Progressive Virtual Beam Lights

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Disney Research
KIT
Université de Montréal

MOTIVATION

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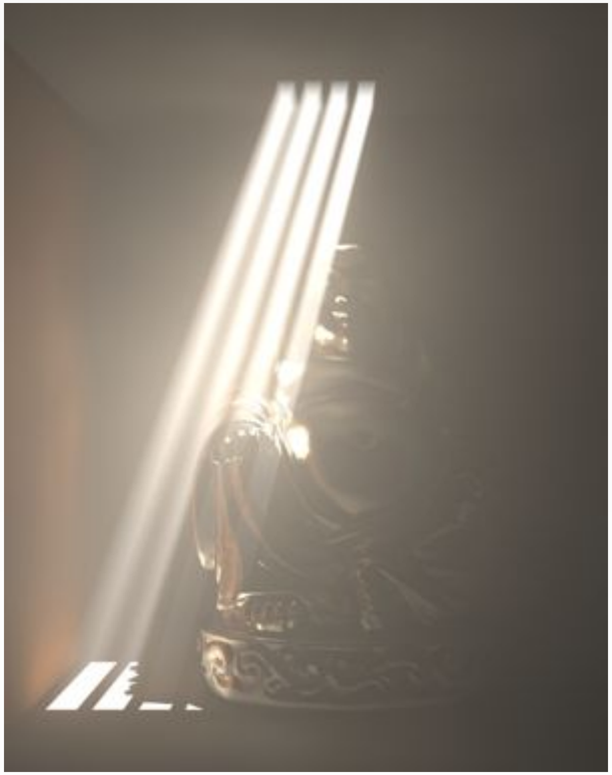
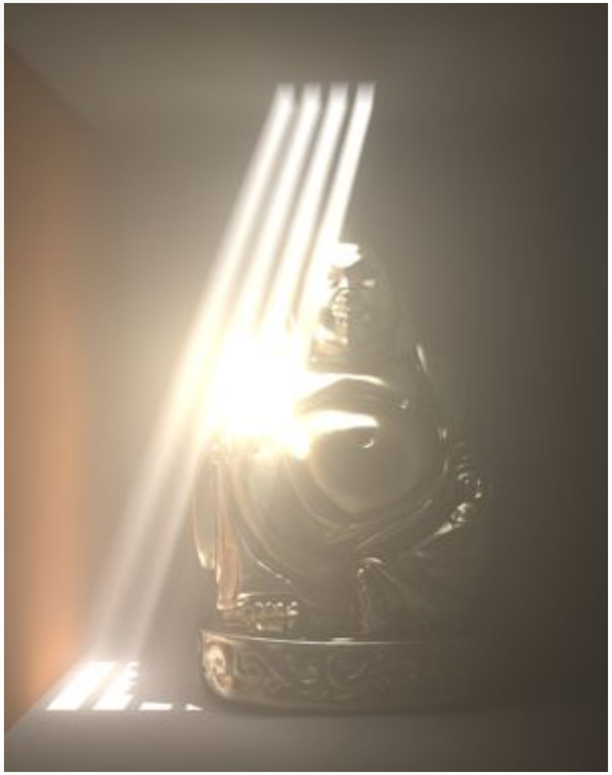
Surface illumination
Single scattering

Surface Illumination
Single + Multiple scattering

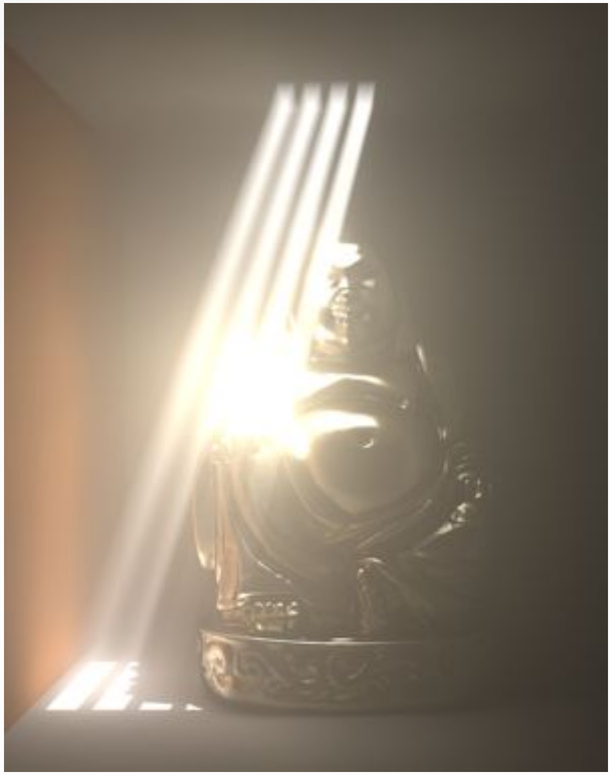


Full Global Illumination



MOTIVATION

Full Global Illumination



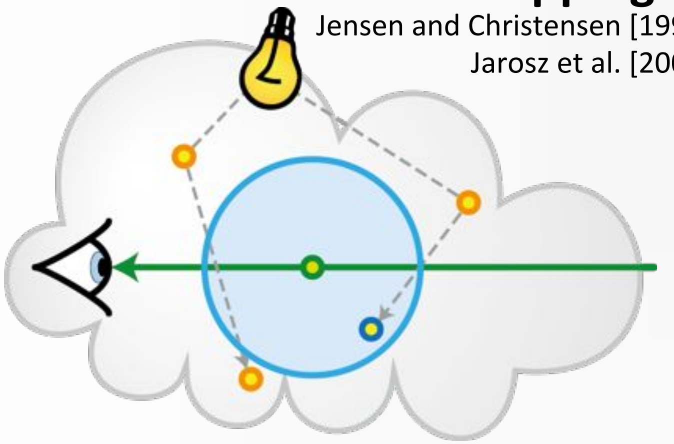
Our approach:

- based on virtual lights
- no singularities (replaced with small amount of bias)
- progressive updates (bias goes to zero in the limit)

PREVIOUS WORK

Volumetric Photon Mapping

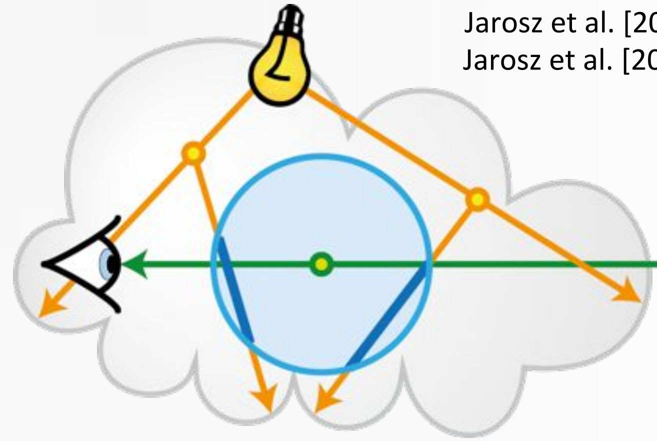
Jensen and Christensen [1998]
Jarosz et al. [2008]



"requires a lot of photons"

Photon Beams

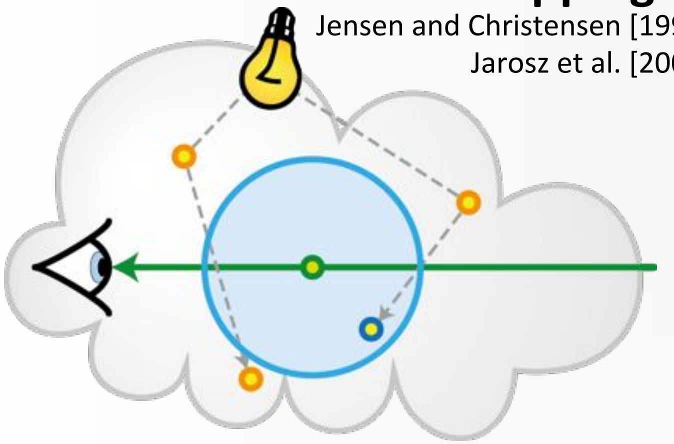
Jarosz et al. [2011a]
Jarosz et al. [2011b]



"great for caustics, less for indirect illum."

