

# Image Based Relighting



C0417 – Advanced Computer Graphics: Photographic Image Synthesis

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Lecture 06, Jan. 25<sup>th</sup> 2019

# Image Based Relighting

Debevec, Hawkins,  
Tchou, Duiker, Sarokin,  
and Sagar. *Acquiring  
the Reflectance Field  
of a Human Face.*  
SIGGRAPH 2000

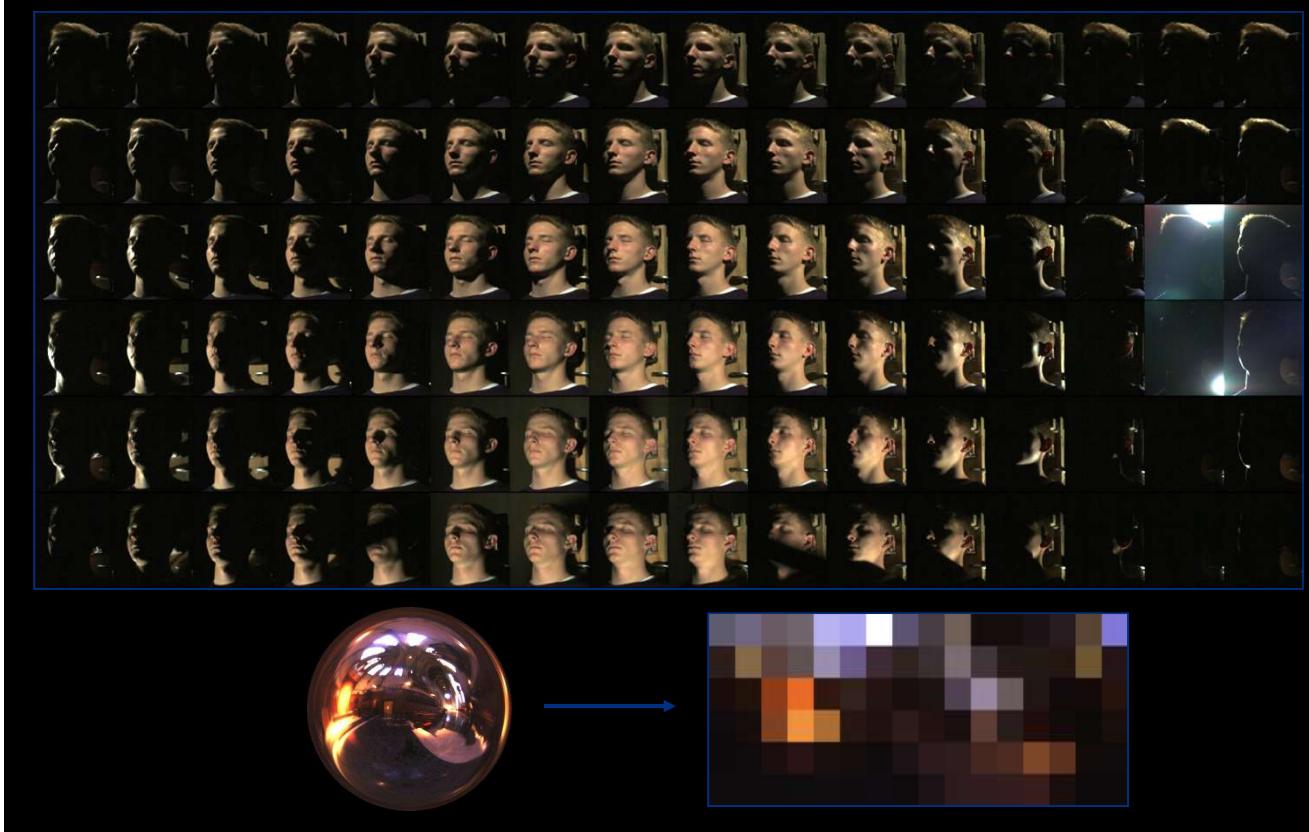


Light Stage 1:  
60-second exposure



3

## Light Stage 4D Reflectance Field

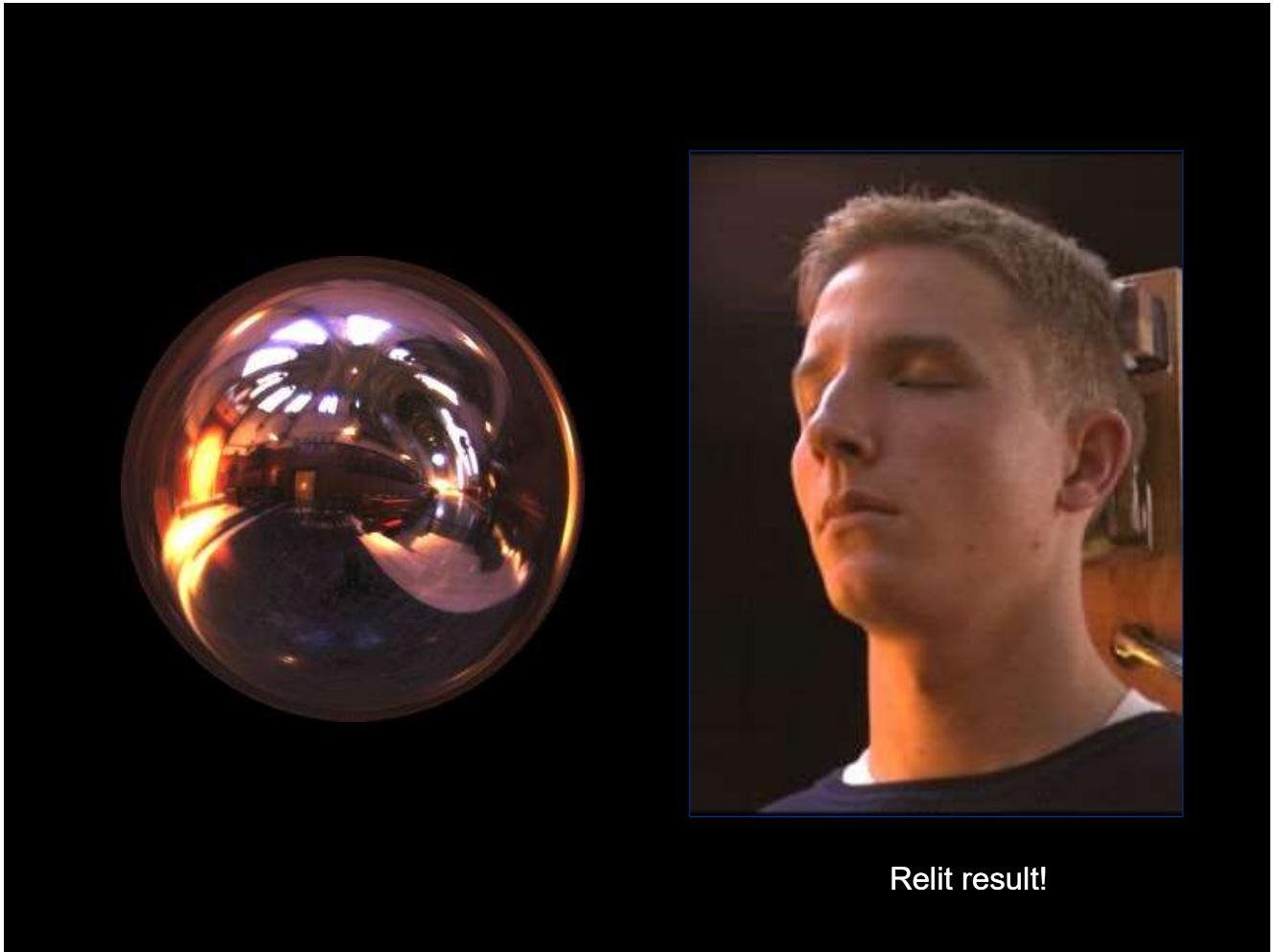


4

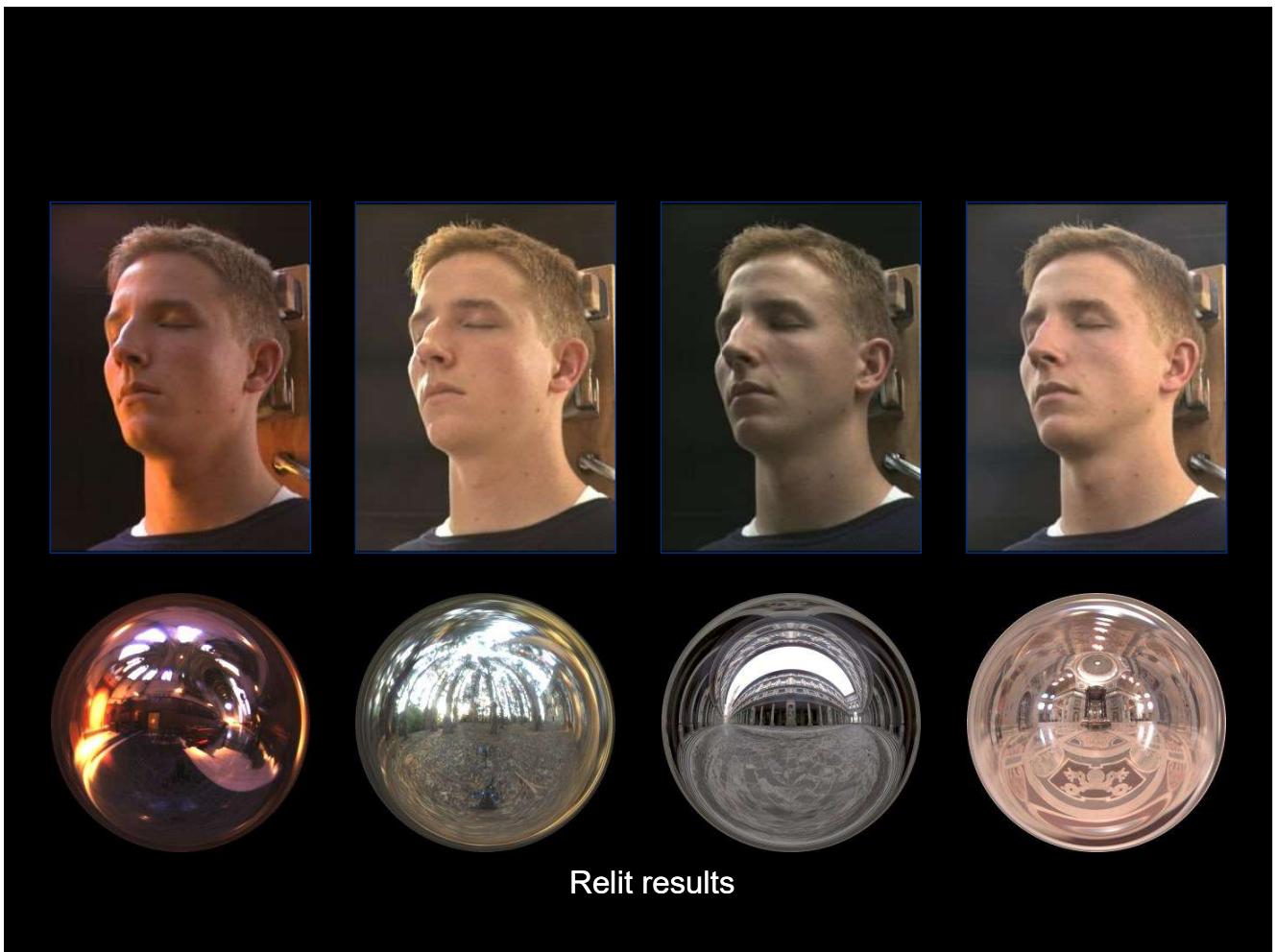
## Light Stage 4D Reflectance Field



Dot product of  
reflectance field and  
light probe



Relit result!

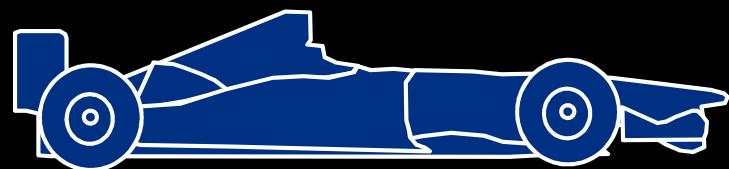


Relit results

# Conventional Modeling



# Conventional Modeling



Acquire Geometry

# Conventional Modeling



Acquire Textures

# Conventional Modeling



Material Properties



Assign Material Properties

# Conventional Modeling



Material Properties

BRDF: Bidirectional Reflectance  
Distribution Function



# Conventional Modeling



Material Properties

BRDF: Bidirectional Reflectance  
Distribution Function



# Conventional Modeling



Material Properties

BRDF: Bidirectional Reflectance  
Distribution Function



# Conventional Modeling



Material Properties

Mirror-like material

BRDF: Bidirectional Reflectance  
Distribution Function



# Conventional Modeling



Material Properties  
Diffuse material

BRDF: Bidirectional Reflectance  
Distribution Function



# Conventional Modeling

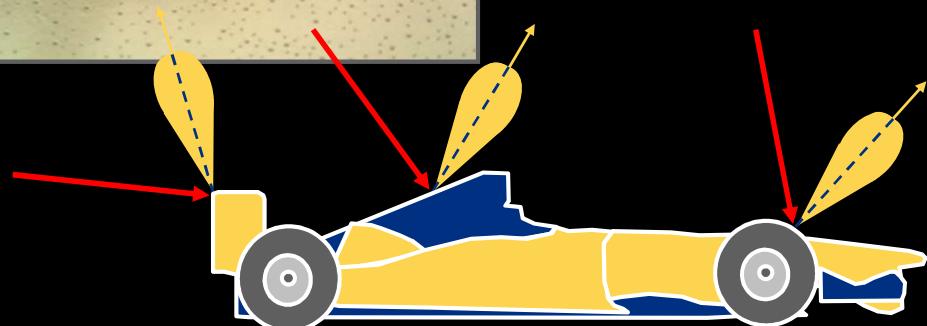


Material Properties

BRDF: Bidirectional Reflectance  
Distribution Function

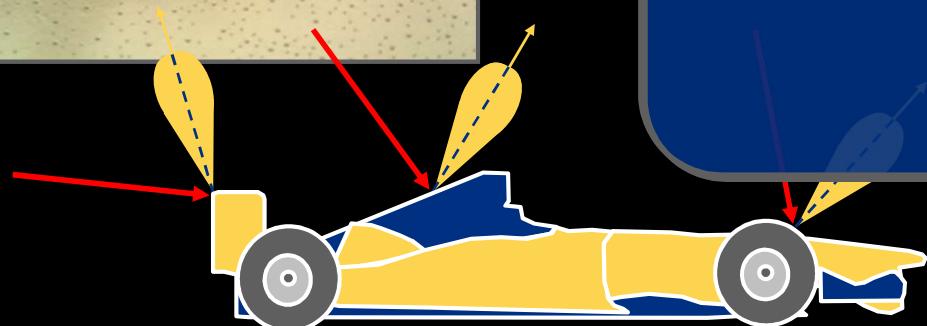


# Conventional Modeling



Render

# Conventional Modeling

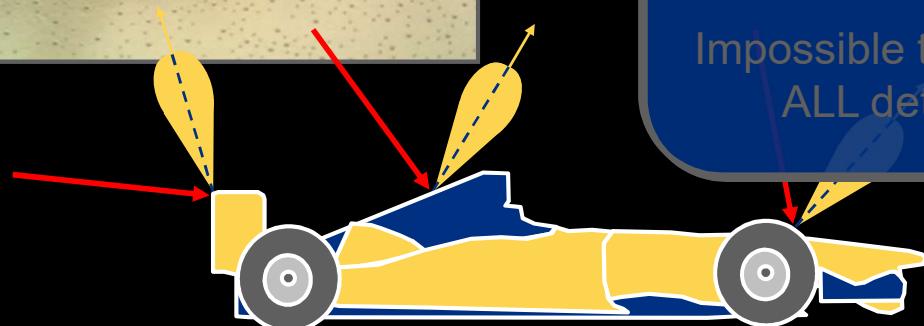


## Disadvantages

Quality depends on:

- Visualisation Tool
- Models used

# Conventional Modeling



## Disadvantages

Quality depends on:

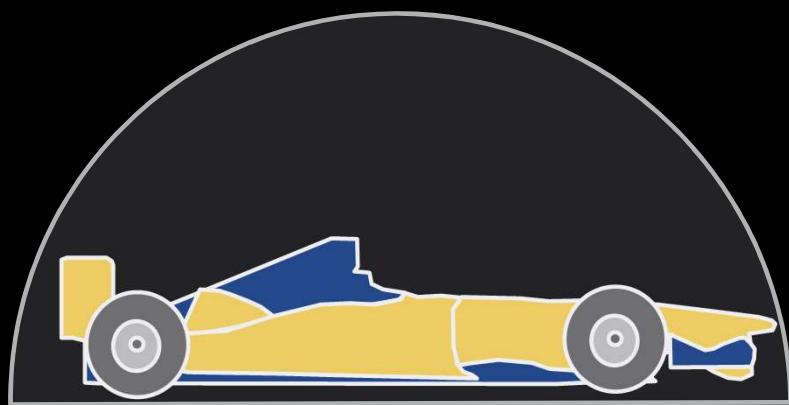
- Visualisation Tool
- Models used

Impossible to model  
ALL details

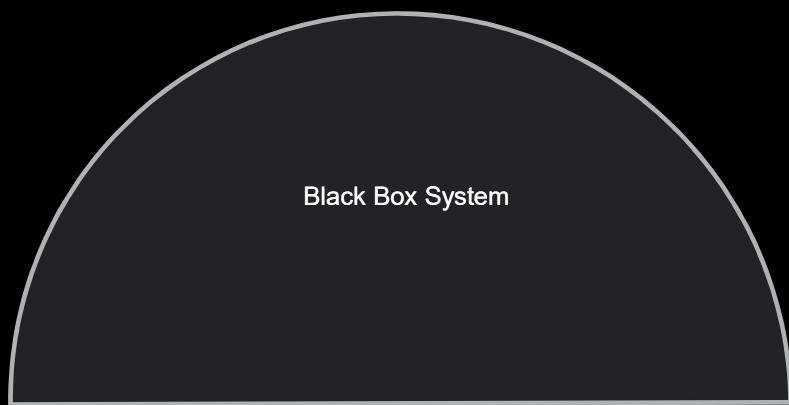
# Reflectance Field



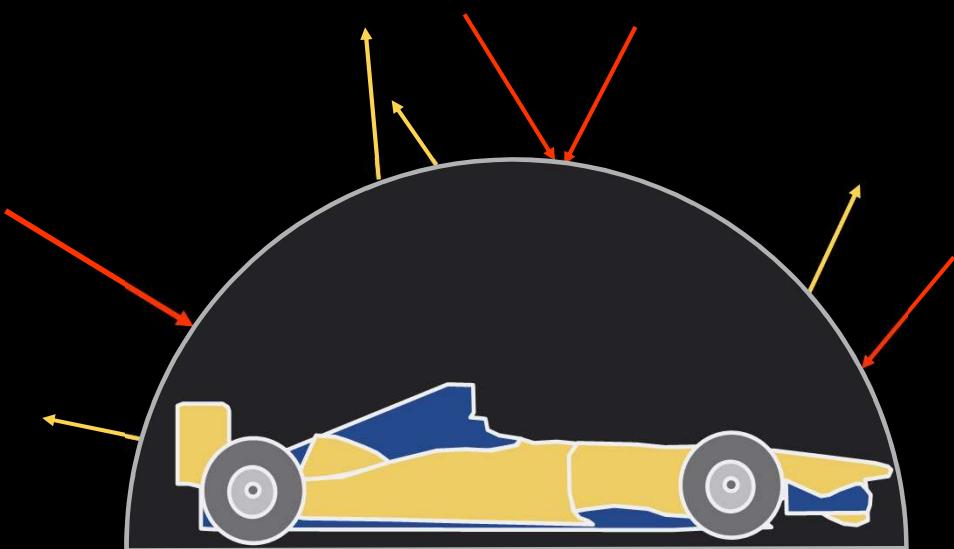
# Reflectance Field



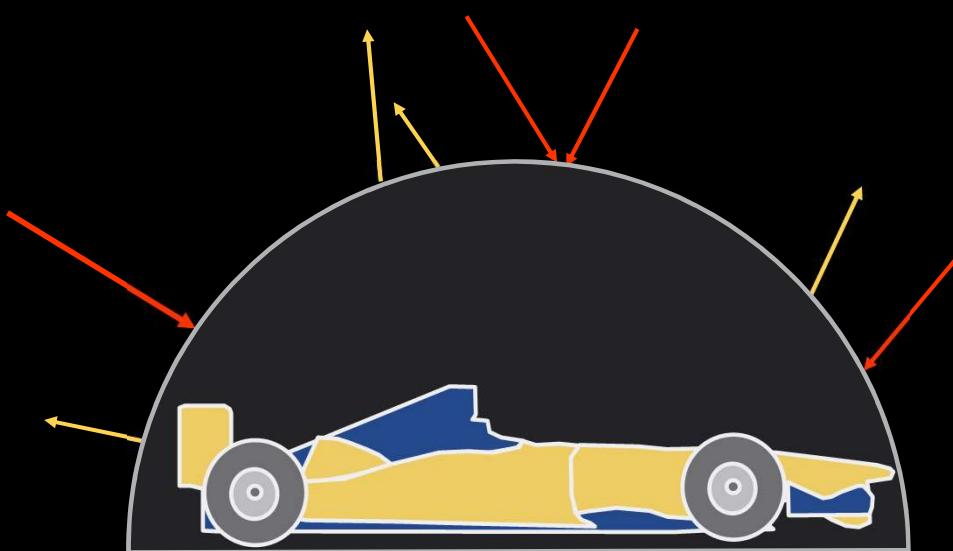
# Reflectance Field



# Reflectance Field

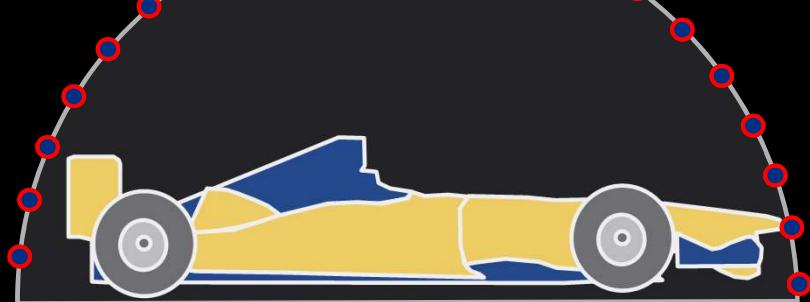


# Reflectance Field



8D Function

# Reflectance Field



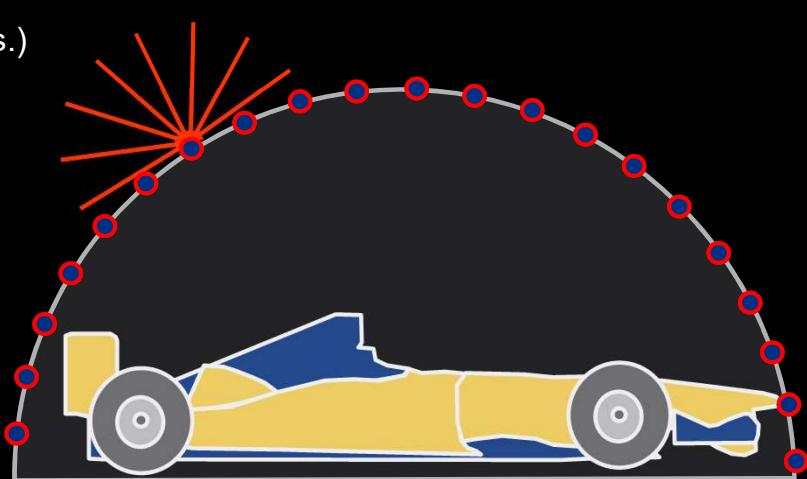
8D Function

# Reflectance Field

4D Incident Light Field

2D for angle  
(spherical cords.)

