1.1_SIMES

March 8, 2018

1 AKARI-SEP master catalogue

1.1 Preparation of Spitzer SIMES data

The Spitzer catalogues were produced by the datafusion team are available in `dmu0_SIMES`. Lucia told that the magnitudes are aperture corrected.

In the catalouge, we keep:

- The internal identifier (this one is only in HeDaM data);
- The position;
- The fluxes in aperture 1 (4.8 arcsec);
- The total flux;
- The stellarity in each band

Paper descirbing data: http://irsa.ipac.caltech.edu/data/SPITZER/SEP/documentation/baronchelli16.pdf

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

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

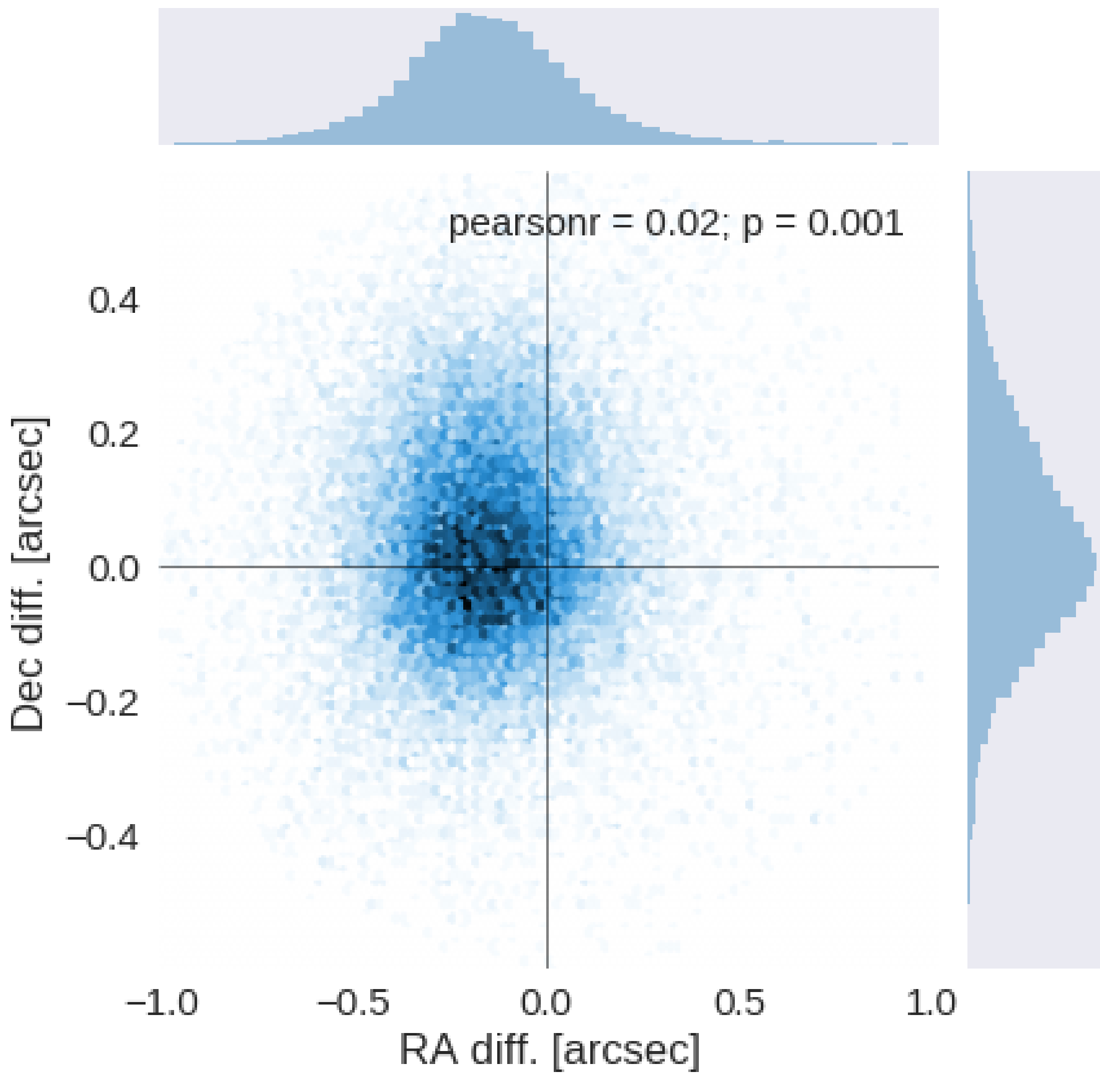
We remove duplicated objects from the input catalogues.

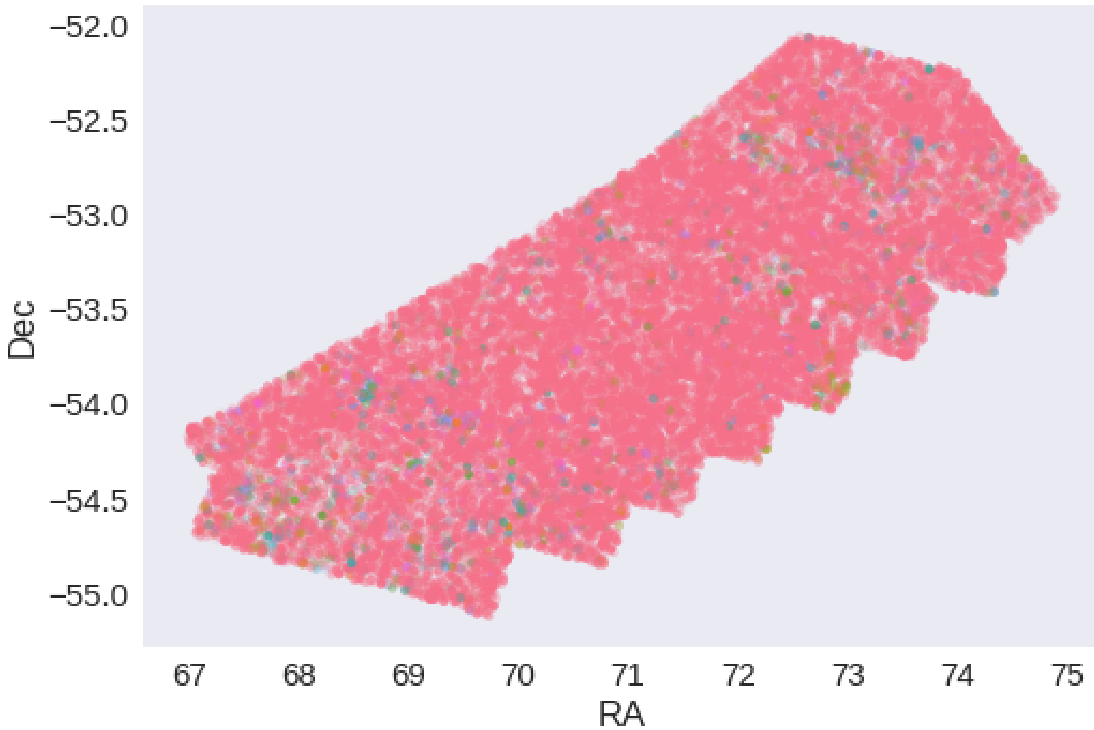
```
/opt/anaconda3/envs/herschelhelp_internal/lib/python3.6/site-packages/astropy/table/column.py:10
Check the NumPy 1.11 release notes for more information.
  ma.MaskedArray.__setitem__(self, index, value)
```

```
The initial catalogue had 301420 sources.
The cleaned catalogue has 301420 sources (0 removed).
The cleaned catalogue has 0 sources flagged as having been cleaned
```

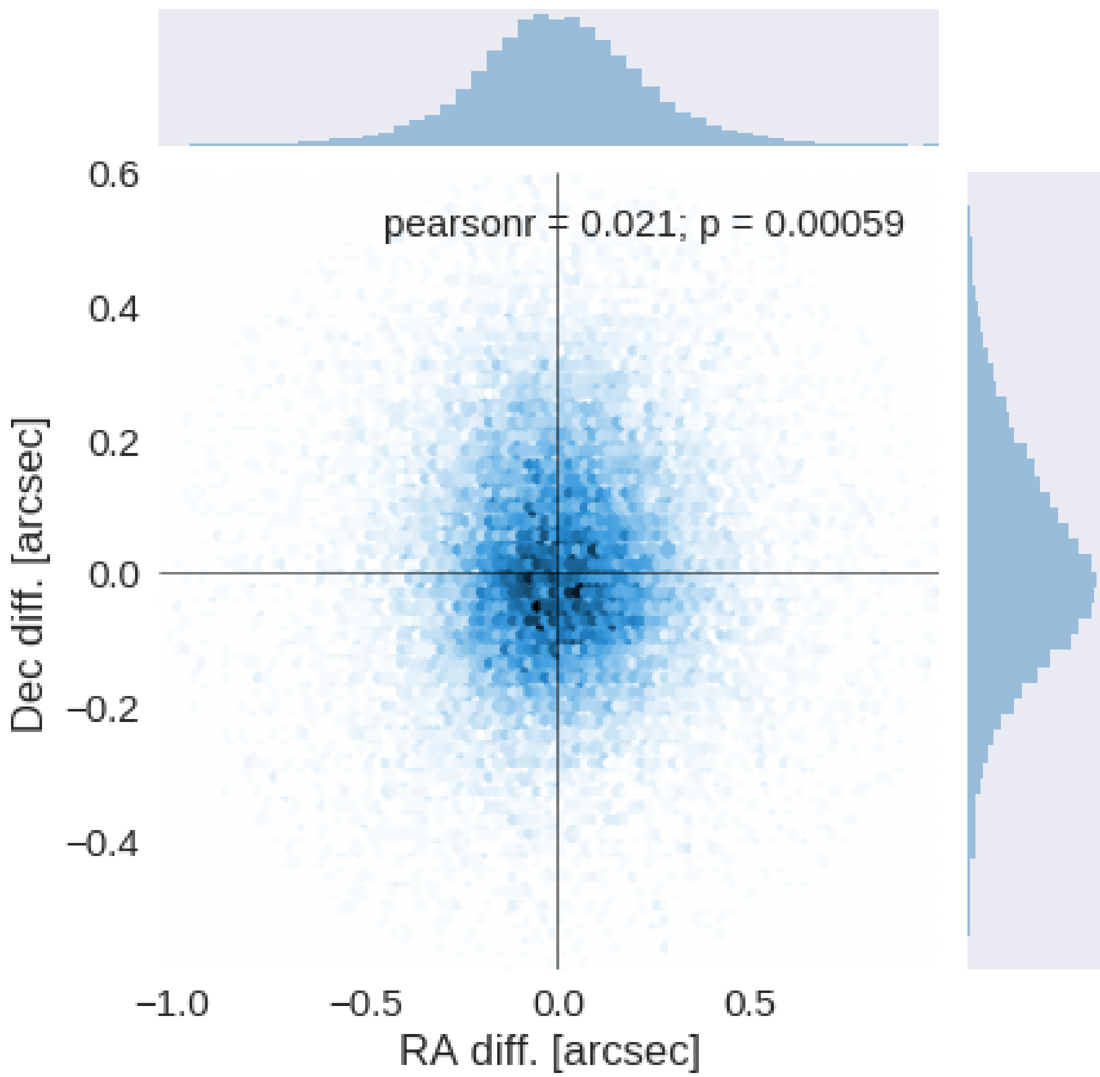
1.4 III - Astrometry correction

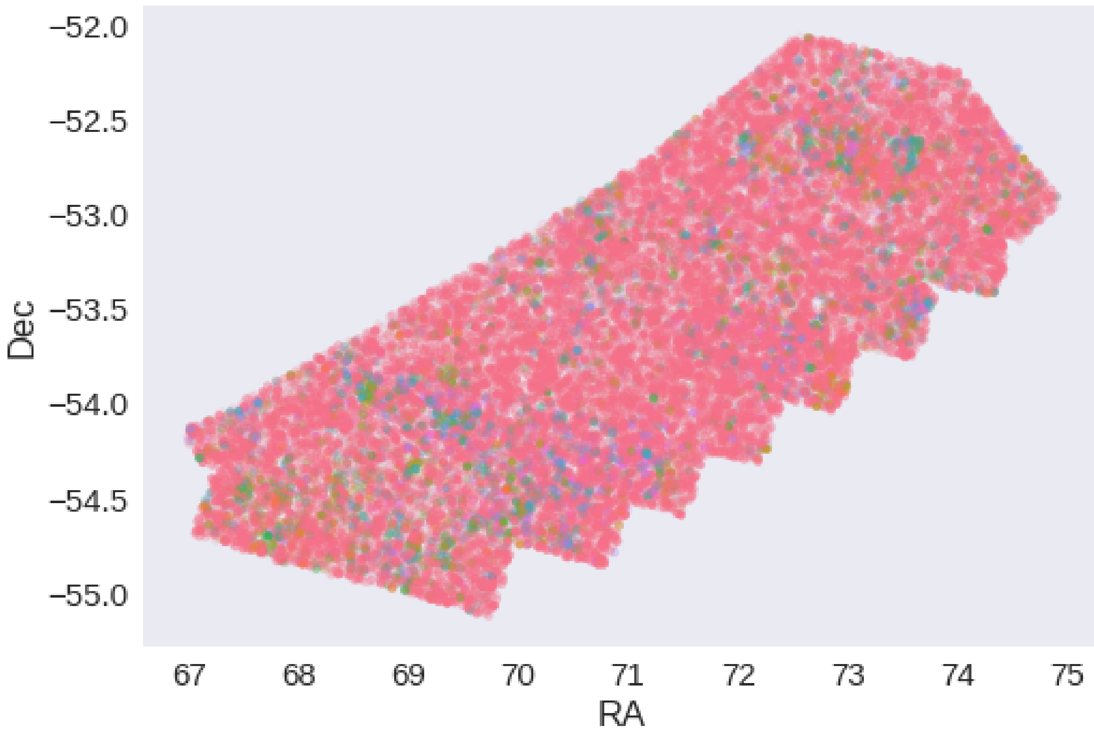
We match the astrometry to the Gaia one. We limit the Gaia catalogue to sources with a g band flux between the 30th and the 70th percentile. Some quick tests show that this give the lower dispersion in the results.






```
RA correction: 0.1570059799291812 arcsec
Dec correction: -0.025493045217217514 arcsec
```


pearsonr = 0.021; p = 0.00059
0.6
0.4
0.2
0.0
−0.2
−0.4
Dec diff. [arcsec]
−1.0
−0.5
0.0
0.5
RA diff. [arcsec]



1.5 IV - Flagging Gaia objects

```
28971 sources flagged.
```

1.6 V - Saving to disk

1.2_VISTA-VHS

March 8, 2018

1 AKARI-SEP master catalogue

1.1 Preparation of VHS data

VISTA telescope/VHS catalogue: the catalogue comes from `dmu0_VHS`.

