EE 604
Digital Image Processing

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Indian Institute of Technology, Kanpur

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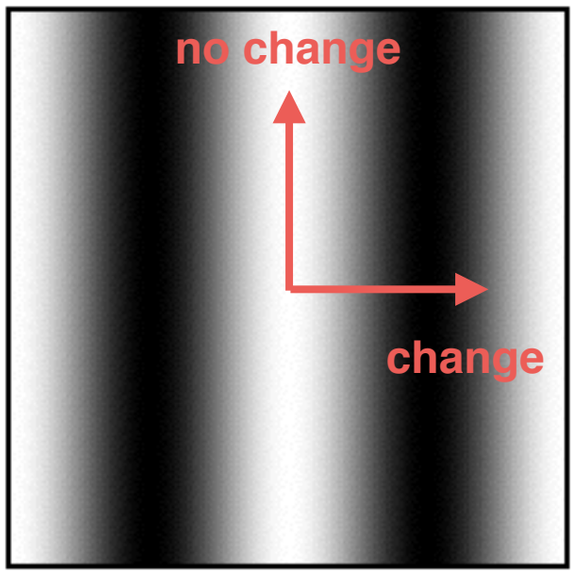
Aug - Nov 2017

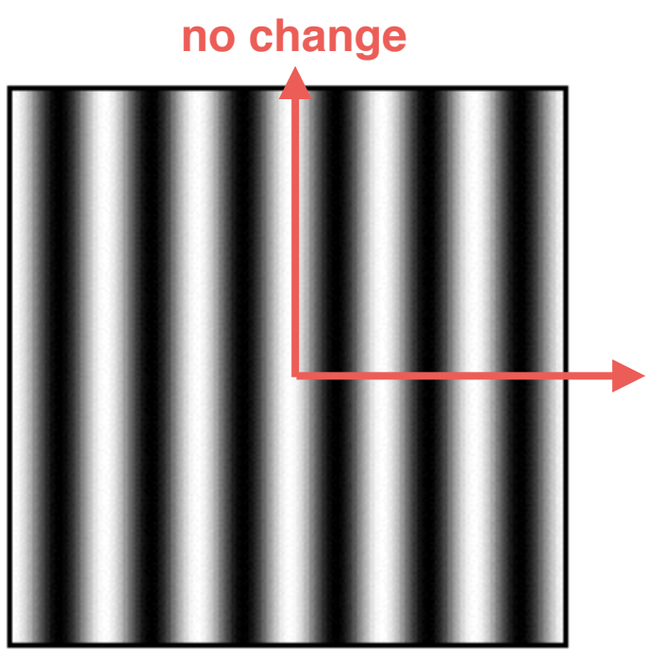
Lecture outline

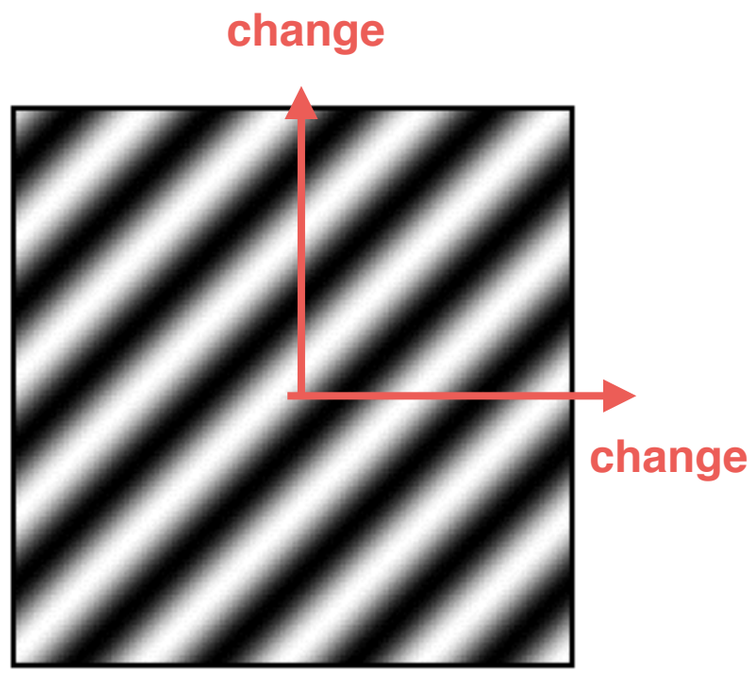
- **Visualizing Fourier transform in 2D**
- **Homomorphic filtering**
- **Image restoration**
    - **Noise models**
    - **Denoising methods**

