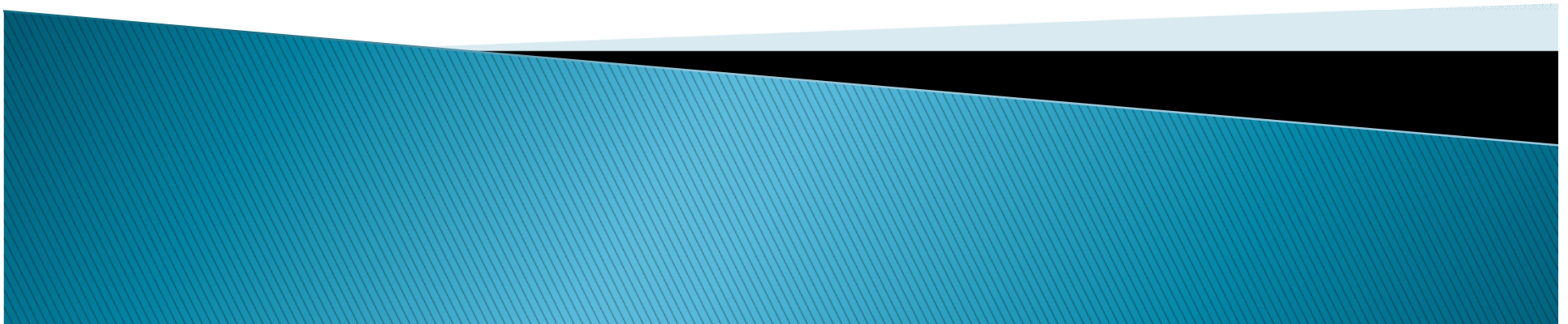


# IMAGE QUALITY OF RADIOLOGIC IMAGES



# Image Clarity

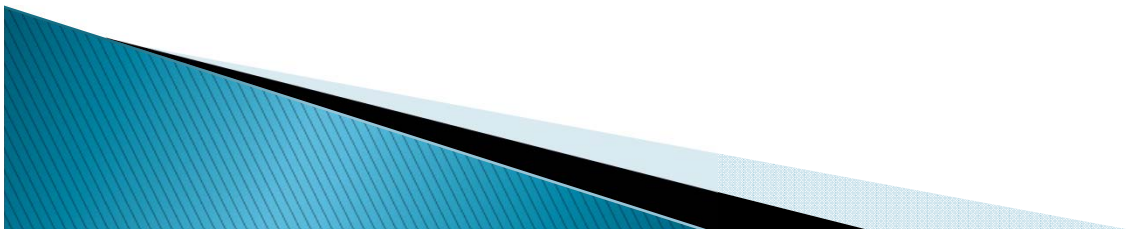
- ▶ Image clarity is a measure of how well information of interest to the physician is displayed in a radiologic image
- ▶ **IMAGE CLARITY** is affected by
  - UNSHARPENESS
  - DISTORSION AND ARTIFACTS
  - CONTRAST
  - NOISE



# IMAGE UNSHARPENESS

It is the blurring of sharp edges in an image

- ▶ GEOMETRIC UNSHARPENESS
- ▶ SUBJECT UNSHARPENESS
- ▶ RECEPTOR UNSHARPENESS
- ▶ MOTION UNSHARPENESS



# Contrast in diagnostic imaging

- ▶ Contrast of an image is a product of complex interactions among the anatomic and physiologic attributes of the region of interest
- ▶ **IMAGE CONTRAST**
  - **INTRINSIC CONTRAST**
  - **TECHNIQUE SELECTION**
  - **RECEPTOR CONTRAST**
  - **CONTRAST AGENTS**



# Physical Properties that influence image contrast for various imaging modalities

Radiography	Nuclear Medicine	Ultrasound	Computed Tomography	Magnetic Resonance
Atomic Number	Activity	Velocity	Physical density	Proton density
Physical density	Distribution	Physical density	Electron density	Relaxation times
Thickness	Thickness	Thickness	Flow	Flow



# CONTRAST AGENTS

- ▶ In some radiologic examinations a substance can be introduced into the body to enhance the contrast of tissues in the region of interest
- ▶ **ANGIOGRAPHY** – Water soluble agent containing IODINE is injected into the circulatory system to displace blood and thereby enhance the contrast of blood vessels by increasing the attenuation of X-Ray impinging in the vessels.

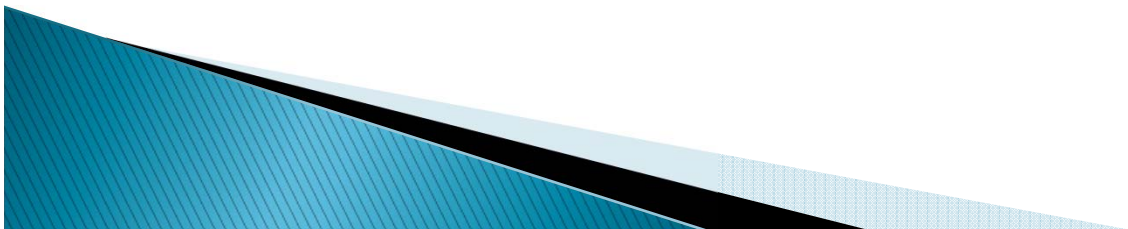


- ▶ **Myelography** – For the studies of spinal cord, the contrast agent IODINE is used
- ▶ **Computed Tomography** – Iodine contrast is used
- ▶ **Gastrointestinal Tract Radiologic examination** – Barium compound as contrast agent is used
- ▶ **Ultrasound Imaging** – solution containing dissolved ‘micro-bubbles’ of carbon dioxide is used
- ▶ **Magnetic Resonance Imaging** – Gadolinium is used as contrast agent