In the catalogue, we keep:

- The identifier (it's unique in the catalogue);
- The position;
- The stellarity;
- The magnitude for each band.
- 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]
```

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

1.3 II - Removal of duplicated sources

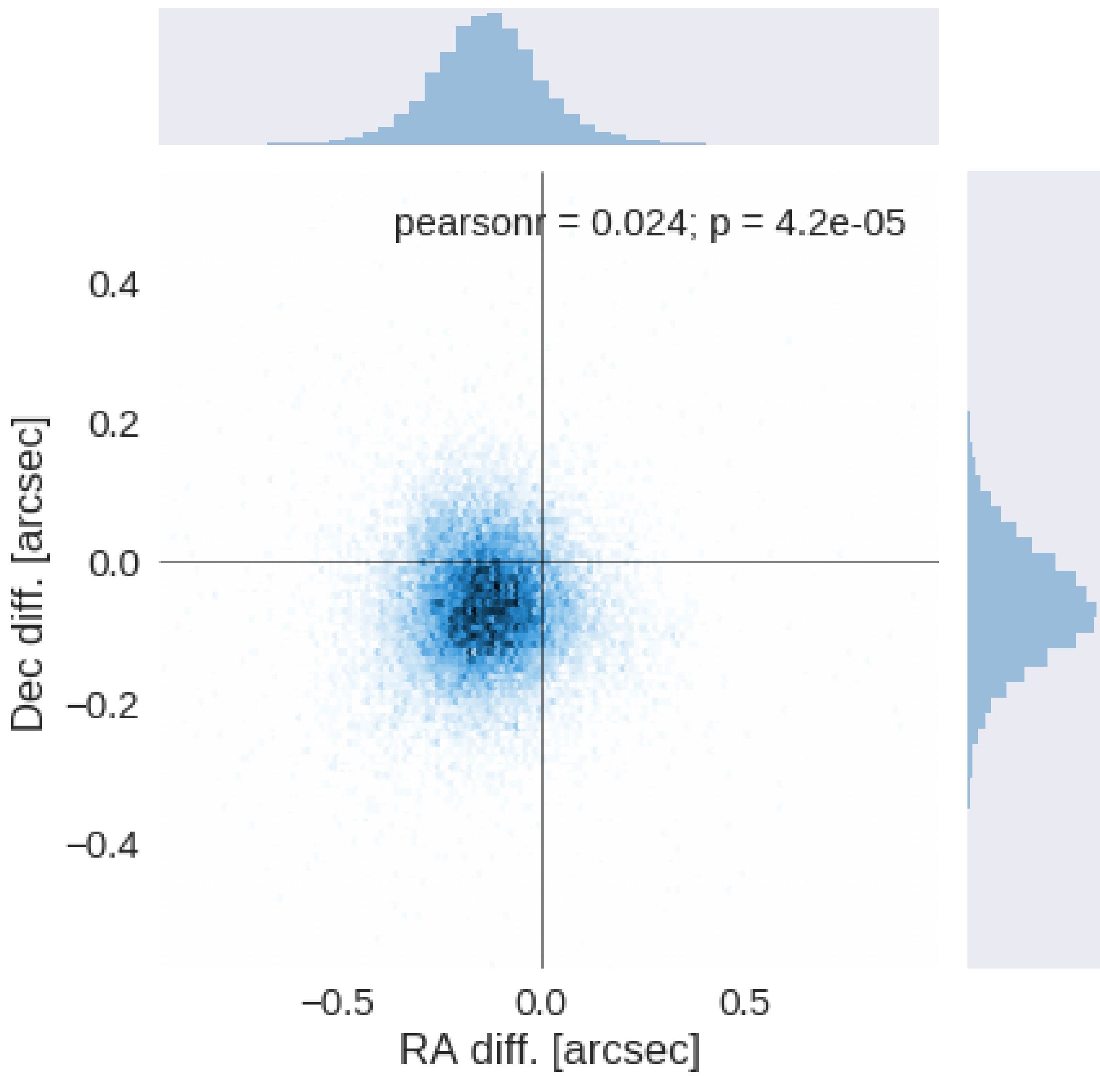
We remove duplicated objects from the input catalogues.

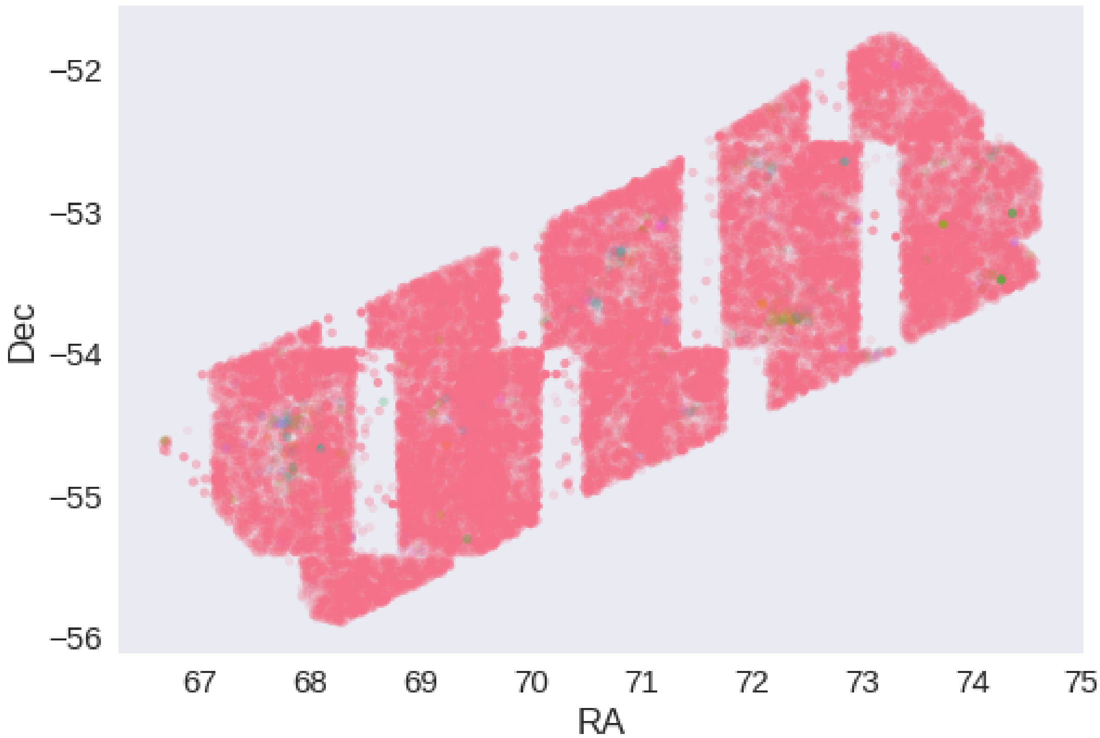
```
/opt/anaconda3/envs/herschelhelp_internal/lib/python3.6/site-packages/astropy/table/column.py:10
Check the NumPy 1.11 release notes for more information.
  ma.MaskedArray.__setitem__(self, index, value)
```

```
The initial catalogue had 160013 sources.
The cleaned catalogue has 159999 sources (14 removed).
The cleaned catalogue has 14 sources flagged as having been cleaned
```

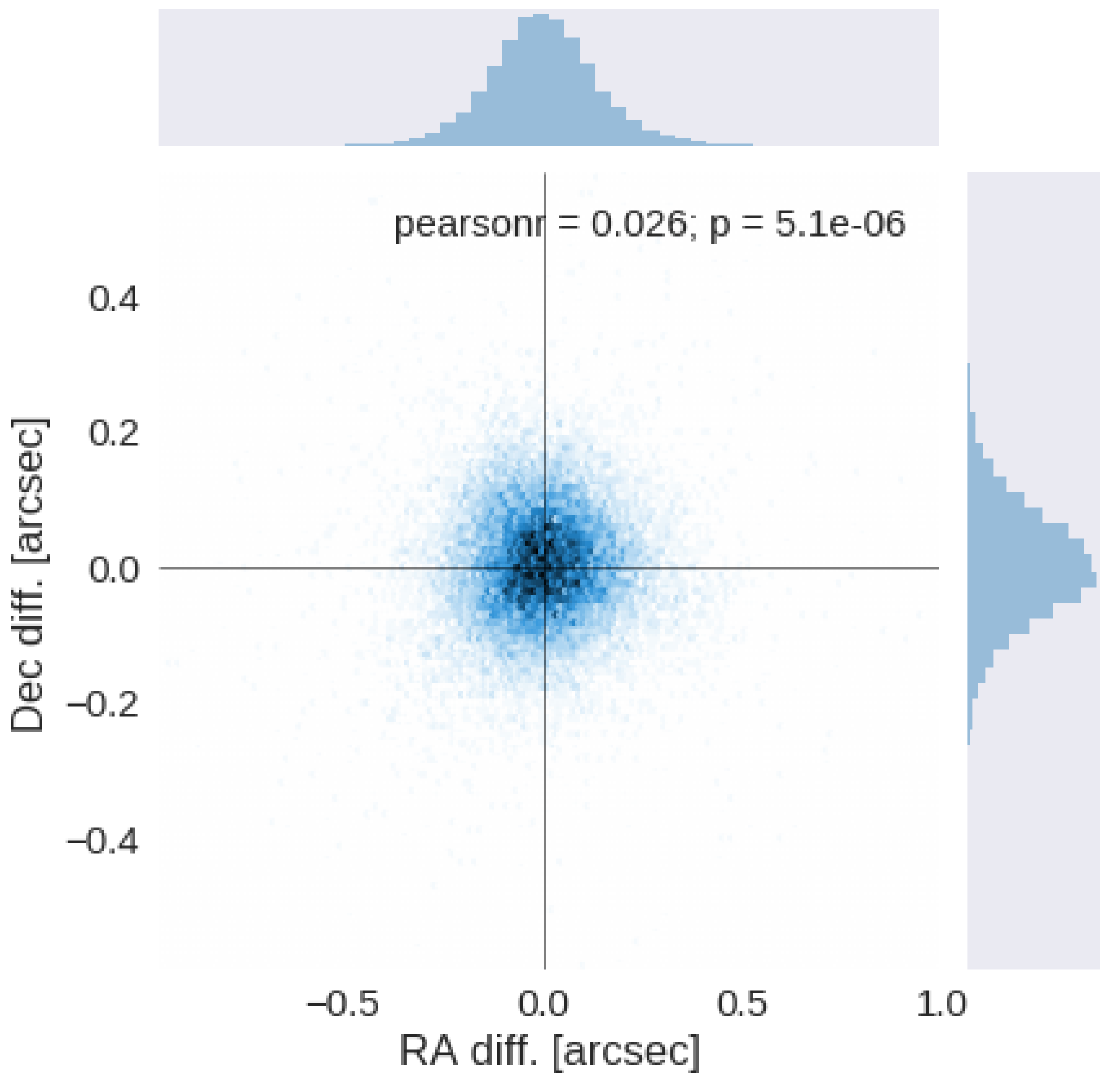
1.4 III - Astrometry correction

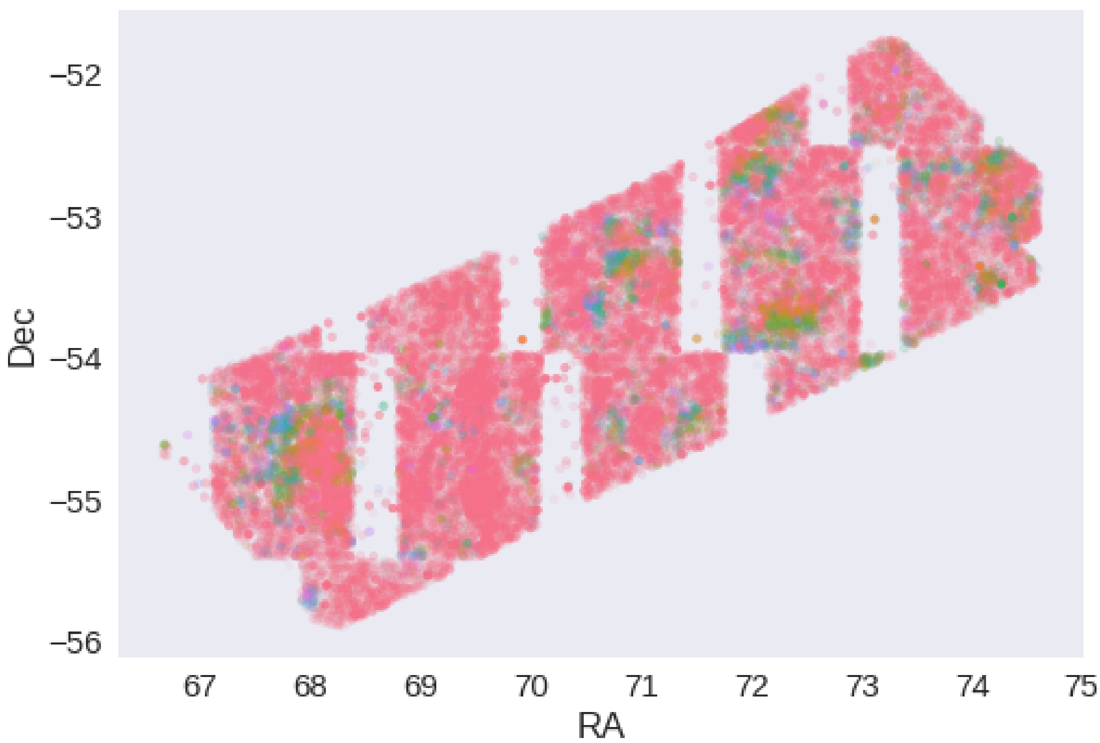
We match the astrometry to the Gaia one. We limit the Gaia catalogue to sources with a g band flux between the 30th and the 70th percentile. Some quick tests show that this give the lower dispersion in the results.






```
RA correction: 0.13254794655779278 arcsec
Dec correction: 0.06519666017936743 arcsec
```


pearsonr = 0.026; p = 5.1e-06
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

```
30228 sources flagged.
```

1.6 V - Flagging objects near bright stars

2 VI - Saving to disk

1.3_DES

March 8, 2018

1 AKARI-SEP master catalogue

1.1 Preparation of DES data

Blanco DES catalogue: the catalogue comes from `dmu0_DES`.

In the catalogue, we keep:

- The identifier (it's unique in the catalogue);
- The position;
- The G band stellarity;
- The magnitude for each band.
- The auto/kron magnitudes/fluxes to be used as total magnitude.
- The aperture magnitudes, which are used to compute a corrected 2 arcsec aperture magnitude.

We don't know when the maps have been observed. We will take the final observation date as 2017.