Visualizing Fourier transform

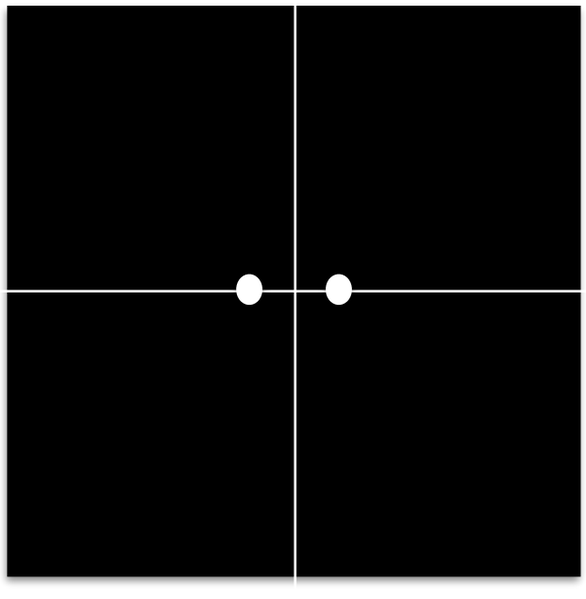
Image space

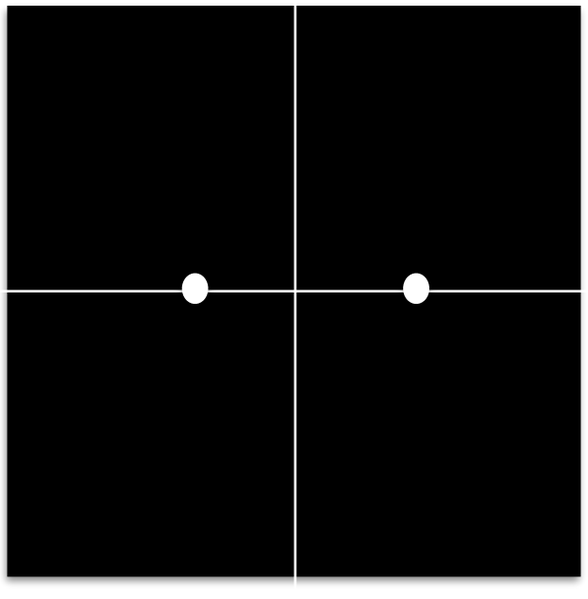


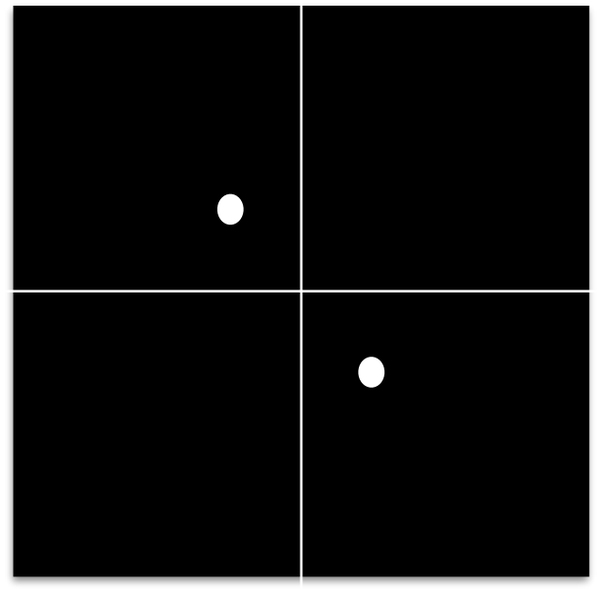




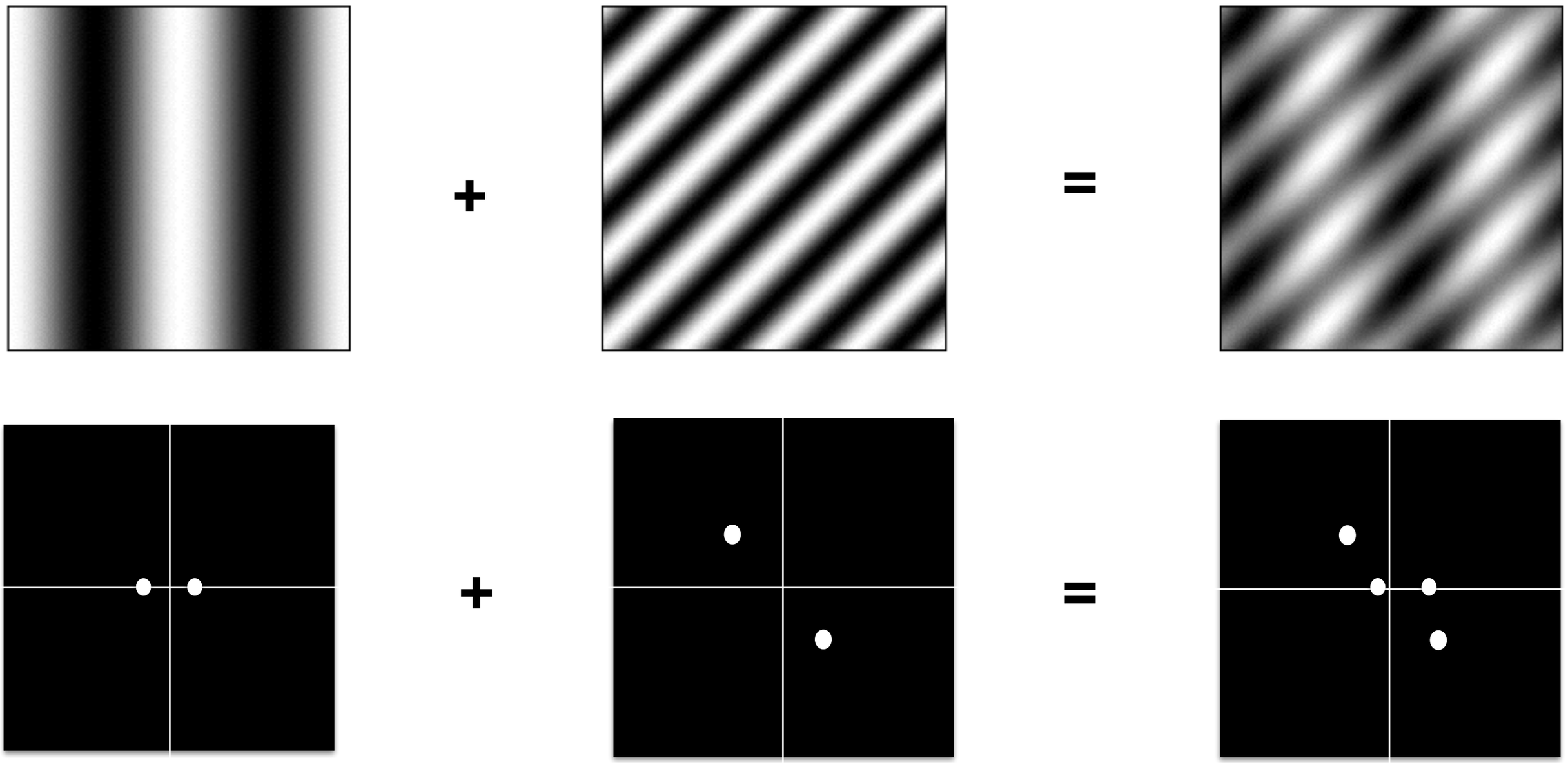
Fourier space



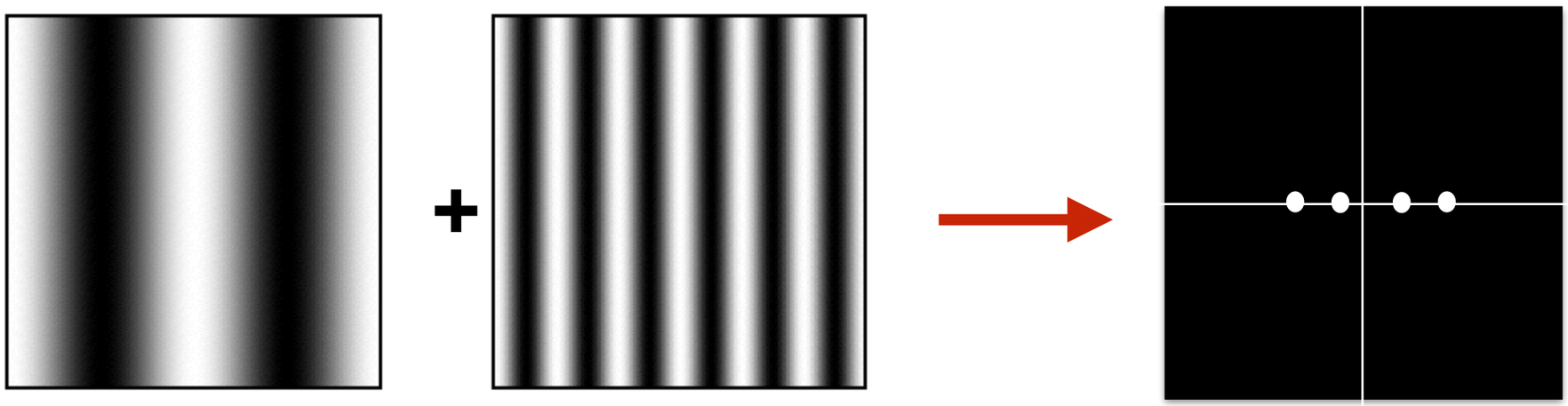


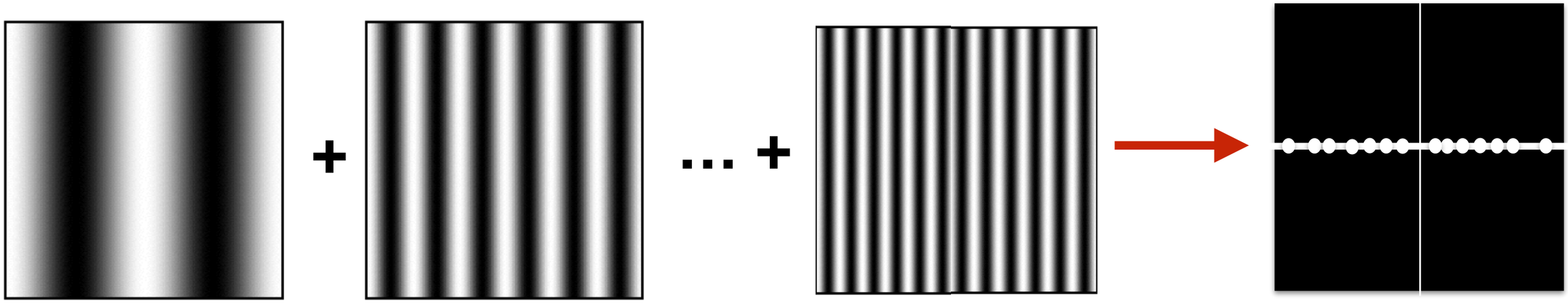


