MEDICAL PHYSICS LAB

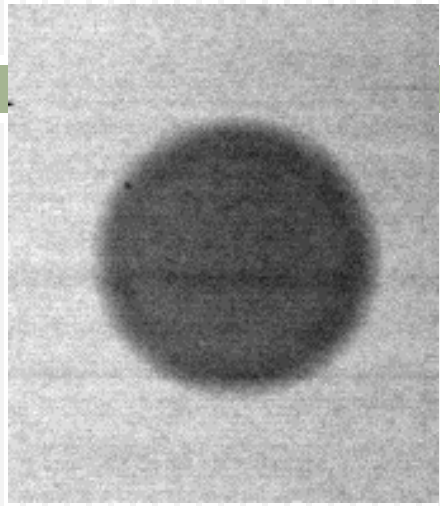
LECTURE 2 – ROSE MODEL

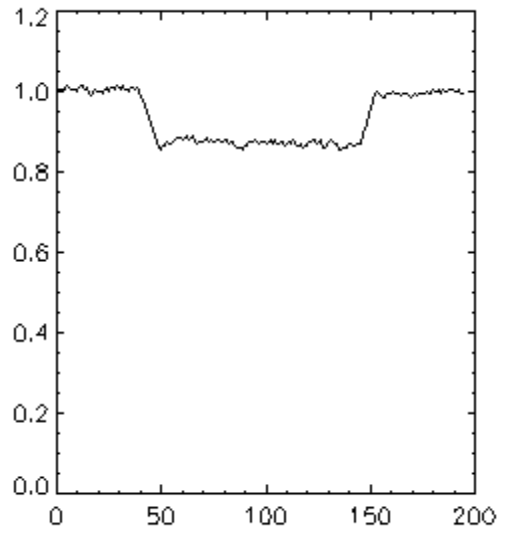
Luigi Rigon
University of Trieste and INFN

Part 1 – Rose Model

Source: Ian A. Cunningham, Chapter 2 in Handbook of medical imaging. Volume 1, Physics and psychophysics. Richard Van Metter, Jacob Beutel, Harold Kundel, editors.

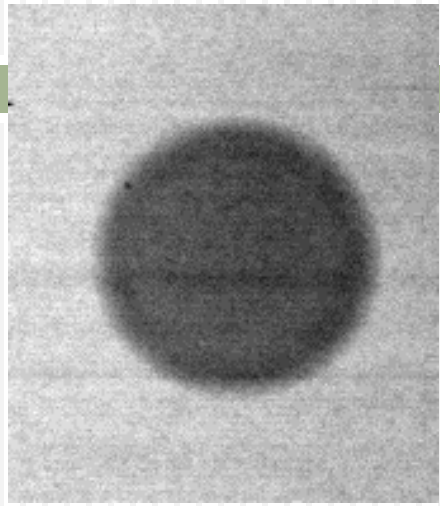
Signal and contrast

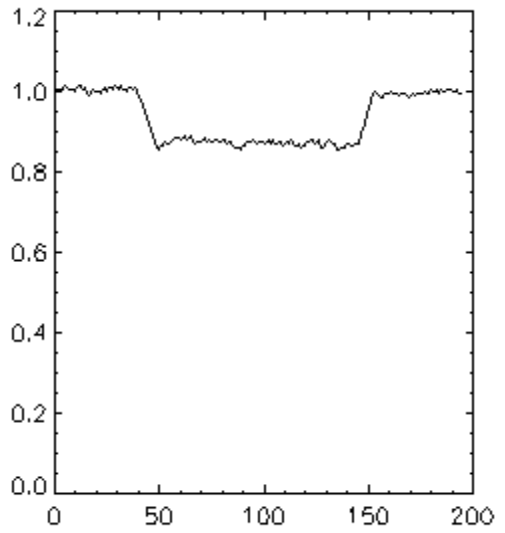




- Consider the round detail in the image, which profile is shown in the plot on the right-hand side
- We define
  - A the area of the detail (in pixel)
  - N_2 the <u>average</u> number of photons/pixel in the area A of the detail
  - N_1 the <u>average</u> number of photons/pixel in a similar area A in the background
  - note that A represents the number of pixels over which the average values N_1 and N_2 are evaluated

