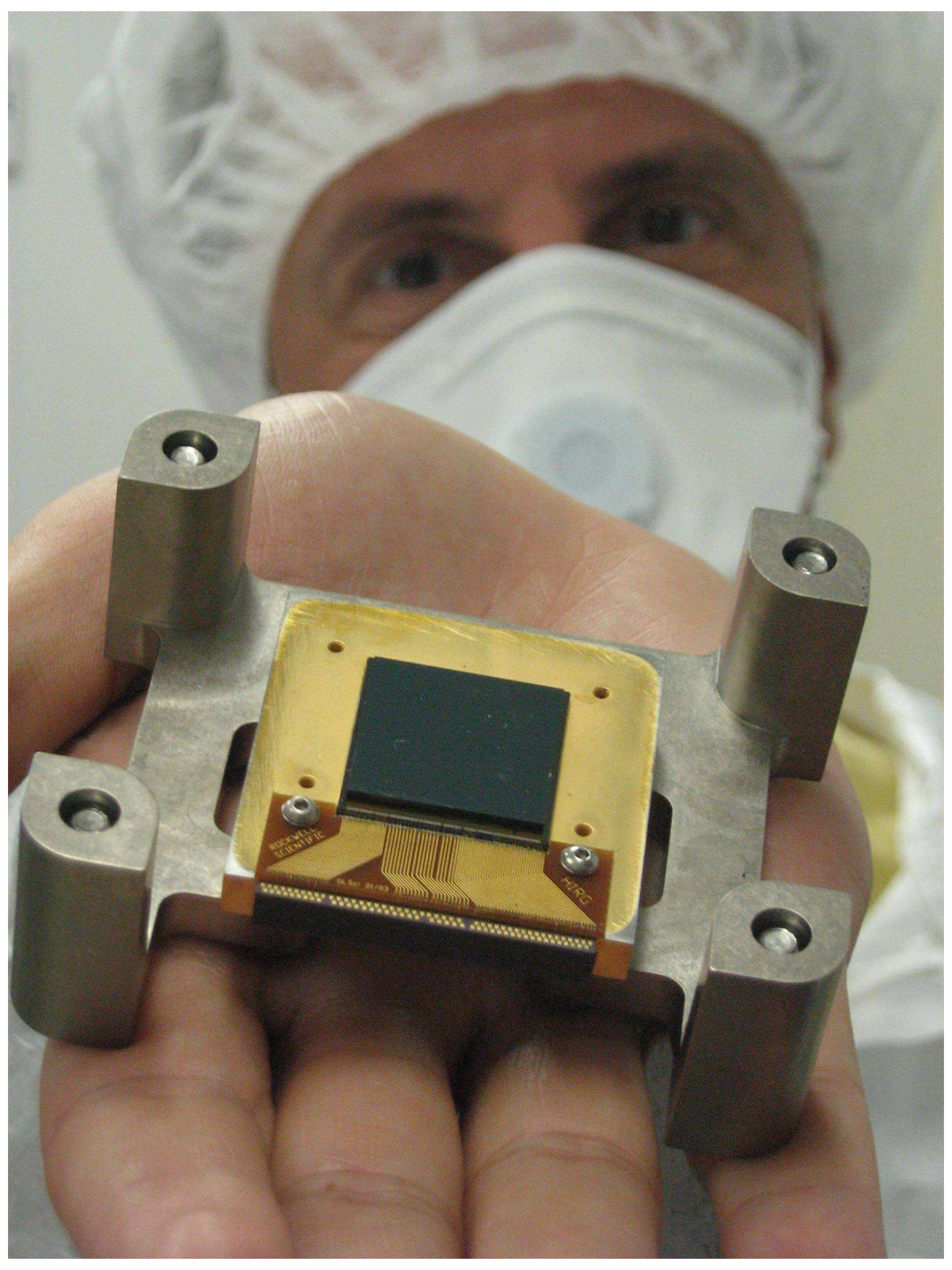

# Noise Performance of the H2RG # 40 Detector : 1/f noise spectrum extraction and long exposure time impact on photometry

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An analysis of the noise of a H2RG HgCdTe NIR (1.7µm cutoff) detector from Teledyne is performed. The noise is evaluated through a temporal analysis of individual pixels over long times, varying the non destructive readouts frequencies. A generic 1/f noise spectrum is then assumed to ajust its weights and power parameters through an astute calculation. The uncertainties over the low flux and long exposure times are evaluated for this acquisition scheme.

