EE123

Digital Signal Processing

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Electrical Engineering and Computer Science, UC Berkeley, CA

Information

- Class webpage:
  - http://inst.eecs.berkeley.edu/~ee123/fa11/

Project

upsample,modulate,
play sound

record,demodulate/filter/
process, downsample,
display

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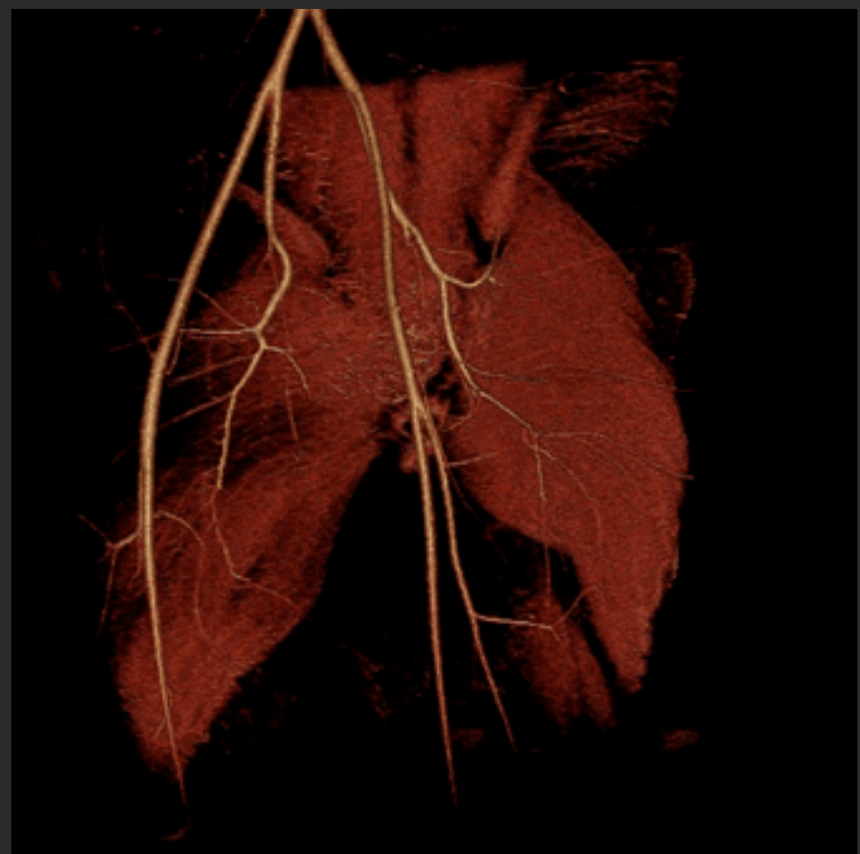
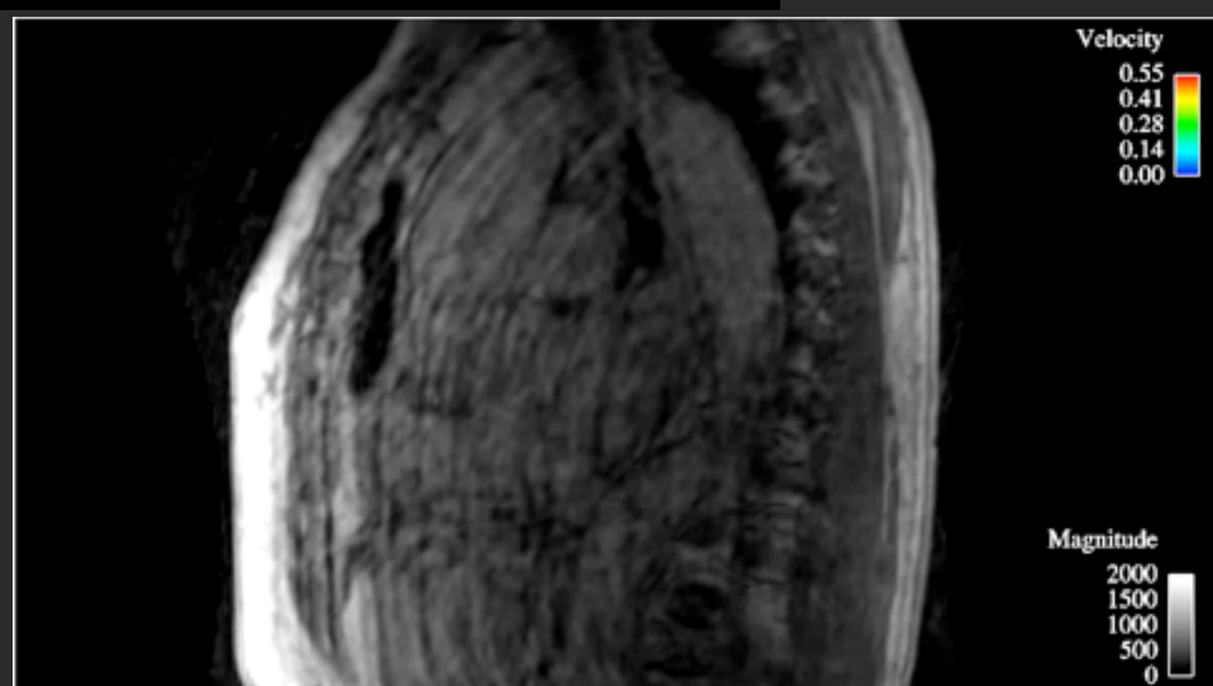
My Research




WL: 9208 WW: 17269
SRA
L
AL
PR
IIP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0.41
0.28
0.14
0.00
Magnitude
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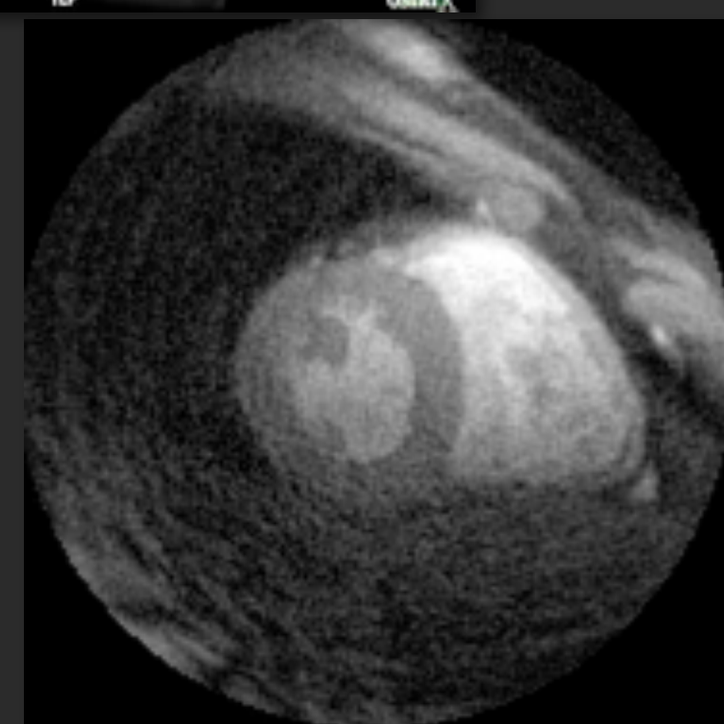
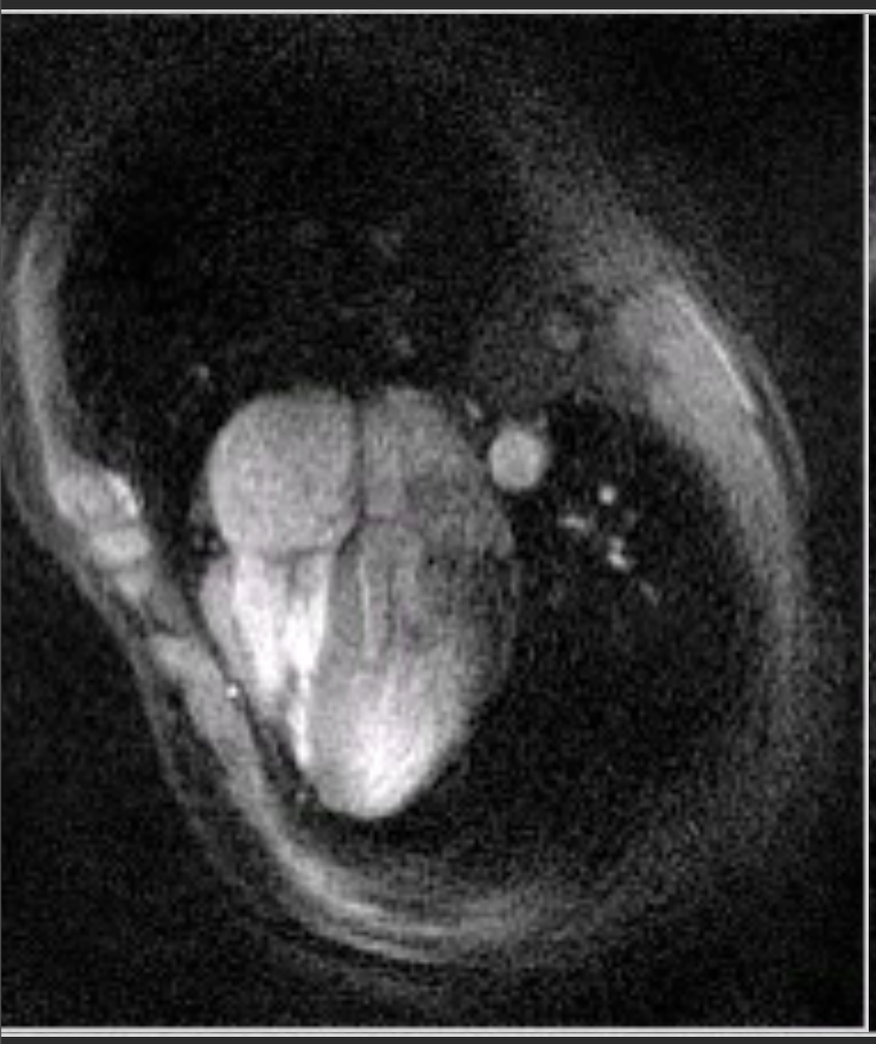
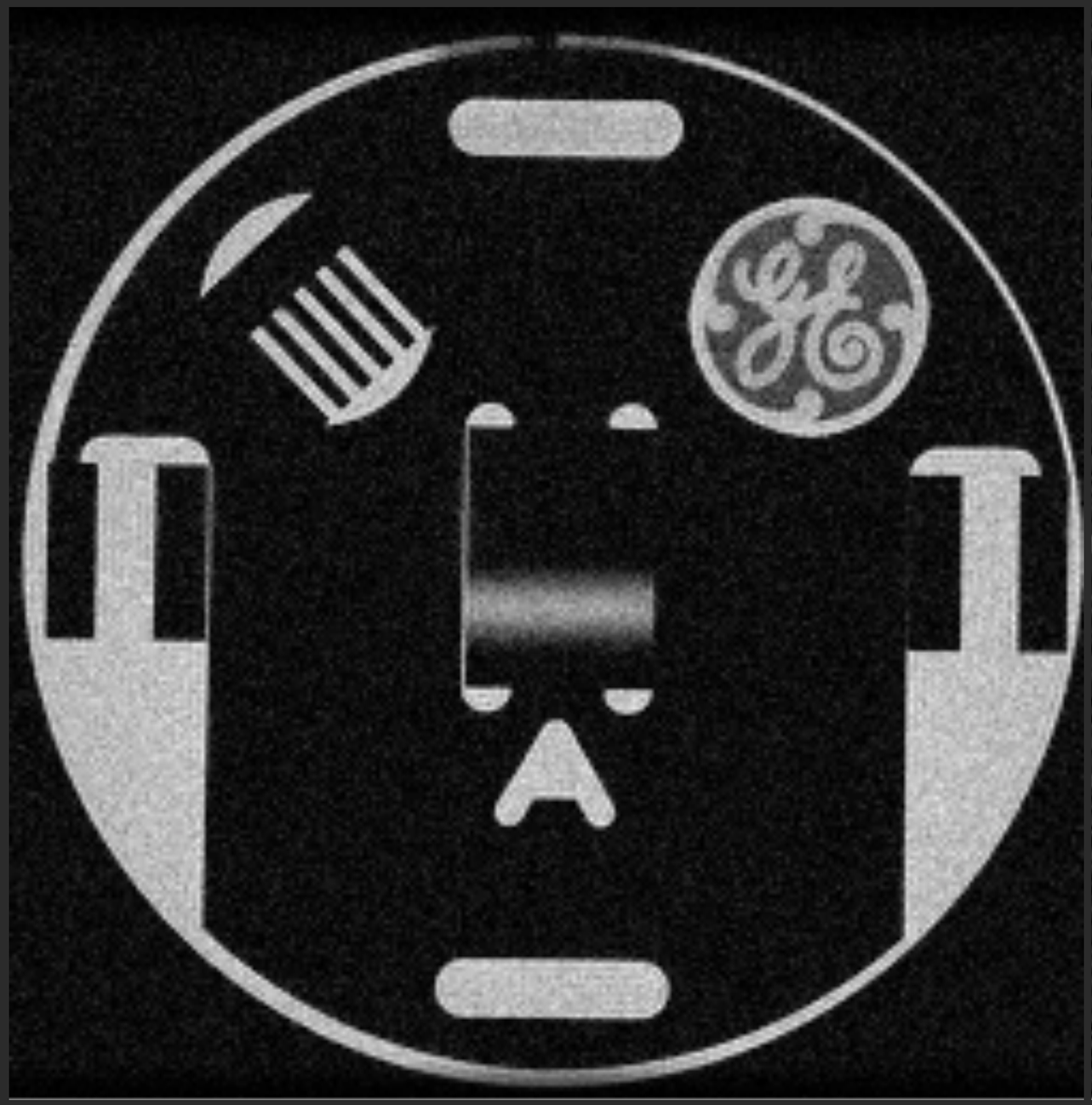
1500
1000
500
0



