Using R to find Gamma Ray Bursts

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Contents

Don't be fooled by the title, this is mainly a talk on my experience with the statistical analysis tool **R**; GRB finding is just a case study, see next three talks for serious things.

A big thank to **M.Frailis** (Udine), **N.Omodei** (Pisa) and **R.Rando** (Padova) for helpful discussion and suggestions.

Slides made in ConTEXt, edited in emacs, rendered in PDF. Calvin and Hobbes by Bill Watterson.

ONYATTL

I know what you are thinking: **oh no, yet another tool to learn !!!** ...
... But

- Really easy
- In some way similar to **Matlab**, **Octave** (maybe also IDL?)
- It does not replace science tools, it can be used as a
  - FITS viewer (like fv or DS9)
  - tool to try in a fast way new algorithms and ideas to implement later in another way
  - graphics tools to produce plots, histograms, maps etc etc
  - statistics calculator
  - much more ...

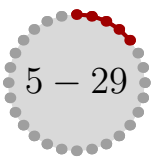
Why R?

- A statistical tool and language targeted to data analysis and exploration; it is mostly an implementation of **S language**
- Open source
- Multiplatform (**Linux**, **Windows**, **MacOS**)
- Many out of the box functionalities and a real simple **array oriented language** to do your own
- Big user community and lot of already available extra packages (from wavelet to decisional trees, from NN to custering algorithms and more)
- You can extend it in **Fortran**, **C** and **C++** (and in some way also in Python and Ruby) .. useful for performance boost and to interface to external data format.

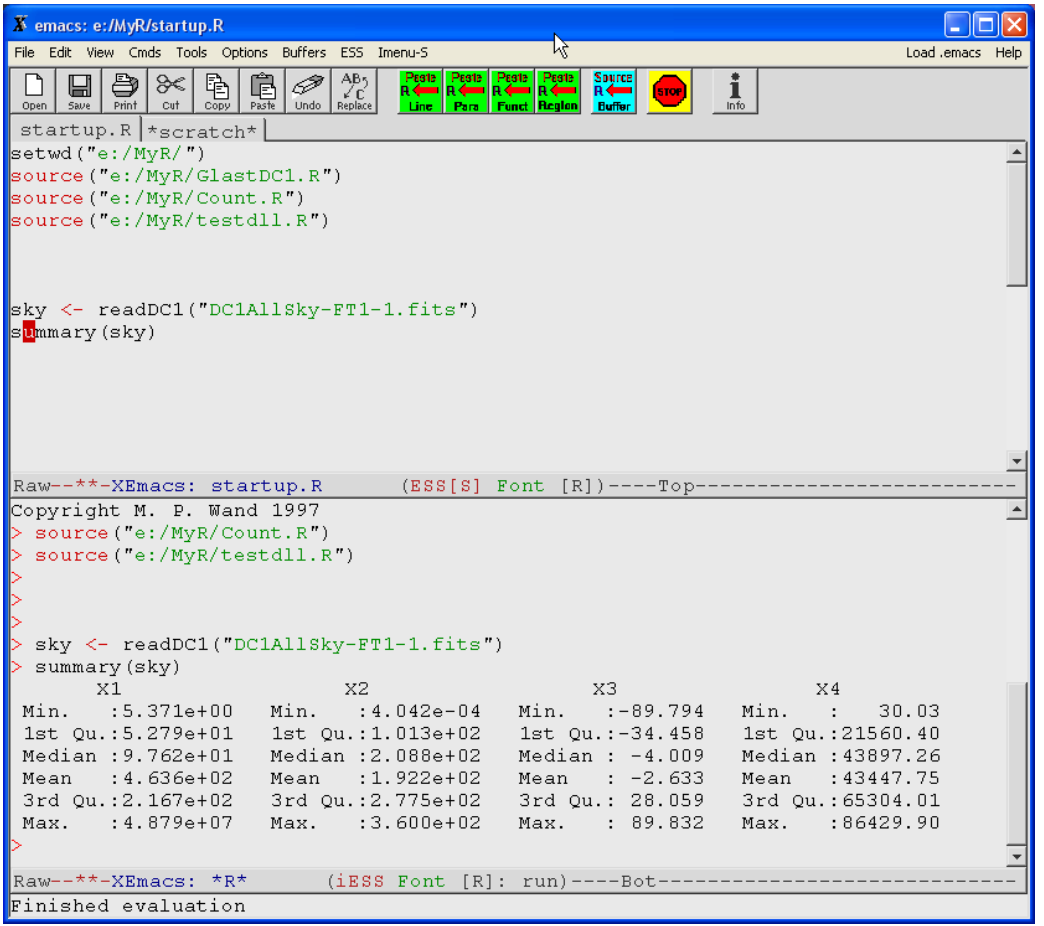
DC1 Postcards

For DC1 we need an interface to FITS files

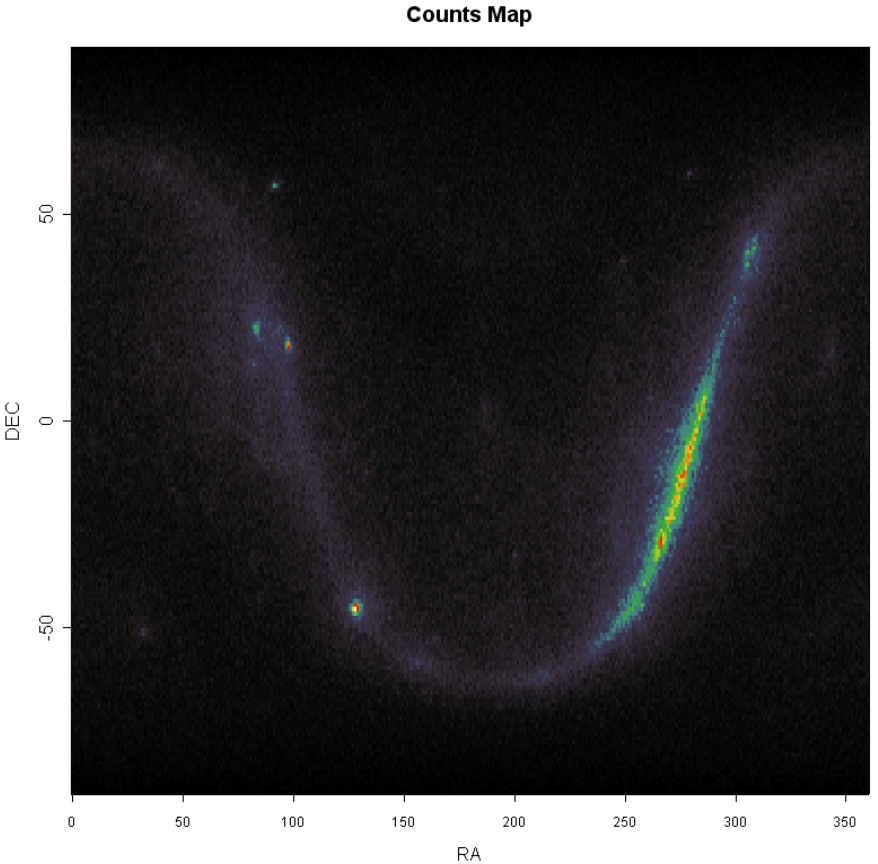
- Quite easy to build a dynamic library loadable by R using **CFITSIO**
- It is not yet a generic FITS interface, it is targeted to DC1 format
- At the moment it reads just the **ENERGY**, **TIME**, **RA** and **DEC** and fill a **data frame**, that is an etherogeneous R table
- Ask me privately if you are interested in this interface code



