A deconvolution technique for VHE gamma-ray astronomy, and its application to the morphological study of shell supernova remnants

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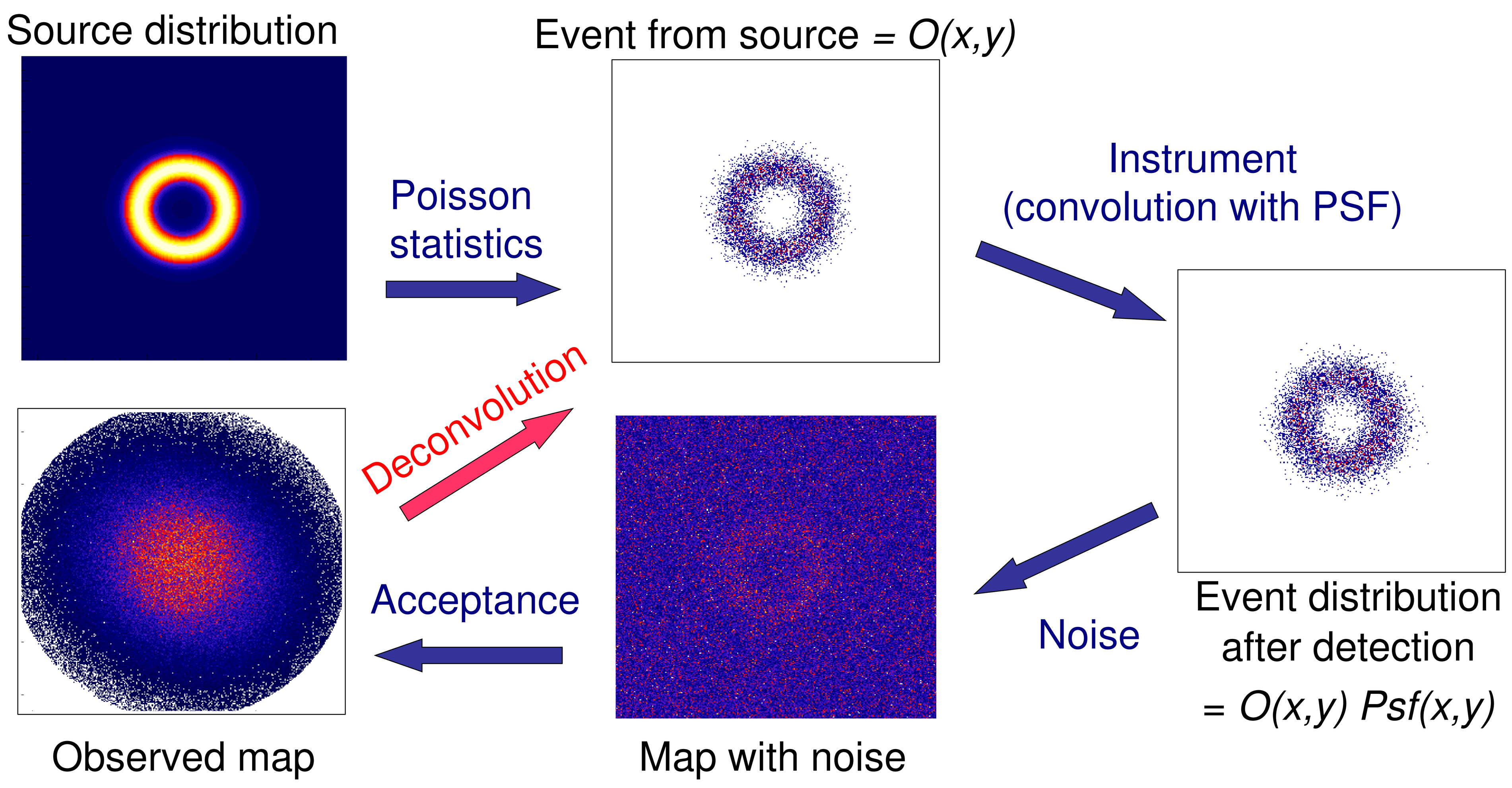
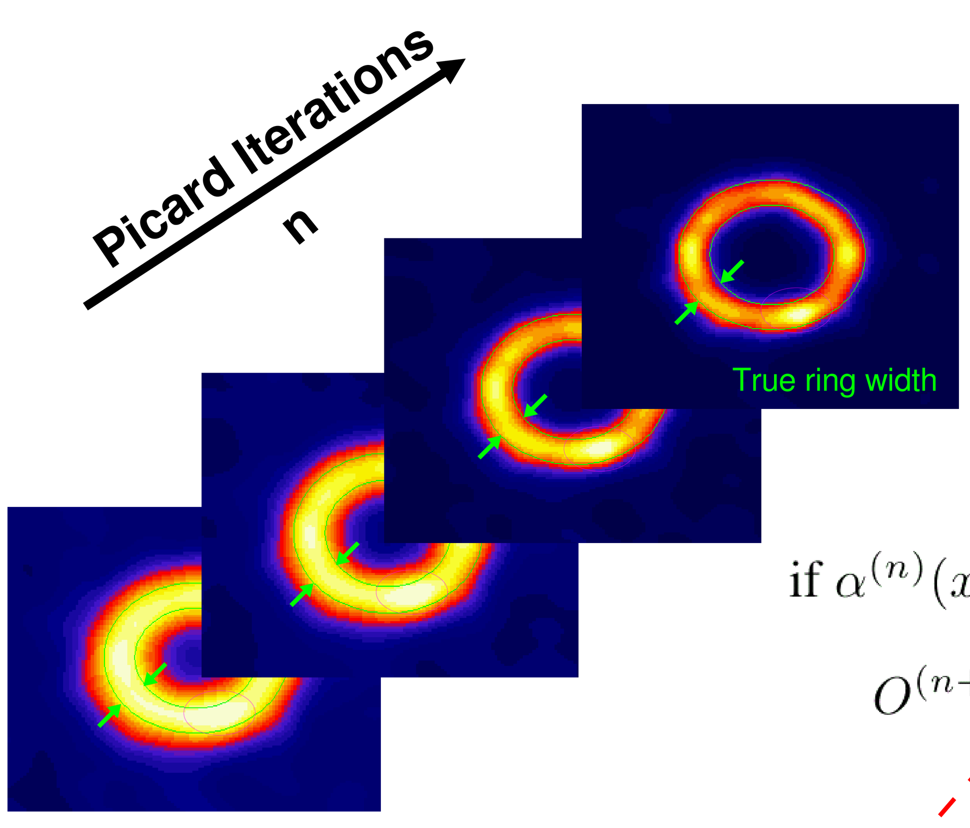
Introduction :

