Parameter Estimation of BSSRDF for Heterogeneous Translucent Materials

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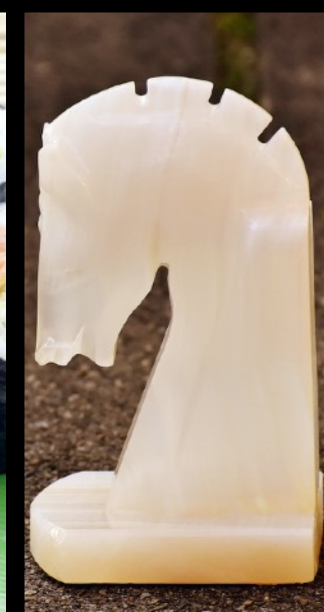
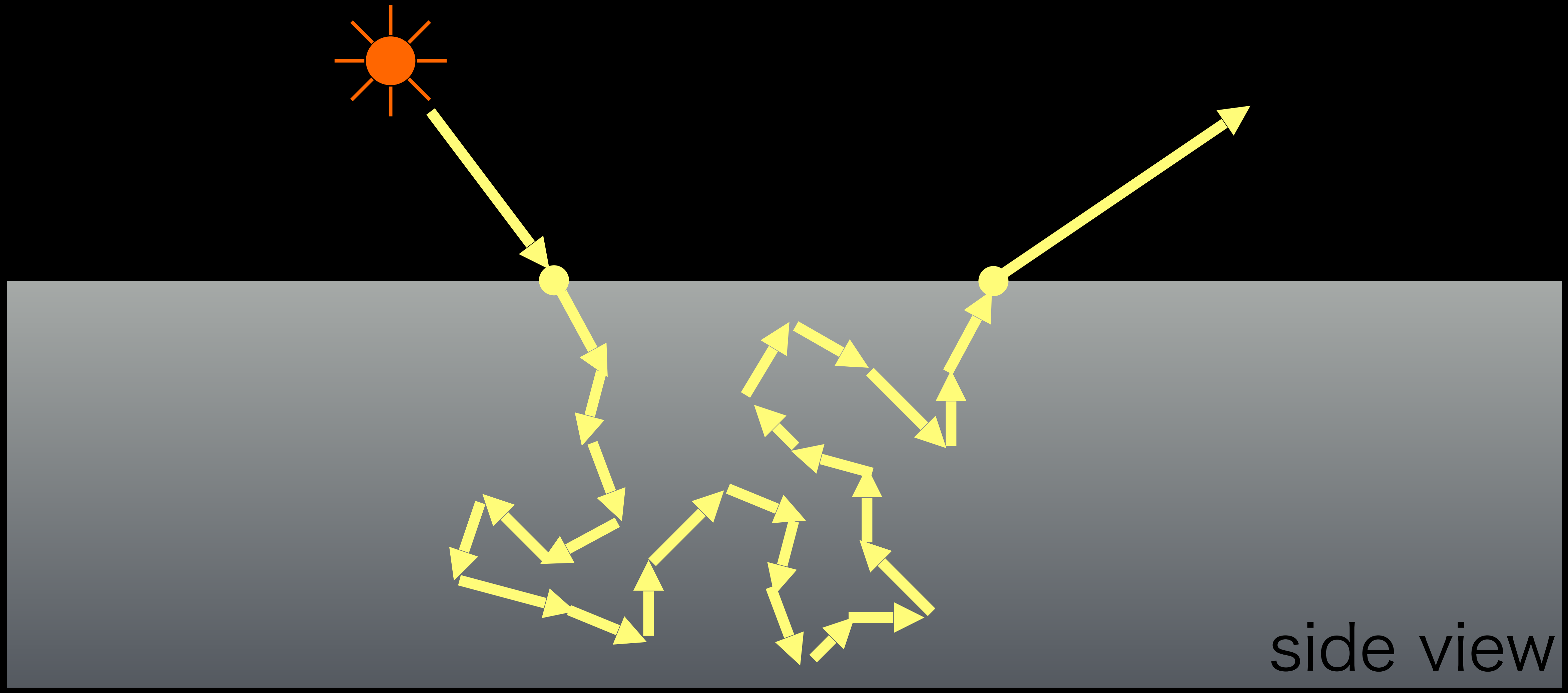
Translucent Materials

≒ Highly scattering objects

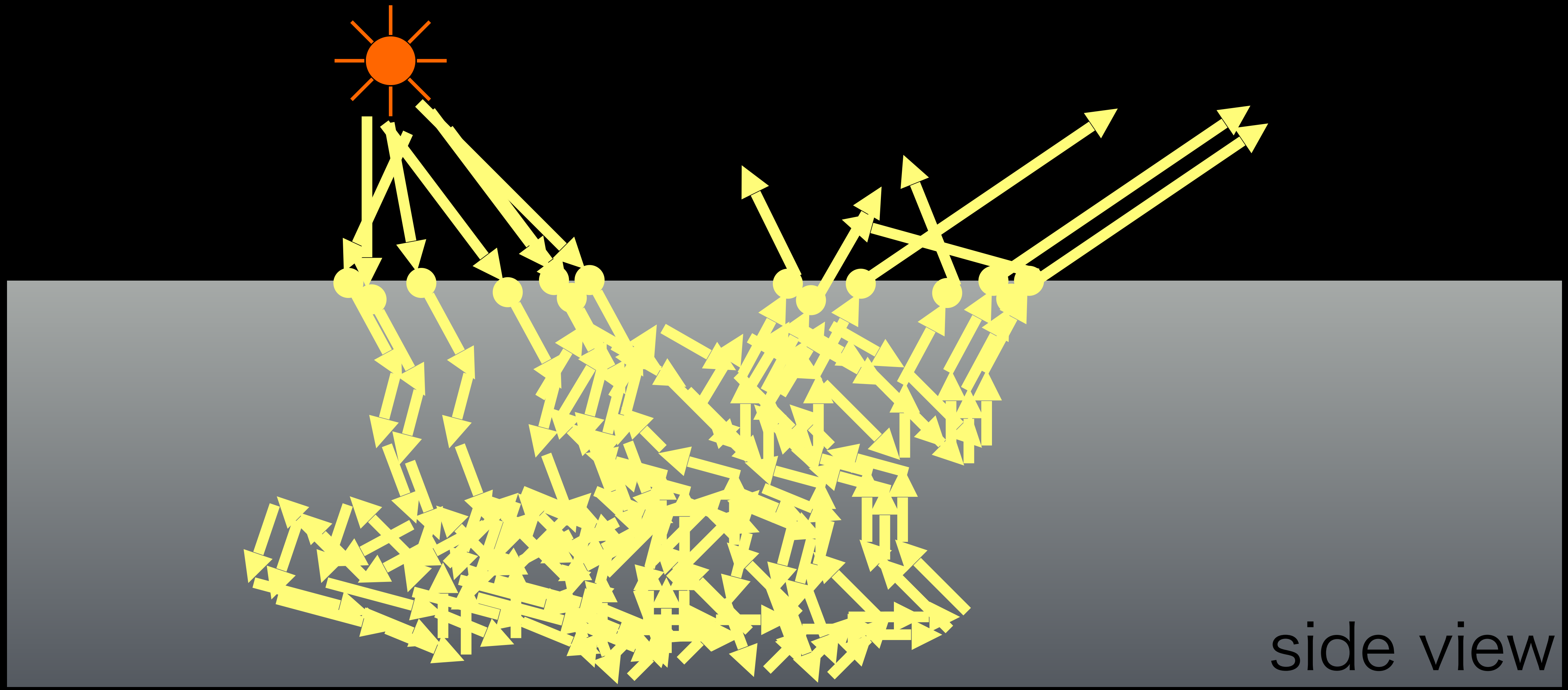
Subsurface Scattering (SSS)

Notably affects to the appearance of translucent materials



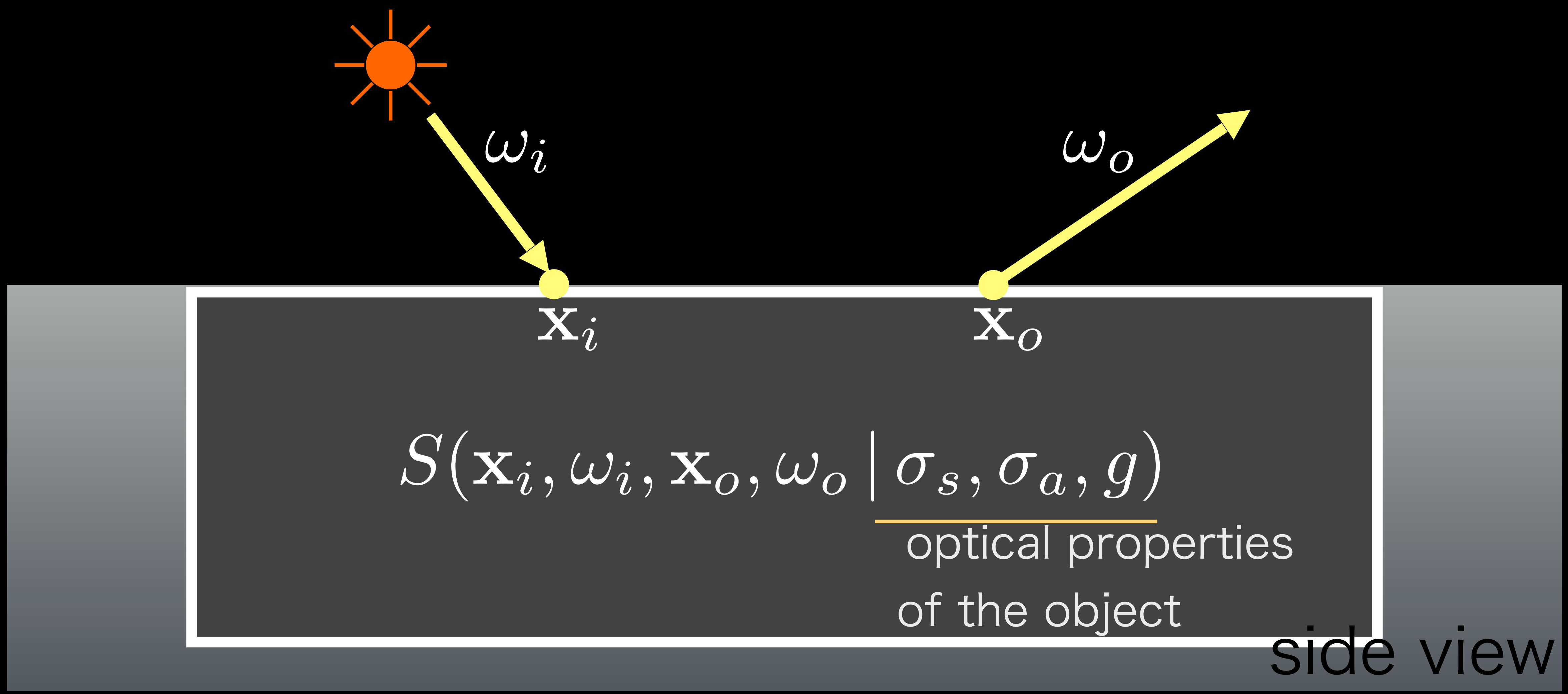
Monte Carlo Path Tracing

Requires long time to exactly simulate



Bidirectional Surface Scattering Reflectance Distribution Function (BSSRDF)

Functional representation of SSS
(Generally, based on diffusion theory)



Existing BSSRDFs

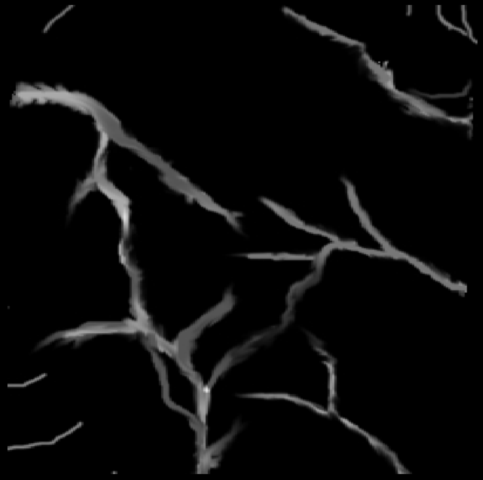
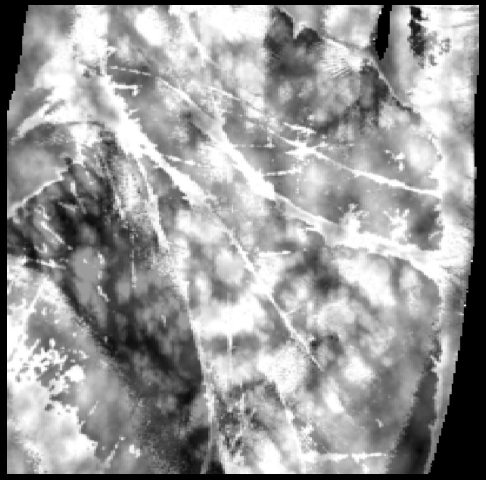
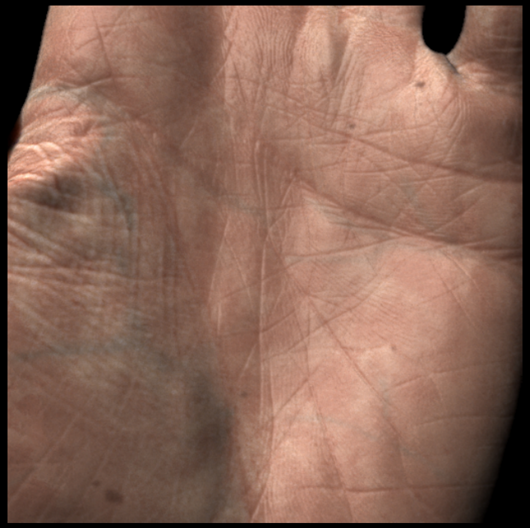
- Dipole [Jensen et al. 2001]
- Multipole [Donner & Jensen 2005]
- Photon diffusion [Donner & Jensen 2007]
- Empirical BSSRDF [Donner et al. 2009]
- Quantized diffusion [d'Eon & Irving 2011]
- Photon beam diffusion [Habel et al. 2013]
- Dual-beam BSSRDF [d'Eon 2014]
- Directional dipole [Frisvad et al. 2014]
- Normalized diffusion [Burley 2015; Christensen 2015]

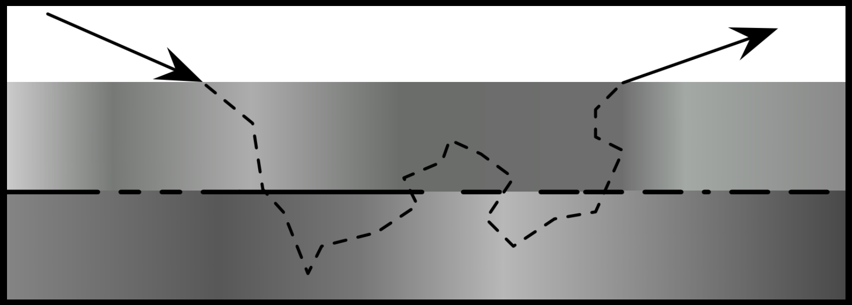
Focus on homogeneous (constant) media

	Heterogeneous	Fast
Monte Carlo	✔	
BSSRDF		✔
Our Goal	✔	✔

Related Work: Layered heterogeneous skin [Donner et al. 2008]

Heterogeneous transmittance/absorption among multiple layers
(Not for diffuse reflectance of single layer)



Related Work: Real-time Heterogeneous SSS [Chen et al. 2012]

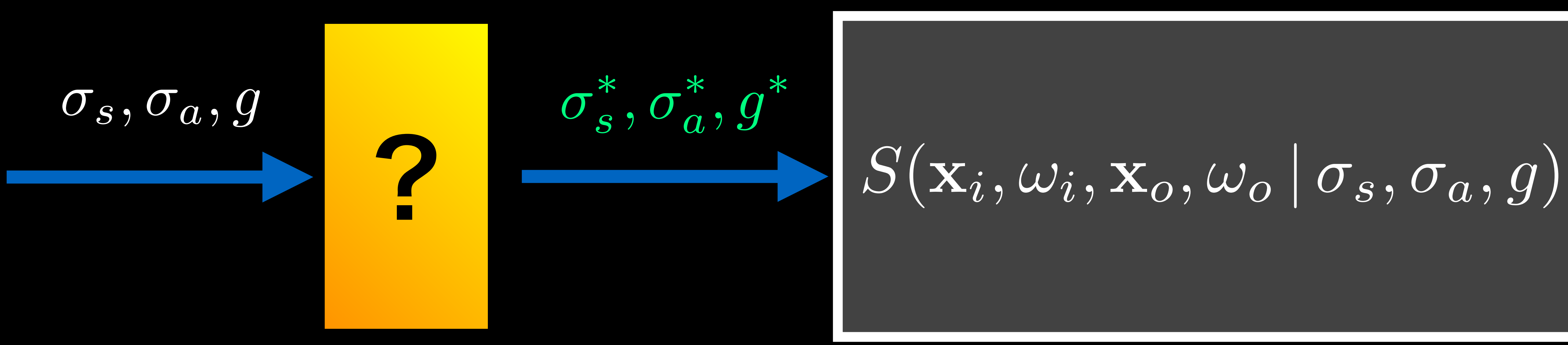
Mixing precomputed reflectance

$$R_d(\mathbf{x}_i, \mathbf{x}_o) = \sqrt{P_{\mathbf{x}_i}(r) P_{\mathbf{x}_o}(r)}$$