2D for position  
(black box  
surface)



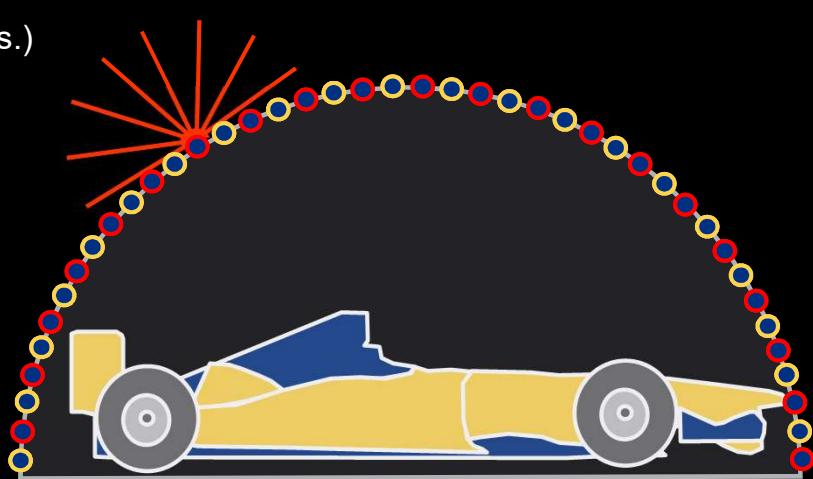
8D Function

# Reflectance Field

4D Incident Light Field

2D for angle  
(spherical cords.)

2D for position  
(black box  
surface)



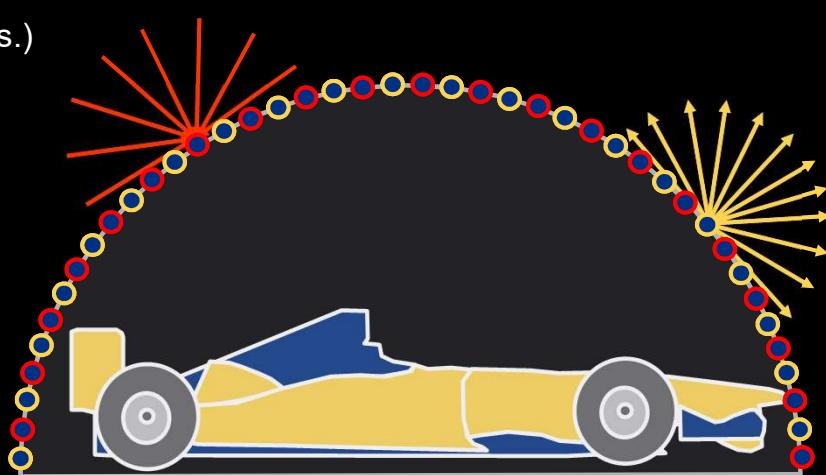
# Reflectance Field

4D Incident Light Field

4D Outgoing Light Field

2D for angle  
(spherical cords.)

2D for position  
(black box  
surface)

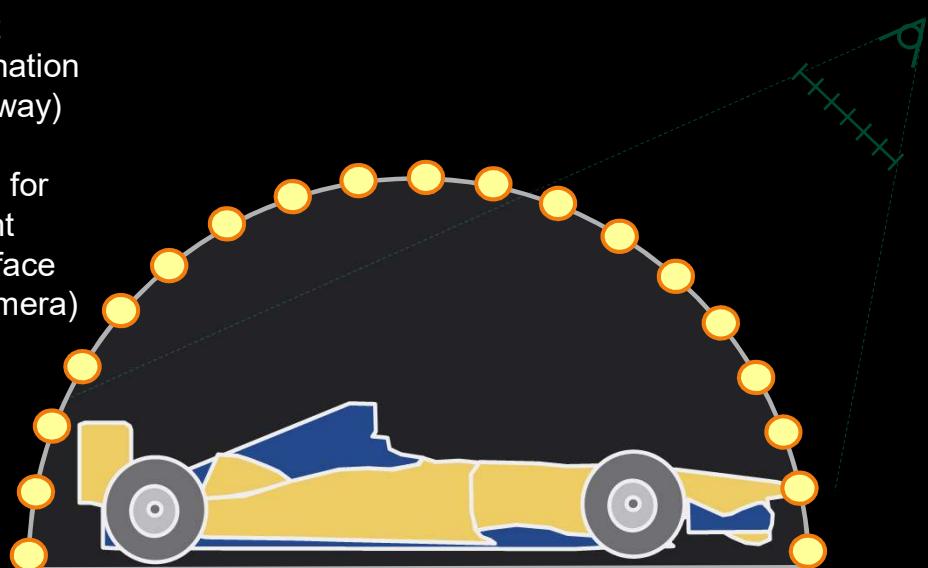


8D Function

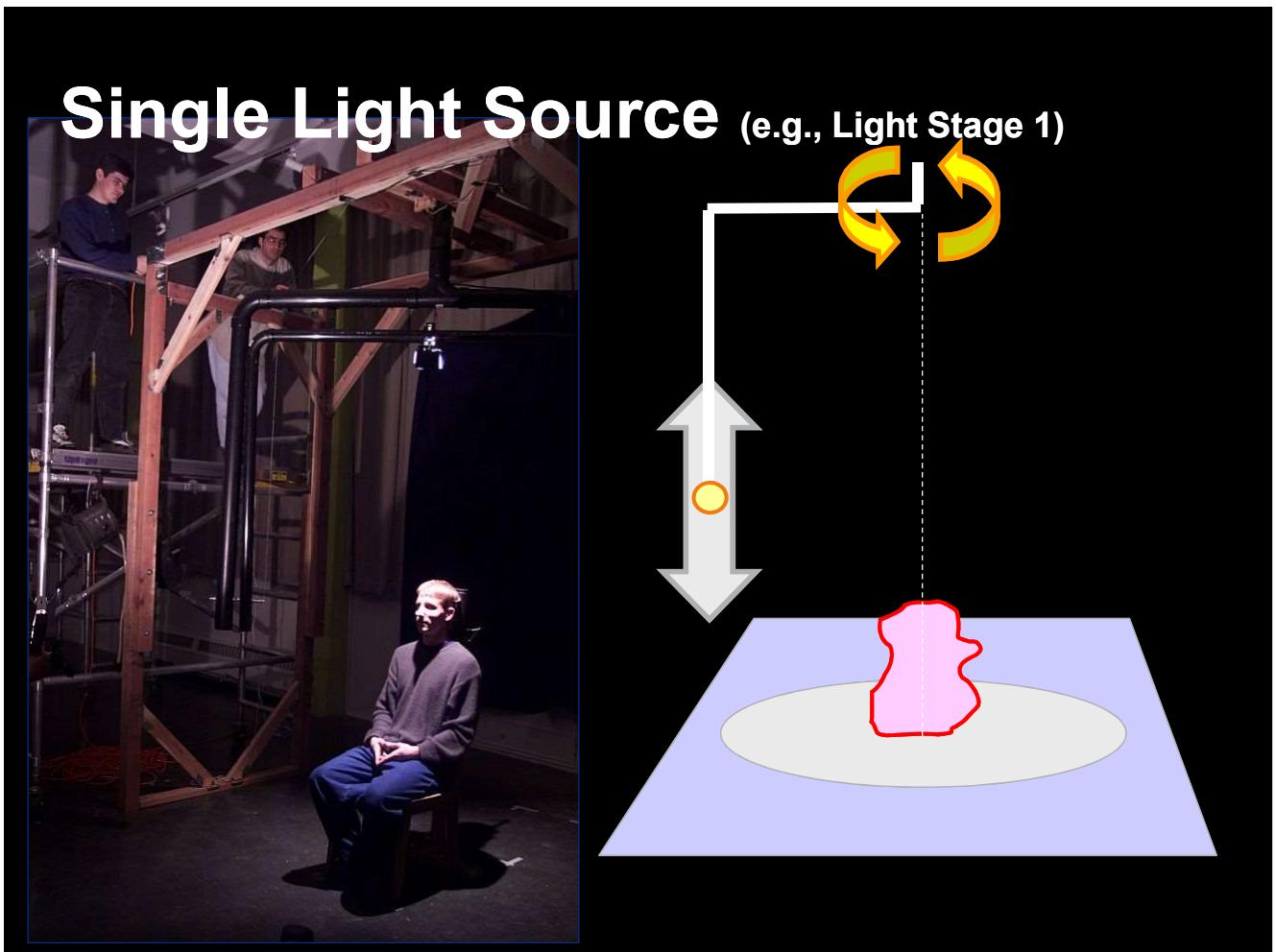
# Light Stage [Debevec et al. 2000]

2D for incident  
angle of illumination  
(infinitely far away)

2D for position for  
fixed view-point  
(black box surface  
as seen by camera)

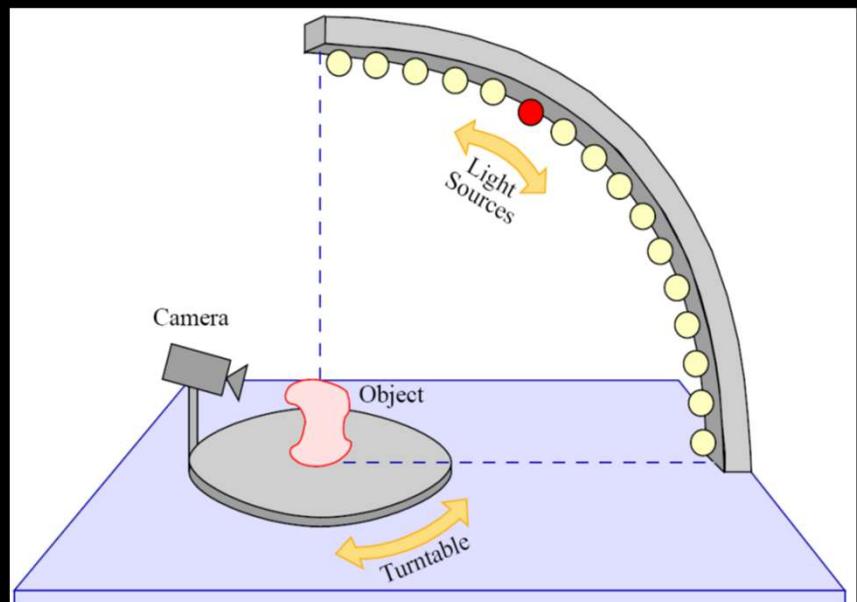


4D Approximation

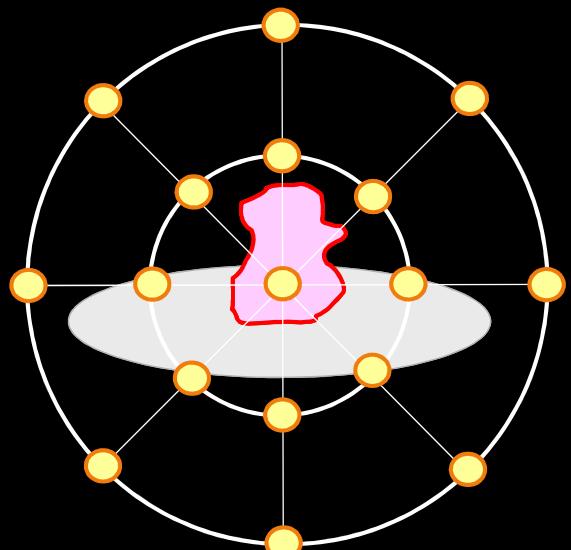
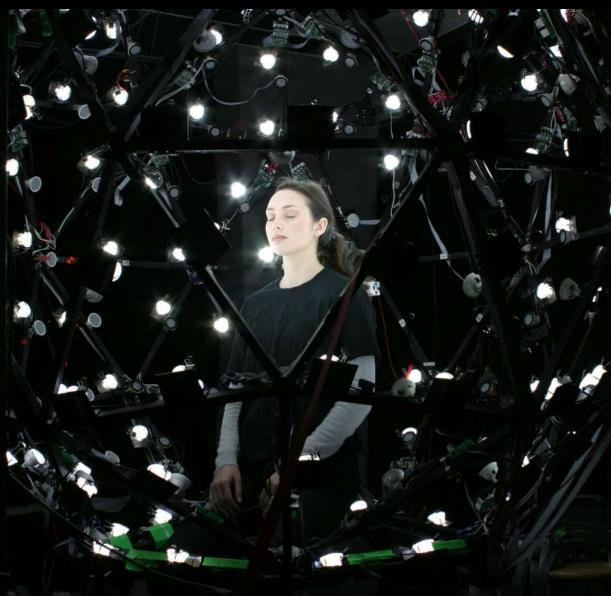


31

## Arc of Lights (e.g., Light Stage 2, Masselus et al. 2004)

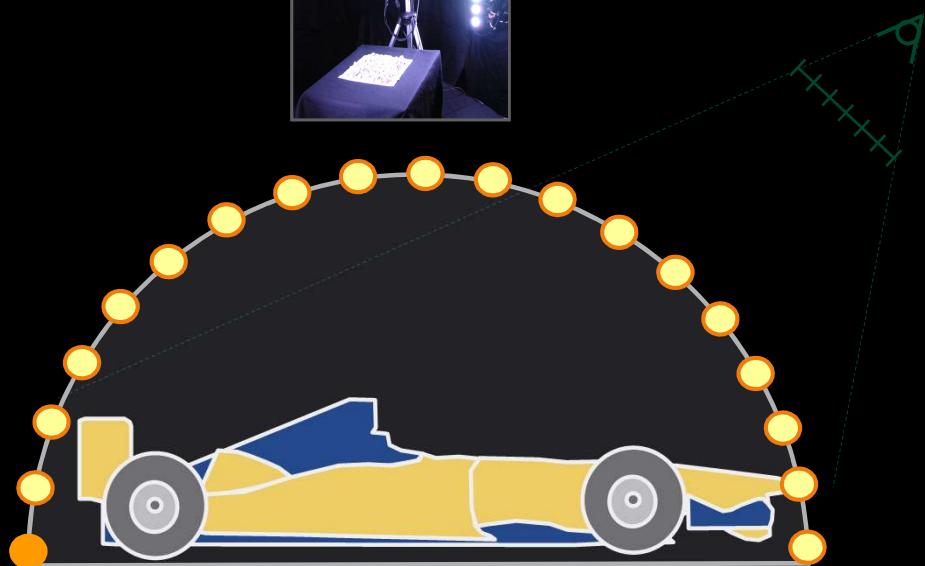


## Light Dome (e.g, LED sphere)



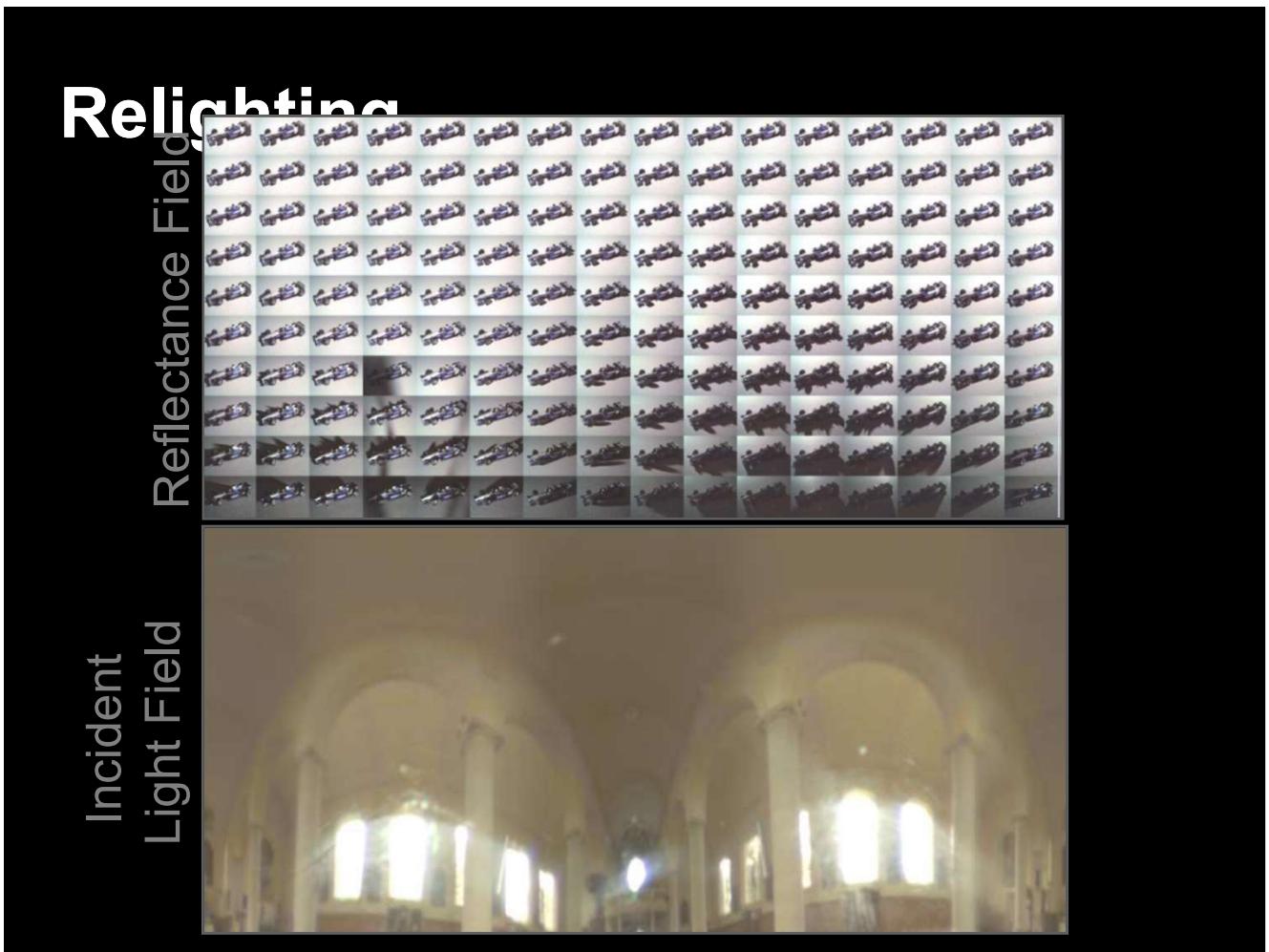
Type	Advantages	Disadvantages
Single Light Source	<ul style="list-style-type: none"> <li>Inexpensive</li> <li>Any Resolution</li> </ul>	<ul style="list-style-type: none"> <li>Slow Acquisition</li> <li>Difficult to automate</li> </ul>
Light Arc	<ul style="list-style-type: none"> <li>High Resolution</li> <li>Moderately Fast</li> </ul>	<ul style="list-style-type: none"> <li>Limited Acquisition Volume</li> </ul>
Light Dome	<ul style="list-style-type: none"> <li>Very Fast</li> <li>Fully Automated</li> </ul>	<ul style="list-style-type: none"> <li>Expensive</li> <li>Complex</li> <li>Low Resolution</li> </ul>

