Color and Radiometry

Digital Image Synthesis

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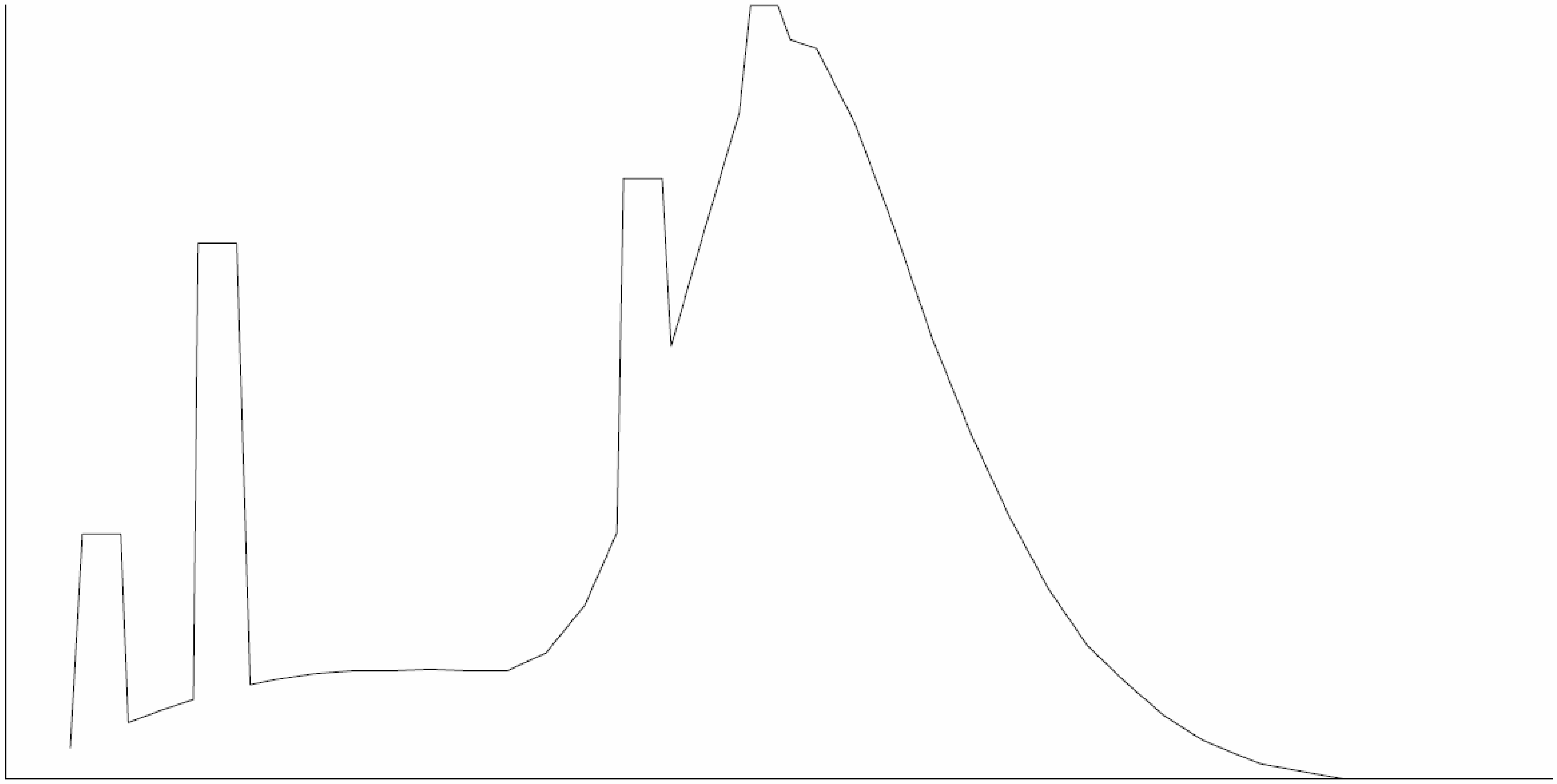
with slides by Pat Hanrahan and Matt Pharr

