Light and Color

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Key issues

- Physical
  - what makes a pixel take its brightness values?
- Inference
  - what can we recover from the world using those brightness values?
- Human
  - What can people do?
    - which suggests problems we might be able to solve

By nickwheeleroz, on Flickr

By nickwheeleroz, on Flickr

Processes

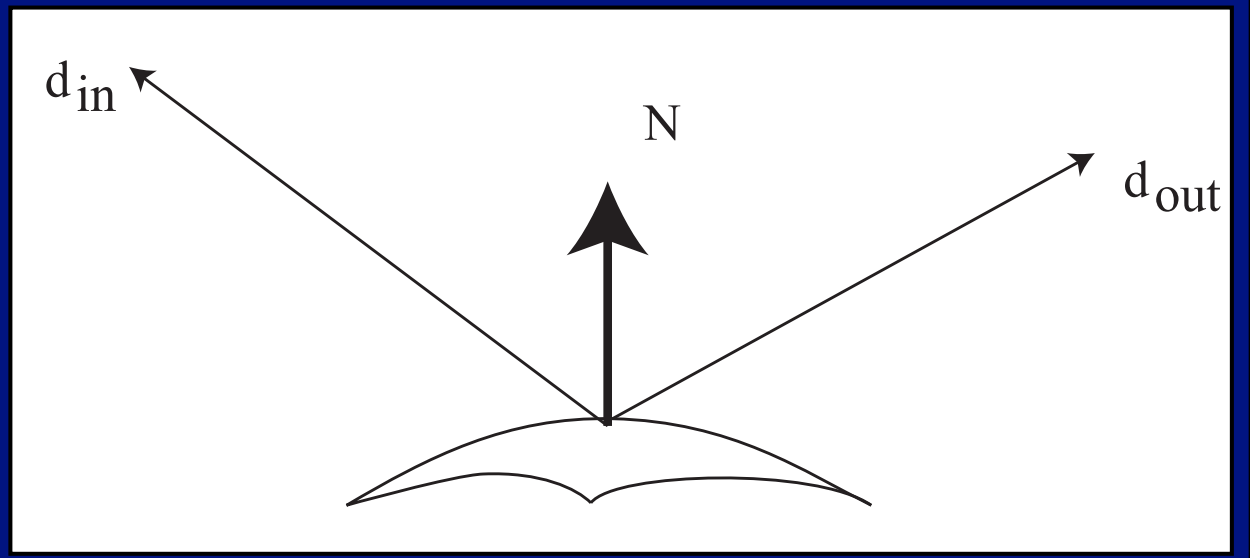
- Cameras
  - film: non-linear
  - CCD: linear, with non-linearities made by electronics
- Light
  - is reflected from a surface
  - got there from a source
- Many effects when light strikes a surface -- could be:
  - absorbed; transmitted; reflected; scattered
  - Simplify
    - Assume that
      - surfaces don't fluoresce
      - surfaces don't emit light (i.e. are cool)
      - all the light leaving a point is due to that arriving at that point


White light (indoor)


UV light (black-light)

Specularities

- For some surfaces, reflection depends strongly on angle
  - mirrors (special case)
    - incoming direction, normal and outgoing direction are coplanar
    - angle din, normal and angle dout, normal are the same
  - specular surfaces
    - light reflected in a “lobe” of directions
    - eg slightly battered metal surface
    - can see light sources specularly reflected
      - specularities



Flickr, by suzysputnik

Flickr, by piratejohnny

- Specularities are relatively easy to detect
  - small and bright (usually)

