GDR1 photometry

CU5/DPCI team

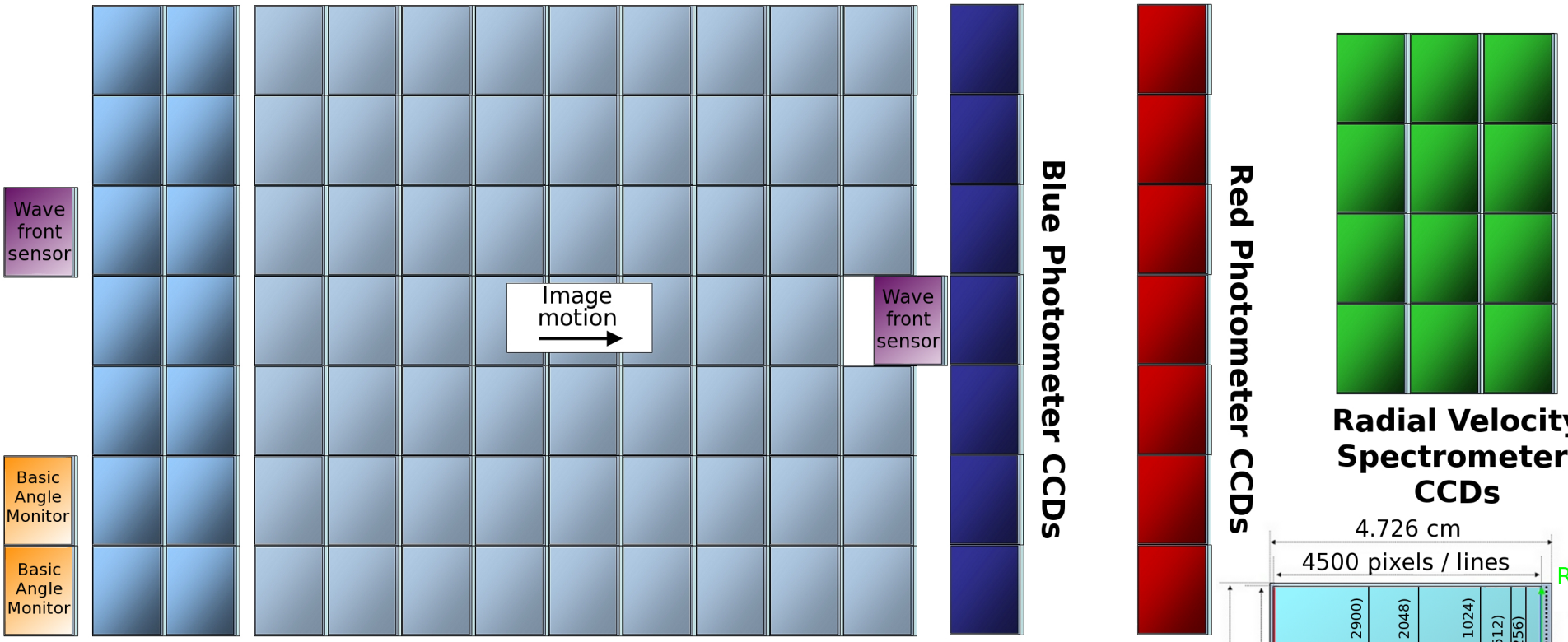
What is, or isn't included

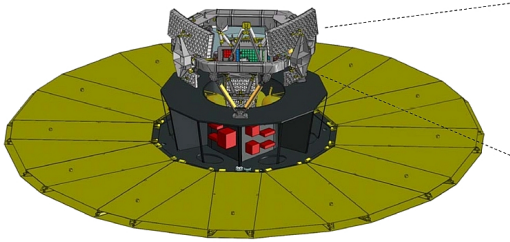
- GDR1 only provides G mean flux and error
  - Derived mean magnitude, all entries
    - Zero point used is in Vega system
    - Zero point for AB system also available
  - Variability flag (partially implemented)
  - Number of observations (CCD transits)
- Not included:
  - BP, RP integrated fluxes (GDR2)
  - BP, RP spectra (GDR2)

Overview of issues

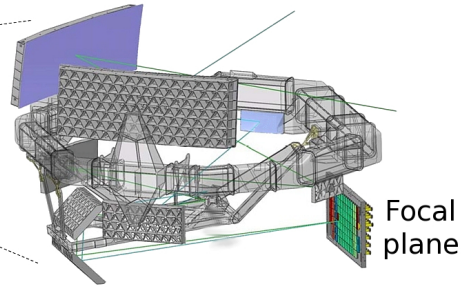
- The instrument
  - Contamination, background, XM issues
- The calibration units
  - Windows, gates, coverage, saturation
- Internal calibrations
  - System definition, linking calibration units, large & small scale calibrations
- External calibrations

Gaia Focal Plane
106 CCDs = 938 million pixels = 2800 cm²

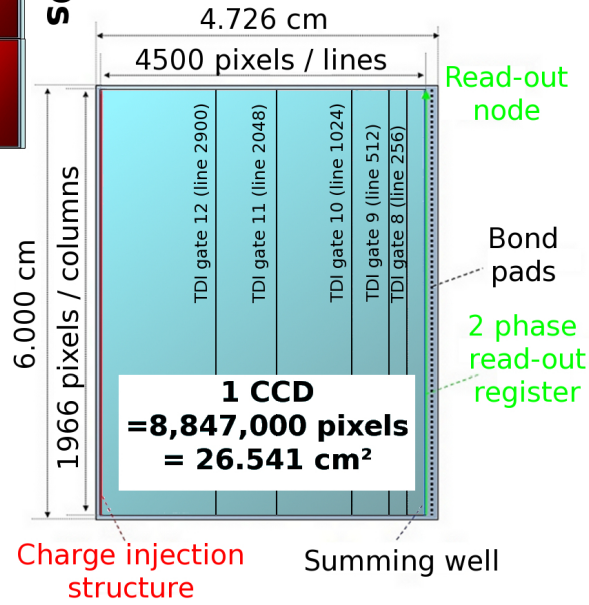




Gaia (MLI removed)



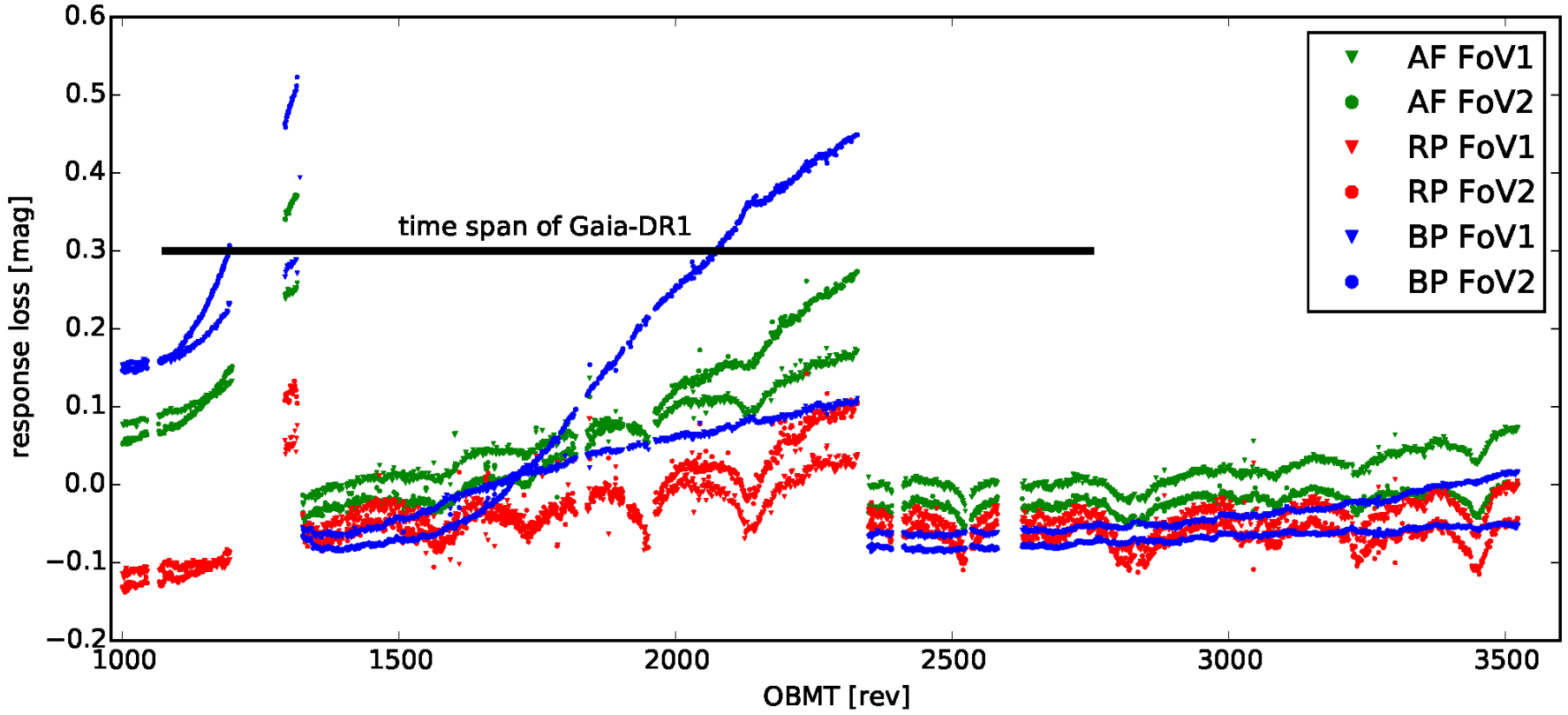
Payload Module (telescopes)

