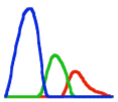
Camera summary

- Model for the brightness due to light reaching a region (say, CCD element)

$(R,G,B) = \int_{380}^{780}$  $*$  $d\lambda$

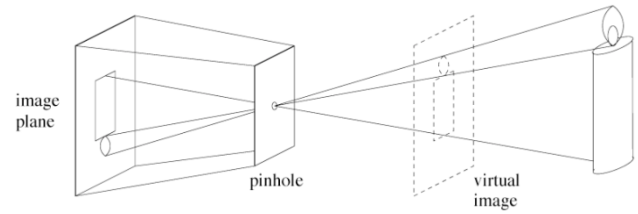
$$\upsilon^{(k)} = F^{(k)}(\rho^{(k)}) = F^{(k)}\left(\int L(\lambda)R^{(k)}(\lambda)d\lambda\right)$$

or

$$\rho^{(k)} = \mathbf{L} \bullet \mathbf{R}^{(\mathbf{k})}$$

- Spectral camera calibration task is to determine R (and F) from data.

- Model the image location corresponding to a point in the world by projection (developed using pinhole camera model).



- Represent using matrix multiplication in homogenous coordinates

- (u,v,w) = **M** * (X, Y, Z, 1)

- Geometric camera calibration task is to determine **M** from data.

Supplementary material

Real cameras

(Supplementary material on these topics posted on-line)

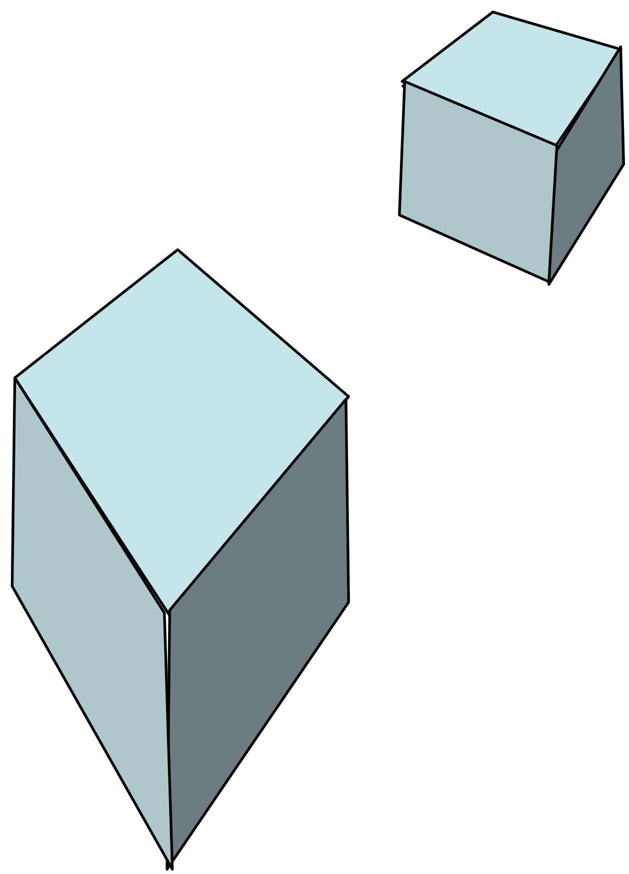
- Real cameras need lenses
  - Degree of focus now depends on distance (unlike pinhole cameras)
  - Various aberrations and distortions
    - E.g. Chromatic aberration
- Brightness falls off towards edges
  - Fall off due to projection onto flat surface
  - Vignetting
- Scattering at optical surfaces (flare)
- Capture process has many sources of noise

Big Picture (abstract template)

- What is the forward problem (and how do we model it)?
- What is the backwards (inverse) problem (and how can we solve it)?
- How does the forward model (prior knowledge), together with data (evidence) constrain the solution of the backwards problem?
- What ambiguities remain and how can they be resolved?

