

# Optimizing SExtractor Parameters for Subaru MACS Fields

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August 6, 2006

## Abstract

Astronomers use SExtractor to extract and classify photometric sources according to their properties—photometric, morphological, or statistical. The benefits of SExtractor output are used in many subfields of astronomy, but its configuration must be altered upon each use for the most optimal and accurate science. The Subaru MAssive Cluster Survey (MACS) fields are particularly problematic due to the high concentration of galaxy cluster objects towards the frame centers, making it difficult for SExtractor to deblend adjacent objects and fit the appropriate apertures. Herein I describe the appropriate SExtractor parameter configuration for the MACS SUBARU observations, and describe a parallel technique used by COSMOS (Scoville, et al, ApJS, in press 2007) in extracting sources and subsequently assigning photometric redshifts.

## 1 The Configuration File

Among all of the parameters in the SExtractor configuration file, only a couple are pertinent to detection of galaxies in crowded fields. We consider the following parameters:

- DETECT\_MINAREA
- DETECT\_THRESH
- DEBLEND\_NTHRESH
- DEBLEND\_MINCONT

While the background is vital to the object detection process, here we manipulate object specific parameters, and not those depending greatly on the background fit. Later, I describe the use of the weight image for the Subaru MACS fields, and none of the parameters above will be effected by the consideration of the weight image. The characteristic length scale of an object in the Subaru fields ranges from 30 pixels diameter to 100 pixels diameter (6" to 20" with a 0.2" *pixel*<sup>-1</sup> scale), so we use a background grid size of *BACK\_SIZE* = 300 pixels. The test image already has a fairly isotropic background, so we set the background filter smoothing parameter to *BACK\_FILTERSIZE* = 5 pixels. These are held constant unless otherwise stated.

### 1.1 DETECT\_MINAREA

This parameter is the minimum number of continuous adjacent pixels with flux values over the DETECT\_THRESH limit. If an object does not have more than this number of high-flux pixels, then SExtractor does not count it as an object. Initial visual tests on the Subaru images reveal that a reasonable value is 10 pixels, and practical values range from about 3 to 20 pixels.

In Figure 1, we see the effect of varying DETECT\_MINAREA on detection of fainter, extended objects. With a low value, at 3, we see more detections and significantly better results than higher values like 15 and 20.

## 1.2 DETECT\_THRESH

This value sets the number of  $\sigma$ 's above the local background that an object must be to be detected. *DETECT\_THRESH* is used for photometry at a later point.

Since this variable is fairly straightforward, we can quickly settle on an intermediate value of 3.5 after testing the range 1.5 to 4.5. If *DETECT\_THRESH* is lowered significantly, we not only see noisy false detections appearing, but also in crowded areas, bright objects are more likely blended together than distinguished individually; this is an artifact of the background fit, since crowded areas lie on flux plateaux with respect to the rest of the image. These effects can be seen in Figure 2.

## 1.3 DEBLEND\_NTHRESH

*DEBLEND\_NTHRESH* is the number of levels allowed between the threshold and the maximum count in the object. A level is defined when two sections of the object split off into branches, where the pixels inbetween have lower flux values. SExtractor only seems to accept values that are powers of 2. The default value is 32, but the testing ranges from 2 to 64.

It is fairly unclear if this parameter has much of an impact on the choice of detections. Rather, it changes the aperture shape and orientation; at higher values, we see larger fitted apertures and more blends than at smaller values. At *DEBLEND\_NTHRESH* = 2, we see the objects will be individually resolved with equally skewed apertures. The best value for these Subaru images is 16 (although the default was 32). Figure 3 shows illustrates these effects.

## 1.4 DEBLEND\_MINCONT

SExtractor constructs a 'tree' of objects, and can successively break up an object into smaller and higher branches depending on count value. If a small galaxy is hovering in the wing of a bright star, then this fraction, *DEBLEND\_MINCONT*, sets the minimum flux ratio between the small galaxy and the bright star for which the galaxy will successfully be detected. We find that lowering it to ridiculously small percents gives better results, but we will start out with 0.005 (0.5 %) and progress towards 0.00005 (0.005 %).

While higher percentage values might be more useful in stellar, non-crowded fields, here we must lower the fraction significantly to pick up on faint objects sitting in the wings of bright objects. We tested the fractions 0.05, 0.005, 0.0005, and 0.00005. The lowest value, 0.00005, gave the best results. See Figure 4 for examples.

