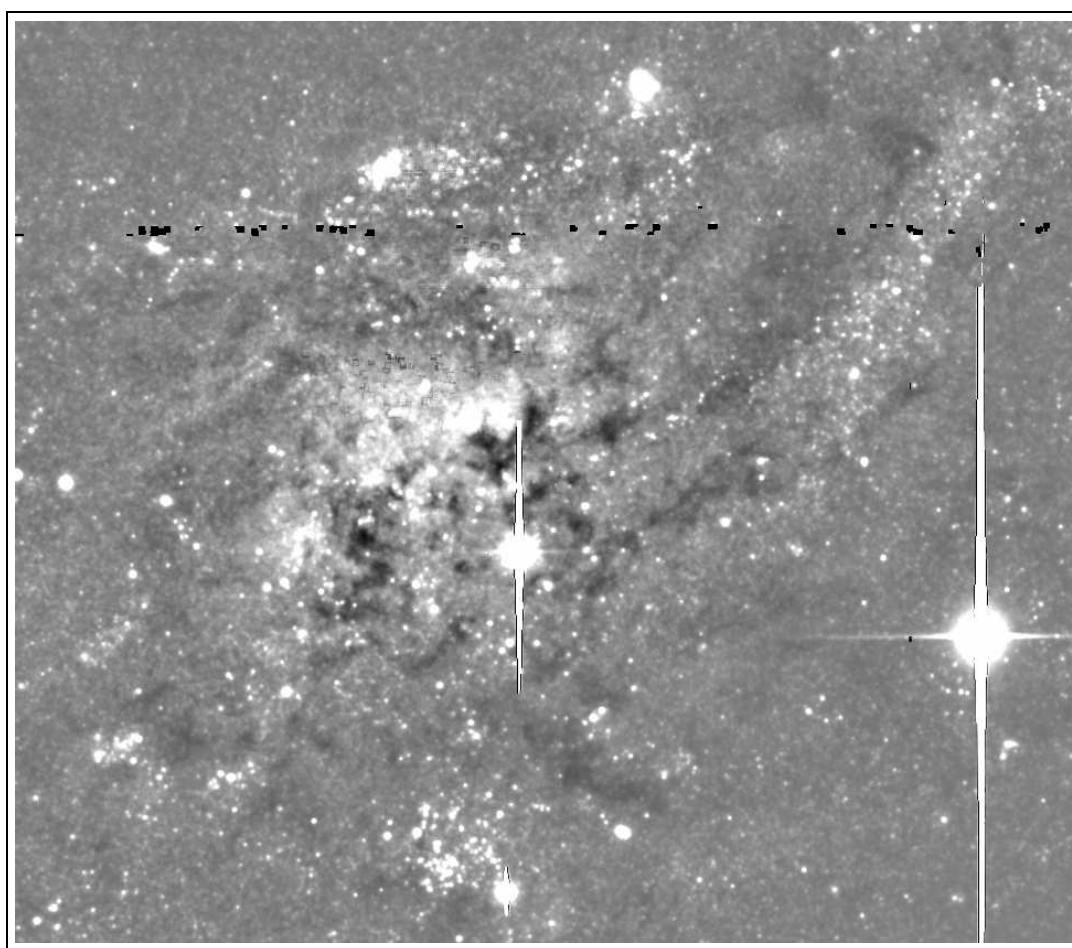


Terapix Processing Report on
MegaCam RunID 07BH10 data,
PI Miguel Urbaneja

Y. Mellier
Terapix/Institut d'Astrophysique de Paris

April 7, 2008



Scope and Content

This report presents a summary of the processing done by Terapix for the MegaCam RunID 07BH10 data. They were produced CFHT for Miguel Urbaneja (PI). It also provides a description of the directories contained in the archive delivered to the PI. The data are u , g and i images centered on NGC 2403. This summary provides an overview of the processing, but does not show all results in details: most output files or relevant statistics for the quality assessments are provided in the archive delivered to the PI.

The report includes a presentation of a series of tests done by Terapix to optimize the background subtraction parameters. This field is dominated by the very extended spiral galaxy NGC 2403 that fills most of the MegaCam field, so its processing need special attention. A recommendation on the best suited parameters is suggested, based on these tests. For practical and immediate scientific usage, most directories are therefore useless. In short, the most important data of the archive delivered to the PI are `Merged-ugICAT-and-PLOTS-summary` and the FITS stacks in `AllStacks/StacksMedianBack064`.

- I. Relevant files
- II. Operation sequence:
- III. Investigation of the background and selection of best
- IV. Filenames and Directories in the archive delivered to the PI
- V. Useful references and links.

