High Dynamic Range Imaging and Tone Mapping

Paul Debevec's SIGGRAPH Course

Dynamic Range in the Real World

Sony VX2000 video camera

Office interior

Indirect light from window

1/60th sec shutter

f/5.6 aperture

0 ND filters

0dB gain

Dynamic Range in the Real World

Outside in the shade

1/1000th sec shutter

f/5.6 aperture

0 ND filters

0dB gain

16 times the light as inside

Dynamic Range in the Real World

64 times the light as inside

Outside in the sun

1/1000th sec shutter

f/11 aperture

0 ND filters

0dB gain

Dynamic Range in the Real World

Straight at the sun

1/10,000th sec shutter

f/11 aperture

13 stops ND filters

0dB gain

5,000,000 times the light as inside

Dynamic Range in the Real World

Very dim room

1/4th sec shutter

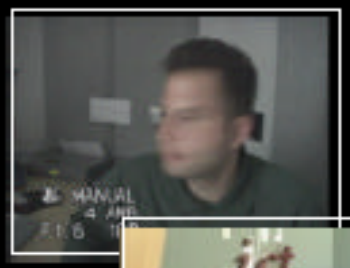
f/1.6 aperture

0 stops ND filters

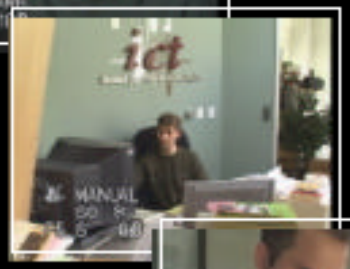
18dB gain

1/1500th the light than inside

