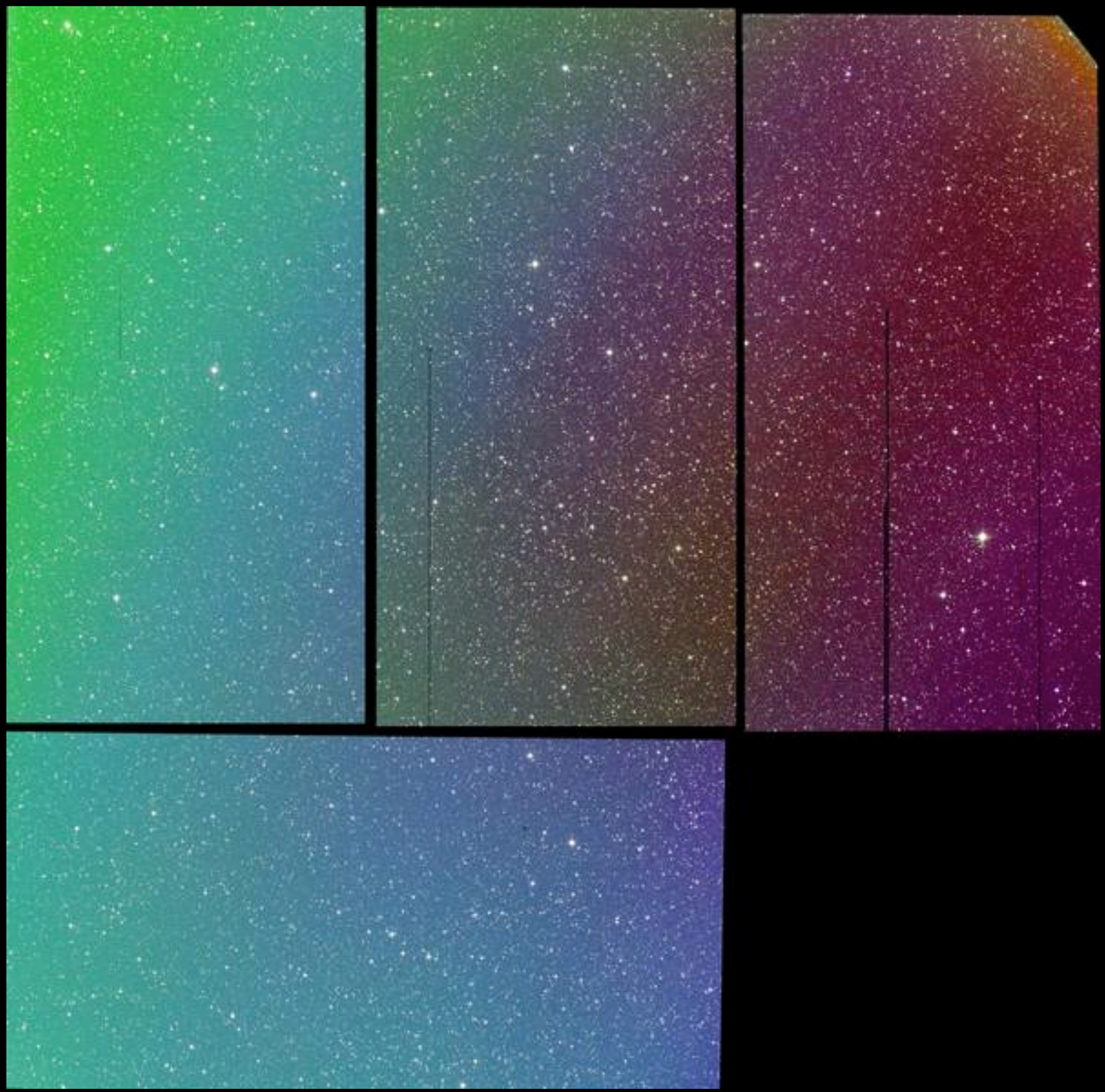
# We systematically checked for clouds or noise by cross-matching the fieldpairs