Volumetric Photon Mapping

Jensen and Christensen [1998]
Jarosz et al. [2008]



"requires a lot of photons"

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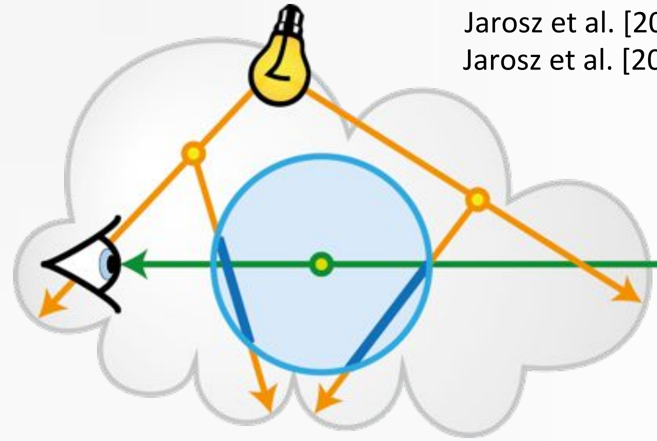
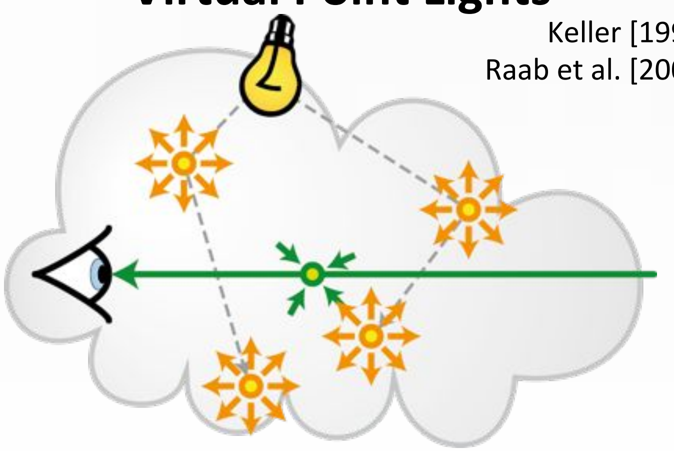


"great for caustics, less for indirect illum."

Virtual Point Lights

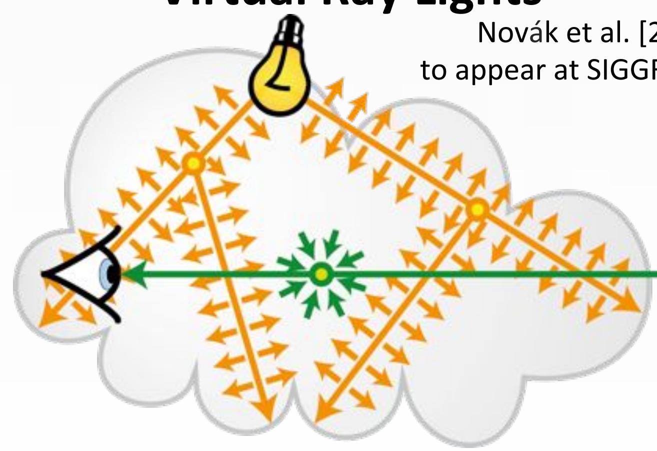
Keller [1997]
Raab et al. [2008]



"suffer from singularities"

Virtual Ray Lights

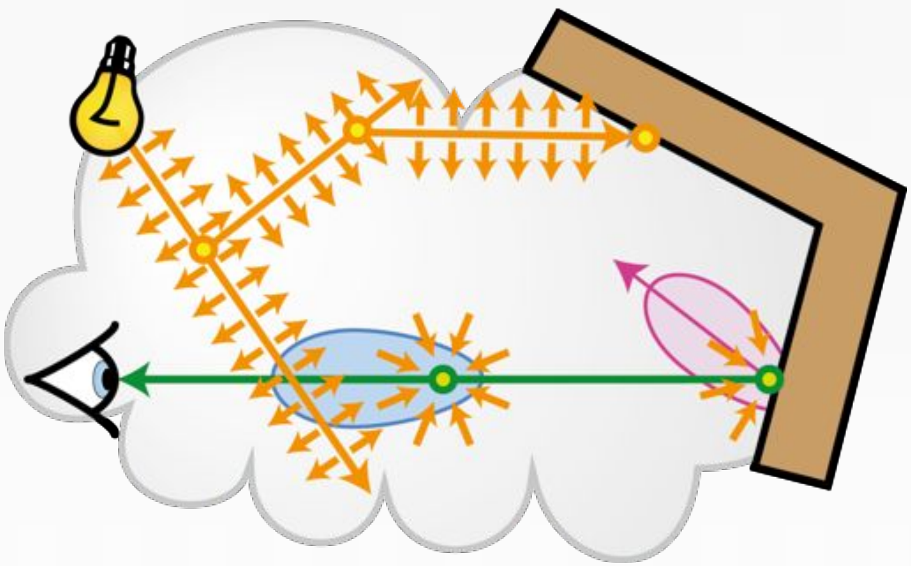
Novák et al. [2012]
to appear at SIGGRAPH



OVERVIEW

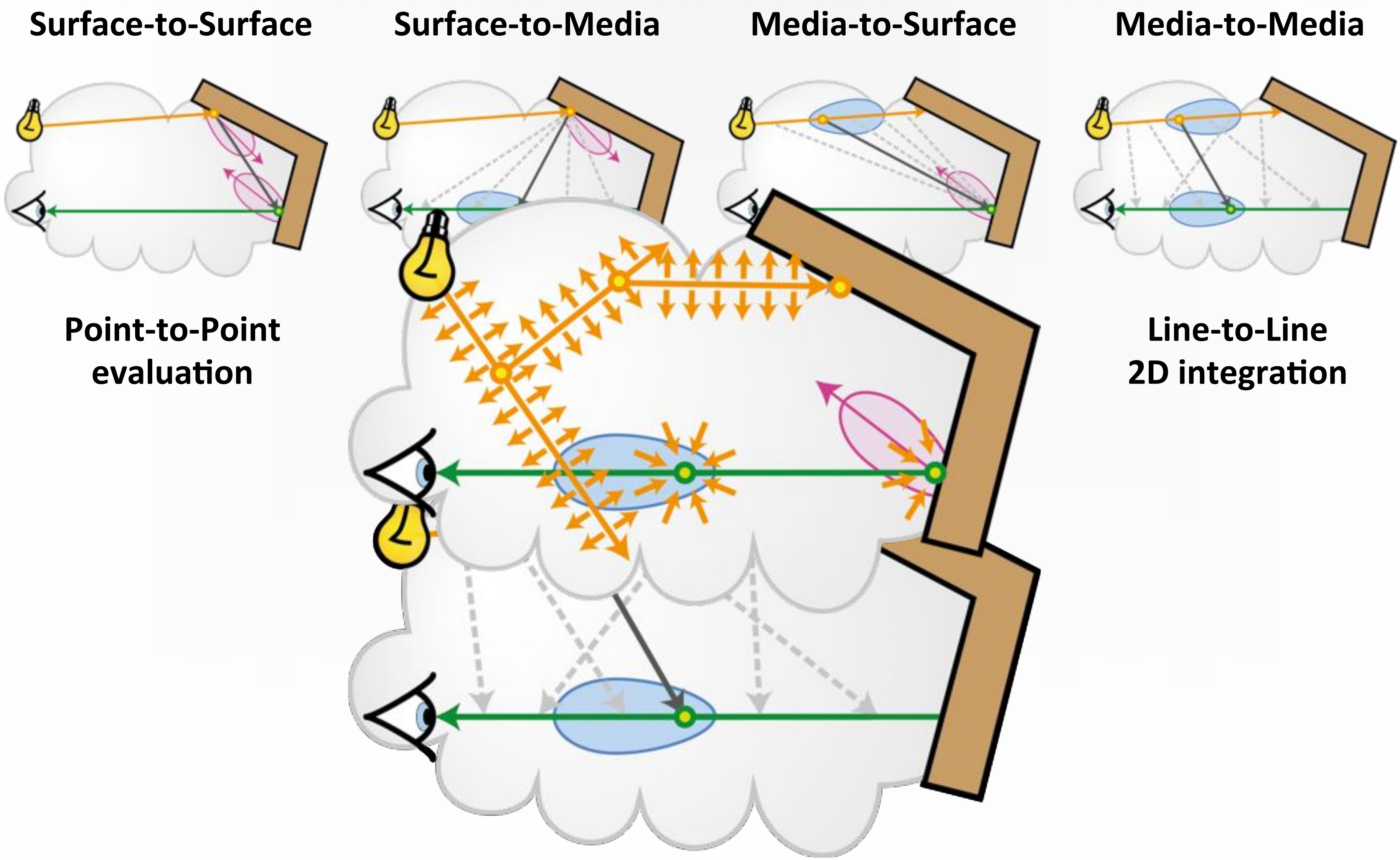
- background: **Virtual Ray Lights**
- new method: **Virtual Beam Lights**
- results