Radiometry

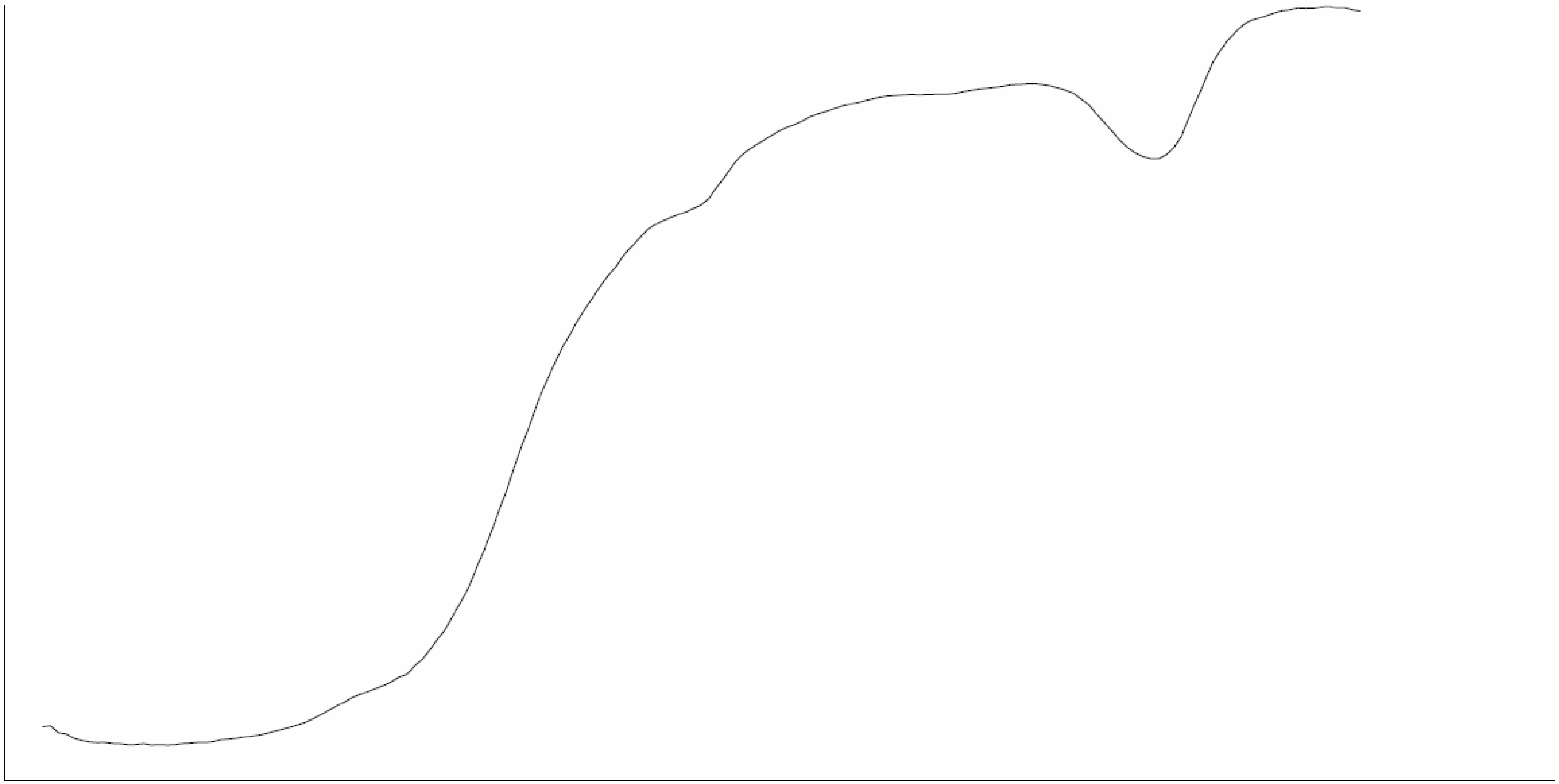
- Radiometry: study of the propagation of electromagnetic radiation in an environment
- Four key quantities: flux, intensity, irradiance and radiance
- These radiometric quantities are described by their spectral power distribution (SPD)

