1.1_DataFusion-Spitzer

March 8, 2018

1 xFLS master catalogue

1.1 Preparation of DataFusion-Spitzer data

The catalogue comes from `dmu0_DataFusion-Spitzer`.

In the catalogue, we keep:

- The identifier (it's unique in the catalogue);
- The position;
- The stellarity;
- The aperture magnitude.
- The total magnitude.

We don't know when the maps have been observed. We will use the year of the reference paper.

```
This notebook was run with herschelhelp_internal version:
255270d (Fri Nov 24 10:35:51 2017 +0000)
```

1.2 I - Column selection

```
/opt/herschelhelp_internal/herschelhelp_internal/utils.py:76: RuntimeWarning: invalid value enco
  magnitudes = 2.5 * (23 - np.log10(fluxes)) - 48.6
```

```
Out[6]: <IPython.core.display.HTML object>
```

1.3 II - Removal of duplicated sources

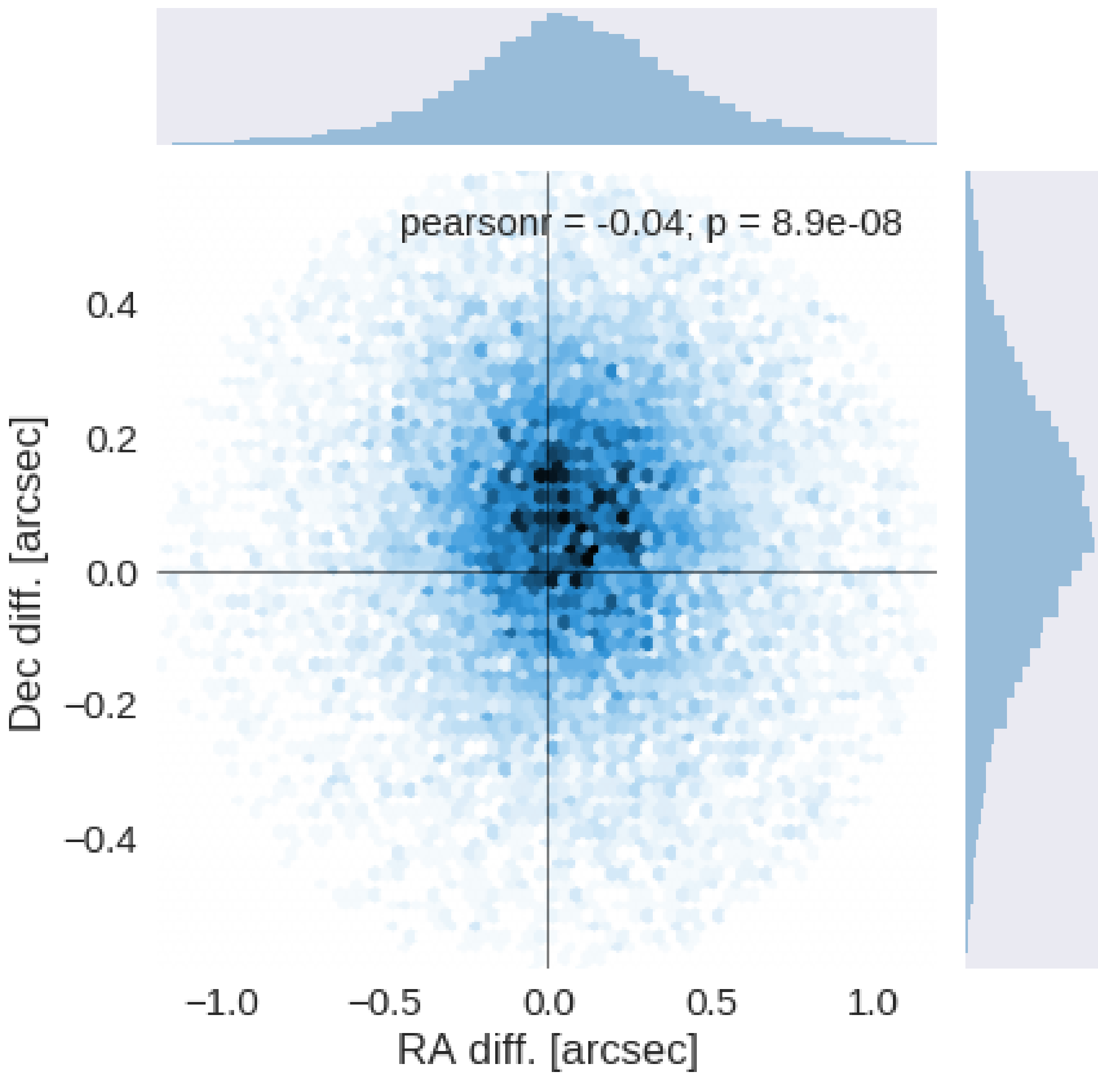
We remove duplicated objects from the input catalogues.

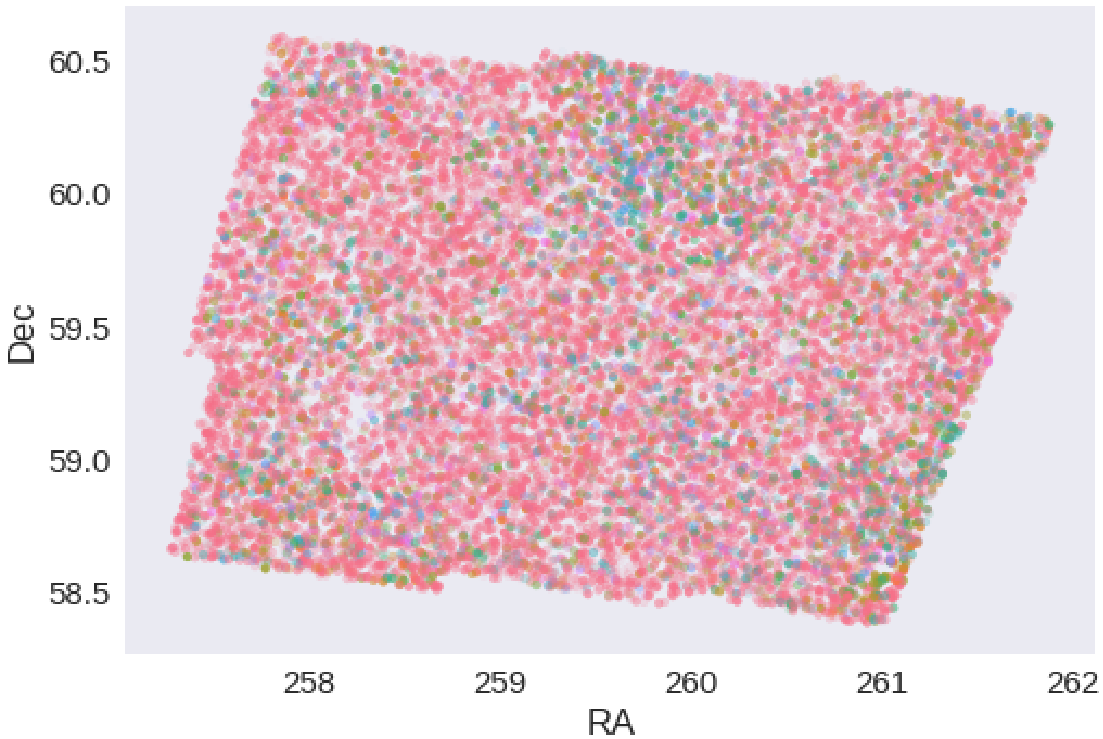
```
/opt/anaconda3/envs/herschelhelp_internal/lib/python3.6/site-packages/astropy/table/column.py:10
Check the NumPy 1.11 release notes for more information.
  ma.MaskedArray.__setitem__(self, index, value)


The initial catalogue had 228354 sources.
The cleaned catalogue has 228354 sources (0 removed).
The cleaned catalogue has 0 sources flagged as having been cleaned
```

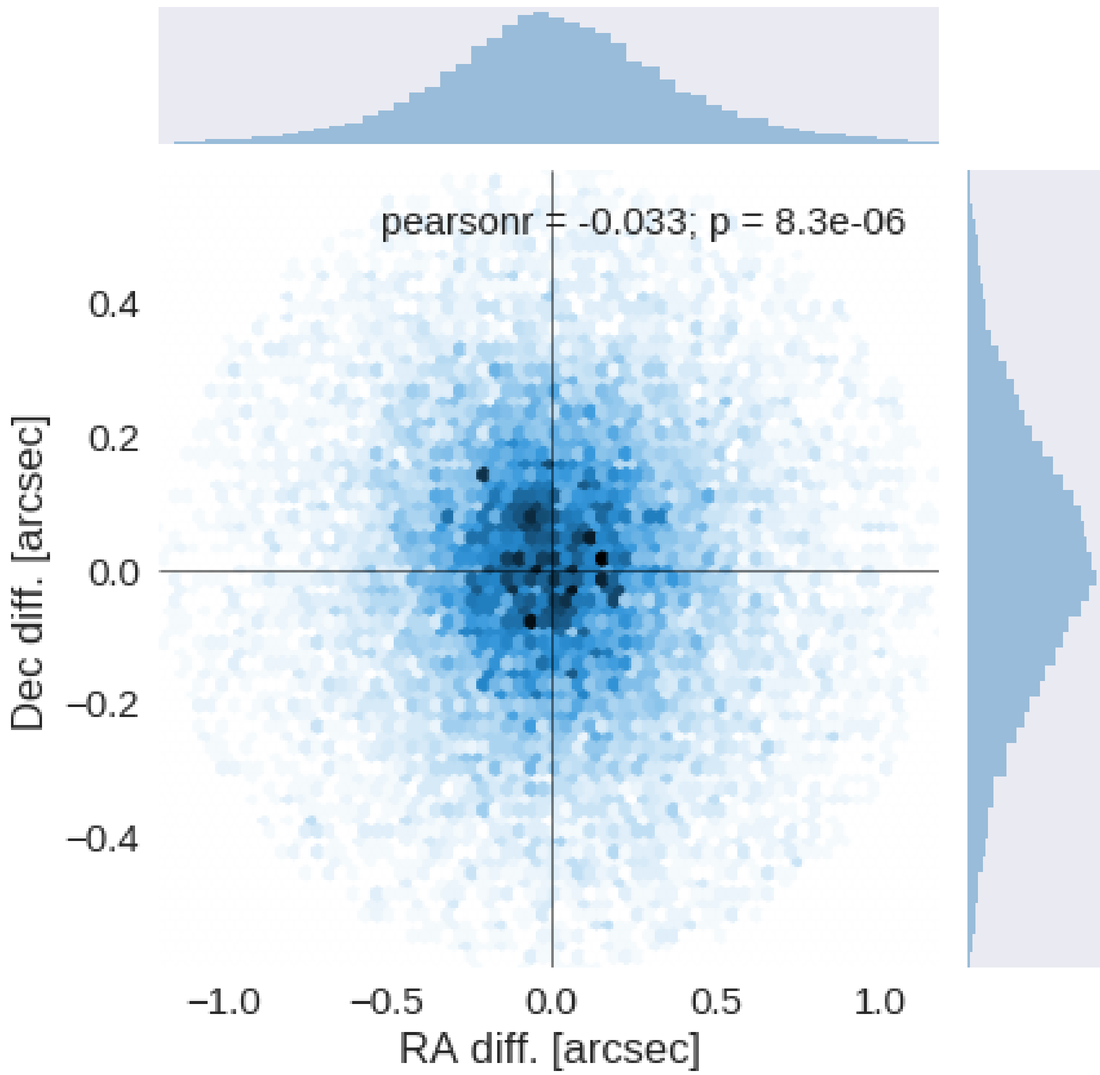
1.4 III - Astrometry correction

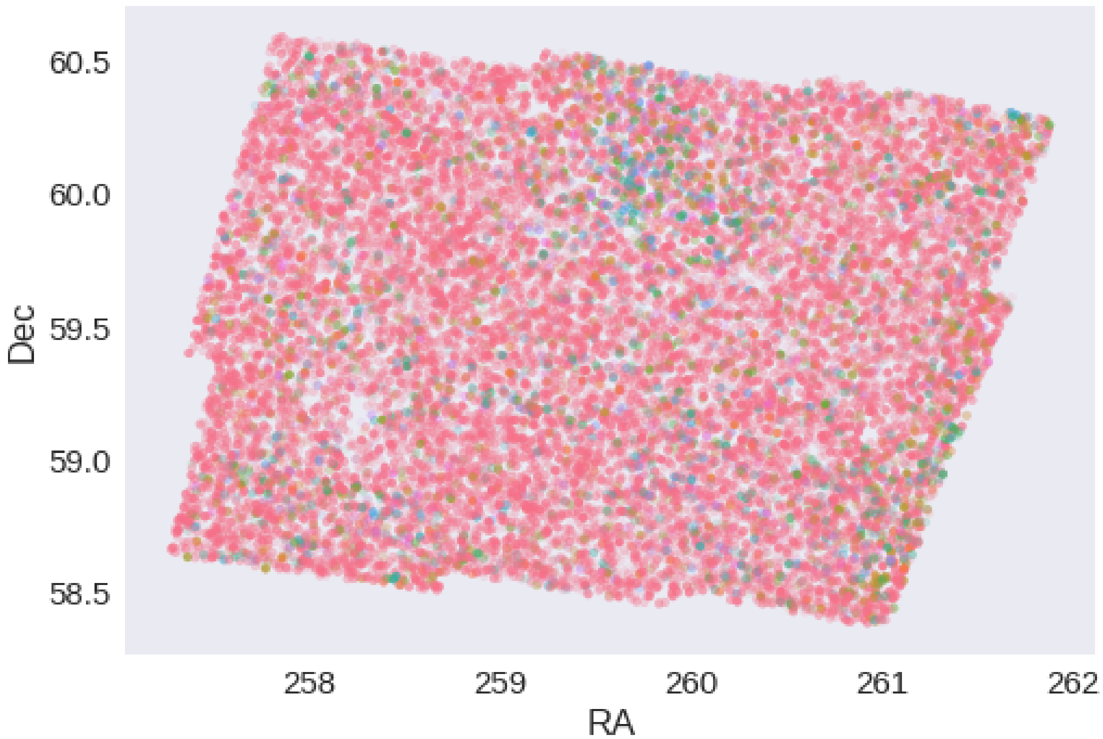
We match the astrometry to the Gaia one. We limit the Gaia catalogue to sources with a g band flux between the 30th and the 70th percentile. Some quick tests show that this give the lower dispersion in the results.






```
RA correction: -0.07282967051196465 arcsec
Dec correction: -0.06646679910460307 arcsec
```


pearsonr = -0.033; p = 8.3e-06
0.4
0.2
0.0
−0.2
−0.4
Dec diff. [arcsec]
−1.0
−0.5
0.0
0.5
1.0
RA diff. [arcsec]



1.5 IV - Flagging Gaia objects

```
21058 sources flagged.
```

2 V - Saving to disk

1.2_INT-WFC

March 8, 2018

1 xFLS master catalogue

1.1 Preparation of Isaac Newton Telescope / Wide Field Camera (INT/WFC) data

Isaac Newton Telescope / Wide Field Camera (INT/WFC) catalogue: the catalogue comes from `dmu0_INTWFC`.

In the catalogue, we keep:

- The identifier (it's unique in the catalogue);
- The position;
- The stellarity;
- The magnitude for each band in apertude 4 ($1.2 * \sqrt{2}$ arcsec = 1.7 arcsec).
- The kron magnitude to be used as total magnitude (no "auto" magnitude is provided).

We don't know when the maps have been observed. We will use the year of the reference paper.

```
This notebook was run with herschelhelp_internal version:
255270d (Fri Nov 24 10:35:51 2017 +0000)
```

1.2 I - Column selection

```
/opt/anaconda3/envs/herschelhelp_internal/lib/python3.6/site-packages/ipykernel/__main__.py:8: R
/opt/anaconda3/envs/herschelhelp_internal/lib/python3.6/site-packages/ipykernel/__main__.py:9: R
```

```
Out[6]: <IPython.core.display.HTML object>
```

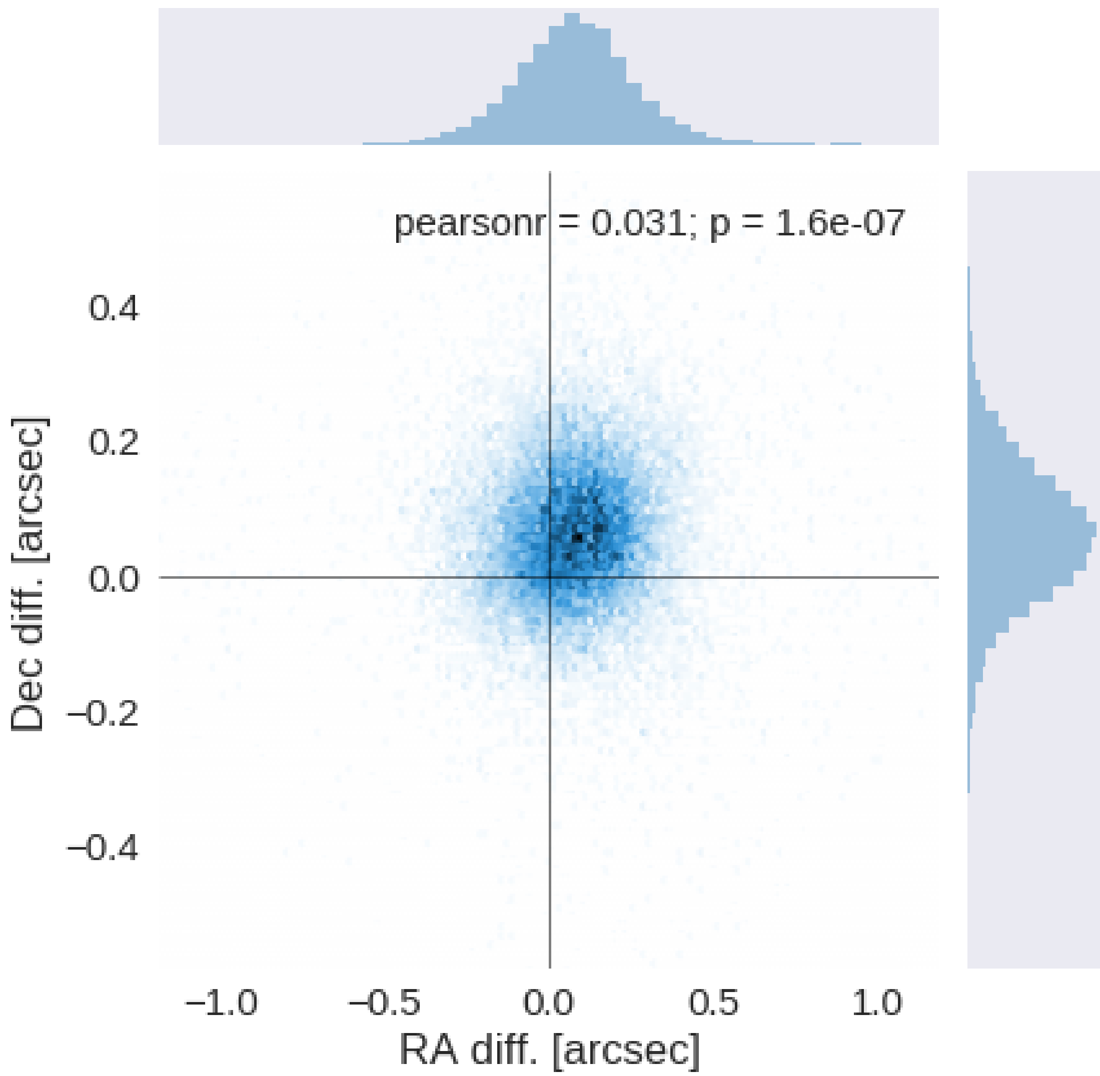
1.3 II - Removal of duplicated sources

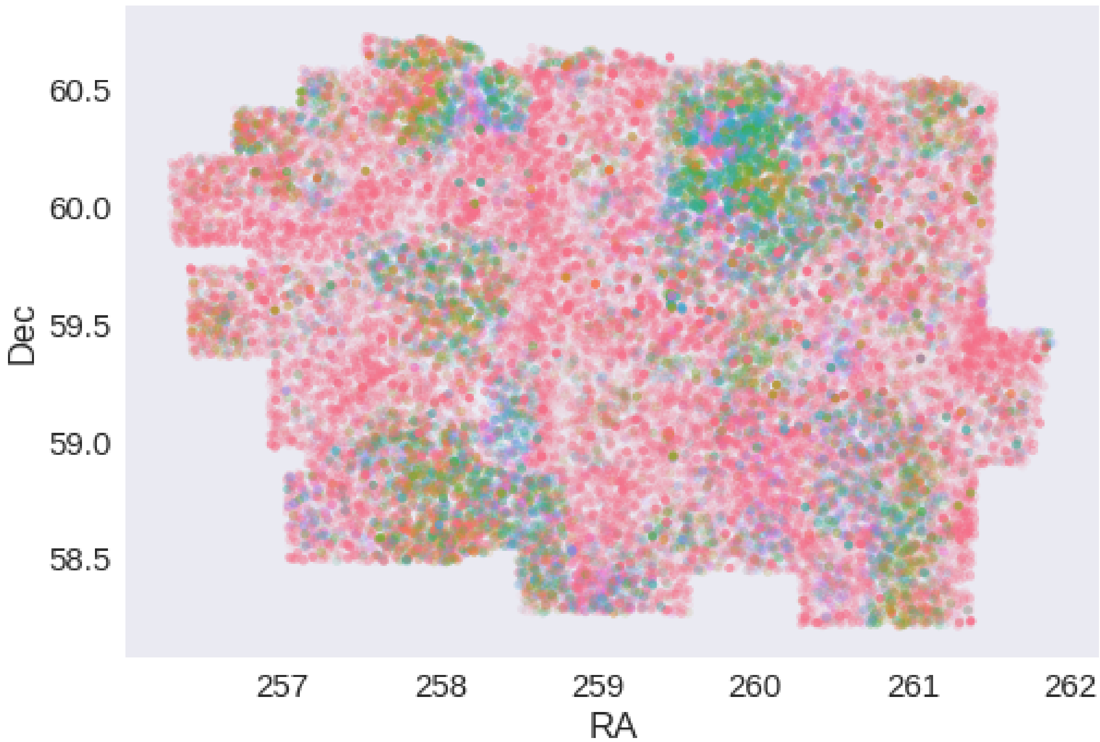
We remove duplicated objects from the input catalogues.

```
The initial catalogue had 490954 sources.
The cleaned catalogue has 490467 sources (487 removed).
The cleaned catalogue has 487 sources flagged as having been cleaned
```

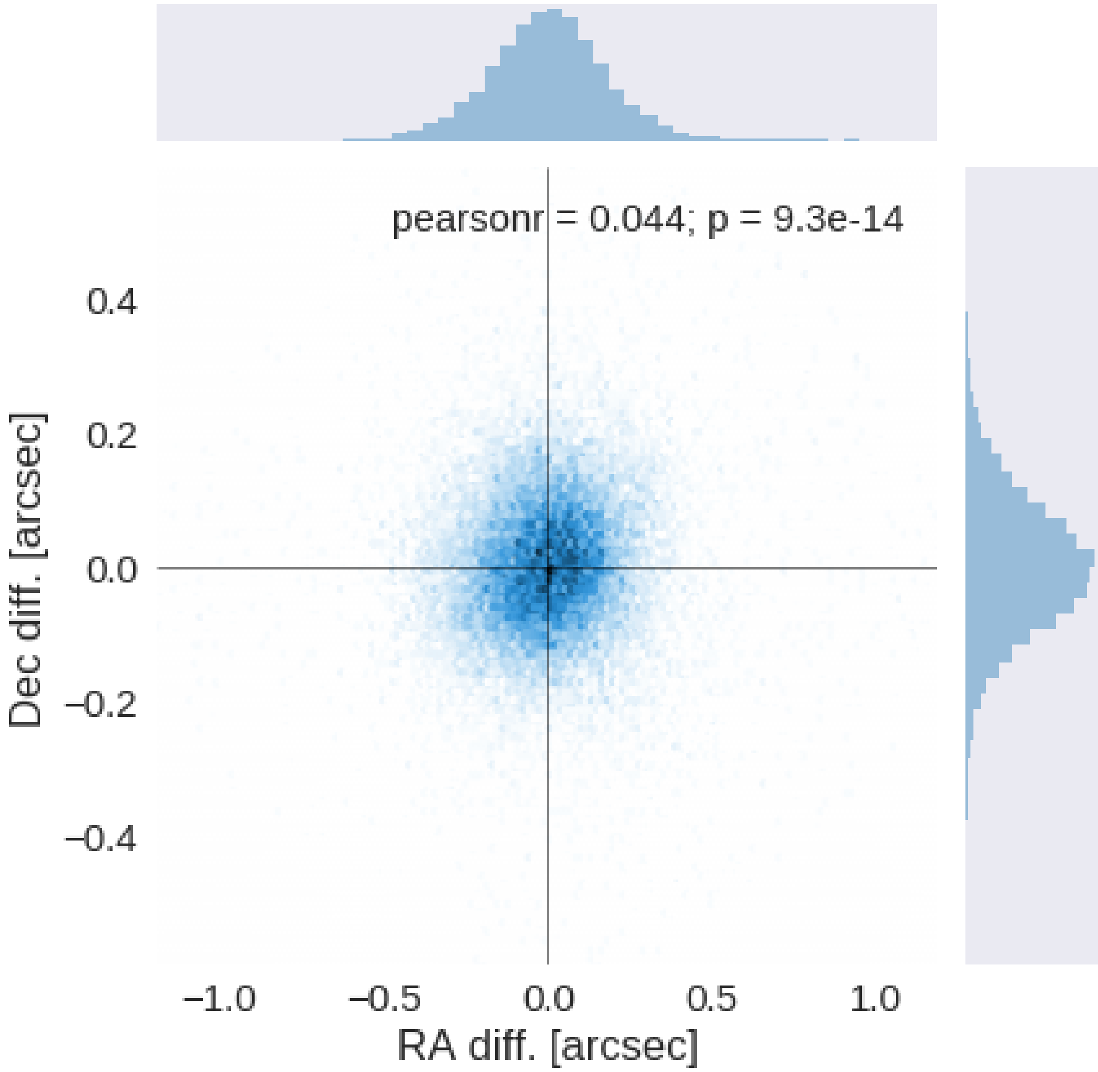
1.4 III - Astrometry correction

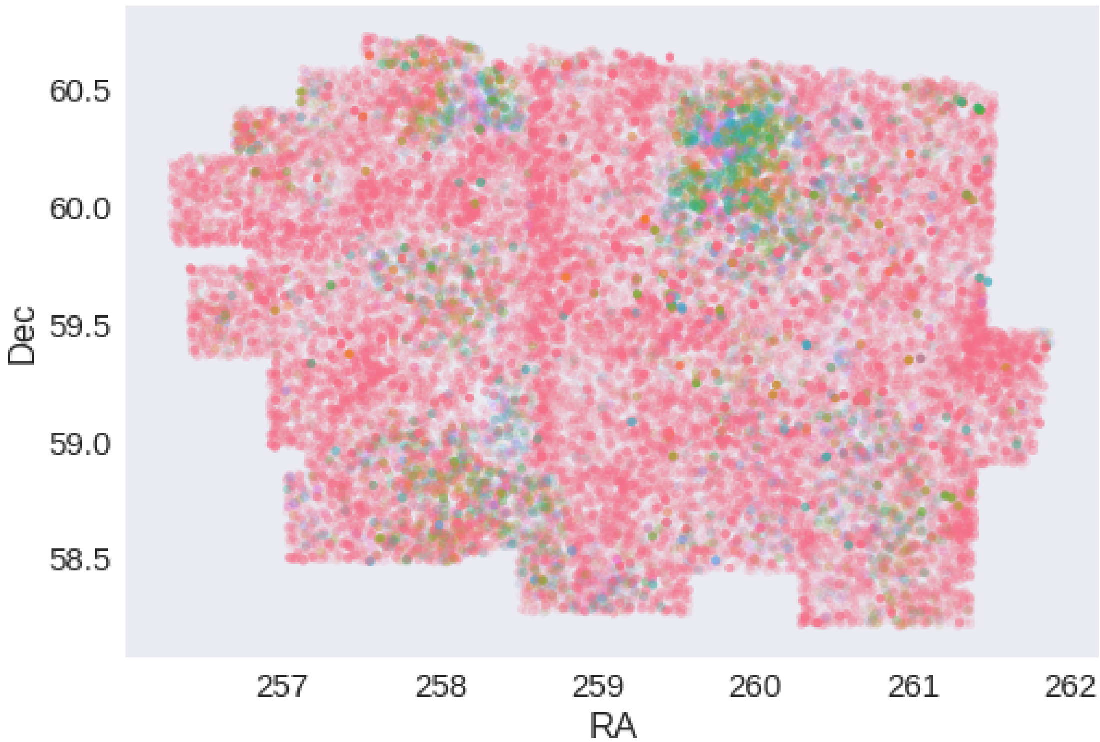
We match the astrometry to the Gaia one. We limit the Gaia catalogue to sources with a g band flux between the 30th and the 70th percentile. Some quick tests show that this give the lower dispersion in the results.






```
RA correction: -0.07881807600824686 arcsec
Dec correction: -0.05963852196089192 arcsec
```


pearsonr = 0.044; p = 9.3e-14
0.4
0.2
0.0
−0.2
−0.4
Dec diff. [arcsec]
−1.0
−0.5
0.0
0.5
1.0
RA diff. [arcsec]



1.5 IV - Flagging Gaia objects

```
31269 sources flagged.
```

2 V - Saving to disk

1.3_KPNO-FLS

March 8, 2018

1 xFLS master catalogue

1.1 Preparation of KPNO-FLS data

KPNO-FLS catalogue: the catalogue comes from `dmu0_KPNO-FLS`.

In the catalogue, we keep:

- The identifier (it's unique in the catalogue);
- The position;
- The stellarity;
- The aperture magnitude;
- The total magnitude.

