The codes provided here are used for the automated objects detection in astronomical images based on image processing technology. There are two detection pipelines, local detection method and global detection method. You can directly run the script "Main_Local_Detection.m" and "Main_Global_Detection.m" in MATLAB in Windows to execute the local detection method and global detection method, respectively.

Testing the crucial parameters in our pipeline:

There are several crucial parameters which determine the results of detection. In order to get how these parameters affect the objects detection pipeline, we tested the pipeline "Main_Local_Detection.m" on DLS dataset by setting different values for these parameters. The total numbers of objects detected by each parameter setting were counted. Due to lack of the ground-truth, the detection results in B-, V-, and z-bands were compared to results in the superior R-band, in general, which can show how many detected objects are true-positives in B-, V-, and z-bands. The following figures are the detection results by different parameters setting, when we tested one of parameters, other parameters were set to the default values.

1. The parameter "*objects_num*": the number of bright objects which selected as the seed points for the watershed partition.

The value of this parameter was set from 10 to 100 at interval 10. The detection results and comparison results of different setting are provided in the Fig. 1 and Fig.2, respectively. From the Fig. 1 and Fig.2, it can be seen that the numbers of detected objects increase along with rising parameter value in general, but the percentages of the B-, V-, z-band matched objects in the R-band image decrease. So we need to make a trade-off between them when setting this parameter. we set the number of bright objects to 30 as default value.

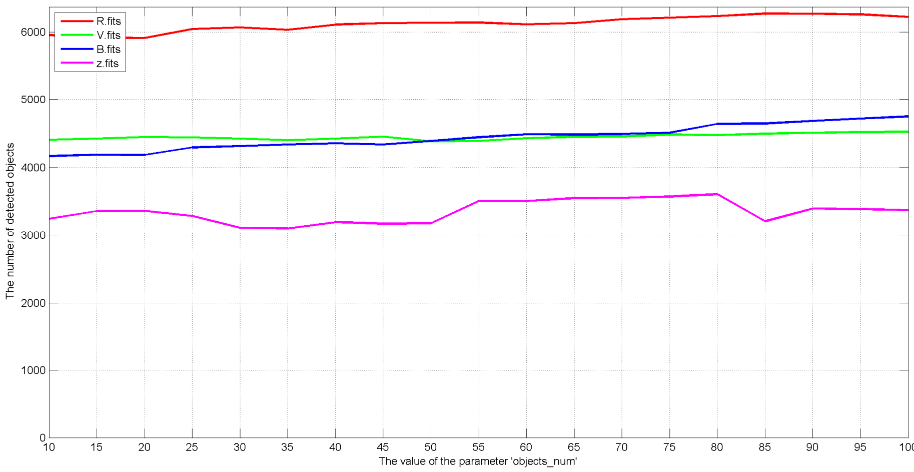

Fig.1. Detection results. X-axis represents the different value of the parameter "*objects_num*", and Y-axis represents the total number of detected objects.

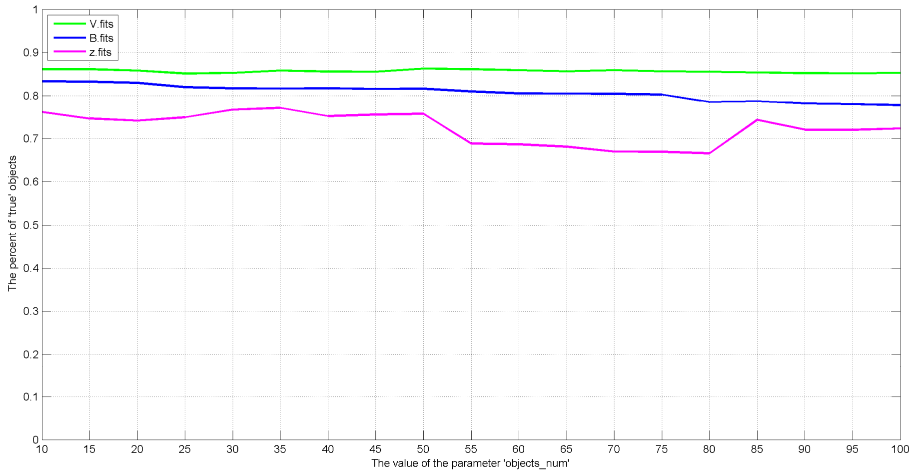

Fig.2. Results of comparing V-,B- and z-band image objects to the objects in the R-band image. X-axis represents the different value of the parameter "*objects_num*", and Y-axis represents the percent of matched objects.