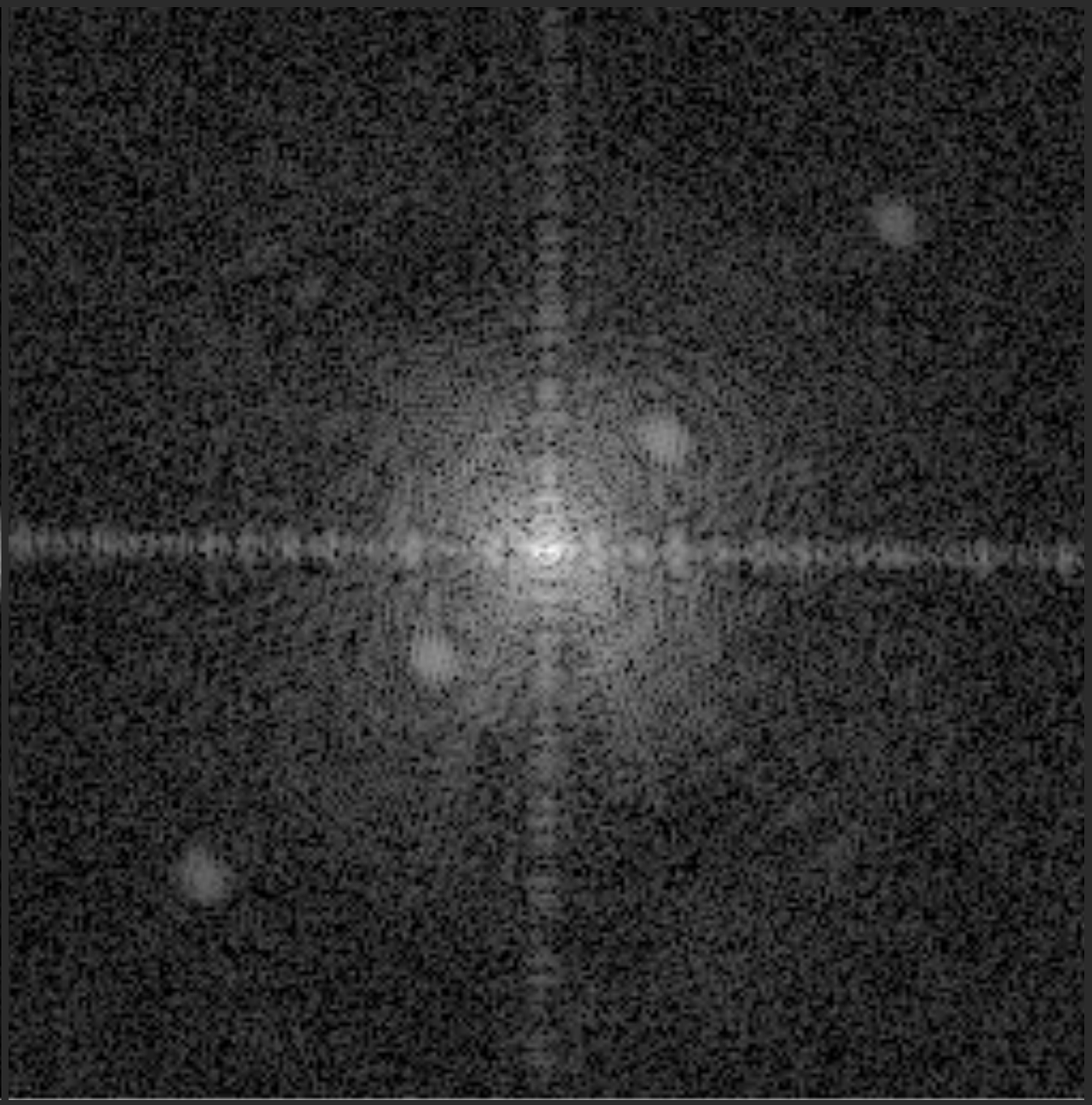
Me - Exposed



MRI Image of a
Water/plastic phantom



MRI Raw-data
(2D Fourier transform)



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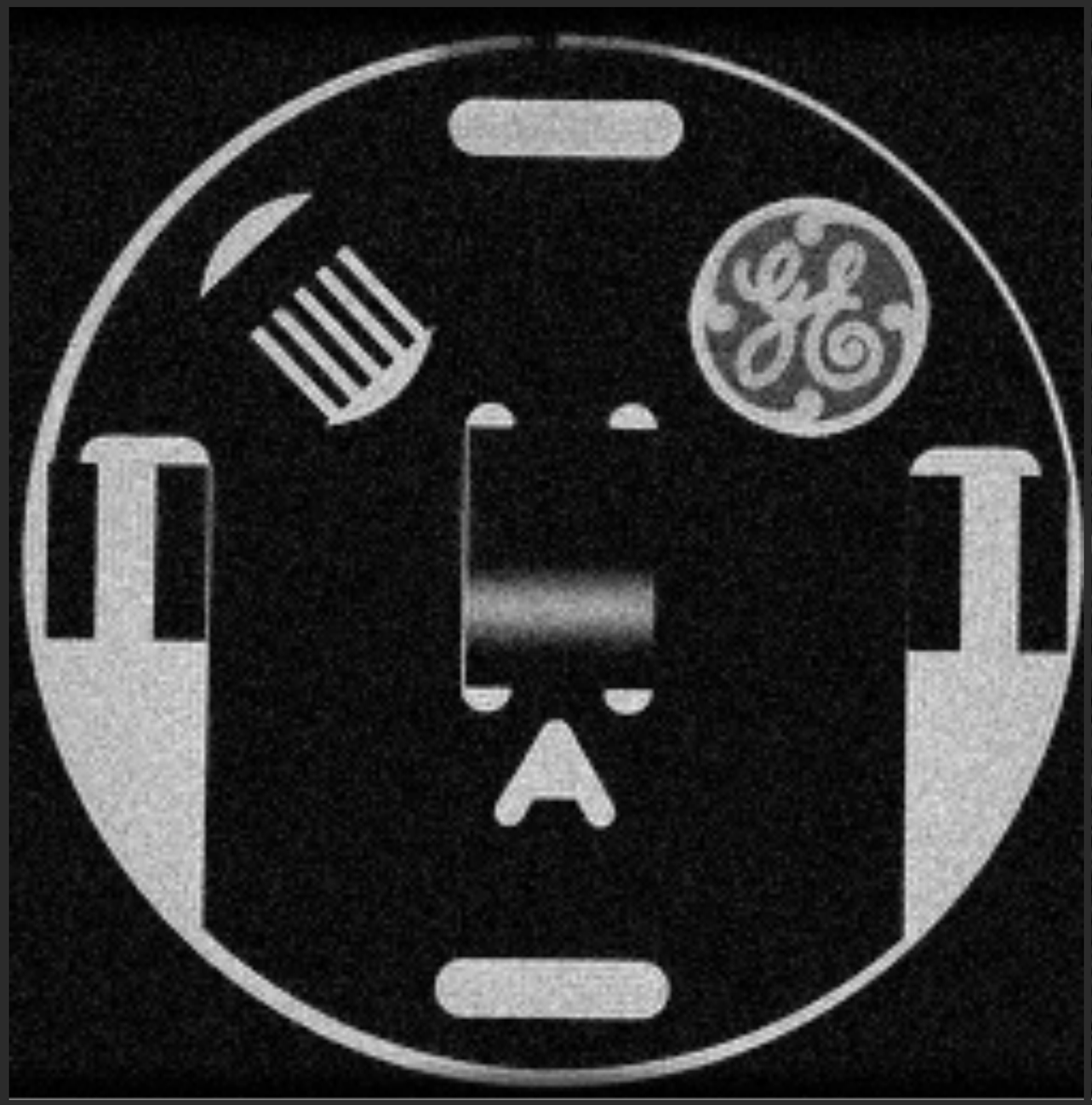

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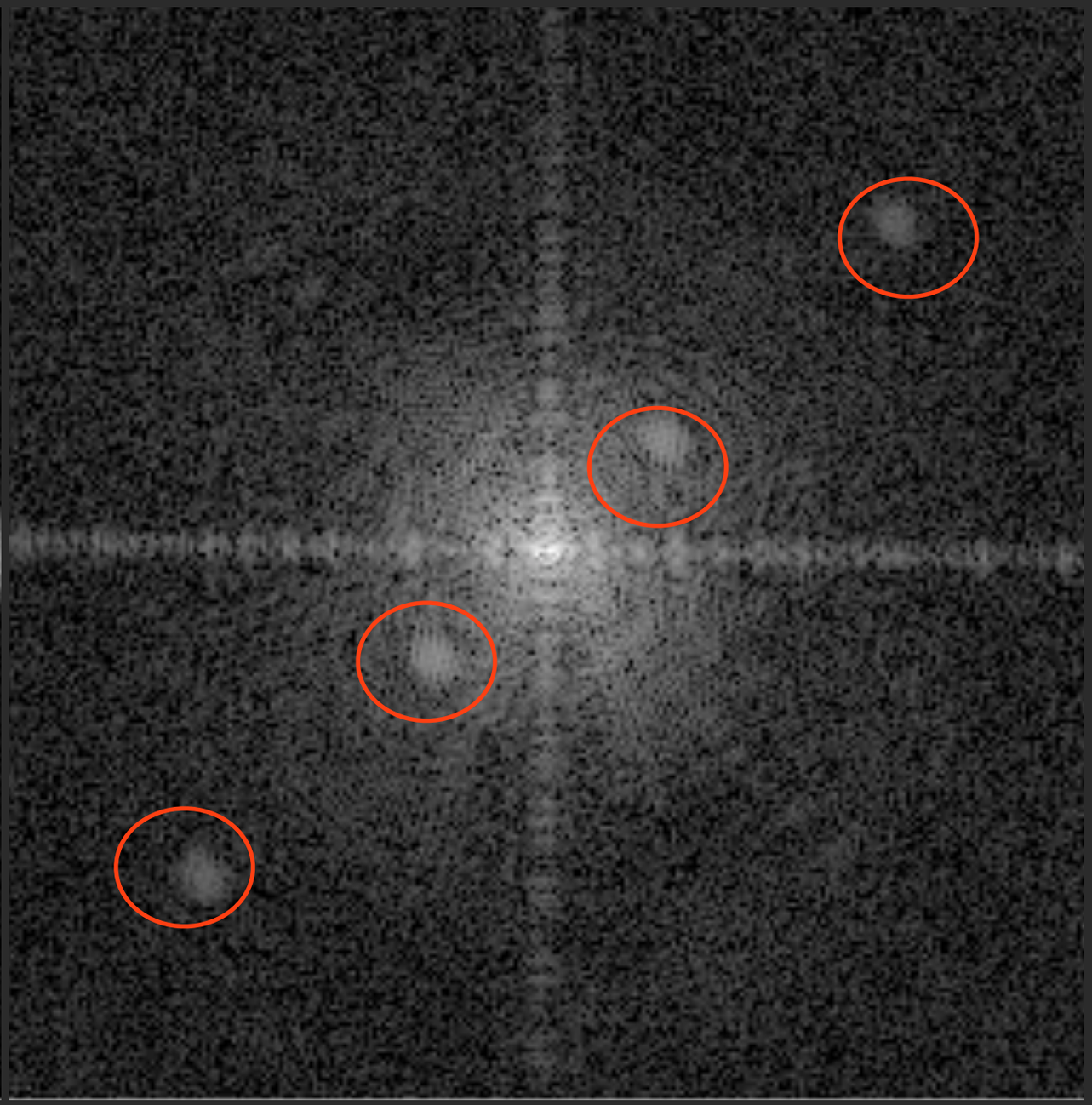

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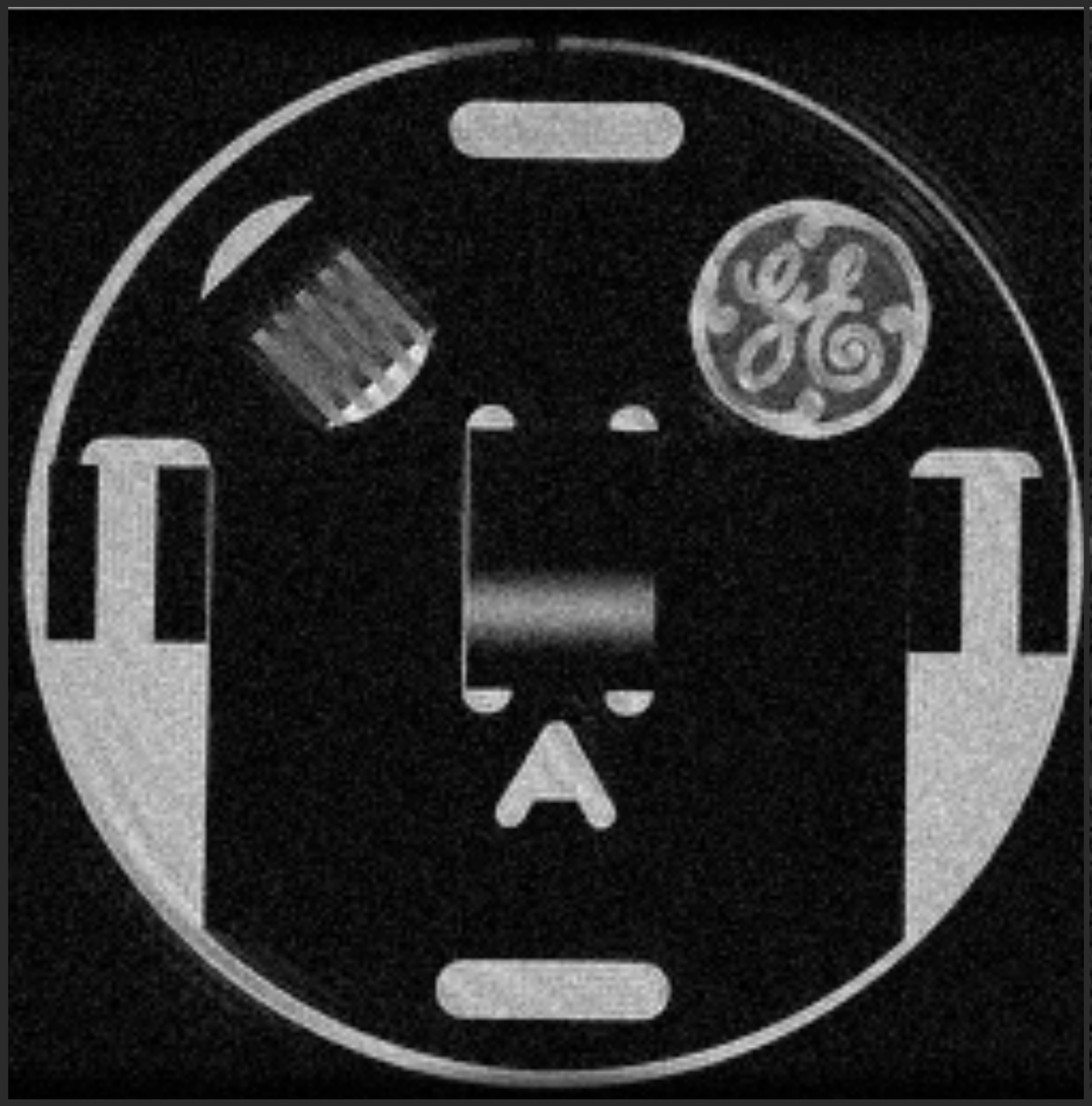