```
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 16:17:43.581984
```

1.2 1 - Aperture correction

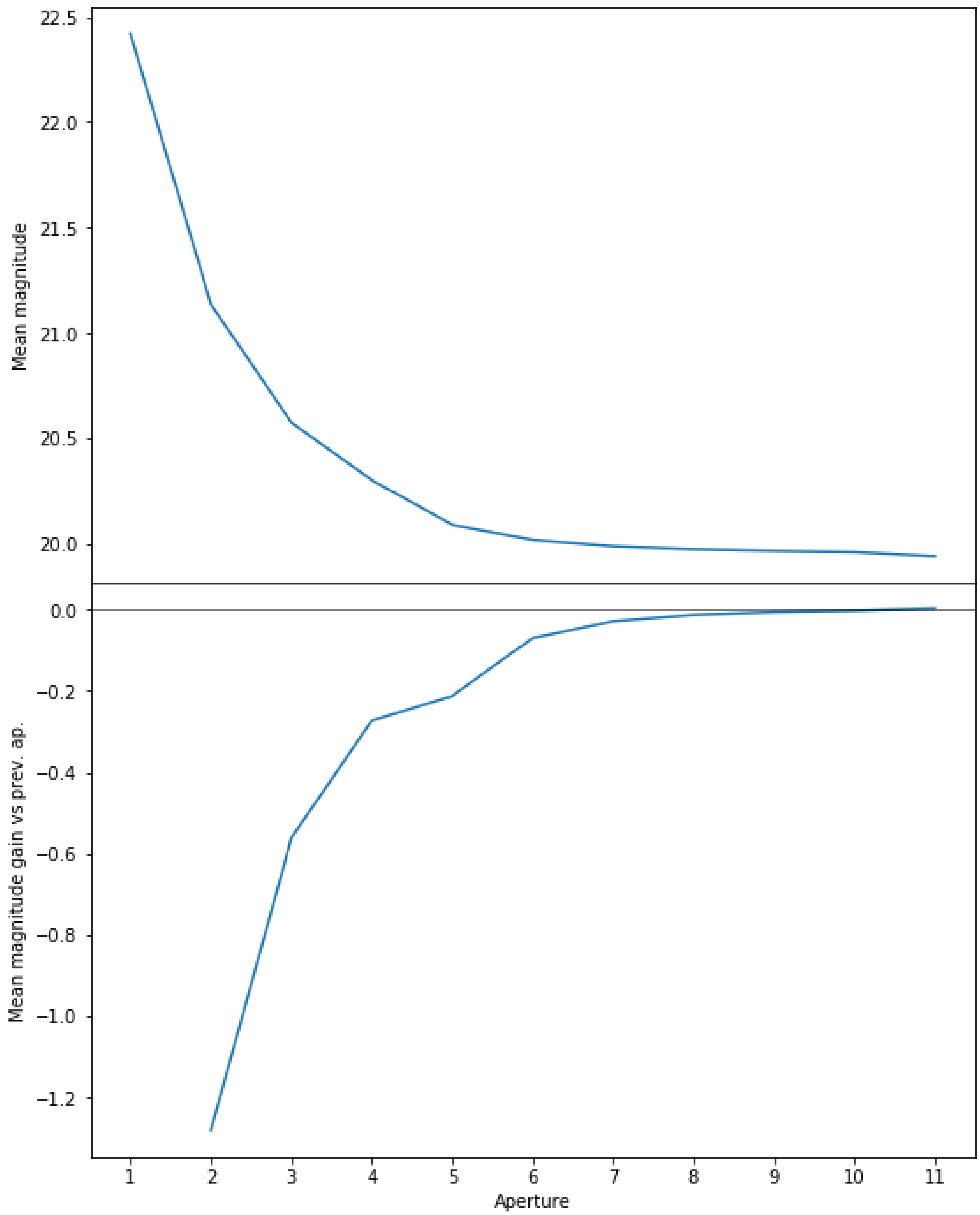
To compute aperture correction we need to dertermine two parametres: the target aperture and the range of magnitudes for the stars that will be used to compute the correction.

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

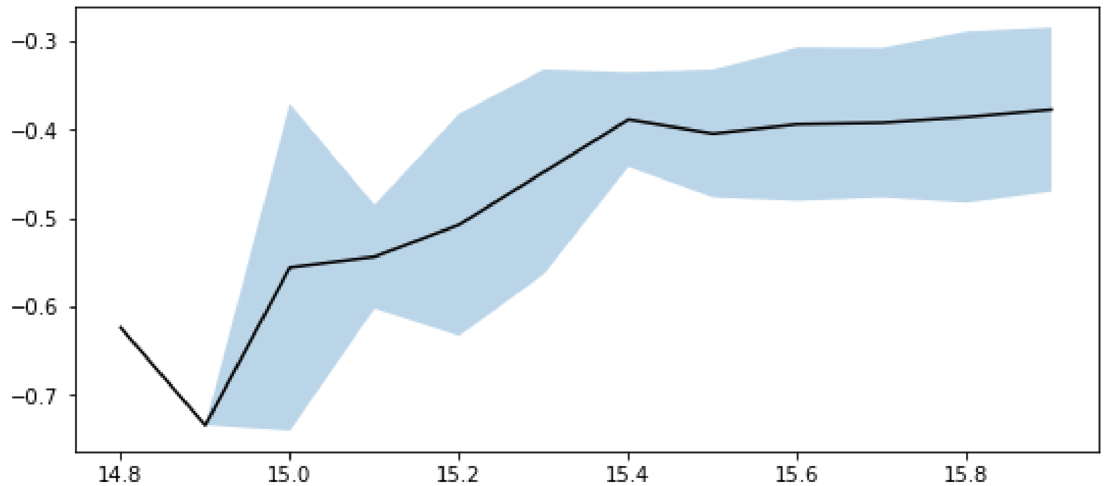
The evolution of the magnitudes of the objects by plotting on the same plot aperture number vs the mean magnitude. The mean gain (loss when negative) of magnitude is each aperture compared to the previous (except for the first of course). As target aperture, we should use the smallest (i.e. less noisy) 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.

1.2.1 I.a - g band



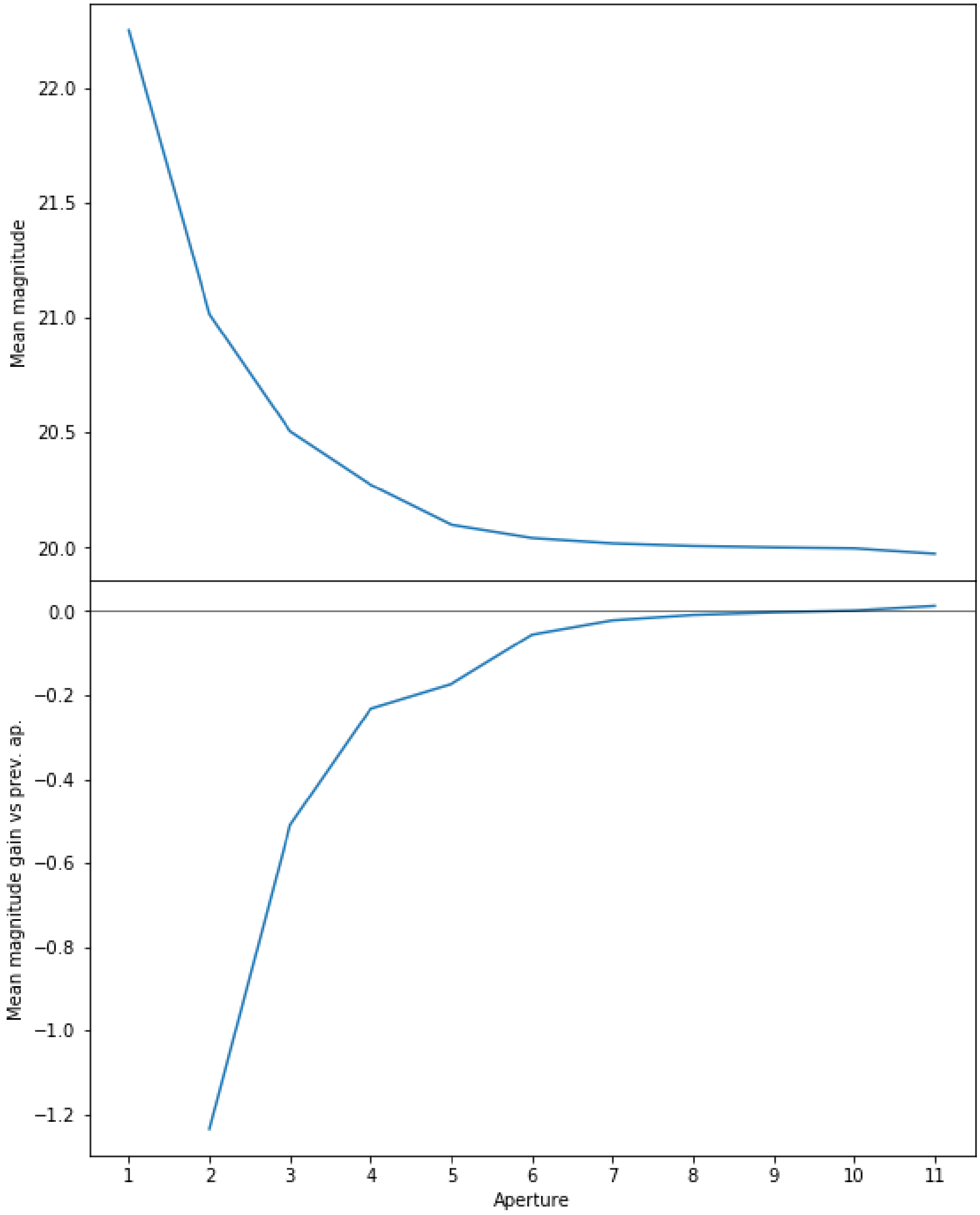
We will use aperture 10 as target.



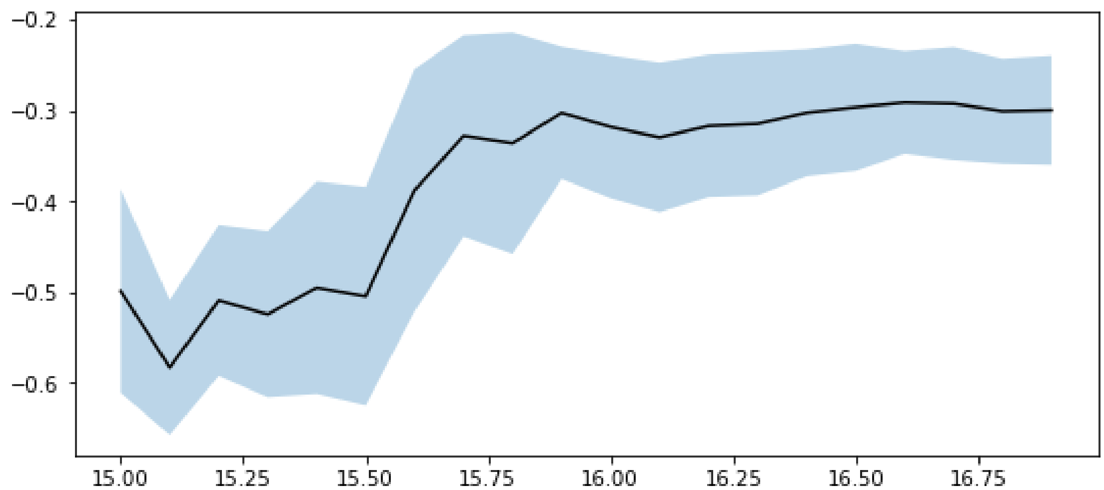
We will use magnitudes between 15.0 and 16.0

```
Aperture correction for g band:
Correction: -0.38942670822143555
Number of source used: 1053
RMS: 0.08962199868657524
```

1.2.2 I.b - r band



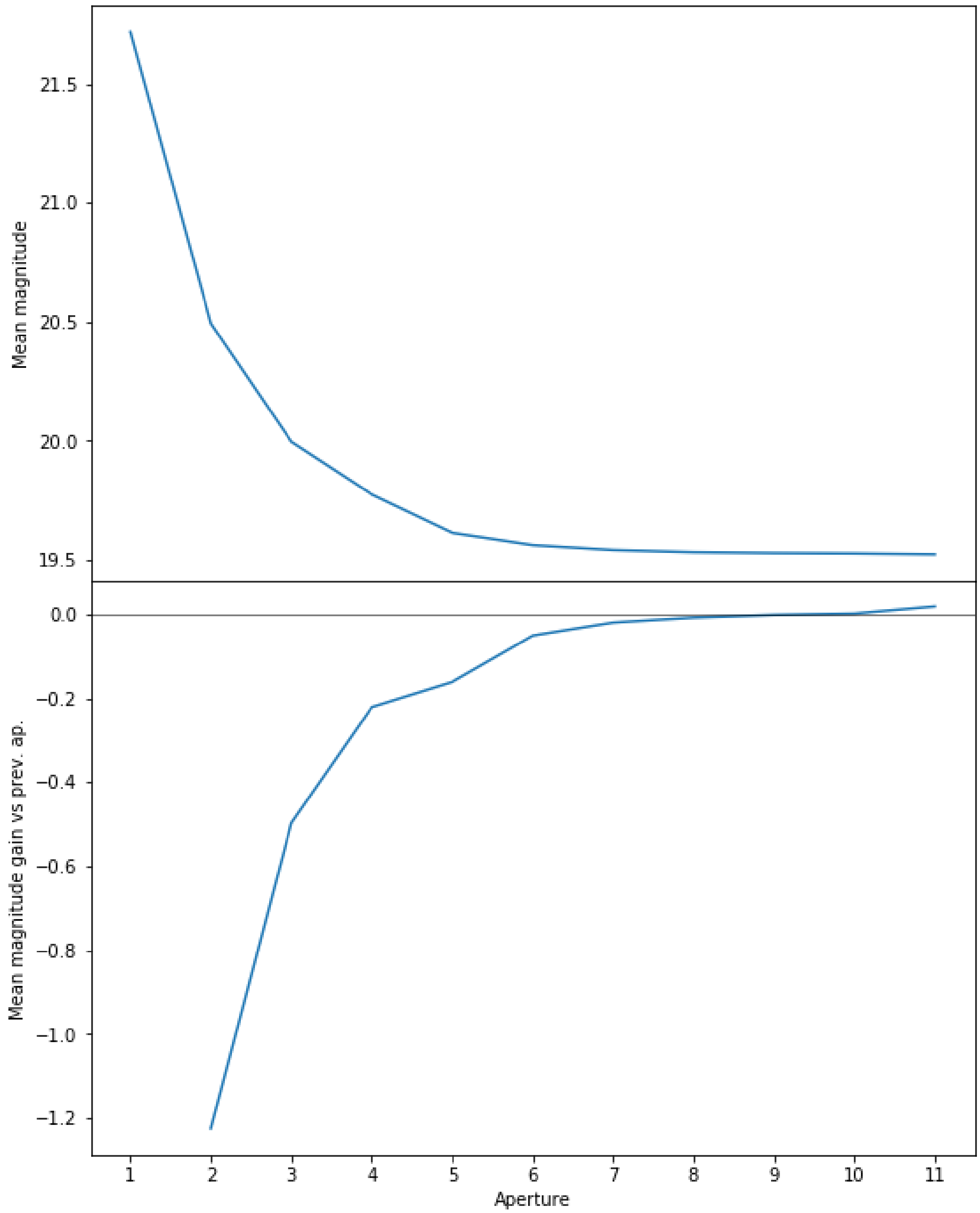
We will use aperture 10 as target.



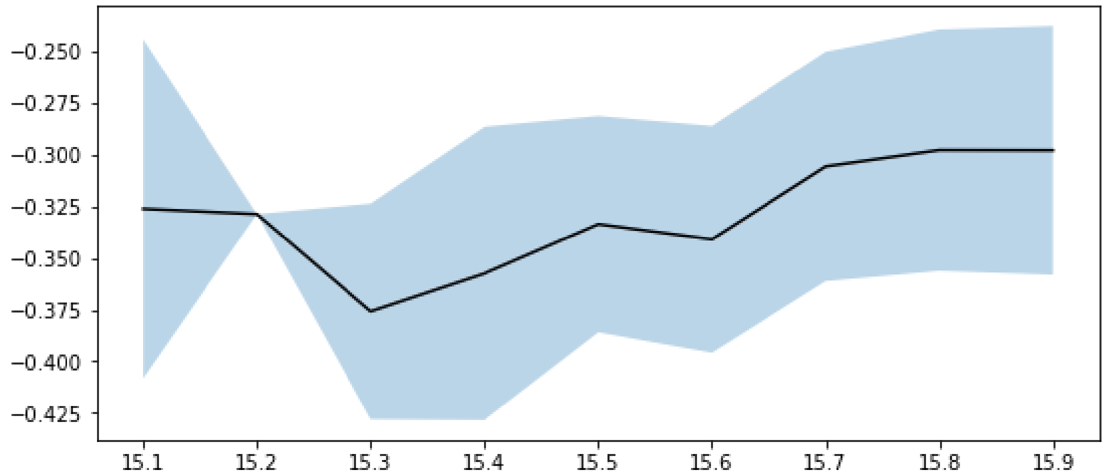
We use magnitudes between 15.0 and 16.0.