Signal and contrast





- The signal of the detail is defined as

$$Signal = A(N_1 - N_2)$$

- While its contrast is

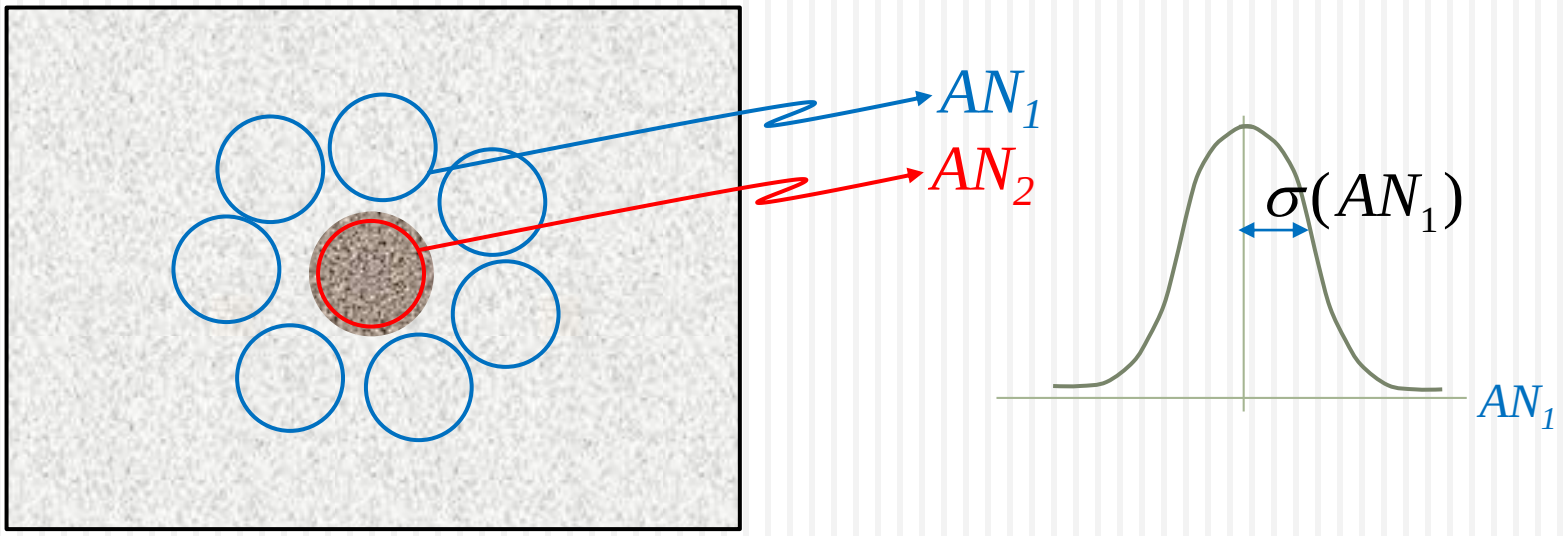
$$C = \frac{N_1 - N_2}{N_1}$$

SNR

- However, the visibility of the detail is due to its signal-to-noise ratio (SNR):

$$SNR = \frac{Signal}{\sigma(AN_1)} = \frac{A(N_1 - N_2)}{\sigma(AN_1)} = \frac{ACN_1}{\sigma(AN_1)}$$

- where $\sigma(AN_1)$ is the standard deviation of the number of counts found in an area A in the background



SNR

- $\sigma(AN_1)$ is the standard deviation of the distribution of number of counts that could be found choosing different Regions Of Interest (ROIs), all of area A, in the background
- Let σ_1 be the standard deviation of the distribution of the number of counts evaluated on a pixel-per-pixel basis *inside a single ROI* of area A in the background
- Then: $\sigma(N_1) = \frac{\sigma_1}{\sqrt{A}}$