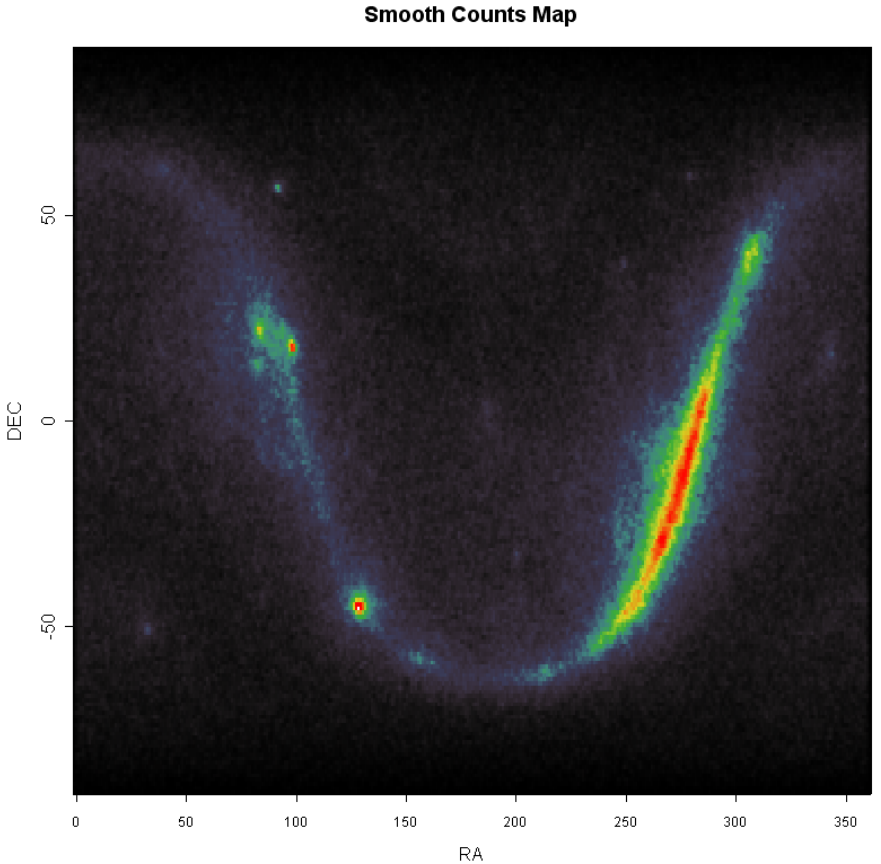
Here is an example of loading the FITS file and create a summary (the interface is with **Emacs**, but there are others if you dislike Ctrl-stuff)



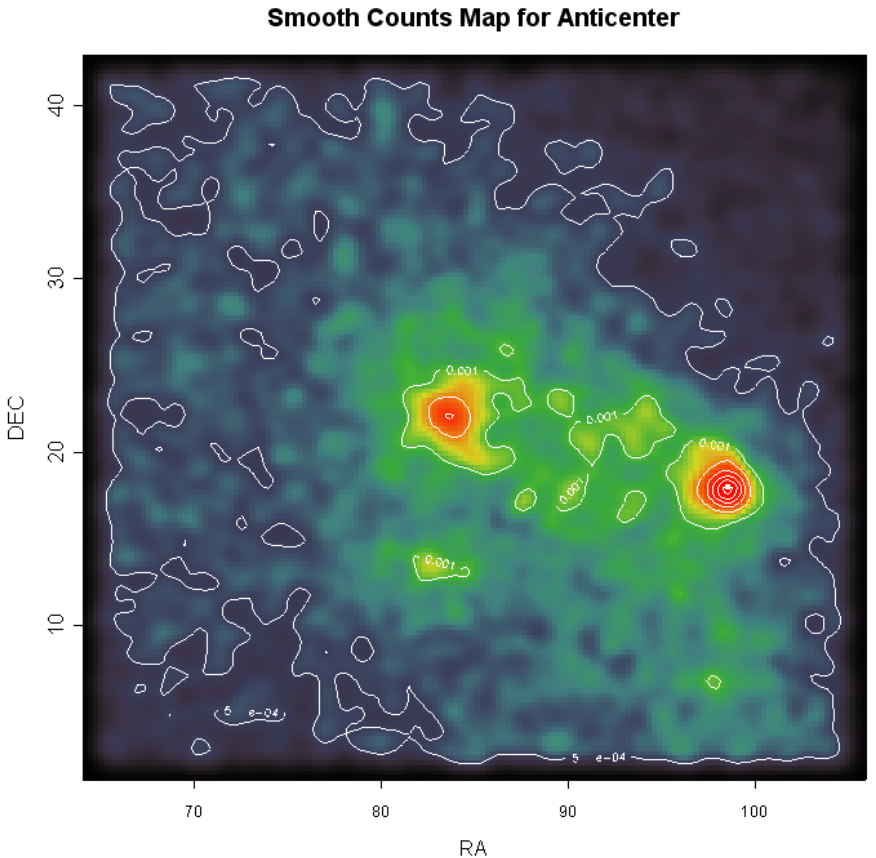
I than wrote some small useful functions that help looking at the data; for example here it is a count map of the first day of DC1