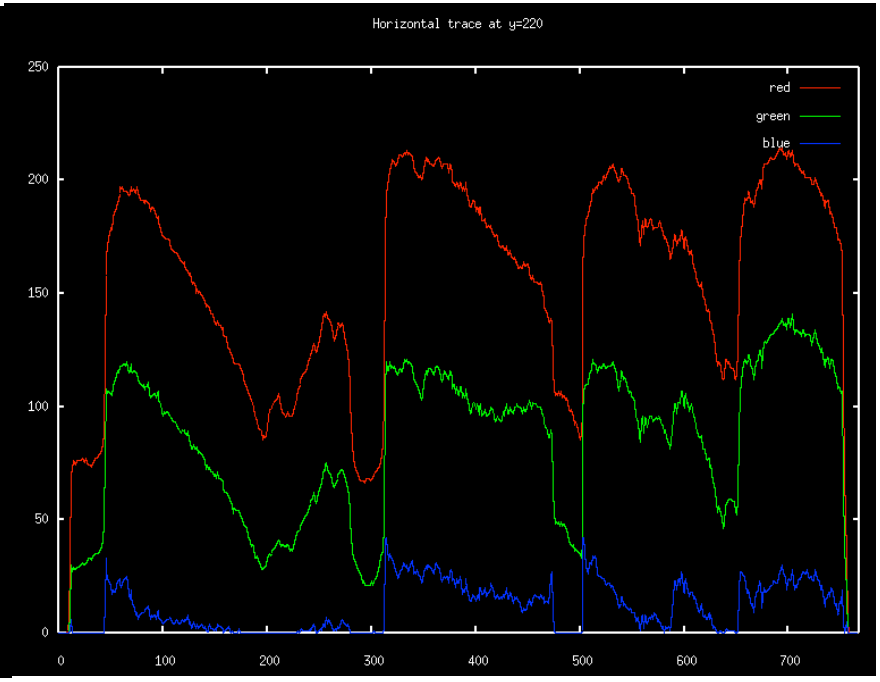
Big Picture (ambiguities)

- Given an image, what are the ambiguities and how can they be resolved?



Light interacting with the world

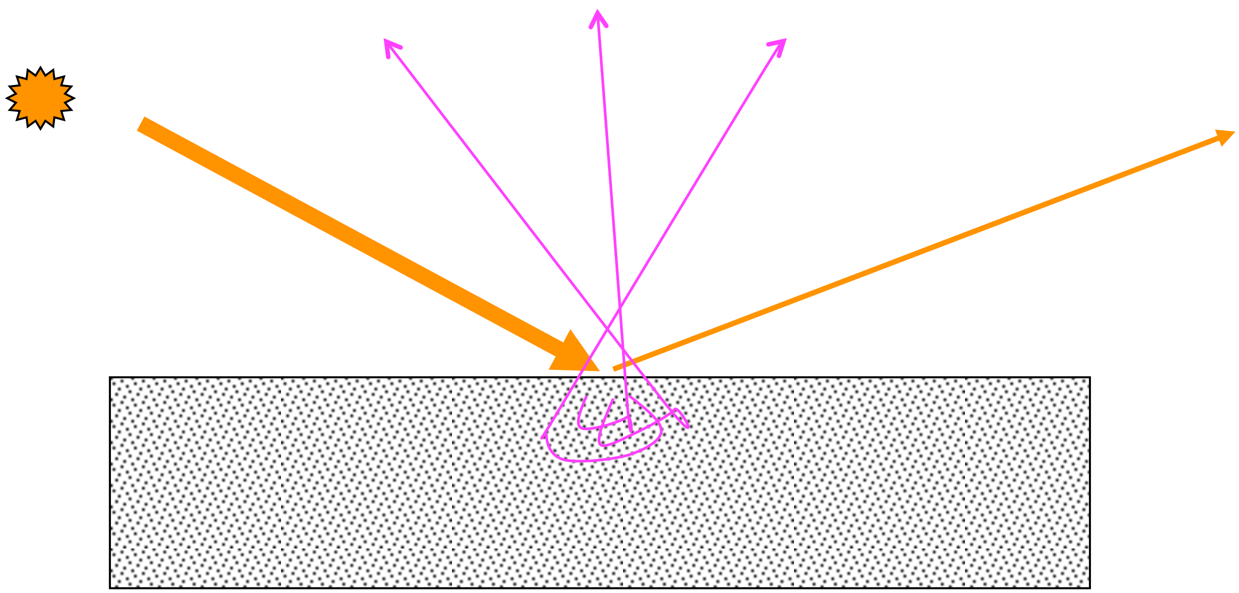
- The light captured by camera caries information about what is in the world **because** what is in the world interacts with it differently depending on 1) surface properties; and 2) geometry.



Light interacting with the world

- The light captured by camera caries information about what is in the world **because** what is in the world interacts with it differently depending on 1) surface properties; and 2) geometry.

- Many effects when light strikes a surface. It could be:
  - absorbed
  - transmitted
  - reflected
  - scattered (in a variety of directions!)