We don't know when the maps have been observed. We will use the year of the reference paper.

```
This notebook was run with herschelhelp_internal version:
0246c5d (Thu Jan 25 17:01:47 2018 +0000) [with local modifications]
This notebook was executed on:
2018-02-21 12:24:27.728133
```

1.2 I - Column selection

```
Out[6]: <IPython.core.display.HTML object>
```

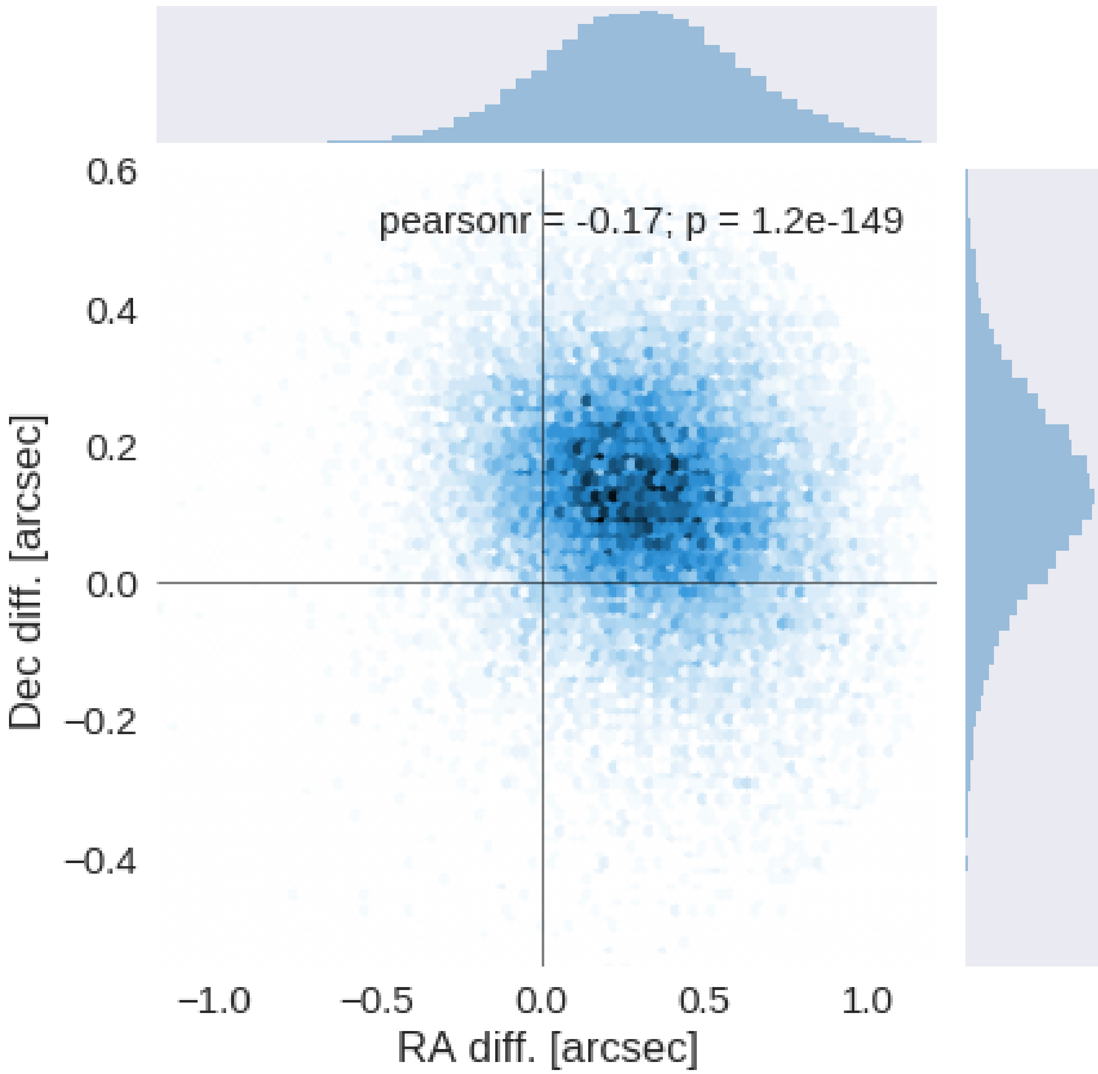
1.3 II - Removal of duplicated sources

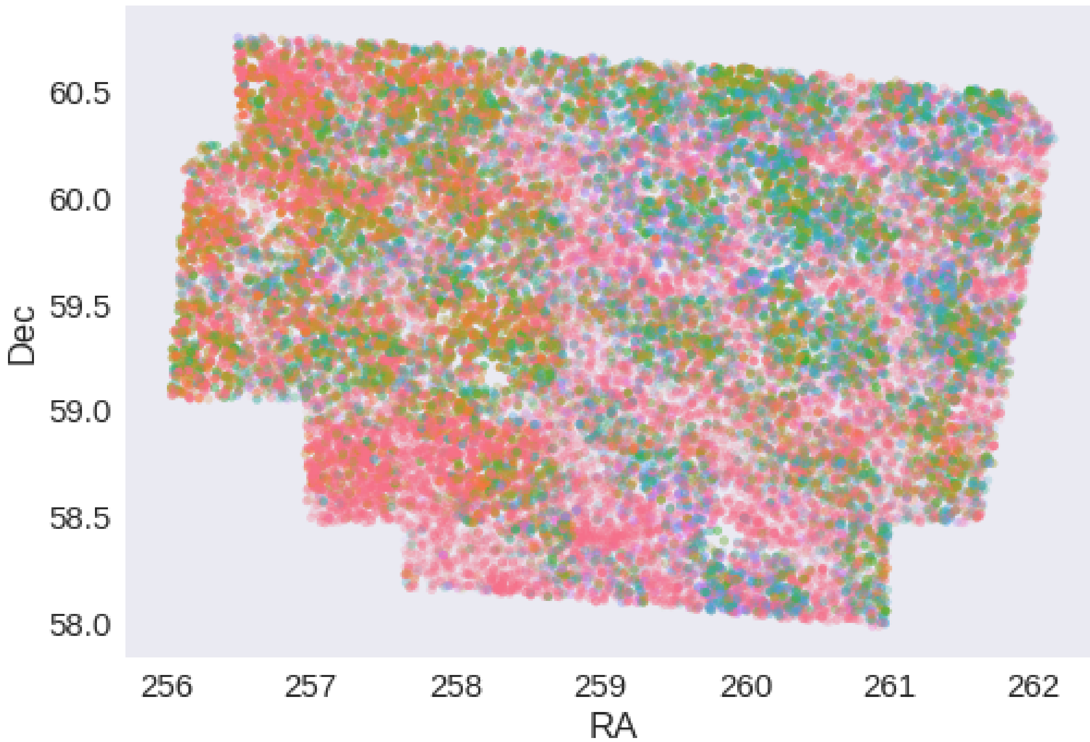
We remove duplicated objects from the input catalogues.

```
The initial catalogue had 722525 sources.
The cleaned catalogue has 670833 sources (51692 removed).
The cleaned catalogue has 50497 sources flagged as having been cleaned
```

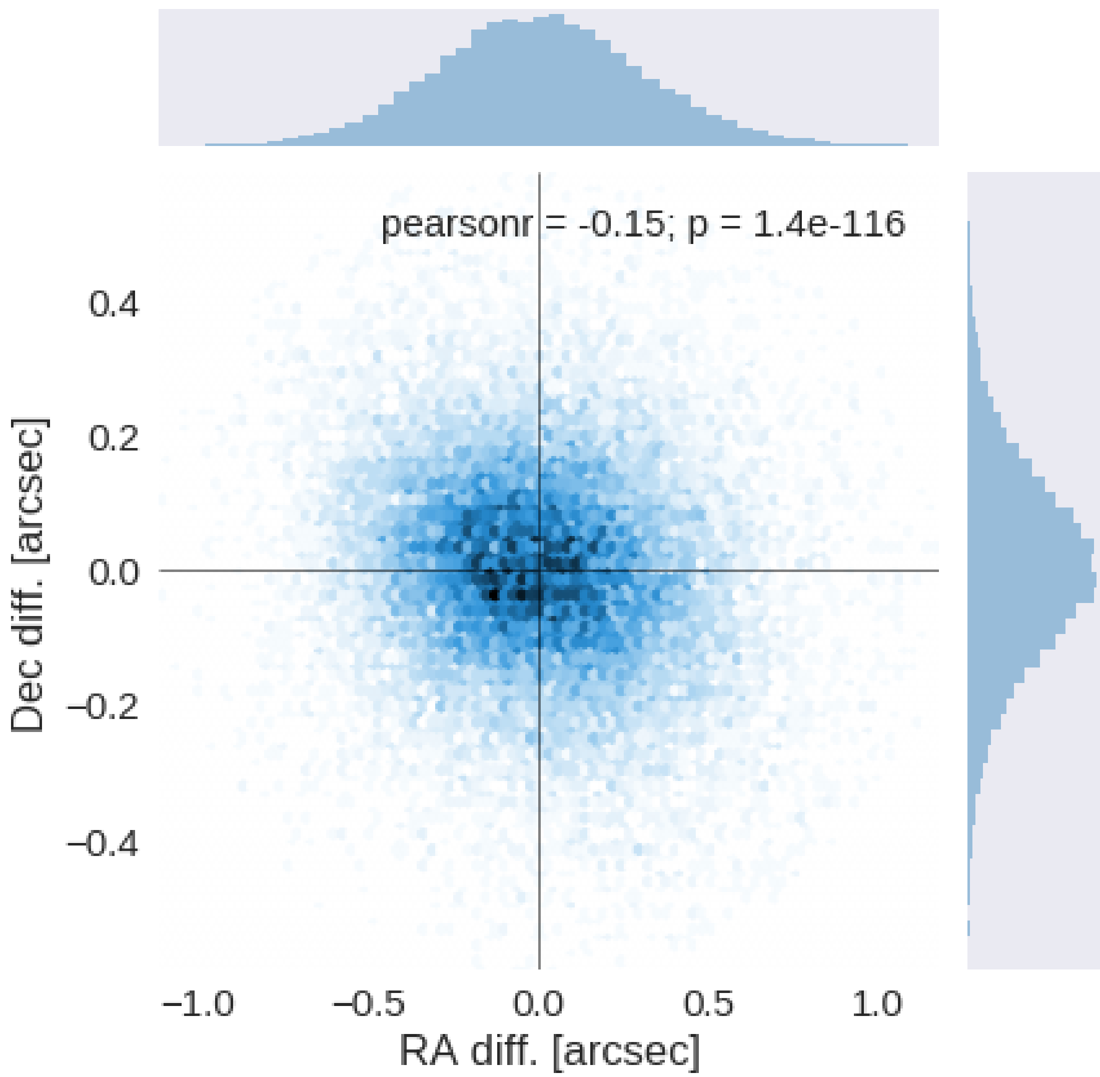
1.4 III - Astrometry correction

We match the astrometry to the Gaia one. We limit the Gaia catalogue to sources with a g band flux between the 30th and the 70th percentile. Some quick tests show that this give the lower dispersion in the results.

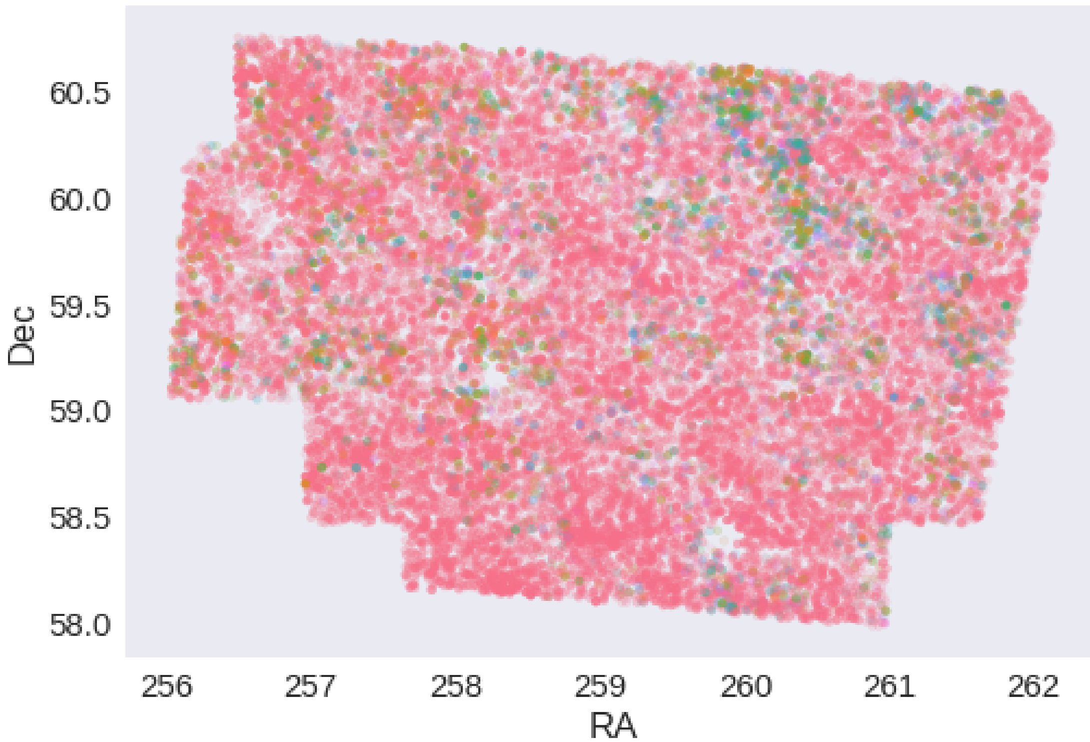





```
RA correction: -0.3095527144182597 arcsec
Dec correction: -0.12726026545522018 arcsec
```



pearsonr = -0.15; p = 1.4e-116
0.4
0.2
0.0
−0.2
−0.4
Dec diff. [arcsec]
−1.0
−0.5
0.0
0.5
1.0
RA diff. [arcsec]



1.5 IV - Flagging Gaia objects

```
24932 sources flagged.
```

2 V - Saving to disk

1.4_PanSTARRS-3SS

March 8, 2018

1 xFLS master catalogue

1.1 Preparation of Pan-STARRS1 - 3pi Steradian Survey (3SS) data

This catalogue comes from `dmu0_PanSTARRS1-3SS`.

In the catalogue, we keep:

- The `uniquePspsSTid` as unique object identifier;
- The r-band position which is given for all the sources;
- The grizy `<band>FApMag` aperture magnitude (see below);
- The grizy `<band>FKronMag` as total magnitude.

The Pan-STARRS1-3SS catalogue provides for each band an aperture magnitude defined as "In PS1, an 'optimal' aperture radius is determined based on the local PSF. The wings of the same analytic PSF are then used to extrapolate the flux measured inside this aperture to a 'total' flux."

The observations used for the catalogue where done between 2010 and 2015 (ref).

TODO: Check if the detection flag can be used to know in which bands an object was detected to construct the coverage maps.

TODO: Check for stellarity.

```
This notebook was run with herschelhelp_internal version:
255270d (Fri Nov 24 10:35:51 2017 +0000)
```

1.2 I - Column selection

```
/opt/anaconda3/envs/herschelhelp_internal/lib/python3.6/site-packages/astropy/table/column.py:10
Check the NumPy 1.11 release notes for more information.
  ma.MaskedArray.__setitem__(self, index, value)
```

```
Out[6]: <IPython.core.display.HTML object>
```

1.3 II - Removal of duplicated sources

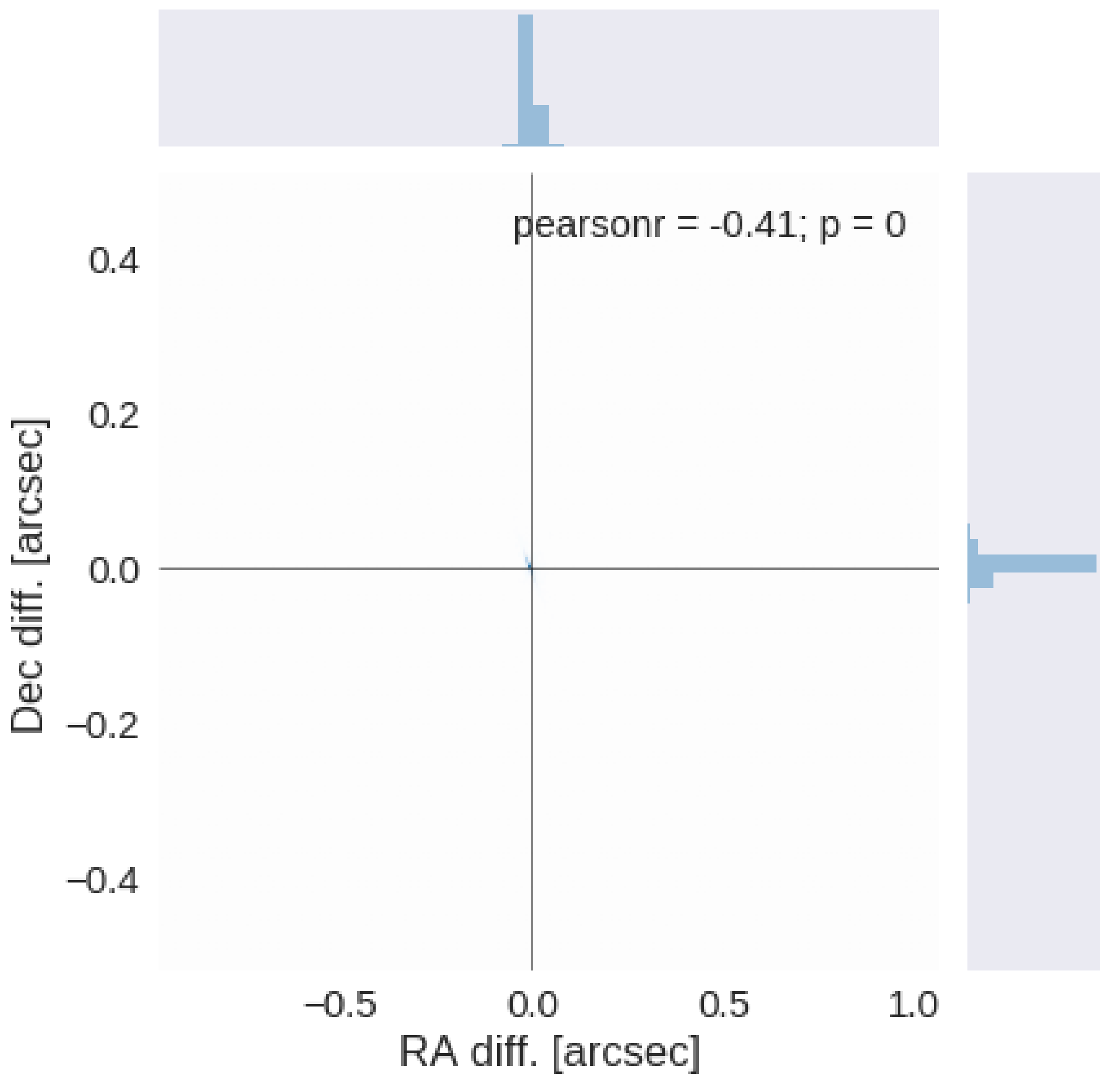
We remove duplicated objects from the input catalogues.

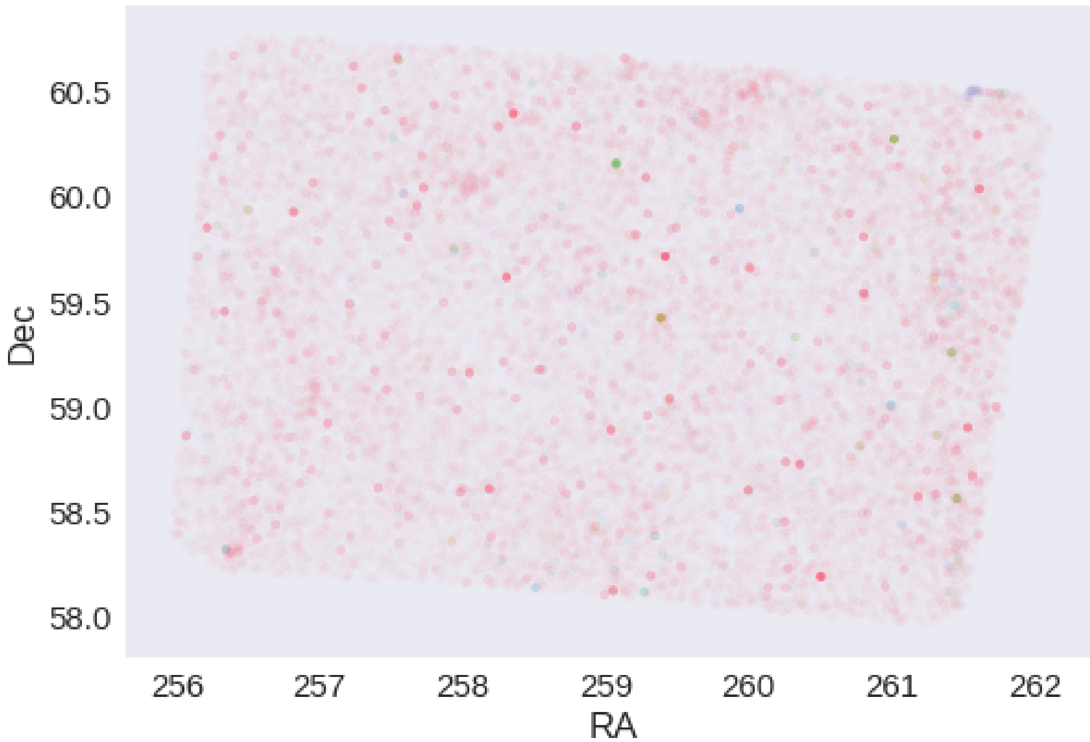
```
/opt/anaconda3/envs/herschelhelp_internal/lib/python3.6/site-packages/astropy/table/column.py:10
Check the NumPy 1.11 release notes for more information.
  ma.MaskedArray.__setitem__(self, index, value)
```

```
The initial catalogue had 168951 sources.
The cleaned catalogue has 168911 sources (40 removed).
The cleaned catalogue has 40 sources flagged as having been cleaned
```

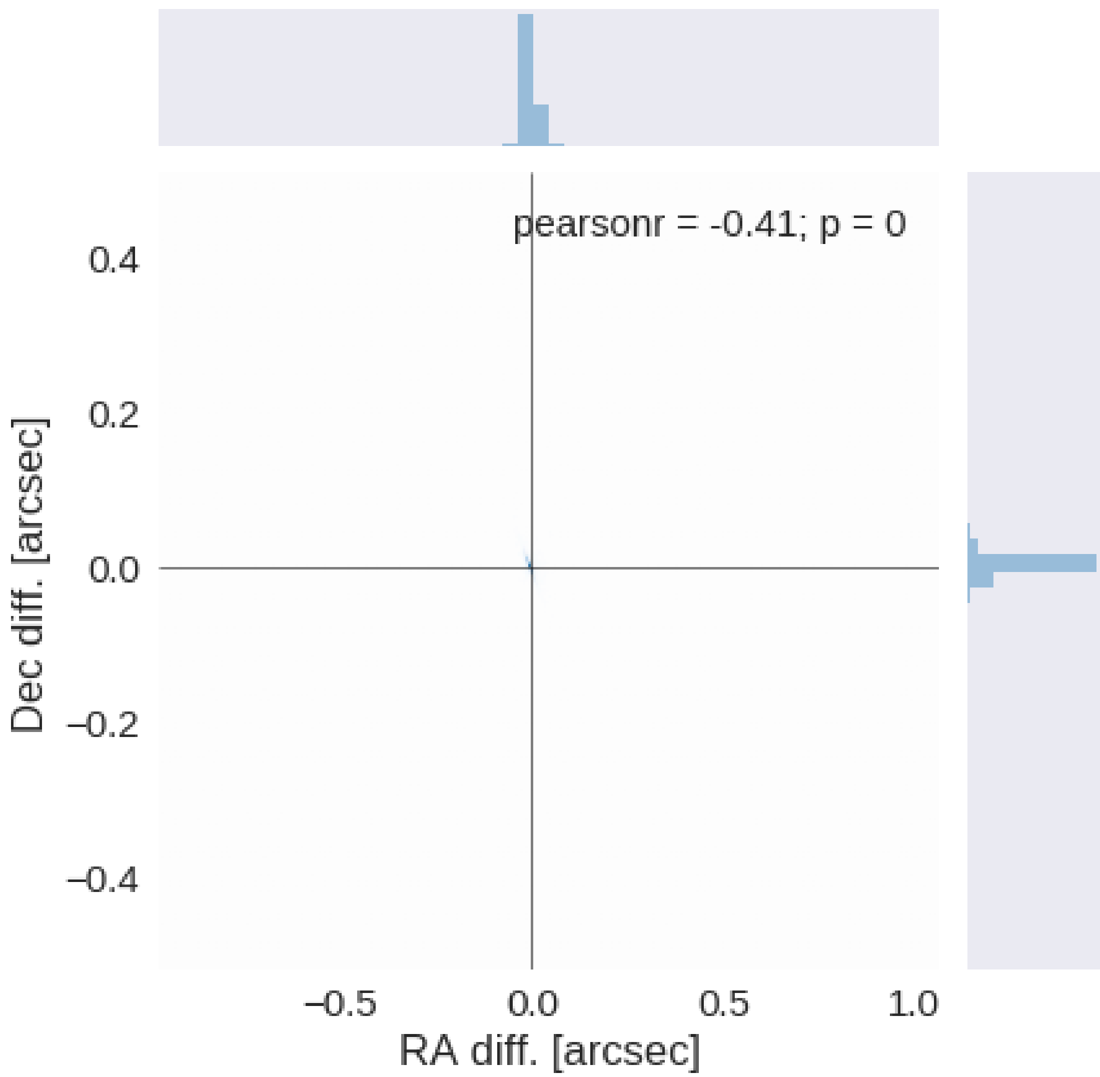
1.4 III - Astrometry correction

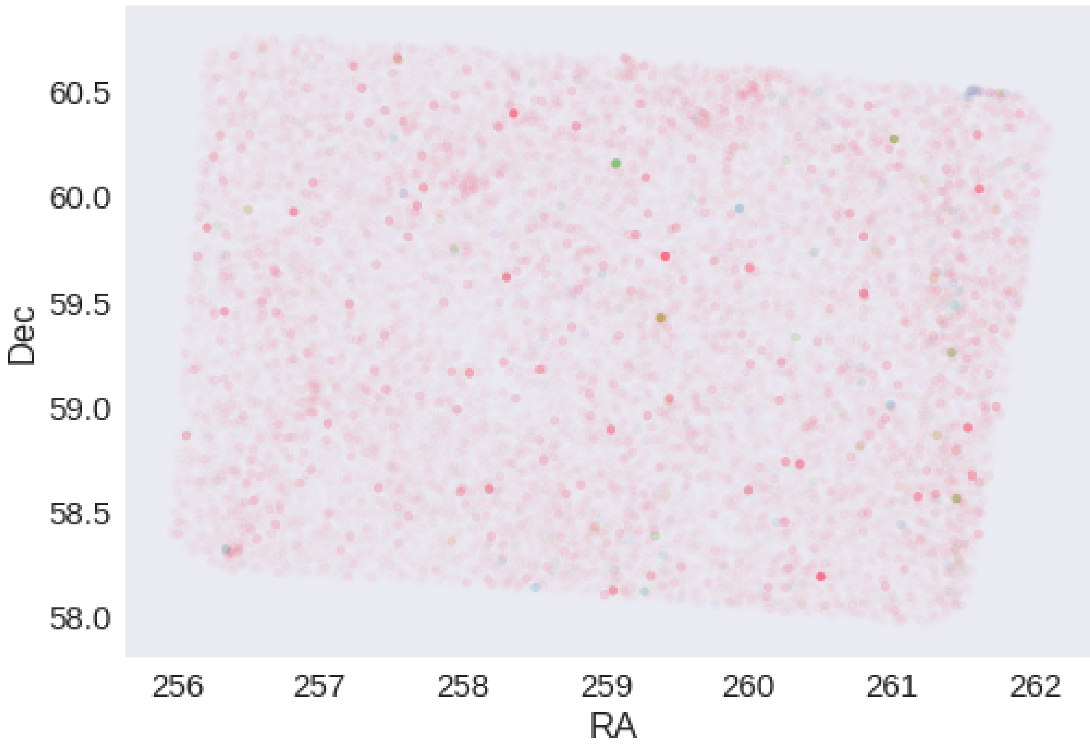
We match the astrometry to the Gaia one. We limit the Gaia catalogue to sources with a g band flux between the 30th and the 70th percentile. Some quick tests show that this give the lower dispersion in the results.






```
RA correction: 0.00047764447117515374 arcsec
Dec correction: -0.001210390917094628 arcsec
```


pearsonr = -0.41; p = 0
0.4
0.2
0.0
−0.2
−0.4
Dec diff. [arcsec]
−0.5
0.0
0.5
1.0
RA diff. [arcsec]



1.5 IV - Flagging Gaia objects

```
39668 sources flagged.
```

2 V - Saving to disk

1.5_LegacySurvey

March 8, 2018

1 xFLS master catalogue

1.1 Preparation of Legacy Survey data

The catalogue comes from `dmu0_LegacySurvey`.

In the catalogue, we keep:

- The identifier (it's unique in the catalogue);
- The position;
- The stellarity;
- The aperture fluxes. Are these aperture corrected?
- The kron magnitude to be used as total magnitude (no "auto" magnitude is provided).

We don't know when the maps have been observed. We will use the year of the reference paper.

```
This notebook was run with herschelhelp_internal version:
0246c5d (Thu Jan 25 17:01:47 2018 +0000) [with local modifications]
This notebook was executed on:
2018-02-21 12:25:31.671735
```

```
WARNING: UnitsWarning: '1/deg^2' did not parse as fits unit: Numeric factor not supported by FIT
WARNING: UnitsWarning: 'nanomaggy' did not parse as fits unit: At col 0, Unit 'nanomaggy' not su
WARNING: UnitsWarning: '1/nanomaggy^2' did not parse as fits unit: Numeric factor not supported
WARNING: UnitsWarning: '1/arcsec^2' did not parse as fits unit: Numeric factor not supported by
```

1.2 I - Aperture correction

To compute aperture correction we need to dertermine two parametres: the target aperture and the range of magnitudes for the stars that will be used to compute the correction.

Target aperture: To determine the target aperture, we simulate a curve of growth using the provided apertures and draw two figures:

- The evolution of the magnitudes of the objects by plotting on the same plot aperture number vs the mean magnitude.

- The mean gain (loss when negative) of magnitude is each aperture compared to the previous (except for the first of course).

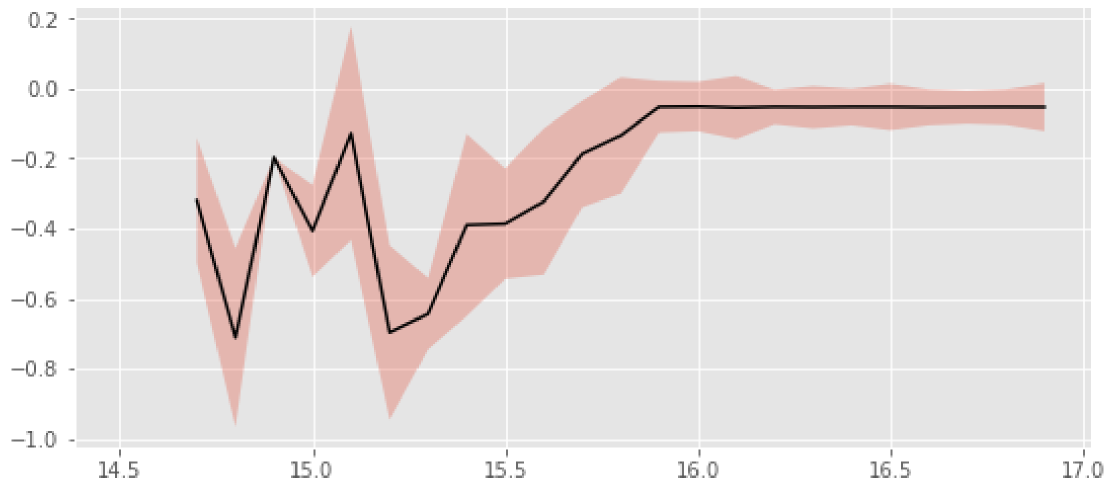
As target aperture, we should use the smallest (i.e. less noisy) aperture for which most of the flux is captures.

Magnitude range: To know what limits in aperture to use when doing the aperture correction, we plot for each magnitude bin the correction that is computed and its RMS. We should then use the wide limits (to use more stars) where the correction is stable and with few dispersion.

```
/opt/herschelhelp_internal/herschelhelp_internal/utils.py:76: RuntimeWarning: invalid value enco
  magnitudes = 2.5 * (23 - np.log10(fluxes)) - 48.6
/opt/herschelhelp_internal/herschelhelp_internal/utils.py:76: RuntimeWarning: divide by zero enc
  magnitudes = 2.5 * (23 - np.log10(fluxes)) - 48.6
/opt/herschelhelp_internal/herschelhelp_internal/utils.py:80: RuntimeWarning: invalid value enco
  errors = 2.5 / np.log(10) * errors_on_fluxes / fluxes
```

1.2.1 I.a - g band

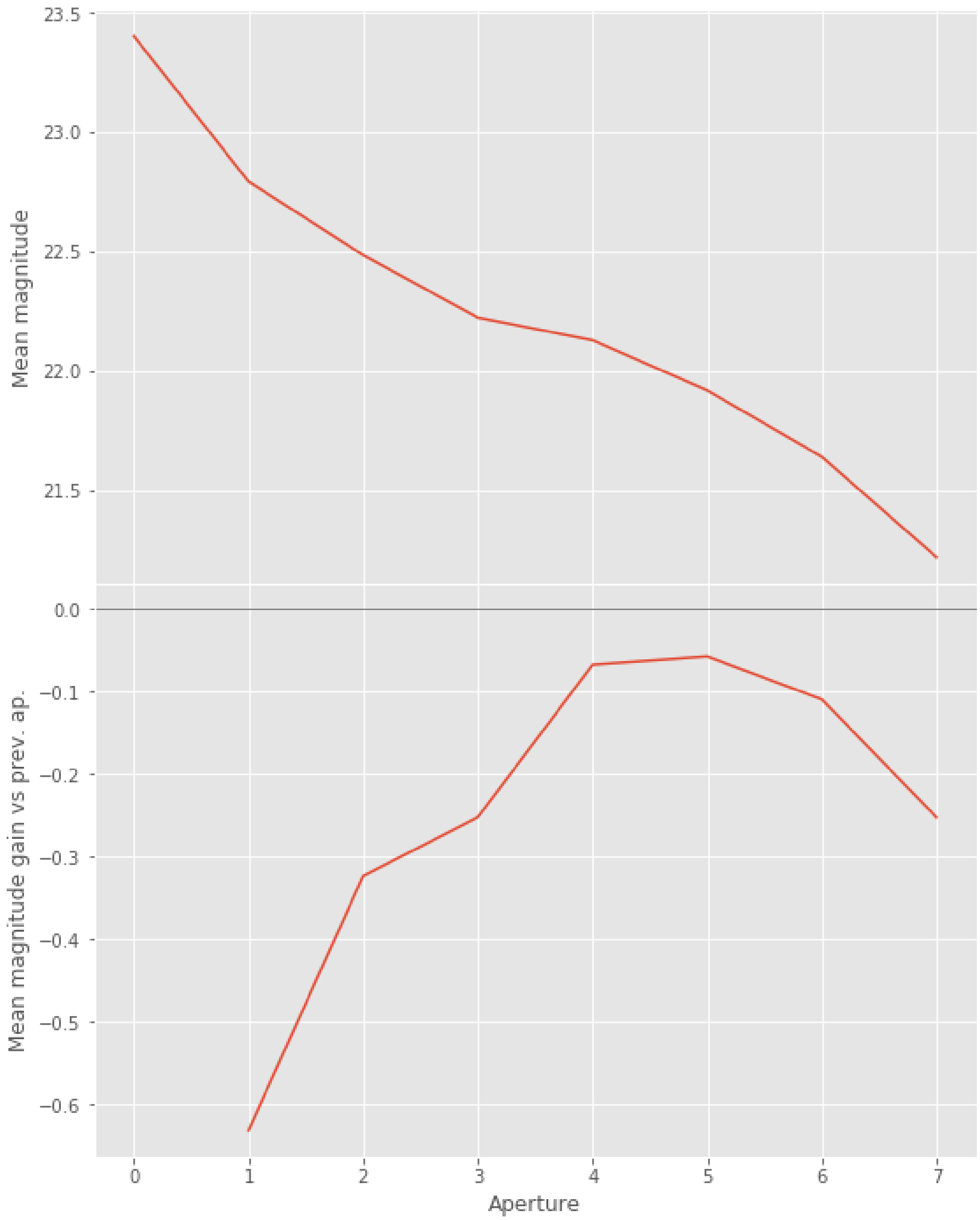
We will use aperture 5 as target.