I. Inventory of Relevant files

The following tables provide the image lists that have been used during the various steps of the selection processes and the processing.

I.1. Input images delivered by CFHT

In table I all images relevant for Terapix and provided by CFHT on the 07BH10 archive are listed as well as the most useful parameters for the selection of images.

The master files have been produced by CFHT using ELIXIR. Only those that are relevant for Terapix are listed: the master masks and master flat files are used by `QualityFITS` to produce weightmap images. The filters are the current MegaCam filters. i_2 refers to the new i-band filter. It replaces the old i broken in September 2007.

Terapix only selects validated images by CFHT. They are labelled as `VAL`. Images with the photometric flag "P" have been obtained during photometric nights. Otherwise, they have a "A" flag.

Table 1: Full Master and Detrended image list provided by CFHT.

| File name | Status | Filter | Photometric Flag |
|---------------------------|---------------|---------------|-------------------------|
| 07Bm03.flat.g.36.02.fits | Master flat | <i>g</i> | - |
| 07Bm03.flat.u.36.02.fits | Master flat | <i>u</i> | - |
| 07Bm04.flat.i2.36.01.fits | Master flat | <i>i2</i> | - |
| 2003A.mask.0.36.01.fits | Master mask | - | - |
| 947437p.fits | OBS | <i>u</i> | P |
| 947456p.fits | OBS | <i>g</i> | P |
| 947457p.fits | OBS | <i>g</i> | P |
| 947541p.fits | OBS | <i>g</i> | A |
| 947592p.fits | OBS | <i>g</i> | P |
| 947593p.fits | OBS | <i>g</i> | P |
| 947594p.fits | OBS | <i>g</i> | P |
| 947715p.fits | OBS | <i>u</i> | P |
| 947716p.fits | OBS | <i>u</i> | P |
| 947717p.fits | OBS | <i>u</i> | P |
| 947718p.fits | OBS | <i>u</i> | P |
| 947719p.fits | OBS | <i>u</i> | P |
| 947720p.fits | OBS | <i>u</i> | P |
| 947721p.fits | OBS | <i>u</i> | A |
| 947875p.fits | VAL | <i>u</i> | P |
| 947876p.fits | VAL | <i>u</i> | P |
| 947877p.fits | VAL | <i>u</i> | P |
| 947878p.fits | VAL | <i>u</i> | P |
| 947879p.fits | VAL | <i>u</i> | P |
| 948269p.fits | OBS | <i>g</i> | A |
| 948464p.fits | VAL | <i>g</i> | P |
| 948465p.fits | VAL | <i>g</i> | P |
| 948466p.fits | VAL | <i>g</i> | P |
| 948467p.fits | VAL | <i>g</i> | P |
| 948468p.fits | VAL | <i>g</i> | P |
| 955098p.fits | VAL | <i>i</i> | P |
| 955099p.fits | VAL | <i>i</i> | P |
| 955100p.fits | VAL | <i>i</i> | A |
| 955101p.fits | OBS | <i>i</i> | A |
| 955282p.fits | VAL | <i>i</i> | P |
| 955283p.fits | VAL | <i>i</i> | P |
| 955422p.fits | VAL | <i>i</i> | P |

Table 2: Terapix image selection list

| File name | Filter | Exp. time |
|------------------|---------------|------------------|
| 947875p | <i>u</i> | 600s |
| 947876p | <i>u</i> | 600s |
| 947877p | <i>u</i> | 600s |
| 947878p | <i>u</i> | 600s |
| 947879p | <i>u</i> | 600s |
| | | Total: 3000s |
| 948464p | <i>g</i> | 200s |
| 948465p | <i>g</i> | 200s |
| 948466p | <i>g</i> | 200s |
| 948467p | <i>g</i> | 200s |
| 948468p | <i>g</i> | 200s |
| | | Total: 1000s |
| 955098p | <i>i</i> | 520s |
| 955099p | <i>i</i> | 520s |
| 955100p | <i>i</i> | 520s |
| 955282p | <i>i</i> | 520s |
| 955283p | <i>i</i> | 520s |
| 955422p | <i>i</i> | 520s |
| | | Total: 3120s |

I.2. Selected Images

The selection list contains the Terapix parent sample for the whole processing. In practice it is composed of all images with a "VAL" status.