Spectral representation



fluorescent light

SPD



lemmon skin

Color

- Need a compact, efficient and accurate way to represent functions like these
- Find proper basis functions to map the infinite-dimensional space of all possible SPD functions to a low-dimensional space of coefficients
- For example, $B(\lambda)=1$, bad approximation

Spectrum

- In **core/color.***
- Not a plug-in, to use inline for performance
- **Spectrum** stores a fixed number of samples at a fixed set of wavelengths. Better for smooth functions.

```
#define COLOR_SAMPLE 3
class COREDLL Spectrum {
public:
  <arithmetic operations>
private:
  float c[COLOR_SAMPLES];
  ...
}
```

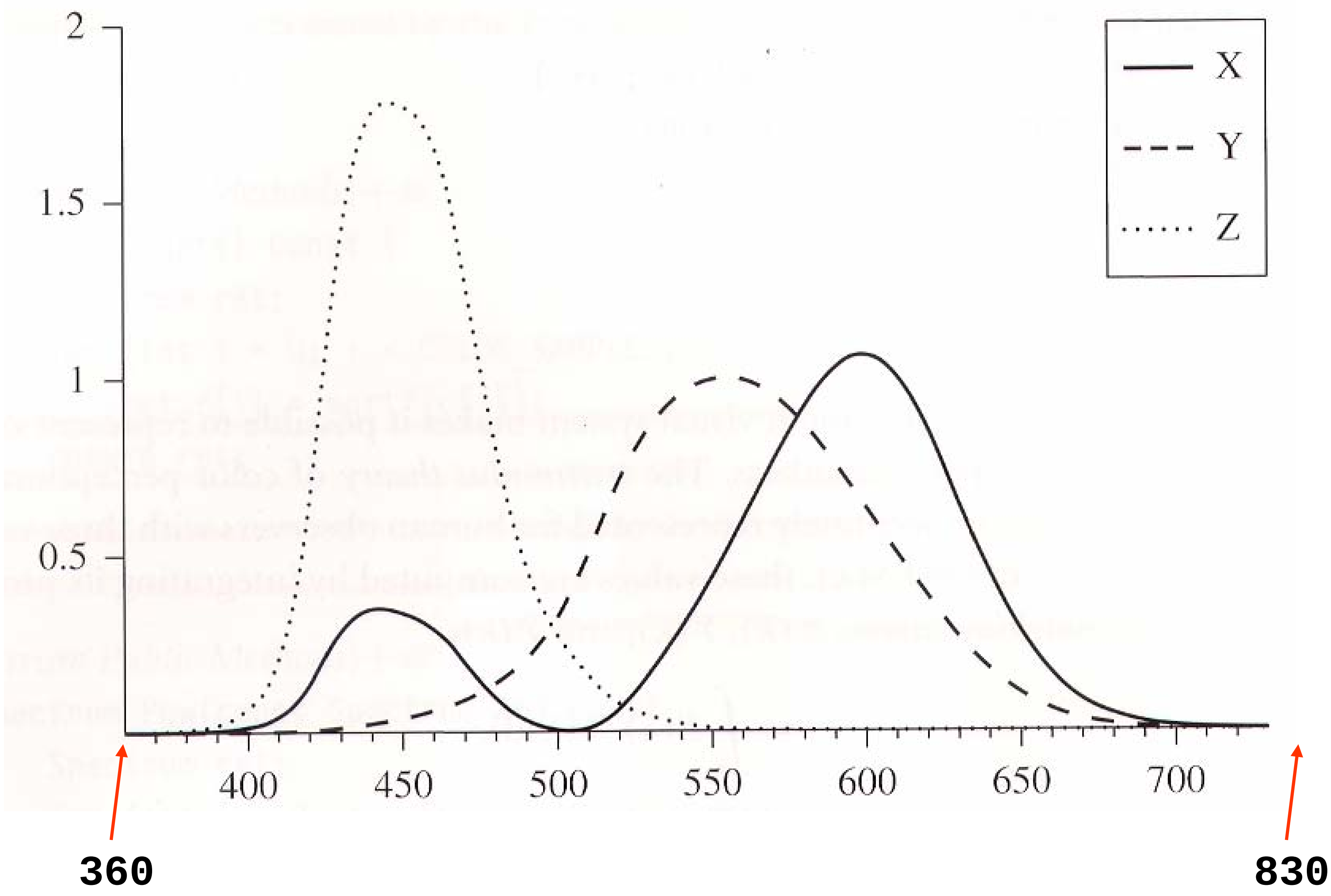
Human visual system

- Tristimulus theory: all visible SPDs can be accurately represented for human observers with three values, x_λ, y_λ and z_λ.
- The basis are the *spectral matching curves*, $X(\lambda)$, $Y(\lambda)$ and $Z(\lambda)$.
- Not a good model for computation

$$x_\lambda = \int_\lambda S(\lambda)X(\lambda)d\lambda$$

$$y_\lambda = \int_\lambda S(\lambda)Y(\lambda)d\lambda$$

$$z_\lambda = \int_\lambda S(\lambda)Z(\lambda)d\lambda$$


2
1.5
1
0.5
400
