1.1_PanSTARRS

March 8, 2018

1 SPIRE-NEP 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).

```
This notebook was run with herschelhelp_internal version:
04829ed (Thu Nov 2 16:57:19 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

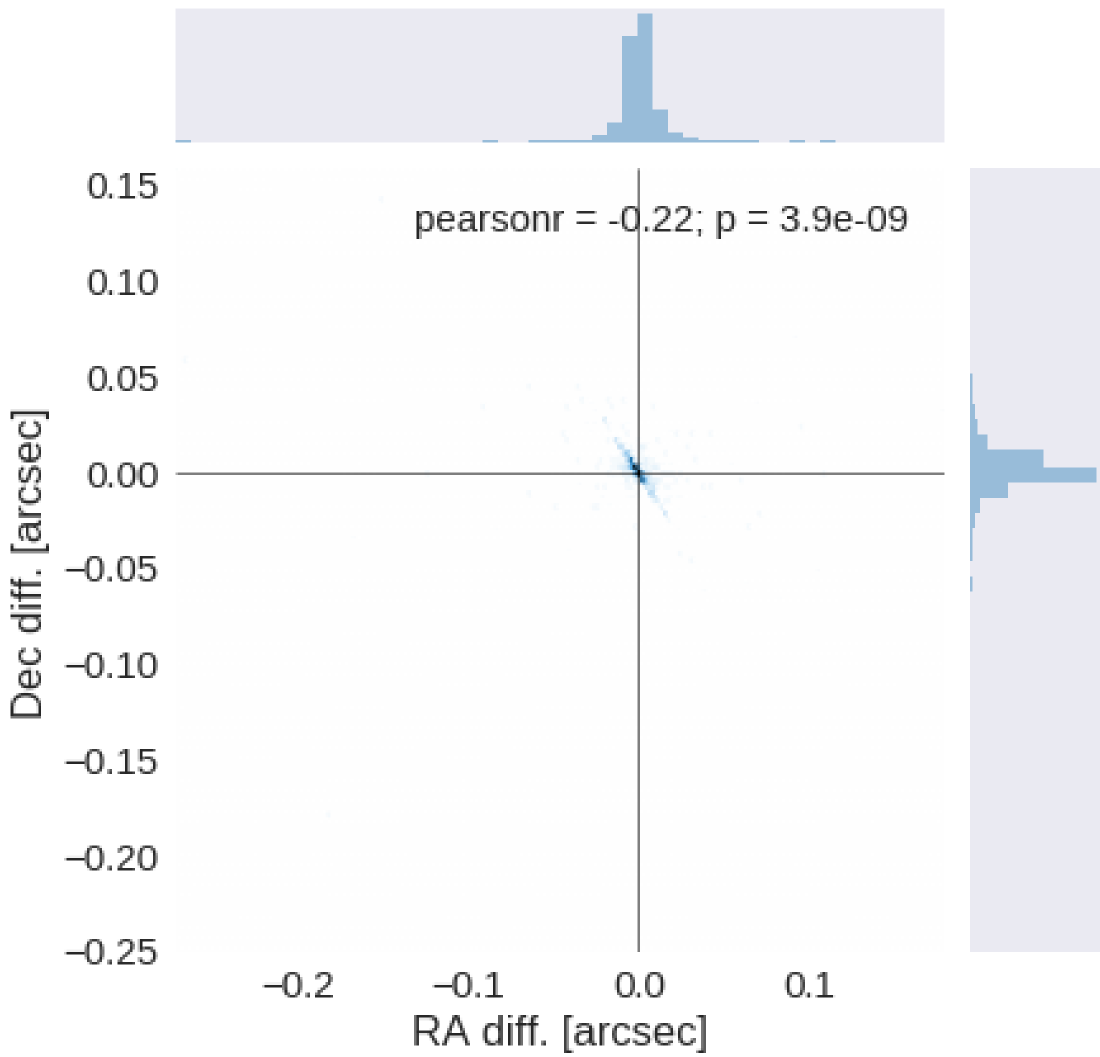
We remove duplicated objects from the input catalogues.

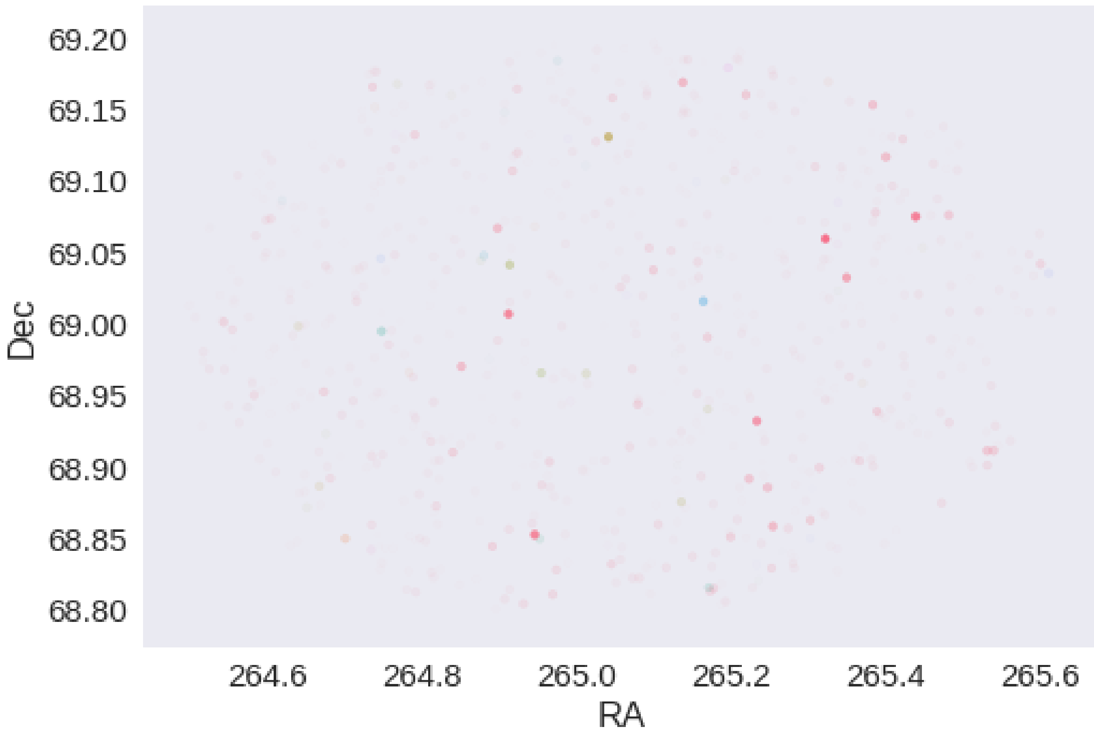
```
/opt/anaconda3/envs/herschelhelp_internal/lib/python3.6/site-packages/astropy/table/column.py:10
Check the NumPy 1.11 release notes for more information.
  ma.MaskedArray.__setitem__(self, index, value)
```