PREVIOUS WORK: INDIRECT ILLUMINATION with RAY LIGHTS



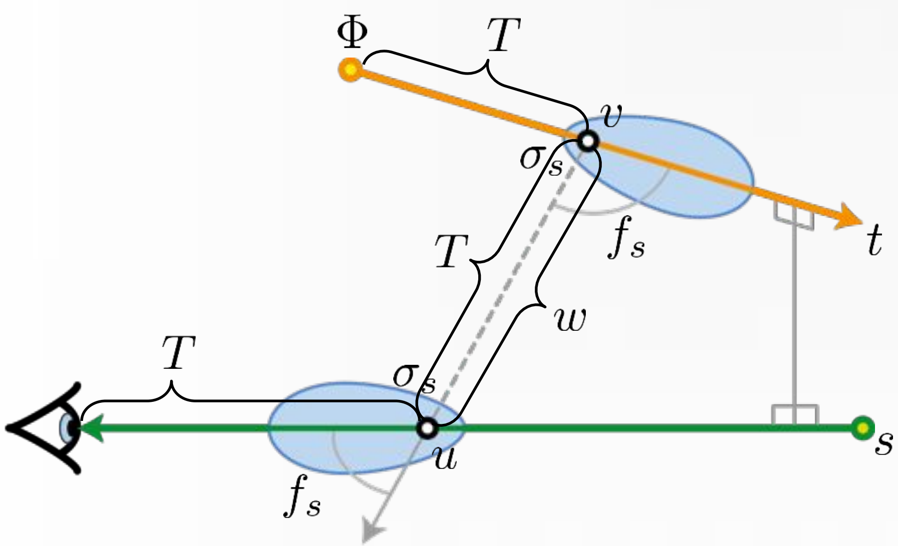
Indirect Illumination: $L(\mathbf{x}, \vec{\omega}) = L_m + L_s$

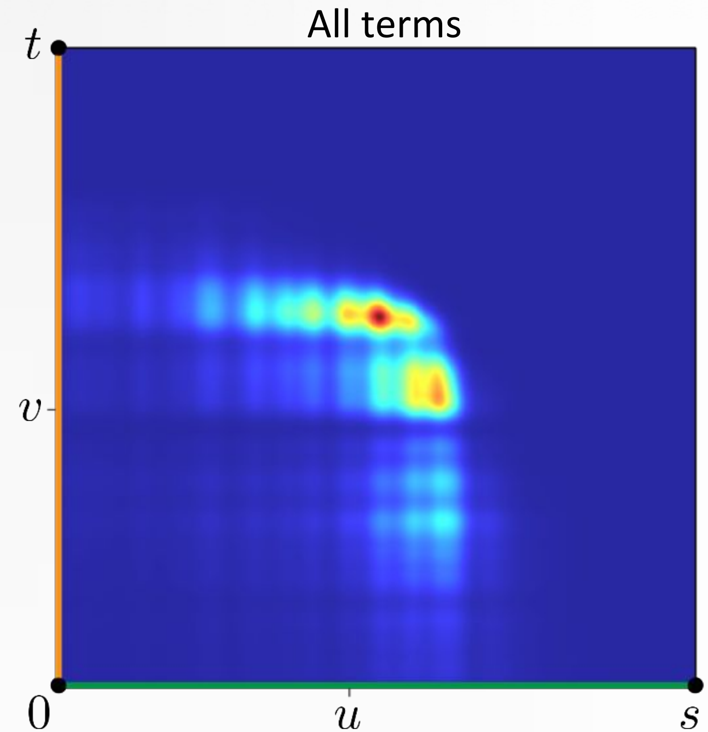
PREVIOUS WORK: INDIRECT ILLUMINATION with RAY LIGHTS