All images or maps obtained with a telescope are a statistical realization of the real source distribution degraded by the instrument response and with a certain noise: a point sources appears thus with a spread distribution called the point spread function (PSF).

Deconvolution process consists thus in correcting this spreading out taking into account the instrument acceptance, and, in the case of very high energy gamma-ray astronomy with low statistics and big hadronic contamination, applying a good treatment of the background noise.



$$\Rightarrow \quad \bar{N}_{on}(x,y) = (O(x,y) * Psf(x,y))A(x,y) + N_{off}(x,y)$$



* Small hot spots due to local fluctuations

We start from a distribution $O^{(0)}$ = constant map

if $\alpha^{(n)}(x,y) > \beta$

$$O^{(n+1)}(x,y) = \alpha^{(n)}(x,y) O^{(n)}(x,y)$$

β is chosen (typically 1%)

Convergence test:
stop when each pixel is not modified any more

We calculate

$$\alpha^{(n)}(x,y) = \frac{\frac{N_{on}(x,y)A(x,y)}{(O^{(n)}(x,y)*Psf(x,y))A(x,y)+N_{off}(x,y)} * Psf(x,y)}{A(x,y) * Psf(x,y)}$$

Smoothing to reduce effect of local fluctuation

The new method :

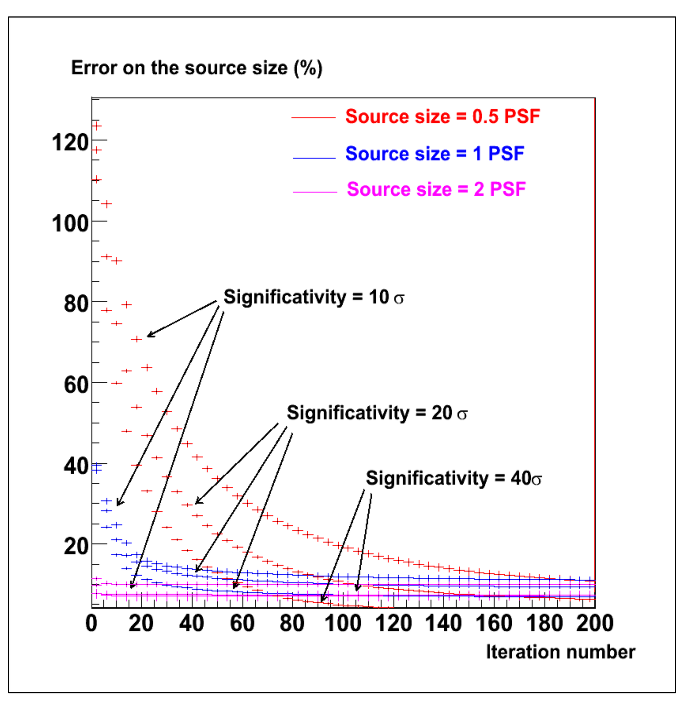
An iterative algorithm of maximum likelihood, based on **Richardson-Lucy** deconvolution which takes into account:

- the Poisson statistic (with reduction of local fluctuation effects by smoothing)
- the background evaluation by external measurements (ring, template, off region method...)
- the sharp acceptance of the camera

and with a simple convergence test.