```
The initial catalogue had 2675 sources.
The cleaned catalogue has 2674 sources (1 removed).
The cleaned catalogue has 1 sources flagged as having been cleaned
```

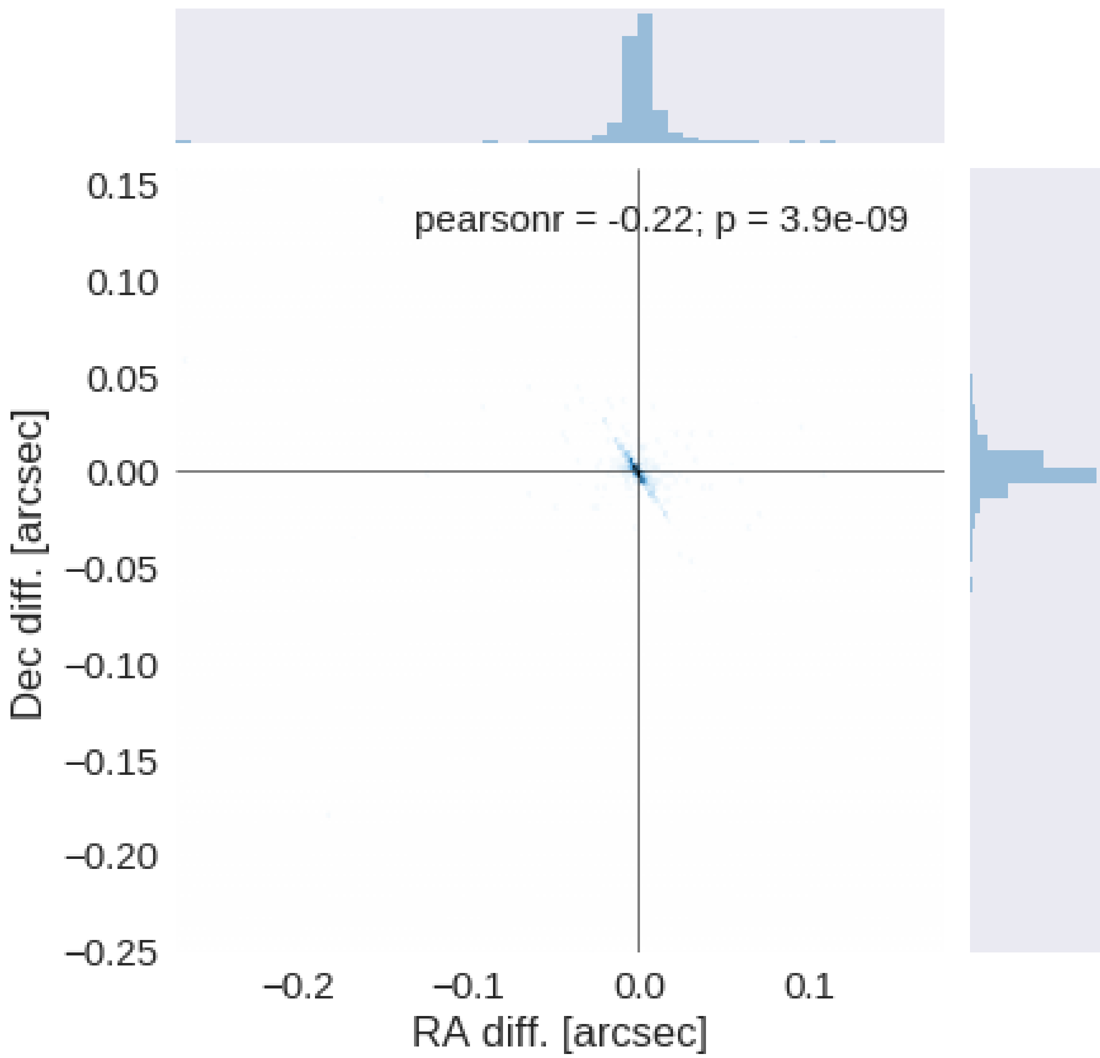
1.4 III - Astrometry correction

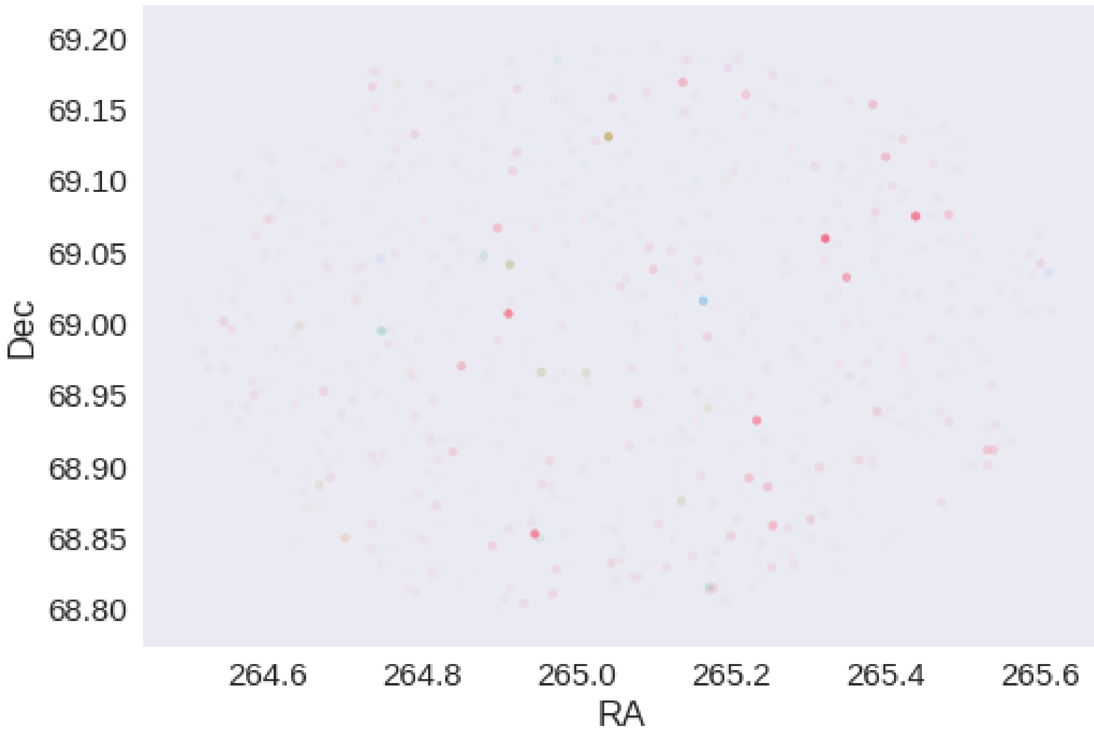
We match the astrometry to the Gaia one. We limit the Gaia catalogue to sources with a g band flux between the 30th and the 70th percentile. Some quick tests show that this give the lower dispersion in the results.






```
RA correction: -0.00015501241250603925 arcsec
Dec correction: -0.0003735176392183348 arcsec
```


pearsonr = -0.22; p = 3.9e-09
0.15
0.10
0.05
0.00
−0.05
−0.10
−0.15
−0.20
−0.25
Dec diff. [arcsec]
−0.2
−0.1
0.0
0.1
RA diff. [arcsec]



1.5 IV - Flagging Gaia objects

```
730 sources flagged.
```

1.6 V - Flagging objects near bright stars

2 VI - Saving to disk

2_Merging

March 8, 2018

1 SPIRE-NEP master catalogue

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

```
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:
2018-02-20 16:17:05.784701
```

1.1 I - Reading the prepared pristine catalogues

1.2 II - Merging tables

We first merge the optical catalogues and then add the infrared ones: DECaLS, HSC, KIDS, PanSTARRS, UKIDSS-LAS, and VISTA-VIKING.

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 DECaLS

1.2.2 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[7]: <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.

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

We only have PanSTARRS on SPIRE-NEP

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 catalogue. 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?**

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

```
['ps1_id', 'help_id', 'specz_id', 'sdss_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 SPIRE-NEP master catalogue

1.1 Checks and diagnostics

```
This notebook was run with herschelhelp_internal version:
0246c5d (Thu Jan 25 17:01:47 2018 +0000) [with local modifications]
```

```
Diagnostics done using: master_catalogue_spire-nep_20180220.fits
```

1.2 0 - Quick checks

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

```
/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)
```