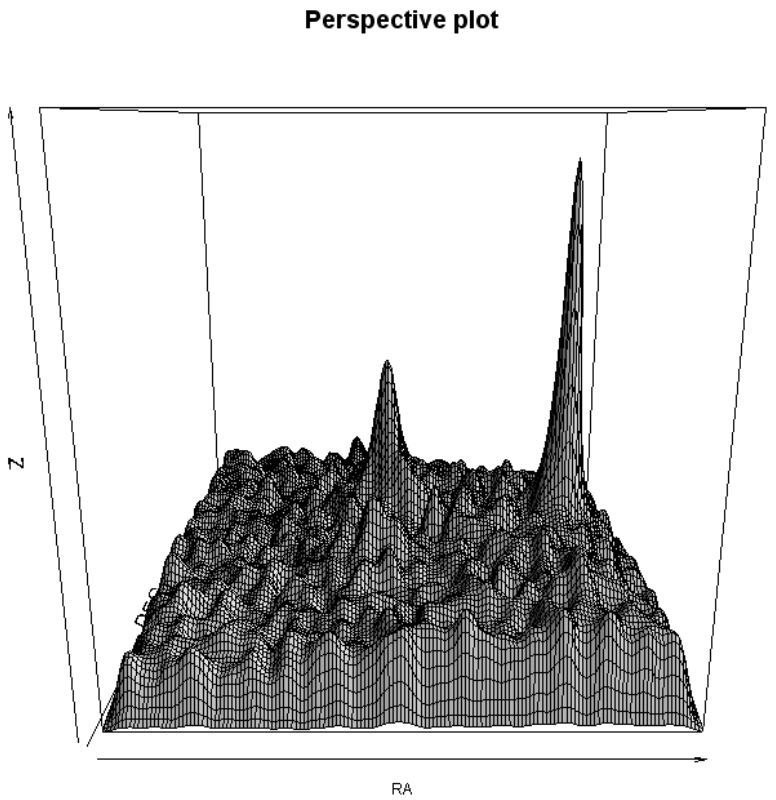
An alternative to count map is given by **kernel smoothed density map** techniques



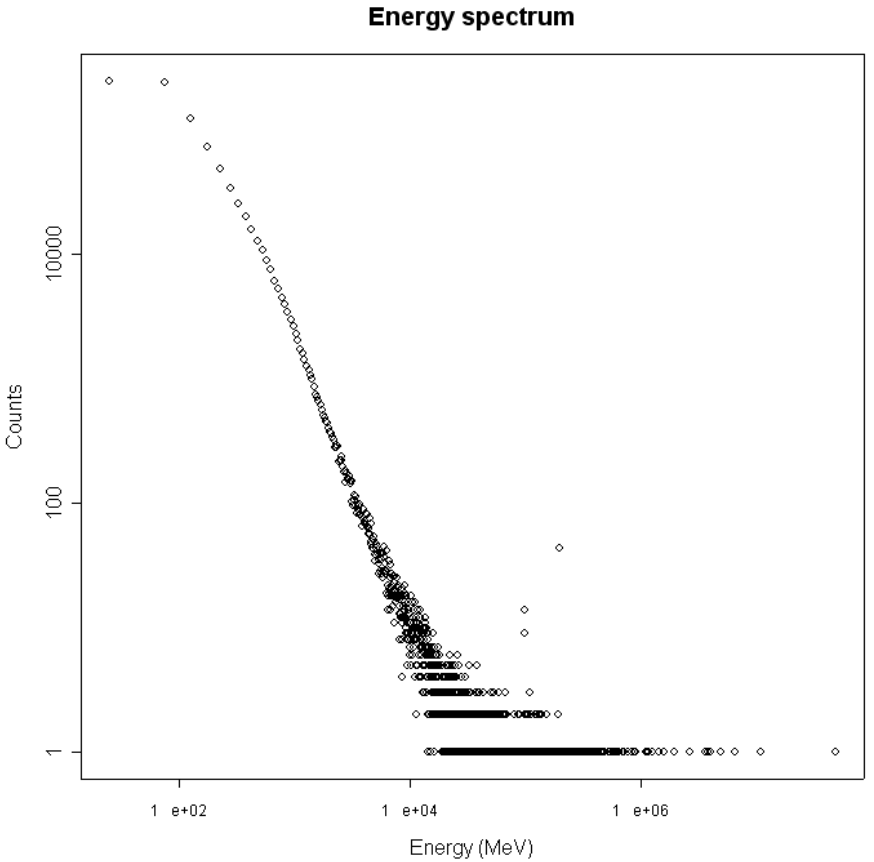
I selected a detail of the anticenter region and show its smooth map with contour plot (out of the box)



Ant here it is a 3D perspective view of the same anticenter region

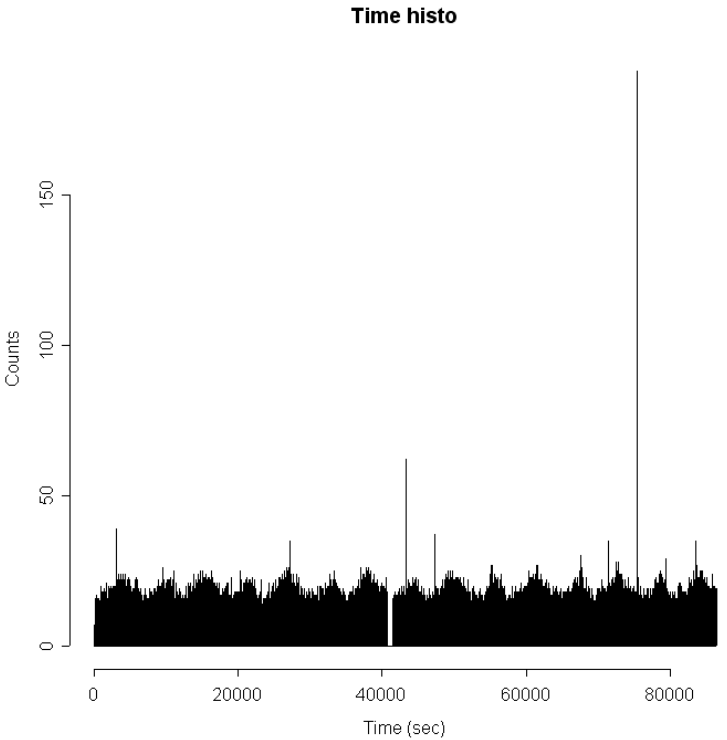


The spectrum (not exactly) can be extracted easily and plotted in log-log scale.