(precomputed) reflectance at incident and exitant points

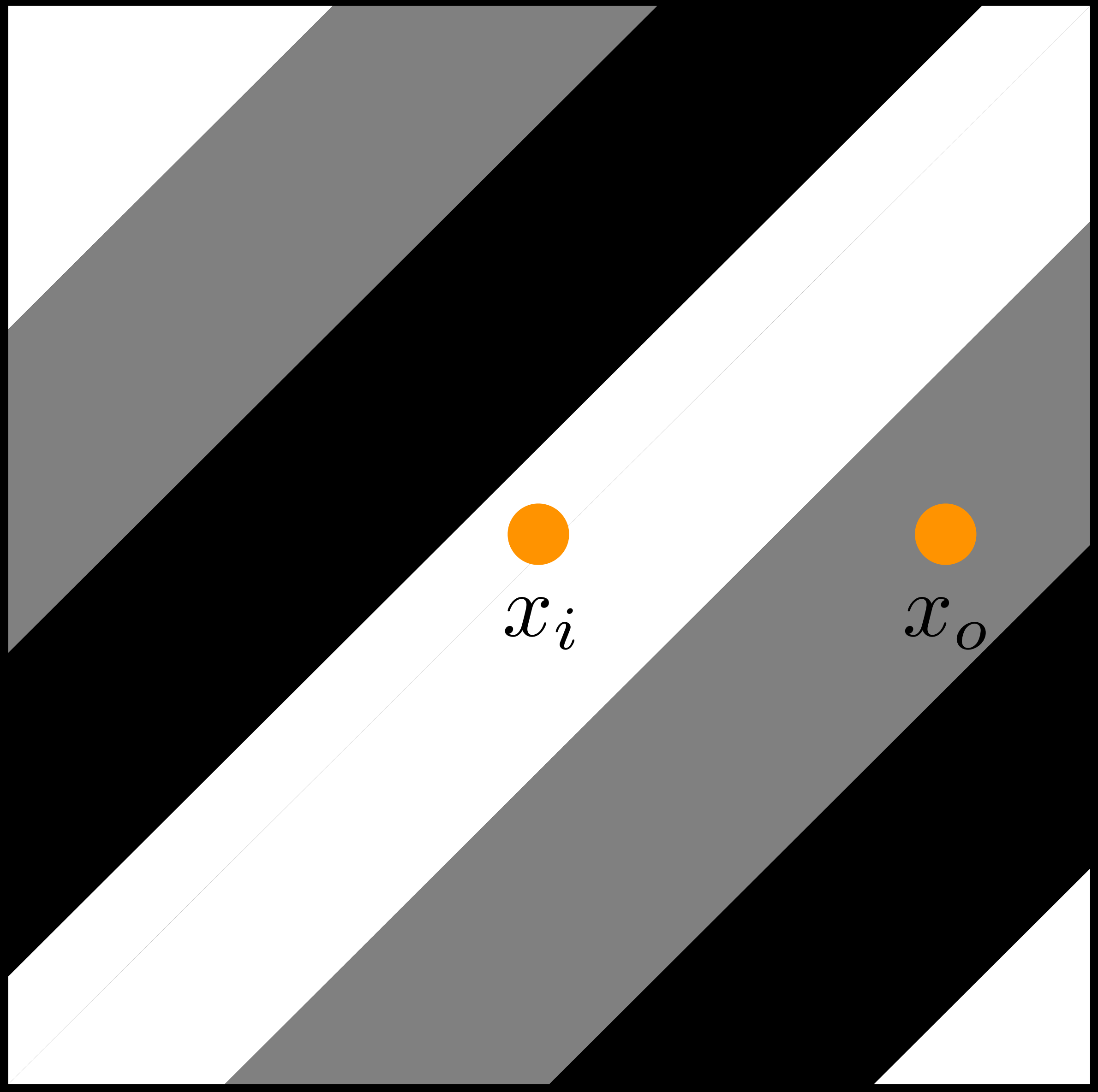
Another Approach

Compute scattering and absorption coefficients before evaluating BSSRDF models



Using parameters at incident and/or exitant points

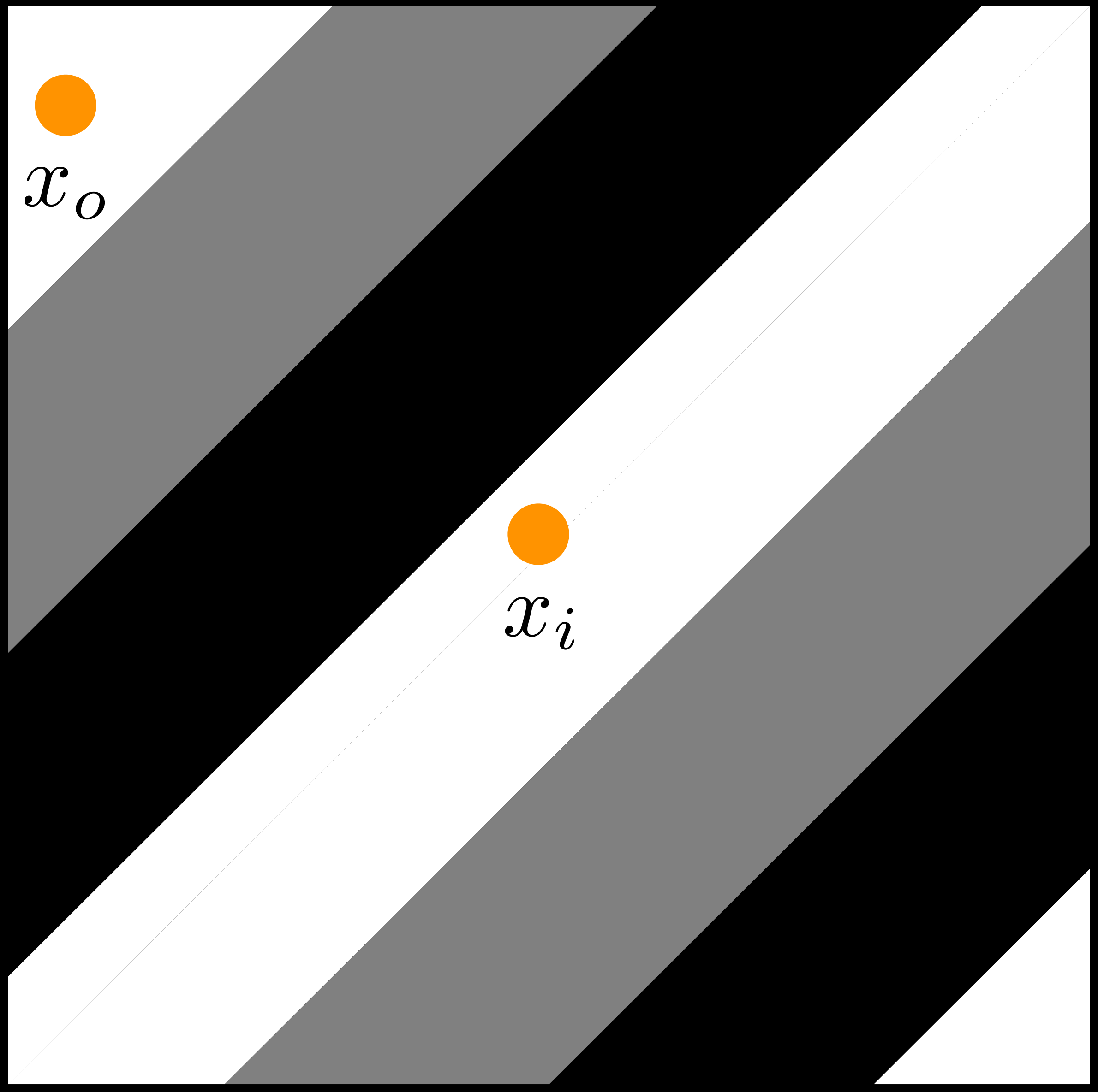
[Jensen et al. 2001; Jensen and Buhler 2002]



top view

Using parameters at incident and/or exitant points

[Jensen et al. 2001; Jensen and Buhler 2002]

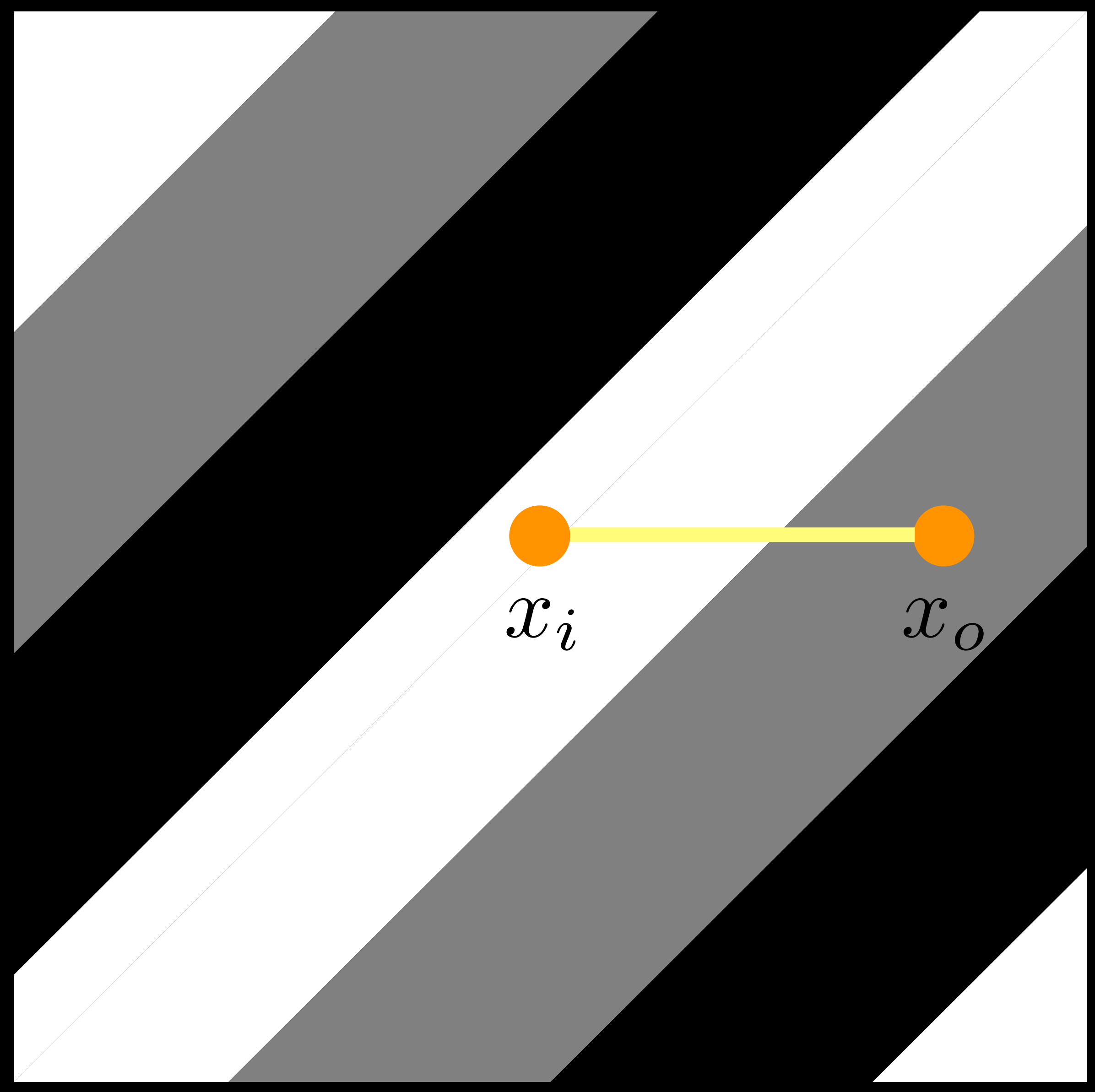


Handled as homogeneous

top view

Averages of parameters on a line

[d'Eon & Irving 2011]



top view

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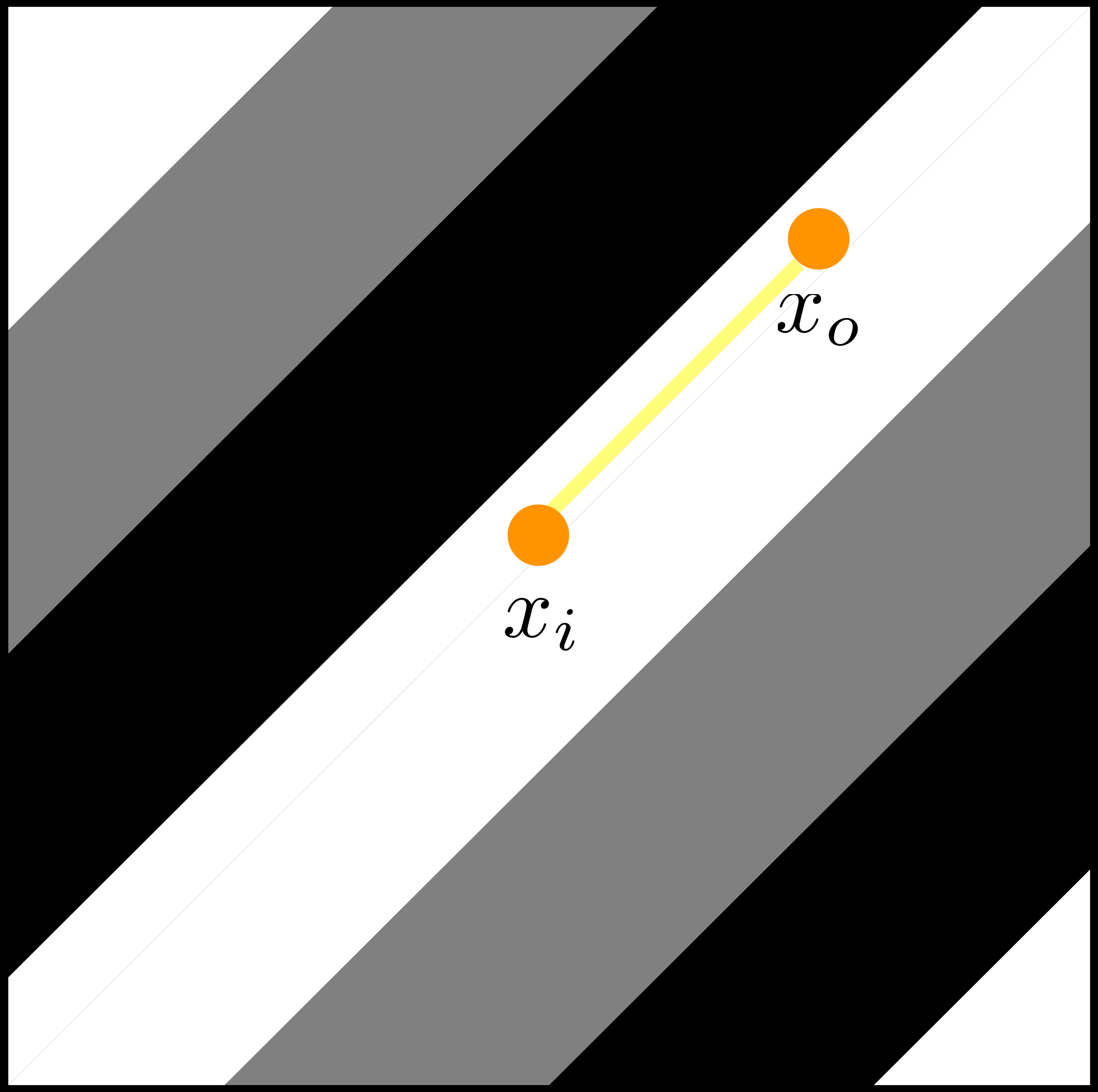
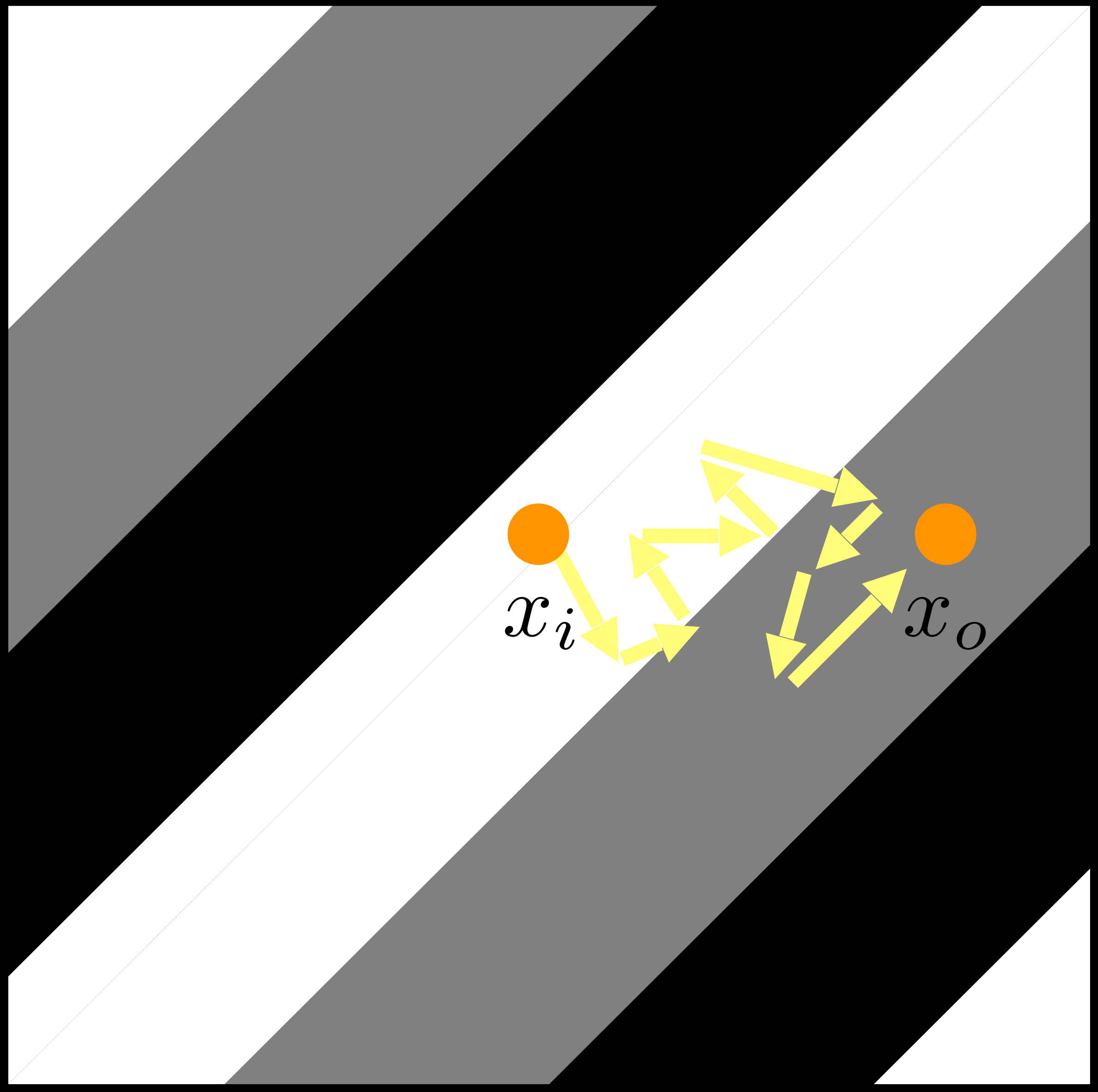