# Light Stage



# Reflectance Field





37

# Relighting

Incident  
Light Field

Reflectance Field

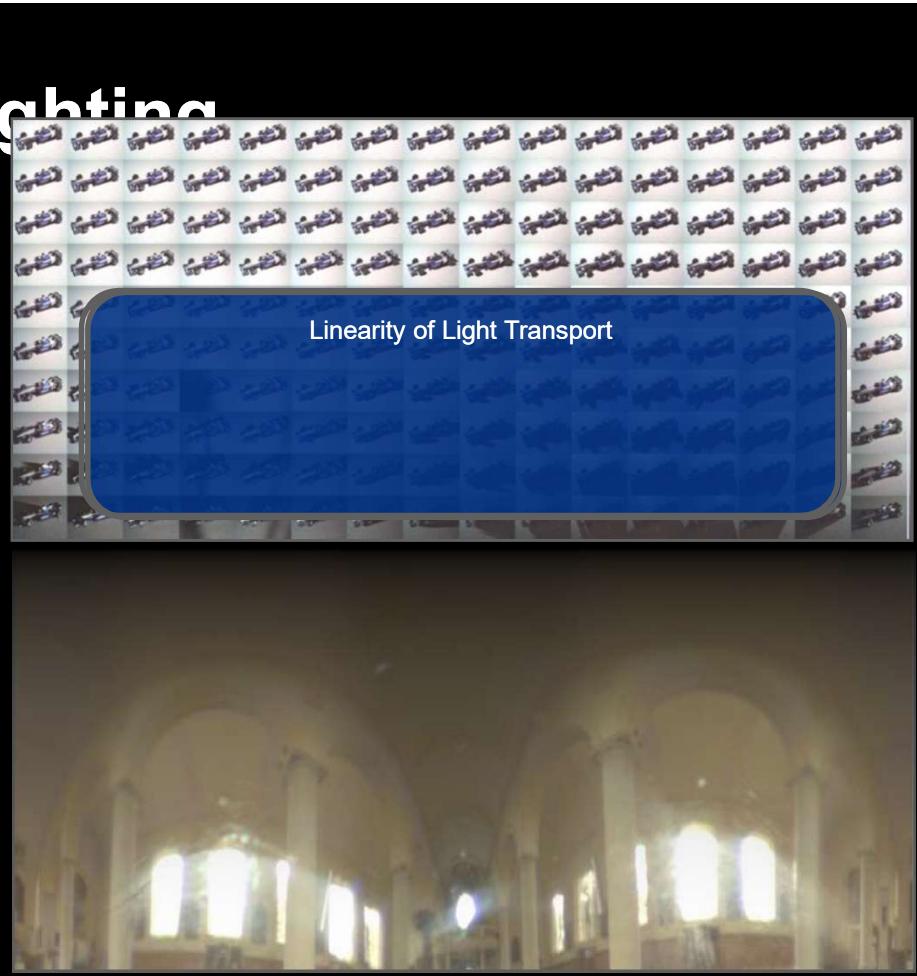
Compensate for Solid Angle



# Relighting

Incident  
Light Field

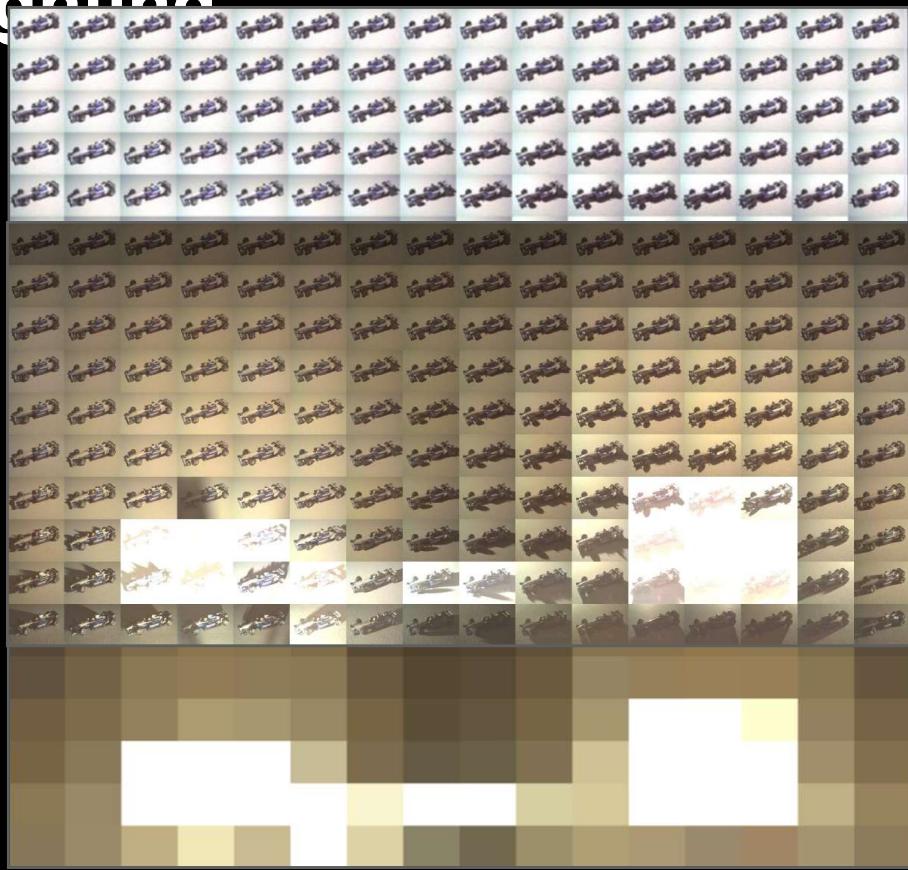
Reflectance Field



# Relighting

Incident  
Light Field

Reflectance Field



# Relighting

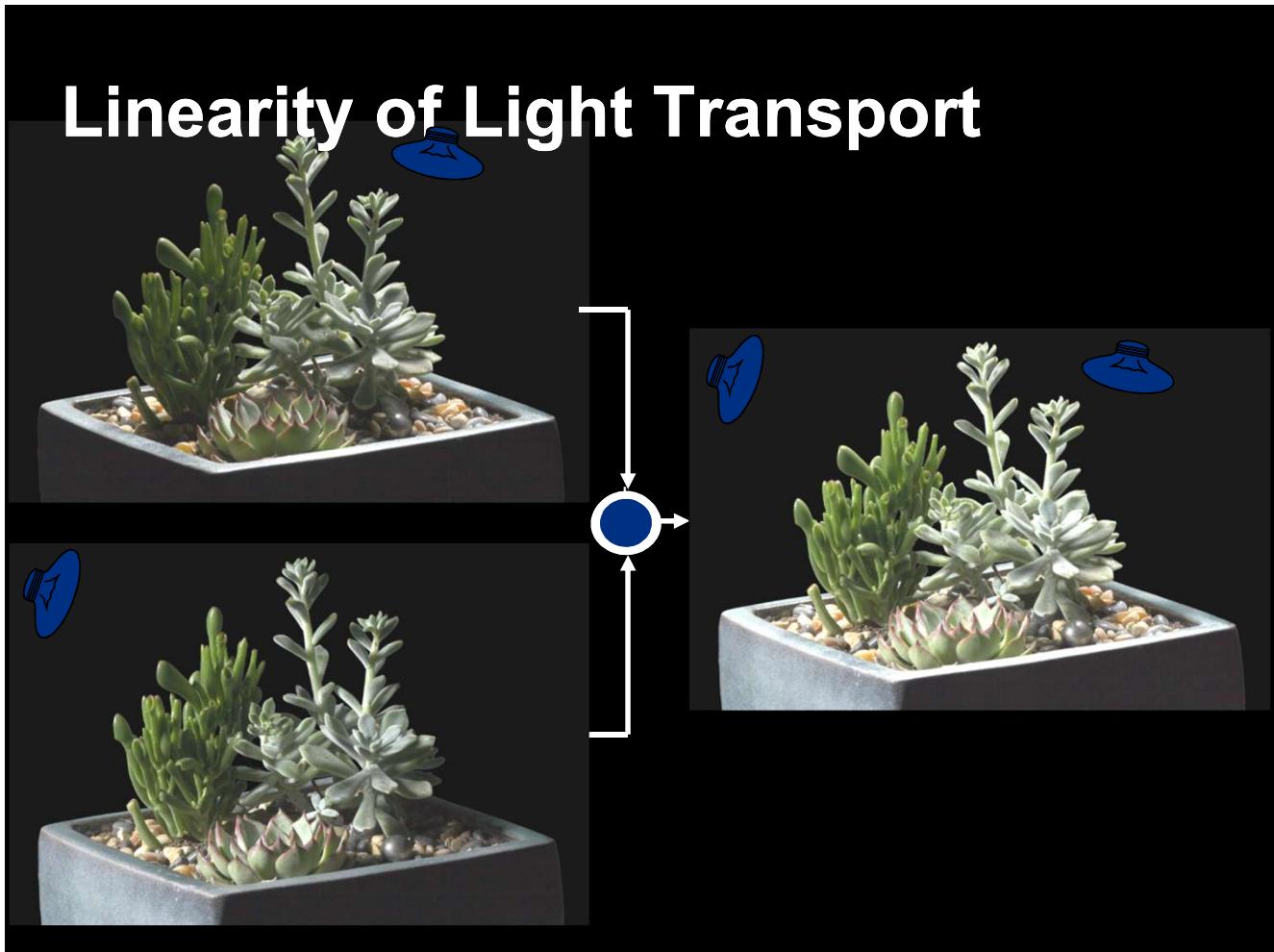
$\Sigma$



## Relighting: Result



# Linearity of Light Transport

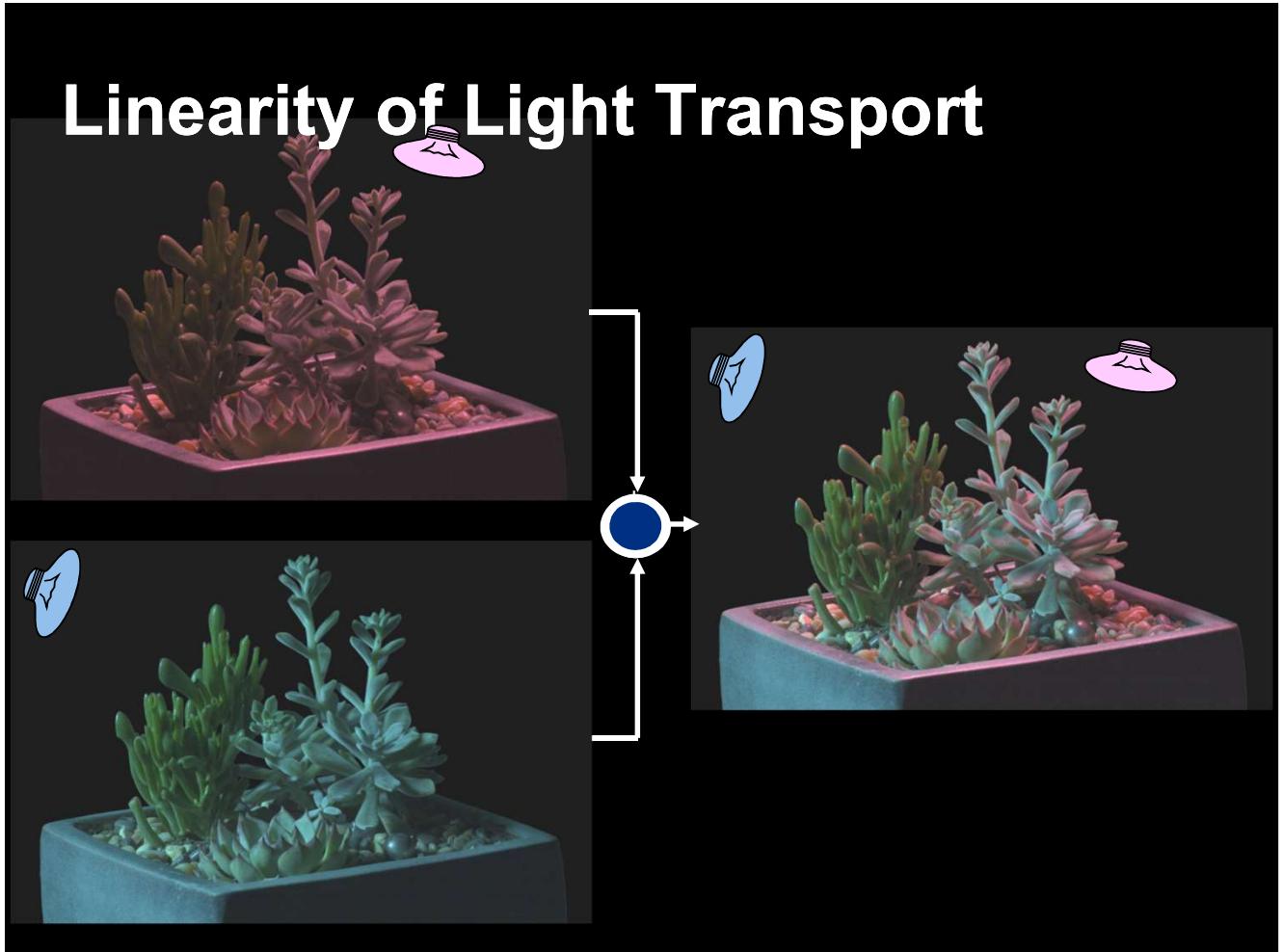


43

# Linearity of Light Transport

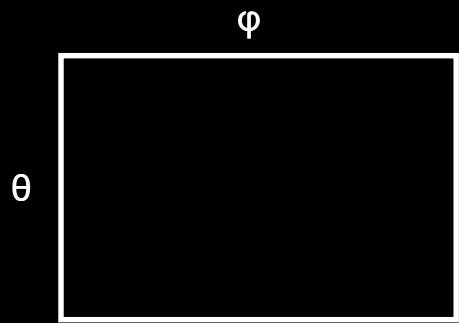
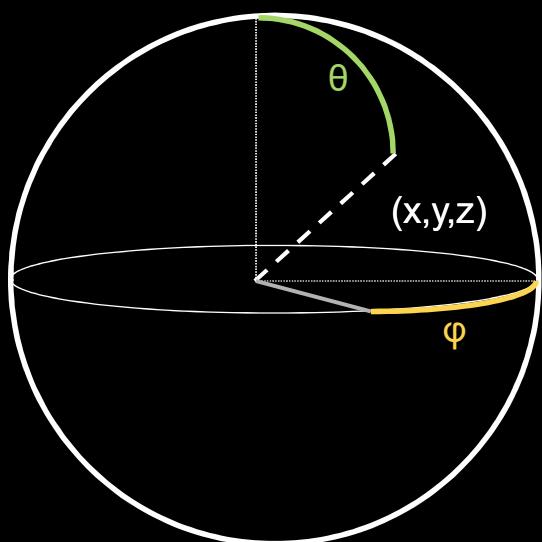


# Linearity of Light Transport



45

# Compensate Solid Angle

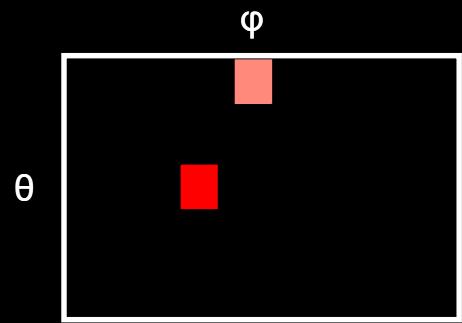
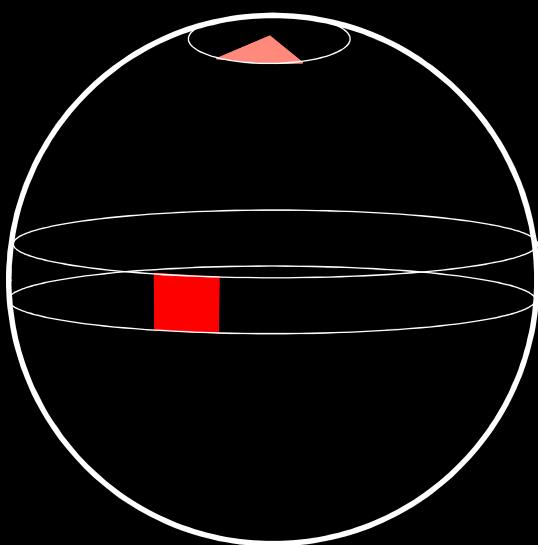


$$X = \cos \varphi \sin \theta$$

$$Y = \sin \varphi \sin \theta$$

$$Z = \cos \theta$$

# Compensate Solid Angle

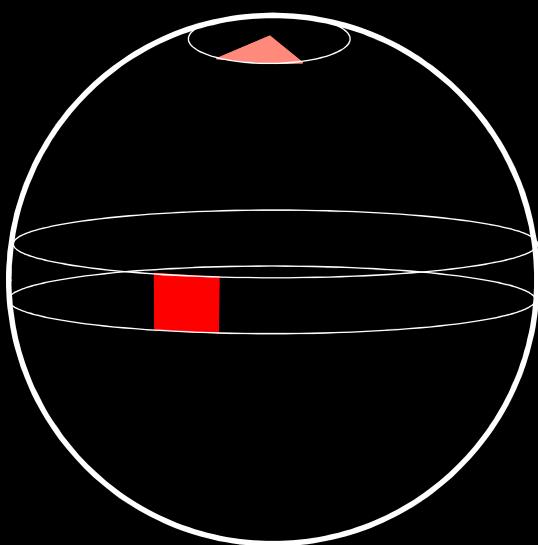


$$X = \cos \varphi \sin \theta$$

$$Y = \sin \varphi \sin \theta$$

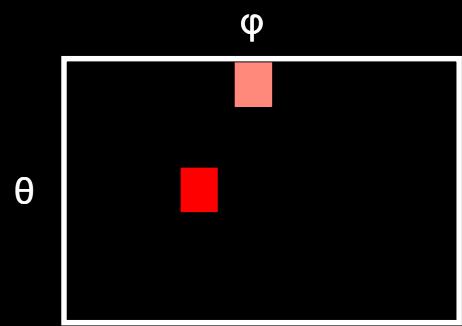
$$Z = \cos \theta$$

# Compensate Solid Angle



$$J = |\sin \theta|$$

(Jacobian)



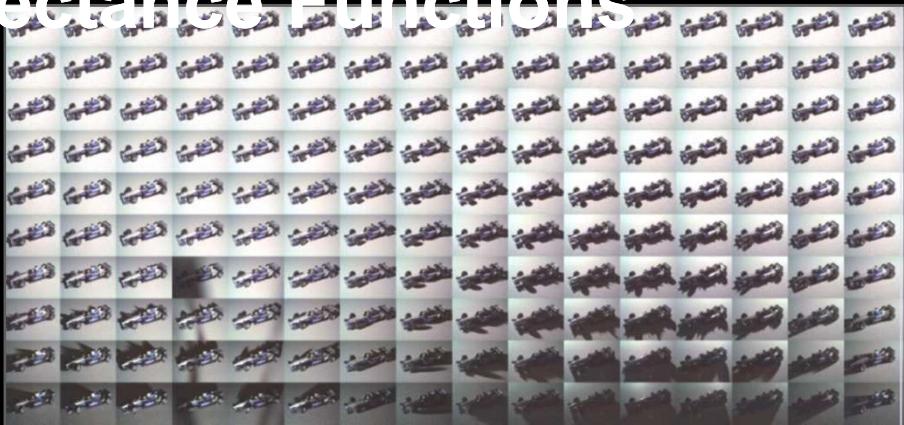
$$X = \cos \varphi \sin \theta$$

$$Y = \sin \varphi \sin \theta$$

$$Z = \cos \theta$$

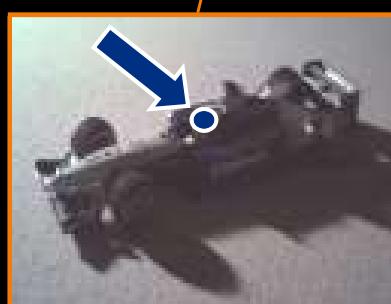
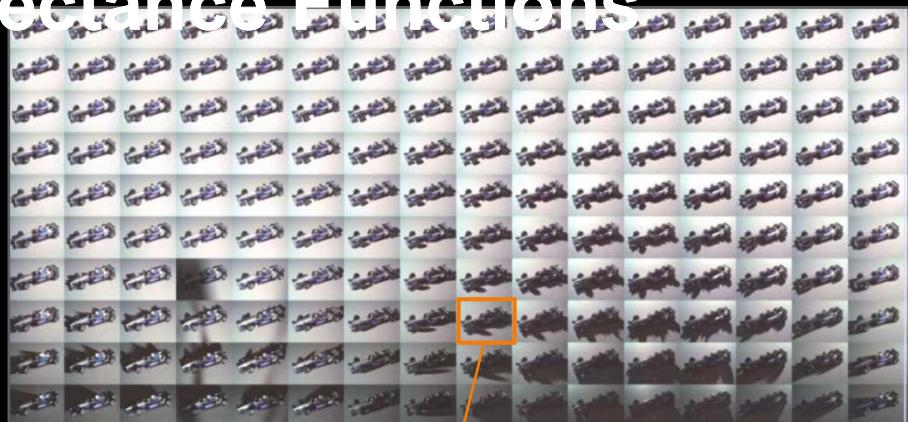
# Reflectance Functions