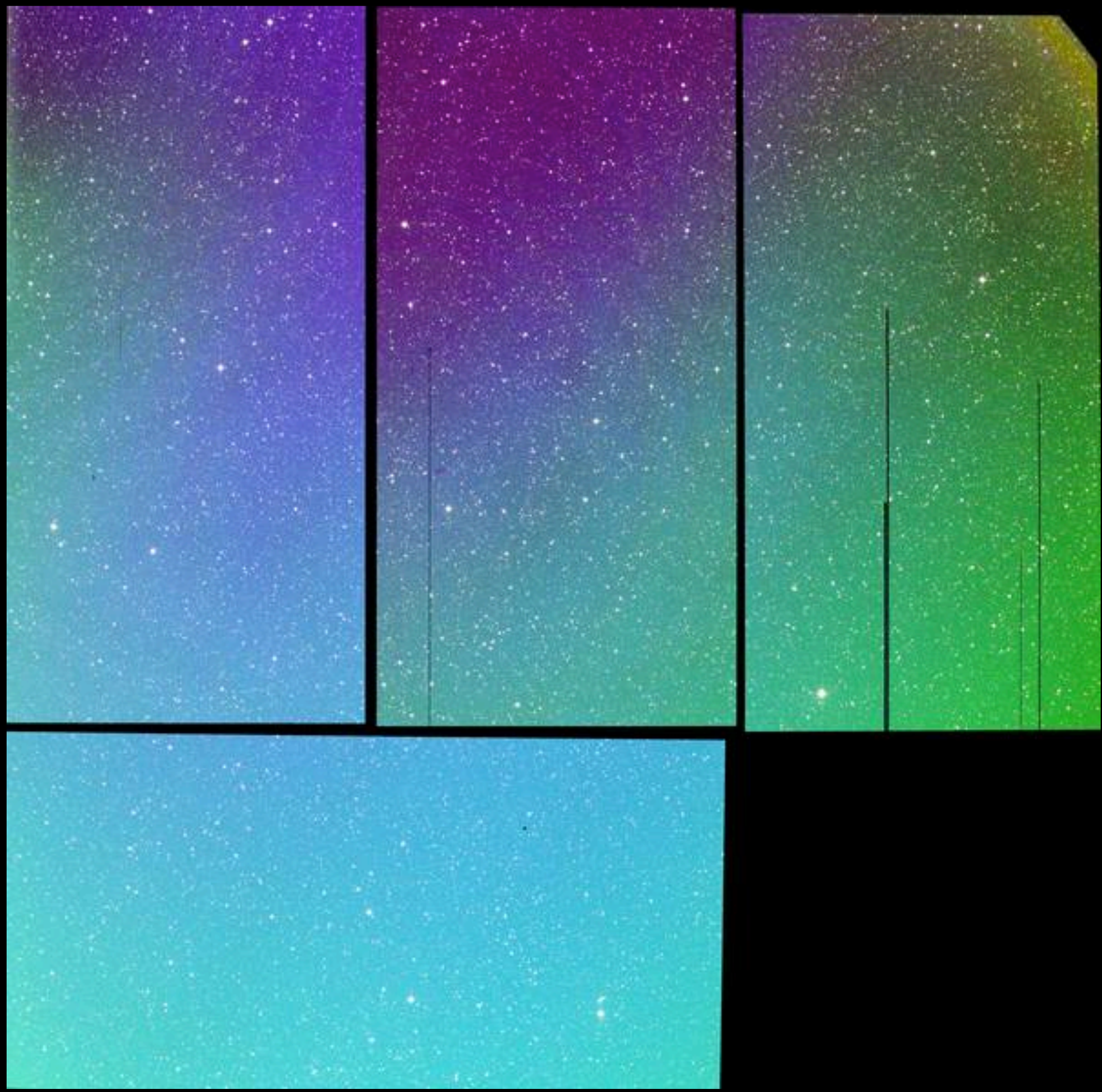


# Clouds, electronic noise or scattered light can be detected by checking for inconsistent fieldpair photometry

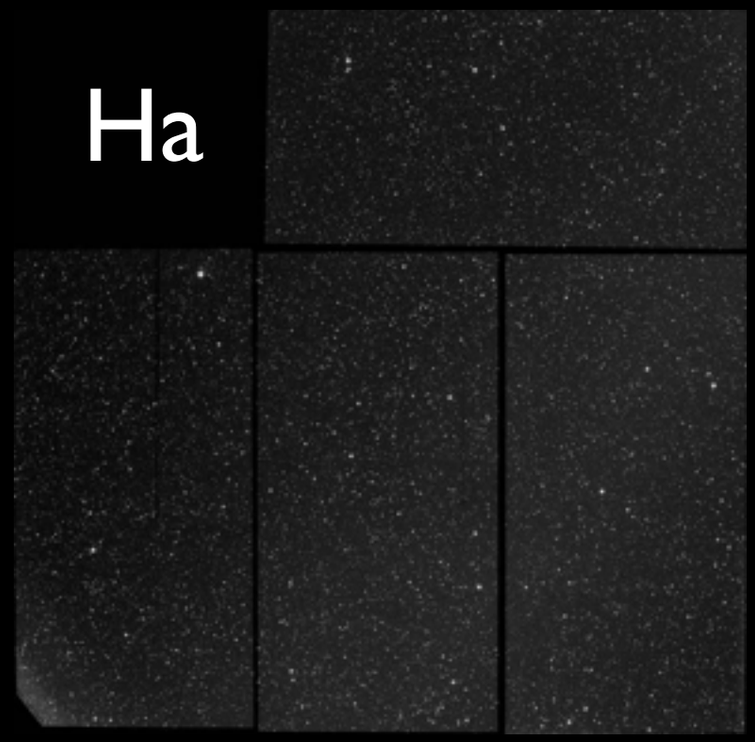


# Clouds

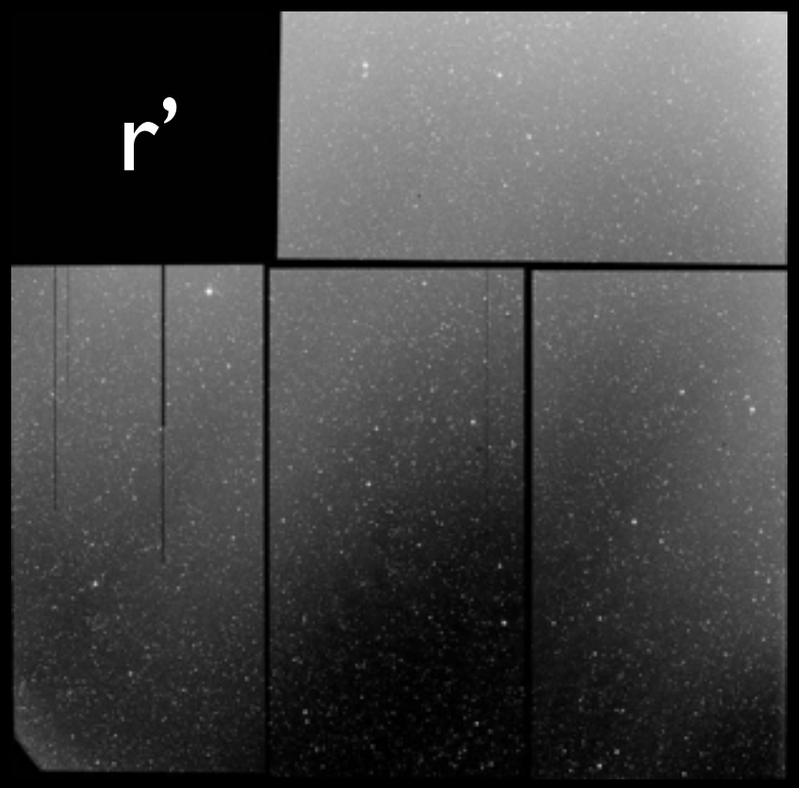




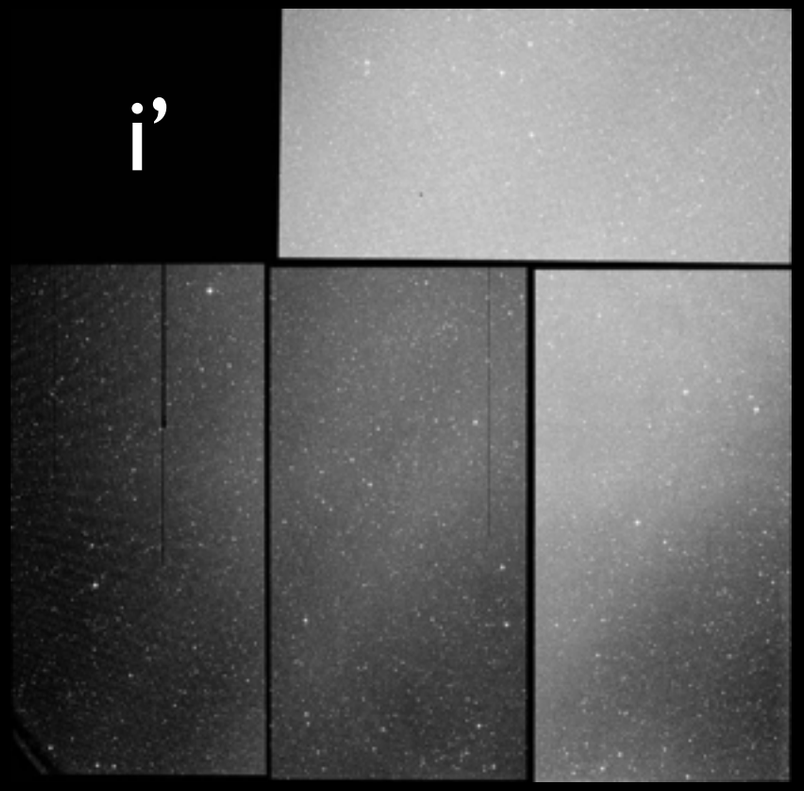
Ha



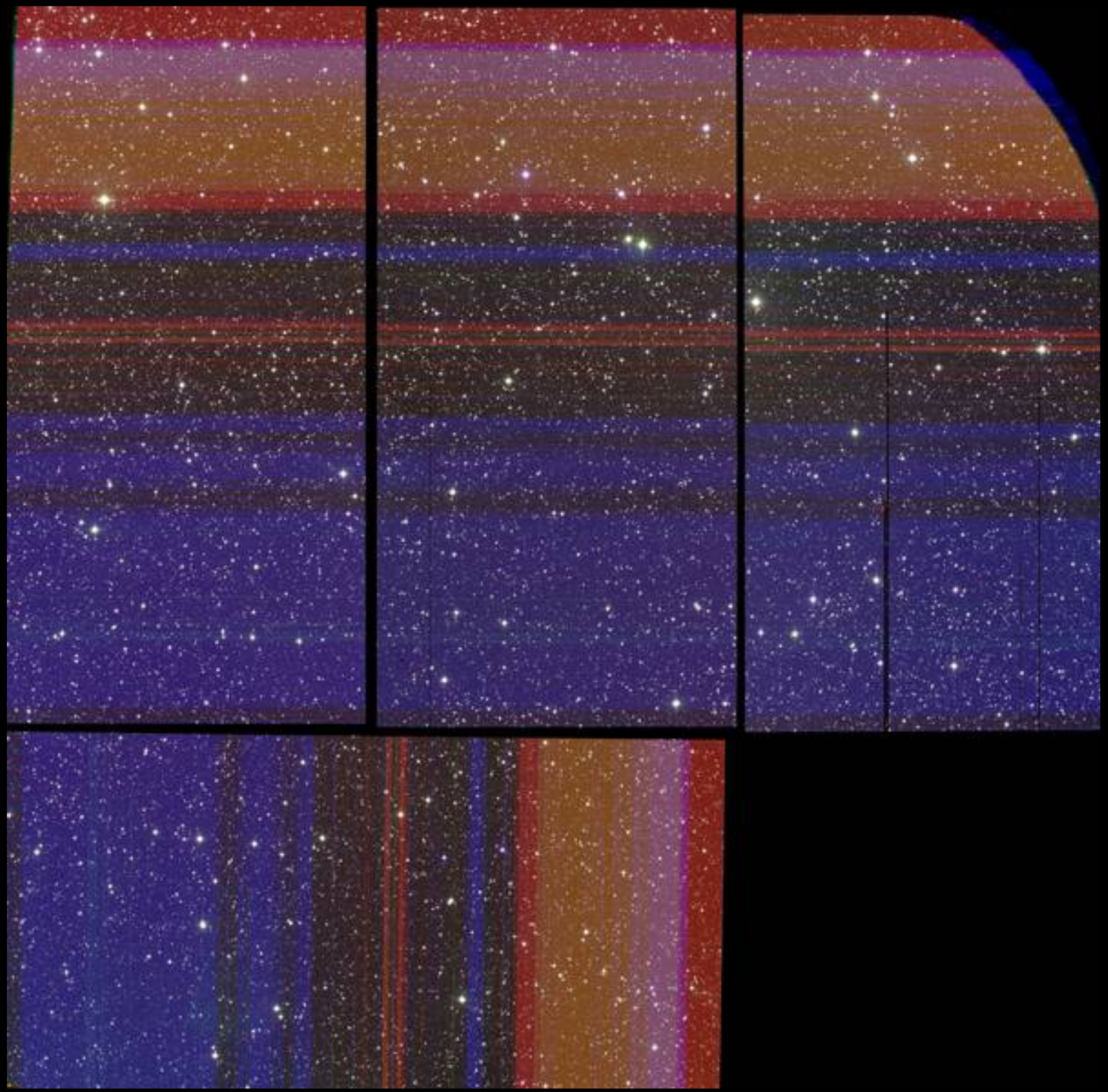
r’

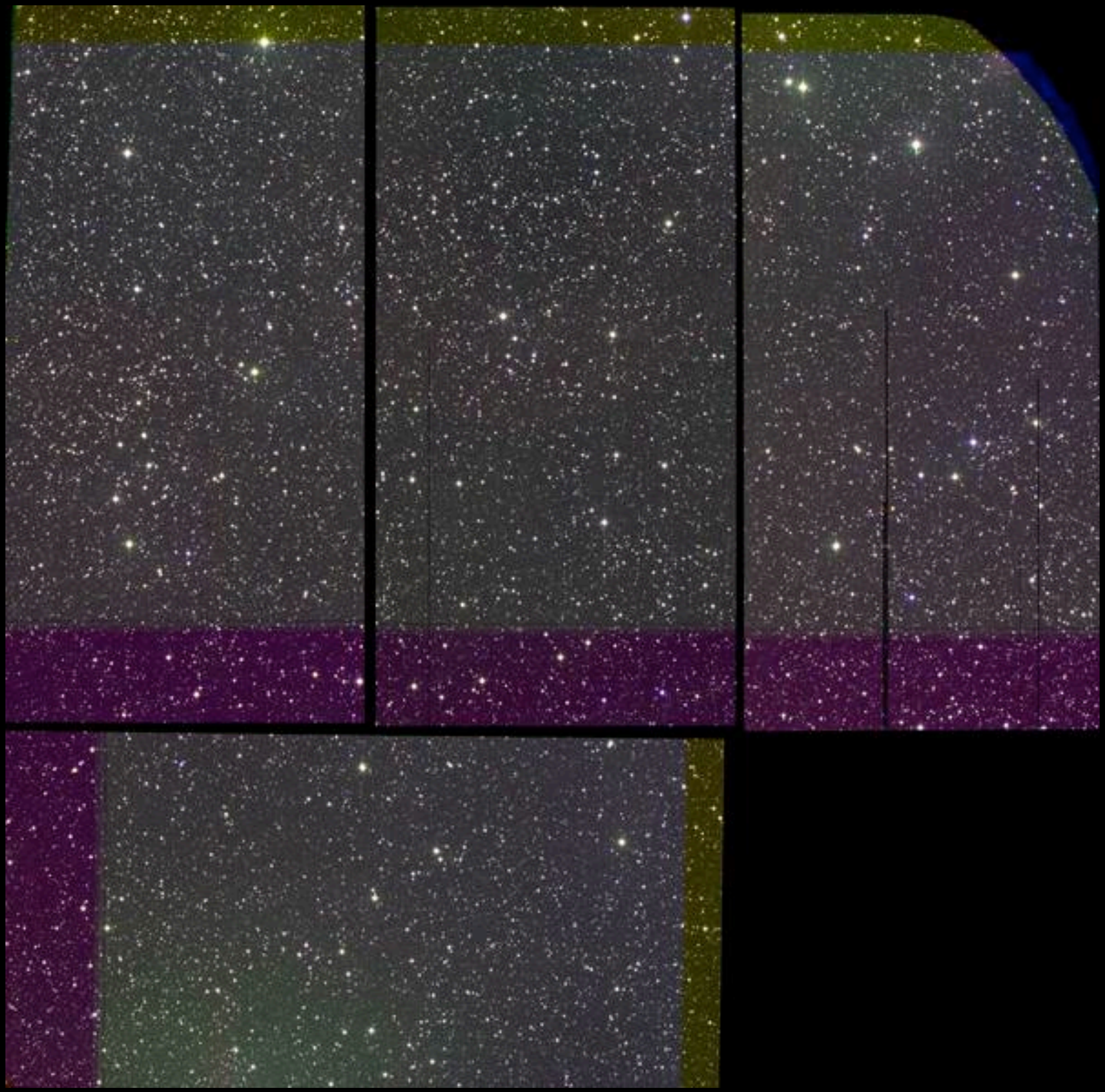


i’



# Electronic noise





SAOImage ds9

File Edit View Frame Bin Zoom Scale Color Region WCS Analysis Help

| | | | | |
|---|---|---|---|---|
| File | r947694 | | | |
| Object | uvex_1470o U | | | |
| Value | | | | |
| WCS | | | | |
| Physical | X | | Y | |
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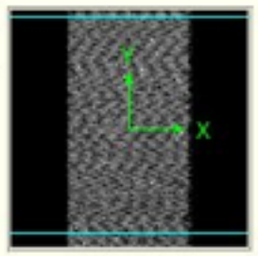
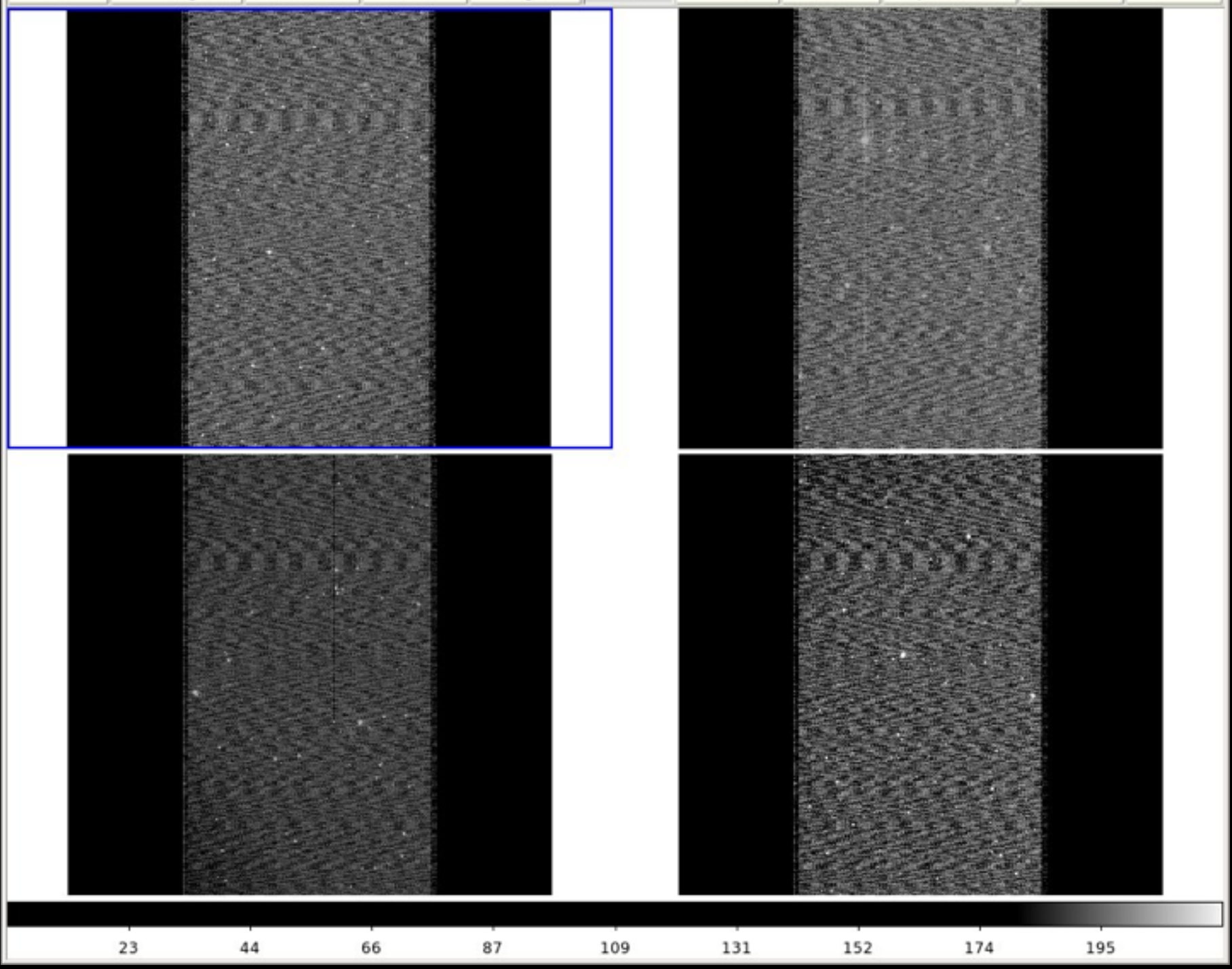
| Frame 1 | Zoom | 0.093 | Angle | 0.000 |