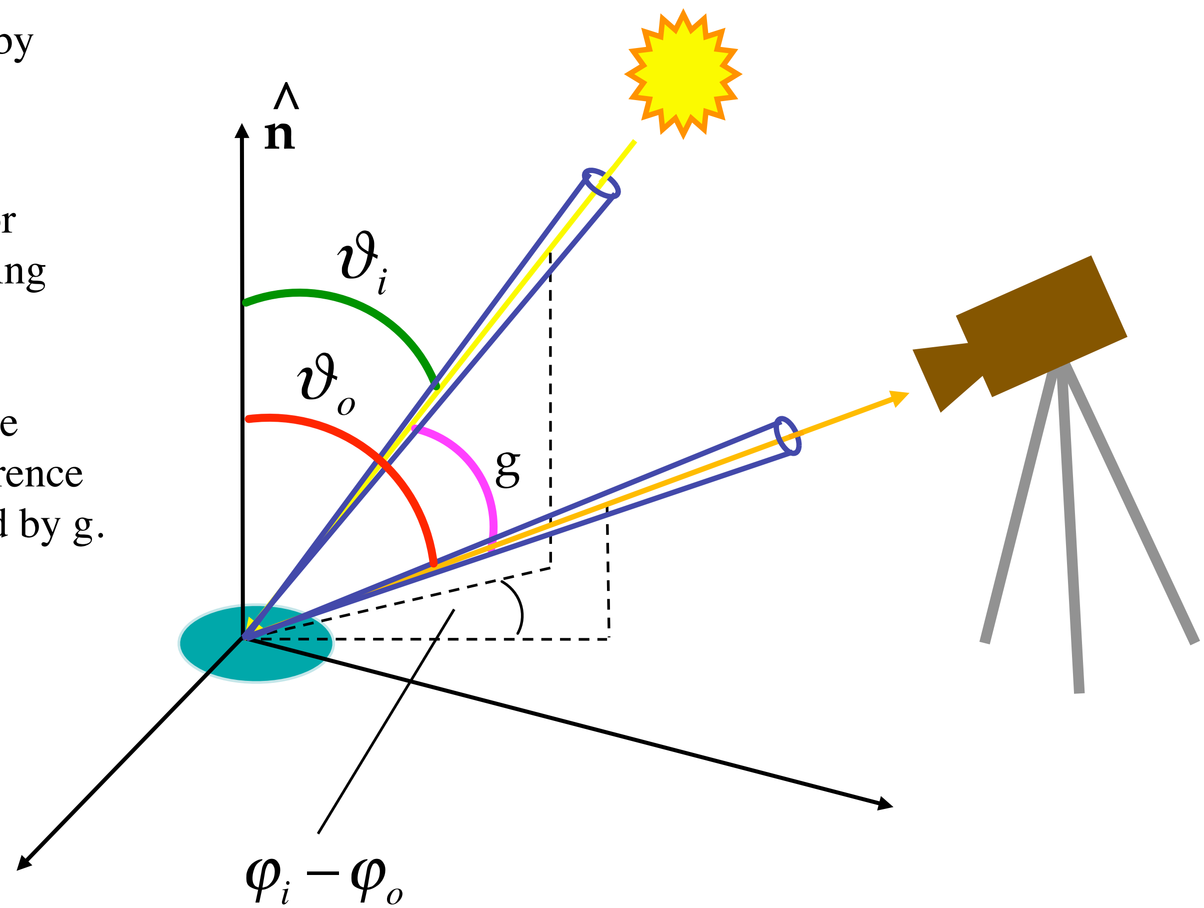
Bidirectional Reflectance Distribution Function (BRDF)

- The BRDF is a technical way of specifying how light from sources interacts with the matter in the world
- Understanding images requires understanding that this varies as a function of materials. The following “look” different
  - mirrors
  - white styrofoam
  - colored construction paper
  - colored plastic
  - gold
- The BRDF is the **ratio** of what comes out to what came in
- What comes out <--> “radiance”
- What goes in <--> “irradiance”
- Details on the BRDF available as supplementary material

Light incident on a spot from one particular direction characterized by angles (θ_i, φ_i), and reflected in one particular direction characterized by angles (θ_o, φ_o).