Handled as homogeneous

top view

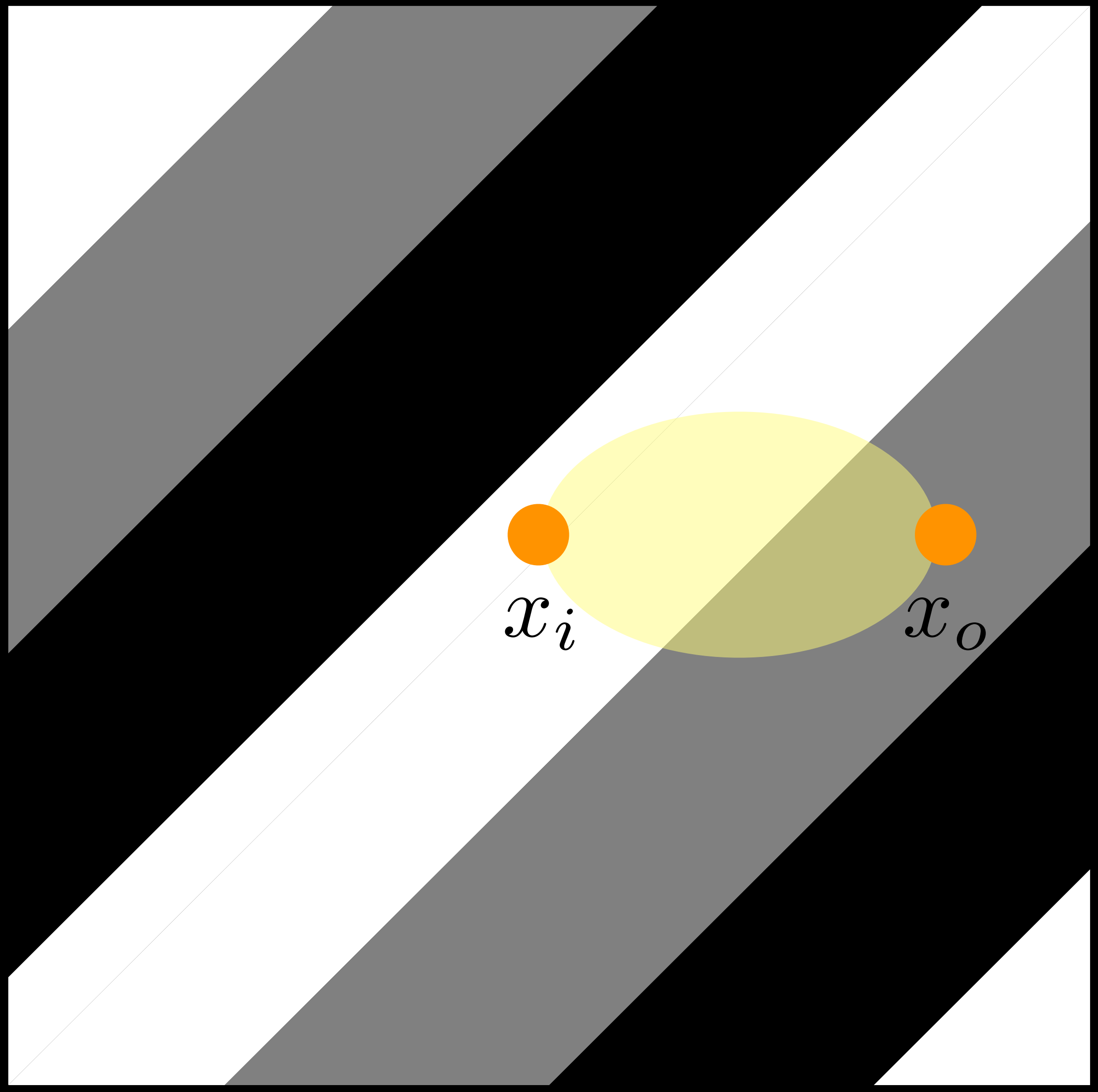
Our Solution



*Assumption

top view

Our Solution



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top view

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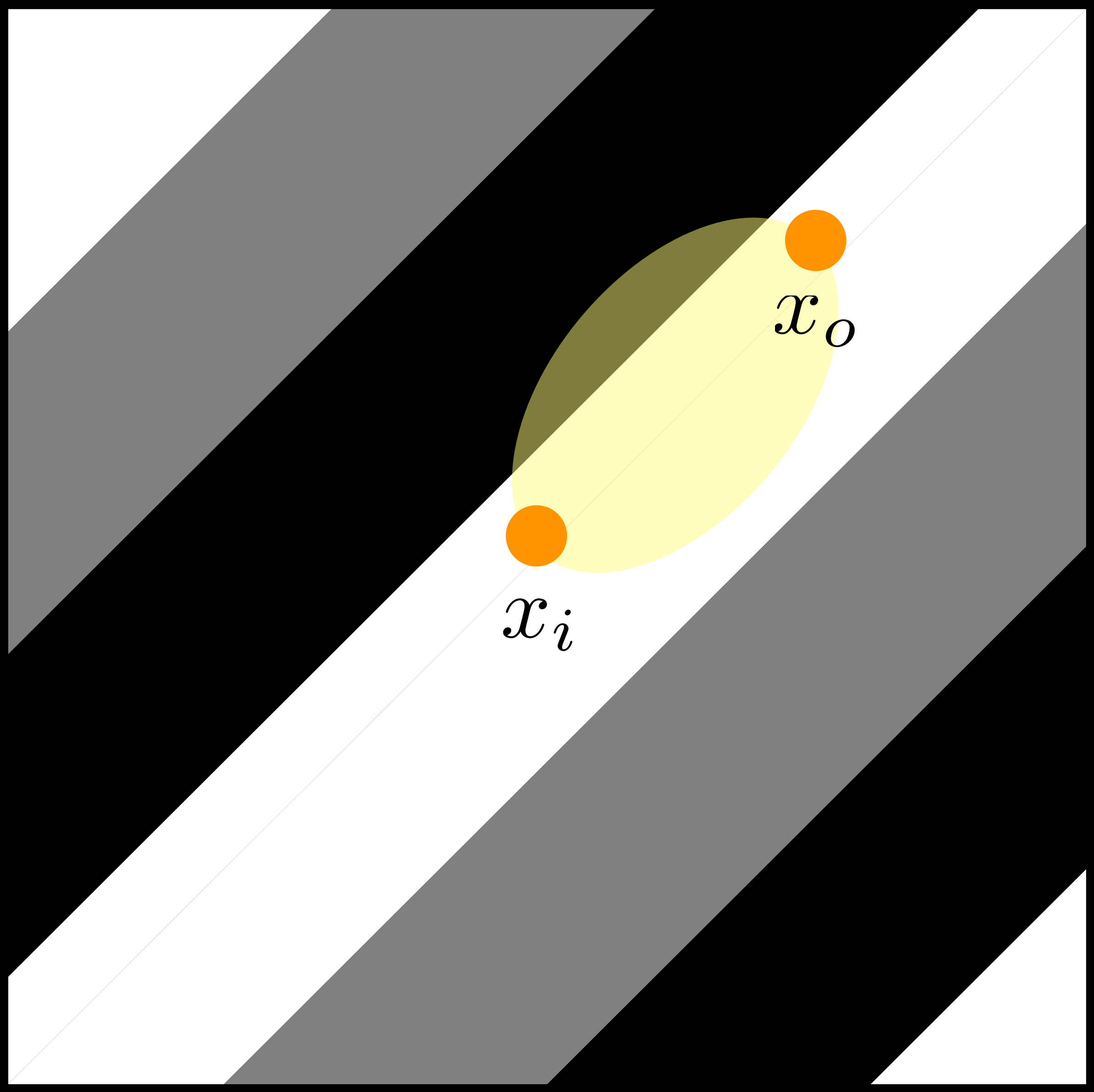
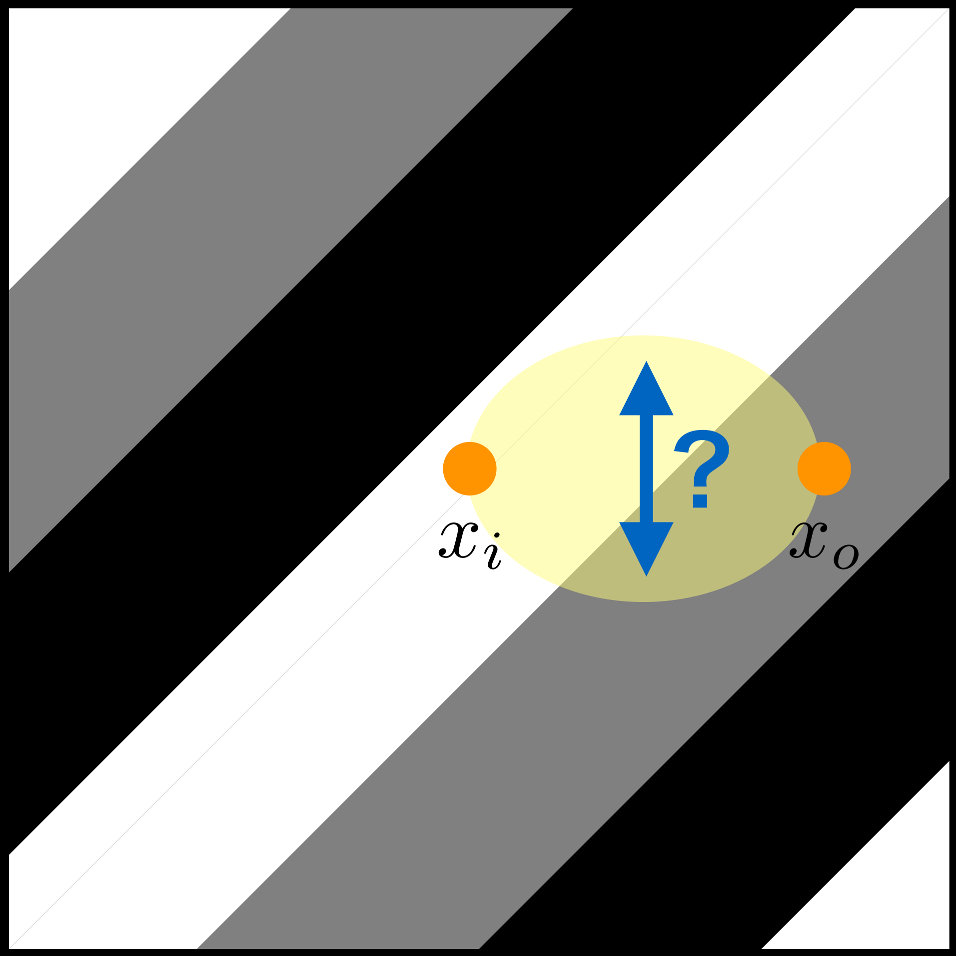


*Assumption

top view

Challenge

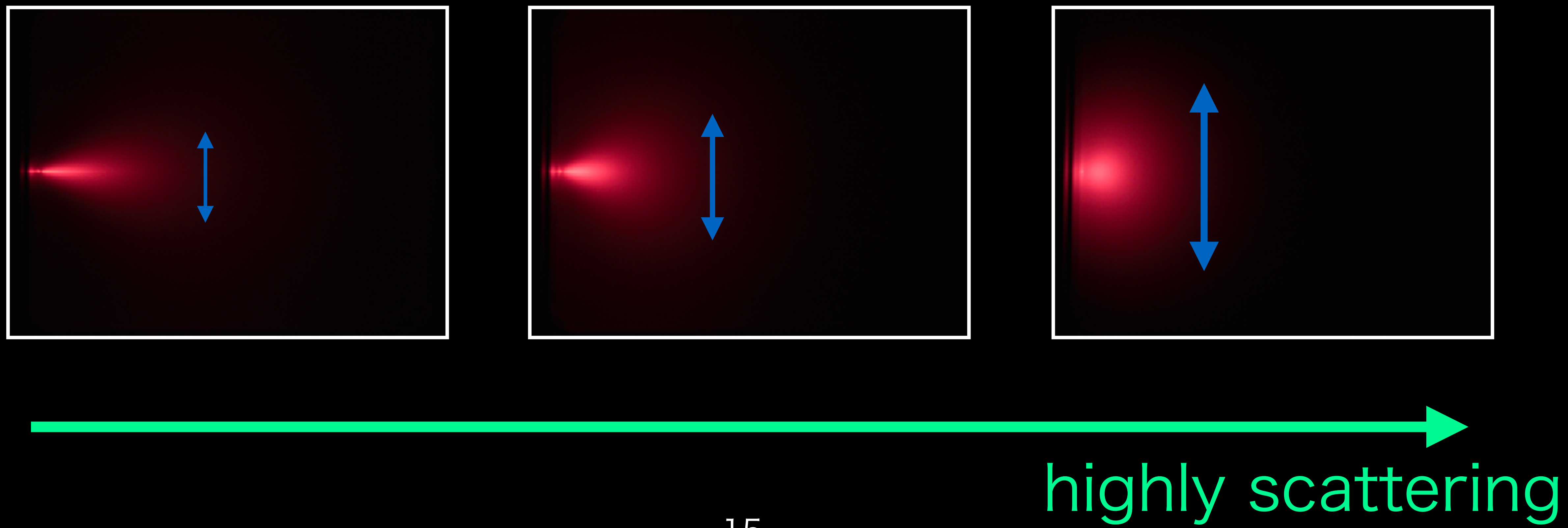
How much the light will be spread?



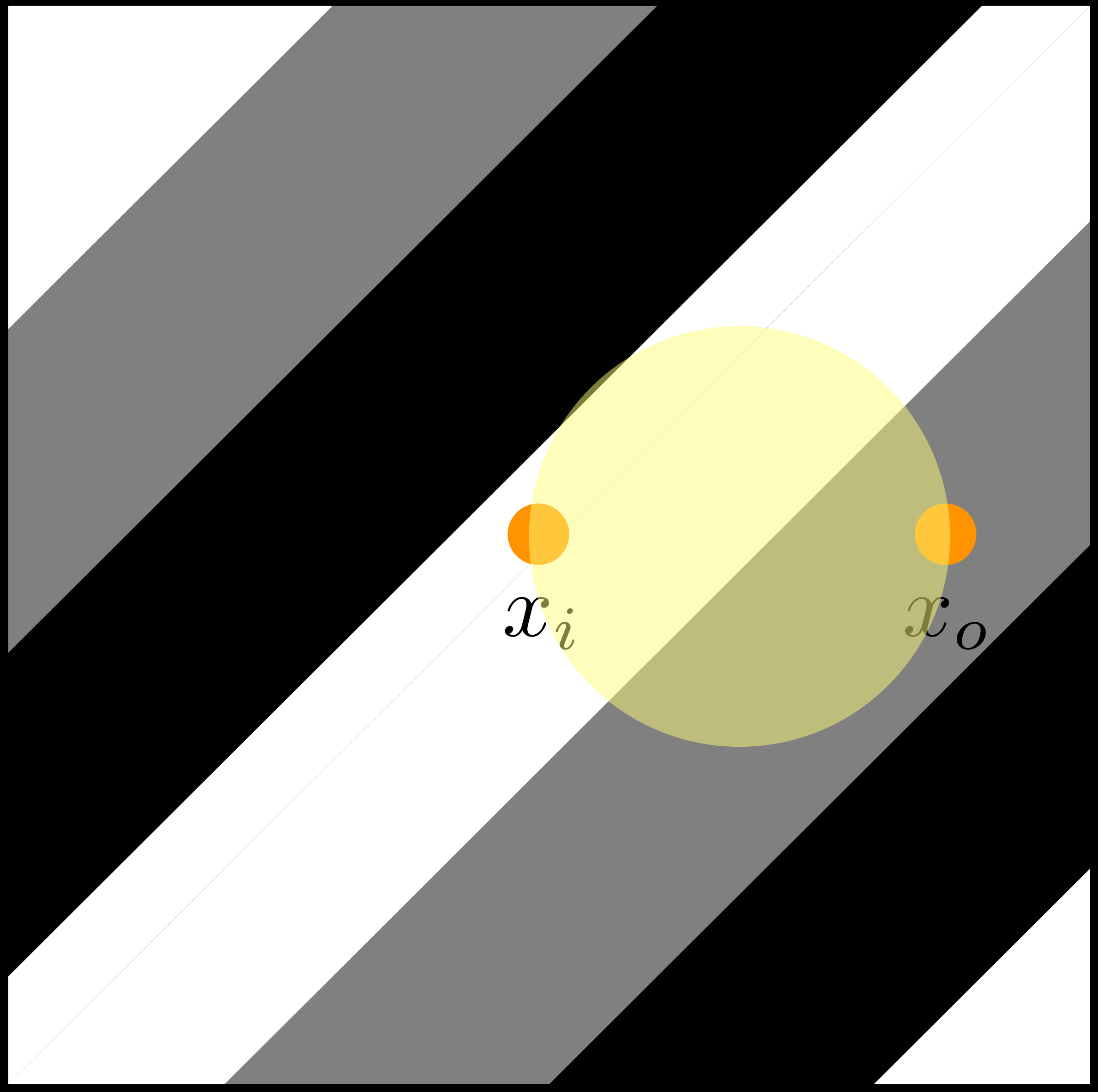
top view

Blur width of light [Premože et al. 2004]

