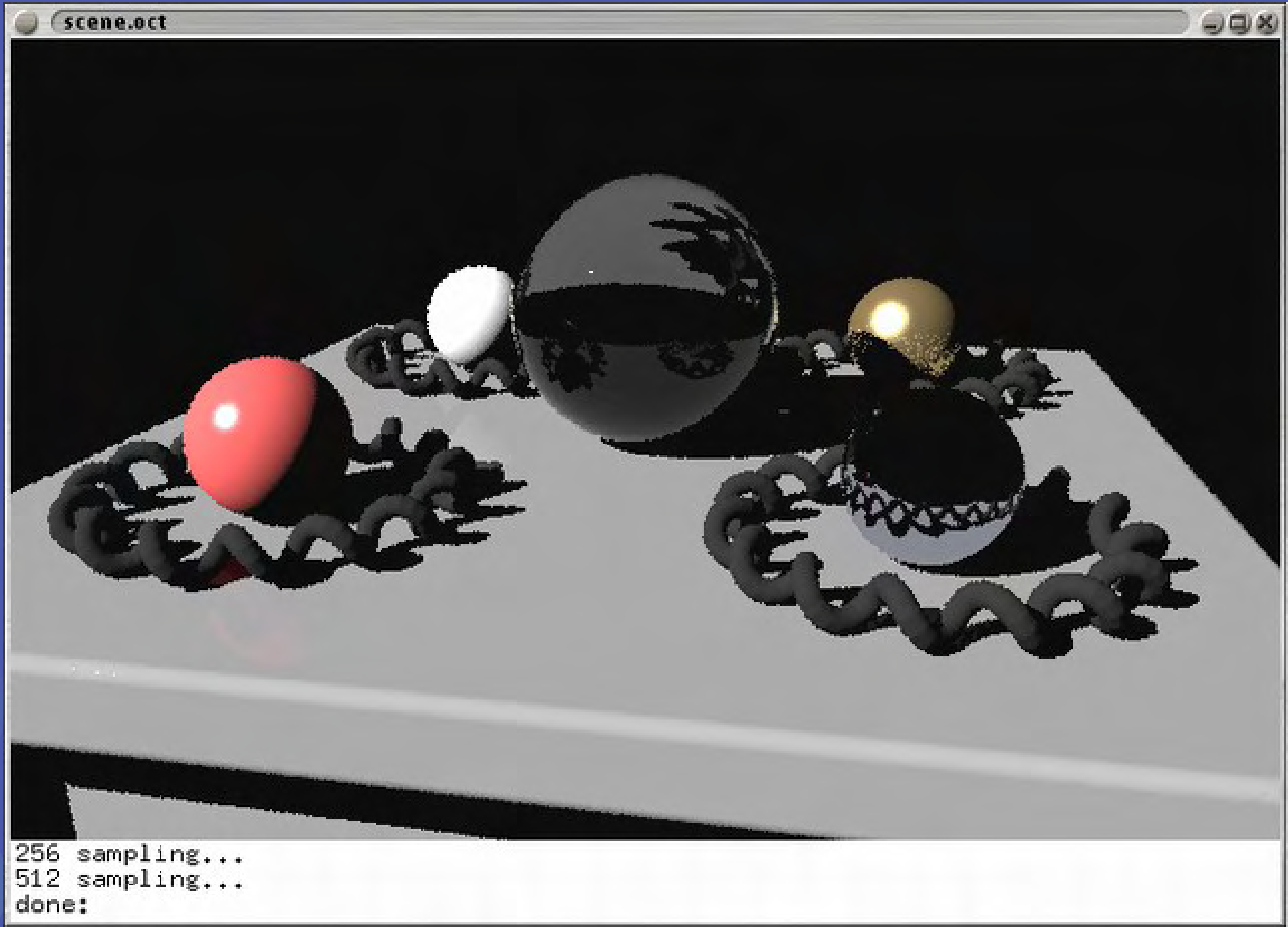
Environment Maps and Tone Mapping

© Clément Poline

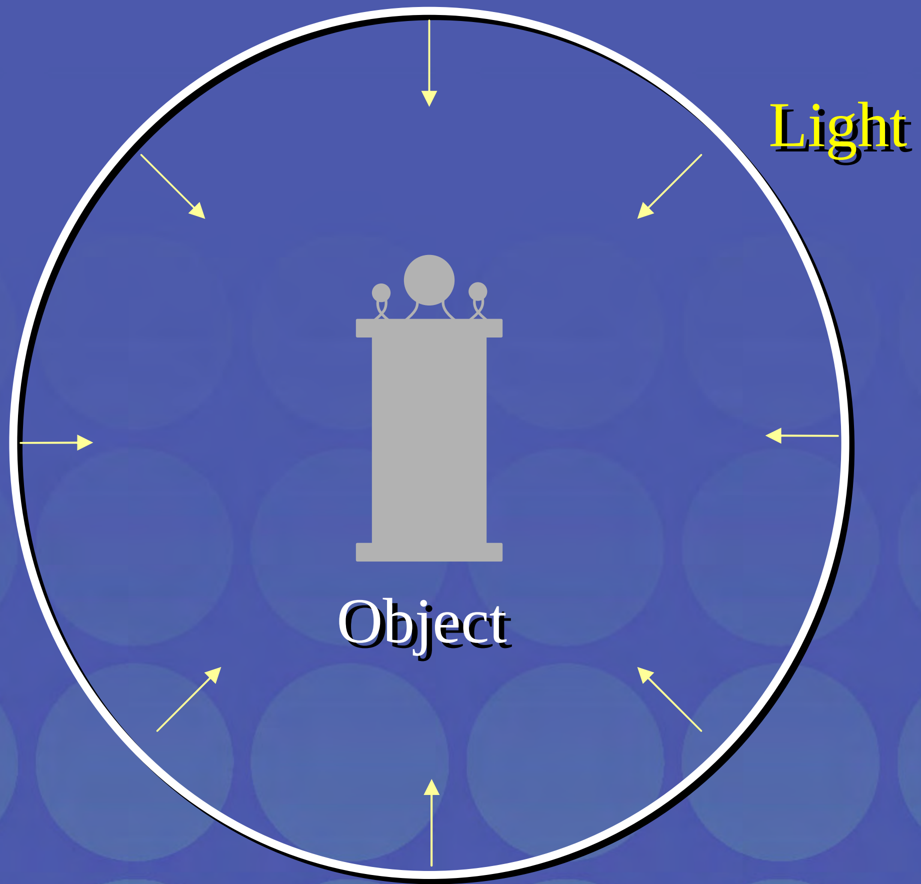
…with a lot of slides
donated by Paul Debevec



H2004

CG Objects Illuminated by a Traditional CG Light Source

Illuminating Objects using Measurements of Real Light



Paul Debevec. A Tutorial on Image-Based Lighting. IEEE Computer Graphics and Applications, Jan/Feb 2002.

Environment Map / Reflection Map

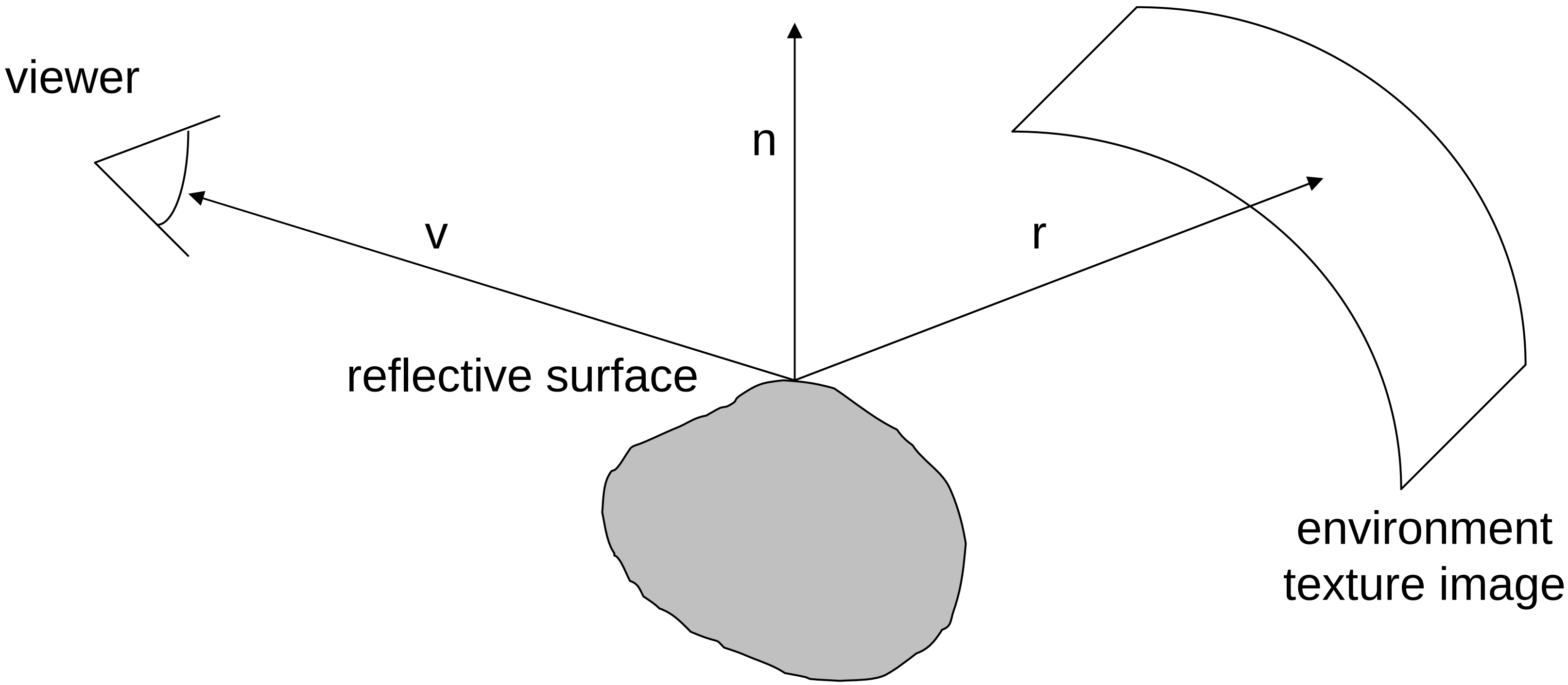
Simple solution for shiny objects

- Models complex lighting as a panoramic image
- i.e. amount of radiance coming in from each direction
- A plenoptic function!!!

Environment Mapping

Reflected ray: $\boldsymbol{r}=2(\boldsymbol{n}\cdot\boldsymbol{v})\boldsymbol{n}-\boldsymbol{v}$

projector function converts reflection vector (x, y, z) to texture image (u, v)



Texture is transferred in the direction of the reflected ray from the environment map onto the object

What is in the map?

What approximations are made?

The map should contain a view of the world with the point of interest on the object as the Center of Projection

- We can’t store a separate map for each point, so one map is used with the COP at the center of the object
- Introduces distortions in the reflection, but we usually don’t notice
- Distortions are minimized for a small object in a large room

The object will not reflect itself!

Environment Maps

The environment map may take various forms:

- Cubic mapping
- Spherical mapping
- other

Describes the shape of the surface on which the map "resides"

Determines how the map is generated and how it is indexed

Cubic Mapping

The map resides on the surfaces of a cube around the object

- Typically, align the faces of the cube with the coordinate axes

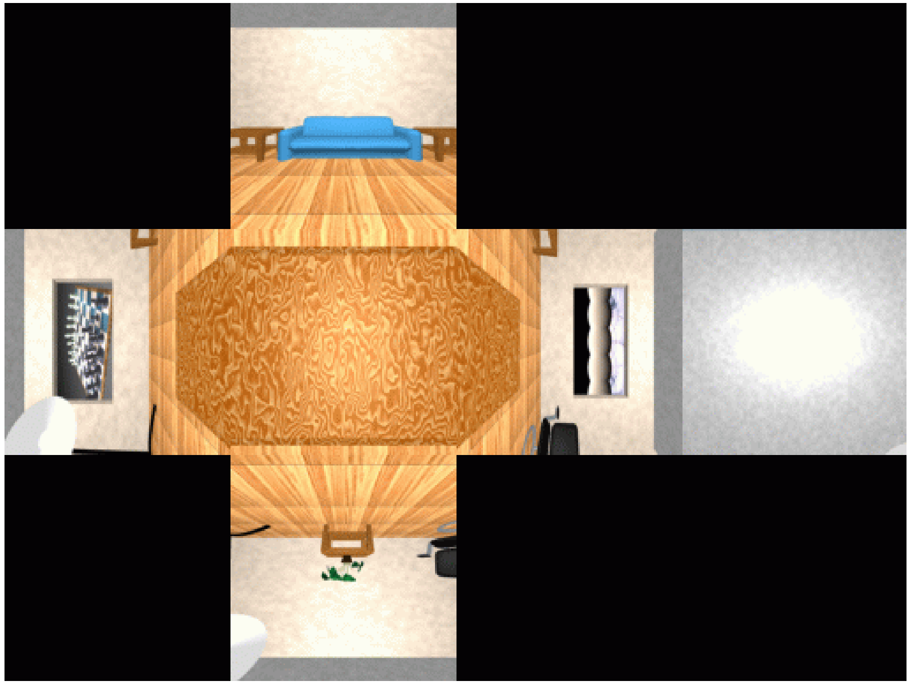
To generate the map:

- For each face of the cube, render the world from the center of the object with the cube face as the image plane
  - Rendering can be arbitrarily complex (it’s off-line)

To use the map:

- Index the R ray into the correct cube face
- Compute texture coordinates

Cubic Map Example



Sphere Mapping

Map lives on a sphere

To generate the map:

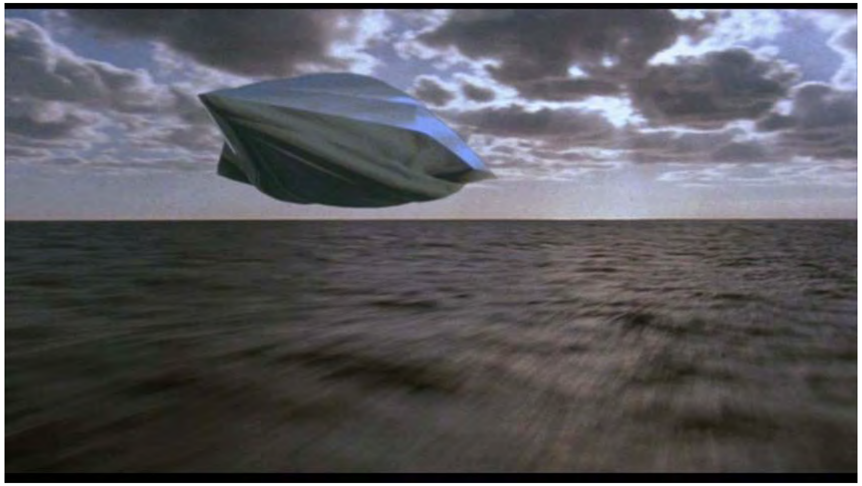
- Render a spherical panorama from the designed center point

To use the map:

- Use the orientation of the R ray to index directly into the sphere

Example

What about real scenes?



From *Flight of the Navigator*

It’s not that hard!

Real environment maps

We can use photographs to capture environment maps

- The first use of panoramic mosaics

How do we deal with light sources? Sun, lights, etc?