file edit view frame bin zoom scale color region wcs help

new new rgb delete clear single tile blink first previous next last



SAOImage ds9

File Edit View Frame Bin Zoom Scale Color Region WCS Analysis Help

| | | | | |
|---|---|---|---|---|
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| Object | SA112 Ha | | | |
| Value | | | | |
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| Physical | X | | Y | |
| Image | X | | Y | |
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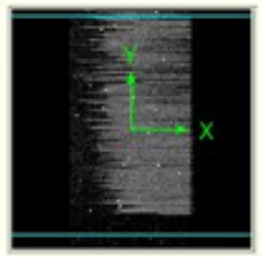
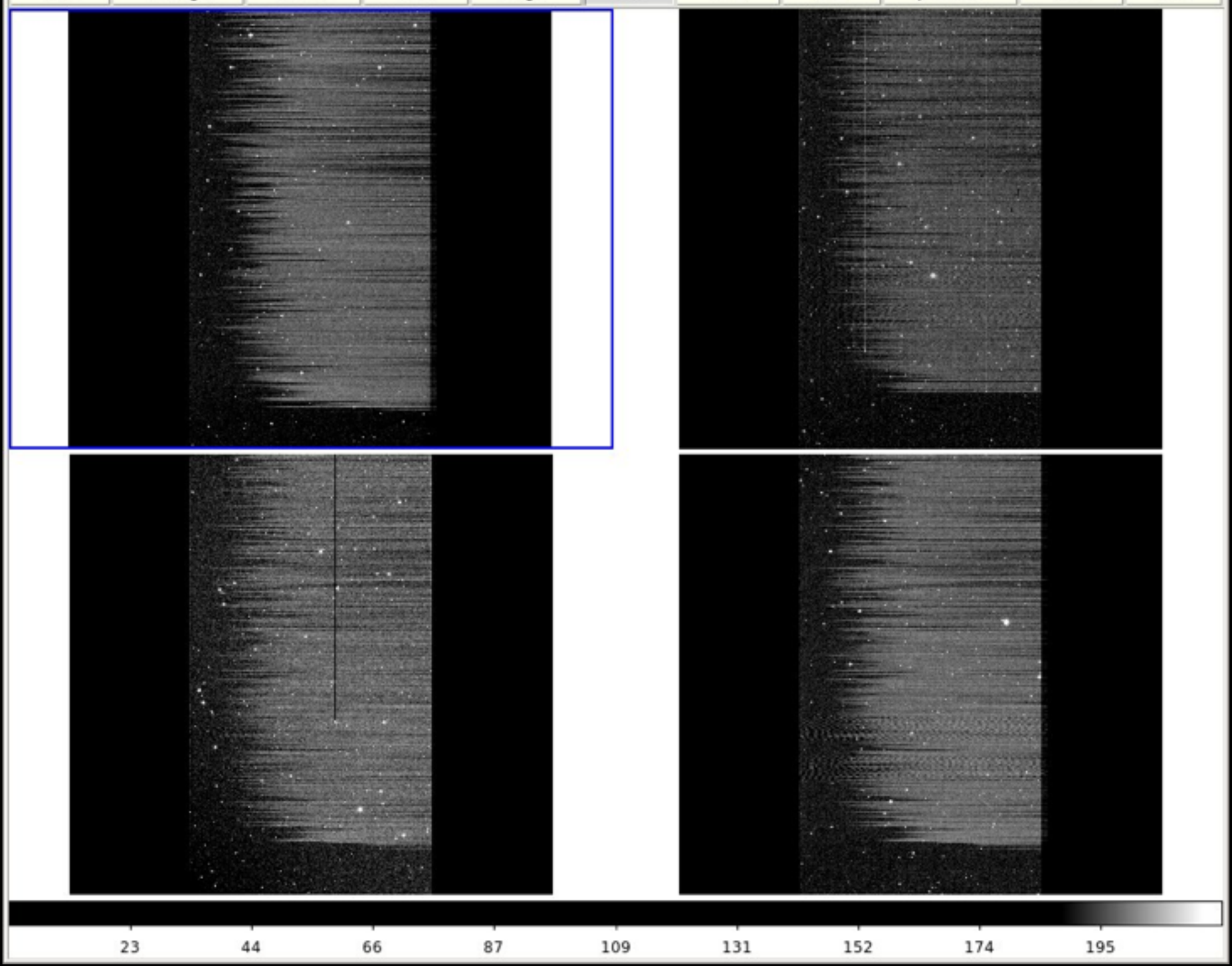



file edit view frame bin zoom scale color region wcs help

new new rgb delete clear single tile blink first previous next last



SAOImage ds9

File Edit View Frame Bin Zoom Scale Color Region WCS Analysis Help

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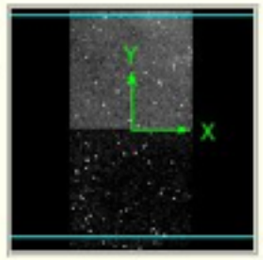
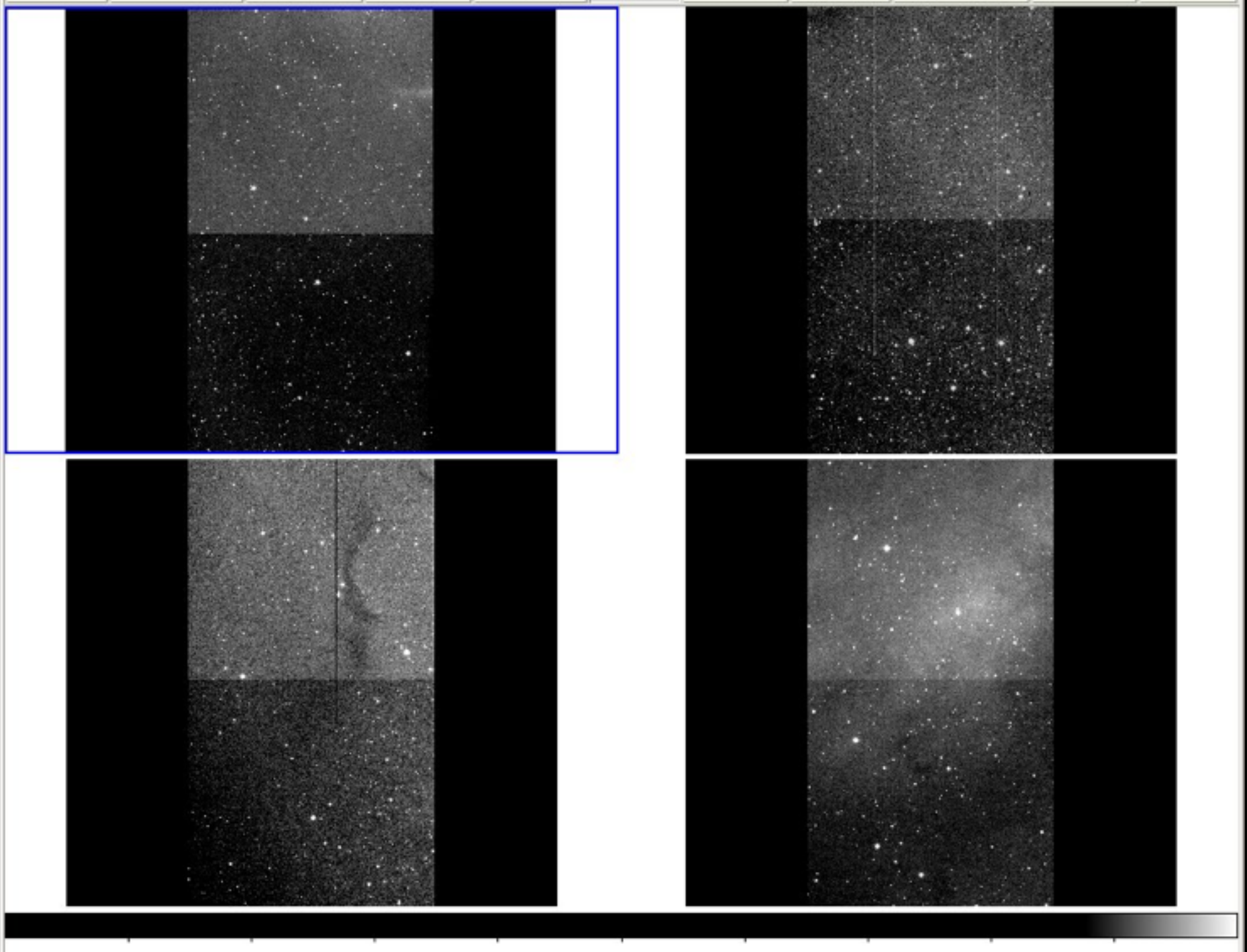
| Object | intphas_7398 Ha | | | |
| Value | | | | |
| WCS | | | | |
| Physical | X | | Y | |
| Image | X | | Y | |
| Frame 1 | Zoom | 0.093 | Angle | 0.000 |




file edit view frame bin zoom scale color region wcs help

new new rgb delete clear single tile blink first previous next last



23 44 66 87 109 131 152 174 195

# Scattered light

Scattered light affects
at least 800 pointings.

In this image, the moon is 42° away,
but it is full and at 86° altitude.

The effects of scattered light are clearly visible in 5°x5° mosaics

# Quality criteria

(1) *Fieldpair consistency*
reject outliers at the 95%-level

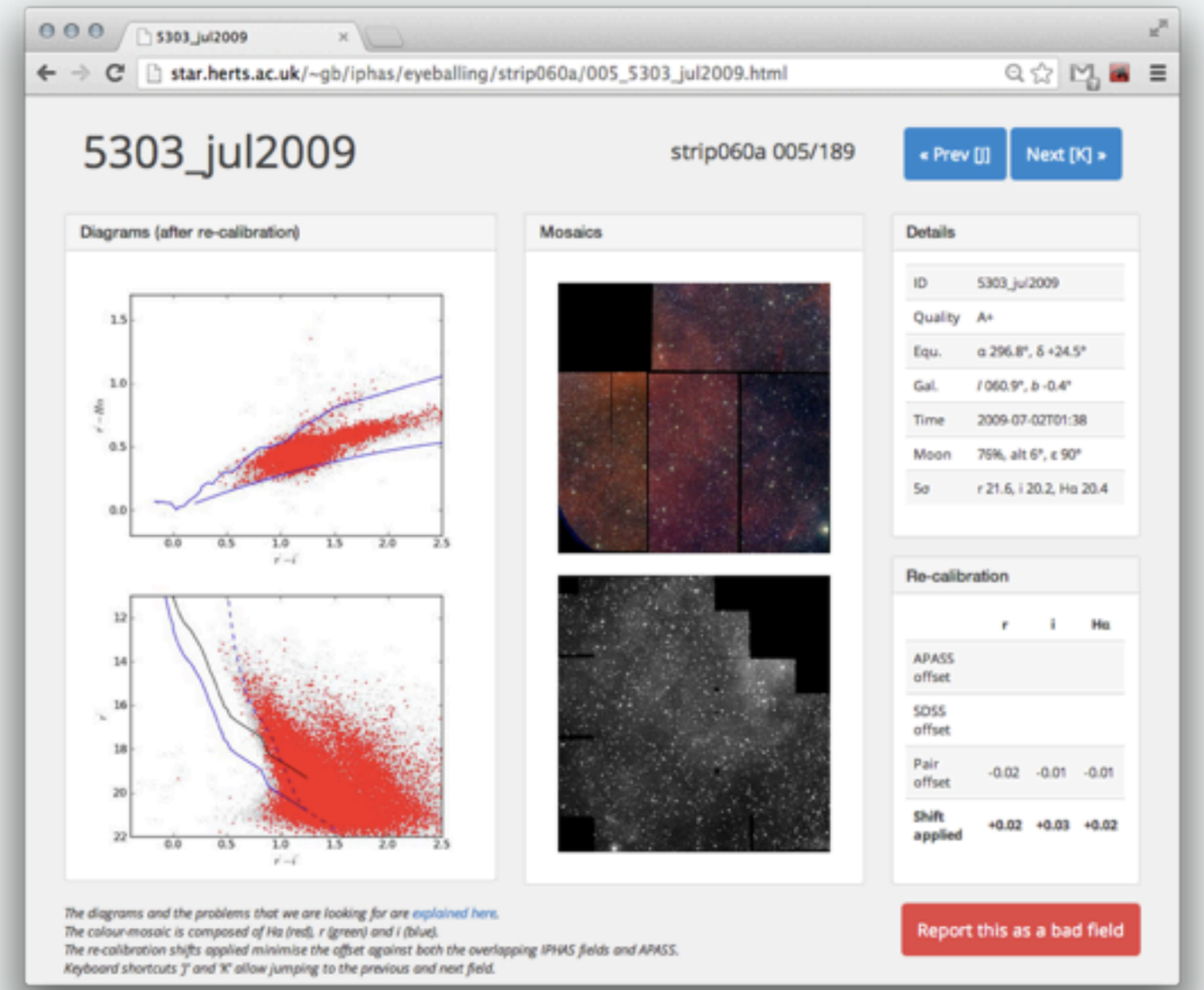
(2) *Limiting magnitude*
r > 20, i > 19, Hα > 19

(3) *Seeing*
< 2.5 arcsec

(4) *Ellipticity*
< 0.3

(5) *Eye-balling*.
Photometric diagrams and colour mosaics.

**94% of the survey footprint now passes**



# 2. The new data release

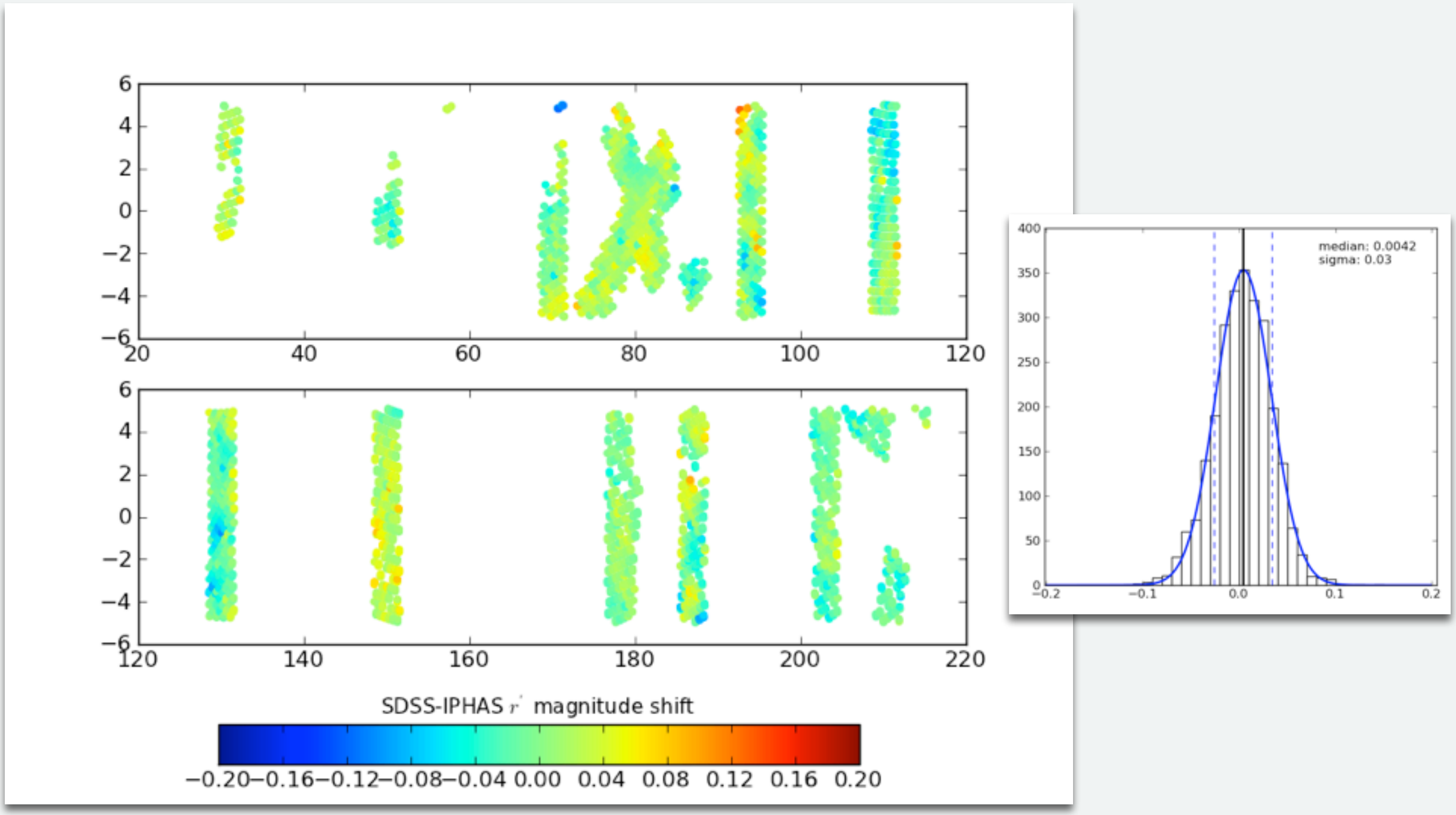
- quality control
- **re-calibration**
- catalogue building

## Nightly standard field observations did not provide a satisfactory calibration

- 9% of DR2 had to be re-calibrated by >0.1 mag.
- Rapid zeropoint variations are common due to high clouds, transparency changes and WFC exposure time foibles.
- Surveys with dedicated telescopes can discard non-photometric nights, but IPHAS time was limited.