The spatial spreading of the most probable light path as predicted by the path integral



Algorithm



top view

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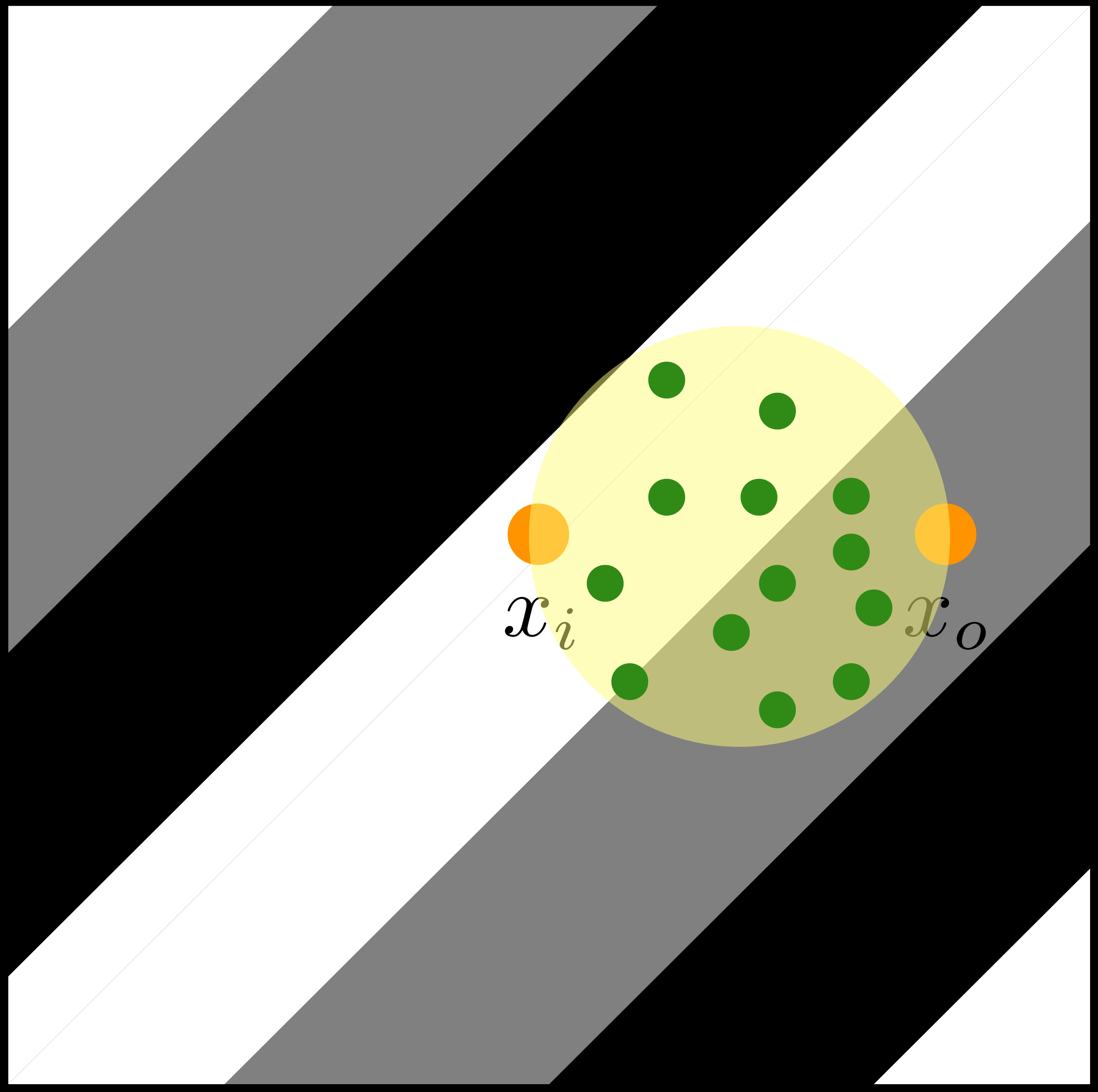

top view

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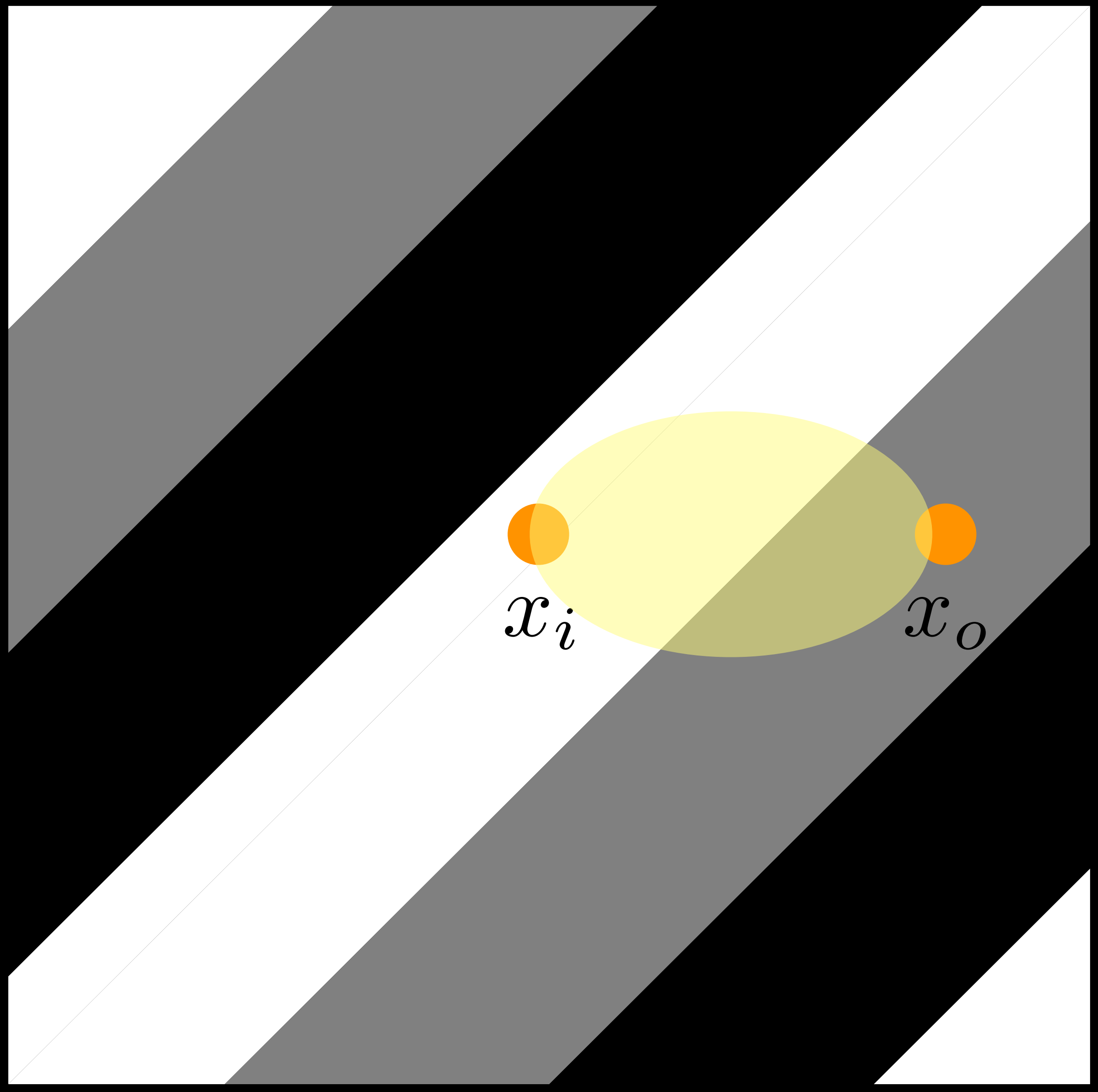

top view

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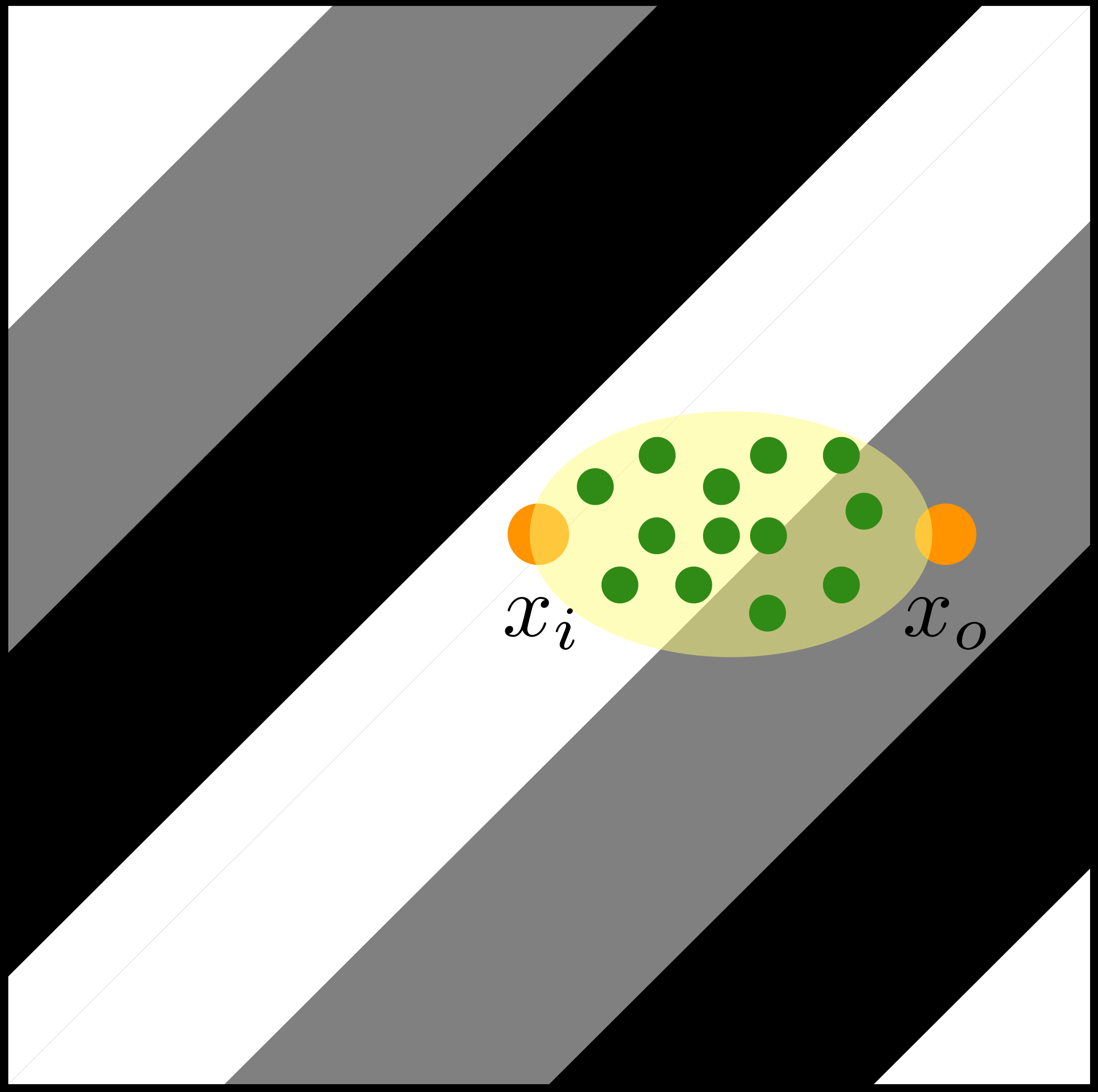
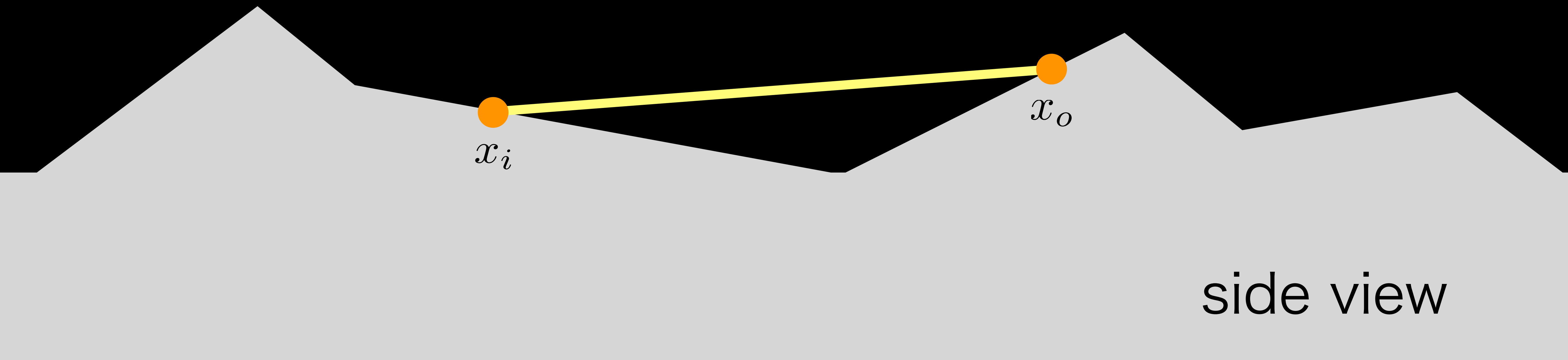


top view

Sampling on complex geometries



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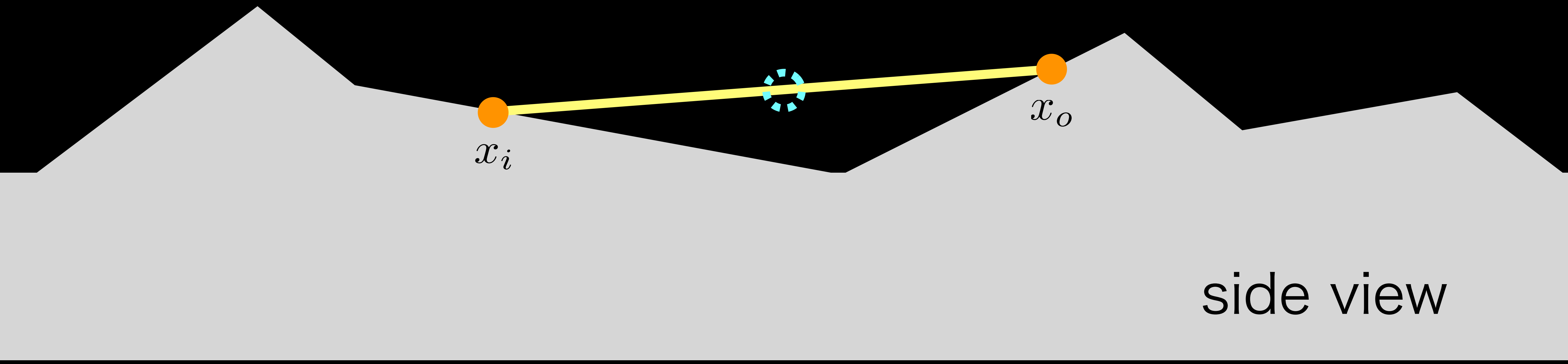
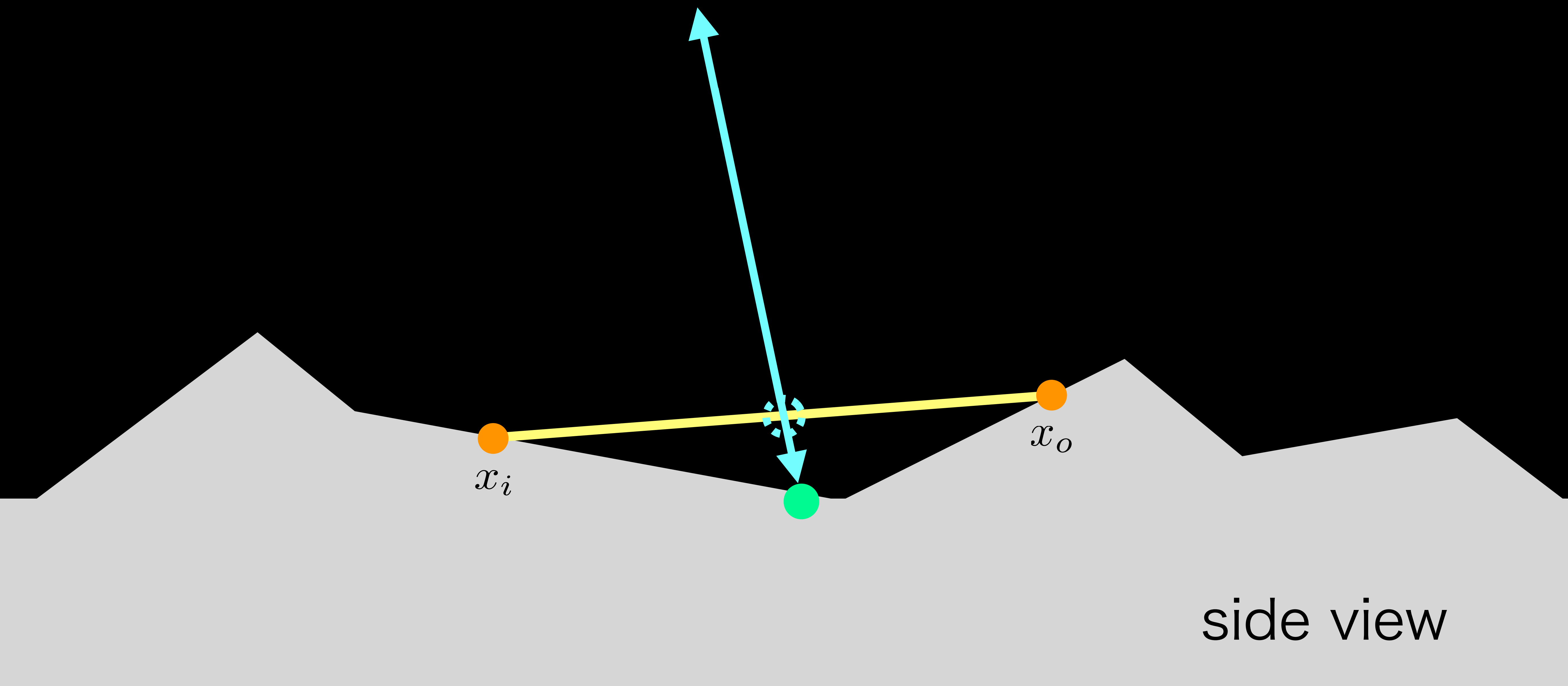