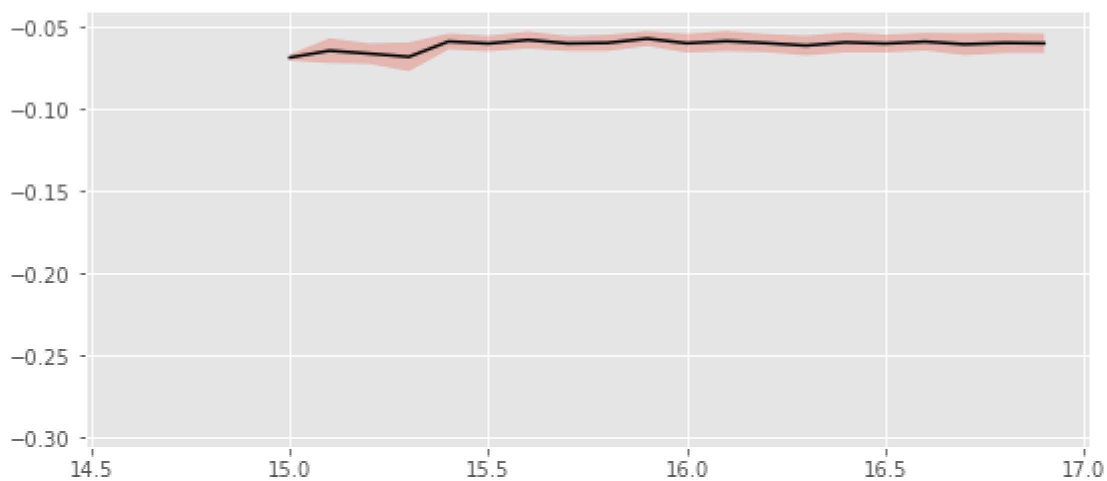
We will use magnitudes between 17.0 and 18.5

```
Aperture correction for g band:
Correction: -0.052710849784986635
Number of source used: 4025
RMS: 0.055636831447624685
```

1.2.2 I.b - r band



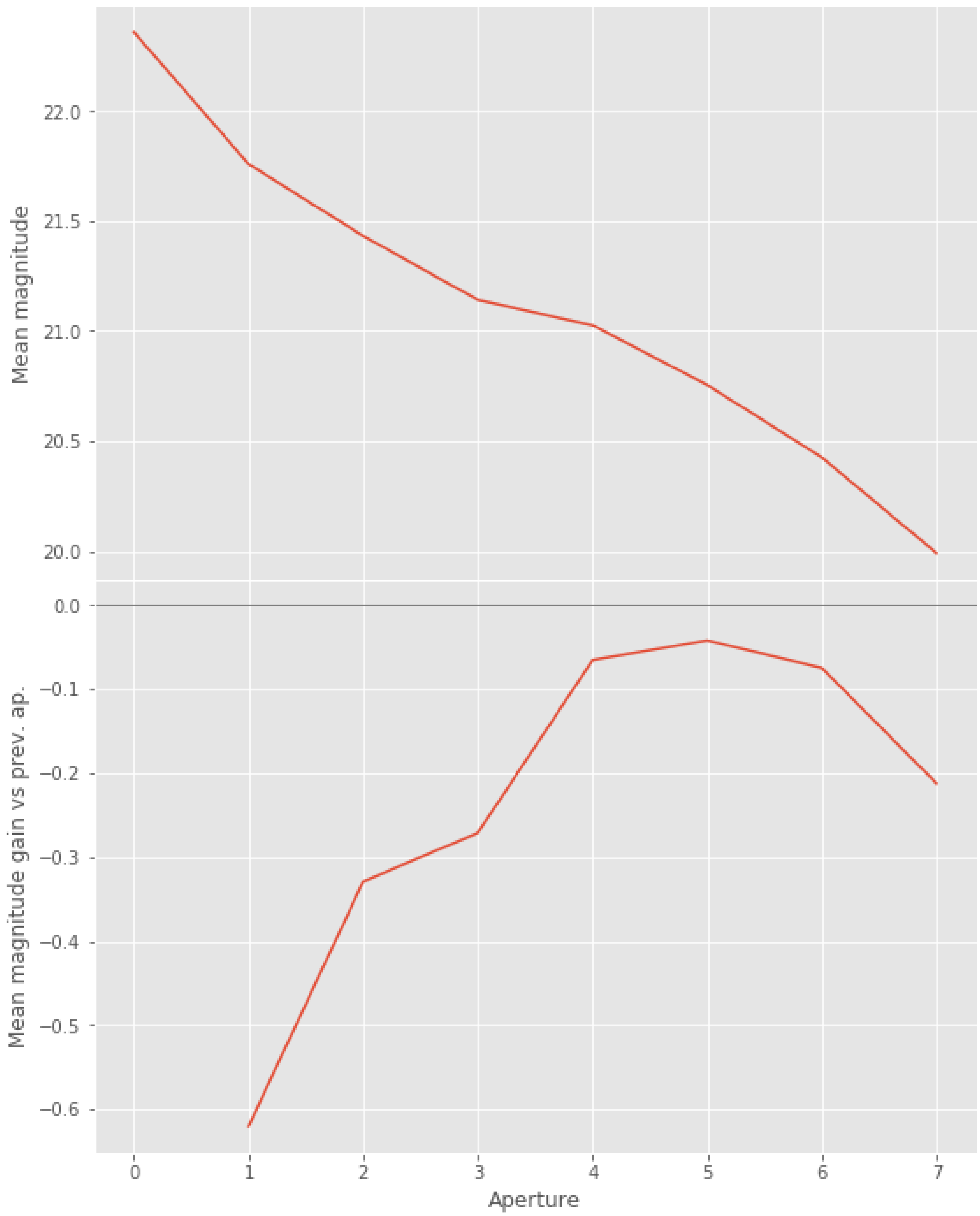
We will use aperture 5 as target.



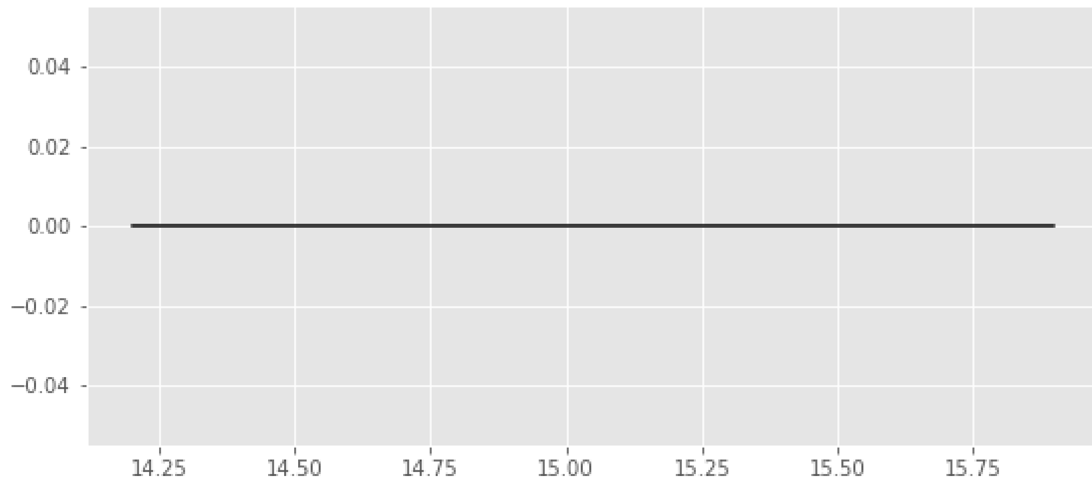
We use magnitudes between 17.0 and 18.5.

```
Aperture correction for r band:
Correction: -0.05966928398234472
Number of source used: 1570
RMS: 0.007477466189163089
```

1.2.3 I.c - z band



We will use aperture 4 as target.



We use magnitudes between 16.0 and 17.5.

```
Aperture correction for z band:
Correction: -0.09809793899898978
Number of source used: 3027
RMS: 0.053383225487848615
```

1.3 II - Stellarity

Legacy Survey does not provide a 0 to 1 stellarity so we replace items flagged as PSF accpording to the following table:

$$P(star) = \frac{\prod_i P(star)_i}{\prod_i P(star)_i + \prod_i P(galaxy)_i}$$

where i is the band, and with using the same probabilities as UKDISS:

HSC flag	UKIDSS flag	Meaning	P(star)	P(galaxy)	P(noise)	P(saturated)
	-9	Saturated	0.0	0.0	5.0	95.0
	-3	Probable galaxy	25.0	70.0	5.0	0.0
	-2	Probable star	70.0	25.0	5.0	0.0
0	-1	Star	90.0	5.0	5.0	0.0
	0	Noise	5.0	5.0	90.0	0.0
1	+1	Galaxy	5.0	90.0	5.0	0.0

1.4 II - Column selection

```
/opt/anaconda3/envs/herschelhelp_internal/lib/python3.6/site-packages/ipykernel/__main__.py:19:
/opt/herschelhelp_internal/herschelhelp_internal/utils.py:76: RuntimeWarning: divide by zero enc
  magnitudes = 2.5 * (23 - np.log10(fluxes)) - 48.6
```

```
/opt/herschelhelp_internal/herschelhelp_internal/utils.py:76: RuntimeWarning: invalid value enco
  magnitudes = 2.5 * (23 - np.log10(fluxes)) - 48.6
/opt/herschelhelp_internal/herschelhelp_internal/utils.py:80: RuntimeWarning: divide by zero enc
  errors = 2.5 / np.log(10) * errors_on_fluxes / fluxes
```

```
Out[19]: <IPython.core.display.HTML object>
```

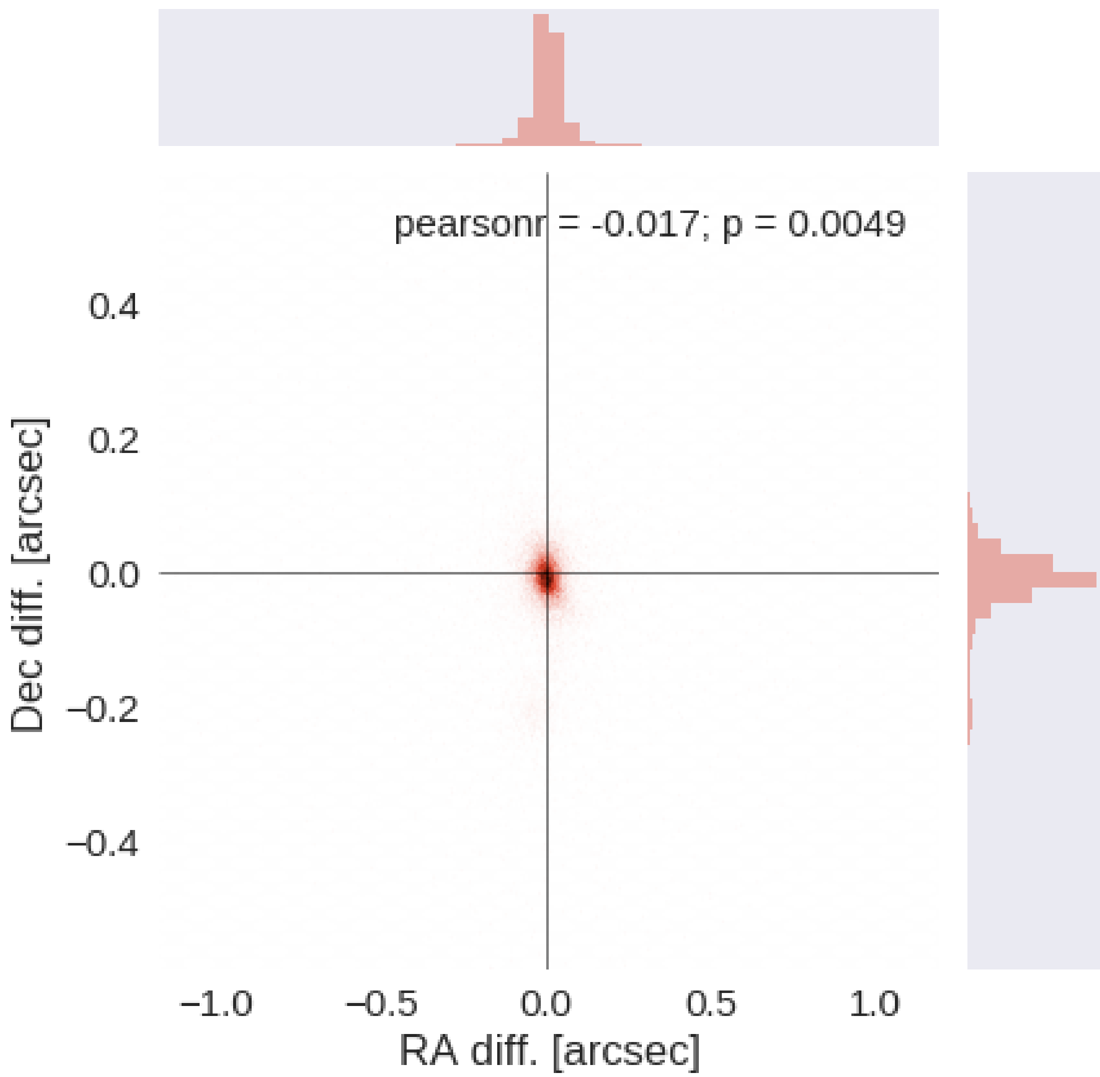
1.5 III - Removal of duplicated sources

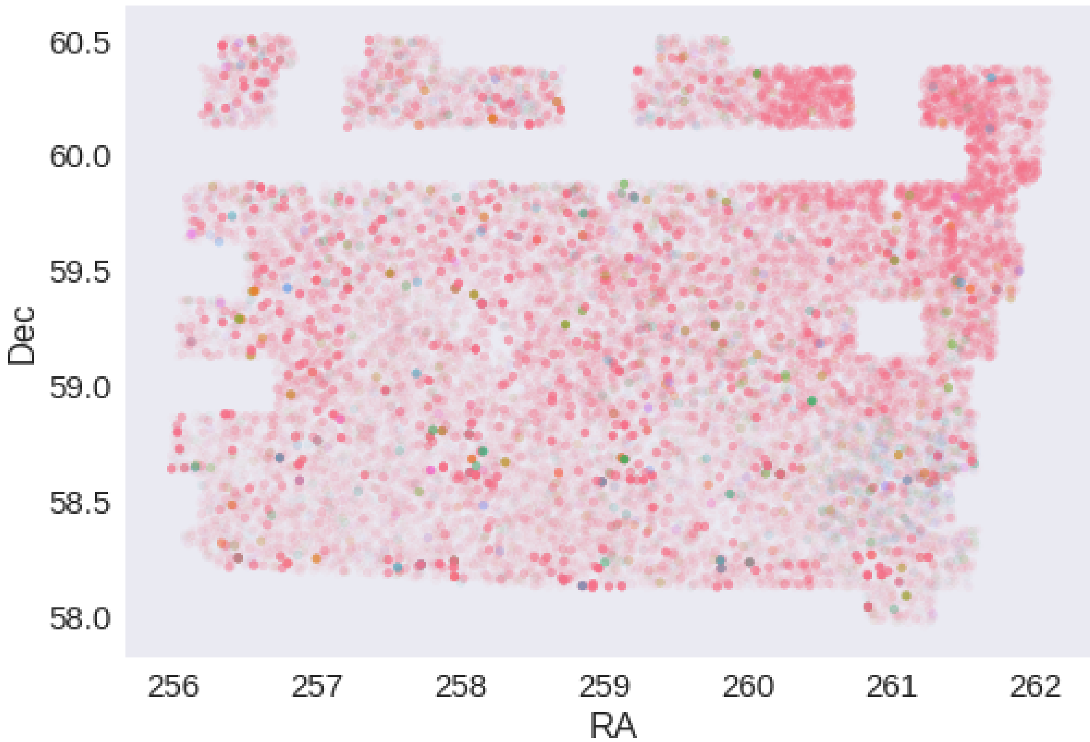
We remove duplicated objects from the input catalogues.

```
The initial catalogue had 183157 sources.
The cleaned catalogue has 179896 sources (3261 removed).
The cleaned catalogue has 3214 sources flagged as having been cleaned
```

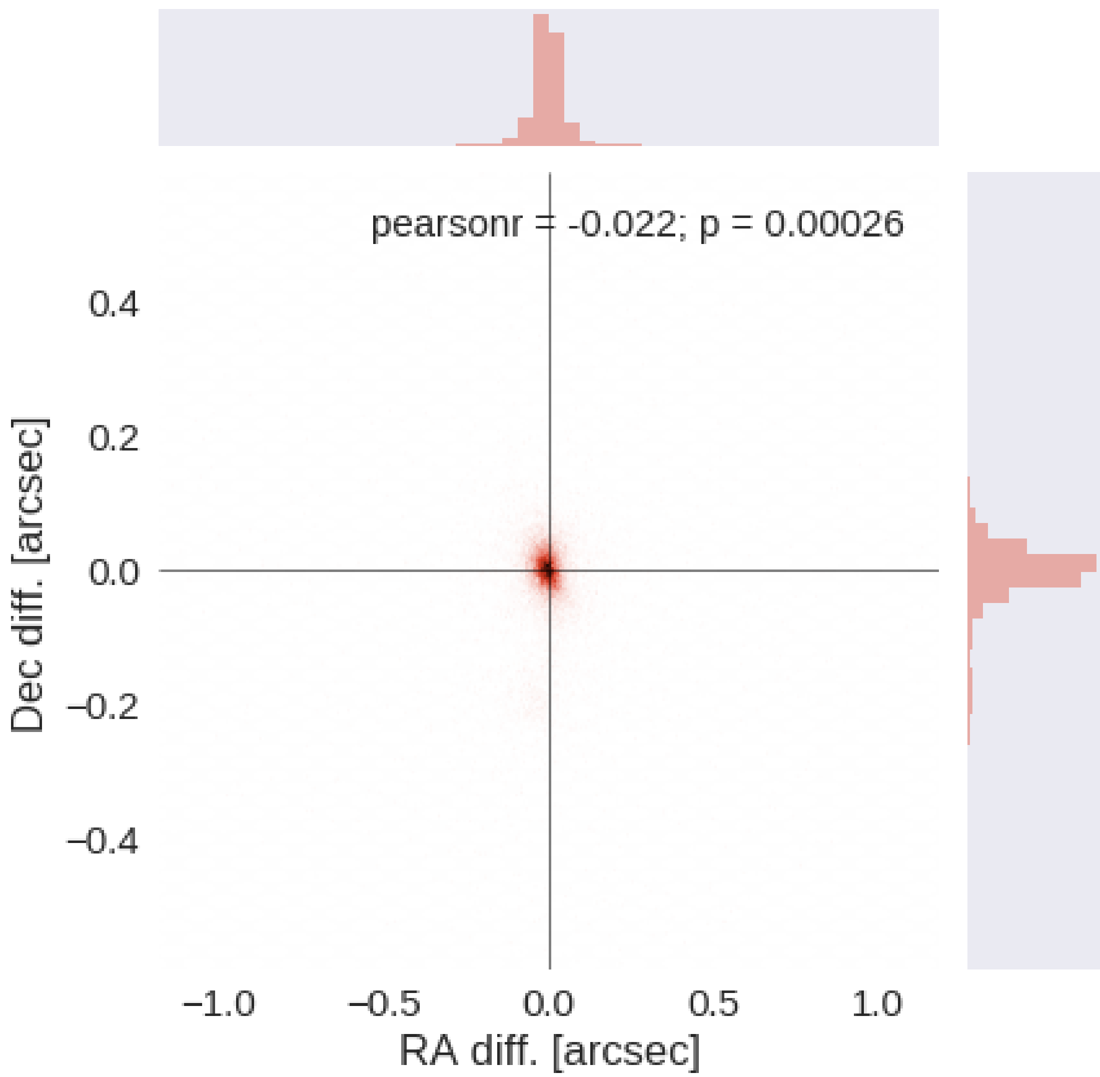
1.6 III - Astrometry correction

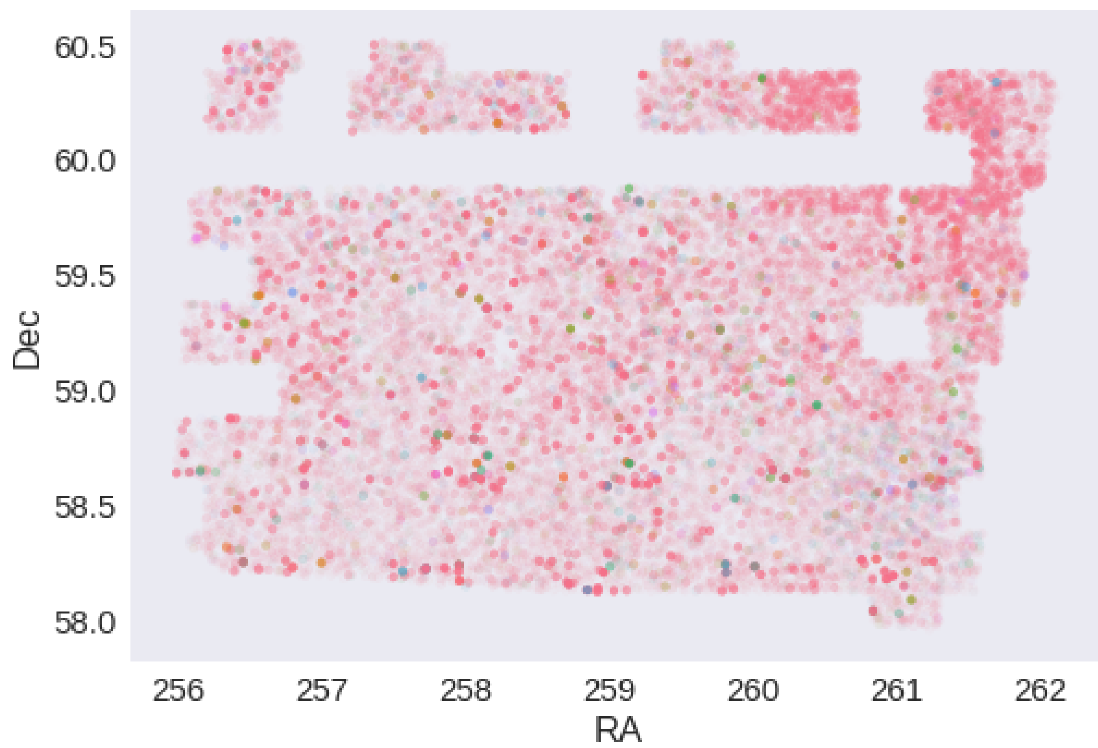
We match the astrometry to the Gaia one. We limit the Gaia catalogue to sources with a g band flux between the 30th and the 70th percentile. Some quick tests show that this give the lower dispersion in the results.


pearsonr = -0.017; p = 0.0049
0.4
0.2
0.0
−0.2
−0.4
Dec diff. [arcsec]
−1.0
−0.5
0.0
0.5
1.0
RA diff. [arcsec]




```
RA correction: -0.00725189001968829 arcsec
Dec correction: 0.0062373993586106735 arcsec
```


pearsonr = -0.022; p = 0.00026
0.4
0.2
0.0
−0.2
−0.4
Dec diff. [arcsec]
−1.0
−0.5
0.0
0.5
1.0
RA diff. [arcsec]



1.7 IV - Flagging Gaia objects

```
29450 sources flagged.
```

2 V - Saving to disk

1.6_UHS

March 8, 2018

1 xFLS master catalogue

1.1 Preparation of UKIRT Hemisphere Survey (UHS) data

The catalogue comes from `dmu0_UHS`. This is a J band only survey documented in https://arxiv.org/pdf/1707.09975.pdf

In the catalogue, we keep:

- The identifier (it's unique in the catalogue);
- The position;
- The stellarity;
- The magnitude for each band in aperture 4 (2 arcsec aperture corrected).
- The kron magnitude to be used as total magnitude (no "auto" magnitude is provided).

We don't know when the maps have been observed. We will use the year of the reference paper.

```
This notebook was run with herschelhelp_internal version:
0246c5d (Thu Jan 25 17:01:47 2018 +0000) [with local modifications]
This notebook was executed on:
2018-02-21 12:28:29.652196
```

1.2 I - Column selection

```
0.925175419285
```

```
/opt/anaconda3/envs/herschelhelp_internal/lib/python3.6/site-packages/astropy/table/column.py:10
Check the NumPy 1.11 release notes for more information.
  ma.MaskedArray.__setitem__(self, index, value)
```

```
Out[7]: <IPython.core.display.HTML object>
```

1.3 II - Removal of duplicated sources

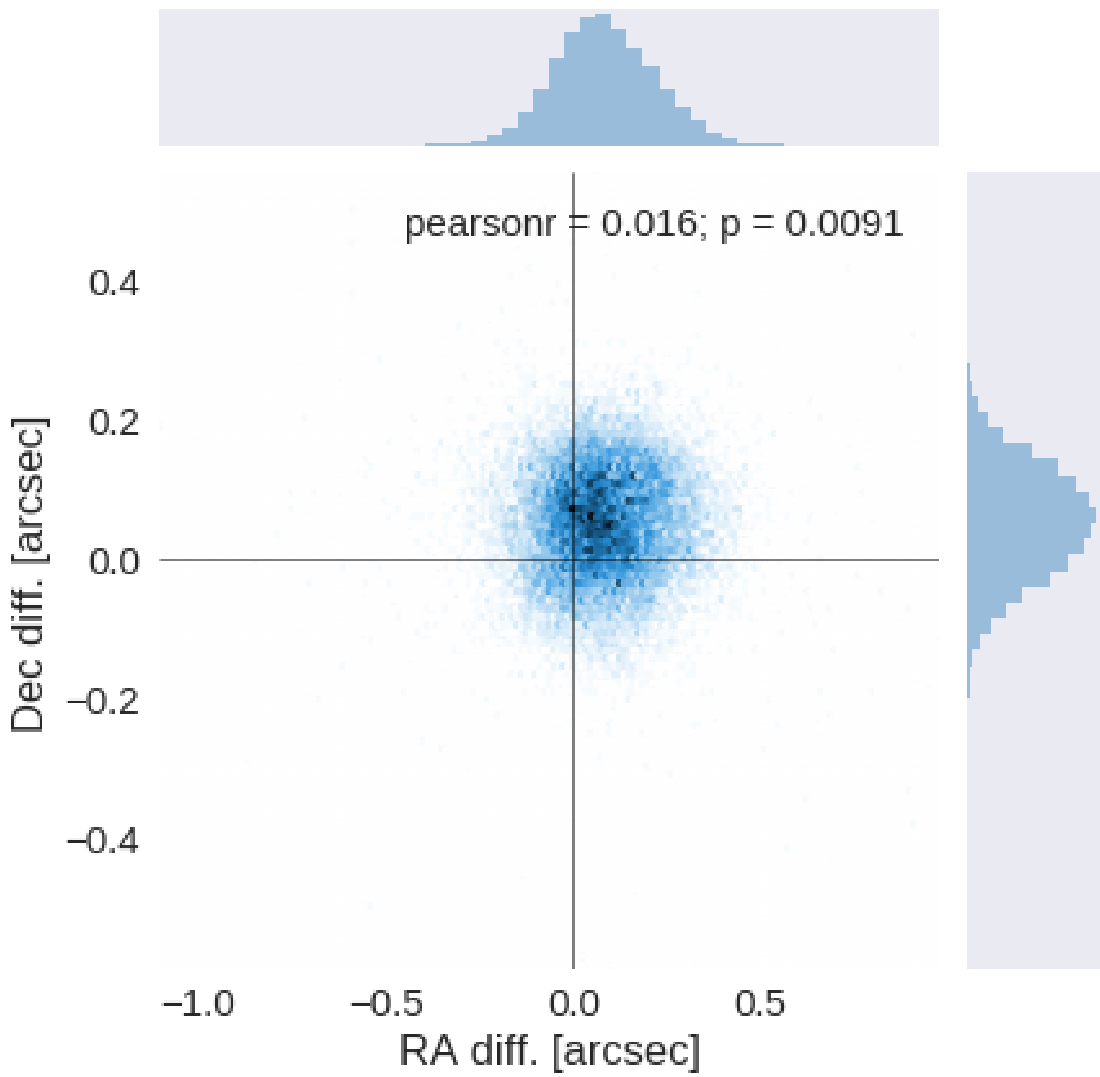
We remove duplicated objects from the input catalogues.

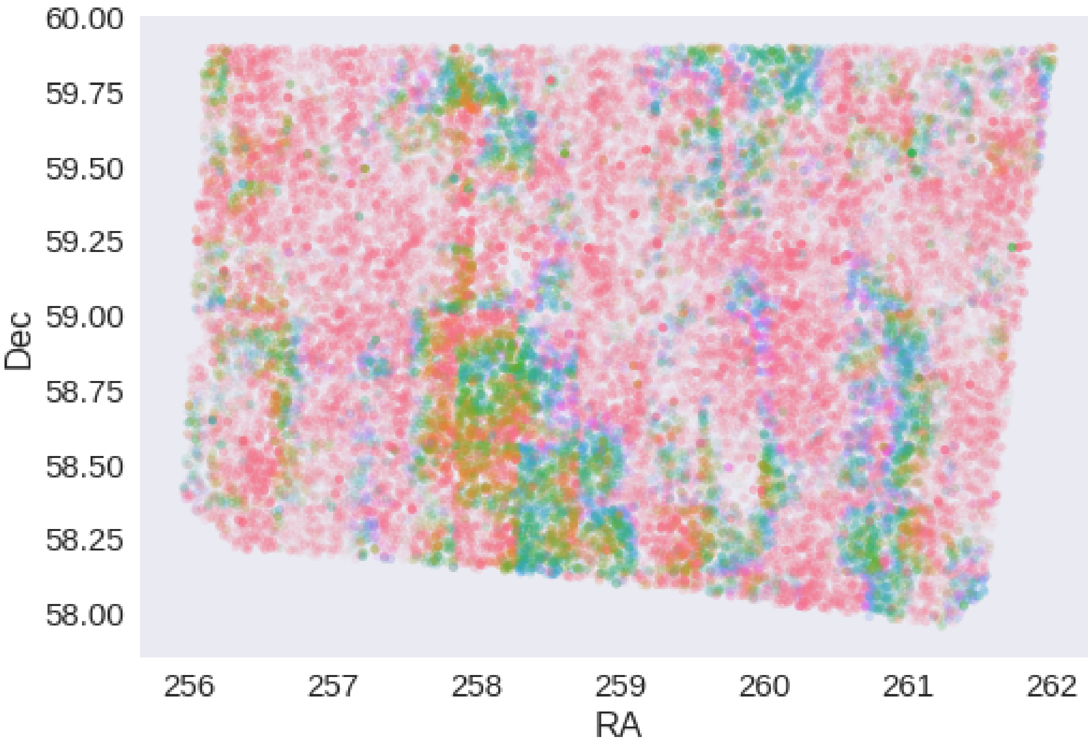
```
/opt/anaconda3/envs/herschelhelp_internal/lib/python3.6/site-packages/astropy/table/column.py:10
Check the NumPy 1.11 release notes for more information.
  ma.MaskedArray.__setitem__(self, index, value)


The initial catalogue had 87317 sources.
The cleaned catalogue has 81760 sources (5557 removed).
The cleaned catalogue has 5356 sources flagged as having been cleaned
```

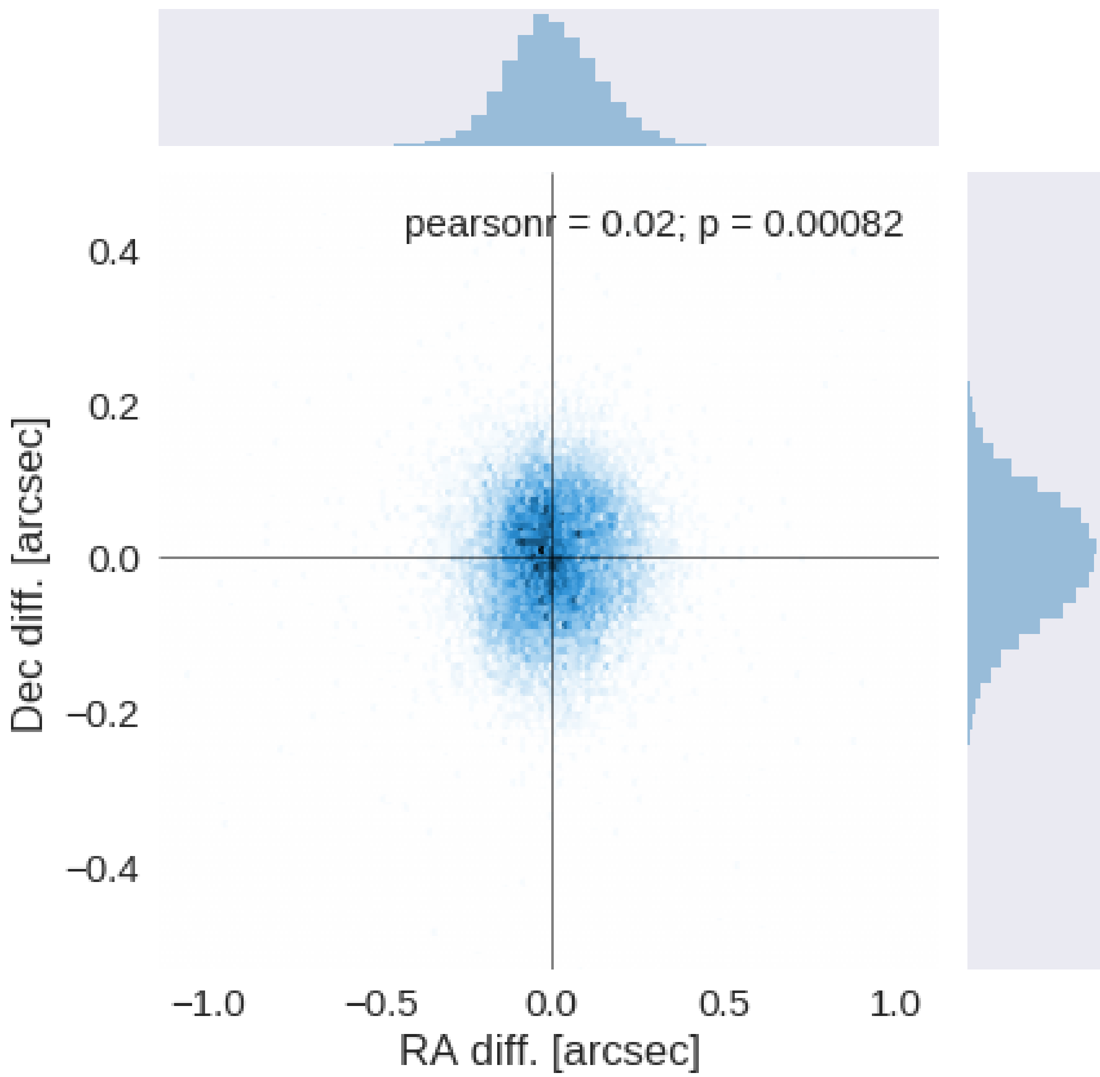
1.4 III - Astrometry correction

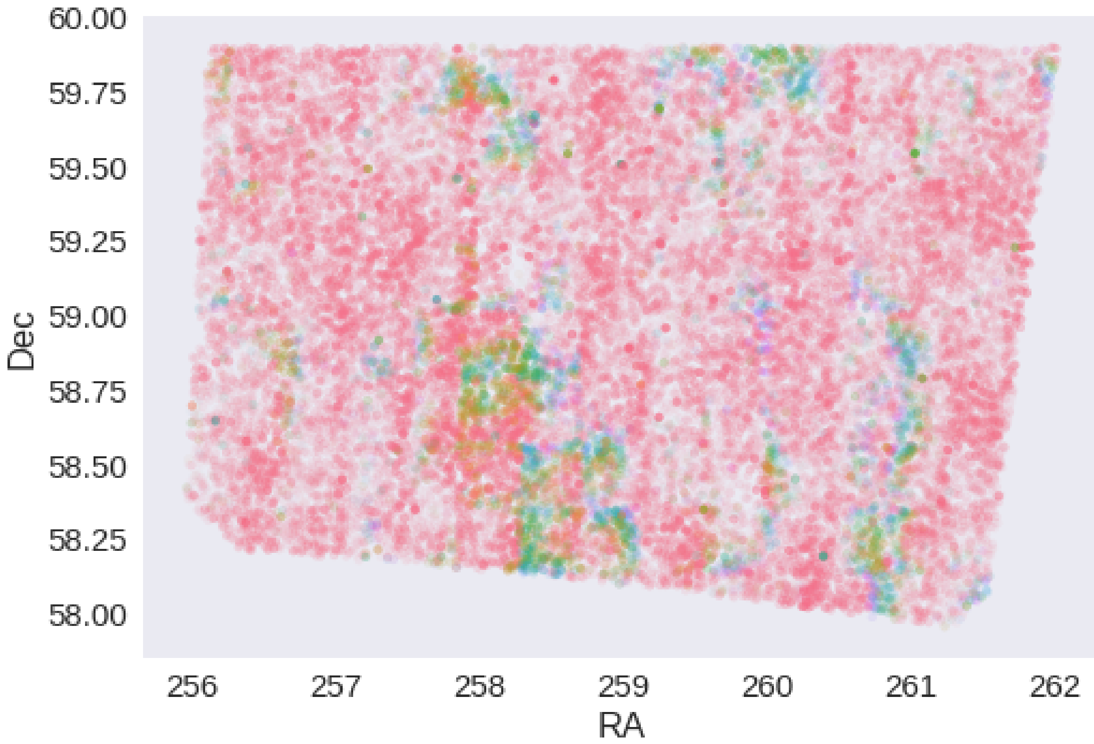
We match the astrometry to the Gaia one. We limit the Gaia catalogue to sources with a g band flux between the 30th and the 70th percentile. Some quick tests show that this give the lower dispersion in the results.