450
500
550
600
650
700
X
Y
Z
360
830

XYZ color

```
void XYZ(float xyz[3]) const {
  xyz[0] = xyz[1] = xyz[2] = 0.;
  for (int i = 0; i < COLOR_SAMPLES; ++i) {
    xyz[0] += XWeight[i] * c[i];
    xyz[1] += YWeight[i] * c[i];
    xyz[2] += ZWeight[i] * c[i];
  }
}
```

pbrt uses RGB

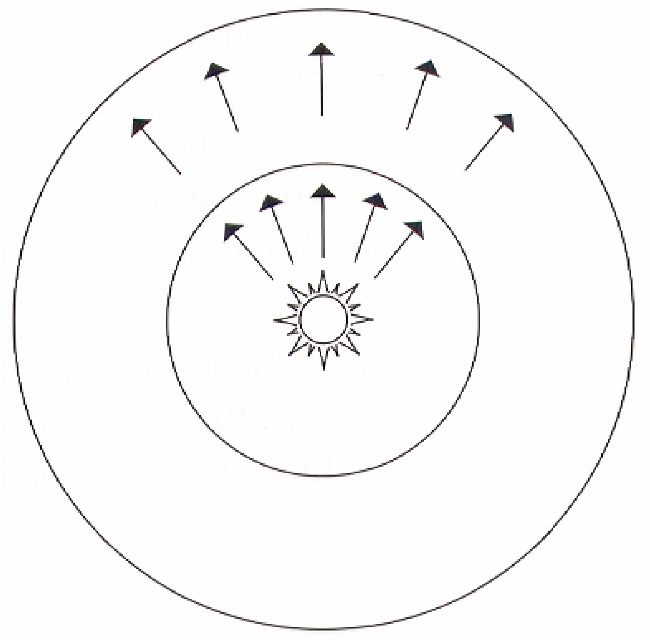
```
float Spectrum::XWeight[COLOR_SAMPLES] = {
  0.412453f, 0.357580f, 0.180423f
};
float Spectrum::YWeight[COLOR_SAMPLES] = {
  0.212671f, 0.715160f, 0.072169f
};
float Spectrum::ZWeight[COLOR_SAMPLES] = {
  0.019334f, 0.119193f, 0.950227f
};
Spectrum FromXYZ(float x, float y, float z) {
  float c[3];
  c[0] =  3.240479f * x + -1.537150f * y + -
  0.498535f * z;
  c[1] = -0.969256f * x +  1.875991f * y +
  0.041556f * z;
  c[2] =  0.055648f * x + -0.204043f * y +
  1.057311f * z;
  return Spectrum(c);
}
```

Basic radiometry

- Pbrt is based on Radiative transfer: study of the transfer of radiant energy based on radiometric principles and operates at the geometric optics level (light interacts with objects much larger than the light's wavelength)
- Based on the particle model, diffraction and interference can't be easily accounted for.