- They are much much brighter than the rest of the enviarnment

User High Dynamic Range photography

Several ways to acquire environment maps:

- Stitching mosaics
- Fisheye lens
- Mirrored Balls

Scanning Panoramic Cameras

Pros:

- *very* high res (10K x 7K+)
- Full sphere in one scan – no stitching
- Good dynamic range, some are HDR

Issues:

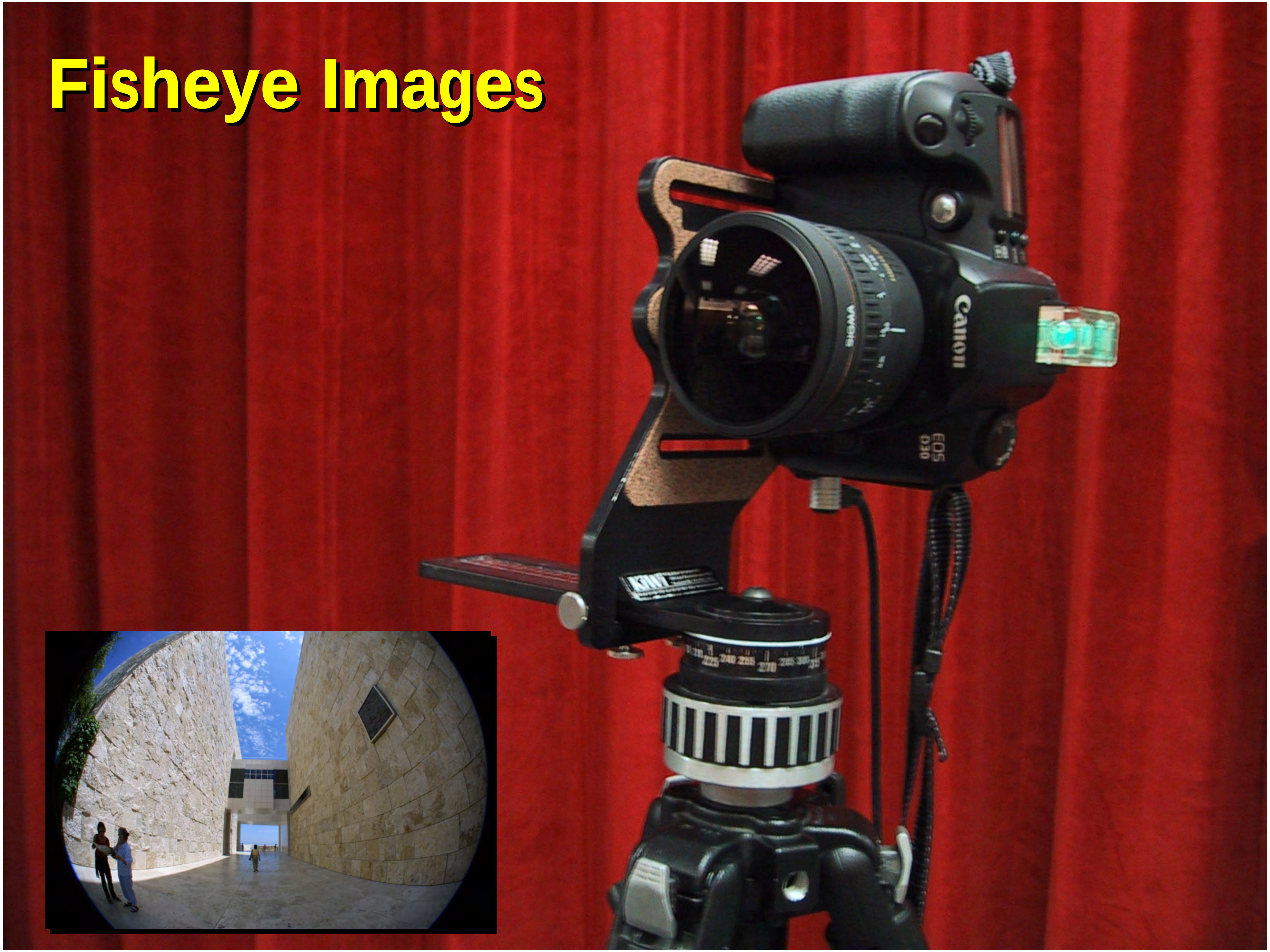
- More expensive
- Scans take a while

Companies: Panoscan, Sphereon

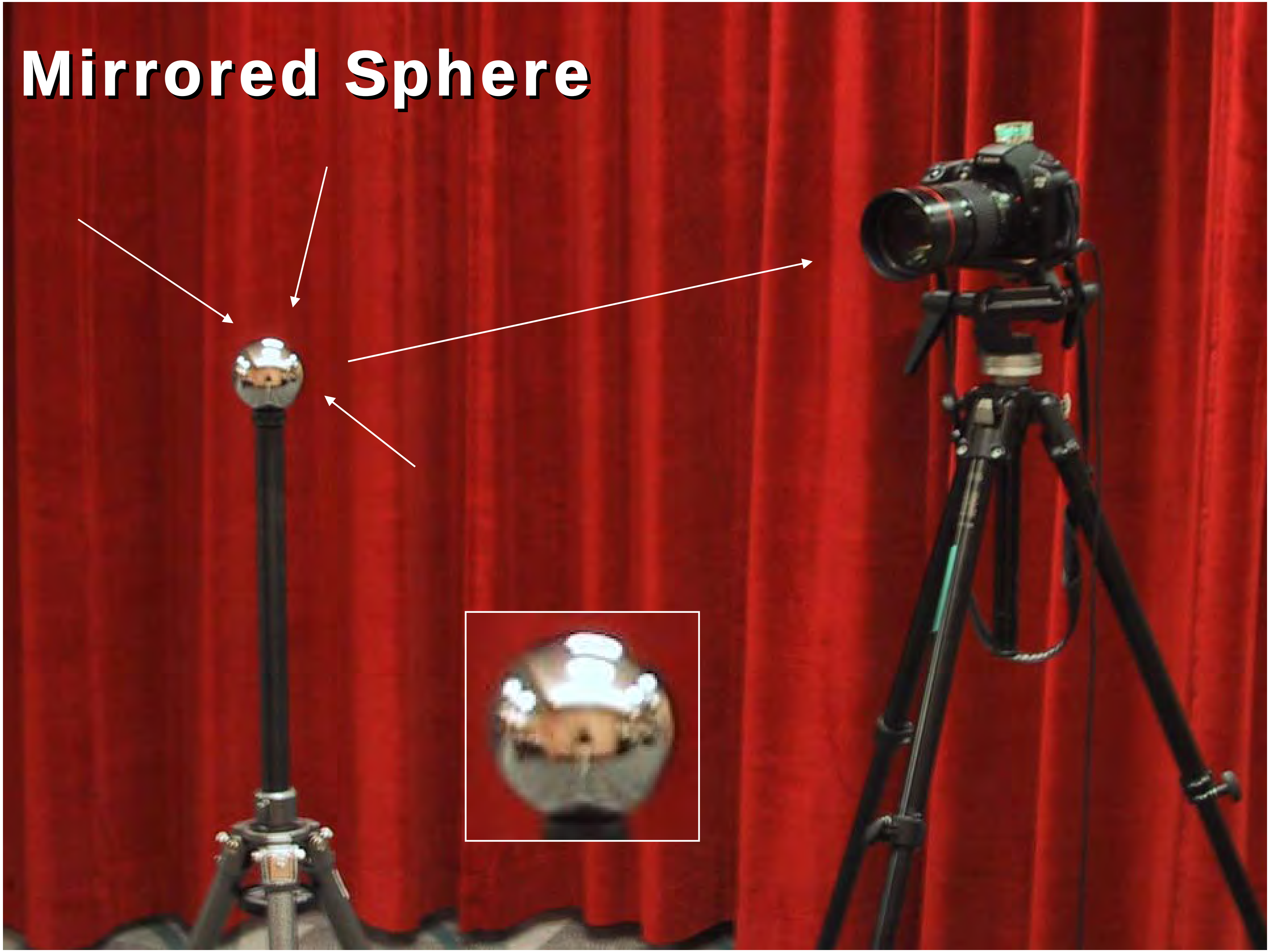
SIGGRAPH2004

See also www.kaidan.com

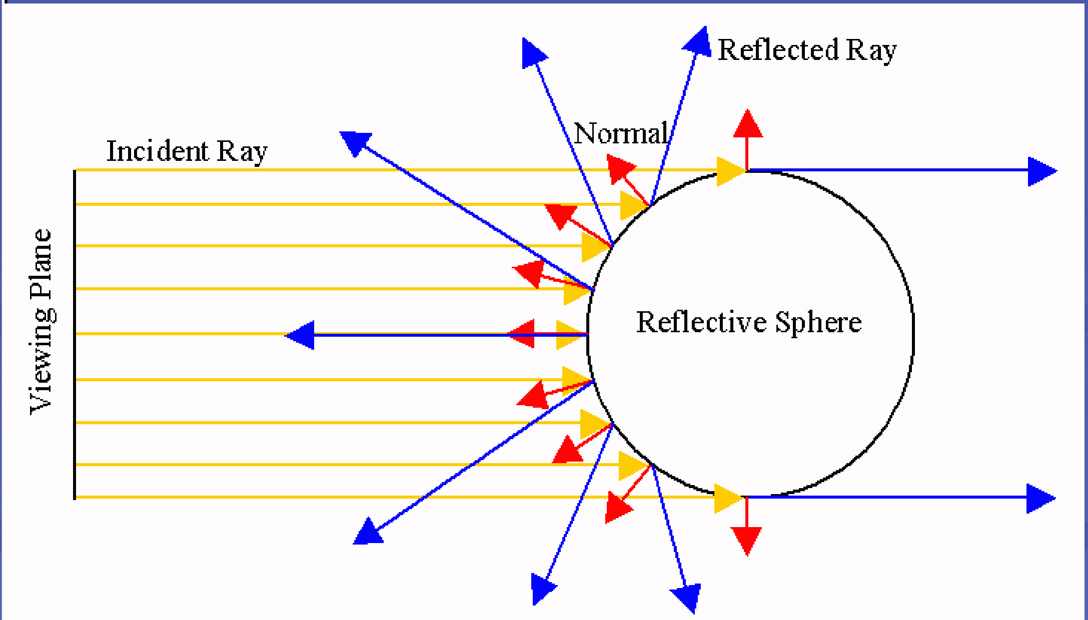
Fisheye Images



Mirrored Sphere

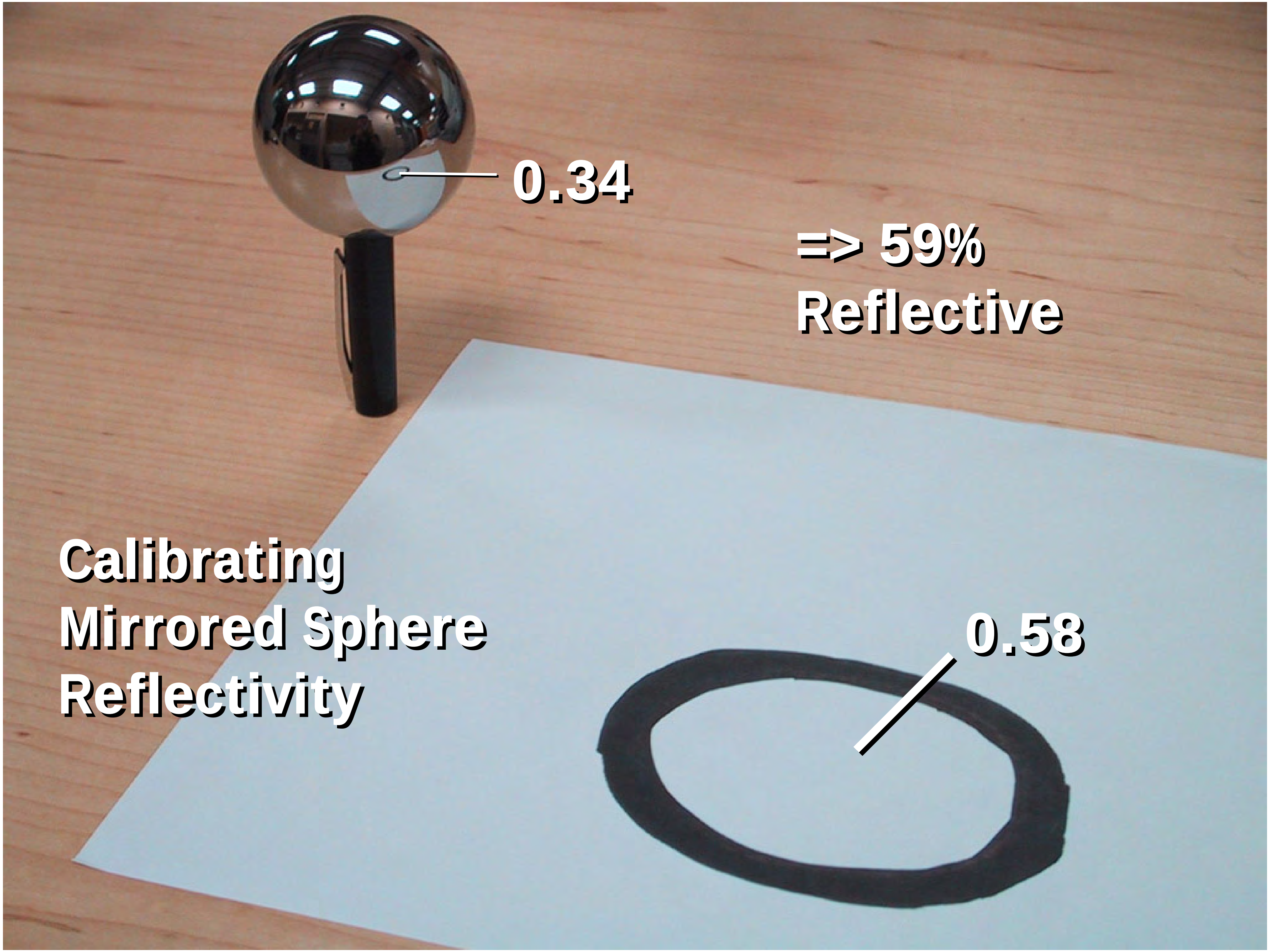



Canon
Canon
REMOTE SWITCH


Reflected Ray
Normal
Incident Ray
Viewing Plane
Reflective Sphere

Sources of Mirrored Balls

- 2-inch chrome balls ~ $20 ea.
  - McMaster-Carr Supply Company
    www.mcmaster.com
- 6-12 inch large gazing balls
  - Baker’s Lawn Ornaments
    www.bakerslawnorn.com
- Hollow Spheres, 2in – 4in
  - Dube Juggling Equipment
    www.dube.com
- FAQ on www.debevec.org/HDRShop/


0.34
=> 59%
Reflective
Calibrating
Mirrored Sphere
Reflectivity
0.58

Real-World HDR Lighting Environments

Funston Beach

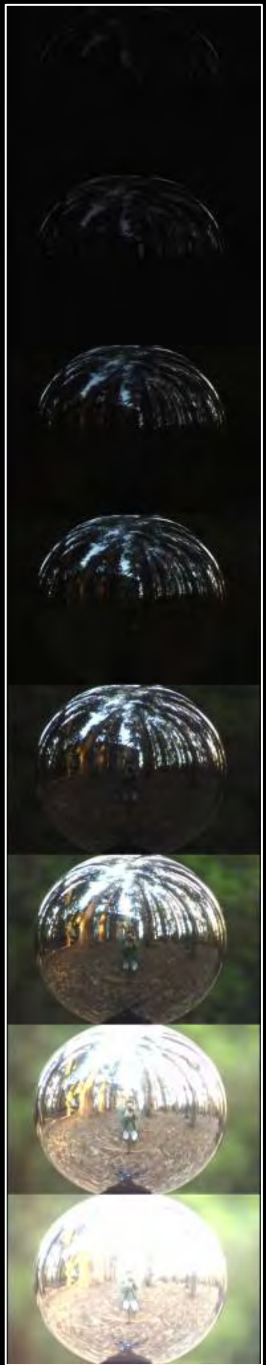
Eucalyptus Grove

Uffizi Gallery

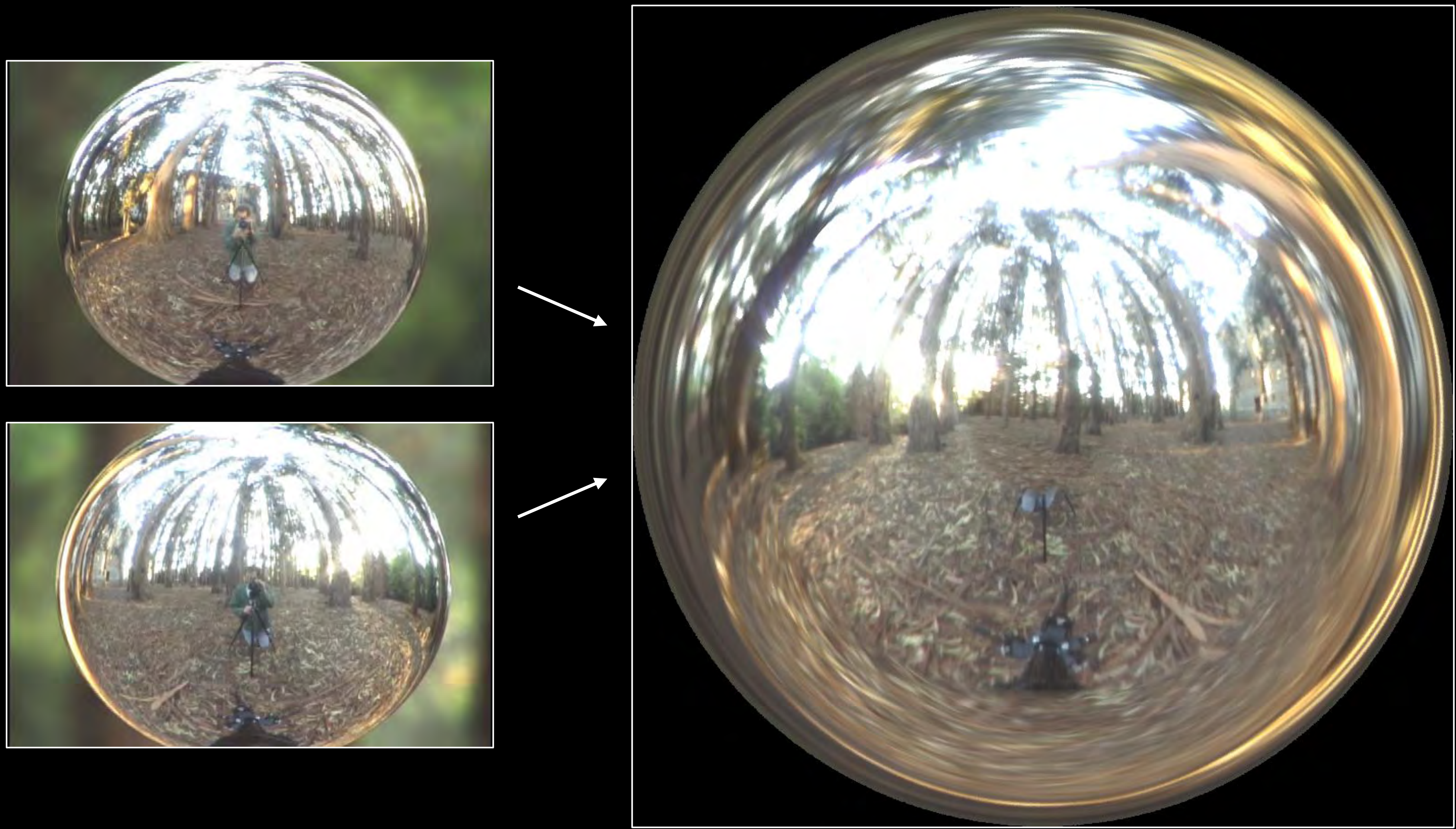
Grace Cathedral

Lighting Environments from the Light Probe Image Gallery:
http://www.debevec.org/Probes/