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

1.3 I - Summary of wavelength domains

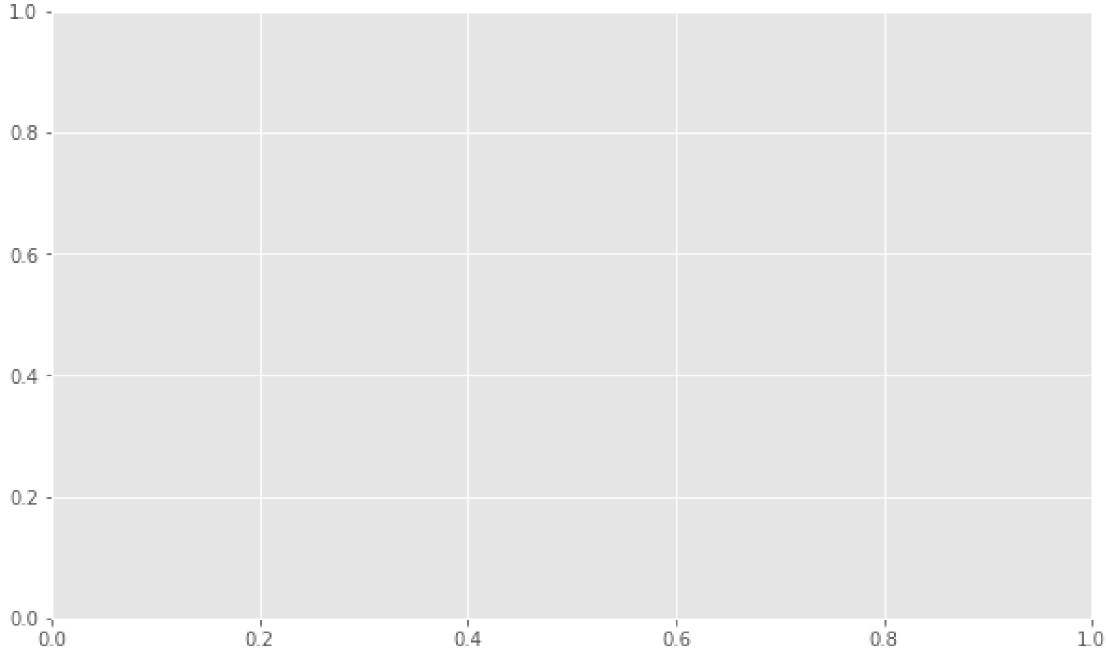
1.4 II - Comparing magnitudes in similar filters

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.

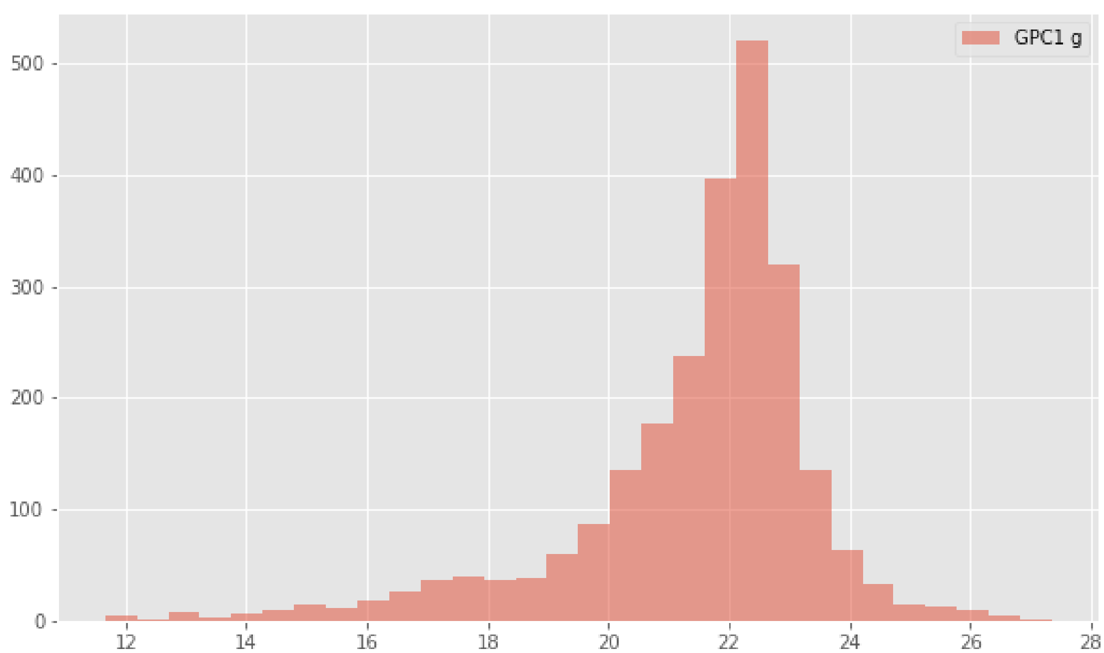
1.4.1 II.a - Comparing depths

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

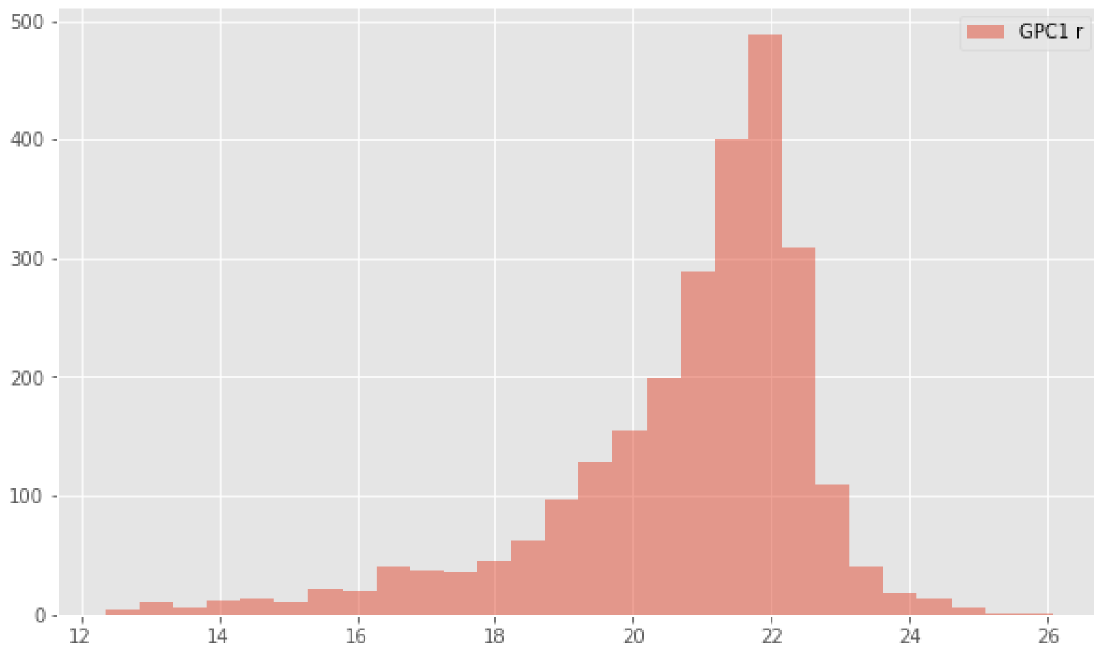
```
/opt/anaconda3/envs/herschelhelp_internal/lib/python3.6/site-packages/matplotlib/axes/_axes.py:5
  warnings.warn("No labelled objects found. "
```