II. Terapix operation sequence and data flow:

- II.1. **QualityFITS**: quality assessments and "ID-card" of each input image, weightmap image production. There is one summary index.html produced per image. the main steps of the processing are:
 - II.1a. input image analysis, CFHT astrometric calibration assesement,
 - II.1b. weightmap image production (filename: imagenamefile_weight.fits),
 - II.1c. input ldac catalogue (early basic object catalogue needed for further astrometry study)
 - II.1d. **QualityFITS** is ran once, no double-pass mode is needed for the sky model
- II.2. **Scamp**: astrometric and relative photometric calibration (field to field rescaling) using the early ldac catalogues produced by **QualityFITS**. There is one summanry scamp.xml file for all images calibrated together, as well as a series of astrometric and photometric assessment files. The quality assessments are provided in the scamp.xml XML file readable by the PI-preferred browser. The main steps are:

- II.2a production of .ahead photometric calibration files (T=photometric, F=non photometric)
- II.2b astrometric calibration. The astrometric reference catalogue is: 2MASS.
- II.2c relative photometric rescaling
- II.2d production of .head astrometric calibration files
- II.3. **Swrap**, **SExtractor** and **AutoMask**: production of *u*, *g* and *i*2 stacks and a catalogue for each stack. There is one swarp*.xml produced per stack.
 - II.3.a The stacked images have the following properties (defined in the swarp.conf configuration file):
 - * All images have
 - the same pixel scale : 0.186"/pixel,
 - the same size : 19354 × 19354, pixels,
 - the same center position : J2000 07:36:50,+65:36:21.0.
 - * The stacks are produced by
 - a median of an input image list, weighted accordingly, and
 - combined using a **Lanczos3** interpolation kernel,
 - * The reference system is
 - the Equatorial coordinate system, J2000 (FK5) and
 - the projection type is the distorted tangential TAN.
 - II.3b. *u*, *g* and *i* stacked images + weightmaps, then production of ldac catalogues. Parameter definitions and content of catalogues can be found at the following URL (definitions) http://terapix.iap.fr/article.php?id_article=715 and at (catalogue content) http://terapix.iap.fr/article.php?id_article=628.
 - II.3c. production of mask .reg ds9 compliant ASCII file in WCS coordinates

Important notice: for the 07BH10 data, a series of stacks has been produced using different parameters to compute the background in order to explore their impact on the detection and the photometry of objects and to set optimum parameters. Most stacks are therefore experiments not suitable for science. However, we deliver all *u*,*g*, and *i* stacks/catalogues we did to keep informed PIs' and leave them the final decision on the best parameters according to their ultimate science goals. Please have a look at Sec. III of this summary: we find the best output products are for the following **Swrap** background parameters

- BACK_SIZE=64, BACK_FILTERSIZE=3 (BackMesh64-BackFiltSiz3)
- BACK_SIZE=32, BACK_FILTERSIZE=5 (BackMesh32-BackFiltSiz5)
- BACK_SIZE=128, BACK_FILTERSIZE=3 (BackMesh128-BackFiltSiz3)

All tests are in directories with self-explanatory names defined see Sect. IV.

- II.4. **Swrap** in dual mode and **SExtractor**: Chi2 image/catalogue and merged catalogue production (one scamp*.xml).
 - II.4a. The swarp.conf is the same as the non-dual mode of the previous sections
 - II.4b. *ugi*2-chi2 image + weightmap production
 - II.4c. chi2+*u* chi2+*g* and chi2+*i* catalogues (*.cat ASCII files). All catalogues should have the same number of objects inside.

- II.4d. merged *ugi* catalogue
Chi2- $[u, g, i]$ catalogue parameters: see http://terapix.iap.fr/article.php?id_article=628
Information/definition: see http://terapix.iap.fr/article.php?id_article=715
- II.4d. stellar color-color tracks and comparison with Pickles

Important notice: 3 chi2 images and merged catalogues have been produced. They correspond to the best parameters for the background subtraction listed in the previous item. All chi2/catalogues produced for the three sets are put in the archive.

Note that no E(B-V) has been applied to object catalogues nor to images.

III. Investigation of the background and selection of best Swarp parameters for NGC 2403

Scope: The 07BH10 Megacam program, PI Miguel Urbaneja, consists of observations of a very extended (i.e. much larger than a Megacam CCD size) galaxy NGC 2403. **Swarp** fails in getting a good background subtraction when a very extended object is located in the field because it contaminates all pixels. Prior to deliver these data to the PI, several tests have been done on 07BH10 data. These experiments were used to derive the best background subtraction process, to check the reliability and the stability of both the detection and photometry computed by **SExtractor**, and finally to explore the sensitivity of output catalogues to background parameter settings used in **Swarp**.

The current default value of the mesh size in **Swarp** is 256 pixels. In the following, several other mesh sizes (**Swarp** BACK_SIZE background parameter) and background filter sizes (**Swarp** BACK_FILTERSIZE background parameter) have been used. As discussed below, we conclude the best mesh size is 64 pixels, if BACK_FILTERSIZE=3, or 32 pixels, if BACK_FILTERSIZE=5.