```
Aperture correction for r band:
Correction: -0.3422098159790039
Number of source used: 489
RMS: 0.12592138188610189
```

1.2.3 I.b - i band



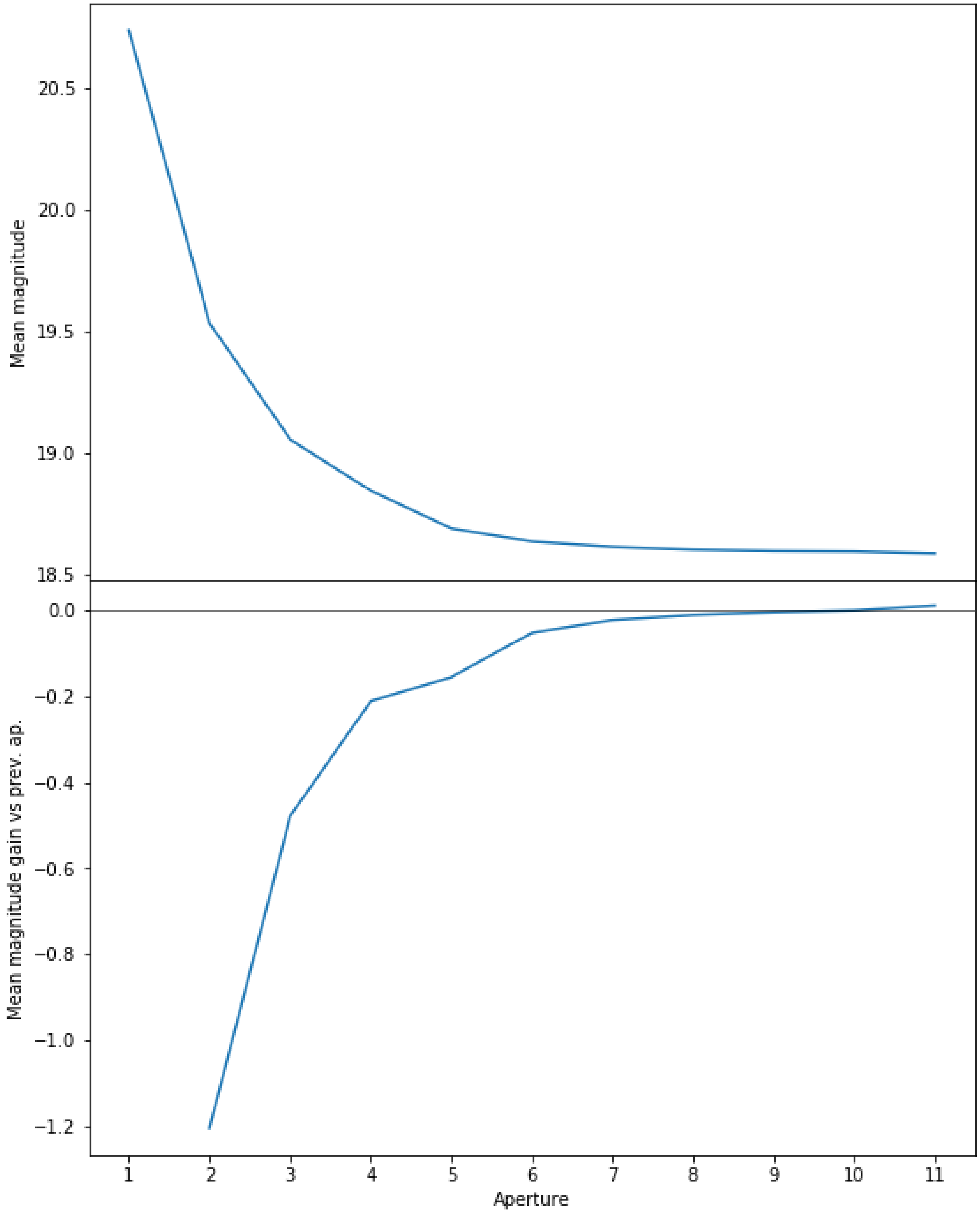
We will use aperture 10 as target.



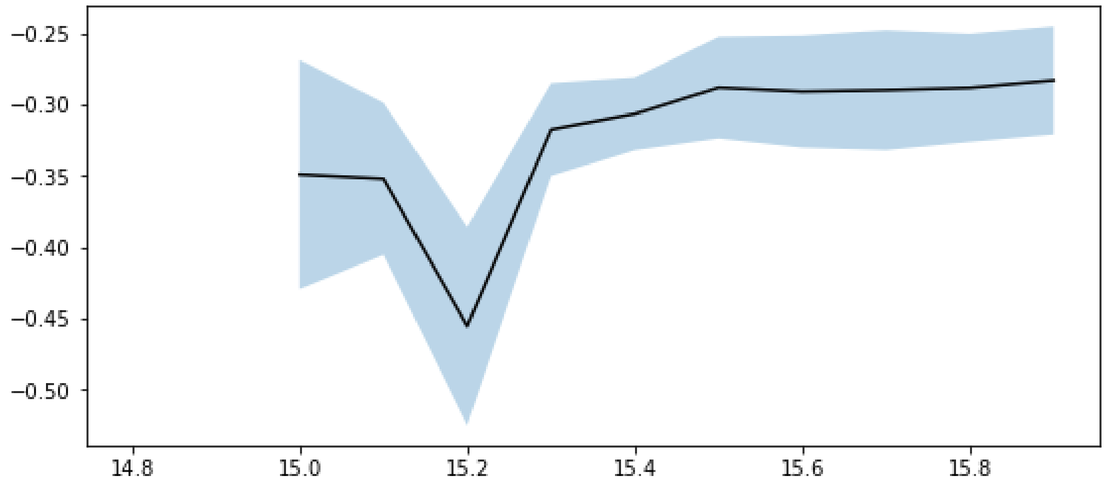
We use magnitudes between 15.0 and 16.0.

```
Aperture correction for i band:
Correction: -0.301821231842041
Number of source used: 622
RMS: 0.05961582248775093
```

1.2.4 I.b - z band



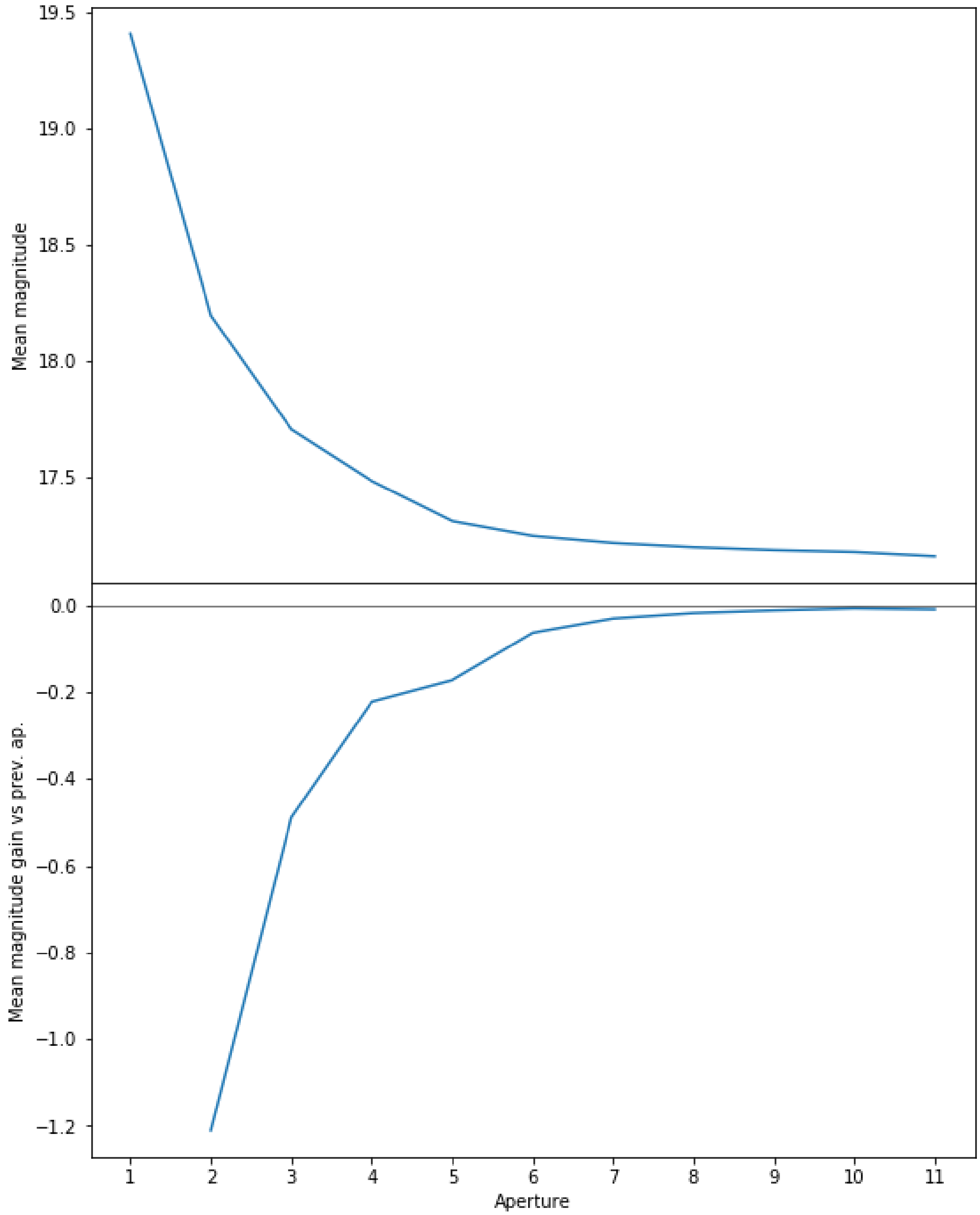
We will use aperture 57 as target.



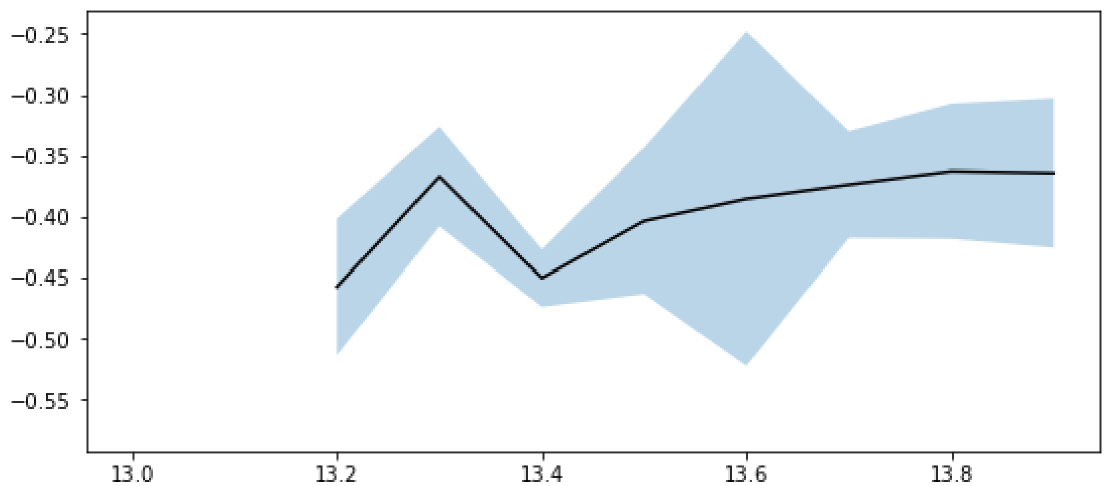
We use magnitudes between 15.0 and 16.0.

```
Aperture correction for z band:
Correction: -0.28810548782348633
Number of source used: 1401
RMS: 0.03921546691432963
```

1.2.5 I.b - y band



We will use aperture 10 as target.



We use magnitudes between 15.0 and 16.0.

```
Aperture correction for y band:
Correction: -0.31262969970703125
Number of source used: 1232
RMS: 0.03825225295979008
```

1.3 2 - 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[24]: <IPython.core.display.HTML object>
```

1.4 II - Removal of duplicated sources

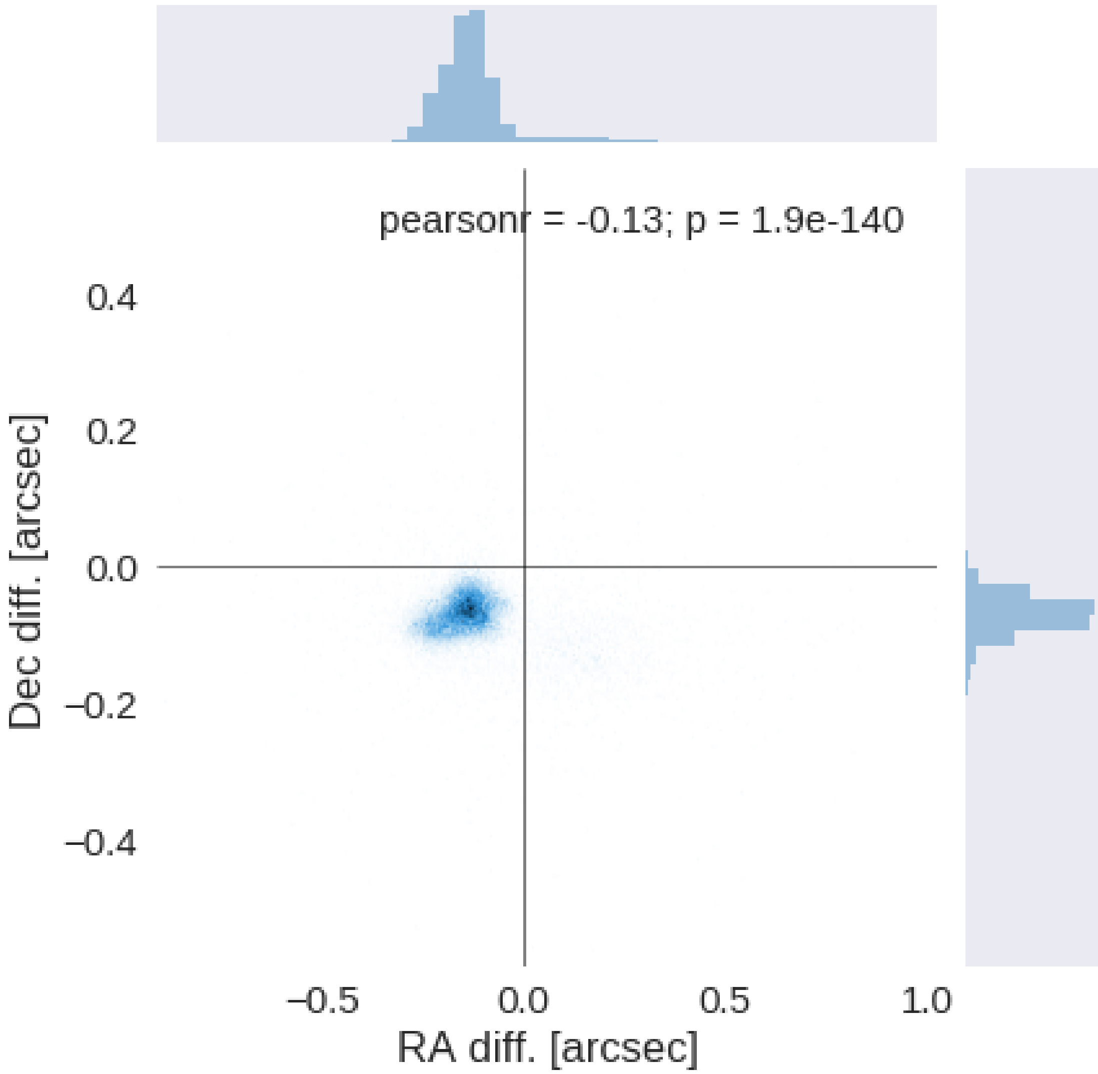
We remove duplicated objects from the input catalogues.