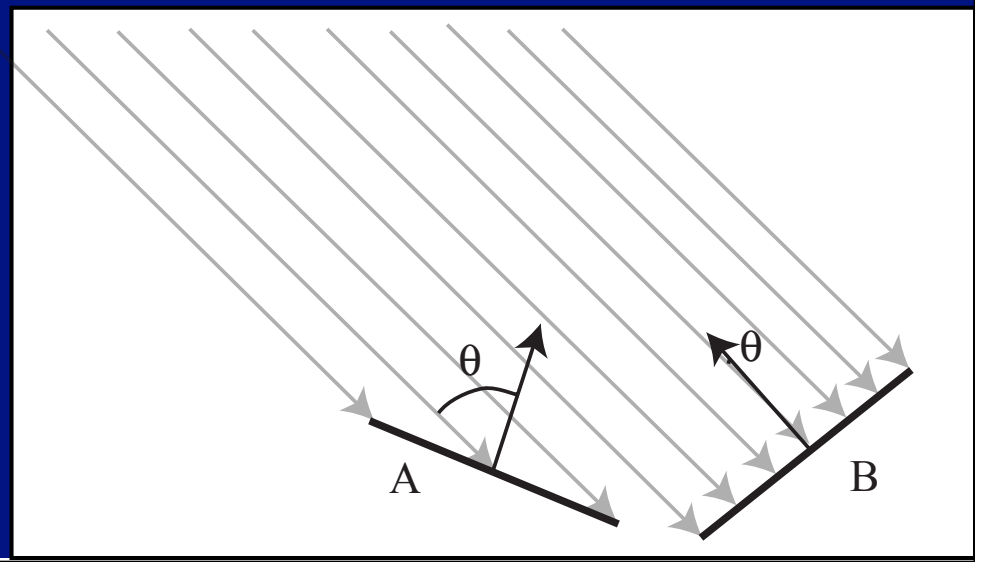
Diffuse reflection

- Light leaves the surface evenly in all directions
  - cotton cloth, carpets, matte paper, matte paints, etc.
  - most “rough” surfaces
  - Parameter: Albedo
    - percentage of light arriving that leaves
    - range 0-1
      - practical range is smaller

Point source at infinity

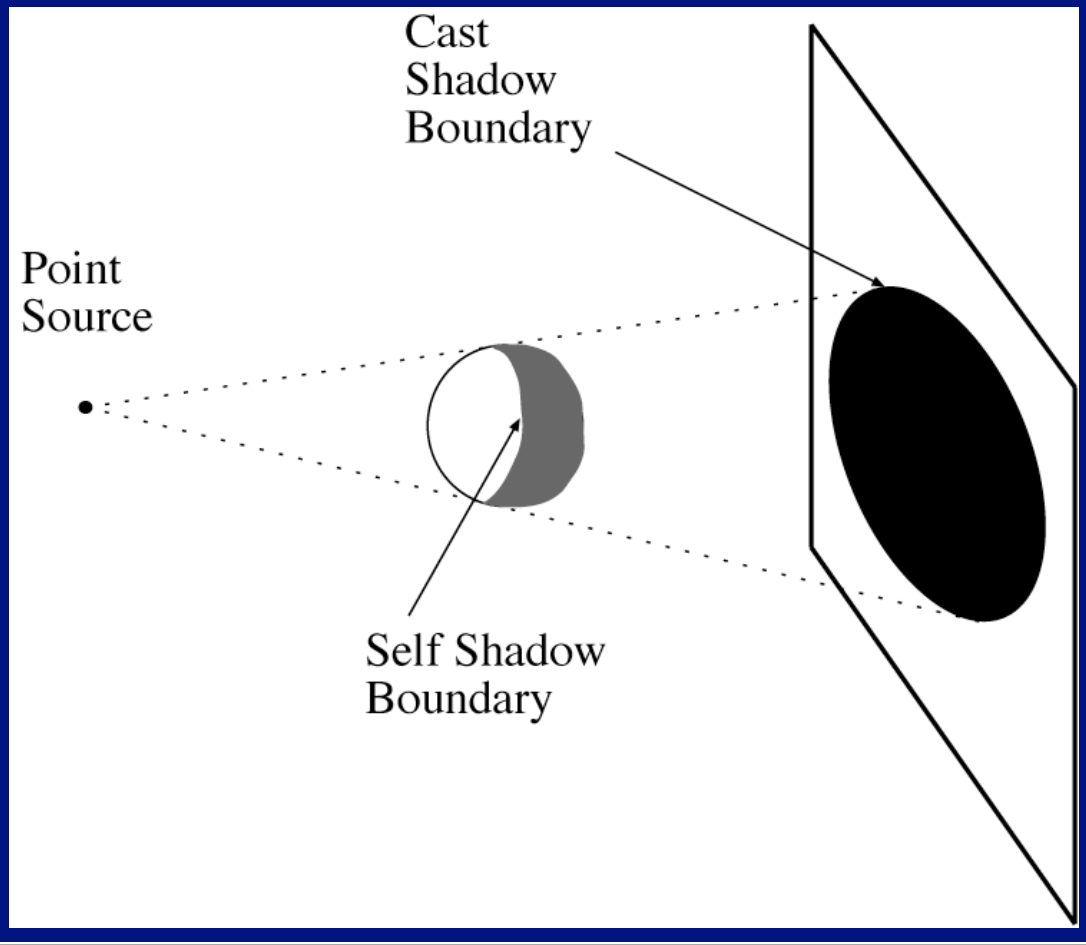
- E.g. the sun
  - energy travels in parallel rays
  - energy density received is proportional to cos theta
- Write:
  - p for albedo
  - S for source vector
  - N for normal
  - I for image intensity