We start from the default "default-auto.swarp" configuration file Terapix uses for all CFHTLS data. All input data use the same **Scamp** output parameters. All tests done with *u*, *g* and *i* data.

All output images and catalogues are archived in the current processing directory and, from there, in self explanatory sub-directories.

Comparison will often discuss the residuals observed at three reference positions common to all images and also on one large scale feature:

1. the extended galaxy: centre Megacam position, hereafter G0 (NGC 2403),
2. the bright star at (center pixel 13000,11000), hereafter S1,
3. the merging galaxies at (centre pixel 1660,8748), hereafter MG2, and
4. the large scale CCD to CCD background residual fluctuations.

The locations of MG2, G0 and S1 are indicated in Fig 1. These references provide three object types where we expect critical sensitivity to the background definition: G0 is bright, extended and very clumpy, S1 is saturated, very bright and produces multiple light scatterings that contaminate the background at all scales around the star, and MG2 is an intermediate size object (i.e. much smaller than G0, but significantly larger than the mean size of galaxies in the field that currently set the optimal background mesh size). Having these three objects in the field implies it is unlikely we can find a set of parameters that will be suitable for all of them.

This is therefore an interesting but difficult case. The ultimate choice will then strongly depend on the scientific objectives of the PI.

- III.1. Use MEDIAN filter and subtract background using different mesh sizes:
 - III.1.1 Mesh size tested with BACK_FILTERSIZE=3: 4096, 2048, 1024, 512, 256, 128, 64, 24 and 16 pixels (best 64)
 - III.1.2 Mesh size tested with BACK_FILTERSIZE=5: 64, 48 and 32 pixels (best 32)
 - III.1.3 Mesh size tested with BACK_FILTERSIZE=7: 32 pixels only.
- III.2 Specific comments: (if not specified in the filename BACK_FILTERSIZE=3)
 - III.2.1 All mesh sizes with BACK_FILTERSIZE=3
 - * Mesh 16 and 24 pixels: the spiral large scale structure and the innermost region of G0 vanish or look too fragmented.
 - * Mesh 4096, 2048, 1024 and 512 pixels: the CCD edges show strong discontinuities in the residual background pattern.
 - * Mesh 256: close to good, but CCD edges too sharp in the central region of G0.
 - * Mesh 128, 64: seem the optimal results. Mesh 128 seem better preserve the central large scale G0 light distribution, but still show CCD sharp discontinuities. For mesh 64, the sharp discontinuities almost vanish, but the central large scale light distribution of G0 looks a bit degraded. Mesh 64 seem the best.
 - III.2.2 Comparison: BackMesh64-BackFiltSiz3, BackMesh64-BackFiltSiz5, and also BackMesh48-BackFiltSiz5: worse is BackMesh64-BackFiltSiz5. CCD edges more visible on BackMesh48-BackFiltSiz5.
 - III.2.3. Test with BackMesh32-BackFiltSiz5: CCDs sharp edges totally suppressed, but part of large scale innermost G0 removed and important negative values of the background residual inside the bulge. The BackMesh32-BackFiltSiz5 is better than BackMesh32-BackFiltSiz7 and BackMesh64-BackFiltSiz3 in *u*-band. The BackMesh32-BackFiltSiz5 better remove background residual near S1.

For further chi2 exploration we decided to focus only on BackMesh32-BackFiltSiz5 versus BackMesh64-BackFiltSiz3: run chi2 images on both. We will include however a test chi2 image with BackMesh128-BackFiltSiz3 to check consistency between each stack as function of the background mesh size.

- III.3 Results and recommendation

As the front cover image shows (this is a MegaCam image of NGC 2403, in *i*-band. The stack was obtained with BackMesh64-BackFiltSiz3), none of the parameter sets we tested provide a fully satisfactory result for G0, S1 and MG2 and for the large scale feature we considered as references. When the small scale features seem well detected and resolved inside NGC 2403, we see a deep halo surrounding MG2 that produces wrong background estimate on scale close to the size of MG2. In contrast, when the large scale CCD to CCD residual background fluctuations are perfectly removed, we cannot detect features inside NGC 2403. On the other hand, if the mesh size is too large as compared to the CCD size, then the CCD to CCD fluctuations increase. The three best options we selected are therefore compromises, but only correspond to a trade off between all scales. Fortunately, as discussed below, for these parameter sets, the detection and the photometry look reasonably good and stable.