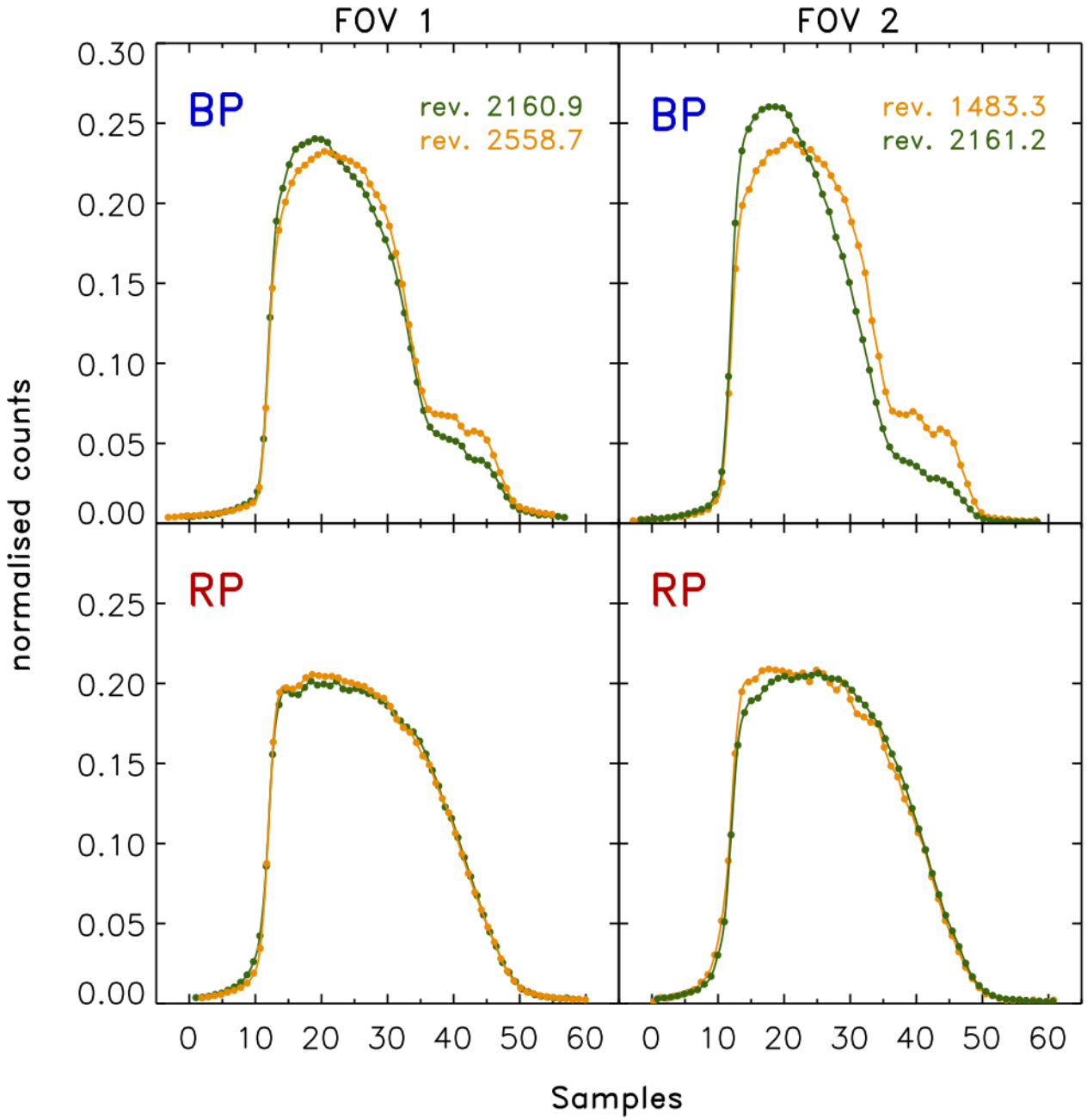


Instrument evolution in GDR1

- Contamination, de-contamination
  - Effects on pass bands
- Focus evolution
  - Effects of re-focus, PSF changes
- Background
  - Scattered sun light
  - Illegal optical path through telescope

Mirror contamination

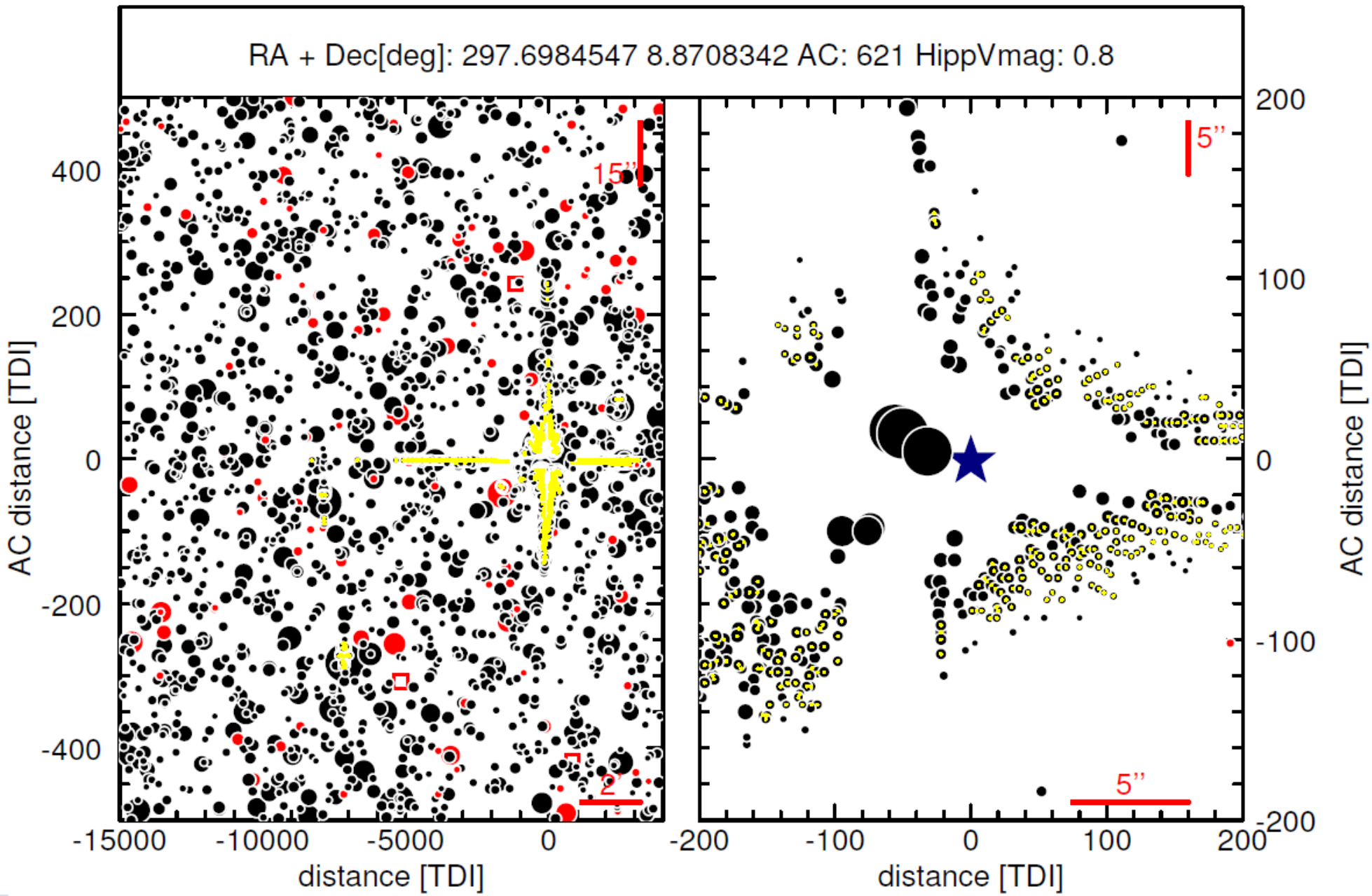




Mirror contamination as reflected in BP/RP spectra

Cross-match issues

- Fake images from on-board detection
  - Mainly due to spikes from bright stars
  - 6^{th} magn. Star could create some 30000 fake images
  - Situation has improved significantly beyond GDR1, data segment 2 onwards
- On ground:
  - Double identifications in reference catalogue


G 5.75 NN: 4050 B-R: -0.23 TID-12278395878560365 DR: -37.0 ROW5 T1
RA + Dec[deg]: 297.6984547 8.8708342 AC: 621 HippVmag: 0.8
15''
2
5''
5''
AC distance [TDI]
distance [TDI]
AC distance [TDI]
distance [TDI]
400
200
0
-200
-400
-15000
-10000
-5000
0
-200
-100
0
100
200
200
100
0
-100
-200

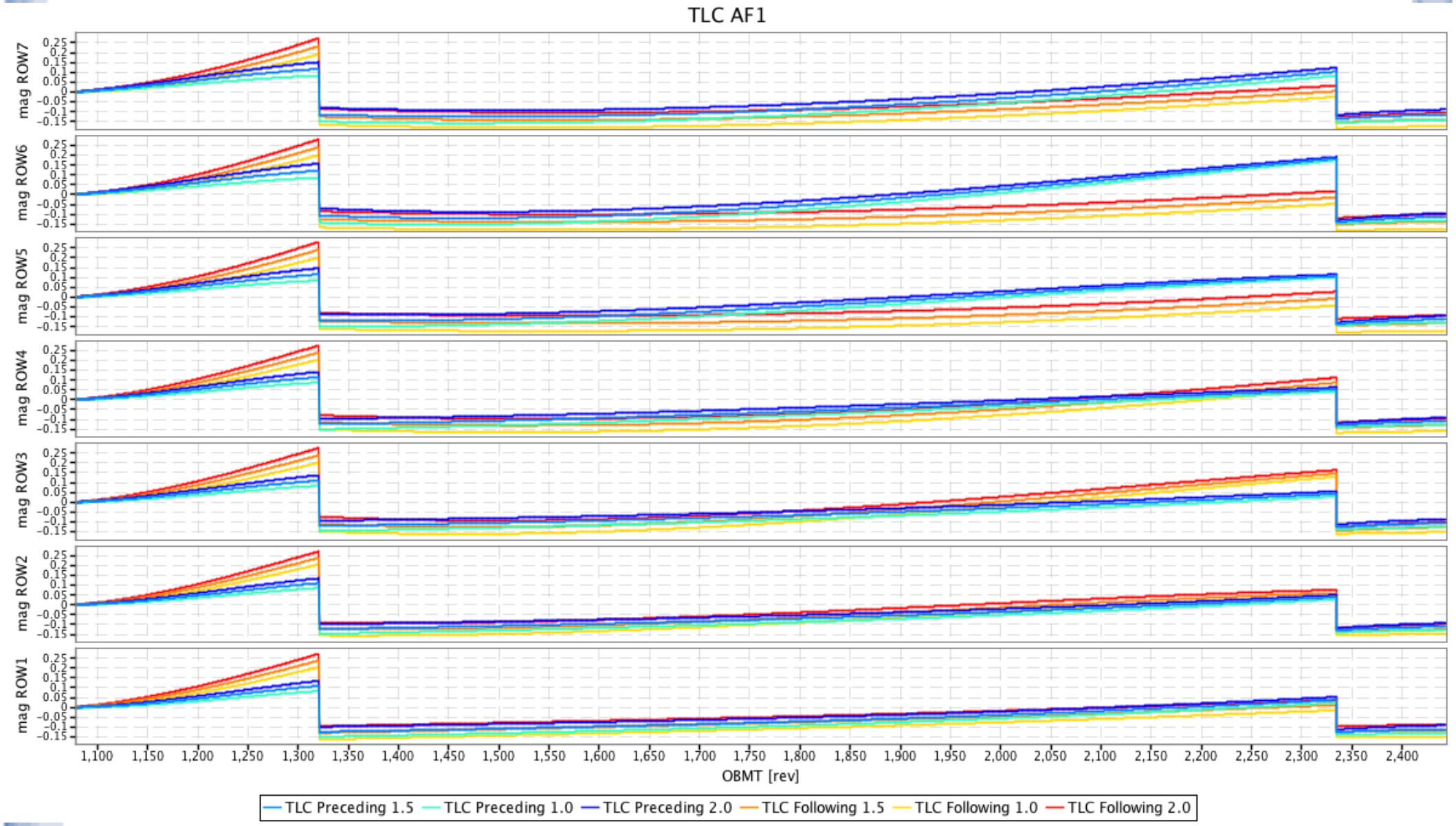
Calibration units

- Gaia is not one, but very many instruments:
  - AF field:
    - 62 CCDs, 8 gate settings for 2D windows, 2 1D window classes, 2 fields of view: 1240 units
  - SM:
    - 2 * 7 CCDs, 2 window classes: 28 units
  - BP, RP:
    - 2 window classes, 5 gate settings, 14 CCDs, 2 fields of view: 168 units
  - SSCs:
    - 4 * 168 = 672 units

