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Principled Kernel Prediction for Spatially Varying BSSRDFs

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DiSTRO

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OF MATHEMATICS
AND PHYSICS
Charles University

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• Computer Graphics Group • Charles University in Prague •

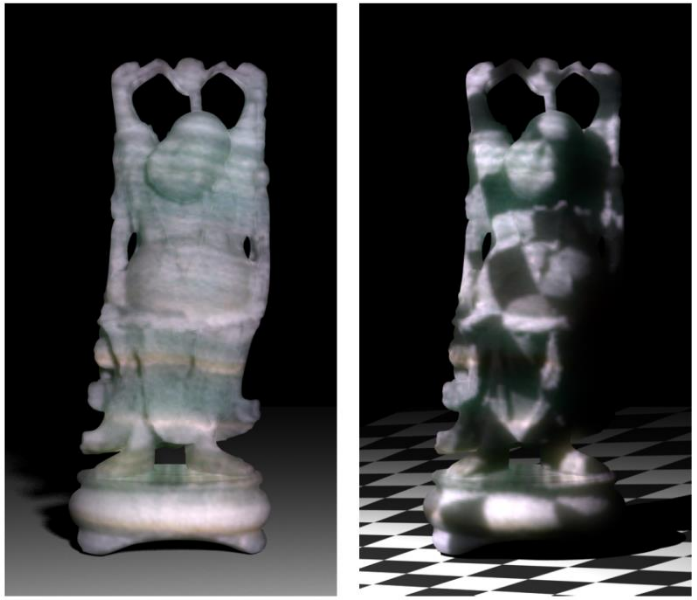
Topic

Prediction of **spatially varying BSSRDF** kernels from optical parameters

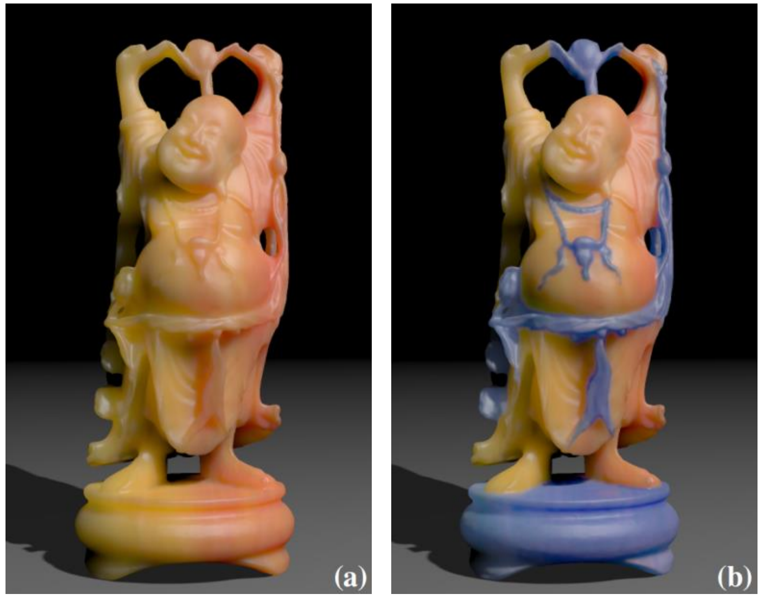
Scattering albedo texture (here 2.5D) | Local approaches | Parameter aggregation | Ours | Path tracing reference

Topic

Not tackling SV-BSSRDF **acquisition / compression / editing**



[Peers et al. @ SIGGRAPH 2006]

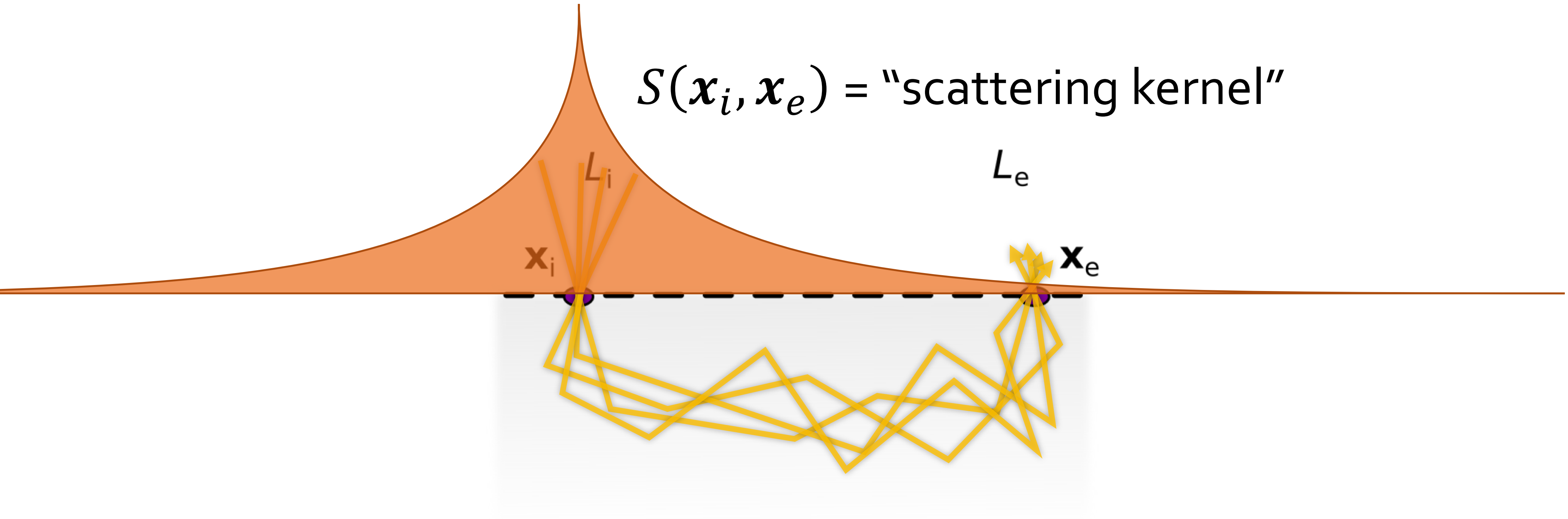


[Song et al. @ SIGGRAPH 2009]

BSSRDF and SV-BSSRDF

Uses and challenges

BSSRDF: Background

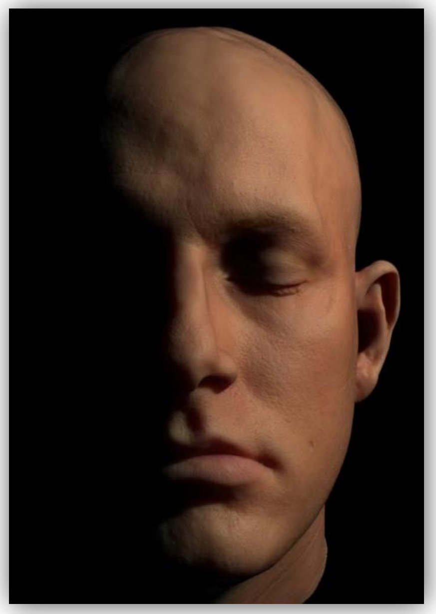


Statistical estimate of point-to-point volumetric light transport

BSSRDF: Background

Great for (quasi-)homogeneous materials with well **localized light transport**...