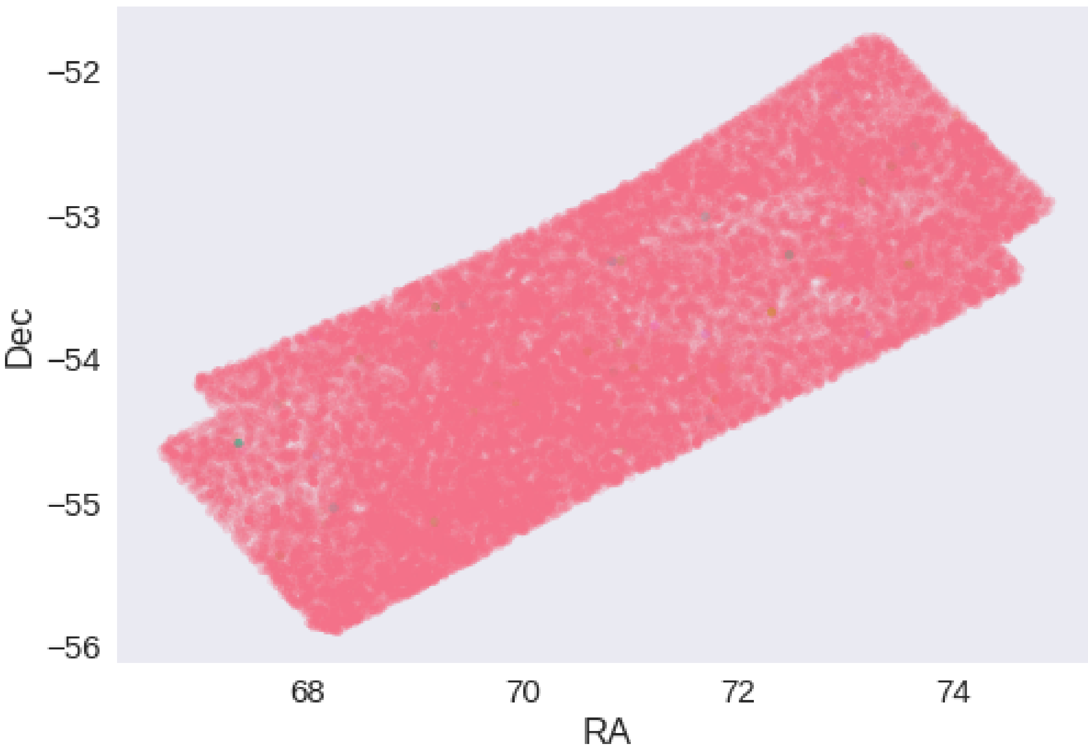
```
/opt/anaconda3/envs/herschelhelp_internal/lib/python3.6/site-packages/astropy/table/column.py:10
Check the NumPy 1.11 release notes for more information.
  ma.MaskedArray.__setitem__(self, index, value)
```

```
The initial catalogue had 729517 sources.
The cleaned catalogue has 729508 sources (9 removed).
The cleaned catalogue has 9 sources flagged as having been cleaned
```

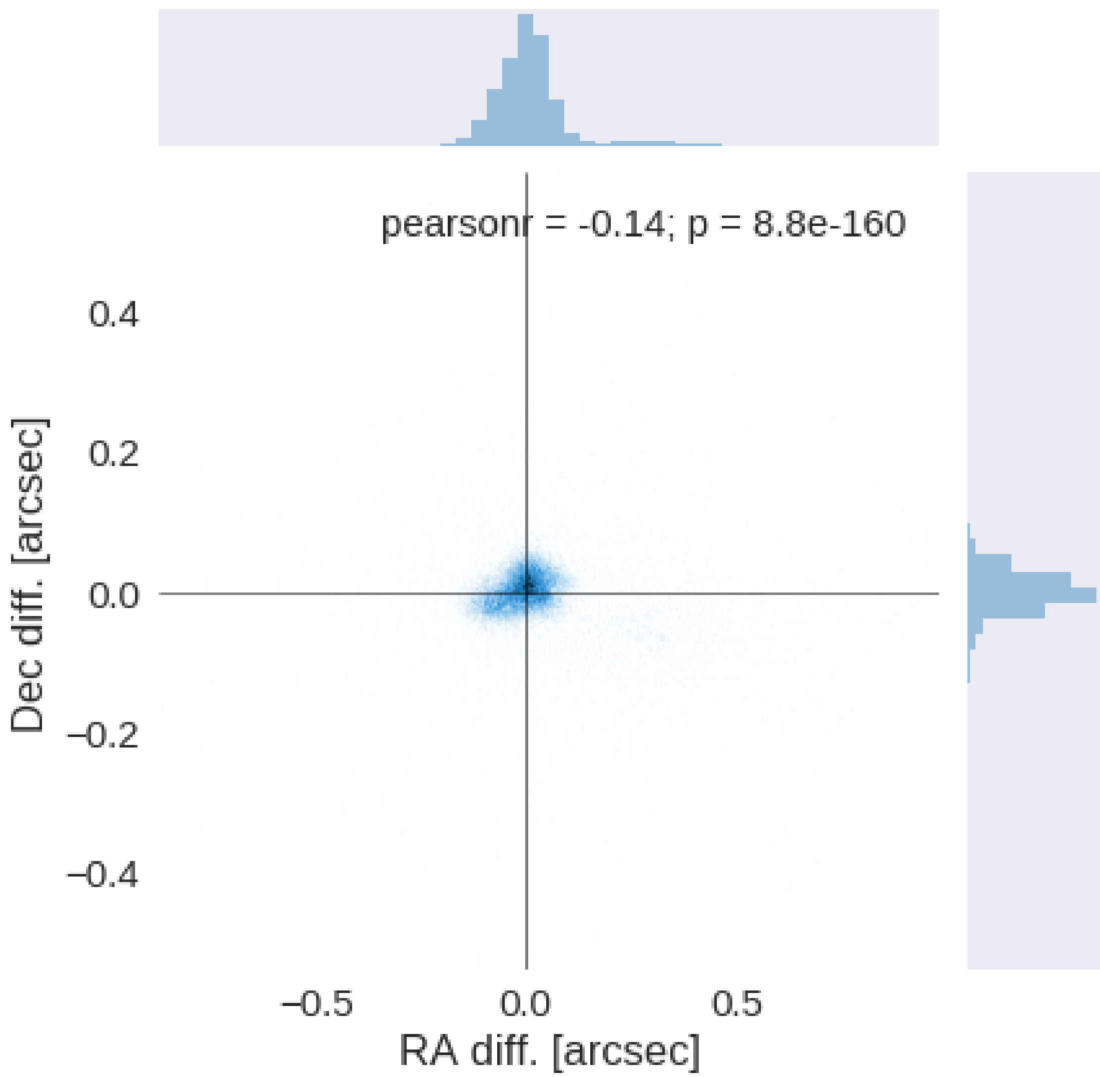
1.5 III - Astrometry correction

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.

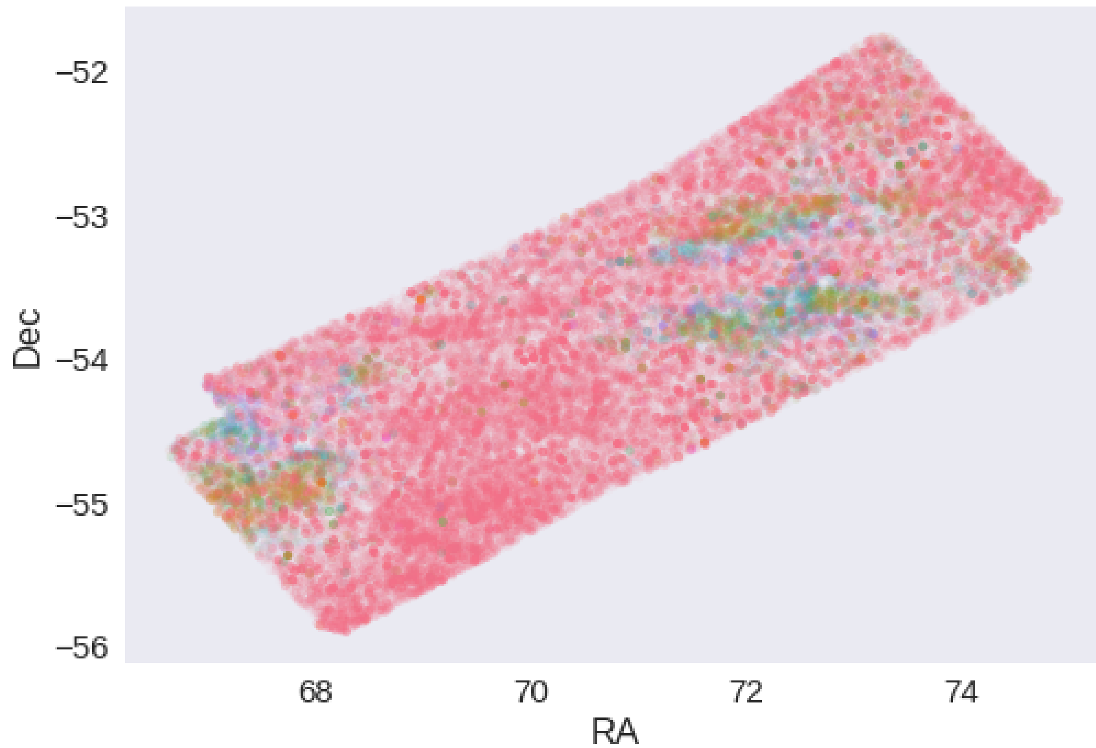





```
RA correction: 0.1438491276047671 arcsec
Dec correction: 0.07049437199100339 arcsec
```



pearsonr = -0.14; p = 8.8e-160
0.4
0.2
0.0
−0.2
−0.4
Dec diff. [arcsec]
−0.5
0.0
0.5
RA diff. [arcsec]



1.6 IV - Flagging Gaia objects

```
39225 sources flagged.
```

1.7 V - Flagging objects near bright stars

2 VI - Saving to disk

2_Merging

March 8, 2018

1 AKARI-SEP master catalogue

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

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

1.1 I - Reading the prepared pristine catalogues

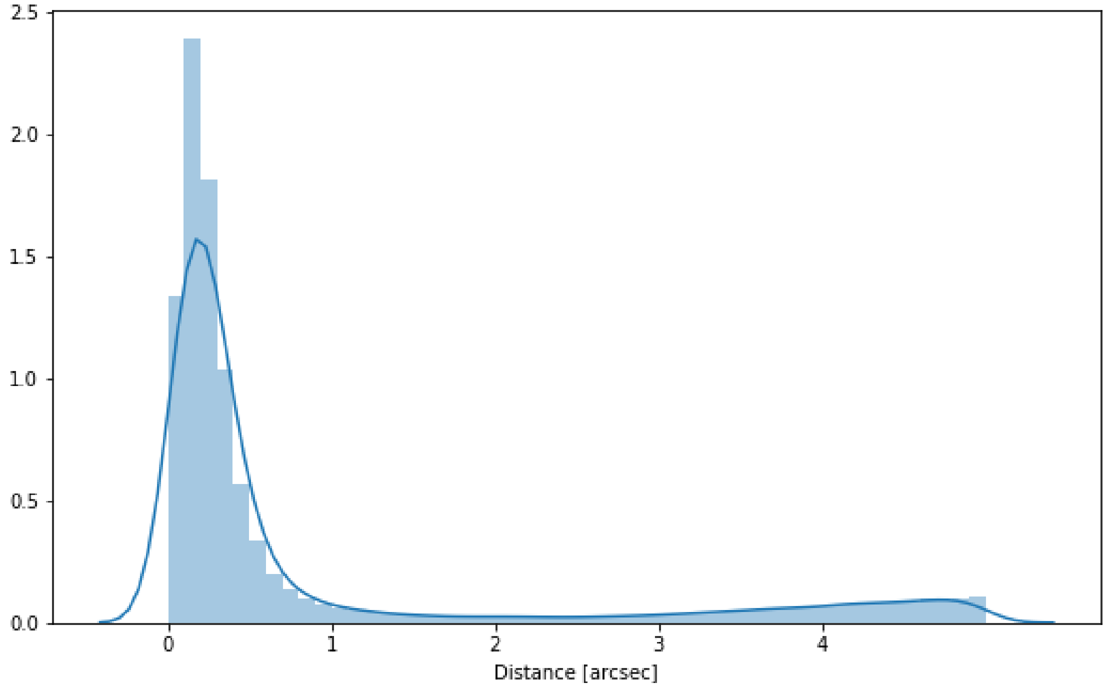
1.2 II - Merging tables

We first merge the optical catalogues and then add the infrared ones: WFC, DXS, SpARCS, HSC, PS1, SERVS, SWIRE.

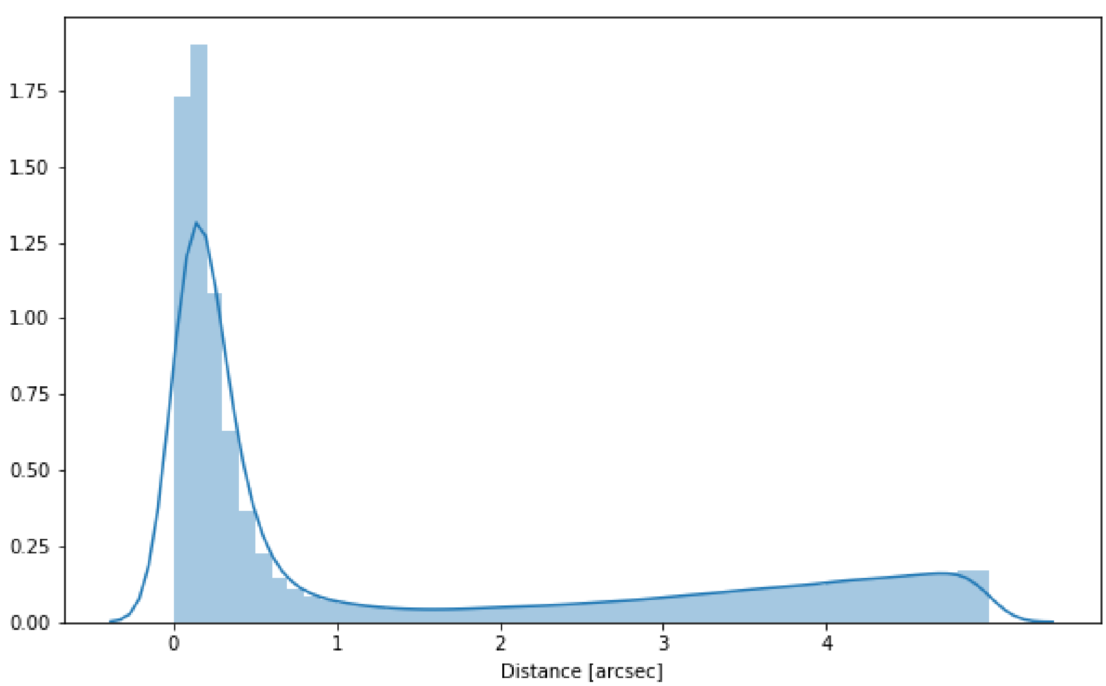
At every step, we look at the distribution of the distances to the nearest source in the merged catalogue to determine the best crossmatching radius.

1.2.1 WFC

1.2.2 Add SIMES



1.2.3 Add DES



1.2.4 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[11]: <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.