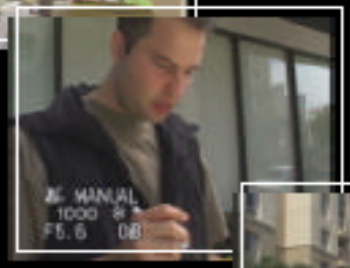
Dynamic Range in the Real World



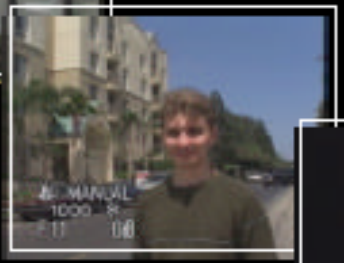
1



1500



25,000



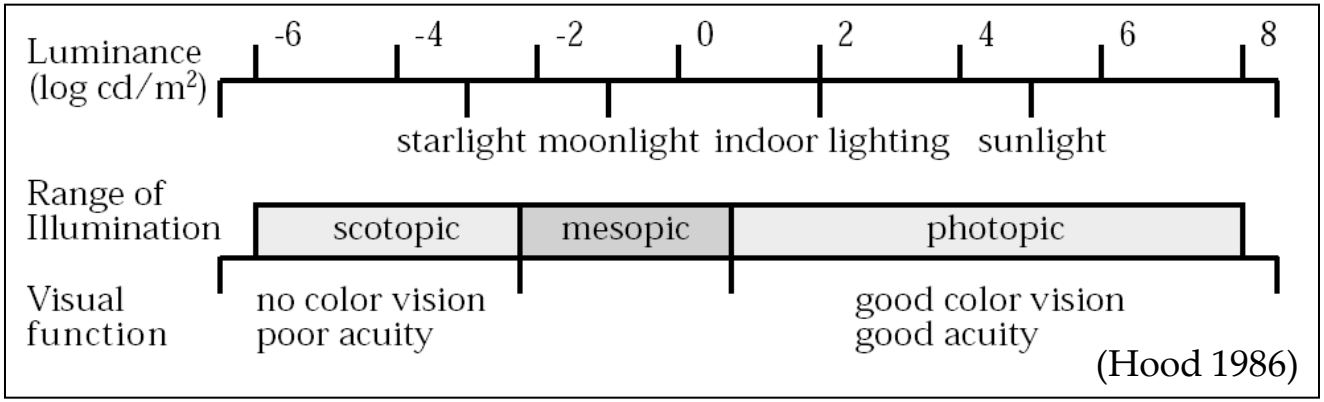
400,000

2,000,000,000

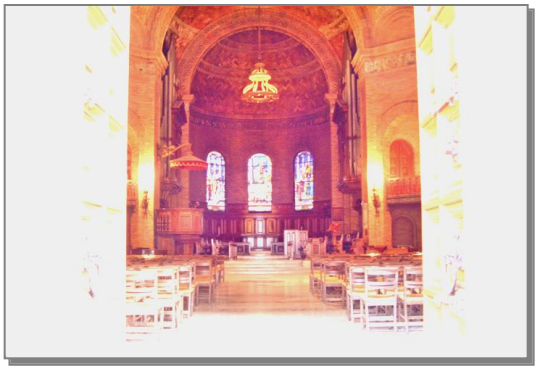
The real world is high dynamic range.

The Problem of Dynamic Range

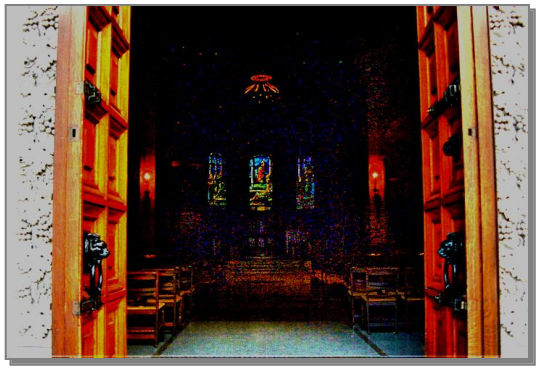
- Dynamic Range: Range of brightness values measurable with a camera



- Today's Cameras: Limited Dynamic Range



High Exposure Image



Low Exposure Image

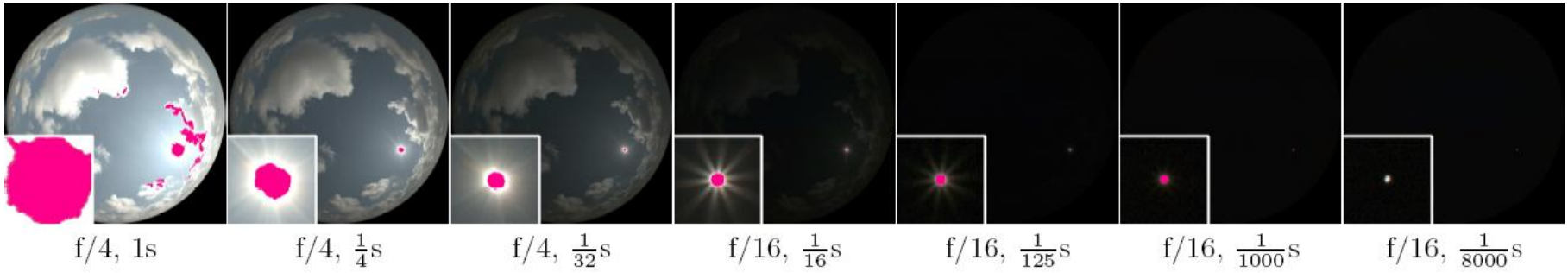
- We need about 5-10 million values to store all brightnesses around us.
- But, typical 8-bit cameras provide only 256 values!!

High Dynamic Range Imaging

- Capture a lot of images with different exposure settings.
- Apply radiometric calibration to each camera.
- Combine the calibrated images (for example, using averaging weighted by exposures).

