

Denoising cosmic rays radio signal using Wavelets techniques

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Motivation

I. Task of denoising cosmic rays induced radio signals experiments.

a. AERA (Auger) experiment.

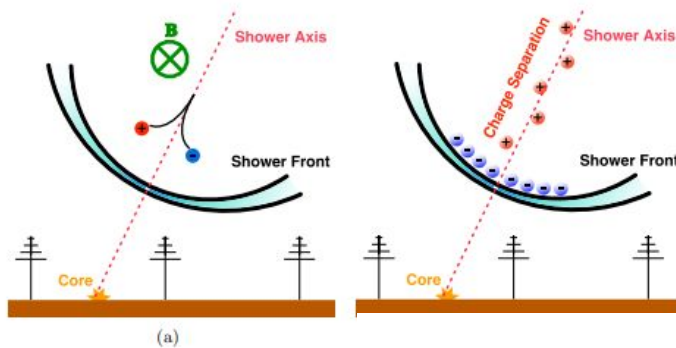
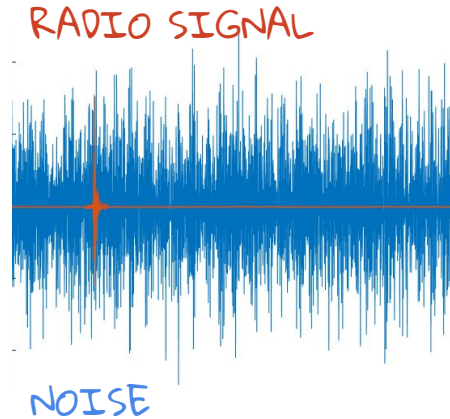


Figure from H. Schoorlemmer, *Tuning in on cosmic rays*, Ph.D. thesis, Radboud Universiteit Nijmegen, 2012

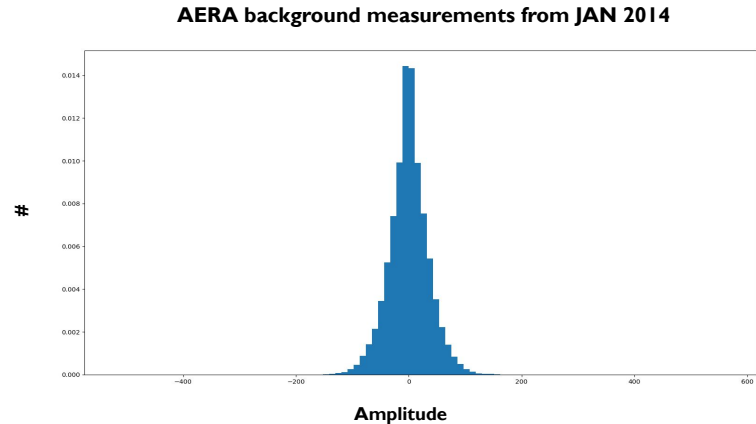
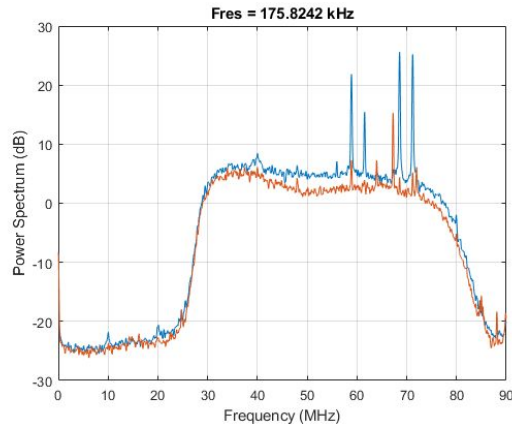


