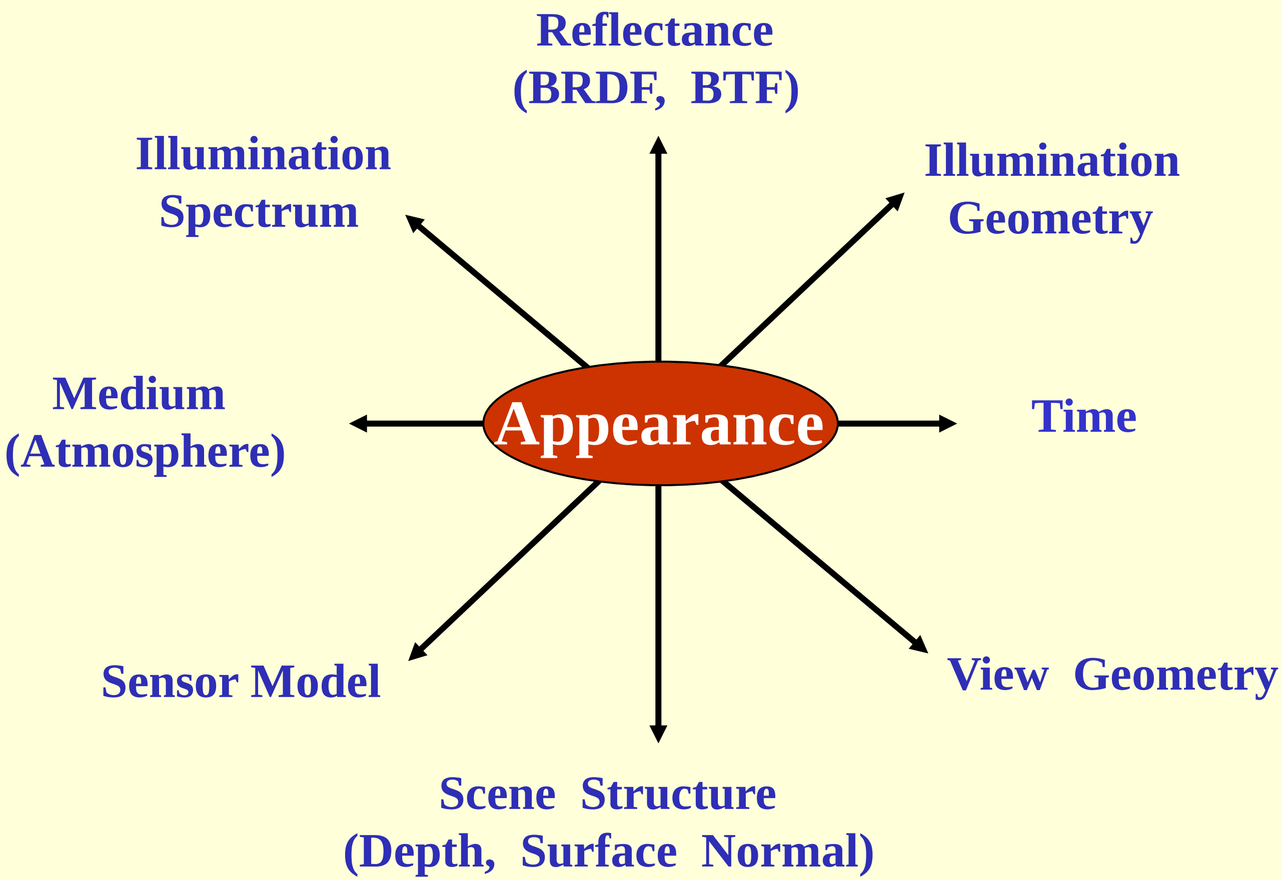
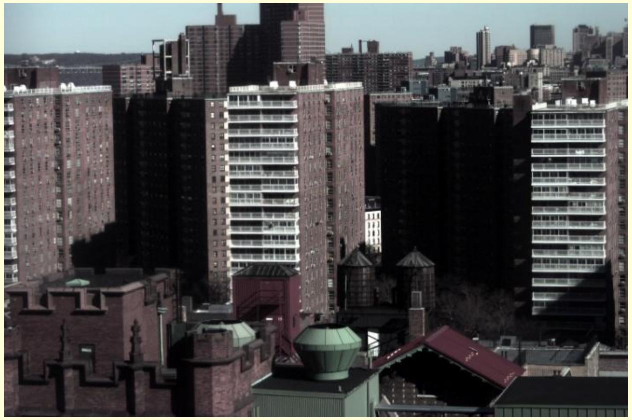
Lighting and Shadows

Thanks to Langer-Zucker, Henrik Wann Jensen, Ravi Ramamoorthi, Hanrahan, Preetham

Appearance of An Outdoor Scene



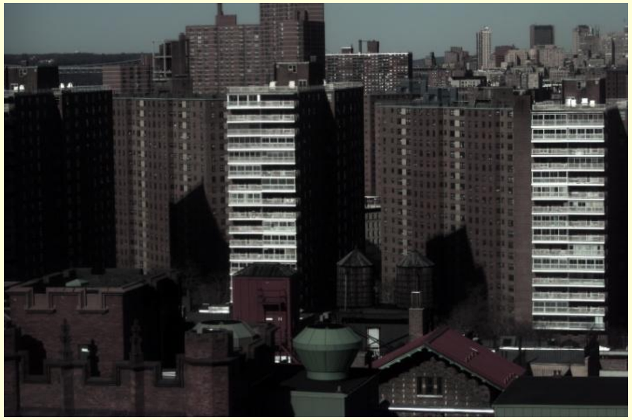
Illumination Direction



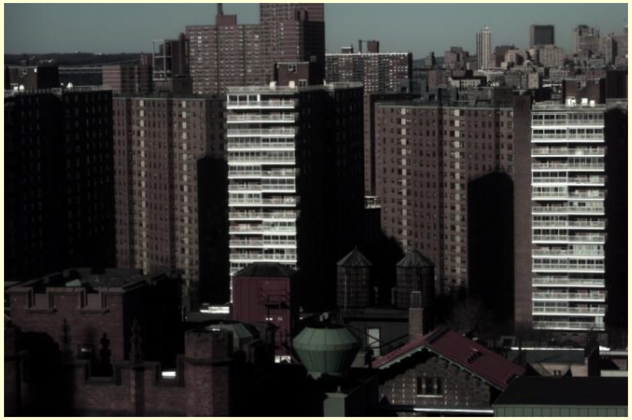
February 18th 2002, 10 AM
Clear and Sunny

February 18th 2002, 11 AM
Clear and Sunny

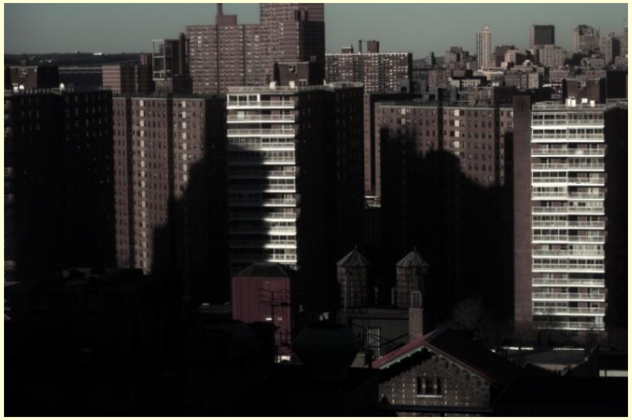
February 18th 2002, 12 Noon
Clear and Sunny