Acquiring the Light Probe



Assembling the Light Probe



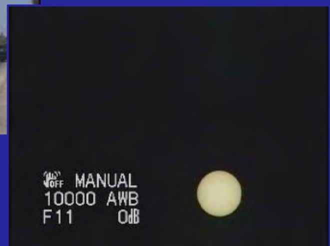
Problem: Dynamic Range

1

1500

25,000

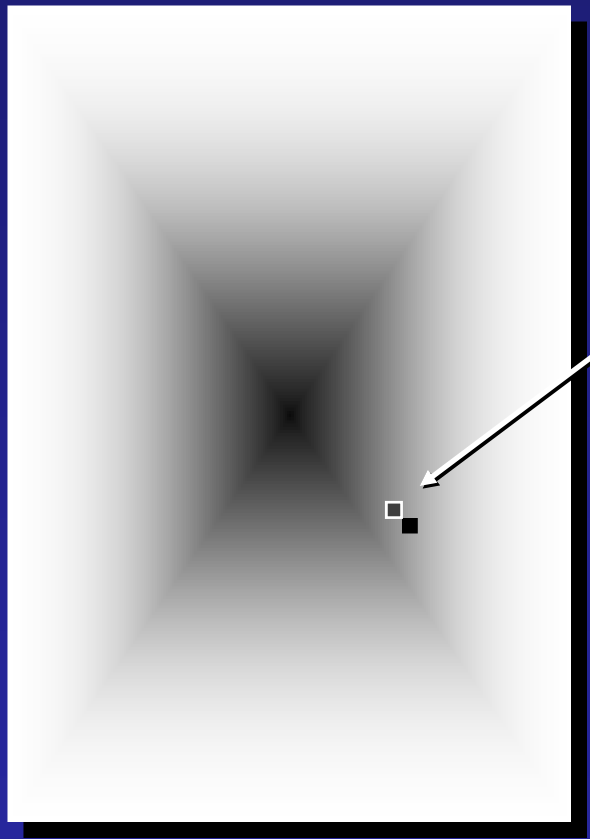
400,000



2,000,000,000

The real world is high dynamic range.

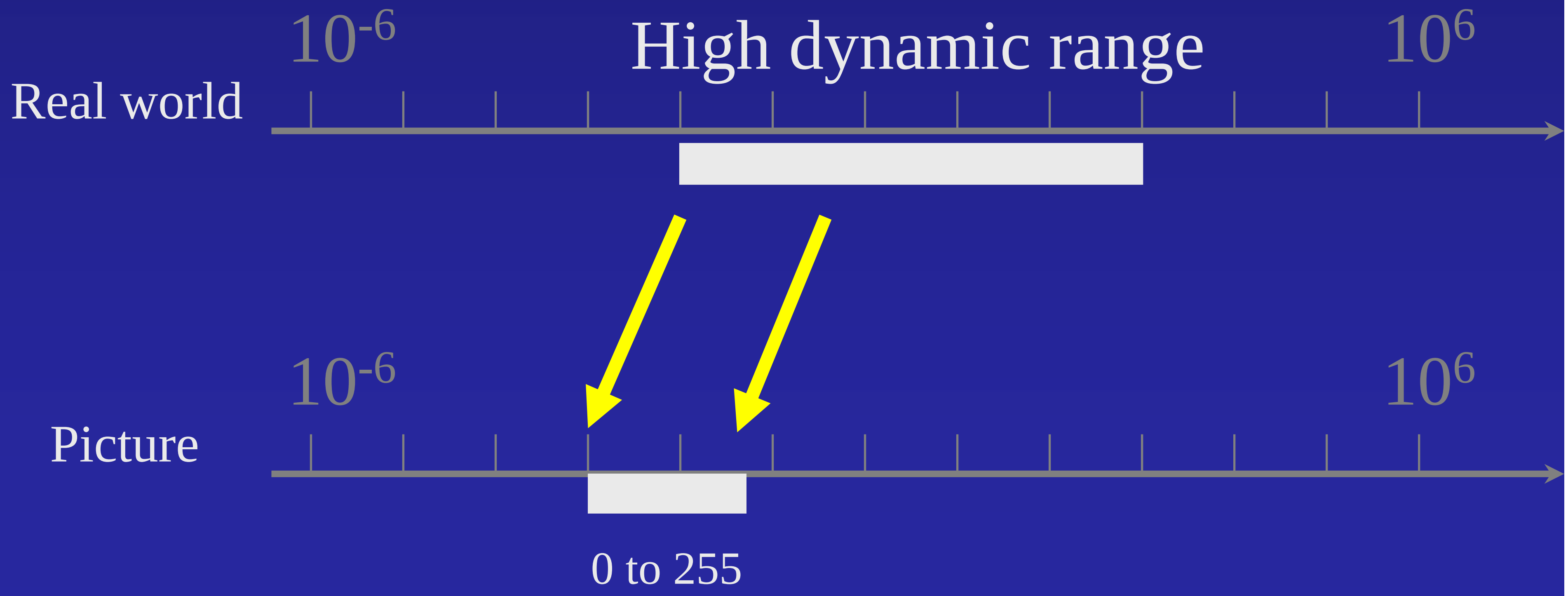
Screen



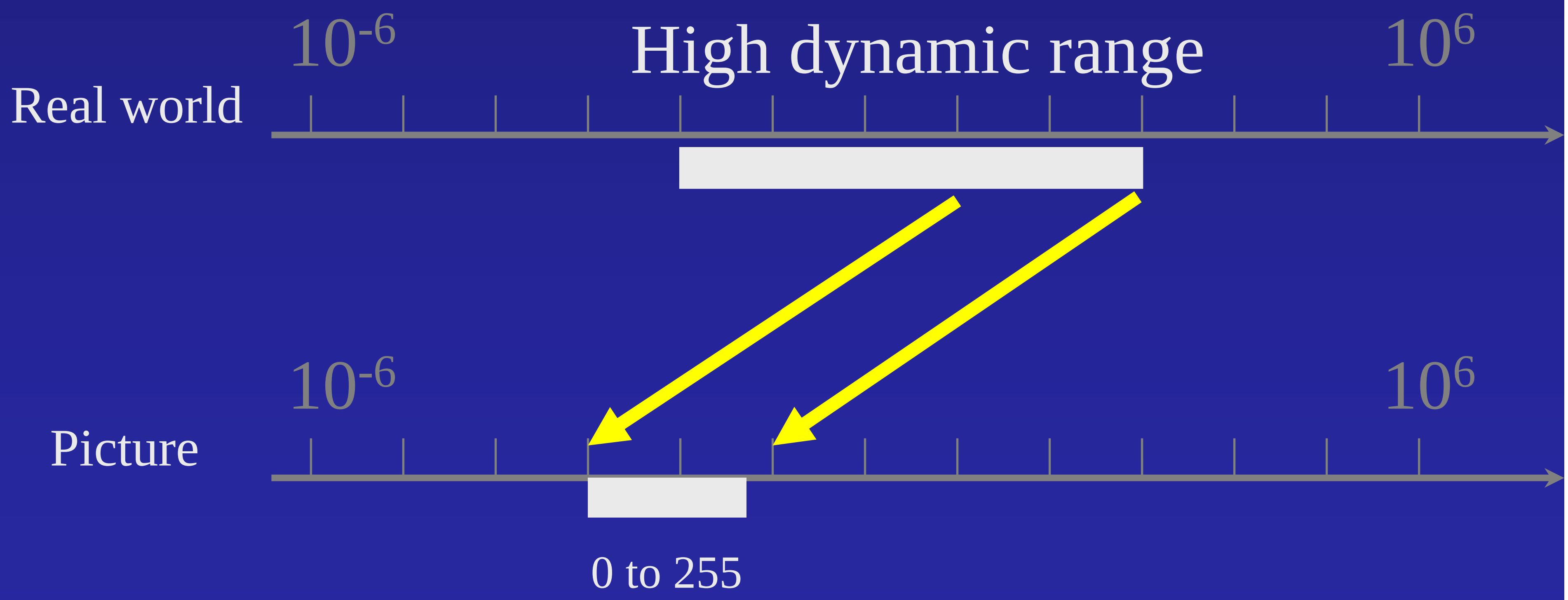
pixel (312, 284) = **42**

42 photos?

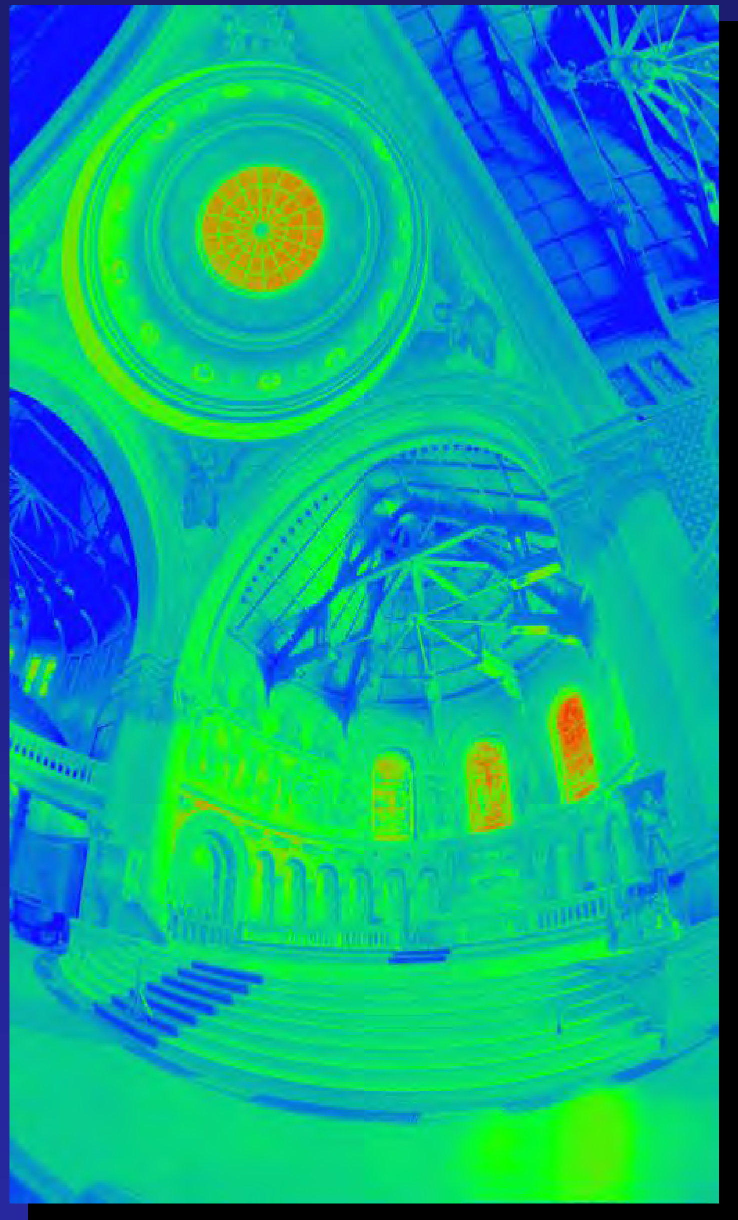
Long Exposure



Short Exposure

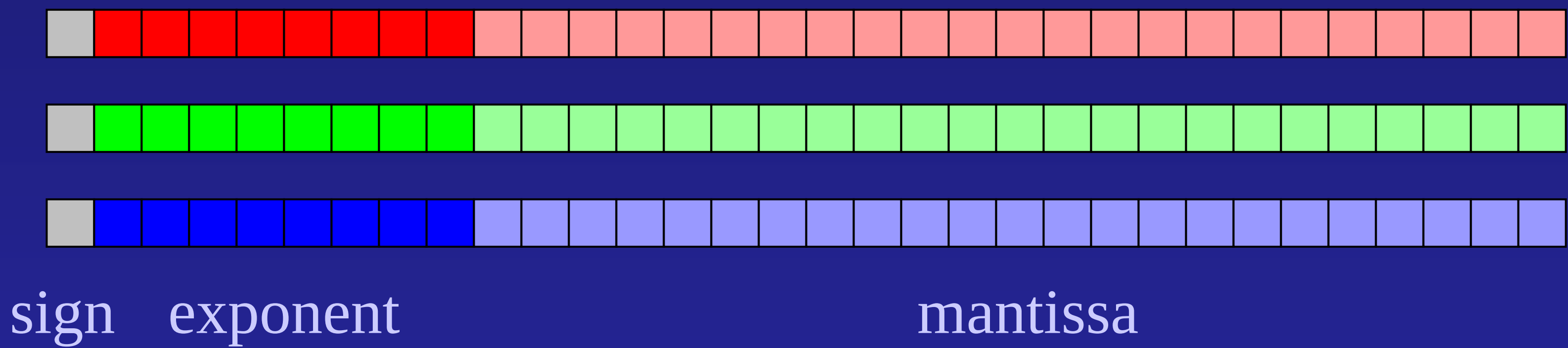


The Radiance Map



Portable FloatMap (.pfm)

- 12 bytes per pixel, 4 for each channel

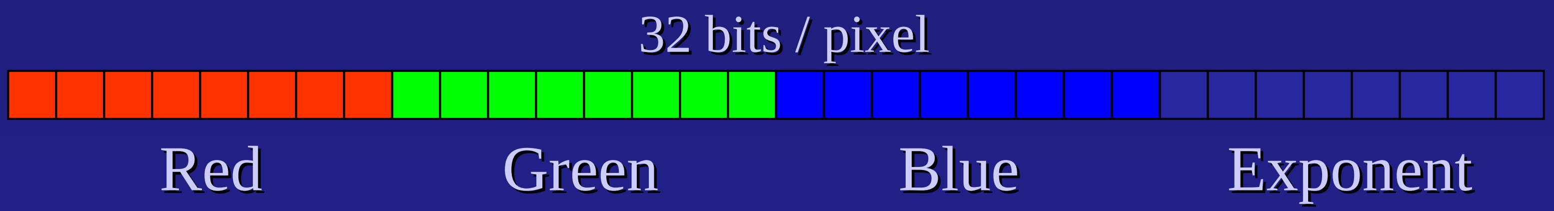


Text header similar to Jeff Poskanzer's .ppm image format:

```
PF
768 512
1
<binary image data>
```

Floating Point TIFF similar

Radiance Format
(.pic, .hdr)



(145, 215, 87, 149) =

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

(1190000, 1760000, 713000)