Link calibrations

- AF observations form the backbone of GDR1 photometry
- Link calibrations connect the data between different calibration units
  - Overlaps in observations
    - Relies on poverty of on-board magn.estimates
    - Good overlaps between gates
    - Poor overlaps between window classes
  - Iterative process

Zero-point calibrations



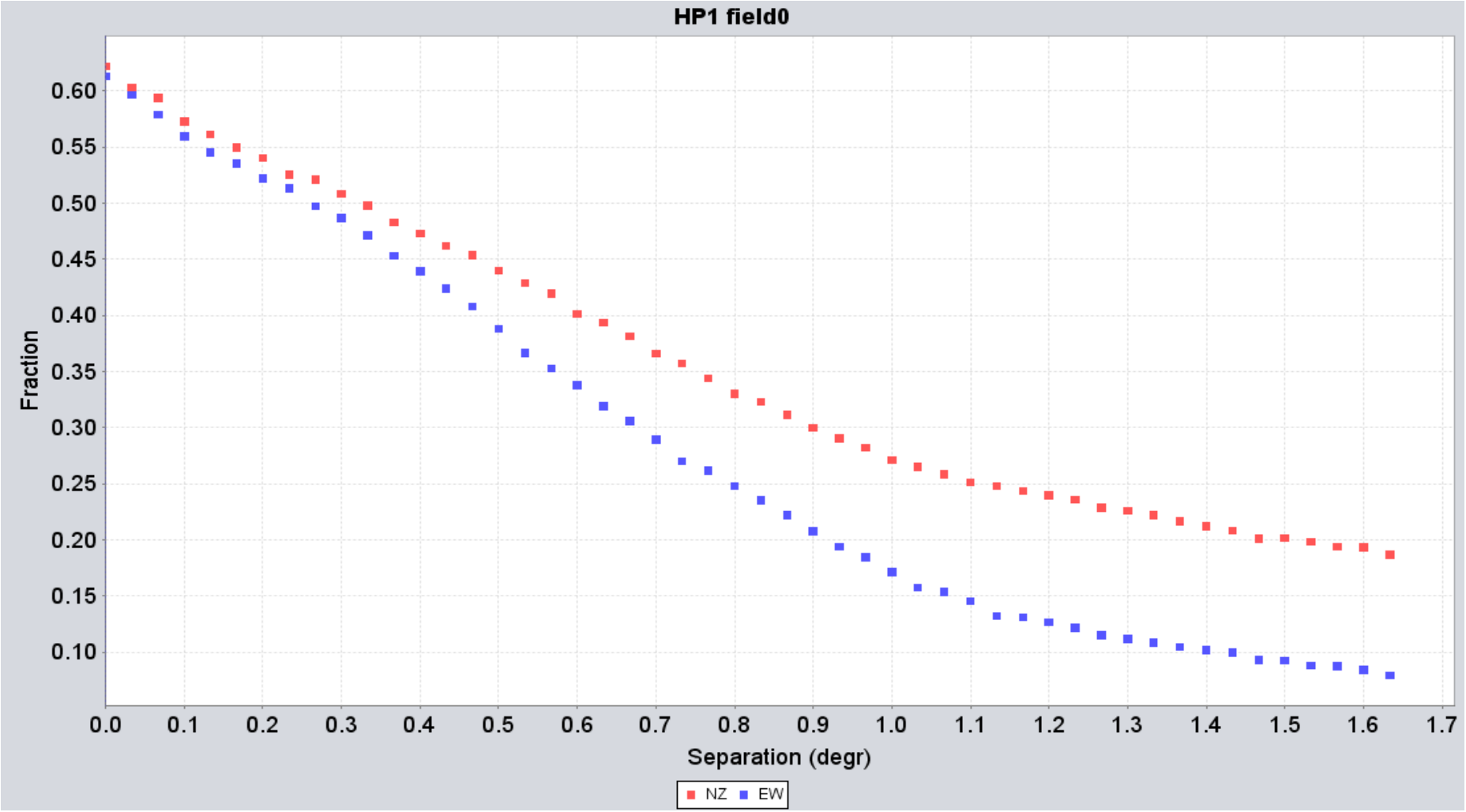
Coverage requirements

- Determined by:
  - Time-scale for instrument evolution
  - Number of usable transits for a calibration unit
    - Typically about 50% of all transits
  - Number of dependencies in the calibration model
  - Coverage over dependencies: colour
- Gets worse towards brighter sources

Coverage issues

- Epoch astrometry for TGAS shows that around 20 to 30% of the data is lost
- For 2D windows the PSF models were still quite primitive
    - No AC drift dependence, AL*AC PSF
    - Very high gof values
    - No accounting for saturation

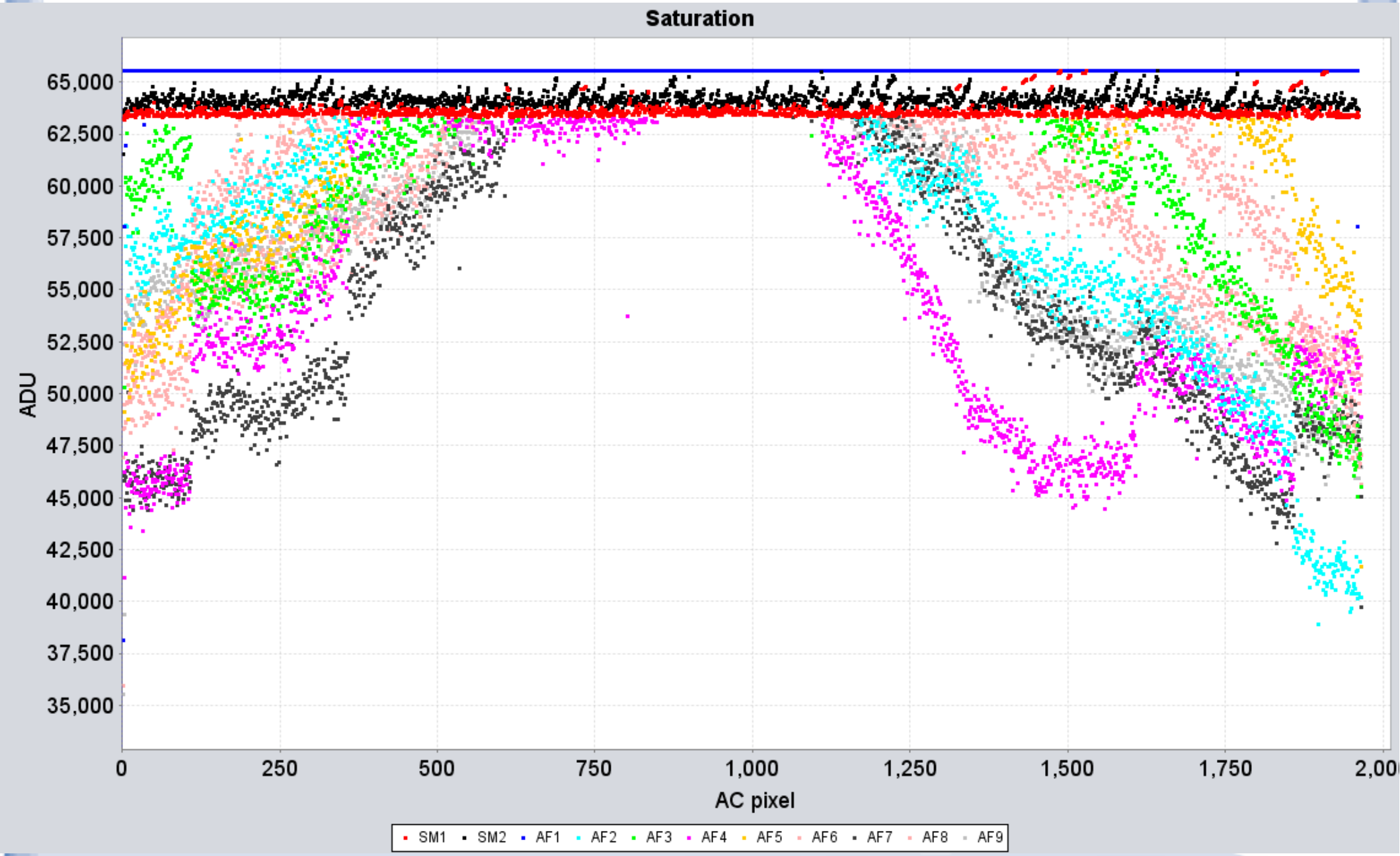
Scan coincidence fraction



Saturation

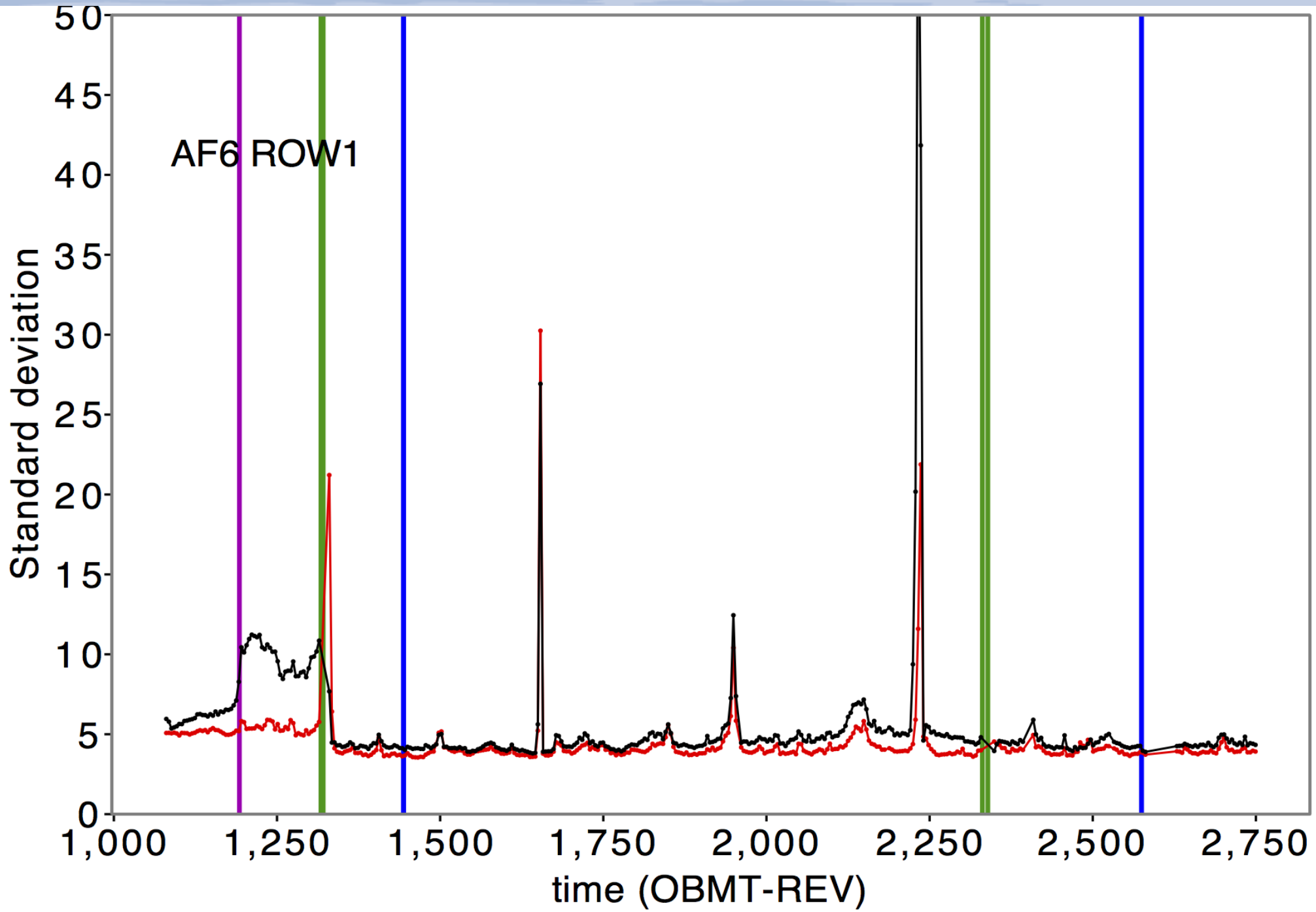
- On-board settings to limit the effects of saturation
  - Not yet fully tuned during EPSL
  - Some cases not clearly determined
  - Effects of saturation were not included in image parameter determination
    - Localized deterioration of bright star data