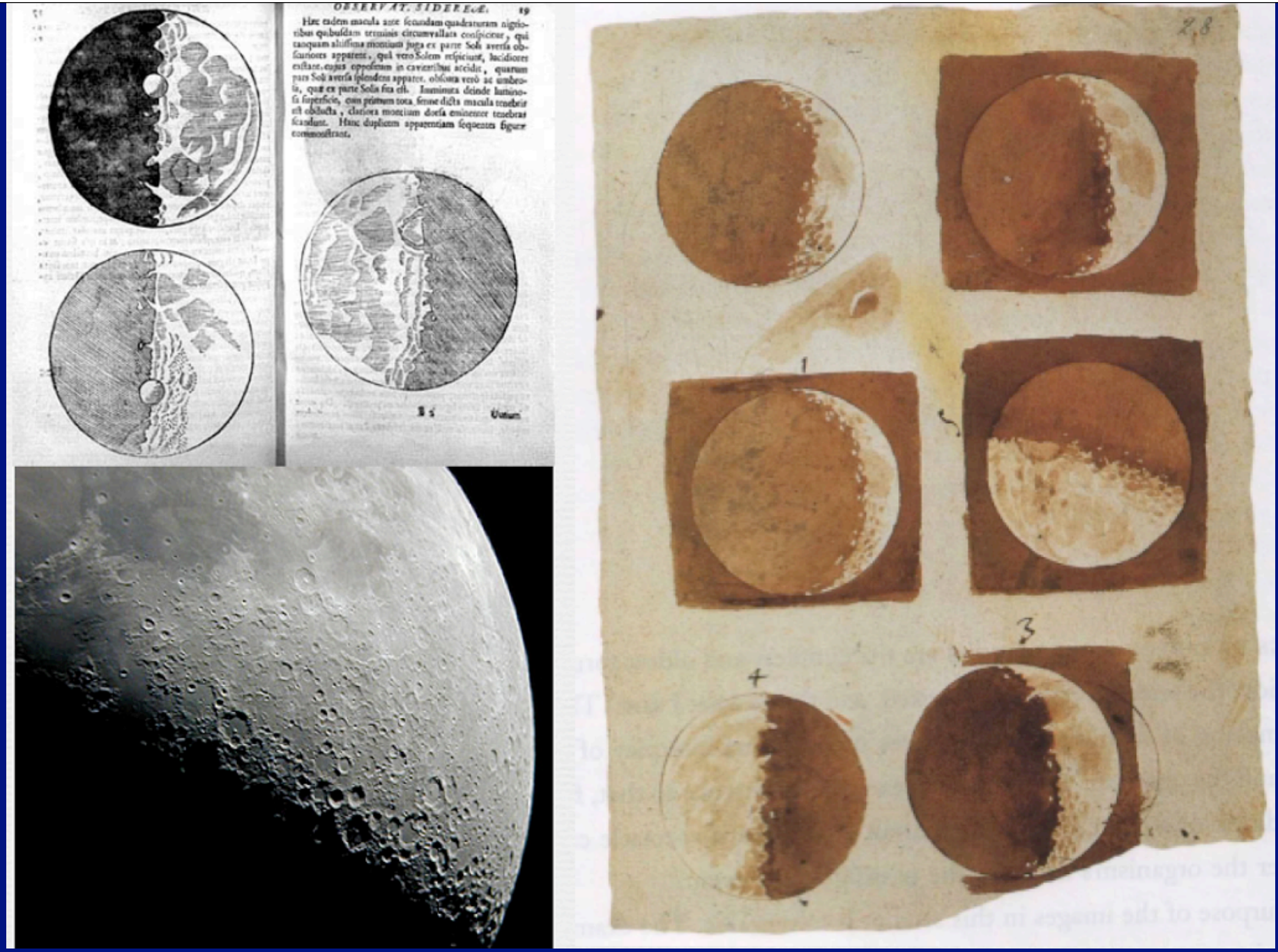
$$I(\mathbf{x}) = \rho(\mathbf{x})\mathbf{S} \cdot \mathbf{N}(\mathbf{x})$$