February 18th 2002, 2 PM
Clear and Sunny



February 18th 2002, 3 PM
Clear and Sunny



February 18th 2002, 4 PM
Clear and Sunny

Illumination Spectra

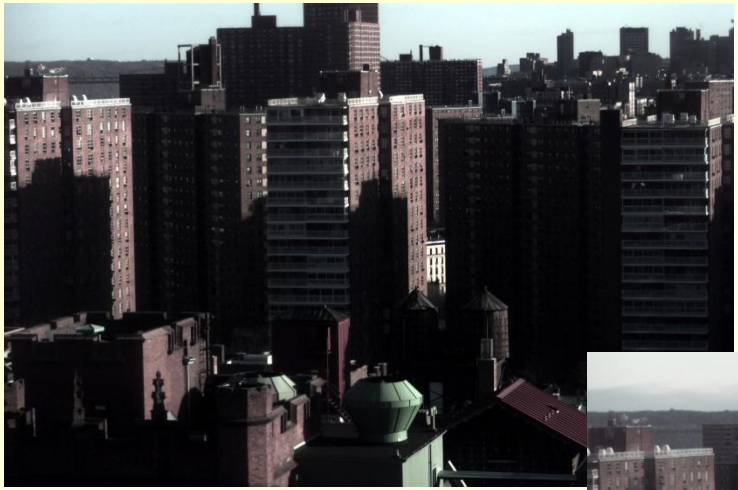
May 4th 2002, 6 AM
Clear Day, Sun Rise

May 4th 2002, 12 Noon
Clear Day, Noon

May 4th 2002, 6 PM
Clear Day, Sun Set

May 4th 2002, 9 PM
Clear Night

Cloud Cover



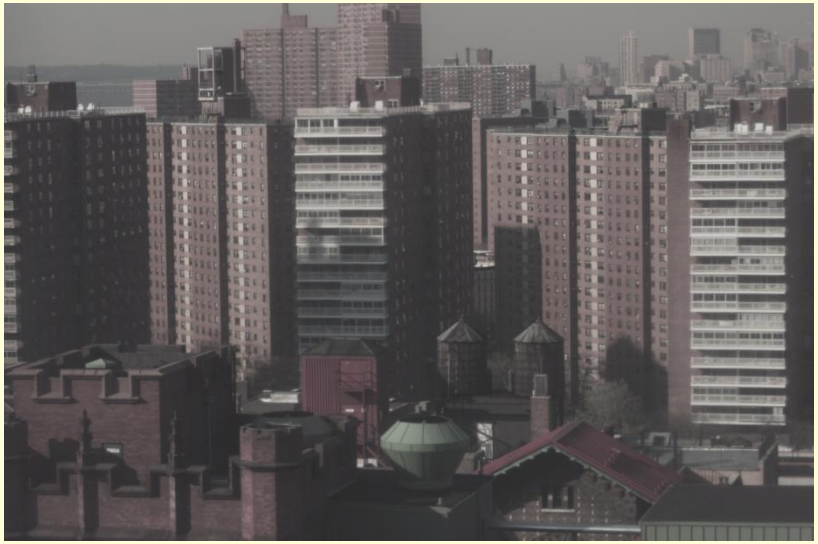
March 22nd 2002, 7 AM
Sunny, No Clouds

March 4th 2002, 7 AM
Partly Sunny, Partly Cloudy

March 13th 2002, 7 AM
Overcast

Sharper Shadows
Decreasing Cloud Cover

Weather Conditions



April 16th 2002, 3 PM
Sunny, Mild Haze

April 12th 2002, 3 PM
Overcast, Light Rain

April 19th 2002, 3 PM
Overcast, Dense Fog

April 28th 2002, 3 PM
Overcast, Dense Mist

Visibility

April 28th 2002, 6 AM
Rain & Mist, Visibility 2.5 miles
0.1 inches Precipitation last hour

April 28th 2002, 9 AM
Rain & Mist, Visibility 1.5 miles
0.23 inches Precipitation last hour

April 28th 2002, 12 Noon
Light Rain & Mist, Visibility 1.25 miles
0.08 inches Precipitation last hour

April 28th 2002, 3 PM
Dense Mist, Visibility 0.75 miles
0.02 inches Precipitation last hour

Four Seasons (New York)

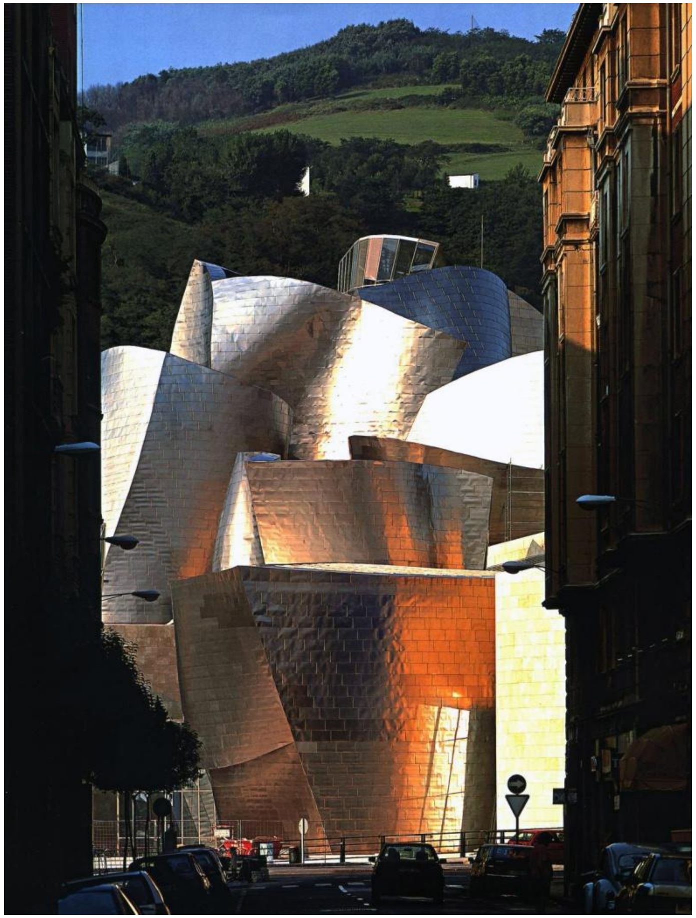
Winter, January 4th 2002, 9 AM
Clear and Sunny

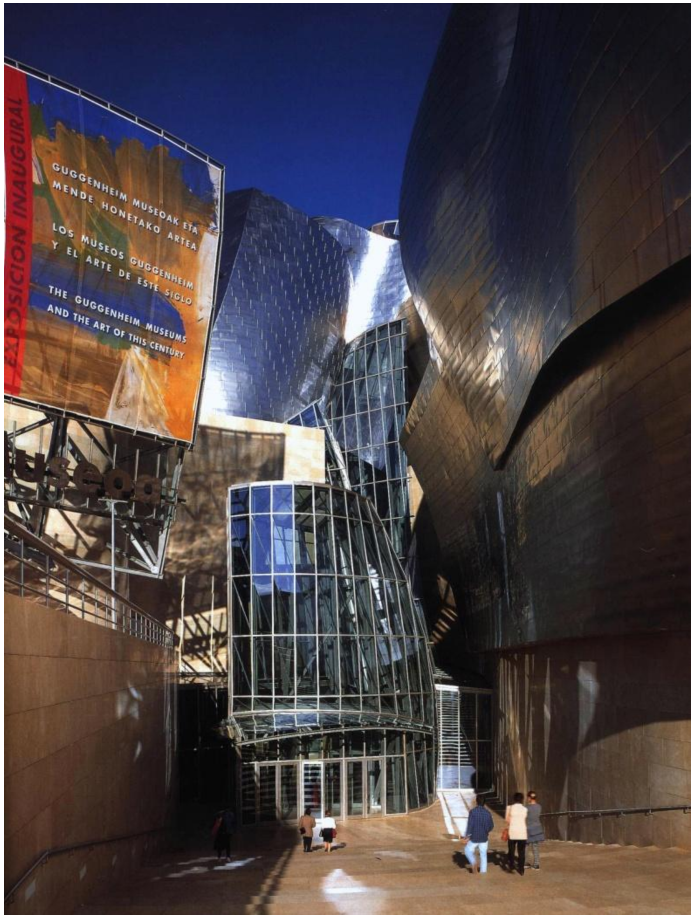
Fall, September 9th 2001, 9 AM
Clear and Sunny