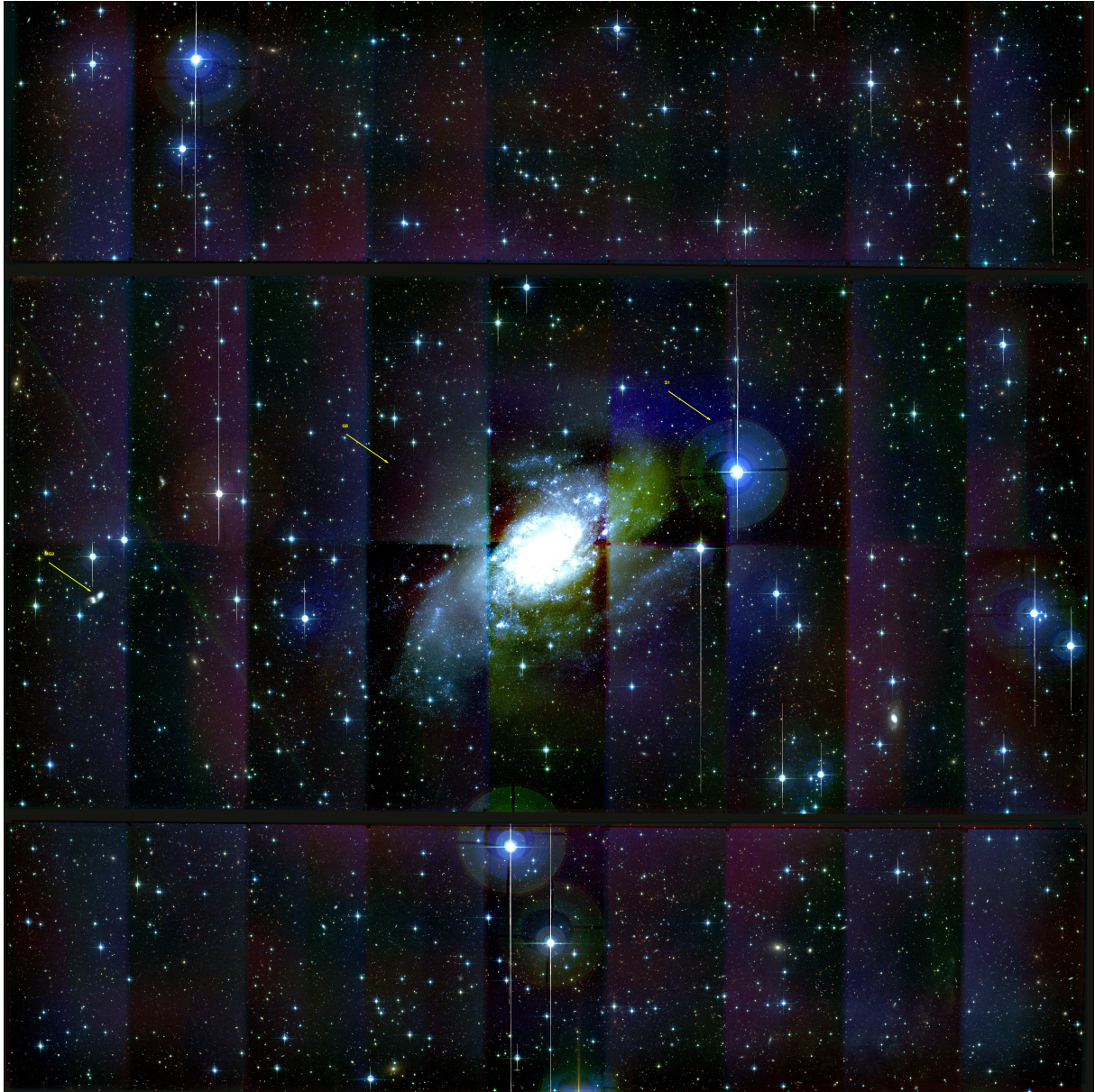


Figure 1: A *ugi2* color image of the NGC 2403 combining the three stacks derived by using a background mesh size of 1024 pixels. The CCD to CCD background residual is clearly visible, illustrating why one cannot use a mesh with size comparable to the CCD size. The three arrows indicate the positions of the reference positions used to compare each stack. From left to right: MG2, G0 and S1.

Fig.2 shows the comparison of the u , g and $i2$ photometry for the three best set of parameters. In order to derive the impact of NGC 2403 on the detection and the photometry, the comparison is done in two decoupled areas of each MegaCam image centered at the NGC 2403 center position: inside the radius $R < 2000$ pixels and outside the radius $R > 3000$ pixels. For each, we compared `BackMesh64-BackFiltSiz3`, `BackMesh32-BackFiltSiz5` and `BackMesh128-BackFiltSiz3` catalogues, we cross-correlated them and only used common objects. Fig.2 demonstrates there is no significant differences between the three best options. The `BackMesh128-BackFiltSiz3` data, in particular at faint magnitude in u band, show a slight deviation from a linear slope=1 correspondance and a larger scatter than the `BackMesh64-BackFiltSiz3` or `BackMesh32-BackFiltSiz3` stacks.