Visualizing Fourier transform

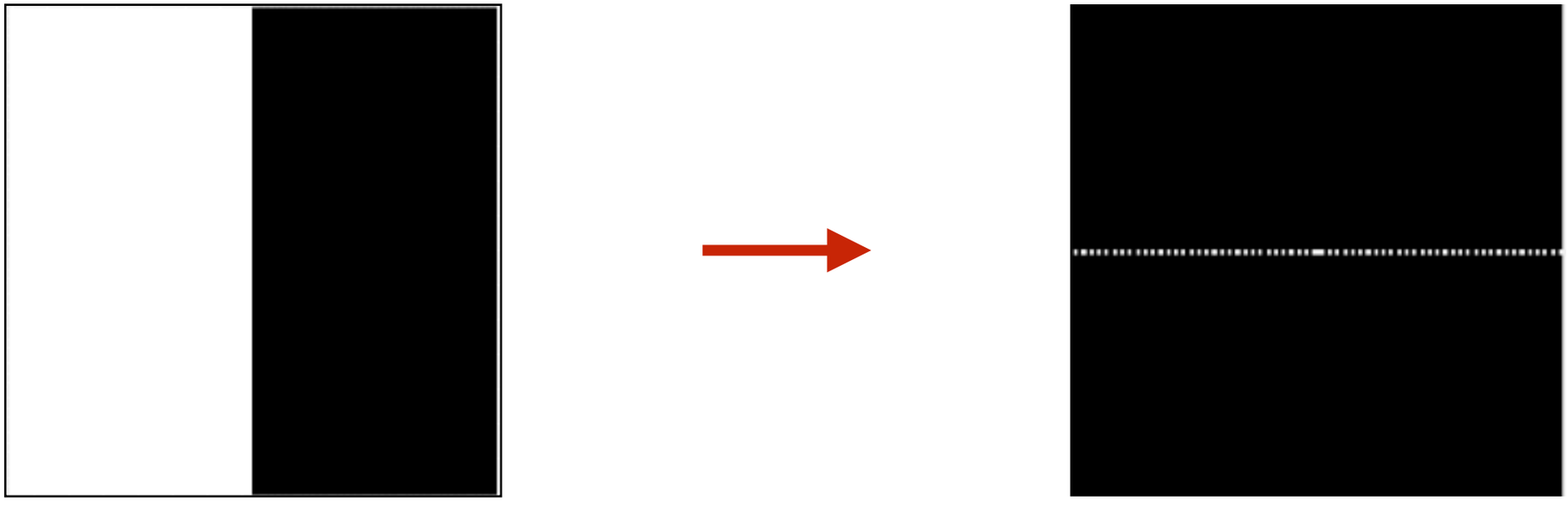


Visualizing Fourier transform





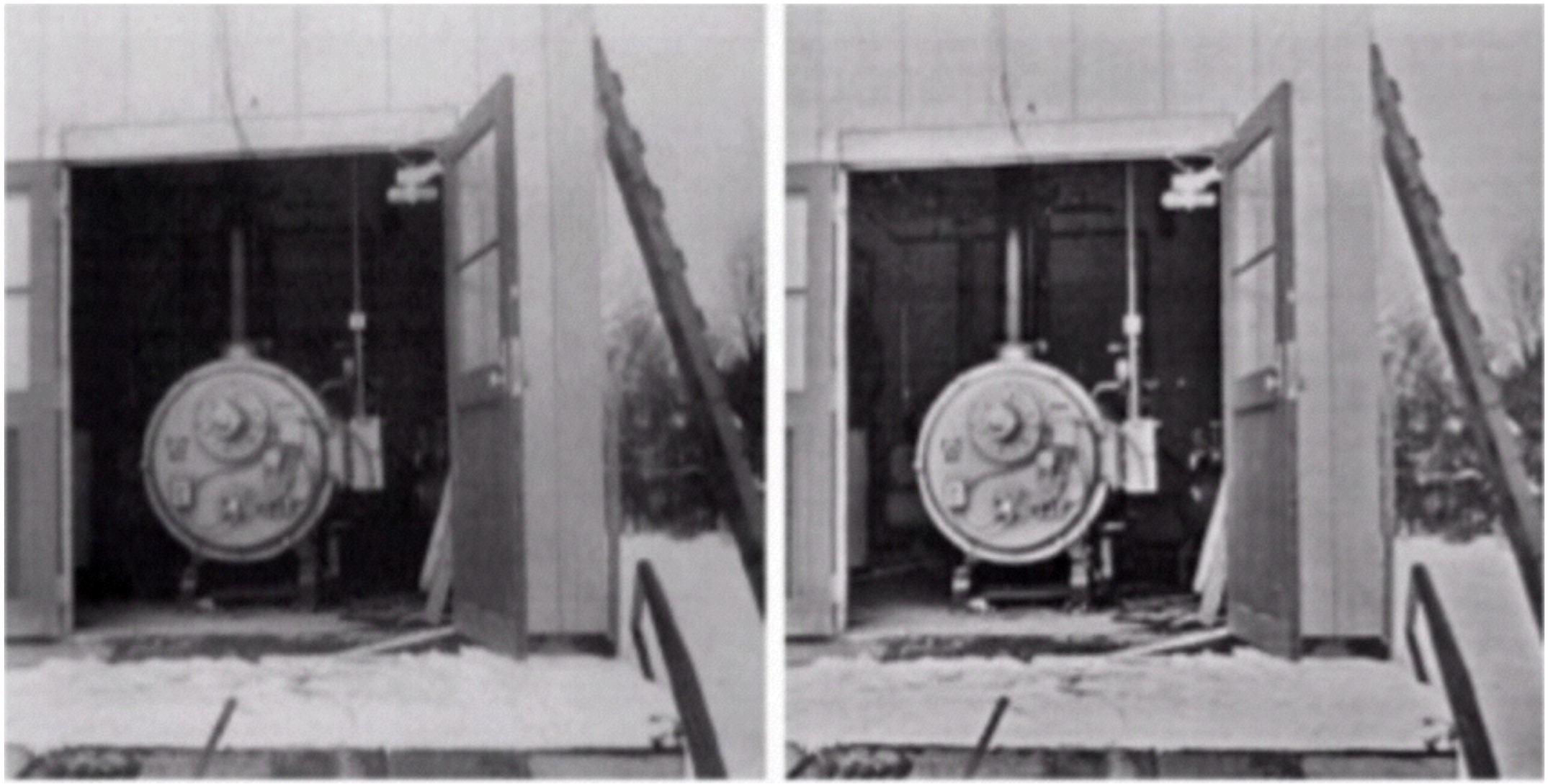
Visualizing Fourier transform



Lecture outline

- Visualizing Fourier transform in 2D
- **Homomorphic filtering**
- Image restoration
    - Noise models