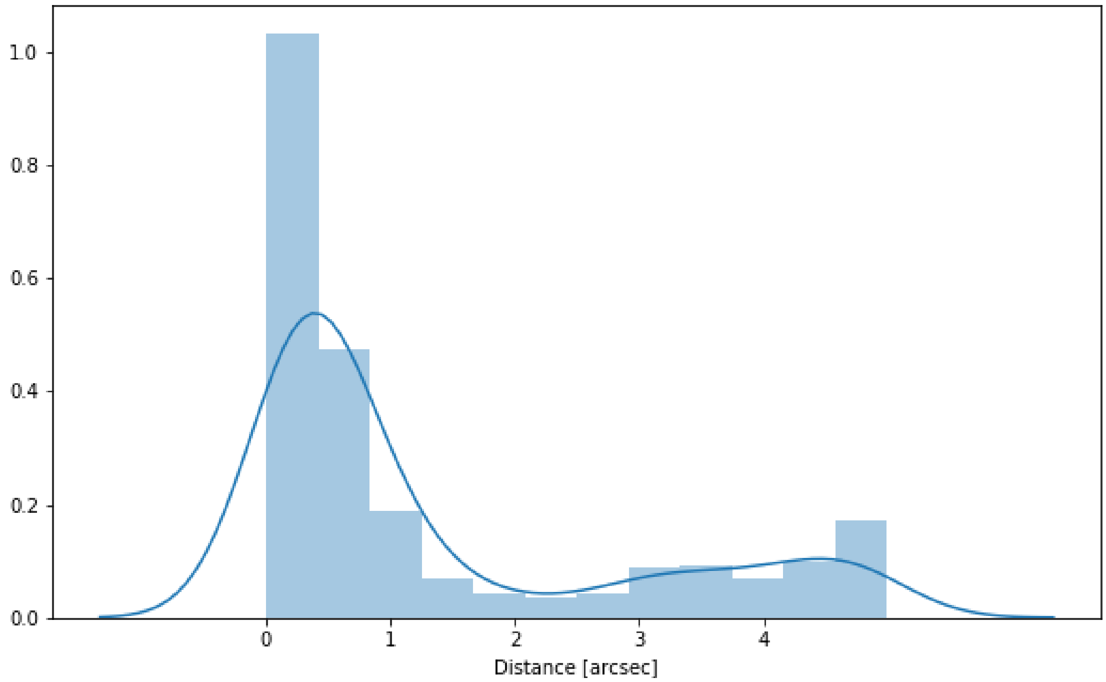
```
vhs_stellarity, simes_stellarity, des_stellarity
```

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 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.

1.8 VIII 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.

1.9 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.

```
['vhs_id', 'simes_id', 'des_id', 'help_id', 'specz_id']
```

1.10 X - Adding HEALPix index

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

1.11 XI - Saving the catalogue

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

3_Checks_and_diagnostics

March 8, 2018

1 AKARI-SEP 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_akari-sep_20180221.fits
```

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)
```

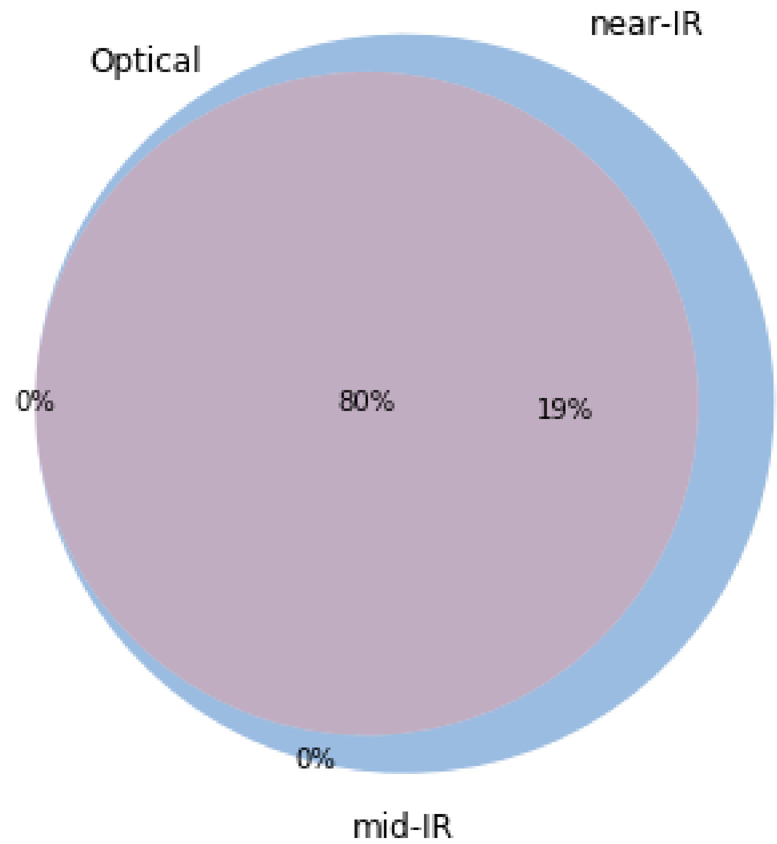
```
Table shows only problematic columns.
```

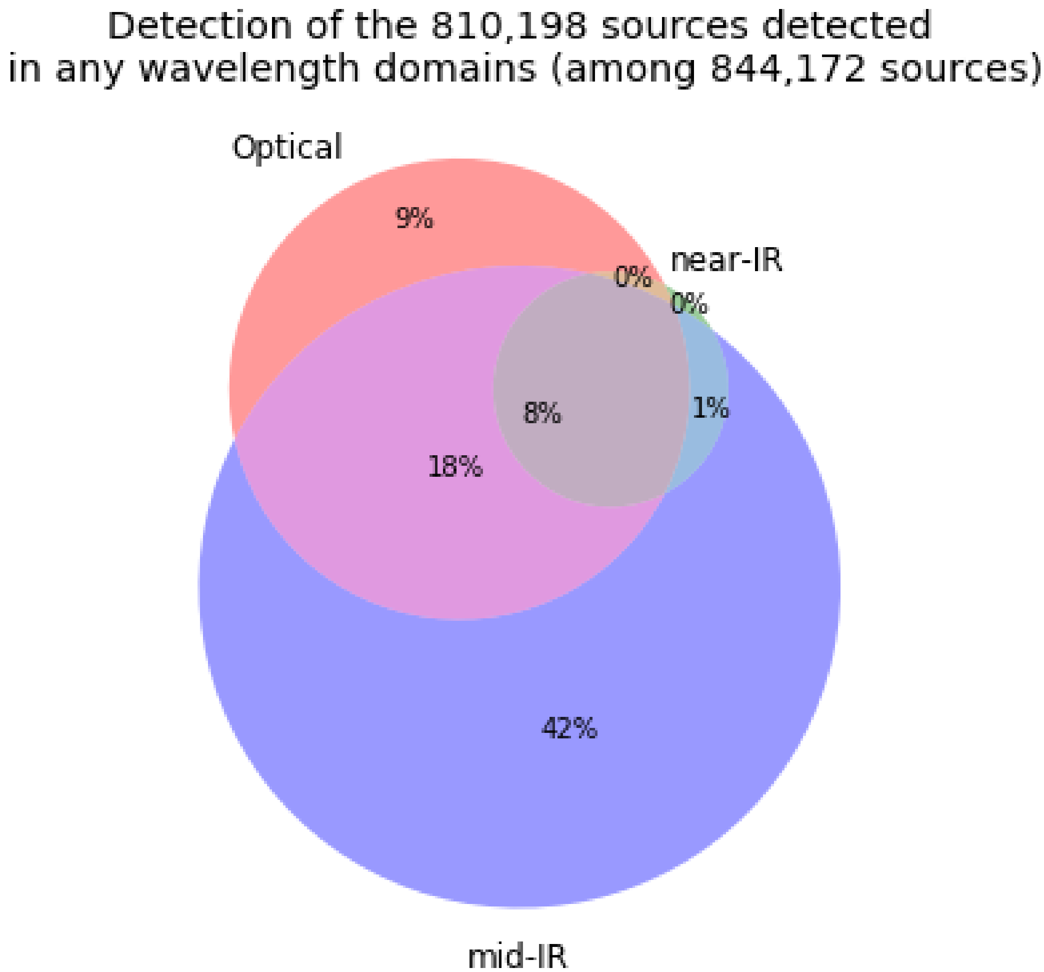
```
Out[4]: <IPython.core.display.HTML object>
```

2.1 I - Summary of wavelength domains

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

Wavelength domain observations



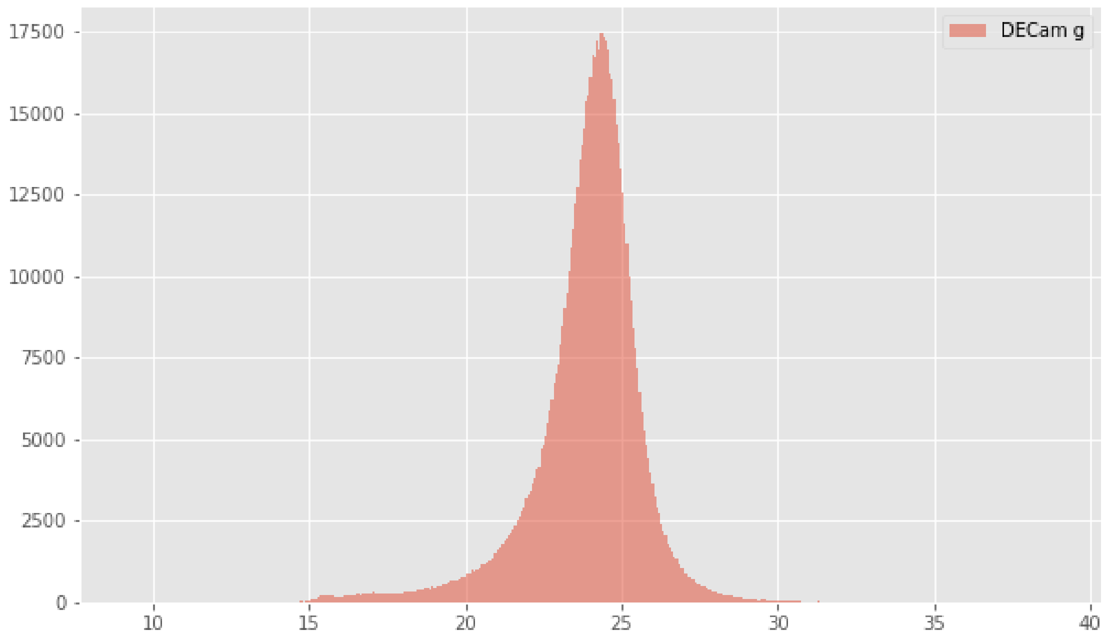


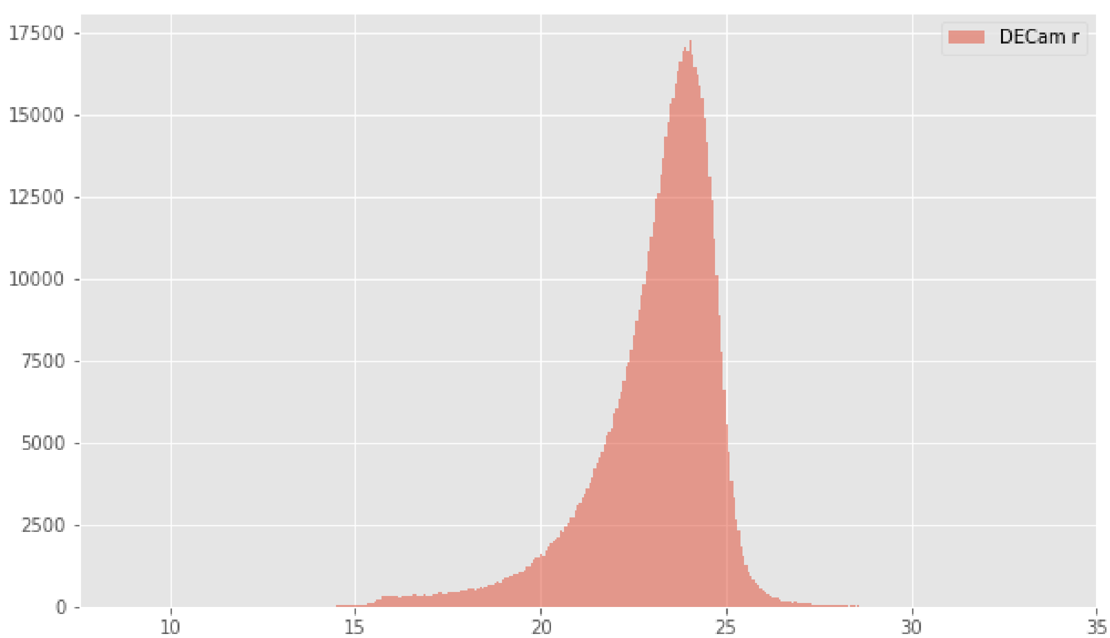
2.2 II - Comparing magnitudes in similar filters

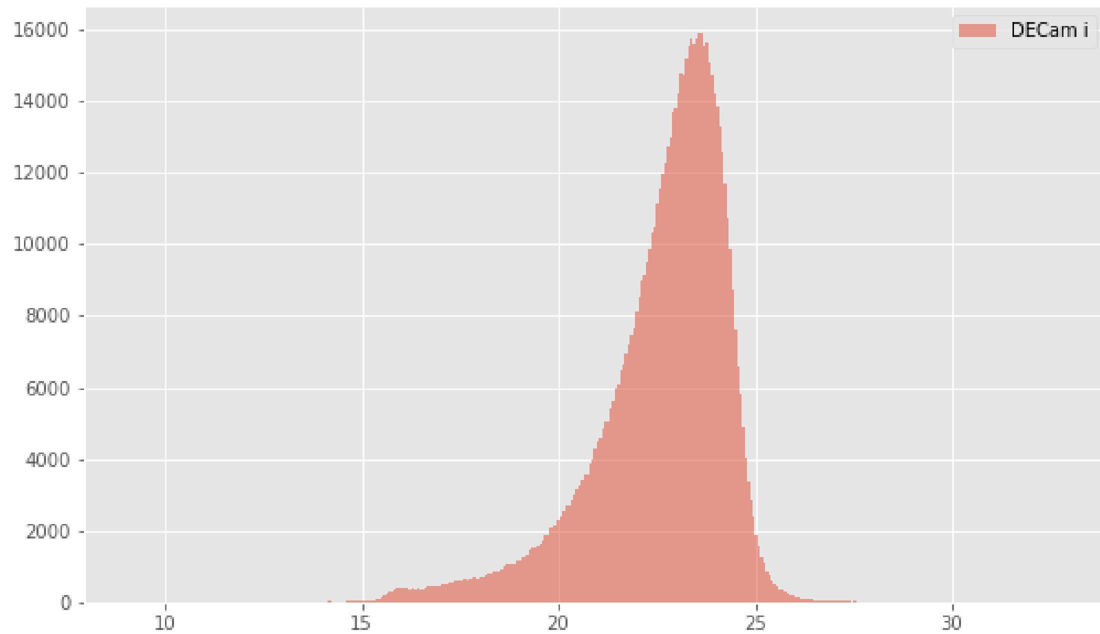
Om AKARI-SEP there are no bands with multiple observations. It is still instructive to plot magnitude histograms to give a measure of depth.