(Mitsunaga)

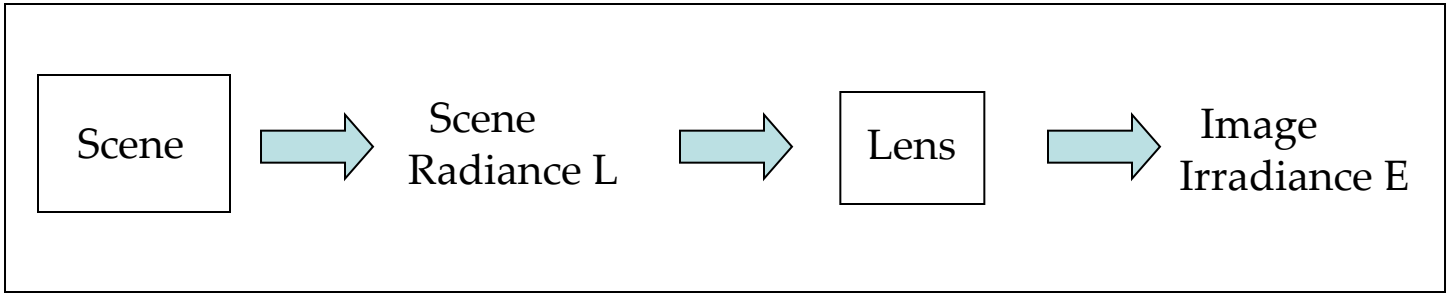
(Debevec)



Images taken with a fish-eye lens of the sky show the wide range of brightnesses.

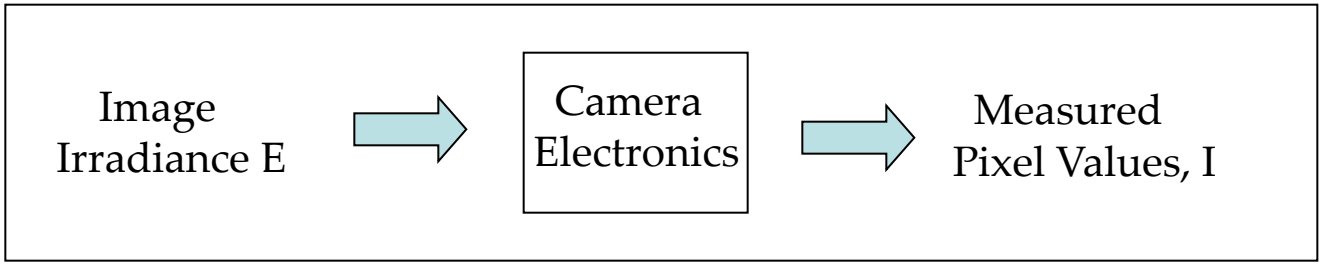
Relationship between Scene and Image Brightness

- Before light hits the image plane:



Linear Mapping!

- After light hits the image plane:



Non-linear Mapping!

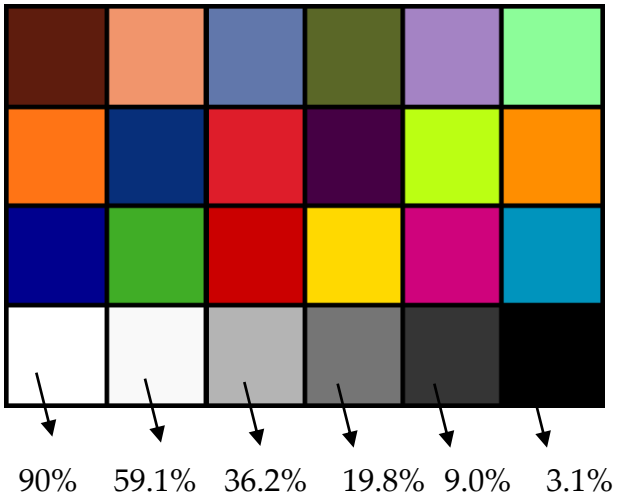
Can we go from measured pixel value, I, to scene radiance, L?