## 2 Detecting Faint and Blended Objects

From multiple tests, we converge on the optimal combination of the previously explained parameters. For the Subaru images, we use

$$DETECT\_MINAREA = 4[\text{pixels}] \quad (1)$$

$$DETECT\_THRESH = 3.0[\sigma] \quad (2)$$

$$DEBLEND\_NTHRESH = 16[\text{branches}] \quad (3)$$

$$DEBLEND\_MINCONT = 0.00005[\text{fraction}] \quad (4)$$

The result is not yet ideal, but is much better suited for faint crowded-field detections than the default values. Figure 5 shows the result.

## 3 Cleaning

In the configuration file, you can choose to 'clean' your image, or not clean it; if you decide to clean the image, you choose a cleaning efficiency between 0.1 and 10. The default value is 1.0. Since cleaning effects the detections made in the wings of bright objects, it is important that we adjust this parameter

to give more leeway for crowded fields. From the original setting of 1.0 efficiency (the value used to test the previously described parameters), we change the efficiency to 5.0; we see far more detections with a 'higher' efficiency, most of which are real objects. If we turn off cleaning completely, we see many more detections, many of which are spurious false detections close to very bright objects. After several test runs, we set the cleaning efficiency to 2.0. Figure 6 shows the effect of changing the cleaning efficiency on the Subaru image.

## 4 Aperture Manipulation

While we might have found a good combination of parameter values that decide what is a detection and what is not, we can choose to further restrict the aperture size and shape which is a critical factor when computing photometry. There are two parameters that can manipulate the aperture size and 'elongation'—both fall under the title PHOT\_AUTOPARAMS. (Since we wish to compute magnitudes using the 'AUTO' aperture, we use PHOT\_AUTOPARAMS and not PHOT\_APERPARAMS.) Both factors depend on the half-light ellipse, and represent scaling factors. The first value under the name PHOT\_AUTOPARAMS is the  $k$  factor, which determines the relative change in ellipticity in an object from its core to its edges (which can be a problem with galaxies with bright central cores and elliptical outer shape). The second factor is the 'Rmin' factor, and says by what scaler you must extend the aperture past the half-light radius to compute the photometry. (The half-light aperture will have some elliptical shape, but this aperture is not the one used for photometry—so these values determined how much that shape is changed)

The default values for  $k$  and Rmin are 2.5 and 3.5 respectively, but to constrain the haphazard shape of the apertures, we manipulate the values in parallel. Figure 7 shows the manipulation of these parameters in the same Subaru image. At values of 2.0 and 3.0 respectively, we see much smaller apertures around the stars and the galaxies. While the smaller apertures around the galaxies is preferred in some instances (where SExtractor fit excessively large apertures before), we find that overall, the small apertures will turn the photometry into rubbish. Since we started out with some apertures that were inappropriately large, we must find some combination of aperture parameters that reduces the largely fitted halos around crowded field objects yet does not obviously cut into the flux of everyday, brighter objects. The best result we have, as seen in Figure 7, is 2.0 for the Kron factor and 4.0 for the Rmin value. While the Kron radius is kept down, the Rmin is raised to keep the apertures large enough for extended galactic sources.

## 5 Weight Images

In lieu of specifying background parameters, you can specify a weight image if you have one. This is a map of the error and the background that SExtractor uses while setting the detection bands. The Subaru MACS weight images are named .exp files for 'exposure time' files, and they contain inverse variance statistics, so when using the weight image, you must specify in the configuration file that 'WEIGHT\_TYPE MAP\_WEIGHT'.

## 6 Extracting Objects in Multiple Bands

For the MACSJ0717 data set, we have five data bands observed on Subaru (BVRIZ), and one on CFHT (U). We hope to extract sources in all six bands, produce reliable photometry, and find photometric redshifts to easily extract cluster members. Since the images can vary drastically from one to another (seeing and instrumental properties), the sextractor parameters must be tweaked individually to fit each respective image. Comparing 0717 data to 0329, we see that there is no relation between filter and number of detections—instead, this variation relates from the quality of the image. Using the same config file for all filters, we see that the variation of number of detections has to do with image quality and not the innate properties of the band. On average, most detections come from the V and the R

bands, with fewest detections in U and I. We prefer not to alter the parameters drastically, but if one band is not producing the necessary detections, then make adjustments accordingly.

### 6.1 Using the ASSOC file in SExtractor

I tested the reliability of ASSOC object matching by comparing the R and I bands. Using the R band as the reference catalog, I used the x, y positions of R objects to extract I band objects. No parameters in the config file were changed, except the additional mention of the assoc file where the nearest neighbor matching algorithm was used. The number of detections between the unassociated I catalog and the associated I catalog did not change, and after quick tests, it was clear that all extracted objects were identical, with some minor (very MINOR) changes in aperture size. Testing the ASSOC process on B, V, and Z revealed the same result – no effect on the output catalog, except for an additional column of information either linking it to an object in the reference field, or a null match. Since we generate this information when we merge the catalogs, there is no benefit in adding the ASSOC process to the sextractor pipeline. In short, the object extraction algorithm is the same.