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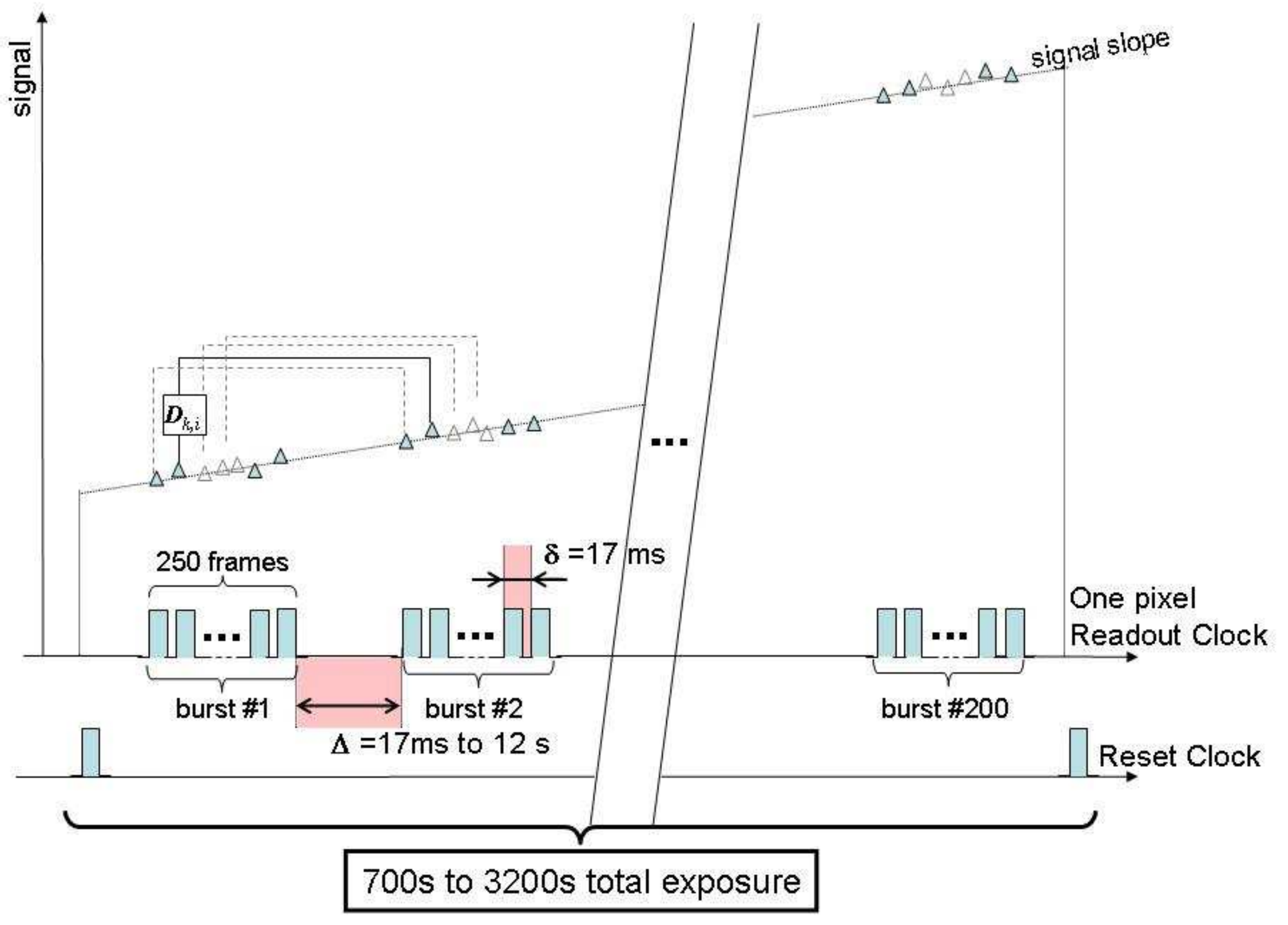
## 1. Setup and apparatus

The setup is the same as the one describe in the previous poster : *Measurement of the Non-linearity and Interpixel Capacitance of a H2RG Detector.* The LED illunation system is not used, only *dark* acquisition will be used at T=110K. Clock frequency is 100kHz and a 30x30 pixels window is used.