pearsonr = 0.016; p = 0.0091
0.4
0.2
0.0
−0.2
−0.4
Dec diff. [arcsec]
−1.0
−0.5
0.0
0.5
RA diff. [arcsec]




```
RA correction: -0.07672536188465529 arcsec
Dec correction: -0.0534351193692828 arcsec
```


pearsonr = 0.02; p = 0.00082
0.4
0.2
0.0
−0.2
−0.4
Dec diff. [arcsec]
−1.0
−0.5
0.0
0.5
1.0
RA diff. [arcsec]



1.5 IV - Flagging Gaia objects

```
28022 sources flagged.
```

2 V - Saving to disk

2_Merging

March 8, 2018

1 xFLS master catalogue

This notebook presents the merge of the various pristine catalogues to produce HELP mater catalogue on xFLS.

```
This notebook was run with herschelhelp_internal version:
0246c5d (Thu Jan 25 17:01:47 2018 +0000) [with local modifications]
This notebook was executed on:
2018-02-21 12:29:07.891160
```

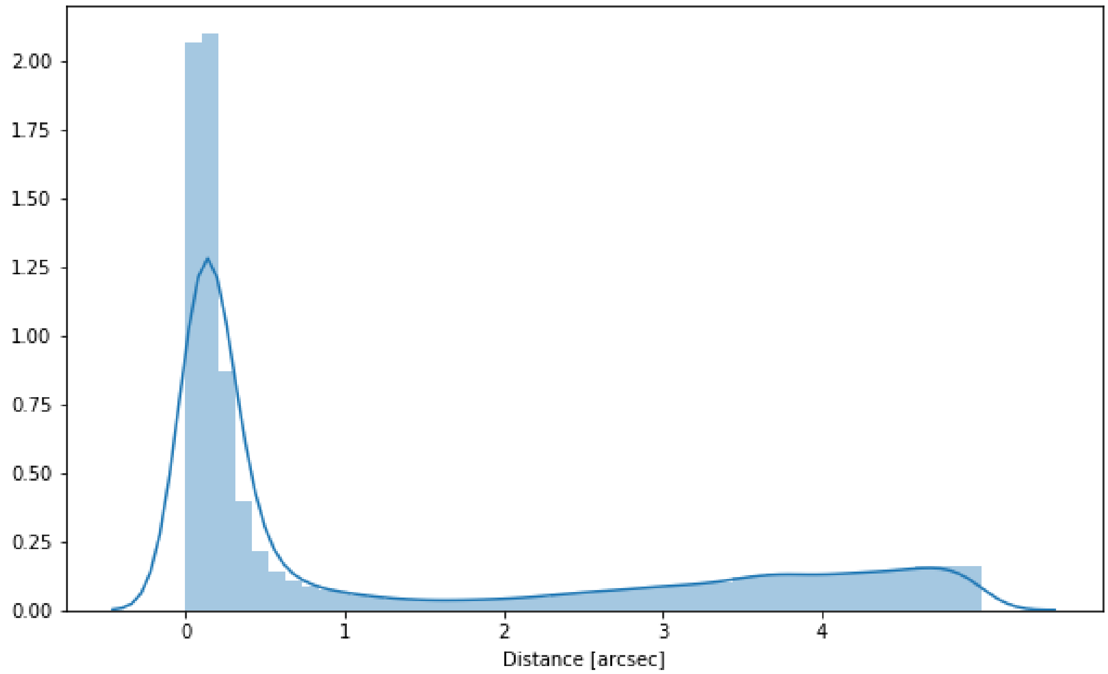
1.1 I - Reading the prepared pristine catalogues

1.2 II - Merging tables

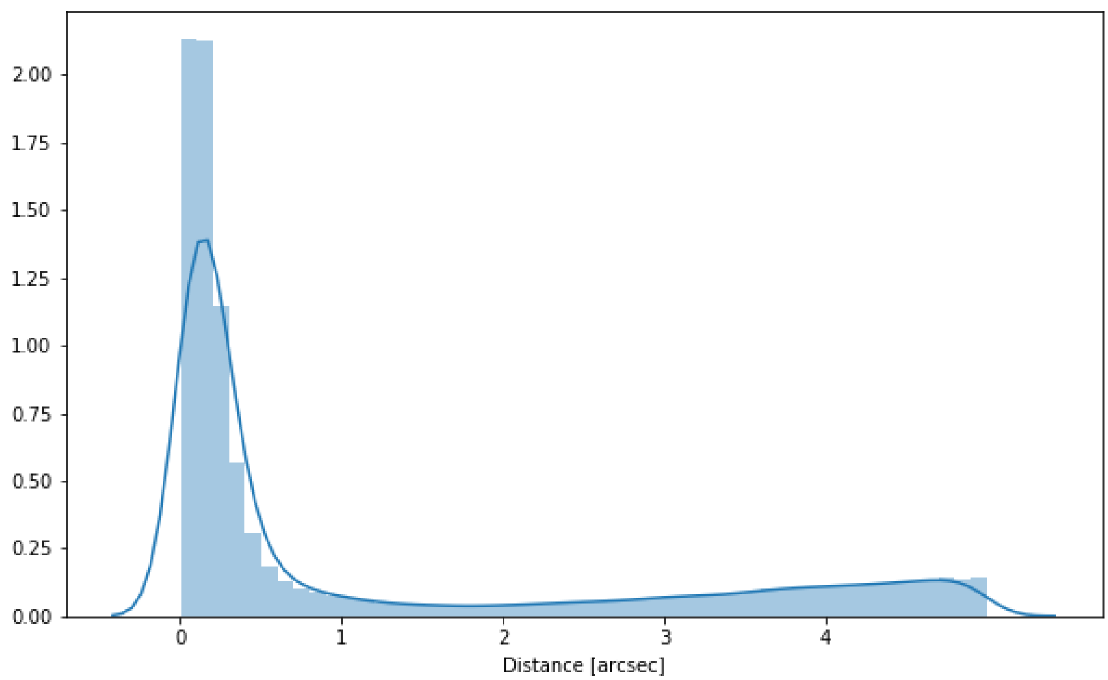
At every step, we look at the distribution of the distances to the nearest source in the merged catalogue to determine the best crossmatching radius.

1.2.1 WFC

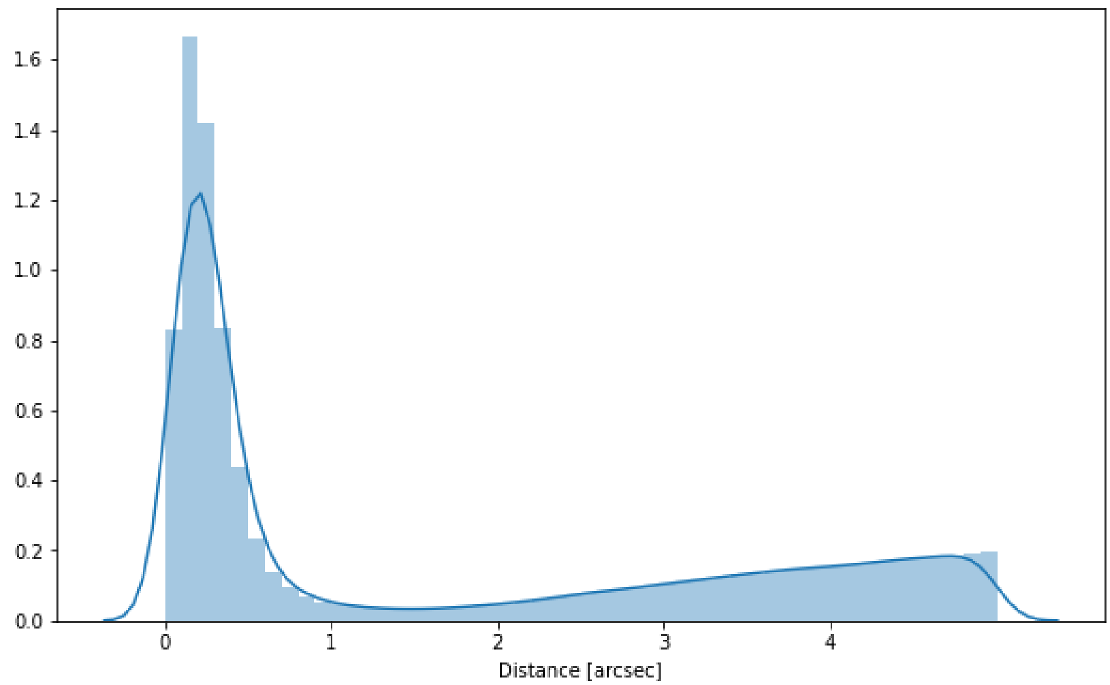
1.2.2 Add PanSTARRS



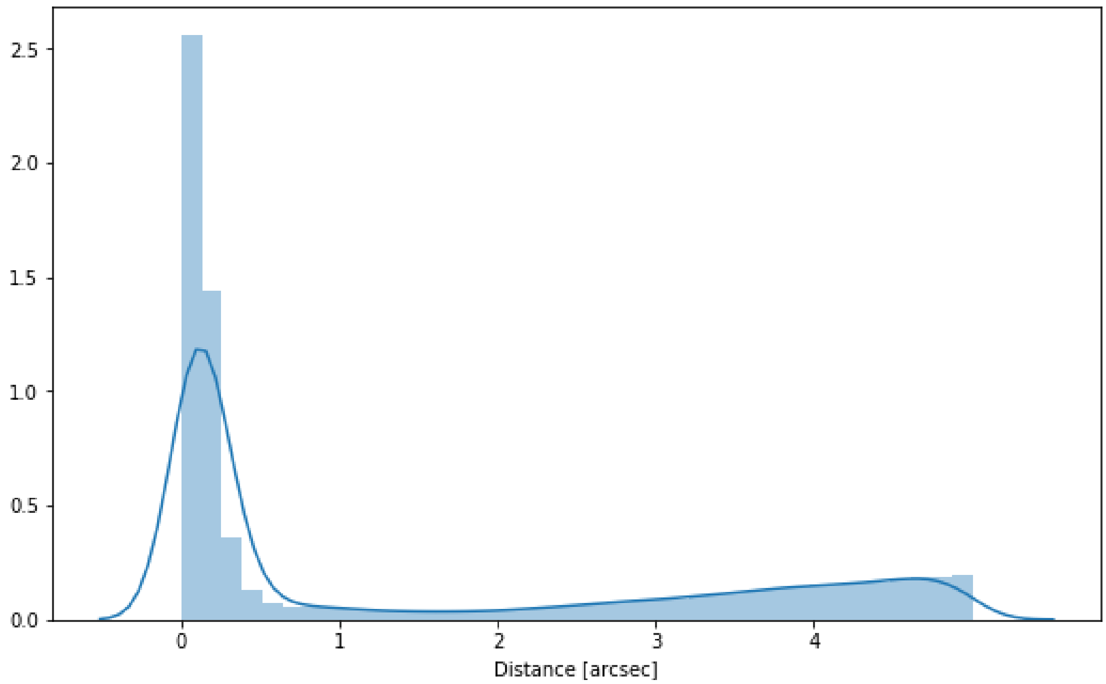
1.2.3 Add Legacy Survey



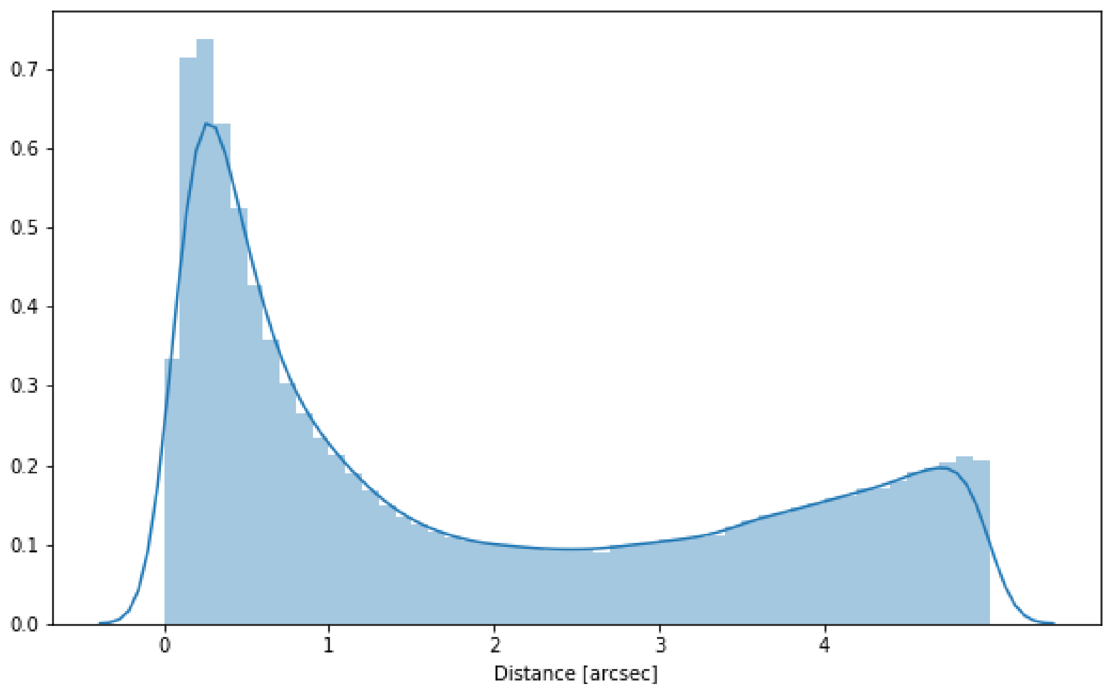
1.2.4 Add KPNO



1.2.5 Add UHS



1.2.6 Add Spitzer



1.2.7 Cleaning

When we merge the catalogues, astropy masks the non-existent values (e.g. when a row comes only from a catalogue and has no counterparts in the other, the columns from the latest are masked for that row). We indicate to use NaN for masked values for floats columns, False for flag columns and -1 for ID columns.

```
Out[17]: <IPython.core.display.HTML object>
```

1.3 III - Merging flags and stellarity

Each pristine catalogue contains a flag indicating if the source was associated to a another nearby source that was removed during the cleaning process. We merge these flags in a single one.

Each pristine catalogue contains a flag indicating the probability of a source being a Gaia object (0: not a Gaia object, 1: possibly, 2: probably, 3: definitely). We merge these flags taking the highest value.

Each prisitine catalogue may contain one or several stellarity columns indicating the probability (0 to 1) of each source being a star. We merge these columns taking the highest value. We keep trace of the origin of the stellarity.

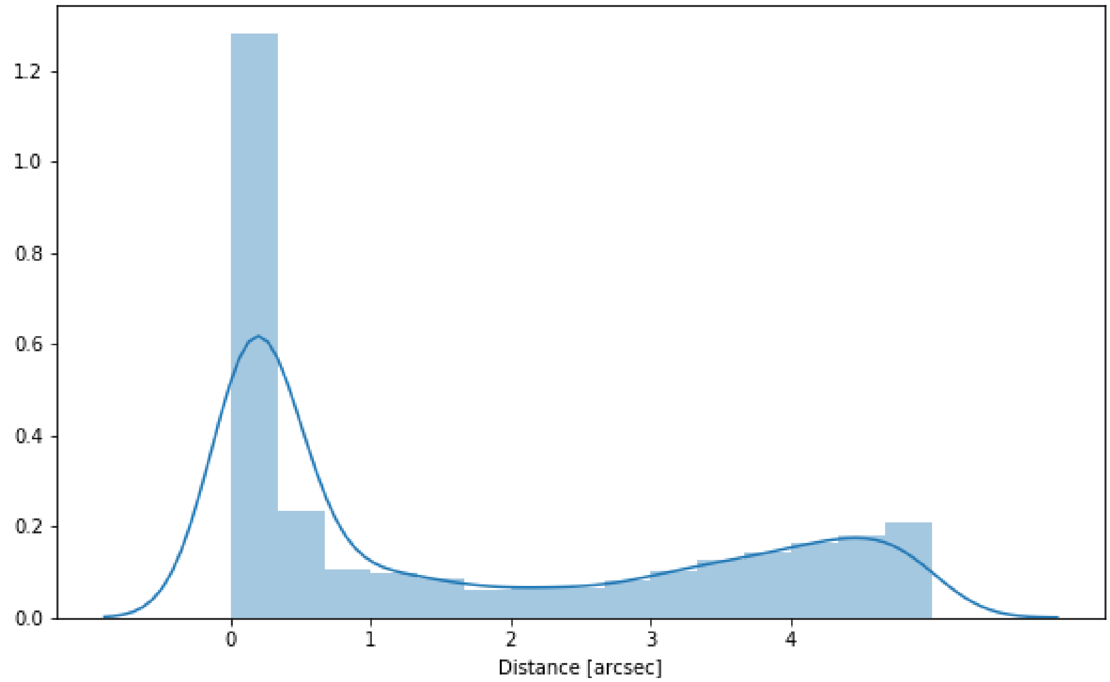
```
wfc_stellarity, legacy_stellarity, kpno_stellarity, uhs_stellarity, spitzer_stellarity
```

1.4 IV - Adding E(B-V) column

1.5 V - Adding HELP unique identifiers and field columns

```
OK!
```

1.6 VI - Cross-matching with spec-z catalogue



1.7 VII - Choosing between multiple values for the same filter

No overlapping filters on xFLS.

1.8 VIII.a Wavelength domain coverage

We add a binary `flag_optnir_obs` indicating that a source was observed in a given wavelength domain:

- 1 for observation in optical;
- 2 for observation in near-infrared;
- 4 for observation in mid-infrared (IRAC).

It's an integer binary flag, so a source observed both in optical and near-infrared by not in mid-infrared would have this flag at 1 + 2 = 3.

Note 1: The observation flag is based on the creation of multi-order coverage maps from the catalogues, this may not be accurate, especially on the edges of the coverage.

Note 2: Being on the observation coverage does not mean having fluxes in that wavelength domain. For sources observed in one domain but having no flux in it, one must take into consideration de different depths in the catalogue we are using.

1.9 VIII.b Wavelength domain detection

We add a binary `flag_optnir_det` indicating that a source was detected in a given wavelength domain:

- 1 for detection in optical;
- 2 for detection in near-infrared;
- 4 for detection in mid-infrared (IRAC).

It's an integer binary flag, so a source detected both in optical and near-infrared by not in mid-infrared would have this flag at 1 + 2 = 3.

Note 1: We use the total flux columns to know if the source has flux, in some catalogues, we may have aperture flux and no total flux.

To get rid of artefacts (chip edges, star flares, etc.) we consider that a source is detected in one wavelength domain when it has a flux value in **at least two bands**. That means that good sources will be excluded from this flag when they are on the coverage of only one band.

1.10 IX - Cross-identification table

We are producing a table associating to each HELP identifier, the identifiers of the sources in the pristine catalogues. This can be used to easily get additional information from them.

For convenience, we also cross-match the master list with the SDSS catalogue and add the objID associated with each source, if any. **TODO: should we correct the astrometry with respect to Gaia positions?**

```
91 master list rows had multiple associations.
```

```
['wfc_id', 'ps1_id', 'legacy_id', 'kpno_intid', 'uhs_id', 'spitzer_intid', 'help_id', 'specz_id'
```

1.11 X - Adding HEALPix index

We are adding a column with a HEALPix index at order 13 associated with each source.

1.12 XI - Saving the catalogue

```
Missing columns: set()
```

3_Checks_and_diagnostics

March 8, 2018

1 xFLS master catalogue

1.1 Checks and diagnostics

These revealed a number of issues to be corrected. There was a unit issue with the BASS Legacy Survey magnitudes and fluxes which needs to be corrected across all the fields. The UHS magnitudes are Vega and needed to be corrected.

```
This notebook was run with herschelhelp_internal version:
0246c5d (Thu Jan 25 17:01:47 2018 +0000) [with local modifications]
This notebook was executed on:
2018-02-21 12:50:45.256741
```

```
Diagnostics done using: master_catalogue_xfls_20180221.fits
```

1.2 0 - Quick checks

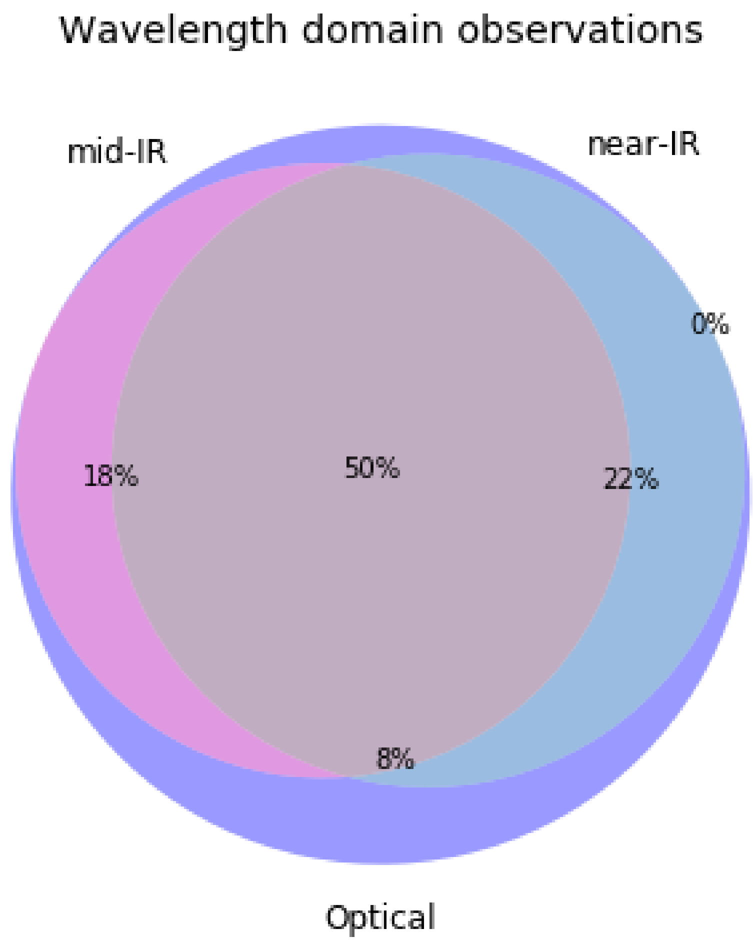
```
/opt/anaconda3/envs/herschelhelp_internal/lib/python3.6/site-packages/numpy/core/numeric.py:301:
  format(shape, fill_value, array(fill_value).dtype), FutureWarning)
/opt/anaconda3/envs/herschelhelp_internal/lib/python3.6/site-packages/numpy/core/numeric.py:301:
  format(shape, fill_value, array(fill_value).dtype), FutureWarning)
```

```
Table shows only problematic columns.
```

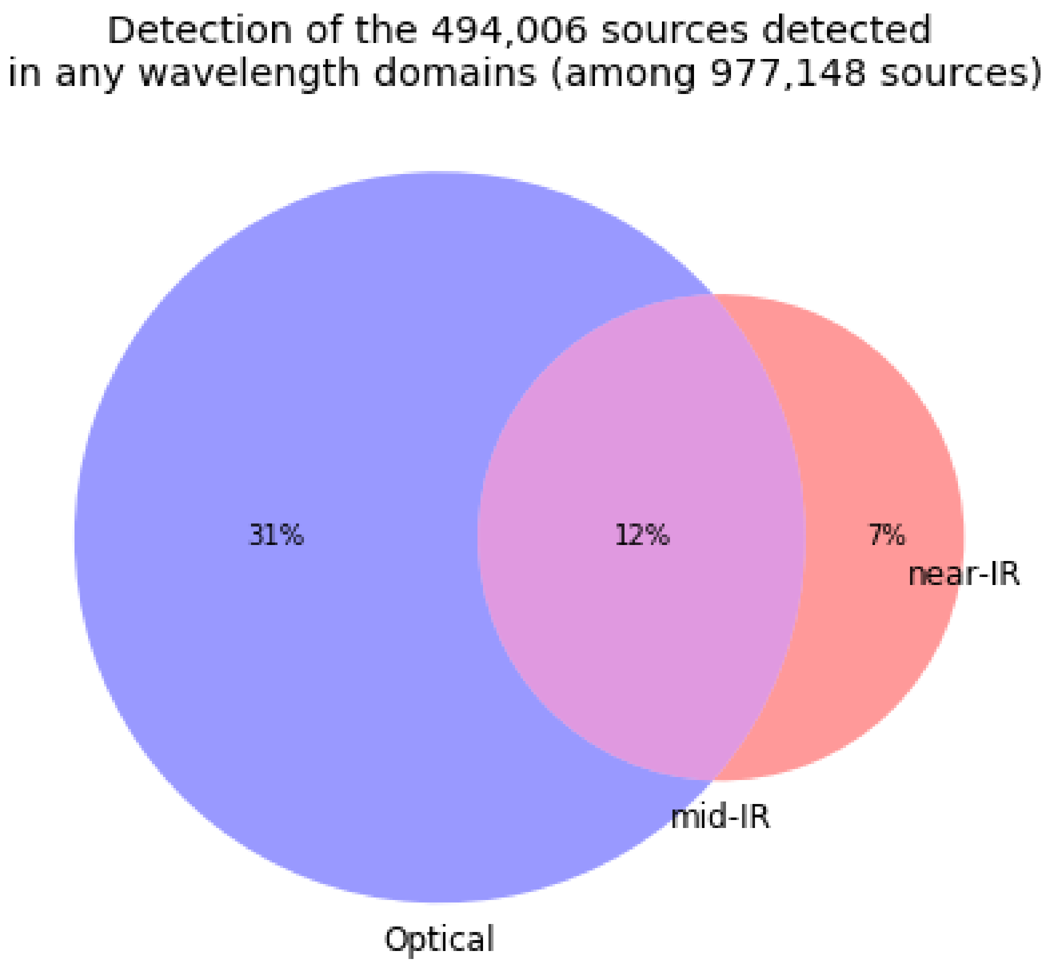
```
Out[4]: <IPython.core.display.HTML object>
```

1.3 I - Summary of wavelength domains

```
/opt/anaconda3/envs/herschelhelp_internal/lib/python3.6/site-packages/matplotlib_venn/_venn3.py:
  warnings.warn("Bad circle positioning")
```




```
/opt/anaconda3/envs/herschelhelp_internal/lib/python3.6/site-packages/matplotlib_venn/_venn3.py:
  warnings.warn("Circle B has zero area")
```

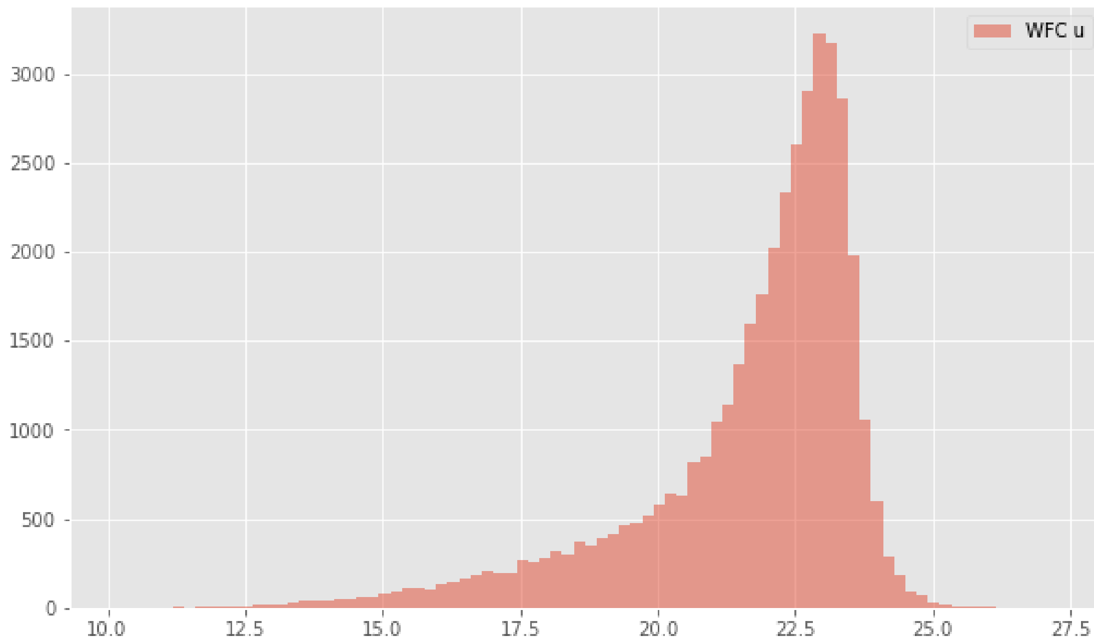


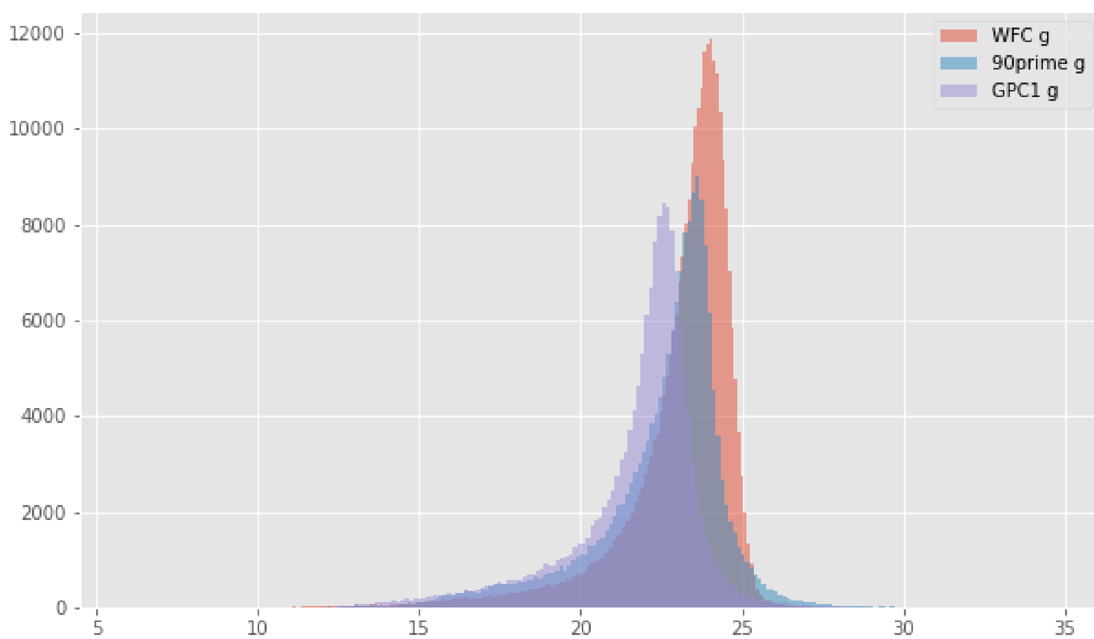
1.4 II - Comparing magnitudes in similar filters

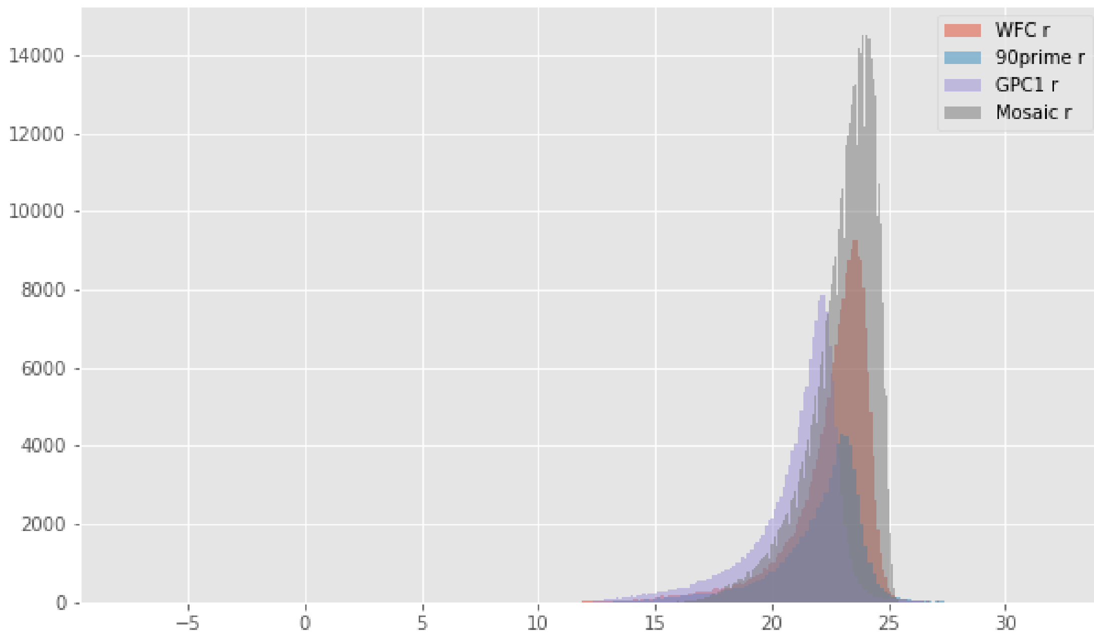
The master list if composed of several catalogues containing magnitudes in similar filters on different instruments. We are comparing the magnitudes in these corresponding filters.