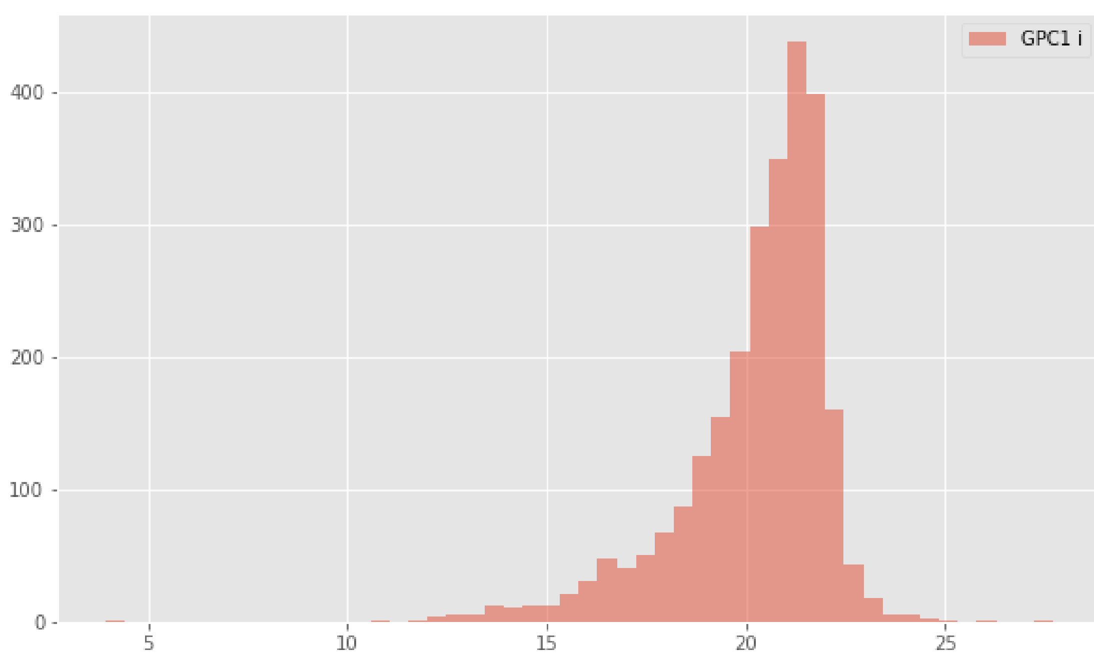


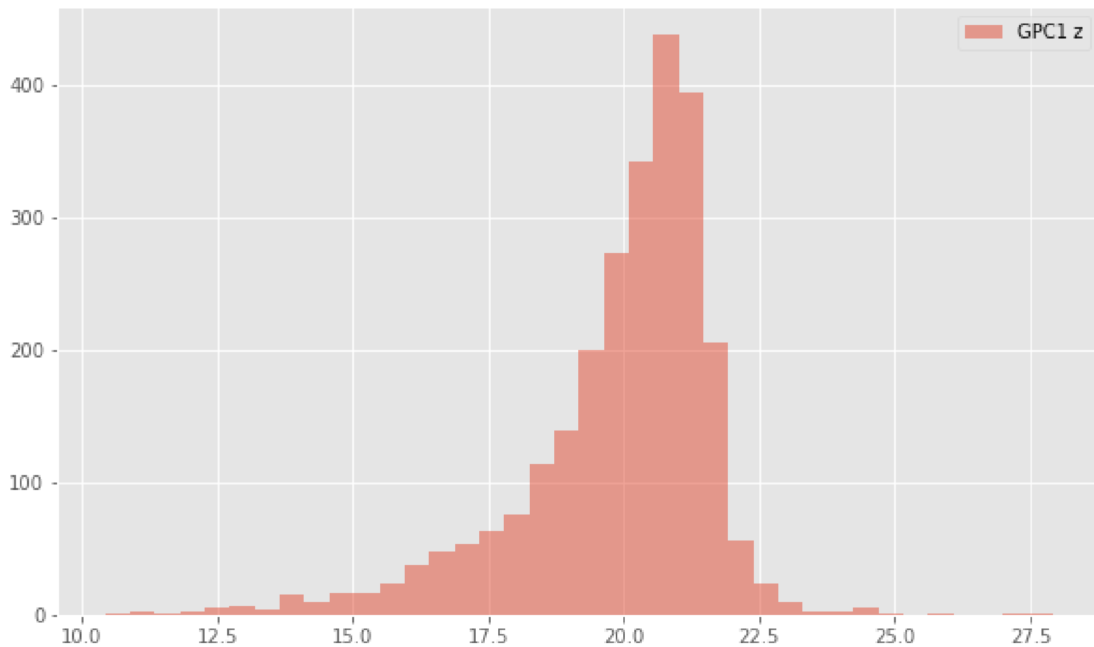
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0

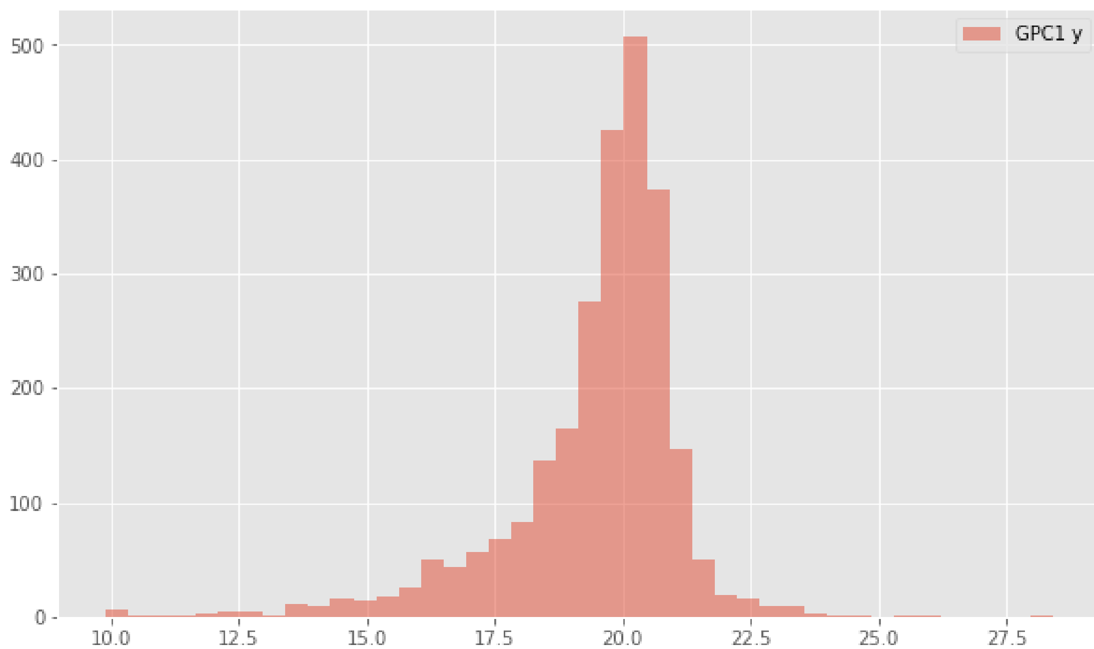


GPC1 g
500
400
300
200
100
0
12
14
16
18
20
22
24
26
28


GPC1 r


GPC1 i





1.4.2 II.b - Comparing magnitudes

We compare one to one each magnitude in similar bands.