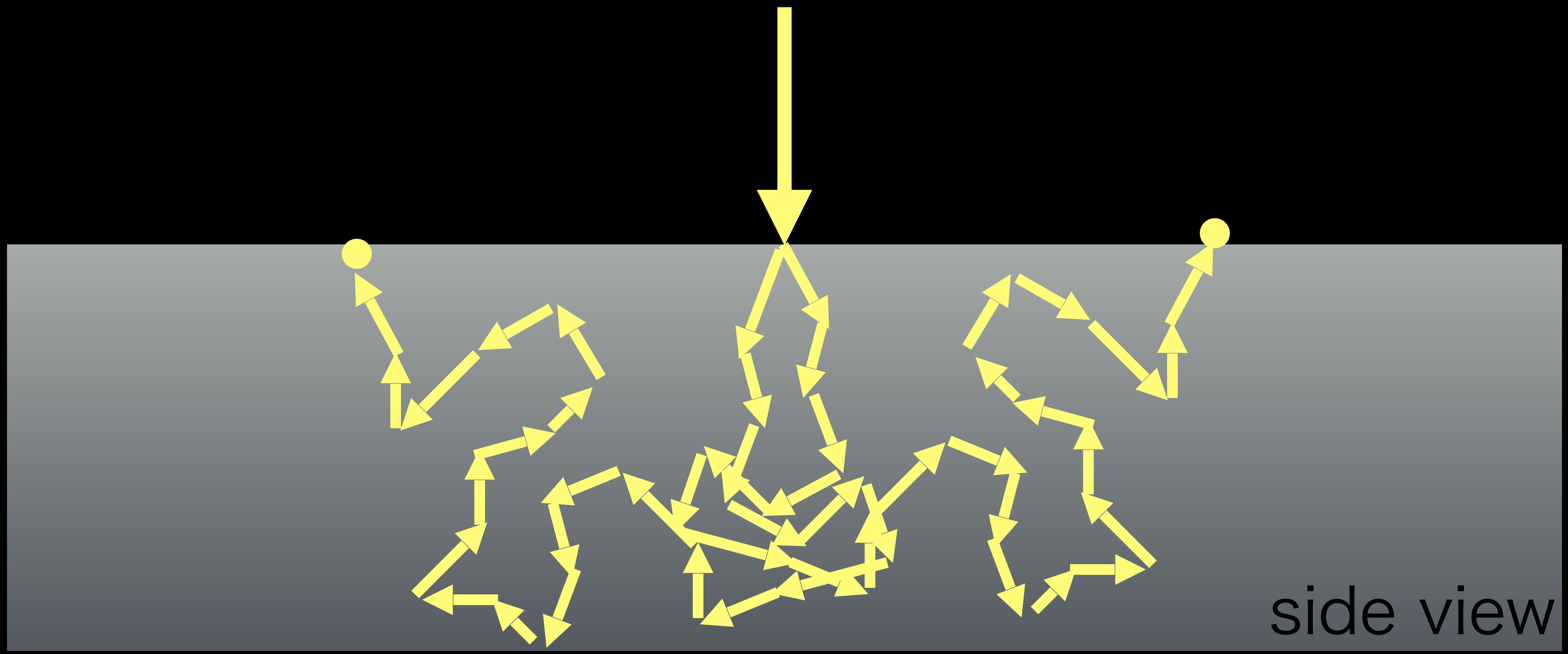
Sampling on complex geometries



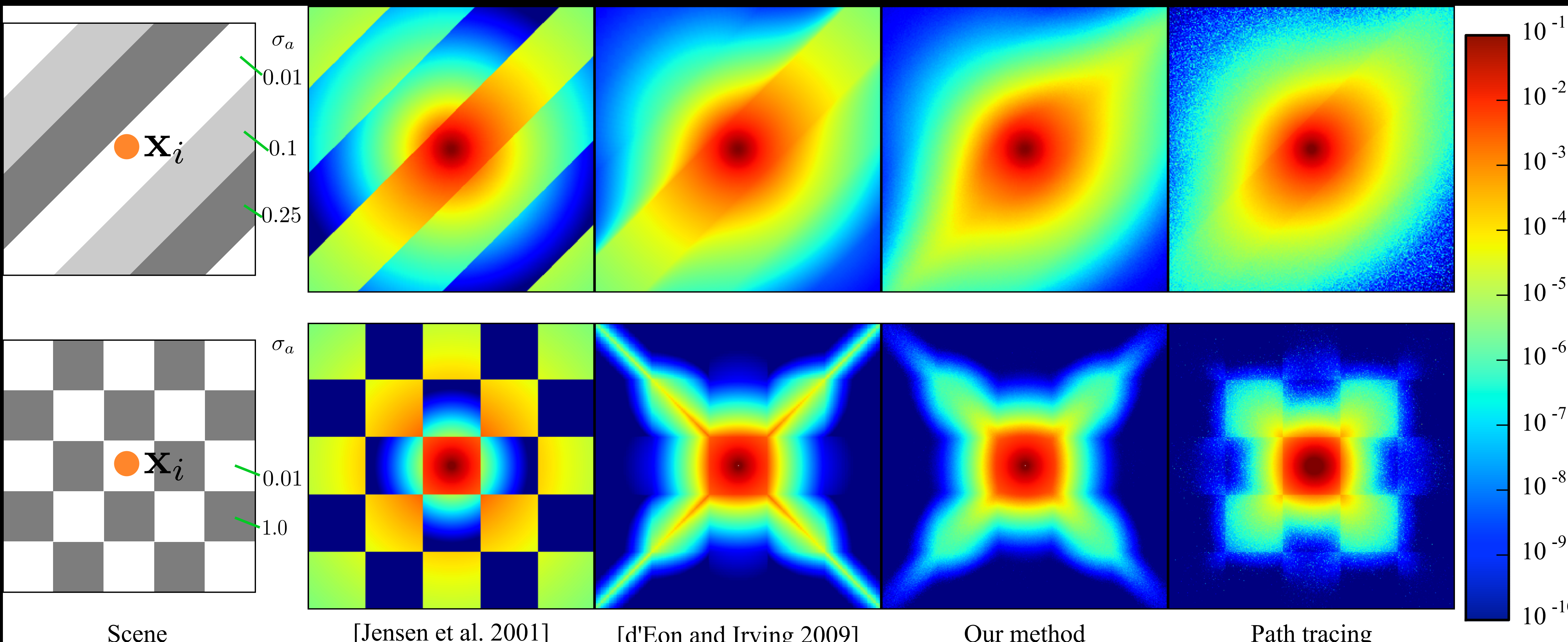
Experimentation

Plot reflectance for normally incident ray

*ideal scenario for existing BSSRDF models

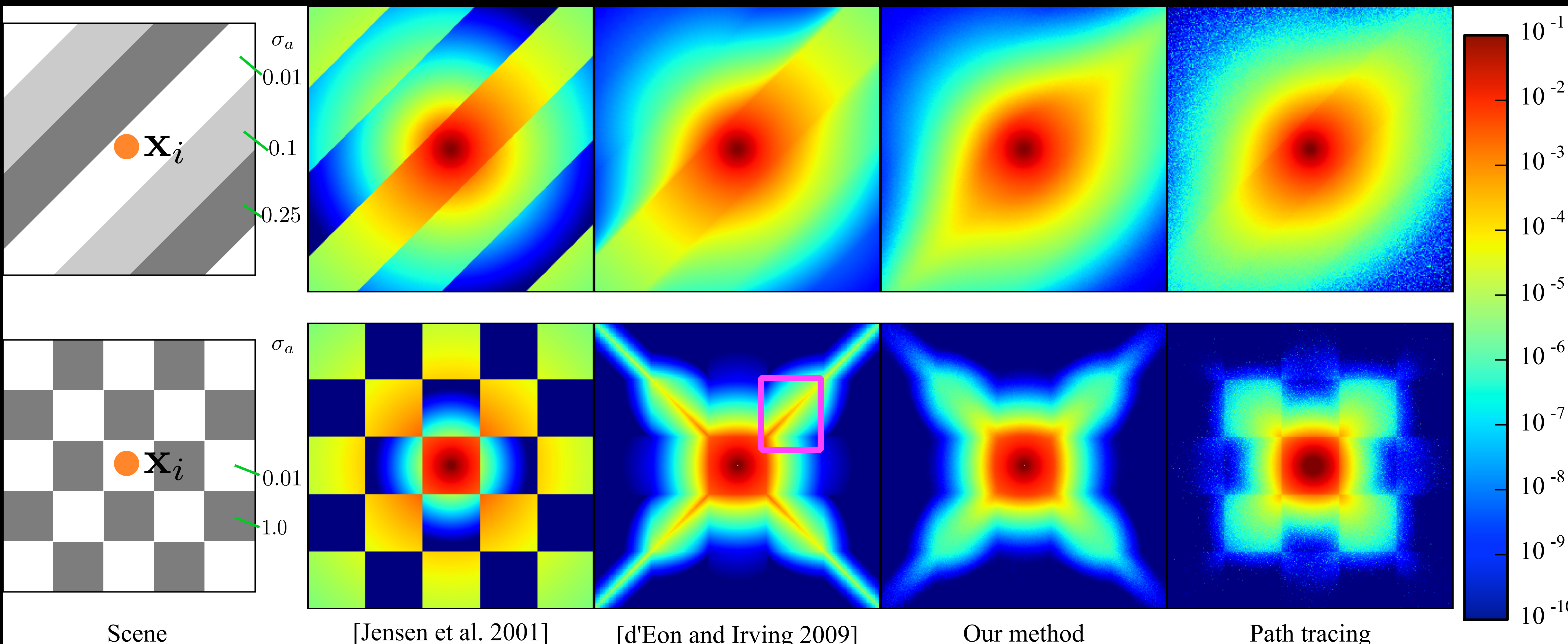


Results



plot range: [15×15] top view

Results



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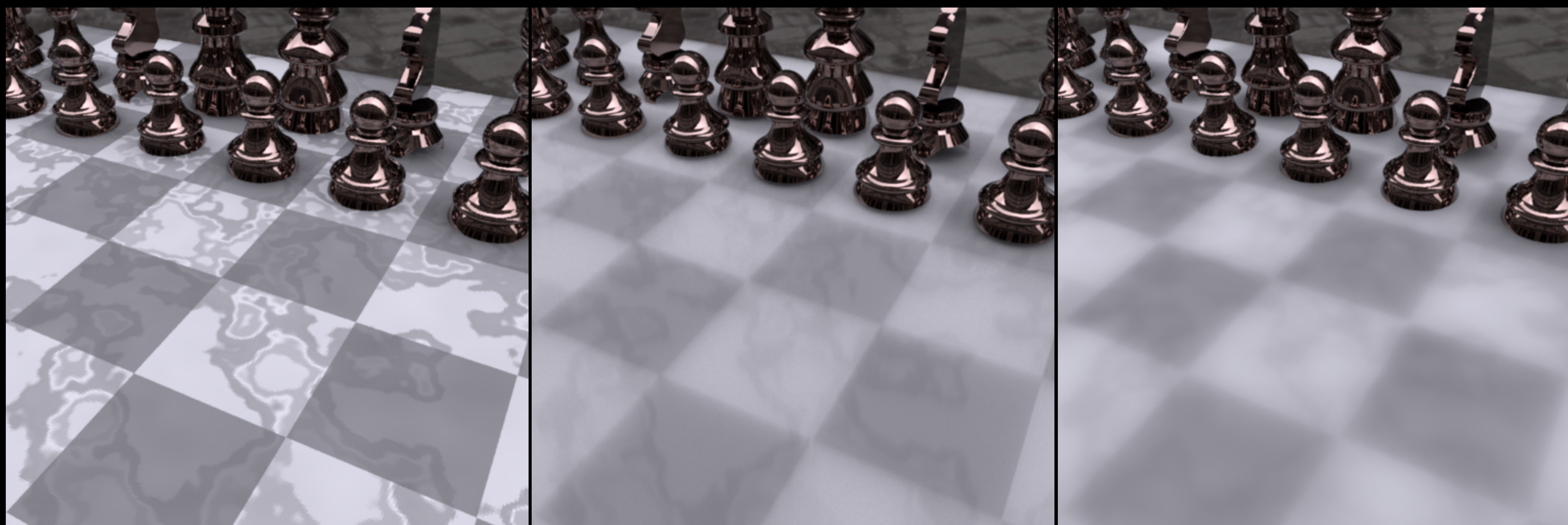
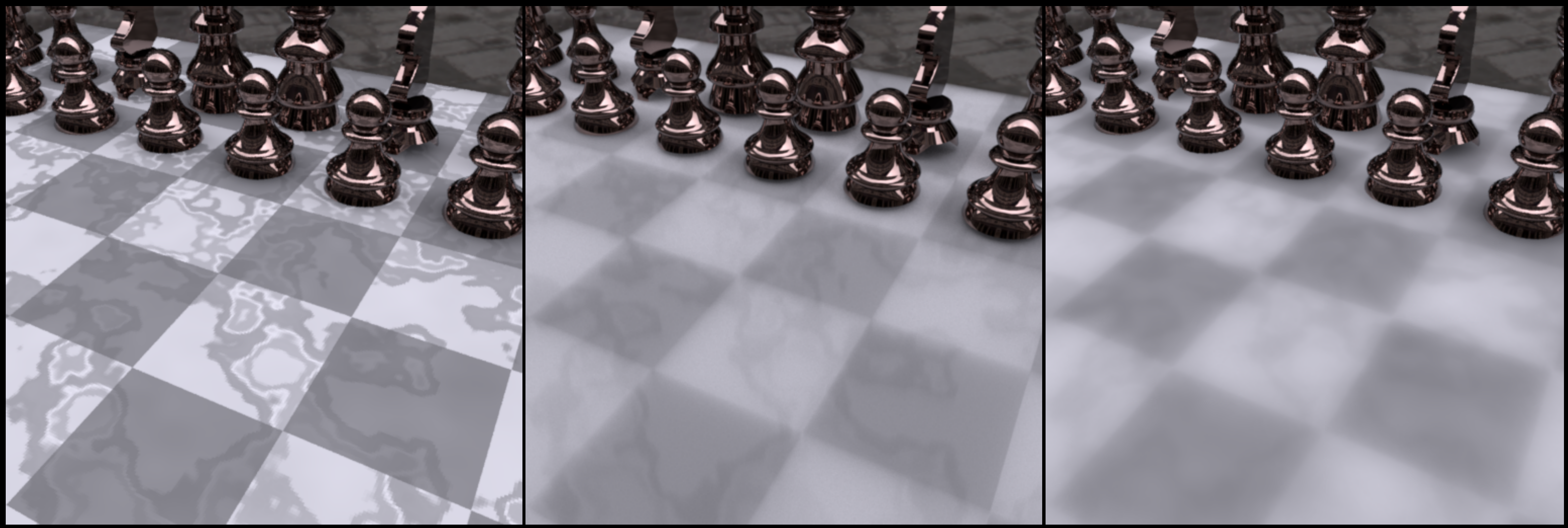


[Jensen et al. 2001]
41.93 sec

Path tracing
34.95 min.

Our technique
4.26 min.

Results



[Jensen et al. 2001]
41.93 sec

Path tracing
34.95 min.

Our technique
4.26 min.