Solution: we computed the magnitude offsets across (a) exposure overlaps and (b) against the APASS survey, and then found the zeropoints which minimised these offsets.

# Post-calibration: consistent with SDSS to within 3% (one sigma)



# 2. The new data release

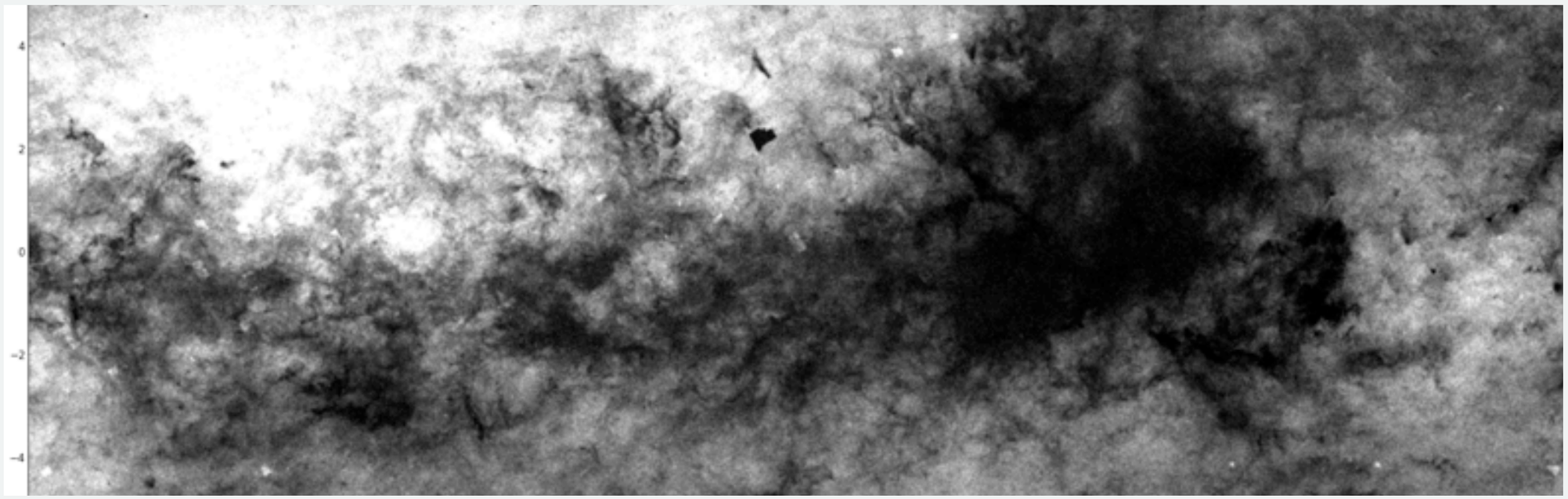
- quality control
- re-calibration
- **catalogue building**

## Catalogue building required several steps

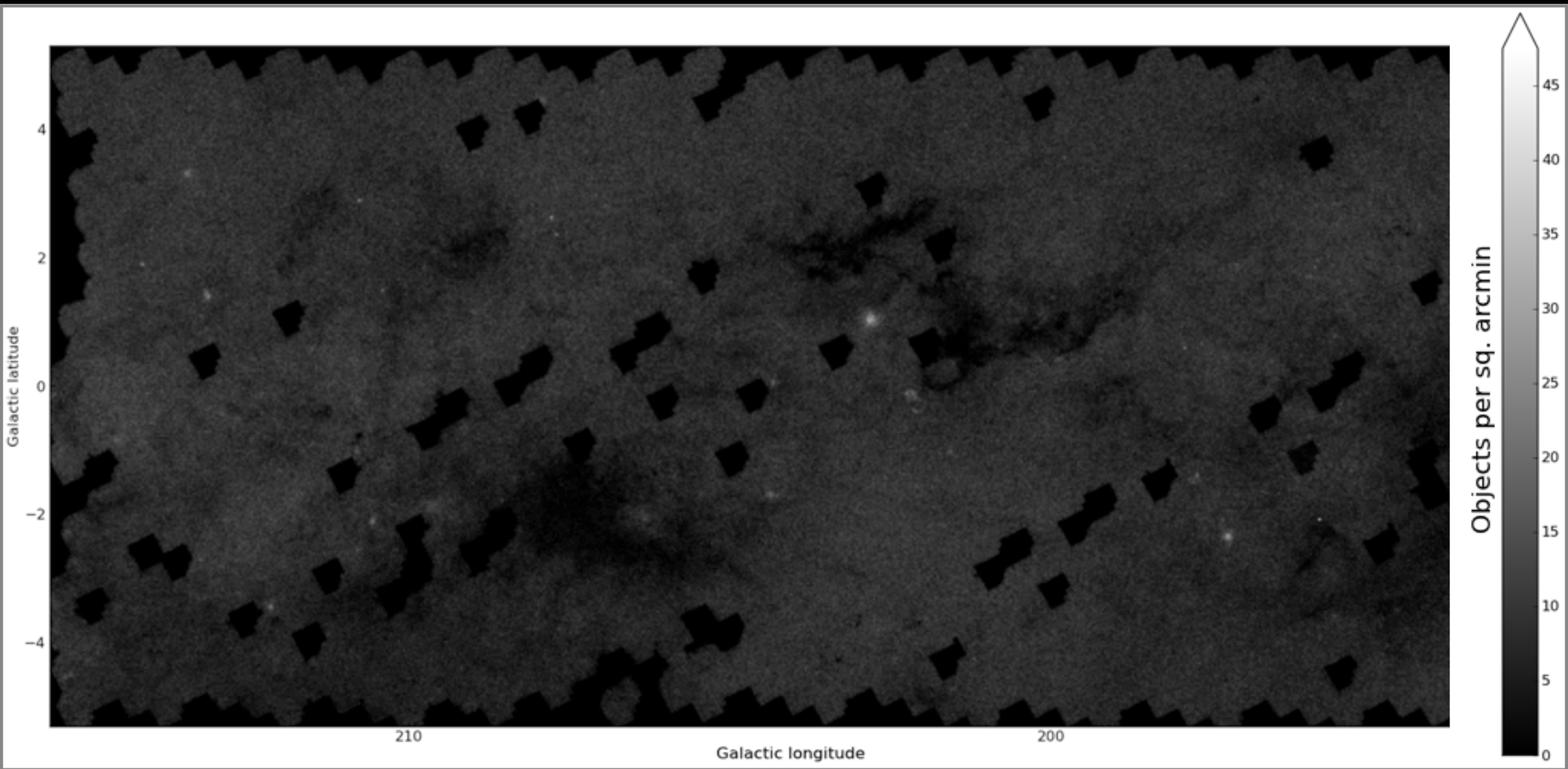
1. Apply re-calibration.
2. Band-merge the r, i, Hα detections.
3. Create user-friendly columns and warning flags (we followed UKIDSS conventions).
4. Flag the ‘best’ detection of each unique source.

## The result is a huge FITS table (50 GB)

- 220 million unique sources with SNR > 5 in one band;
- 109 million with SNR > 5 in all bands.

