Wavelet Analysis for Sources Detection

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Method:

WT is a multiscale transform suitable for source detection and analysis of images features spanning a range of sizes

The wavelet method gives information on position and flux of detected sources

A more precise determination of the flux can be obtained using Likelihood analysis with a list of sources resulting from wavelet algorithm

INPUT→ fits image

to test the method →
gaussian sources generated with a poissonian background

DC1 analysis (1 day) →
Anticenter region
All Sky

OUTPUT→ fits images

*background estimated map
*threshold maps at different scales
*WT maps
*list of detected sources (position, sigma,flux)

Recipe: Damiani et al. *APJ* 483, 1997

Hypothesis:
Gaussian sources with a Poissonian background

Threshold definition:
Semianalytical study gives the relationship between threshold (w_0) for source detection and background density (n) for each WT scale (a)

$$w_0 = k \cdot \sqrt{2\pi q} + (c1 + c2 \cdot k + c3 \cdot k^2) \qquad (1)$$

K = # sigma for the threshold (3,4)
$q = n \cdot a^2$

Background estimation:

In order to have a threshold definition, background is estimated using standard procedure (gaussian filter, sigma-clipping, median or mode bilinear interpolation) applied to input image

Source detection:

For each scale:

- calculation of the WT using as mother wavelet "mexican hat"

$$g\left(\frac{r}{a}\right) = \left(2 - \frac{r^2}{a^2}\right) e^{-\frac{r^2}{2a^2}}$$

- threshold definition using (1)
- selection of contribution over threshold (WT of sources)
- search of the peak position for each source

Source parameters estimation:

As the WT of a gaussian (σ , N) is known

$$w(r,a) = \frac{N}{(1+\frac{\sigma^2}{a^2})^2}\left(2 - \frac{r^2}{a^2+\sigma^2}\right)e^{-\frac{r^2}{2\cdot(a^2+\sigma^2)}}$$

we can derive the relationship between σ and $w_{peak}(a)$ and N

$$w_{peak}(a) = \frac{2N}{(1+\frac{\sigma^2}{a^2})^2}$$

And the relation between counts and sigma (N, σ) and the WT coeff (w1,w2) at two different scales a1,a2

$$N(a) = w(a)\left[1+\left(\frac{\sigma^2}{a^2}\right)\right]^2 \cdot 0.5$$

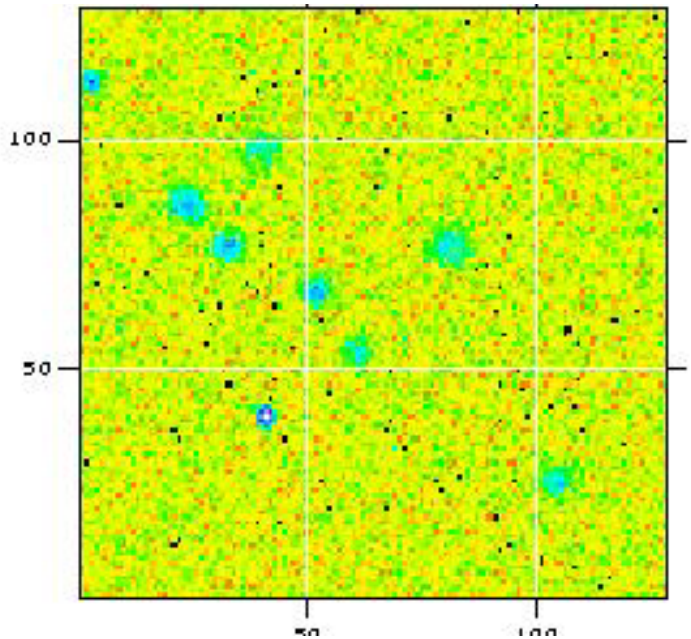
$$\sigma = a1\sqrt{\frac{k-\alpha^2}{1-k}}$$