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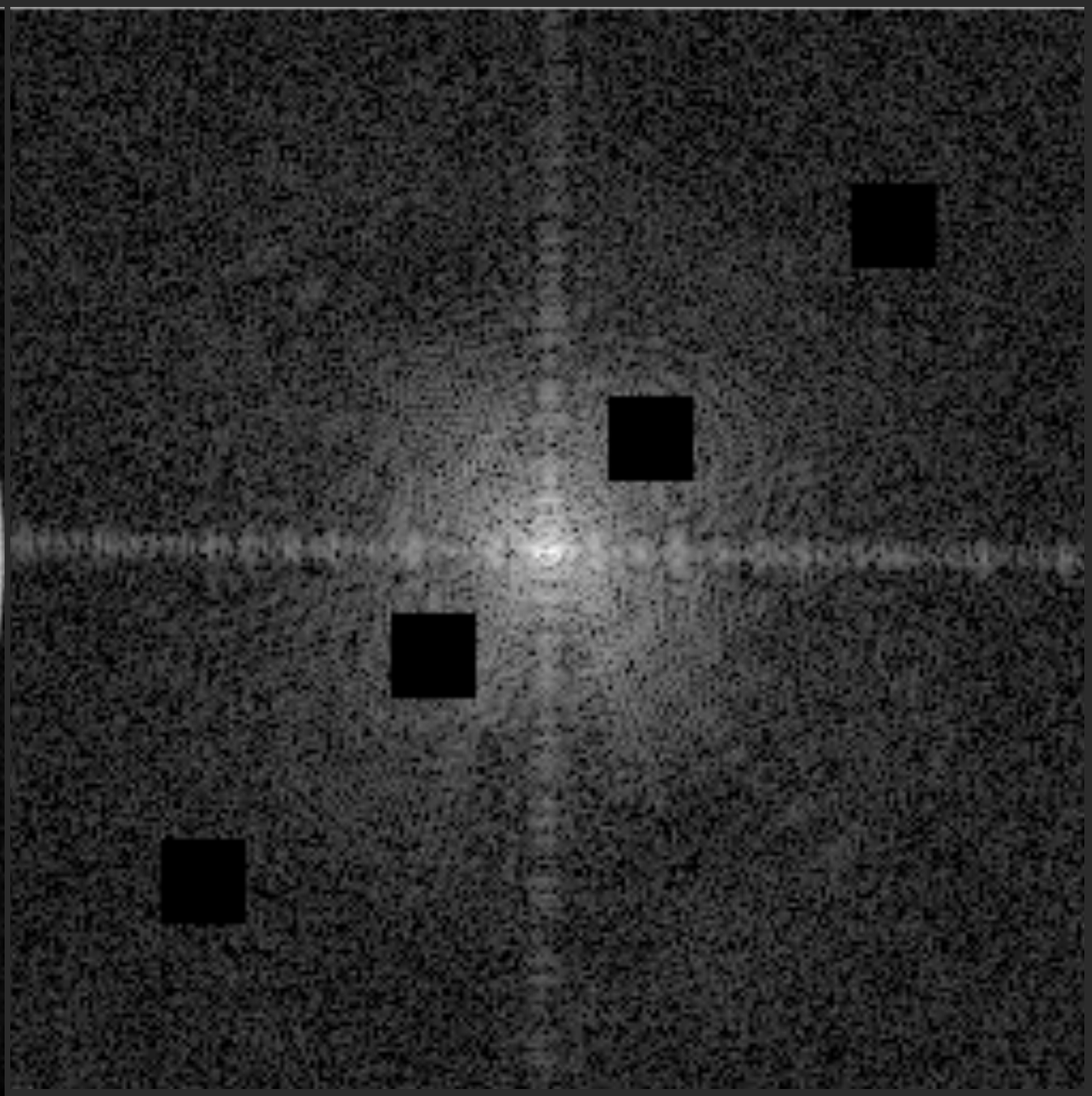

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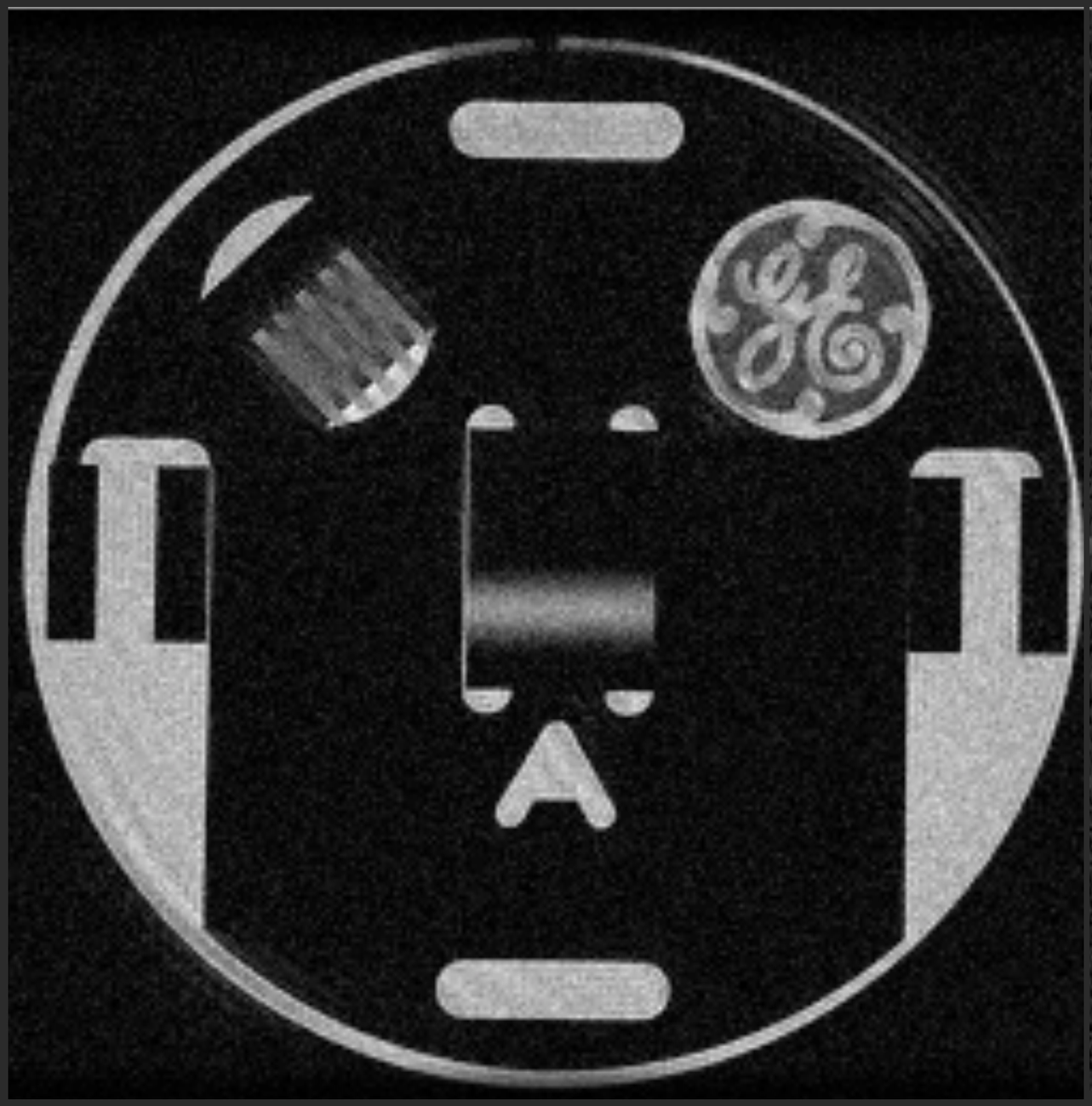

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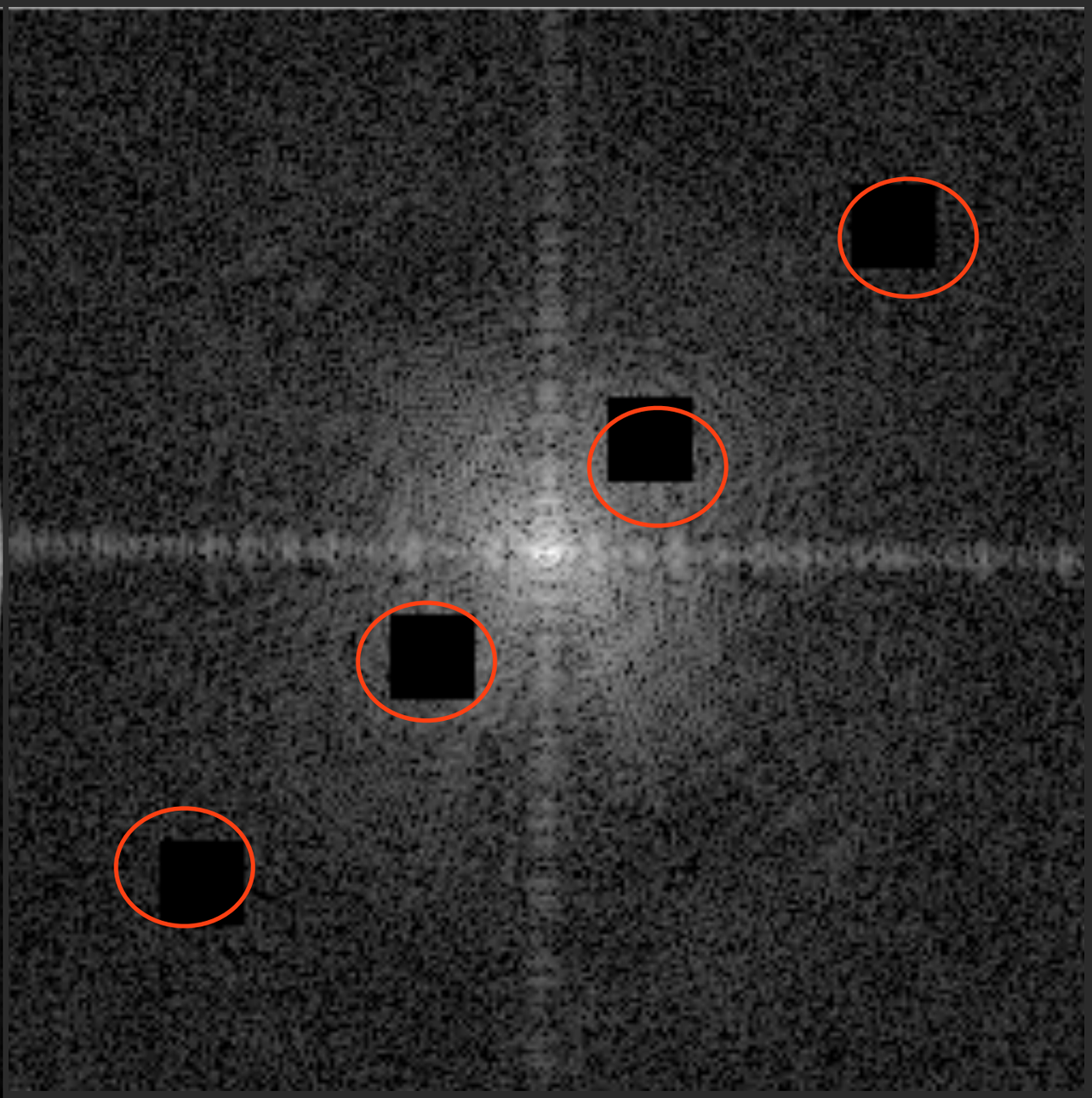
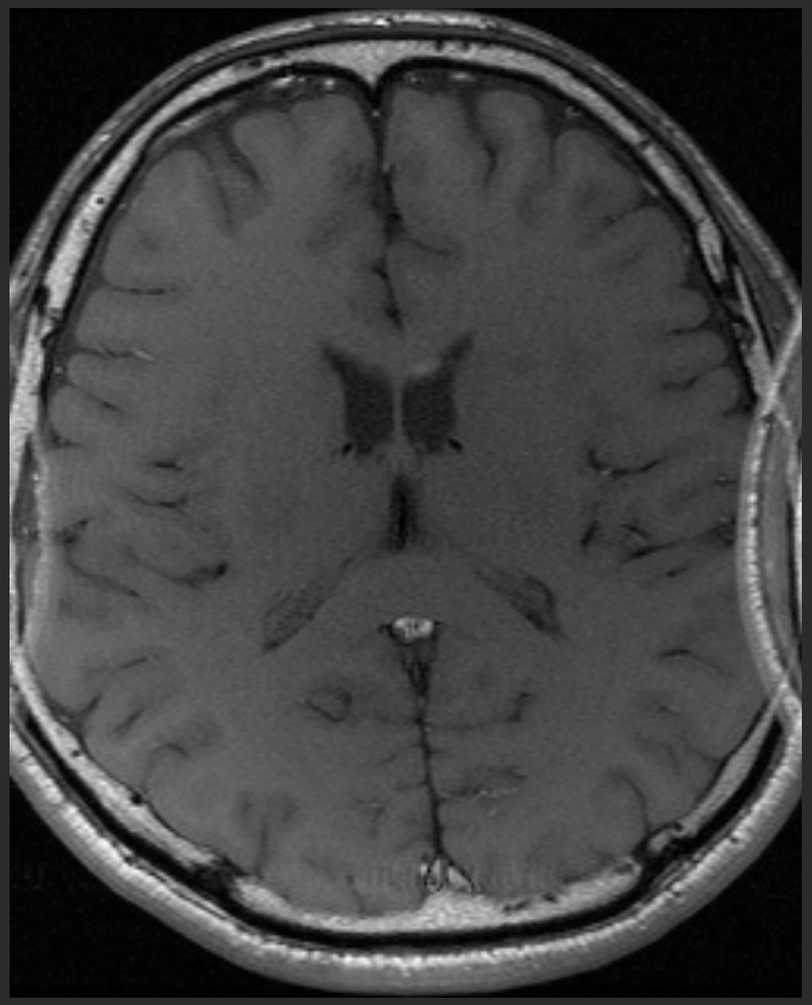


“Aliasing”