## 2. Measurement method and acquisition scheme

The goal in terms of noise performance, is to measure the photometric error for low photon rates (typically 0.05 photon/pixel/s) over long exposure time (typically few thousands of seconds). The acquisition scheme choosen is a variant of the so called *Up-the-Ramp* acquisition mode, where every pixel is read non destructively all along the exposure time, but where the readouts are splitted between several groups or *bursts* of *frames*.



In our measurements we took :

- window size = 30x30 pixels
- clock frequency = 100kHz
- 250 frames by burst → δ=17ms/frame
- 200 bursts
- Δ = 17ms to 12s between bursts
- total expoture time = 700s to 3200s

The noise is caracterised by several observables :

- the frame to frame variance (δ = 17ms interval)
- the **burst to burst variance** by the spread of the mean difference between consecutive burst (Δ = 17ms to 12s interval)

Only burst to burst variance as well as photometric error wil be treated in this poster.

## 3. Burst to Burst noise

The Burst to Burst noise is evaluated in each pixel from the differences $D_k$ of the average signal over n frames between bursts k and k - 1

$$D_k = \frac{1}{n}\sum_{i=1}^{n} D_{k,i} - D_{k,i-1}$$

where $D_{k,i}$ is the signal of the considered pixel in burst k and frame i (see acquisition scheme).
It can be also writen as :

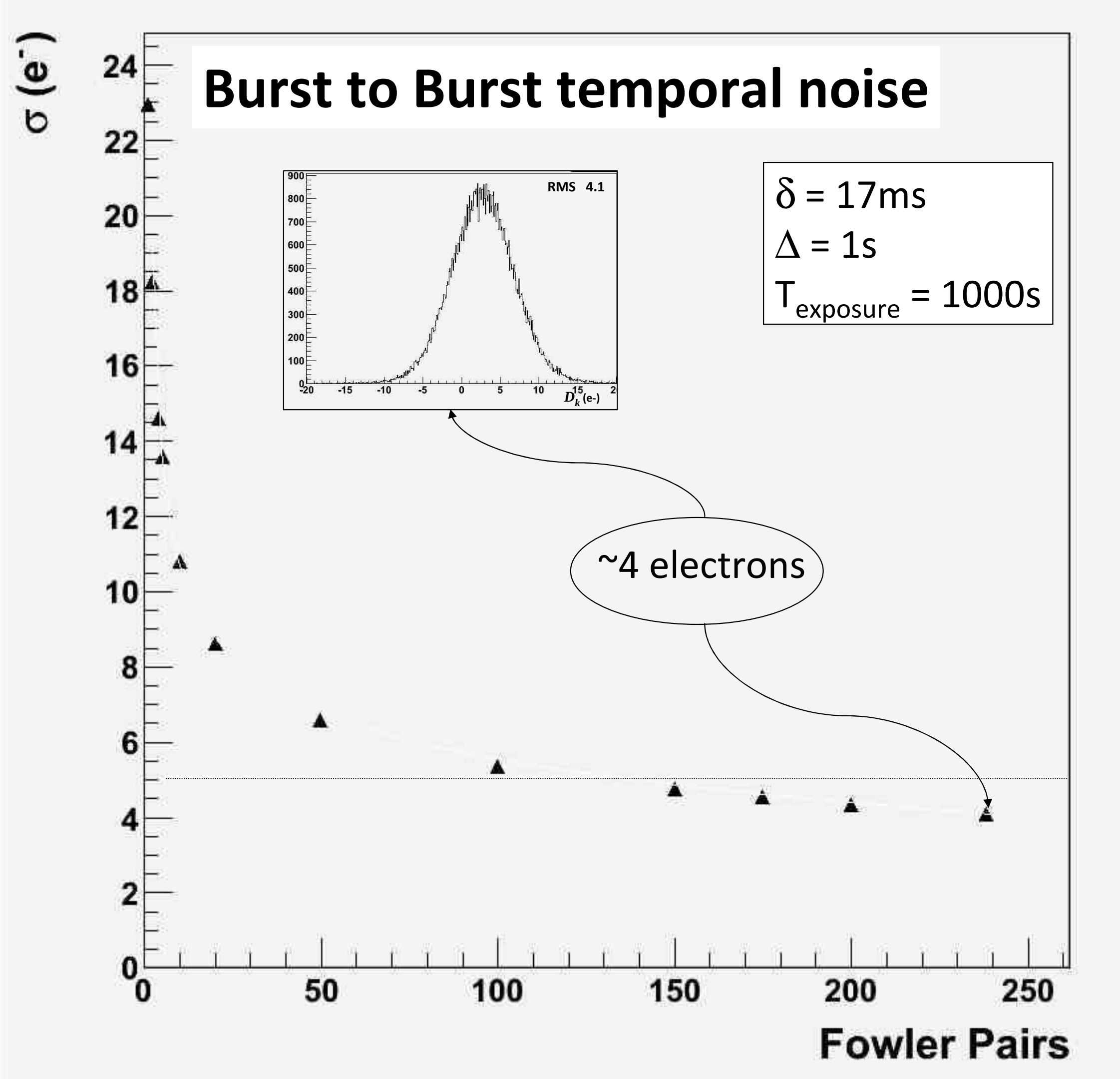
$$D_k = \frac{1}{n}\sum_{i=1}^{i=n} s_i(t_0 + k\Delta + i\delta) - s_{i-1}(t_0 + (k-1)\Delta + i\delta)$$