[Jensen et al. @ SIGGRAPH 2001]



[Donner et al. @ SIGGRAPH 2005]

[Frisvad et al. @ ACM ToG 2014]

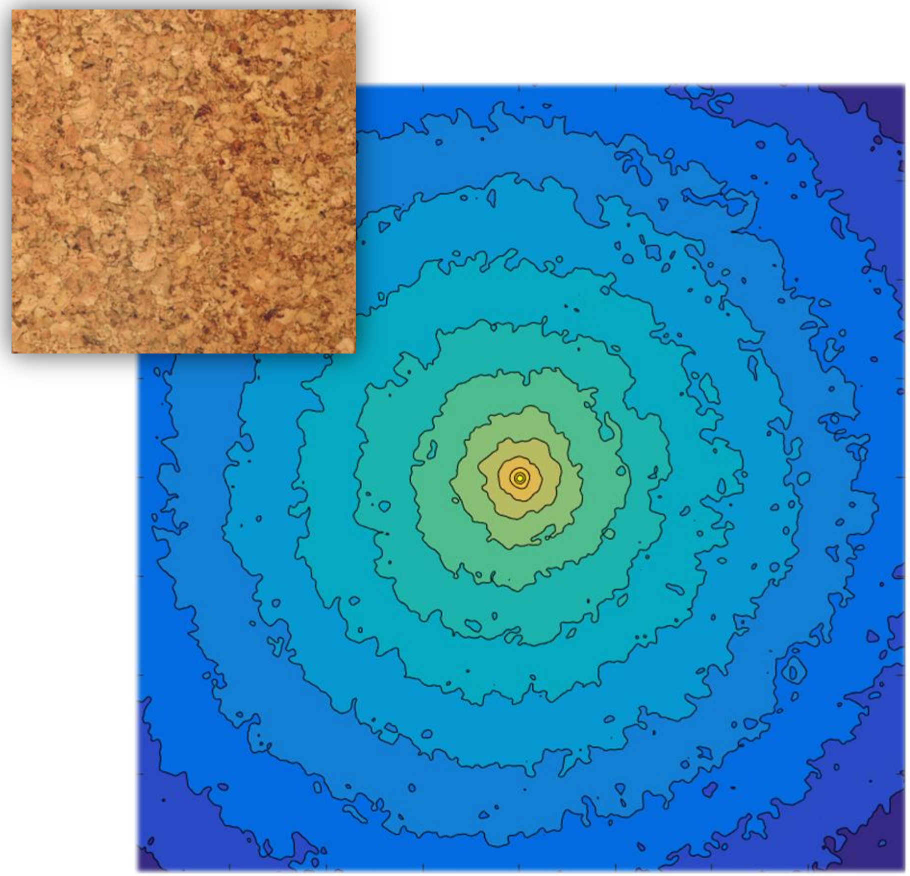
BSSRDF: Background

…but not so great when the **transport scale exceeds the feature scale**

[Elek, Sumin et al. @ SIGGRAPH Asia 2017]

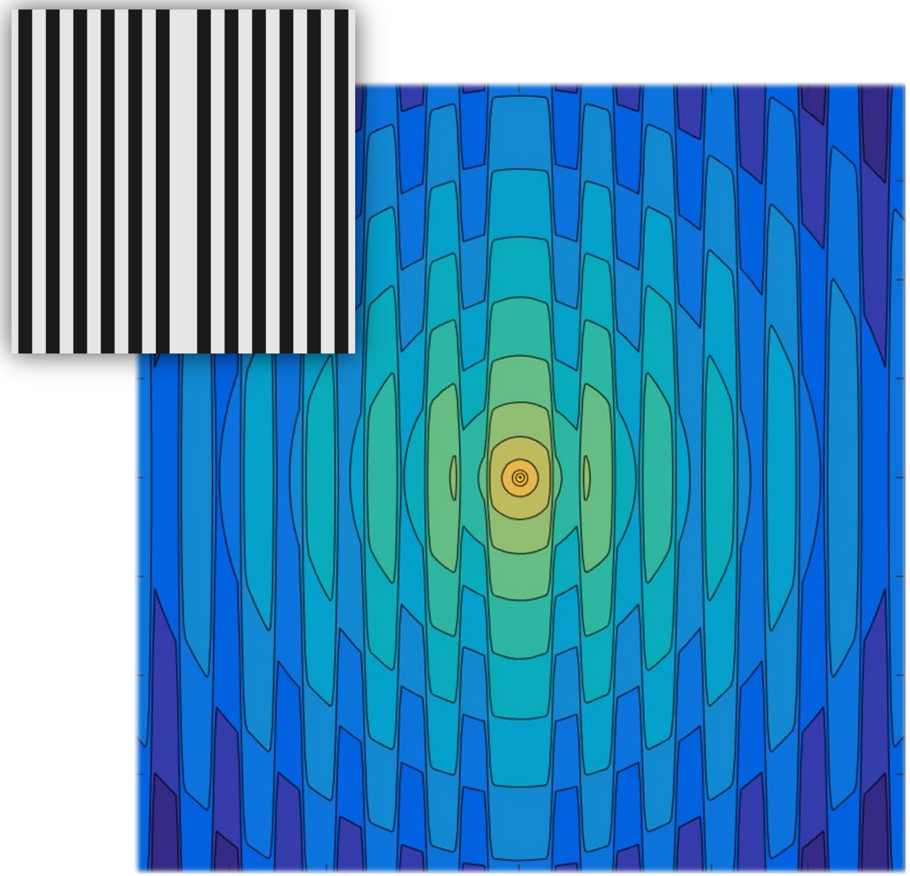
SV-BSSRDF: Kernel Shape

Albedo



Point response (“kernel”)

Albedo



Point response (“kernel”)