Shadows cast by a point source

- A point that can't see the source is in shadow
- For point sources, the geometry is simple



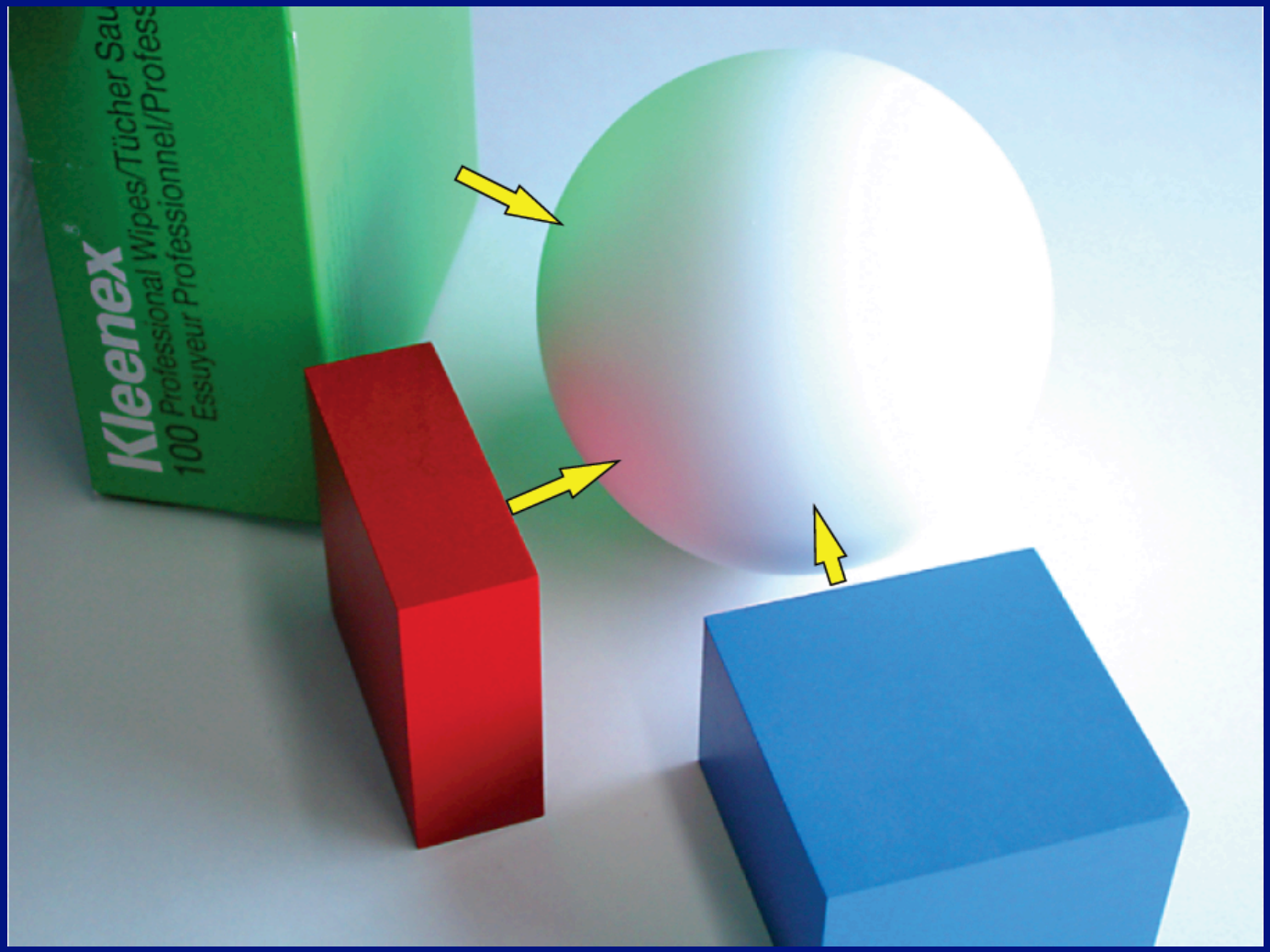


From Koenderink slides on image texture and the flow of light

Interreflections

- Issue:
  - local shading model is a poor description of physical processes that give rise to images
    - because surfaces reflect light onto one another
  - This is a major nuisance; the distribution of light (in principle) depends on the configuration of every radiator; big distant ones are as important as small nearby ones (solid angle)
  - The effects are easy to model
  - It appears to be hard to extract information from these models