# Image Noise

- ▶ Structure Noise
- ▶ Radiation Noise
- ▶ Receptor Noise
- ▶ Quantum Mottle



# Perception of Visual Information

## ▶ Detection

- Signal–Noise Model
- Computational Model
- Signal Channel Model

COGNITIVE  
MODEL

## ➤ Recognition and interpretation



# Good X-Ray Image



**GOOD RECORDED DETAIL**




The contrast of an object is expressed relative to its surrounding background.

That is what determines its visibility.

**OBJECT CONTRAST**

**OBJECT**

**BACKGROUND**



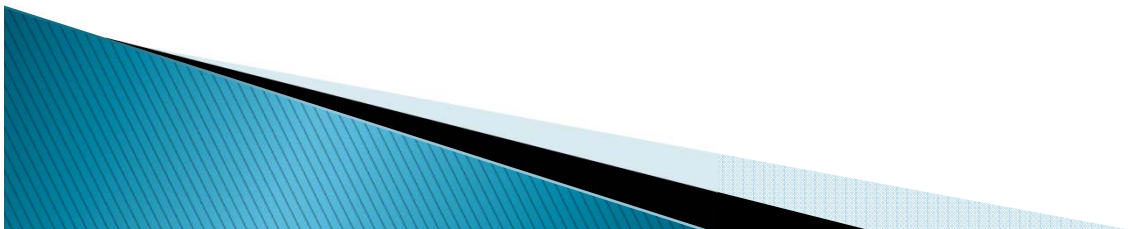
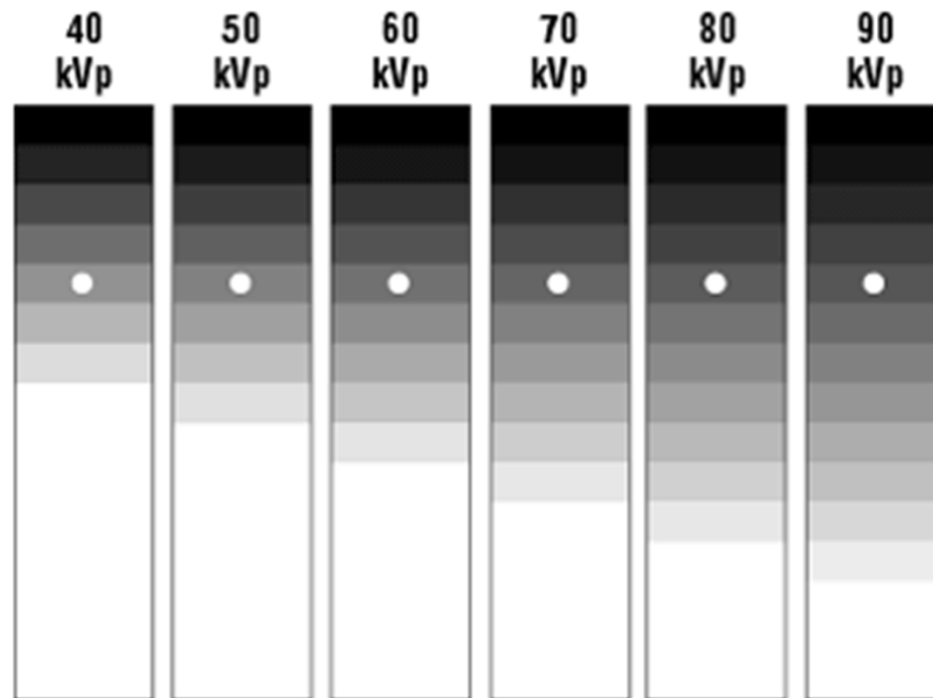
**FILM DENSITY**  
**CONTRAST =  $D_o - D_{bg}$**