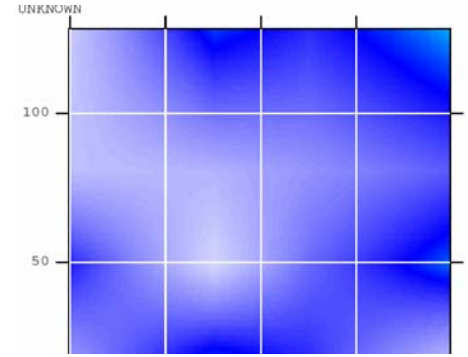
$$k = \sqrt{\frac{w1\cdot a2}{w2\cdot a1}}\cdot\alpha^3$$

$$\alpha = \frac{a2}{a1}$$

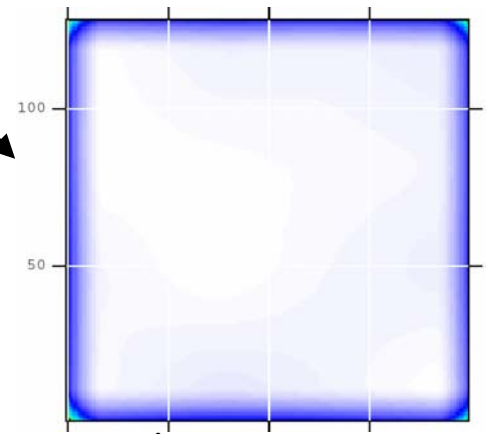
Test: 10 gaussian sources with poissonian background

Input image





Background estimation (median value) = 5 counts



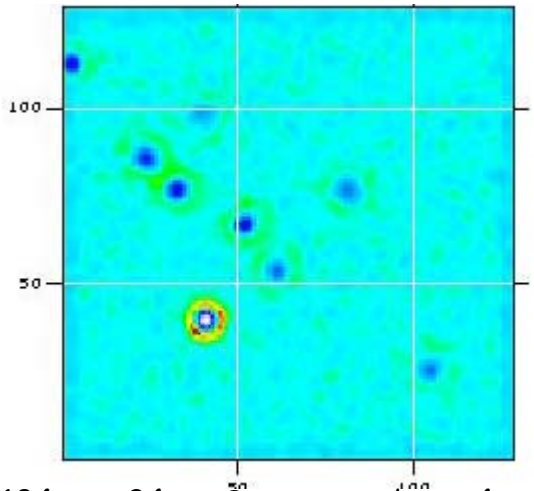
Threshold estimation (median value) = 35 counts

at scale=2 pixels

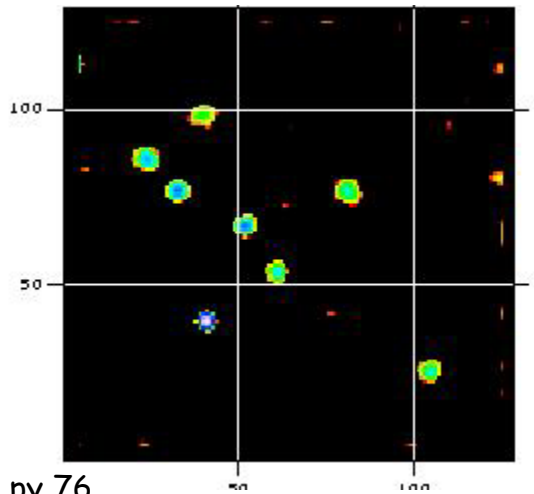
- sigma of simulated sources from 1 to 3 pixels
- poissonian background with mean value 5 counts
- maximum number of counts for each sources = 1000
- WT from scale 1 pixel (0.5 deg) to 4 pixels (2 deg)

Results: 8 sources found

WT at scale 2



Source over thresh at scale 2



Source number : 0 px 104 py 24
sigma = 1.39547
Number of photons = 199

Source number : 1 px 40 py 39
sigma = 1.06984
Number of photons = 972

Source number : 2 px 60 py 53
sigma = 1.95073
Number of photons = 373

Source number : 3 px 50 py 66
sigma = 1.8775
Number of photons = 597

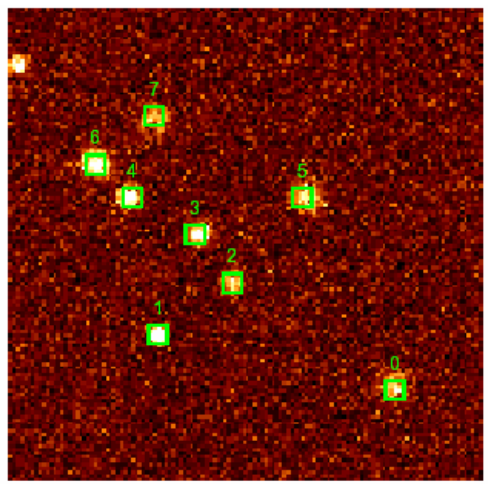
Source number : 4 px 33 py 76
sigma = 1.72959
Number of photons = 516