Interreflections



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Causes of colour

- The sensation of colour is caused by the brain.
- One way to get it is the response of the eye to the presence/absence of light at various wavelengths.
  - Dreaming, hallucination, etc.
  - Pressure on the eyelids
- Light could be
  - emitted with wavelengths absent (flourescent light vs. incandescent light)
  - differentially reflected - e.g. paint on a surface
  - differentially refracted - e.g. Newton's prism
  - subject to wavelength dependent specular reflection (most metals).
  - Flourescence -
    - invisible wavelengths absorbed and reemitted at visible wavelengths.
  - Phosphorescence (ditto, energy, longer timescale)


XXXXX
BLUE
YELLOW
XXXXX
GREEN
BLUE
XXXXX
RED
GREEN
XXXXX
YELLOW
RED
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BLUE
YELLOW
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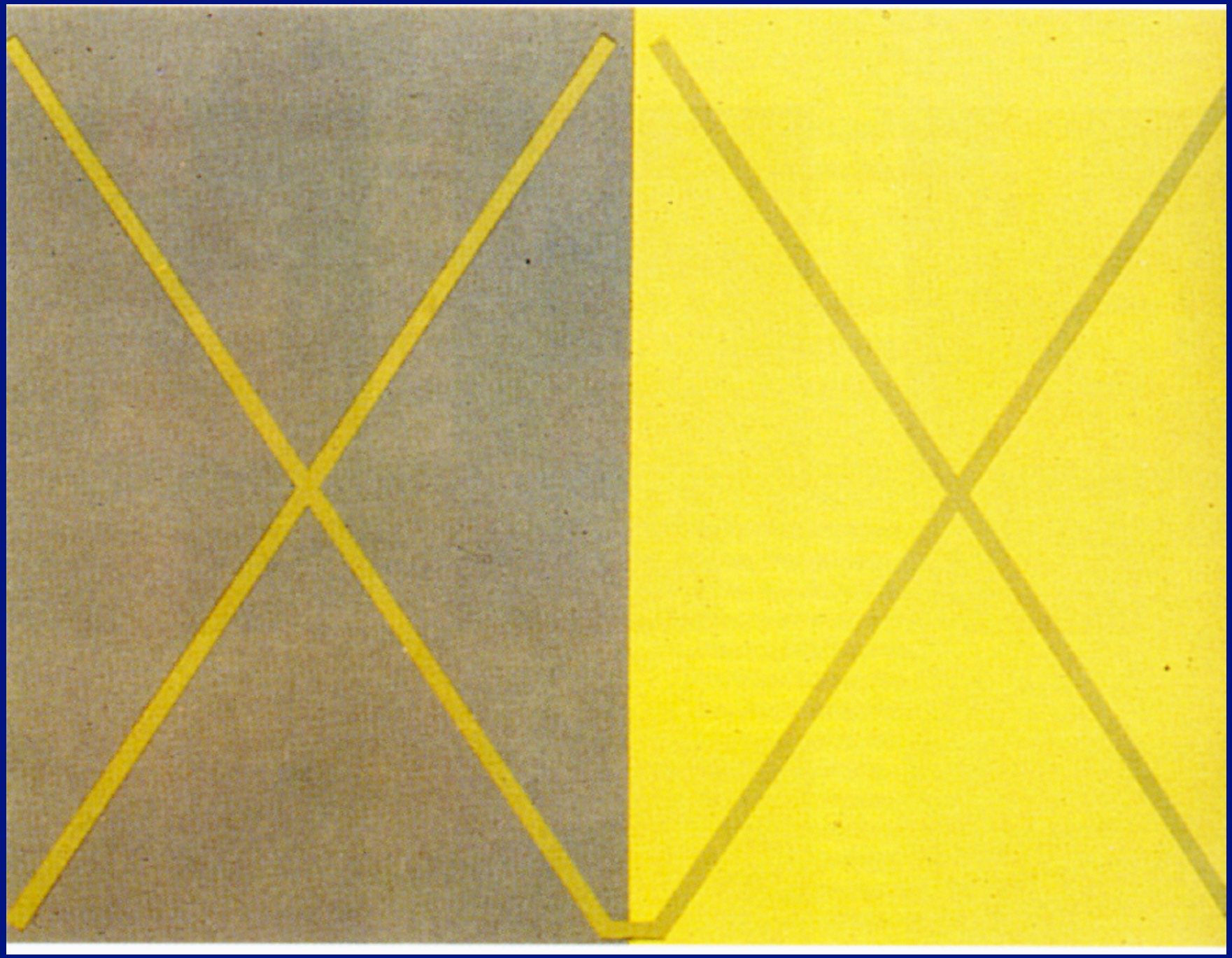
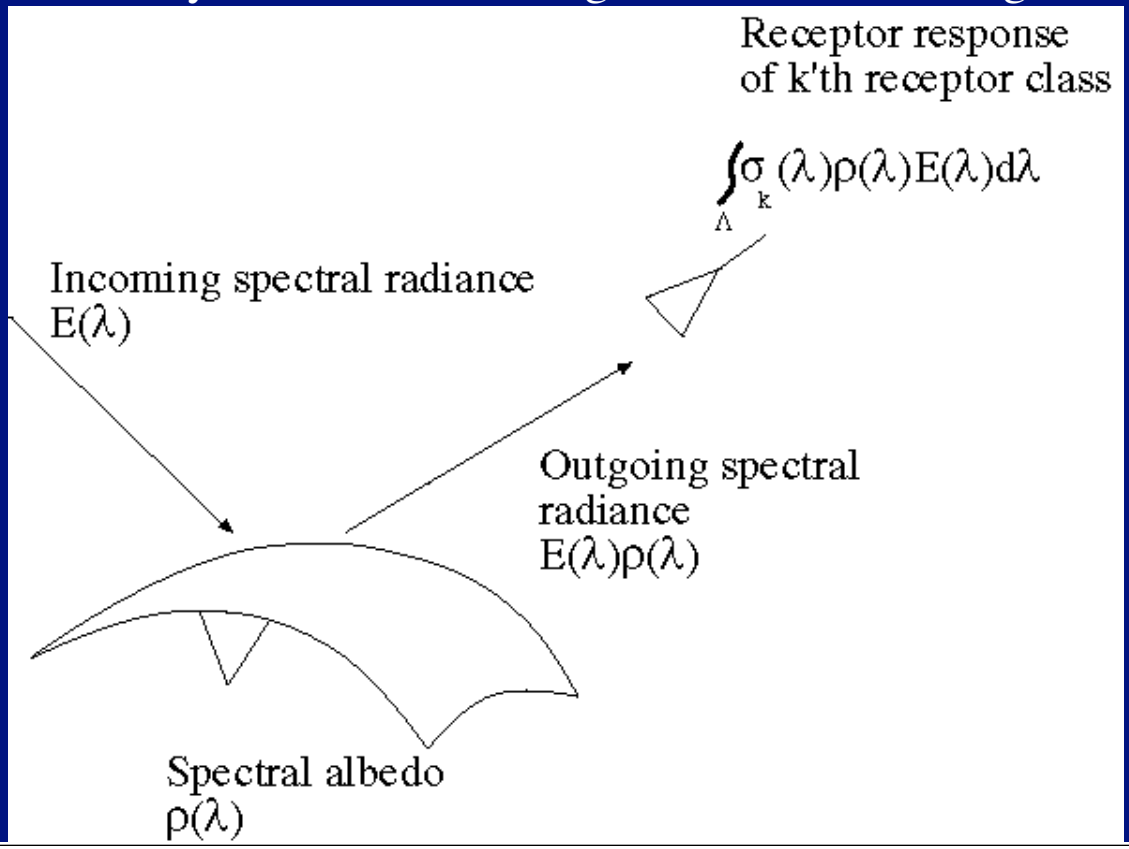


Trichromacy

- By experience, it is possible to match almost all colors, viewed in film mode using only three primary sources - the principle of trichromacy
- Other modes may have more dimensions
  - Glossy-matte
  - Rough-smooth
  - Most of what follows discusses film mode.