**IMAGE BRIGHTNESS**  
**CONTRAST =  $B_o / B_{bg}$**

*Sprawls*

# Radiographic Contrast

- ▶ Is the product of image receptor contrast and subject contrast



# IMAGE CONTRAST

**LOW**



**OPTIMUM**



**HIGH**



*Sprawls*

**CONTRAST SENSITIVITY**

**X-RAY IMAGING**

**OBJECT**



**PHYSICAL CONTRAST**

**PHYSICAL DENSITY**

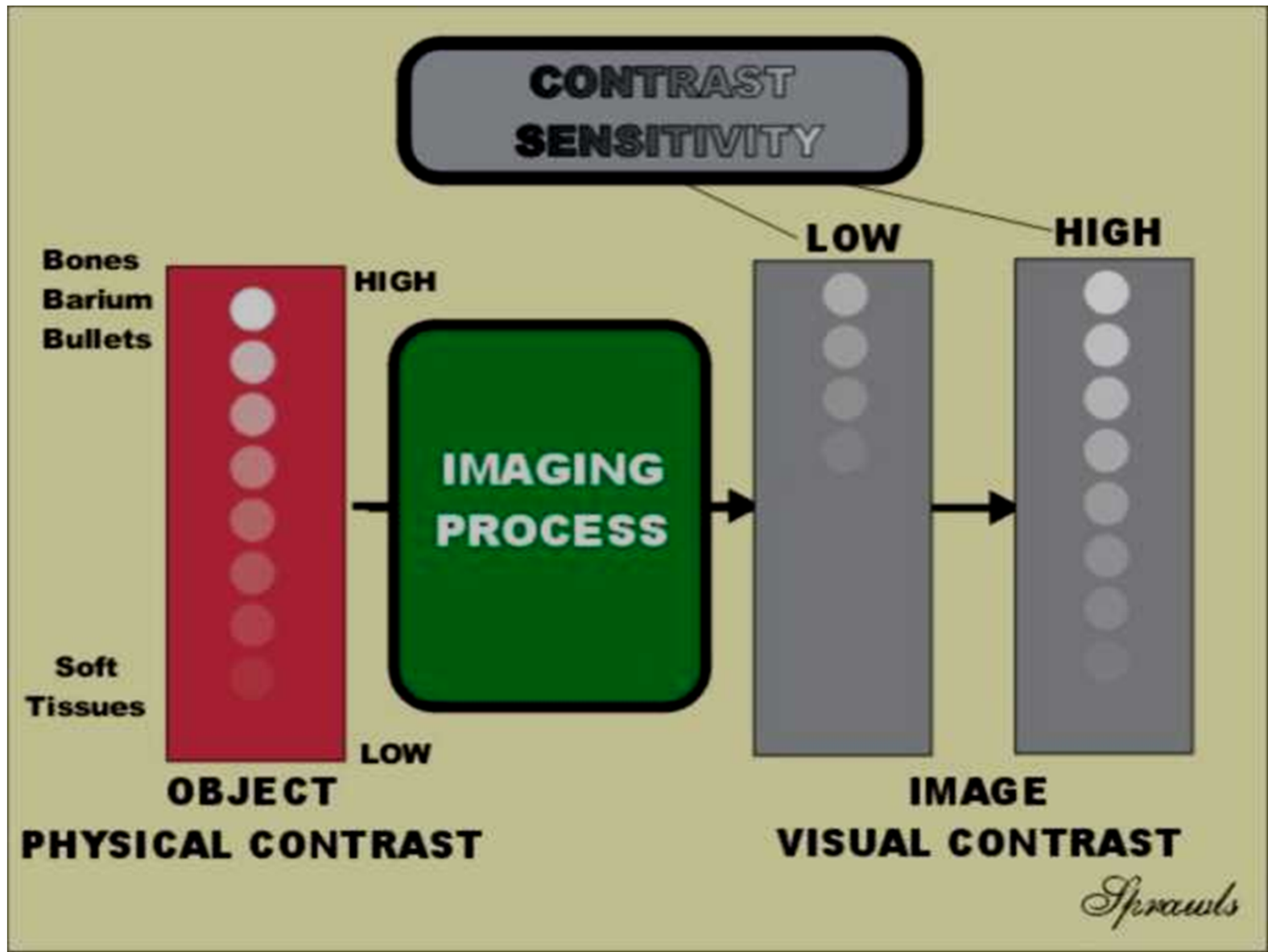


**ATOMIC NUMBER (Z)**



**Iodine & Barium**

*Sprawls*



# Radiographic Noise

- ▶ Film graininess – distribution & size of the silver halide grains in the emulsion
- ▶ Structure mottle – speed of the intensifying screen. Phosphor size & DQE/CE
- ▶ Not under the control of the technologist



# Quantum Mottle

- ▶ An image produced with just a few x-rays will have more quantum mottle.
- ▶ The use of very fast intensifying screens or not enough mA or kV will increase quantum mottle



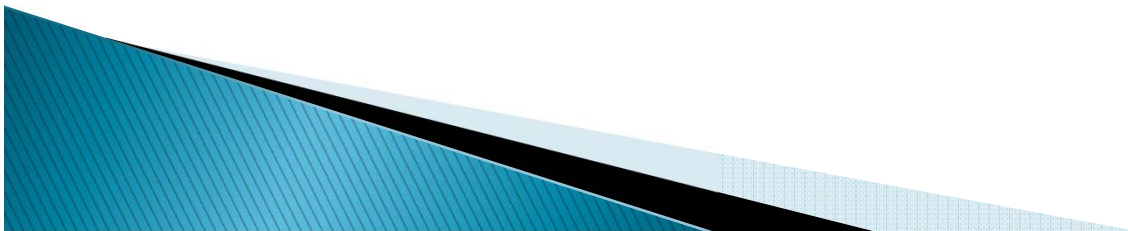
(Courtesy Tim Gienapp.)