Spring, March 14th 2001, 9 AM
Clear and Sunny

Summer, May 15th 2002, 9 AM
Clear and Sunny

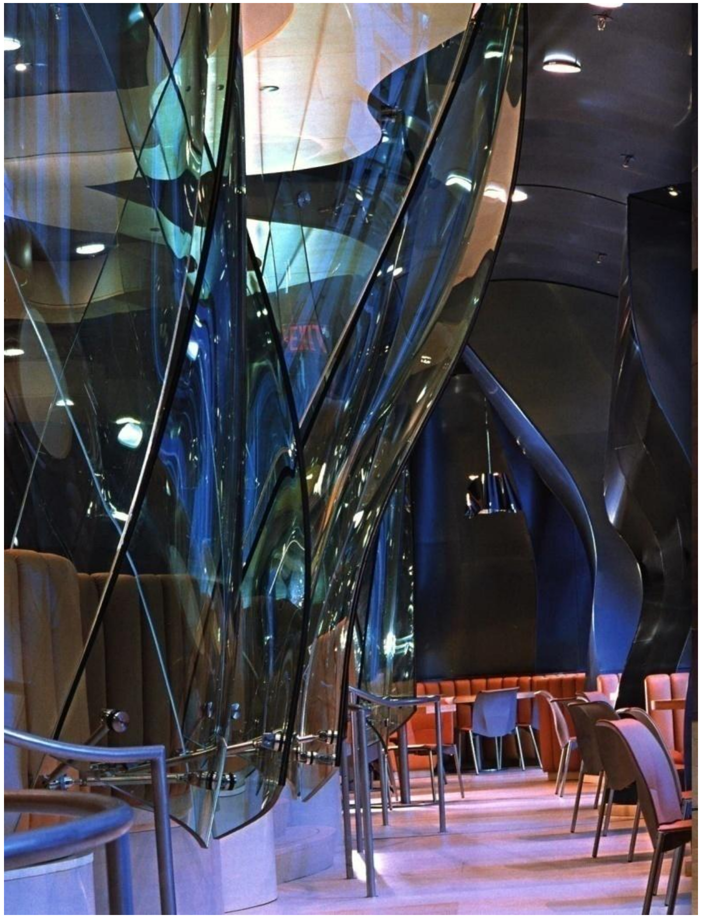
Lighting Design





- From *Frank Gehry Architecture*, Ragheb ed. 2001

Lighting Design

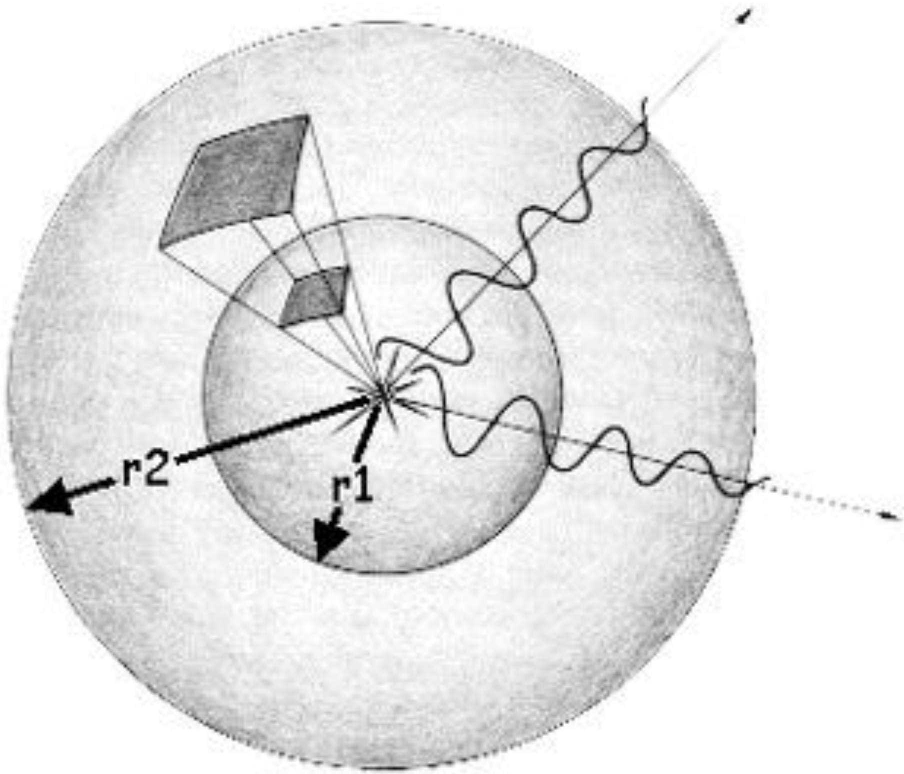


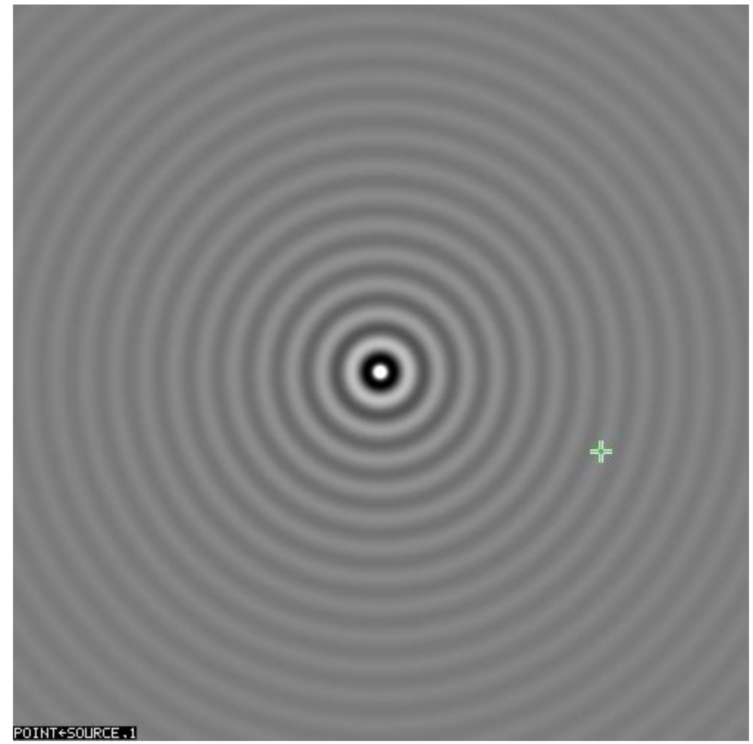
- From *Frank Gehry Architecture*, Ragheb ed. 2001

Nomenclature for Lighting

Size:	point line area volume	Distance:	infinity near-field
Directionality:	collimated divergent convergent	Temporal:	static time-varying
Natural	sun sky firefly moon	Artificial	halogen fluorescent flash projector laser