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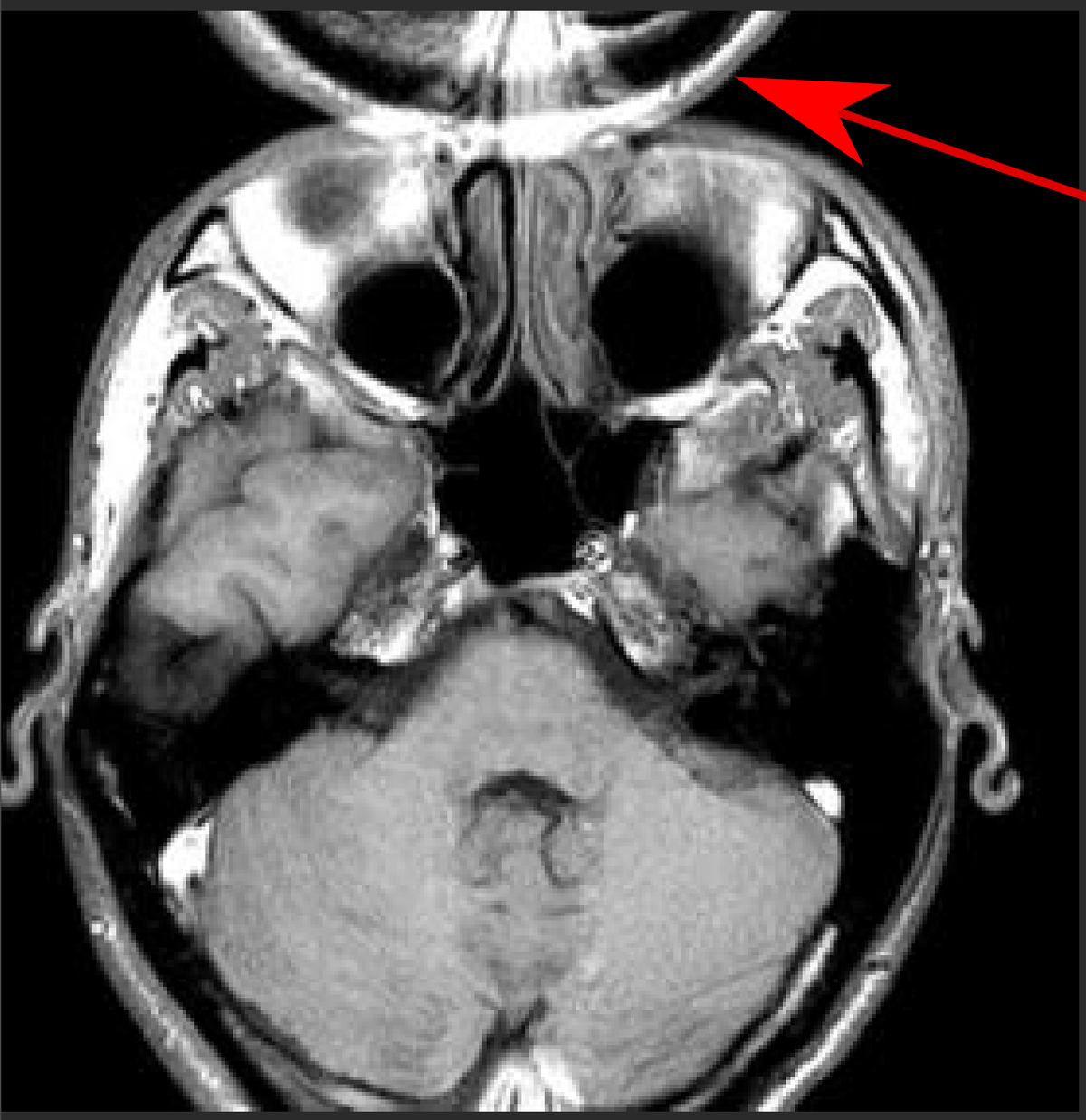

Signal Processing in General

- Convert one signal to another (e.g. filter, generate control command, etc.)
- Interpretation and information extraction (e.g. speech recognition)

Digital Signal Processing

- Discrete Samples
- Discrete Representation (on a computer)

- Can be samples of a Continuous-Time signal: $x[n] = X(nT)$
- Inherently discrete (example?)

Why Learn DSP?

- Swiss-Army-Knife of modern EE
- Impacts all aspects of modern life
  - Communications (wireless, internet, GPS...)
  - Control and monitoring (cars, machines...)
  - Multimedia (mp3, cameras, videos, restoration ...)
  - Health (medical devices, imaging....)
  - Economy (stock market, prediction)
  - More....

Advantages of DSP

- Flexibility
- System/implementation does not age
- "Easy" implementation
- Reusable hardware
- Sophisticated processing
- Process on a computer
- (Today) Computation is cheaper and

Example I: Audio Compression

- Compress audio by 10x without perceptual loss of quality.
- Sophisticated processing based on models of human perception
- 3MB files instead of 30MB - Entire industry changed in less than 10 years!

CD mp3 Error x10

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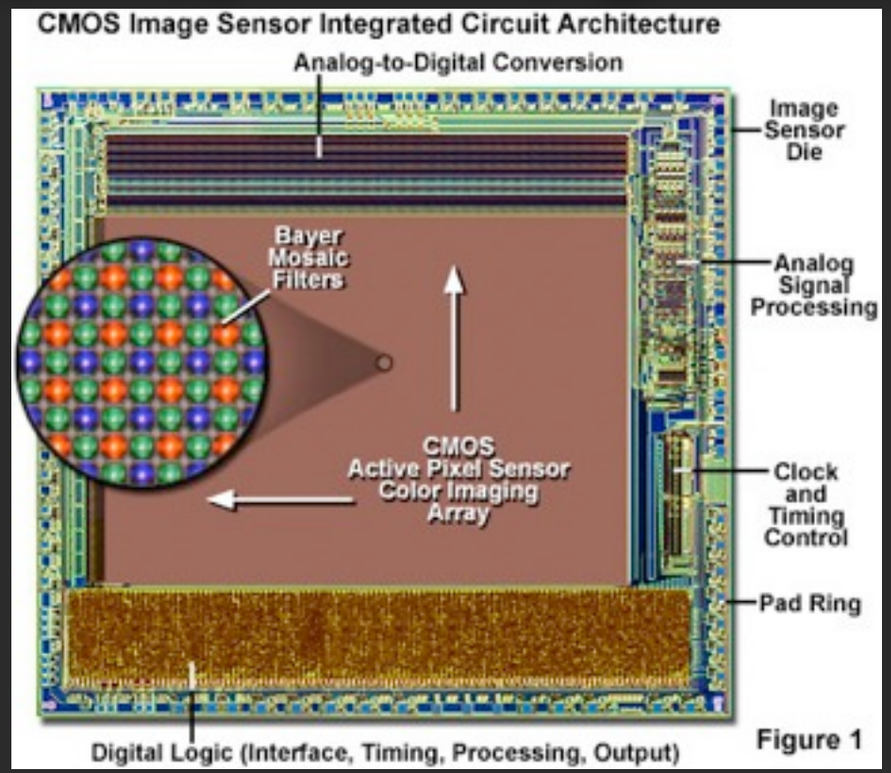
Example II: Digital Camera



Focus/exposure Control → preprocessing → white-balancing → demosaic → Color transform → Post-processing → Compression

http://micro.magnet.fsu.edu/primer/digitalimaging/cmosimagesensors.html

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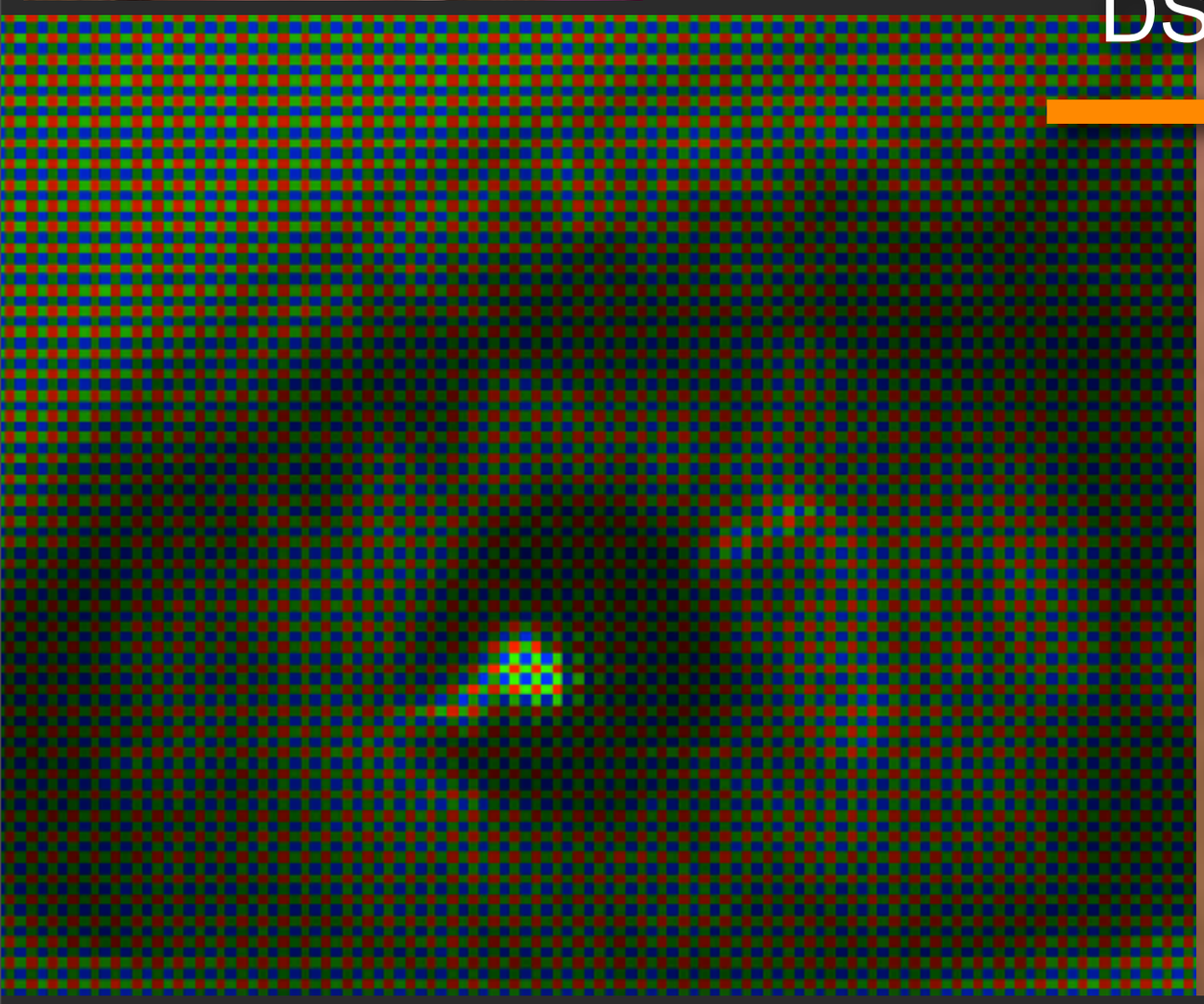
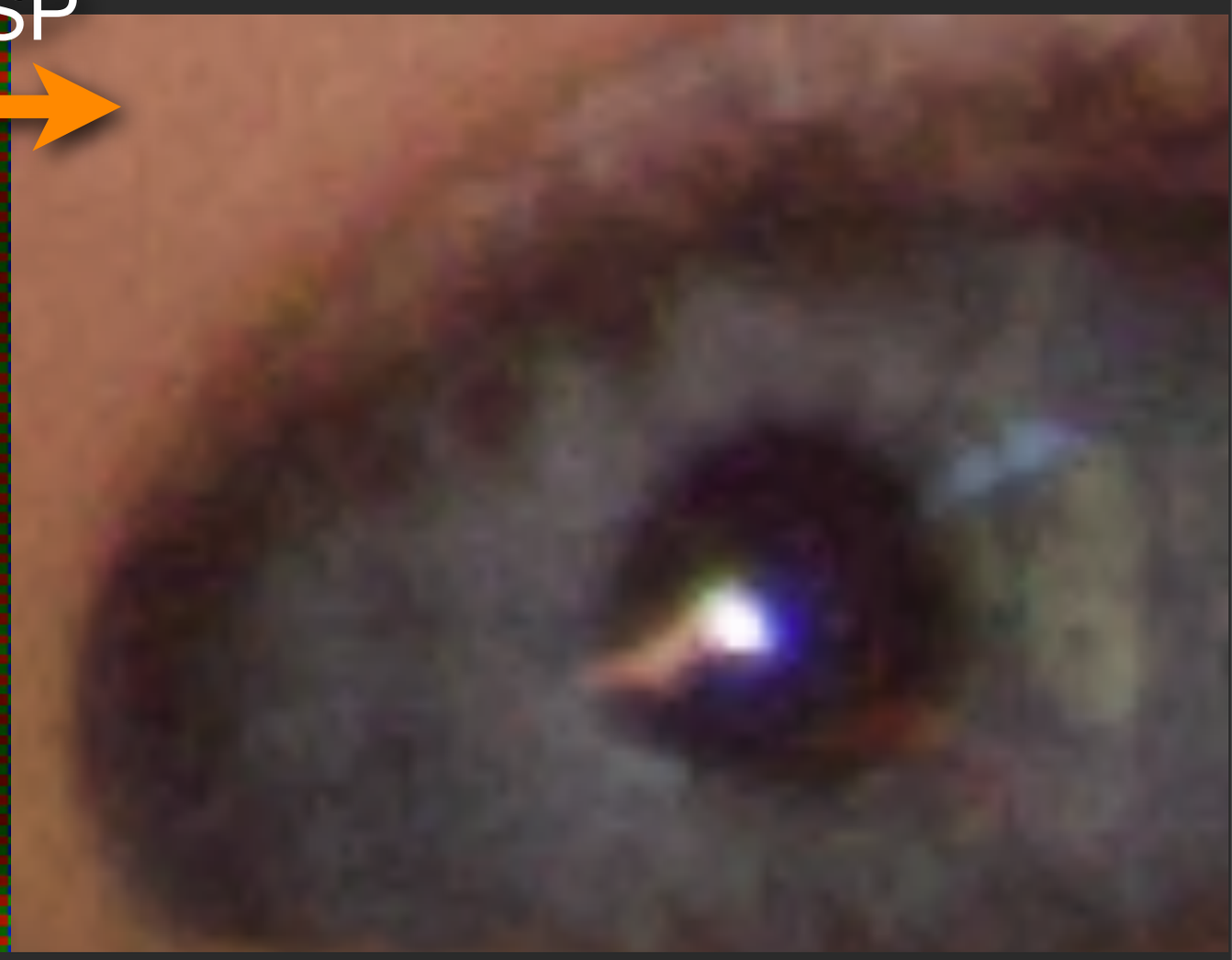