# Modulation

The modulation of periodic signal  $f(x,y)$  with max and min values  $f_{\max}$  and  $f_{\min}$

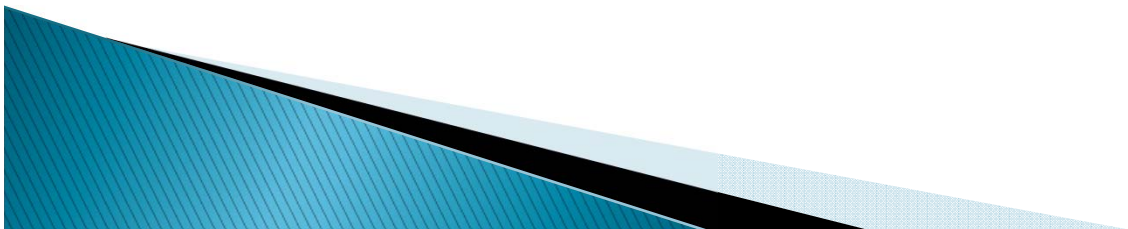
$$\text{Modulation, } m_f = \frac{f_{\max} - f_{\min}}{f_{\max} + f_{\min}}$$

The modulation refers to the contrast of the periodic signal  $f(x,y)$



# Measurements of Image Quality

- ▶ PSF = Point Spread Function
- ▶ LSF = Line Spread Function
- ▶ CTF = Contrast Transfer Function
- ▶ MTF = Modulation Transfer Function



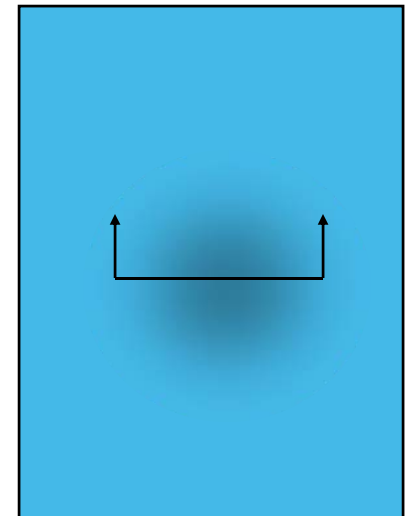
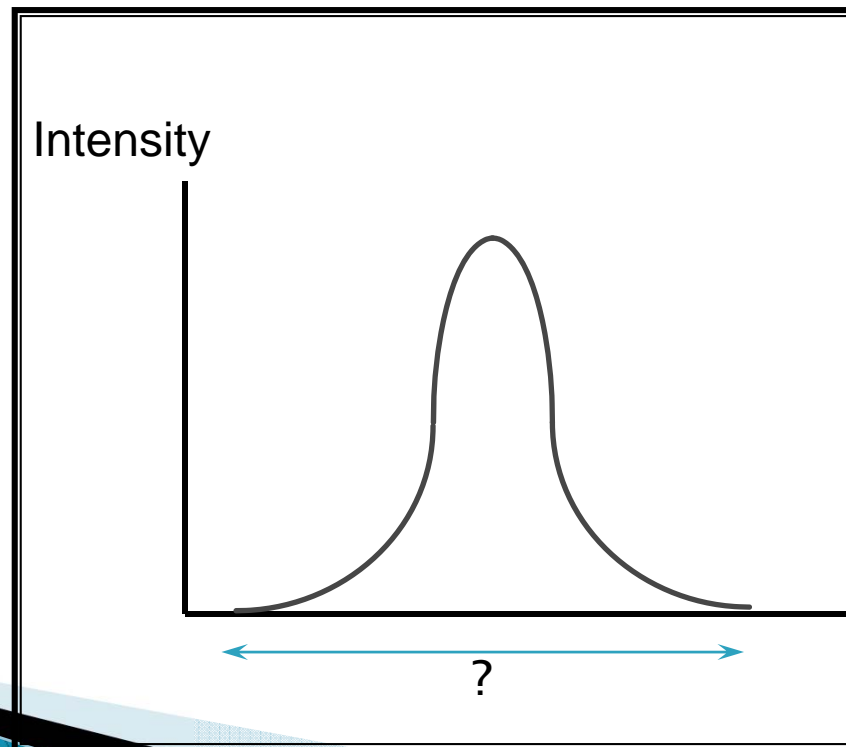
# Point Spread Function [PSF]

- ▶ “Point” object imaged as **circle** due to blurring
- ▶ Causes
  - finite focal spot size
  - finite detector size
  - finite matrix size
  - Finite separation between object and detector
    - Ideally zero
  - Finite distance to focal spot
    - Ideally infinite