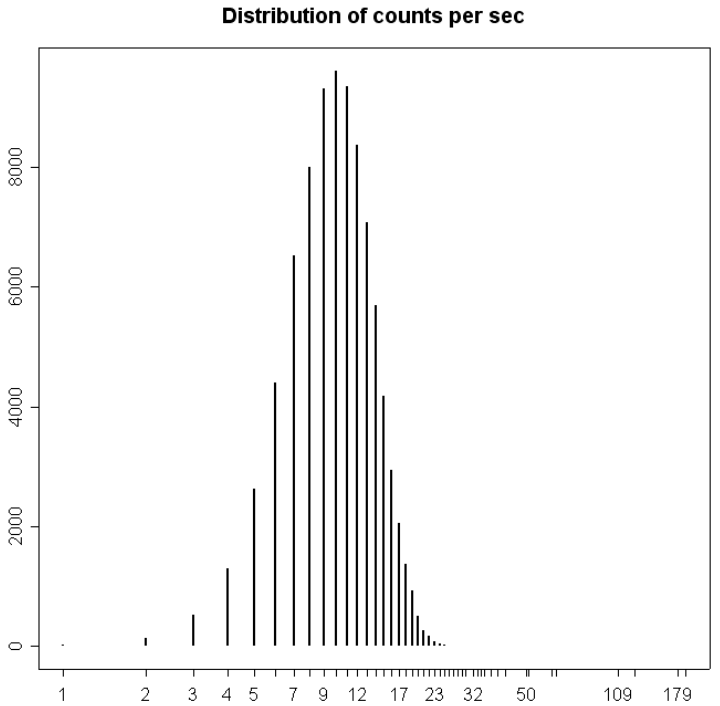


Finding GRB

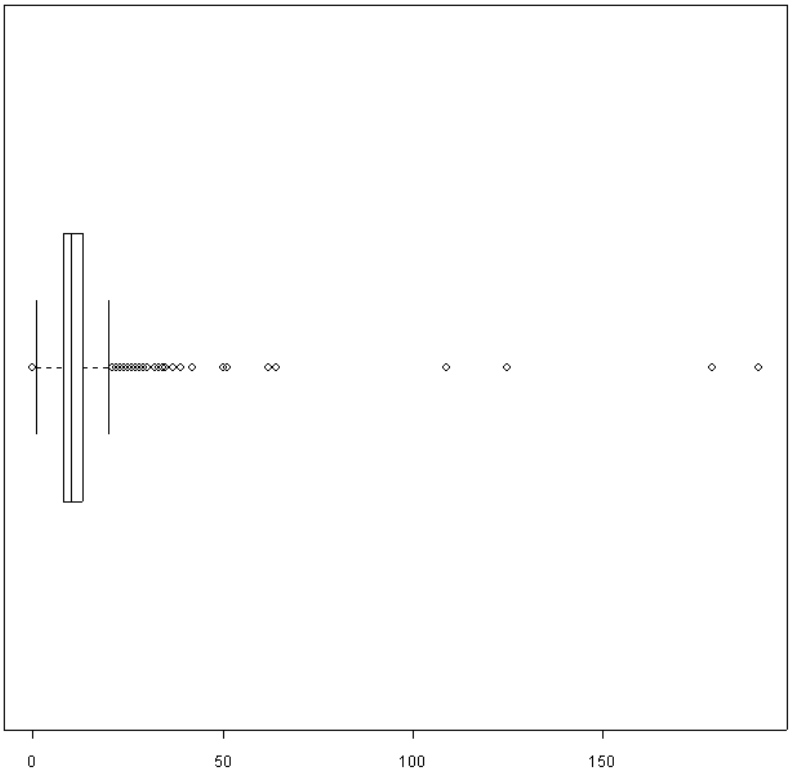
Let's start by looking at the histogram of counts per seconds; there are "evident" outliers that can be used as GRB candidates



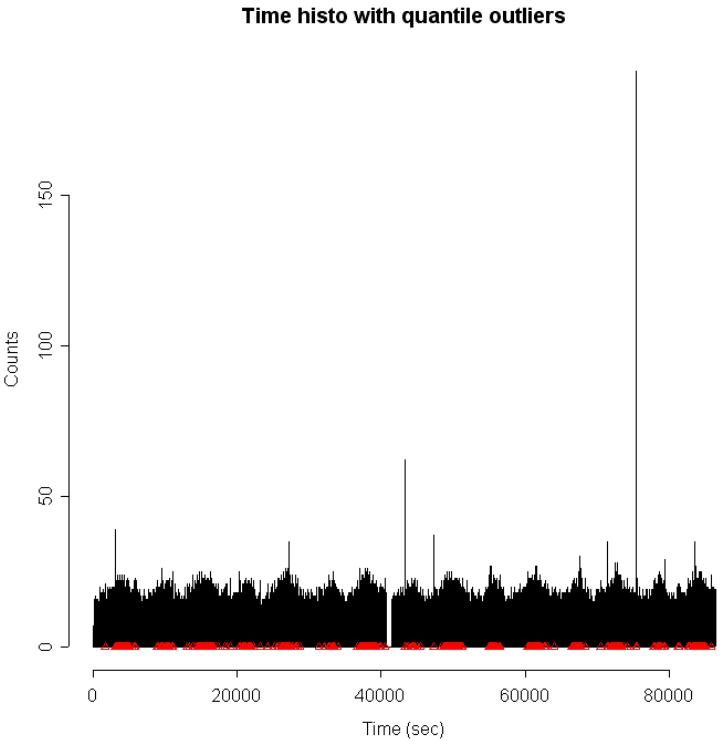
The distribution of counts can be easily plotted ...