Source number : 5 px 79 py 76
sigma = 1.8754
Number of photons = 307

Source number : 6 px 23 py 85
sigma = 1.97818
Number of photons = 528

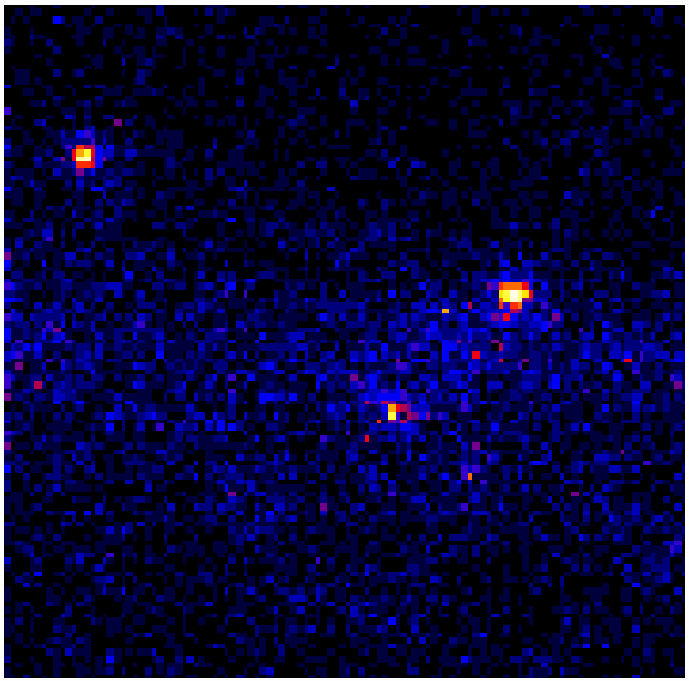
Source number : 7 px 39 py 98
sigma = 2.83359
Number of photons = 564

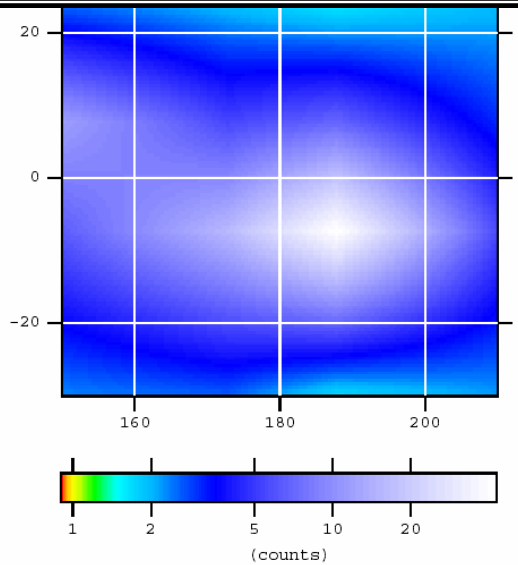
Detected sources



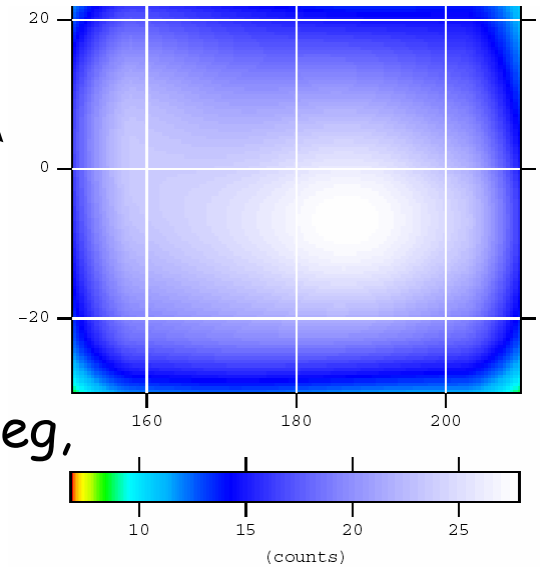
DC1 data 1 day anticenter region :