We then compared the stellar color-color tracks derived on the 3 stacks using their common stars. They are shown on Fig.3. Each star is represented by a triplet of red, blue and green points corresponding to each stack. In order to better distinguish them, a small shift of 0.01 mag. has been applied in both axes. So, in case of perfect overlaps, each star is represented by a small 3-color segment aligned the first diagonal of the plot. The triplets are clearly visible and, for most, there are oriented along the diagonal. It shows there is no significant differences in color in the common star sample for the three sets of the best `Swarp` background parameters. Further, all overlap very well with the Pickles data points, showing that the photometry seems reasonably good.

In summary, we found the `BackMesh128-BackFiltSiz3` option has larger scatter and show (small) deviations with respect to the two other sets of background parameters we analysed. We think `BackMesh64-BackFiltSiz3` or `BackMesh32-BackFiltSiz5` provide more stable results. They indeed correspond to the best suited options we anticipated in view of the huge crowding produced by NGC 2403. Therefore, we recommend to use (by decreasing priority)):

- 1. `BackMesh64-BackFiltSiz3` or `BackMesh32-BackFiltSiz5`,
- 2. `BackMesh128-BackFiltSiz3`.
- 3. All others do not seem suitable, but we recommend the PI to check whether some may be better for their own scientific objectives.

Note that we made few tests using the `AVERAGE` instead of the `MEDIAN` to stack the images. We did not see significant differences, though `MEDIAN` should be better since we only stacks 5-6 images in each filter.

IV. Filenames and Directories

- IV.a. - Directory `AllQFITS` Directory with `log`, `ldac` and directory of all outputs for each image
 - `947875p`: Directory with `QualityFITS` output (`947875p` taken as an example, but the directory name and its content apply to all images). In order to have an overview of the `947875p` quality assessment, go to the `qualityFITS` directory and run "yourpreferred browser index.html"
 - `947875p.ldac`: Initial `ldac` catalog (usage; astrometry). Binary FITS Table.
 - `947875p.log`: ASCII log file of the `QualityFITS` processing history
- IV.b. - Directory `AllSingleImage` (images and weightmaps images): Weightmap image produced by `QualityFITS`. `947875p.fits.gz` and `947875p_weight.fits.gz` FITS images

Stability photometry as function of background subtraction parameters

Radius: radial distance from the center of NGC 2403

R<2000 = inside NGC2403
R>3000 = outside NGC2403

back64 = Swarp parameter Back_Size=64, Back_FilterSize=3
back32 = Swarp parameter Back_Size=32, Back_FilterSize=5
back128 = Swarp parameter Back_Size=128, Back_FilterSize=3