Flux (Φ)

- Radiant flux, power
- Total amount of energy passing through a surface per unit of time (J/s,W)



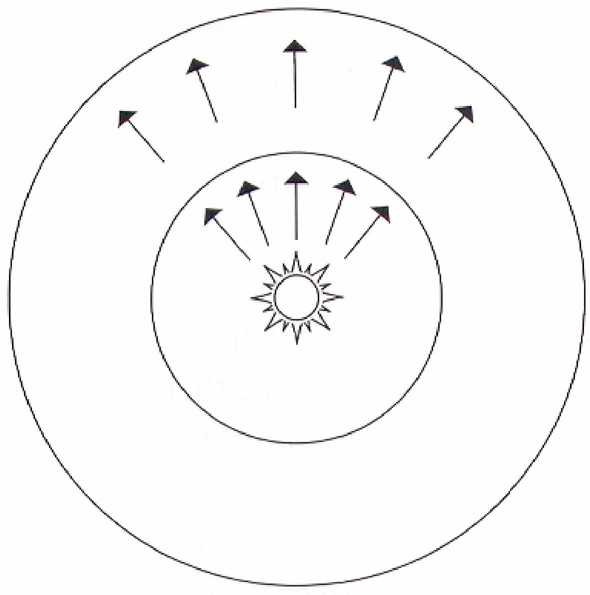
Irradiance (E)

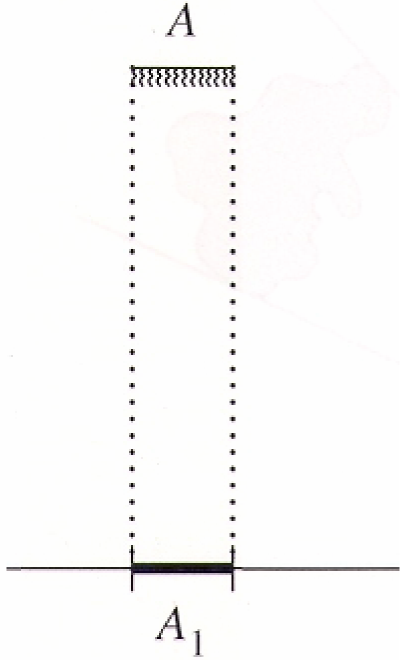
- Area density of flux (W/m^2) $E = \frac{d\Phi}{dA}$