(145, 215, 87, 103) =

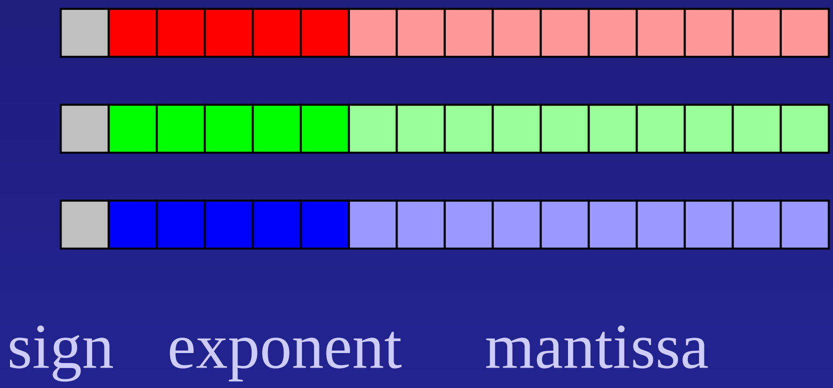
$(145, 215, 87) * 2^{(103-128)}$ =

(0.00000432, 0.00000641, 0.00000259)

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

ILM's OpenEXR (.exr)

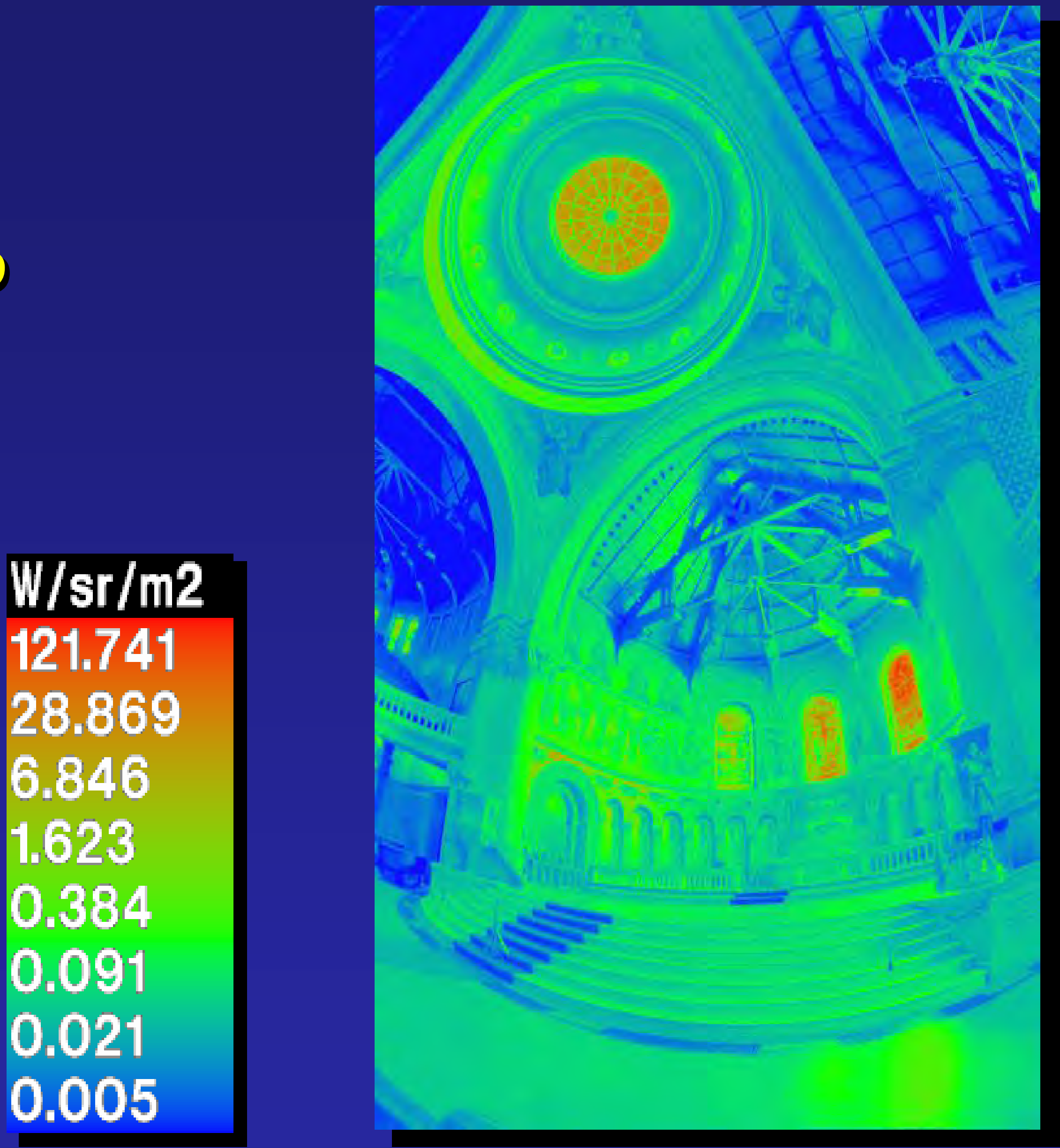
- 6 bytes per pixel, 2 for each channel, compressed



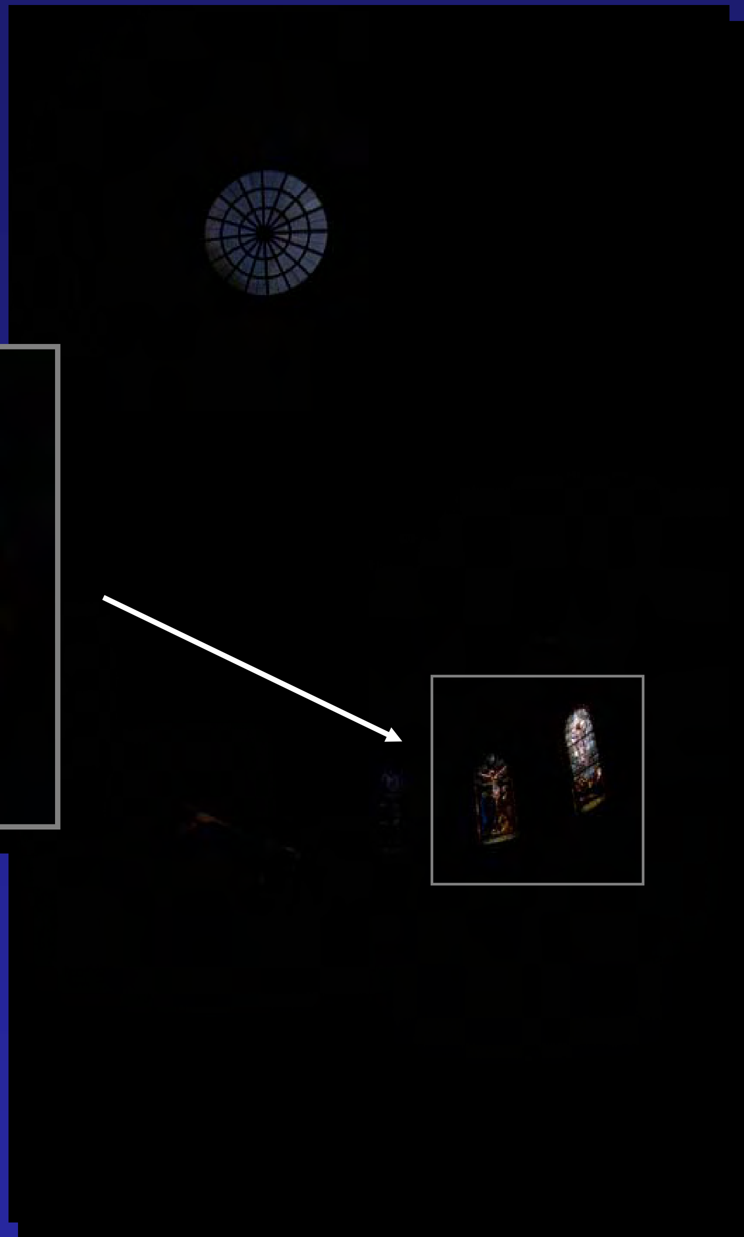
- Several lossless compression options, 2:1 typical
- Compatible with the "half" datatype in NVidia's Cg
- Supported natively on GeForce FX and Quadro FX

- Available at http://www.openexr.net/

Now What?



The Radiance Map

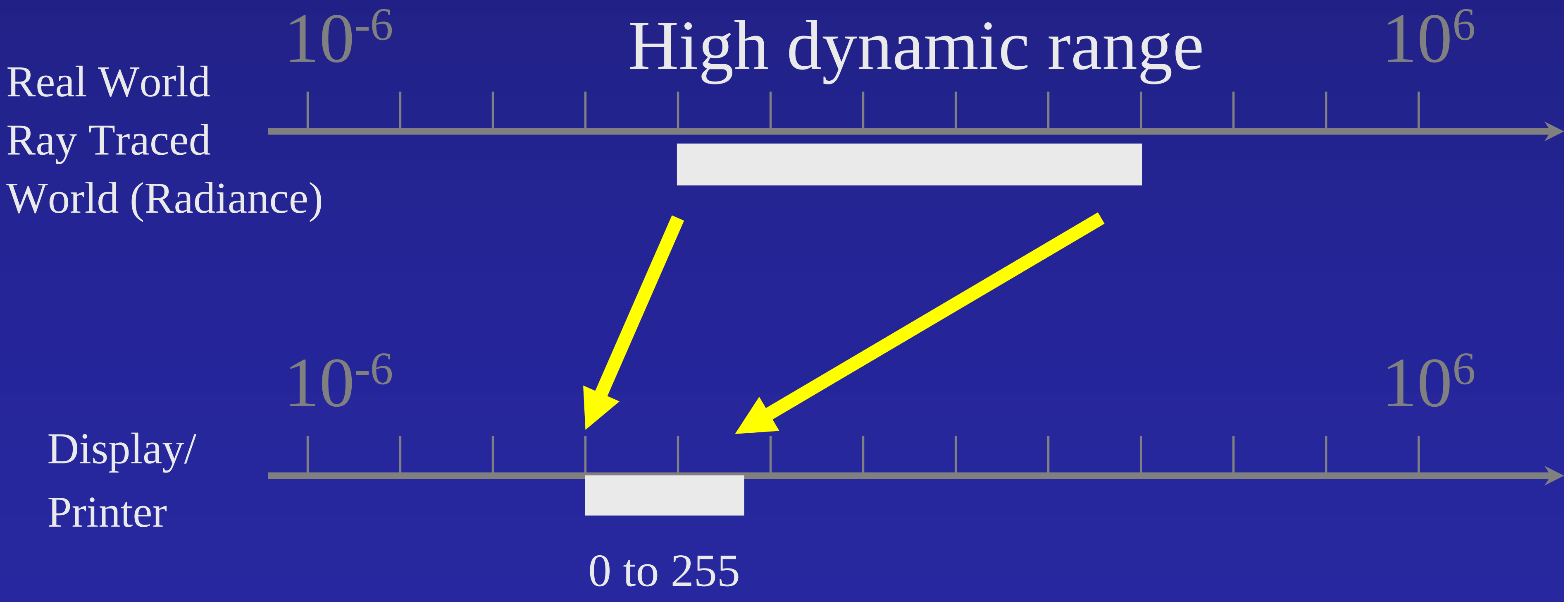


Linearly scaled to display device

Tone Mapping

- How can we do this?

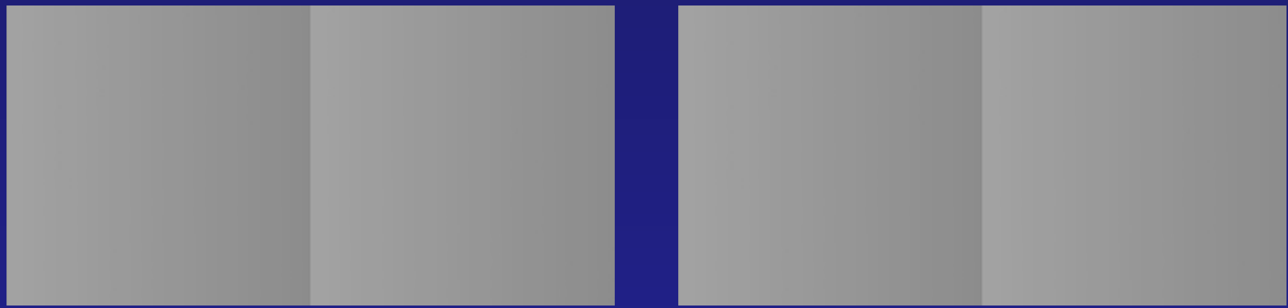
  Linear scaling?, thresholding? Suggestions?

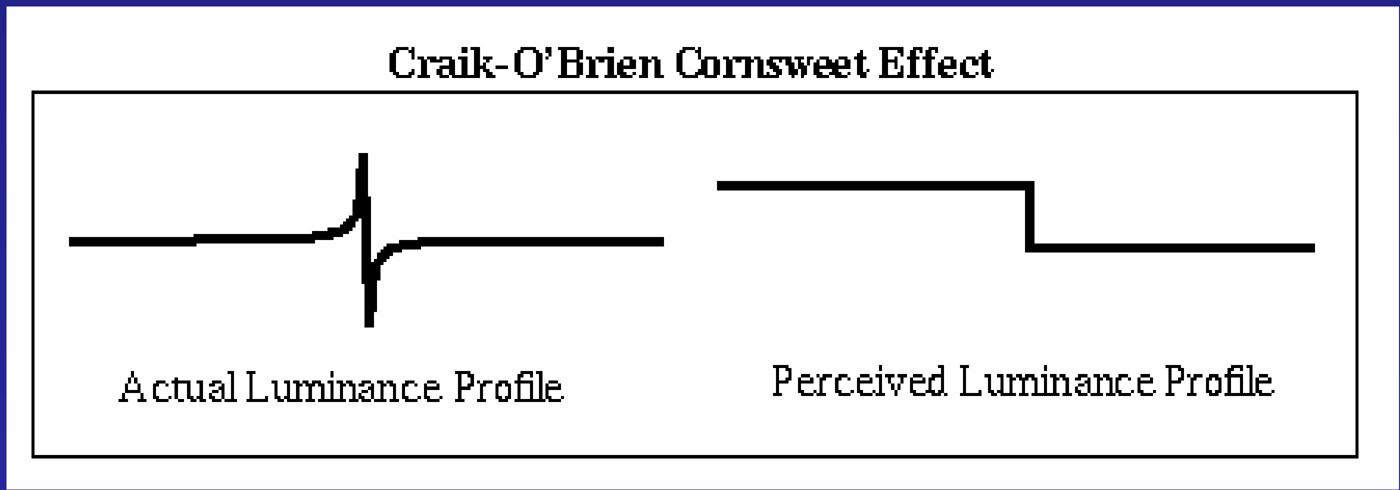


Linear

Darkest 0.1% scaled to display device

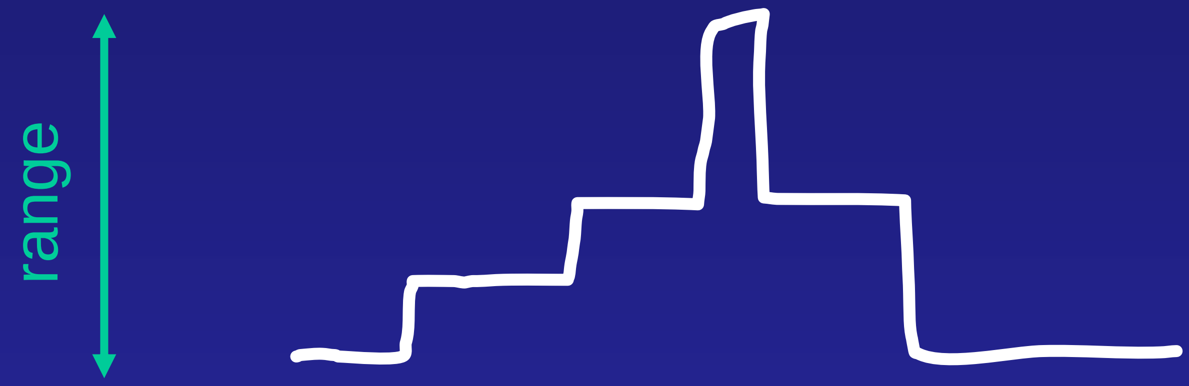
Metamores





Can we use this for range compression?