SV-BSSRDF: Kernel Shape

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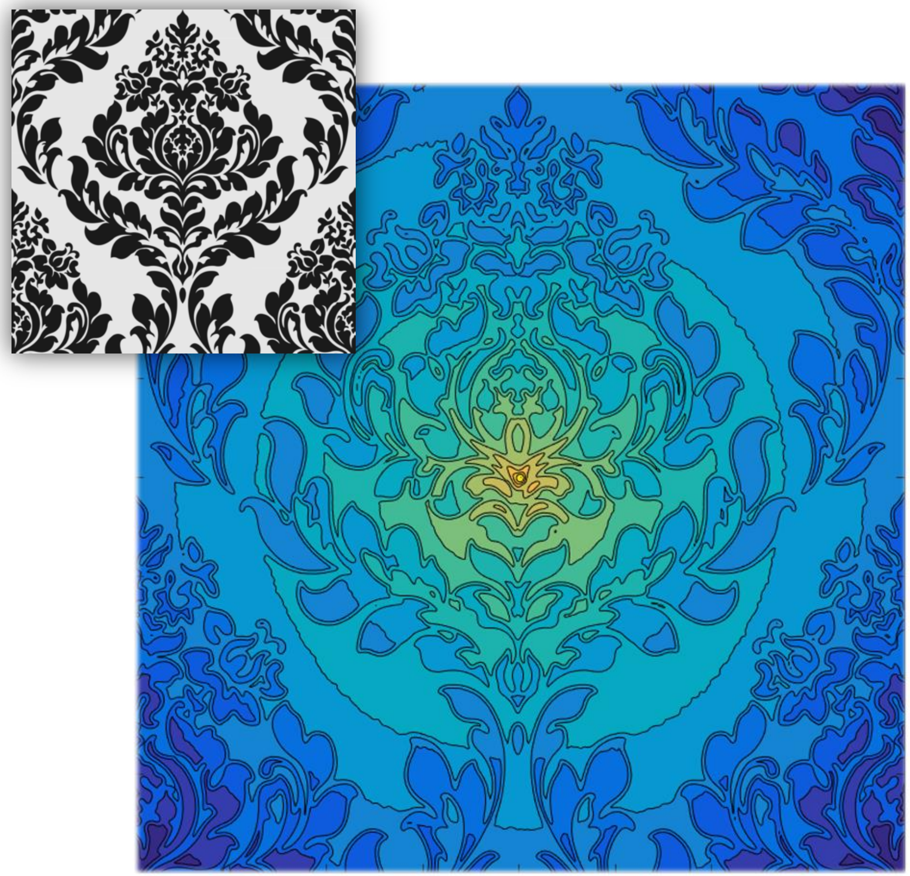
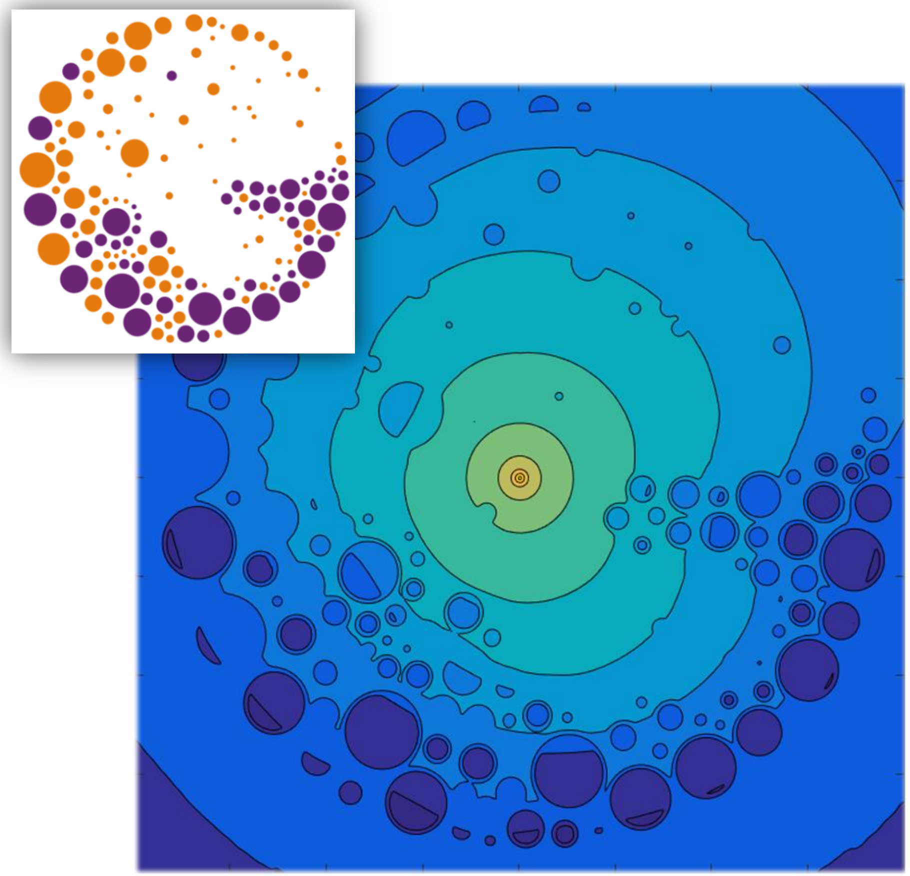
Albedo



Point response (“kernel”)

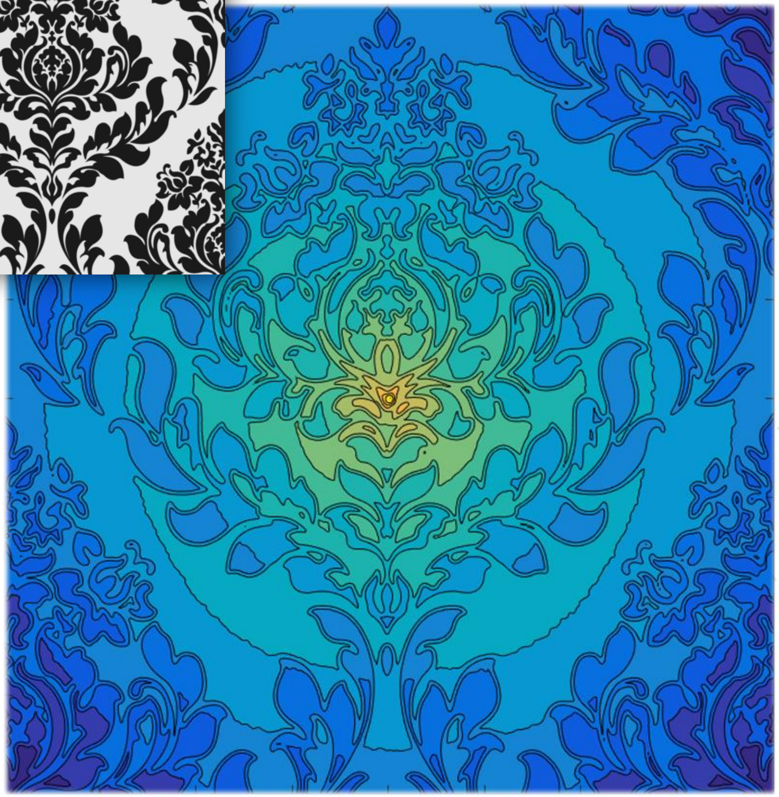
Albedo



Point response (“kernel”)

SV-BSSRDF: Kernel Shape

Albedo



Point response (“kernel”)

Two key ideas:

1. Data-driven **parameter aggregation**
2. Decomposition of transport into **local** and **global**

Methodology

Step-by-step walkthrough

Method Outline

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Preprocessing:

i. Derive a basis (homogeneous) BSSRDF
ii. For each (x_i, x_e) estimate the transport path distribution connecting them
iii. Fit a generic parametric model to the distribution (e.g. Gaussian mixture)