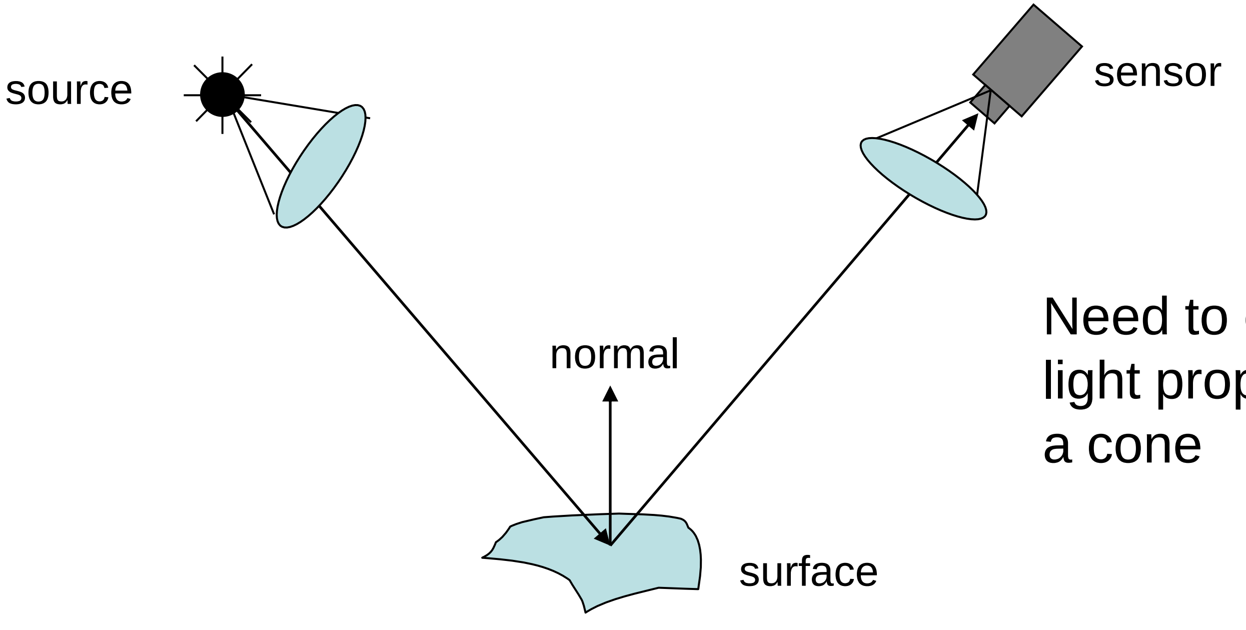
Isotropic Point Light Source





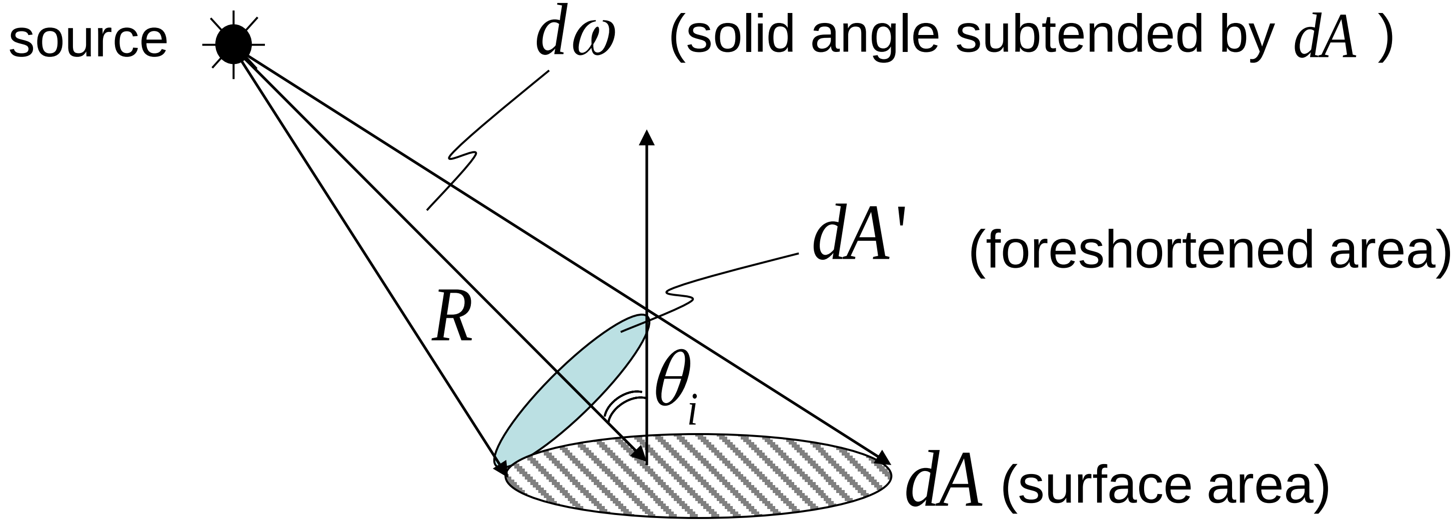
We see an inverse distance squared fall off in intensity.
Here light does not weaken, but only spreads in a sphere.

How to quantify light?



Need to consider light propagation in a cone

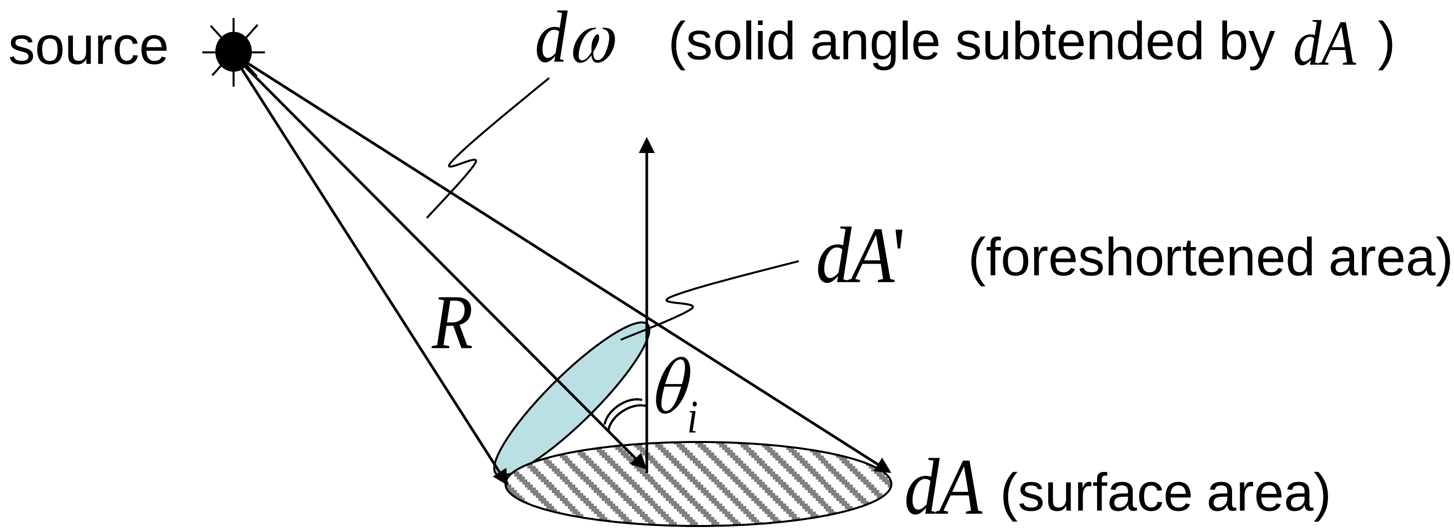
Solid Angle



Solid Angle : $$d\omega = \frac{dA'}{R^2} = \frac{dA\cos\theta_i}{R^2}$$ (steradian)

What is the solid angle subtended by a hemisphere?

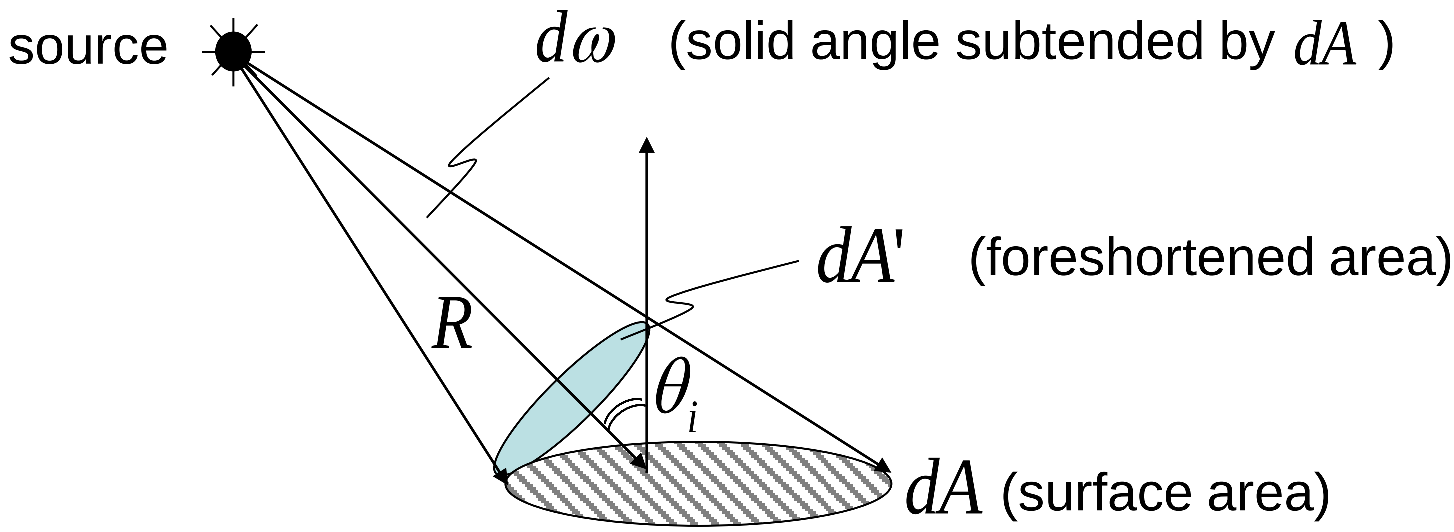
Radiant Intensity of Source



Radiant Intensity of Source : $$I = \frac{d\Phi}{d\omega}$$ (watts / steradian)