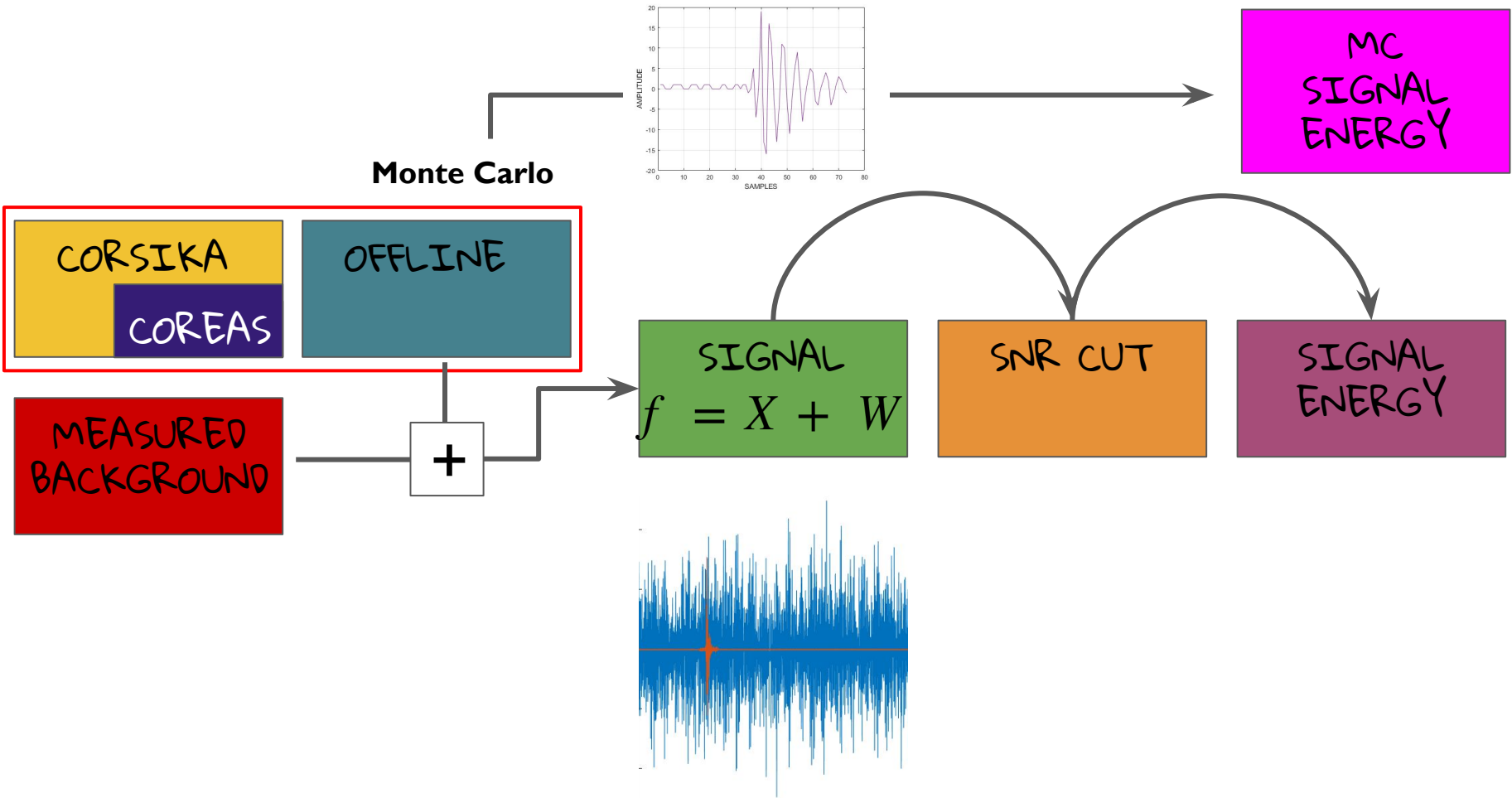
AERA (Auger)



Image from <https://www.auger.org/index.php/observatory/aera> (Auger website)

- ❖ From the well established Auger experiment, AERA is a (10 years long) radio experiment using antenna system to measure short radio pulses emitted by cosmic ray air showers of the highest energies.
- ❖ Complex background with colored noise (non gaussian distribution).