    - Denoising methods

Homomorphic filtering



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- Visualizing Fourier transform in 2D
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What is image restoration?

- Recovering the original image from its corrupted version
- For some cases, enhancement and restoration are the same

Degradation model

$$g(x,y) = h(x,y) * f(x,y) + n(x,y)$$

Task: find original image f(x,y) from observed image g(x,y)

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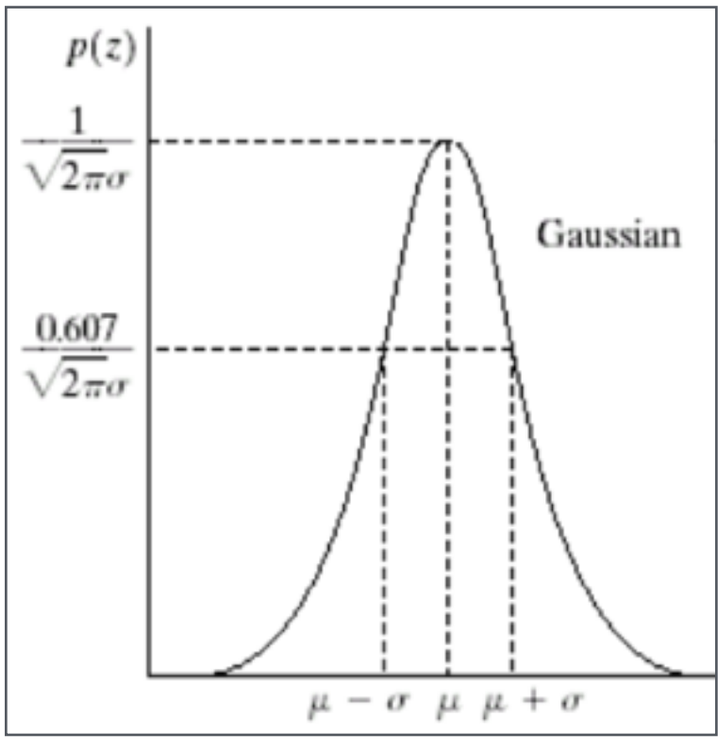
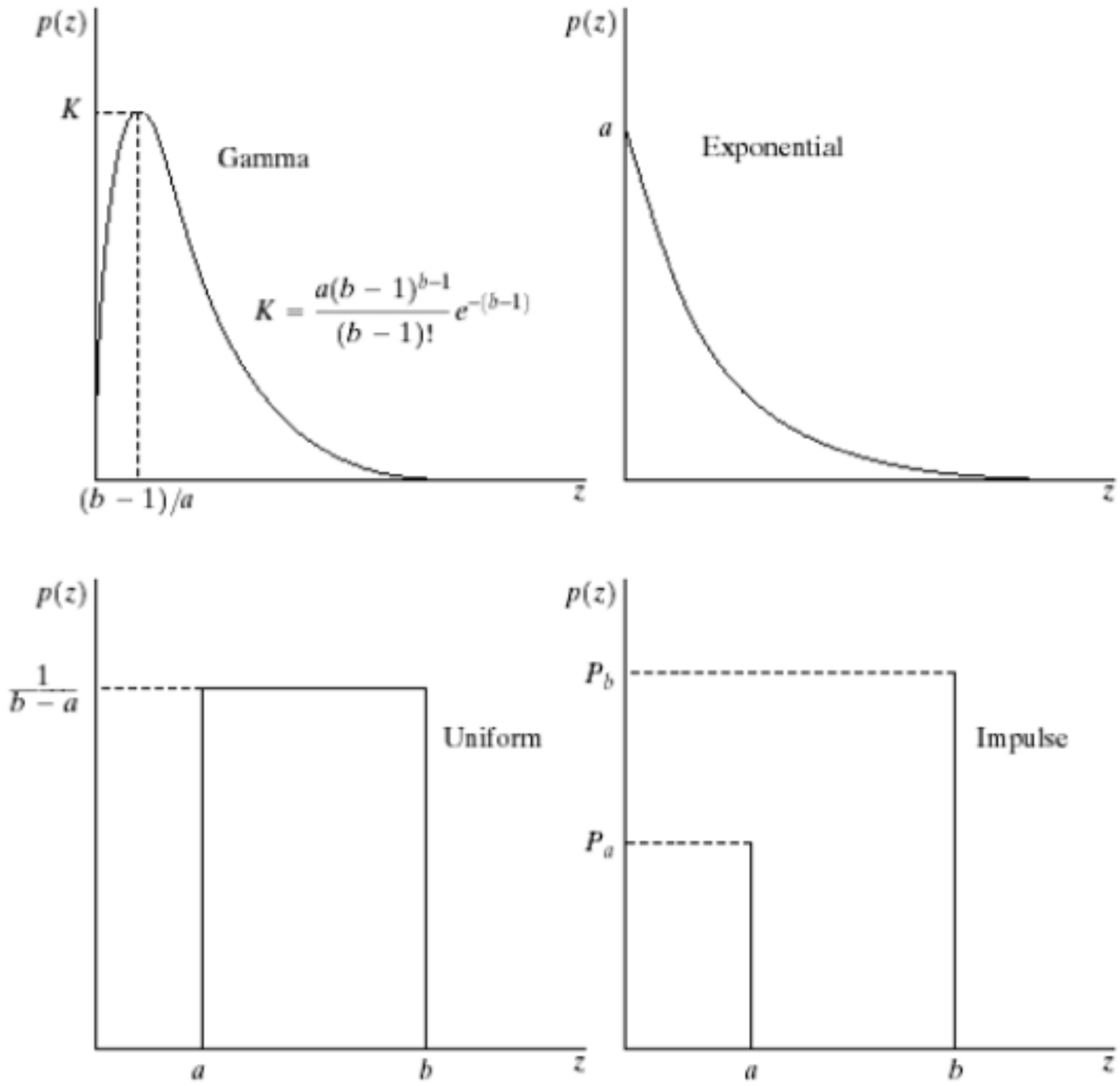
Noise models