Runtime:

1) Use standard MC to select x_e
2) For given (x_i, x_e) aggregate the material properties using the kernel from **iii.**
3) Separate the transport kernel into the local and global components
4) Use point-evaluated properties to compute the local components
5) Use the aggregate properties from **3)** to compute the global component

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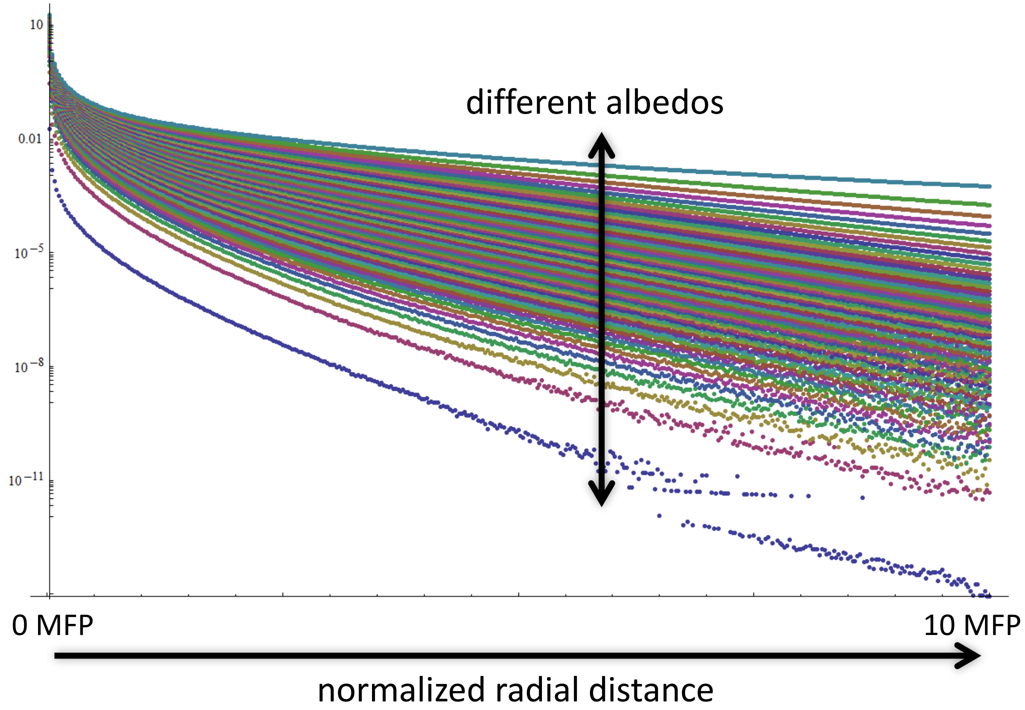

BSSRDF kernel:

$$S \cong \sum_i A_i \cdot e^{-r \cdot B_i}$$

Also see [Christensen and Burley @ SIGGRAPH Talks 2015]

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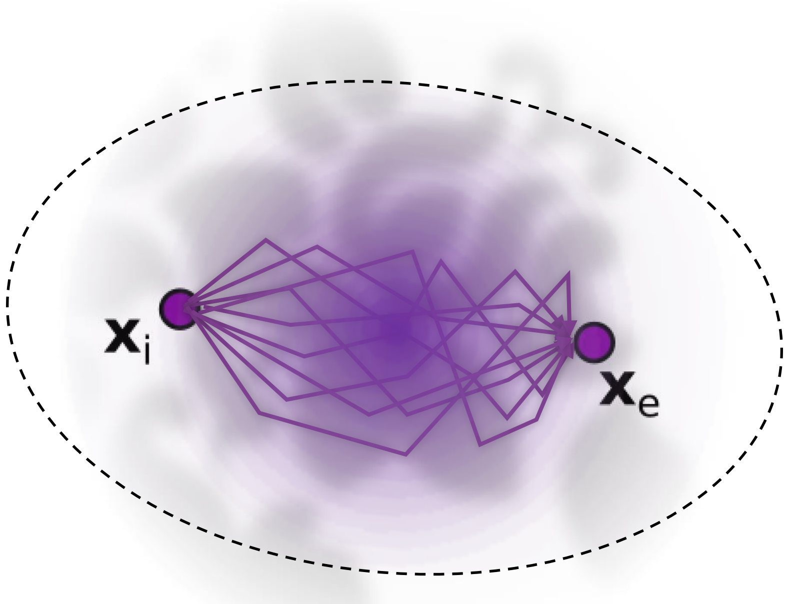
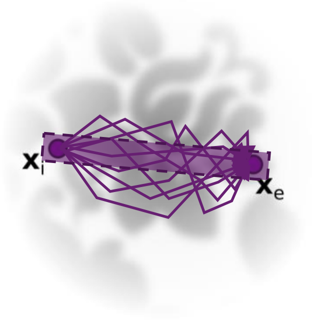
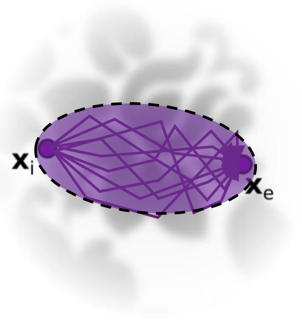


Distribution of **unweighted sub-surface paths**



Line: [d’Eon and Irving @ SIGGRAPH 2011]



Ellipse: [Sone et al. @ EG Shorts 2017]

Method Outline

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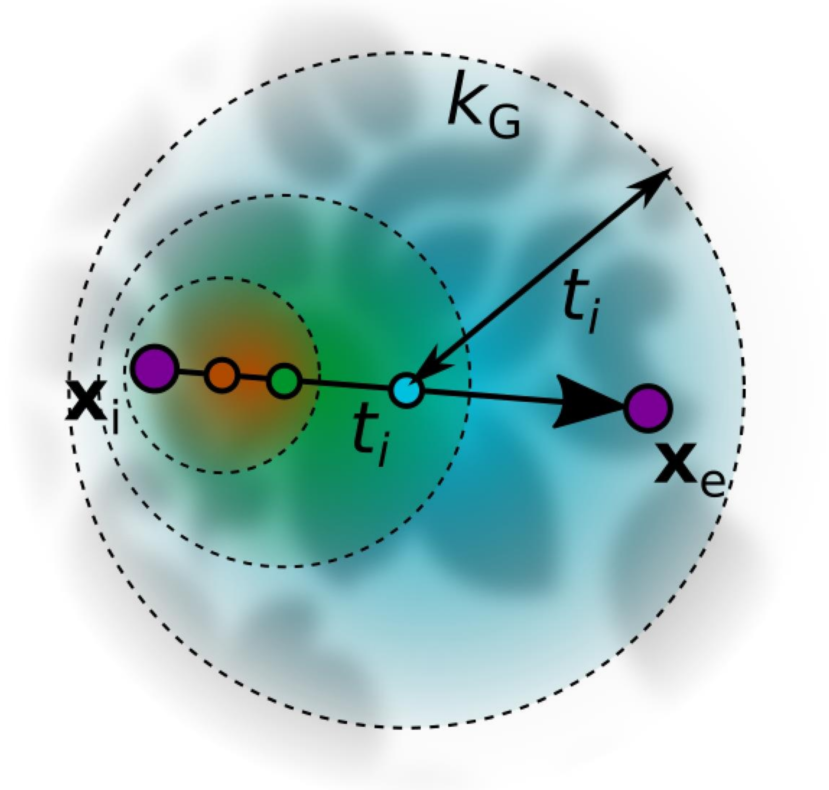