Input image





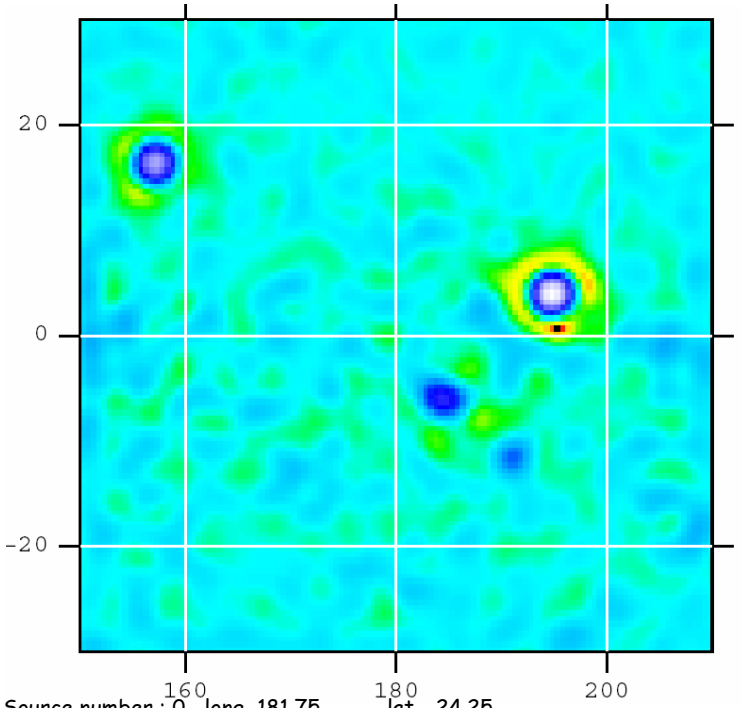
Background estimation with sigma clipping



Threshold estimation at scale 3 pixels

WT analysis from scale 3 pixel (1.5 deg, about PSF value) to 8 pixel (4 deg)

WT at scale 3



Source number : 0 long 181.75 lat -24.25
sigma = 1.9681
flux = 2.51848e-007

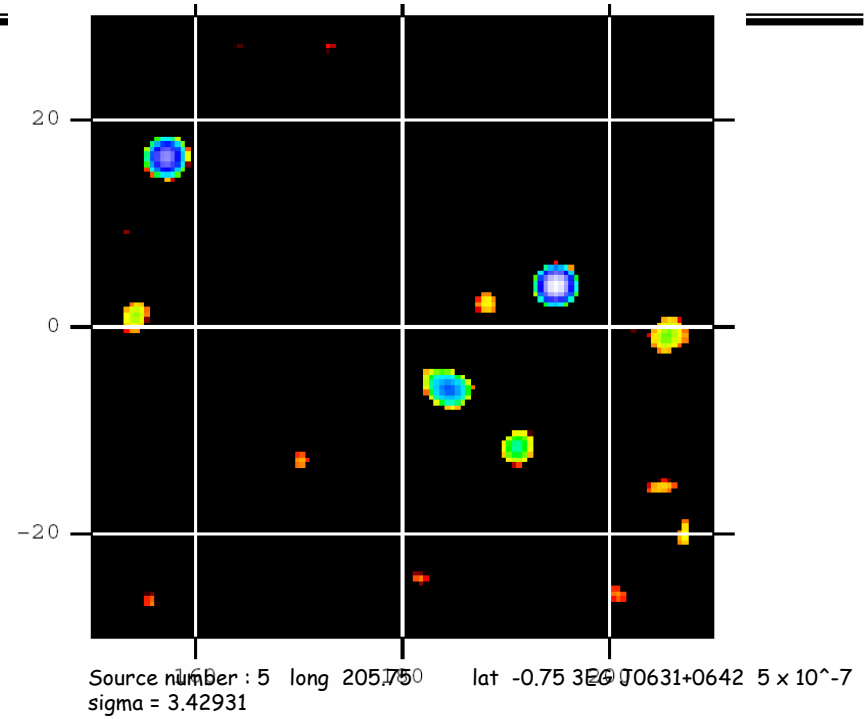
Source number : 1 long 204.75 lat -15.25 3EG J0631+0642
sigma = 1.5737
flux = 2.52442e-007