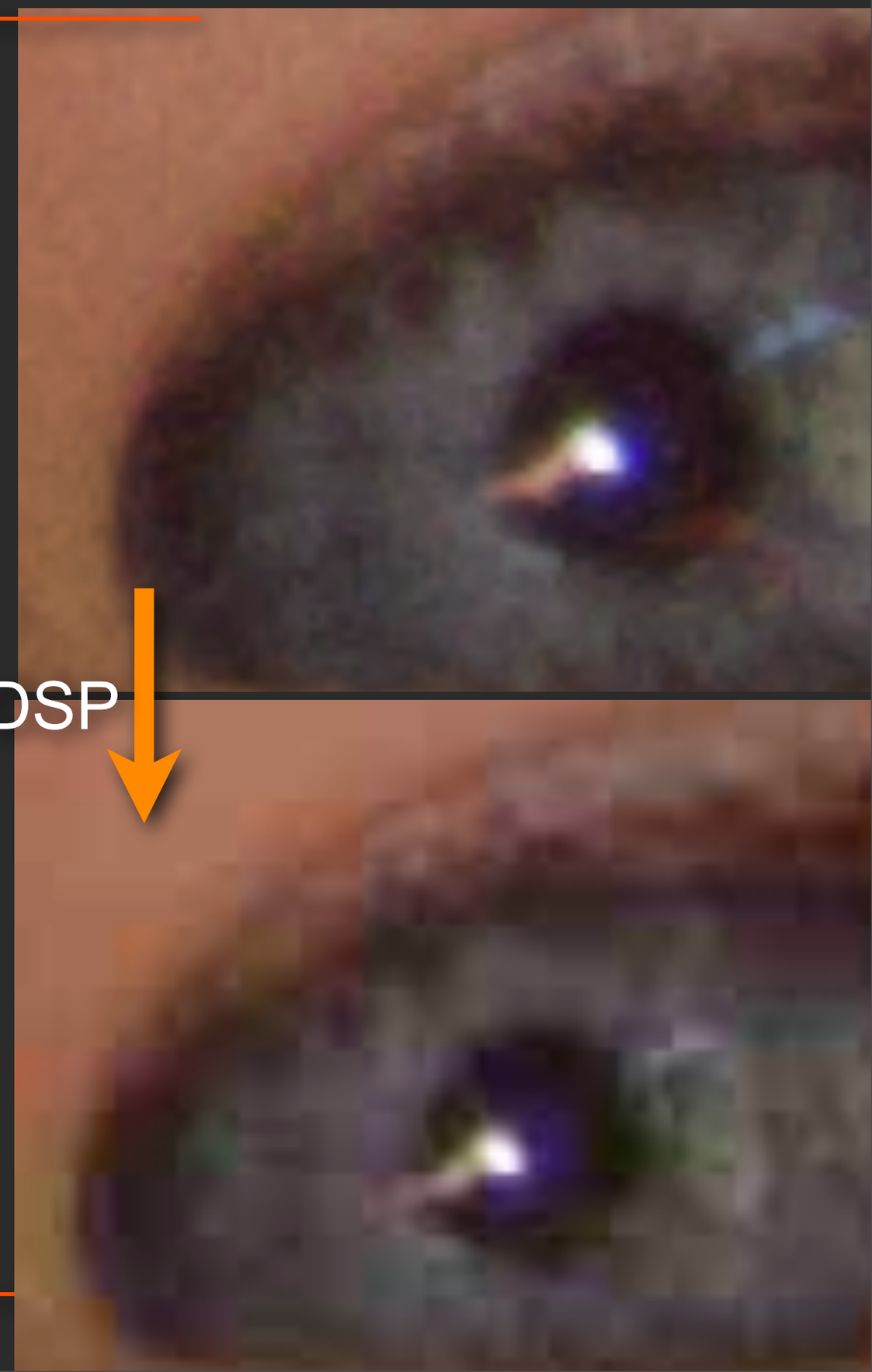
DSP



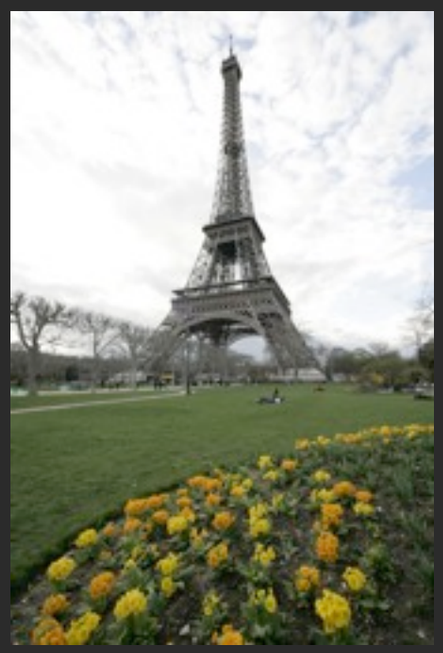
Example II: Digital Camera

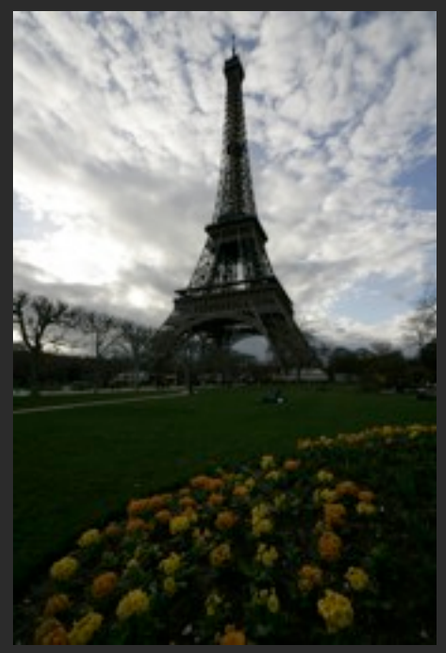
- Compression of 40x without perceptual loss of quality.

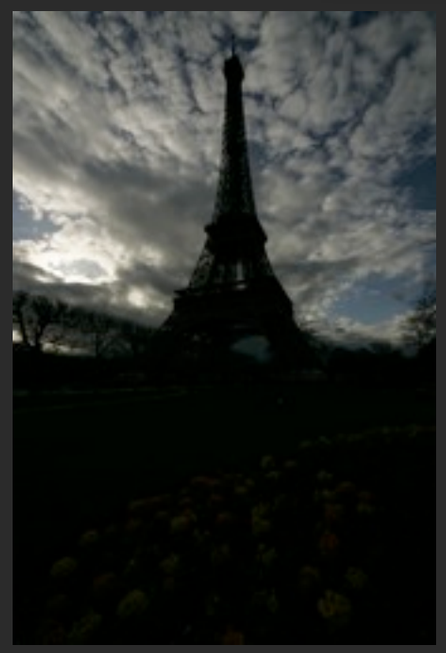
- Example of slight overcompression: difference enables x60 compression!



Computational Photography



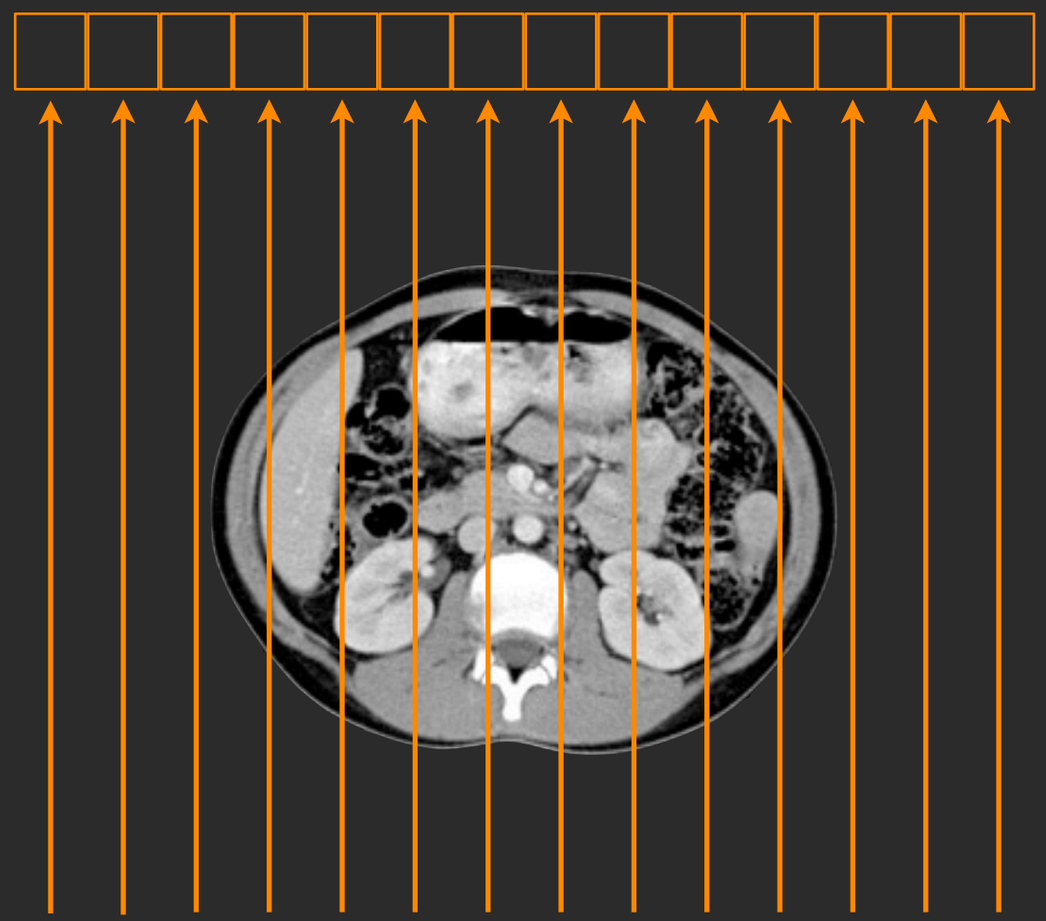




DSP

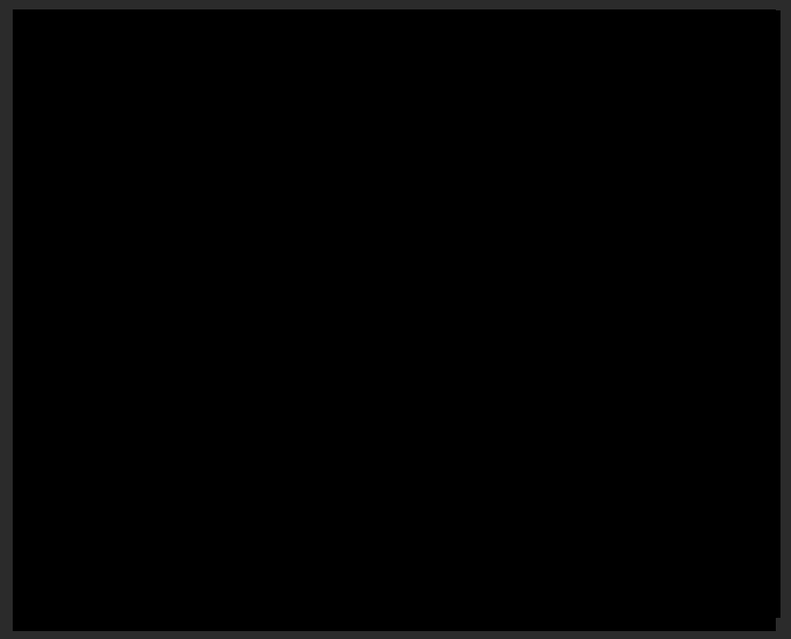
*www.hdrsoft.com

Example III: Computed Tomography



x-ray source

Sinogram



cross-section

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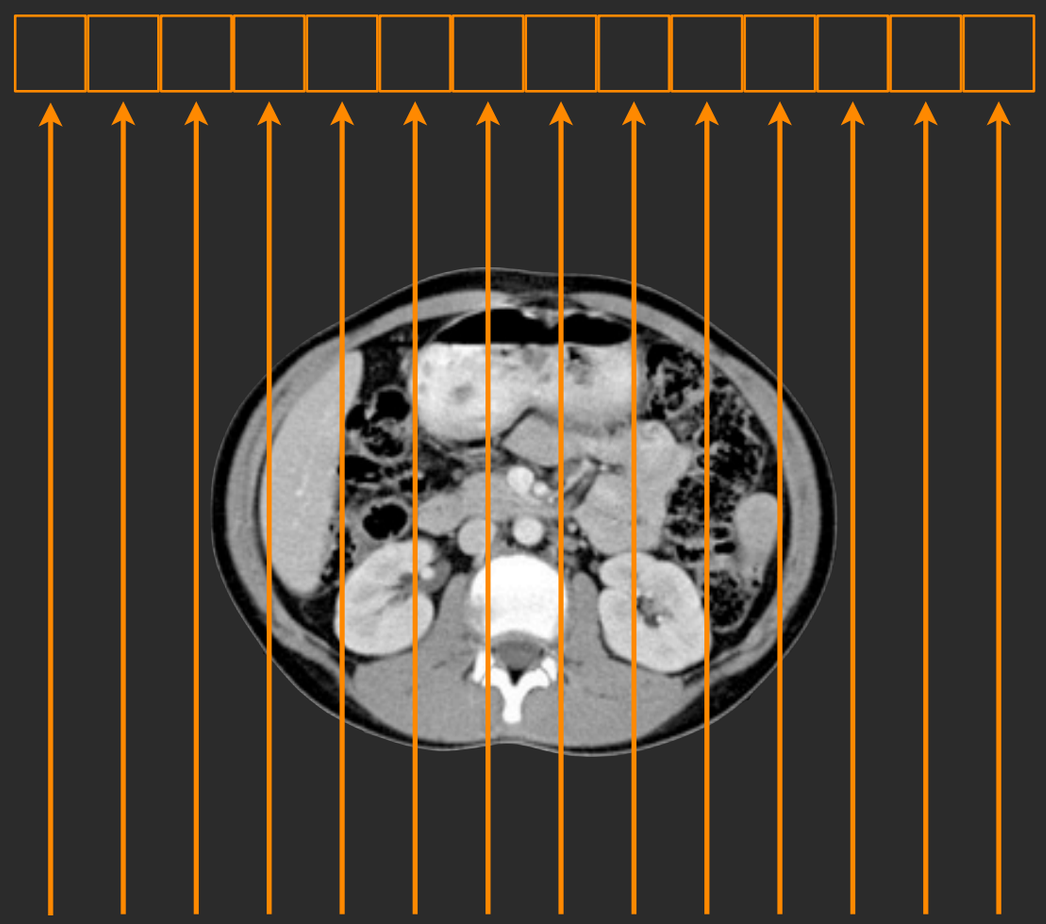
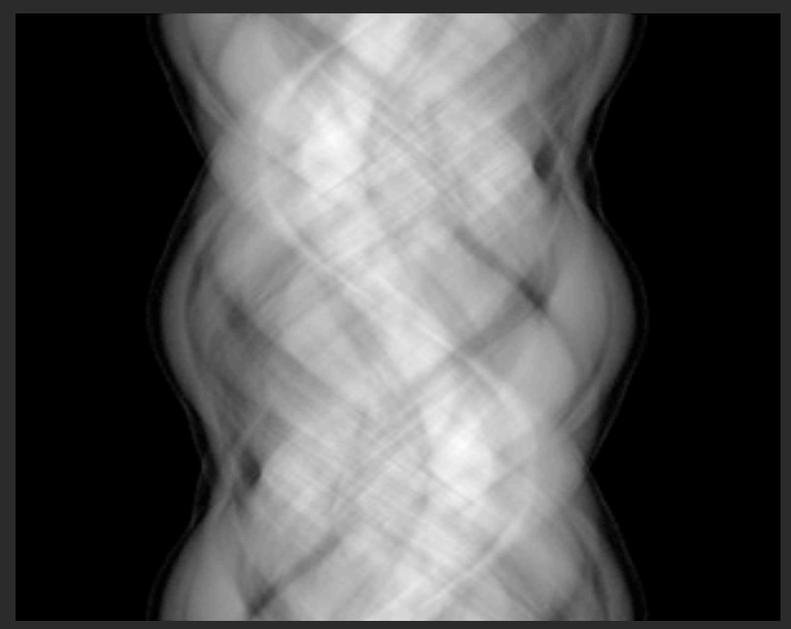