CCD Row 6, saturation



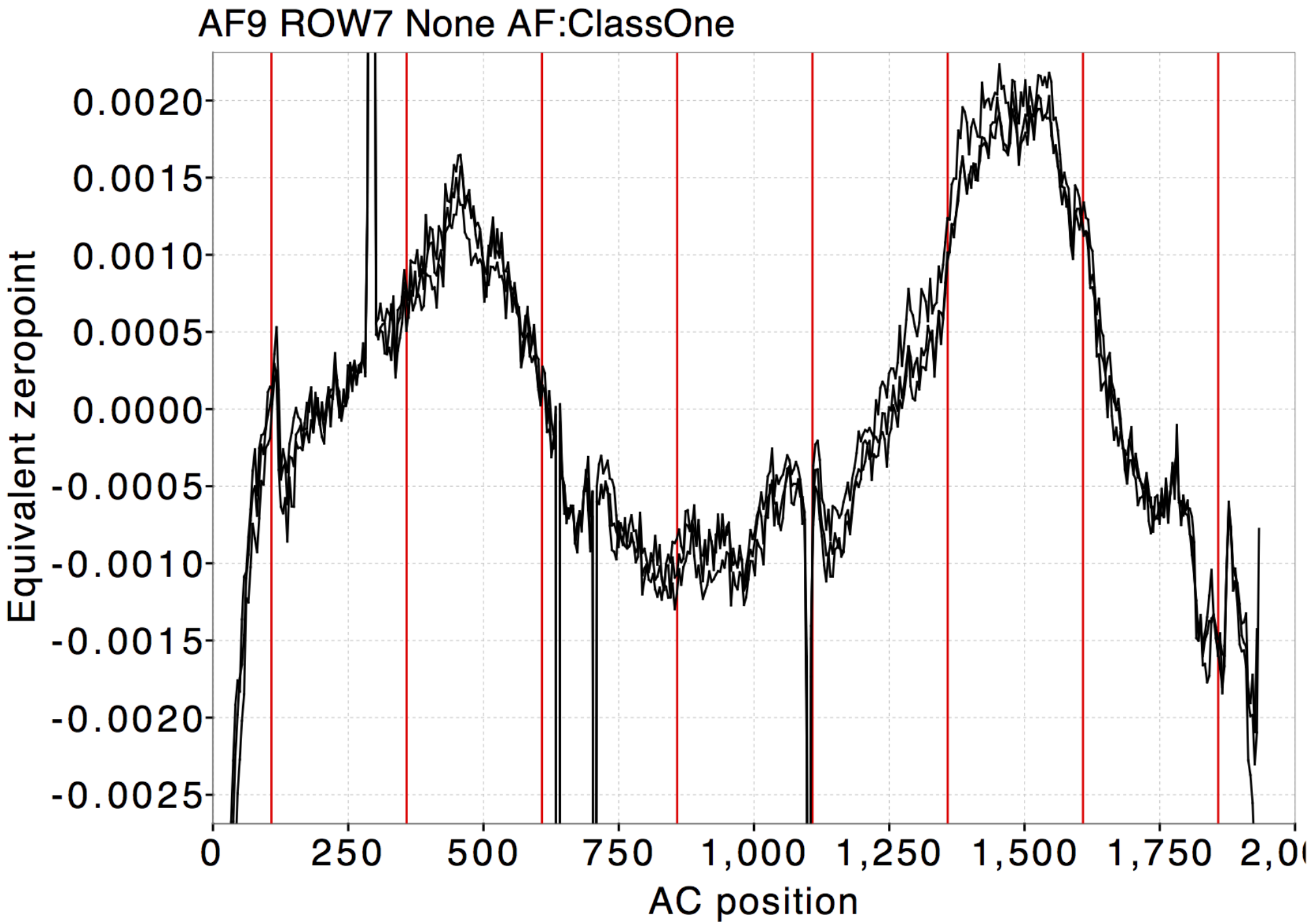
Internal calibrations, large scale

- Gaia photometry is a self-calibrating system
  - Using the internal consistency of the “sky”
  - Large numbers of not-variable stars down to the level of a few mmag.
  - Main dependencies: Colour and AC position
    - Colour compensates for QE differences (CCDs, gates), mirror contamination (time), limited range
    - AC position: Saturation, focus, CCD response

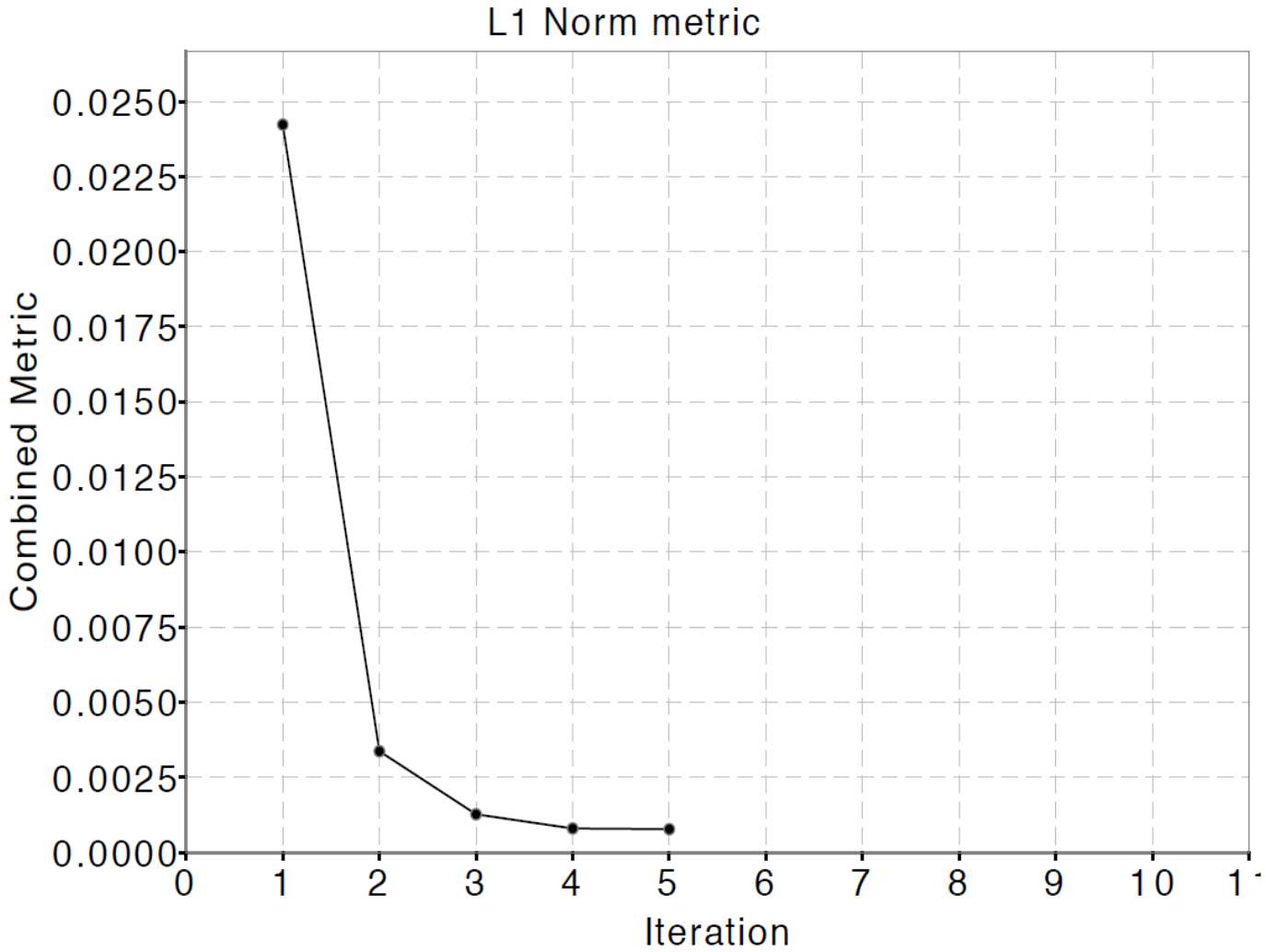

AF6 ROW1
Standard deviation
0
5
10
15
20
25
30
35
40
45
50
1,000
1,250
1,500
1,750
2,000
2,250
2,500
2,750
time (OBMT-REV)

Internal calibrations, small scale

- Local CCD response variations
  - Two fields of view combined
  - Resolved on small groups of pixel columns
  - Colour dependencies (not in GDR1)
  - Fixed over long time intervals
    - All 14 months for GDR1
- Iterative solution with large-scale calibration


AF9 ROW7 None AF:ClassOne
Equivalent zeropoint
0.0020
0.0015
0.0010
0.0005
0.0000
-0.0005
-0.0010
-0.0015
-0.0020
-0.0025
0
250
500
750
1,000
1,250
1,500
1,750
AC position