Reflectance Field



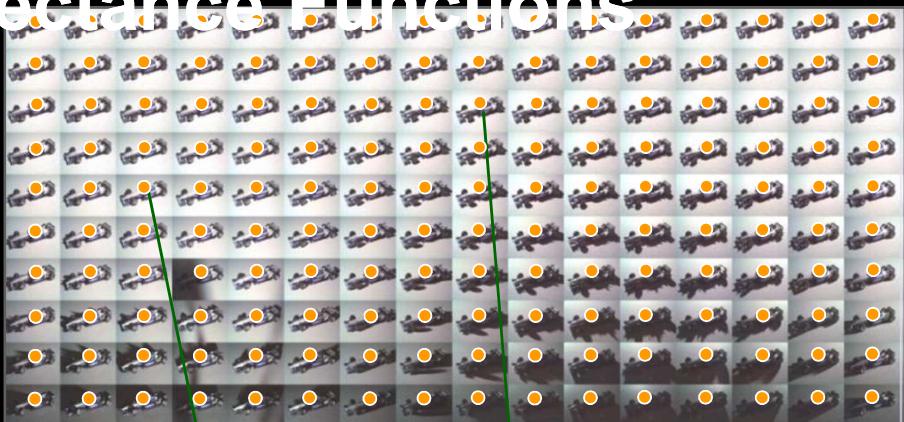
# Reflectance Functions

Reflectance Field



# Reflectance Functions

Reflectance Field



# Reflectance Functions: Relighting



Relit Image



# Reflectance Functions: Relighting

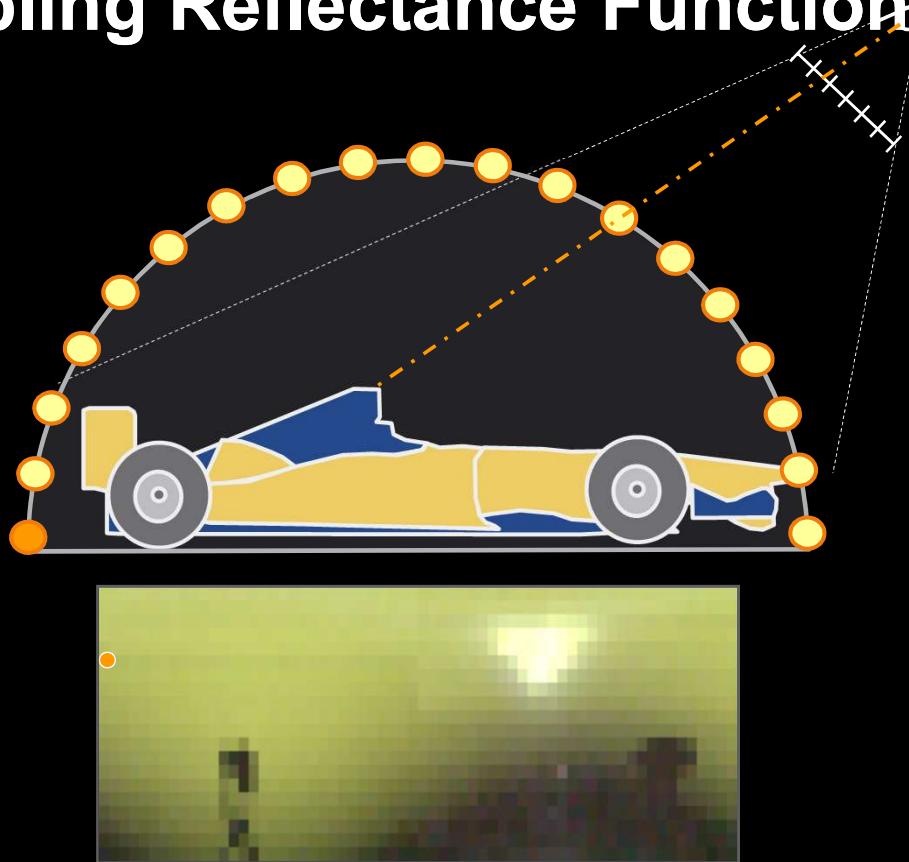
$$\sum( \text{Reflectance Function} \times \text{Incident Illumination} )$$

Relit Image

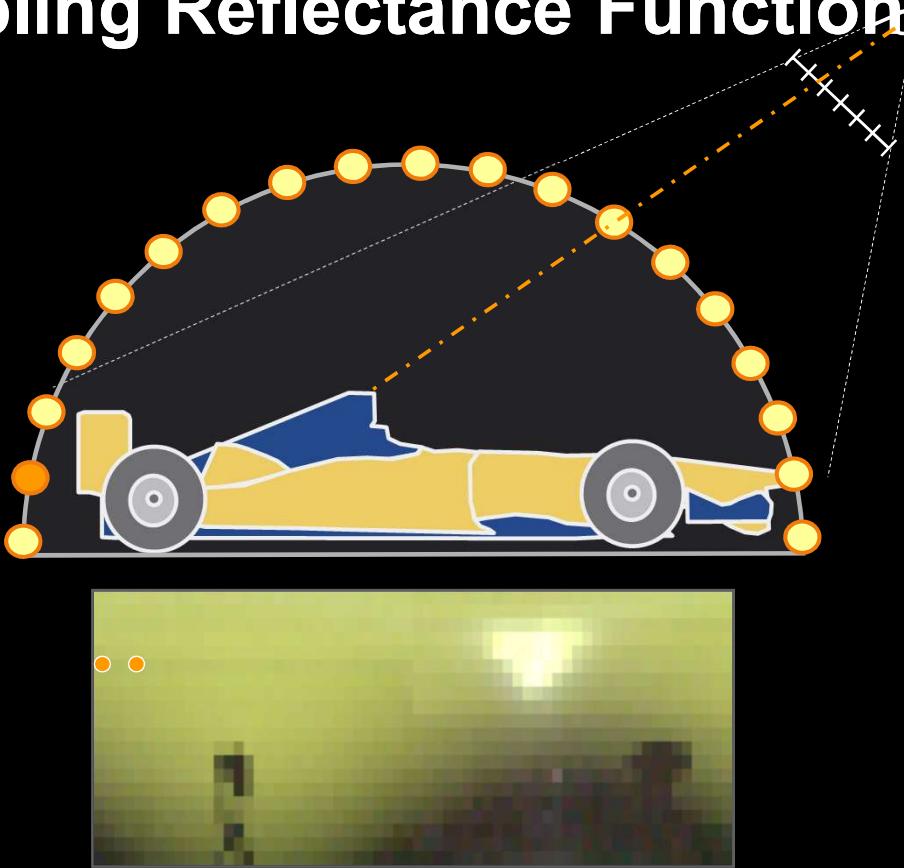
Reflectance Function

Incident Illumination

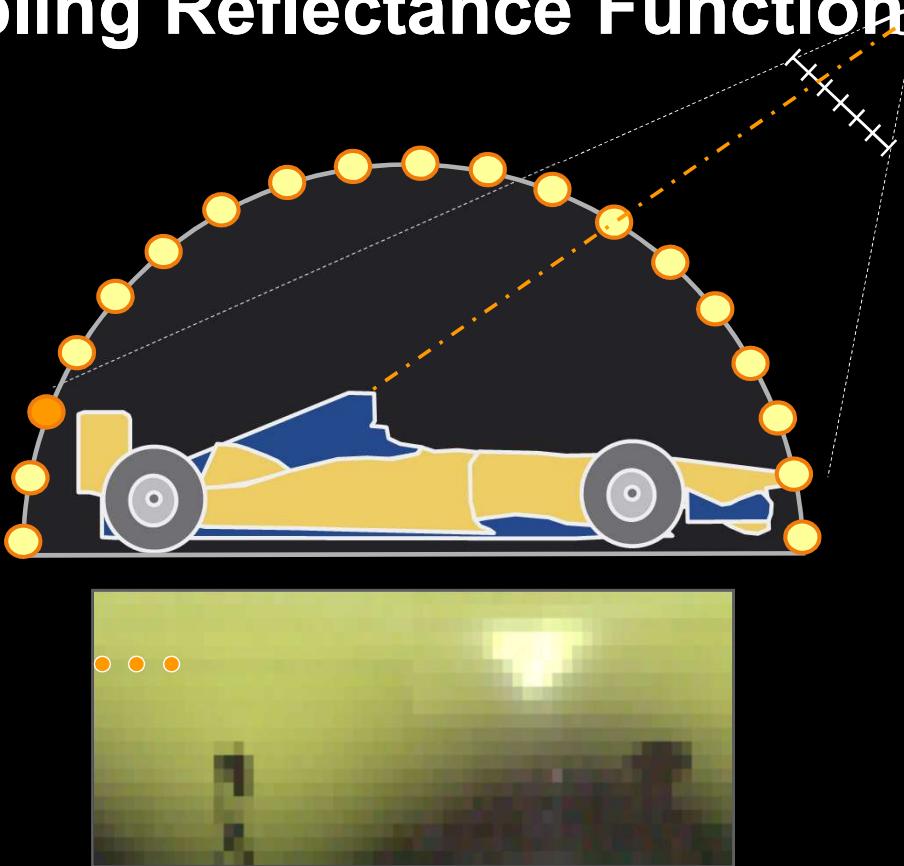
# Sampling Reflectance Functions



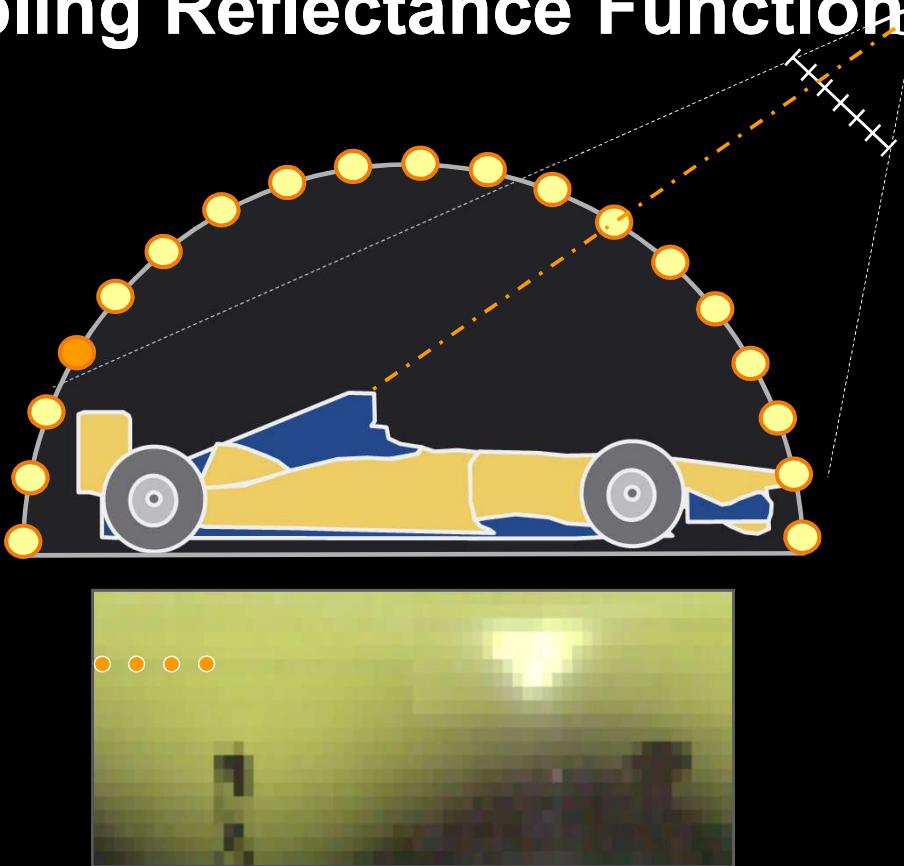
# Sampling Reflectance Functions



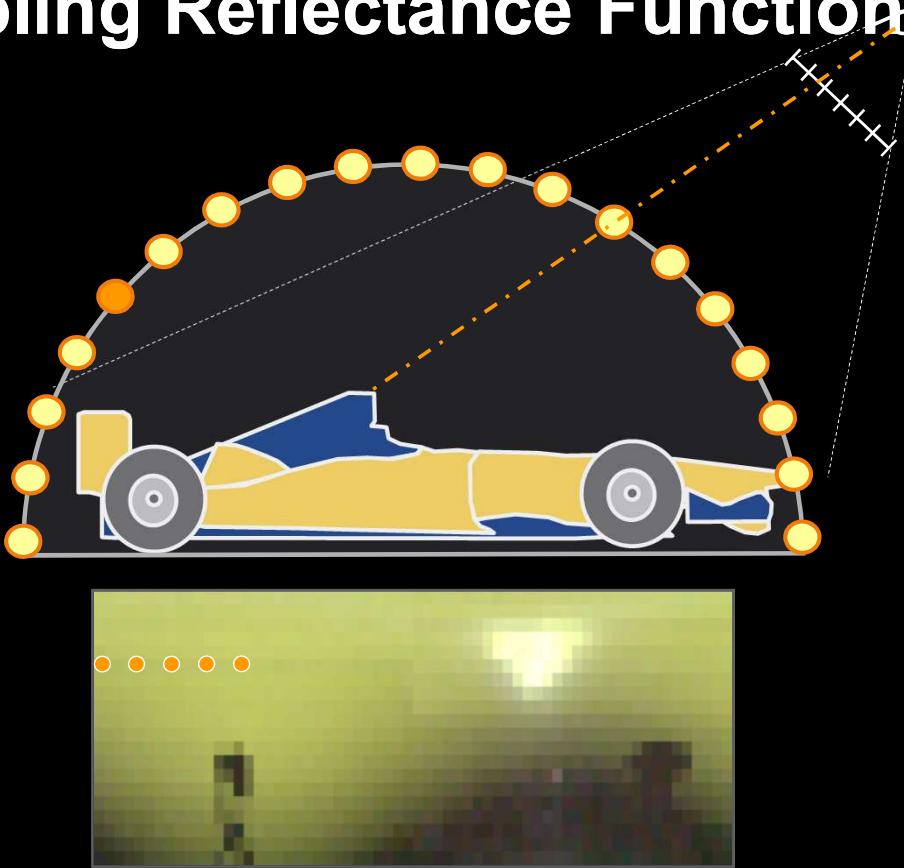
# Sampling Reflectance Functions



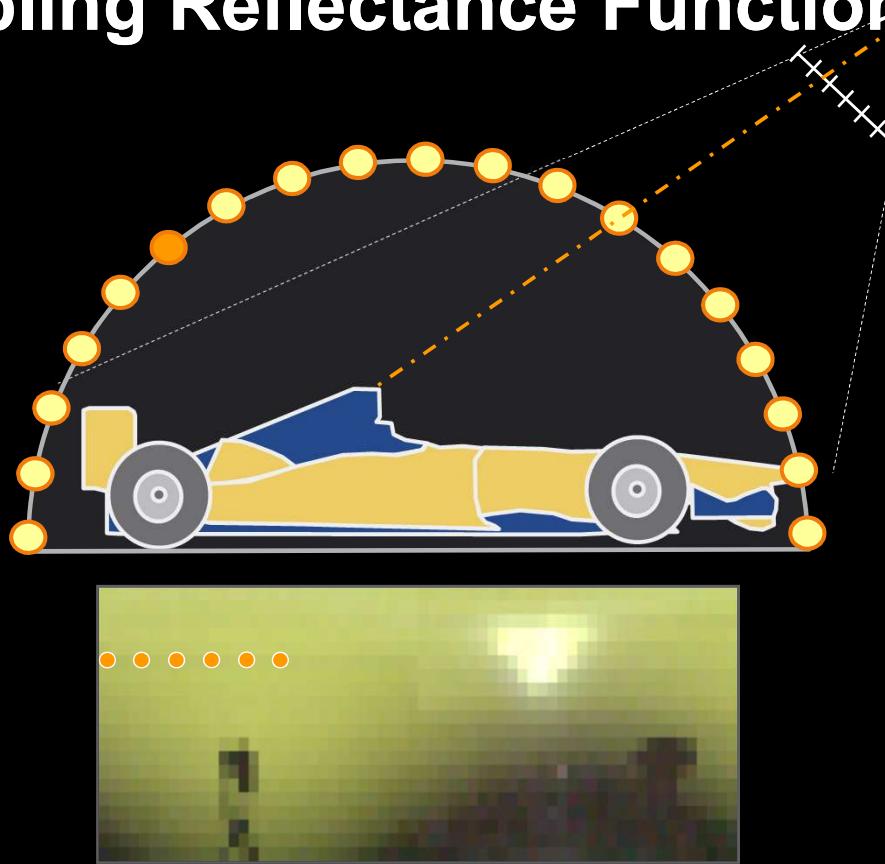
# Sampling Reflectance Functions



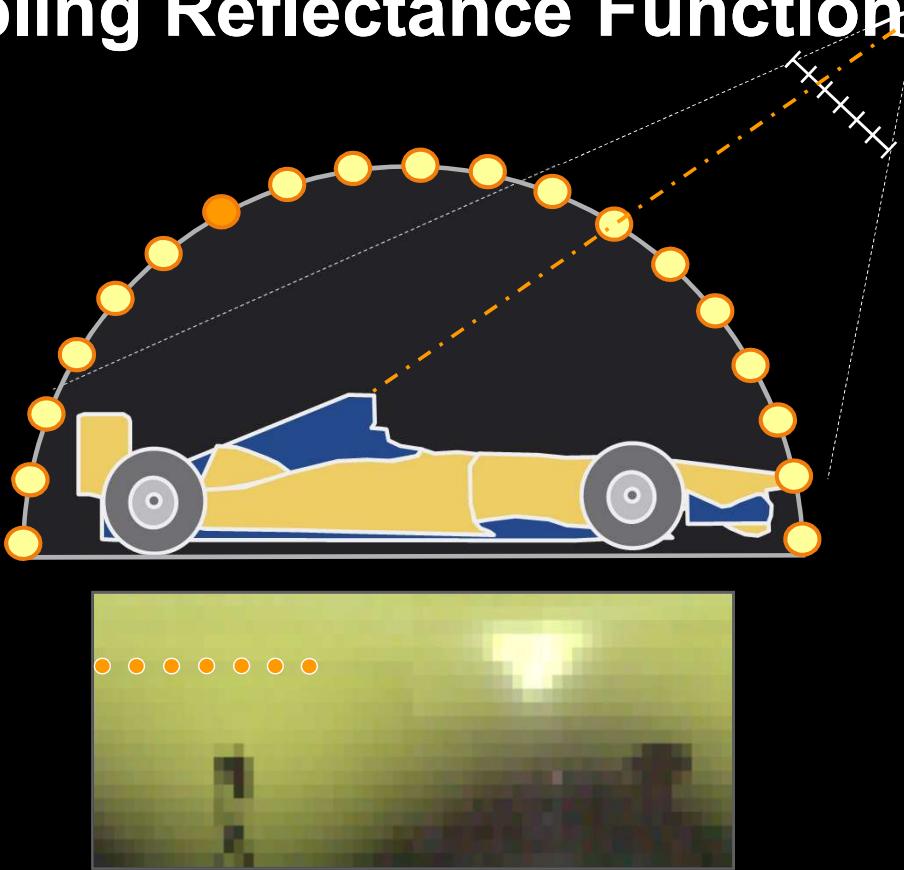
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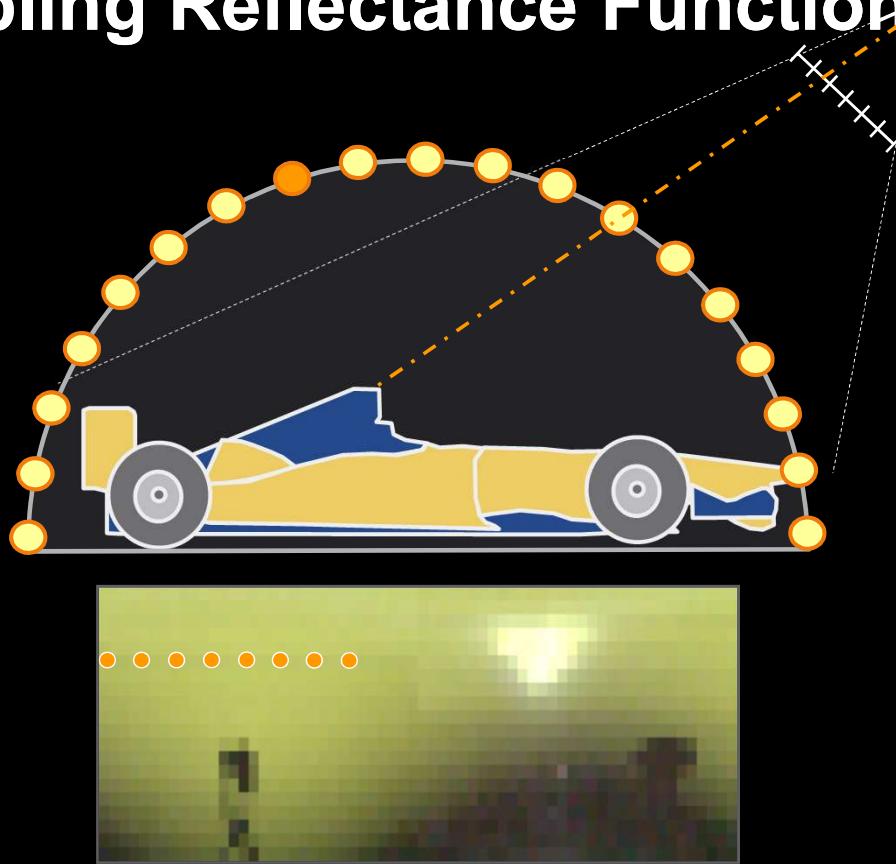
# Sampling Reflectance Functions