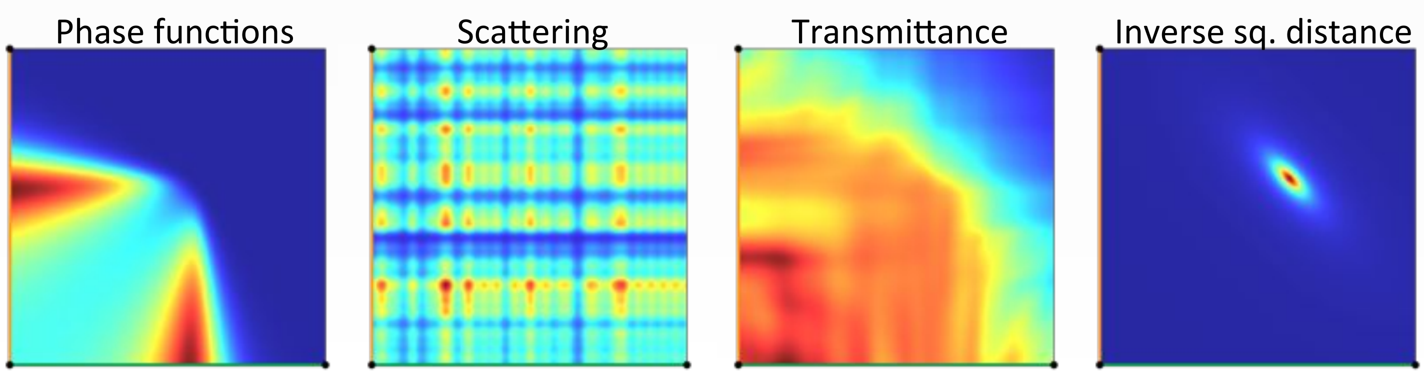


PREVIOUS WORK: MEDIA-to-MEDIA with RAY LIGHTS

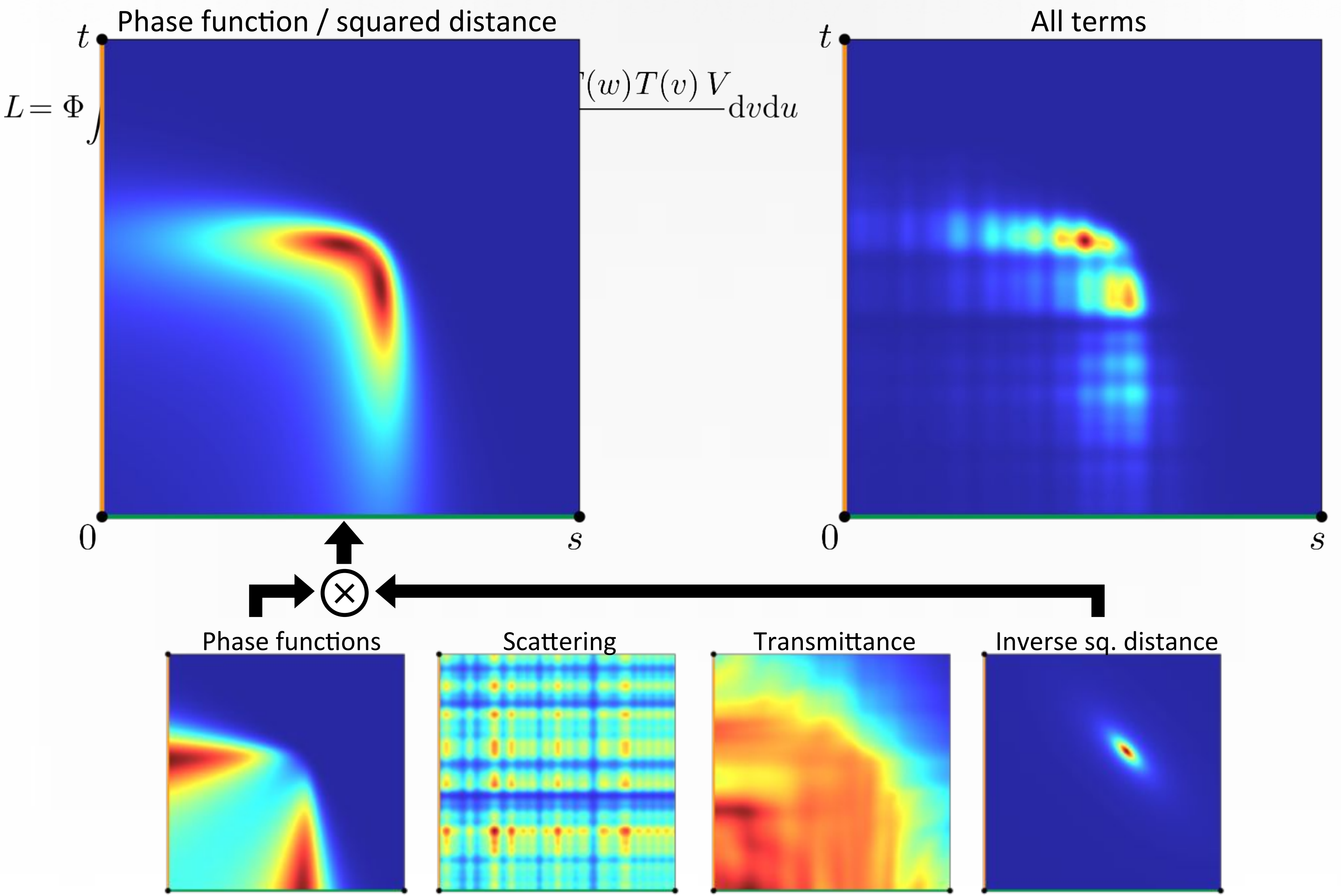
$$L = \Phi \int_0^s \int_0^t \frac{f_s(\theta_u) f_s(\theta_v)\ \sigma_s(u)\sigma_s(v)\ T(u)T(w)T(v)\ V}{w(u,v)^2} \mathrm{d}v\mathrm{d}u$$



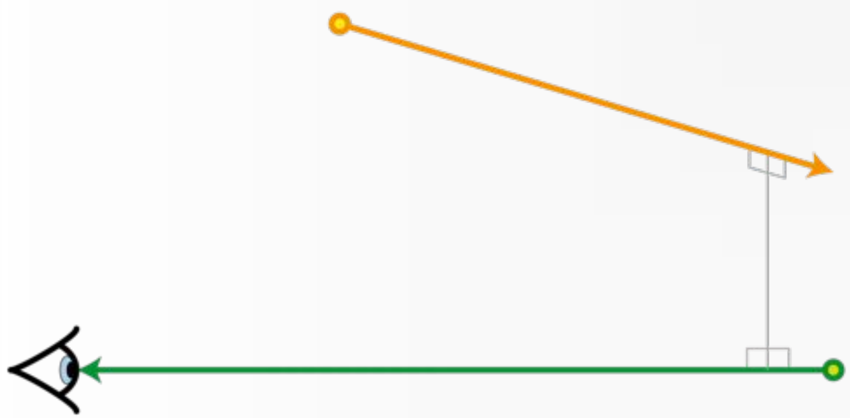




PREVIOUS WORK: MEDIA-to-MEDIA with RAY LIGHTS

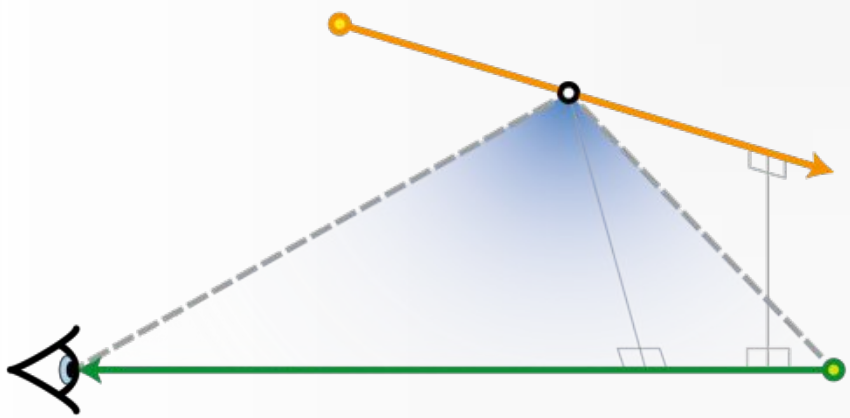


PREVIOUS WORK: MEDIA-to-MEDIA with RAY LIGHTS



Two-step importance sampling:

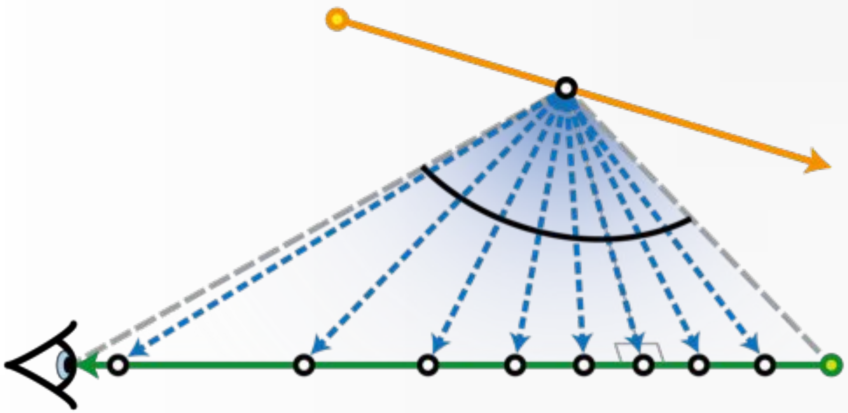
PREVIOUS WORK: MEDIA-to-MEDIA with RAY LIGHTS



Two-step importance sampling:

1) Choose a point along the **ray light** using analytic marginal PDF for **inverse squared distance**