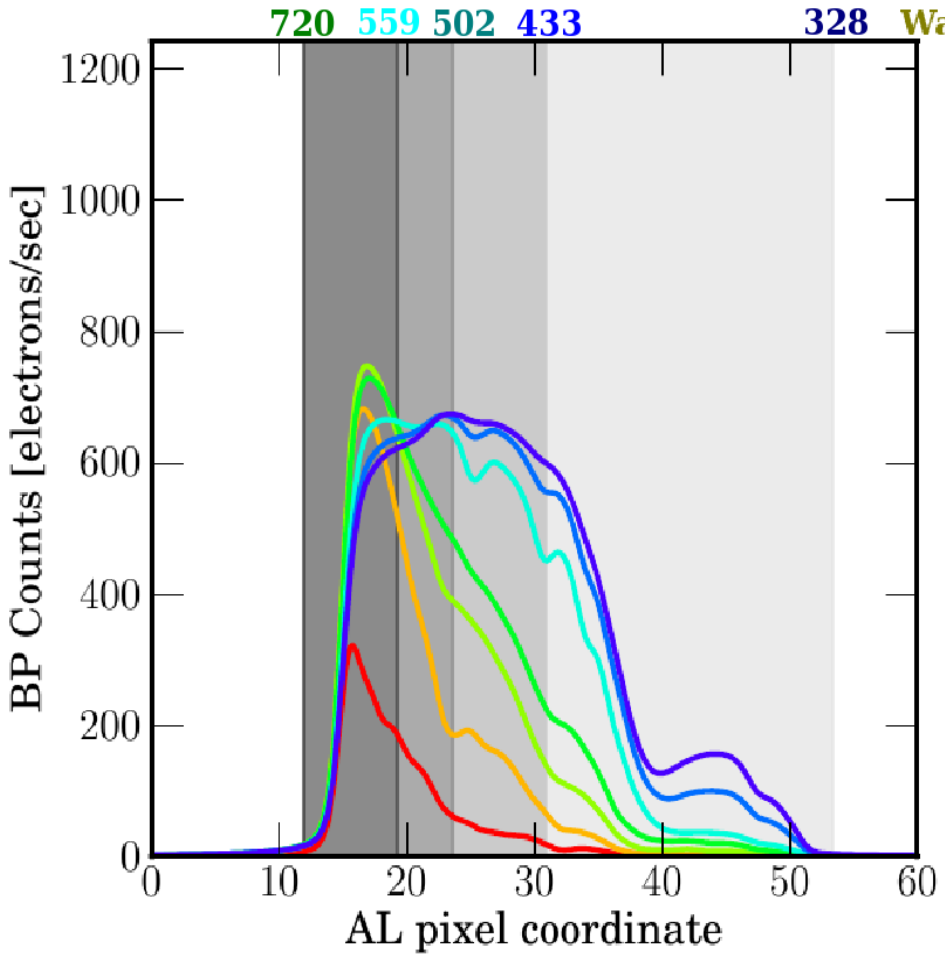
Convergence of the iteration

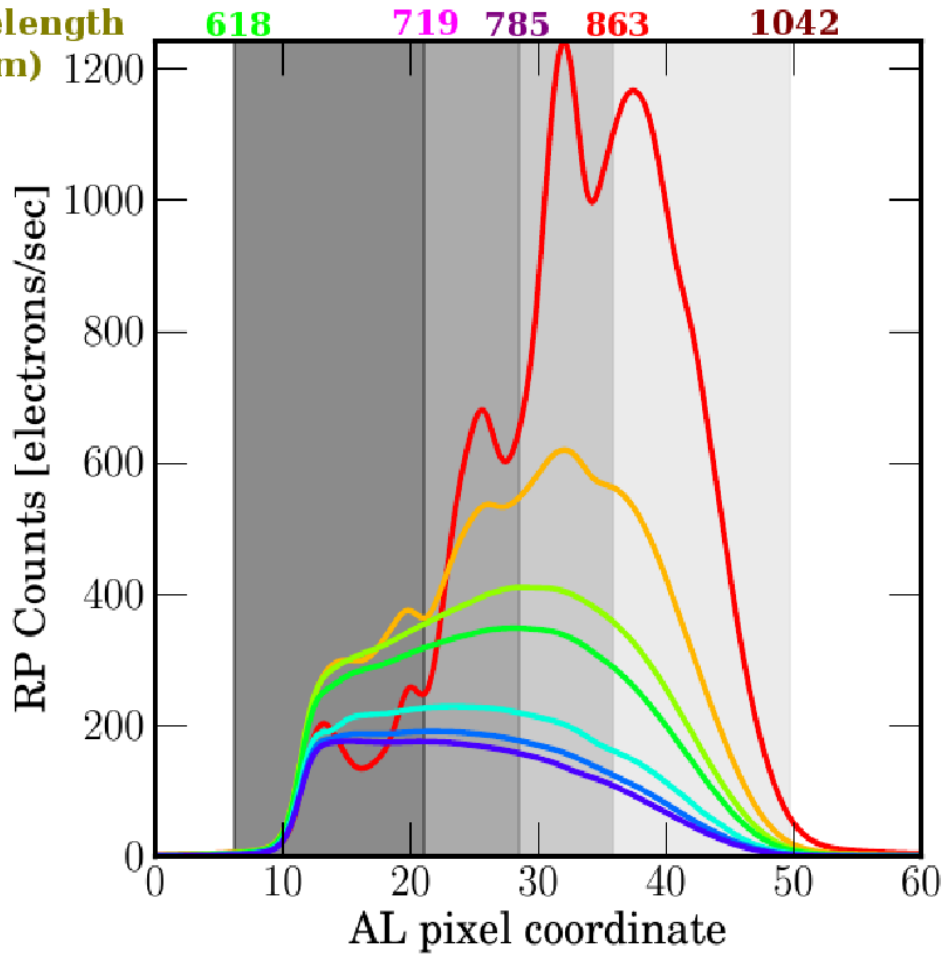


Colour dependencies

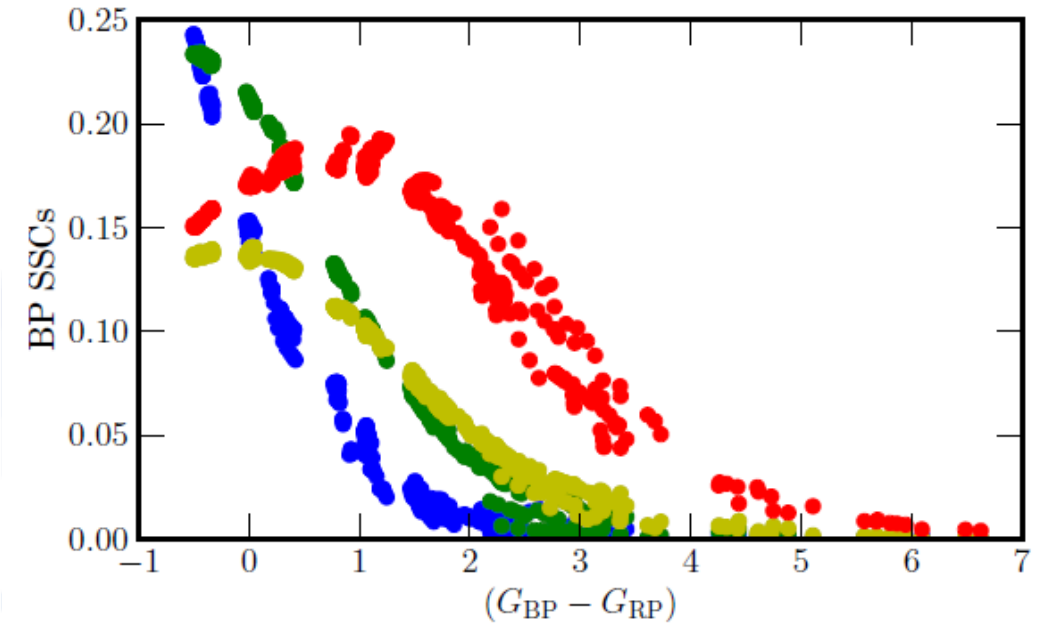
- Spectral Shape Coefficients
  - Fixed-wavelengths intervals of BP and RP dispersion spectra
    - Mean spectra for constant (else epoch spectra)
  - Pseudo pass bands
    - Give a better resolution between log g and Teff
    - Possibly also in some cases reddening
  - Problematic for faint stars
    - Requires accumulated BP/RP spectra