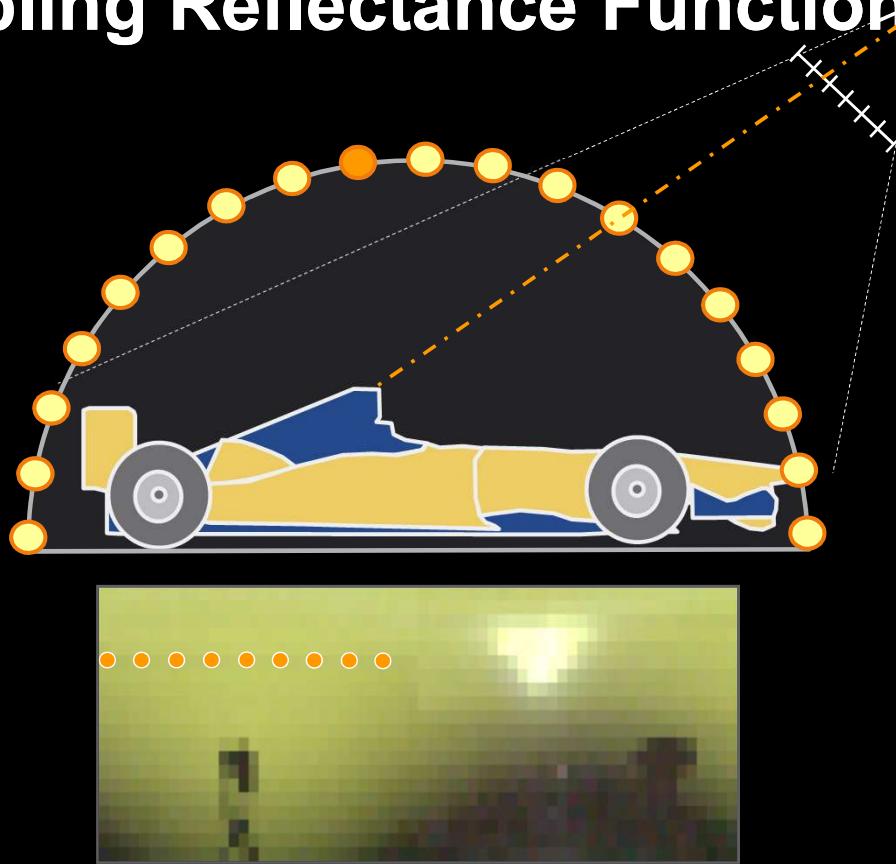
# Sampling Reflectance Functions



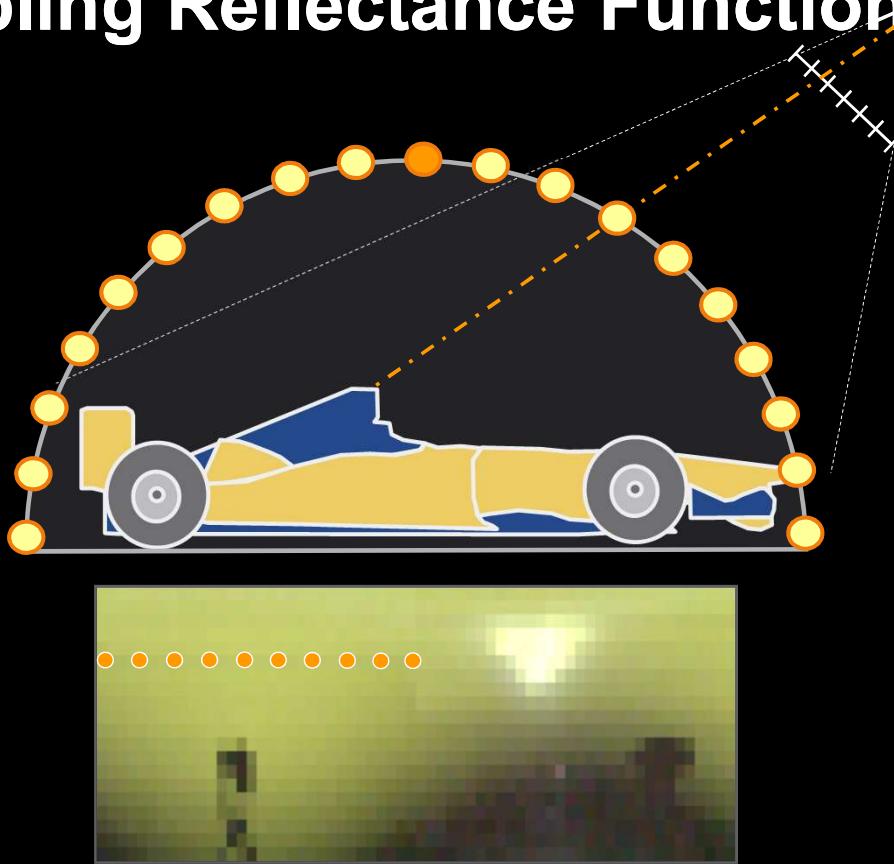
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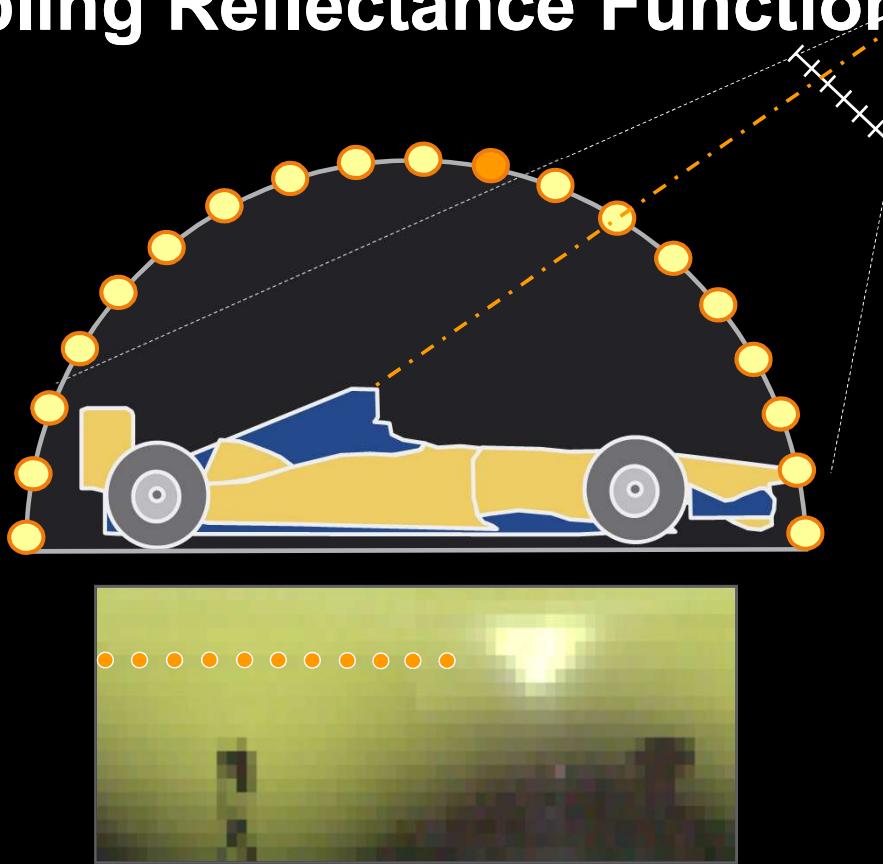
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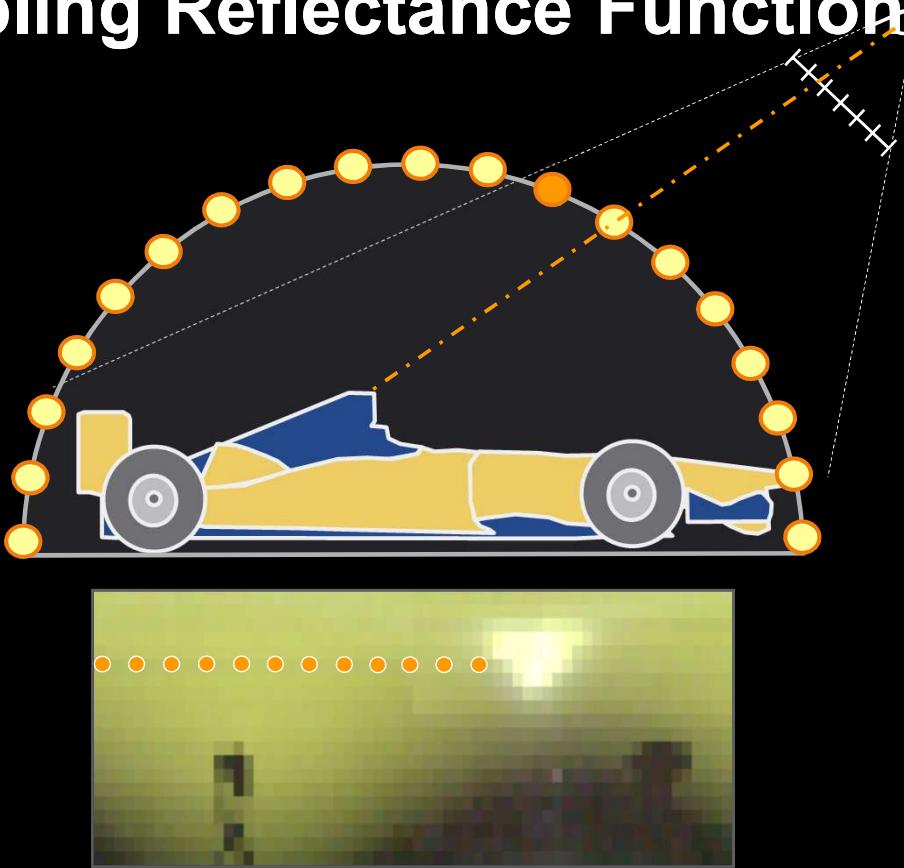
# Sampling Reflectance Functions



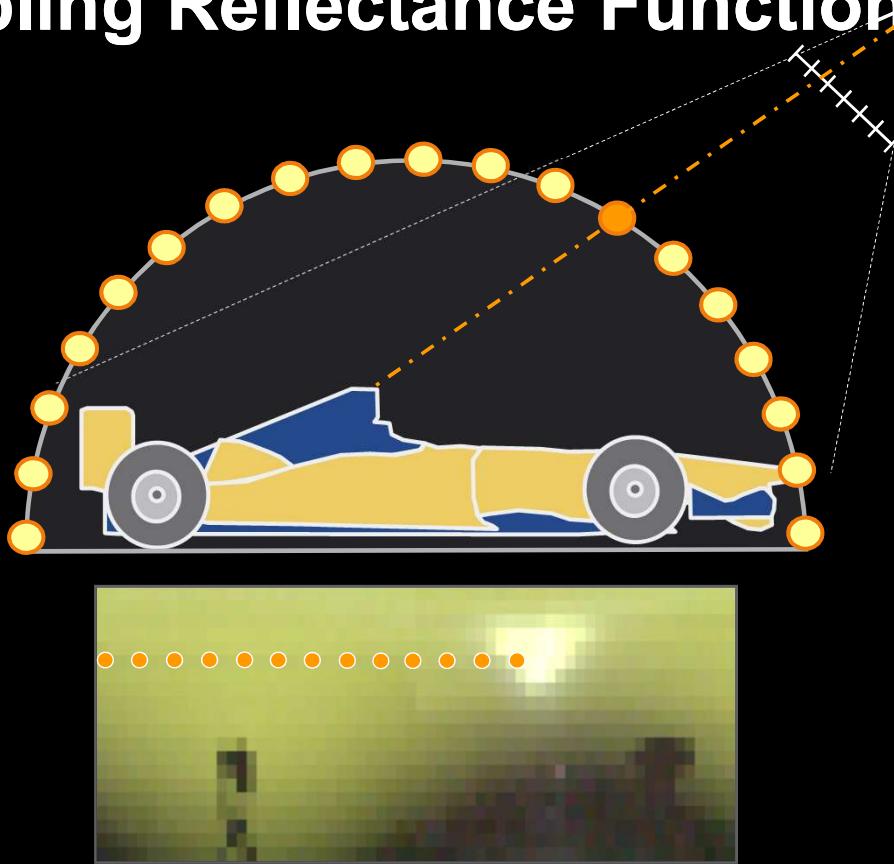
# Sampling Reflectance Functions



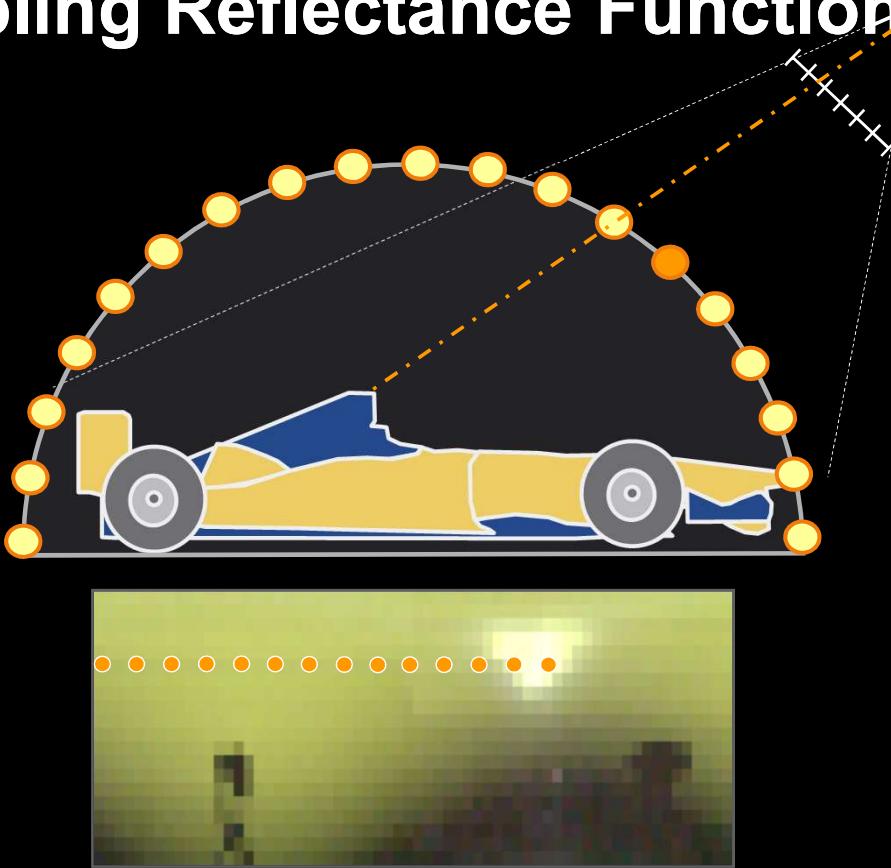
# Sampling Reflectance Functions



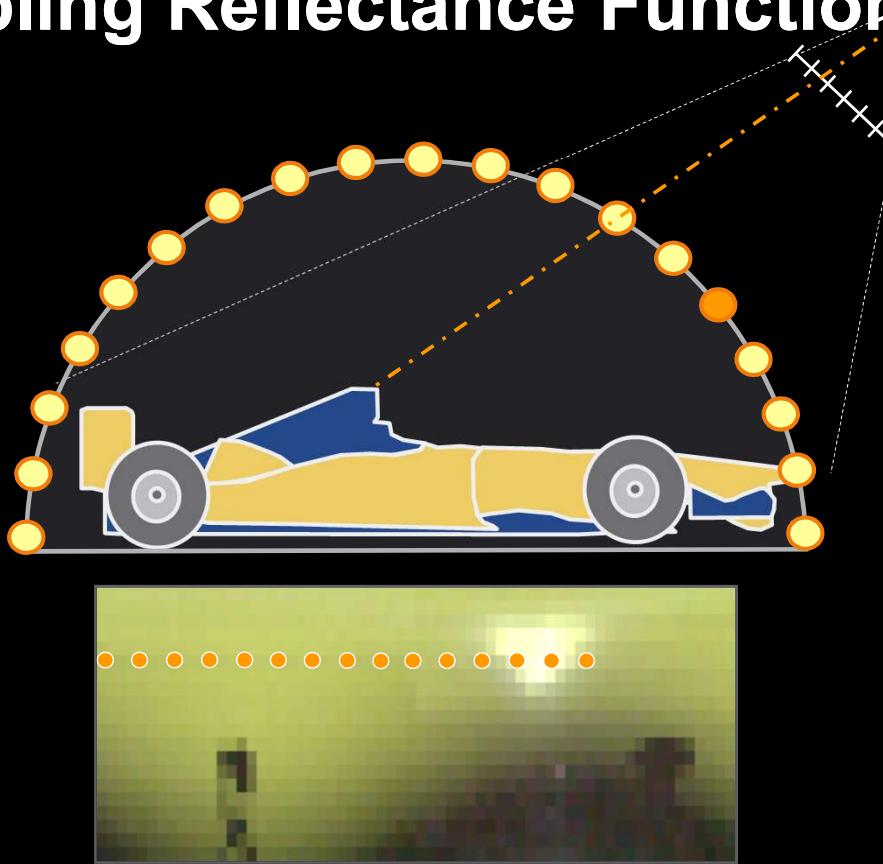
# Sampling Reflectance Functions



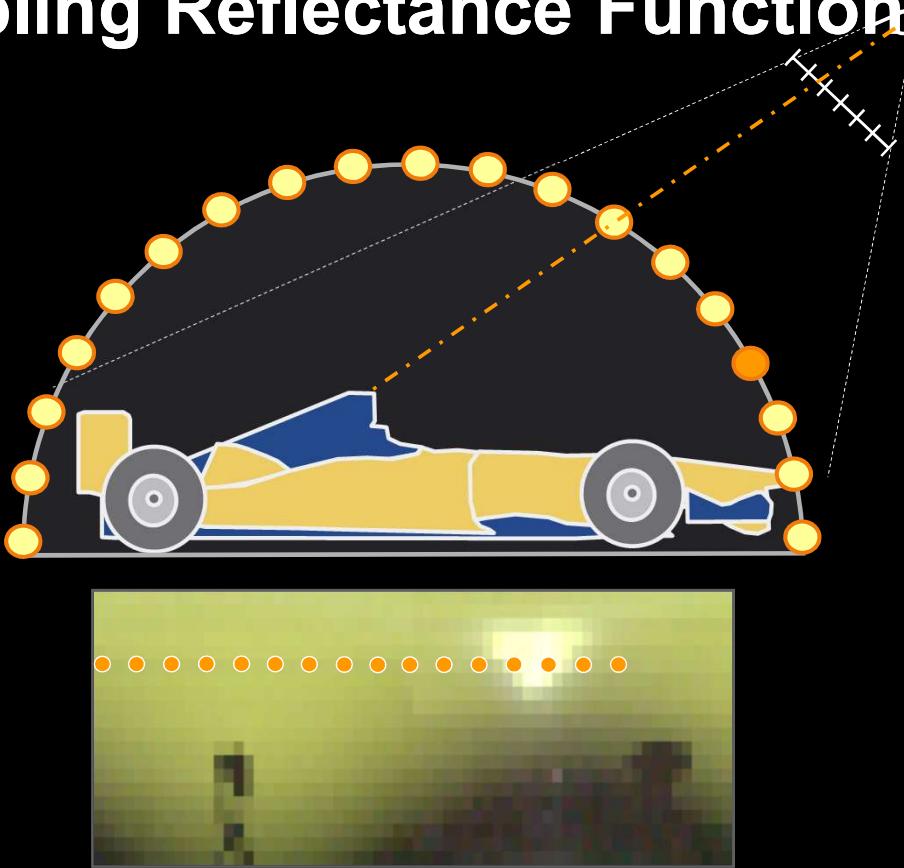
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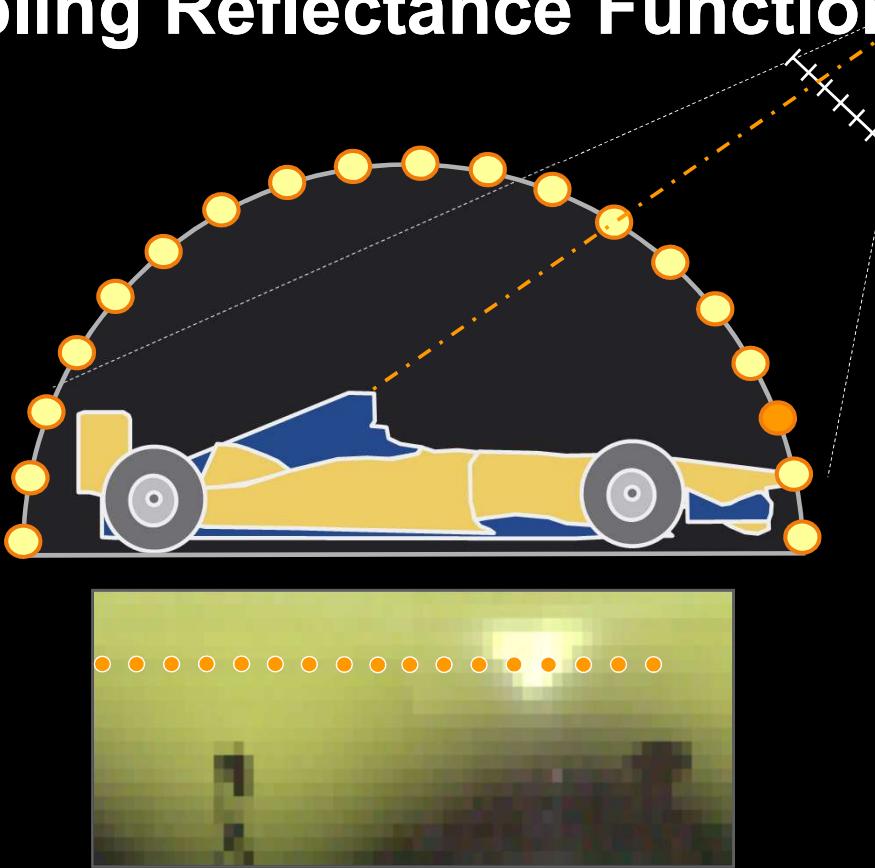
# Sampling Reflectance Functions