1.5 III - Comparing magnitudes to reference bands

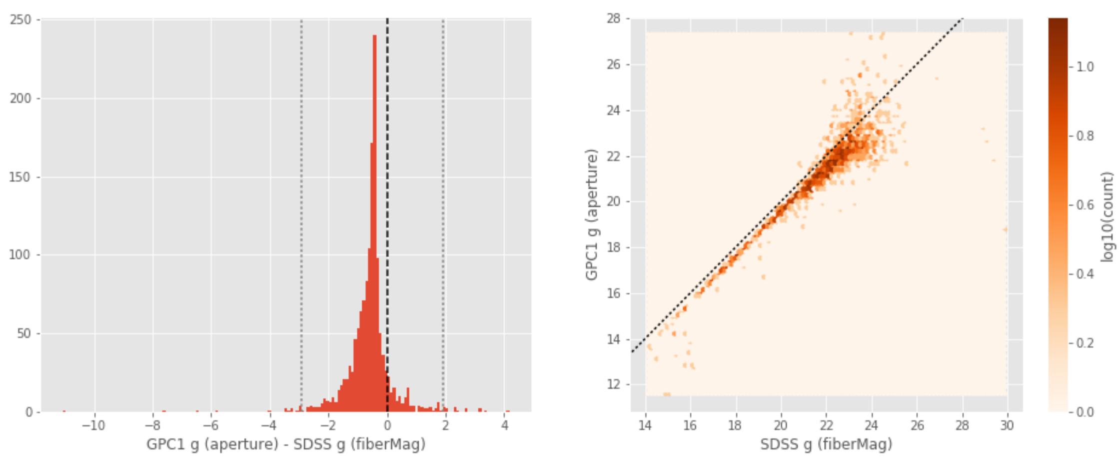
Cross-match the master list to SDSS to compare magnitudes.

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

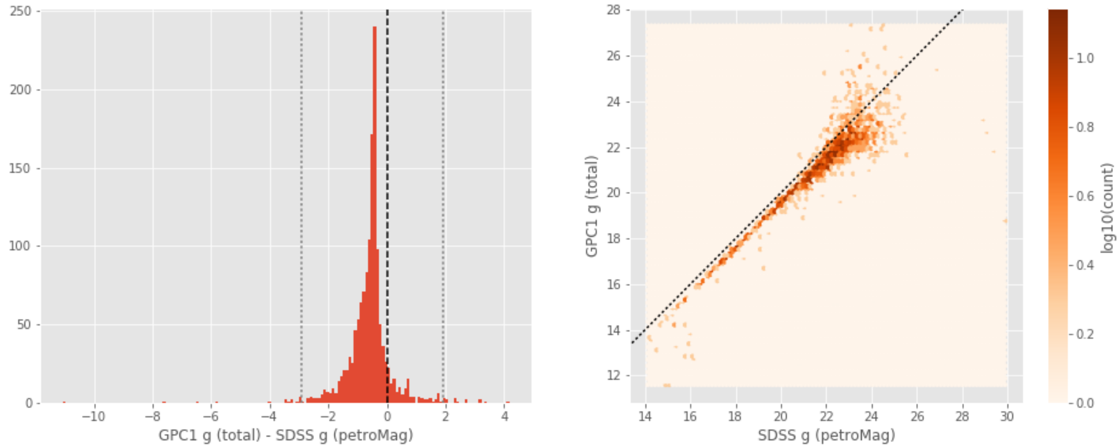
The catalogue is cross-matched to SDSS-DR13 withing 0.2 arcsecond.

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.

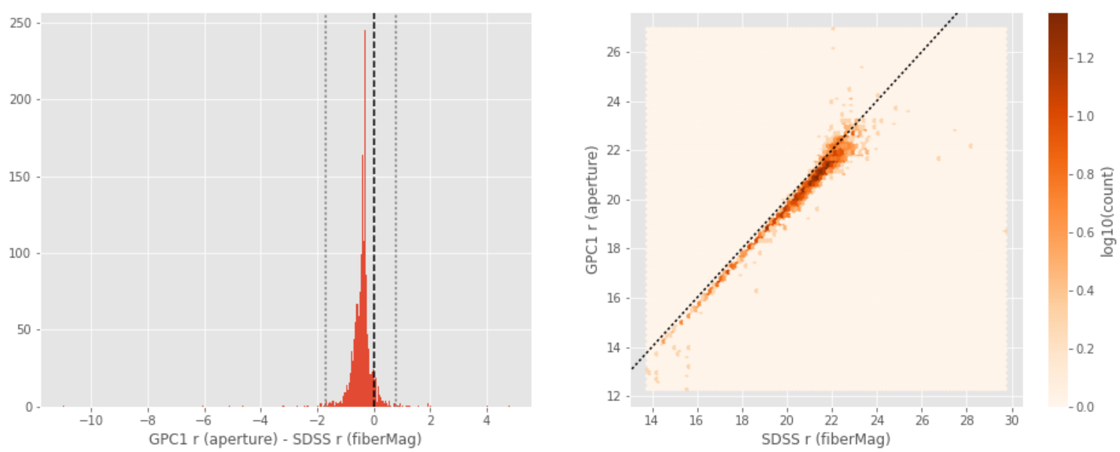
```
GPC1 g (aperture) - SDSS g (fiberMag):
- Median: -0.51
- Median Absolute Deviation: 0.23
- 1% percentile: -2.928476228713989
- 99% percentile: 1.917575302124025
```



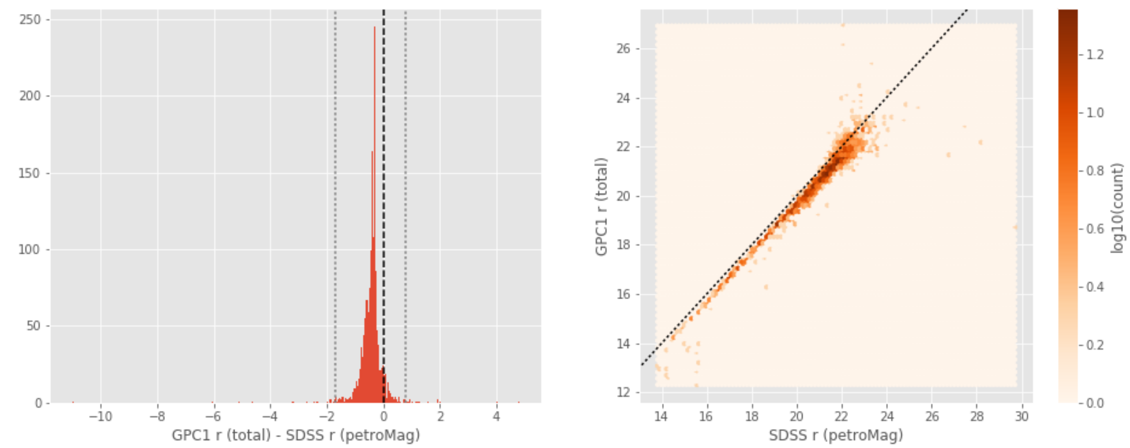

```
GPC1 g (total) - SDSS g (petroMag):
- Median: -0.51
- Median Absolute Deviation: 0.23
- 1% percentile: -2.928476228713989
- 99% percentile: 1.917575302124025
```