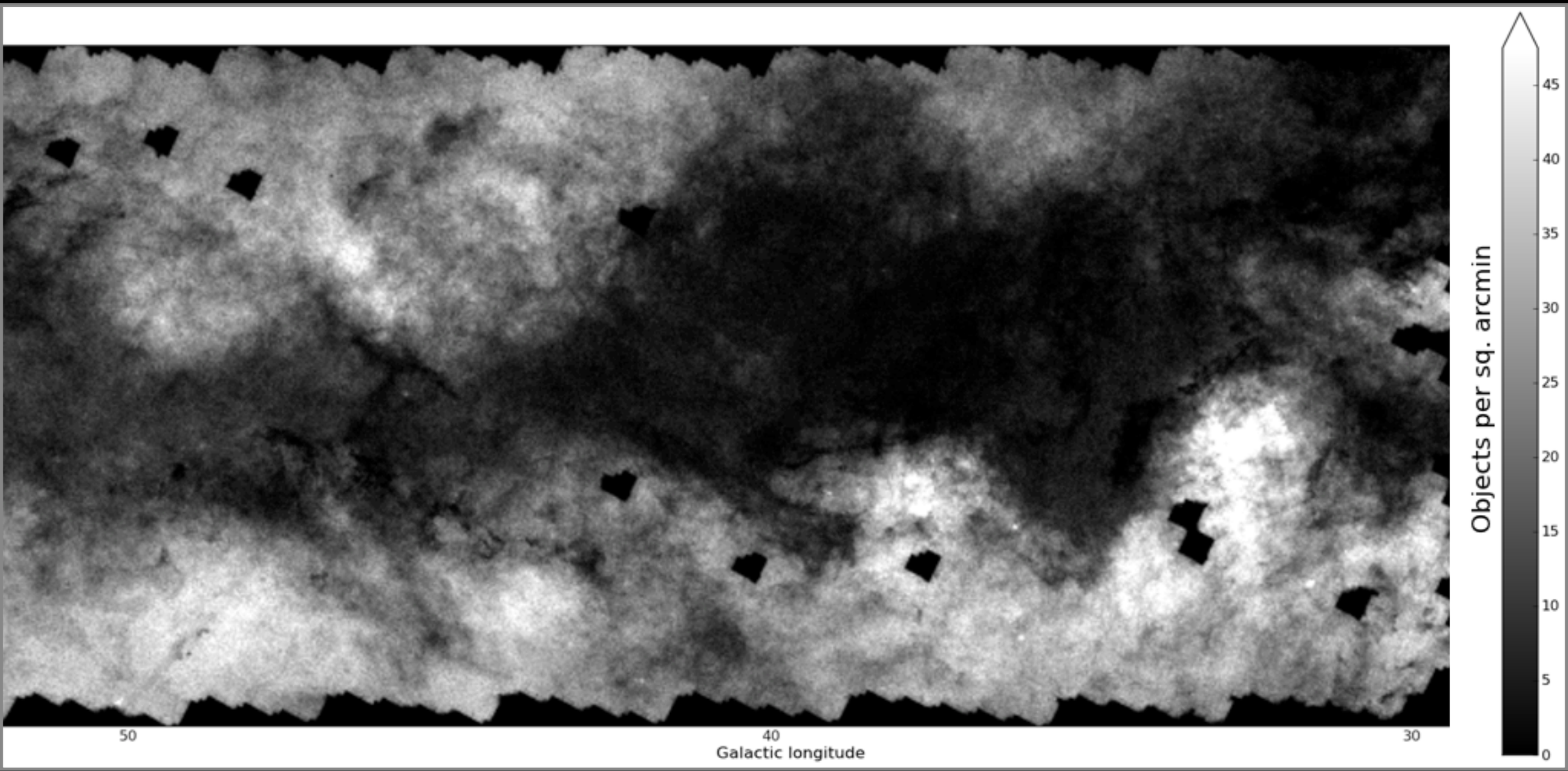


# IPHAS DR2 stellar density map



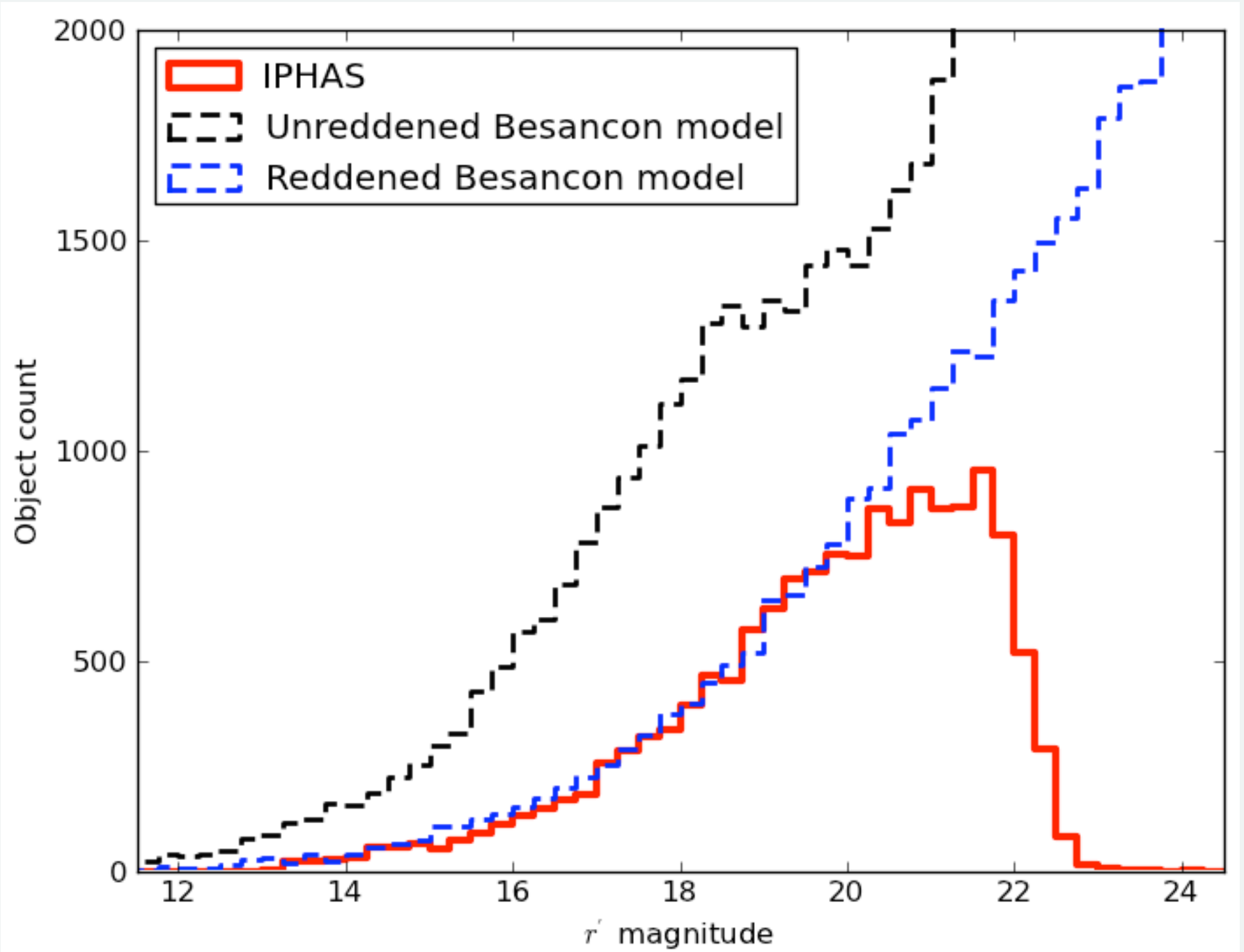

Credit: Hywel Farnhill

# IPHAS DR2 stellar density map



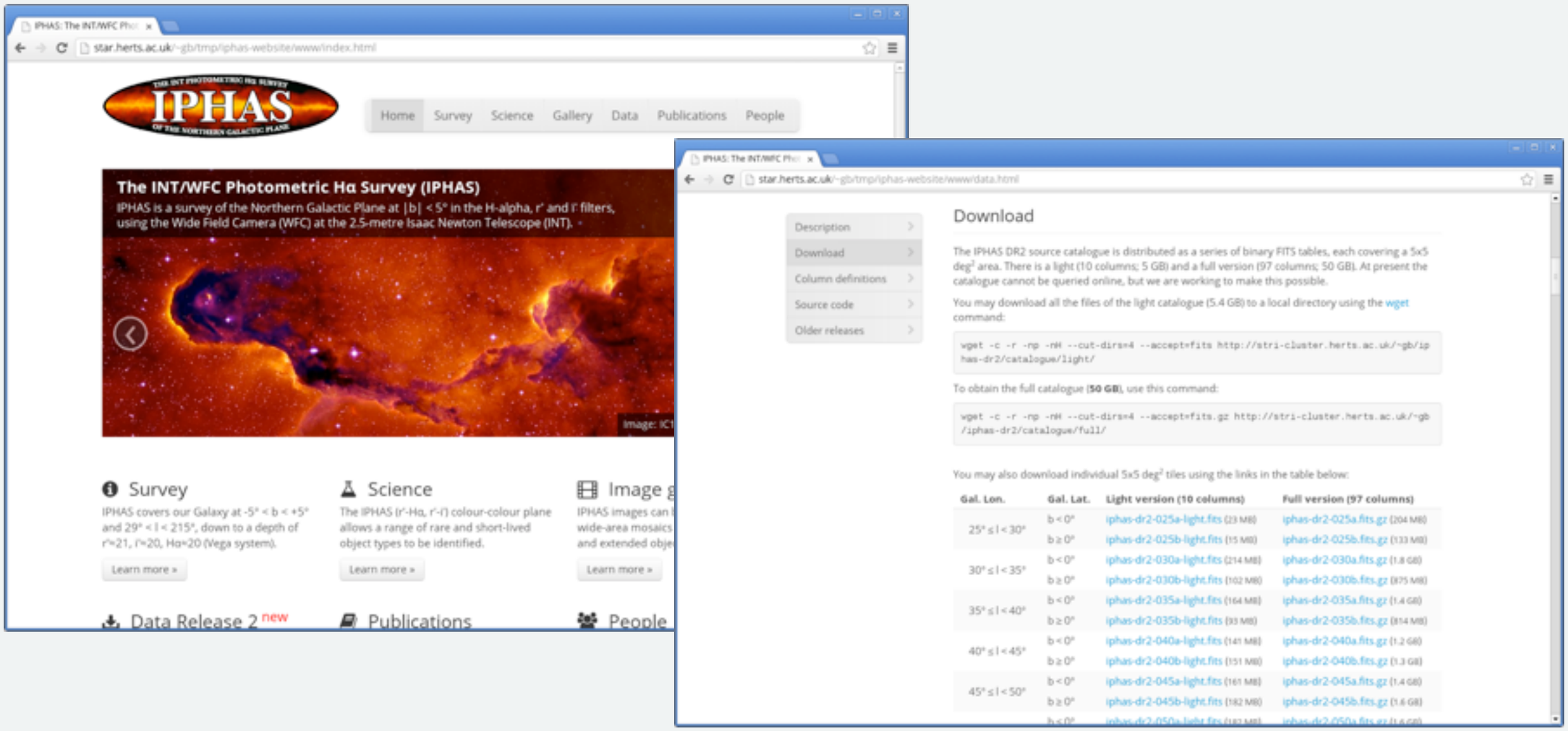

Credit: Hywel Farnhill

# IPHAS stellar densities constrain Galactic models (Farnhill et al., in preparation)

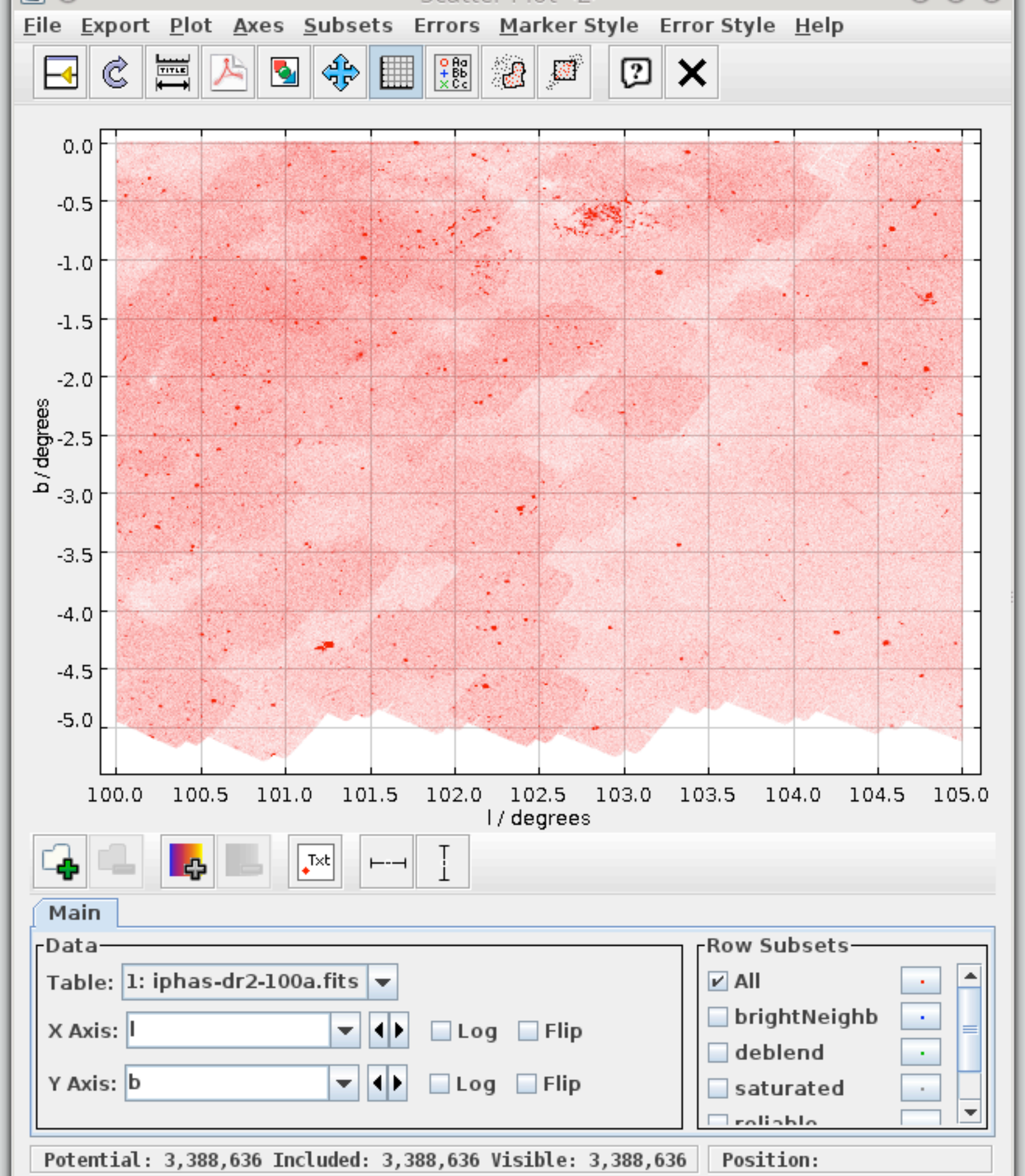


# Catalogue is ready and is available to the collaboration for review

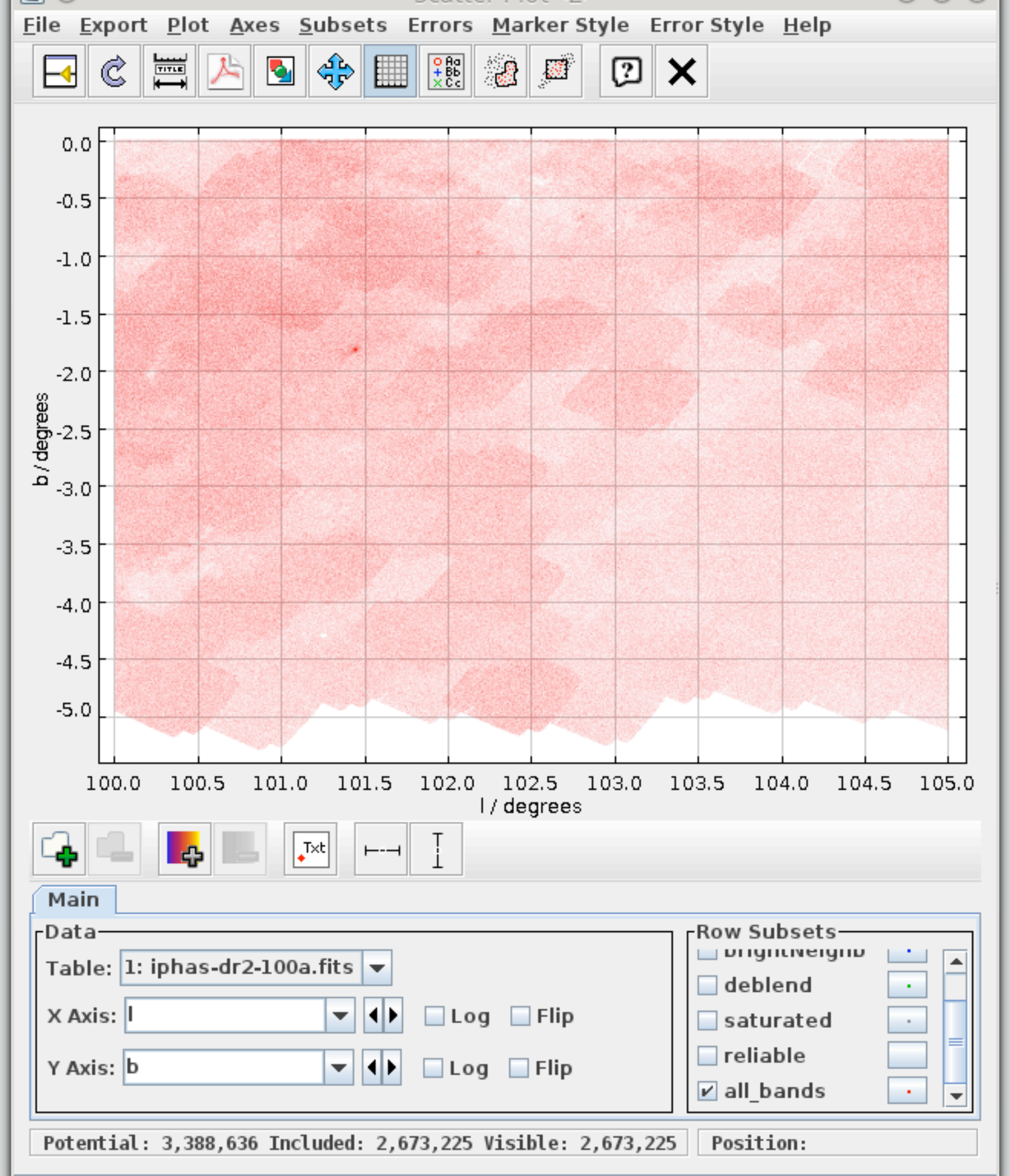
- ~1 GB FITS tables, each covering 5x5 square degrees.
- Talk to us if you want to join the review.
- Public release will be available via SQL through CDS/Vizier, once the accompanying paper is accepted (in preparation).