# Quantifying Blurring

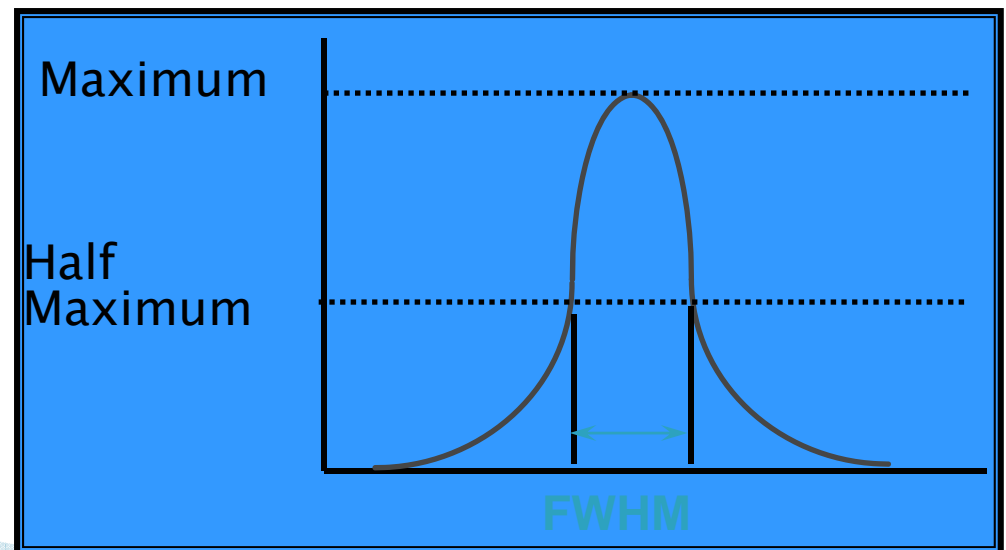
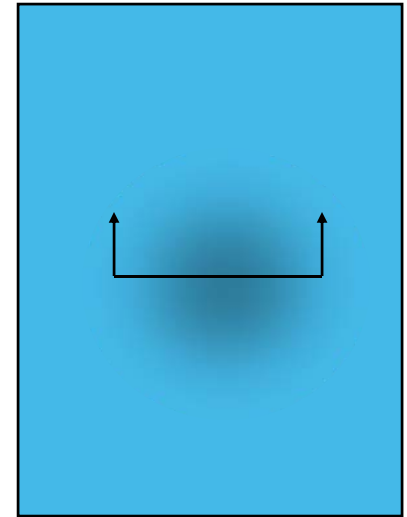
- ▶ Object point becomes image circle
- ▶ Difficult to quantify total image circle size
  - difficult to identify beginning & end of object



# Quantifying Blurring

## Full Width at Half Maximum (FWHM)

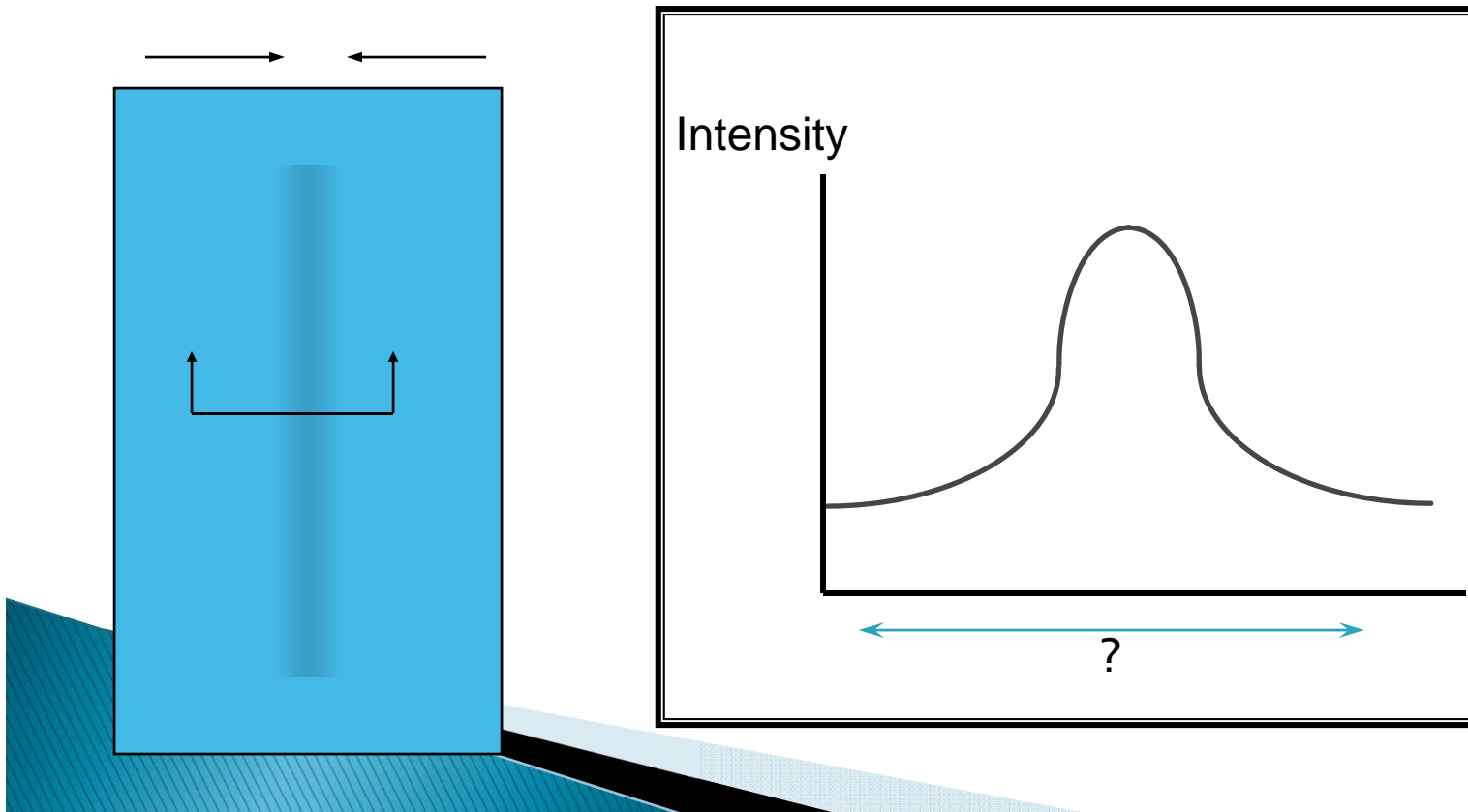
- ▶ width of point spread function at half its maximum value
- ▶ Maximum value easy to identify
- ▶ Half maximum value easy to identify
- ▶ Easy to quantify width at half maximum