x-ray source

Sinogram



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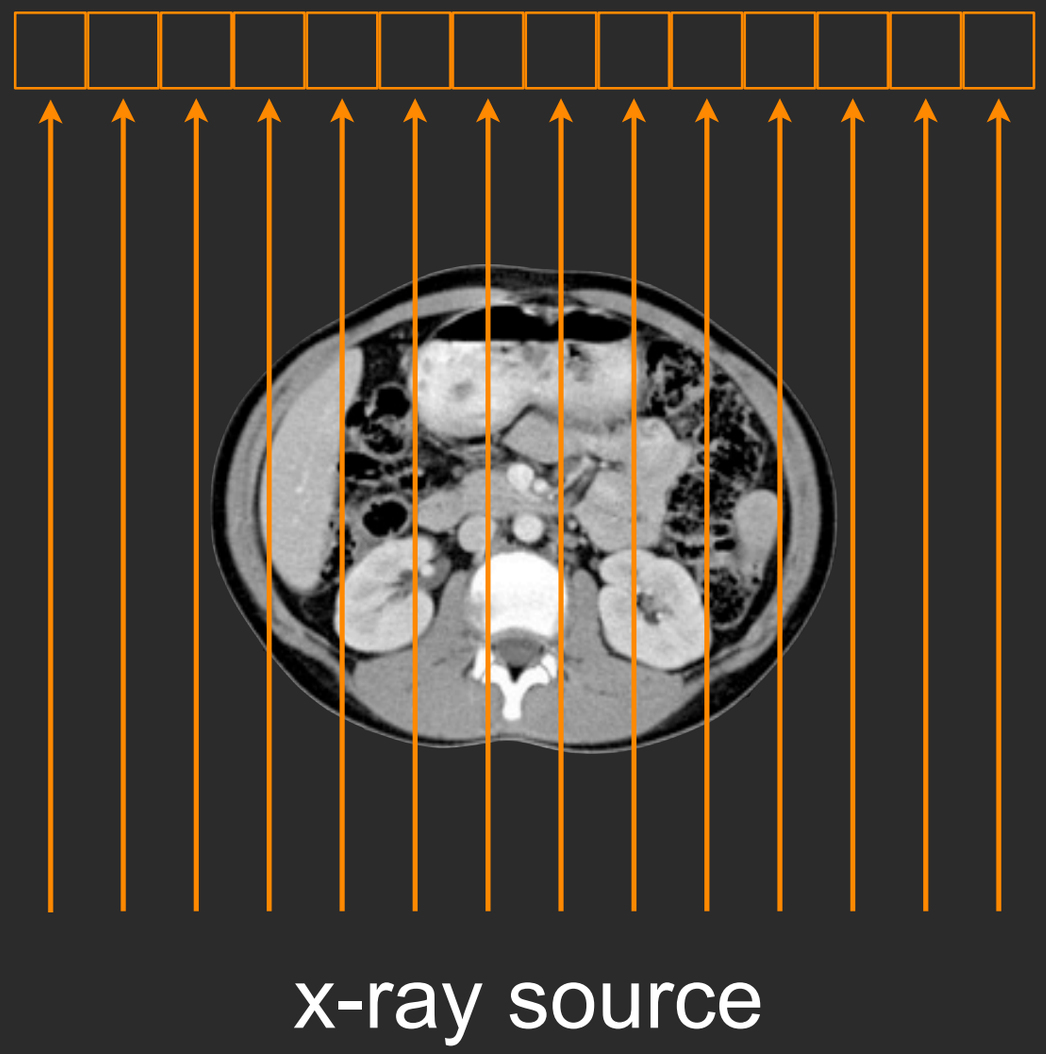

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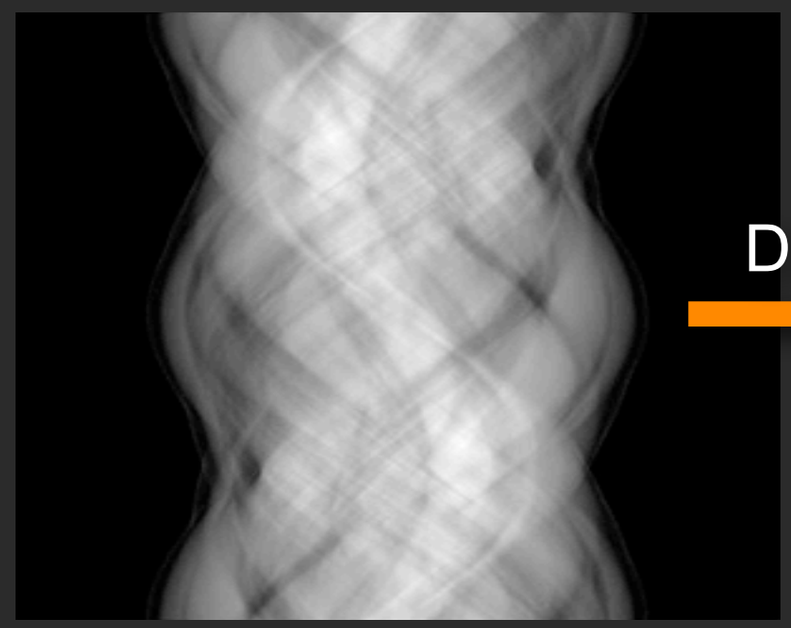

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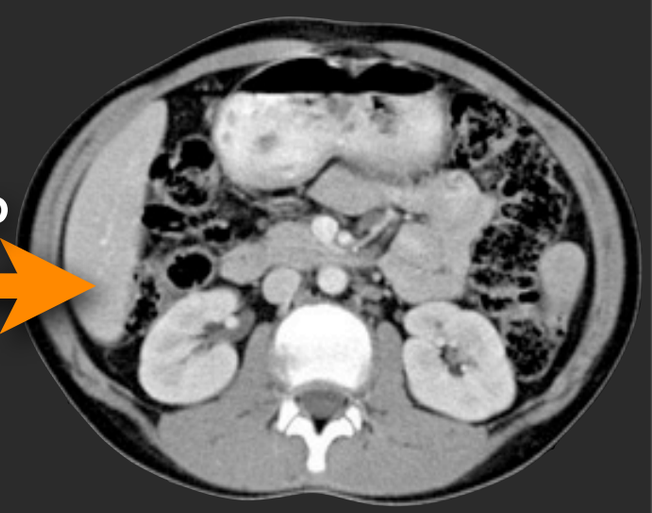


Example IV: MRI (again!)

Fourier

k-space (Raw Data)

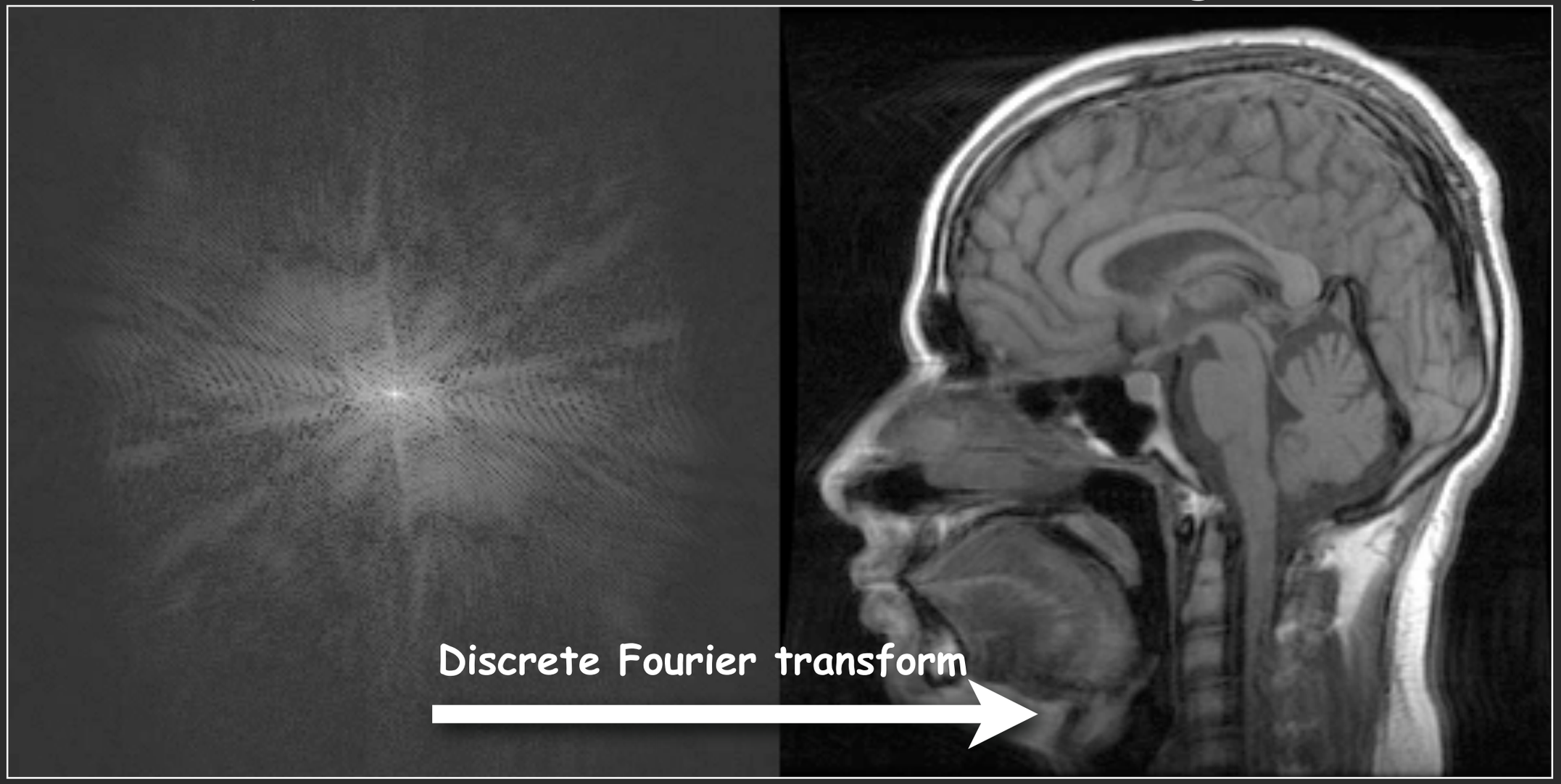
Image

Discrete Fourier transform

Example IV: MRI (again!)

Fourier

k-space (Raw Data) | Image



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Fourier

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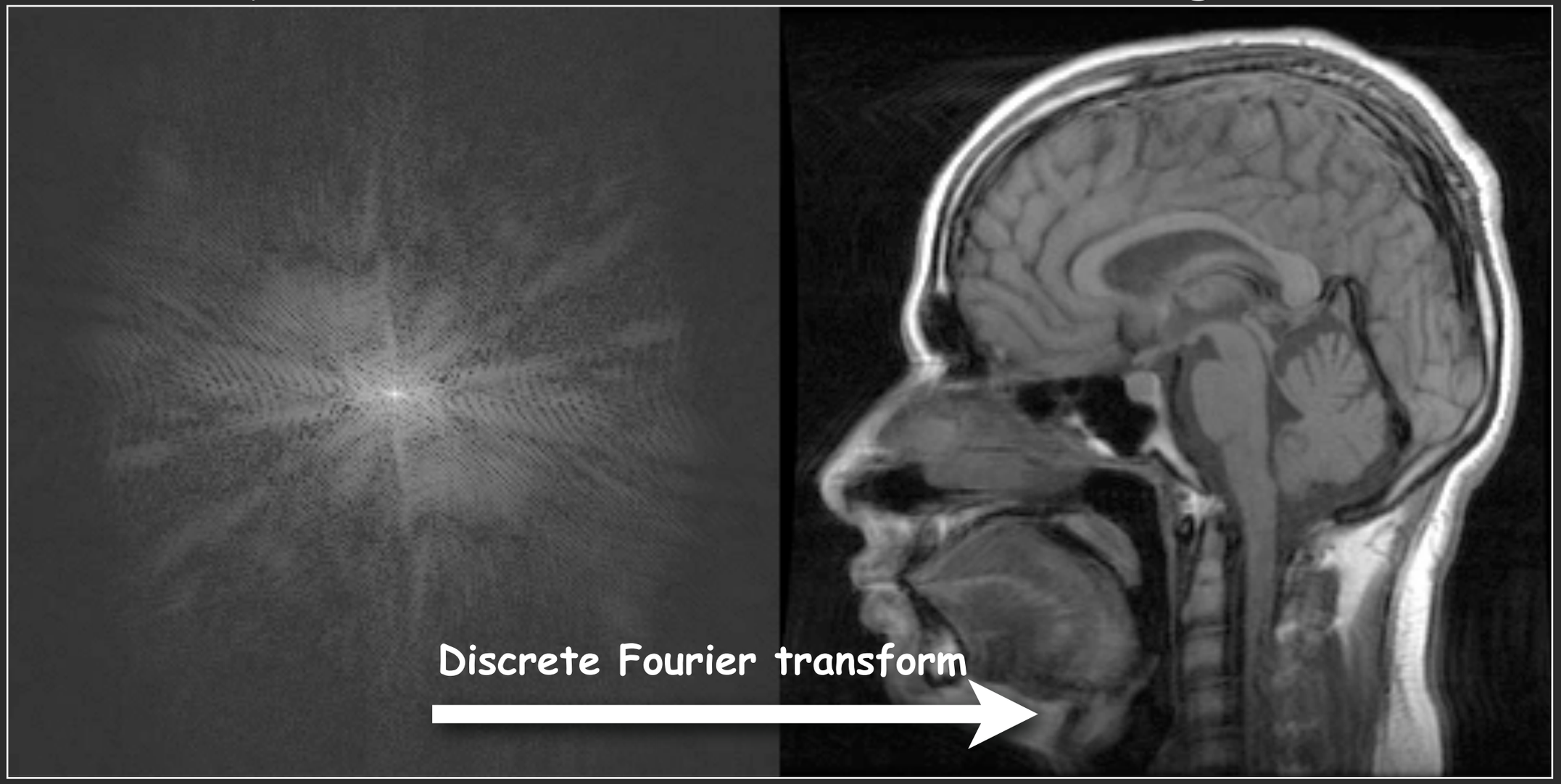
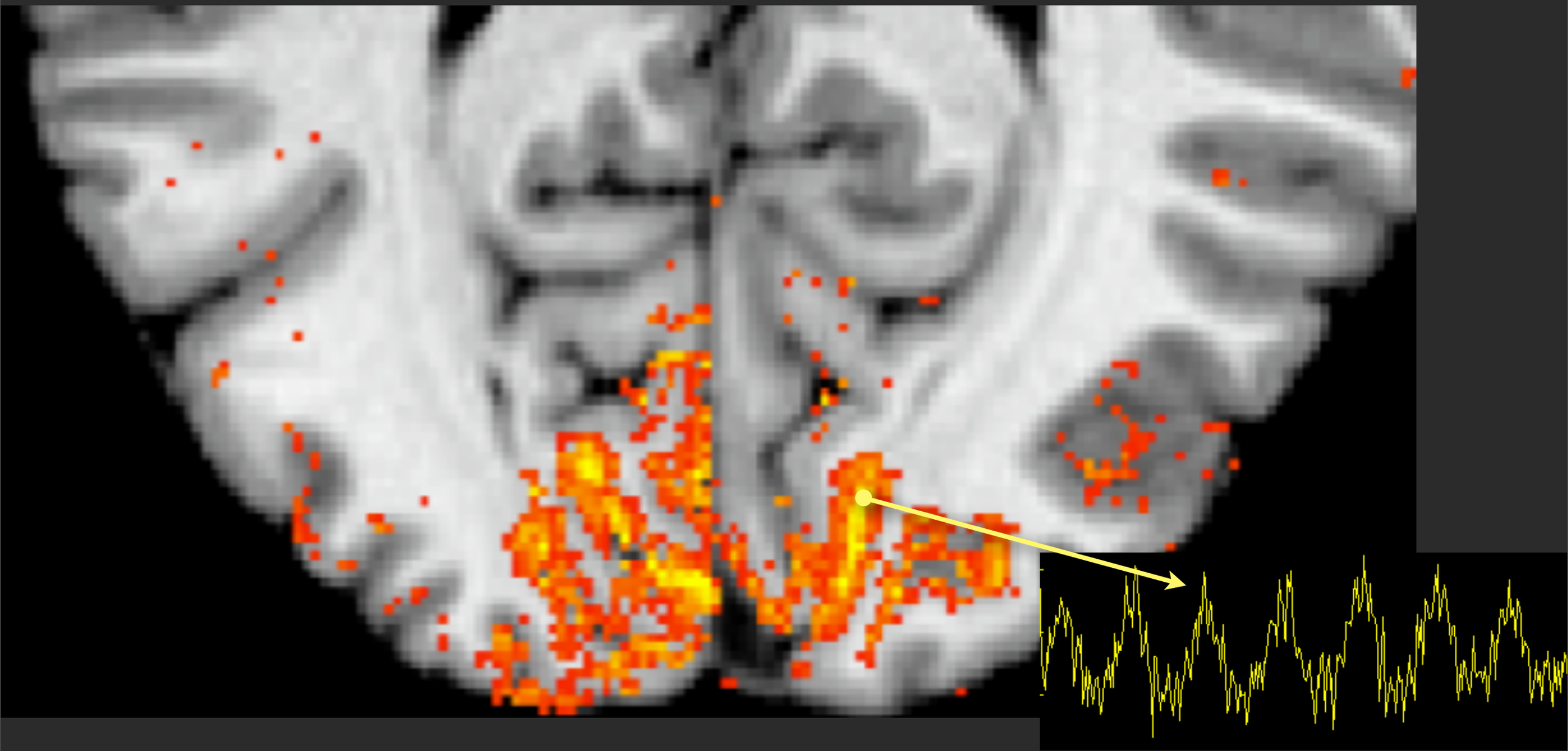