Catalogue contains all sources having SNR > 5 in at least one band



## nBands == 3


File Export Plot Axes Subsets Errors Marker Style Error Style Help
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
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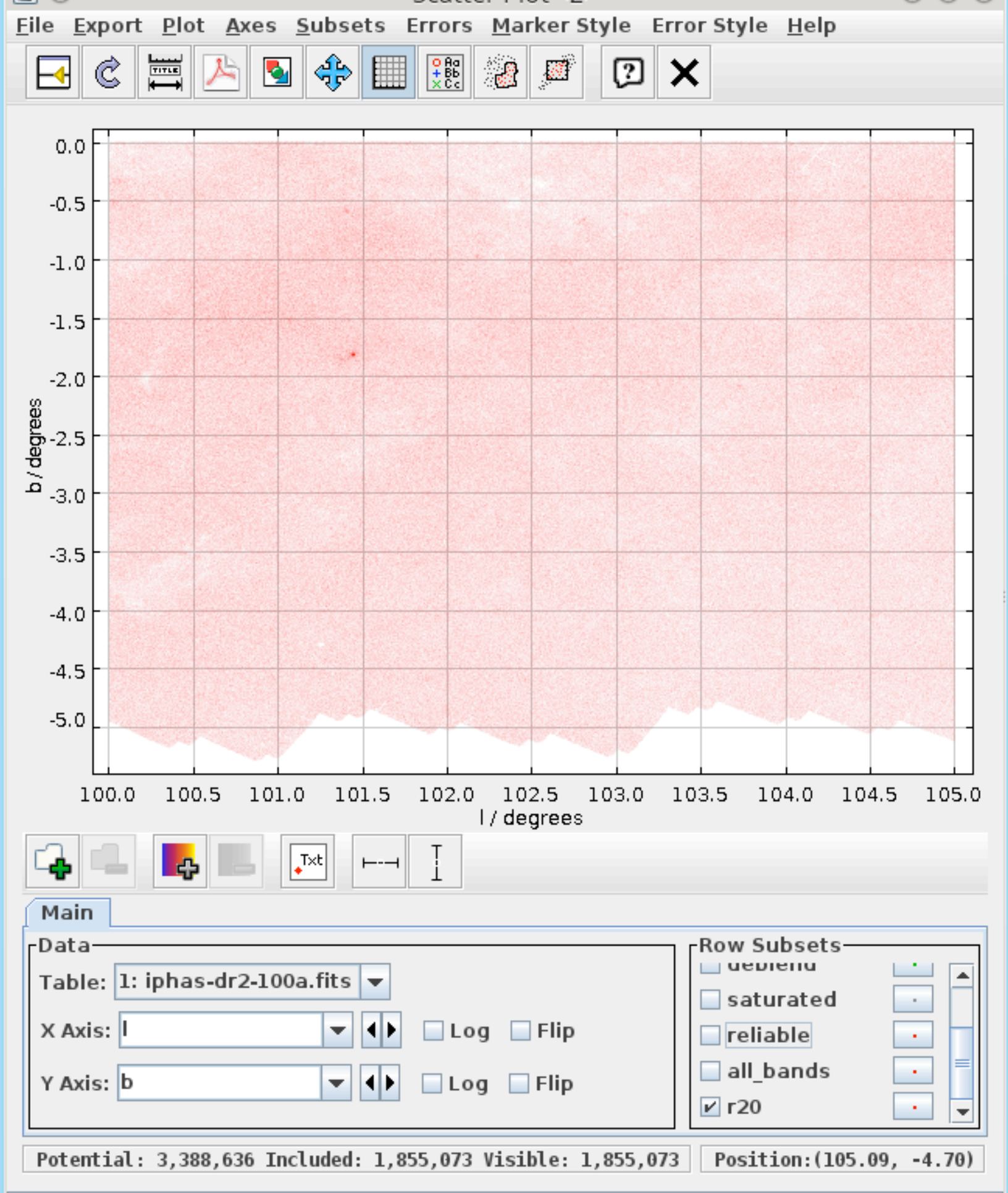
-4.5
-5.0
b / degrees
100.0 100.5 101.0 101.5 102.0 102.5 103.0 103.5 104.0 104.5 105.0
l / degrees
Txt
Main
Data
Table: 1: iphas-dr2-100a.fits
X Axis: l
Log Flip
Y Axis: b
Log Flip
Row Subsets
deblend
saturated
reliable
all_bands
Potential: 3,388,636 Included: 2,673,225 Visible: 2,673,225
Position:

nBands == 3
& r < 20


File Export Plot Axes Subsets Errors Marker Style Error Style Help
0.0
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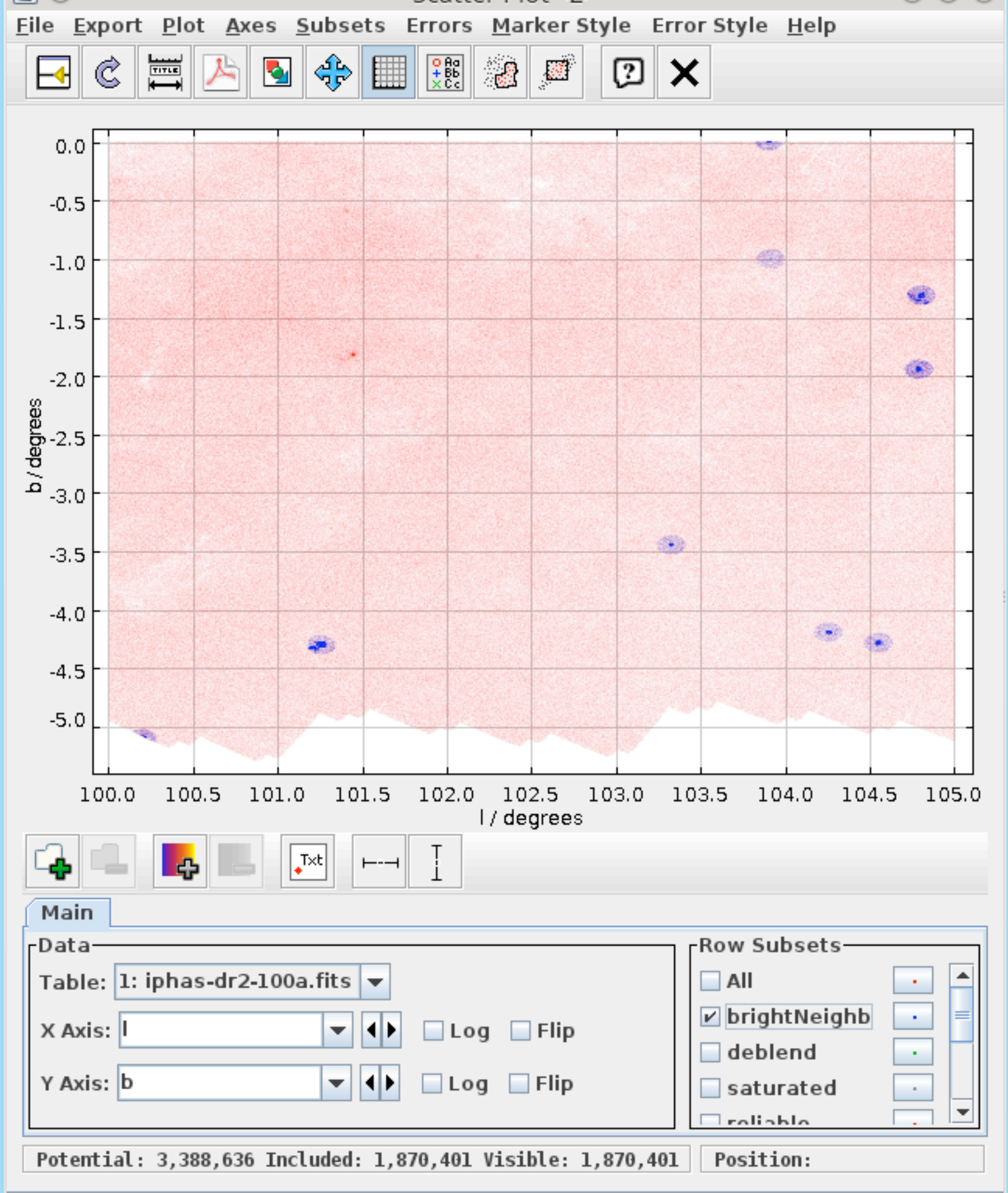
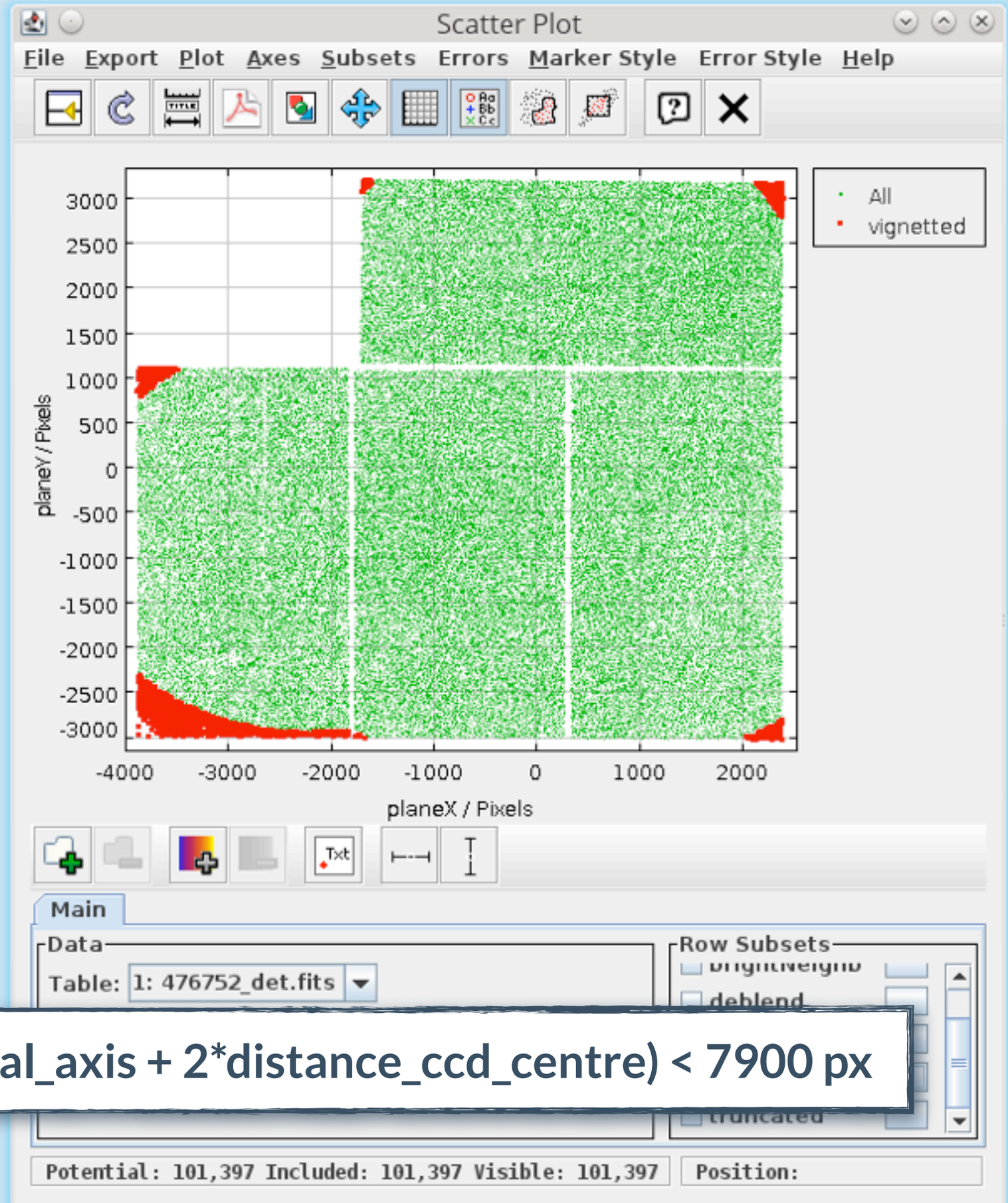
-5.0
b / degrees
100.0 100.5 101.0 101.5 102.0 102.5 103.0 103.5 104.0 104.5 105.0
l / degrees
Txt
Main
Data
Table: 1: iphas-dr2-100a.fits
X Axis: l
Log Flip
Y Axis: b
Log Flip
Row Subsets
saturated
reliable
all_bands
r20
Potential: 3,388,636 Included: 1,855,073 Visible: 1,855,073
Position:(105.09, -4.70)