PREVIOUS WORK: MEDIA-to-MEDIA with RAY LIGHTS

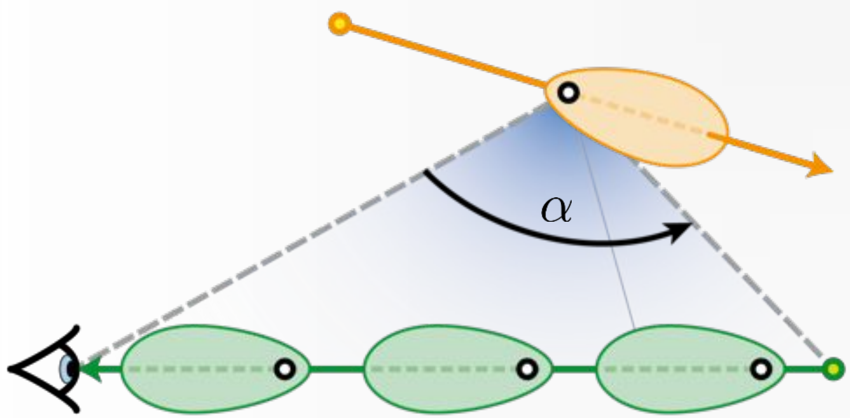


Equiangular sampling

Two-step importance sampling:

1) Choose a point along the **ray light** using analytic marginal PDF for **inverse squared distance**
2) Choose a point along the **eye ray**

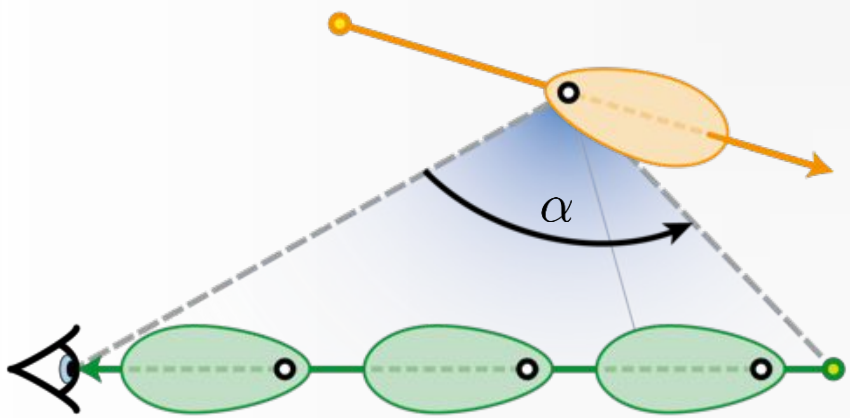
PREVIOUS WORK: MEDIA-to-MEDIA with RAY LIGHTS

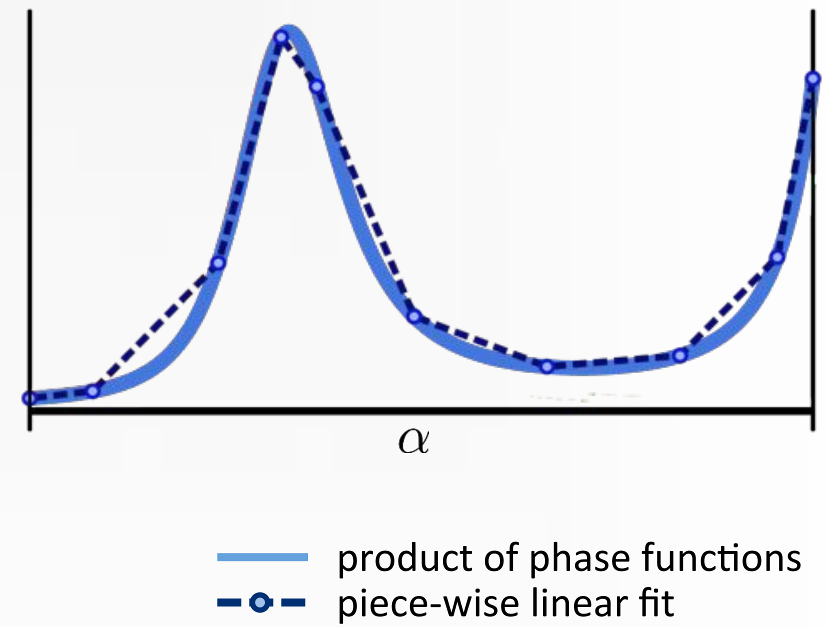


Two-step importance sampling:

1) Choose a point along the **ray light** using analytic marginal PDF for **inverse squared distance**
2) Choose a point along the **eye ray**

PREVIOUS WORK: MEDIA-to-MEDIA with RAY LIGHTS



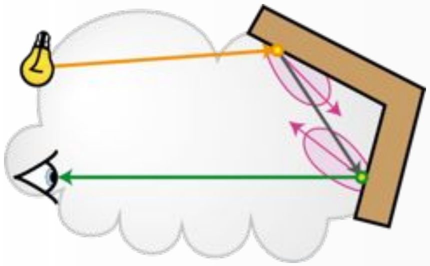


Two-step importance sampling:

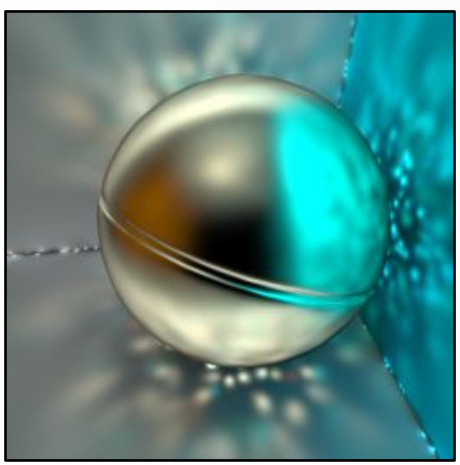
1) Choose a point along the **ray light** using
   analytic marginal PDF for **inverse squared distance**
2) Choose a point along the **eye ray**
   Numeric conditional piece-wise linear PDF for the **product of phase functions**

PREVIOUS WORK: RAY LIGHTS – OVERVIEW

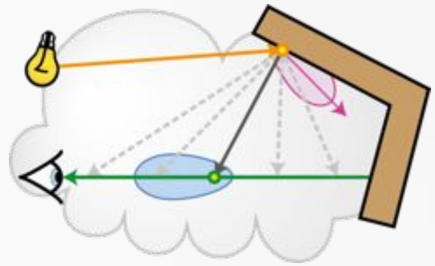
Surface-to-Surface



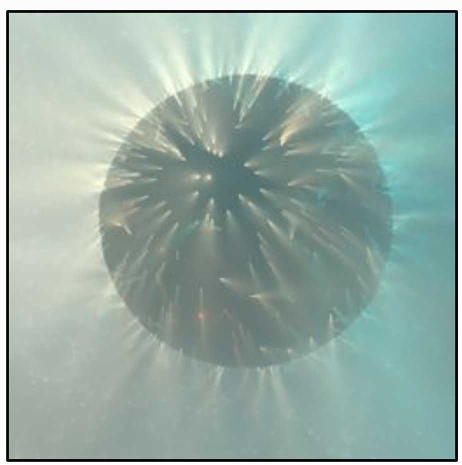
1) evaluate transport



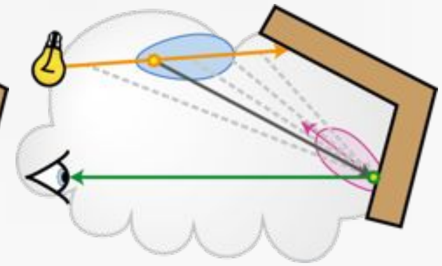
Surface-to-Media



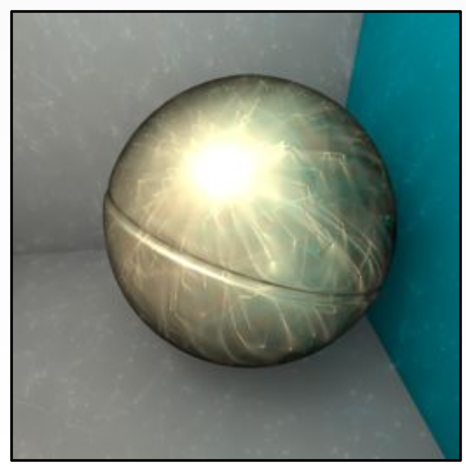
1) construct **BRDF*PF** PDF and sample **eye ray**
2) evaluate transport