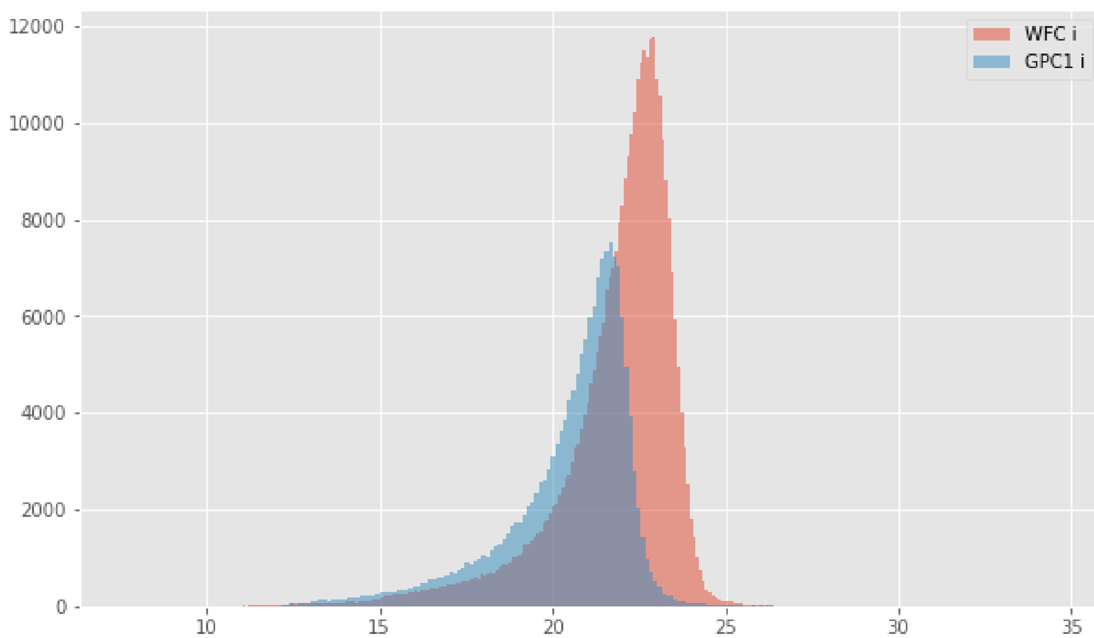
1.4.1 II.a - Comparing depths

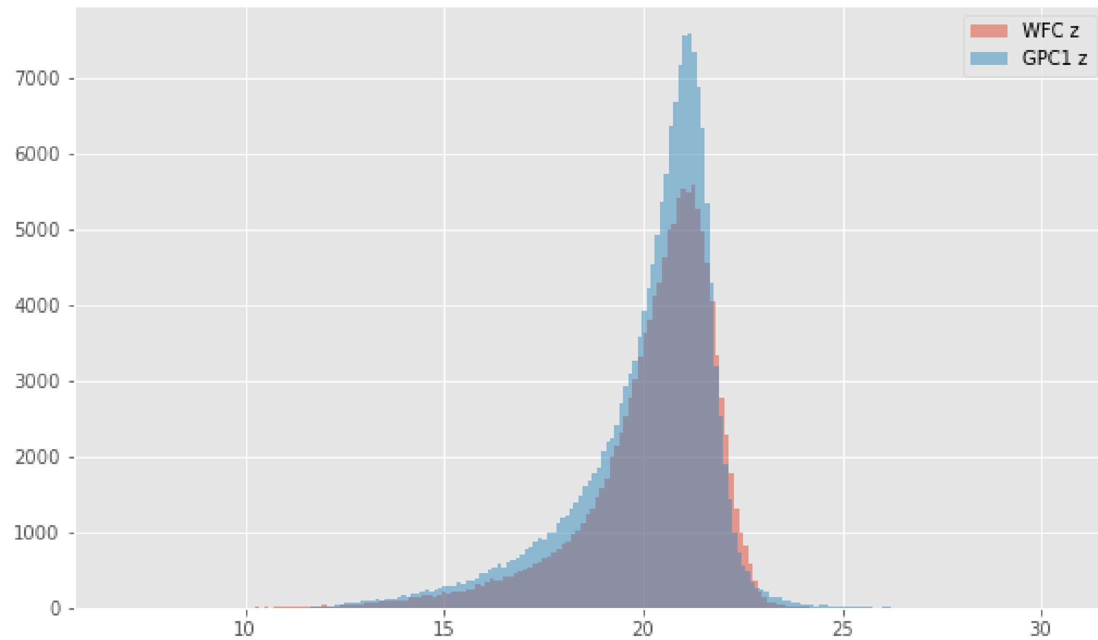
We compare the histograms of the total aperture magnitudes of similar bands.

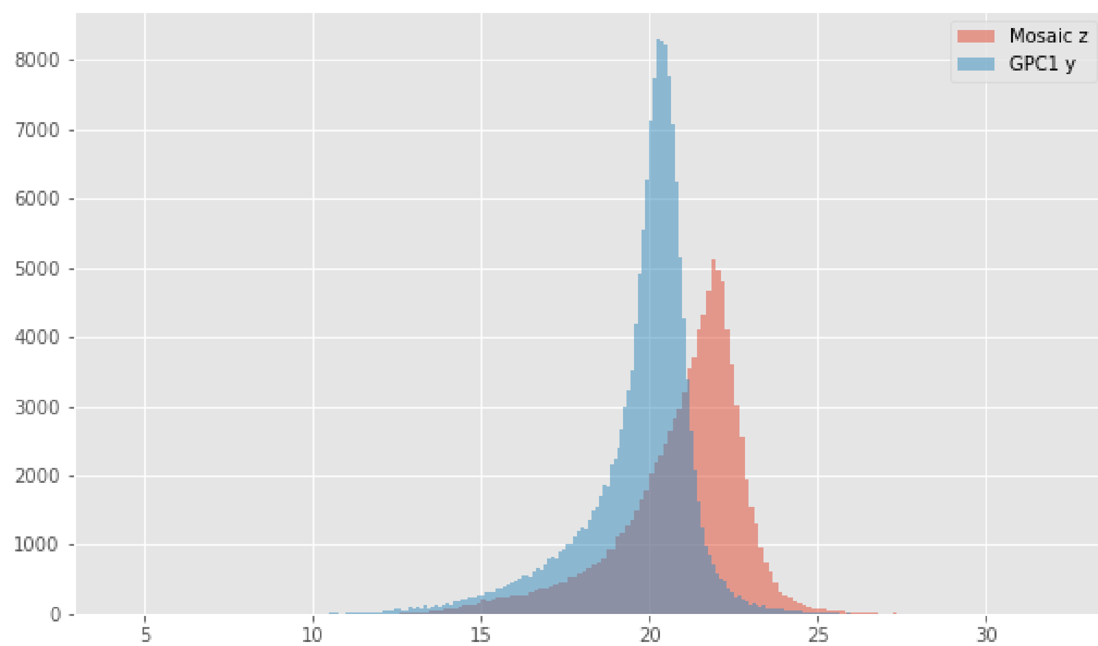

WFC u
3000
2500
2000
1500
1000
500
0
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5


WFC g
90prime g
GPC1 g
12000
10000
8000
6000
4000
2000
0
5
10
15
20
25
30
35


WFC r
90prime r
GPC1 r
Mosaic r


WFC i
GPC1 i

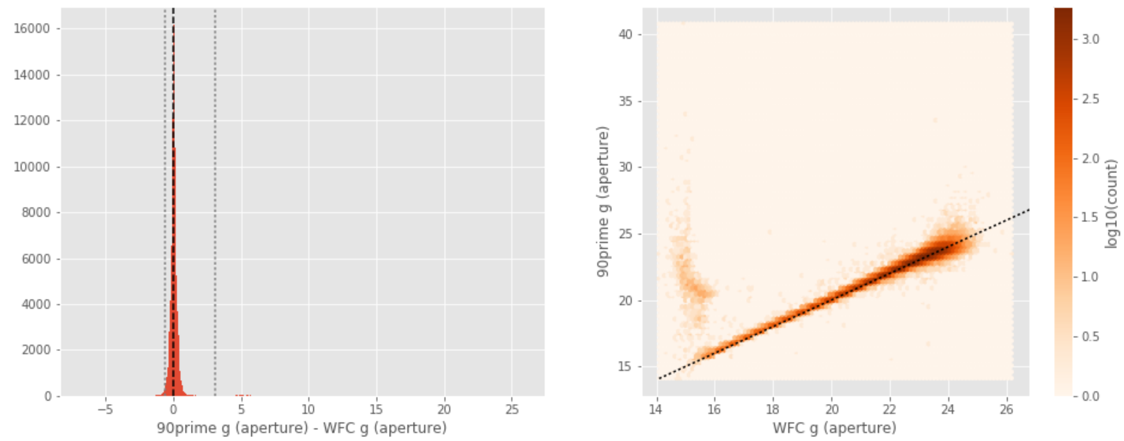




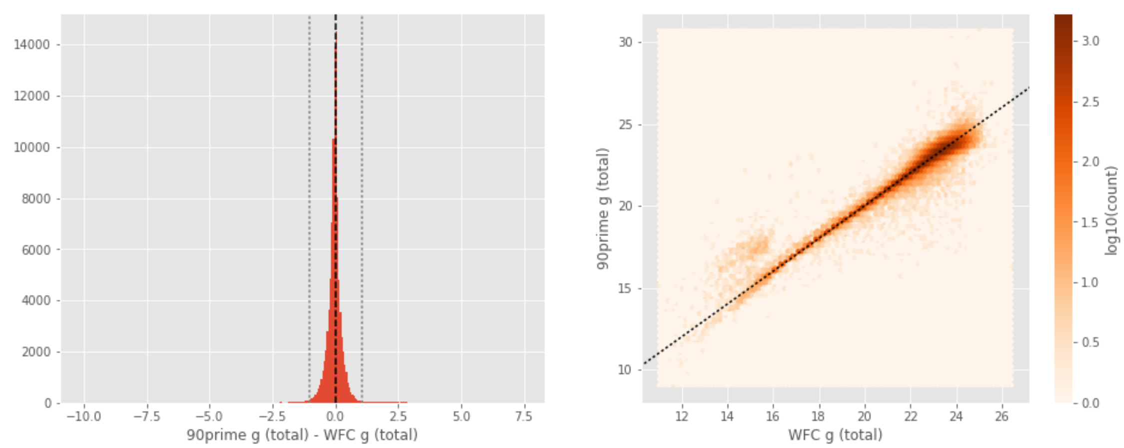
1.4.2 II.b - Comparing magnitudes

We compare one to one each magnitude in similar bands.

90prime g (aperture) - WFC g (aperture):
- Median: 0.05
- Median Absolute Deviation: 0.13
- 1% percentile: -0.6256225967407226
- 99% percentile: 3.0758930015563952

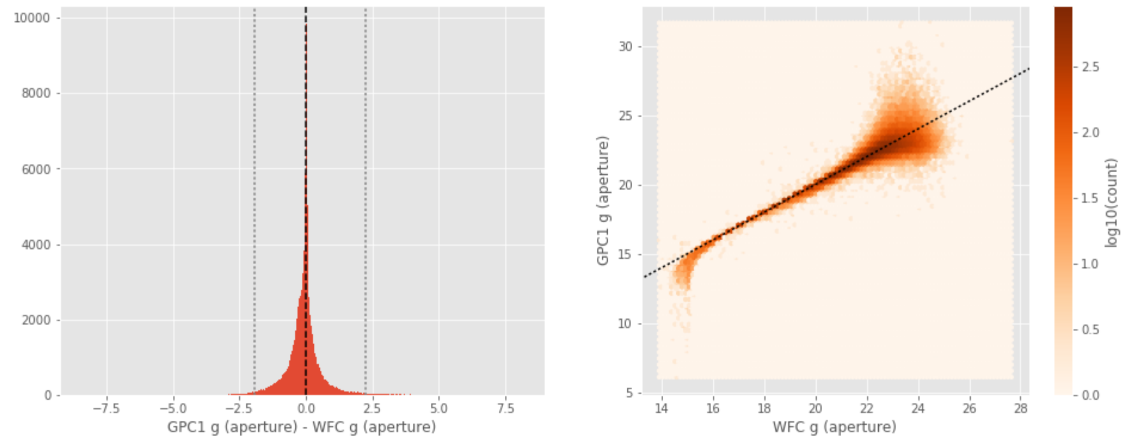


90prime g (total) - WFC g (total):
- Median: -0.02
- Median Absolute Deviation: 0.12
- 1% percentile: -1.0549715042114258
- 99% percentile: 1.0528565597534065

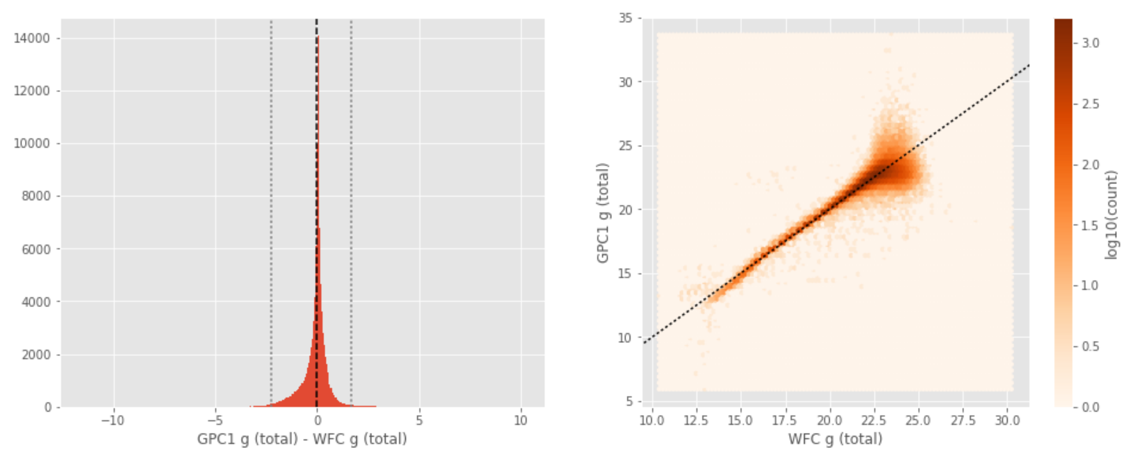


GPC1 g (aperture) - WFC g (aperture):
- Median: -0.03

- Median Absolute Deviation: 0.22
- 1% percentile: -1.936893730163574
- 99% percentile: 2.239777622222912

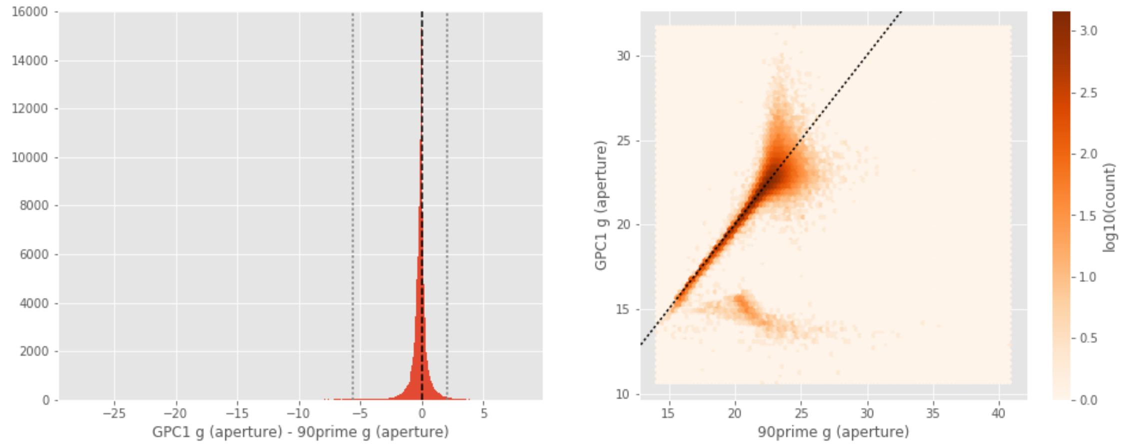


GPC1 g (total) - WFC g (total):
- Median: 0.03
- Median Absolute Deviation: 0.19
- 1% percentile: -2.26982141494751
- 99% percentile: 1.678289241790777

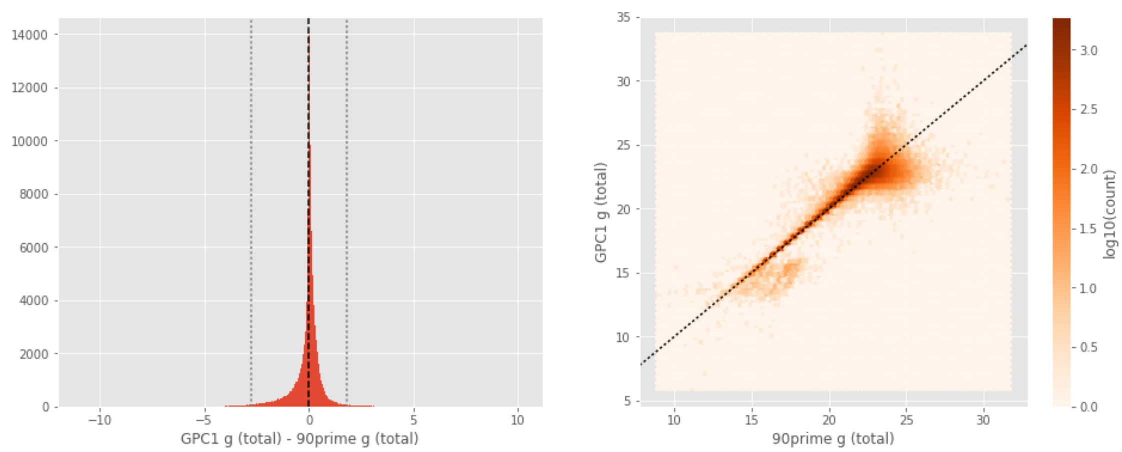


GPC1 g (aperture) - 90prime g (aperture):
- Median: -0.11
- Median Absolute Deviation: 0.22
- 1% percentile: -5.588285446166992

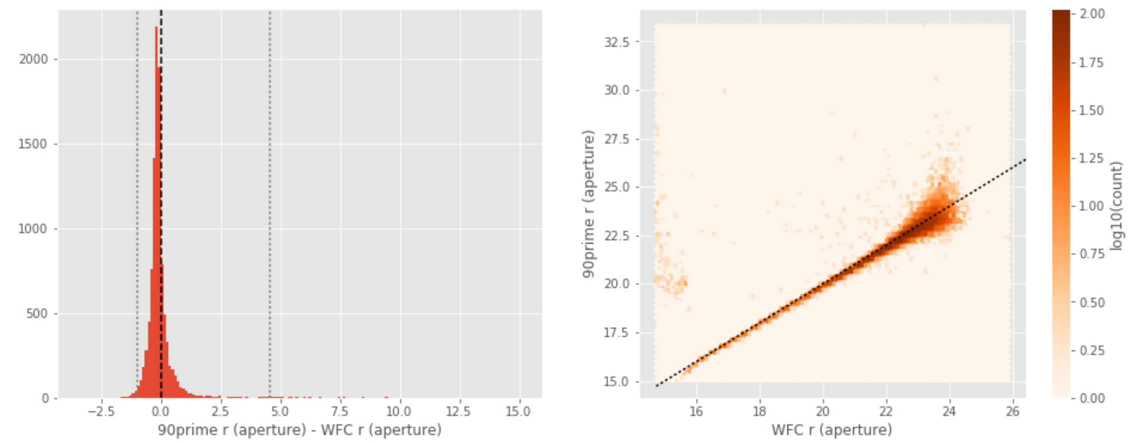
- 99% percentile: 2.078149032592774



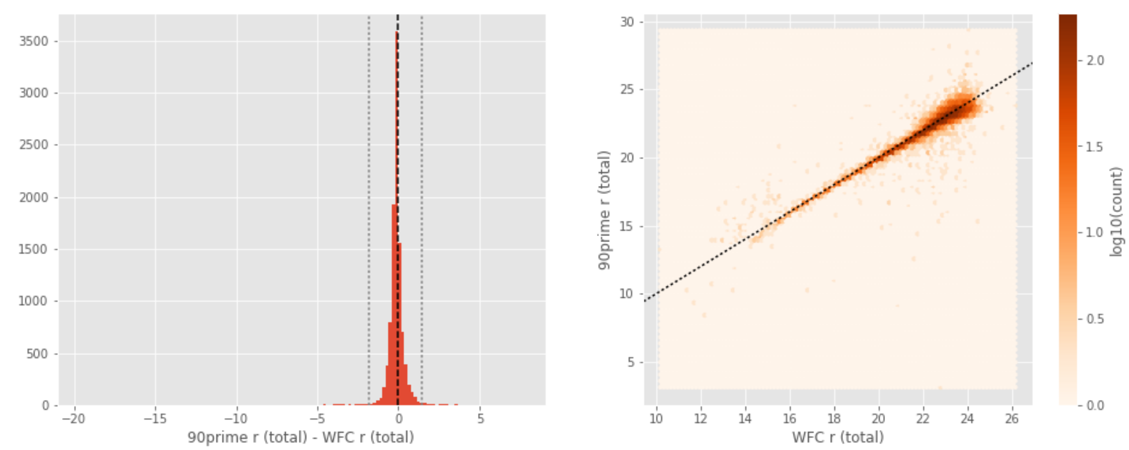
GPC1 g (total) - 90prime g (total):
- Median: 0.03
- Median Absolute Deviation: 0.18
- 1% percentile: -2.754972381591797
- 99% percentile: 1.8167191314697235



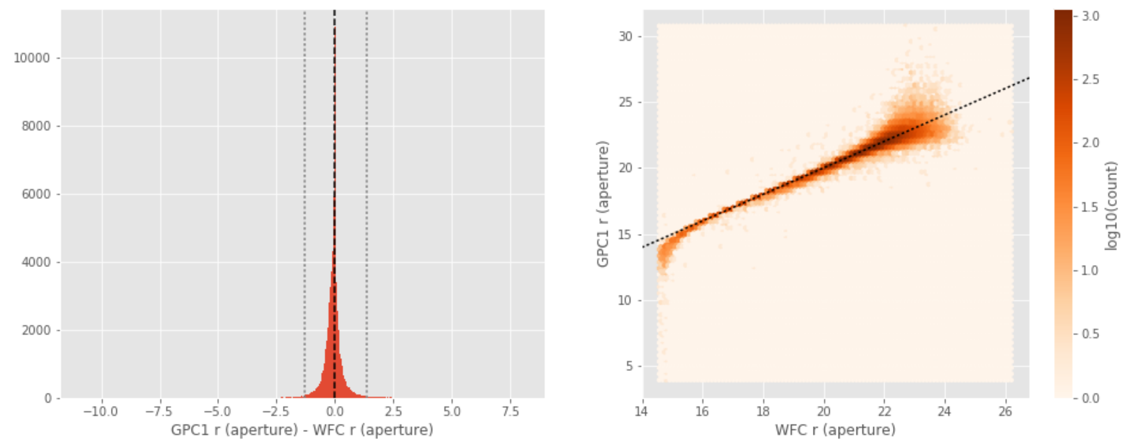
90prime r (aperture) - WFC r (aperture):
- Median: -0.13
- Median Absolute Deviation: 0.15
- 1% percentile: -1.005444869995117
- 99% percentile: 4.584682769775396



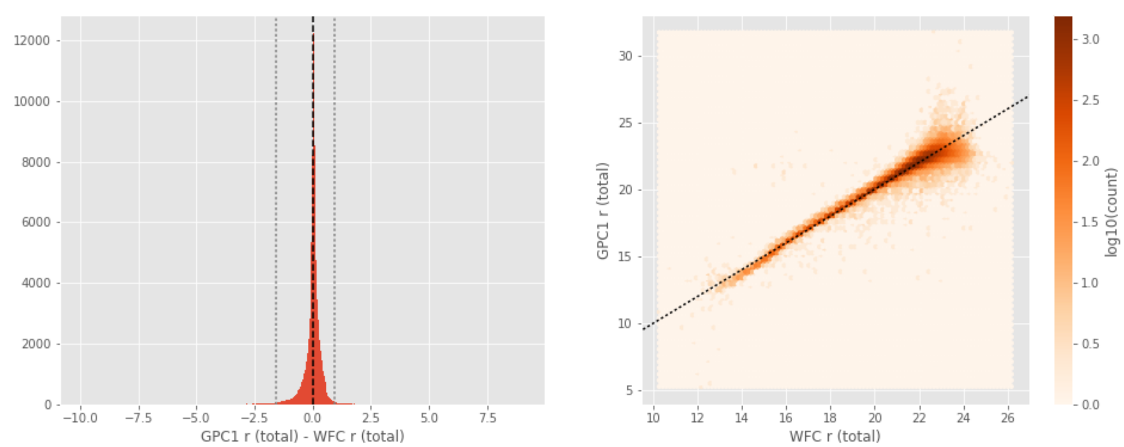
90prime r (total) - WFC r (total):
- Median: -0.13
- Median Absolute Deviation: 0.16
- 1% percentile: -1.8431853485107421
- 99% percentile: 1.4611610031127977



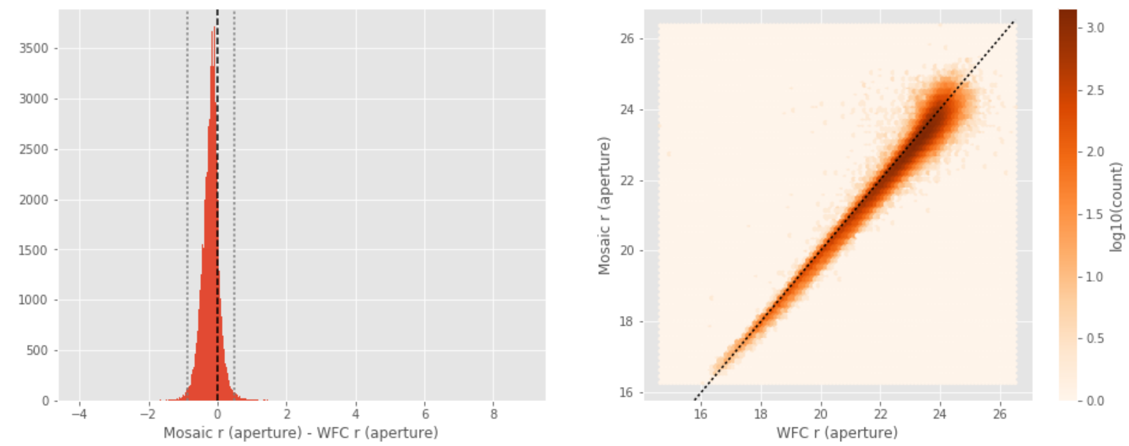
GPC1 r (aperture) - WFC r (aperture):
- Median: -0.03
- Median Absolute Deviation: 0.14
- 1% percentile: -1.2797001647949218
- 99% percentile: 1.3428354644775493



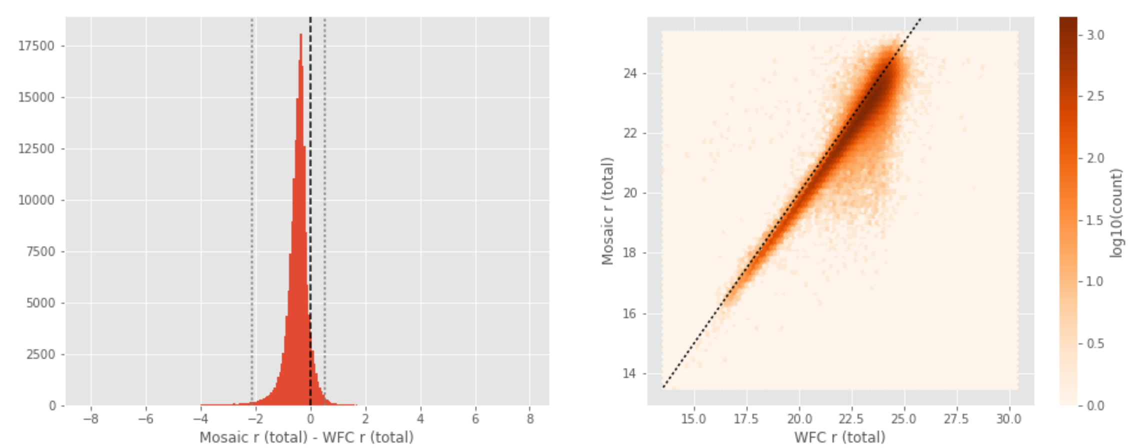
GPC1 r (total) - WFC r (total):
- Median: 0.05
- Median Absolute Deviation: 0.12
- 1% percentile: -1.5688879203796386
- 99% percentile: 0.9246087837219206



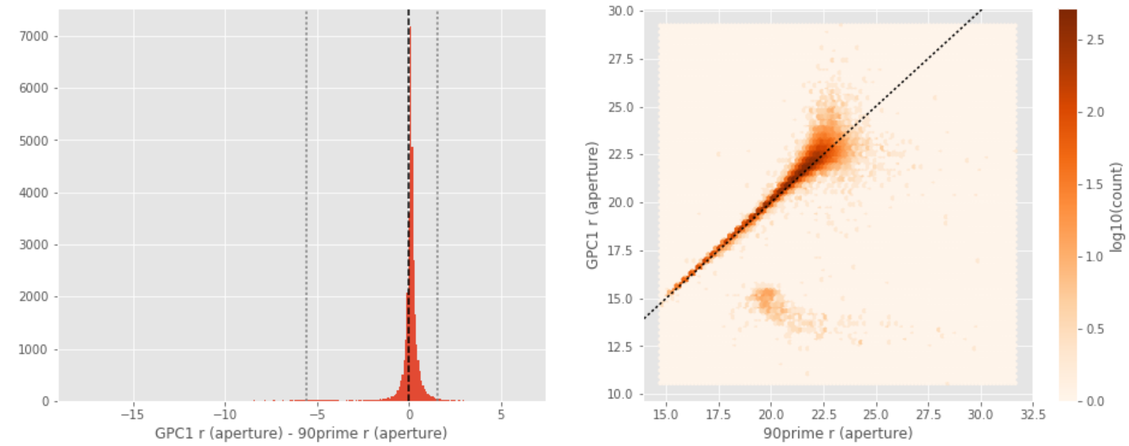
Mosaic r (aperture) - WFC r (aperture):
- Median: -0.17
- Median Absolute Deviation: 0.14
- 1% percentile: -0.8770008087158203
- 99% percentile: 0.5059786605835066



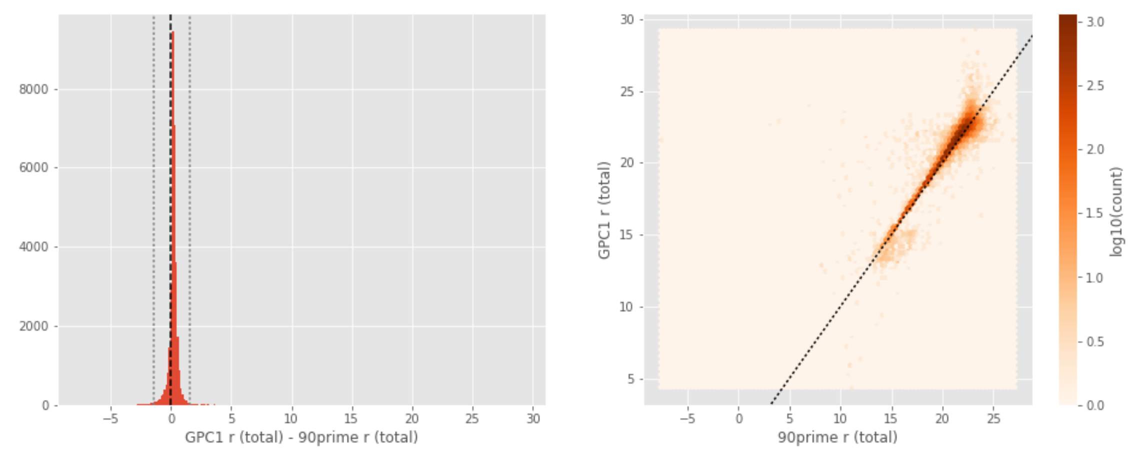
Mosaic r (total) - WFC r (total):
- Median: -0.41
- Median Absolute Deviation: 0.19
- 1% percentile: -2.126770496368408
- 99% percentile: 0.5179996490478516



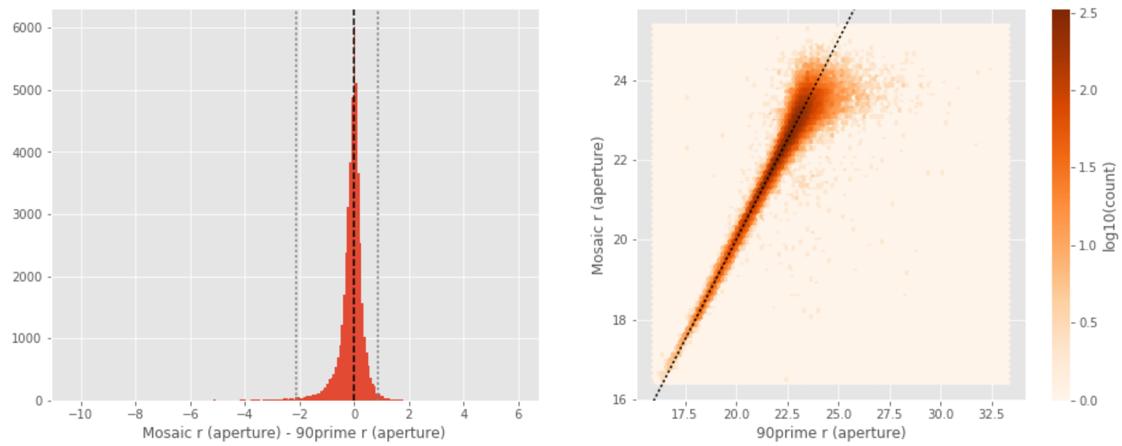
GPC1 r (aperture) - 90prime r (aperture):
- Median: 0.10
- Median Absolute Deviation: 0.13
- 1% percentile: -5.567615804672242
- 99% percentile: 1.5617235946655268



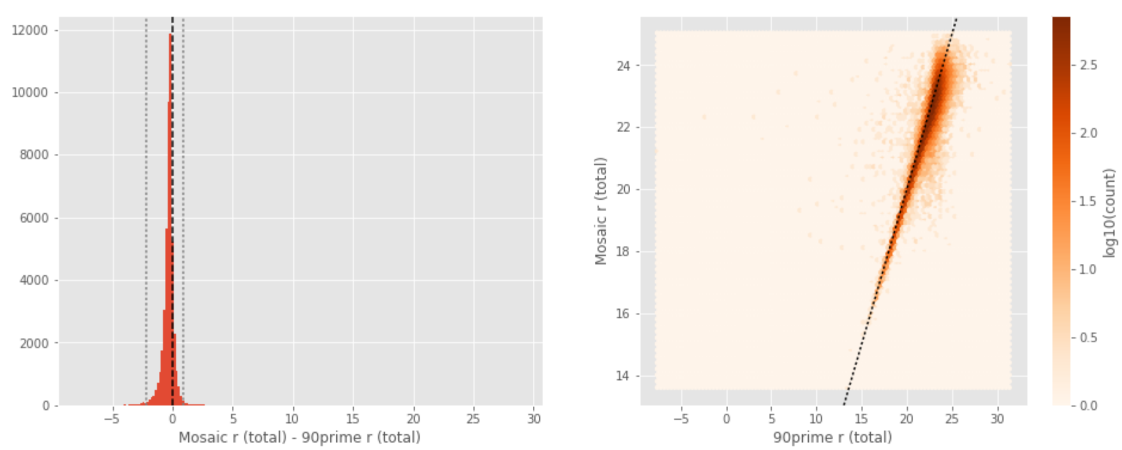
GPC1 r (total) - 90prime r (total):
- Median: 0.21
- Median Absolute Deviation: 0.13
- 1% percentile: -1.4610954570770263
- 99% percentile: 1.5784747123718255