Functional MRI Example

Sensitivity to blood oxygenation - response to brain activity

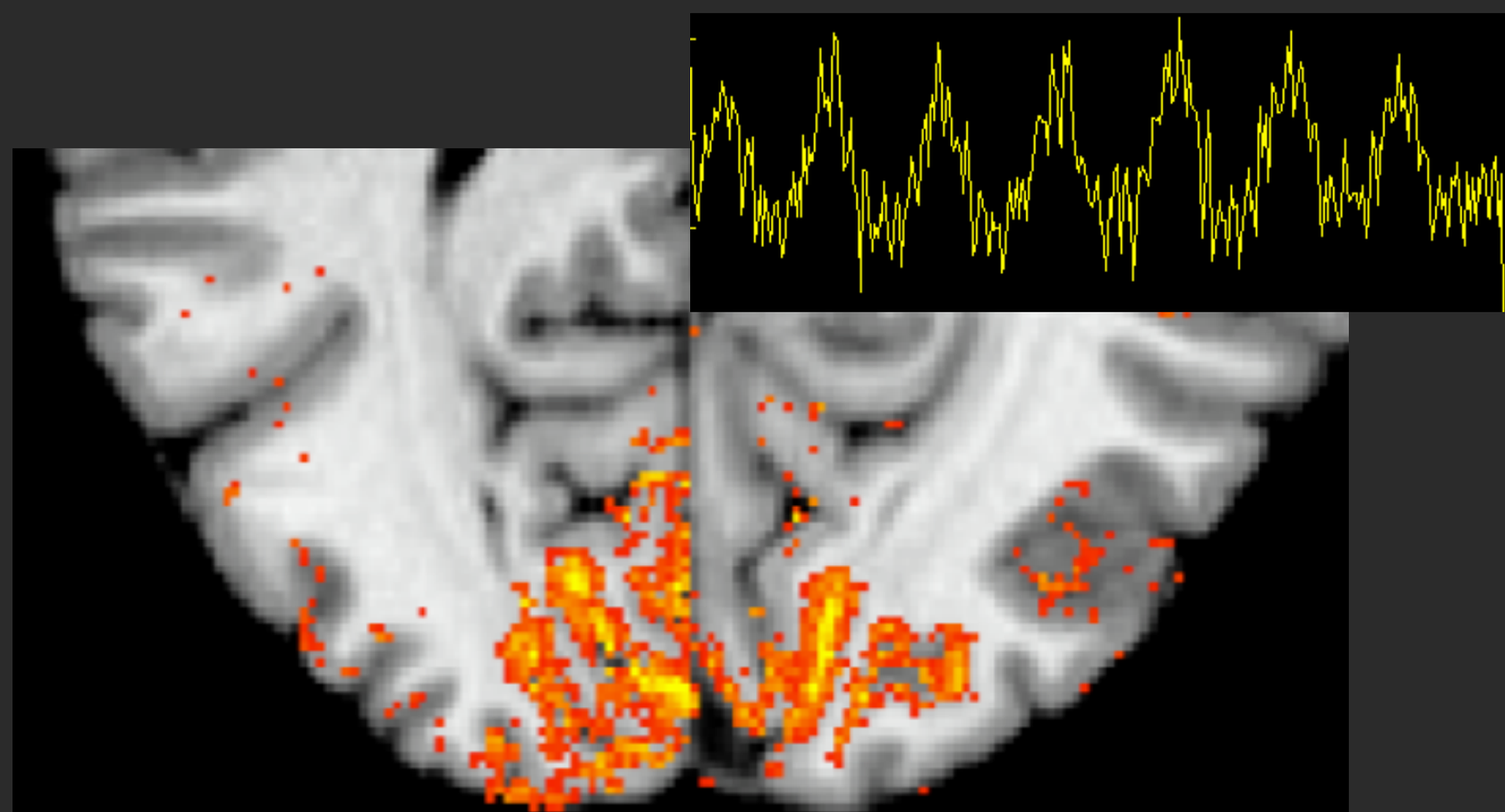
Convert from one signal to another

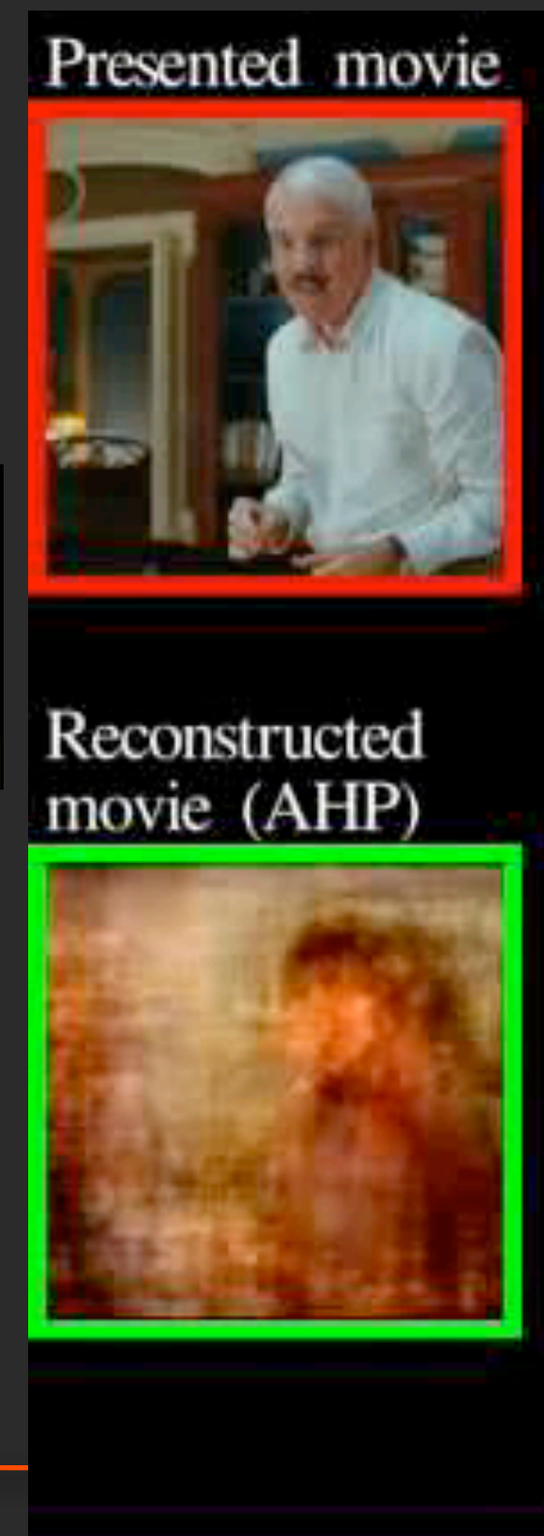


*Karla Miller, Oxford
*Brian Wandell, Stanford

Taking fMRI further

- fMRI decoding : "Mind Reading" Gallant Lab, UC Berkeley
- Interpretation of signals