Aggregation kernel:

$$K = \sum k_G$$

'Transport' albedo:

$$\alpha_t = \int K(\boldsymbol{x})$$

Method Outline

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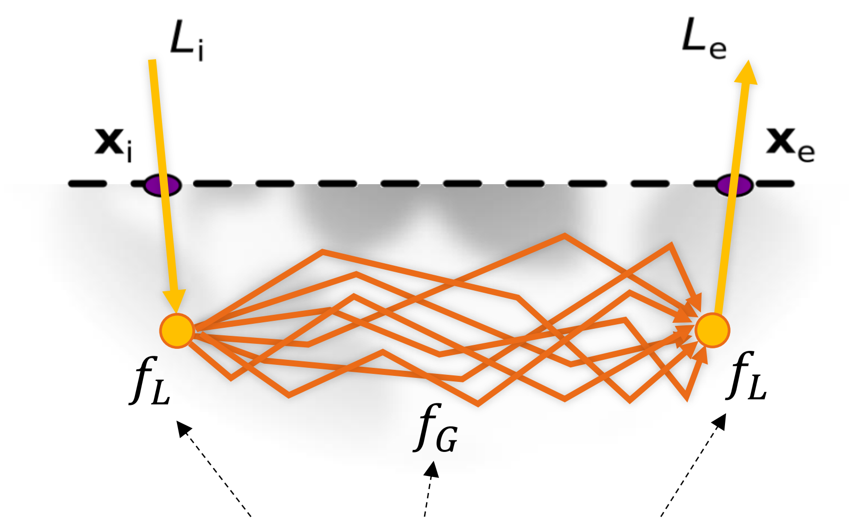
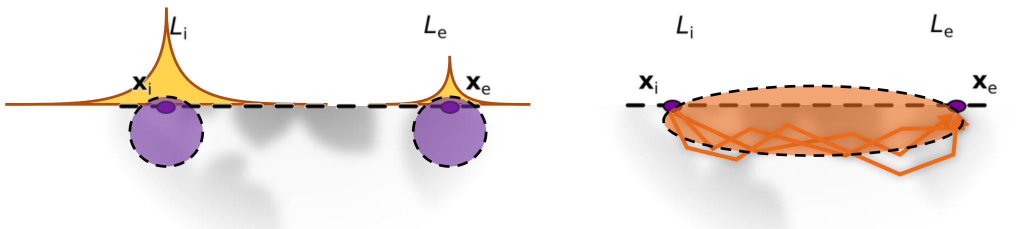


$$S_V = f_L(\boldsymbol{x}_i) \cdot f_G(\boldsymbol{x}_i, \boldsymbol{x}_e) \cdot f_L(\boldsymbol{x}_e)$$

$$= \frac{\alpha_i}{\alpha_t} \cdot S(\alpha_t) \cdot \frac{\alpha_e}{\alpha_t}$$



Factorization:

$$S_V = \sqrt{S(\alpha_i) \cdot S(\alpha_e)}$$

[Song et al. @ SIGGRAPH 2009]

Aggregation:

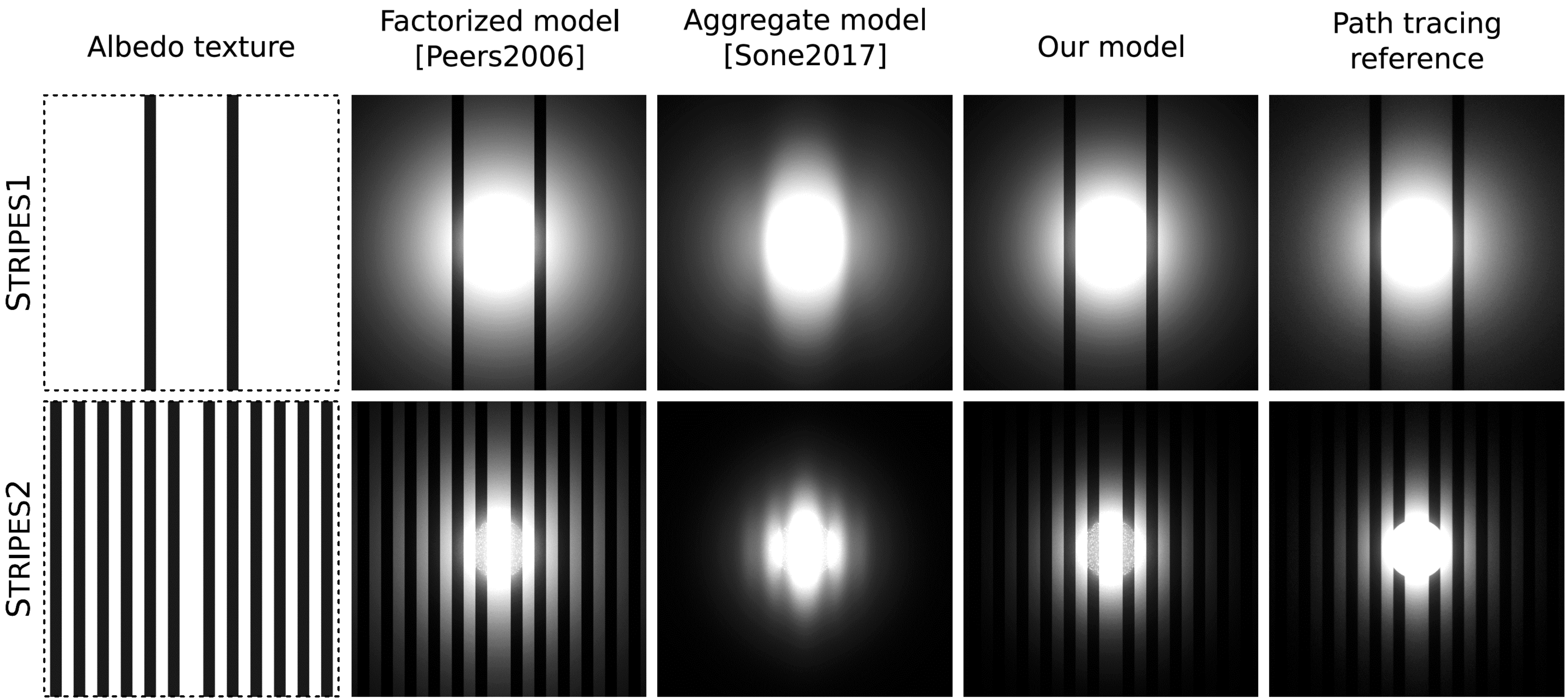
$$S_V = S(\alpha_t)$$

[Sone et al. @ EG Shorts 2017]