Source number : 2 long 170.25 lat -12.75 3EG J0433+2908
sigma = 2.67558
flux = 5.46813e-007

Source number : 3 long 191.25 lat -11.75 PKS 5.4 x 10^-6
sigma = 1.90799
flux = 8.00495e-007

Source number : 4 long 184.25 lat -5.75 CRAB 9.5 x 10^-6
sigma = 2.38424
flux = 2.25923e-006

Source over thresh at scale 3



Source number : 5 long 205.75 lat -0.75 3EG J0631+0642 5 x 10^-7
sigma = 3.42931
flux = 1.35972e-006

Source number : 6 long 188.25 lat 2.25 3EG J0617+2238 1.7 x 10^-6
sigma = 1.78528
flux = 3.94436e-007

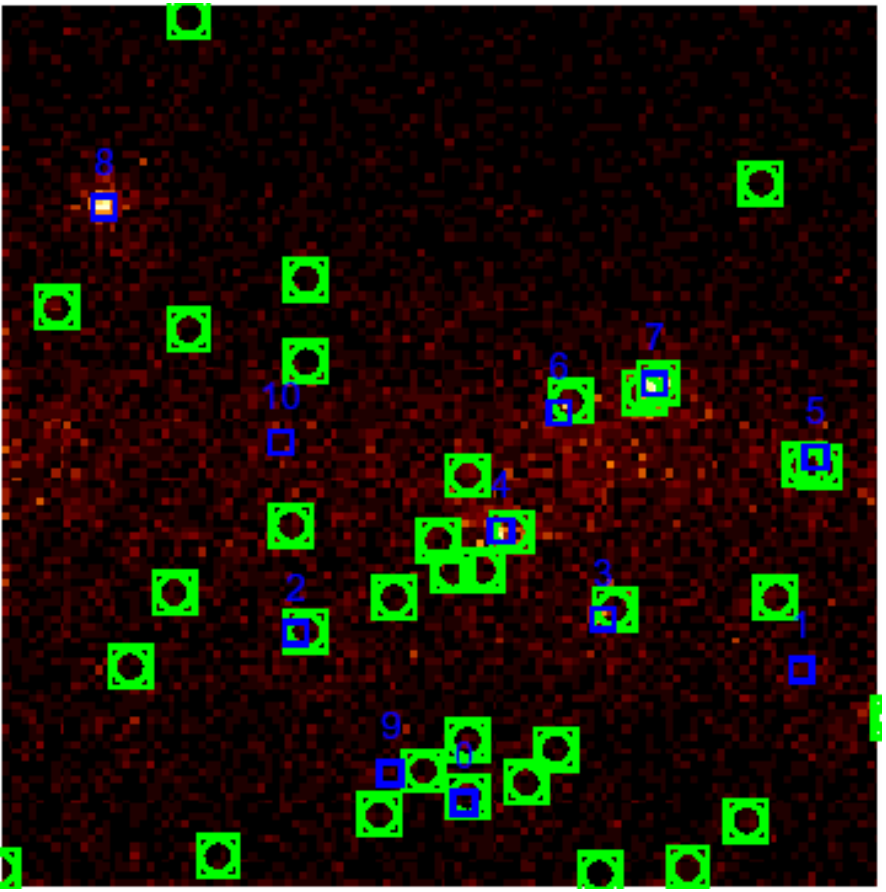
Source number : 7 long 194.75 lat 4.25 Geminga 7.8 x 10^-6
sigma = 1.6108
flux = 4.36938e-006

Source number : 8 long 157.25 lat 16.25
sigma = 1.75214
flux = 3.11576e-006

Source number : 9 long 176.75 lat -22.25 (?)3EG J0423+1707 (178,-22)
sigma = 2.89892
flux = 3.7444e-007