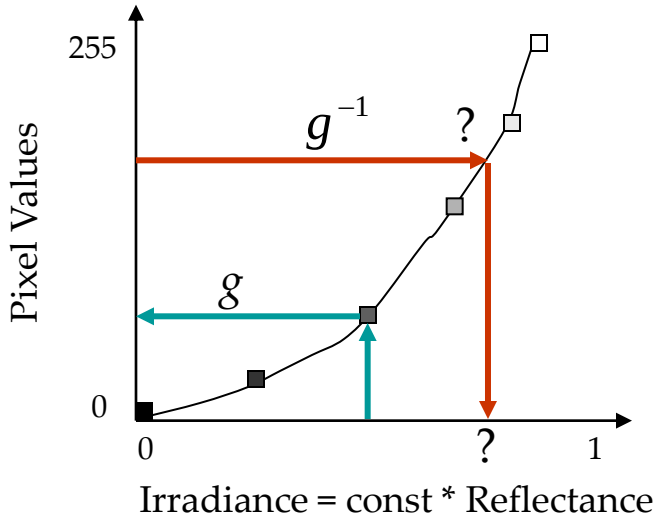
Radiometric Calibration

- Important preprocessing step for many vision and graphics algorithms such as photometric stereo, invariants, de-weathering, inverse rendering, image based rendering, etc.

$$g^{-1} : I \rightarrow E$$

- Use a color chart with precisely known reflectances.





- Use more camera exposures to fill up the curve.
- Method assumes constant lighting on all patches and works best when source is far away (example sunlight).

- Unique inverse exists because g is monotonic and smooth for all cameras.

Ways to vary exposure

- Shutter Speed
- F/stop (aperture, iris)
- Neutral Density (ND) Filters
- Gain / ISO / Film Speed

RADIANCE Format

Greg Ward's "Real Pixels" format

Red Green Blue Exponent

(145, 215, 87, 149) =

(145, 215, 87) * 2^(149-128) =

(1190000, 1760000, 713000)

(145, 215, 87, 103) =

(145, 215, 87) * 2^(103-128) =

(0.00000432, 0.00000641, 0.00000259)

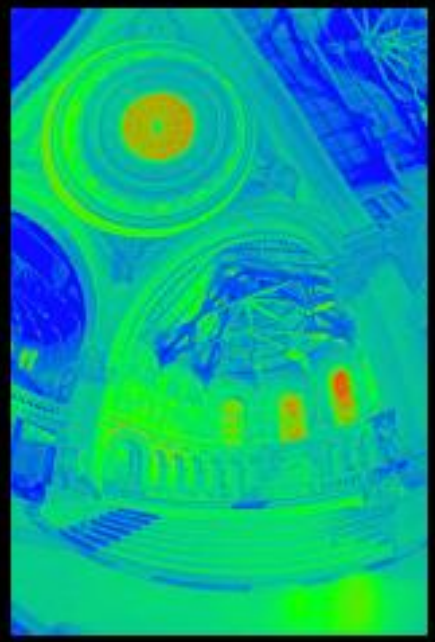
Ward, Greg. "Real Pixels," in Graphics Gems IV, edited by James Arvo, Academic Press, 1994

8-bit Images (TIF, BMP, TGA, JPG, etc.)