$$\sigma(AN_1) = A\sigma(N_1) = A\frac{\sigma_1}{\sqrt{A}} = \sigma_1\sqrt{A}$$

SNR & Rose Model

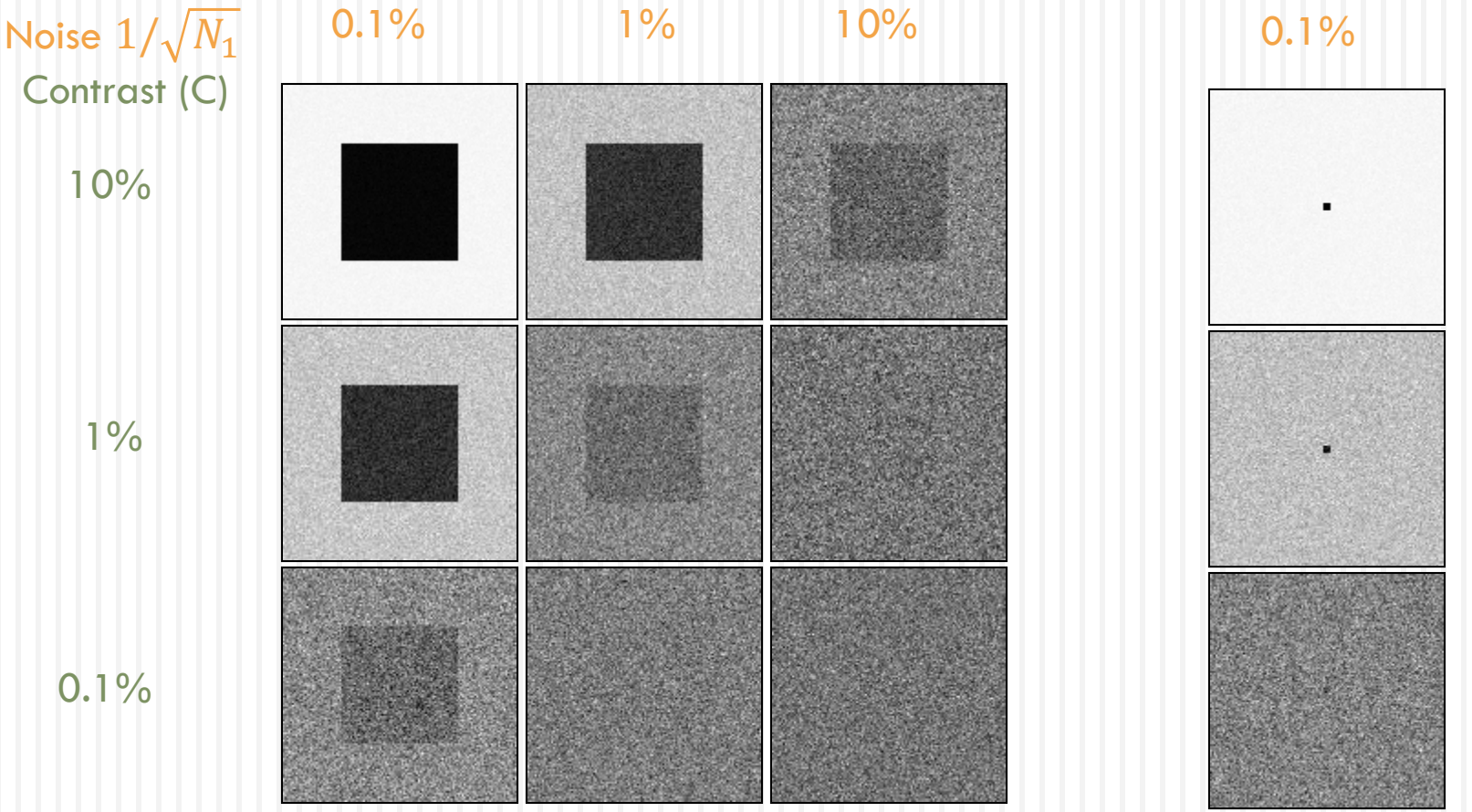
- By substituting the latter in the SNR definition we have

$$SNR = \frac{Signal}{\sigma(AN_1)} = \frac{ACN_1}{\sigma(AN_1)} = \frac{ACN_1}{\sigma_1\sqrt{A}} = \sqrt{A}C\frac{N_1}{\sigma_1}$$