The color of objects

- Colored light arriving at the camera involves two effects
  - The color of the light source
  - The color of the surface
  - Changes caused by different colored light sources can be large



Color receptors and color deficiency

- Trichromacy is justified -
  - in color normal people, there are three types of color receptor (shown by molecular biologists).
- Some people have fewer;
  - most common deficiency is red-green color blindness in men. Red and green receptor genes are carried on the X chromosome. Most red-green color blind men have two red genes or two green genes. Yields an evolutionary story.
- Deficiency
  - can be caused by CNS, by optical problems in the eye, or by absent receptors
- Other color deficiencies:
  - Anomalous trichromacy
  - Achromatopsia
  - Macular degeneration

Stage lighting

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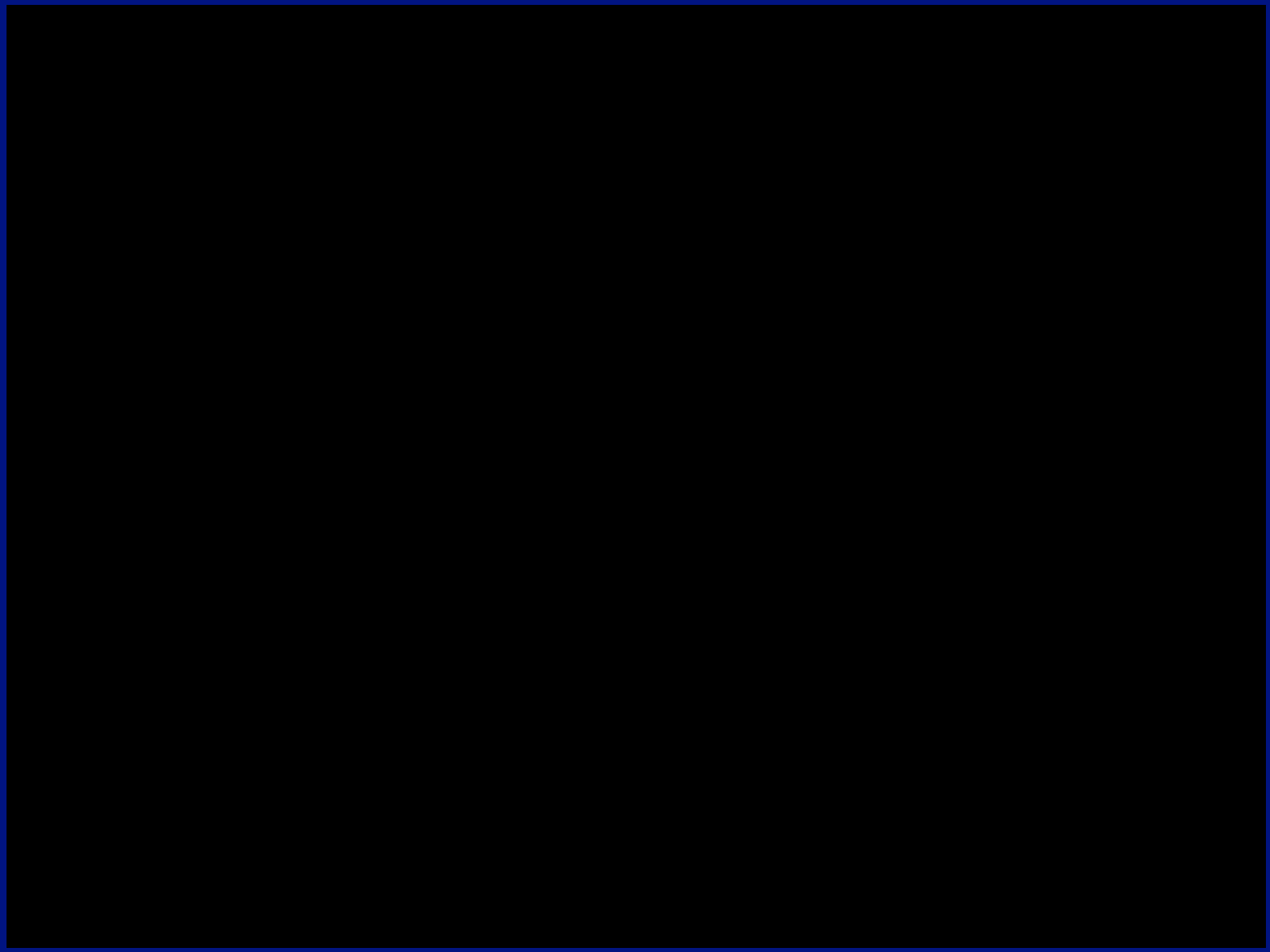

Karsch et al in review 10

Crucial points

- Image brightness affected by
  - albedo
  - surface orientation
  - light intensity
- Image color affected by
  - surface color
  - light color
  - there are methods to disentangle these effects
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