Light Flux (power) emitted per unit solid angle

Surface Irradiance

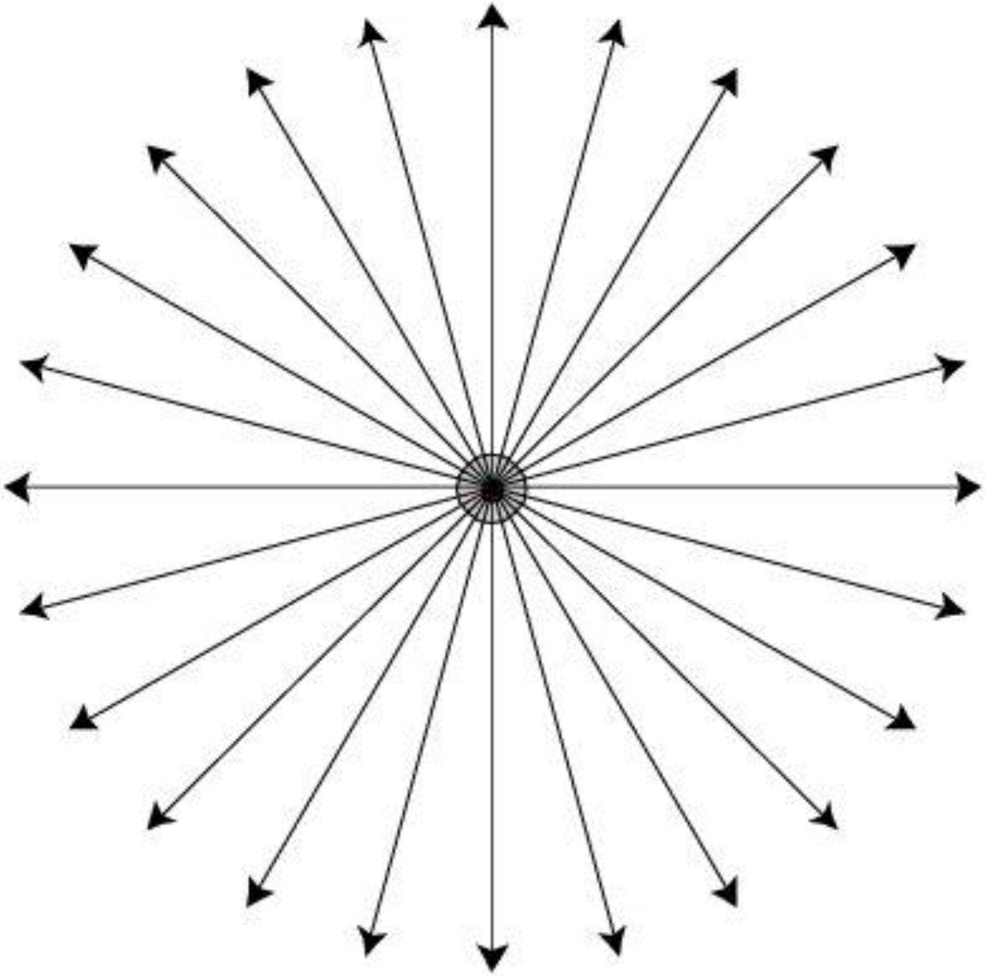


Surface Irradiance : $$E = \frac{d\Phi}{dA}$$ (watts / m^2)

Light Flux (power) incident per unit surface area.

Does not depend on where the light is coming from!

Isotropic Point Source



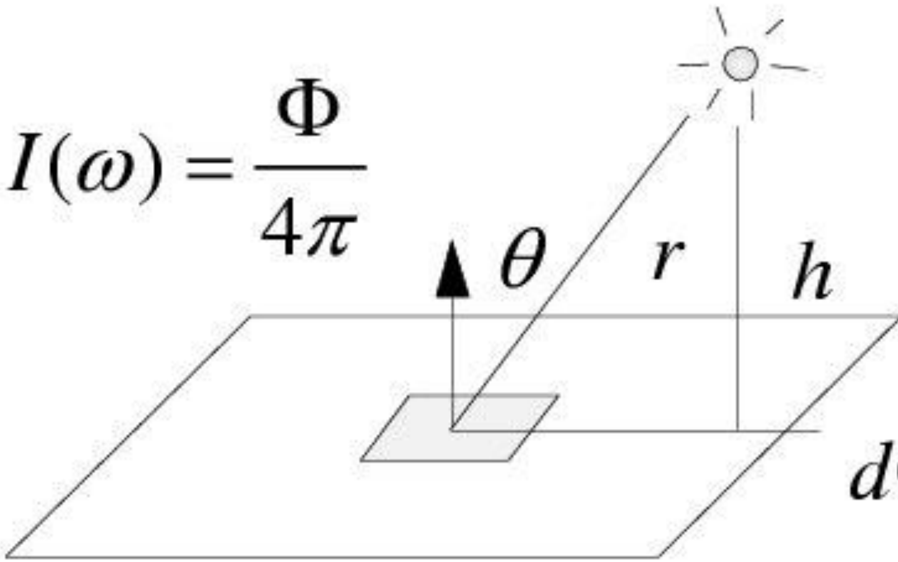
$$\Phi = \int_{S^2} I \, d\omega$$

$$= 4\pi I$$

$$I = \frac{\Phi}{4\pi}$$

Illumination: Isotropic Point Source

$$I(\omega) = \frac{\Phi}{4\pi}$$



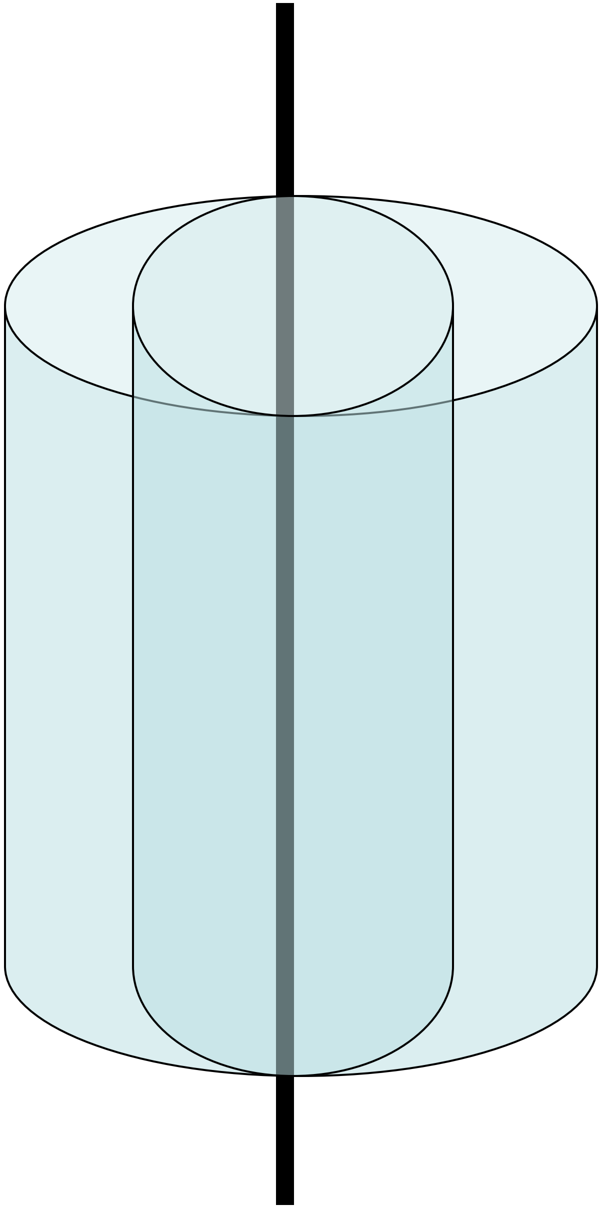
$$d\Phi = I\, d\omega = E\, dA$$

$$I\, d\omega = \frac{\Phi}{4\pi} \frac{\cos\theta}{r^2} dA = E\, dA$$

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

$$\frac{\Phi}{4\pi} \frac{\cos\theta}{r^2} \Rightarrow \frac{\Phi}{4\pi} \frac{\cos^3\theta}{h^2}$$

Infinite Line Source



Line source shows cylindrical symmetry.

The intensity fall-off is inversely proportional to distance from the line source. Why?

$$d\Phi = I \, d\omega = E \, dA$$

Infinite Planar Area Source

- Assume every point on the plane is an isotropic point light source.
- We saw inverse squared fall off, inverse fall off…so, this must be…

- Intensity CONSTANT with respect to distance! WHY?