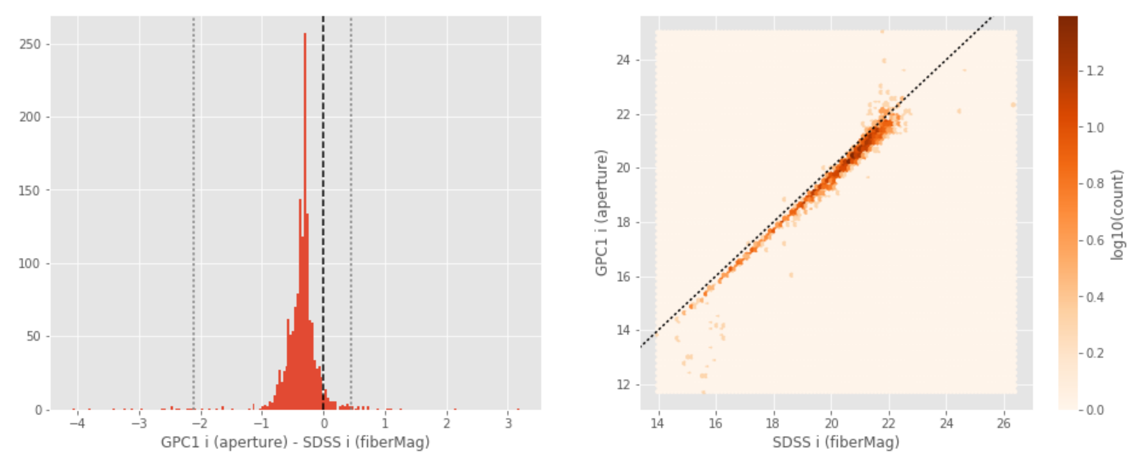
GPC1 r (aperture) - SDSS r (fiberMag):
- Median: -0.38
- Median Absolute Deviation: 0.12
- 1% percentile: -1.6758414459228517
- 99% percentile: 0.773529739379882



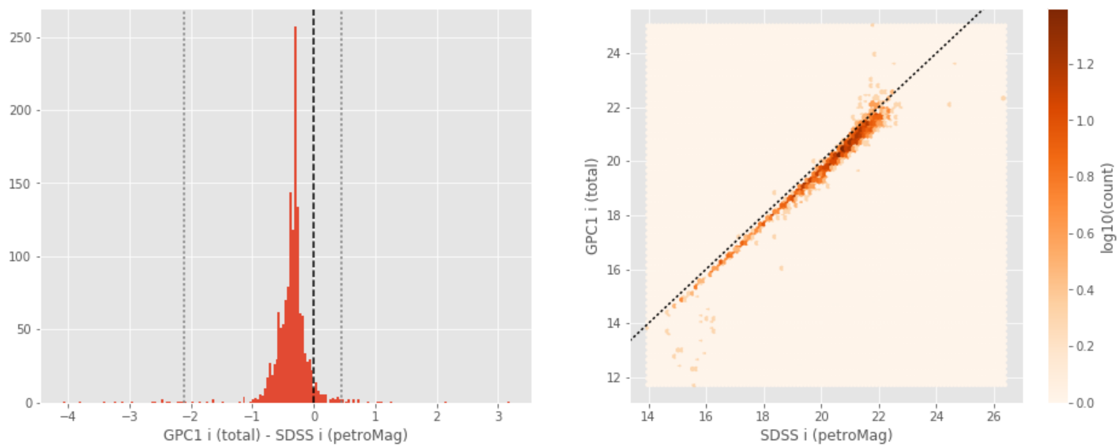
GPC1 r (total) - SDSS r (petroMag):
- Median: -0.38
- Median Absolute Deviation: 0.12
- 1% percentile: -1.6758414459228517
- 99% percentile: 0.773529739379882



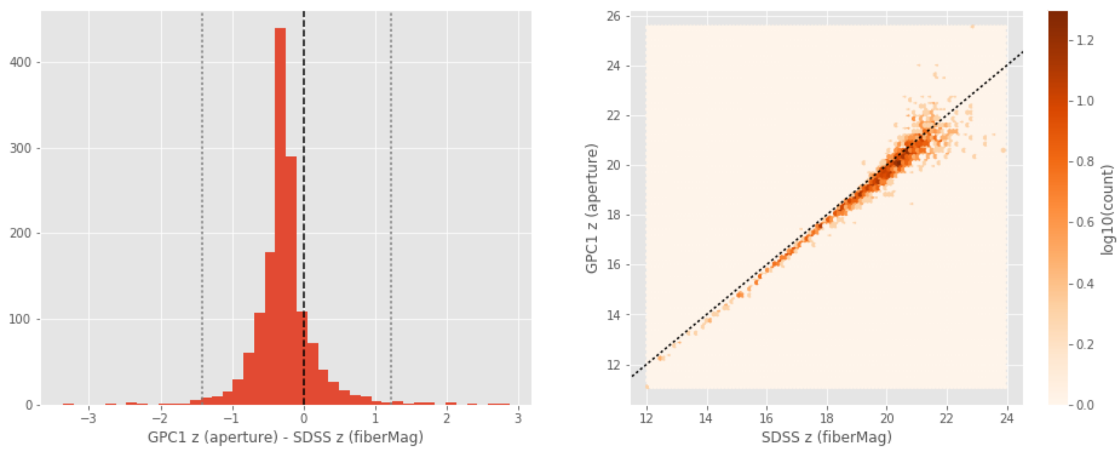
GPC1 i (aperture) - SDSS i (fiberMag):
- Median: -0.33
- Median Absolute Deviation: 0.09
- 1% percentile: -2.1108423233032223
- 99% percentile: 0.45564216613769587



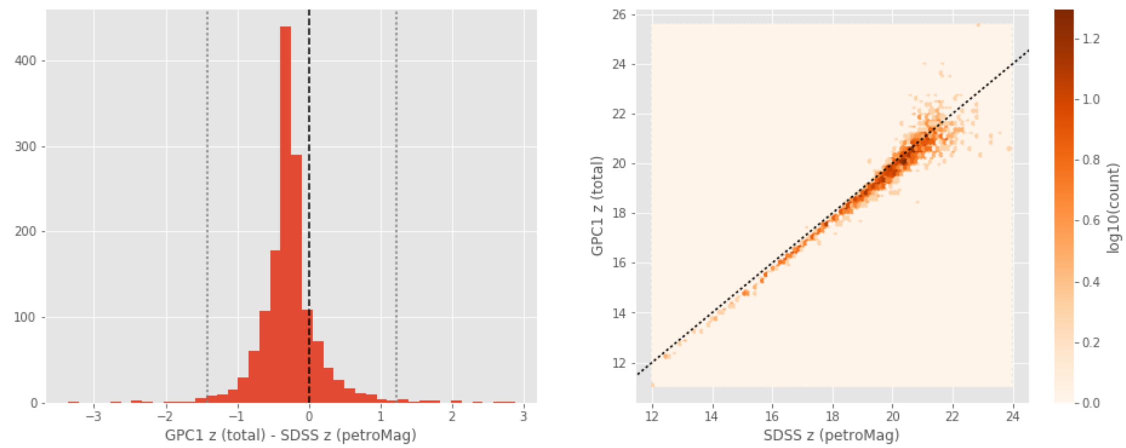
GPC1 i (total) - SDSS i (petroMag):
- Median: -0.33
- Median Absolute Deviation: 0.09
- 1% percentile: -2.1108423233032223
- 99% percentile: 0.45564216613769587



GPC1 z (aperture) - SDSS z (fiberMag):
- Median: -0.28
- Median Absolute Deviation: 0.14
- 1% percentile: -1.4216452217102051
- 99% percentile: 1.2256657981872567