# Line Spread Function

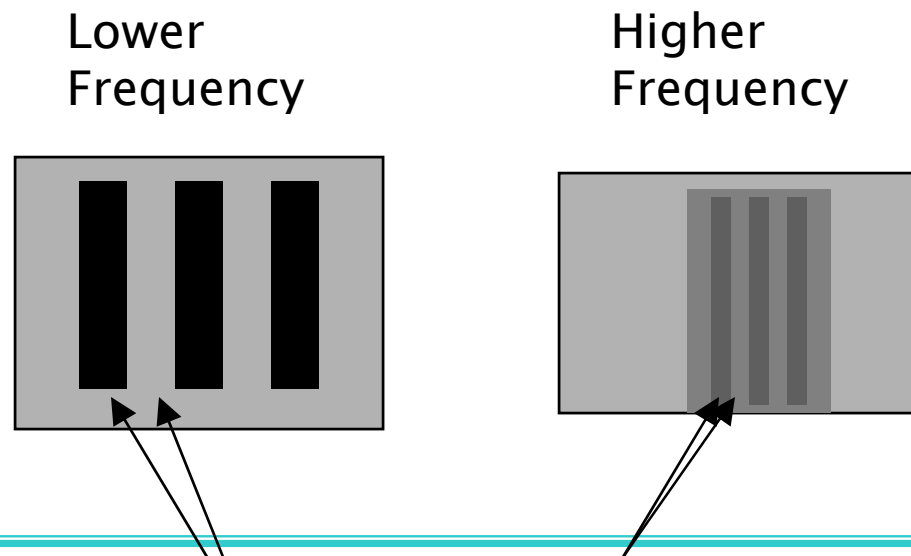
## LSF

- Line object image blurred
- Image width larger than object width



# Contrast Response Function CTF or CRF

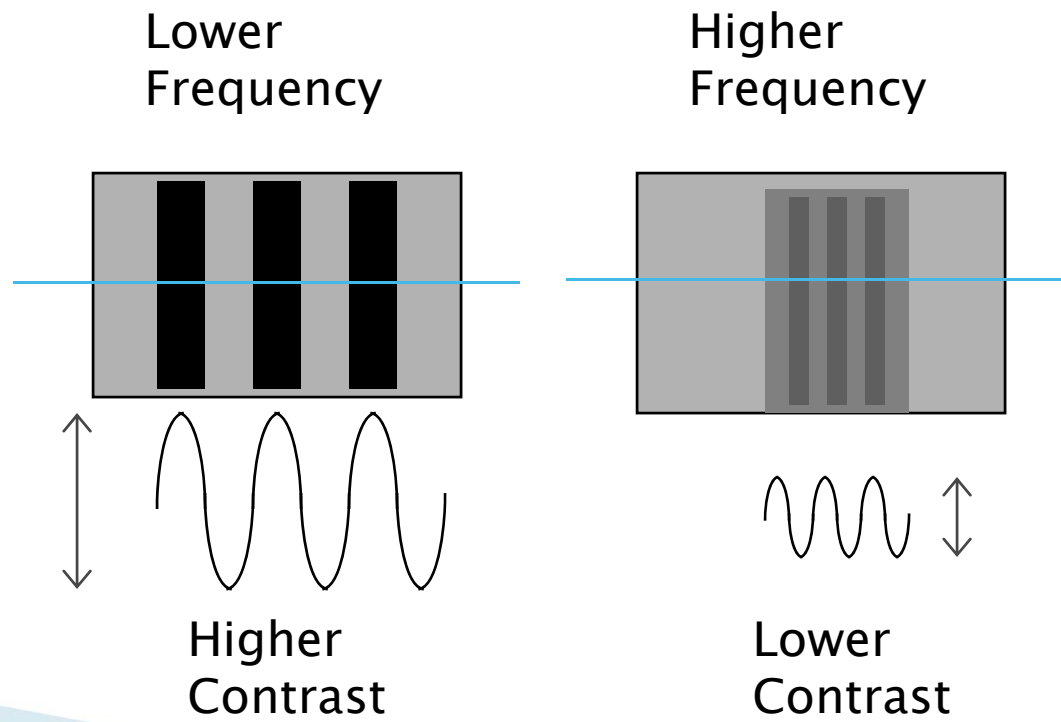
- ▶ Measures contrast response of imaging system as function of spatial frequency



Loss of contrast between light and dark areas as bars & spaces get narrower. Bars & spaces blur into one another.