2. The parameter "*sigmoid_center_p*" : the scale factor for computing the center of the sigmoid function used for stretching image intensities. The center of the sigmoid function is computed by "*sigmoid_center_p*" times the median intensity of each local image.

In order to stretch the image intensities around an appropriate pixel value to make details more obvious, the center of sigmoid function needs to be set an adaptive value when applying it to each sub-image region. Since most of the pixel values lie within a small intensity range near the median in astronomical images, the center of sigmoid function should be set around median intensity for achieving a good stretching. This parameter was set from 0.01 to 3. The detection results are shown in the Fig. 3, and the comparison results are shown in Fig. 4. If "*sigmoid_center_p*" was set too small or too large, the sigmoid function will make an inappropriate transform (the whole sub-image region very dark or bright) which leads to objects can't be detected in this sub-image region (This situation is shown in the far left and right side in the Fig. 3, especially in the detection results in the image R.fits). From the Fig.4, the percentage of the B-, V-, z-band matched objects in the R-band image is also bad when "*sigmoid_center_p*" is too small or too large. So the parameter "*sigmoid_center_p*" was set to 1 as default.

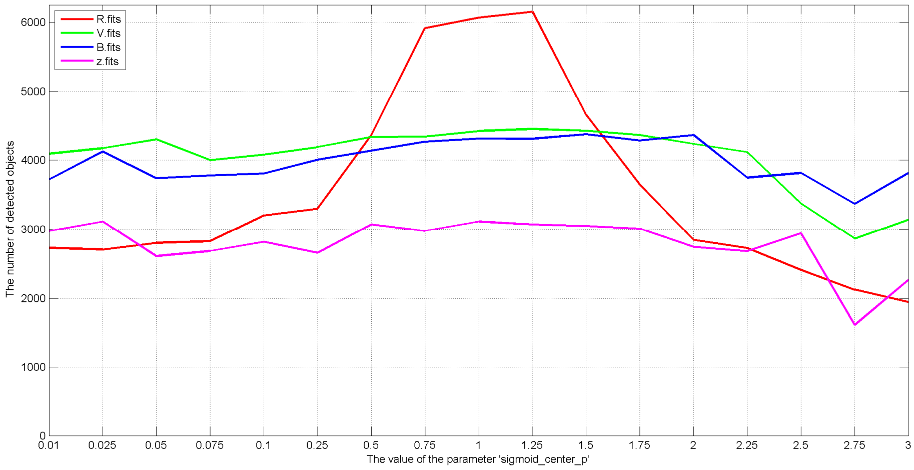

Fig.3. Detection results. X-axis represents the different value of the parameter "*sigmoid_center_p*", and Y-axis represents the total number of detected objects.

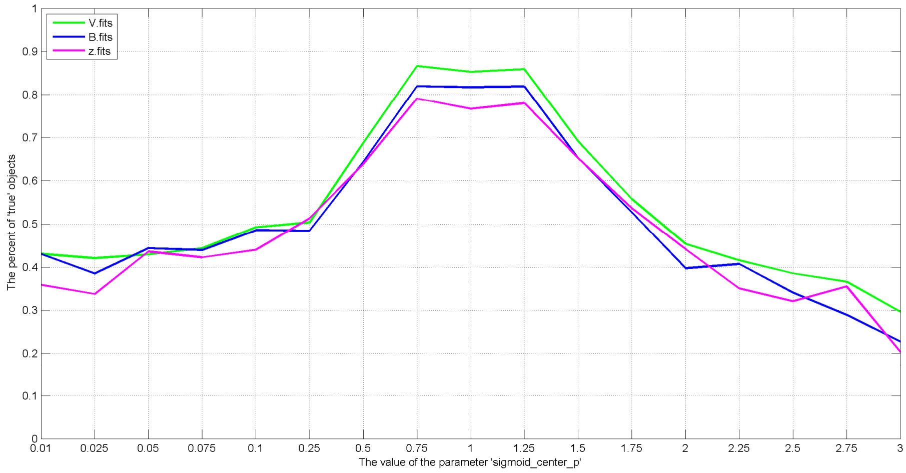

Fig.4. Results of comparing V-,B- and z-band image objects to the objects in the R-band image. X-axis represents the different value of the parameter "*sigmoid_center_p*", and Y-axis represents the percent of matched objects.