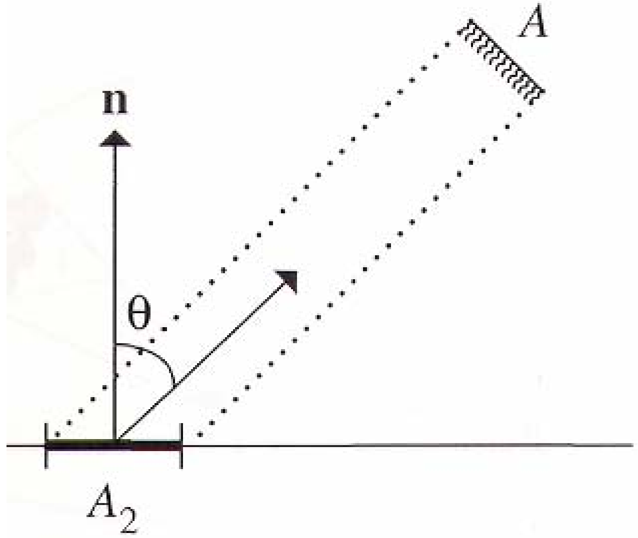
$$E = \frac{\Phi}{4\pi r^2}$$

$$E = \frac{\Phi}{A}$$

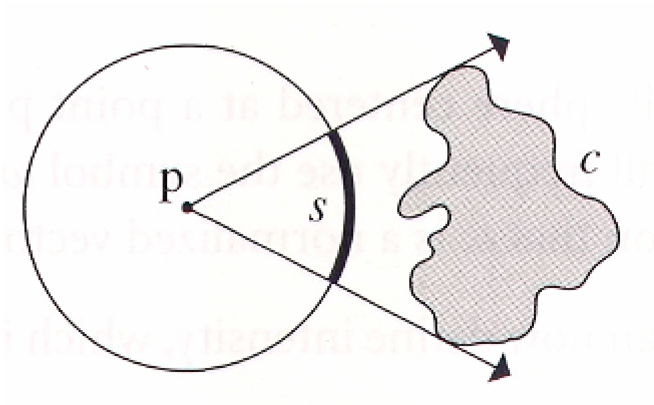
$$E = \frac{\Phi \cos\theta}{A}$$

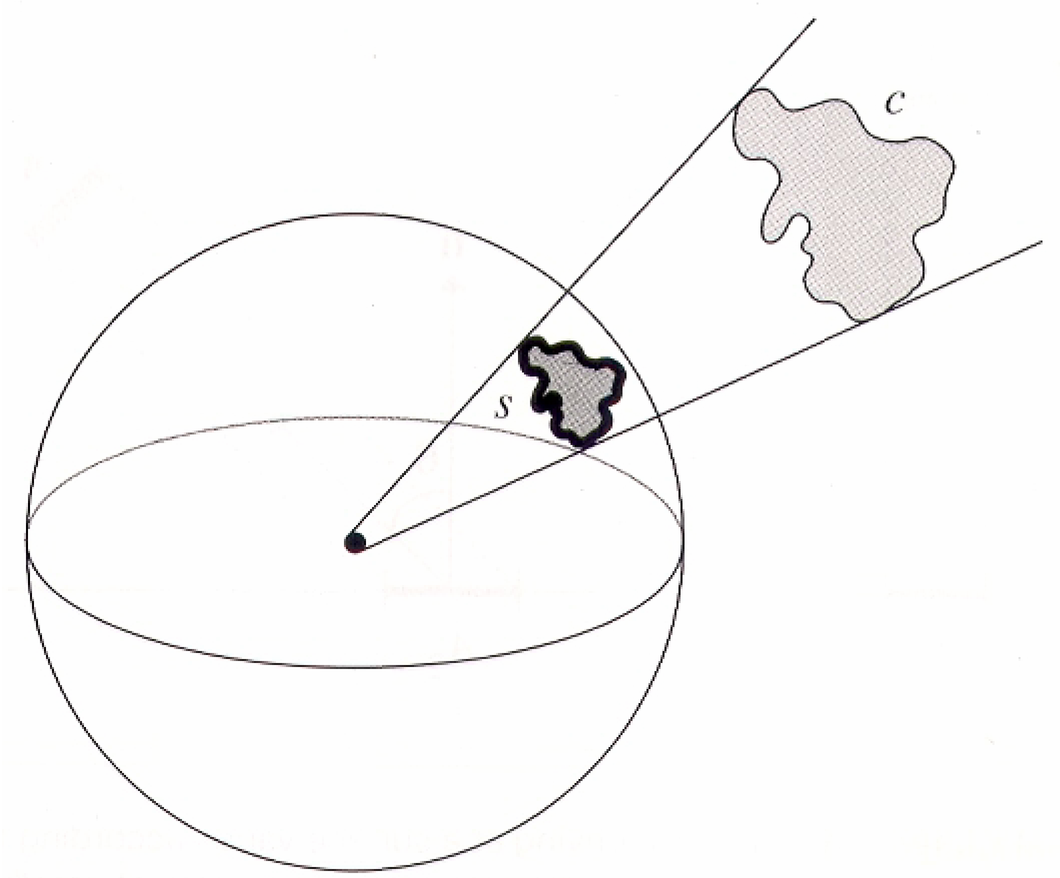






Solid angle





Intensity (I)

- Flux density per solid angle $I = \frac{d\Phi}{d\omega}$
- Intensity describes the directional distribution of light

Radiance (L)

- Flux density per unit area per solid angle

$$L = \frac{d\Phi}{d\omega dA^{\perp}}$$

- Most frequently used, constant along ray.
- All other quantities can be derived from radiance