the associated temporal variance can the be measured calculating

$$\boxed{\sigma^2 = \frac{1}{N-1}\sum_{k=1}^{N}\left(D_k - \langle D_k \rangle\right)^2}$$

where $\langle D_k \rangle = \frac{1}{N}\sum_{k=1}^{N} D_k$ is the mean flux accumulated by the pixel during the time $\Delta$.

We measure s from the variance of the average of the difference of n consecutive frames selected from the same exposure of 250 frames/burst.



RESULTS :

- Fowler 1 ~ 23 electrons
- Fowler 240 ~ 4.1 electrons

The 4.1 electrons increase of about 1 electrons when Δ start from 1s up to 12 s.

## 4. Frequency spectrum of the noise

We have attempted to describe the observed dependence of the burst to burst noise on the number of samplings assuming a two component parameterization of the power spectrum of the noise:

$$\boxed{f(\omega) = A + \frac{B}{\omega^\alpha}}$$

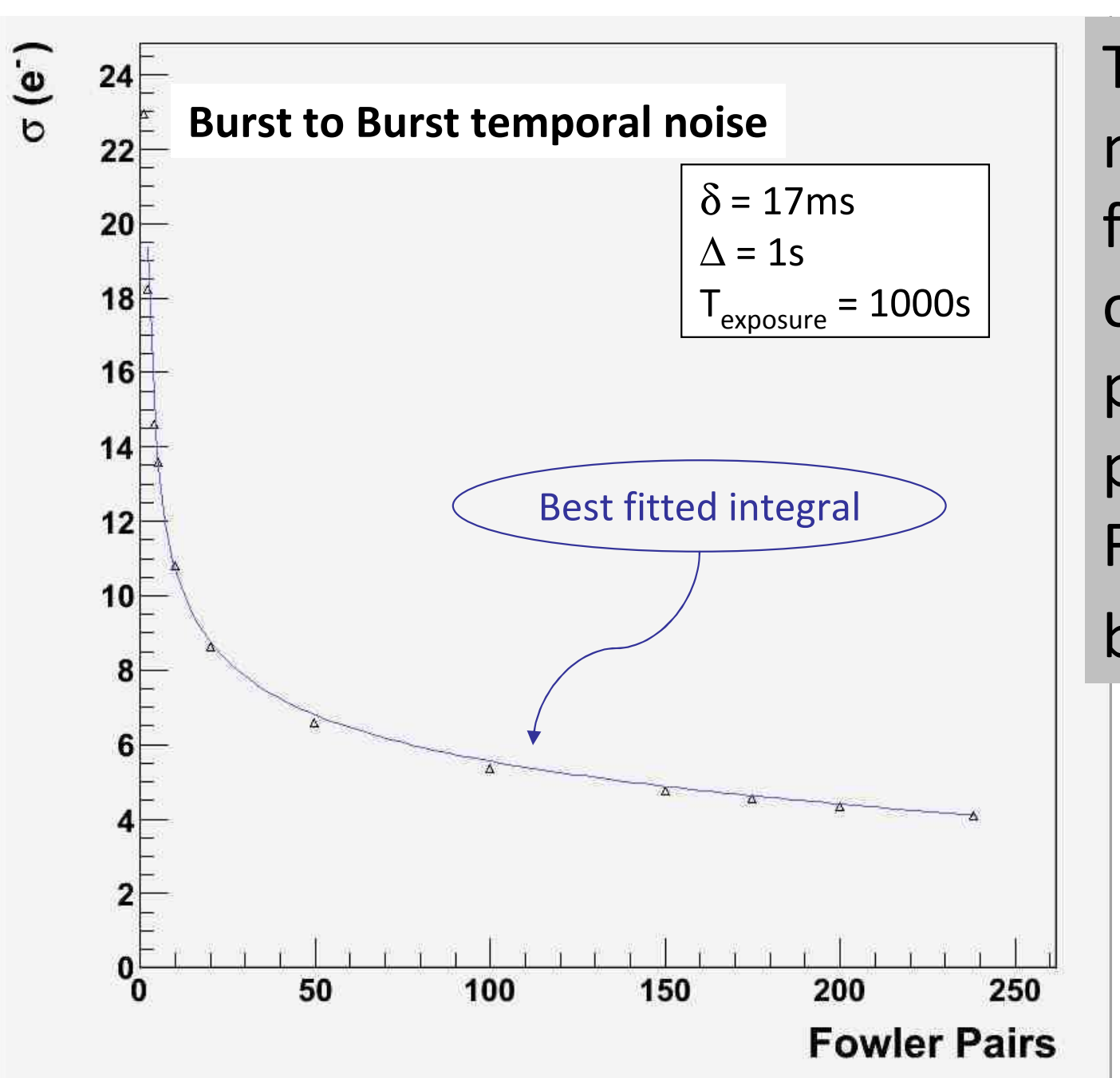
with A is the weight of the white noise and B the one for the 1/f noise.
We assume the usual relation between the autocorrelation of the noise and the frequency power :

$$< S(t)S(t+\tau) >= \int_{\omega 1}^{\omega 2} d\omega cos(\omega\tau) f(\omega)$$