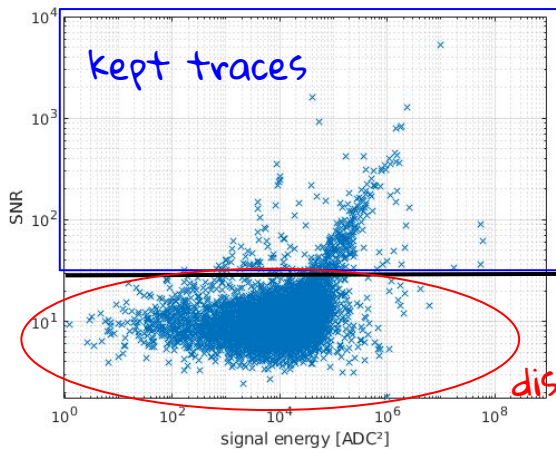
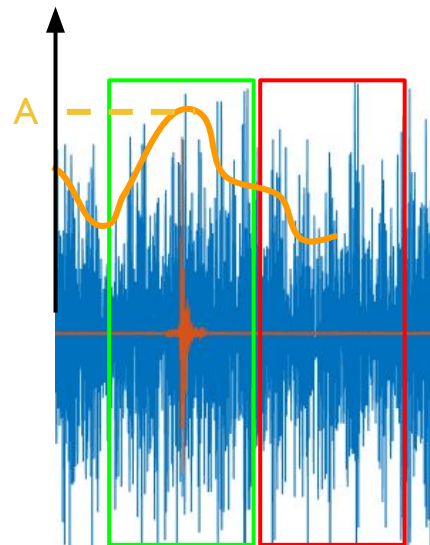




AERA SNR

$$SNR = \frac{A^2}{RMS_{bck}^2}$$

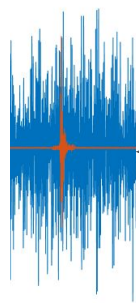
where A is the maximum value of the Hilbert Envelope in the “signal window” and RMS_{bck} is the root-mean-square of the “background window”



SNR CUT ~ 20

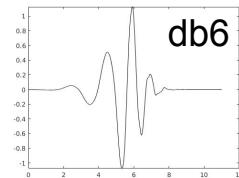
discarded traces

Wavelets in one slide

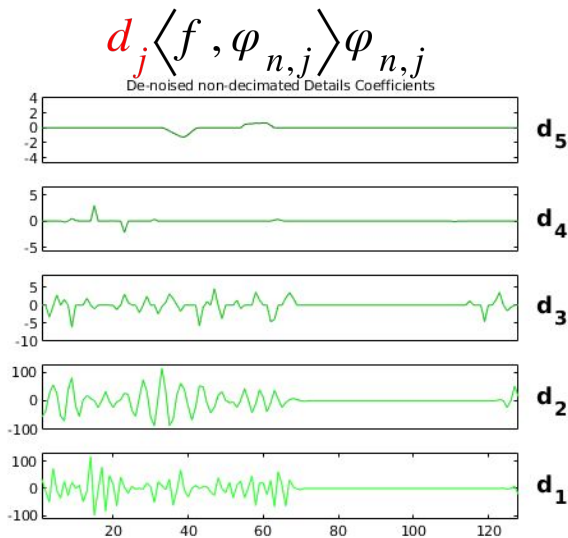
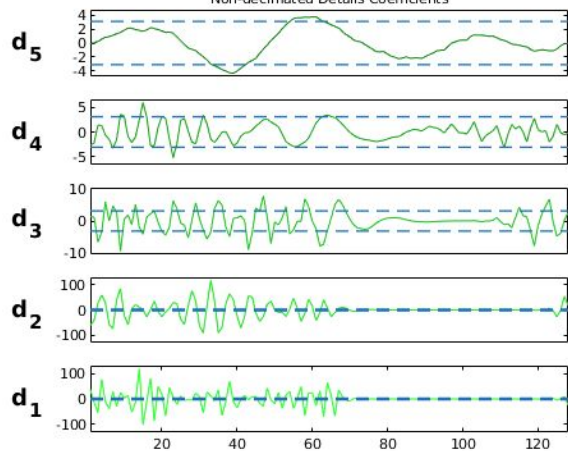


wavelet mother

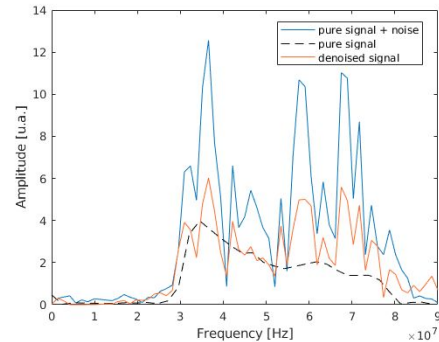
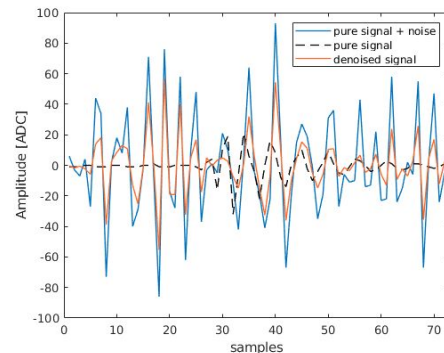
$$\varphi_{n,j} = \frac{1}{\sqrt{2^j}} \varphi\left(\frac{t - n2^j}{2^j}\right)$$