# Contrast Response Function CTF or CRF

- Blurring causes loss of contrast
  - darks get lighter
  - lights get darker



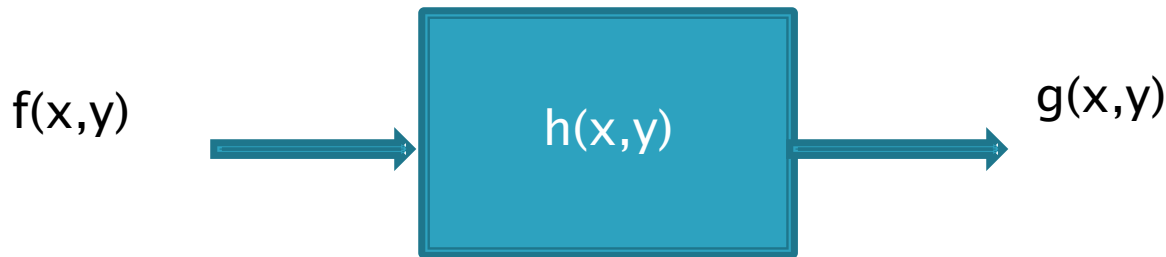
# Modulation Transfer Function (MTF)

- ▶ The sinusoidal object

$$f(x, y) = A + B \sin(2\pi u_0 x)$$

where A and B are nonnegative constants such that  $A \geq B$

$$m_f = \frac{B}{A}$$



$$g(x, y) = AH(0,0) + B |H(u_0,0)| \sin(2\pi u_0 x)$$

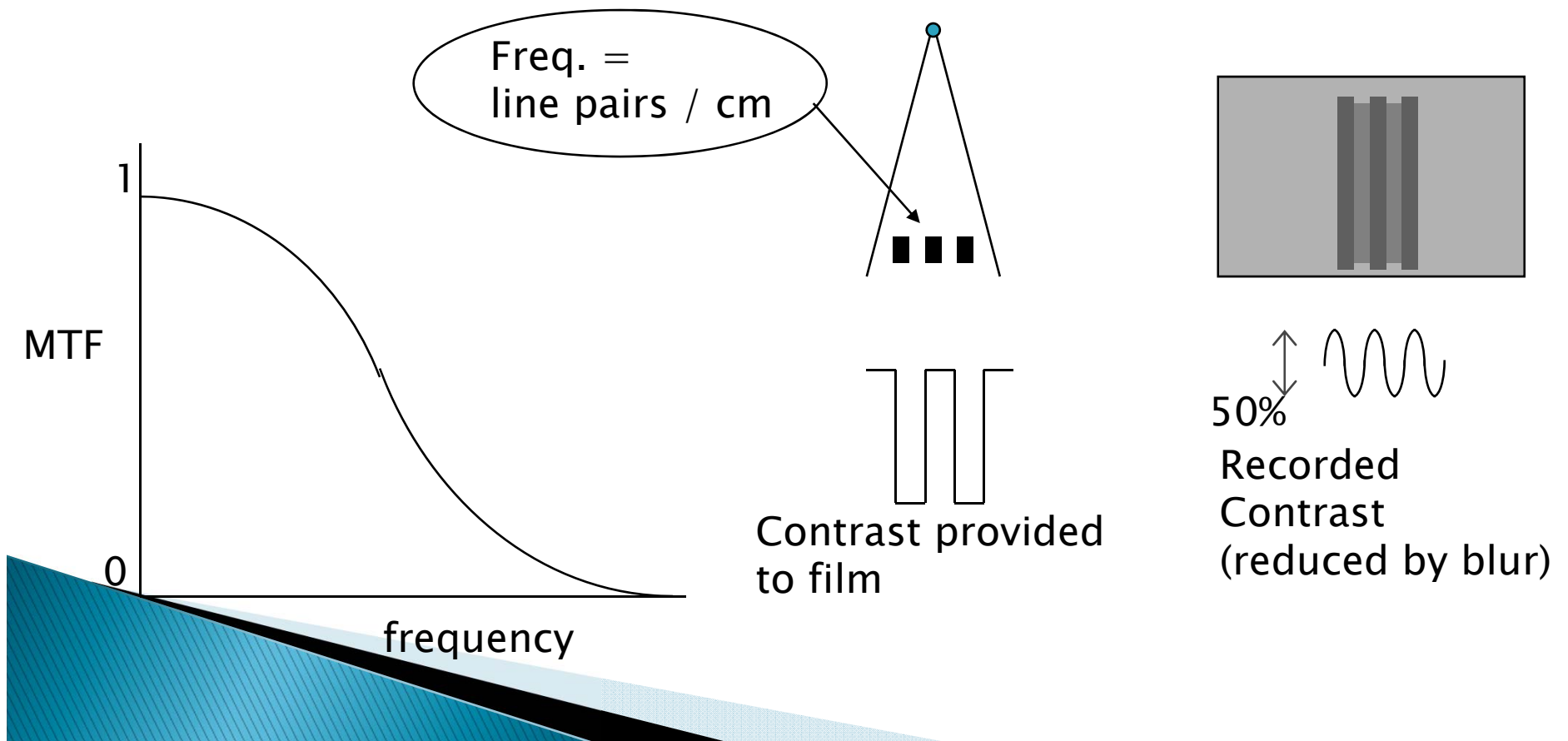
$$m_g = \frac{B |H(u_0,0)|}{AH(0,0)} = m_f \frac{|H(u_0,0)|}{H(0,0)}$$