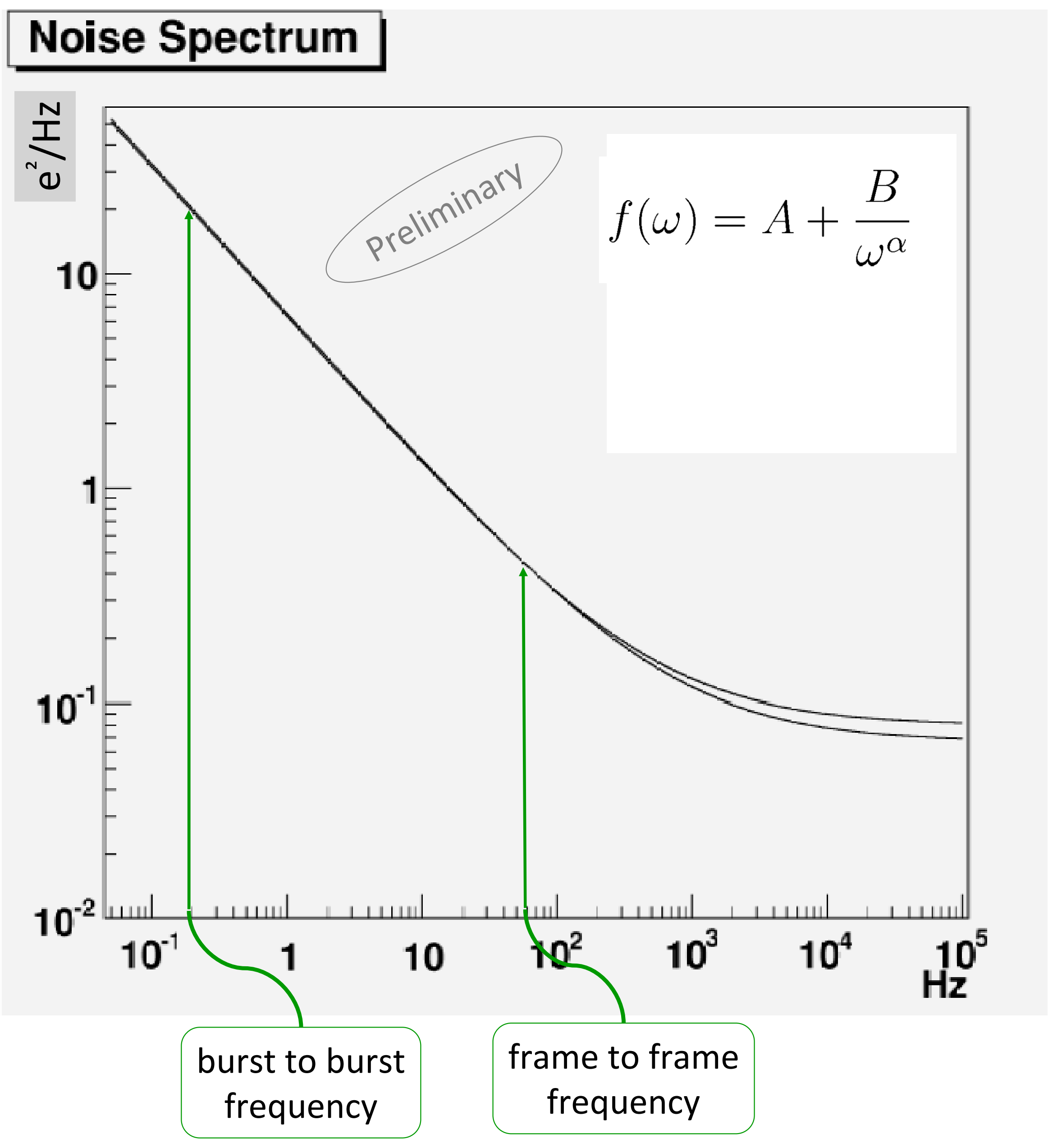
also known as the Wiener-Khintchine theorem.

$\sigma_D^2 = \frac{1}{N-1}\sum_{k=1}^{N}\left(D_k - \langle D_k \rangle\right)^2$ can be explicitely writen as a sum of autocorrelations that can be converted with the Wiener theorem.

One can find after some calculation (to be published soon…) the exact expression of the Burst to Burst noise (also often called Fowler noise) as a function of the power spectrum noise.



The integral is calculated numerically with a low frequencey cutoff of the order of $1/T_{expo}$ . We find the A and B parameters by adjusting the parametrized expression to the Fowler(n) variance measured by a $\chi^2$ fit.



## 4. Photometric uncertainties over long exposure times

We evaluate the photometric for a given exposure time measuring the distribution of the differences $d_k$ between bursts of the mean burst signal