$$p(z) = \frac{1}{\sqrt{(2\pi\sigma^2)}} e^{-(z-\bar{z})^2/2\sigma^2}$$



Noise models

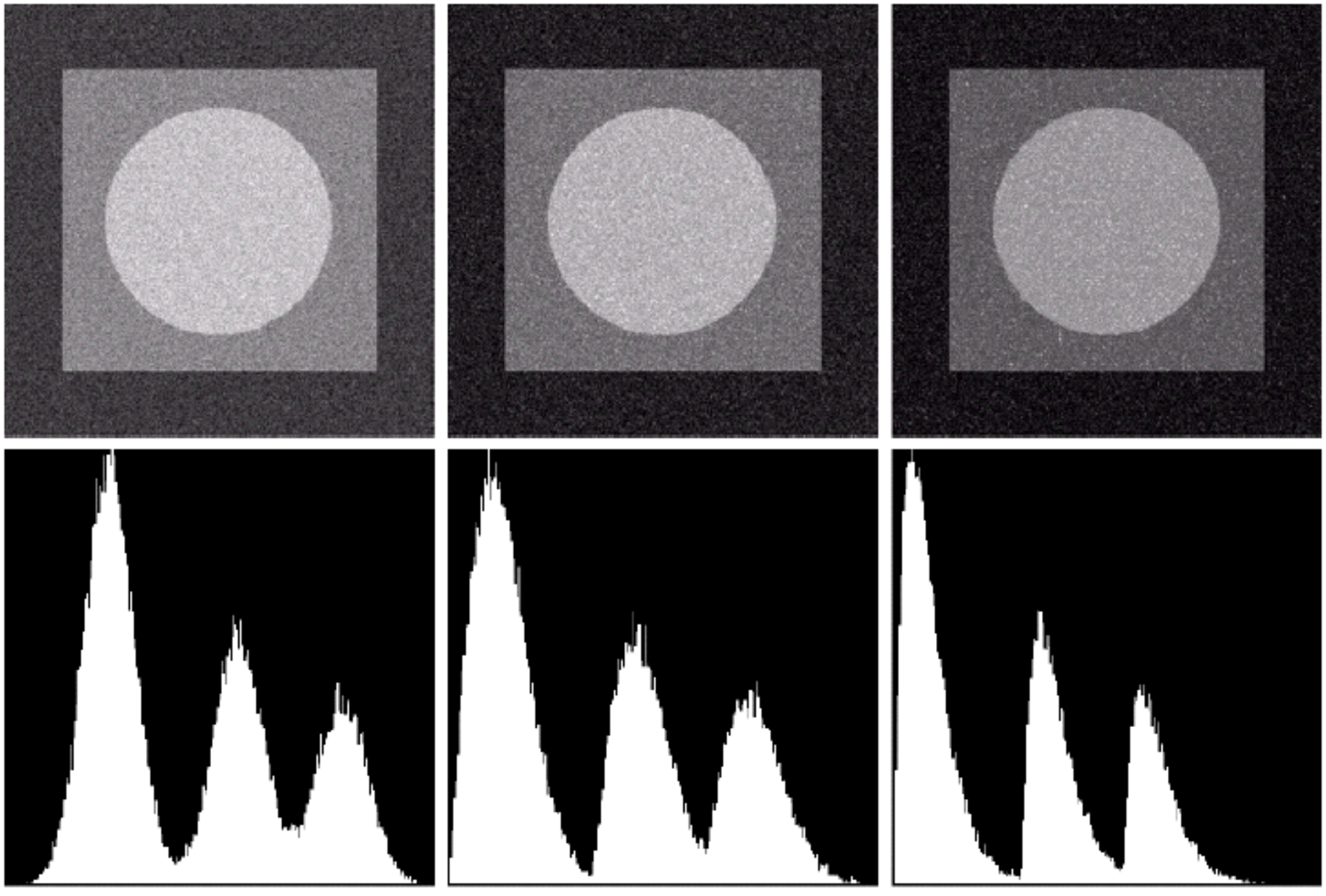


Image restoration

- Consider a noise-only degradation model

$$g(x, y) = f(x, y) + n(x, y)$$

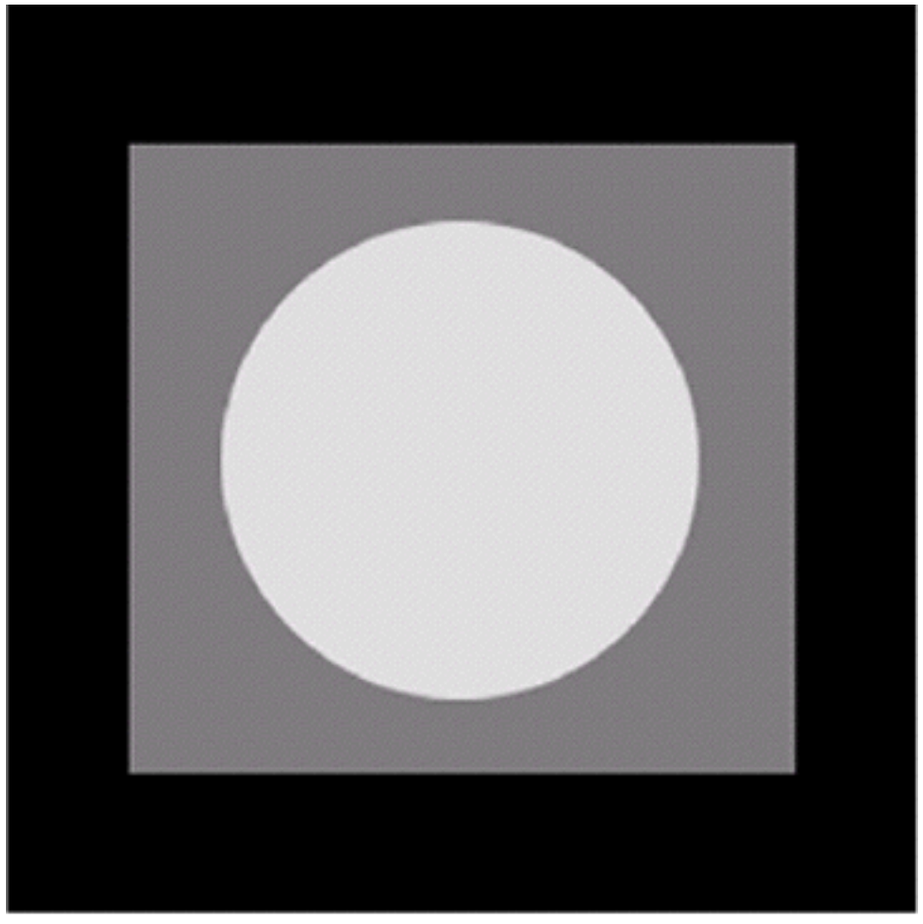
- If noise may be estimated, we can get the original image

- How to estimate noise?

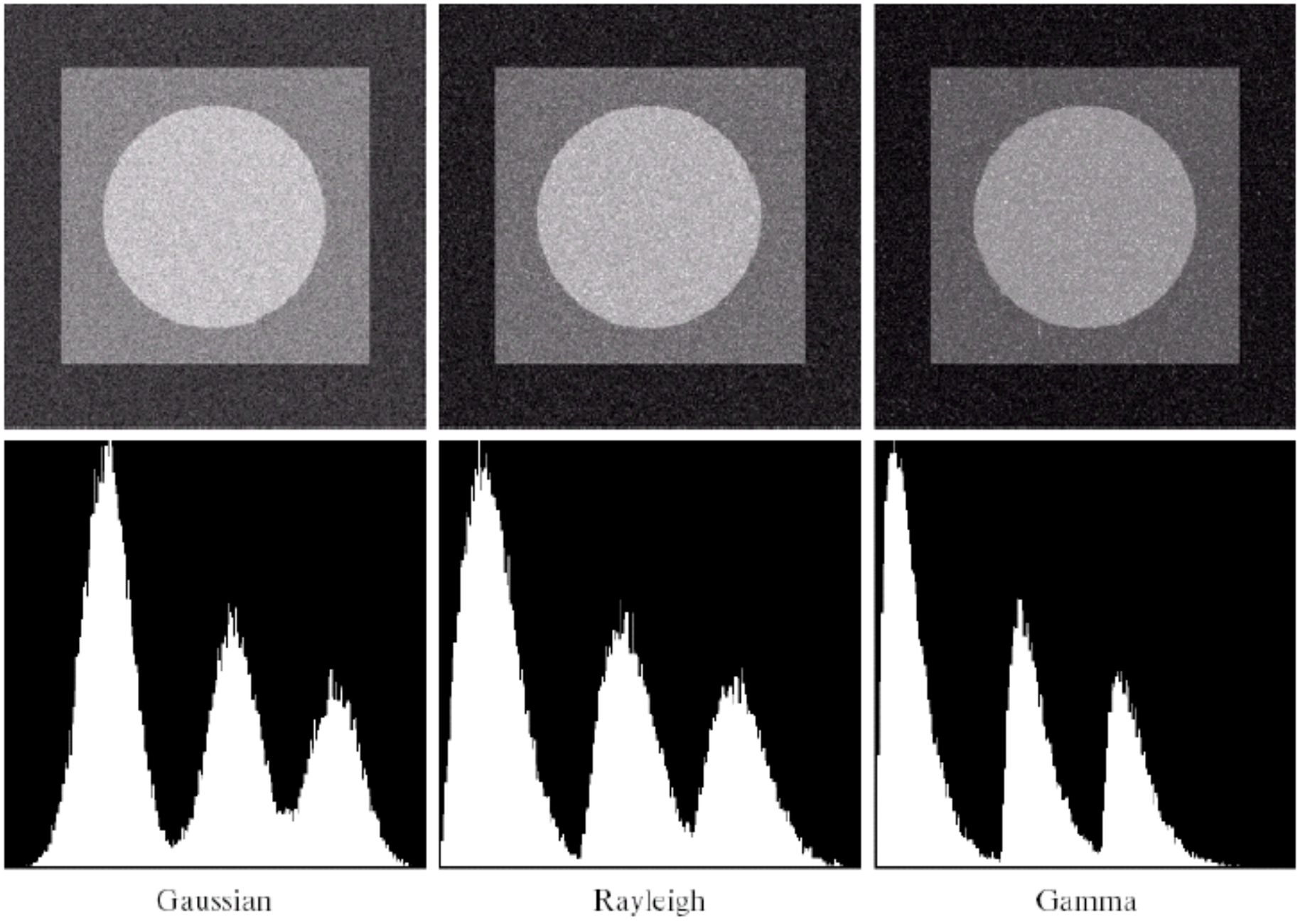
    - Do we have access to the imaging device?