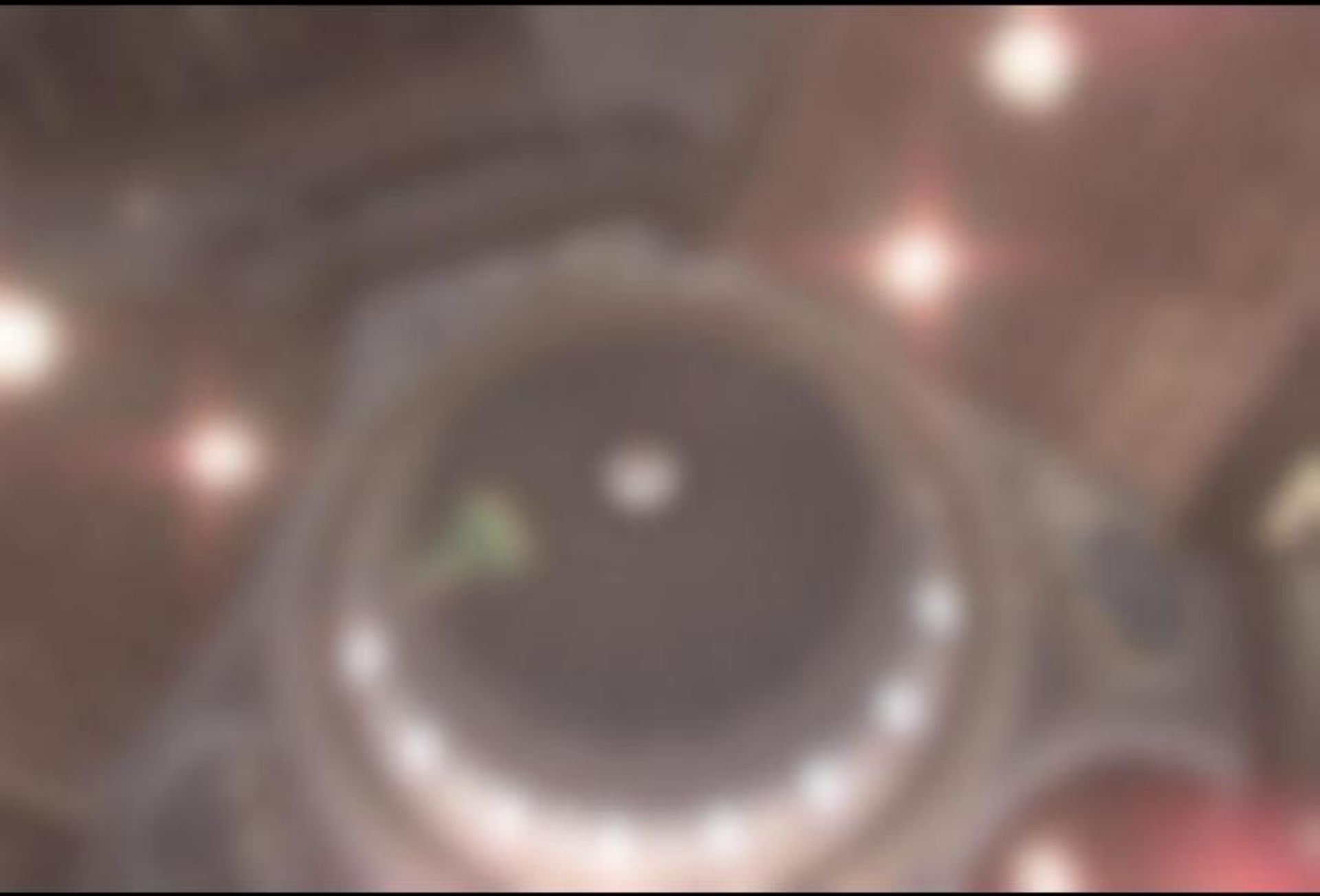
- Useful for representing images to be output on a computer monitor or printer
- Less useful for representing images for film
- Inadequate for representing HDR images
- Usually nonlinearly encoded with a gamma curve, i.e.