Source number : 10 long 169.25 lat 0.25
sigma = 5.10123

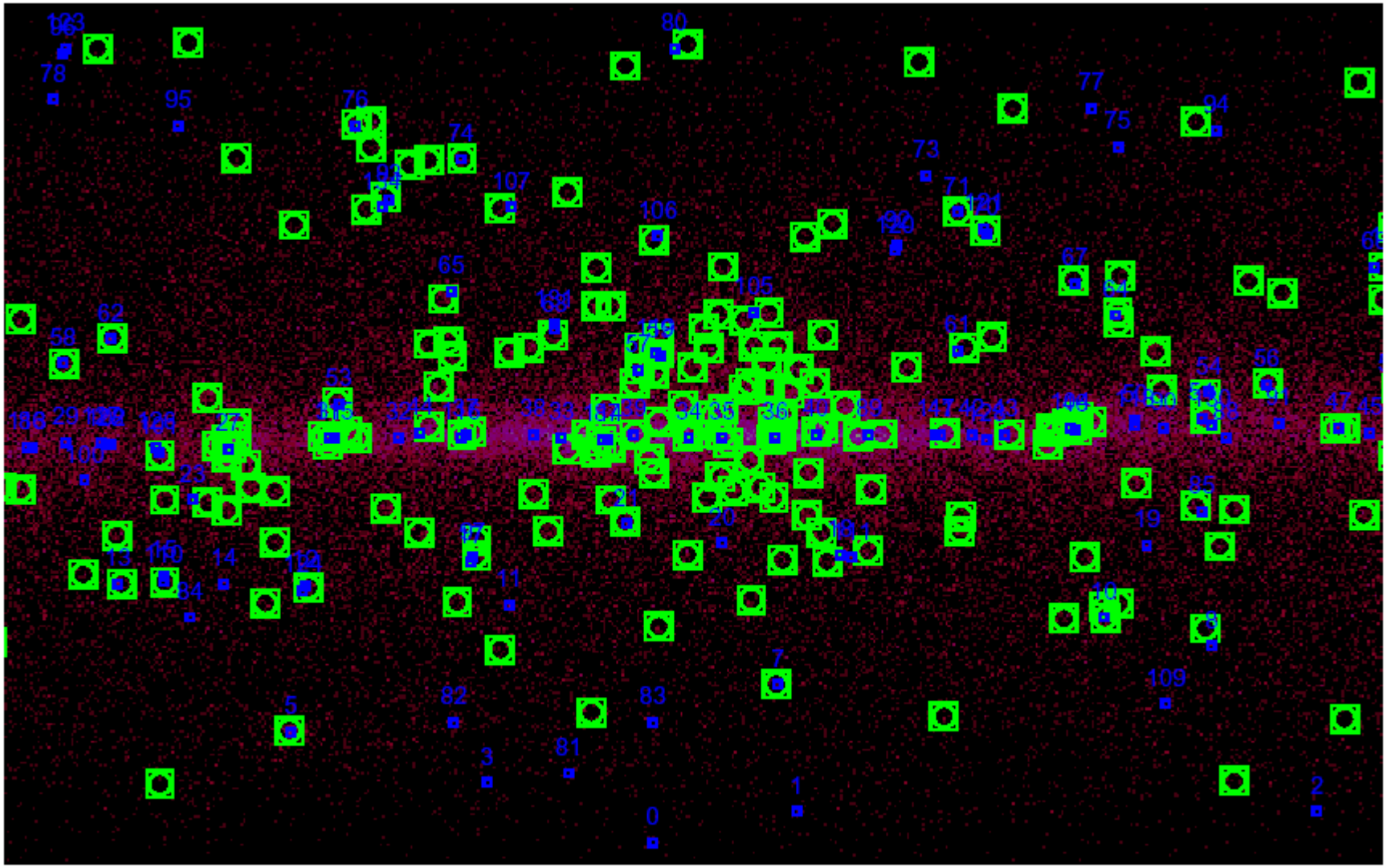
Comparison with 3EG catalog:



8 out of 11 sources in 3EG:

Long	lat	3EG name
204.75	-15.25	3EG J0631+0642
170.25	-12.75	3EG J0433+2908
191.25	-11.75	PKS
184.25	-5.75	CRAB
205.75	-0.75	3EG J0631+0642
188.25	2.25	3EG J0617+2238
194.75	4.25	Geminga
176.75	-22.25	(?)3EG J0423+1707 (178,-22)

All Sky wavelet (blue) vs 3EG (green)



Found within: 1 pixel radius 25/136 2 pixels radius 53/136 3 pixels radius 73/136

Conclusions and perspectives

Wavelet method gives satisfactory results on one day simulation

Good estimation of source positions

Flux estimation can be refined by fitting the source shape with a function reflecting the PSF distribution

- Perform 6 days analysis
- Perform analysis in different energy ranges

Working in progress for improvement!!!