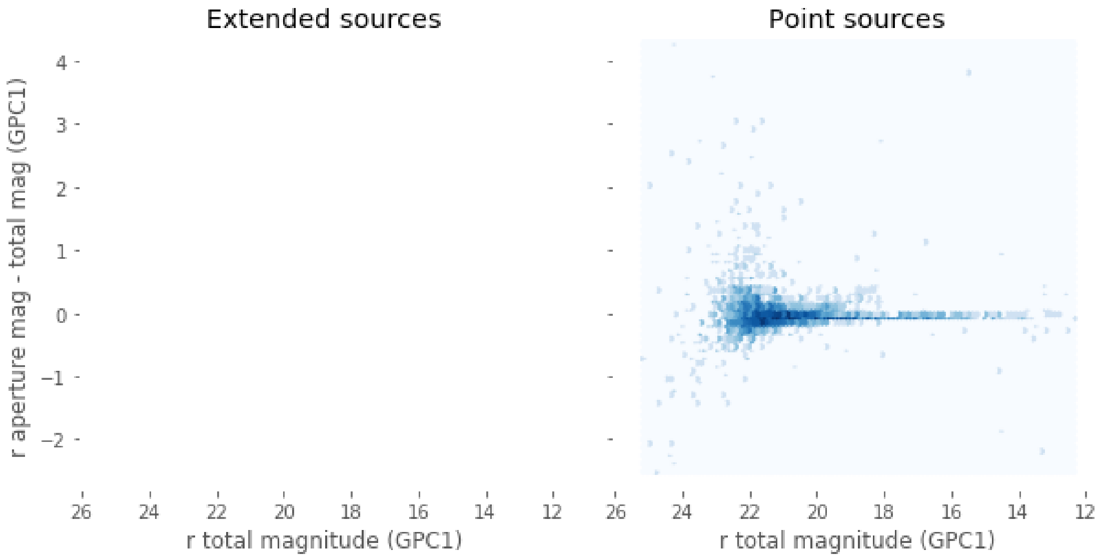


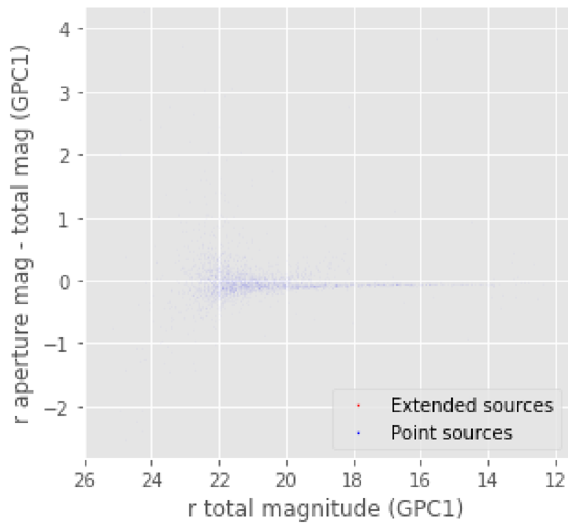
GPC1 z (total) - SDSS z (petroMag):
- Median: -0.28
- Median Absolute Deviation: 0.14
- 1% percentile: -1.4216452217102051
- 99% percentile: 1.2256657981872567



1.6 IV - Comparing aperture magnitudes to total ones.

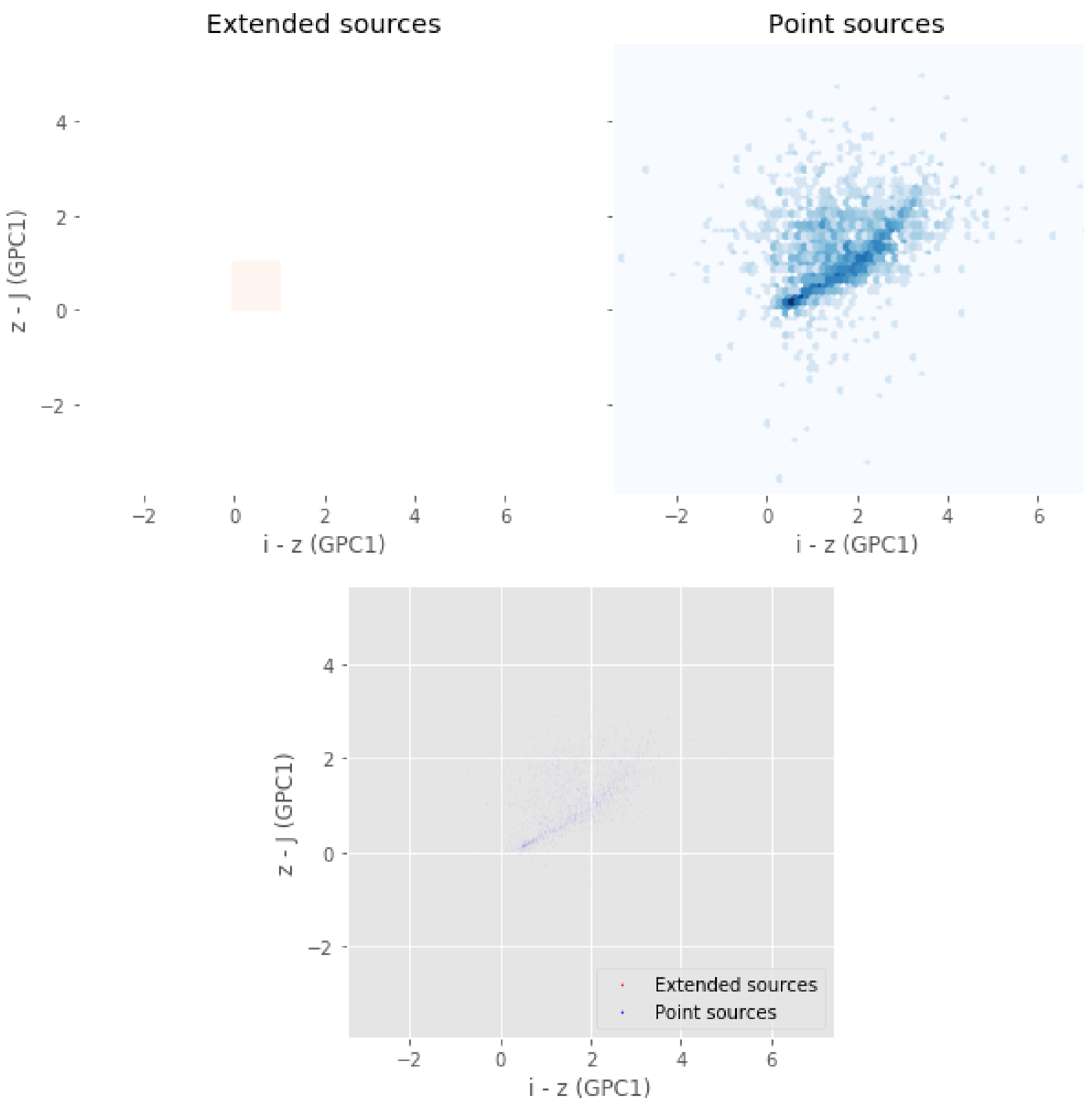
```
Number of source used: 2555 / 2674 (95.55%)
```





1.7 V - Color-color and magnitude-color plots

Number of source used: 2284 / 2674 (85.42%)


Extended sources
Point sources
z - J (GPC1)
i - z (GPC1)
Extended sources
Point sources

4_Selection_function

March 8, 2018

1 SPIRE-NEP 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 11:55:05.637481
```

```
Depth maps produced using: master_catalogue_spire-nep_20180220.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