    - Can we use the noisy image itself?

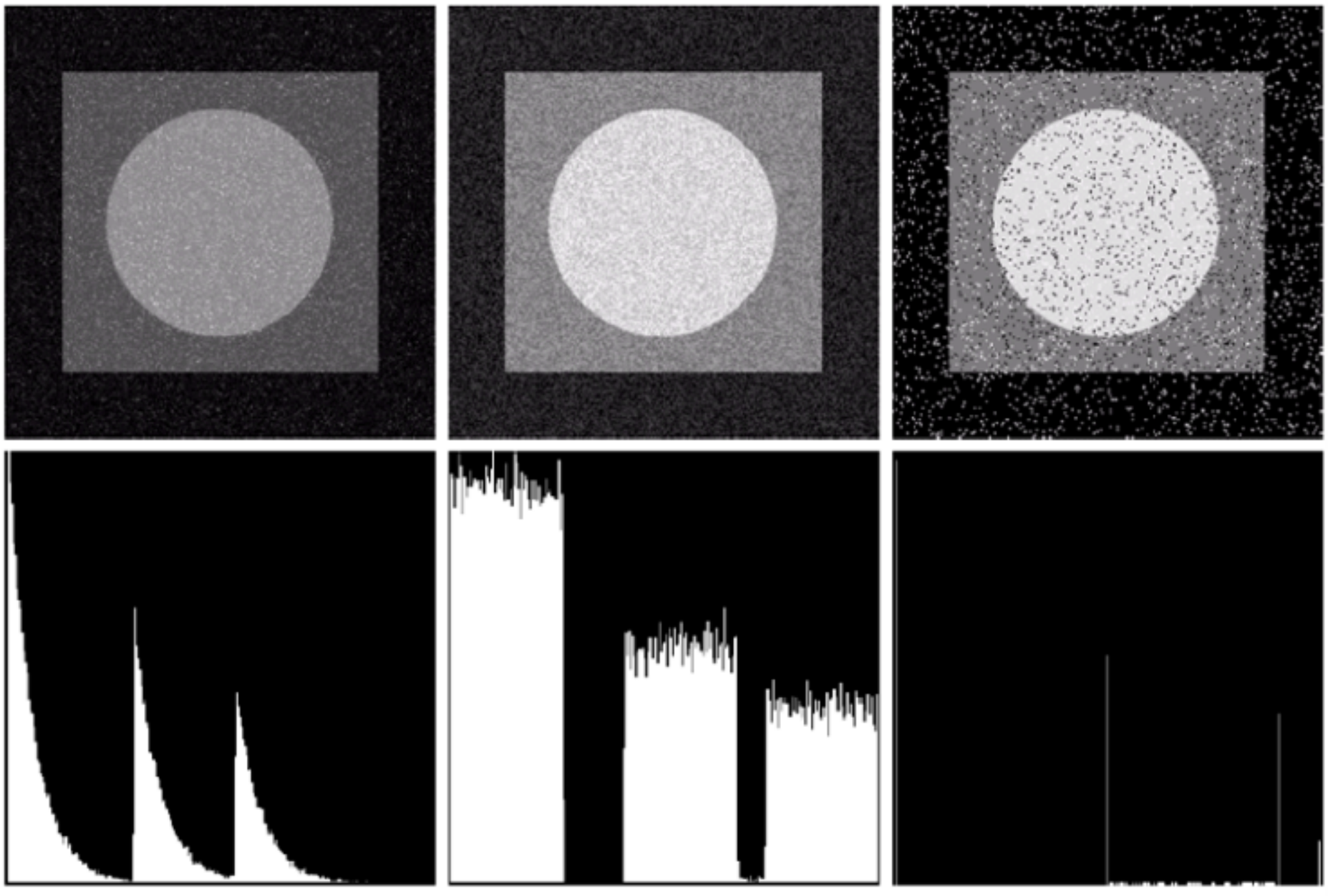
Noise estimation



Noise estimation



Noise estimation



Noise estimation

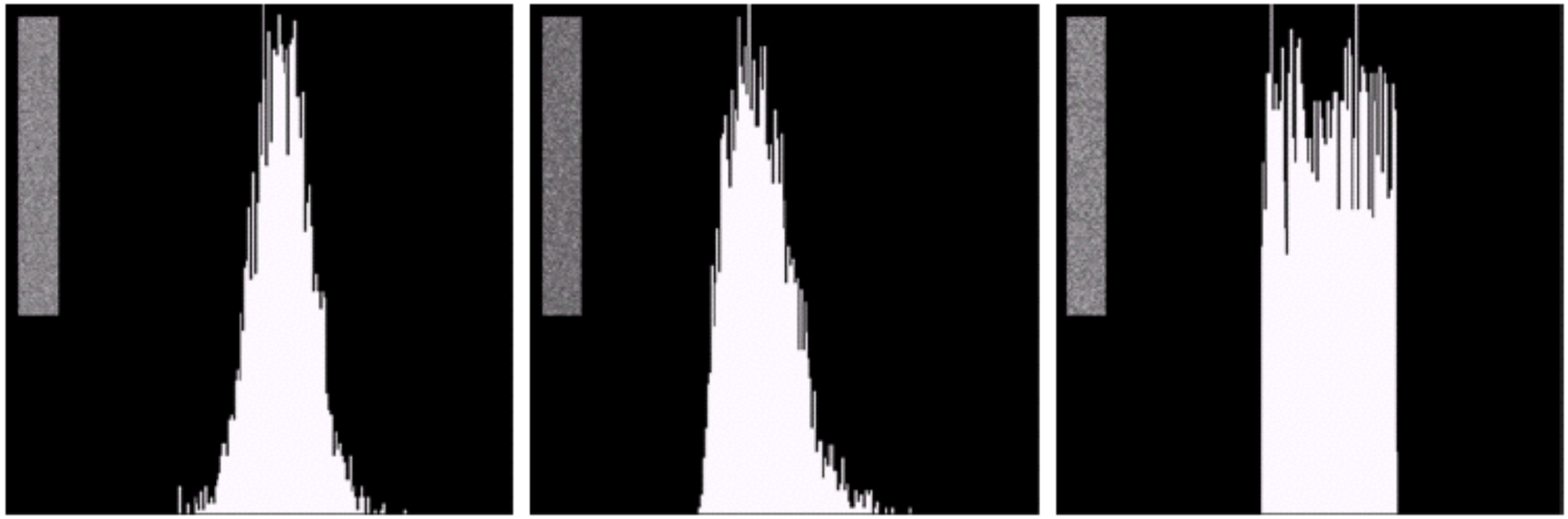


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Image denoising

- In most cases, subtracting noise is not a practical solution.
- **Spatial filtering**
    - Mean filtering, Order-statistic filtering, …

Mean filters

Arithmetic mean filter

$$\hat{f}(x,y) = \frac{1}{mn} \sum_{(s,t)\in S_{xy}} g(s,t)$$

Geometric mean filter

$$\hat{f}(x,y) = \left\{ \prod_{(s,t)\in S_{xy}} g(s,t) \right\}^{\frac{1}{mn}}$$

Weighted mean filter

$$\hat{f}(x,y) = \frac{1}{mn} \sum_{(s,t)\in S_{xy}} w(s,t)g(s,t)$$

S_{xy} : local region

$m \times n$: region size

Mean filtering

Order-statistic filters

Median filter $$\hat{f}(x,y) = \underset{(s,t)\in S_{xy}}{\text{median}} \; g(s,t)$$