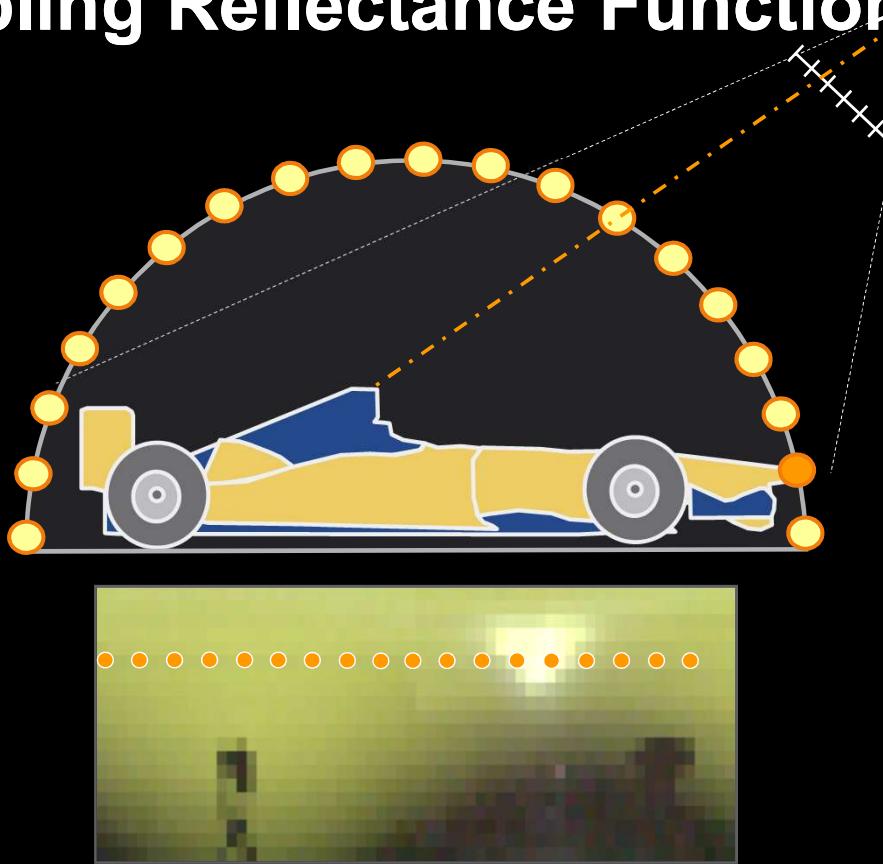
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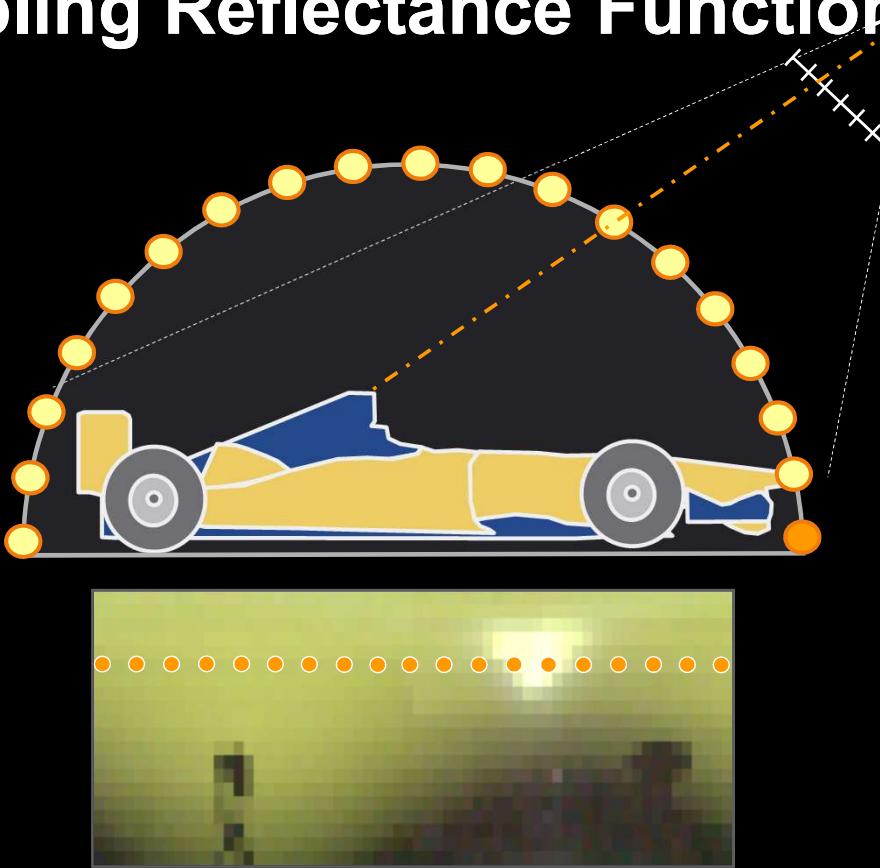
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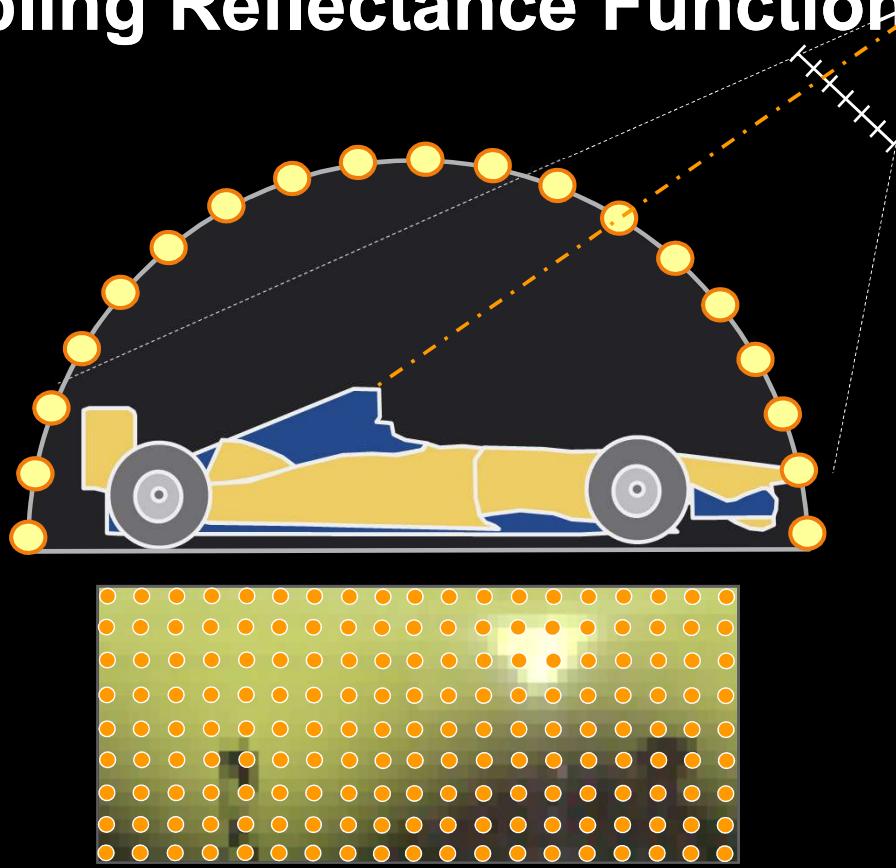
# Sampling Reflectance Functions



# Sampling Reflectance Functions



# Sampling Reflectance Functions



# Nyquist-Shannon Theorem

If a function  $f(t)$  contains no frequencies higher than  $B$ , then it is completely determined by giving its ordinates at a series of points spaced  $1/(2B)$  apart.

## Nyquist-Shannon Theorem

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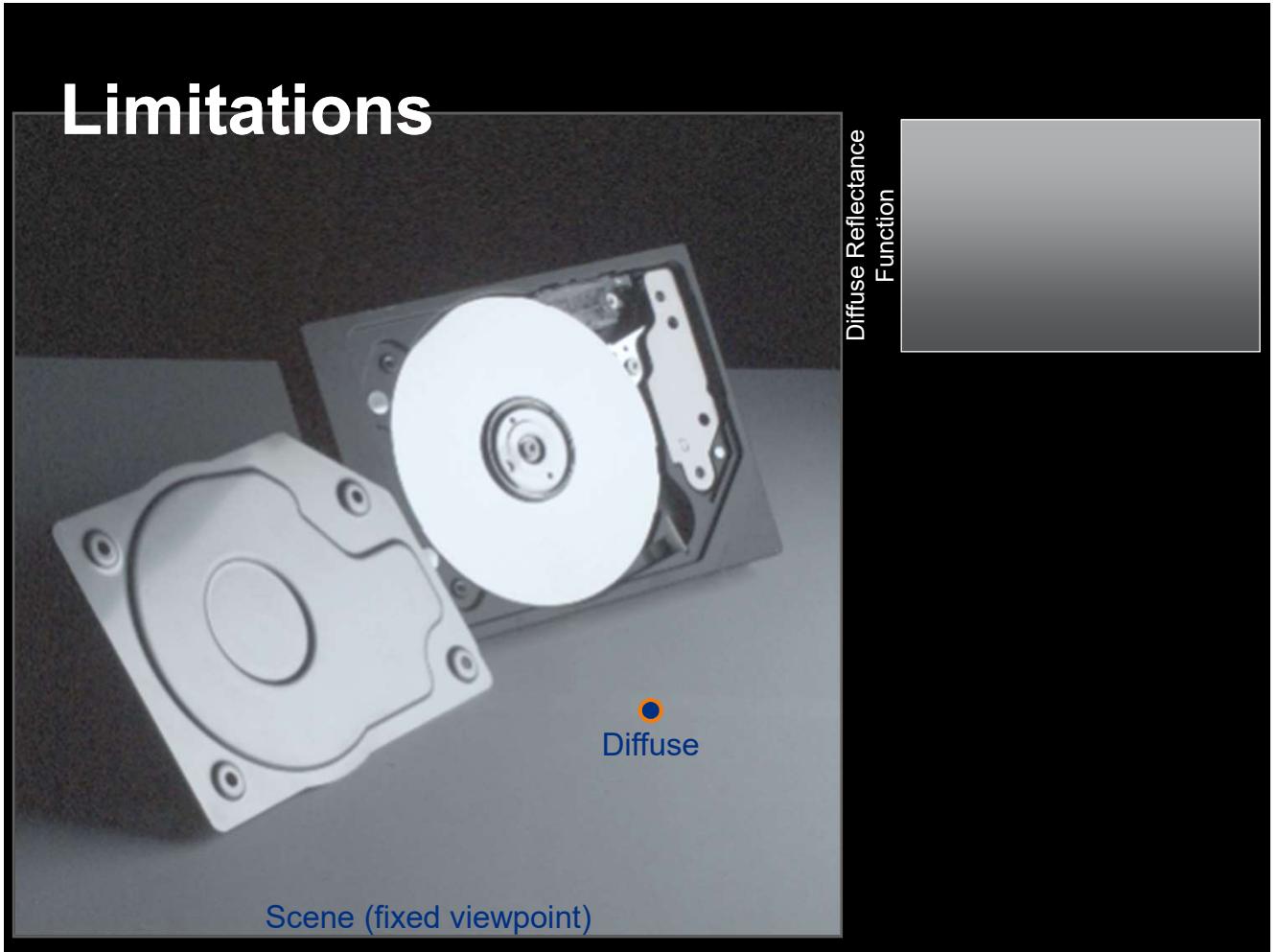
Question: what does this mean for Image-based Relighting

# Limitations

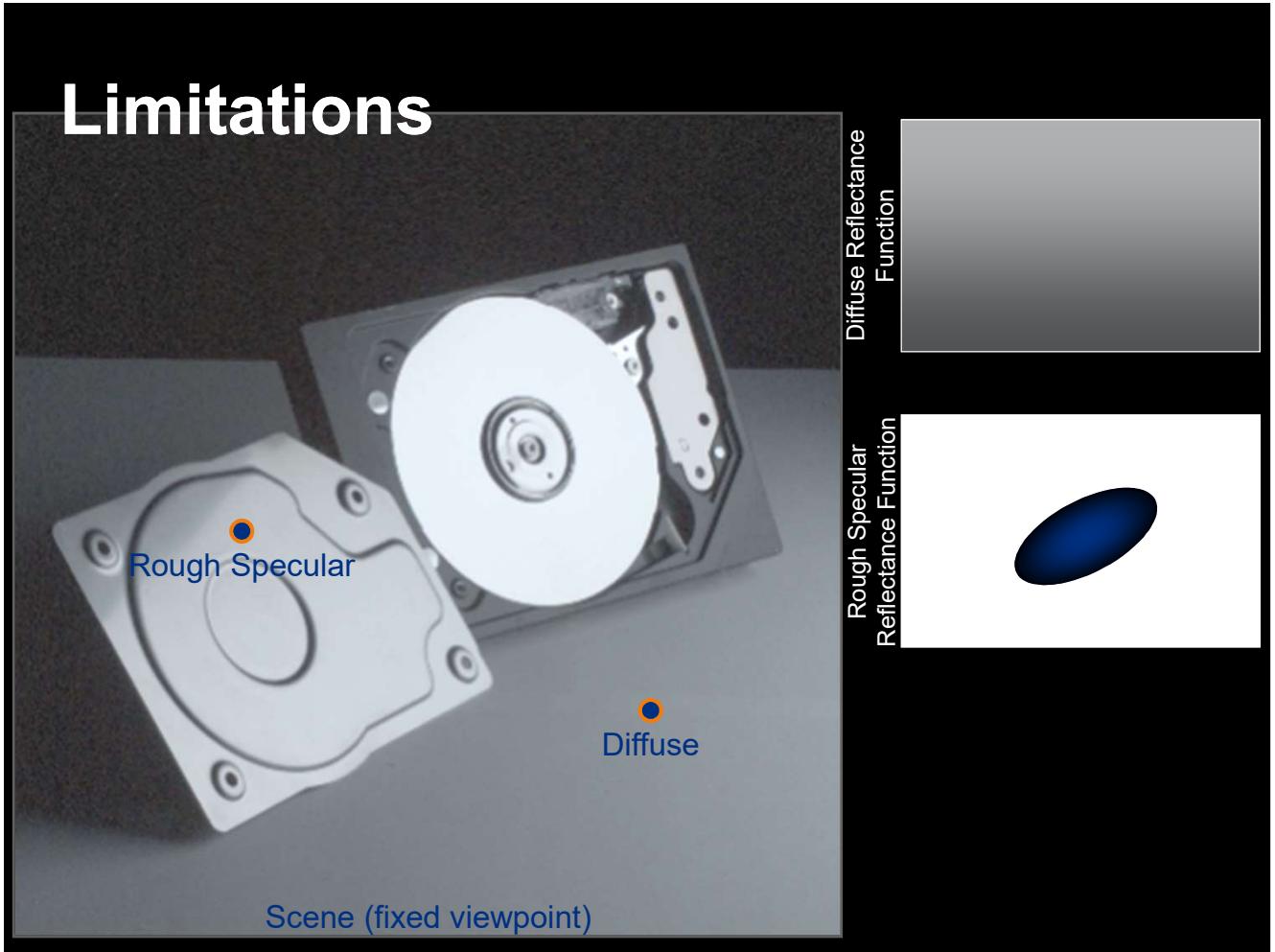


Scene (fixed viewpoint)