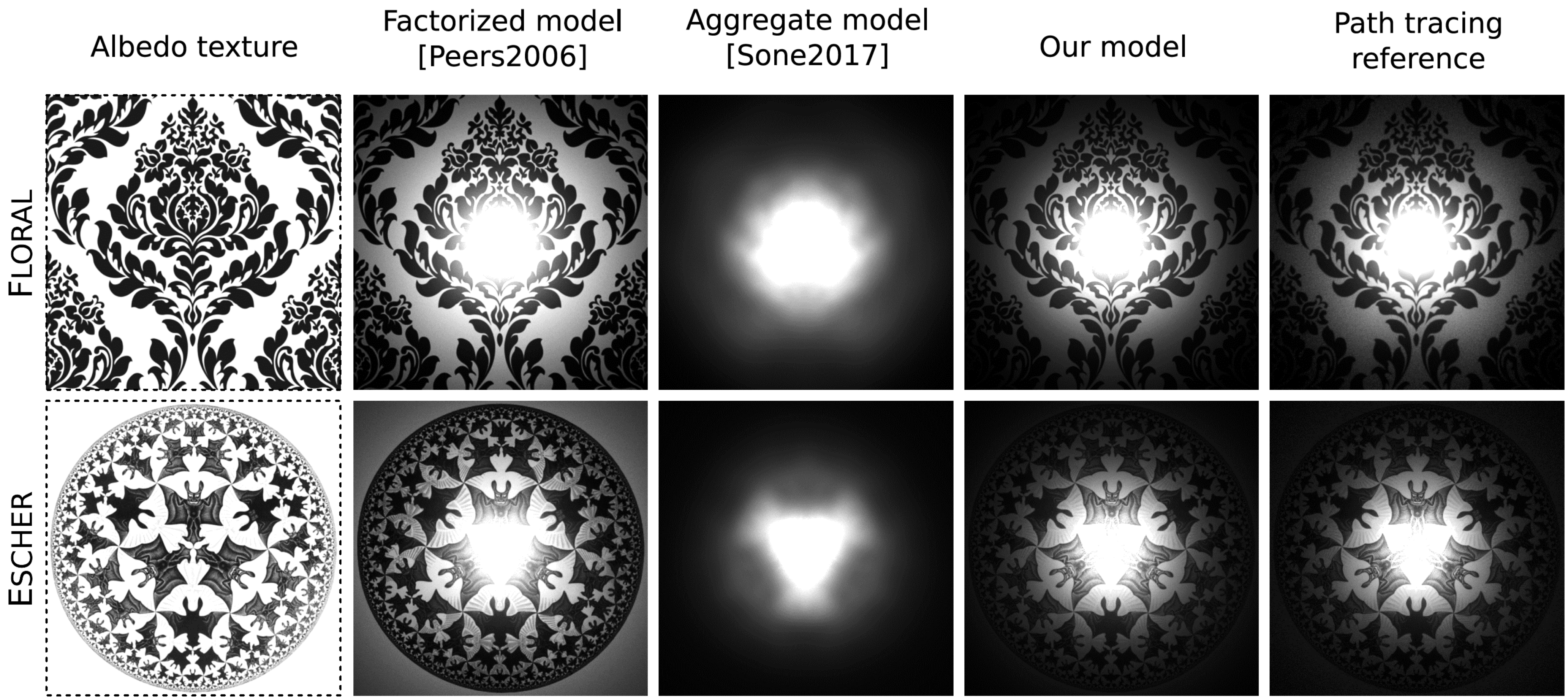
Evaluation

Overall quality and detail preservation

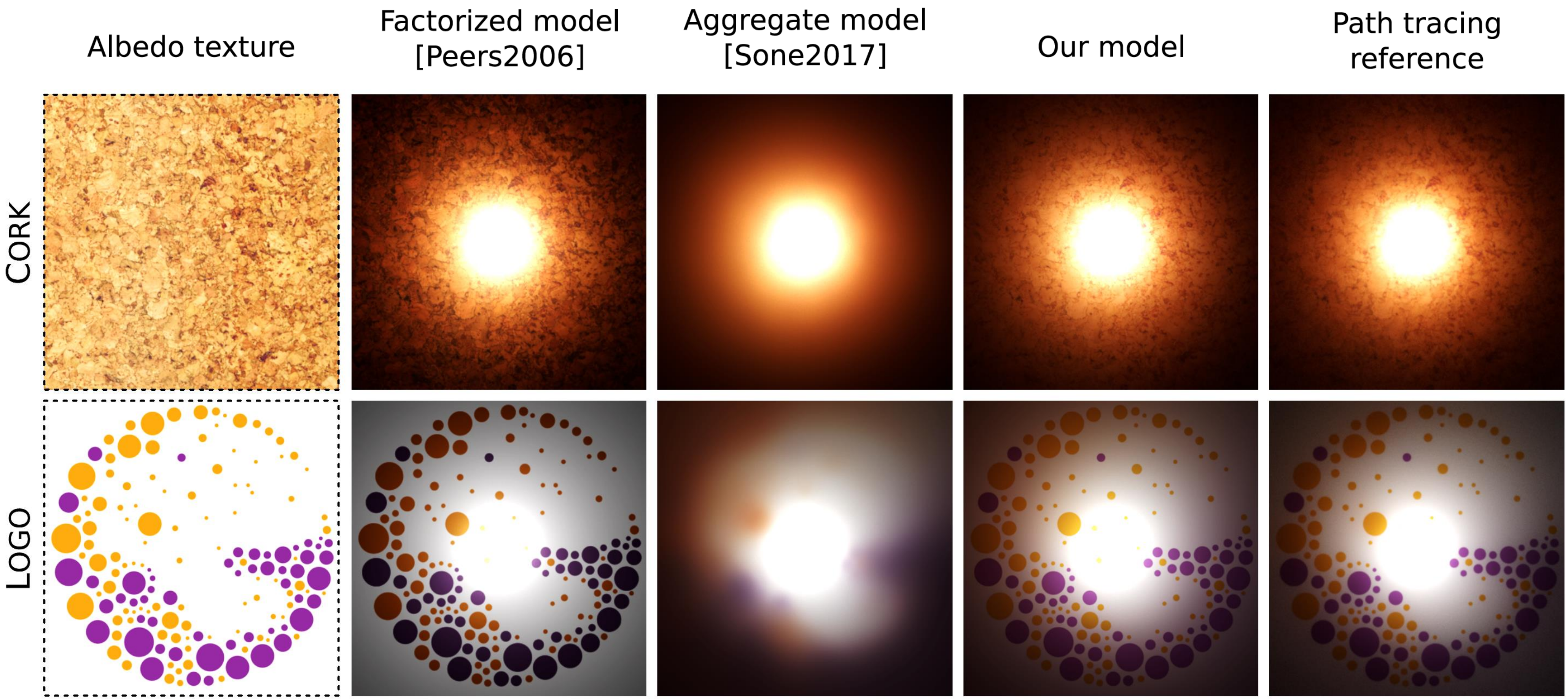
Evaluation: Simple Structures