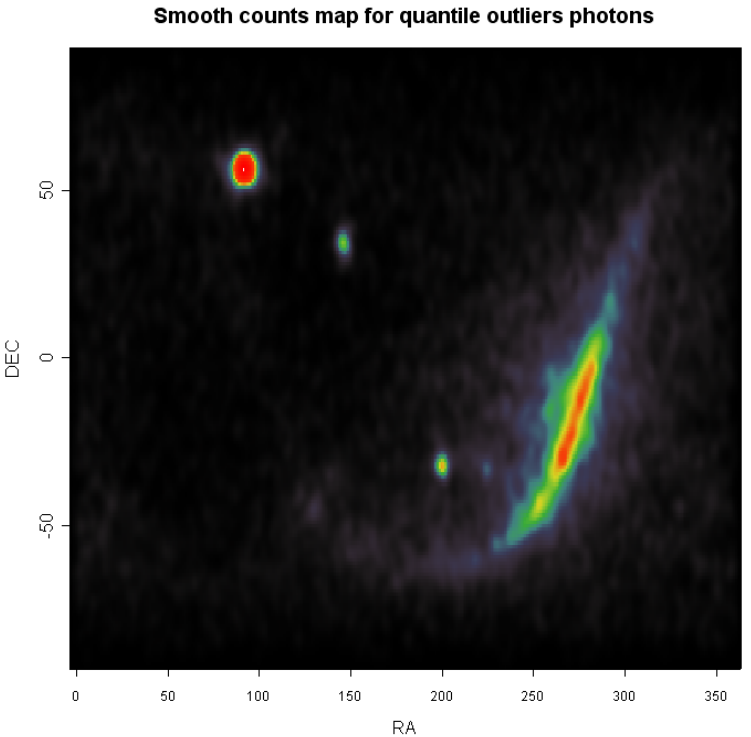
... and also the related **boxplot** that can be used to dermine outliers in a distribution based on the quantiles.



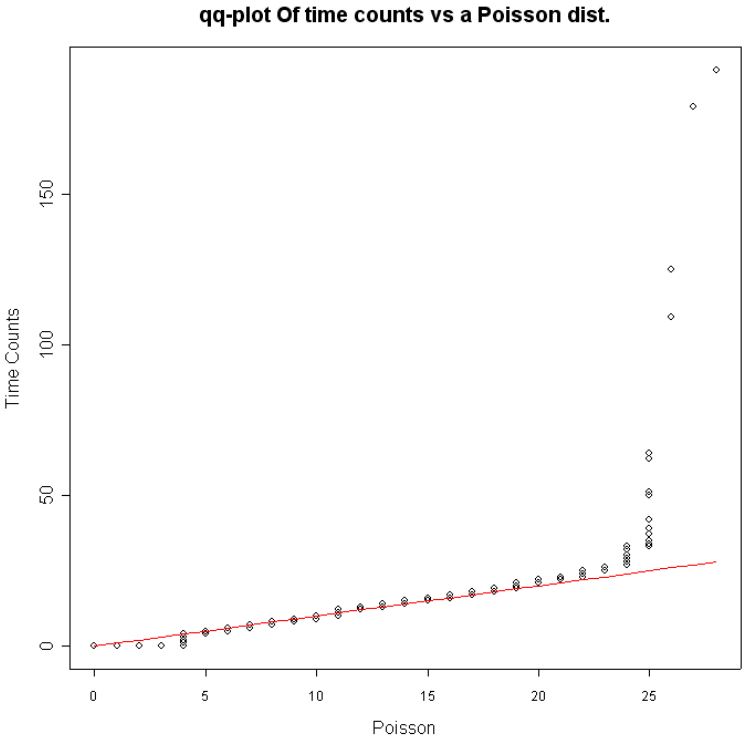
From this we can try to extract the outliers of the counts distribution as possible GRB candidates; in that case they are the seconds with more than 13 counts. This is a too small thresolds, outliers should be take with respect to a Poissons distribution (see later);



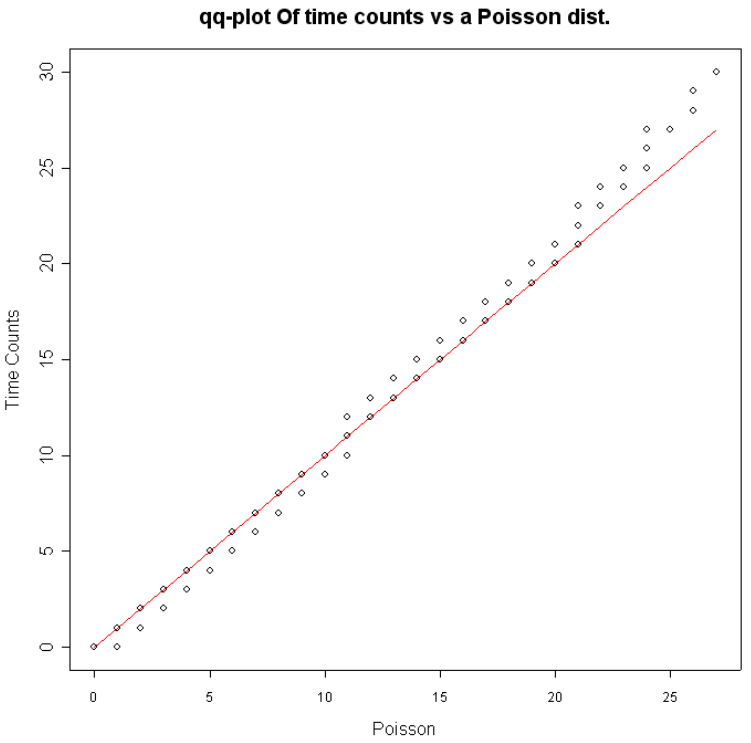
We can than extract all the photons that contribute to the outliers and plot a smoothed counts map.



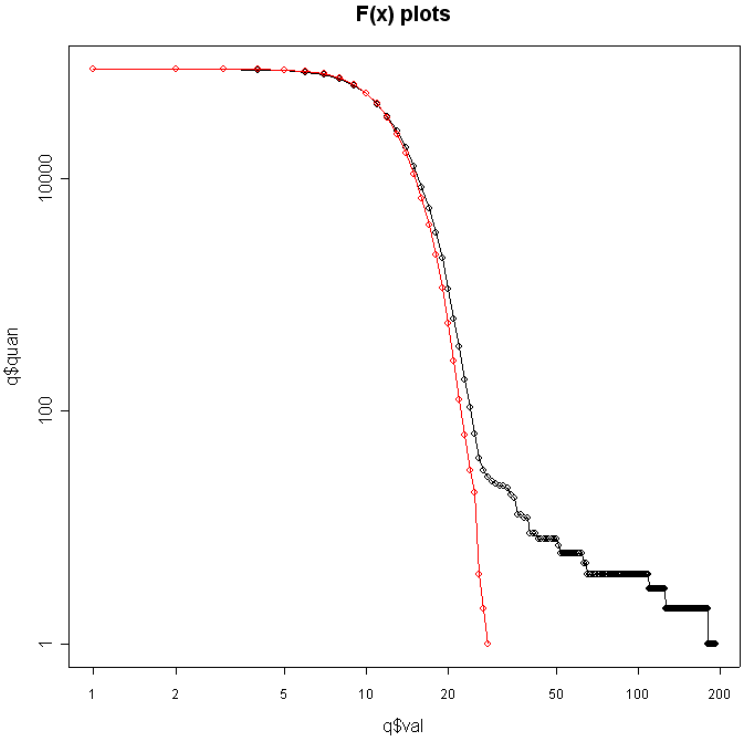
To enhance the result we can multiply the quantile thresold by a constant (as in the WIKI page). A better method is by comparison of the counts distribution with a Poisson distribution (with the same mean) by looking at the **qq-plot**