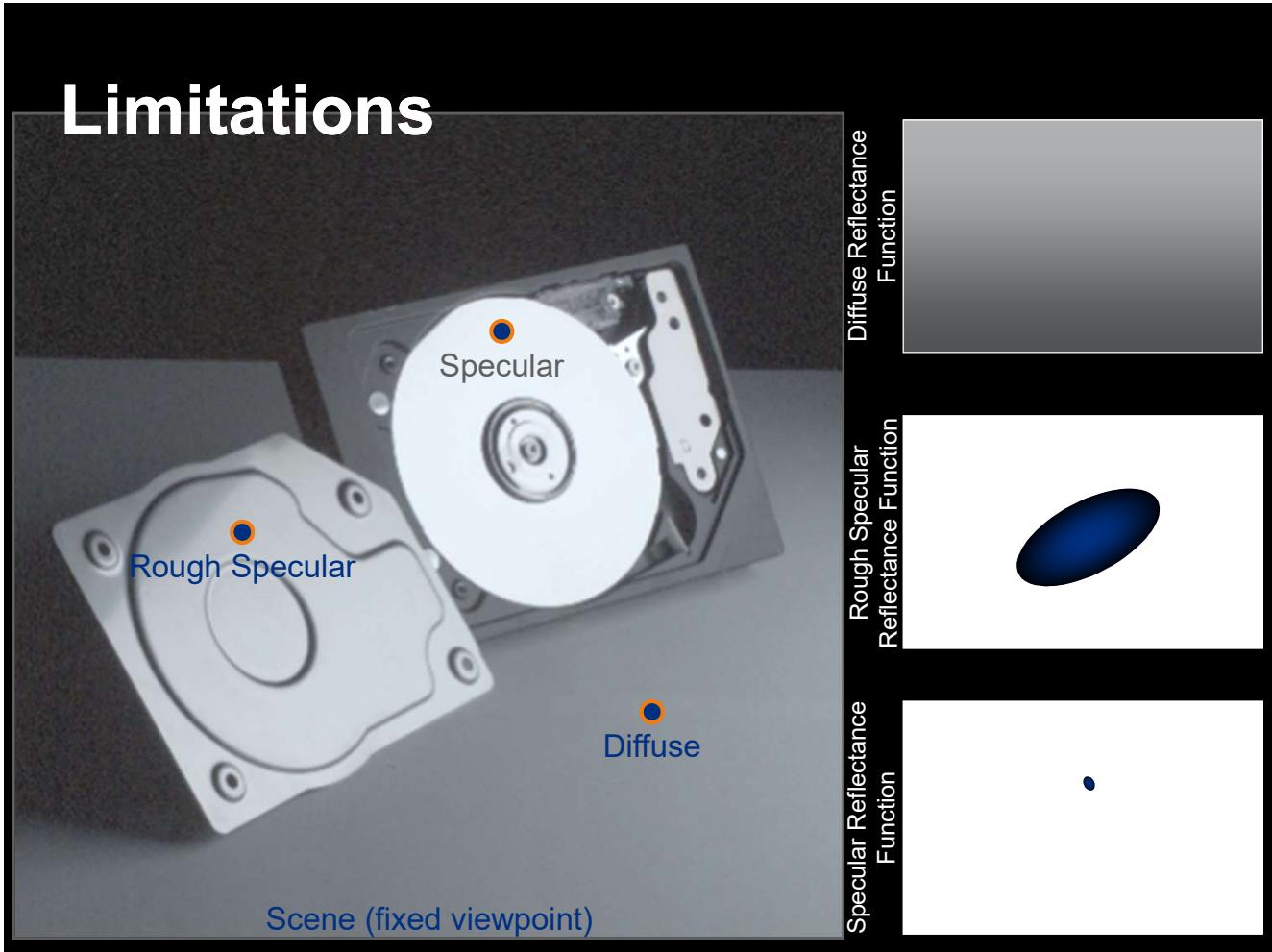
# Limitations



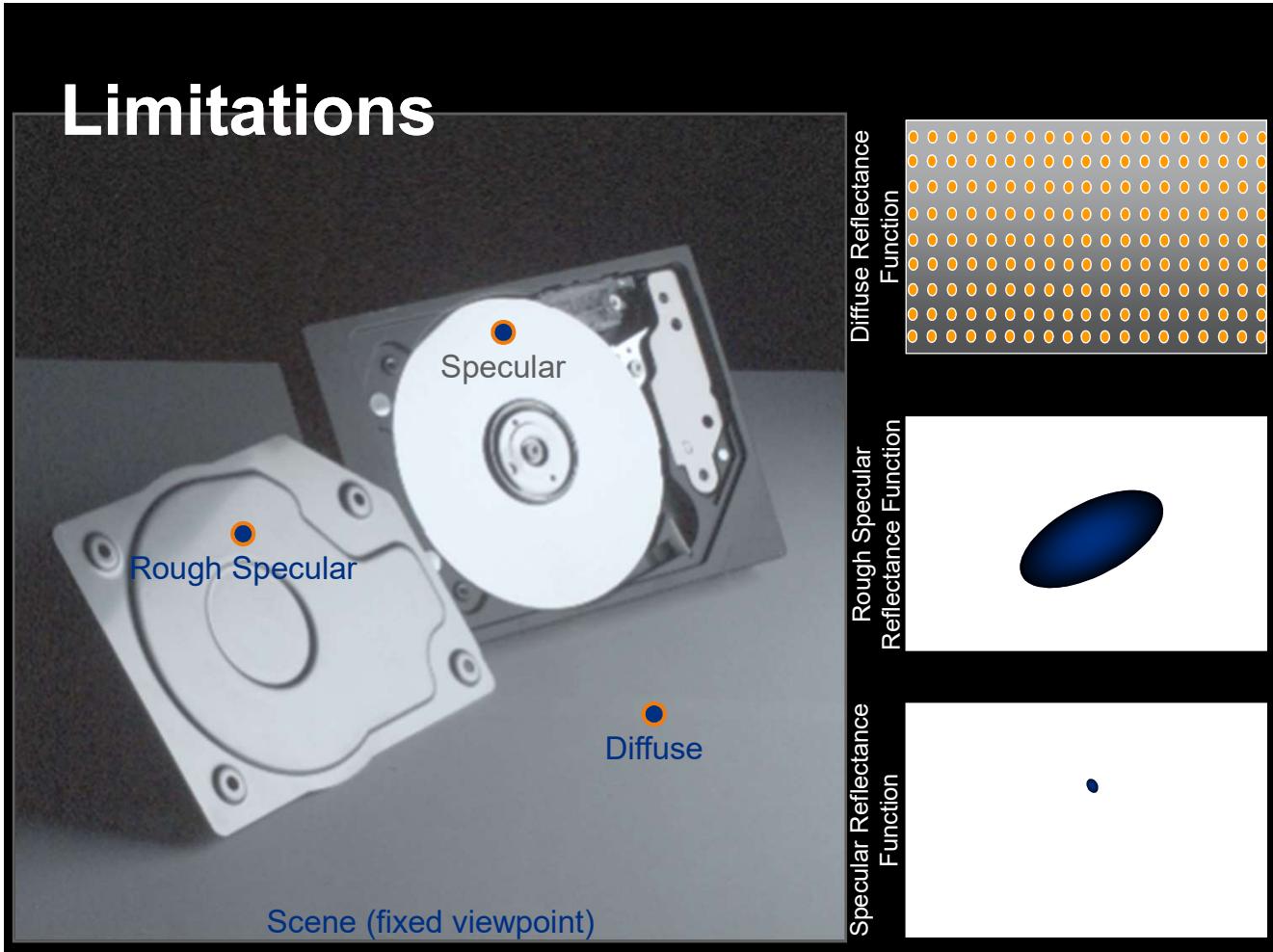
# Limitations



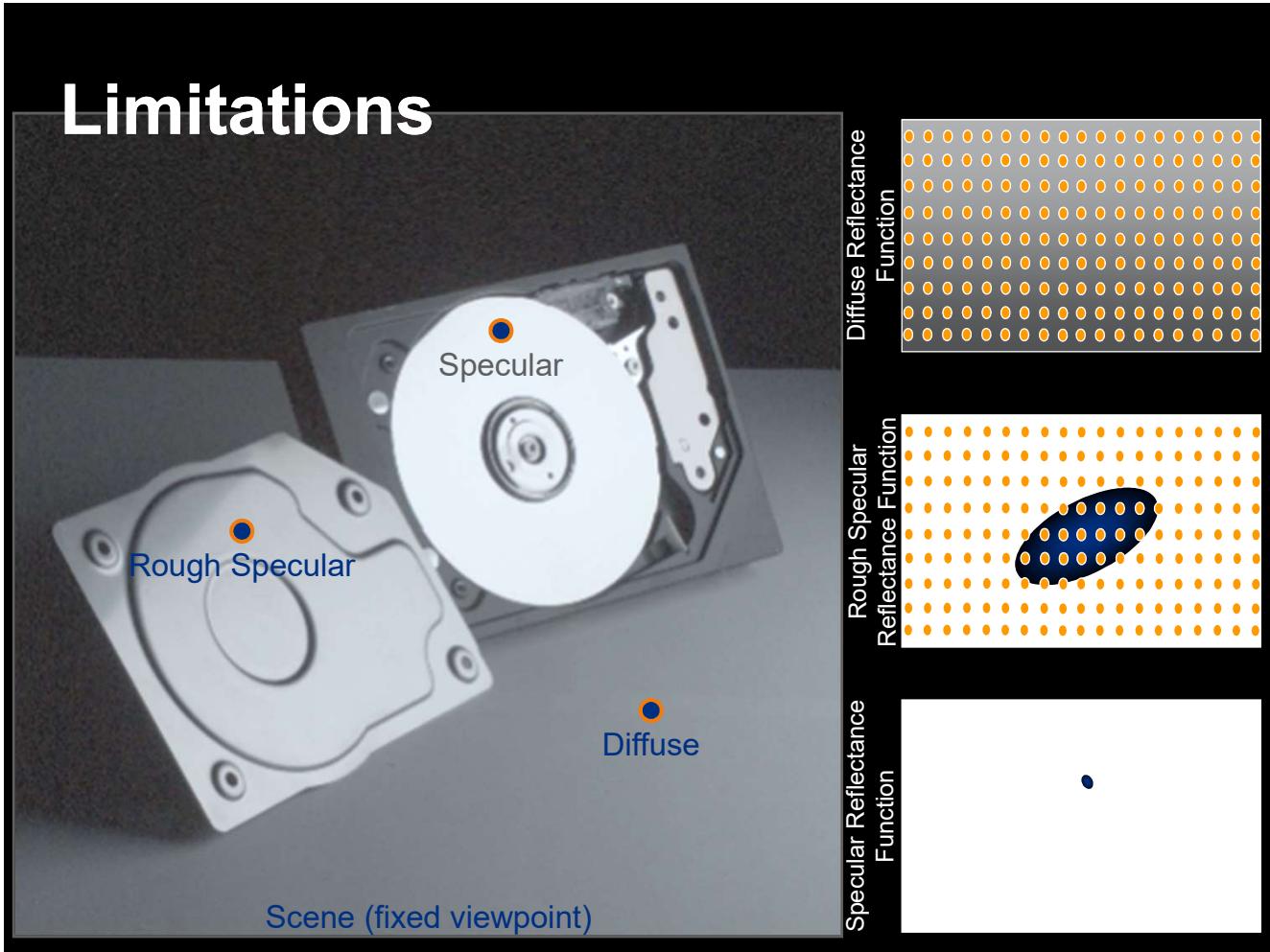
# Limitations



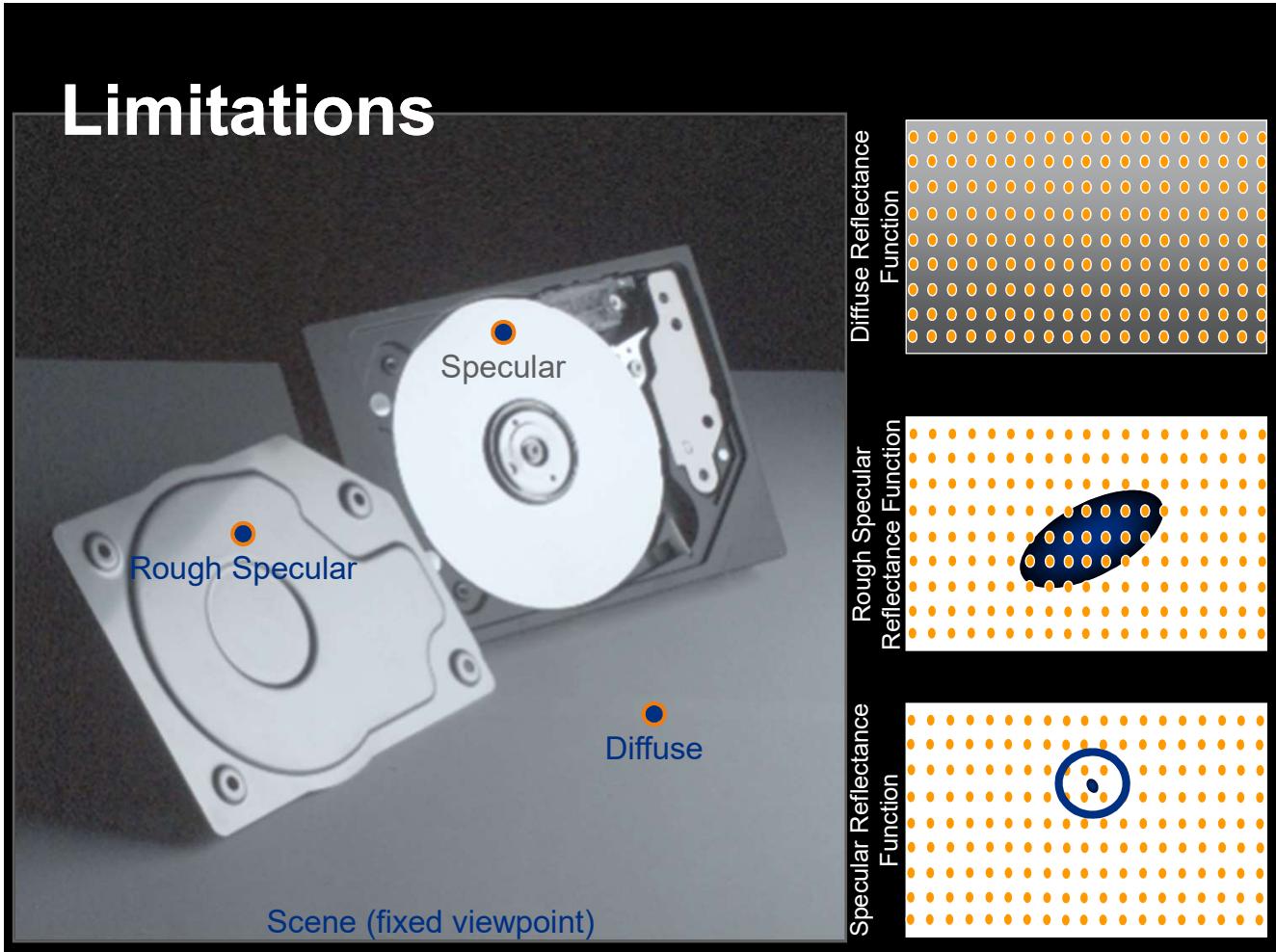
# Limitations



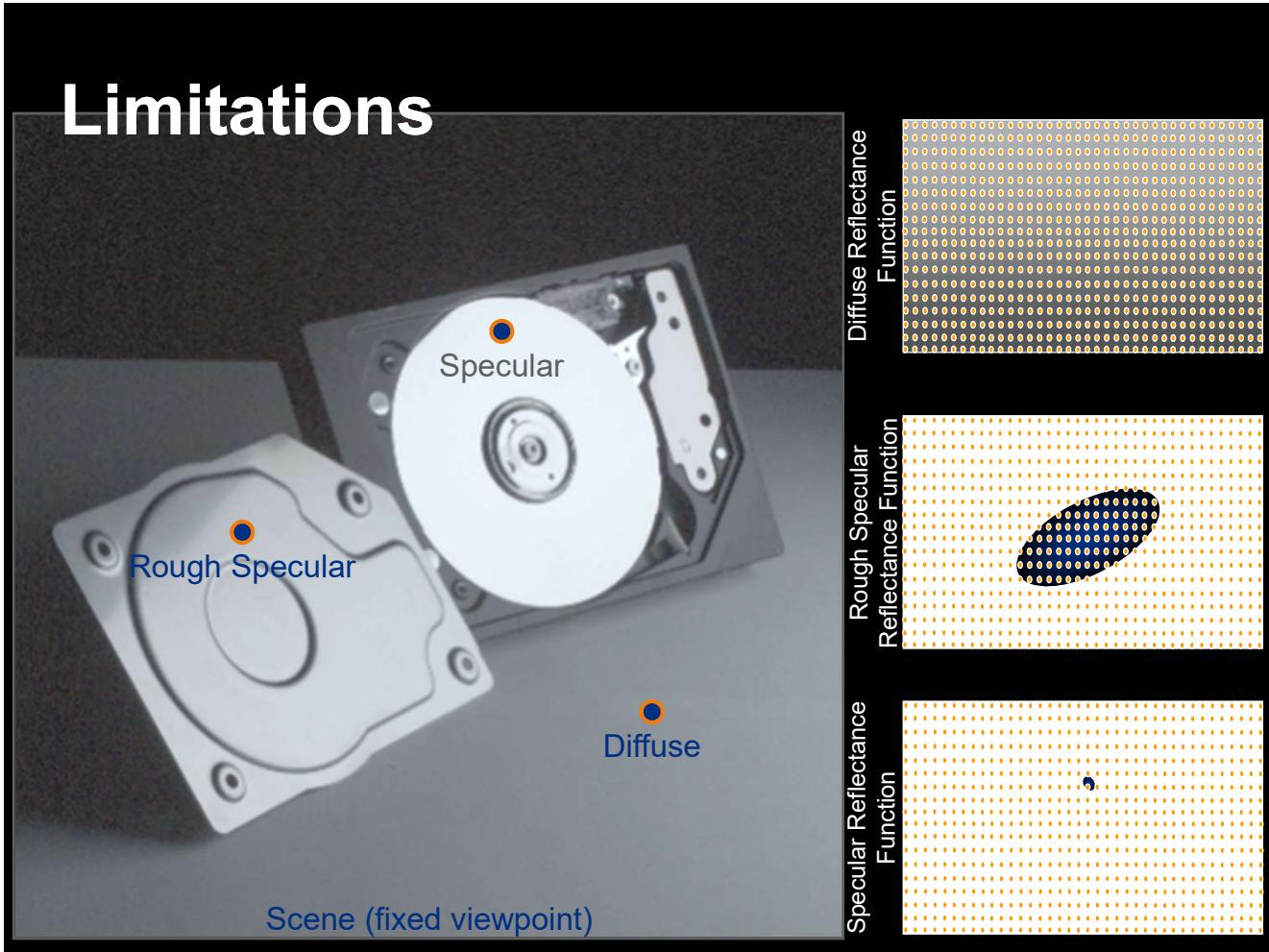
# Limitations



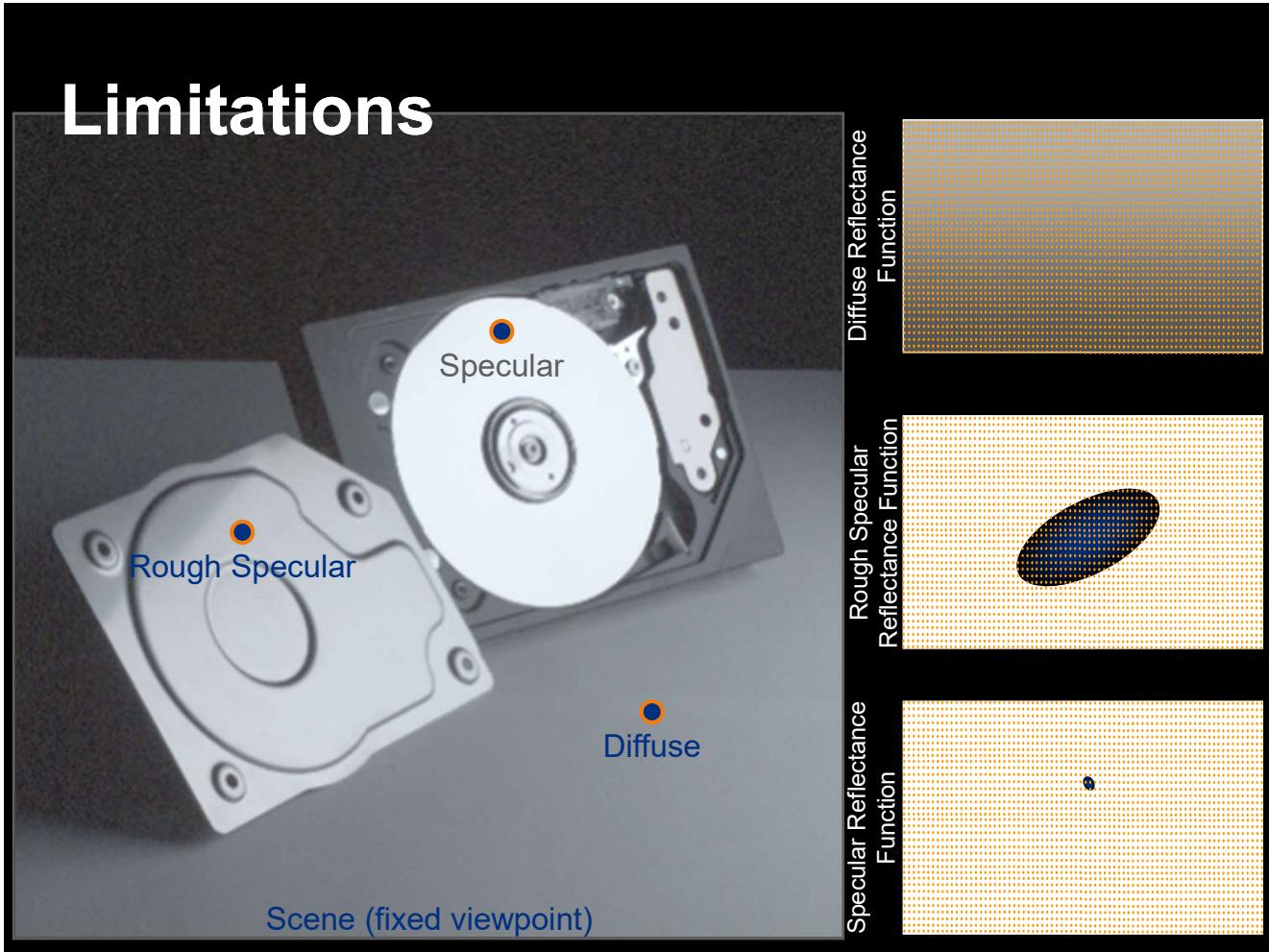
# Limitations



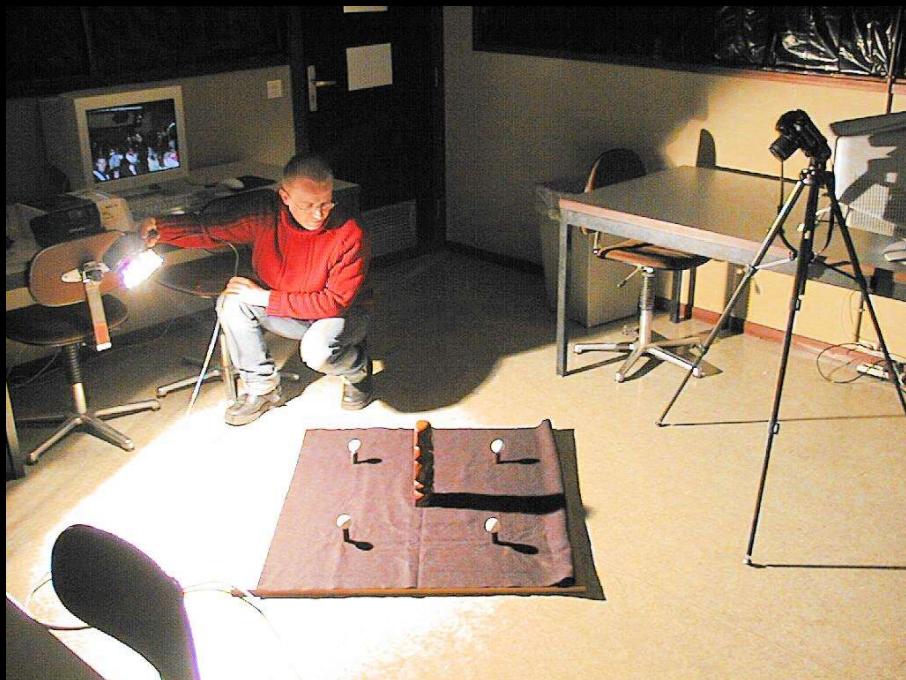
# Limitations



# Limitations



## Free-form Light Stage

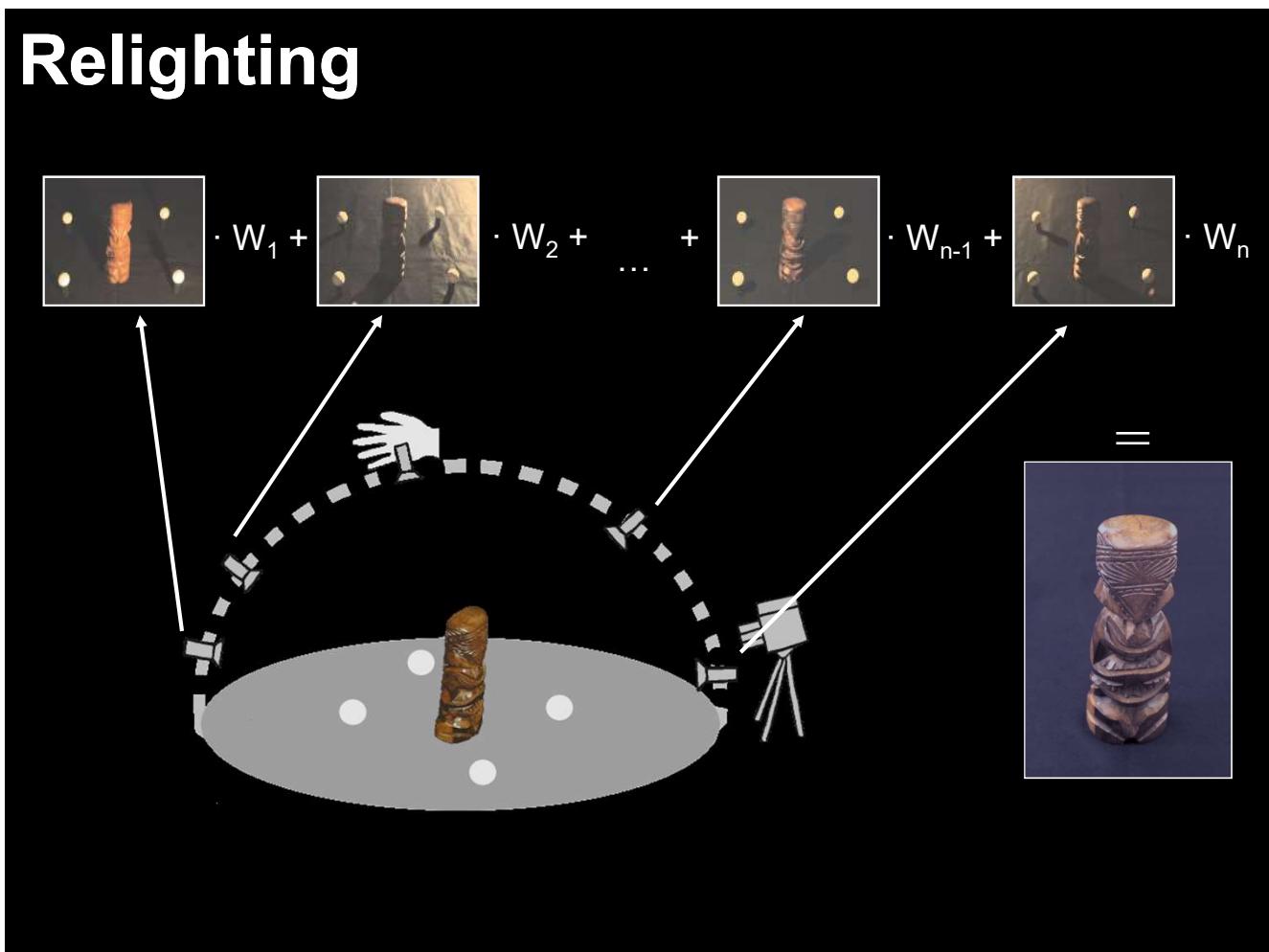


## Free-form Light Stage



Vincent Masselus, Philip Dutré and Frederik Anrys, The Free-form Light Stage, Eurographics Workshop on Rendering 2002