Note: computation time of path tracing can be significantly increased if the object is refractive

Future Work

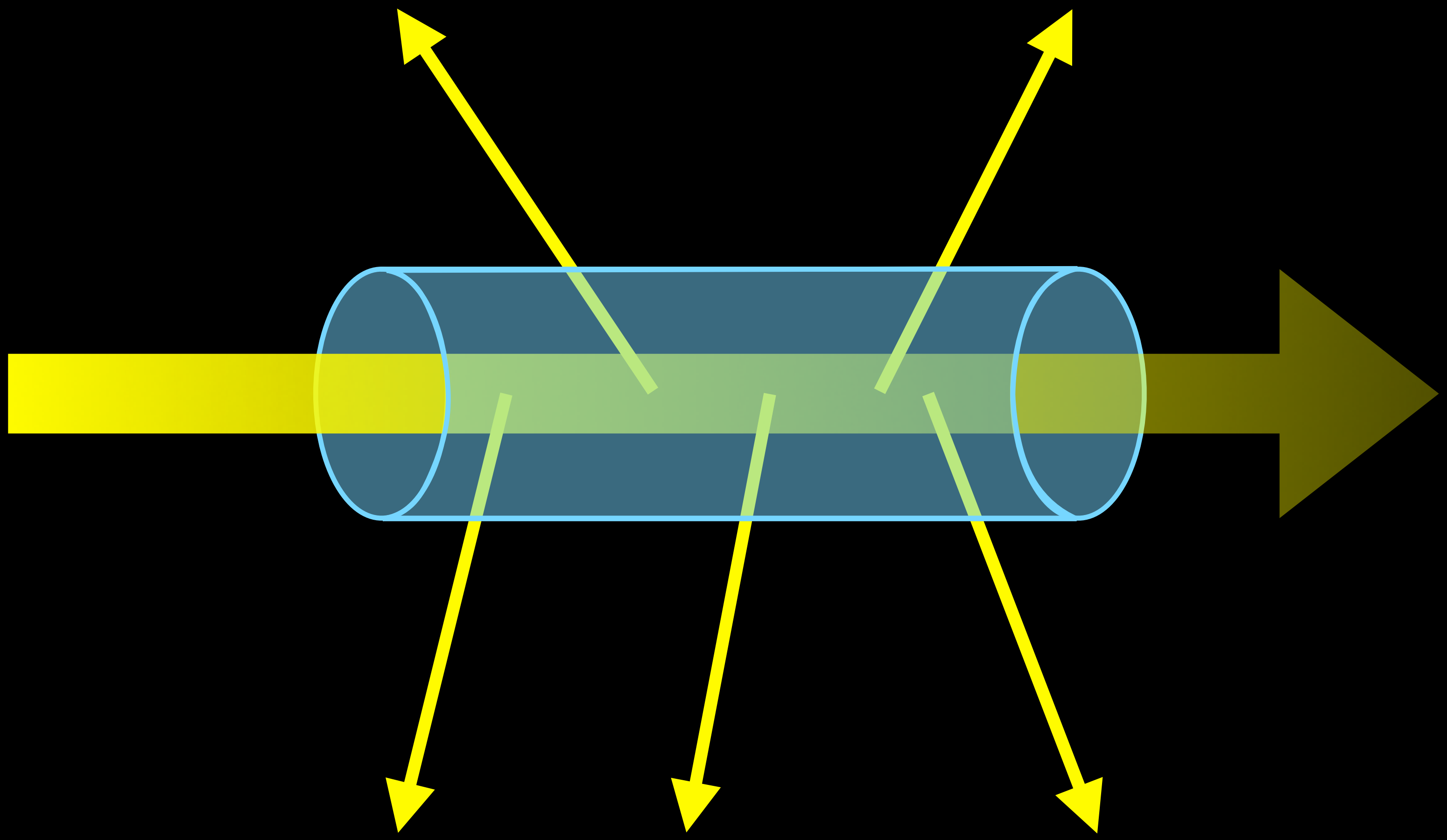
- Elimination of the bottle-neck due to Monte Carlo sampling
- Mathematical or physical analysis
- Address optical properties varying along normal vector
  - Combine with layered method [Donner et al. 2008]?

Conclusion

- Estimation of BSSRDF parameter for heterogeneous materials
  - Easy to integrate to existing rendering system
  - First step toward **practical** methods for accurately rendering heterogeneous materials

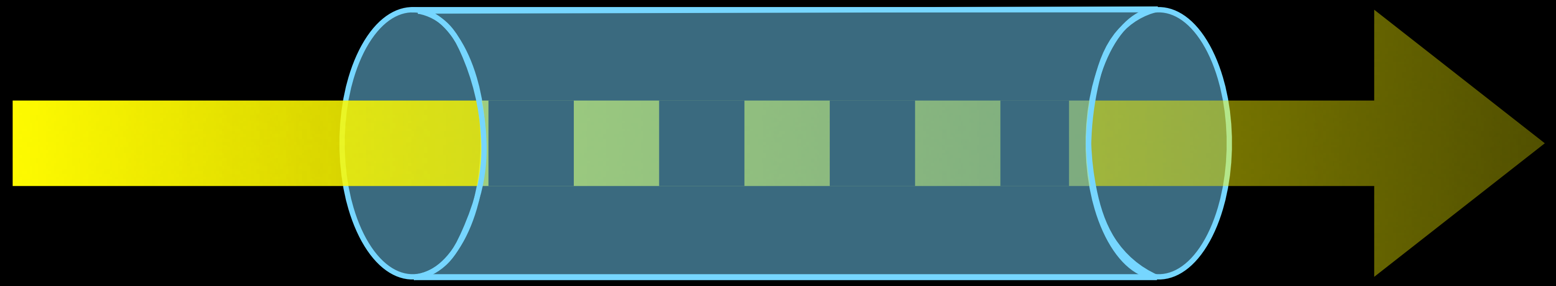
Optical Properties: σ_s

Scattering coefficient



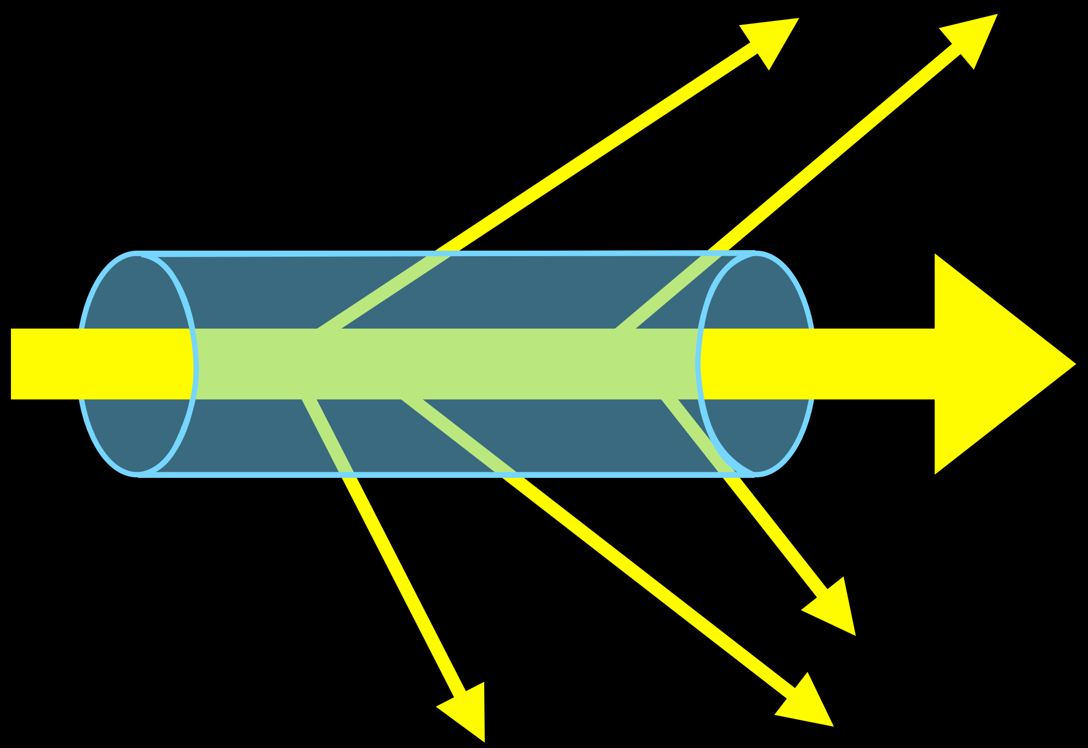
Optical Properties: σ_a

Absorption coefficient



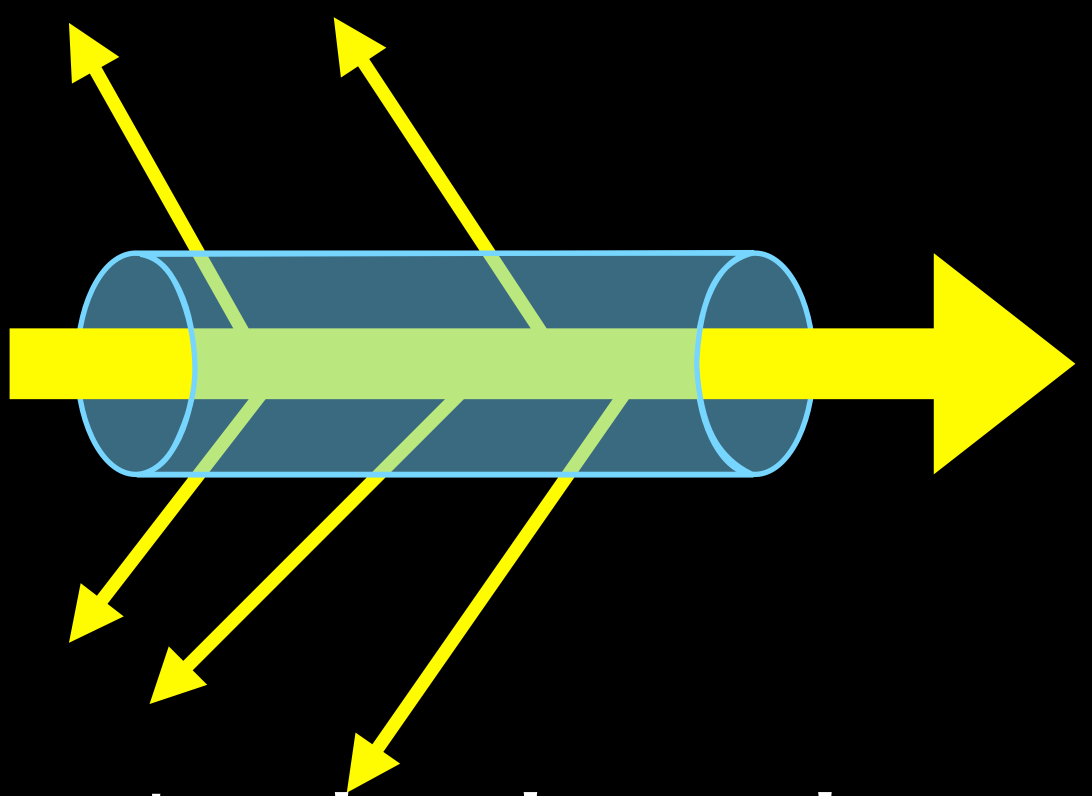
Optical Properties: g

Mean cosine of scattering angle



tend to **forward** scatter

if $g > 0$

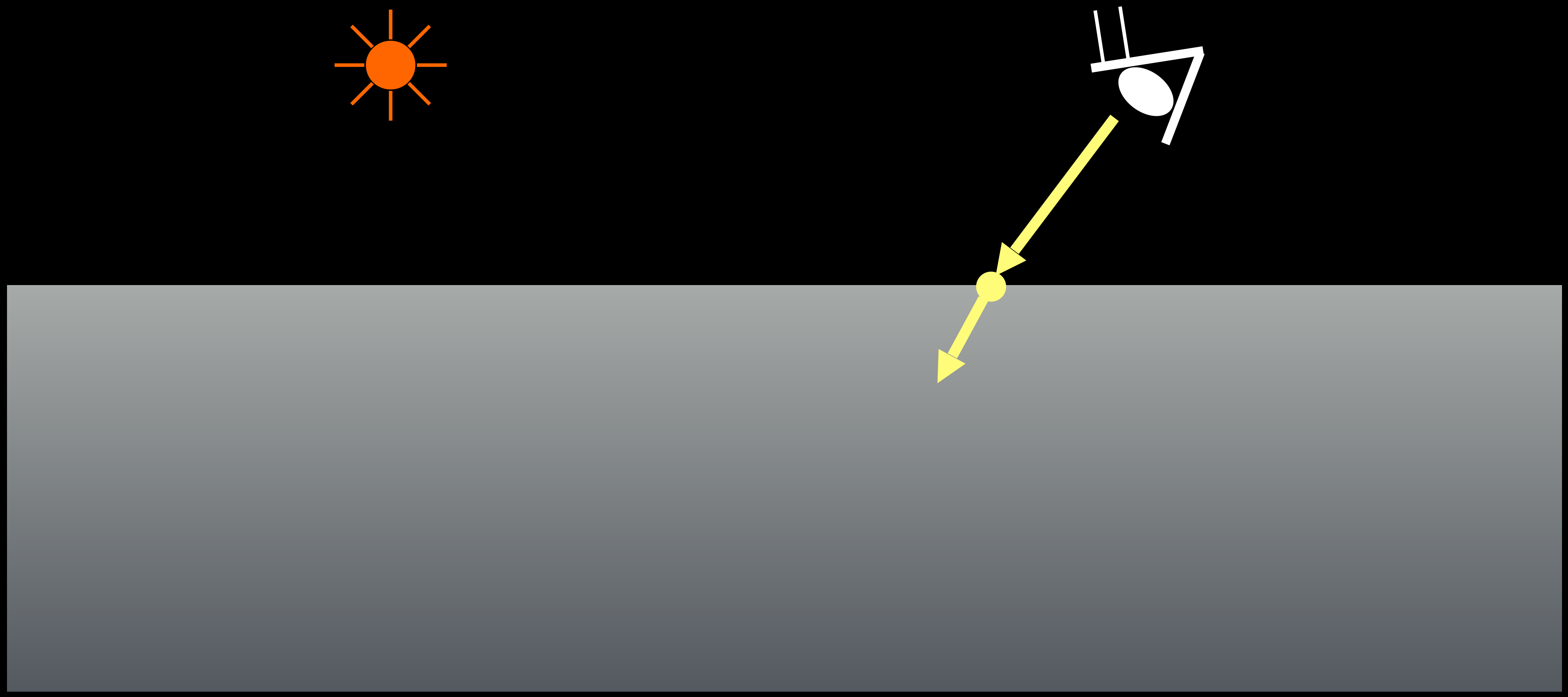


tend to **backward** scatter

if $g < 0$

Non-refractive Object

Trace rays from eye and
explicitly sample direct light



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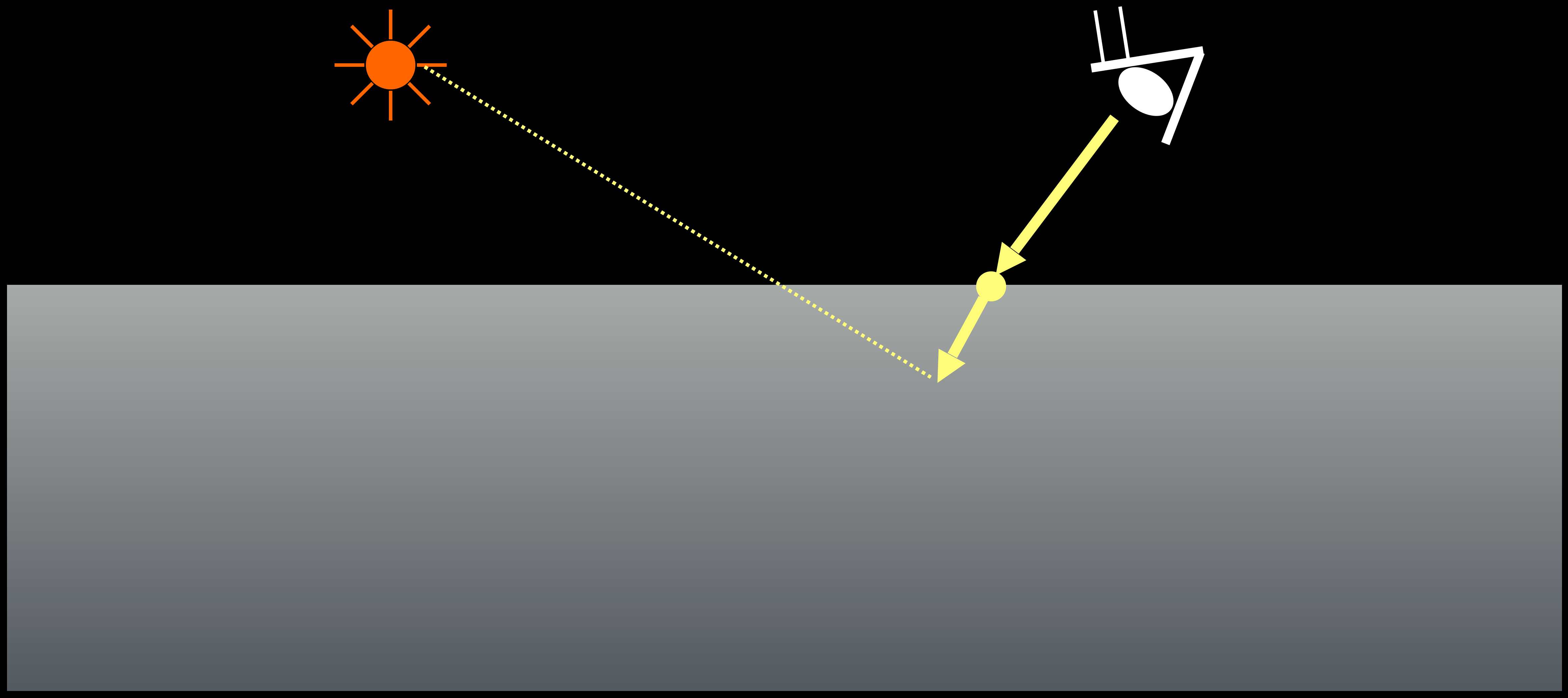