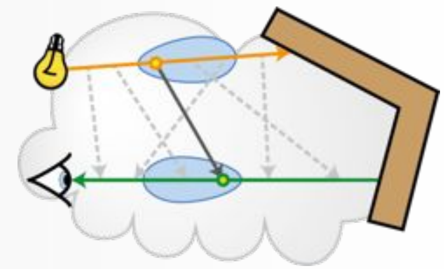
Media-to-Surface



1) construct **PF*BRDF** PDF and sample **ray light**
2) evaluate transport

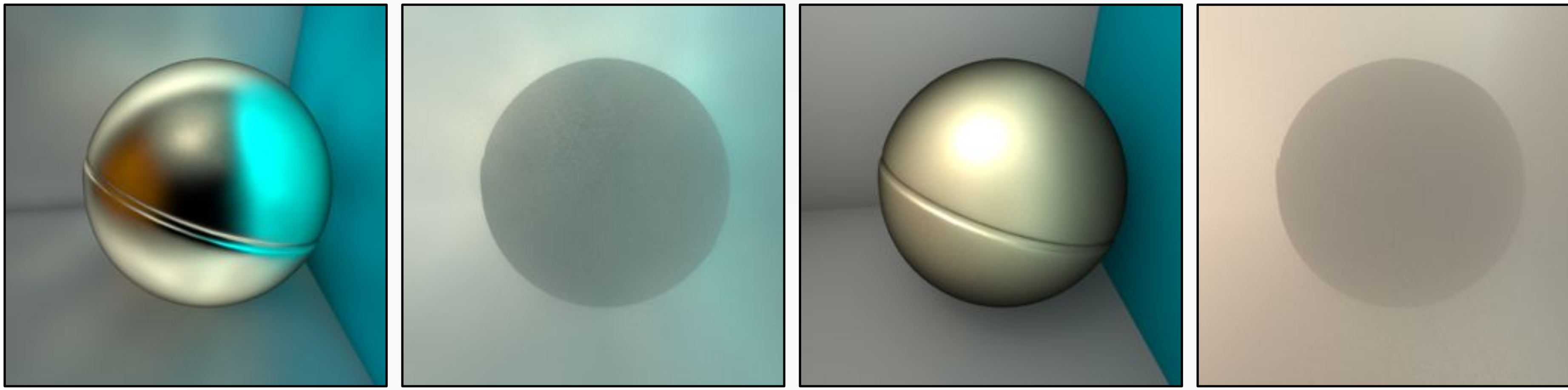


Media-to-Media



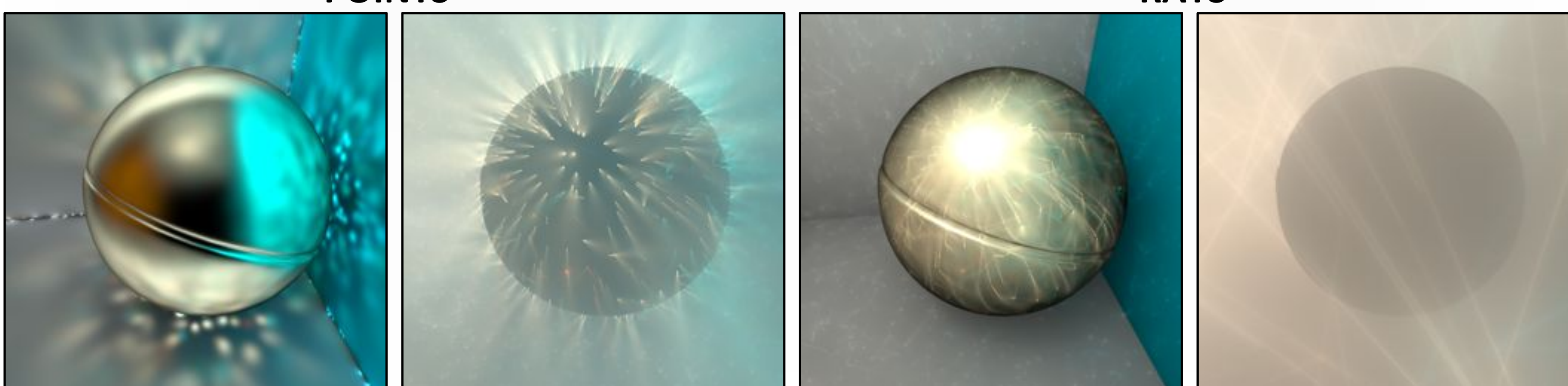
1) sample a position on the **ray light**
2) construct **PF*PF** PDF and sample **eye ray**
3) evaluate transport

PREVIOUS WORK: RAY LIGHTS – OVERVIEW



SPHERES ⇧ POINTS

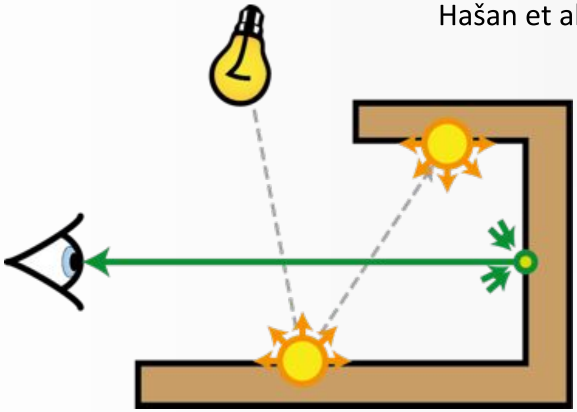
BEAMS ⇧ RAYS



PREVIOUS WORK: AVOIDING SINGULARITIES

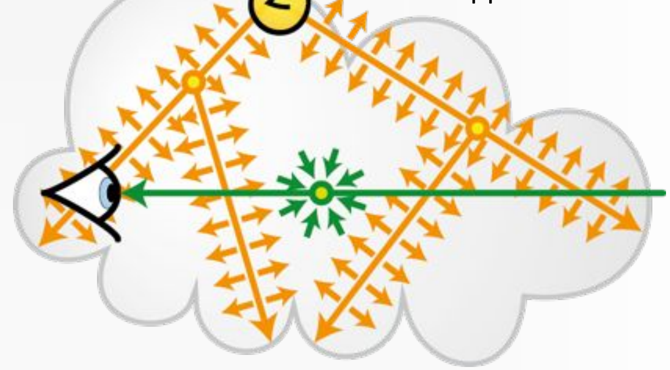
Virtual Spherical Lights

Hašan et al. [2009]