# Bright neighbours indicated

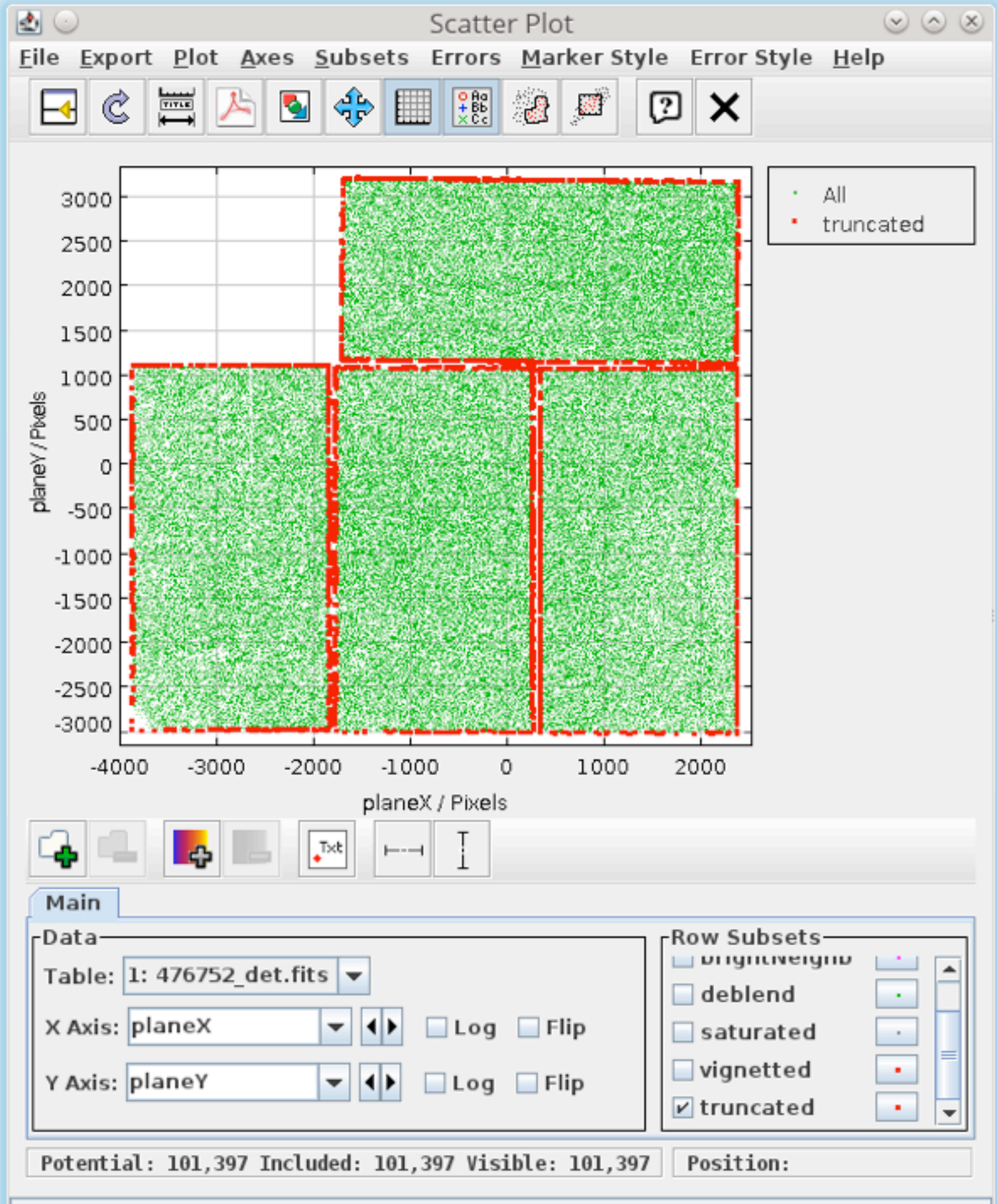


Red areas demonstrate where **vignetted** = True

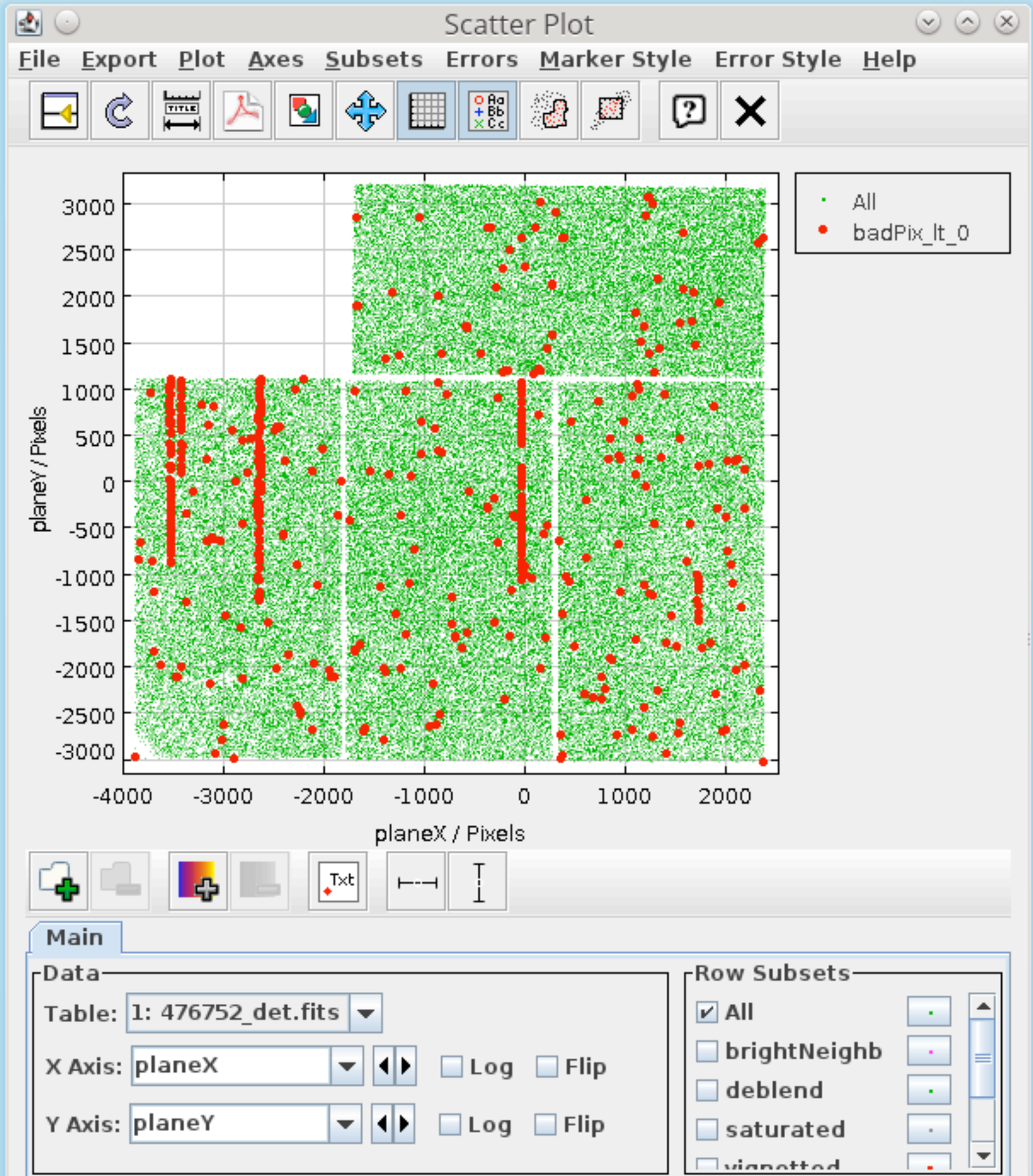



**criterion: (distance_optical_axis + 2*distance_ccd_centre) < 7900 px**

Red areas demonstrate where **truncated** = True

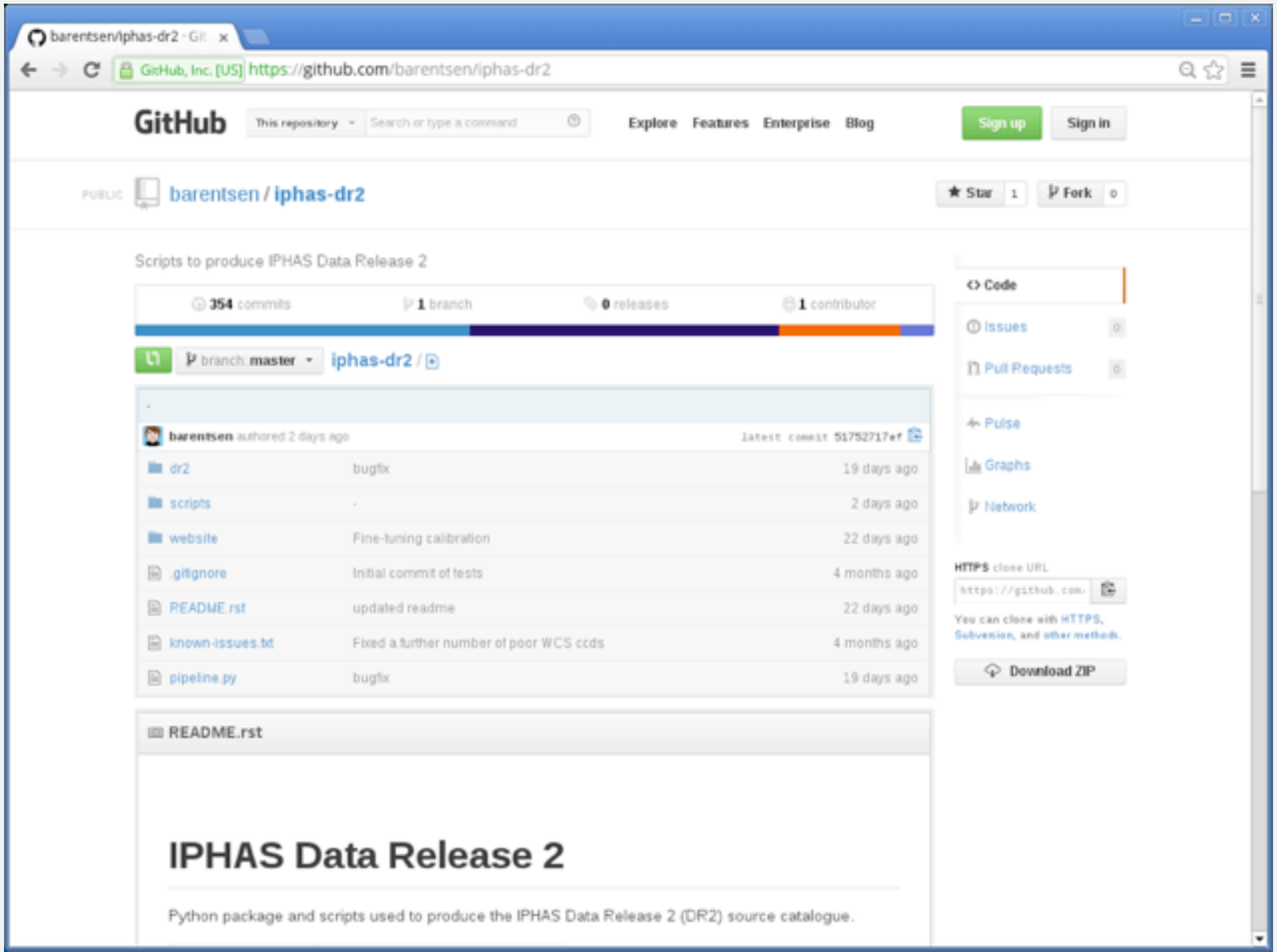


Red areas demonstrate where **badPix** > 0



# Catalogue pipeline is made available as an open source Python package

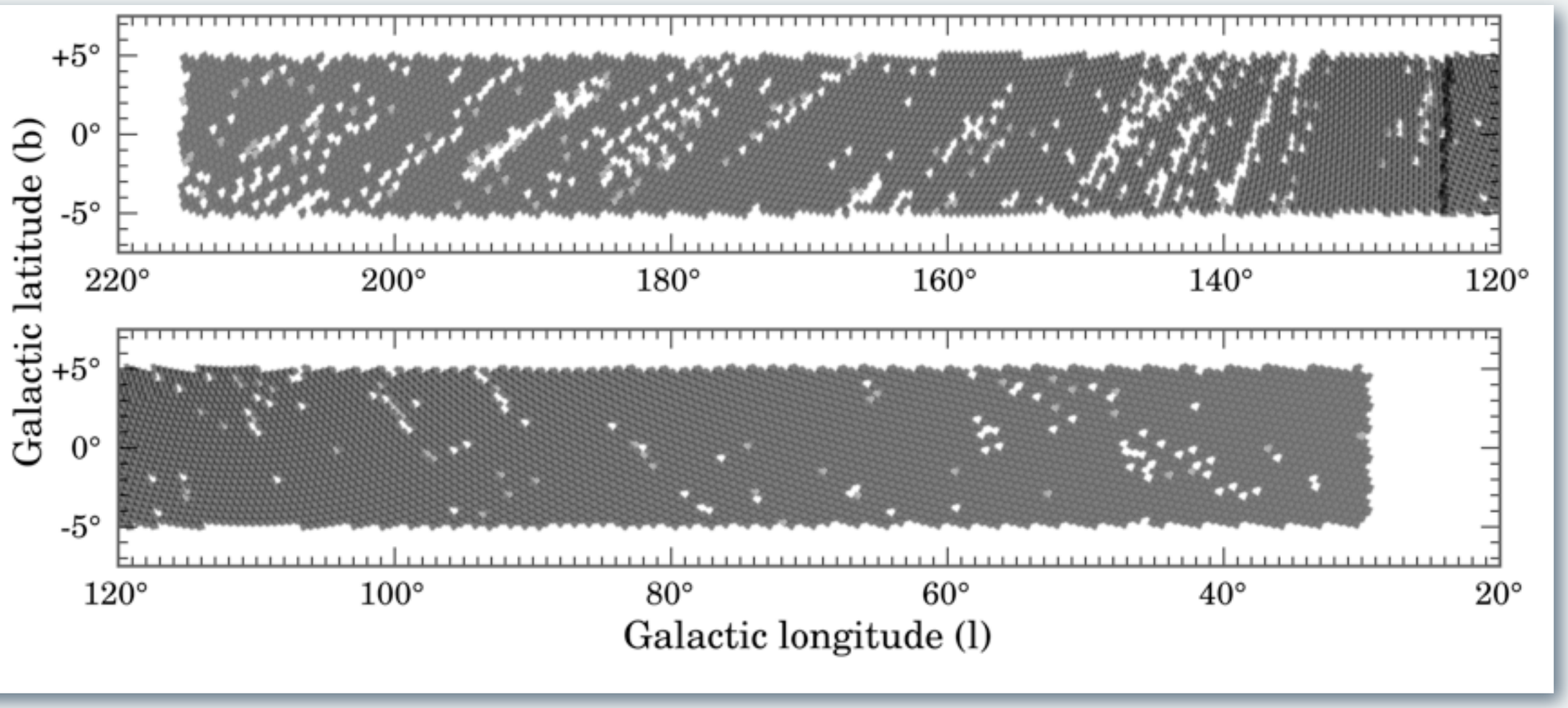
- Parallelised (~500 CPU hours)
- Depends on the “astropy” library (wraps cfitsio, libwcs)
- https://github.com/barentsen/iphas-dr2



# 3. Outstanding challenges and future opportunities

# We would *really* like to finish IPHAS

- Need to repeat 1424 pointings (9%),
  of which 1023 are critical (7%).
- This needs 14 *perfect* nights (10 are critical)
  in **November-December grey time**.
- We secured 10 nights in November 2012, but
  were met with horrible weather and WFC noise.
- We are currently reviewing our strategy ...