As distance increases,

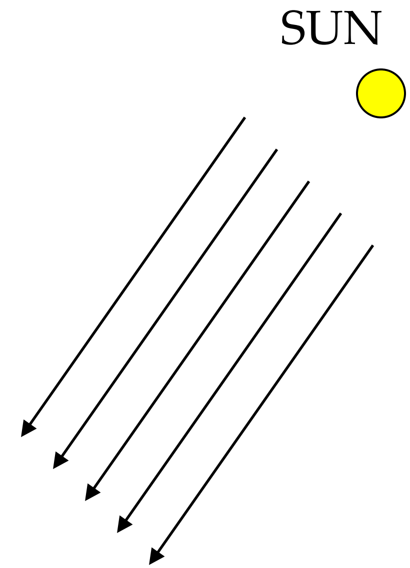
$$d\Phi = I \, d\omega = E \, dA$$

Intensity from one point source decreases

But we add intensities from all point sources on the plane.

Distant and Collimated Lighting

Distant Lighting:



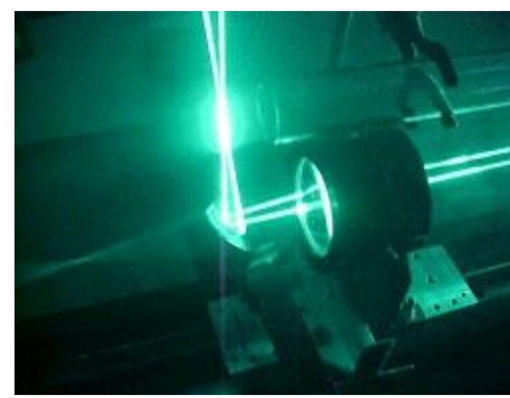
Essentially source at infinity

All surface points receive light from the same direction

Intensity fall must not be ignored!

Most vision and graphics algorithms assume this.

Collimated:

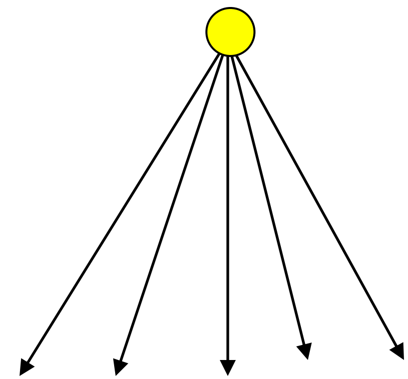


Parallel rays of light on the surface

Lasers (no fall off) - need not be at infinity

Lighting at infinity - (inverse squared fall off)

Divergent and Near-field Lighting

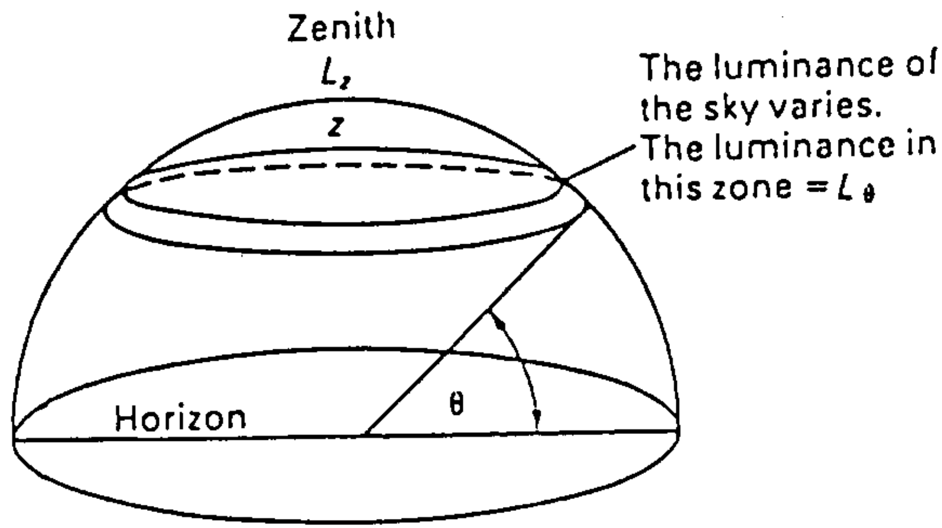


- Every scene point can receive light from a different direction.
- Much harder to model.
- Examples: near by point sources, spot lights
- Assume distant lighting when size of scene is 10% of the distance to the source.

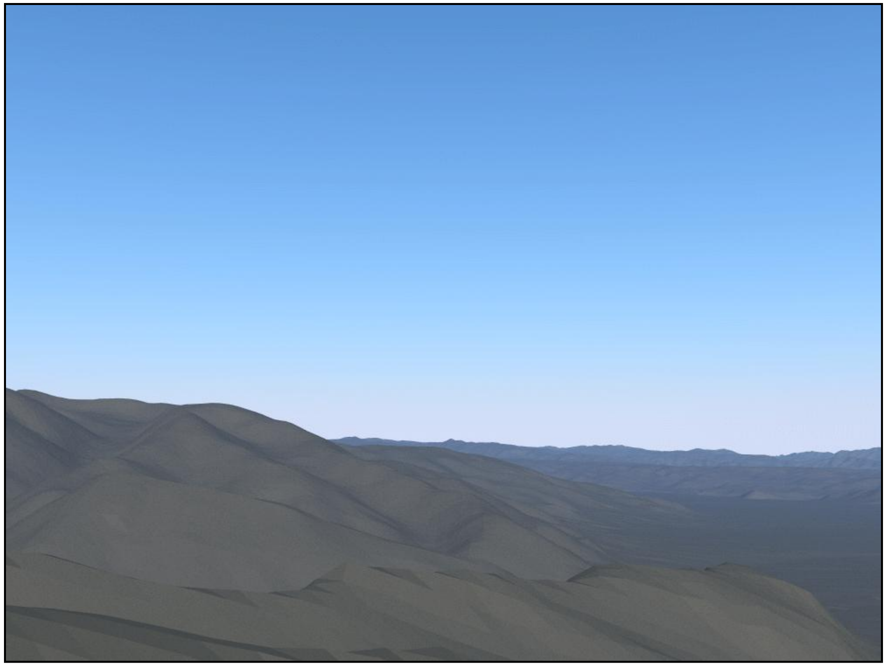
Overcast Sky versus Clear Sky

Which is the brightest region in a overcast sky?
Which is the darkest?

Which is the brightest region in a sunny sky (apart from the sun)?
Which is the darkest?



Overcast Sky versus Clear Sky



Notice reversal of brightness in the two skies.

Fluorescent versus Incandescent Lighting

Fluorescent:

Less heat generated.

More efficient lighting for the same brightness.

Flickers continuously.

Shows sparse, spikes in spectrum.

Incandescent:

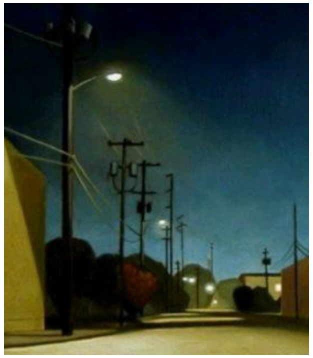
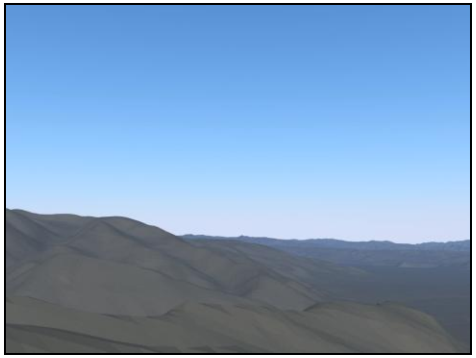
Lots of heat generated.

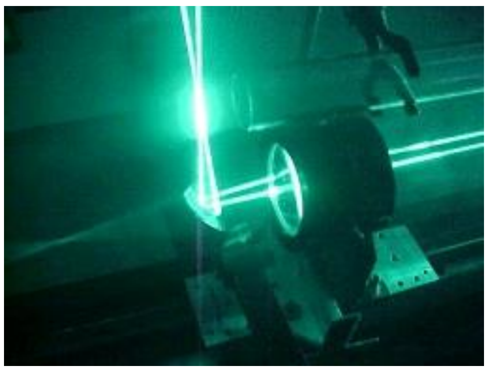
Less efficient lighting for the same brightness.

No flickers.

Shows continuous spectrum.

Is there a unified representation for light sources?