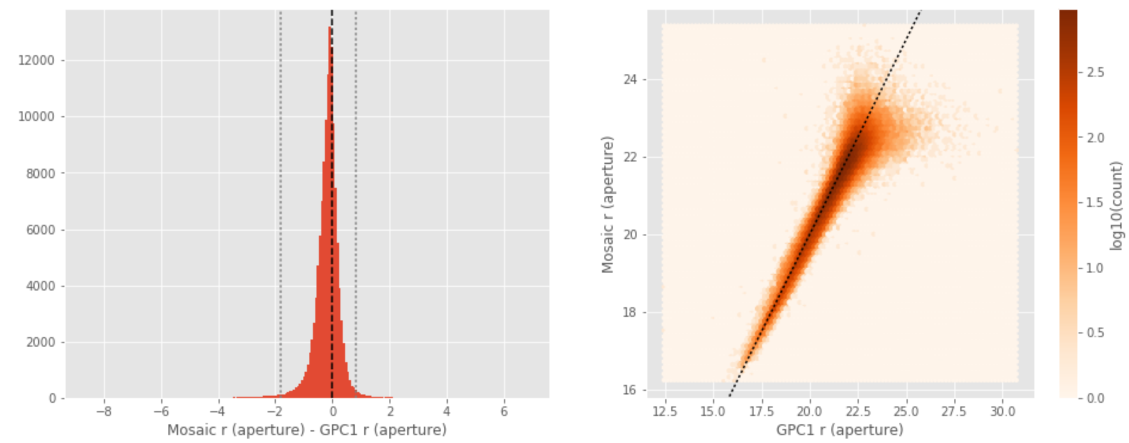
Mosaic r (aperture) - 90prime r (aperture):
- Median: -0.04
- Median Absolute Deviation: 0.18
- 1% percentile: -2.1393571090698242
- 99% percentile: 0.8618970489501949



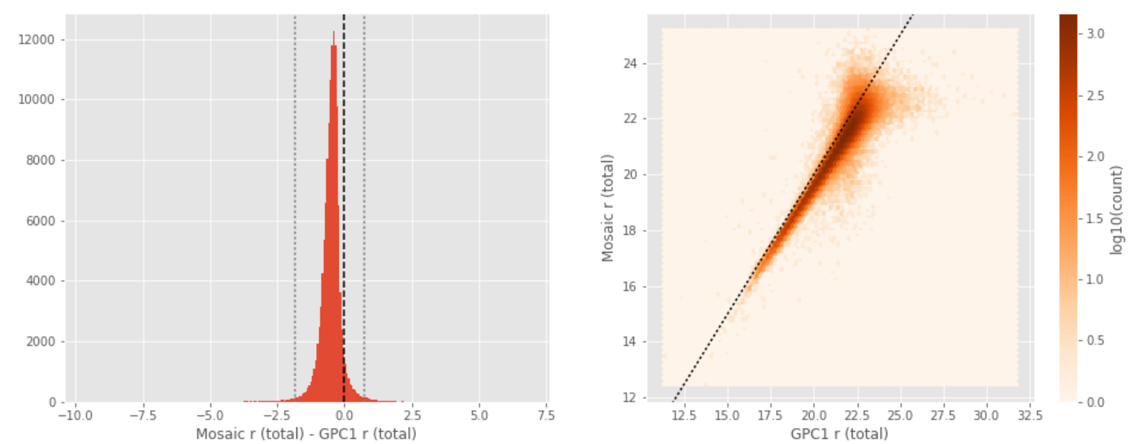
Mosaic r (total) - 90prime r (total):
- Median: -0.27
- Median Absolute Deviation: 0.19
- 1% percentile: -2.146008892059326
- 99% percentile: 0.9464354515075717



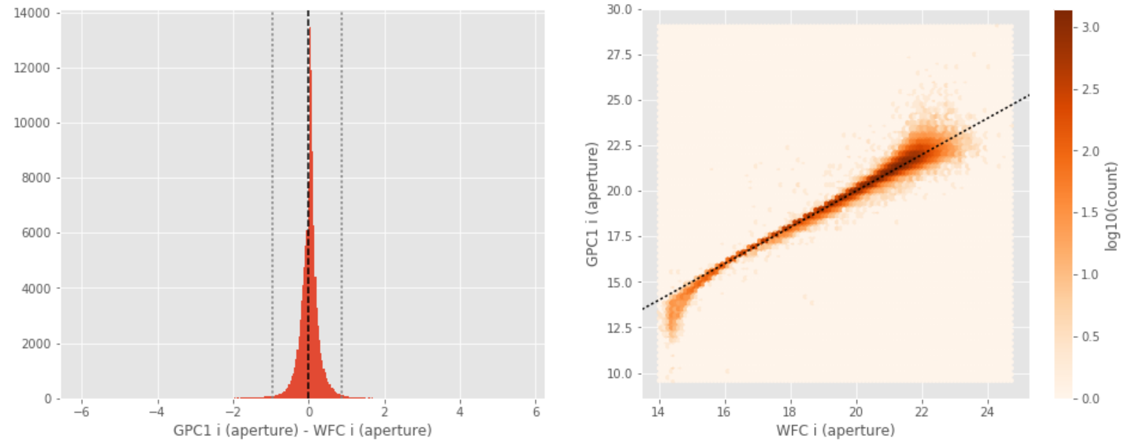
Mosaic r (aperture) - GPC1 r (aperture):
- Median: -0.12
- Median Absolute Deviation: 0.20
- 1% percentile: -1.8193340682983399
- 99% percentile: 0.821635704040526



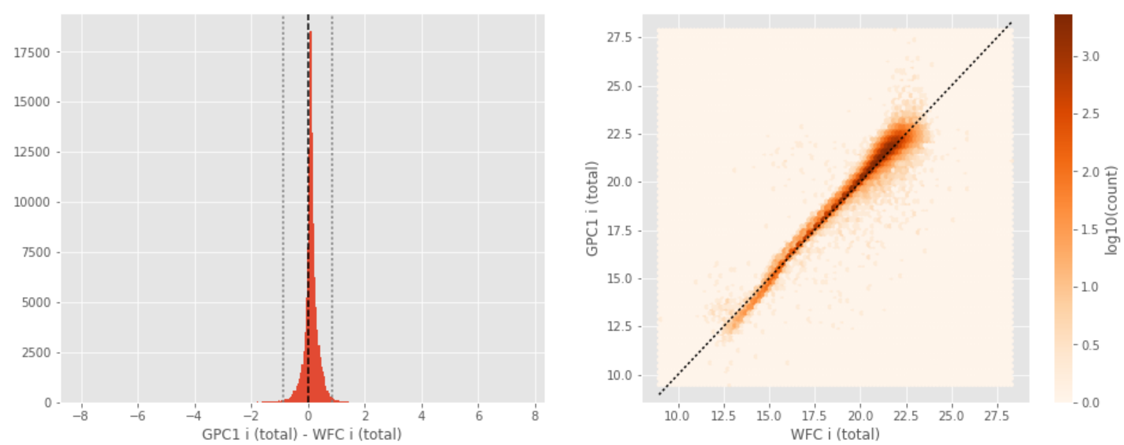
Mosaic r (total) - GPC1 r (total):
- Median: -0.47
- Median Absolute Deviation: 0.18
- 1% percentile: -1.8546954727172853
- 99% percentile: 0.7358176422119134



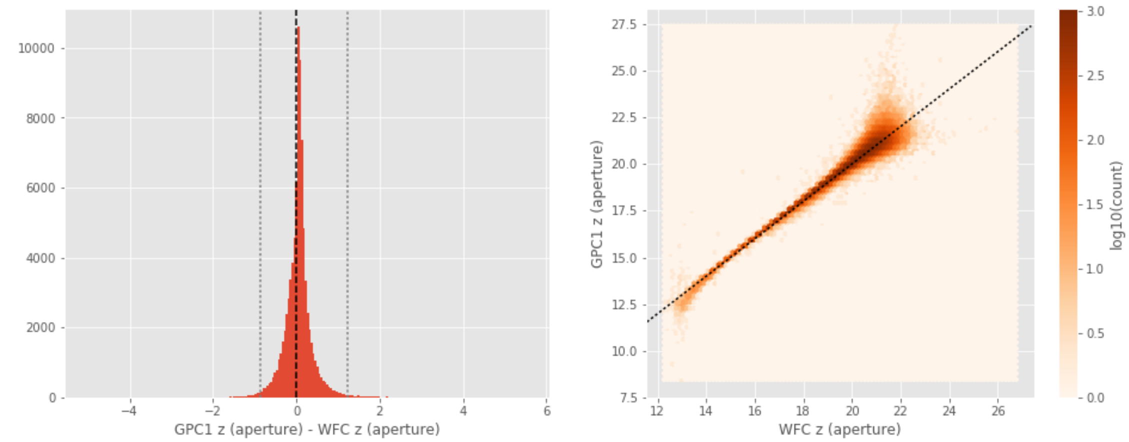
GPC1 i (aperture) - WFC i (aperture):
- Median: 0.04
- Median Absolute Deviation: 0.11
- 1% percentile: -0.952352294921875
- 99% percentile: 0.8918610382079997



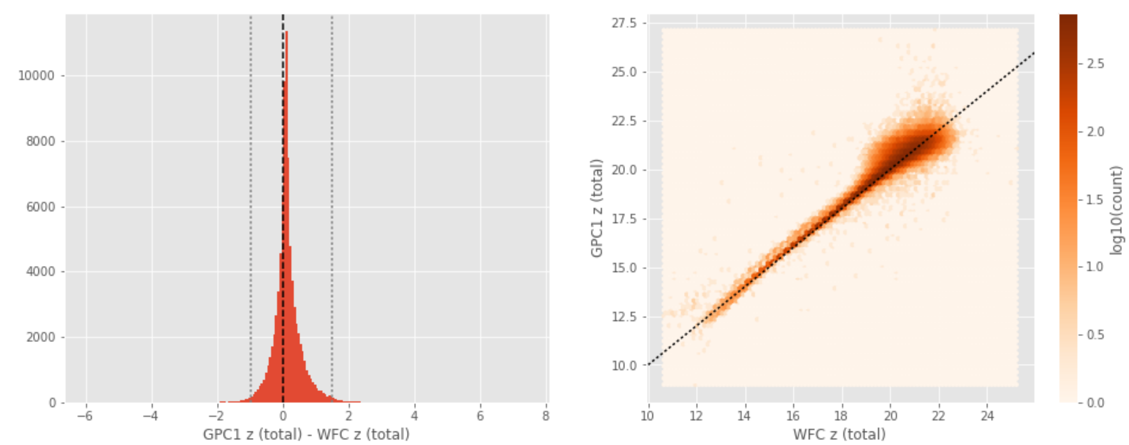
GPC1 i (total) - WFC i (total):
- Median: 0.11
- Median Absolute Deviation: 0.10
- 1% percentile: -0.8853607177734375
- 99% percentile: 0.8438045501708963



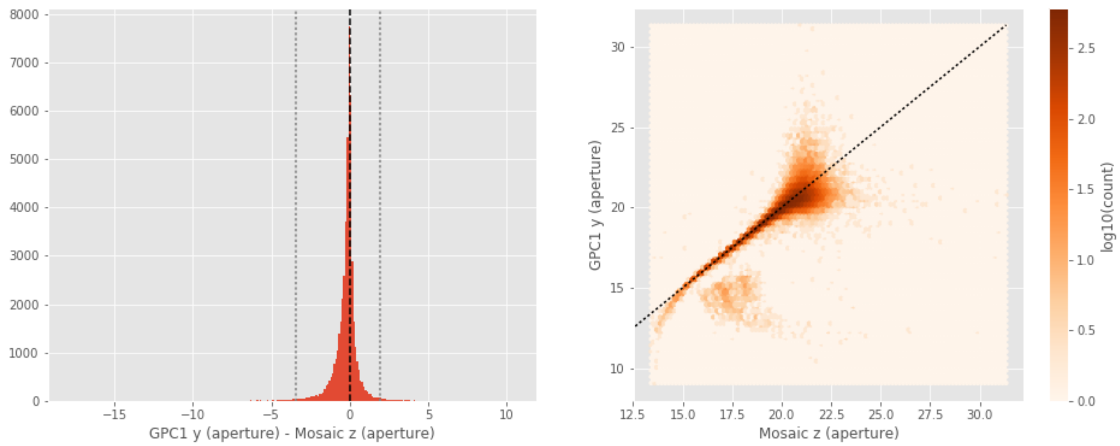
GPC1 z (aperture) - WFC z (aperture):
- Median: 0.06
- Median Absolute Deviation: 0.13
- 1% percentile: -0.8765241622924804
- 99% percentile: 1.23230981826782



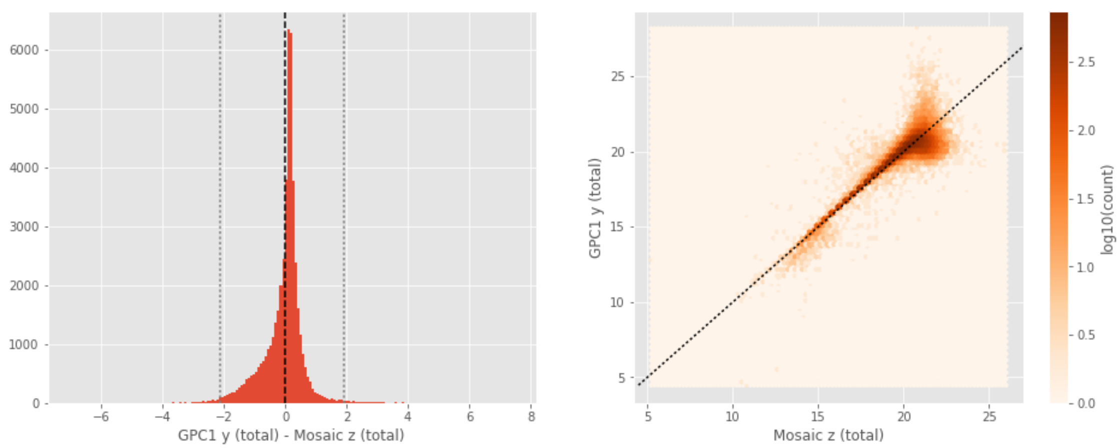
GPC1 z (total) - WFC z (total):
- Median: 0.10
- Median Absolute Deviation: 0.17
- 1% percentile: -0.9696512603759765
- 99% percentile: 1.490121402740476



GPC1 y (aperture) - Mosaic z (aperture):
- Median: -0.10
- Median Absolute Deviation: 0.22
- 1% percentile: -3.4303236579895016
- 99% percentile: 1.9012526702880828




```
GPC1 y (total) - Mosaic z (total):
- Median: 0.08
- Median Absolute Deviation: 0.22
- 1% percentile: -2.127430629730225
- 99% percentile: 1.8989069938659666
```



1.5 III - Comparing magnitudes to reference bands

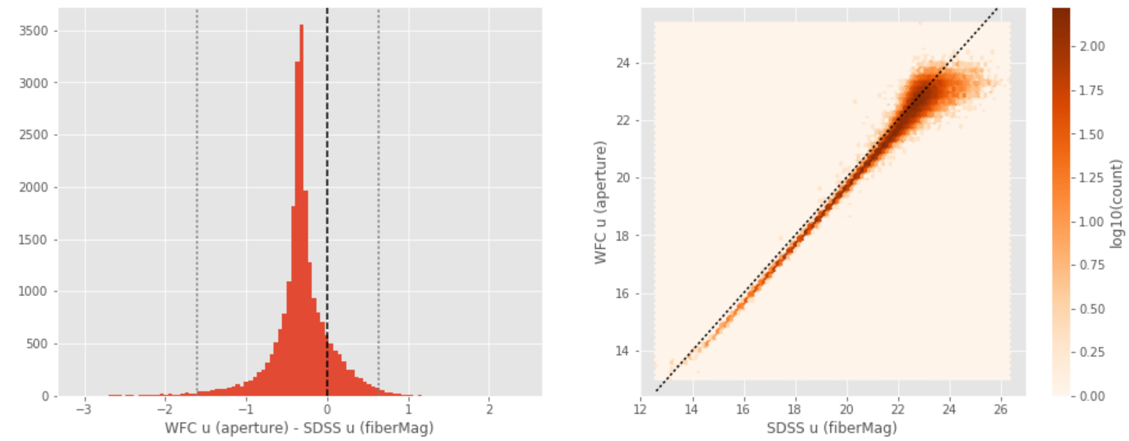
Cross-match the master list to SDSS and 2MASS to compare its magnitudes to SDSS and 2MASS ones.

1.5.1 III.a - Comparing u, g, r, i, and z bands to SDSS

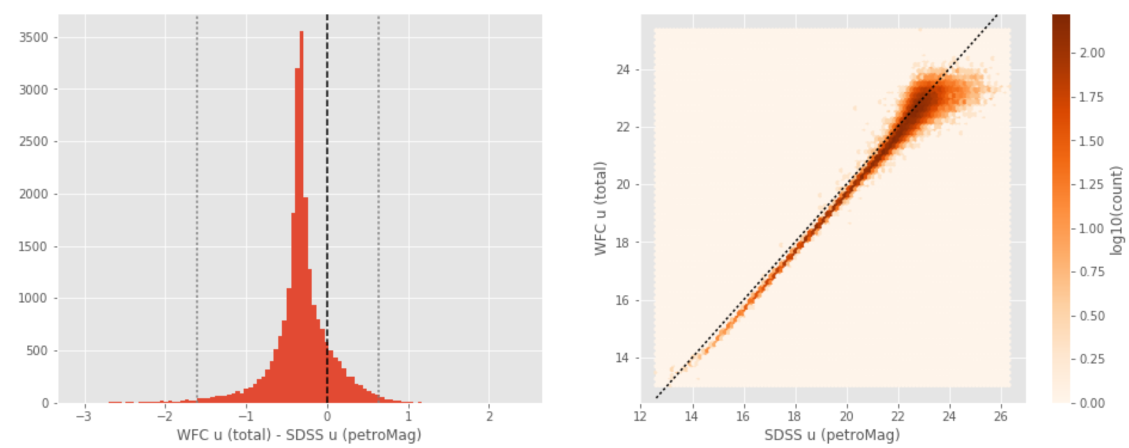
The catalogue is cross-matched to SDSS-DR13 withing 0.2 arcsecond.

We compare the u, g, r, i, and z magnitudes to those from SDSS using `fiberMag` for the aperture magnitude and `petroMag` for the total magnitude.

WFC u (aperture) - SDSS u (fiberMag):
- Median: -0.33
- Median Absolute Deviation: 0.13
- 1% percentile: -1.6017975616455078
- 99% percentile: 0.6325454711914066

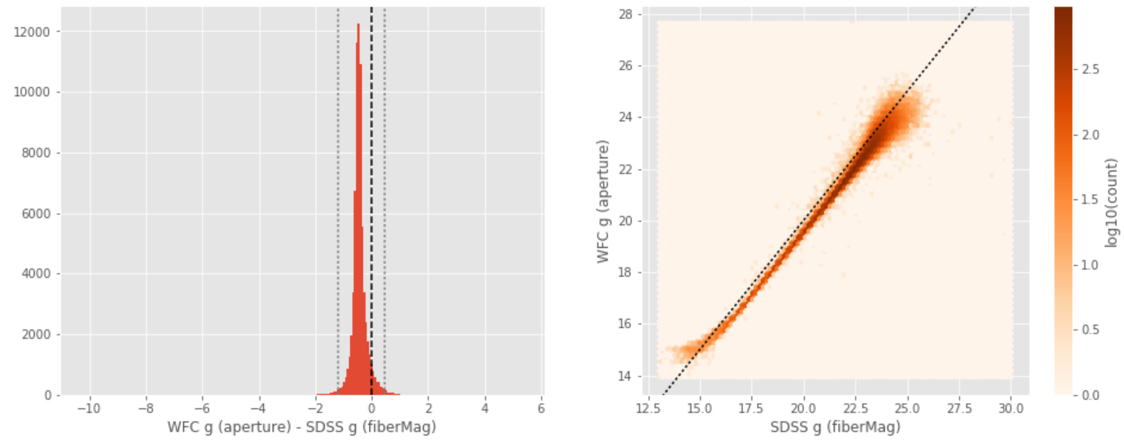


WFC u (total) - SDSS u (petroMag):
- Median: -0.33
- Median Absolute Deviation: 0.13
- 1% percentile: -1.6017975616455078
- 99% percentile: 0.6325454711914066

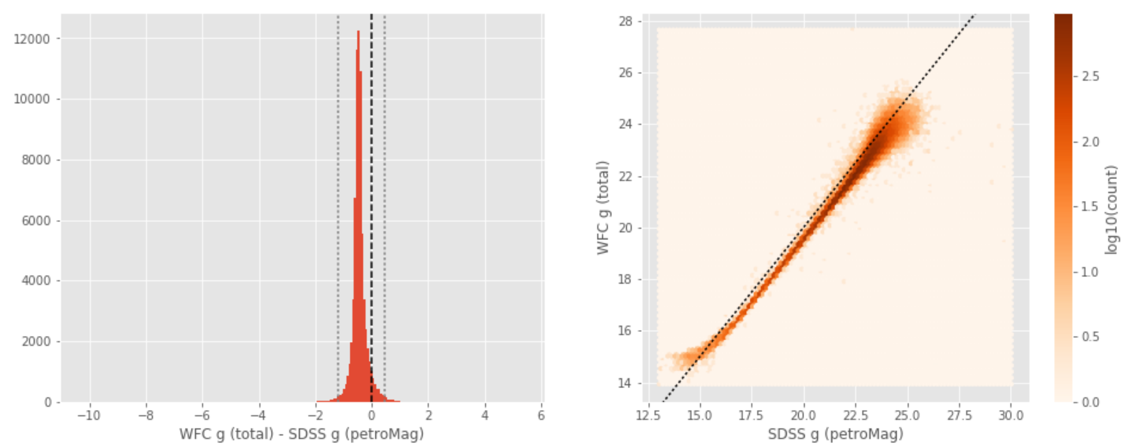


WFC g (aperture) - SDSS g (fiberMag):
- Median: -0.45

- Median Absolute Deviation: 0.10
- 1% percentile: -1.1772414016723634
- 99% percentile: 0.4478158187866218

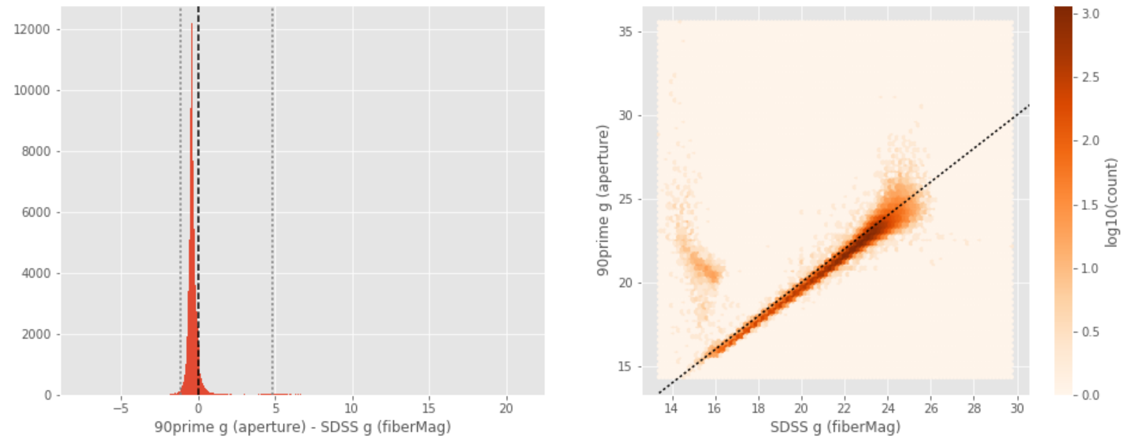


WFC g (total) - SDSS g (petroMag):
- Median: -0.45
- Median Absolute Deviation: 0.10
- 1% percentile: -1.1772414016723634
- 99% percentile: 0.4478158187866218

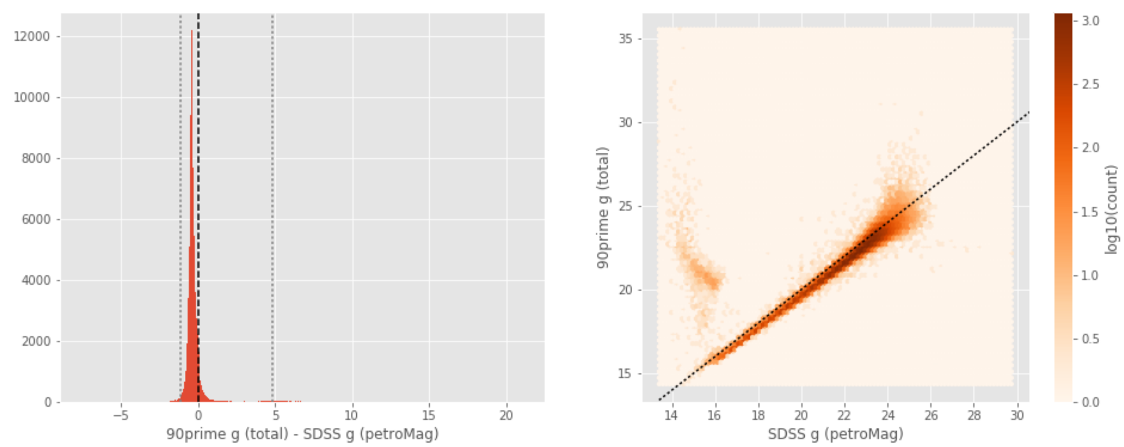


90prime g (aperture) - SDSS g (fiberMag):
- Median: -0.38
- Median Absolute Deviation: 0.14
- 1% percentile: -1.101987075805664

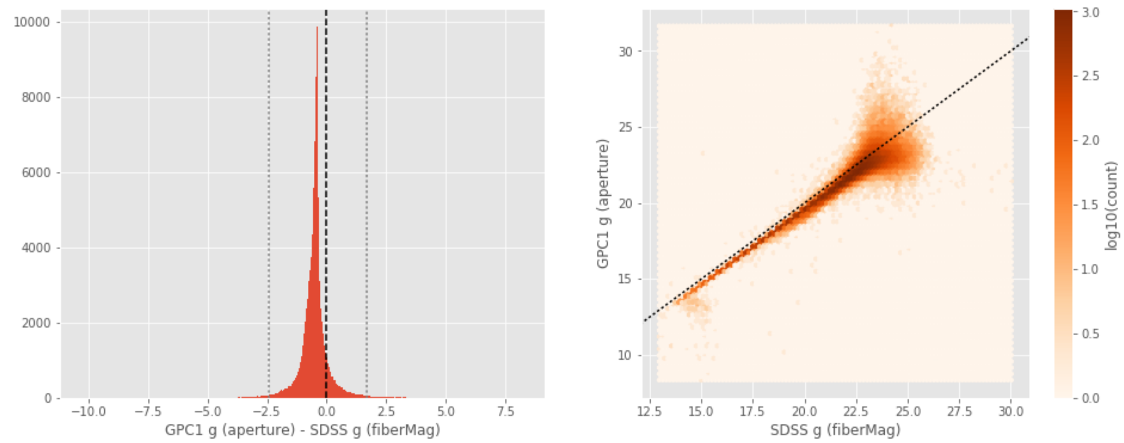
- 99% percentile: 4.830027141571065



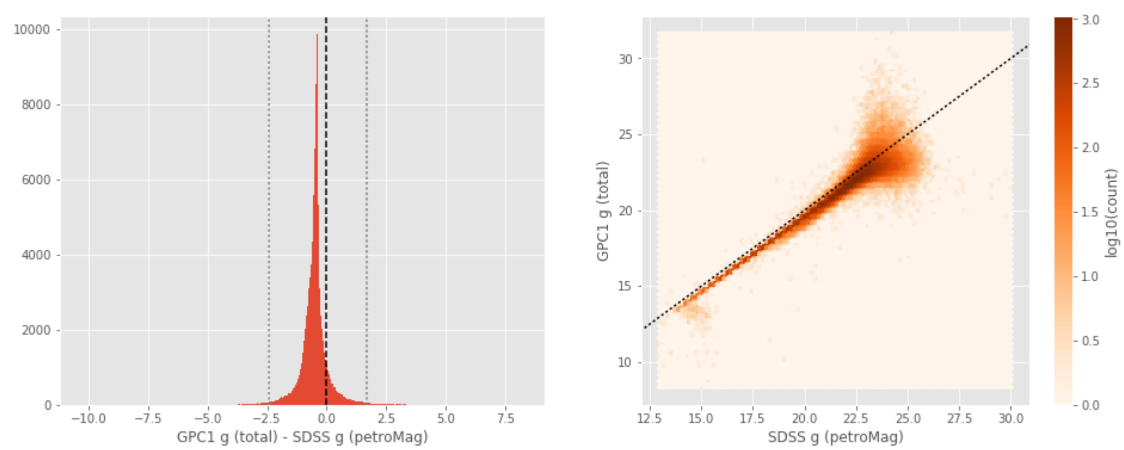
90prime g (total) - SDSS g (petroMag):
- Median: -0.38
- Median Absolute Deviation: 0.14
- 1% percentile: -1.101987075805664
- 99% percentile: 4.830027141571065



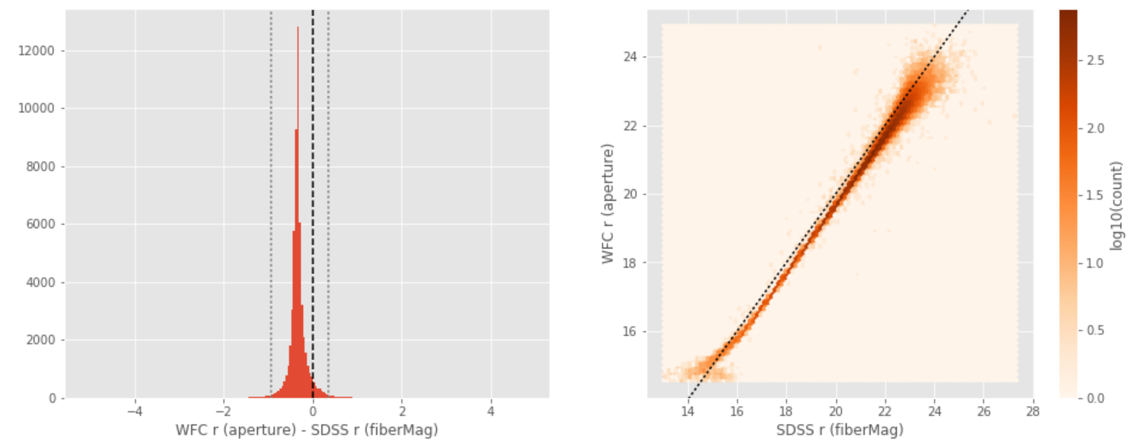
GPC1 g (aperture) - SDSS g (fiberMag):
- Median: -0.47
- Median Absolute Deviation: 0.20
- 1% percentile: -2.4040427207946777
- 99% percentile: 1.6819067001342773



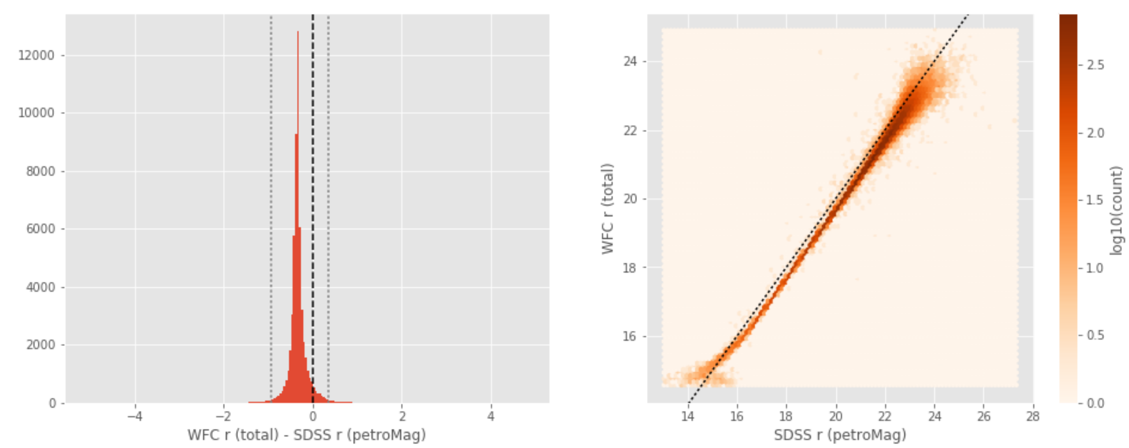
GPC1 g (total) - SDSS g (petroMag):
- Median: -0.47
- Median Absolute Deviation: 0.20
- 1% percentile: -2.4040427207946777
- 99% percentile: 1.6819067001342773



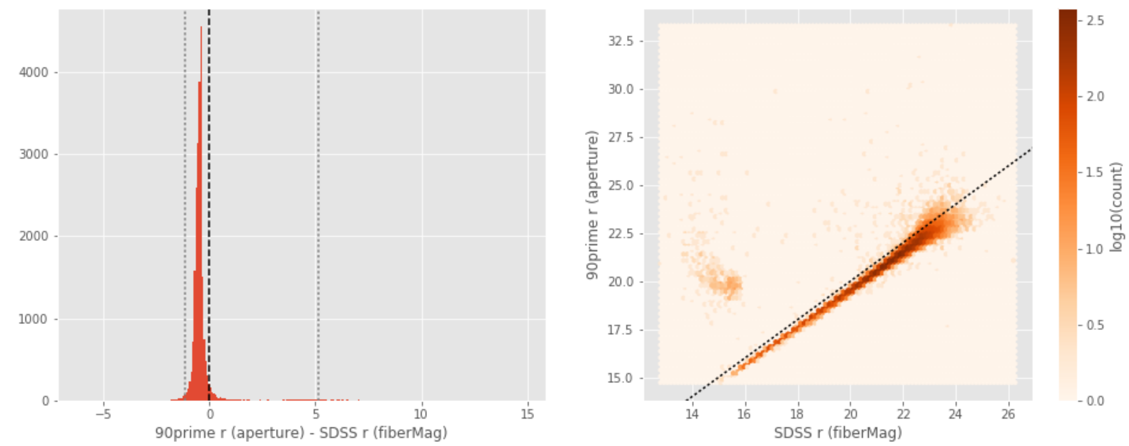
WFC r (aperture) - SDSS r (fiberMag):
- Median: -0.34
- Median Absolute Deviation: 0.06
- 1% percentile: -0.9351469993591308
- 99% percentile: 0.3601674079895015