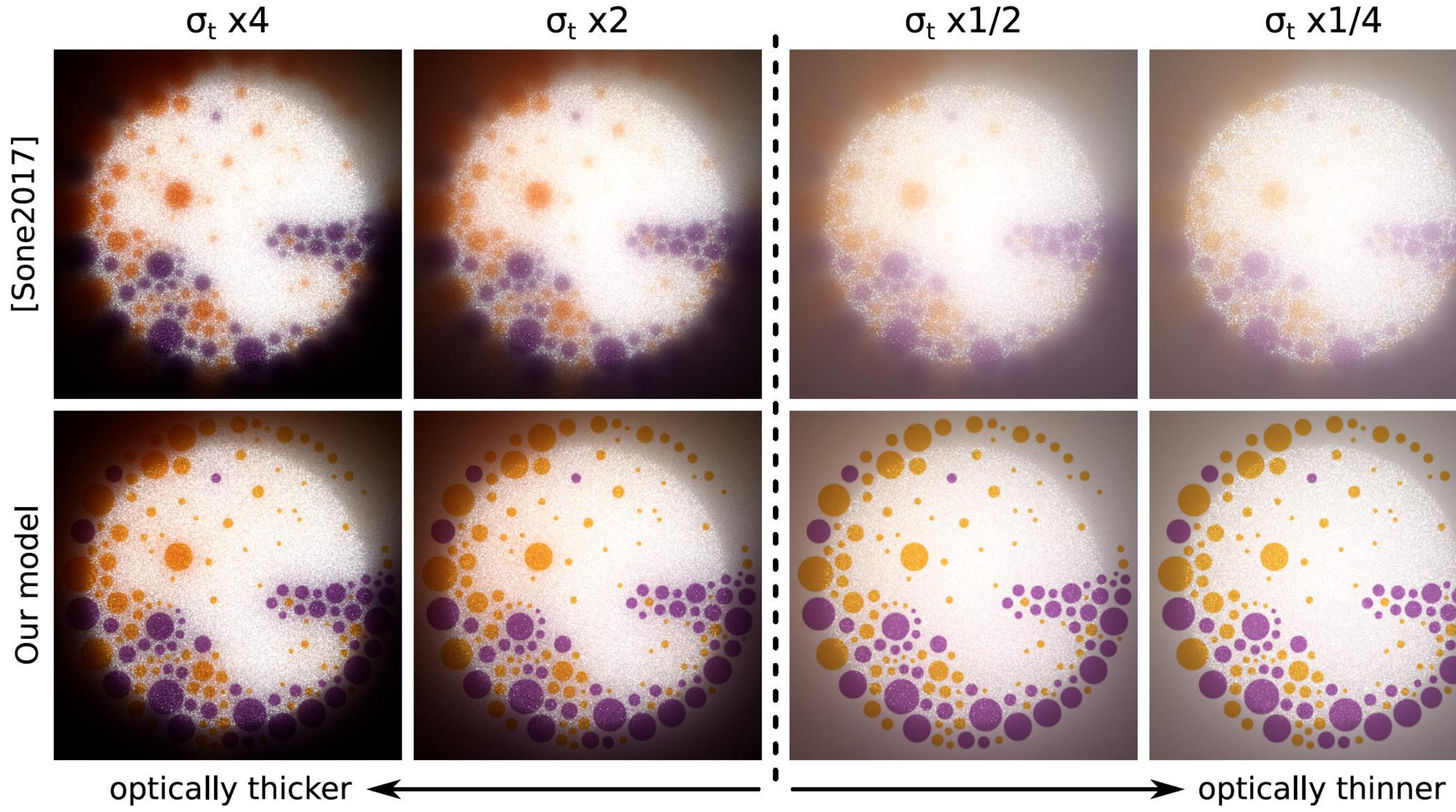
Evaluation: Complex Structures



Evaluation: Color Features



Evaluation: Feature Preservation

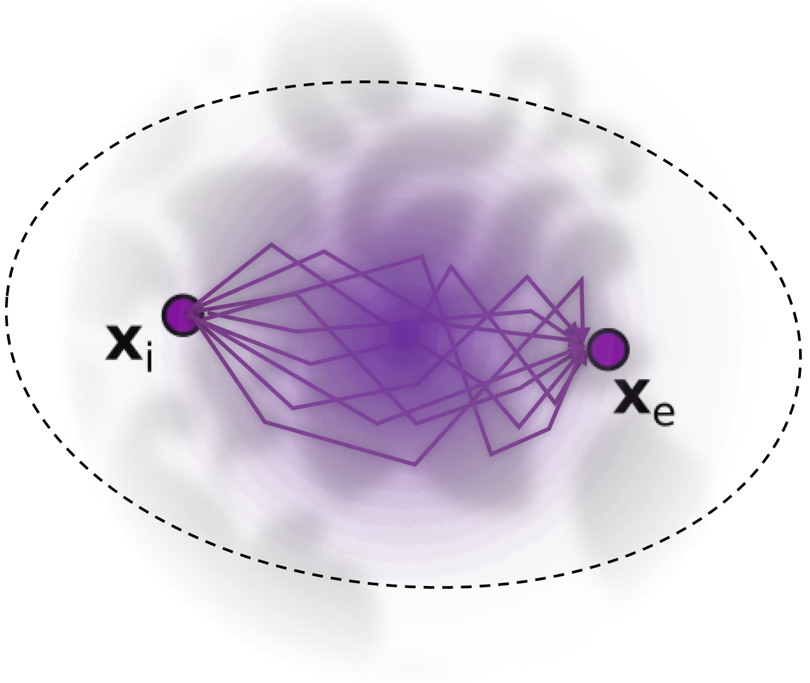


Discussion

What follows?