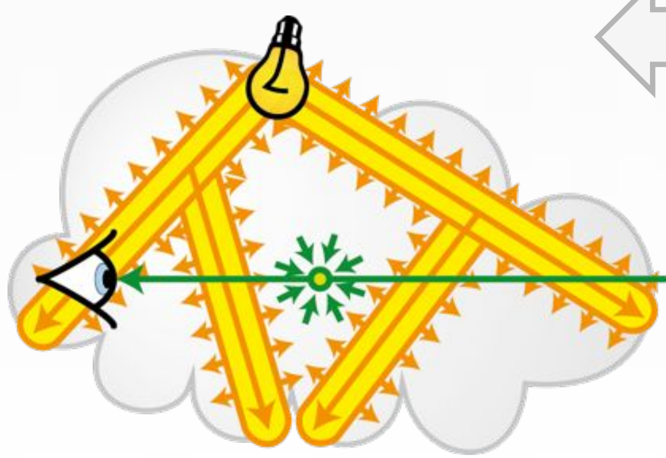


Virtual Ray Lights

Novák et al. [2012]
to appear at SIGGRAPH

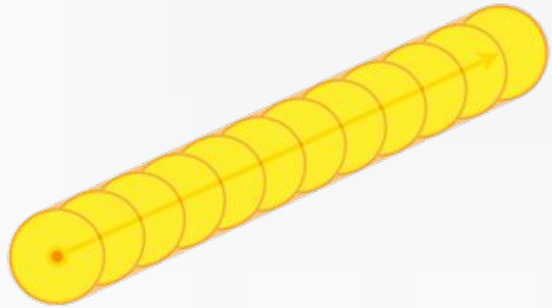


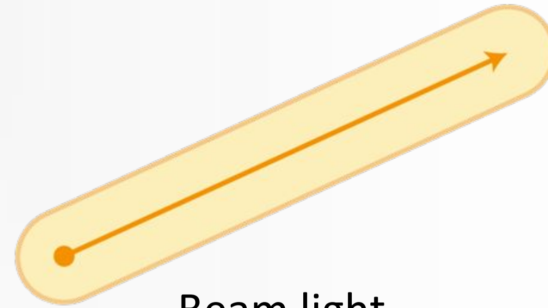
Virtual Beam Lights



BEAM as a SWEPT SPHERE

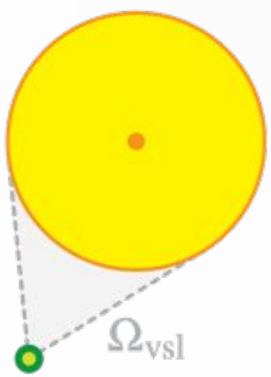
Ray light

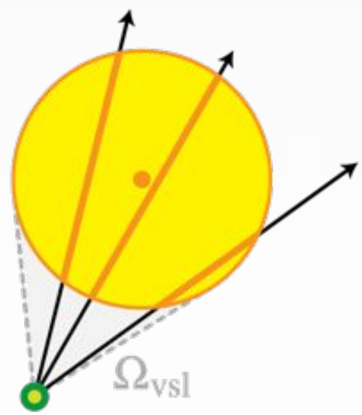




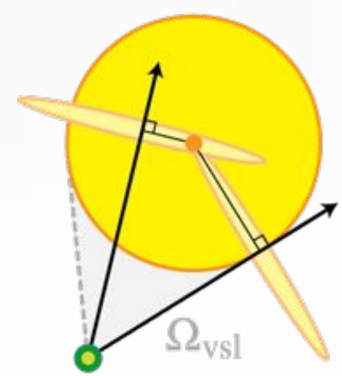
Beam light

Integrating the contribution of the **sphere**





Volumetric photon light

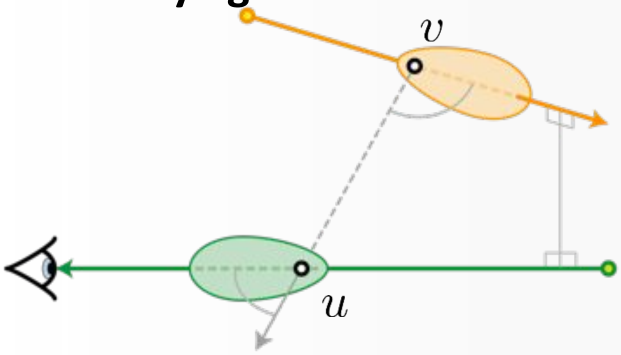


Beam radiance estimate

Jarosz et al. [2008]

RAY LIGHT versus BEAM LIGHT

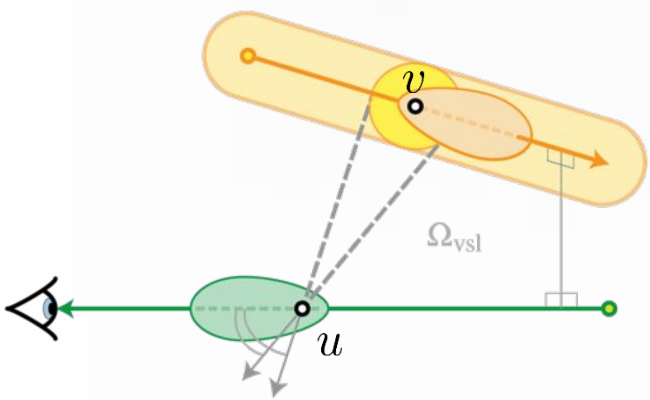
Ray light



Ray-Ray light transport

$$L = \Phi \iint \frac{f_s(\theta_u) f_s(\theta_v) \sigma_s(u) \sigma_s(v) T(u) T(w) T(v) V}{w(u,v)^2} \mathrm{d}v \mathrm{d}u$$

Beam light



Beam-Ray light transport

$$L = \frac{\Phi}{\pi R^2} \iint \sigma_s(u) T(u) \int_{\Omega_{\text{VSL}}} f_s(\theta_u) f_s(\theta_v) \sigma_s(v) T(w) T(v) V \mathrm{d}\omega \mathrm{d}v \mathrm{d}u$$

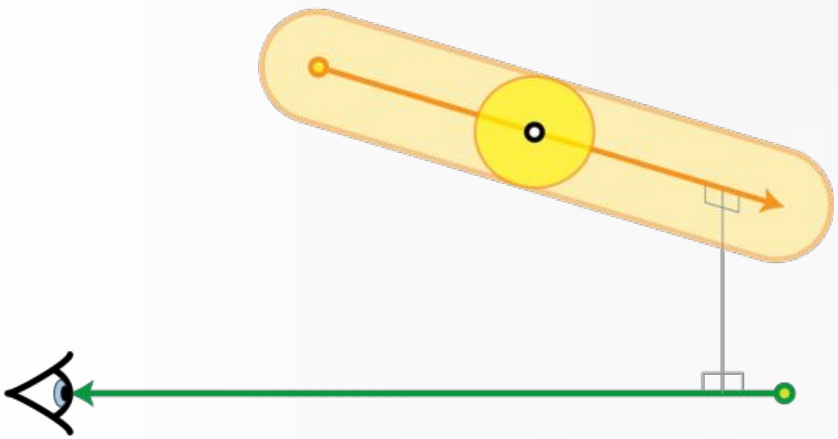
This would require ray casting ☹

Introduce a few approximations (in spirit of Hašan et al. 2009):

$$L = \frac{\Phi}{\pi R^2} \iint \sigma_s(u) \sigma_s(v) T(u) T(w) T(v) V \int_{\Omega_{\text{VSL}}} f_s(\theta_u) f_s(\theta_v) \mathrm{d}\omega \mathrm{d}v \mathrm{d}u$$