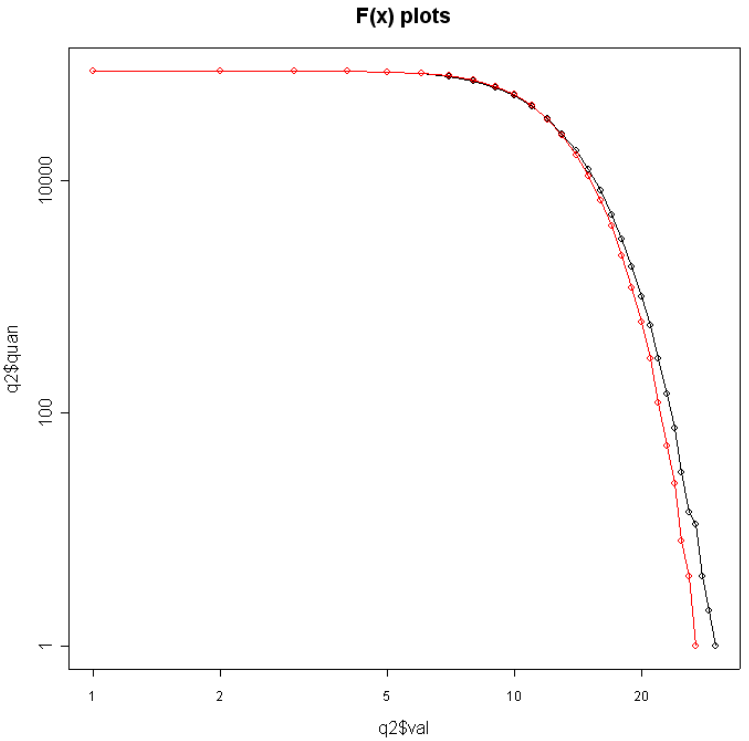
For comparison here it is the same qq-plot for the second day (where no evident GRB are occuring)



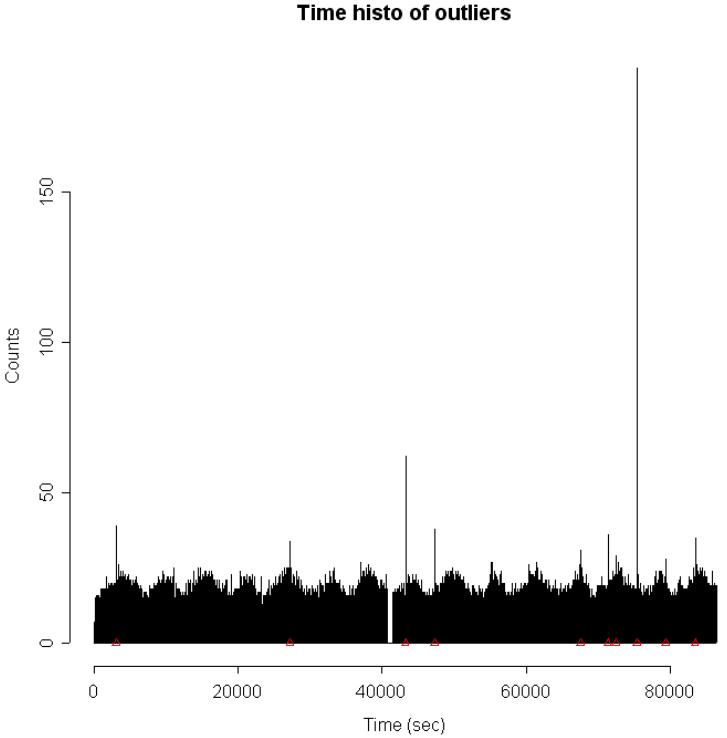
Another way to see at this is to plot the function $F(x) = card\{y : C(y) > x\}$ (with $C(x)$ the counts distribution) for the DC1 data of the first day and for a Poisson distribution with the same mean.



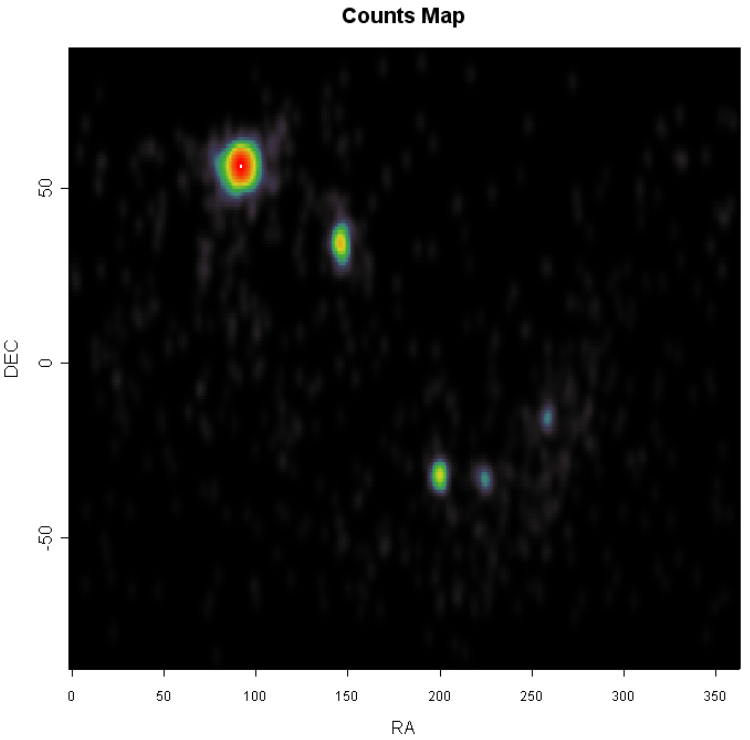
Again here it is the same plot for the second day