Compressing Dynamic Range

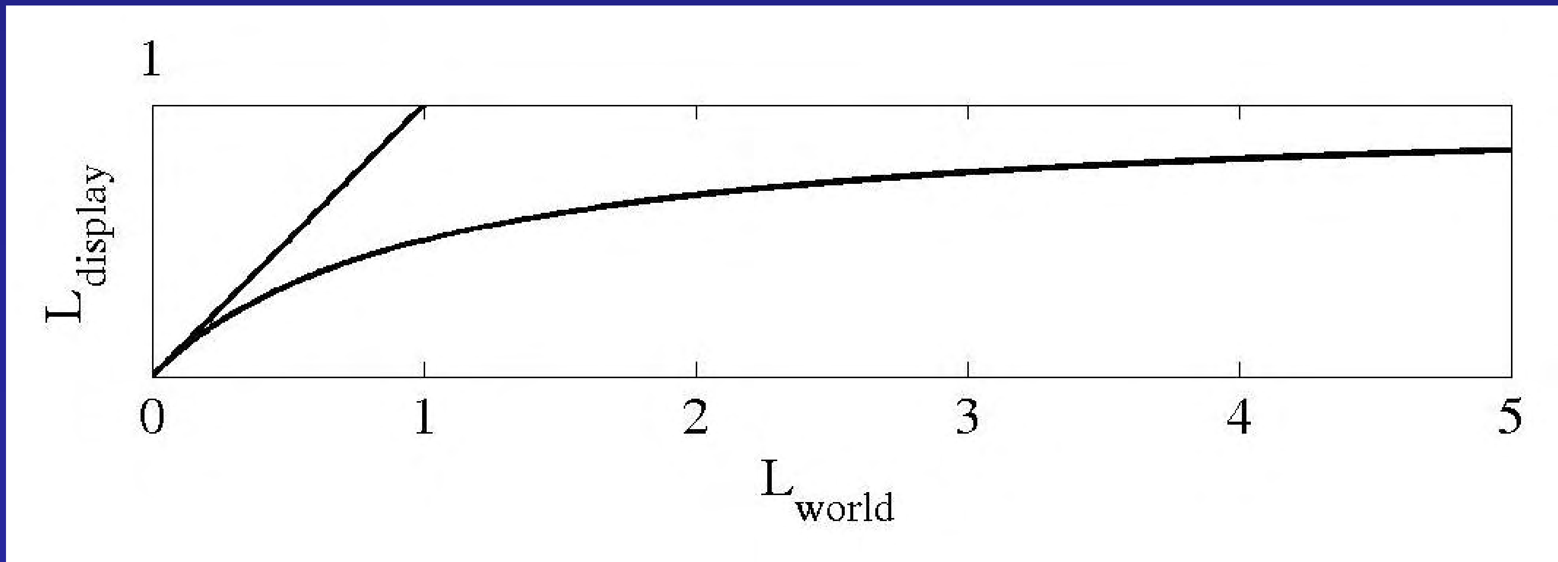


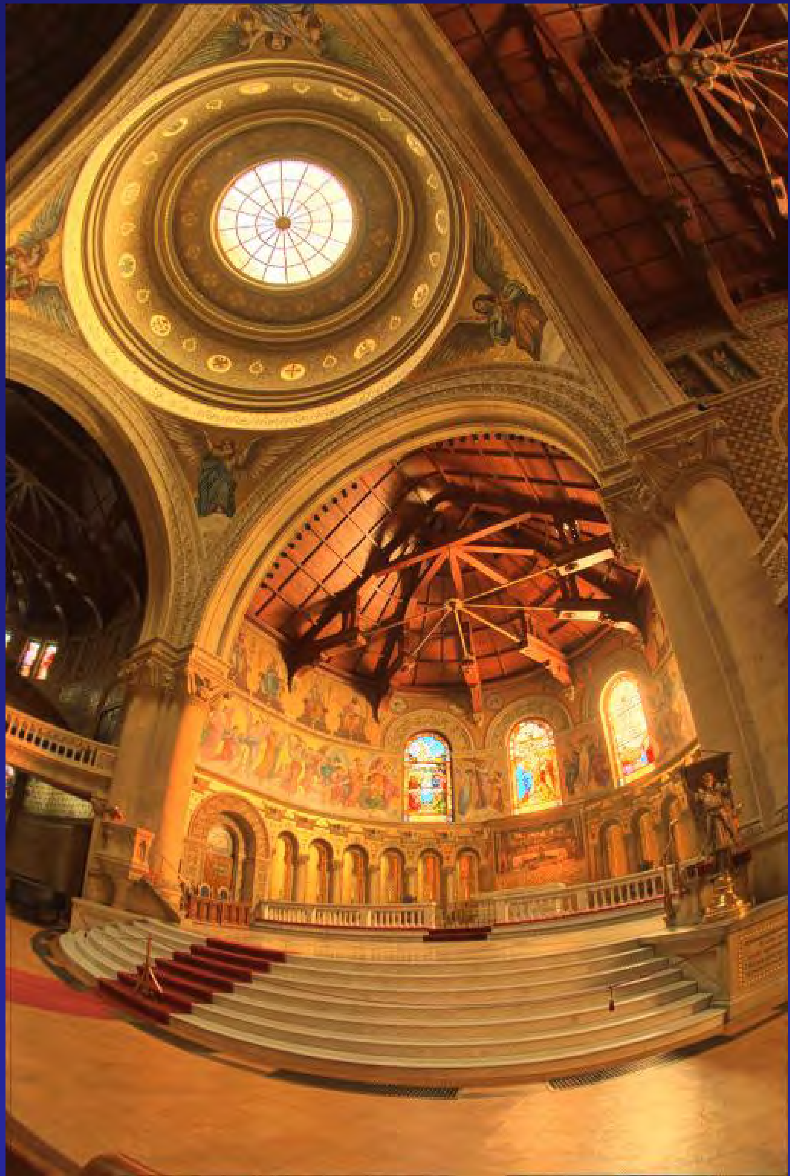
Simple Global Operator

- Compression curve needs to
  - Bring everything within range
  - Leave dark areas alone
- In other words
  - Asymptote at 255
  - Derivative of 1 at 0

Global Operator (Reinhart et al)

$$L_{display} = \frac{L_{world}}{1 + L_{world}}$$





Reinhart Operator

Darkest 0.1% scaled to display device

Global Operator Results

Rendering with Natural Light

SIGGRAPH 98 Electronic Theater


RNL Environment
mapped onto
interior of large
cube

MOVIE!

Direct HDR Capture of the Sun and Sky

SIGGRAPH2004

- Use Sigma 8mm fisheye lens and Canon EOS 1Ds to cover entire sky
- Use 3.0 ND filter on lens back to cover full range of light

Stumpfel, Jones, Wenger, Tchou, Hawkins, and Debevec. “Direct HDR Capture of the Sun and Sky”. To appear in Afrigraph 2004.

Extreme HDR Image Series

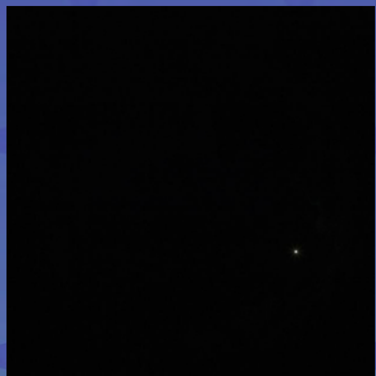
SIGGRAPH2004

1 sec
f/4

1/4 sec
f/4

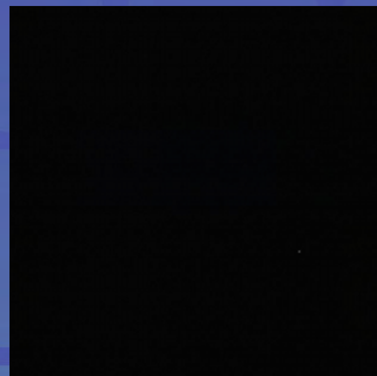
1/30 sec
f/4

1/30 sec
f/16



1/250 sec
f/16

1/1000 sec
f/16



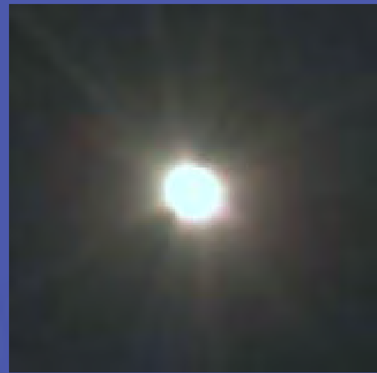
1/8000 sec
f/16

Extreme HDR Image Series

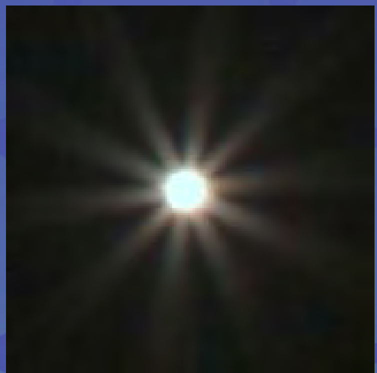
- sun closeup

1 sec
f/4

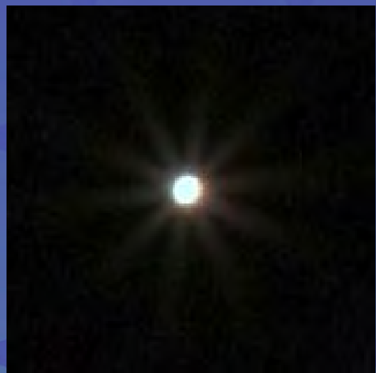
1/4 sec
f/4



1/30 sec
f/4



1/30 sec
f/16

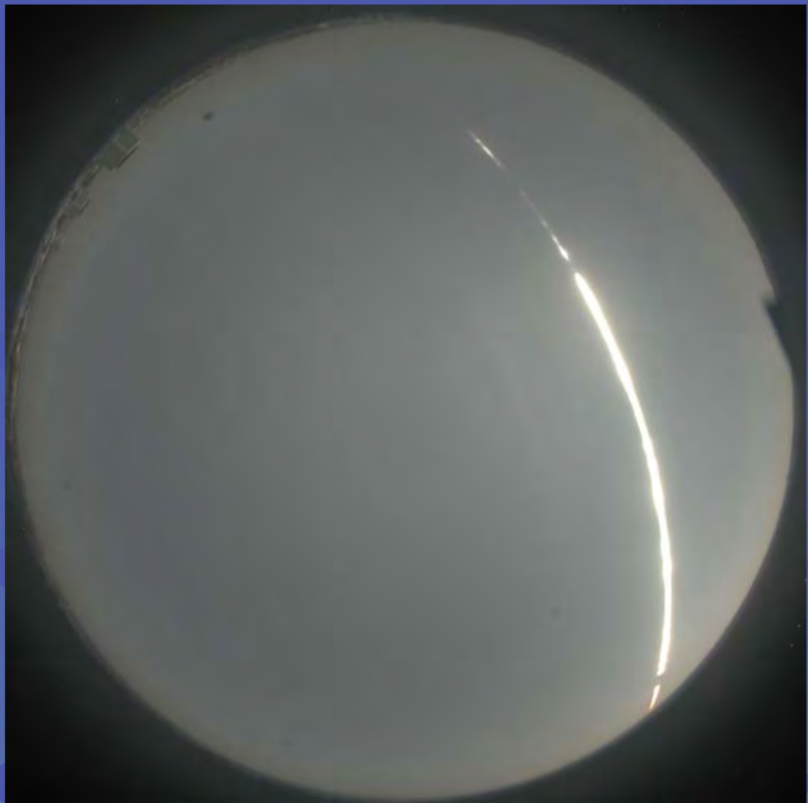


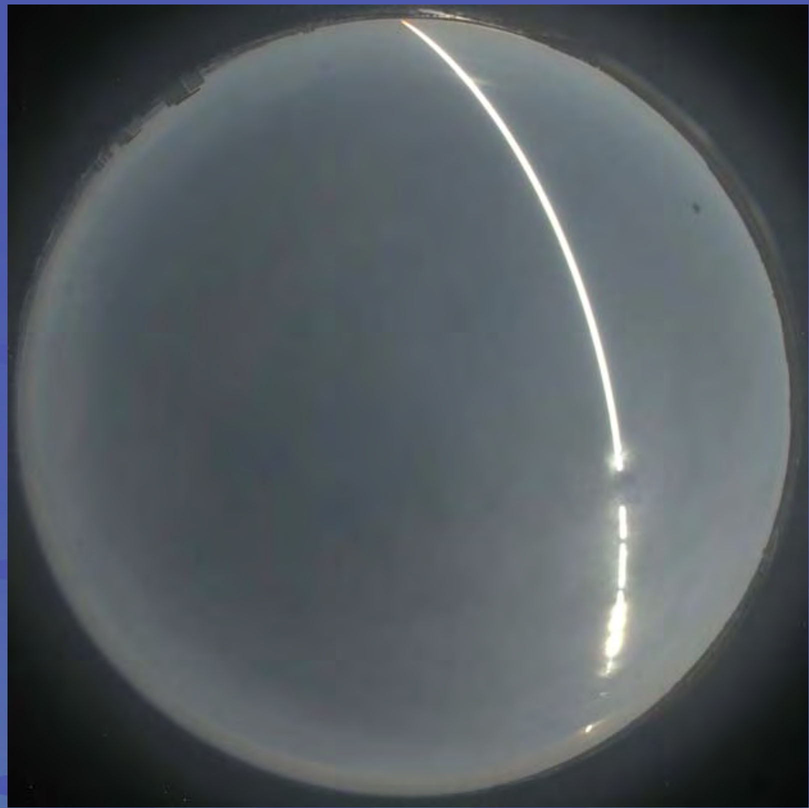
1/250 sec
f/16

1/1000 sec
f/16

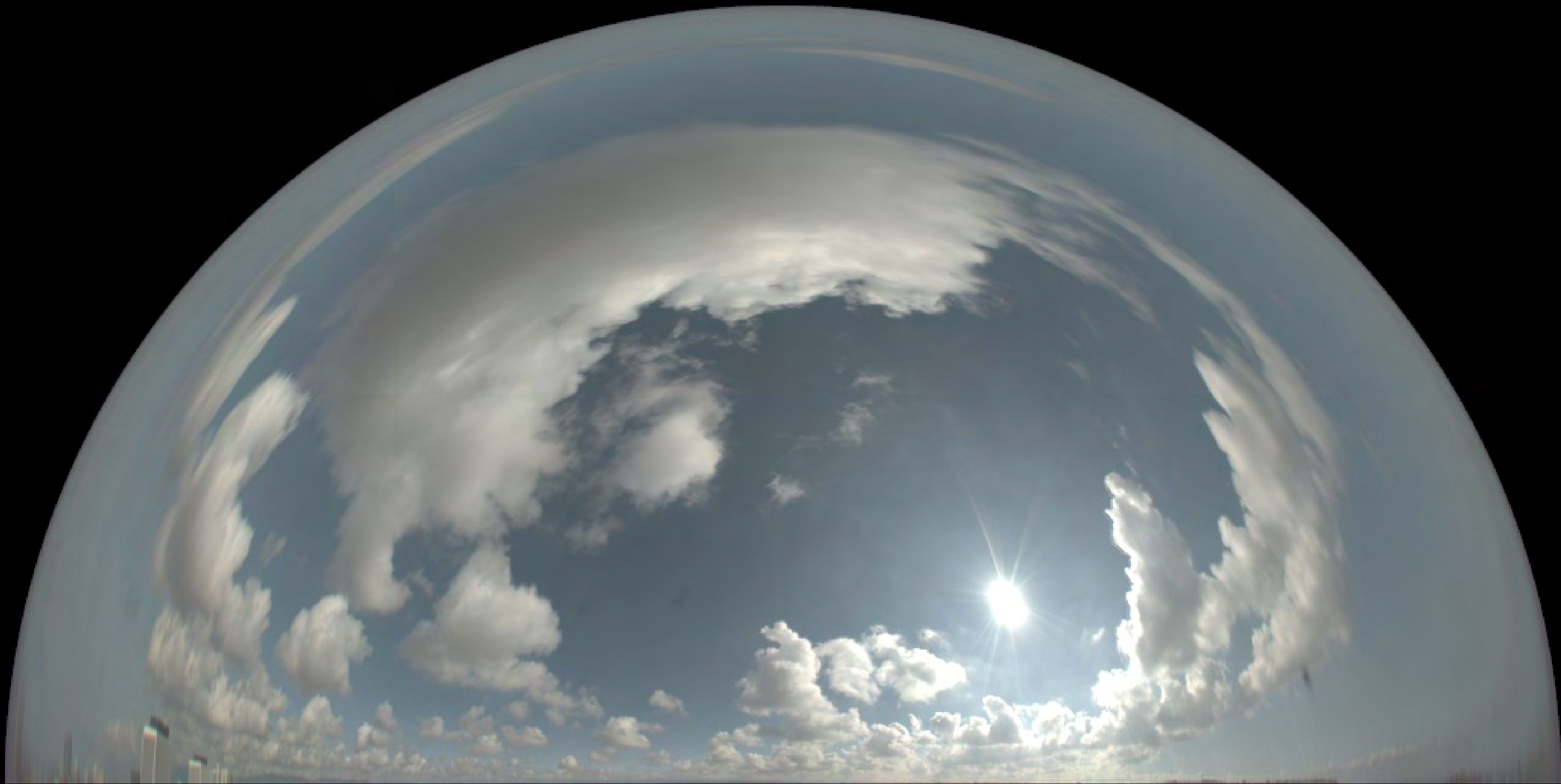
1/8000 sec f/16
only image that does not saturate!