$$\langle f, \varphi_{n,j} \rangle = \int f(t) \varphi_{n,j} dt$$

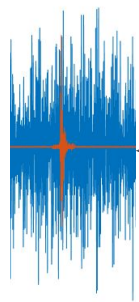


$$f(t) = \sum_{j,n} d_j \langle f, \varphi_{n,j} \rangle \varphi_{n,j}$$

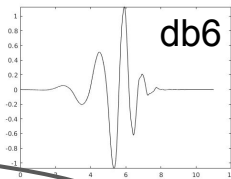


Wavelets in one slide

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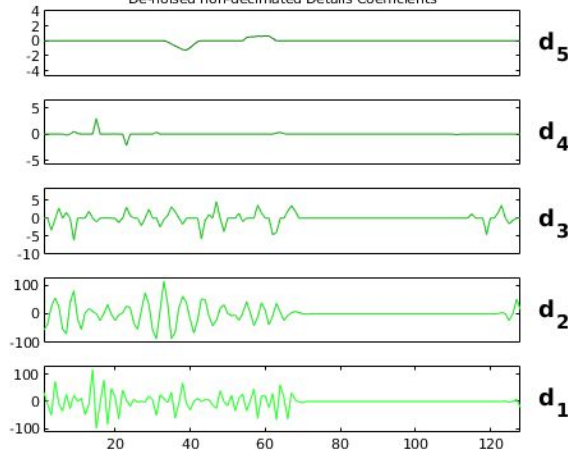
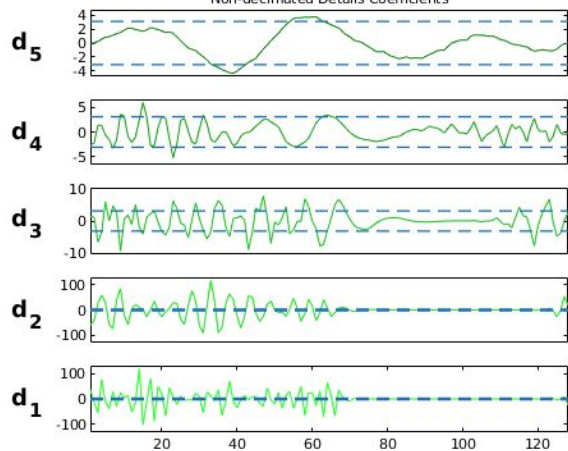


wavelet mother

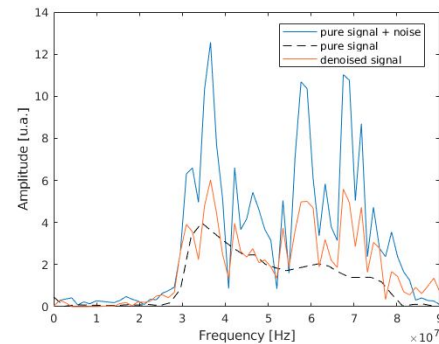
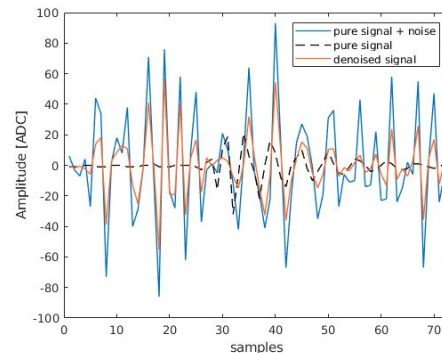


$$\langle f, \varphi_{n,j} \rangle = \int f(t) \varphi_{n,j} dt$$

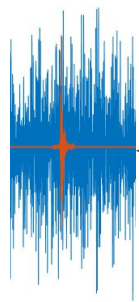
$$d_j \langle f, \varphi_{n,j} \rangle \varphi_{n,j}$$