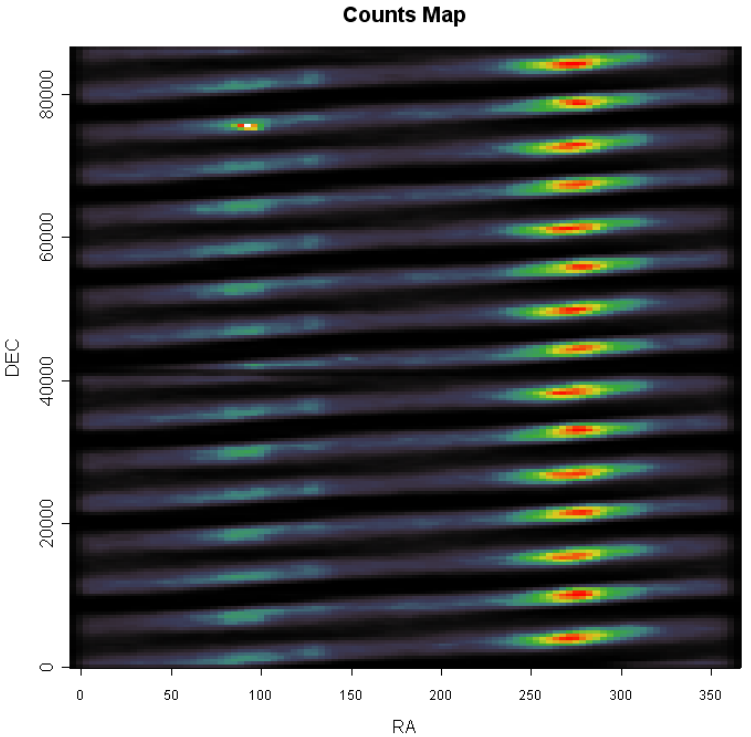
Here is the time counts histogram for the extracted photons



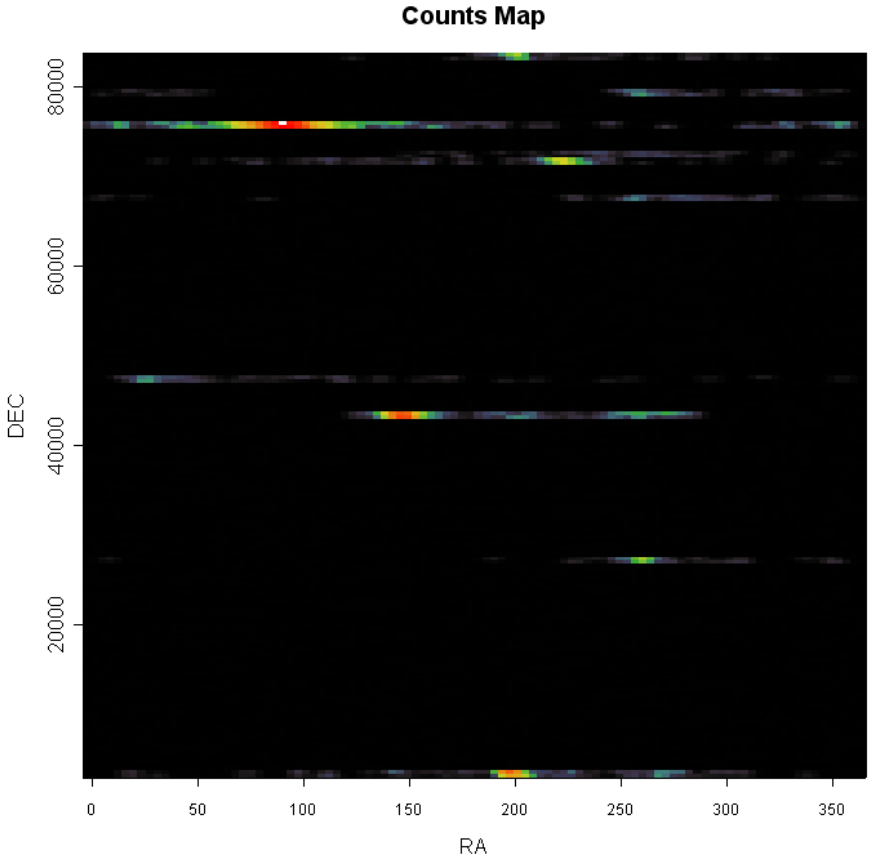
And here there is the counts map



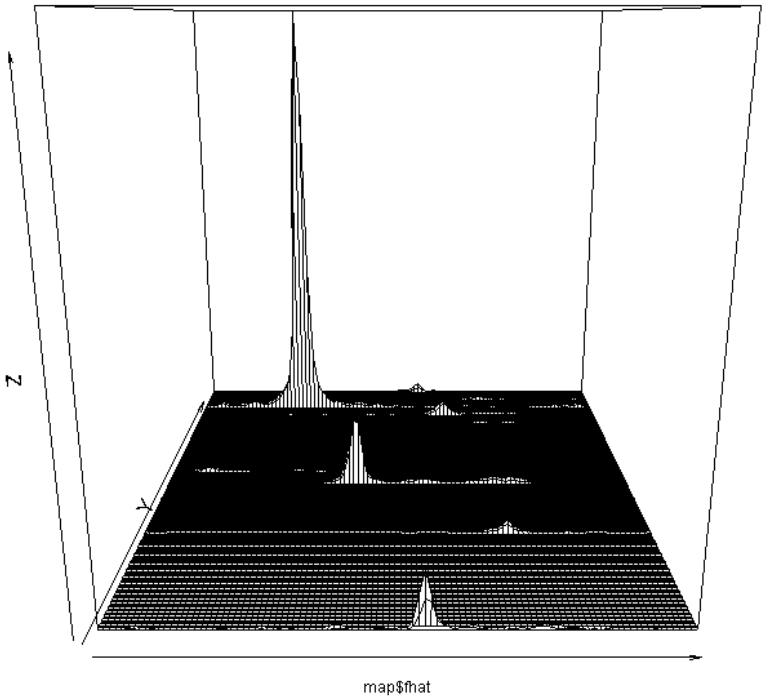
Another way to see the outliers is looking at the (smoothed) counts map for (RA, TIME) coordinates (or for (DEC,TIME)); doing this for all the photons gives