Two Complete days of HDR Lighting





HDRI Sky Probe



Lit by sun and sky

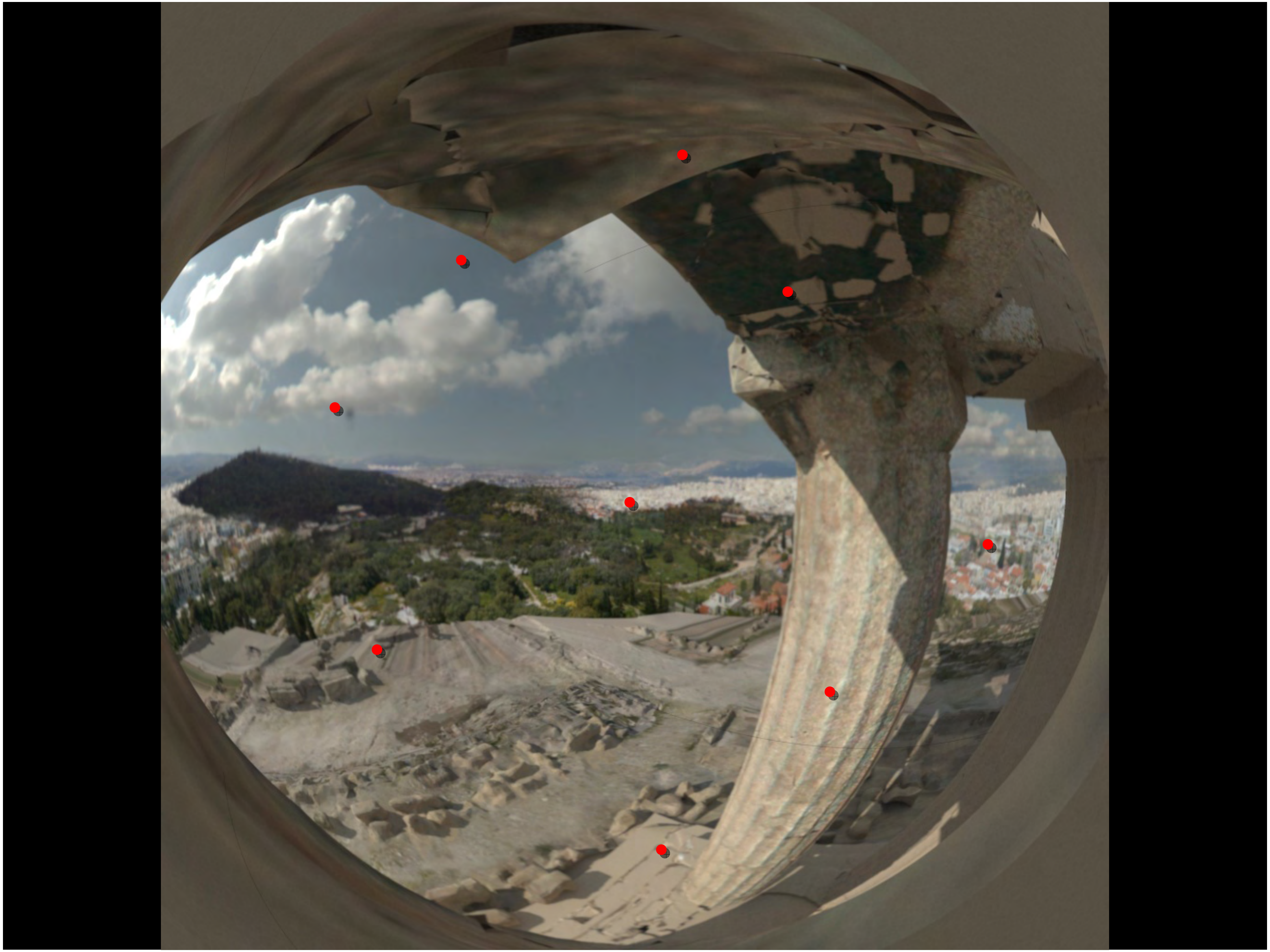
9 samples per pixel, 17 min.

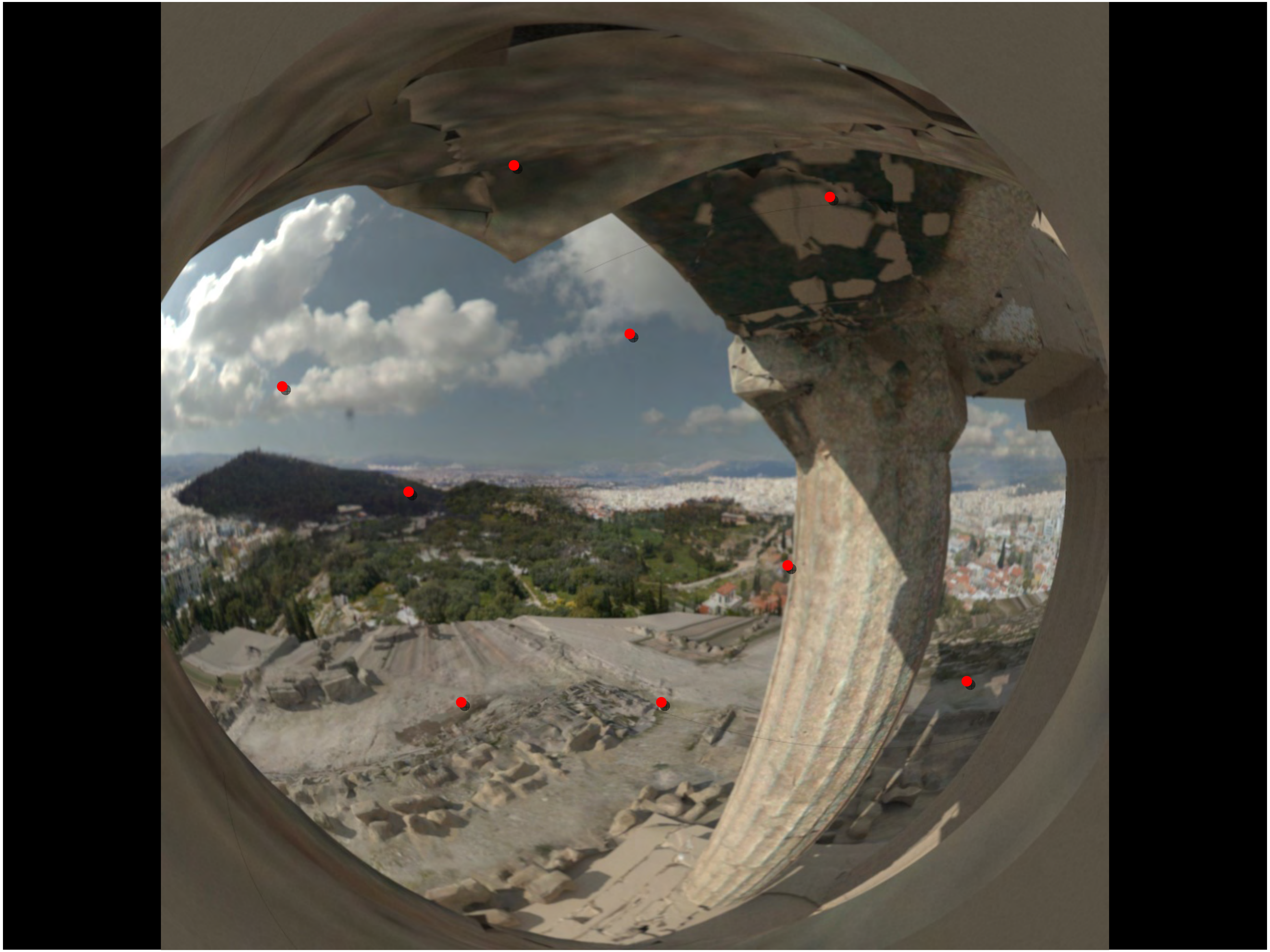
16 samples per pixel, 46 min.

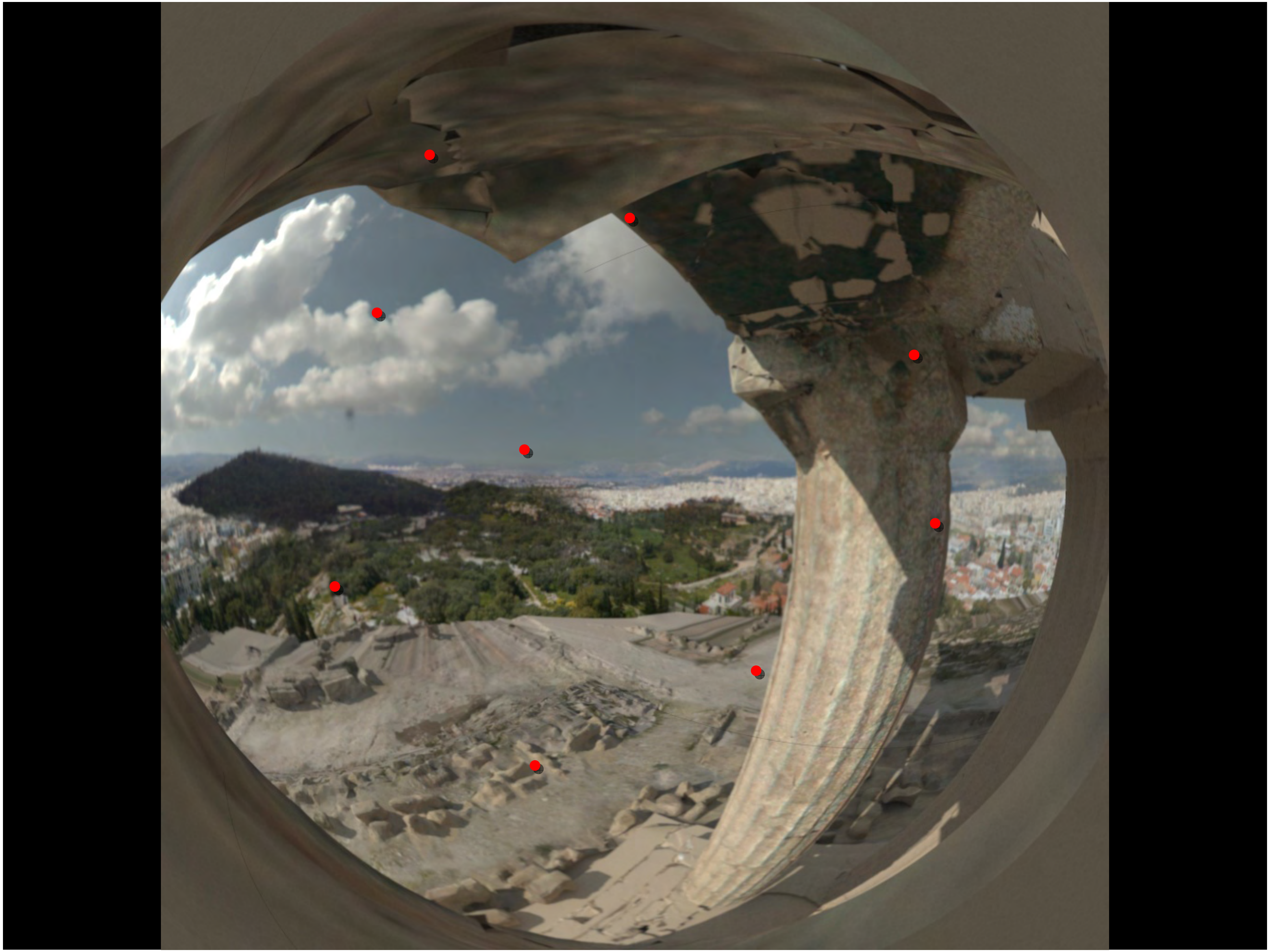
100 samples per pixel, 189 min.

A sunlit sample point

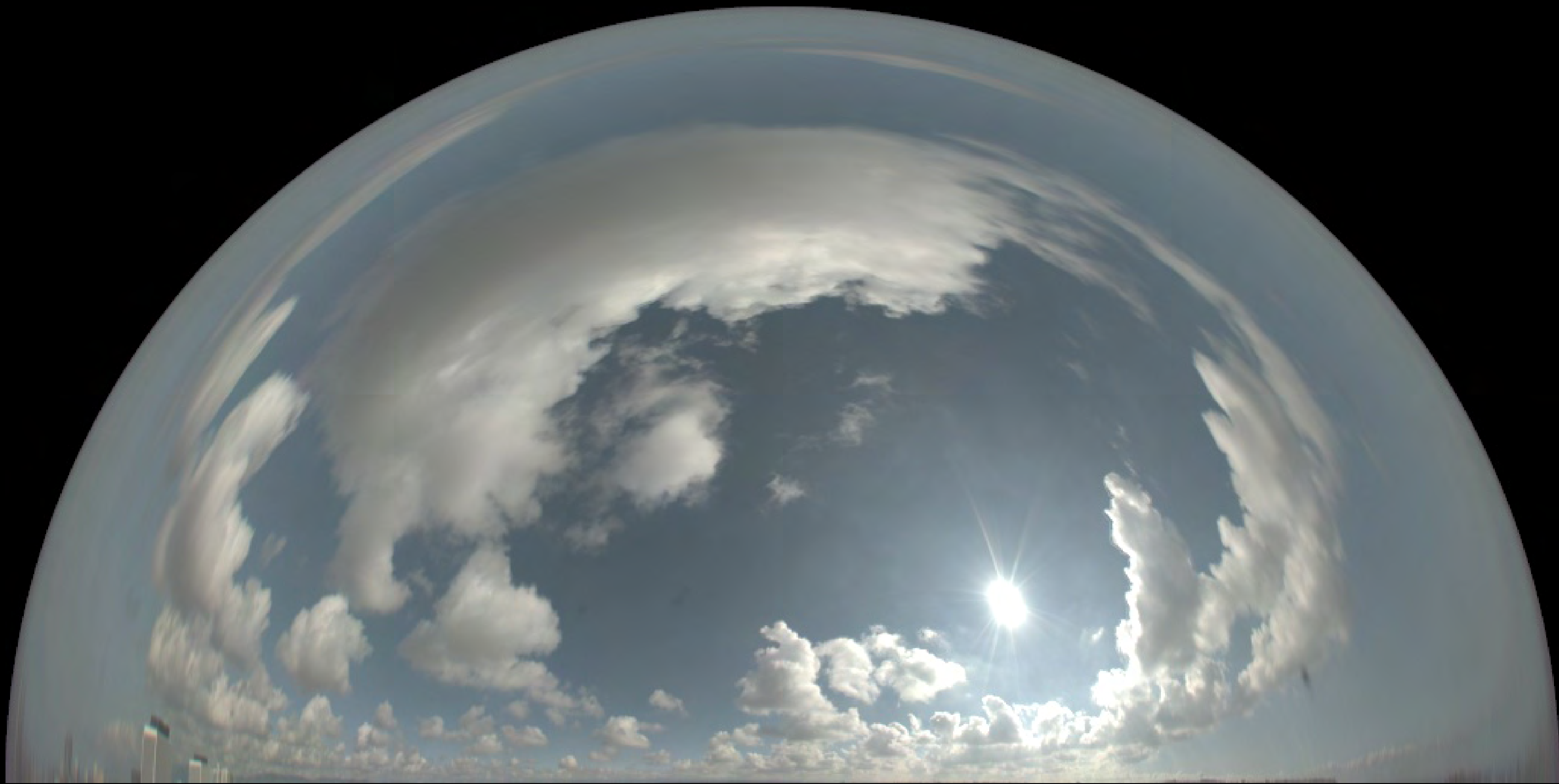
A shadowed sample point





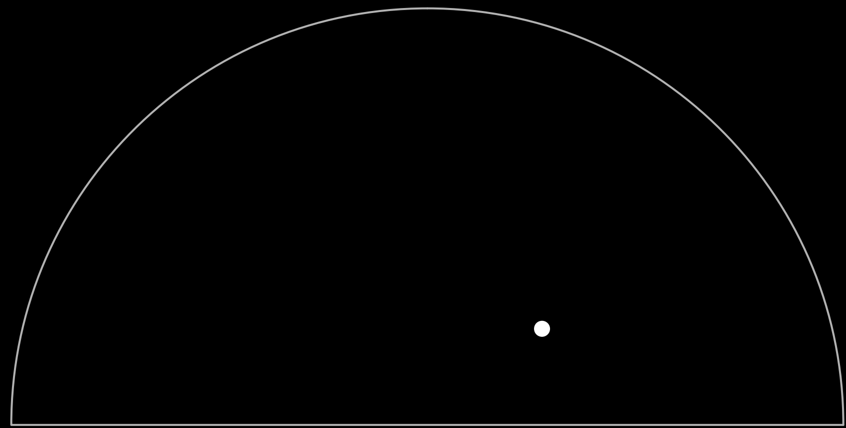


HDRI Sky Probe



Clipped Sky + Sun Source

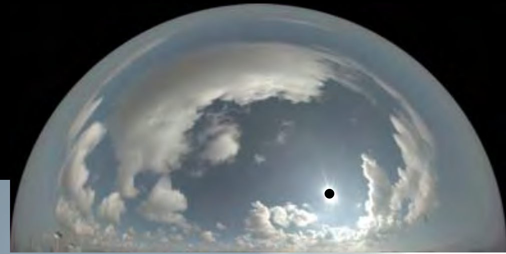
+



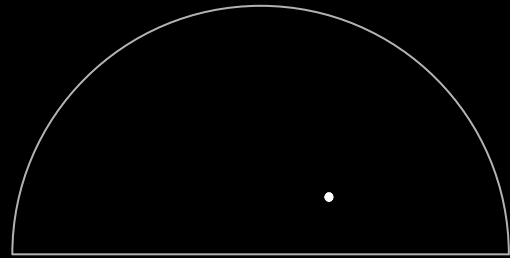
```
texture_map _HDRI_probe_map_clip_
"probe_09-55_clipped.hdr" {
swrap periodic
 filter bilinear
}

shader _HDRI_clip sky_HDRI {
 HDRI_map "_HDRI_probe_map_clip_"
 multiplier 1.000000
}
```

```
light sun directional 1 {
 direction -0.711743 -0.580805 -0.395078
 angle 0.532300
 color 10960000 10280000 866000
}
```

Lit by sky only, 17 min.