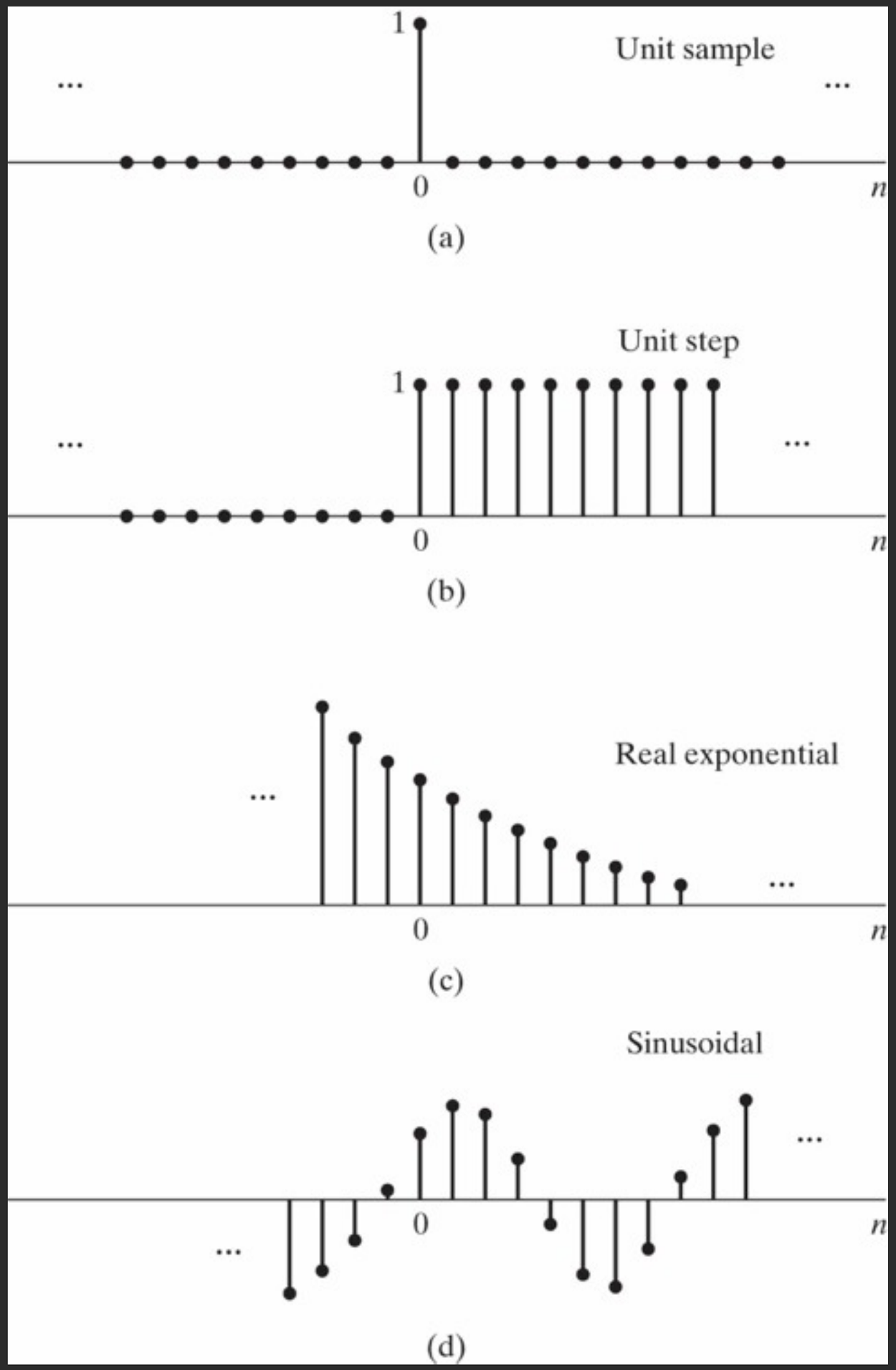




Course Objective

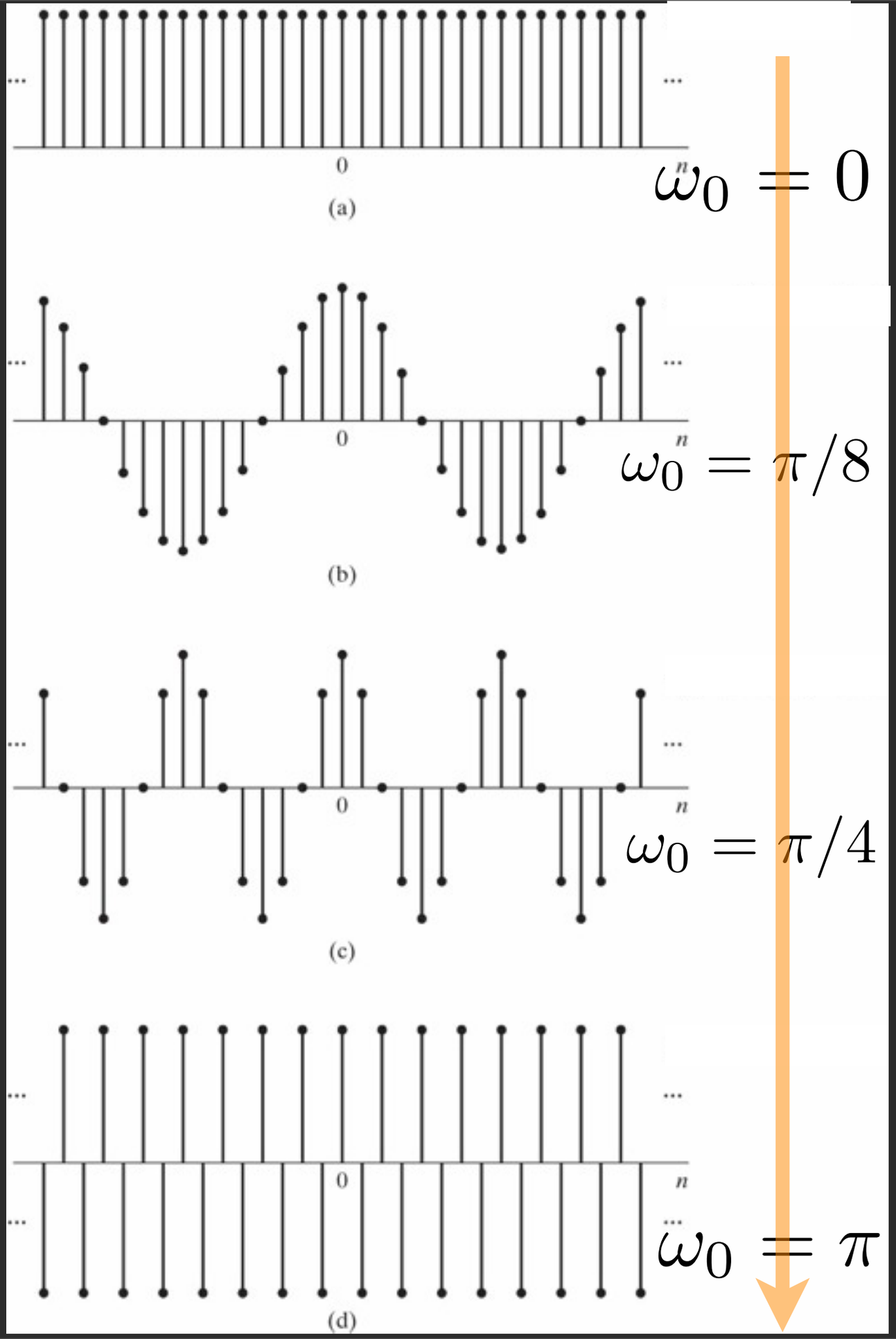
- Develop skills for
  - Analyzing and synthesizing algorithms and systems that process discrete-time signals
  - Emphasis on realization and implementation

Basic Sequences



Sinusoidal sequences

$$\cos(\omega_0 n)$$



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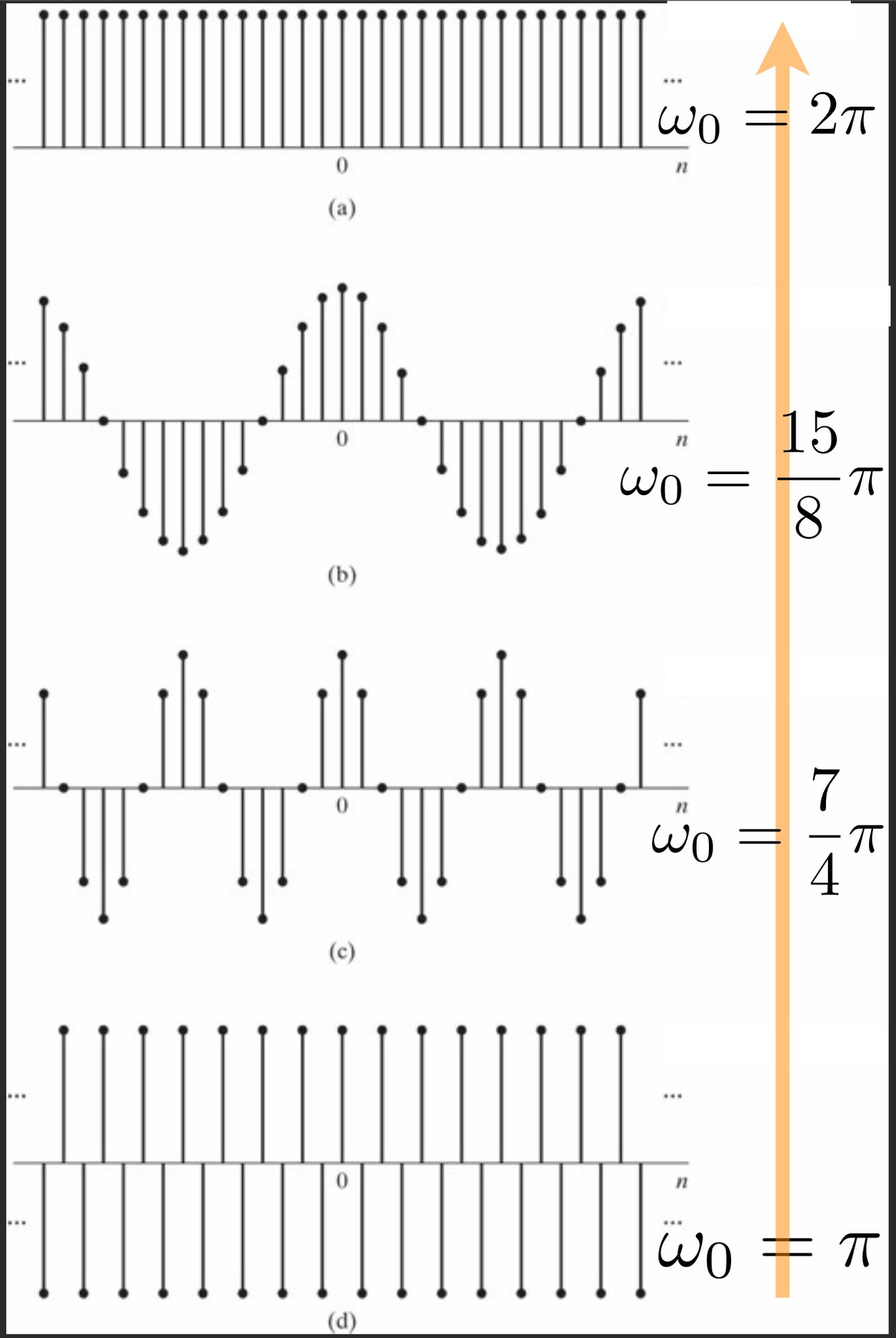
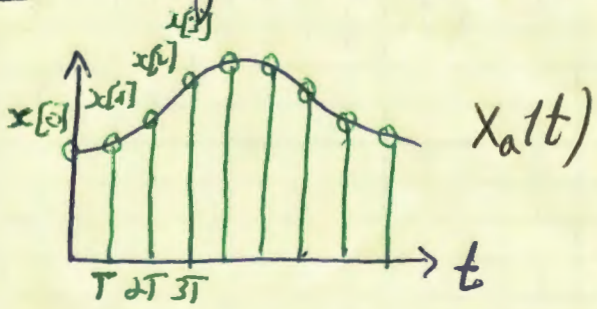


8/29/2011

DT SIGNALS: samples of a CT SIGNAL: $x[n] = x_a(nT)$

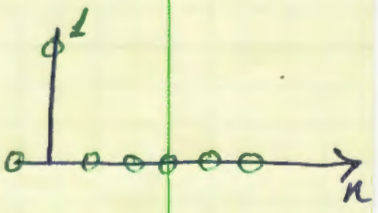
$n = 0, 1, 2, \ldots$



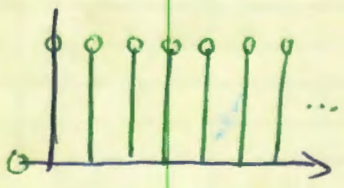
or inherently discrete (Examples?)

BASIC SEQUENCES:

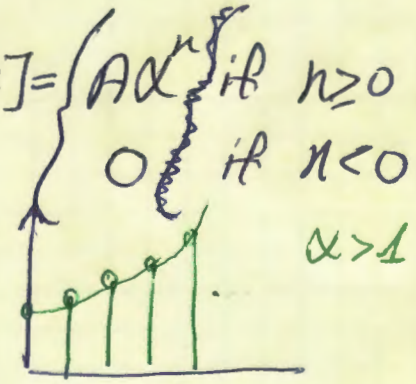
UNIT IMPULSE: $\delta[n] = \begin{cases} 1 & \text{if } n = 0 \\ 0 & \text{if } n \neq 0 \end{cases}$

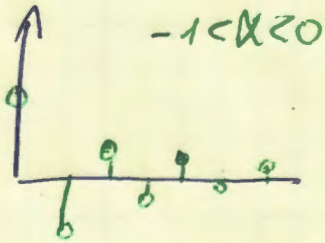


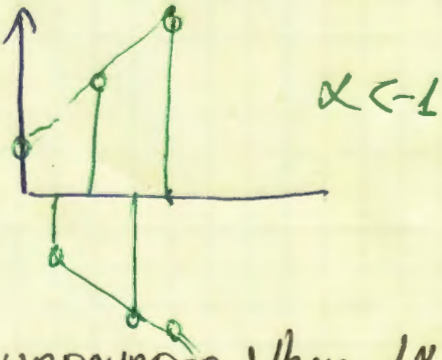
UNIT STEP: $u(n) = \begin{cases} 1 & \text{if } n \geq 0 \\ 0 & \text{if } n < 0 \end{cases}$



EXPONENTIAL: $x[n] = \begin{cases} A\alpha^n & \text{if } n \geq 0 \\ 0 & \text{if } n < 0 \end{cases}$







BOUNDED $|\alpha| < 1$ UNBOUNDED when $|\alpha| > 1$

SINUSOIDAL: $x[n] = A\cos(\omega_0 n + \phi)$ or $\boxed{x[n] = Ae^{(j\omega_0 n + j\phi)}}$

Q: PERIODIC OR NOT? $x[n+N] = x[n]$ for N integer?

A: If ω_0/π is rational (DIFFERENT THAN C.T.)

TO FIND FUNDAMENTAL PERIOD N, FIND SMALLEST INTEGERS k, N S.T.:

$$\omega_0 N = 2\pi k$$

EXAMPLE:

$\cos\left(\frac{5}{7}\pi n\right)$ $N=14$ $(k=5)$

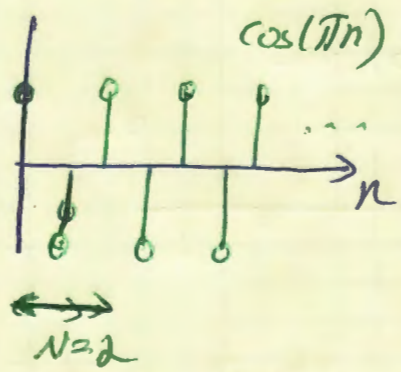
$\cos\left(\frac{\pi}{5} n\right)$ $N=10$ $(k=1)$

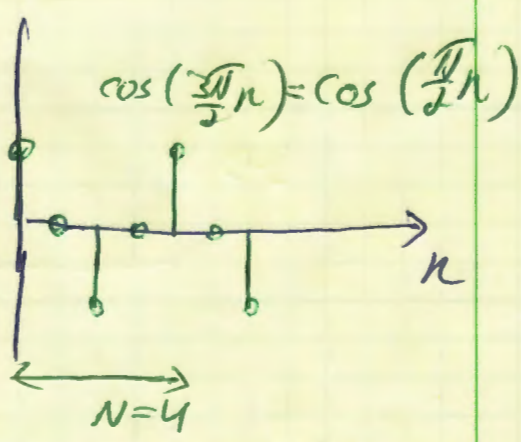
$$\cos\left(\frac{5\pi}{7}n\right) + \cos\left(\frac{\pi}{5}n\right) \Rightarrow N = \text{S.C.M}\{10, 14\} = 70$$

$\hookrightarrow$ ANOTHER DIFFERENCE:

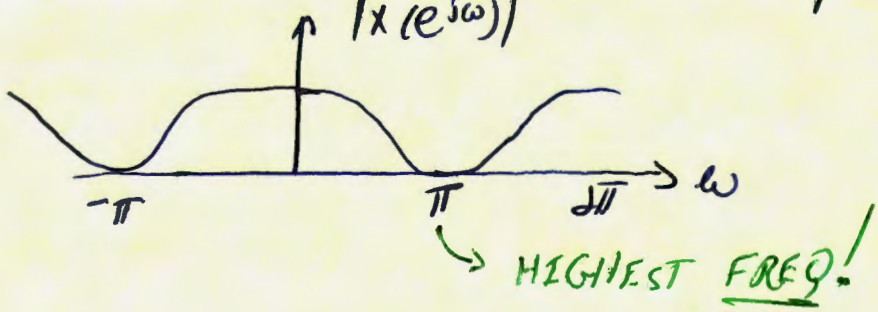
Q: WHICH ONE IS A HIGHER FREQ. $\omega_0 = \pi$ or $\omega_0 = \frac{3\pi}{2}$?

A: $\omega_0 = \pi$



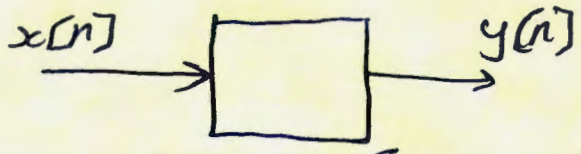


RECALL PERIODICITY and SYMMETRY in DTFT



<SHOW FIG. 2.5>

D.T. SYSTEMS



CAUSAL: OUTPUT depend only on PAST

memoryless: $y[n]$ at n depends only on $x[n]$

EXAMPLE: $y[n] = x[n]^2$

LINEAR: SUPERPOSITION:

$$T\{x_1[n] + x_2[n]\} = T\{x_1[n]\} + T\{x_2[n]\} = y_1[n] + y_2[n]$$

homogeneity:

$$T\{a x[n]\} = a T\{x[n]\} = a y[n].$$