- In the particular case in which N is a poissonian variable $\sigma_1 = \sqrt{N_1}$ and $SNR = \sqrt{AN_1}C$
- In general the SNR increases with the contrast C, the sqrt(area of the detail) $\sqrt{A}$, and with the fluence N_1 while it is inversely proportional to the noise σ_1
- According to the Rose criterion a detail is considered visible when its SNR is in the order of 5 or larger

SNR & Rose Model

$$SNR = \sqrt{AN_1}C$$



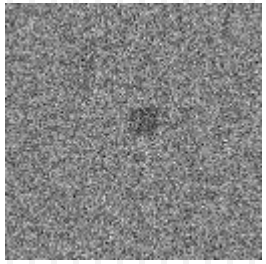
Let's play!

$$SNR = \sqrt{AN_1 C}$$

- Try to spot a square detail on these noisy images (Poissonian noise is assumed, A=196 pixel)

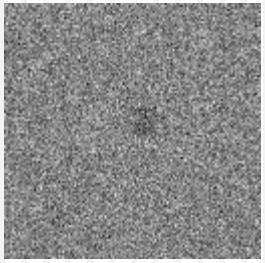
C=1%

N_1=10000



SNR=14

N_1=5000



SNR=9.9

N_1=2500

SNR=7.0

N_1=1250

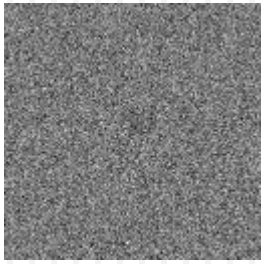
SNR=4.95

N_1=625

SNR=3.5

C=0.5%

N_1=10000

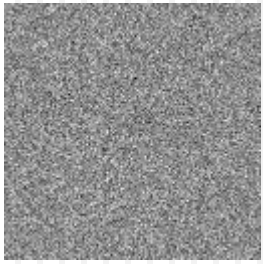


SNR=7

N_1=5000

SNR=4.95

N_1=2500

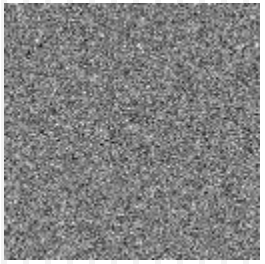


SNR=3.5

N_1=1250

SNR=2.47

N_1=625



SNR=1.75

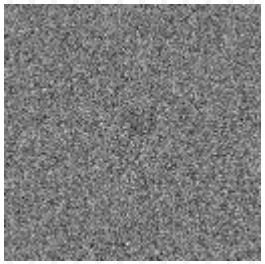
Let's play!

$$SNR = \sqrt{AN_1}C$$

- Try to spot a square detail on these noisy images (Poissonian noise is assumed, C=0.5 %)

A=196

N_1=10000

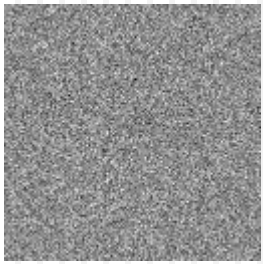


SNR=7

N_1=5000

SNR=4.95

N_1=2500

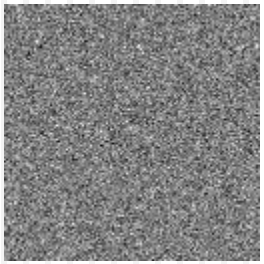


SNR=3.5

N_1=1250

SNR=2.47

N_1=625



SNR=1.75

A=784

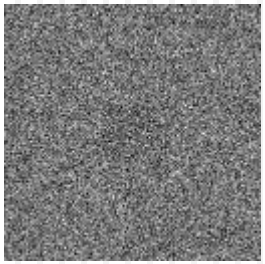
N_1=10000

SNR=14

N_1=5000

SNR=9.9

N_1=2500

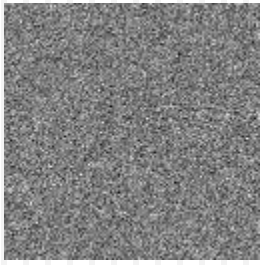


SNR=7.0

N_1=1250

SNR=4.95

N_1=625



SNR=3.5