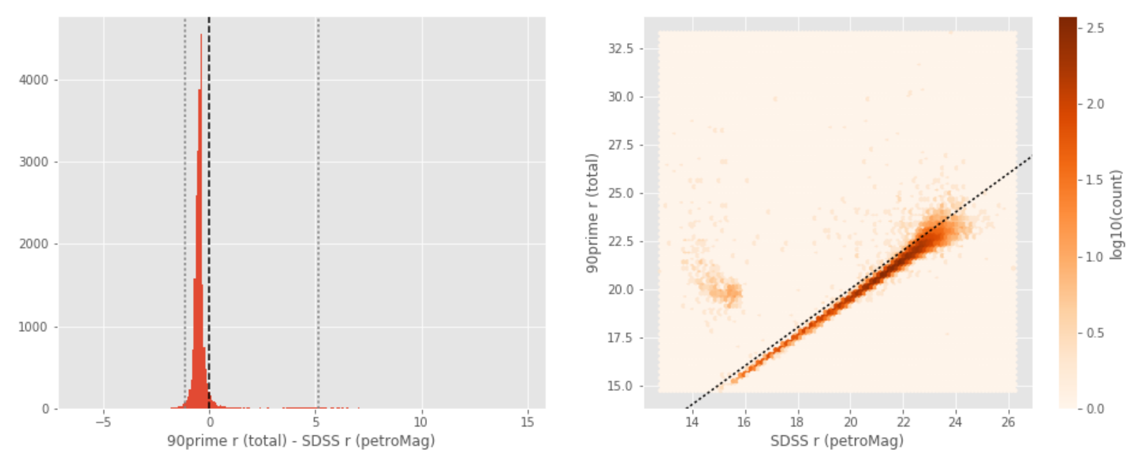
WFC r (total) - SDSS r (petroMag):
- Median: -0.34
- Median Absolute Deviation: 0.06
- 1% percentile: -0.9351469993591308
- 99% percentile: 0.3601674079895015



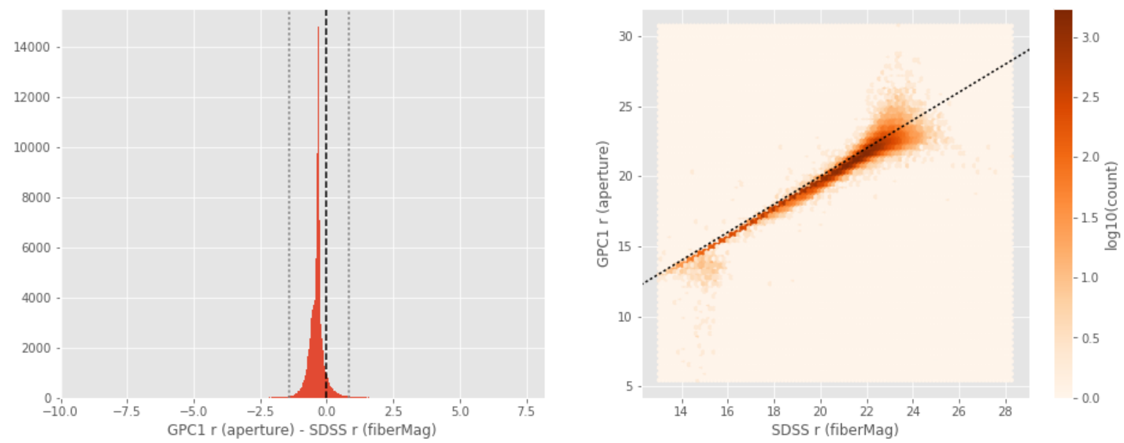
90prime r (aperture) - SDSS r (fiberMag):
- Median: -0.46
- Median Absolute Deviation: 0.11
- 1% percentile: -1.1453510665893556
- 99% percentile: 5.127978057861326



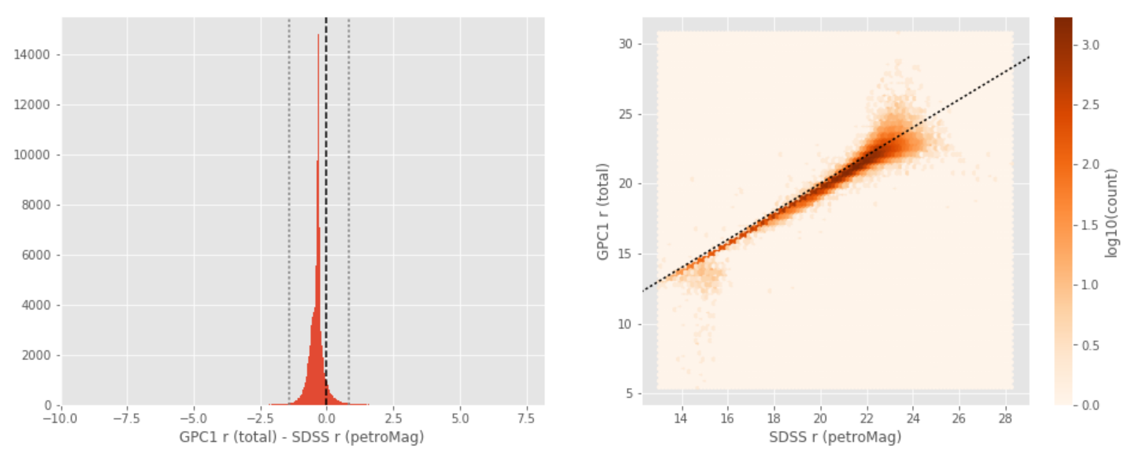
90prime r (total) - SDSS r (petroMag):
- Median: -0.46
- Median Absolute Deviation: 0.11
- 1% percentile: -1.1453510665893556
- 99% percentile: 5.127978057861326



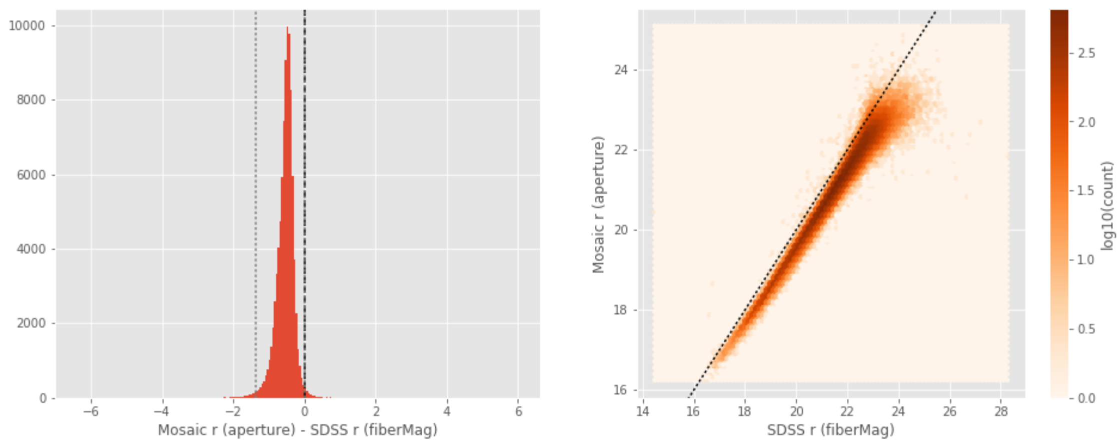
GPC1 r (aperture) - SDSS r (fiberMag):
- Median: -0.34
- Median Absolute Deviation: 0.12
- 1% percentile: -1.4154183197021484
- 99% percentile: 0.8237089157104492



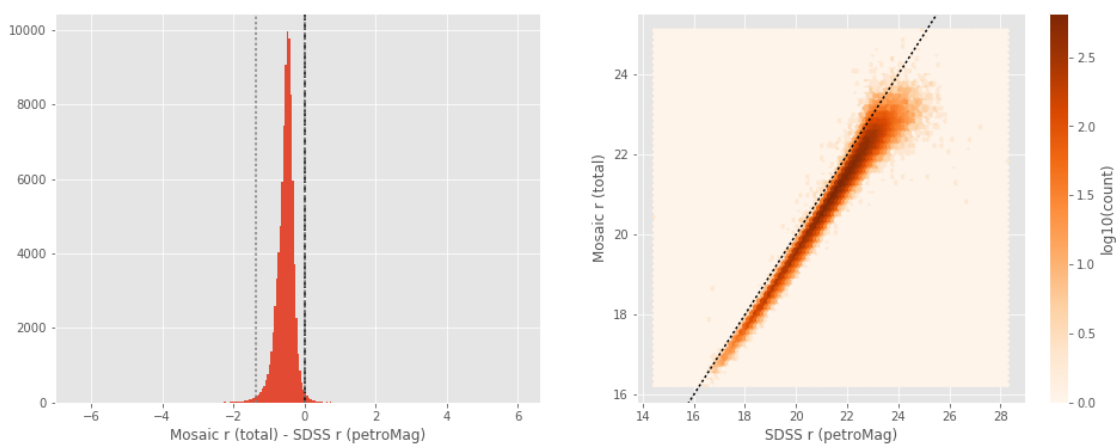
GPC1 r (total) - SDSS r (petroMag):
- Median: -0.34
- Median Absolute Deviation: 0.12
- 1% percentile: -1.4154183197021484
- 99% percentile: 0.8237089157104492



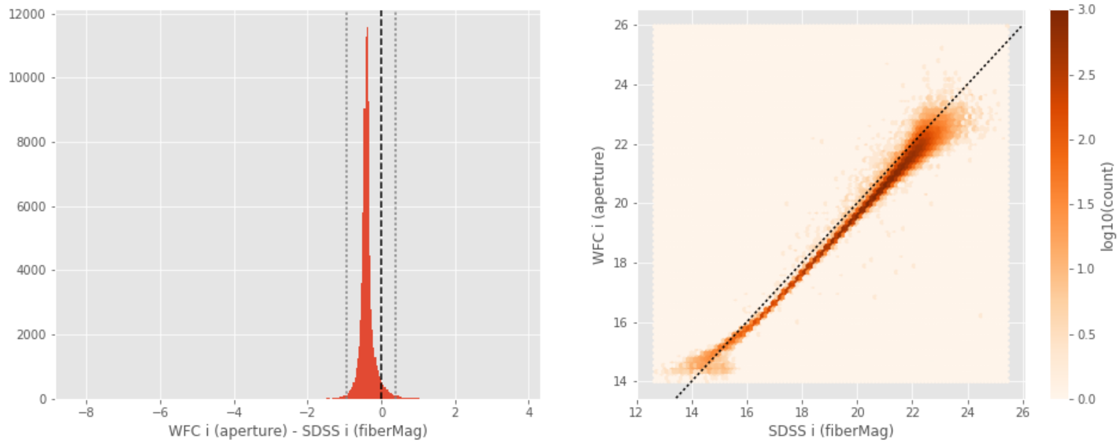
Mosaic r (aperture) - SDSS r (fiberMag):
- Median: -0.50
- Median Absolute Deviation: 0.13
- 1% percentile: -1.3614568710327148
- 99% percentile: 0.02729091644287046



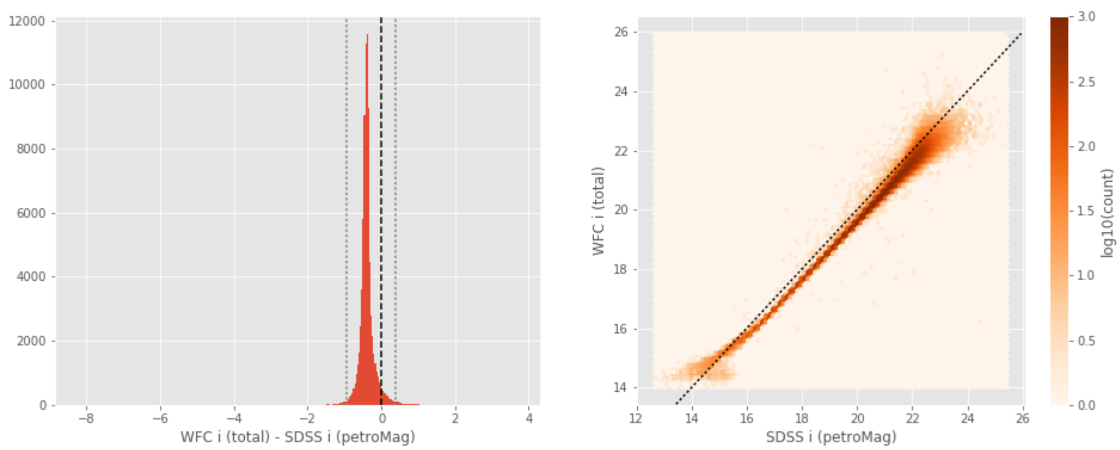
Mosaic r (total) - SDSS r (petroMag):
- Median: -0.50
- Median Absolute Deviation: 0.13
- 1% percentile: -1.3614568710327148
- 99% percentile: 0.02729091644287046



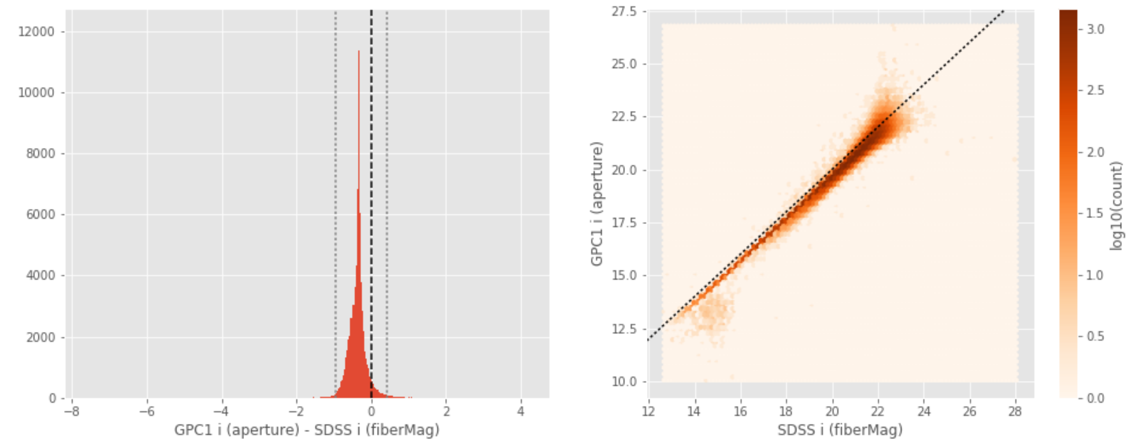
WFC i (aperture) - SDSS i (fiberMag):
- Median: -0.40
- Median Absolute Deviation: 0.07
- 1% percentile: -0.9382619476318359
- 99% percentile: 0.3755919170379611



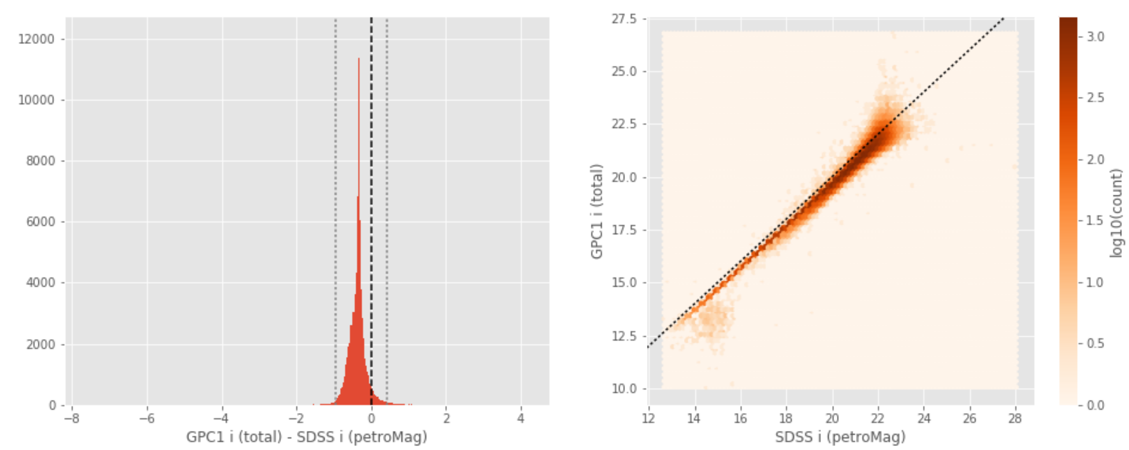
WFC i (total) - SDSS i (petroMag):
- Median: -0.40
- Median Absolute Deviation: 0.07
- 1% percentile: -0.9382619476318359
- 99% percentile: 0.3755919170379611



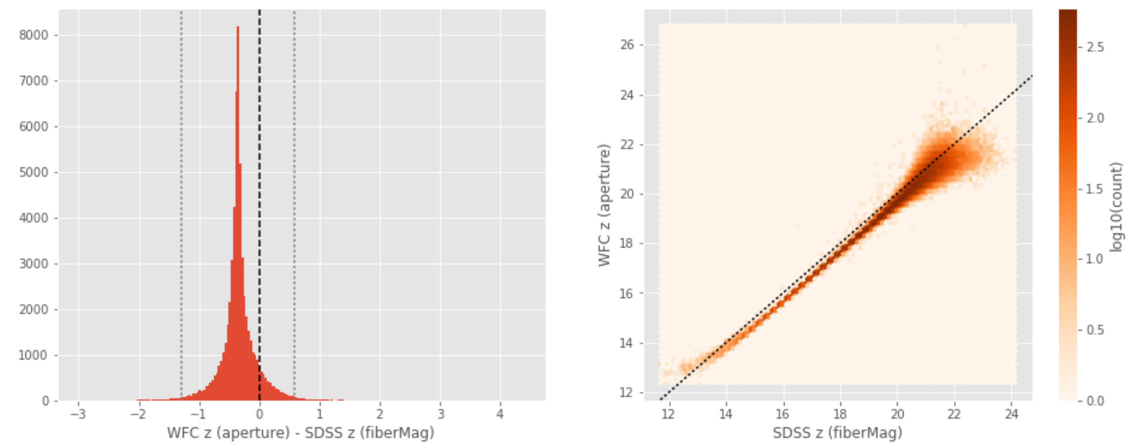
GPC1 i (aperture) - SDSS i (fiberMag):
- Median: -0.34
- Median Absolute Deviation: 0.09
- 1% percentile: -0.9665631103515625
- 99% percentile: 0.4199513244628907



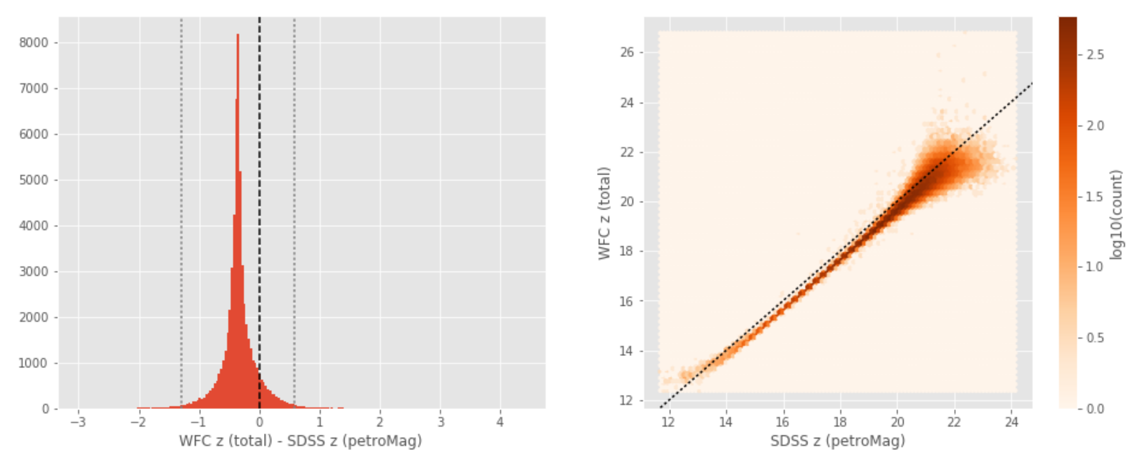
GPC1 i (total) - SDSS i (petroMag):
- Median: -0.34
- Median Absolute Deviation: 0.09
- 1% percentile: -0.9665631103515625
- 99% percentile: 0.4199513244628907



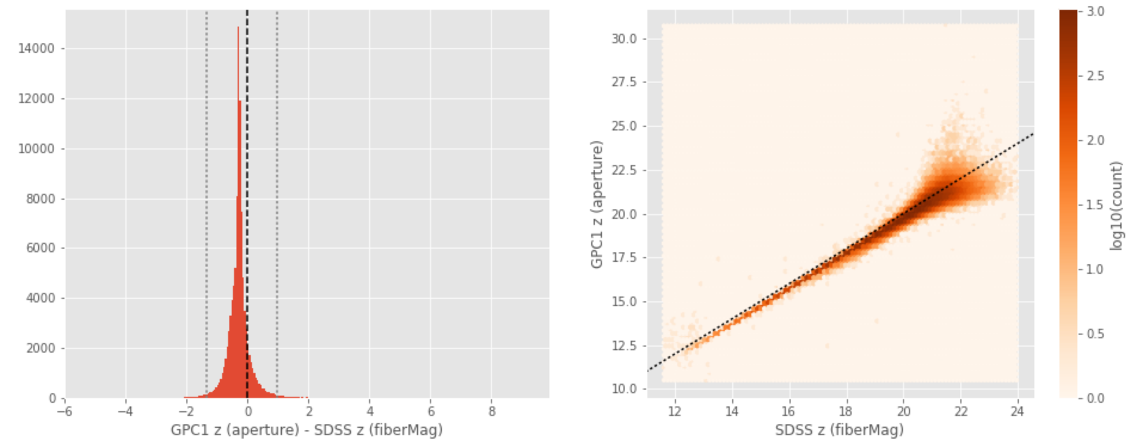
WFC z (aperture) - SDSS z (fiberMag):
- Median: -0.35
- Median Absolute Deviation: 0.10
- 1% percentile: -1.2951622009277344
- 99% percentile: 0.58636474609375



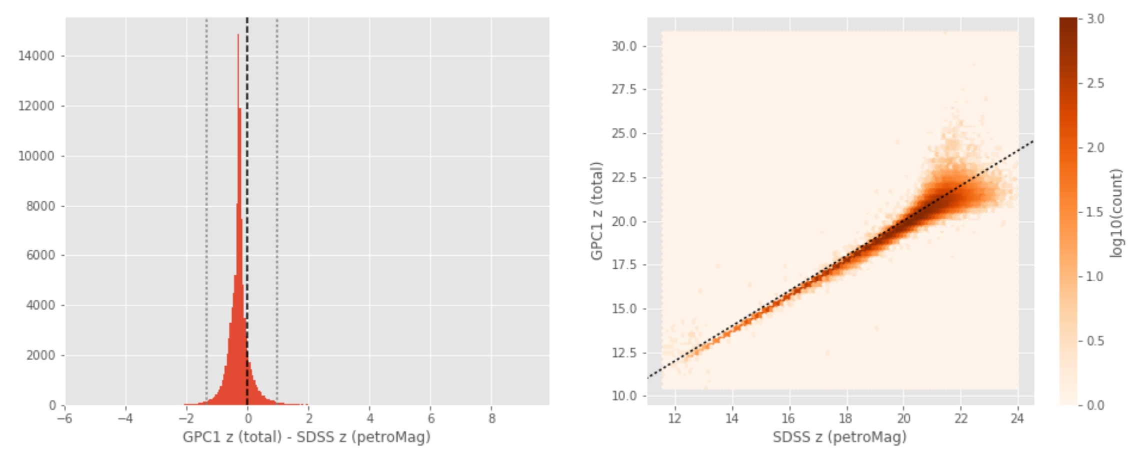
WFC z (total) - SDSS z (petroMag):
- Median: -0.35
- Median Absolute Deviation: 0.10
- 1% percentile: -1.2951622009277344
- 99% percentile: 0.58636474609375



GPC1 z (aperture) - SDSS z (fiberMag):
- Median: -0.29
- Median Absolute Deviation: 0.13
- 1% percentile: -1.3401688385009765
- 99% percentile: 0.9634982299804702




```
GPC1 z (total) - SDSS z (petroMag):
- Median: -0.29
- Median Absolute Deviation: 0.13
- 1% percentile: -1.3401688385009765
- 99% percentile: 0.9634982299804702
```



1.5.2 III.b - Comparing J and K bands to 2MASS

The catalogue is cross-matched to 2MASS-PSC withing 0.2 arcsecond. We compare the UKIDSS total J and K magnitudes to those from 2MASS.

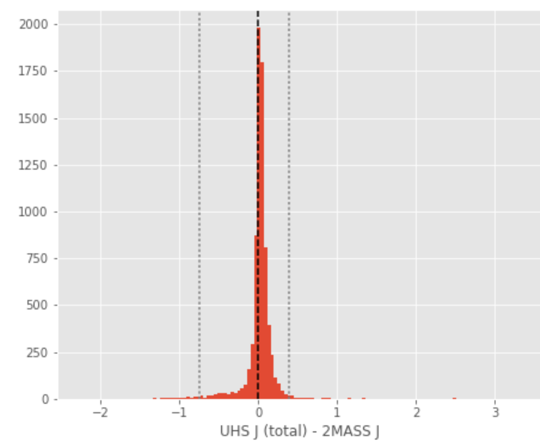
The 2MASS magnitudes are "*Vega-like*" and we have to convert them to AB magnitudes using the zero points provided on this page:

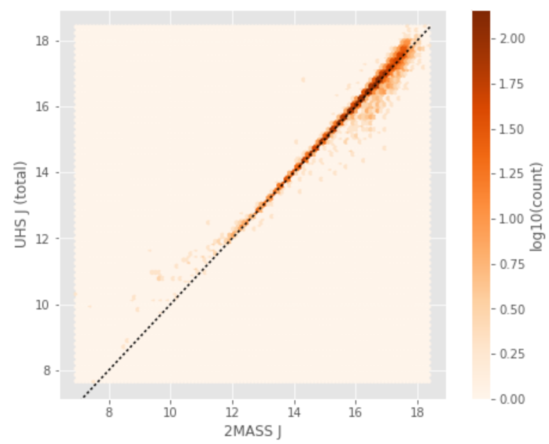
Band	F - 0 mag (Jy)
J	1594
H	1024
Ks	666.7

In addition, UKIDSS uses a K band whereas 2MASS uses a Ks ("short") band, this page give a correction to convert the K band in a Ks band with the formula:

$$K_{s(2MASS)} = K_{UKIRT} + 0.003 + 0.004 * (JK)_{UKIRT}$$

```
UHS J (total) - 2MASS J:
- Median: 0.03
- Median Absolute Deviation: 0.04
- 1% percentile: -0.7433211570646104
- 99% percentile: 0.3831149141023818
```





The graph above originally revealed that UHS needed conversion to AB.

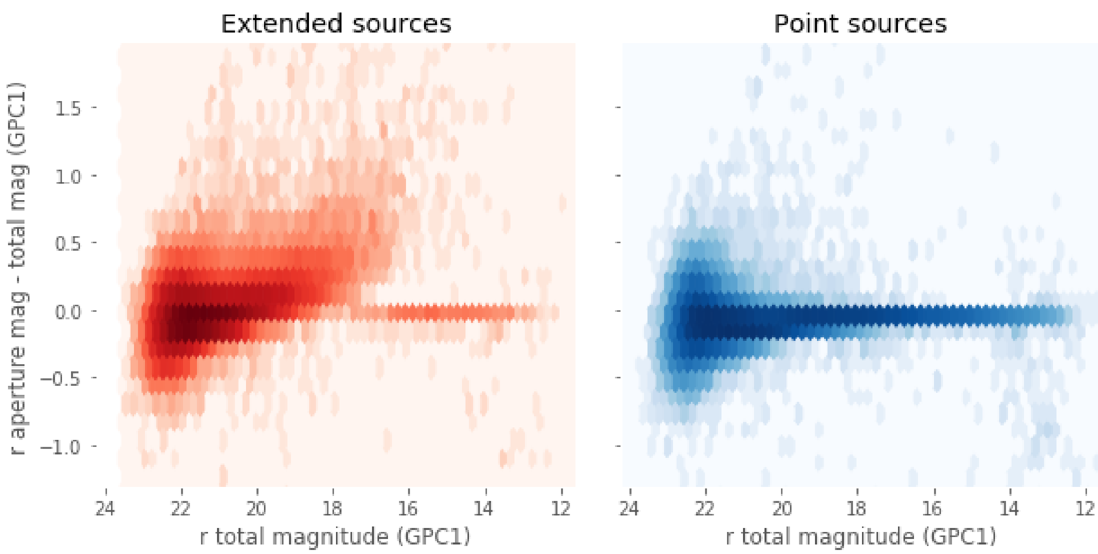
1.6 Keeping only sources with good signal to noise ratio

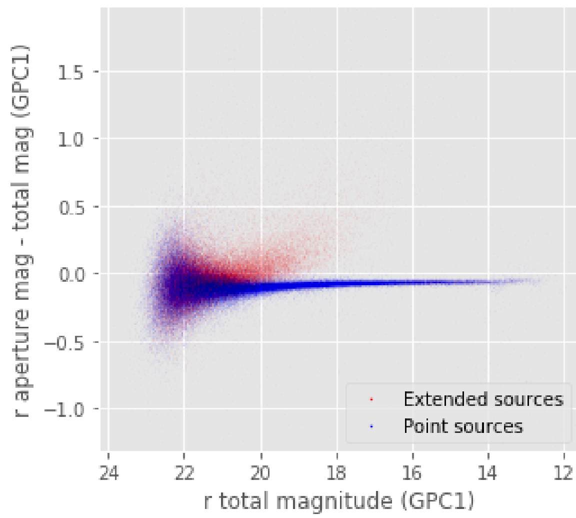
From here, we are only comparing sources with a signal to noise ratio above 3, i.e. roughly we a magnitude error below 0.3.

To make it easier, we are setting to NaN in the catalogue the magnitudes associated with an error above 0.3 so we can't use these magnitudes after the next cell.

1.7 IV - Comparing aperture magnitudes to total ones.

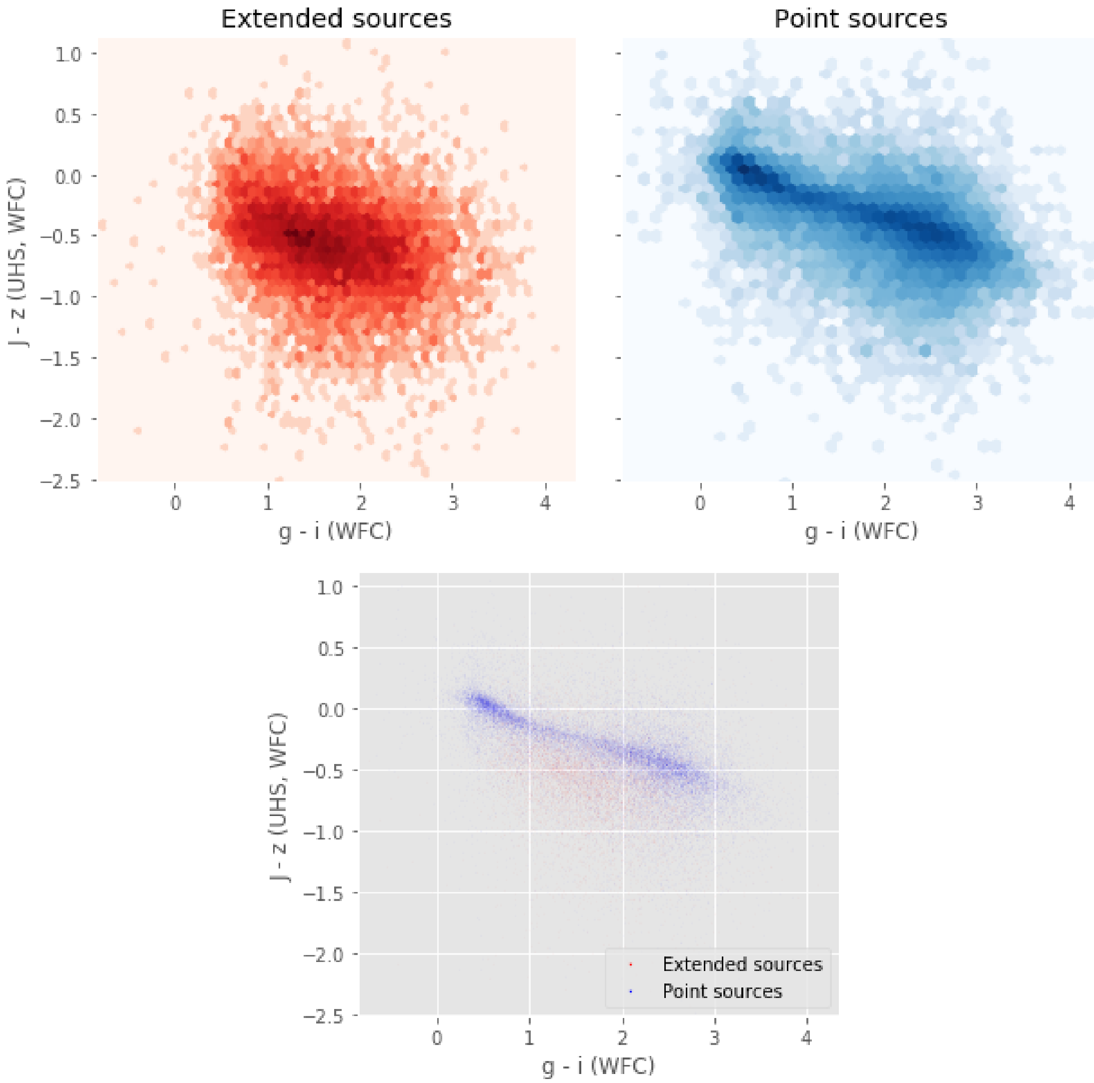
```
Number of source used: 131785 / 977148 (13.49%)
```