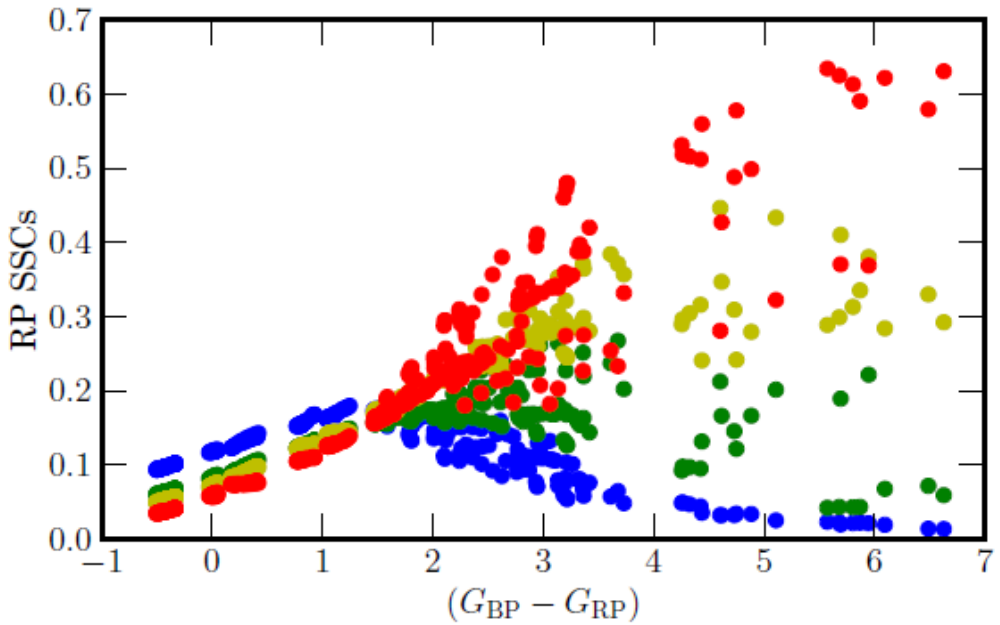
SSC definition





SSC responses

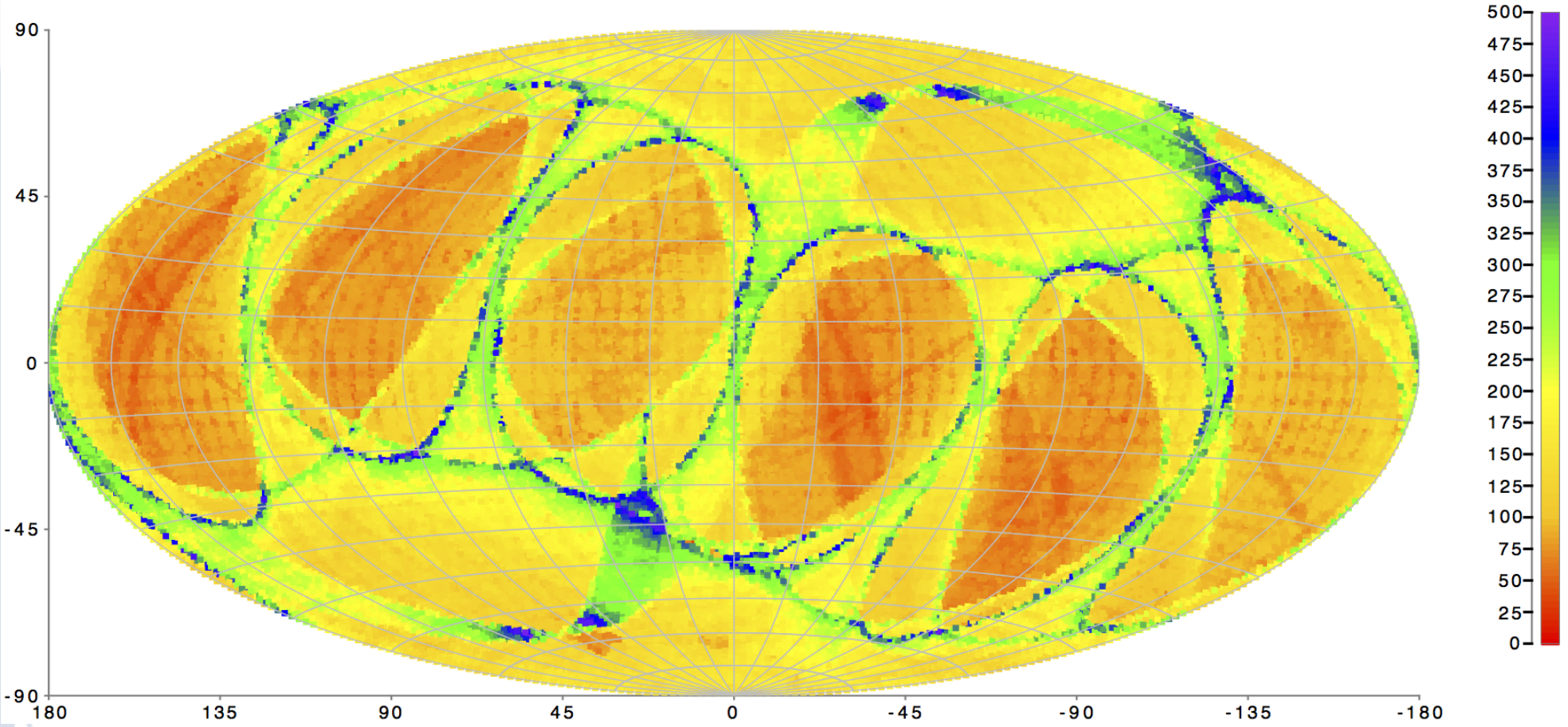


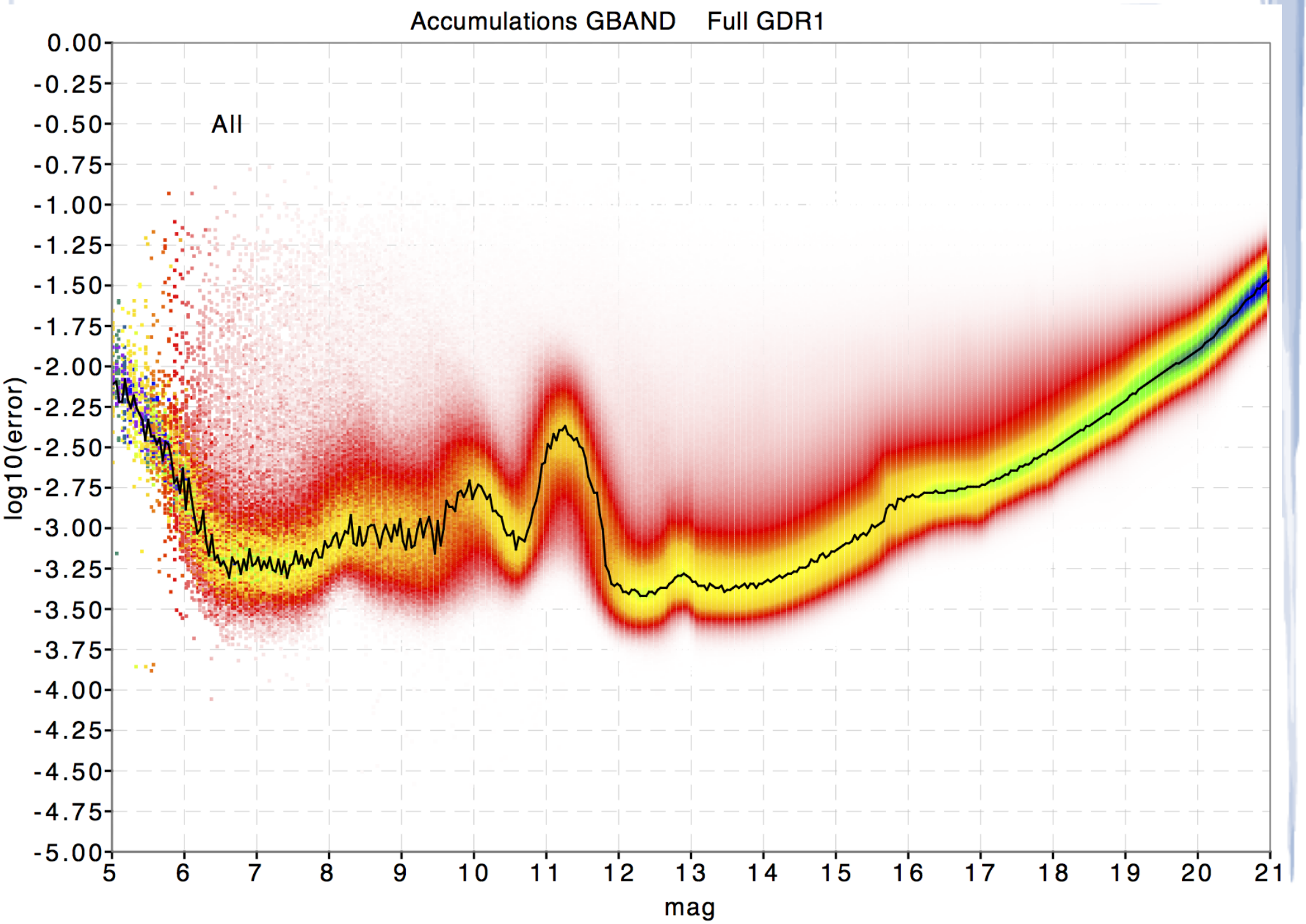


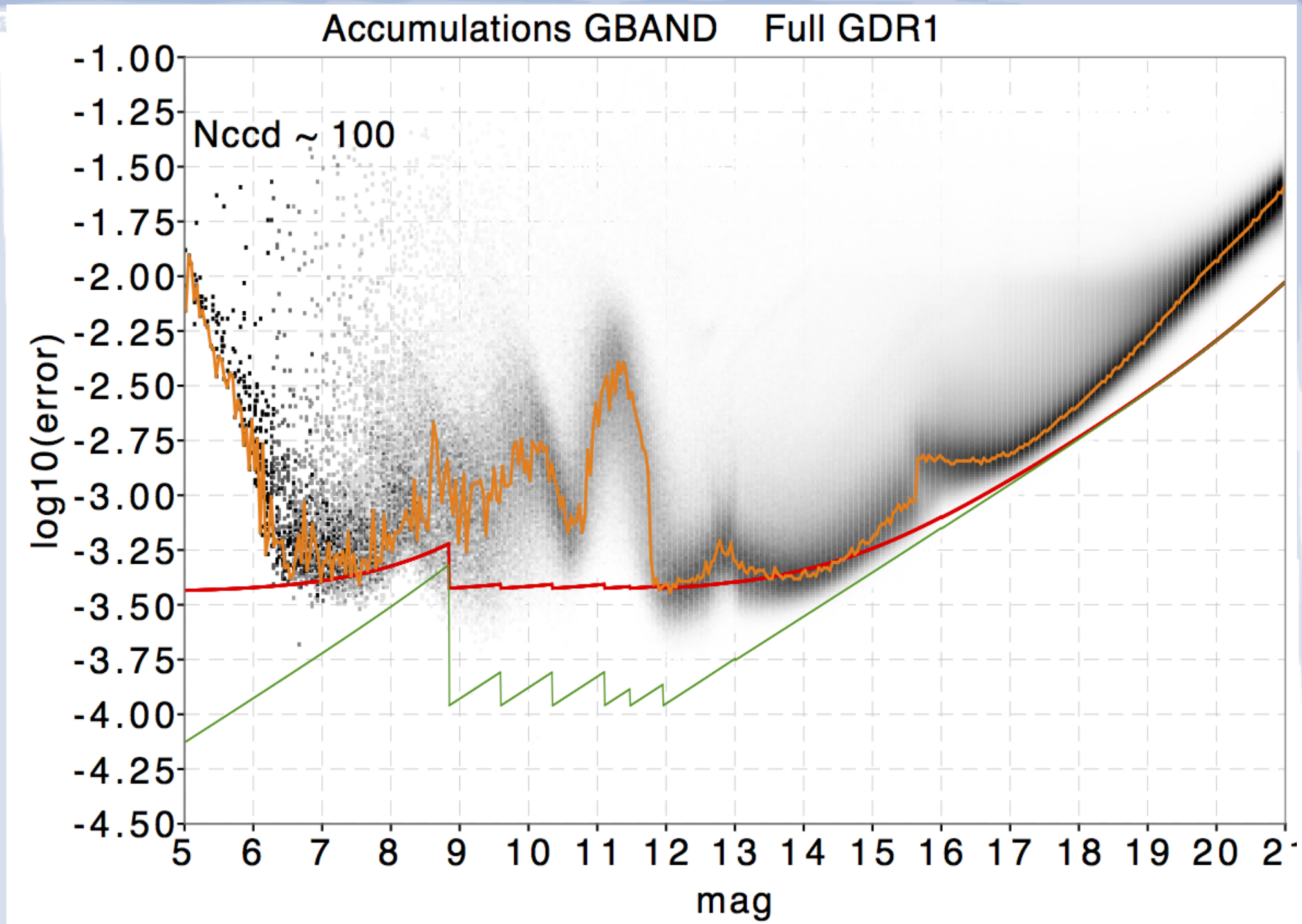
Precision and accuracy

- Precisions determined on basis of standard deviations
  - Ignores residual link-calibration errors
    - Seen around the link magnitudes
- Accuracy determined from external comparisons
  - Very few, if any, systems with similar accuracy all-sky coverage