$$d_k = \langle s_{i,k+1} \rangle_n - \langle s_{i,k} \rangle_n$$

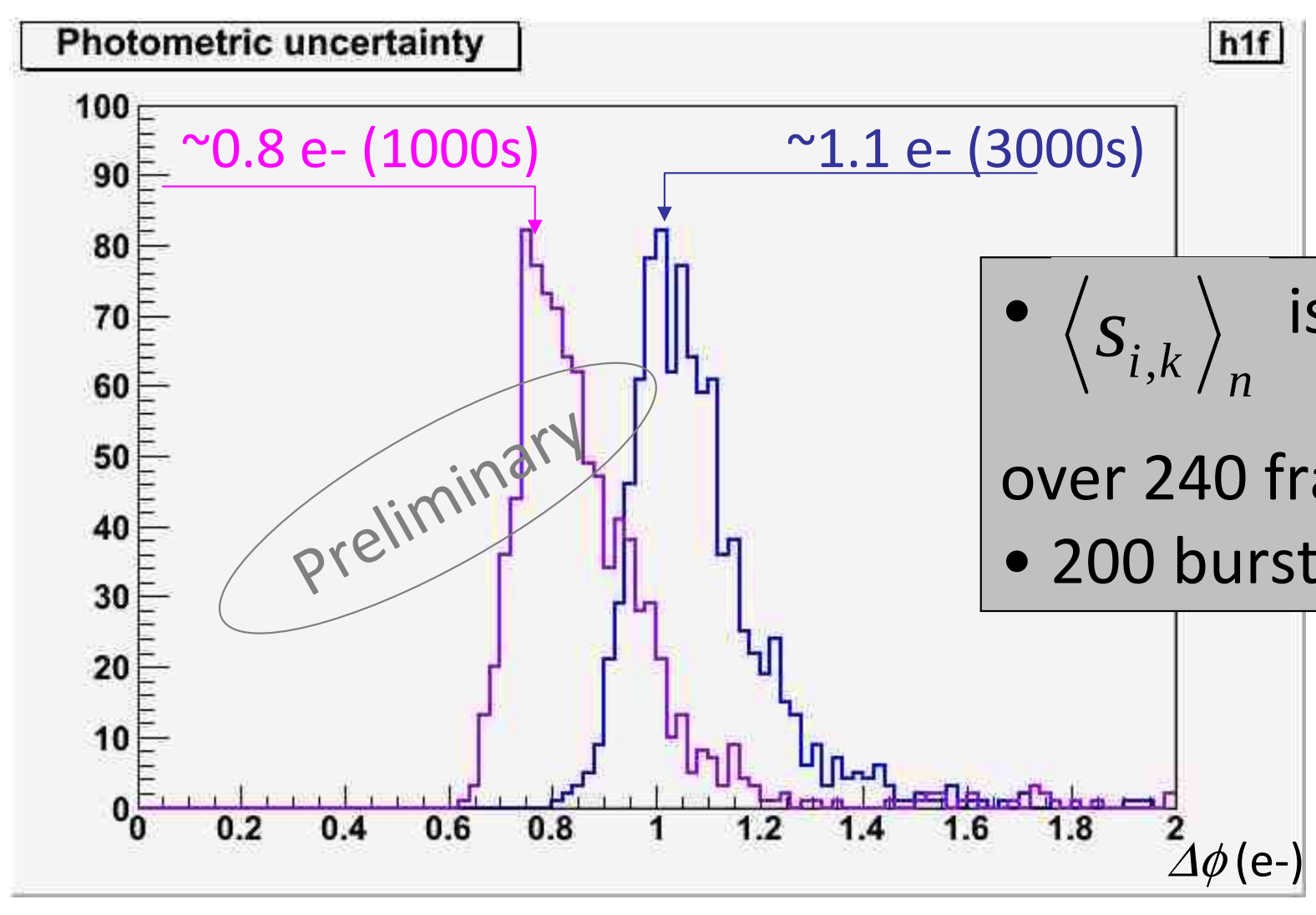
_ where $\langle s_{i,k} \rangle_n = \frac{1}{n}\sum_{i=1}^{nFrames} s_{i,k}$ is the mean signal of a pixel in the burst k
_ and $s_{i,k}$ the pixel signa at the frame i in the burst k.
dk can also be writen as the product of the flux and the exposure time :

$$d_k/\Delta \cdot T_{exposure} = \phi \cdot T_{exposure}$$

a $\chi^2$ minimisation over the $d_k$ can be done, calculating :

$$\chi^2 = \sum_{k,l}(d_k - \phi\Delta)\text{cov}_{k,l}^{-1}(d_l - \phi\Delta)$$

where the error matrix $\text{cov}_{k,l}^{-1}$ is the inverted covariance matrix.
The uncertainty $\Delta\phi$ of the flux $\phi$ can then be computed and we found the following preliminary result :



- $\langle s_{i,k} \rangle_n$ is averaged over 240 frames
- 200 burst are used

Photometric uncertainties at the order of 1 electron is find for exposure time of thousands of seconds.
This great results have to be mitigated in a forthcoming work by a systematic uncertainties study.