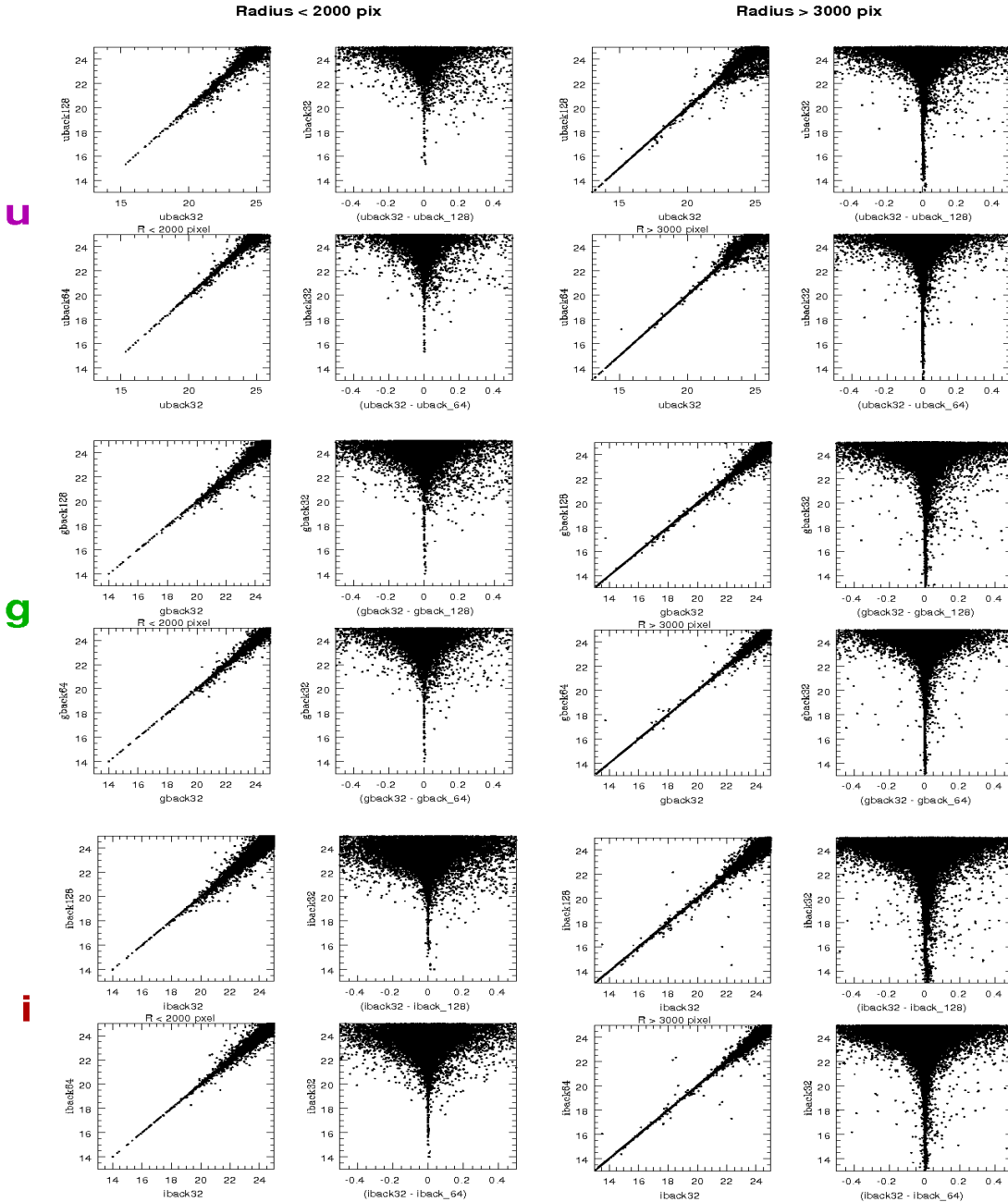


Figure 2: Comparison of the *ugi2* photometry derived on the NGC 2403 field for the 3 best Swarp background parameters (see Sec.IV). The figure shows 3 series (one per filter 4×2 plots). The left panels explore the innermost region ($R < 2000$ pixels), where the contamination by the galaxy is important, the right panels are for the outermost regions, where the contamination should be almost zero ($R > 3000$ pixels). The plots demonstrate the best sets of parameters do not show significant differences in the detection and in the photometry.