Optimal iteration number and resolution improvement:

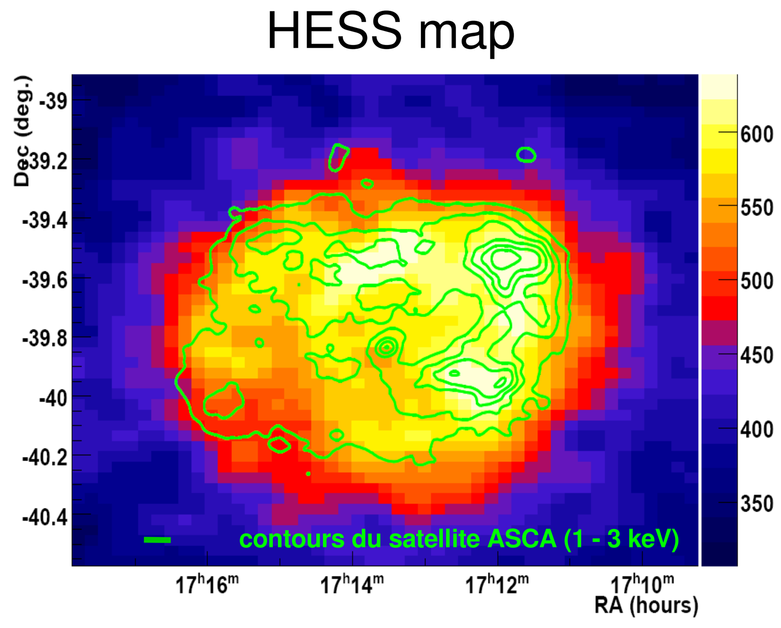
This method makes converge the deconvolution to a limit of resolution depending on the significance and the source size.
The higher the significance or the bigger the source , the better the resolution is.
During the iteration, we impose *O(x,y)* positive. This condition brakes the photometry, but this effect is very weak (<1%).



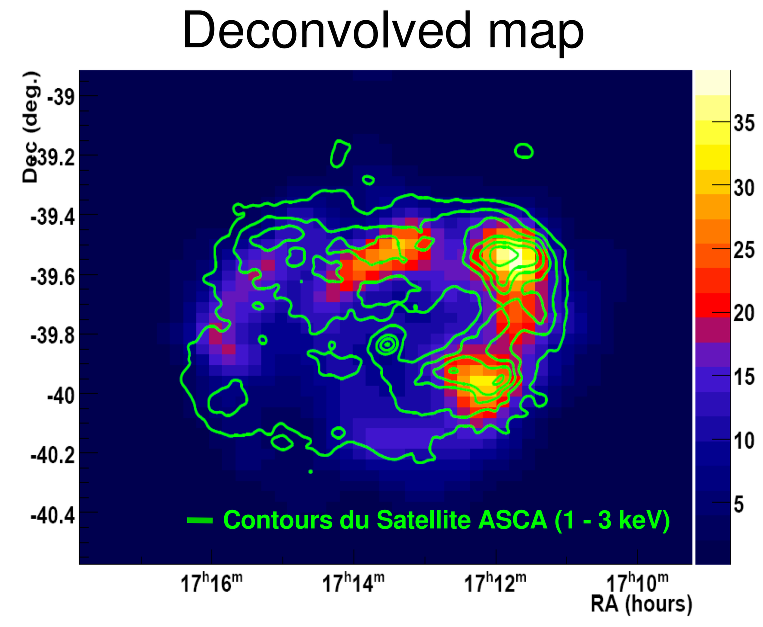
These tests show also that the deconvolution is a slow process after several iterations.

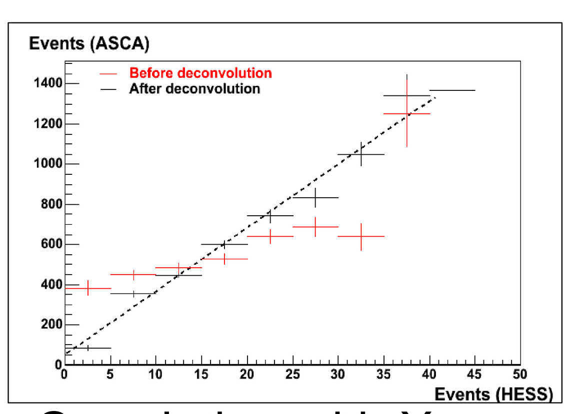
The SNR RXJ1713,7-3946 observed by H.E.S.S.:

HESS map



Deconvolved map





Correlation with X-rays
(1 – 3 keV)

The deconvolution improves clearly the correlation between the TeV emission and the X-ray emission (1-3 keV) as measured by ASCA.

The correlations are important to constrain emission models (leptonic versus hadronic).

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