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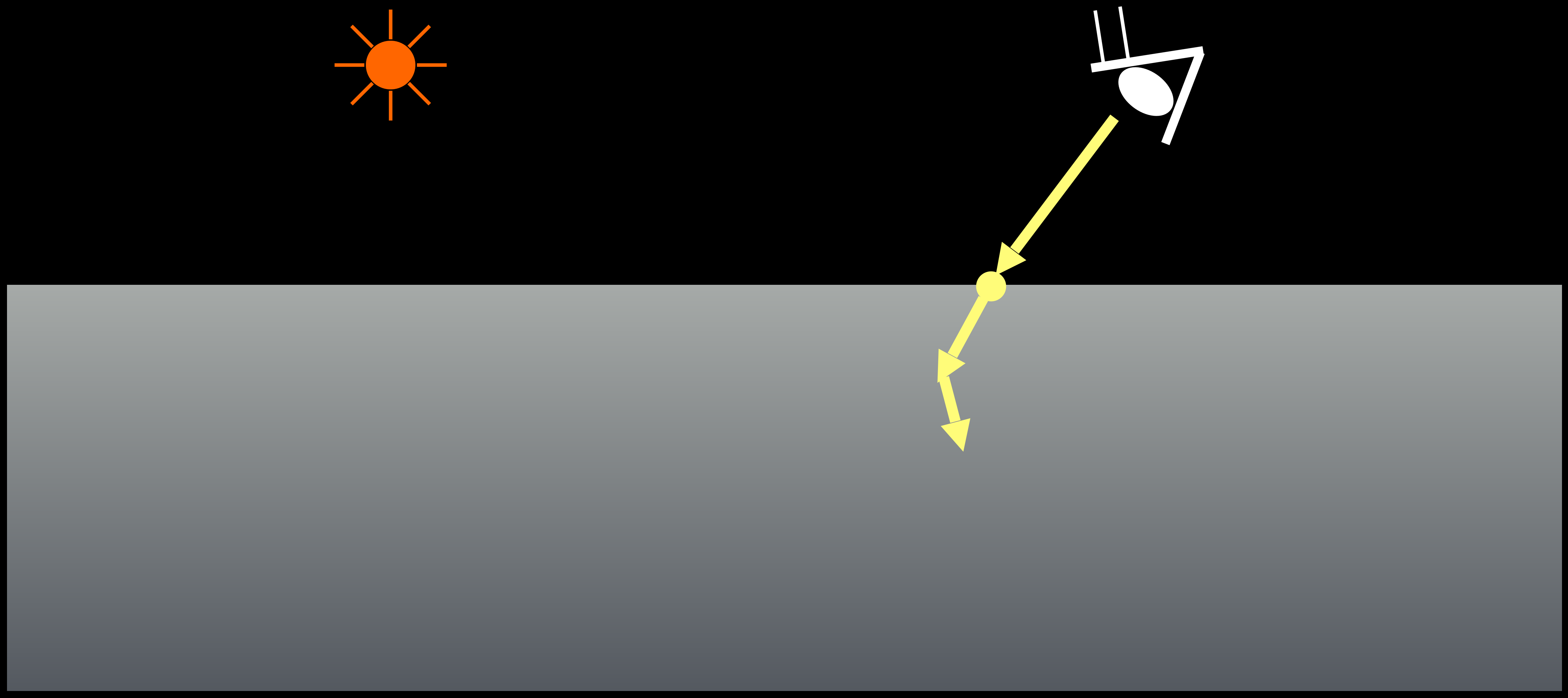

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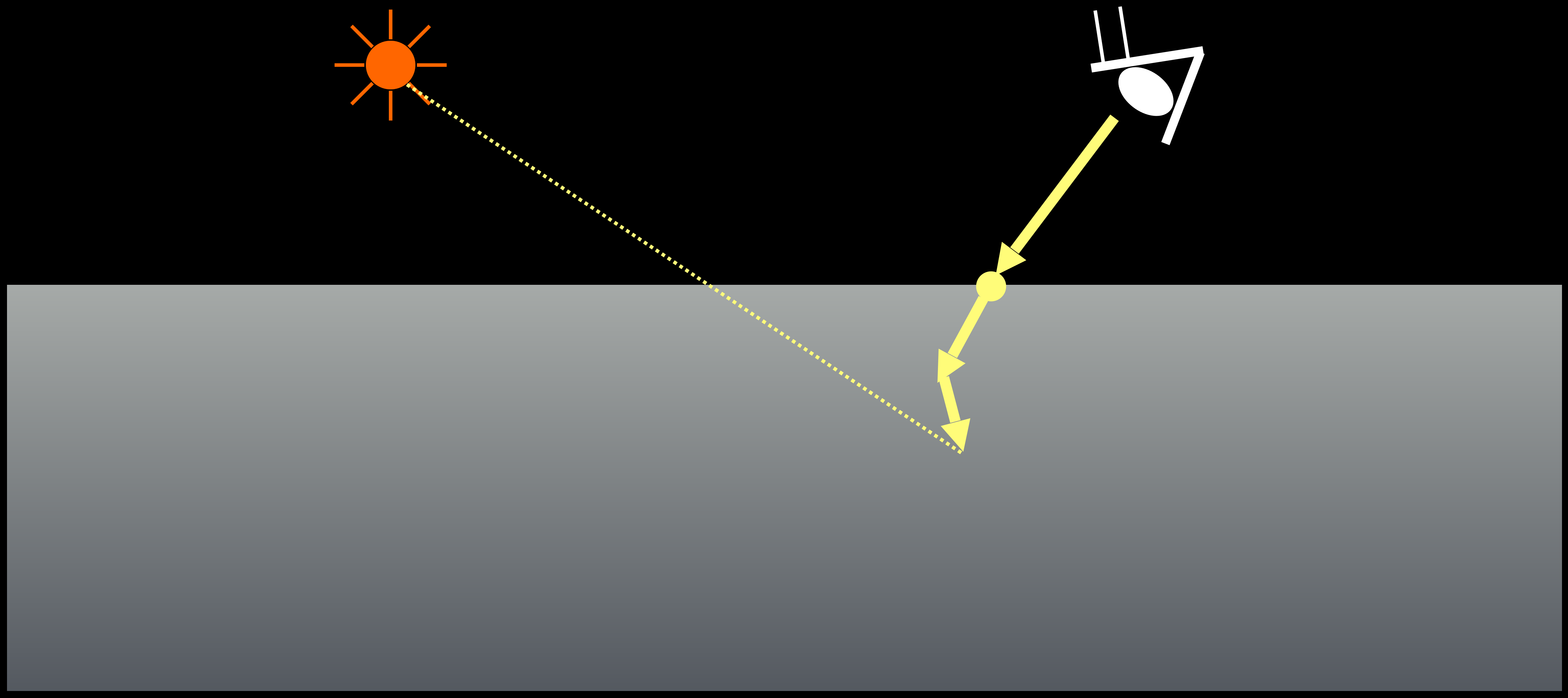

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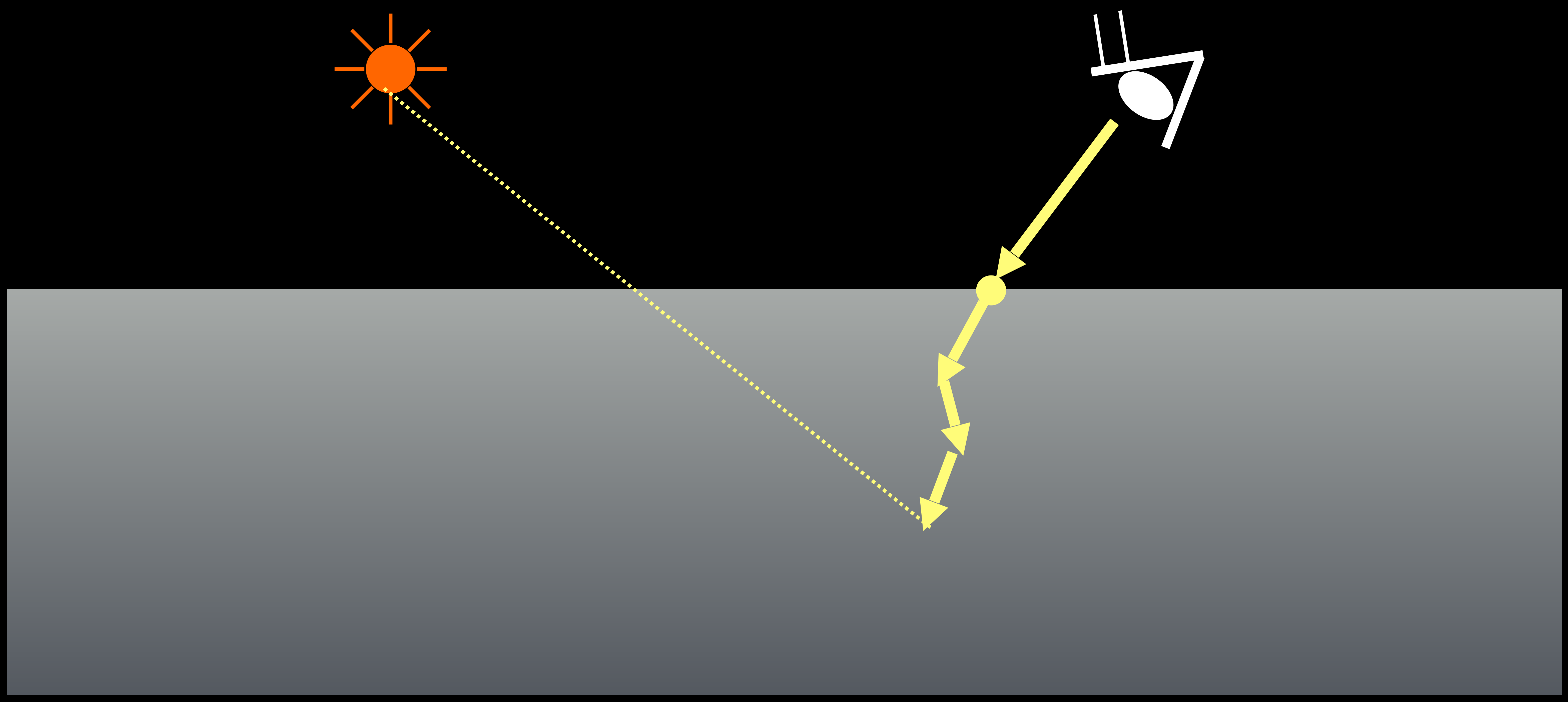

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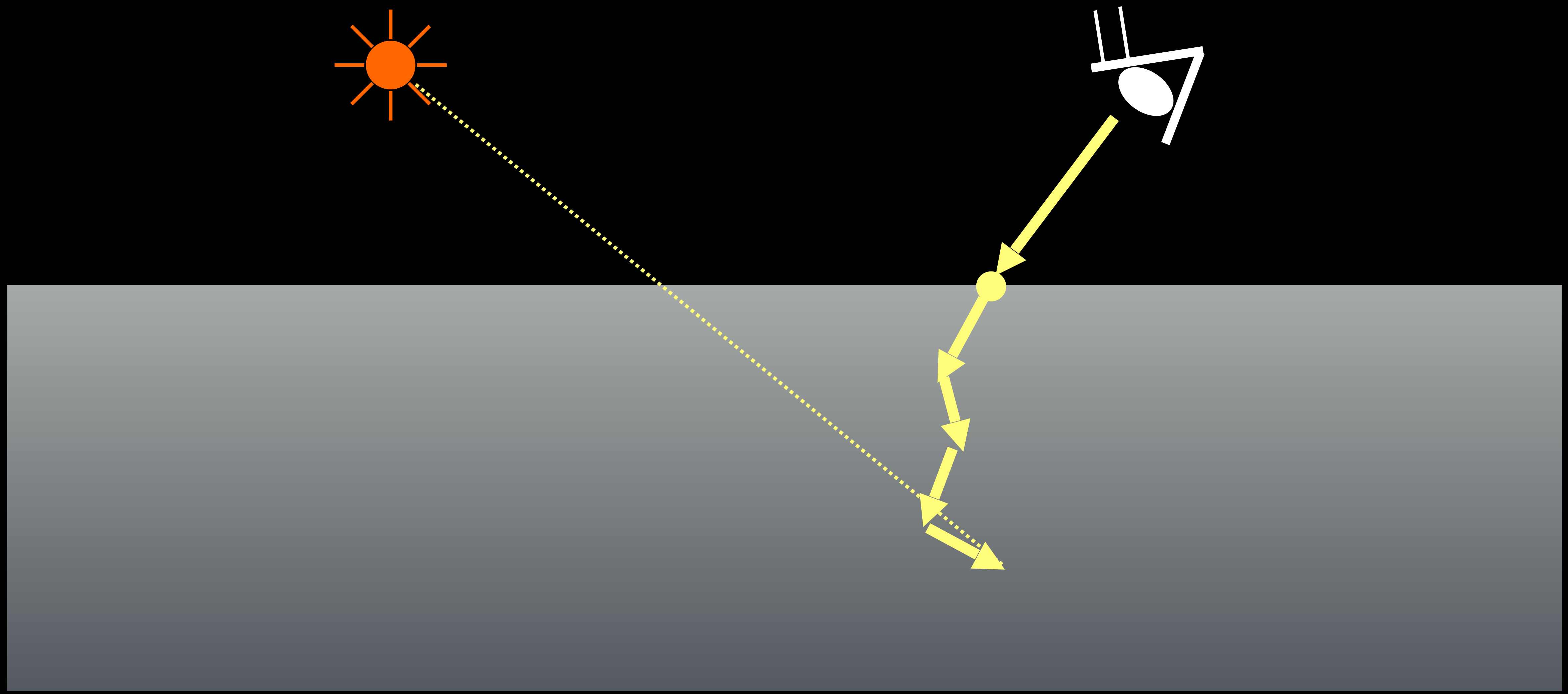
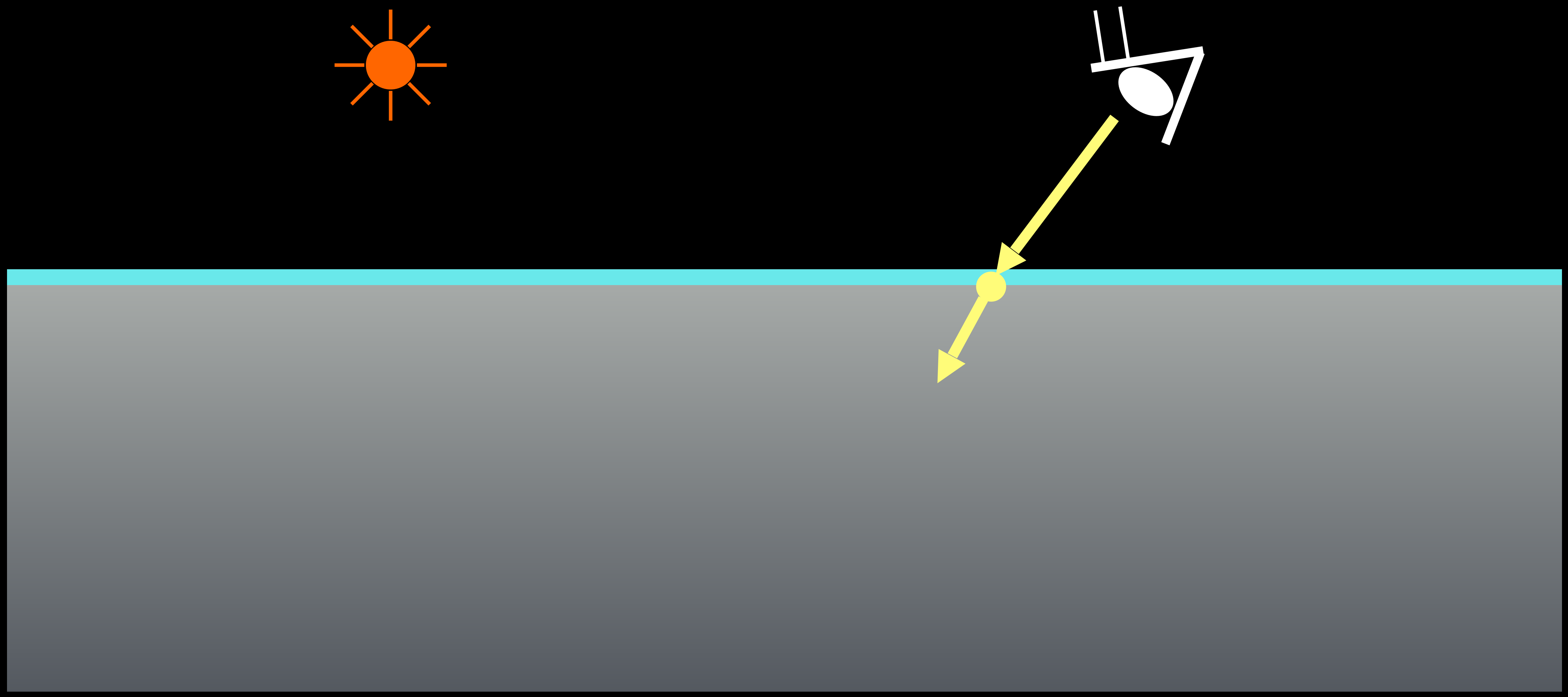


Refractive Object

Cannot explicitly sample direct light

(wish the ray would hit on the light source)