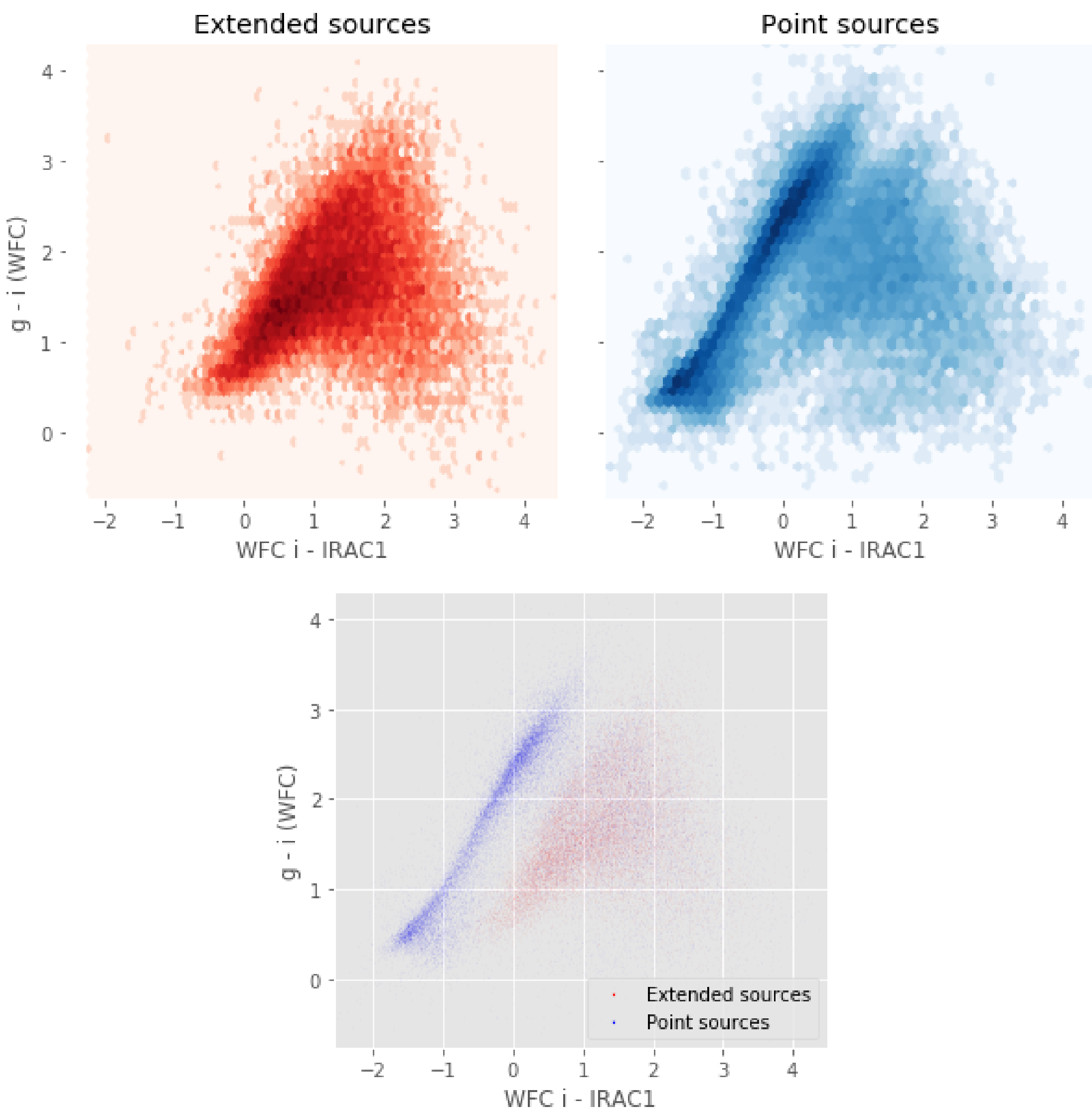


1.8 V - Color-color and magnitude-color plots

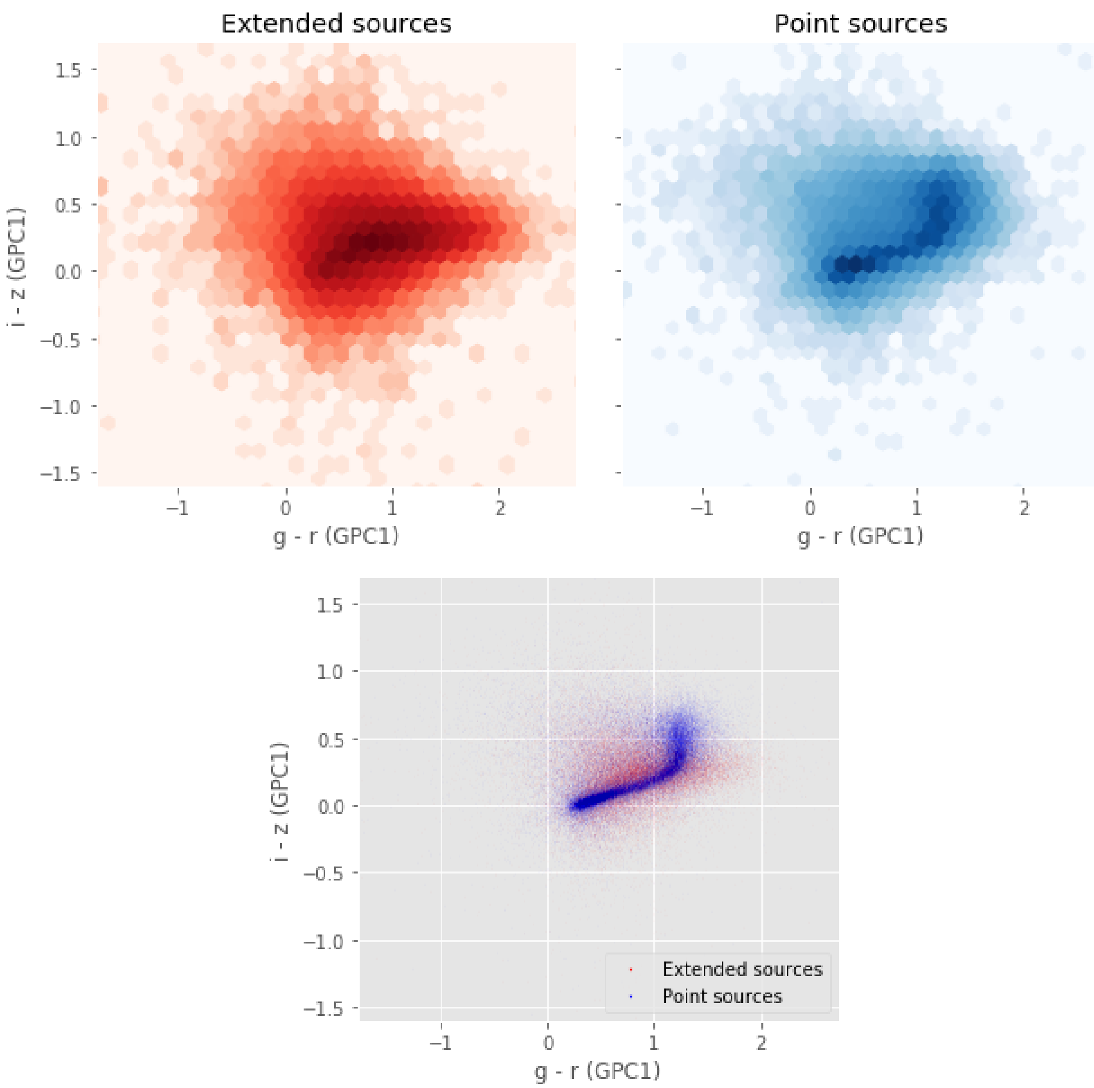
```
Number of source used: 31244 / 977148 (3.20%)
```



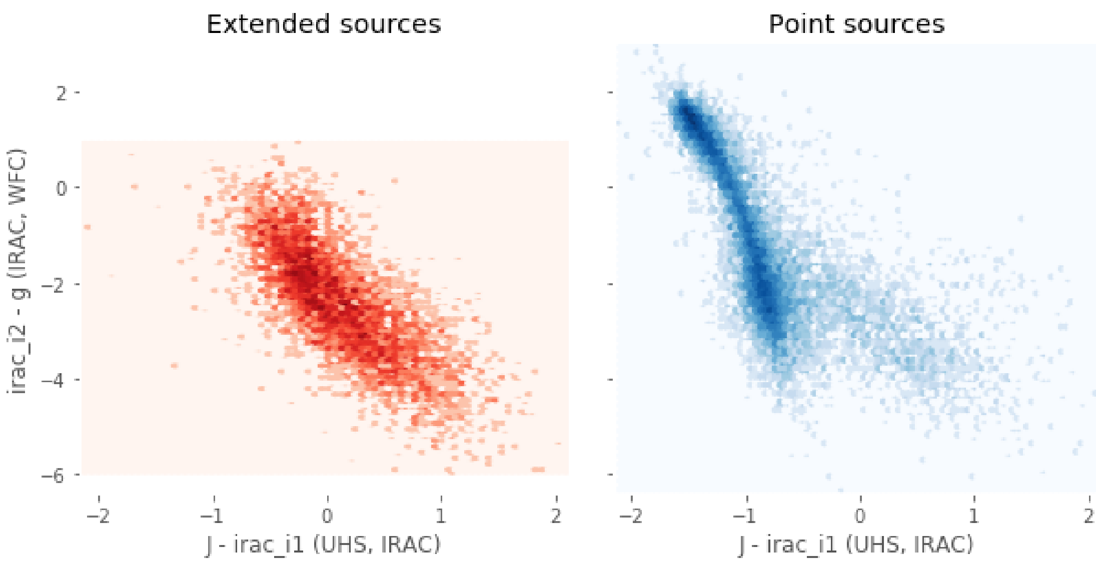
Number of source used: 48841 / 977148 (5.00%)

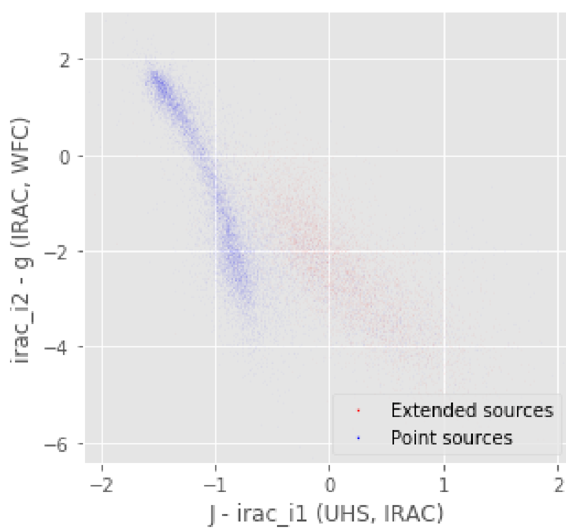


Number of source used: 93631 / 977148 (9.58%)

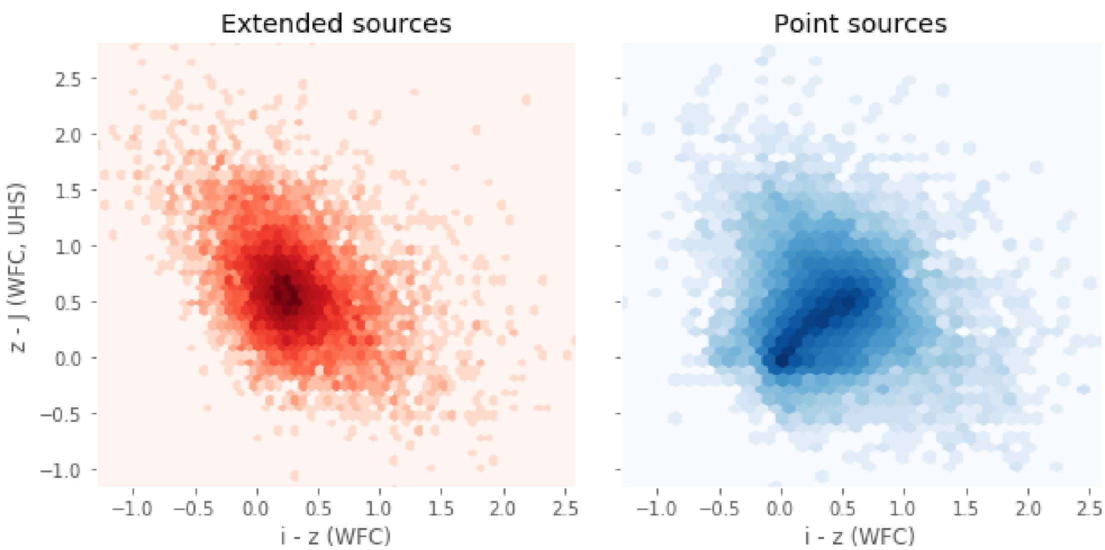


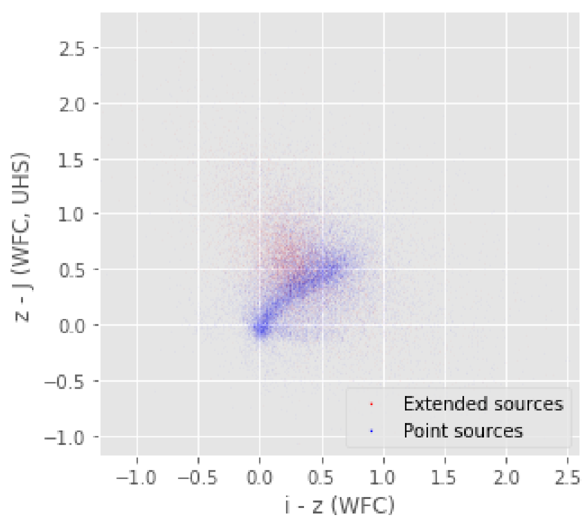
Number of source used: 17883 / 977148 (1.83%)



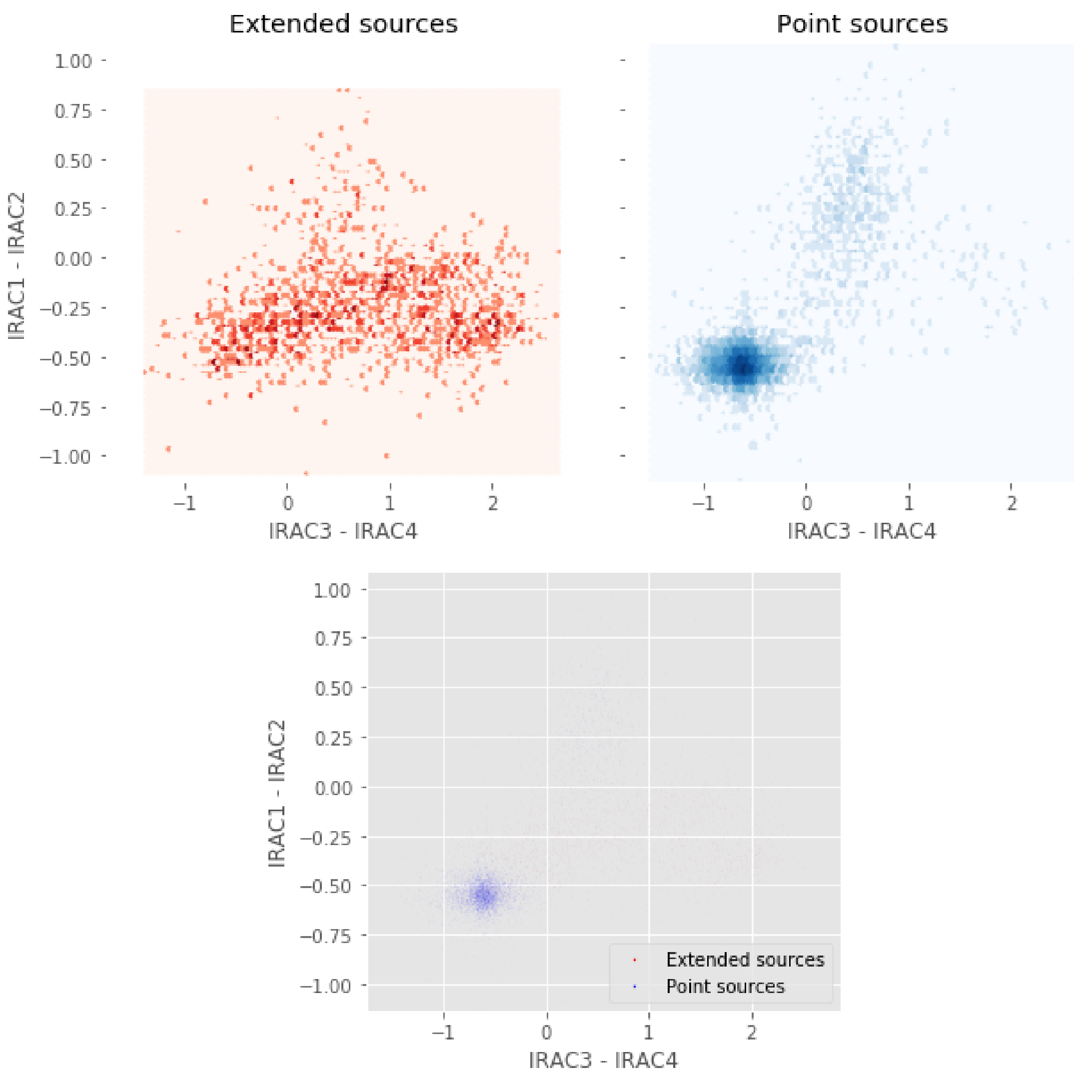



```
Number of source used: 33231 / 977148 (3.40%)
```






```
Number of source used: 6493 / 977148 (0.66%)
```


Extended sources
Point sources
IRAC1 - IRAC2
IRAC3 - IRAC4
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
−1
0
1
2
Extended sources
Point sources

4_Selection_function

March 8, 2018

1 xFLS Selection Functions

1.1 Depth maps and selection functions

The simplest selection function available is the field MOC which specifies the area for which there is Herschel data. Each pristine catalogue also has a MOC defining the area for which that data is available.

The next stage is to provide mean flux standard deviations which act as a proxy for the catalogue's 5σ depth

```
This notebook was run with herschelhelp_internal version:
0246c5d (Thu Jan 25 17:01:47 2018 +0000) [with local modifications]
This notebook was executed on:
2018-02-28 12:39:05.626193
```

```
Depth maps produced using: master_catalogue_xfls_20180221.fits
```

1.2 I - Group masterlist objects by healpix cell and calculate depths

We add a column to the masterlist catalogue for the target order healpix cell per object.

1.3 II Create a table of all Order=13 healpix cells in the field and populate it

We create a table with every order=13 healpix cell in the field MOC. We then calculate the healpix cell at lower order that the order=13 cell is in. We then fill in the depth at every order=13 cell as calculated for the lower order cell that that the order=13 cell is inside.

```
Out[9]: <IPython.core.display.HTML object>
```

```
Out[11]: <IPython.core.display.HTML object>
```

```
Out[12]: <IPython.core.display.HTML object>
```

1.4 III - Save the depth map table

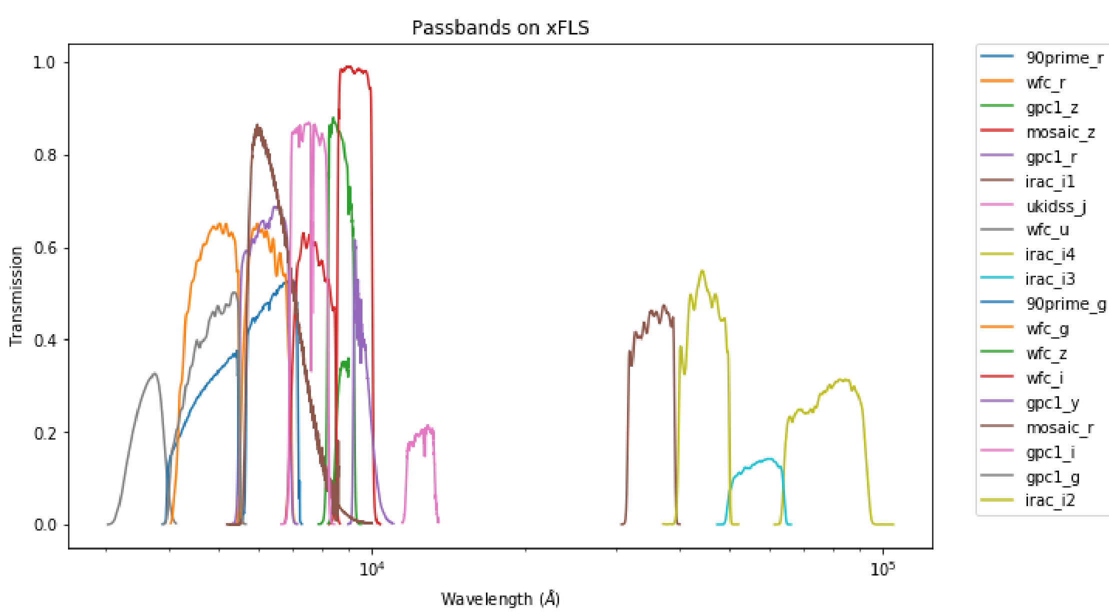
1.5 IV - Overview plots

1.5.1 IV.a - Filters

First we simply plot all the filters available on this field to give an overview of coverage.

```
Out[14]: {'90prime_g',
          '90prime_r',
          'gpc1_g',
          'gpc1_i',
          'gpc1_r',
          'gpc1_y',
          'gpc1_z',
          'irac_i1',
          'irac_i2',
          'irac_i3',
          'irac_i4',
          'mosaic_r',
          'mosaic_z',
          'ukidss_j',
          'wfc_g',
          'wfc_i',
          'wfc_r',
          'wfc_u',
          'wfc_z'}
```

```
Out[15]: <matplotlib.text.Text at 0x7fbf3d3f3550>
```



1.5.2 IV.a - Depth overview

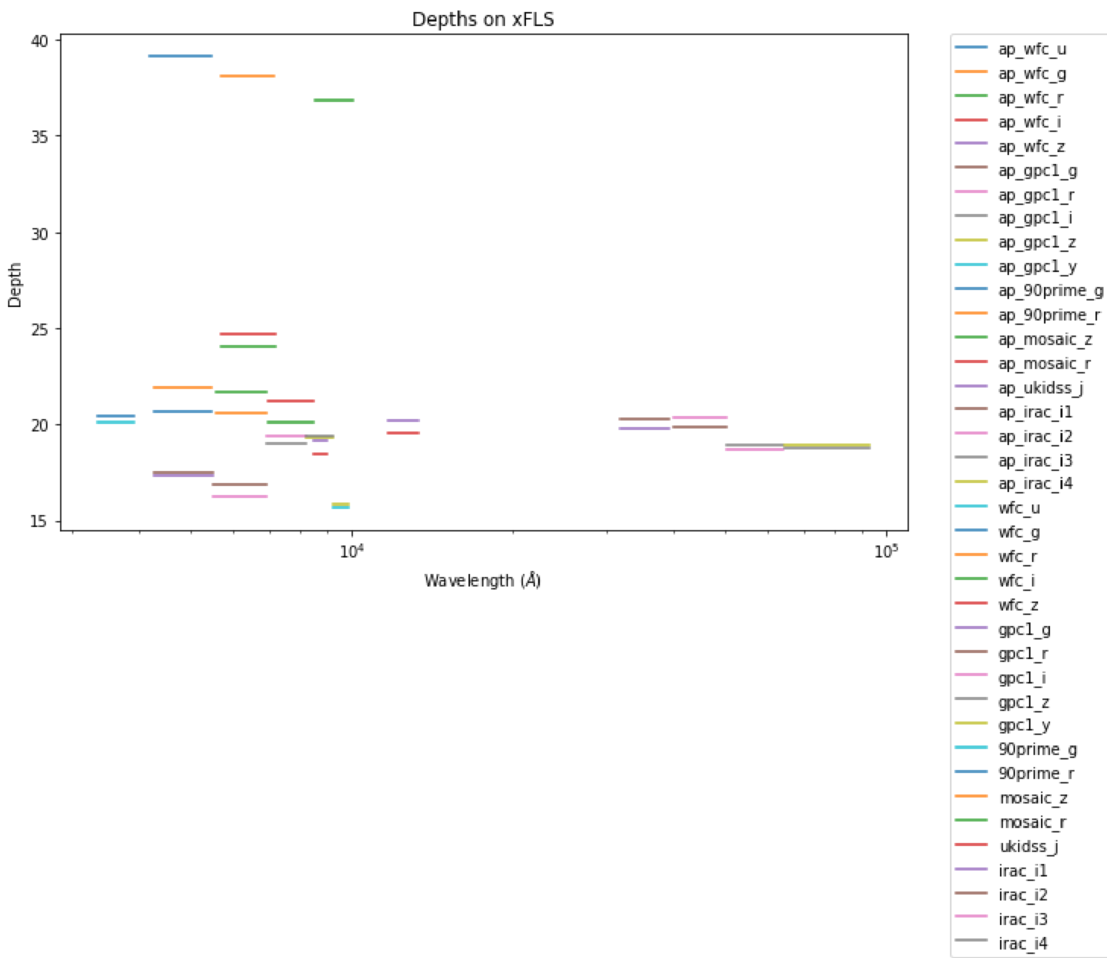
Then we plot the mean depths available across the area a given band is available

```
wfc_u: mean flux error: 5.076475143432617, 3sigma in AB mag (Aperture): 20.943291203110682
wfc_g: mean flux error: 1.23035728931427, 3sigma in AB mag (Aperture): 22.48211874670529
wfc_r: mean flux error: 1.516801118850708, 3sigma in AB mag (Aperture): 22.254875262334885
wfc_i: mean flux error: 2.441751480102539, 3sigma in AB mag (Aperture): 21.737943214089093
wfc_z: mean flux error: 16.176753997802734, 3sigma in AB mag (Aperture): 19.684968410286665
gpc1_g: mean flux error: 75.78848761741543, 3sigma in AB mag (Aperture): 18.00818876152001
gpc1_r: mean flux error: 228.4292055023892, 3sigma in AB mag (Aperture): 16.810317790080028
gpc1_i: mean flux error: 17.959658020702886, 3sigma in AB mag (Aperture): 19.571451706250095
gpc1_z: mean flux error: 13.87429992907835, 3sigma in AB mag (Aperture): 19.851669166526428
gpc1_y: mean flux error: 381.5910077390603, 3sigma in AB mag (Aperture): 16.253201533388783
90prime_g: mean flux error: 1.613032623026811e-07, 3sigma in AB mag (Aperture): 39.6880889858672
90prime_r: mean flux error: 4.0440616544401564e-07, 3sigma in AB mag (Aperture): 38.690152442998
mosaic_z: mean flux error: 1.2728158935715328e-06, 3sigma in AB mag (Aperture): 37.4452828890005
mosaic_r: mean flux error: 0.09364917874336243, 3sigma in AB mag (Aperture): 25.278436930246507
ukidss_j: mean flux error: 6.114259243011475, 3sigma in AB mag (Aperture): 20.74133724131527
irac_i1: mean flux error: 5.836461942838672, 3sigma in AB mag (Aperture): 20.791822718167218
irac_i2: mean flux error: 5.440669724080579, 3sigma in AB mag (Aperture): 20.86806595606469
irac_i3: mean flux error: 19.904765159686086, 3sigma in AB mag (Aperture): 19.459804218053172
irac_i4: mean flux error: 19.47866972636668, 3sigma in AB mag (Aperture): 19.48329862843388
wfc_u: mean flux error: 6.4852681159973145, 3sigma in AB mag (Total): 20.67737702437453
wfc_g: mean flux error: 4.083687782287598, 3sigma in AB mag (Total): 21.179565536282745
wfc_r: mean flux error: 4.159158640675417, 3sigma in AB mag (Total): 21.159683148814132
wfc_i: mean flux error: 6.607170367913834, 3sigma in AB mag (Total): 20.65715809977815
wfc_z: mean flux error: 30.17353630065918, 3sigma in AB mag (Total): 19.008131333382998
gpc1_g: mean flux error: 84.62049680255278, 3sigma in AB mag (Total): 17.888507936392934
gpc1_r: mean flux error: 128.69759763001056, 3sigma in AB mag (Total): 17.433270762951686
gpc1_i: mean flux error: 13.21199952632183, 3sigma in AB mag (Total): 19.90477548957835
gpc1_z: mean flux error: 12.957271263727522, 3sigma in AB mag (Total): 19.925912985884928
gpc1_y: mean flux error: 342.9716913139146, 3sigma in AB mag (Total): 16.3690511754374
90prime_g: mean flux error: inf, 3sigma in AB mag (Total): -inf
90prime_r: mean flux error: inf, 3sigma in AB mag (Total): -inf
mosaic_z: mean flux error: inf, 3sigma in AB mag (Total): -inf
mosaic_r: mean flux error: 0.17217998206615448, 3sigma in AB mag (Total): 24.617240217583863
ukidss_j: mean flux error: 10.784326553344727, 3sigma in AB mag (Total): 20.125214288236343
irac_i1: mean flux error: 8.666832274512162, 3sigma in AB mag (Total): 20.362545883374985
irac_i2: mean flux error: 8.406512976134104, 3sigma in AB mag (Total): 20.39565714399904
irac_i3: mean flux error: 24.813720996072533, 3sigma in AB mag (Total): 19.22046712635251
irac_i4: mean flux error: 23.015498675270777, 3sigma in AB mag (Total): 19.30214589029726
```

```
ap_wfc_u (3355.0, 3925.0, 570.0)
ap_wfc_g (4260.0, 5485.0, 1225.0)
ap_wfc_r (5575.0, 6910.0, 1335.0)
ap_wfc_i (6970.0, 8485.0, 1515.0)
ap_wfc_z (8500.0, 9000.0, 500.0)
```

```
ap_gpc1_g (4260.0, 5500.0, 1240.0)
ap_gpc1_r (5500.0, 6900.0, 1400.0)
ap_gpc1_i (6910.0, 8190.0, 1280.0)
ap_gpc1_z (8190.0, 9210.0, 1020.0)
ap_gpc1_y (9200.0, 9820.0, 620.0)
ap_90prime_g (4180.0, 5470.0, 1290.0)
ap_90prime_r (5680.0, 7150.0, 1470.0)
ap_mosaic_z (8552.0, 10018.0, 1466.0)
ap_mosaic_r (5692.0, 7176.0, 1484.0)
ap_ukidss_j (11695.0, 13280.0, 1585.0)
ap_irac_i1 (31754.0, 39164.801, 7410.8008)
ap_irac_i2 (39980.102, 50052.301, 10072.199)
ap_irac_i3 (50246.301, 64096.699, 13850.398)
ap_irac_i4 (64415.199, 92596.797, 28181.598)
wfc_u (3355.0, 3925.0, 570.0)
wfc_g (4260.0, 5485.0, 1225.0)
wfc_r (5575.0, 6910.0, 1335.0)
wfc_i (6970.0, 8485.0, 1515.0)
wfc_z (8500.0, 9000.0, 500.0)
gpc1_g (4260.0, 5500.0, 1240.0)
gpc1_r (5500.0, 6900.0, 1400.0)
gpc1_i (6910.0, 8190.0, 1280.0)
gpc1_z (8190.0, 9210.0, 1020.0)
gpc1_y (9200.0, 9820.0, 620.0)
90prime_g (4180.0, 5470.0, 1290.0)
90prime_r (5680.0, 7150.0, 1470.0)
mosaic_z (8552.0, 10018.0, 1466.0)
mosaic_r (5692.0, 7176.0, 1484.0)
ukidss_j (11695.0, 13280.0, 1585.0)
irac_i1 (31754.0, 39164.801, 7410.8008)
irac_i2 (39980.102, 50052.301, 10072.199)
irac_i3 (50246.301, 64096.699, 13850.398)
irac_i4 (64415.199, 92596.797, 28181.598)
```

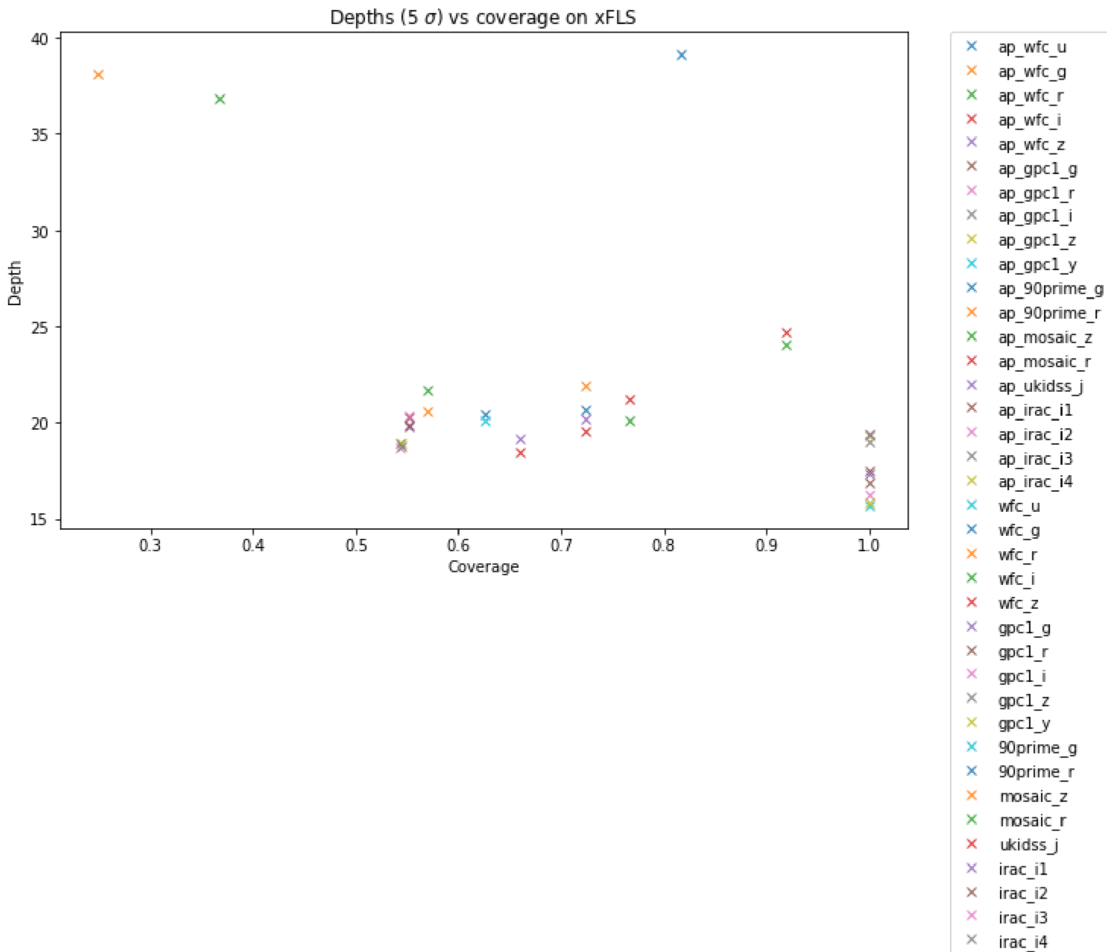
```
Out[20]: <matplotlib.text.Text at 0x7fbf3b46f5f8>
```



1.5.3 IV.c - Depth vs coverage comparison

How best to do this? Colour/intensity plot over area? Percentage coverage vs mean depth?

```
Out[21]: <matplotlib.text.Text at 0x7fbf3b292ef0>
```


Depths (5 σ) vs coverage on xFLS
Depth
Coverage
40
35
30
25
20
15
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
ap_wfc_u
ap_wfc_g
ap_wfc_r
ap_wfc_i
ap_wfc_z
ap_gpc1_g
ap_gpc1_r
ap_gpc1_i
ap_gpc1_z
ap_gpc1_y
ap_90prime_g
ap_90prime_r
ap_mosaic_z
ap_mosaic_r
ap_ukidss_j
ap_irac_i1
ap_irac_i2
ap_irac_i3
ap_irac_i4
wfc_u
wfc_g
wfc_r
wfc_i
wfc_z
gpc1_g
gpc1_r
gpc1_i
gpc1_z
gpc1_y
90prime_g
90prime_r
mosaic_z
mosaic_r
ukidss_j
irac_i1
irac_i2
irac_i3
irac_i4