$$MTF = \frac{m_g}{m_f} = \frac{|H(u_0,0)|}{H(0,0)}$$

# Modulation Transfer Function

## MTF

- ▶ Fraction of contrast reproduced as a function of frequency



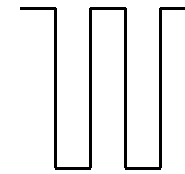
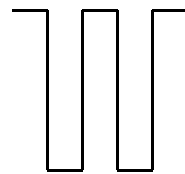
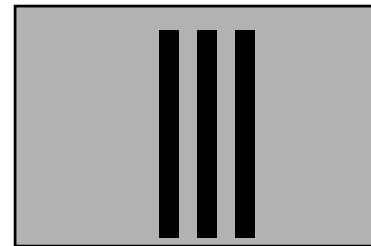
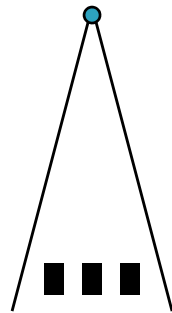
# MTF

- ▶ Can be derived from
  - point spread function
  - line spread function
- ▶  $MTF = 1$  means
  - all contrast reproduced at this frequency
- ▶  $MTF = 0$  means
  - no contrast reproduced at this frequency



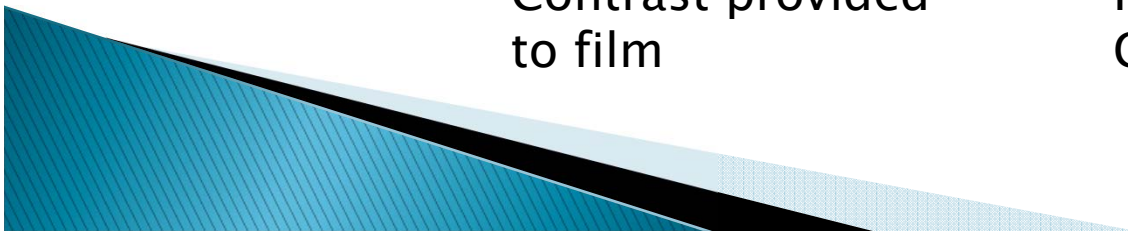
# MTF

- ▶ If  $MTF = 1$ 
  - all contrast reproduced at this frequency



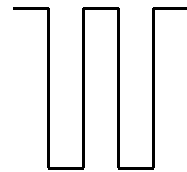
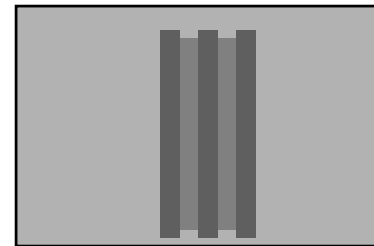
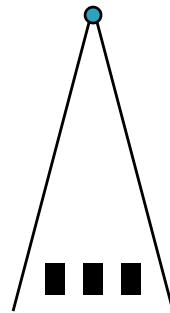
Contrast provided  
to film

Recorded  
Contrast

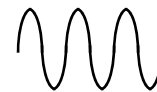


# MTF

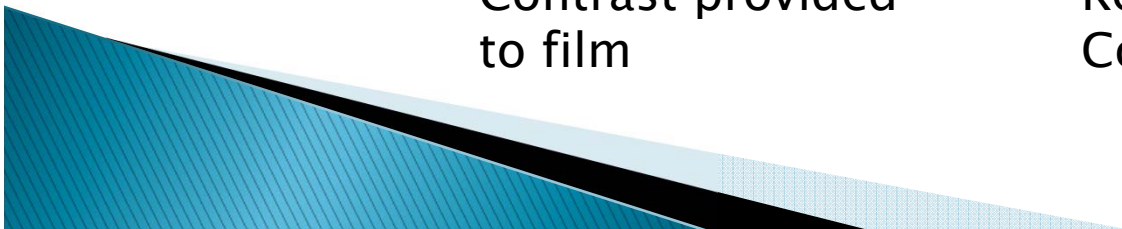
- ▶ If  $MTF = 0.5$ 
  - half of contrast reproduced at this frequency



Contrast provided  
to film

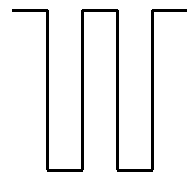
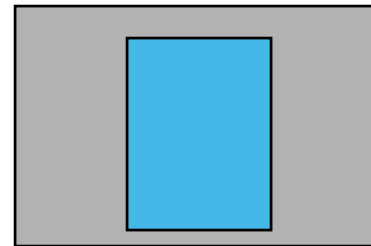
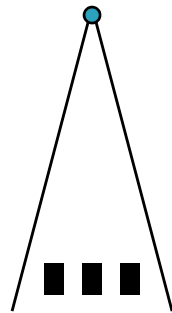


Recorded  
Contrast



# MTF

- ▶ If  $MTF = 0$ 
  - no contrast reproduced at this frequency



Contrast provided  
to film

Recorded  
Contrast