## 7 Double Image Mode

If you wish to produce more reliable colors from SExtractor rather than magnitudes in each band, then you will switch into SExtractor double image mode. This designates one image as the detection band, and another as the measurement band. First, all images must be seeing matched, using the proper smoothing kernels. Then apply a 3 arcsecond diameter fixed circular aperture to objects, with the rest of the parameters as described above. We use our detection band as an effective weighted root  $\chi^2$  image with R, I, and Z bands—the deepest bands, thus creating the most complete catalog. This is the technique used by the COSMOS team; first the images are seeing matched, then using I band as the detection image, apertures are fit to each of the photometry bands *uBVrizk* to extract photometry used for SED fitting. A subsequent catalog, produced by Bob Abraham, includes all morphological information for objects taken from the ACS COSMOS data.

## 8 Acknowledgements

Although the project was not completed, and this only comprises a portion of the larger scientific goal, much was learned along the way, all of which is not discussed herein, but should be acknowledged. Thanks to Harald Ebeling for providing the data for this study, and for the extended, modified use of his IDL library. Thanks to David Donovan for stage one of data reduction and his ongoing help, and to Betsey Adams and Wendy Everett for working with me with fervent enthusiasm. Thanks to Peter Capak for his advice on catalog production, and to him and Nick Scoville for the extended use of the COSMOS catalog. Thanks to the NSF Research Experience for Undergraduates program at the Institute for Astronomy, University of Hawai'i for their support, Drs Jonathan Willams and Tim Slater, and as always, thanks to all of my mentors and colleagues at Steward Observatory and Lunar and Planetary Laboratory, University of Arizona for their enduring support.

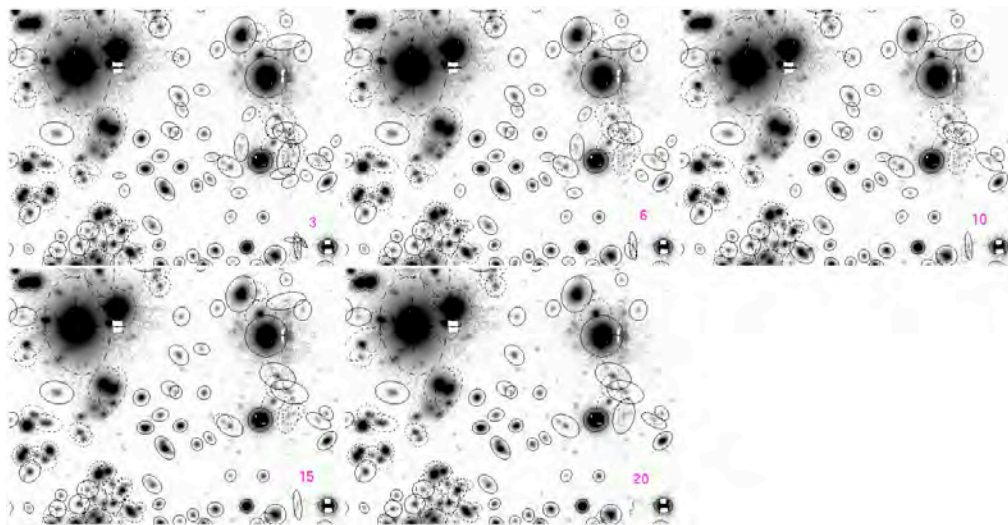


Figure 1: DETECT\_MINAREA continuous pixels.