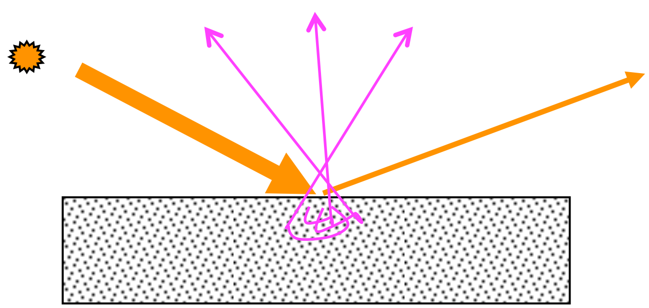
The BRDF records this transfer for **every** pair of incoming and outgoing angles.

If the surface is **isotropic**, then the transfer only depends on the difference $\varphi_i - \varphi_o$, or alternatively, encoded by g.



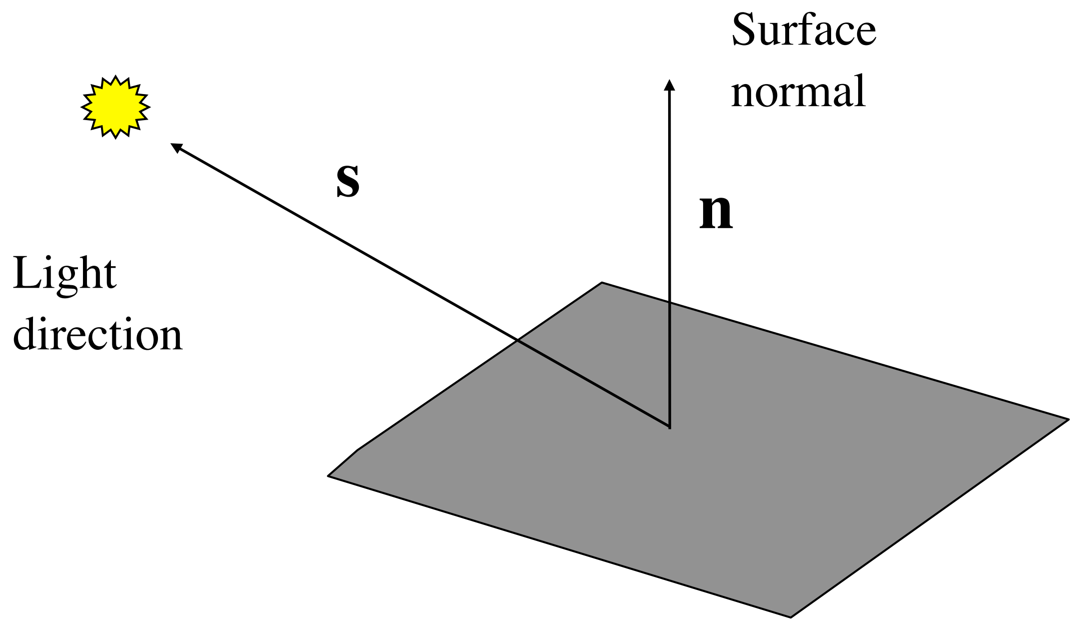
Lambertian surfaces

- Simple special case of reflectance: ideal diffuse or matte surface--e.g. cotton cloth, matte paper.
- Surface appearance is independent of viewing angle.
- Typically such a surface is the result of lots of scattering---the light "forgets" where it came from, and it could end up going in any random direction.



- What counts is how much light power reaches the surface

Lambertian Reflection

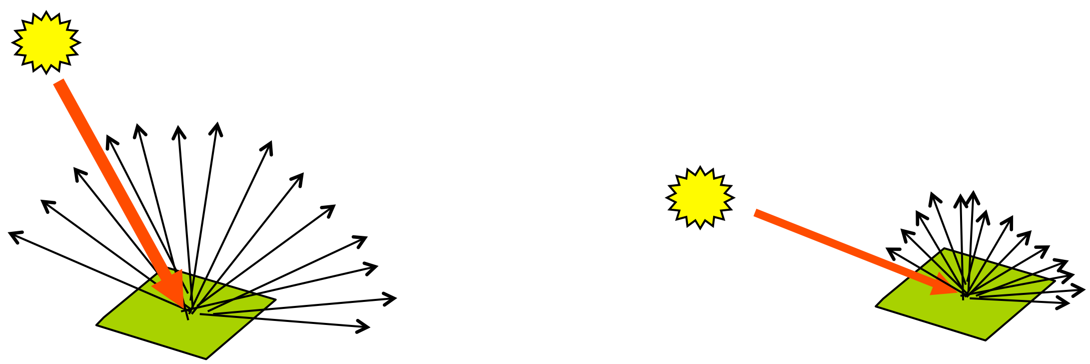


Brightness is proportional to **n•s**

Lambertian Reflection

Why is brightness proportional to **n•s** ?