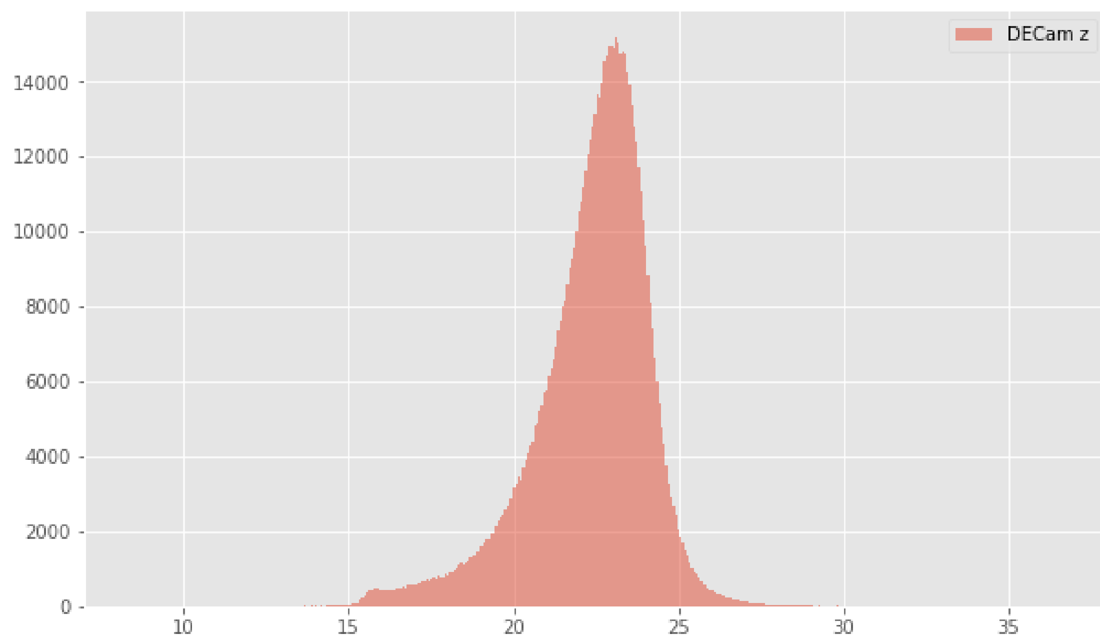
2.2.1 II.a - Comparing depths

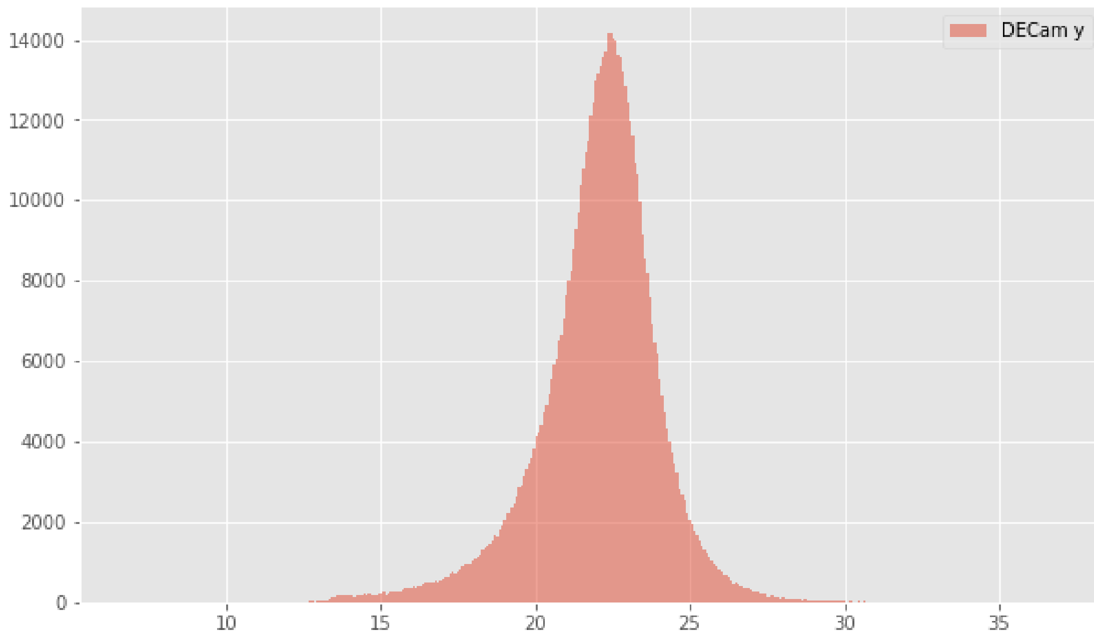
We compare the histograms of the total aperture magnitudes of similar bands. This revealed that there were no VISTA y band measurements in VHS so we removed that column.

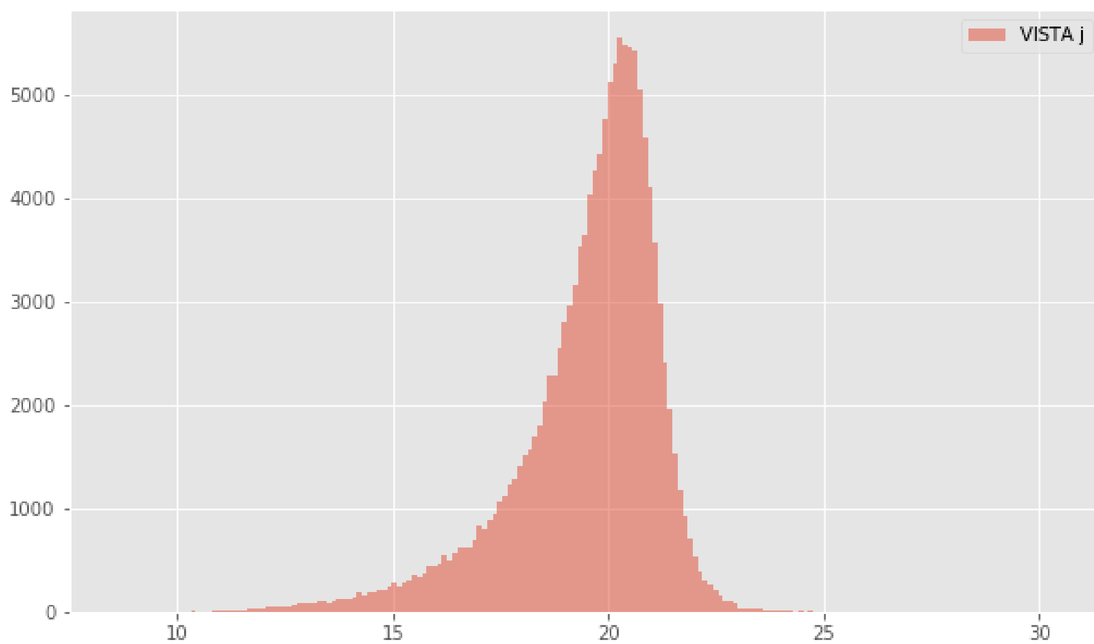

DECam g
17500
15000
12500
10000
7500
5000
2500
0
10
15
20
25
30
35
40

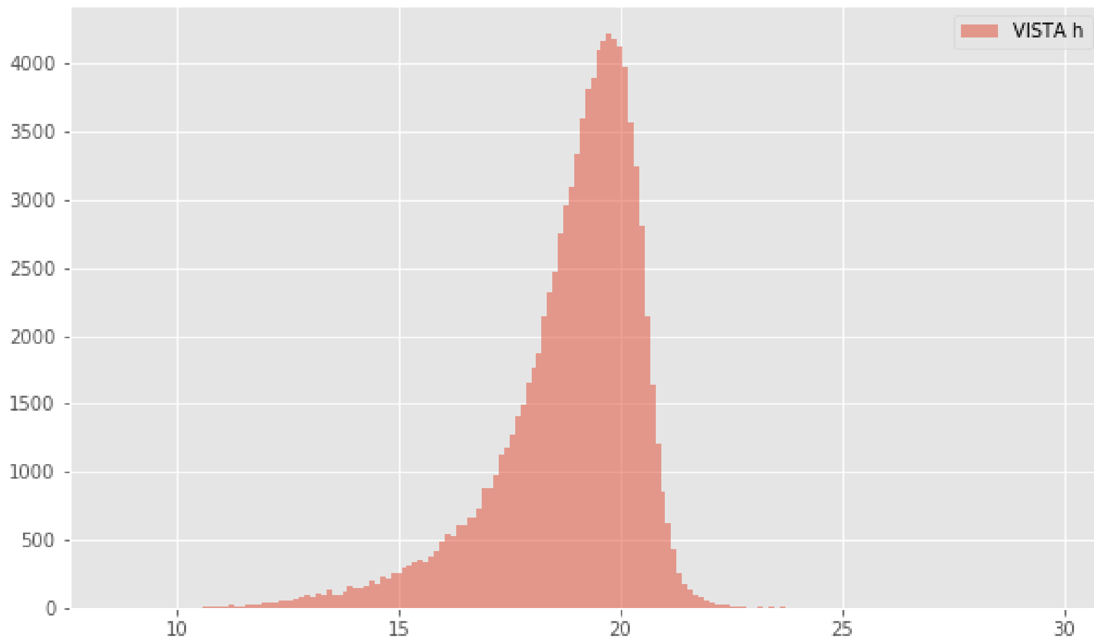

DECam r
17500
15000
12500
10000
7500
5000
2500
0
10
15
20
25
30
35

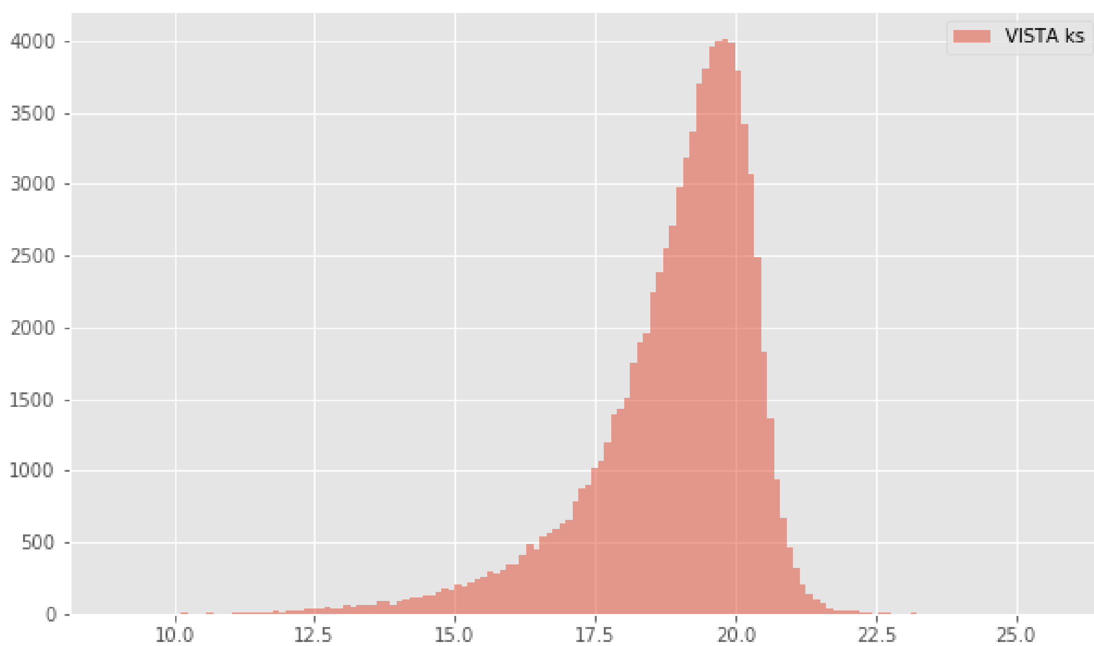

DECam i
0
2000
4000
6000
8000
10000
12000
14000
16000
10
15
20
25
30


DECam z
0
2000
4000
6000
8000
10000
12000
14000
10
15
20
25
30
35


DECam y
14000
12000
10000
8000
6000
4000
2000
0
10
15
20
25
30
35


VISTA j
5000
4000
3000
2000
1000
0
10
15
20
25
30





2.3 III - Comparing magnitudes to reference bands

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

2.3.1 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.

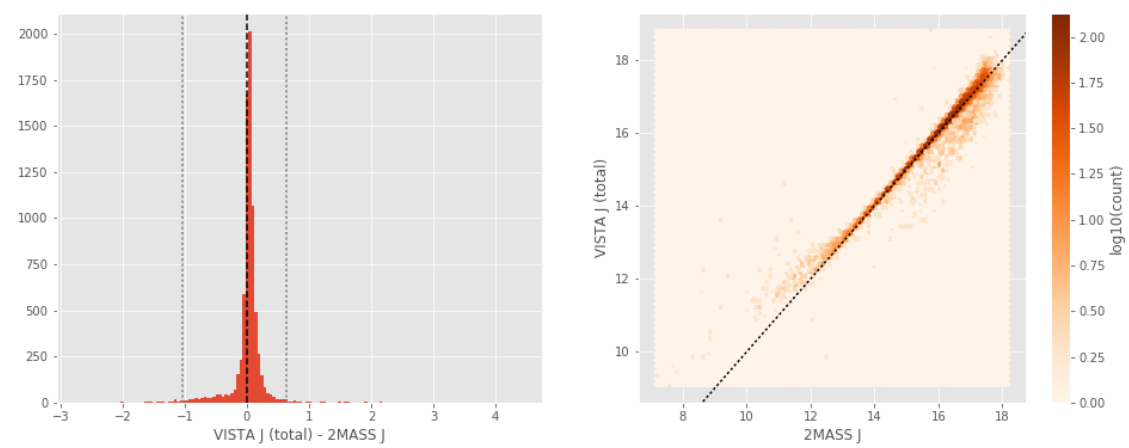
The 2MASS magnitudes are "*Vega-like*" and we have to convert them to AB magnitudes using the zero points provided on this page:

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

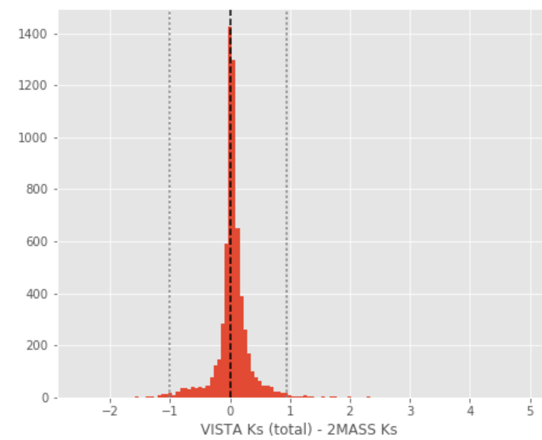
In addition, UKIDSS uses a K band whereas 2MASS uses a Ks ("short") band, this page give a correction to convert the K band in a Ks band with the formula:

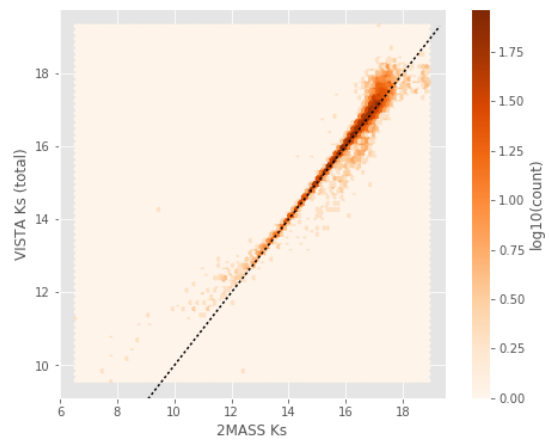
$$K_{s(2MASS)} = K_{UKIRT} + 0.003 + 0.004 * (JK)_{UKIRT}$$

```
VISTA J (total) - 2MASS J:
- Median: 0.03
- Median Absolute Deviation: 0.05
- 1% percentile: -1.0367844232084094
- 99% percentile: 0.6363114506624397
```




```
VISTA Ks (total) - 2MASS Ks:
- Median: 0.04
- Median Absolute Deviation: 0.08
- 1% percentile: -1.0019945516069917
- 99% percentile: 0.9395000327435948
```