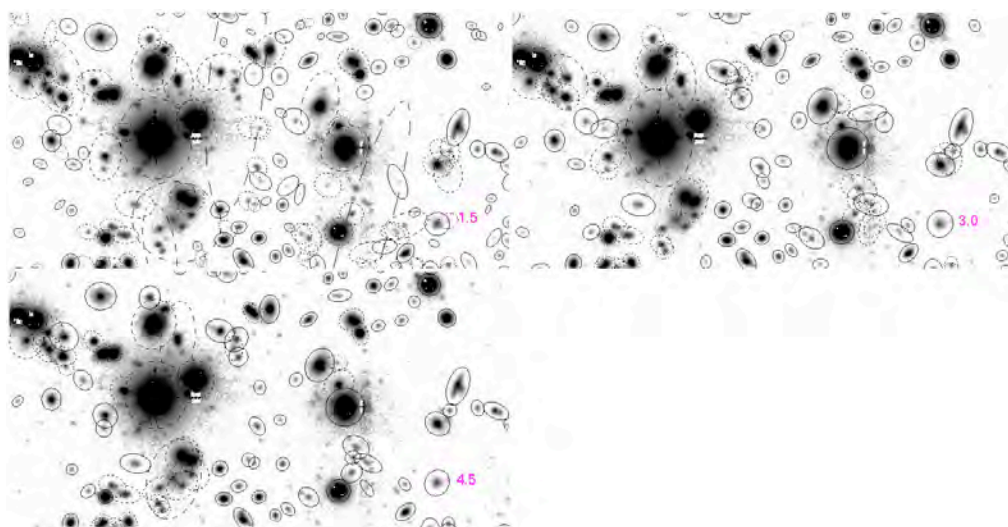


Figure 2: DETECT\_THRESH above the background noise.

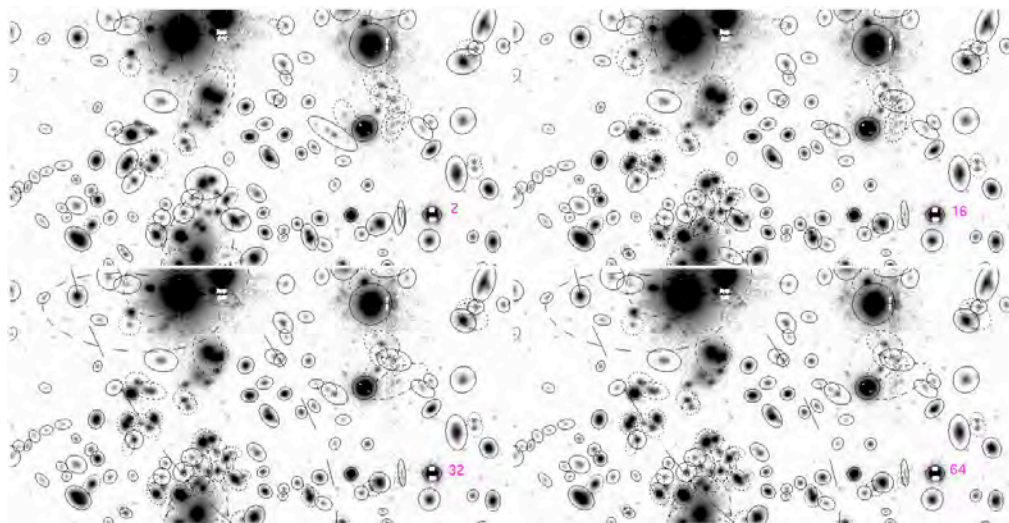


Figure 3: DEBLEND\_NTHRESH branch number

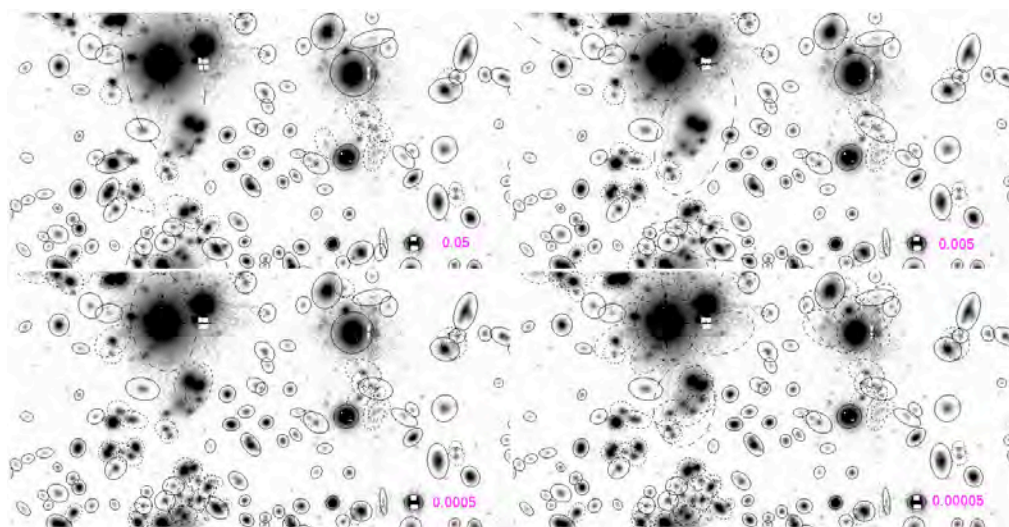


Figure 4: DEBLEND\_MINCONT fraction.