3. The parameter "*sigmoid_slope*" : The slope of the sigmoid function used for stretching image intensities.

This parameter was set from 10 to 100, the detection results and comparison results are shown in the Fig. 5 and Fig.6, respectively. From the Fig.5 and Fig.6, the numbers of objects detected in V-, B-, z-band images increase basically along with the value of "*sigmoid_slope*" rise, the number of objects detected in R-fits changes small. The percents of V-, B-, z-band objects matched with the objects detected in the R-band image are reduced. Take all this into account, the slope parameter was set to 40 as default.

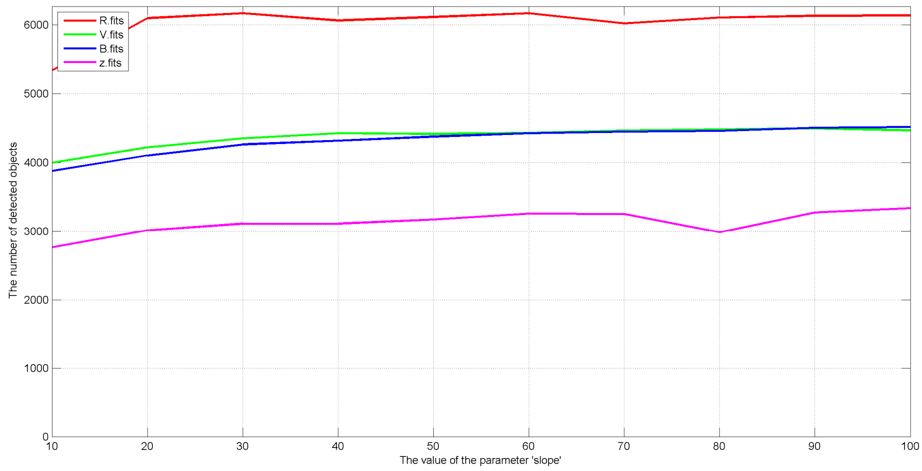

Fig.5. Detection results. X-axis represents the different value of the parameter *"sigmoid_slope"*, and Y-axis represents the total number of detected objects.

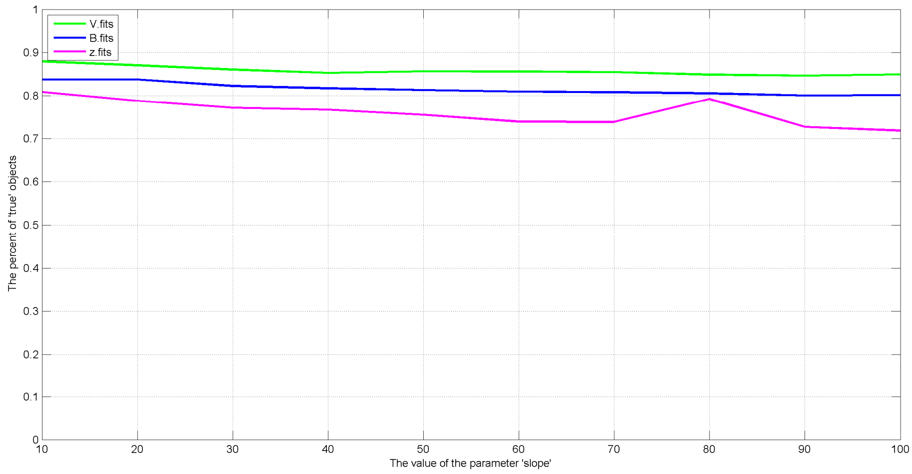

Fig.6. Results of comparing V-,B- and z-band image objects to the objects in the R-band image. X-axis represents the different value of the parameter *"sigmoid_slope"*, and Y-axis represents the percent of matched objects.

4. The parameter *"DEBLEND_NTHRESH"*: the number of deblending sub-thresholds.

This parameter was set from 2 to 45, the detection results are shown in the Fig. 7 and Fig. 8. When the value of *"DEBLEND_NTHRESH"* grows, the number of detected objects increases a little, while the percent of matched objects decrease a little when *"DEBLEND_NTHRESH"* value is larger than 7. In our pipeline, the *" DEBLEND_NTHRESH"* was set to 32 as default values.