Lit by sun only, 21 min.

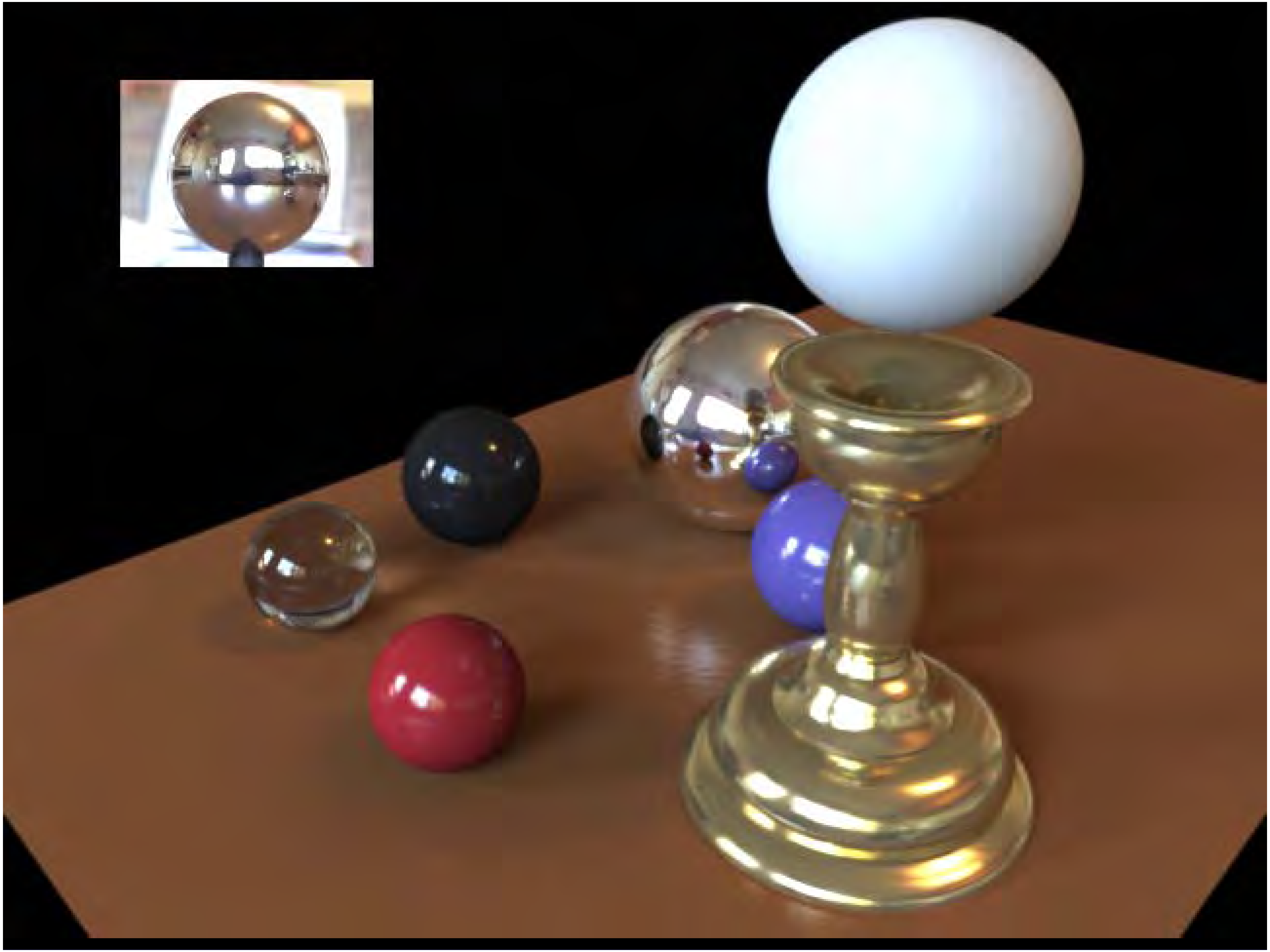


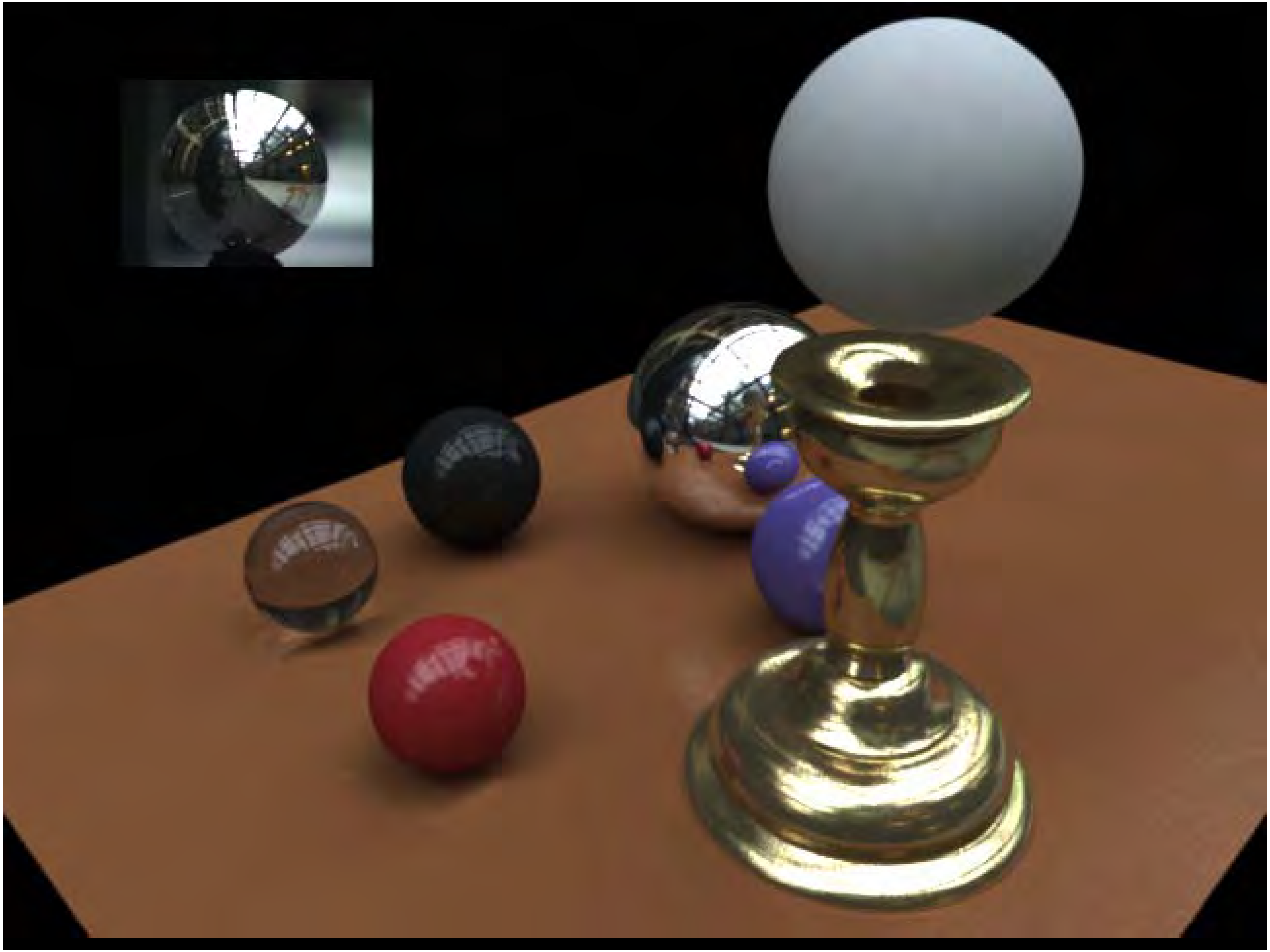
Lit by sun and sky, 25 min

IBL Results

SIGGRAPH2004

Virtual Parthenon model lit by a full day of light captured in Marina del Rey, CA





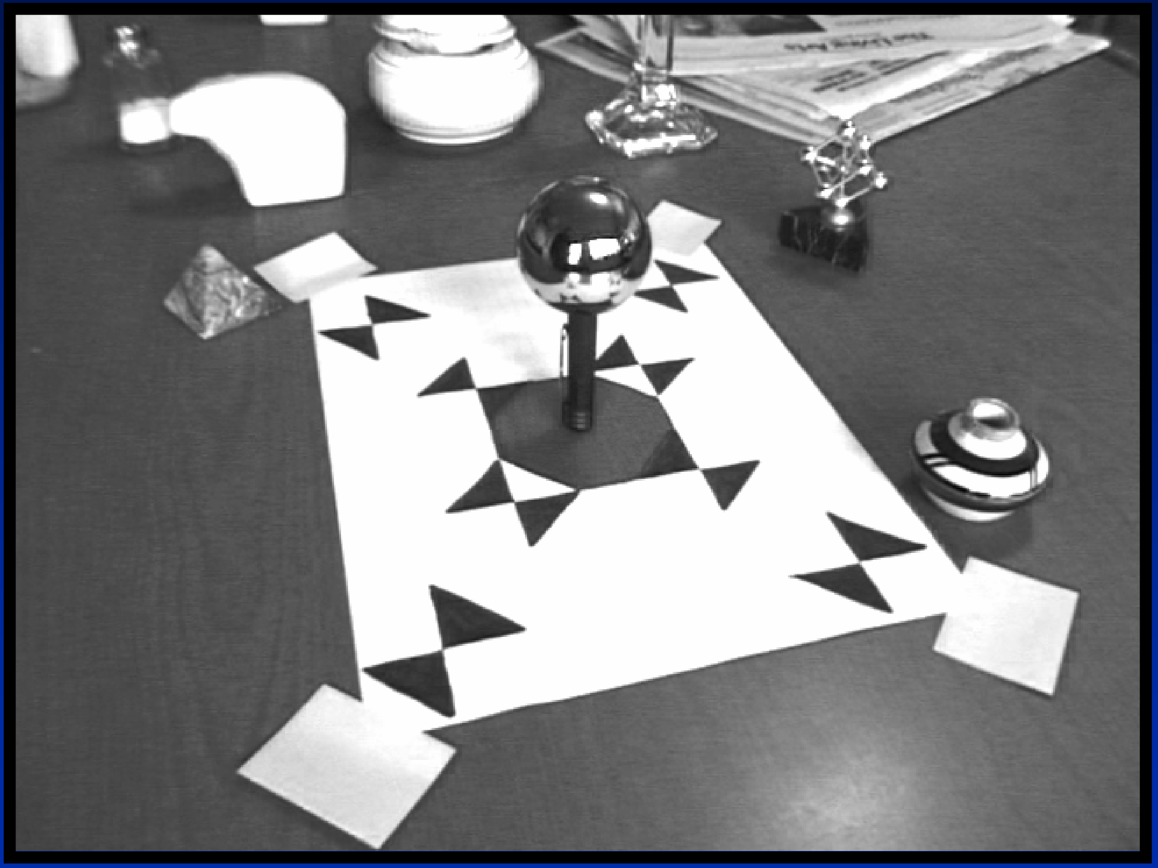
We can now illuminate
synthetic objects with real light.

How do we add synthetic objects to a
real scene?