$$f(t) = \sum_{j,n} d_j \langle f, \varphi_{n,j} \rangle \varphi_{n,j}$$

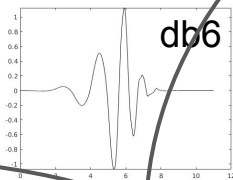


Wavelets in one slide



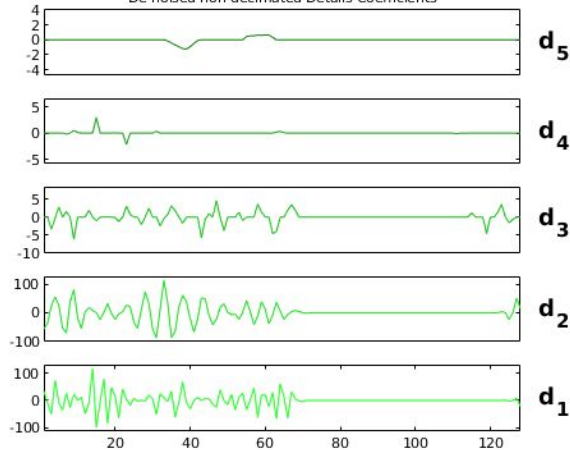
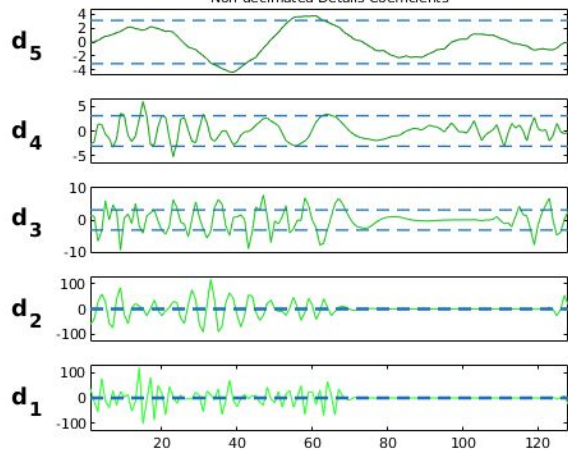
wavelet mother

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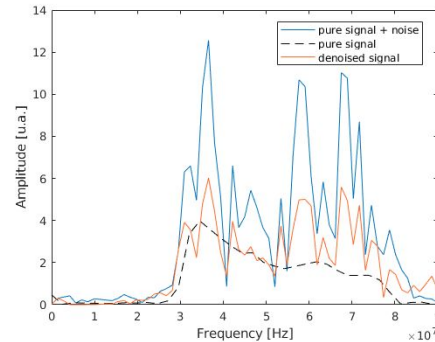
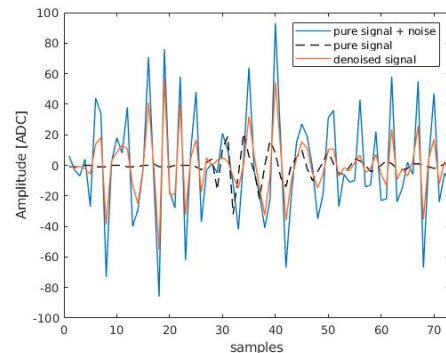