Number of observations

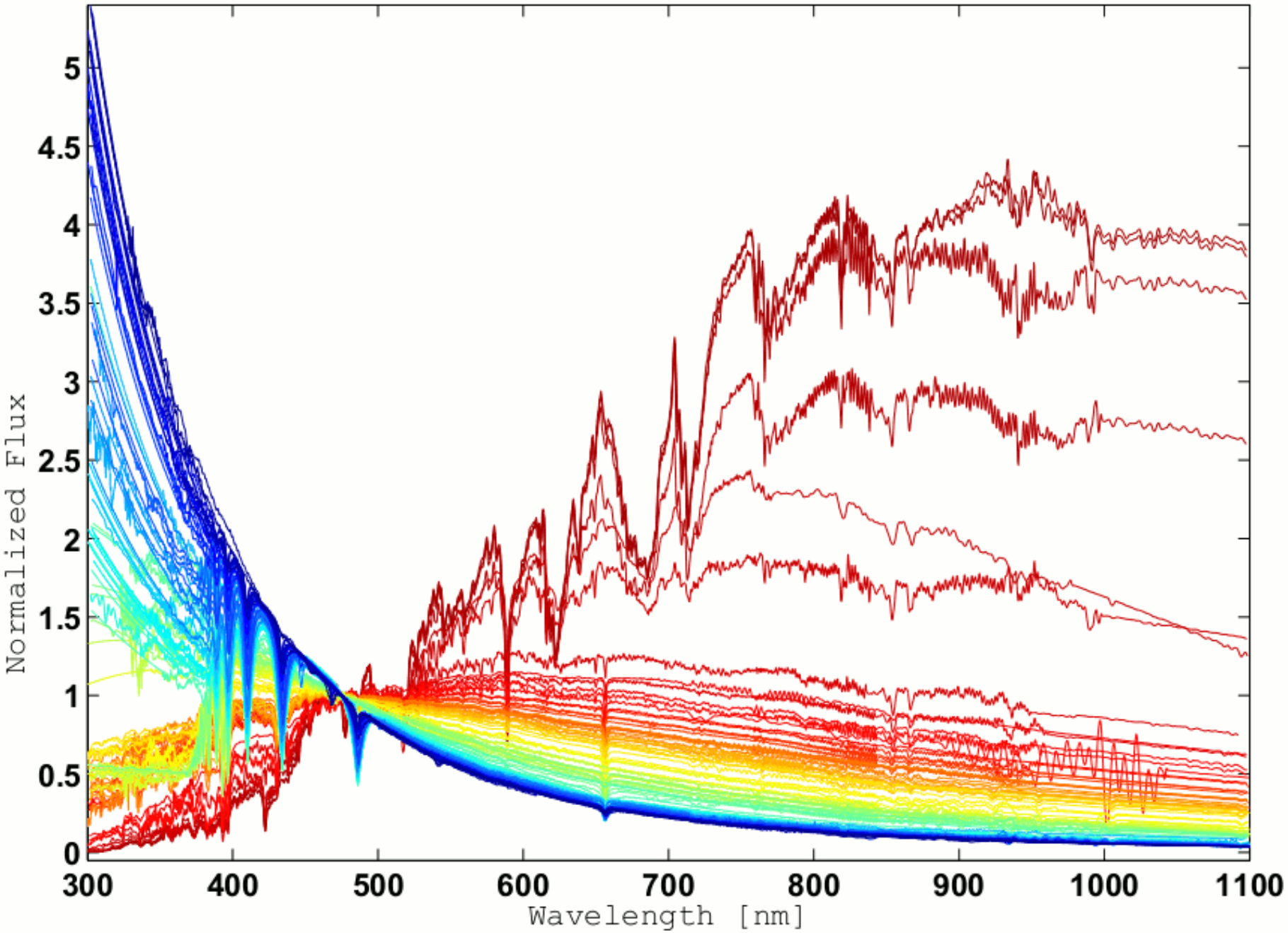



Accumulations GBAND Full GDR1
All
log10(error)
mag
0.00
-0.25
-0.50
-0.75
-1.00
-1.25
-1.50
-1.75
-2.00
-2.25
-2.50
-2.75
-3.00
-3.25
-3.50
-3.75
-4.00
-4.25
-4.50
-4.75
-5.00
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21

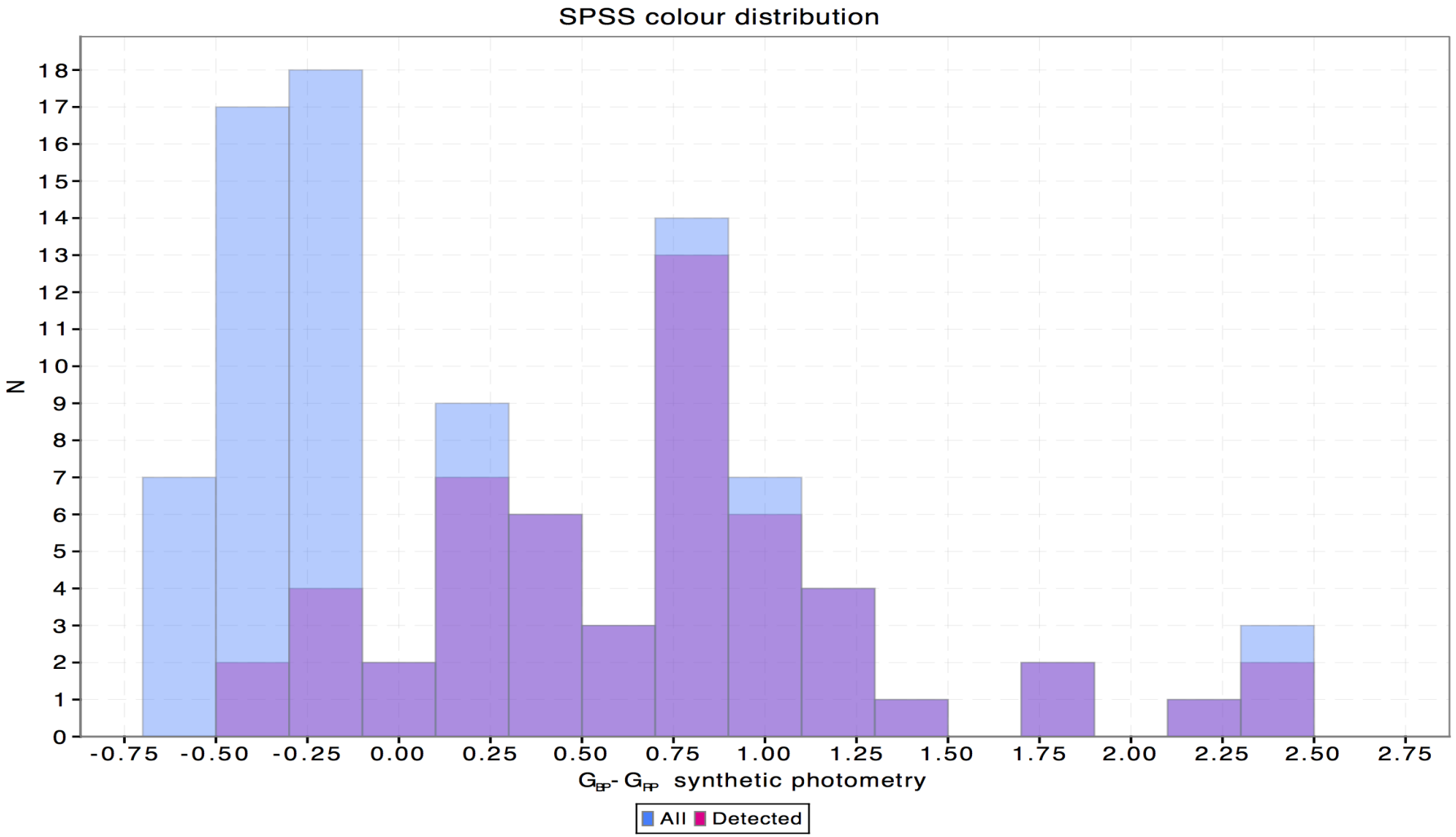

Accumulations GBAND Full GDR1
Nccd ~ 100
log10(error)
-1.00
-1.25
-1.50
-1.75
-2.00
-2.25
-2.50
-2.75
-3.00
-3.25
-3.50
-3.75
-4.00
-4.25
-4.50
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
mag

External calibrations

- Should in principle be a calibration of the pass band
  - Not possible with GDR1
  - Only a provisional calibration of the zero point
  - Zero point defined for Vega system
    - Also calibration available for AB system


Normalized Flux
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
300
400
500
600
700
800
900
1000
1100
Wavelength [nm]