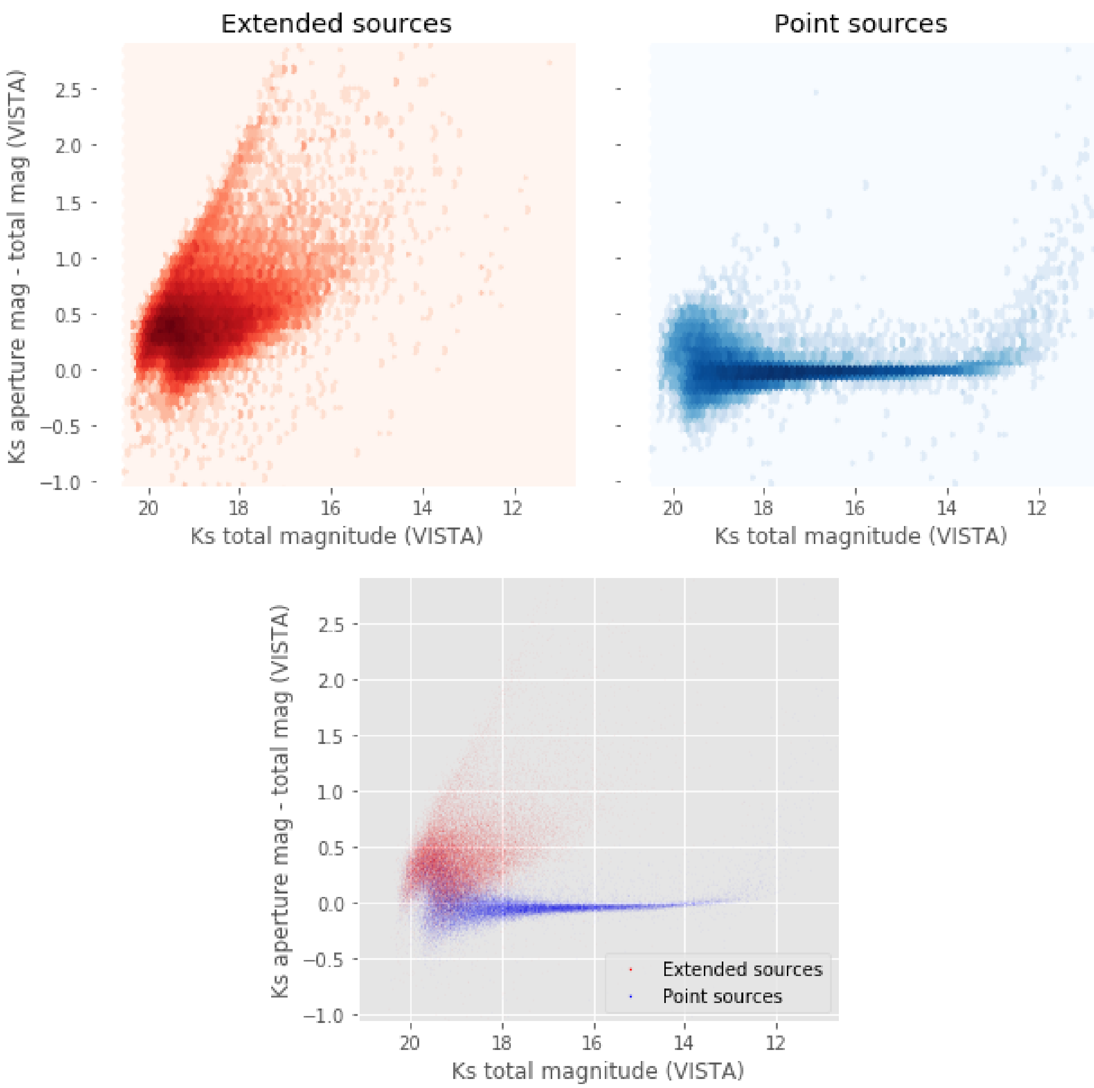
2.4 Keeping only sources with good signal to noise ratio

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.

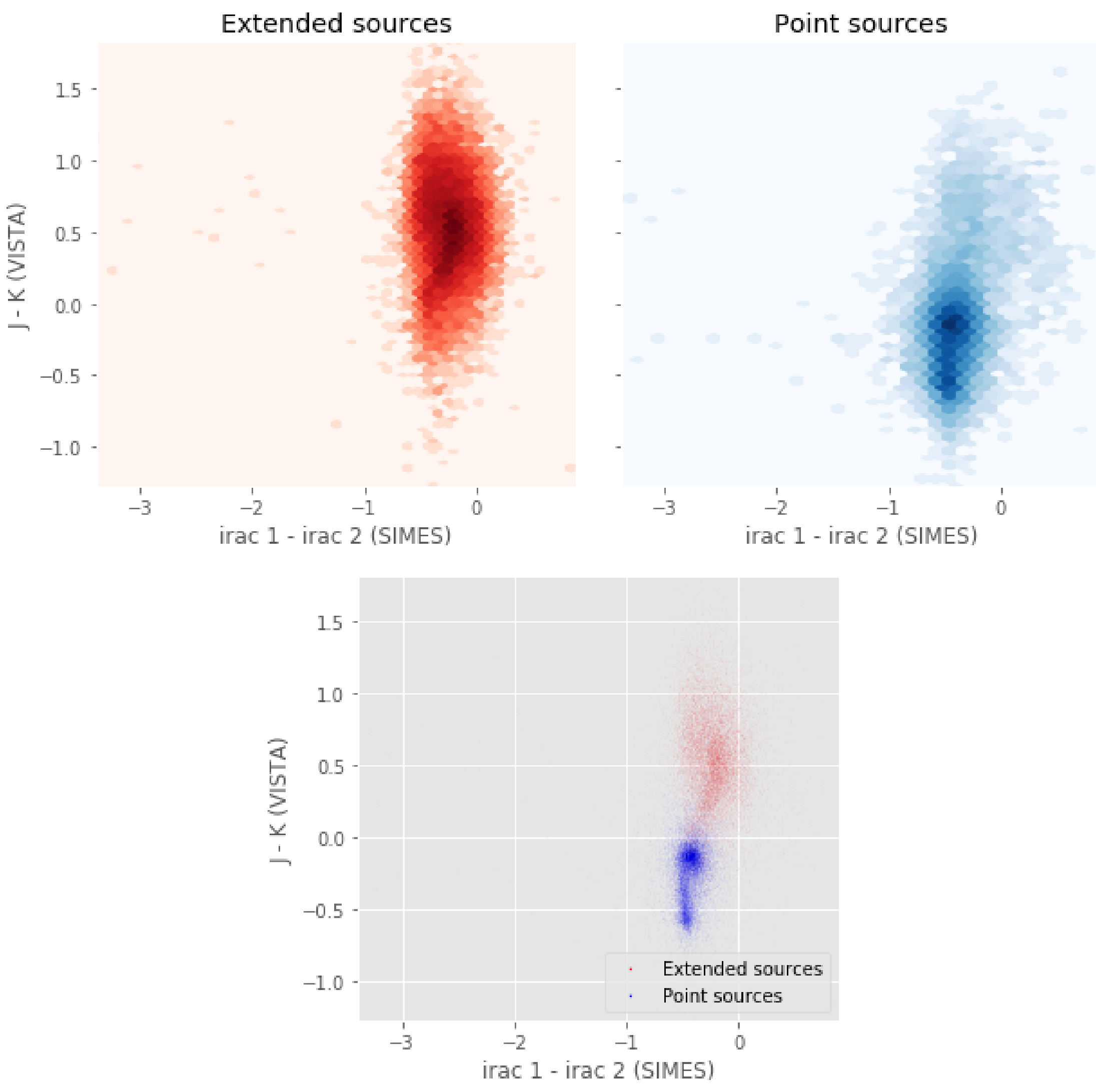
2.5 IV - Comparing aperture magnitudes to total ones.

```
Number of source used: 60282 / 844172 (7.14%)
```



2.6 V - Color-color and magnitude-color plots

```
Number of source used: 33113 / 844172 (3.92%)
```


Extended sources
Point sources
J - K (VISTA)
irac 1 - irac 2 (SIMES)
Extended sources
Point sources

4_Selection_function

March 8, 2018

1 AKARI-SEP 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:
2018-02-27 17:34:48.784227
```

```
Depth maps produced using: master_catalogue_akari-sep_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

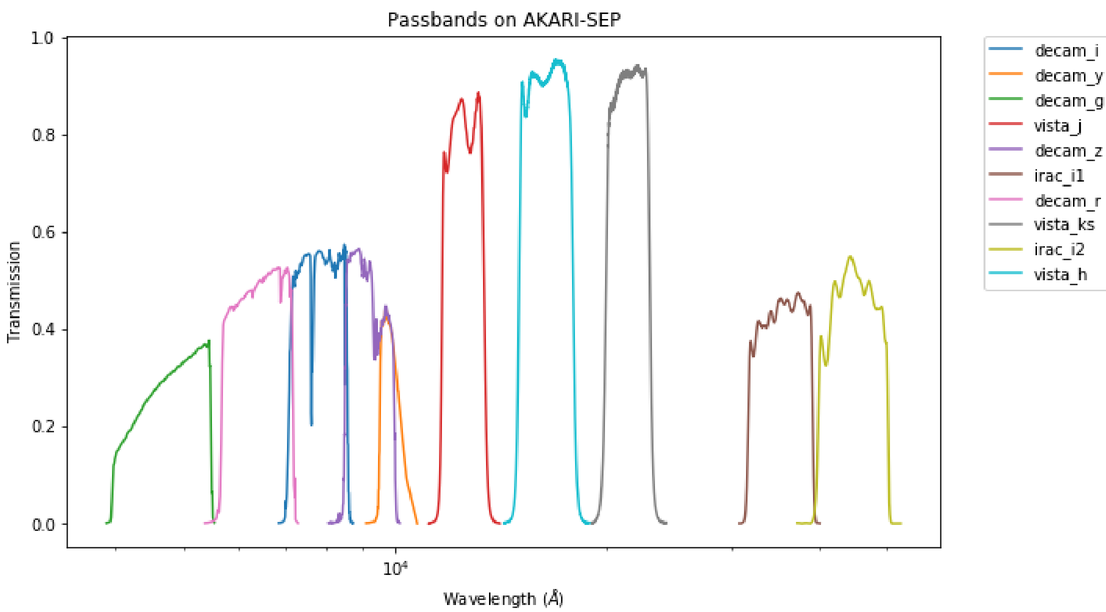
1.5 IV - Overview plots

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]: {'decam_g',
          'decam_i',
          'decam_r',
          'decam_y',
          'decam_z',
          'irac_i1',
          'irac_i2',
          'vista_h',
          'vista_j',
          'vista_ks'}
```

```
Out[15]: <matplotlib.text.Text at 0x7ff30ec4e3c8>
```



1.5.2 IV.a - Depth overview

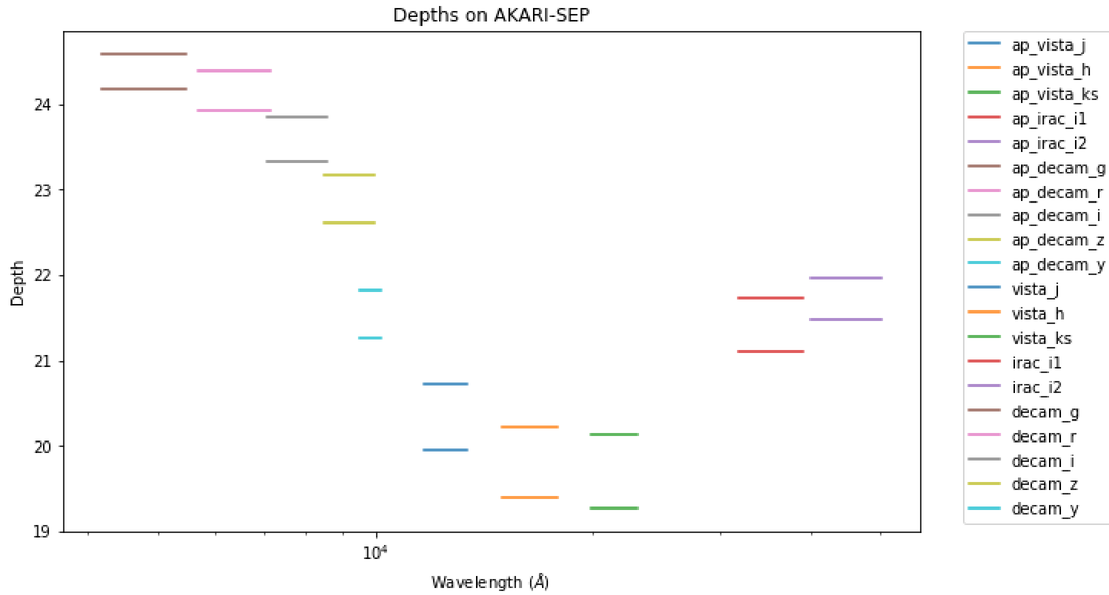
Then we plot the mean depths available across the area a given band is available

```
vista_j: mean flux error: 3.7359588146209717, 3sigma in AB mag (Aperture): 21.276191663444784
vista_h: mean flux error: 5.911341667175293, 3sigma in AB mag (Aperture): 20.77798170900025
vista_ks: mean flux error: 6.426962375640869, 3sigma in AB mag (Aperture): 20.687182469461625
irac_i1: mean flux error: 1.483581781387329, 3sigma in AB mag (Aperture): 22.278918134485288
```

```
irac_i2: mean flux error: 1.1812387704849243, 3sigma in AB mag (Aperture): 22.52635263097286
decam_g: mean flux error: 0.10550510166182817, 3sigma in AB mag (Aperture): 25.14901321245751
decam_r: mean flux error: 0.1277219069632386, 3sigma in AB mag (Aperture): 24.941533377730785
decam_i: mean flux error: 0.20926986973033335, 3sigma in AB mag (Aperture): 24.40543010329315
decam_z: mean flux error: 0.3932180062636109, 3sigma in AB mag (Aperture): 23.720613371061823
decam_y: mean flux error: 1.3569837256612631, 3sigma in AB mag (Aperture): 22.375760265234057
vista_j: mean flux error: 7.652223110198975, 3sigma in AB mag (Total): 20.497727803345207
vista_h: mean flux error: 12.754694938659668, 3sigma in AB mag (Total): 19.94302167370011
vista_ks: mean flux error: 14.317732810974121, 3sigma in AB mag (Total): 19.81751122917145
irac_i1: mean flux error: 2.617389440536499, 3sigma in AB mag (Total): 21.662525998239595
irac_i2: mean flux error: 1.8575319051742554, 3sigma in AB mag (Total): 22.034856158233545
decam_g: mean flux error: 0.15475637329383568, 3sigma in AB mag (Total): 24.733075504441395
decam_r: mean flux error: 0.19579649272025326, 3sigma in AB mag (Total): 24.47768459302491
decam_i: mean flux error: 0.33905077381893145, 3sigma in AB mag (Total): 23.88153501342898
decam_z: mean flux error: 0.6548334382117346, 3sigma in AB mag (Total): 23.166869743238443
decam_y: mean flux error: 2.252593304947897, 3sigma in AB mag (Total): 21.825489890727077
```

```
ap_vista_j (11670.0, 13380.0, 1710.0)
ap_vista_h (15000.0, 17900.0, 2900.0)
ap_vista_ks (19930.0, 23010.0, 3080.0)
ap_irac_i1 (31754.0, 39164.801, 7410.8008)
ap_irac_i2 (39980.102, 50052.301, 10072.199)
ap_decam_g (4180.0, 5470.0, 1290.0)
ap_decam_r (5680.0, 7150.0, 1470.0)
ap_decam_i (7090.0, 8560.0, 1470.0)
ap_decam_z (8490.0, 9960.0, 1470.0)
ap_decam_y (9510.0, 10170.0, 660.0)
vista_j (11670.0, 13380.0, 1710.0)
vista_h (15000.0, 17900.0, 2900.0)
vista_ks (19930.0, 23010.0, 3080.0)
irac_i1 (31754.0, 39164.801, 7410.8008)
irac_i2 (39980.102, 50052.301, 10072.199)
decam_g (4180.0, 5470.0, 1290.0)
decam_r (5680.0, 7150.0, 1470.0)
decam_i (7090.0, 8560.0, 1470.0)
decam_z (8490.0, 9960.0, 1470.0)
decam_y (9510.0, 10170.0, 660.0)
```

```
Out[20]: <matplotlib.text.Text at 0x7ff30ec0fc88>
```



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 0x7ff30e6cf3c8>
```