Future Work

- Principled aggregation kernel
  - Currently only a manual fit



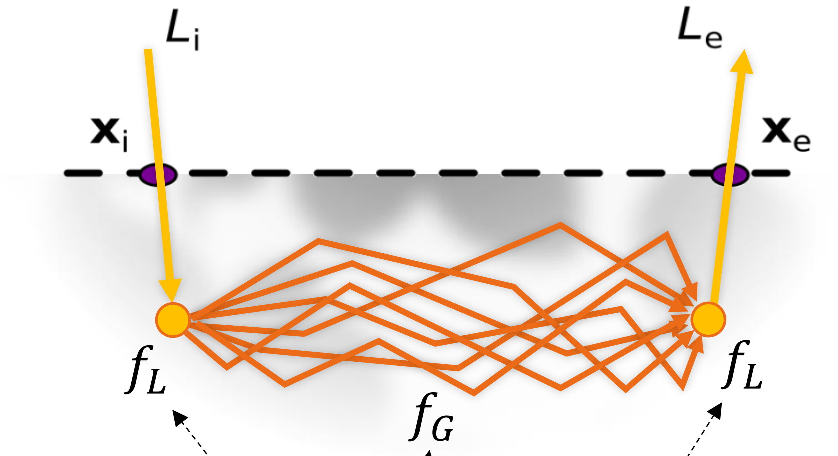
Future Work

- Principled aggregation kernel
- Spatial variation of all material parameters
  - Currently only scattering albedo

[Hasan et al. @ SIGGRAPH 2010]

Future Work

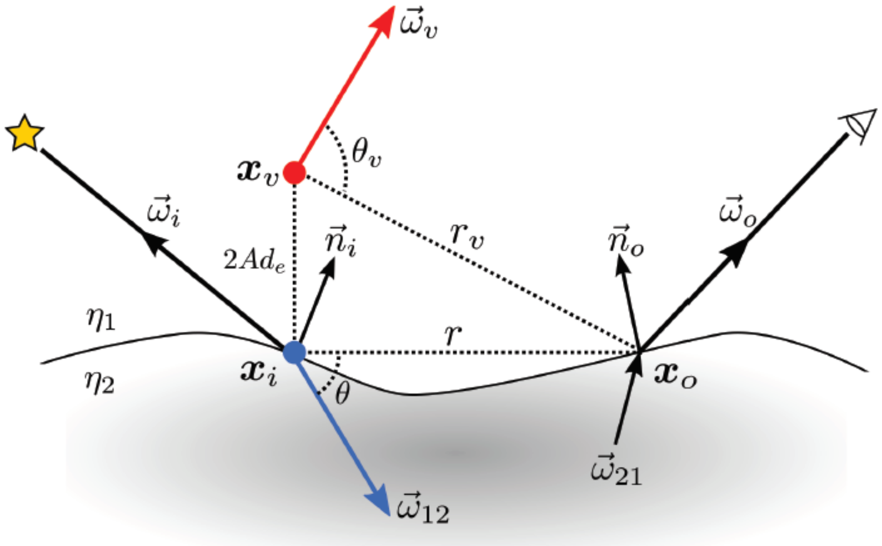
- Principled aggregation kernel
- Spatial variation of all material parameters
- Importance sampling
  - Currently only uniform sampling of incident illumination



$$S_V = f_L(\boldsymbol{x}_i) \cdot f_G(\boldsymbol{x}_i, \boldsymbol{x}_e) \cdot f_L(\boldsymbol{x}_e)$$

Future Work

- Principled aggregation kernel
- Spatial variation of all material parameters
- Importance sampling
- General 3D geometry and parameter distributions
  - Current solution limited to 2.5D objects



[Frisvad et al. @ ACM ToG 2014]

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PRINCIPLED KERNEL PREDICTION FOR SPATIALLY VARYING BSSRDFs

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Extra Slides

Basis BSSRDF

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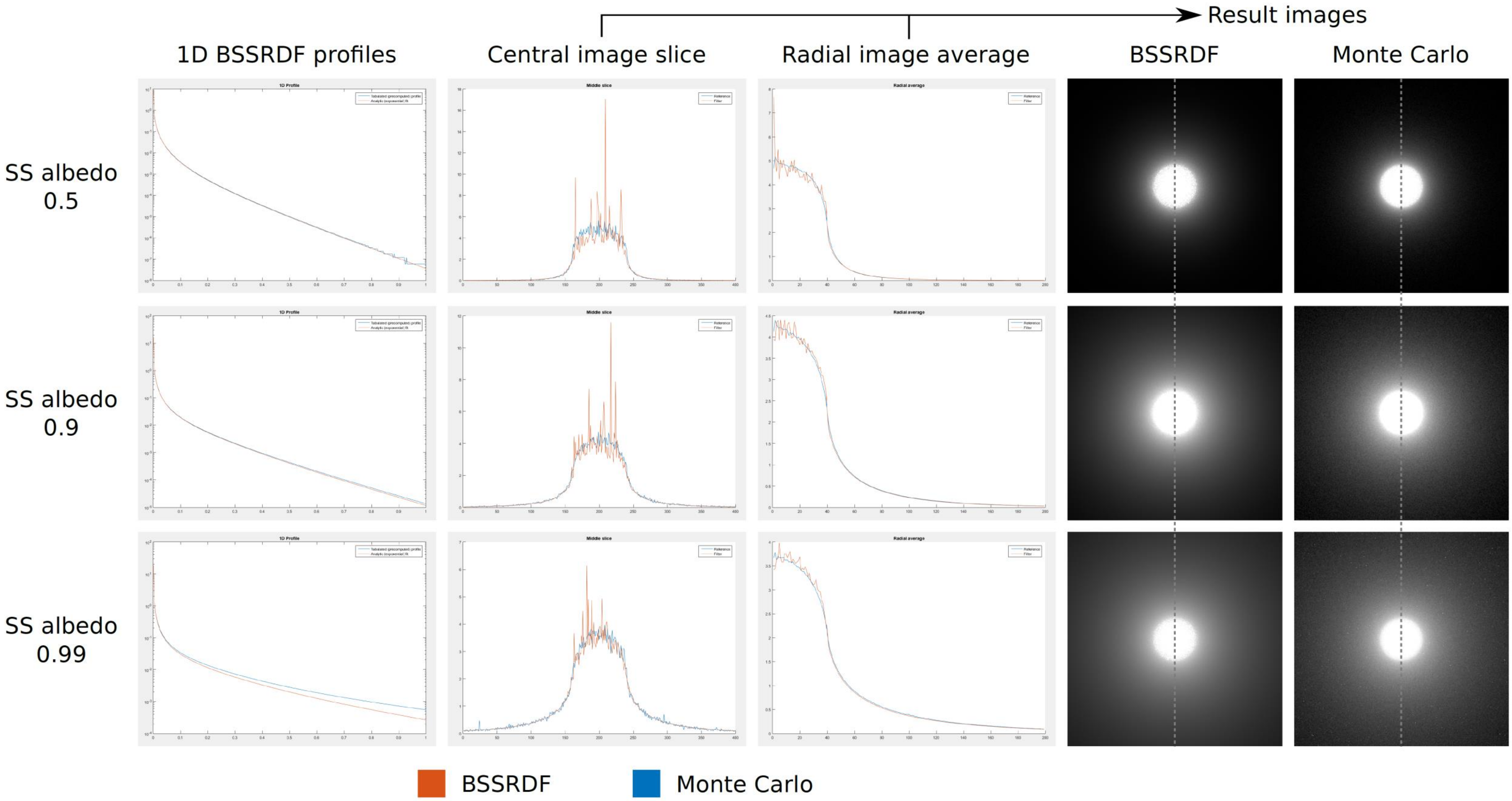

Full Results