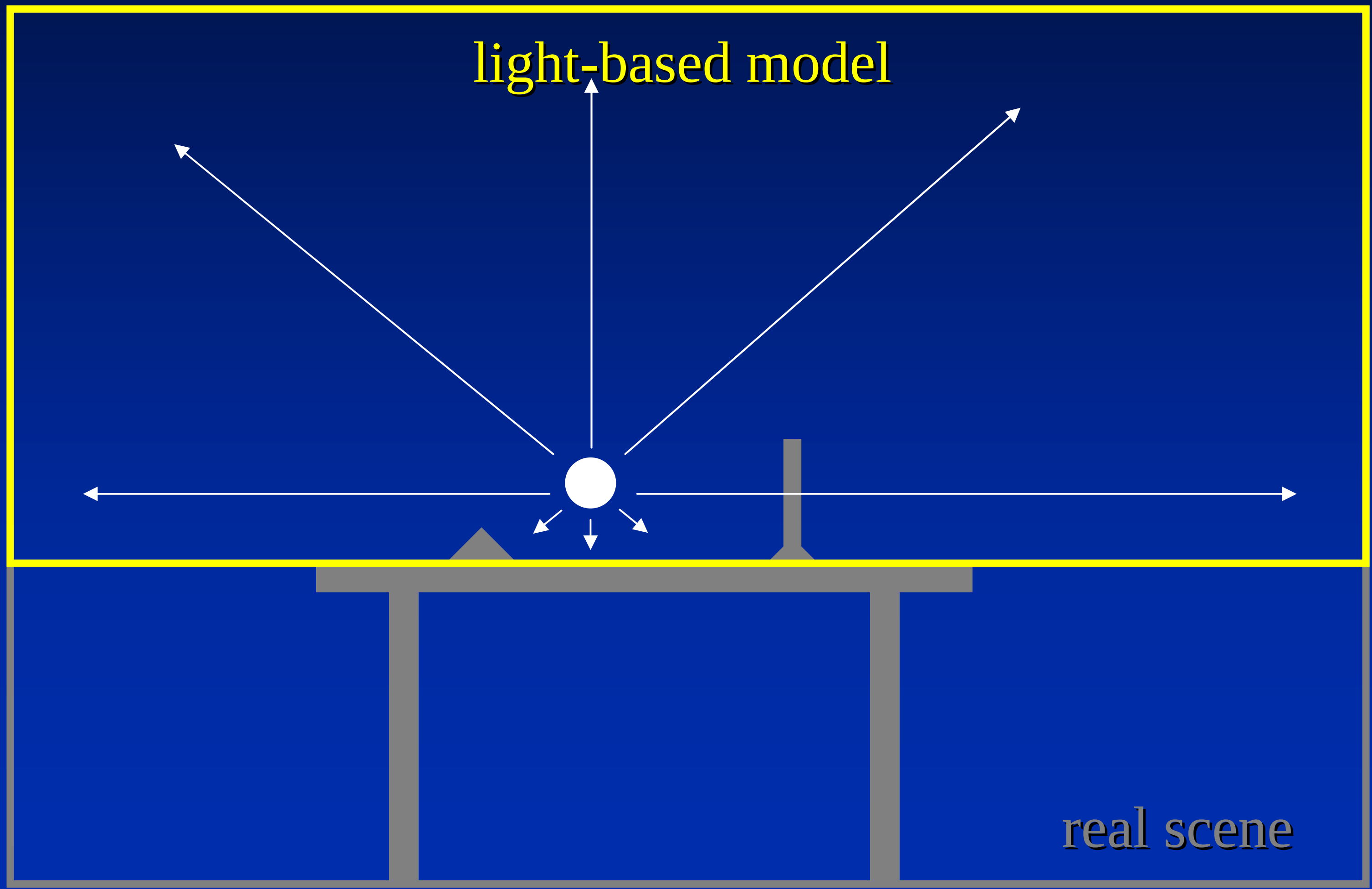
Real Scene Example

Goal: place synthetic objects on table

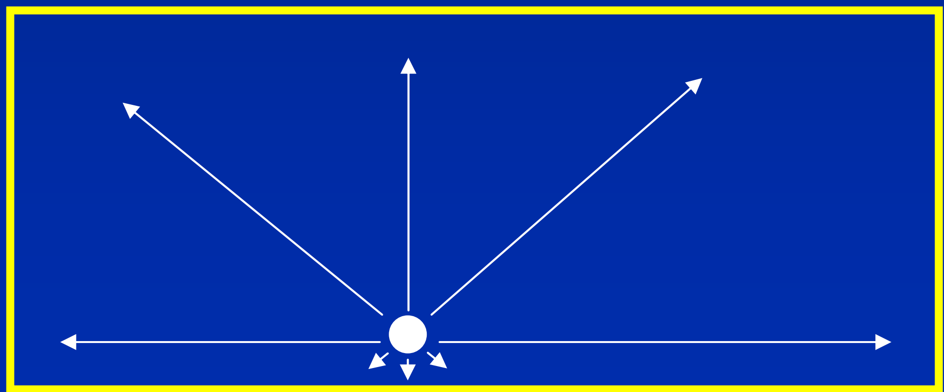
Light Probe / Calibration Grid



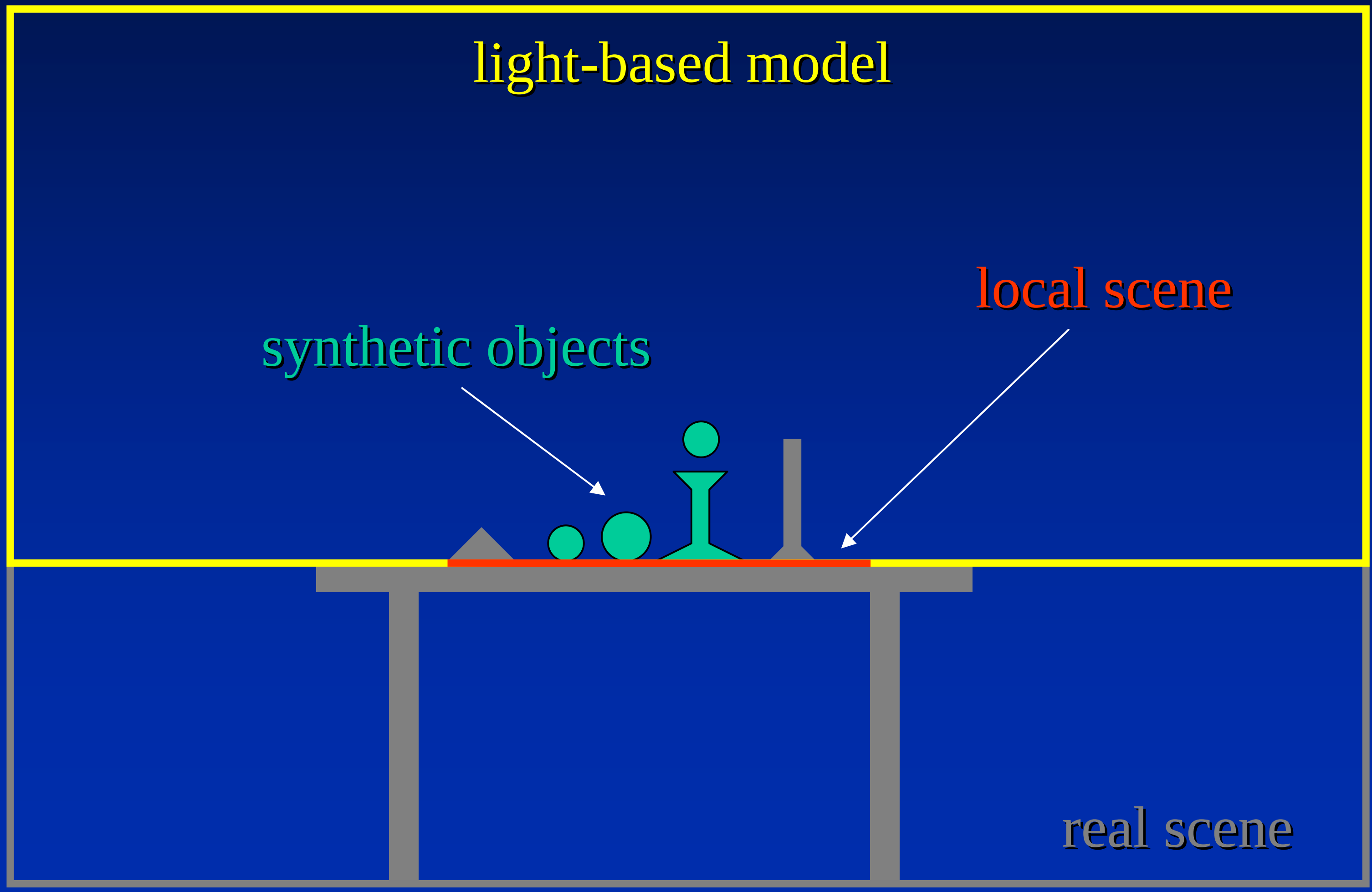
Modeling the Scene



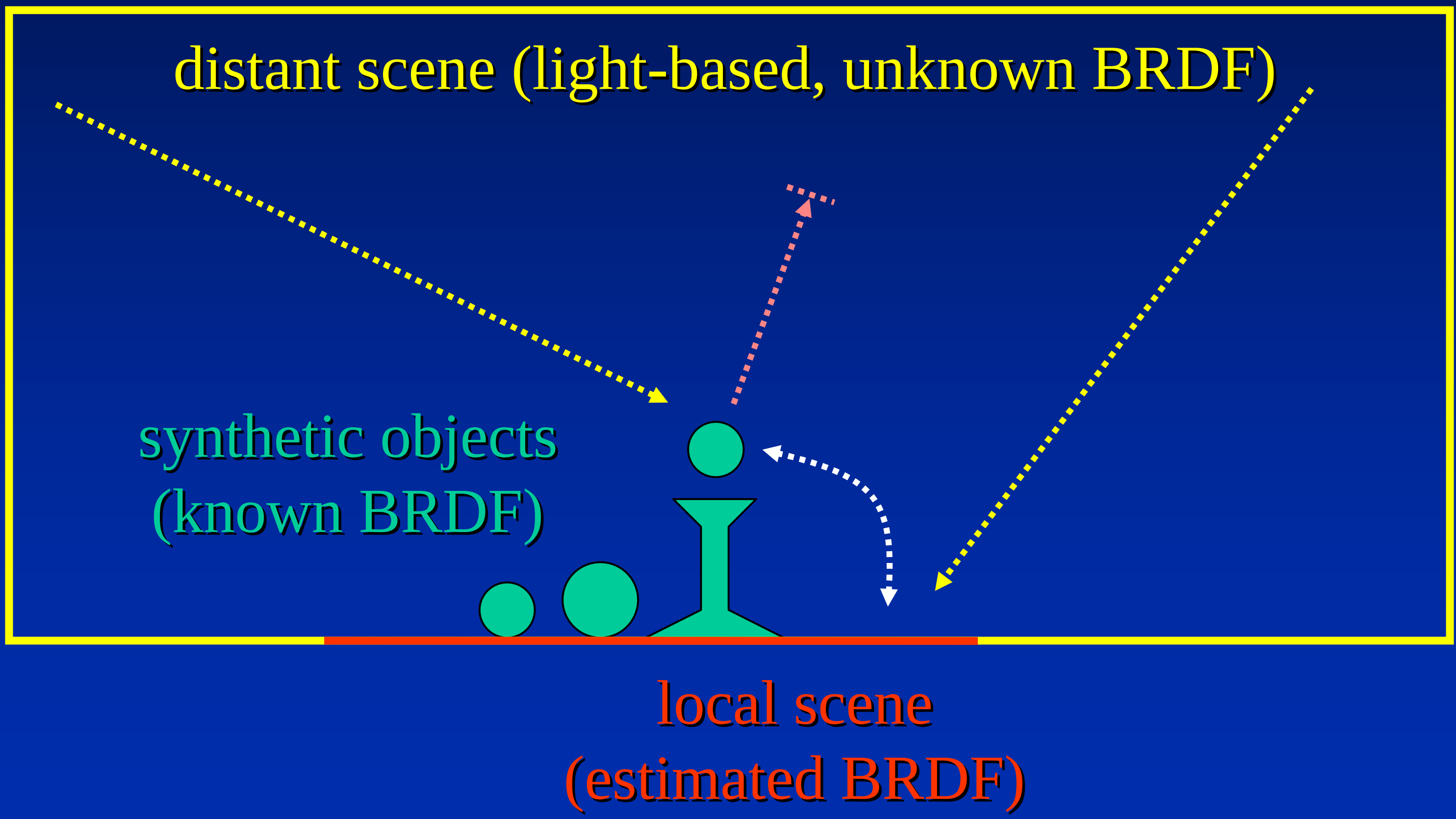
The *Light-Based* Room Model



Modeling the Scene



The Lighting Computation



Rendering into the Scene

Background Plate

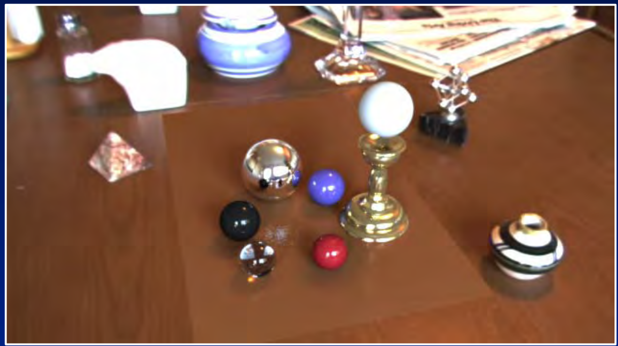
Rendering into the Scene

Objects and Local Scene matched to Scene

Differential Rendering

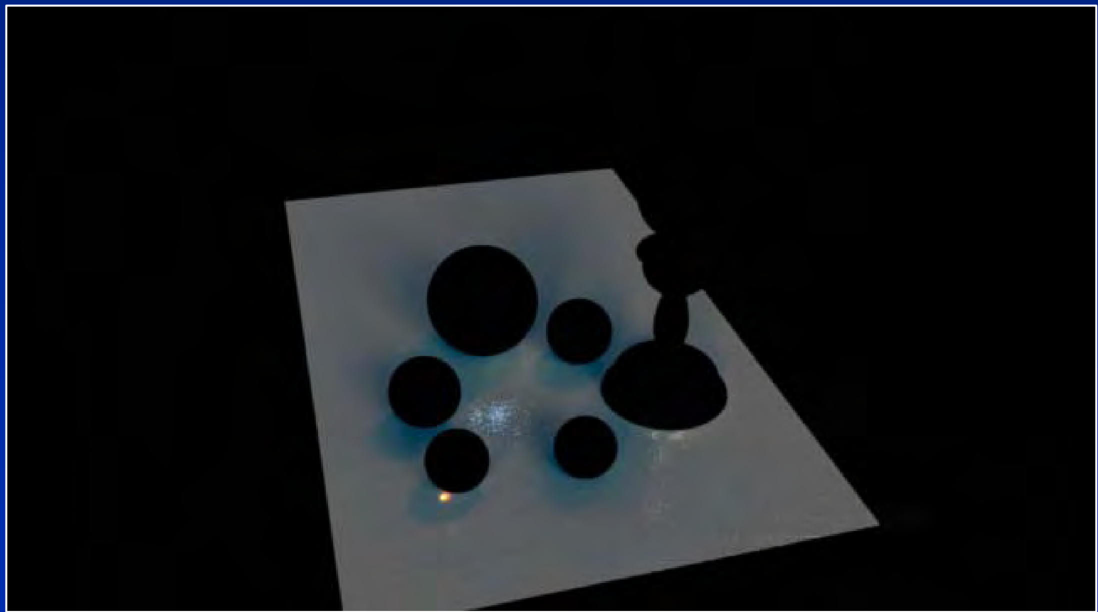
Local scene w/o objects, illuminated by model

Differential Rendering (2)
Difference in local scene



-

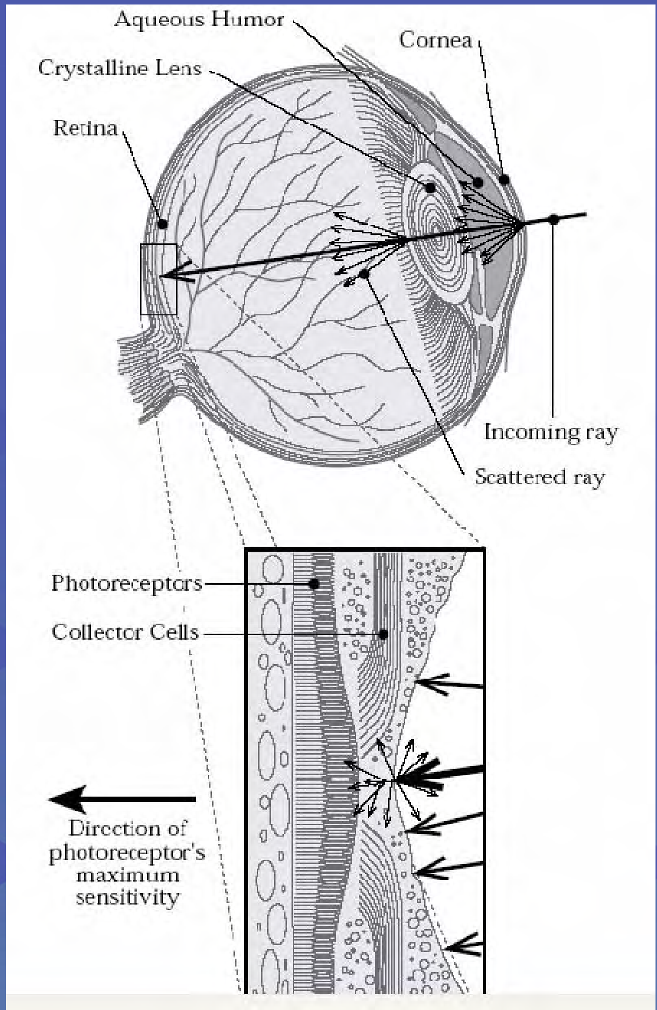
=

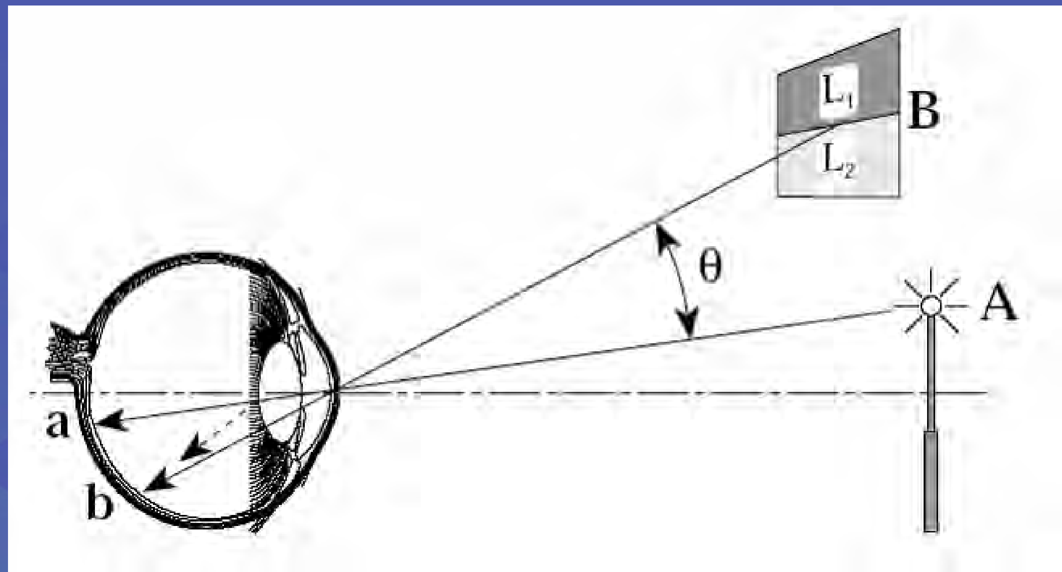


Simulating the Glare in the Human Eye

- Greg Spencer, Peter Shirley, Kurt Zimmerman, and Donald Greenberg. Physically-based glare effects for digital images. SIGGRAPH 95.

Scattering in the eye





What's the scattering model?

HDR Image

Gaussian Blur, LDR information Only

Gaussian Blur, Full HDR Information

Full HDR Disc Blur

Frame Postprocessing in Rendering with Natural Light