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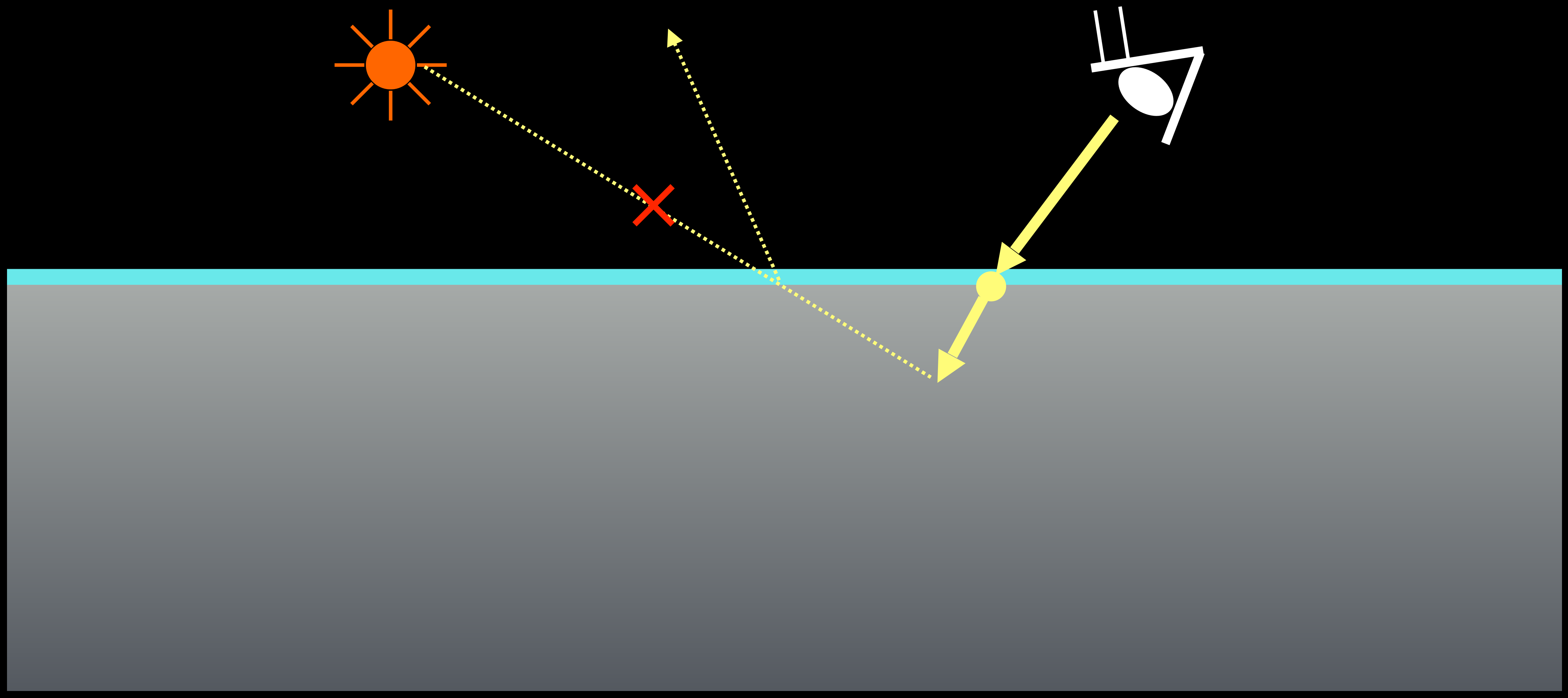

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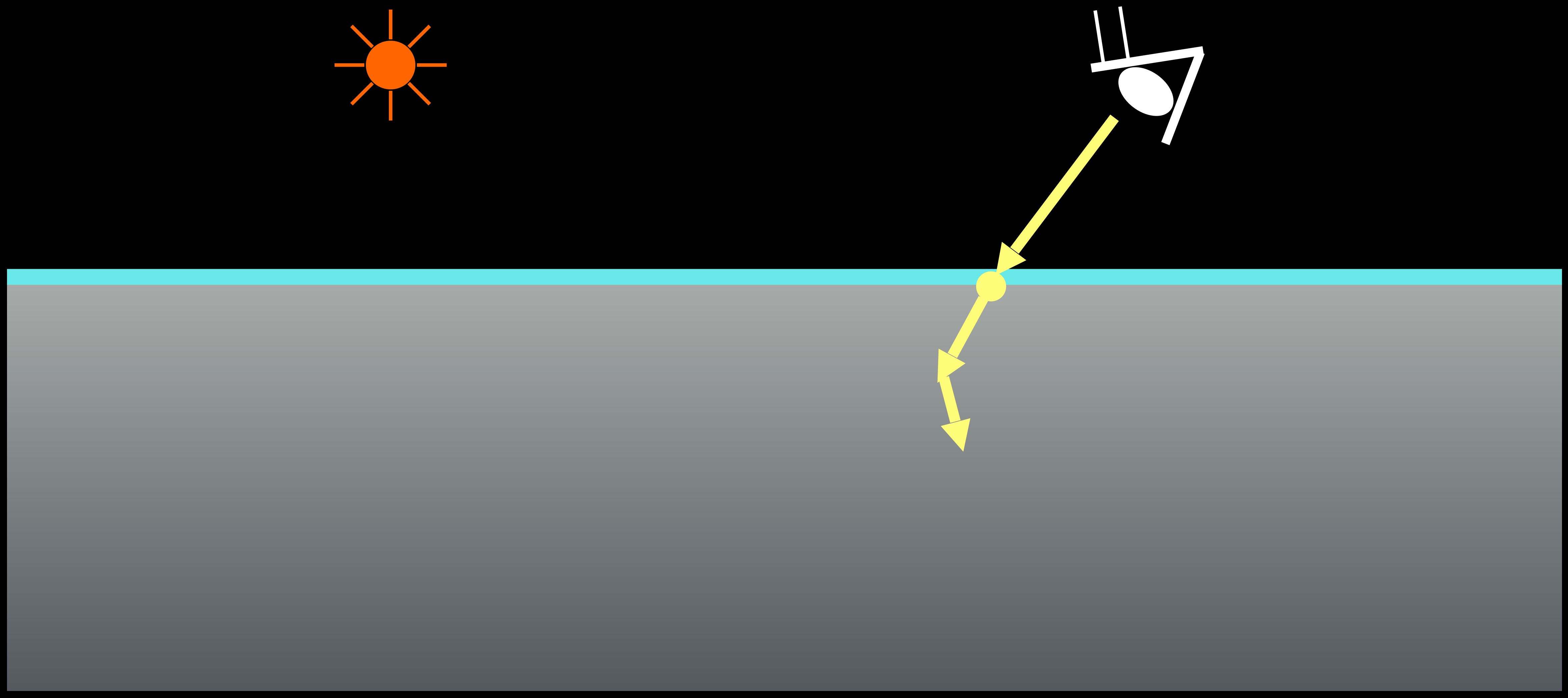

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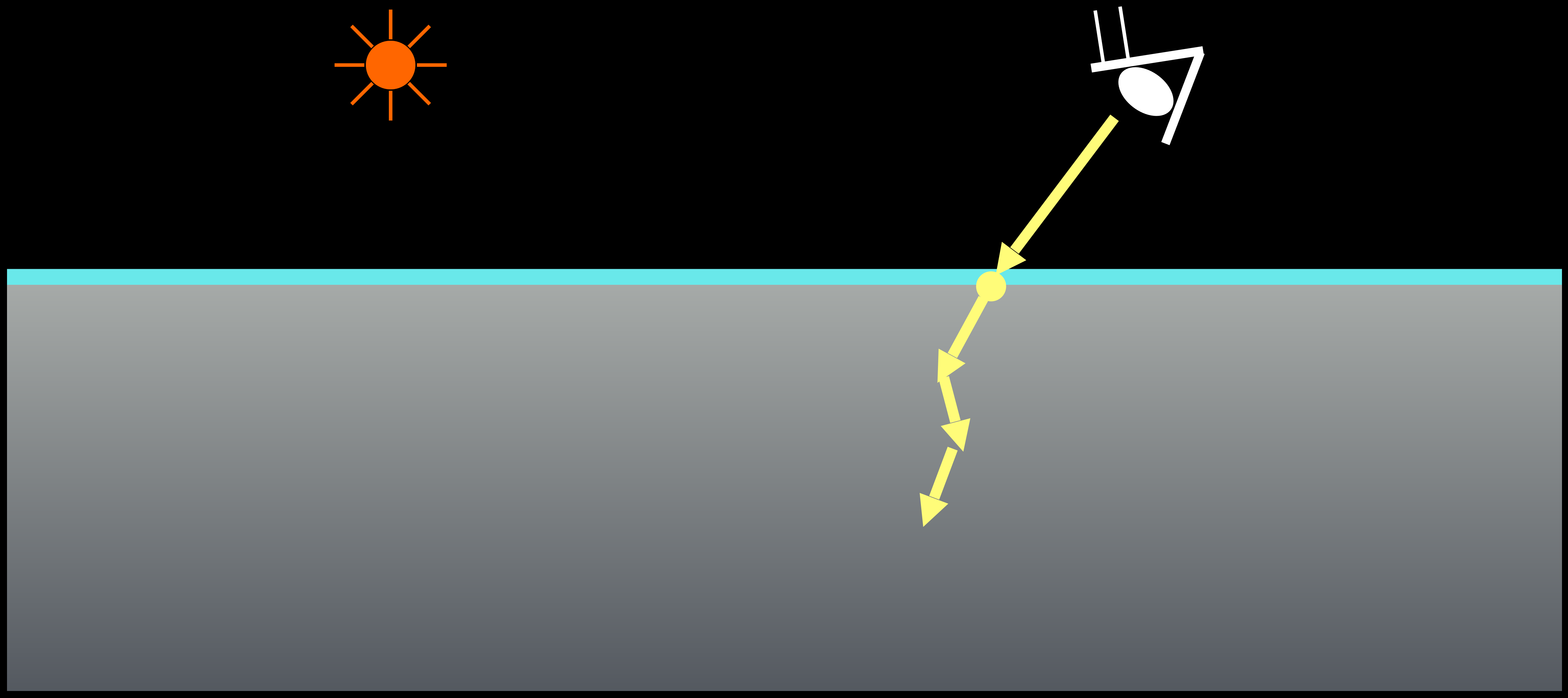

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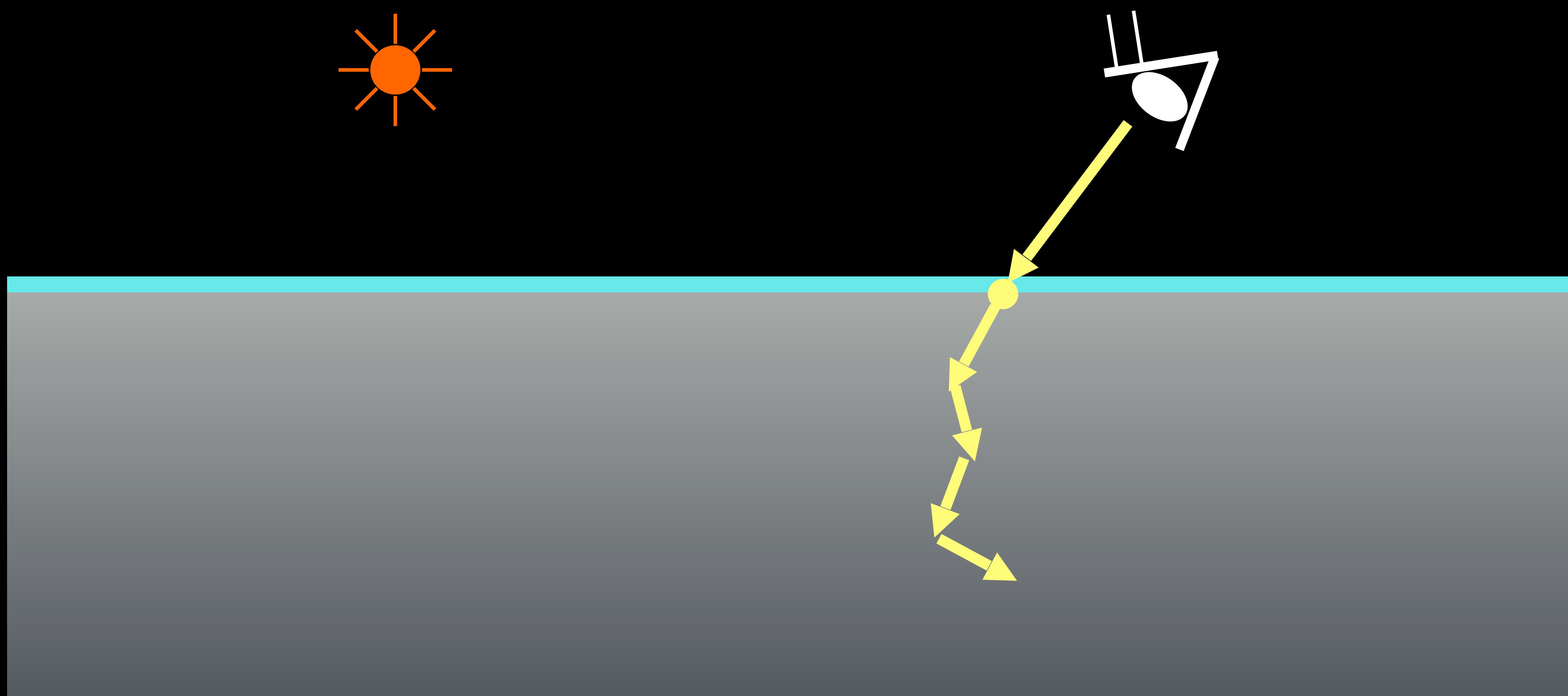


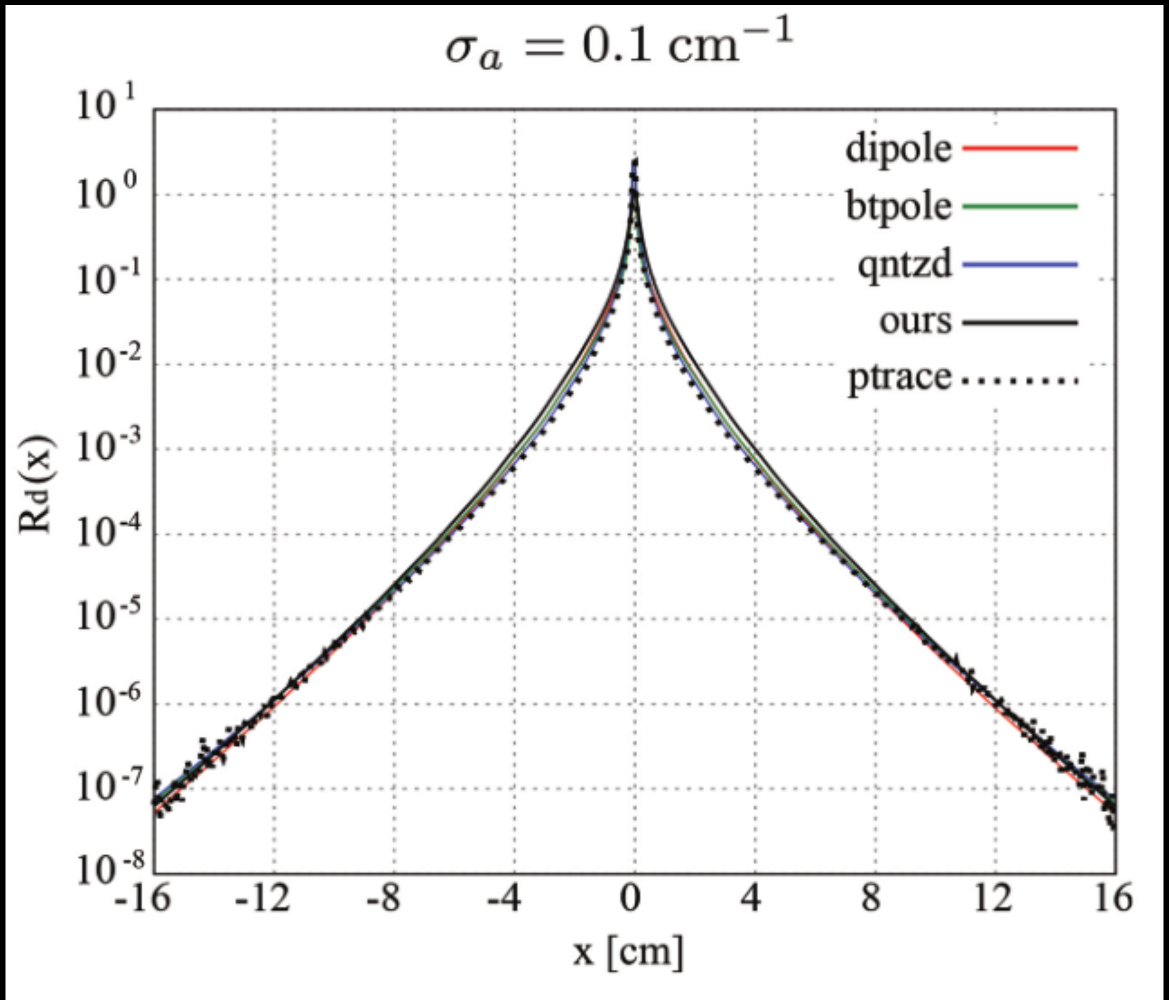
Why not weight sample?

If $\|\mathbf{x}_i - \mathbf{x}_o\|$ is small:
 the ellipse also becomes small

If $\|\mathbf{x}_i - \mathbf{x}_o\|$ is large:
 the diffuse reflectance becomes small
(exponentially decreased w.r.t. $\|\mathbf{x}_i - \mathbf{x}_o\|$)

$\rightarrow$ Weighted sampling cannot be significant

Reflectance is exponentially decreased w.r.t. the distance between $\mathbf{x}_i$ and $\mathbf{x}_o$



[Frisvad et al. 2014]