Typos in the proceedings! Sorry…

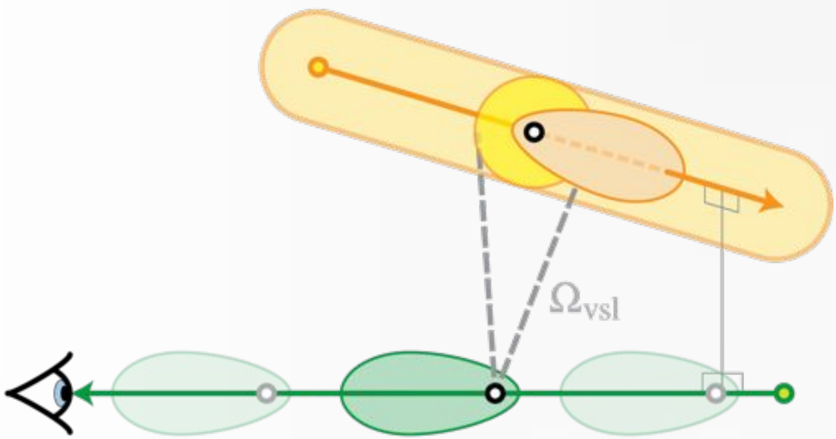
MEDIA-to-MEDIA with BEAM LIGHTS

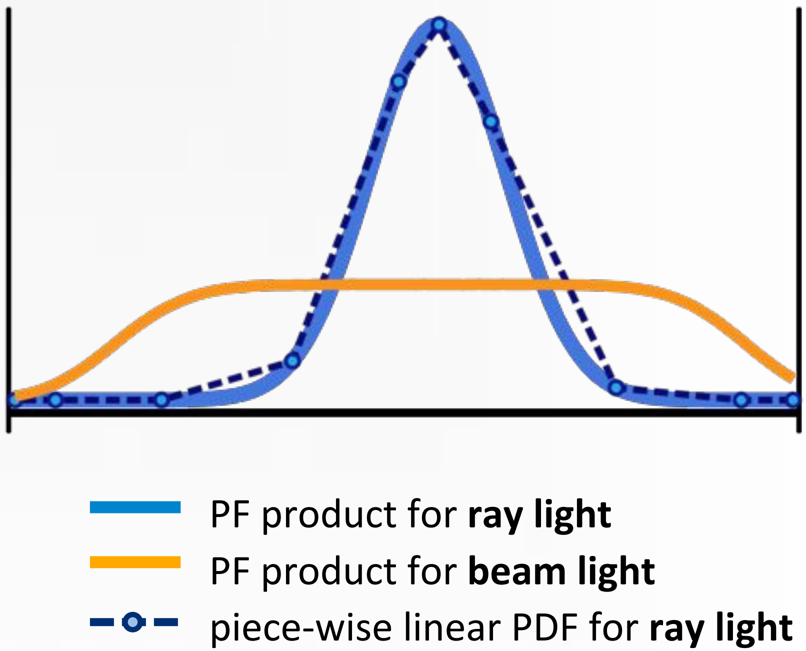


Two-step importance sampling:

1) Choose a point along the **beam light** using analytic marginal PDF for **inverse squared distance**

MEDIA-to-MEDIA with BEAM LIGHTS





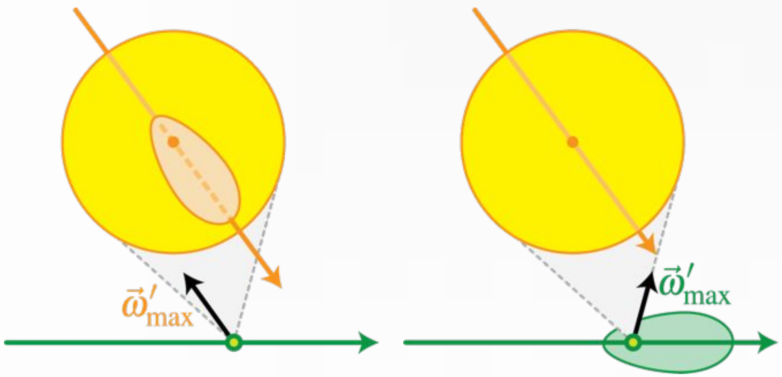
Two-step importance sampling:

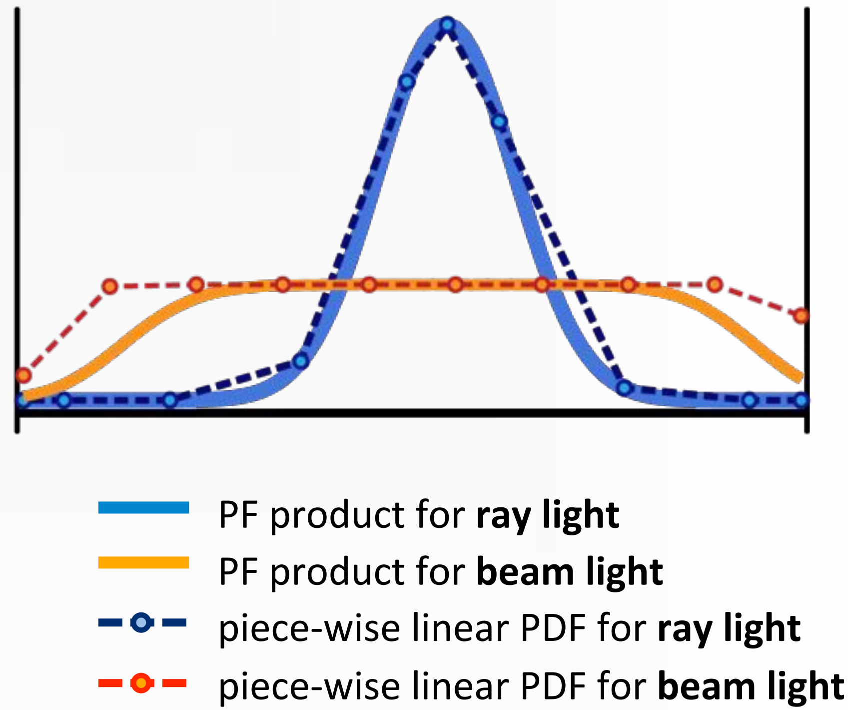
1) Choose a point along the **ray light** using analytic marginal PDF for **inverse squared distance**
2) Choose a point along the **eye ray** 1D fit to the **product of phase functions**

MEDIA-to-MEDIA with BEAM LIGHTS

Construction of the piecewise-linear PDF:

- Integration over Ω_{VSL} would be expensive
- Find directions within Ω_{VSL} where the **beam light PF** or the **eye ray PF** have maximum value

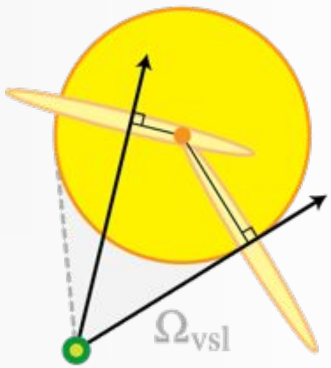




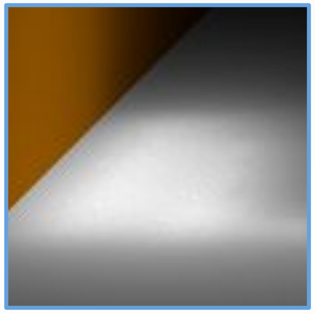
- Evaluate the PF product for both directions and use the bigger value to approximate the integral.

PROGRESSIVE RENDERING

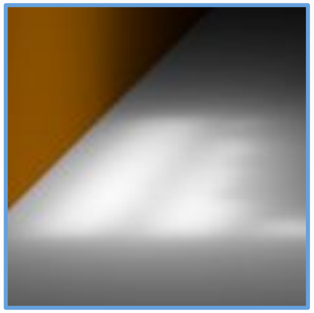
- Spheres and Beams introduce **bias**!
- Fortunately, the integration is formulated using density estimation (in the spirit of BRE [Jarosz et al. 2009])
- We leverage the **radius reduction technique** developed for photon mapping [Knaus and Zwicker 2011]…
- …and **progressively** reduce the radius averaging results over time.



Media-to-Surface



4 seconds



1 minute

1 hour

Reference

RESULTS

BUDDHA

Equal-time comparison

Virtual Ray Lights

Clamped Virtual Ray Lights

Surface-to-Surface

Media-to-Surface

Surface-to-Media

Media-to-Media

Virtual Beam Lights

Surface-to-Surface | Media-to-Surface

Surface-to-Media | Media-to-Media

Virtual Ray Lights

Surface-to-Surface **Media-to-Surface**

Surface-to-Media **Media-to-Media**

Virtual Beam Lights

CARS

Equal-time comparison
Progressive rendering
1280x720

Media-to-Media Transport

VRLs

0.0K VRLs

VBLs

0.0K VBLs

16 seconds

SMOKY ROOM

Equal-time comparison
Progressive rendering
1280x720

Media-to-Media Transport

VRLs | **VBLs**

0.5K VRLs

0.5K VBLs

27 seconds

- **Progressive Virtual Beam Lights**
  - distribute energy along line segments
  - do not rely on density estimation, rather use virtual lights
  - completely avoid singularities by distributing energy over volume
  - progressive and convergent