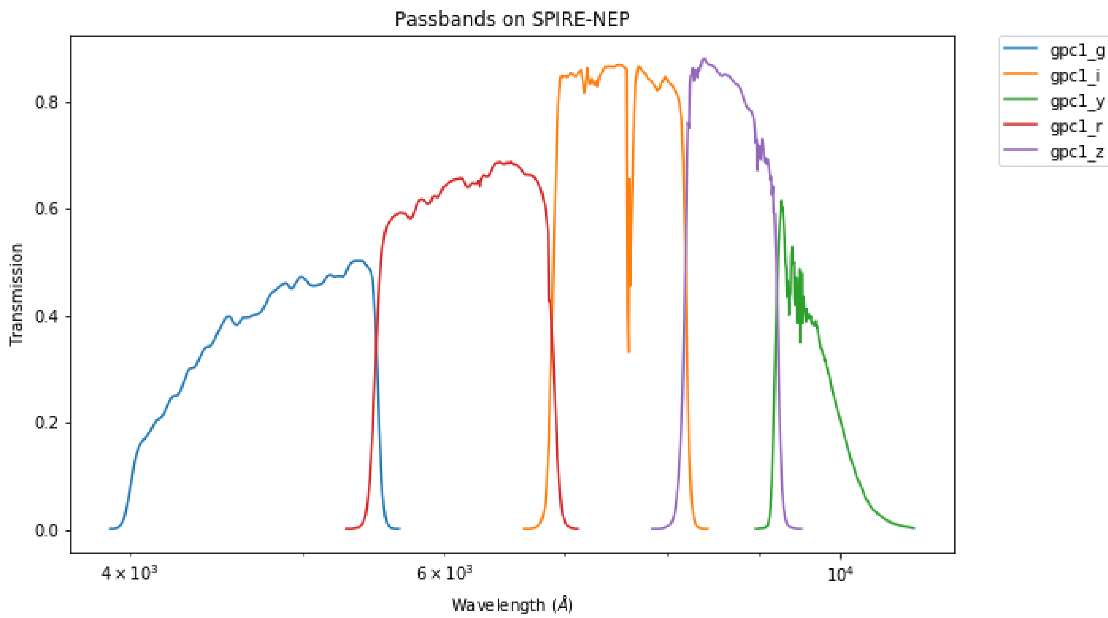
1.5 IV - Overview plots

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]: {'gpc1_g', 'gpc1_i', 'gpc1_r', 'gpc1_y', 'gpc1_z'}
```

```
Out[15]: <matplotlib.text.Text at 0x7fb85c6aa198>
```



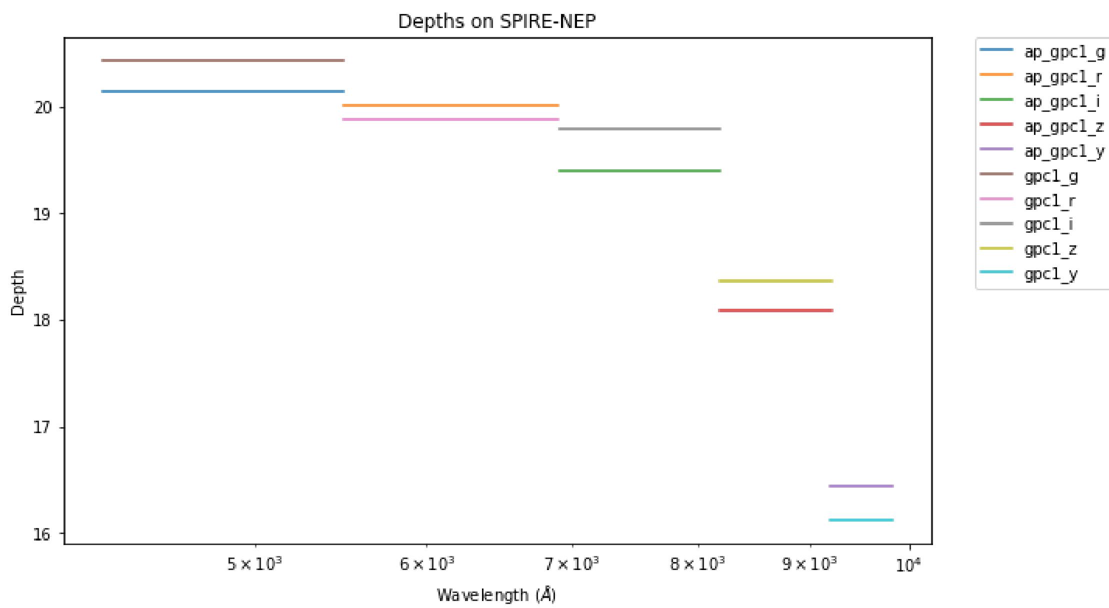
1.5.2 IV.a - Depth overview

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

```
gpc1_g: mean flux error: 6.372303632080981, 3sigma in AB mag (Aperture): 20.696455710210323
gpc1_r: mean flux error: 7.150938523058798, 3sigma in AB mag (Aperture): 20.571289252181693
gpc1_i: mean flux error: 12.640365490473433, 3sigma in AB mag (Aperture): 19.95279778430784
gpc1_z: mean flux error: 42.40776459072416, 3sigma in AB mag (Aperture): 18.6385834121565
gpc1_y: mean flux error: 192.4135309381138, 3sigma in AB mag (Aperture): 16.99660783992956
gpc1_g: mean flux error: 4.845005096679113, 3sigma in AB mag (Total): 20.993961267598458
gpc1_r: mean flux error: 8.071580660010106, 3sigma in AB mag (Total): 20.439800385534532
gpc1_i: mean flux error: 8.737589725547517, 3sigma in AB mag (Total): 20.353717741928783
gpc1_z: mean flux error: 32.958480415580354, 3sigma in AB mag (Total): 18.9122789134614
gpc1_y: mean flux error: 259.6165048763689, 3sigma in AB mag (Total): 16.67136611602256
```

```
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)
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)
```

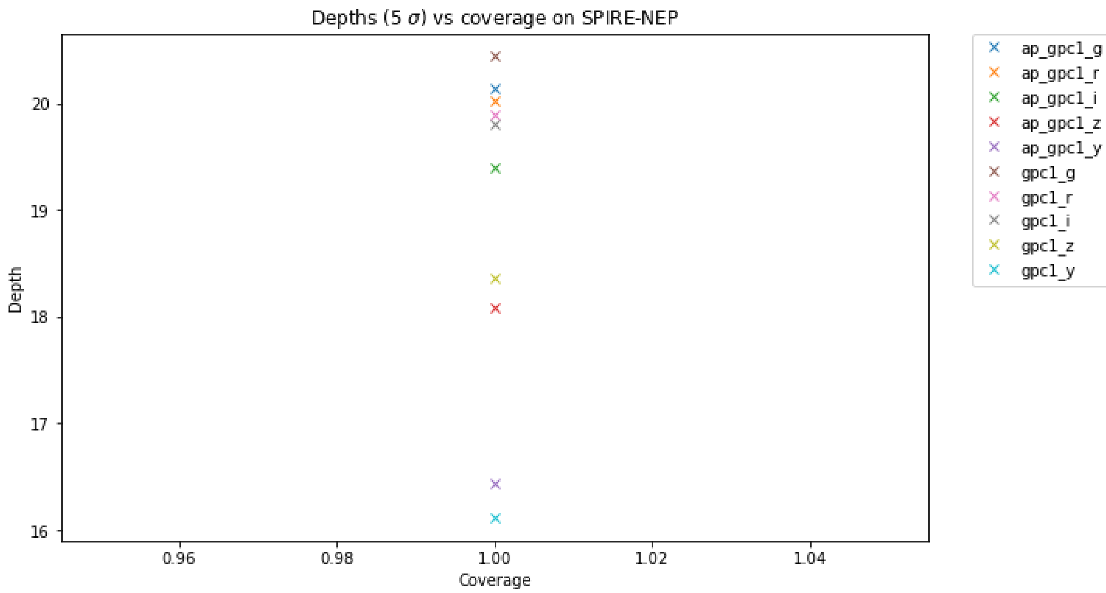
Out[20]: <matplotlib.text.Text at 0x7fb85c22ef98>



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 0x7fb85c9adb00>



Depths (5 σ) vs coverage on SPIRE-NEP
Depth
Coverage
20
19
18
17
16
0.96
0.98
1.00
1.02
1.04
ap_gpc1_g
ap_gpc1_r
ap_gpc1_i
ap_gpc1_z
ap_gpc1_y
gpc1_g
gpc1_r
gpc1_i
gpc1_z
gpc1_y