# Relighting



## Illuminant direction estimation



## Illuminant direction estimation

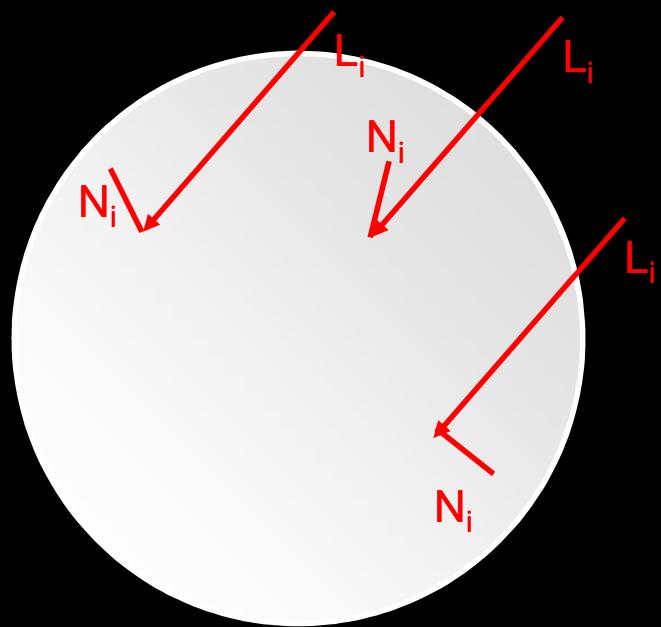


Diffuse white spheres

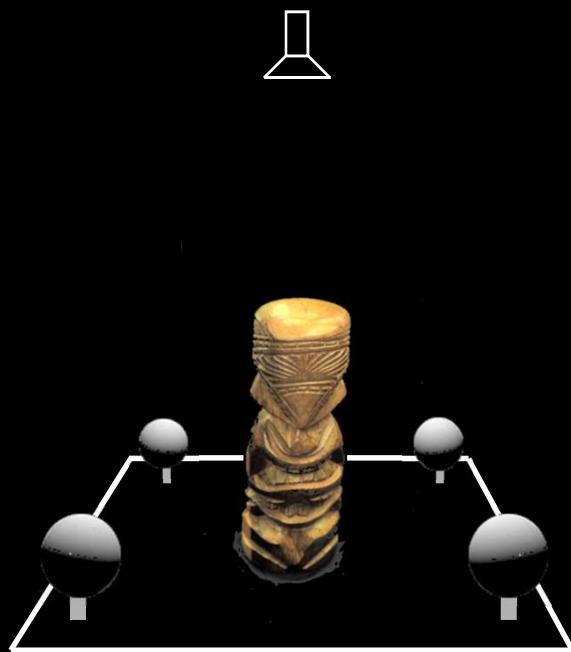
## Illuminant direction estimation

Lamberts Law

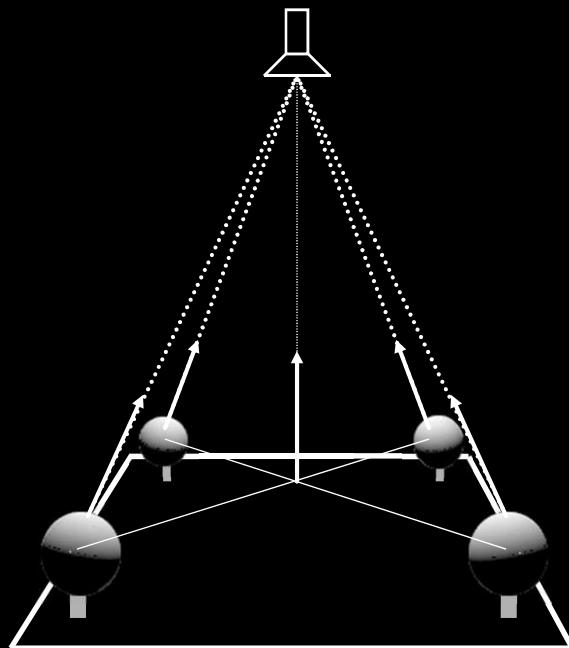
$$I_i = \rho I_L (\vec{N}_i \cdot \vec{L})$$



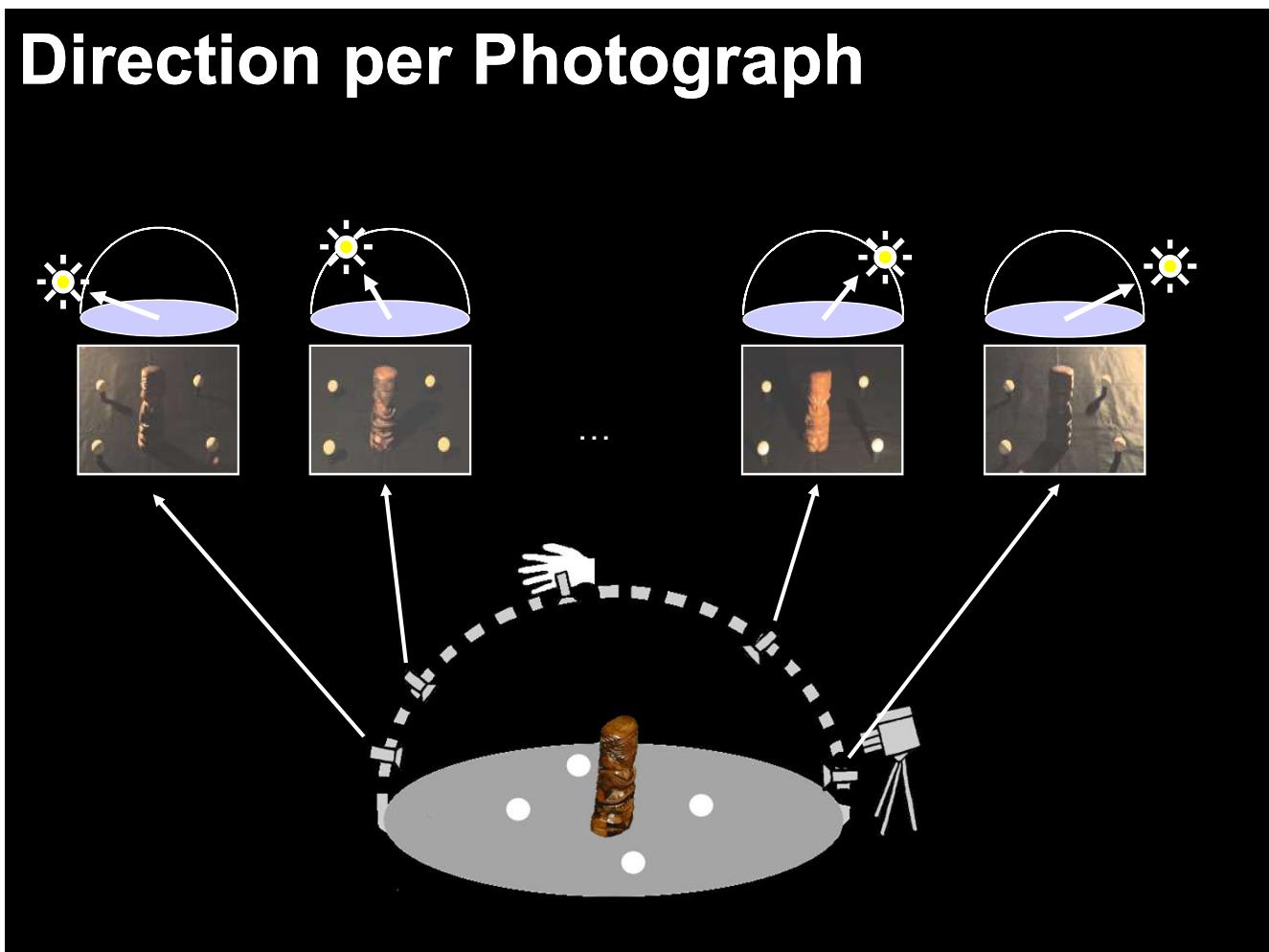
# Illuminant direction estimation



# Illuminant direction estimation

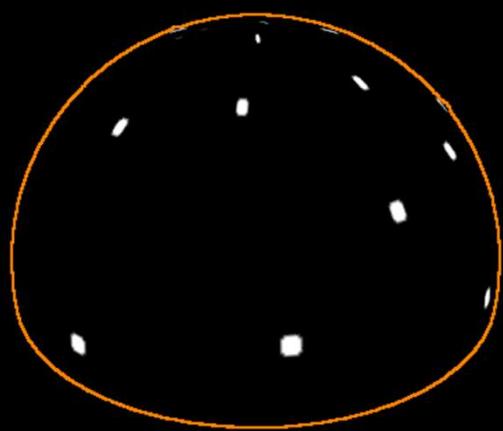


# Direction per Photograph



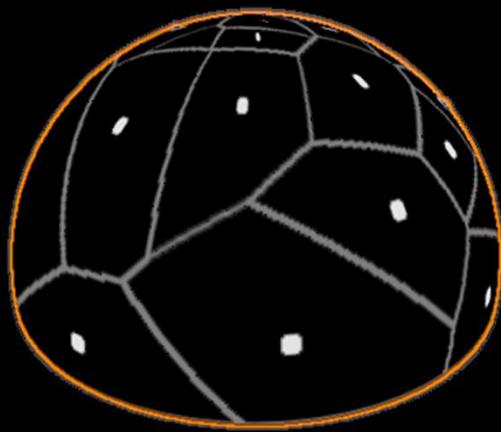
93

## Plot Directions on (hemi-)Sphere



30 light directions

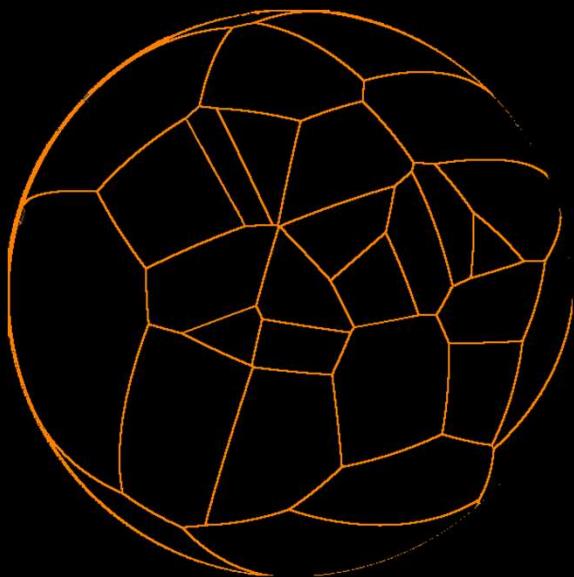
# Angular Voronoi Diagram



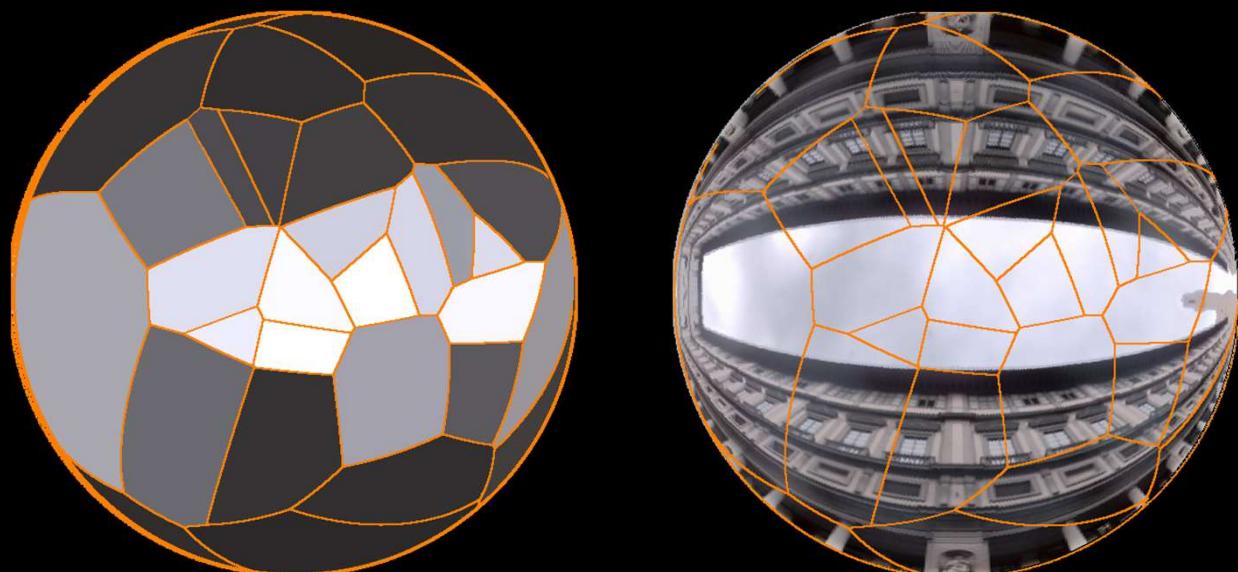
Distance = Angle between vectors

$$= \arccos(v_i \cdot v_k)$$

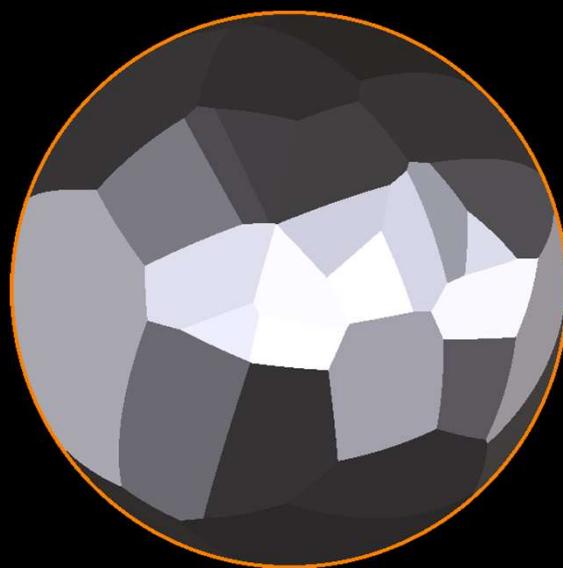
# Angular Voronoi Diagram



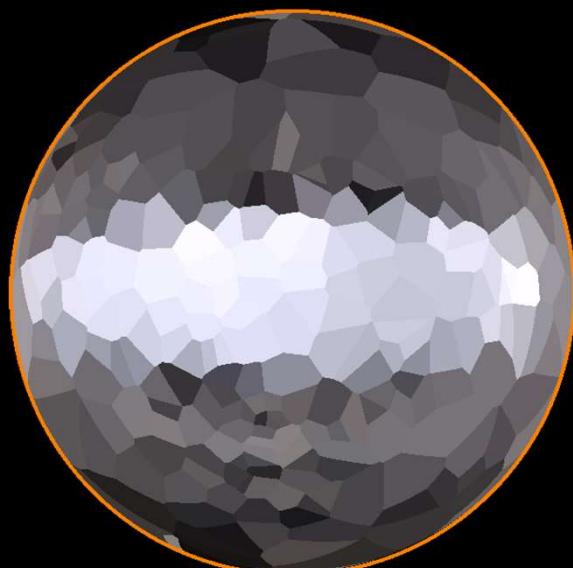
# Angular Voronoi Diagram



## Effect of Sampling Rate

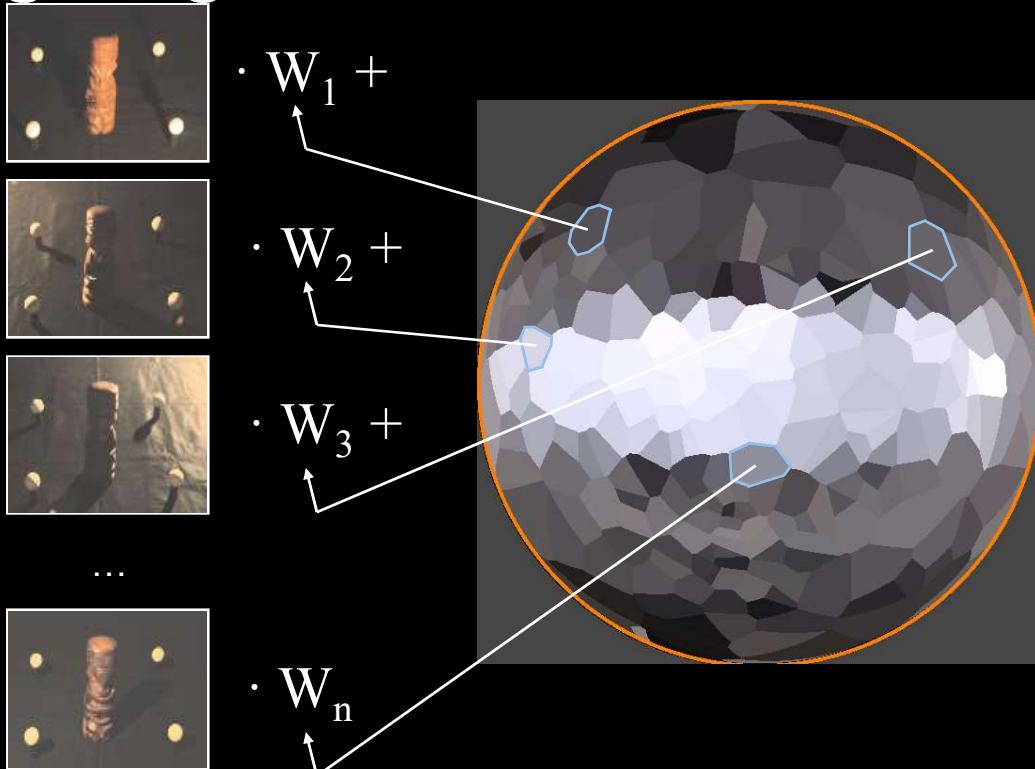


30 light directions



400 light directions

# Relighting



# Relighting



$$\cdot W_1 +$$



$$\cdot W_2 +$$



$$\cdot W_3 +$$

...

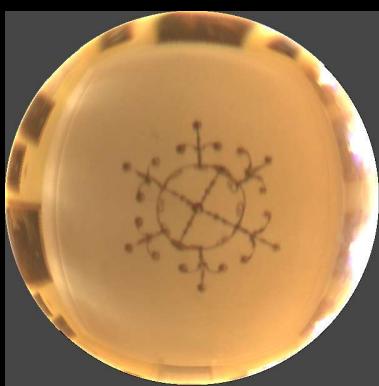


$$\cdot W_n$$

$$\} =$$



# Results



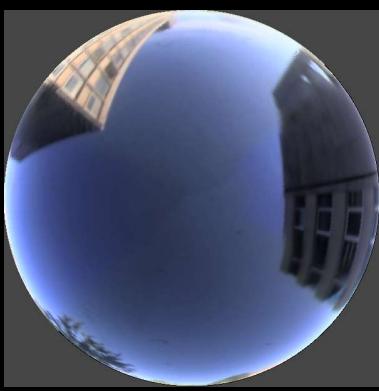
101

101

# Results



# Results



# Results