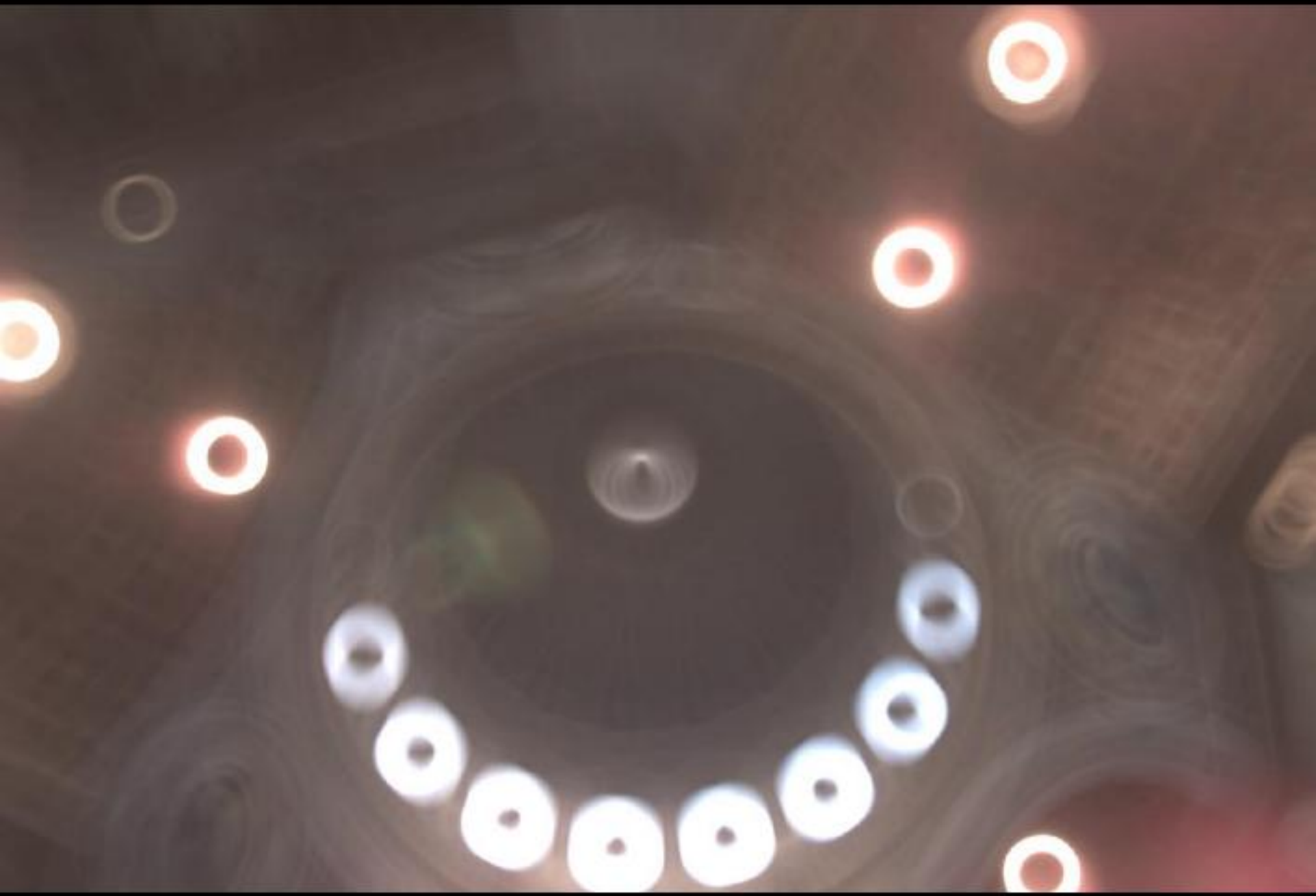
- Amount of light = $(\text{pixel value})^{2.2}$

High-Dynamic Range Photography



300,000 : 1





[Greg Ward]

HDR Tone-mapping

Linear tone-mapping

Non-linear tone-mapping

[Greg Ward]

Veiling Glare Simulation

H D R S h o p

High Dynamic Range Image Processing and Manipulation

www.debevec.org/HDRShop

Introduction | Tutorials | Reference | Plugins | FAQ | Download/Licensing | WWW Links | Mailing List

Capturing Real-World Illumination

Mirrored Ball - Records light in all directions

Brightest regions are saturated

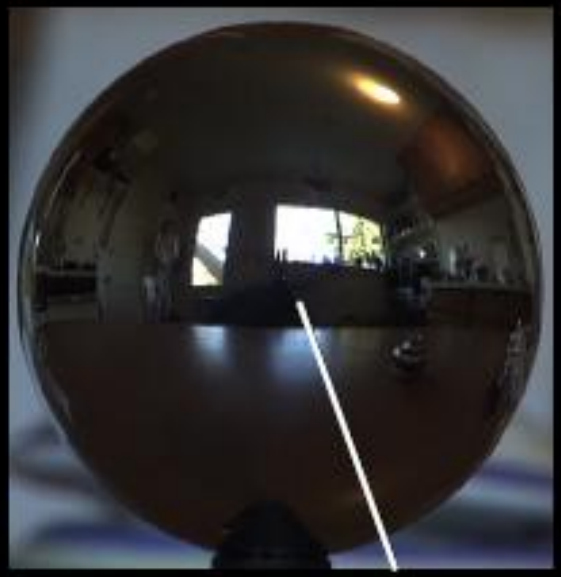
⬇

Intensity and color information lost

HDR Image of a Mirrored Ball

(60,40,35)

(18,17,19)



(620,890,1300)

(5700,8400,11800)

(11700,7300,2600)

Assembled from ten digital images,

Δt = 1/4 to 1/10000 sec


Canon

Sources of Mirrored Balls

2-inch chrome balls < $20 ea.