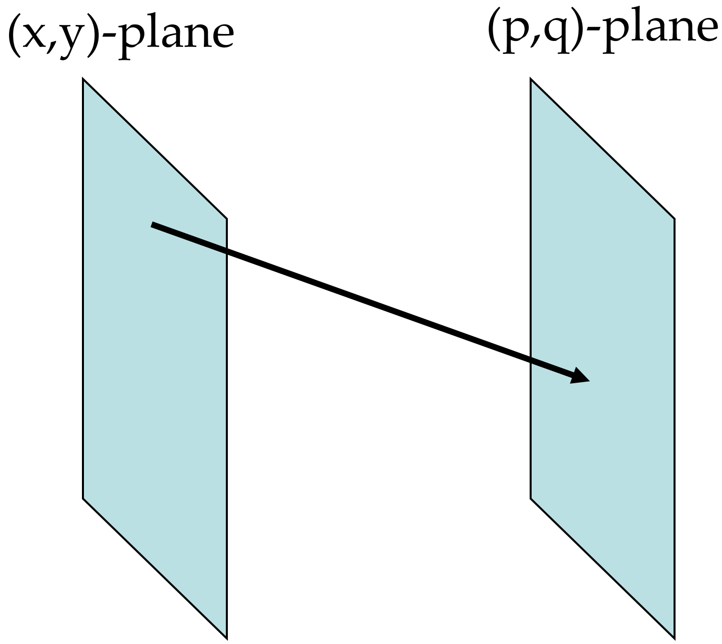



How do we compare the light from a street lamp to that from an overcast sky?

It is important to unify source representation so that algorithms may be developed for all sources instead of one per type of source.

Consider the SPACE of LIGHT RAYS!

4D Hypercube of Rays



- Assumes vacuum (no absorption or scattering)
- No fluorescence, phosphorescence

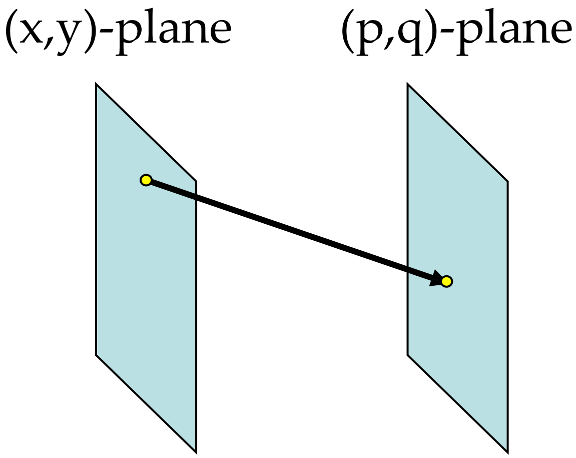
$$\mathcal{M}_{src} \equiv \{ (x,y,p,q) \; : \; x \in [-\frac{h_x}{2}, \frac{h_x}{2}],$$

$$y \in [-\frac{h_y}{2}, \frac{h_y}{2}], p \in [-\frac{h_p}{2}, \frac{h_p}{2}], q \in [-\frac{h_q}{2}, \frac{h_q}{2}] \}.$$