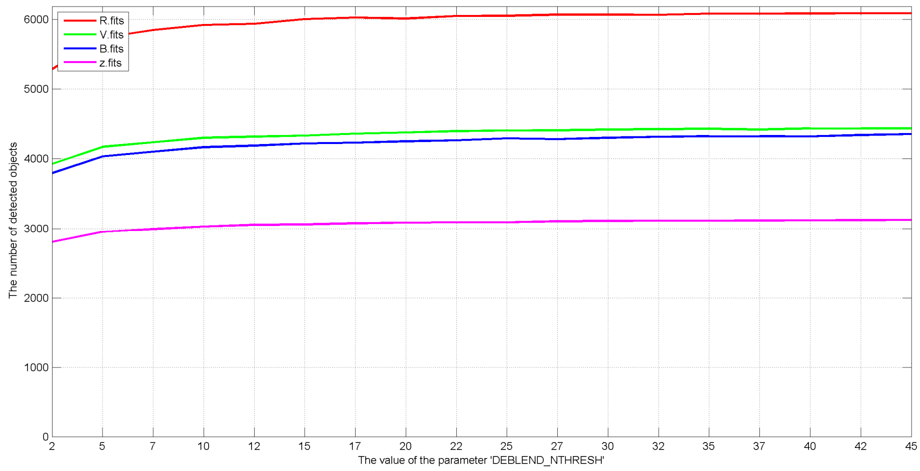

Fig.7. Detection results. X-axis represents the different value of the parameter *“DEBLEND_NTHRESH”*, and Y-axis represents the total number of detected objects.

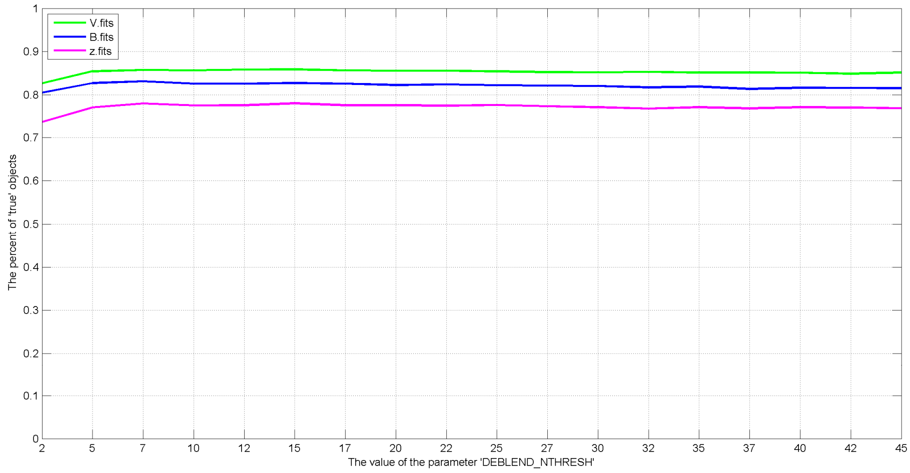

Fig.8. Results of comparing V-, B- and z-band image objects to the objects in the R-band image. X-axis represents the different value of the parameter *“DEBLEND_NTHRESH”*, and Y-axis represents the percent of matched objects.

5. The parameter *“DEBLEND_MINCONT”*: the minimum contrast parameter for deblending.
This parameter was set from 0 to 1, the detection results are shown in the Fig. 9 and Fig. 10. The numbers of objects detected in all band images decrease along with the *“DEBLEND_MINCONT”* increase. Meanwhile, the percents of matched objects are also decreased. We choose 0.001 as the default value in our pipeline to get a more reasonable result. Because if the value of *“DEBLEND_MINCONT”* is set too small, it will consider any smallest pixel set (such as just one pixel) large than a threshold as individual objects, it can’t tolerate the intensity change in galaxies which maybe lead to deblend an galaxy as two or more very small objects (one pixel).