King Bearing, Inc. / Applied Industrial Technologies

(many locations nationally, check www.bigbook.com)

6-12 inch large gazing balls

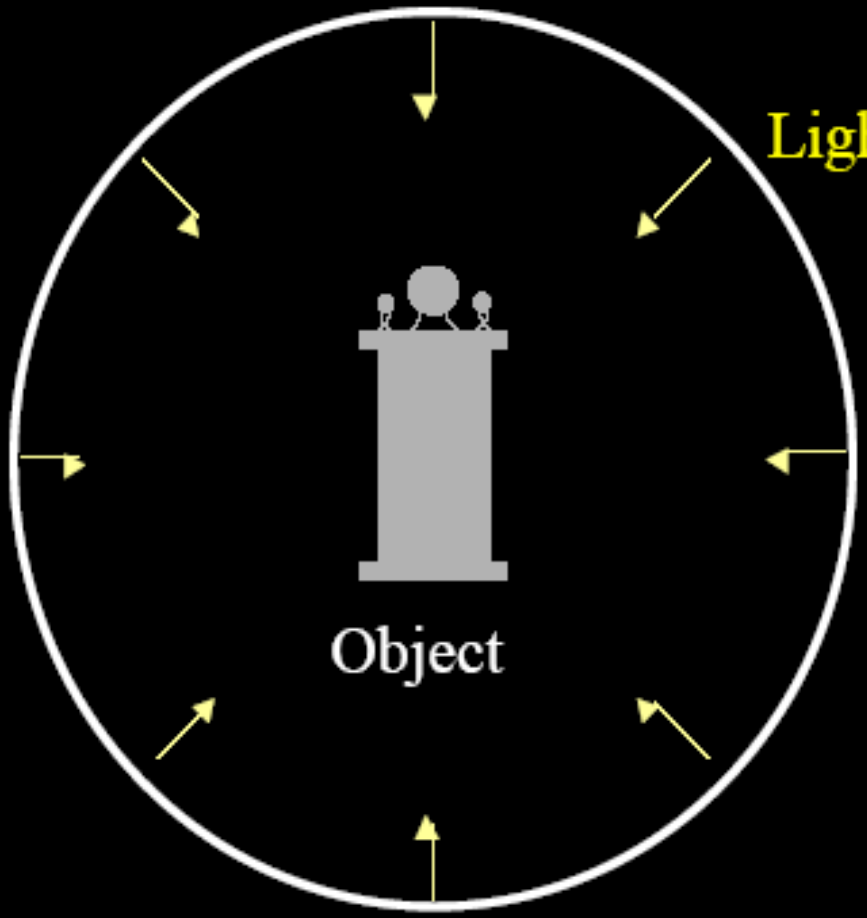
- Baker's Lawn Ornaments
  570 Berlin Plank Road
  Somerset, PA 15501-2413
  814-445-7028
- www.amazon.com - $8

Types of Omnidirectional Images

Latitude/Longitude

Cube Map

Illuminating Objects using Measurements of Real Light



Environment assigned "glow" material property in Greg Larson's RADIANCE system.

http://radsite.lbl.gov/radiance/

See also: Larson and Shakespeare, "Rendering with Radiance", 1998

5. Illuminating Synthetic Objects with Real Light

Comparison: Radiance map versus single image

Making *Rendering with Natural Light*

SIGGRAPH 98 Electronic Theater

Light Probe Images

Eucalyptus Grove
UC Berkeley

Uffizi Gallery
Florence

St. Peter's Basilica
Rome

Grace Cathedral
San Francisco

Light Probe Image Gallery:
www.debevec.org/Probes