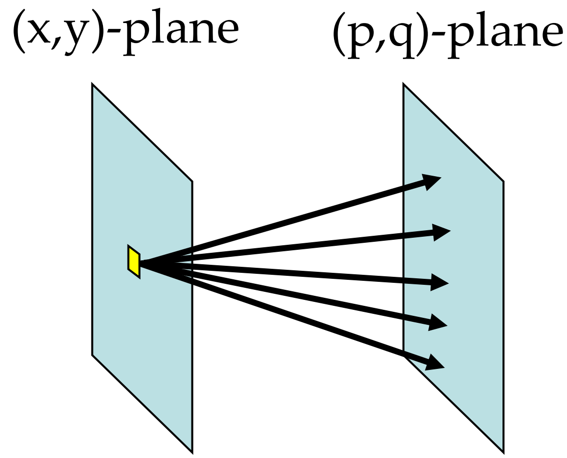
Langer and Zucker, CVPR 97

Representation of Sources

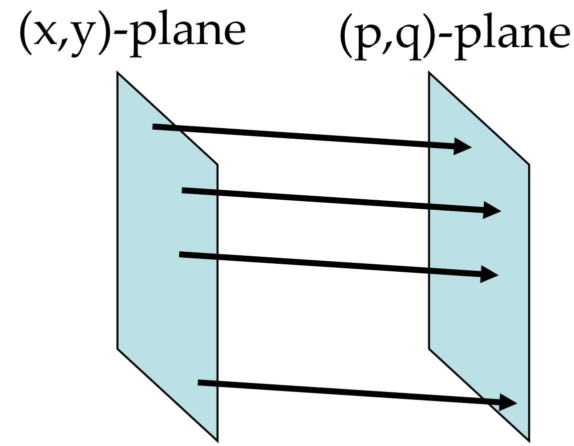
Langer and Zucker, CVPR 97



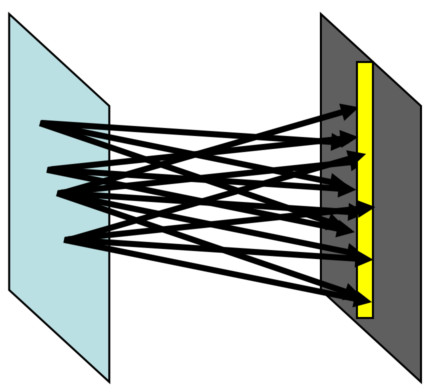
Laser beam – 0D



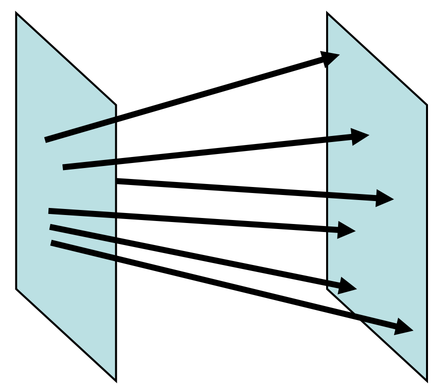
Point source – 2D



Distant Source (Sun) – 2D

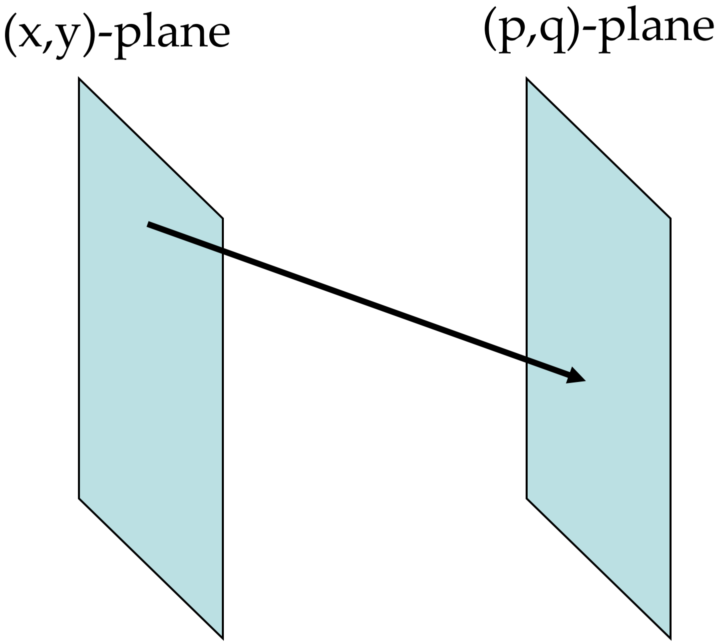


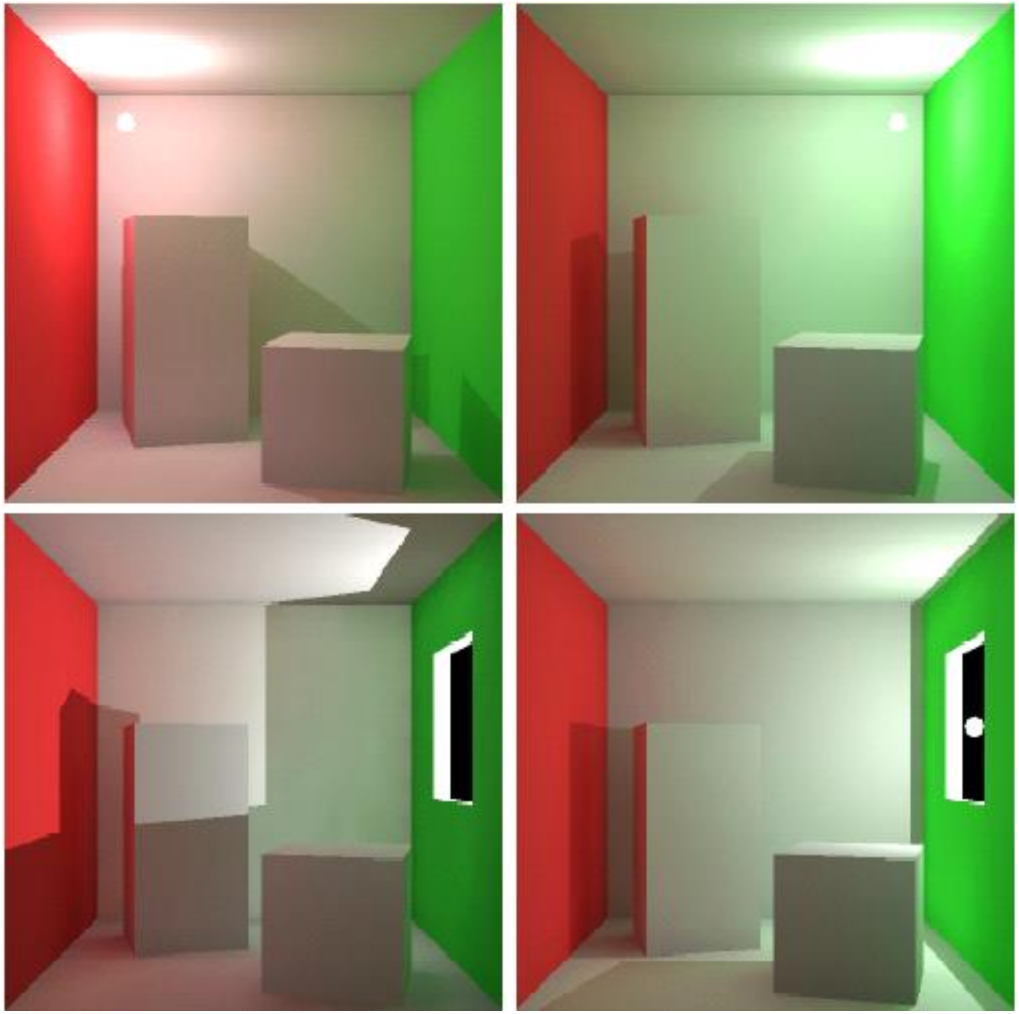
Area source (Sky) with
a crack in the door – 3D



Area source (Sky) with
door completely open – 4D

Examples of sources





What is a Light Source?

Is sky a source? If so, why not a white piece of paper?

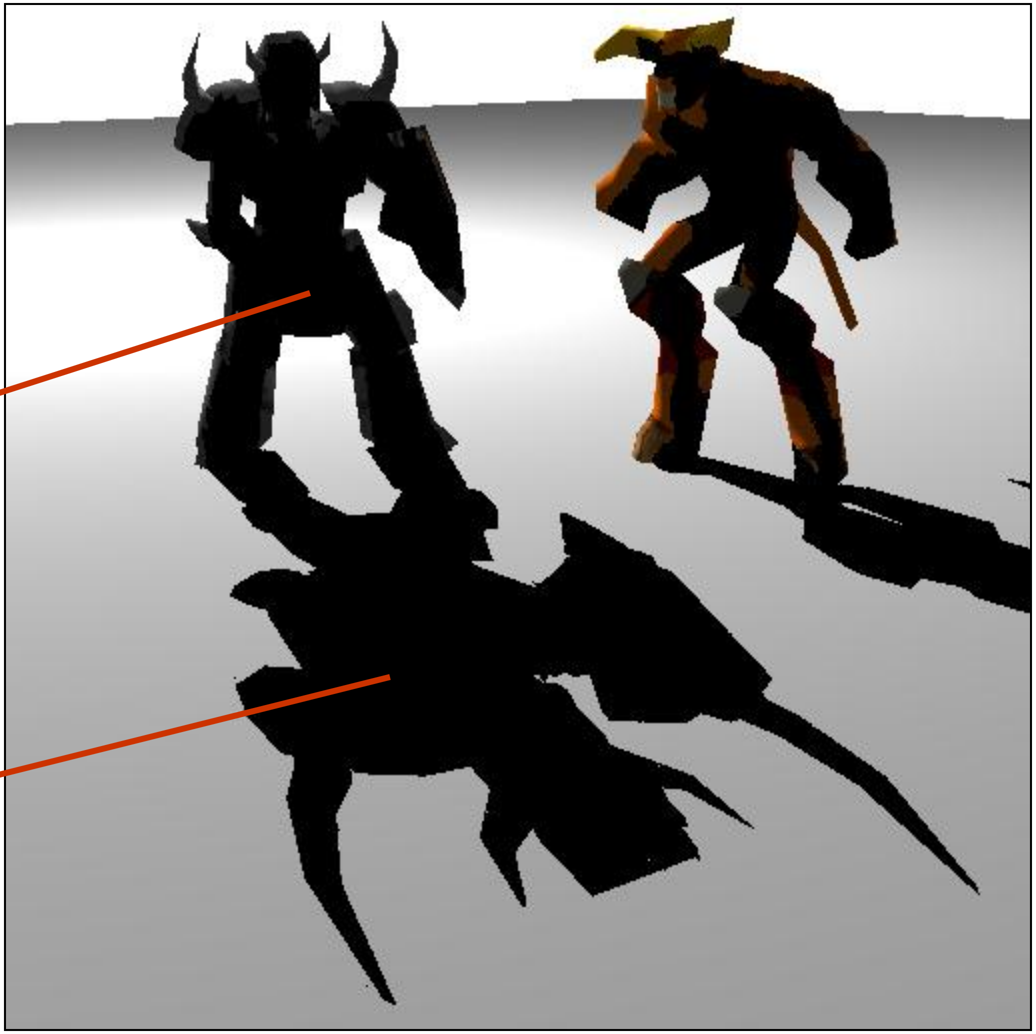
Is a translucent object a source?

How to differentiate between source rays and non-source rays?

> Define a minimum set of absorbants at the ends of rays so that the whole ray space is dark.

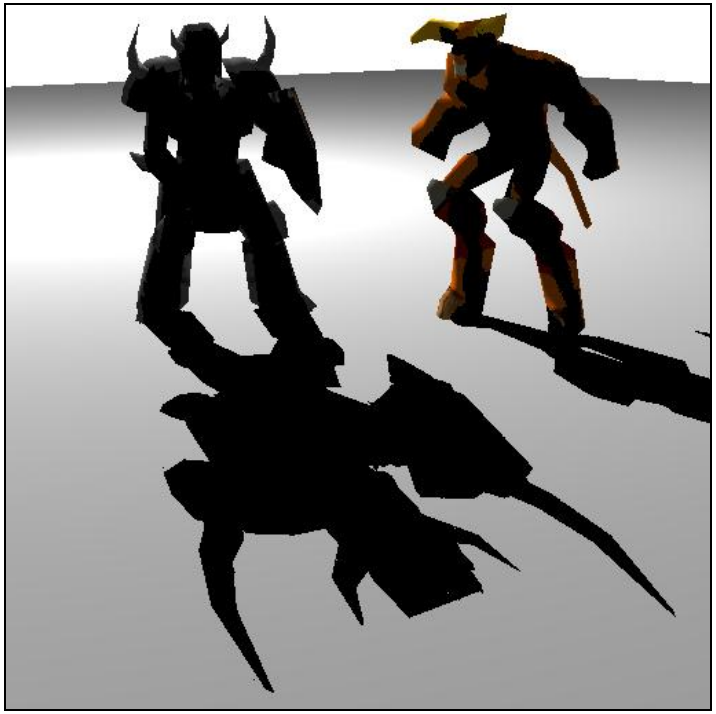
Shadows

Attached and Cast Shadows



Attached shadow

Cast shadow



Sen, Cammarano, Hanrahan, 2003

Sloan, Kautz, Snyder 2002

Very hard shadows

Very soft shadows

All-Frequency Lighting and Shadows

Teapot in Grace Cathedral

Sharper and Softer parts of Shadows

Point source model not good for rendering scenes.