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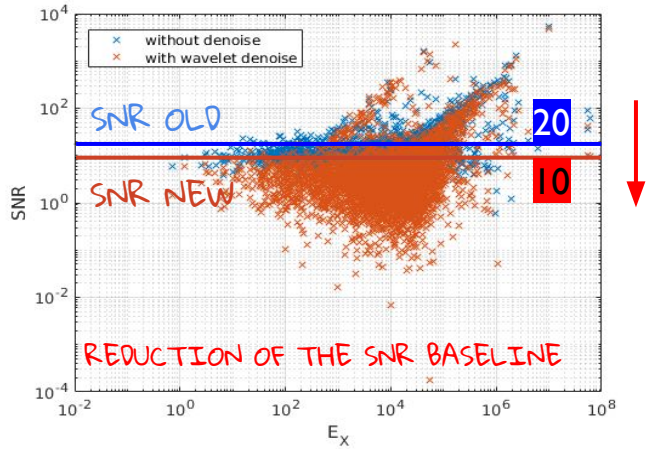
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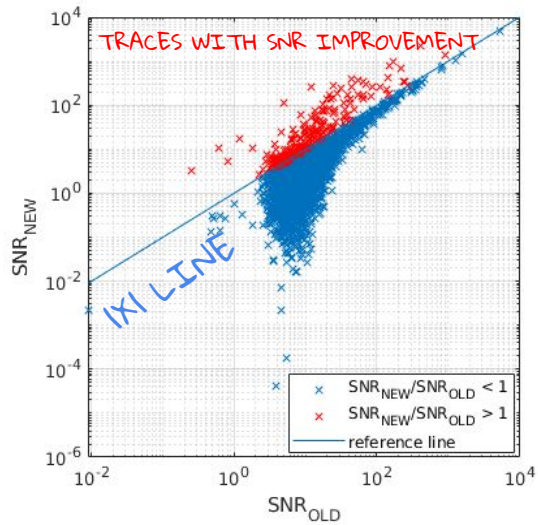
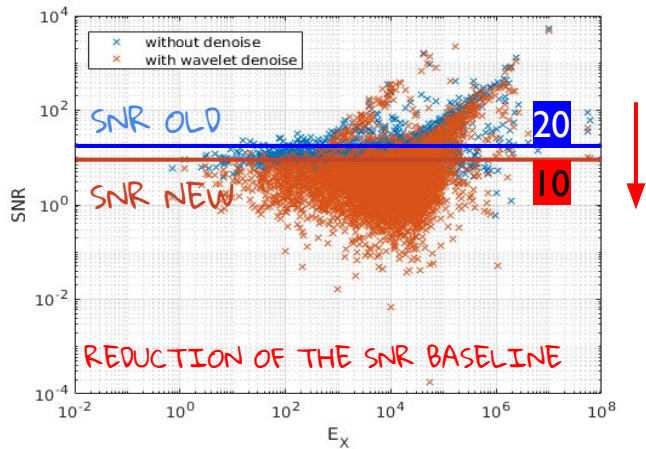
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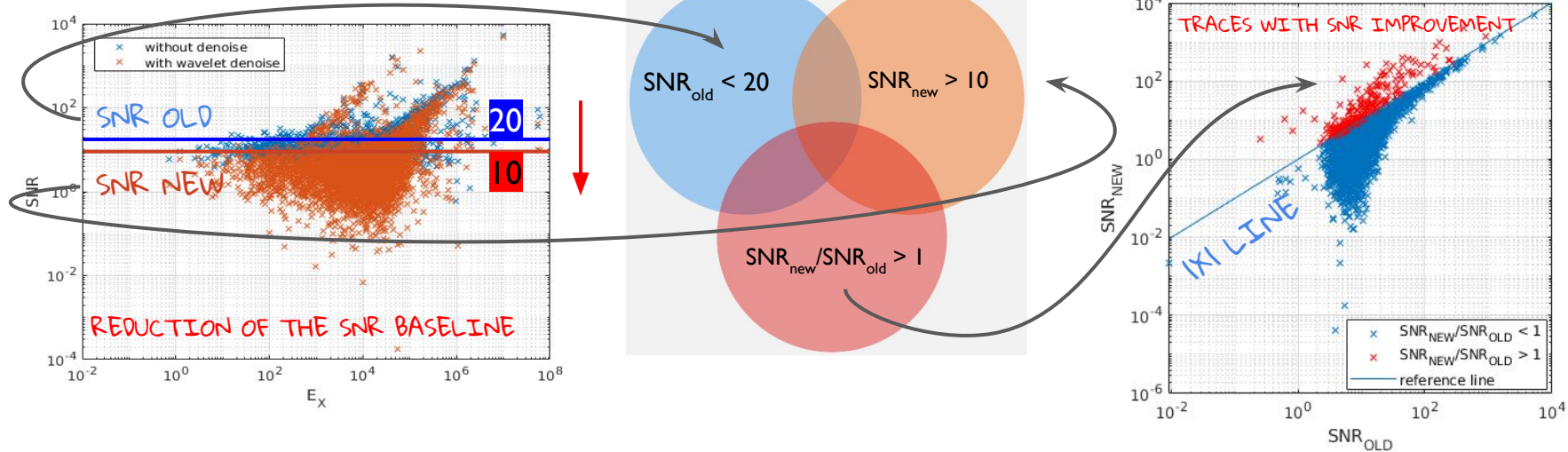
Results



Results



Results



Results