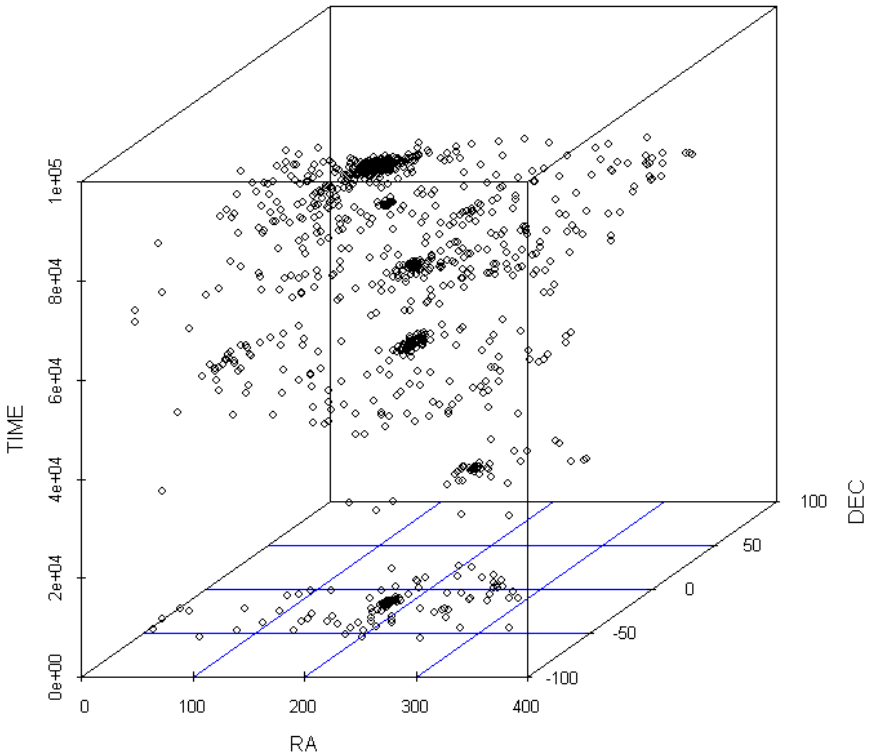
While for the outliers photons gives



Its more evident by looking to it in 3D perspective mode



Finally here there is a 3D scatter plot of the outliers photons



At this point we have a list of candidate GRB from this (naive) temporal analysis; to find "real" GRB we surely need also a spatial analysis on which we are working at the moment (as a rought extimate we are just studing the RA and DEC distribution in search of spatial clusters for the time intervals identified).
Anyway a temporal analysis like the one presented has lots of problems; one is that we are analyzing the full sky, and this means that we are for sure missing faint gamma ray bursts that are not global outliers, but only local ones.
To solve this one can constraint the temporal analysis on small spatial regions (see next talks and the WIKI pages of Nicola Omodei and David Band) or on small temporal regions (smaller than a full day).

Time	RA	DEC
3000	200	-32
27211	260	-16
43255	147	33
47274	???	??
71387	220	-35
75437	92	56
83510	200	-32

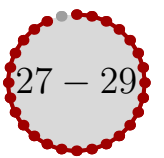
Day 1

Time	RA	DEC
176748	133	62
215701	252	27
220441	134	-3

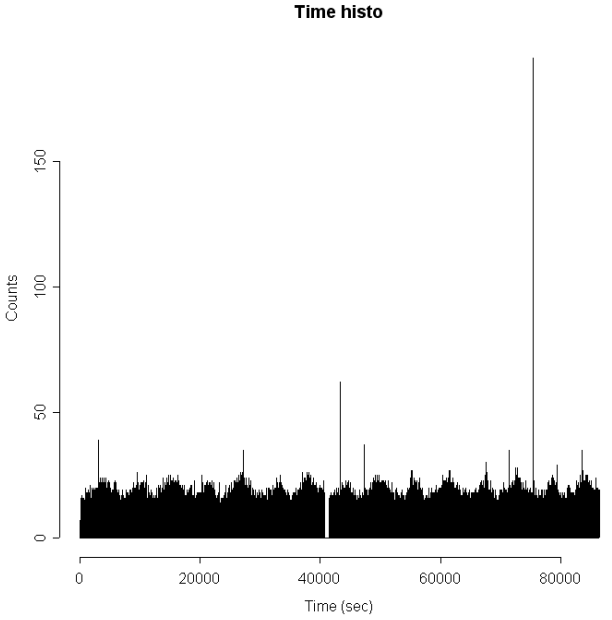
Day 3

Time	RA	DEC
410280	237	40

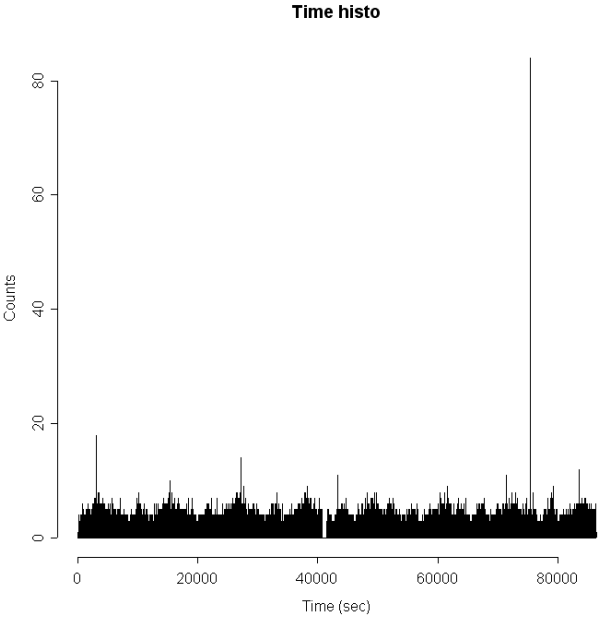
Day 5



To conclude, it is interesting to see what happens if one applies the cuts (**CALIB VERSION**) to the data and look for GRB; from the temporal counts histograms comparison it is possible to see that the outlier at **47274**, one of the more evident, diasppear completely (the others are reduced, but still present). This is confirmed by the spatial analysis around that instant that does not show any evident clustering.



Without cuts



With cuts

Conclusions

Much ado about nothing .. (??)

Few concluding remarks ...

- Lots of things can be done in R
- GRBs search was an excuse to learn such a tool
- We are just R hobbyists at the moment, but the learning curve is quite smooth.
- In the future we are planning to develop more astrophysics related functions and (maybe) an interface to some indexed photons database from R (work with **Marco Frailis** in Udine)
- Give it a try, it's free

http://www.r-project.org/
http://www.fisica.uniud.it/~riccardo/research