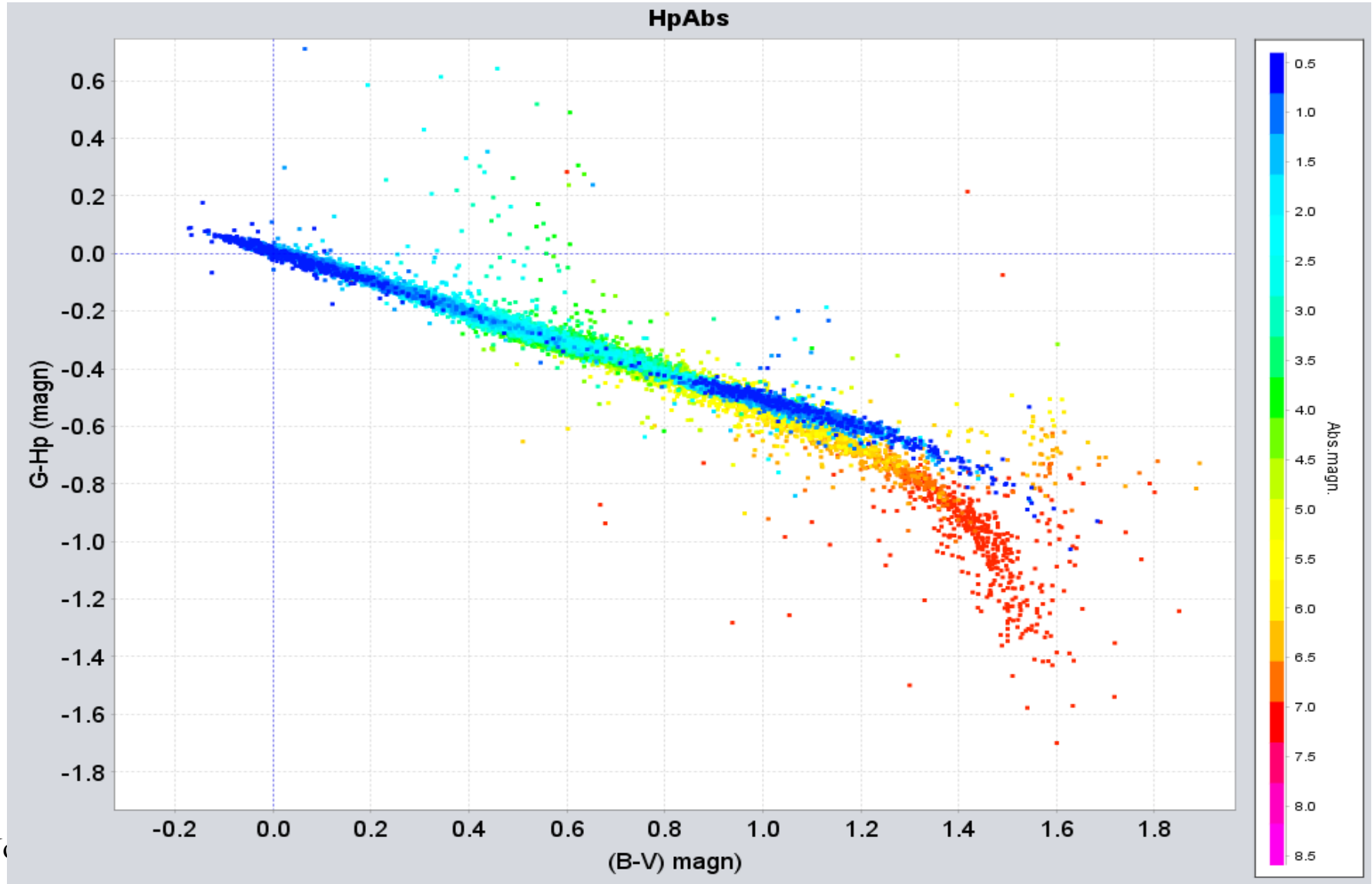
Distributions of standards



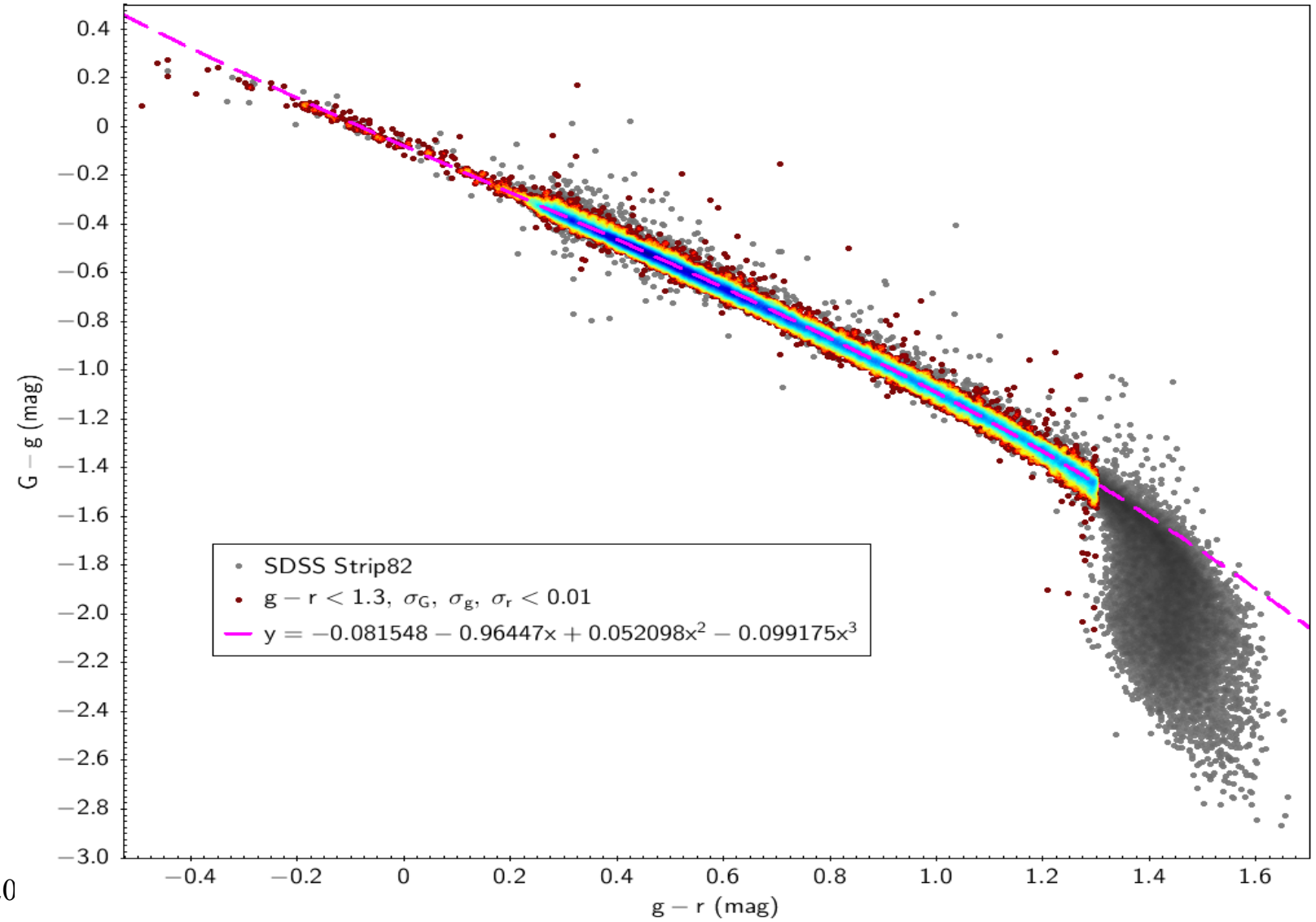
Empirical calibrations

- A number of empirical calibrations to external systems was performed
  - These are of limited value, as they apply to the specific pass band for GDR1
    - This is seriously affected by the mirror contamination early in the mission
  - The pass band for GDR2 will be different
- http://gaia.esac.esa.int/documentation/GDR1/Data_processing/chap_cu5phot/

Comparison with Hipparcos Hp



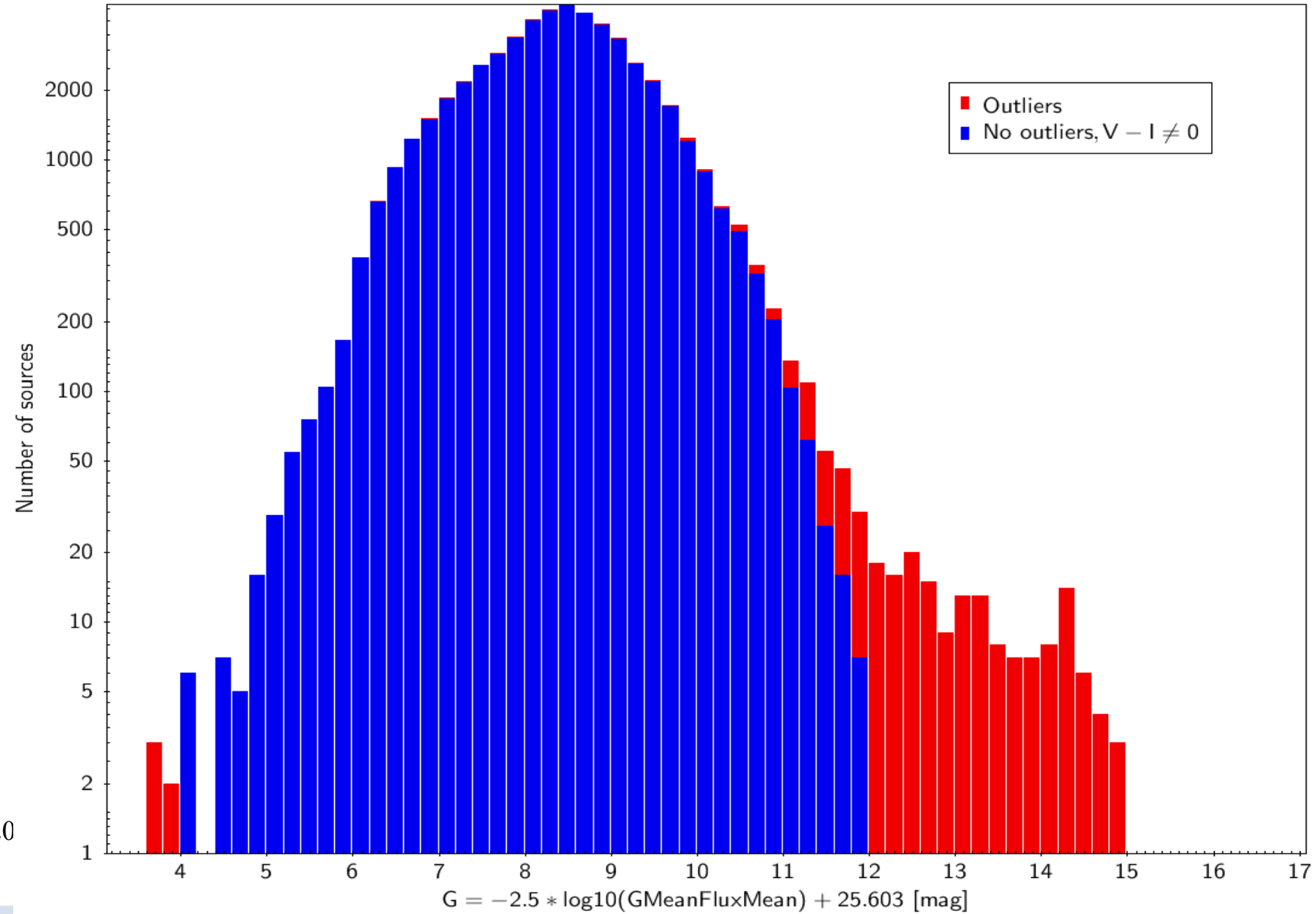
SDSS stripe 82 comparison



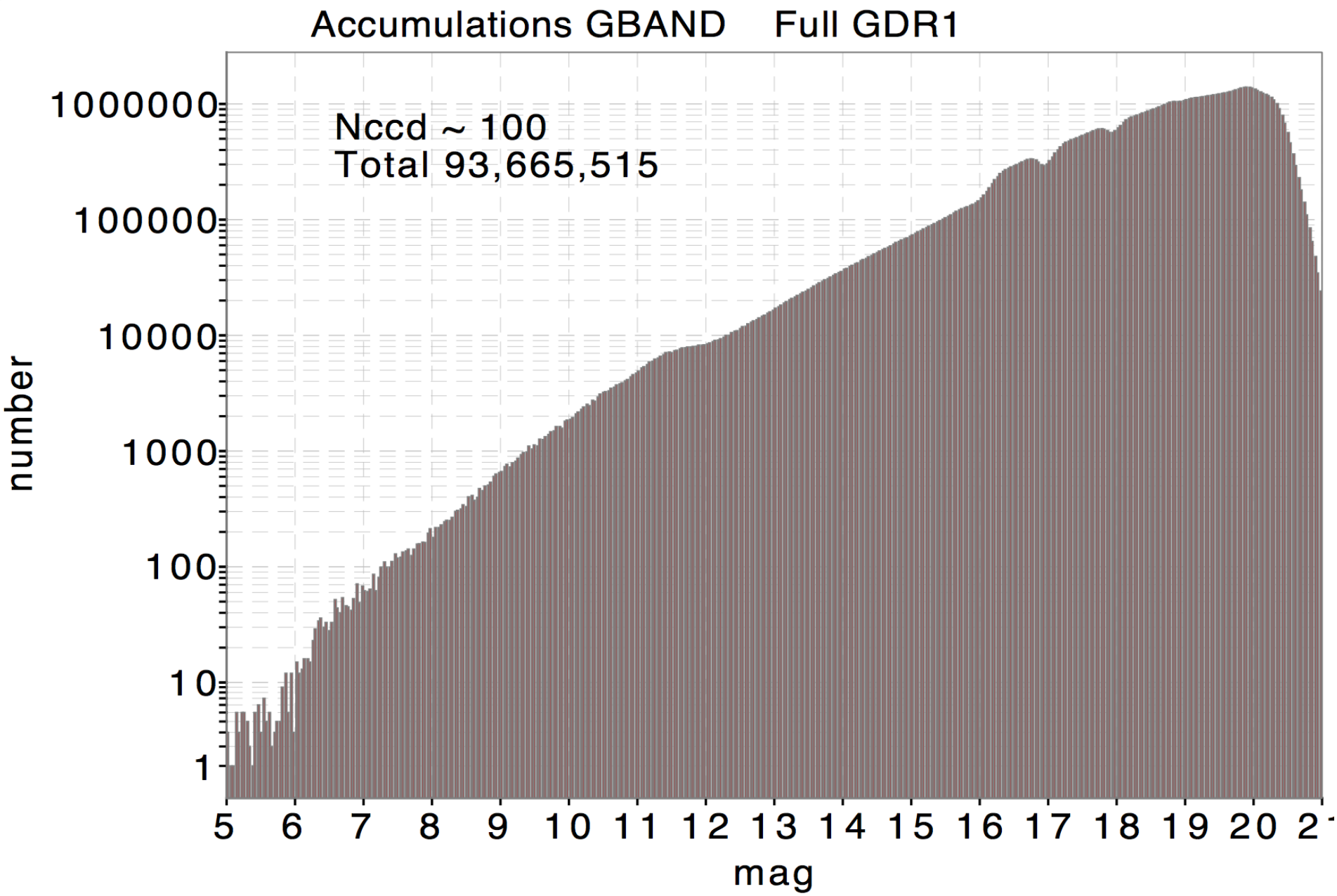
Completeness

- The PhotPipe processing for GDR1 excluded the very blue and very red stars
  - Very small percentage of all stars
  - Was needed to ensure system stability
- Brightest stars not included because of problems in calibrations
  - Insufficient material, very poor image-fit statistics

Hipparcos stars



3 Nov.20


Accumulations GBAND Full GDR1
Nccd ~ 100
Total 93,665,515
number
1000000
100000
10000
1000
100
10
1
5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
mag

Conclusions

- GDR1 has demonstrated the potential and promises of the Gaia data
  - In photometry: better than mmag accuracies are well within reach
- It has shown difficulties still to overcome
  - Details in the linking
  - Handling of extremes in brightness, colours