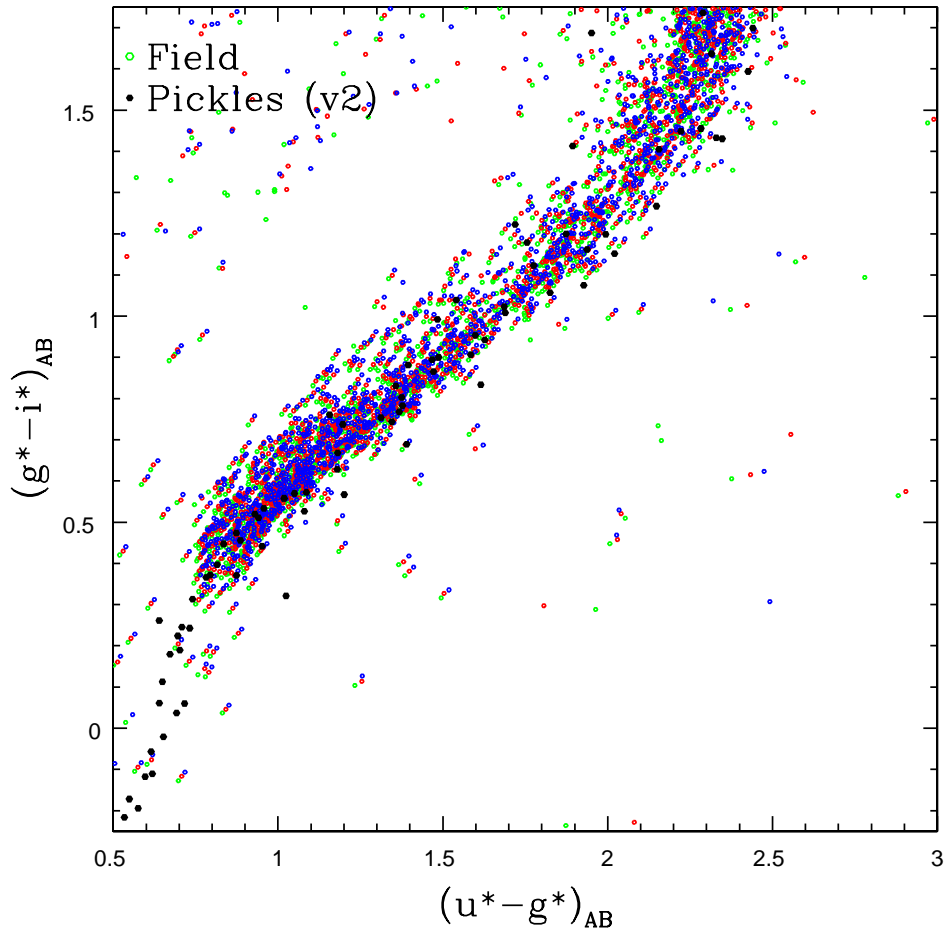


Figure 3: Comparison of the stellar color-color tracks obtained from the analysis of the brightest stars ($18 < i < 21$). The red-green-blue points are the common stars we selected on each stack for the three best set of parameters. They are shifted by 0.01 mag. along both axes to avoid overlaps, for clarity. The dark dots are the Pickles data points.

- IV.c. - Directory AllAstrPhotInOut
 - 947875p.ahead. ASCII file containing input photometric/non photometric status
 - 947875p.head. ASCII File with image astrometric parameters
- IV.d. - MasterImage: Directory with CFHT mask+flat FITS master files
- IV.e. - Merged-ugiCAT-and-PLOTS-summary: Directory with all *ugi*-merged catalogs for the 3 best set of parameters, a series of plots+ a ReadMe file for: `back064-backfiltersize5`, `back032-backfiltersize7`, and `back128-backfiltersize5`.
- IV.f. - Scamp-output: Astrometric/photometric output files. Run "yourpreferred browser scamp.xml"
- IV.g. - Directory AllStacks:
 - On top : `mask07BH10PIMiguelUrbaneja.reg` file is the ASCII ds9 compliant mask file in WCS

- StacksMedianBack064: Directory with stack files in u, g, i using Background Mesh=64 pixels and Background Filter Size = 3 (this is default, so, it is not specified in the directory name). Chi2 image/catalogues are included. All directories contain a ugi color tif image. This tif image is not for poster, but to check the three bands overlap perfectly and whether chromatic effects are present (in particular at the extreme edges of the fields).
- StacksMedianBack032-BckFilsiz5: Directory with stack files in u, g, i using Background Mesh=32 pixels and Background Filter Size = 5 Chi2 image/catalogues computed
- StacksMedianBack128: Directory with stack files in u, g, i using Background Mesh=128 pixels and Background Filter Size = 3 Chi2 image/catalogues computed.
- StacksMedianBack016: Directory with stack files in u, g, i using Background Mesh=16 pixels and Background Filter Size = 3 (this is default, not specified)
- StacksMedianBack024: Directory with stack files in u, g, i using Background Mesh=24 pixels and Background Filter Size = 3 (this is default, not specified)
- StacksMedianBack032-BckFilsiz7: Directory with stack files in u, g, i using Background Mesh=32 pixels and Background Filter Size = 7
- StacksMedianBack048-BckFilsiz5: Directory with stack files in u, g, i using Background Mesh=48 pixels and Background Filter Size = 5
- StacksMedianBack064-BckFilsiz5: Directory with stack files in u, g, i using Background Mesh=64 pixels and Background Filter Size = 5
- StacksMedianBack1024: Directory with stack files in u, g, i using Background Mesh=1024 pixels and Background Filter Size = 3
- StacksMedianBack2048: Directory with stack files in u, g, i using Background Mesh=2048 pixels and Background Filter Size = 3
- StacksMedianBack256: Directory with stack files in u, g, i using Background Mesh=256 pixels and Background Filter Size = 3
- StacksMedianBack4096: Directory with stack files in u, g, i using Background Mesh=4096 pixels and Background Filter Size = 3
- StacksMedianBack512: Directory with stack files in u, g, i using Background Mesh=512 pixels and Background Filter Size = 3

1 Useful references and links

- Scamp: <http://terapix.iap.fr/IMG/pdf/scamp.pdf>
- Swarp : <http://terapix.iap.fr/IMG/pdf/swarp.pdf>
- SExtractor : <http://terapix.iap.fr/IMG/pdf/sextractor.pdf>
- Parameter listed in each catalogue: http://terapix.iap.fr/article.php?id_article=628
- Catalogue parameter definitions: http://terapix.iap.fr/article.php?id_article=715