Intuitive argument: The surface scatters light in all directions equally, but as the angle of the light becomes oblique, the amount of light per unit area received is reduced (foreshortened) by a factor of the cosine of the angle.

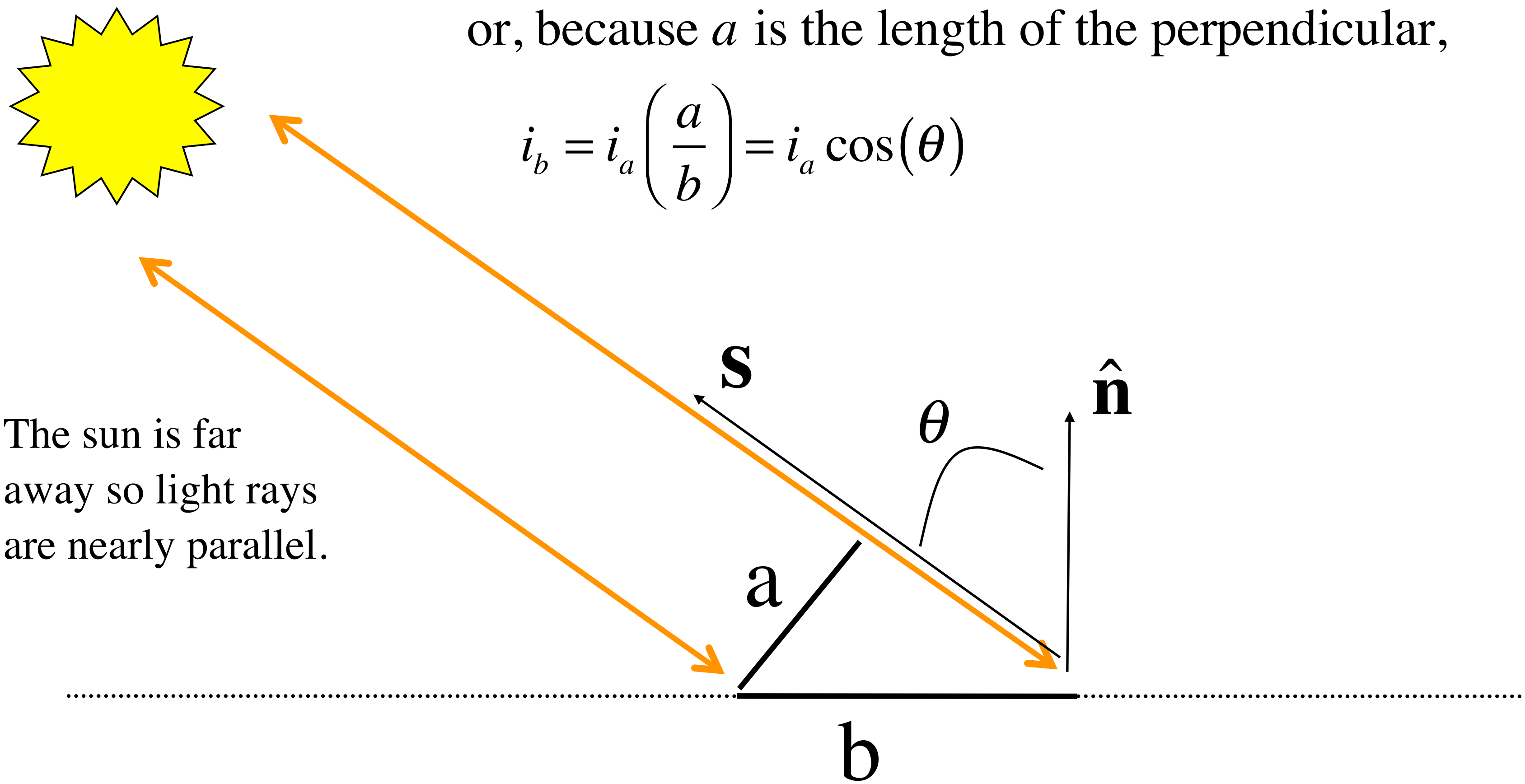


The same light spread over a, giving intensity, i_a, is also spread over b, giving intensity, i_b. This means that:

$$a \bullet i_a = b \bullet i_b$$

or, because a is the length of the perpendicular,

$$i_b = i_a \left(\frac{a}{b} \right) = i_a \cos(\theta)$$



The sun is far away so light rays are nearly parallel.