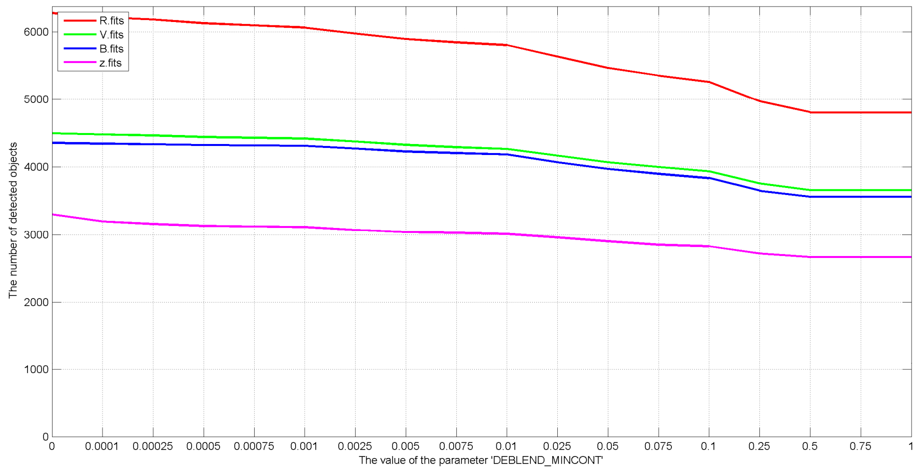

Fig.9. Detection results. X-axis represents the different value of the parameter *"DEBLEND_MINCONT"*, and Y-axis represents the total number of detected objects.

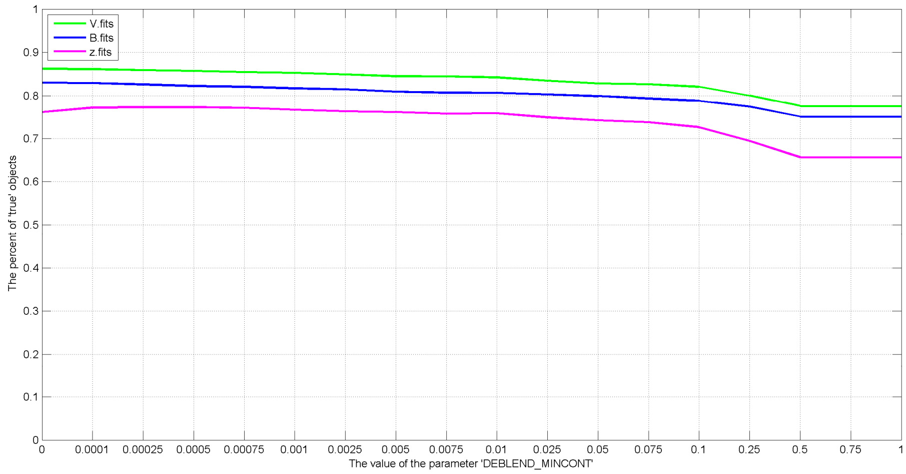

Fig.10. Results of comparing V-, B- and z-band image objects to the objects in the R-band image. X-axis represents the different value of the parameter *"DEBLEND_MINCONT"*, and Y-axis represents the percent of matched objects.

Other simple parameters in the pipeline of the local detection method (we suggest you adjust these parameters based on your own dataset if you want to get the best detection results):

6. "FilterName": the filter method, the default is Gaussian filter.
7. "FilterSize": the size of filter window, the default value is [7, 7].
8. "FilterSigmal": standard deviation SIGMA (positive), the default value is 1.5.
9. "Noise_T1" and "Noise_T2": the threshold for adjusting the filter window size. (We suggest setting these parameters based on the histogram distribution of the noise levels in all local images. "Noise_T1" is set to a value which close to the maximum value of the histogram bar, and the Noise_T2 is set to a value which close to the minimum value of the histogram bar.)
10. "Size_thresh": the threshold for defining how large the object you want to process it by the layer detection scheme.

11. “Deblend_method”: the deblending method name. (Here we provide two methods for deblending, one is based on the multi-threshold method and the watershed method, the other is directly using watershed method. The former is more accurate while the latter is simpler and also can obtain an acceptable result)

The following parameters are only used in the pipeline of the global detection method:
12. Size_scalor: the scaling factor for defining how large the object you want to clean the artifacts (noise) around it, the default value is 2.
13. Rincrease: the parameter for expending the local area of the large object which needs to be clean the artifacts (noise) around it, the default value is 30.