Max filter $$\hat{f}(x,y) = \underset{(s,t)\in S_{xy}}{\max} \; g(s,t)$$

Min filter $$\hat{f}(x,y) = \underset{(s,t)\in S_{xy}}{\min} \; g(s,t)$$

Median filtering

Image denoising

- In most cases, subtracting noise is not a practical solution.
- **Spatial filtering**
    - Mean filtering, Order-statistic filtering, …
- **Freq domain filtering**
    - High pass filtering, band-pass filtering

Periodic Noise

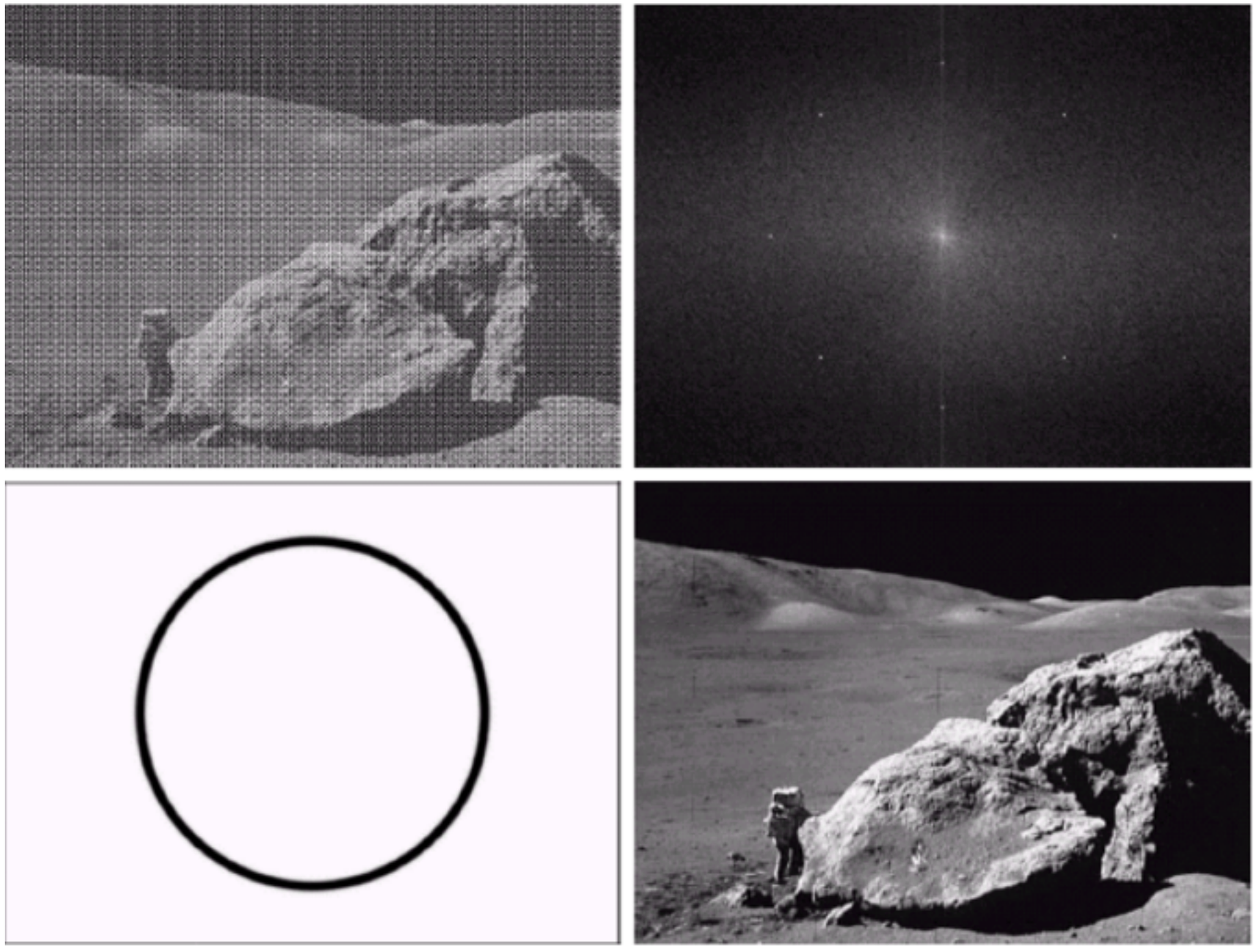

Image denoising

- In most cases, subtracting noise is not a practical solution.

- **Spatial (local) filtering**

    - Mean filtering, Order-statistic filtering, …

- **Freq domain filtering**

    - Low pass filtering, band-pass filtering

- **Non-local filtering**

    - Non local means filtering [Buades et al., A non-local algorithm for image denoising, CVPR 2005]