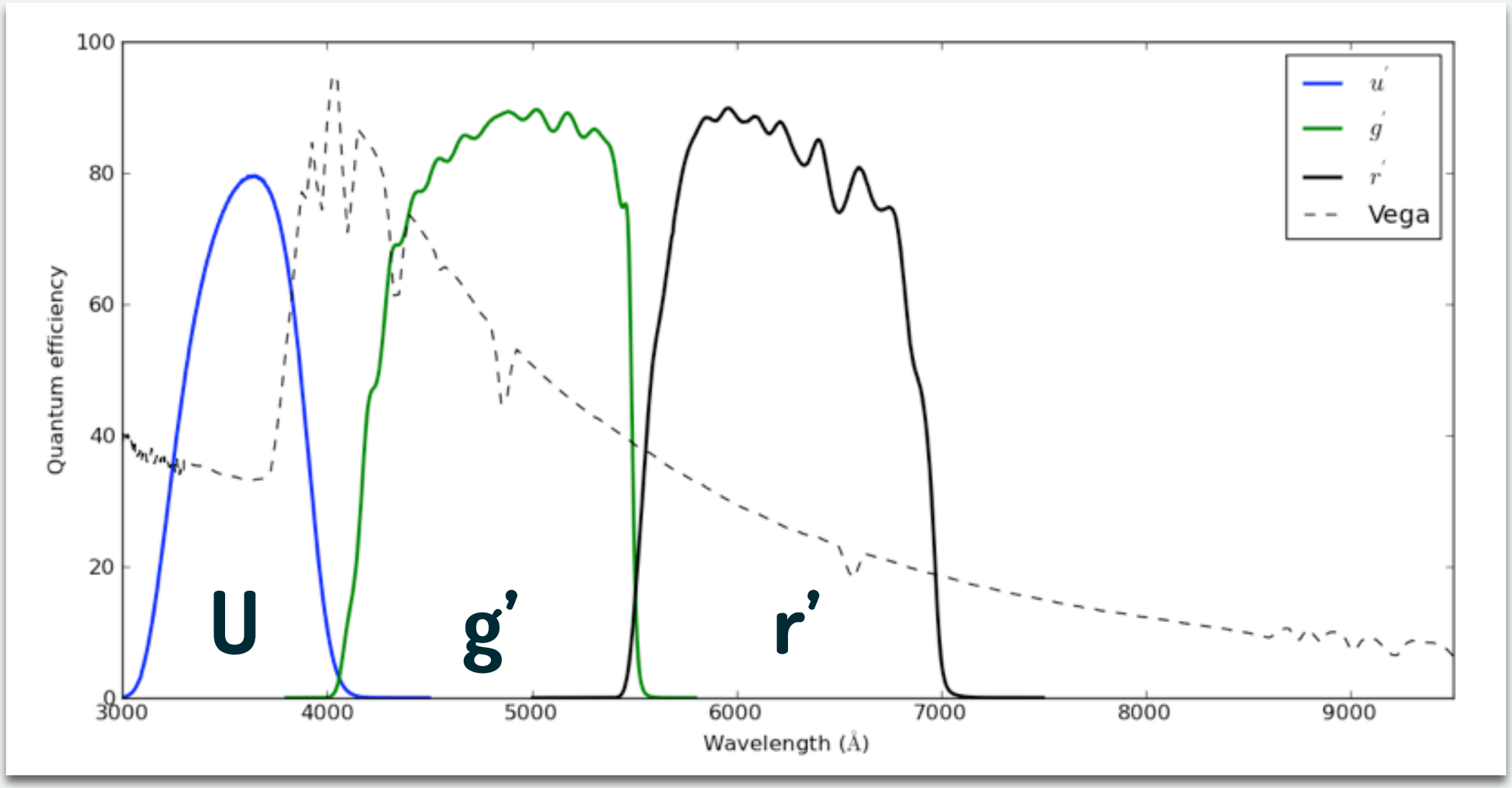


# DR2 is not the end, we want to take the data exploitation further

- IPHAS DR3 catalogue planned ~1 year from now.
- We are currently bidding for funding to prepare a full-survey mosaic at arcsecond-resolution.
- We will also be bidding for funding to continue our data release work, with the eventual aim of building an integrated IPHAS+UVEX+UKIDSS catalogue which exploits PSF fitting.

ULTRAVIOLET EXCESS SURVEY
UVEX
OF THE NORTHERN GALACTIC PLANE

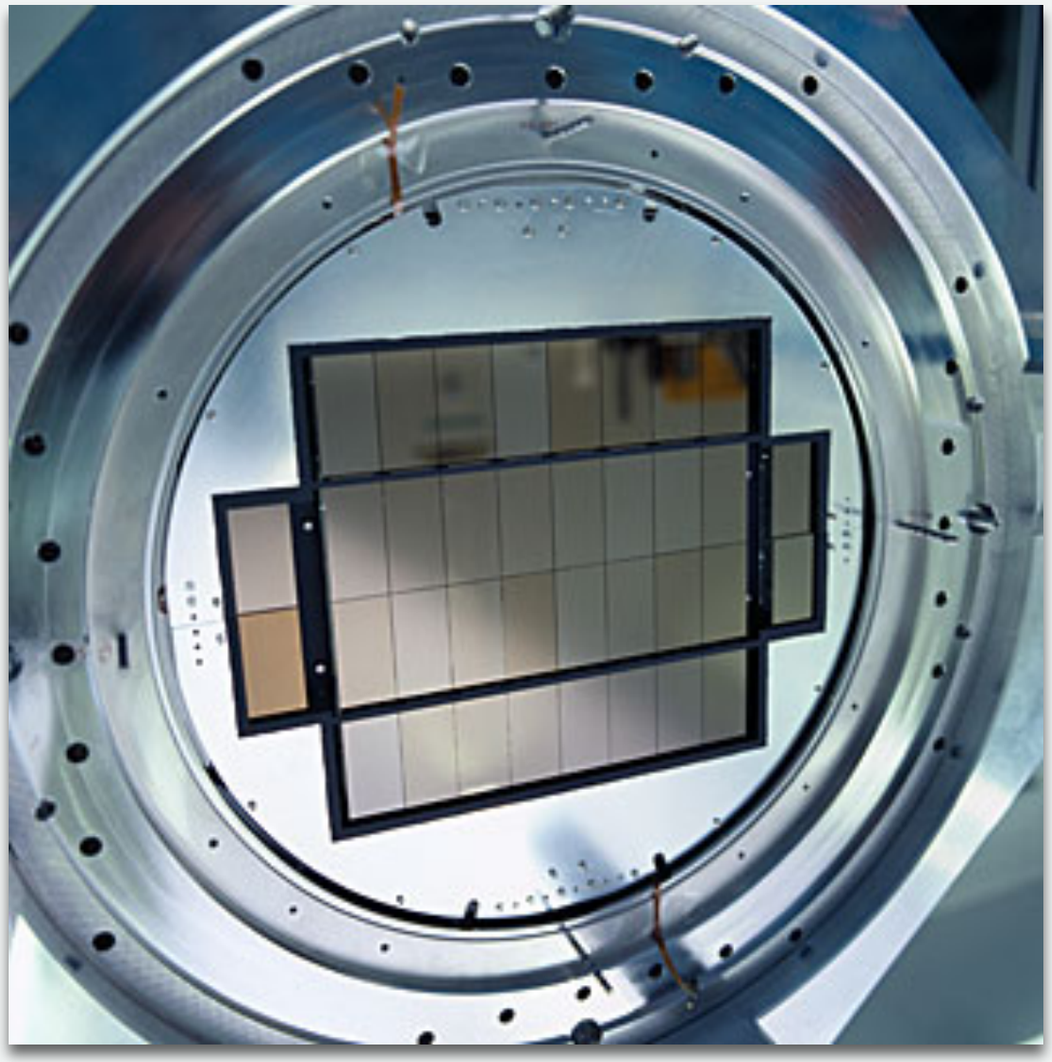
- Identical footprint to IPHAS
- U, g, r, (He I) photometry
- The g band, in particular, aids several Galactic science applications.



THE VST PHOTOMETRIC Hα SURVEY
VPHAS+
OF THE SOUTHERN GALACTIC PLANE

- VST Photometric Hα Survey
- ESO public survey, started in early 2012.
- Southern Galactic plane (180-by-10 degrees) and bulge (20 by 20 degrees)

VLT Survey Telescope (Paranal)

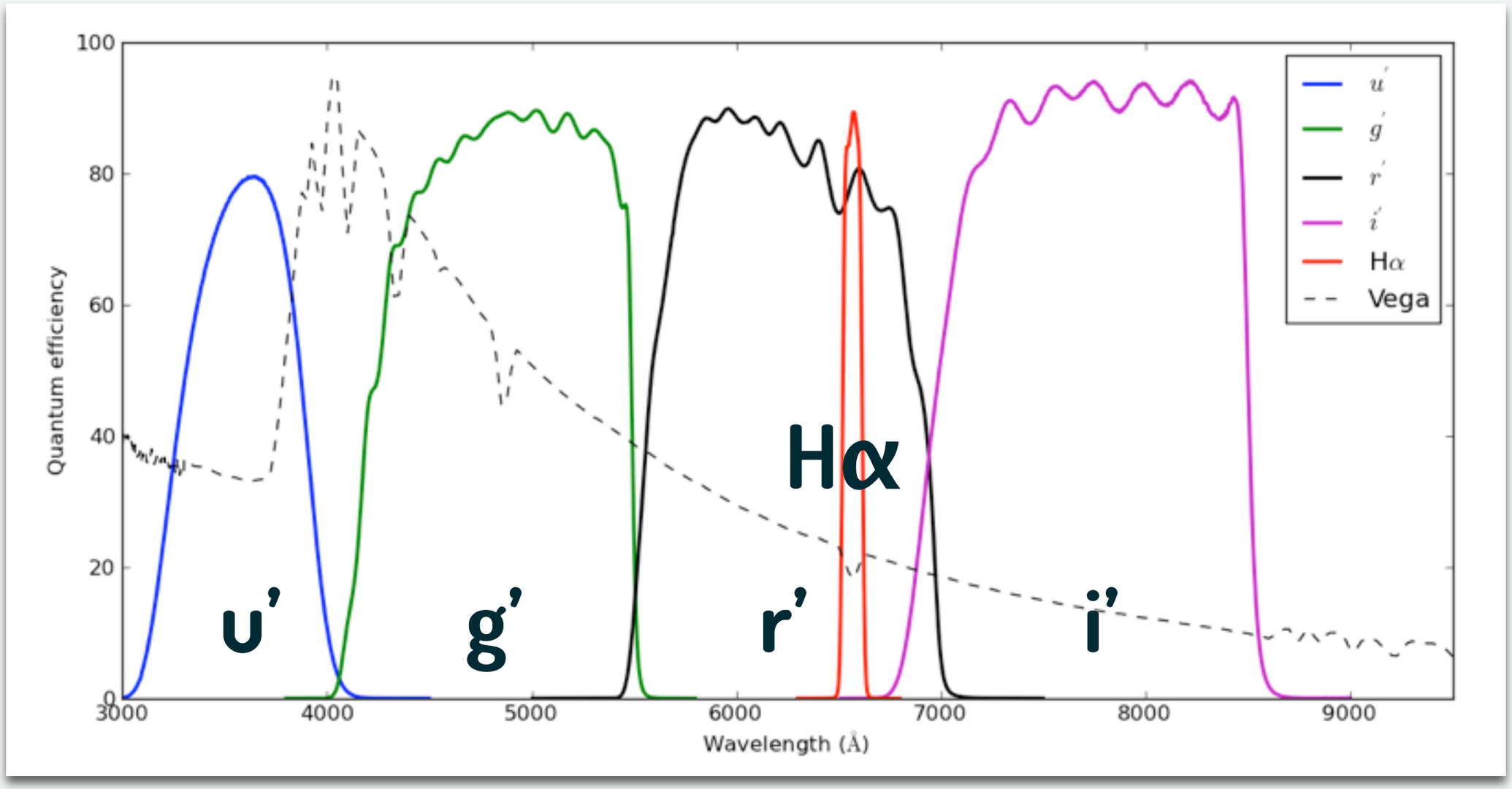


Omegacam

THE VST PHOTOMETRIC Hα SURVEY

# VPHAS+

OF THE SOUTHERN GALACTIC PLANE



# Conclusions

- The biggest program in the history of the INT, IPHAS, is about to release a major legacy data product.
- DR2 offers calibrated r, i, Hα photometry for up to 220 million sources across 93% of the northern Galactic plane.
- We still need 10-14 good, grey, Nov-Dec nights to finish.
- IPHAS DR2 is a template for future IPHAS/UVEX/VPHAS data releases, subject to manpower.

# Credits

*Collaboration*:
University of Hertfordshire (IPHAS/VPHAS PI)
University of Nijmegen (UVEX PI)
University of Cambridge (pipeline)
University of Graz

*Other members:*
Instituto de Astrofísica de Canarias, Harvard/Smithsonian CfA, University College London, Imperial College London, University of Warwick, University of Manchester, University of Southampton, Armagh Observatory, Macquarie University, Tautenburg Observatory, ESTEC, University of Valencia.

*Key individuals:*
Janet Drew (IPHAS lead), Hywel Farnhill, Geert Barentsen, Robert Greimel, Mike Irwin, Eduardo Gonzalez-Solares, Romano Corradi, Paul Groot (UVEX lead), Danny Steeghs, and many more.

More info:
www.iphas.org


@GeertMcTwit

www.geert.io

github.com/barentsen