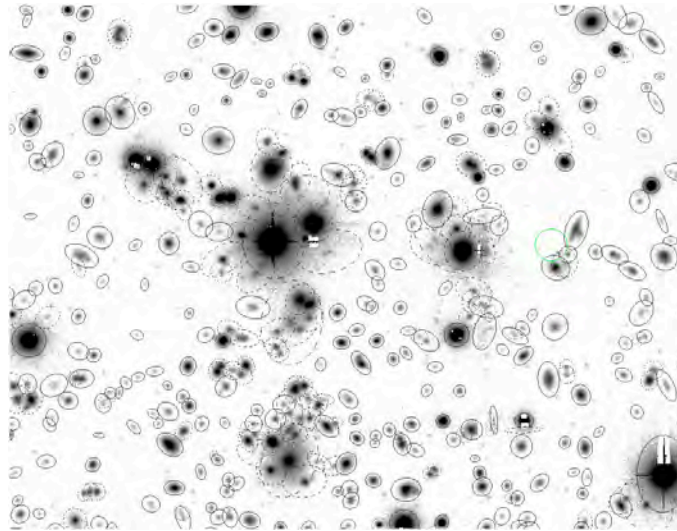


Figure 5: Ideal.fits. The best parameter combination for object detection.

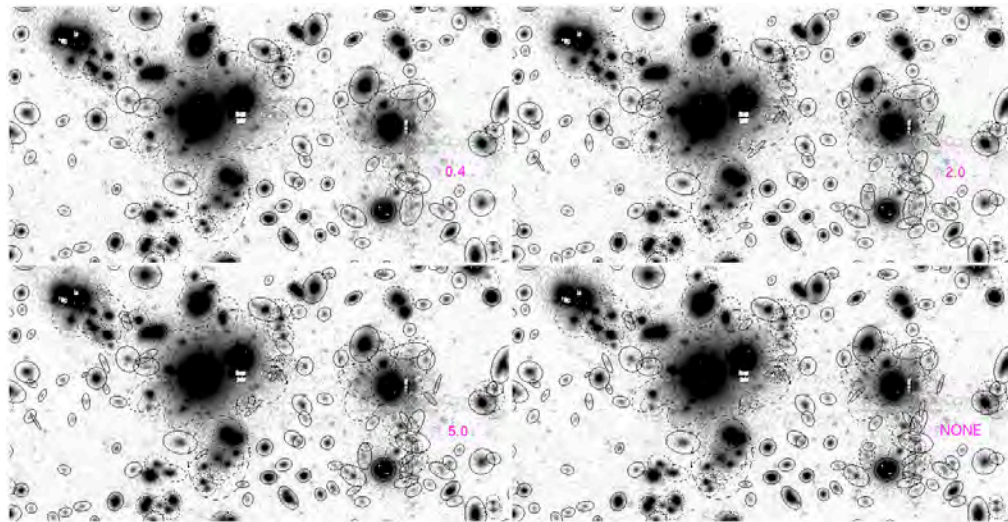


Figure 6: Cleaning Effects.

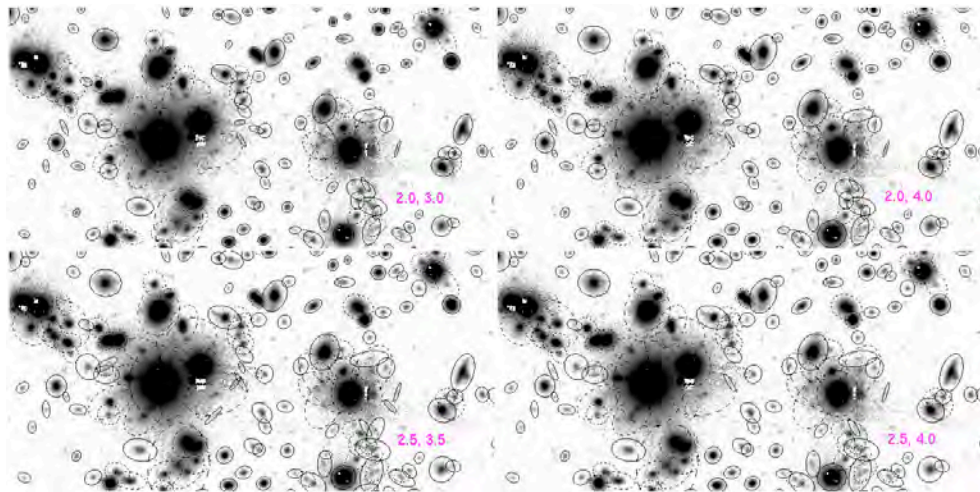


Figure 7: Aperture shape and size manipulation.