SIGGRAPH 2024
DENVER+ 28 JUL — 1 AUG

THE PREMIER CONFERENCE & EXHIBITION ON COMPUTER GRAPHICS & INTERACTIVE TECHNIQUES

FROM MICROFACETS TO PARTICIPATING MEDIA: A UNIFIED THEORY OF LIGHT TRANSPORT WITH STOCHASTIC GEOMETRY

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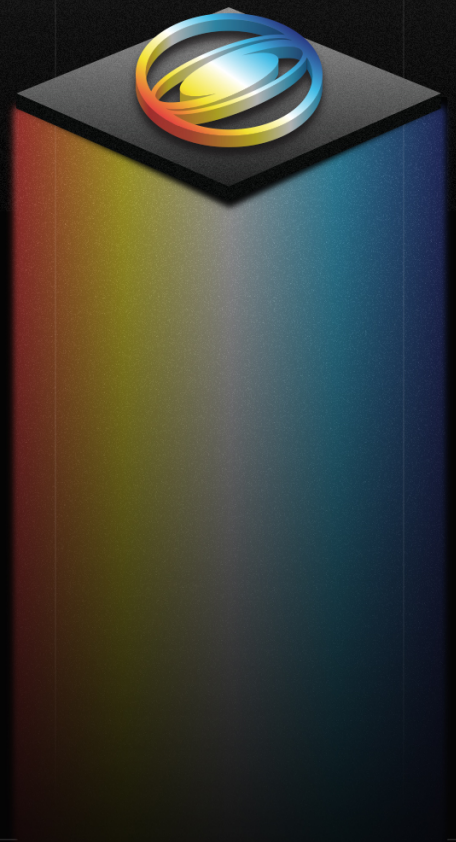
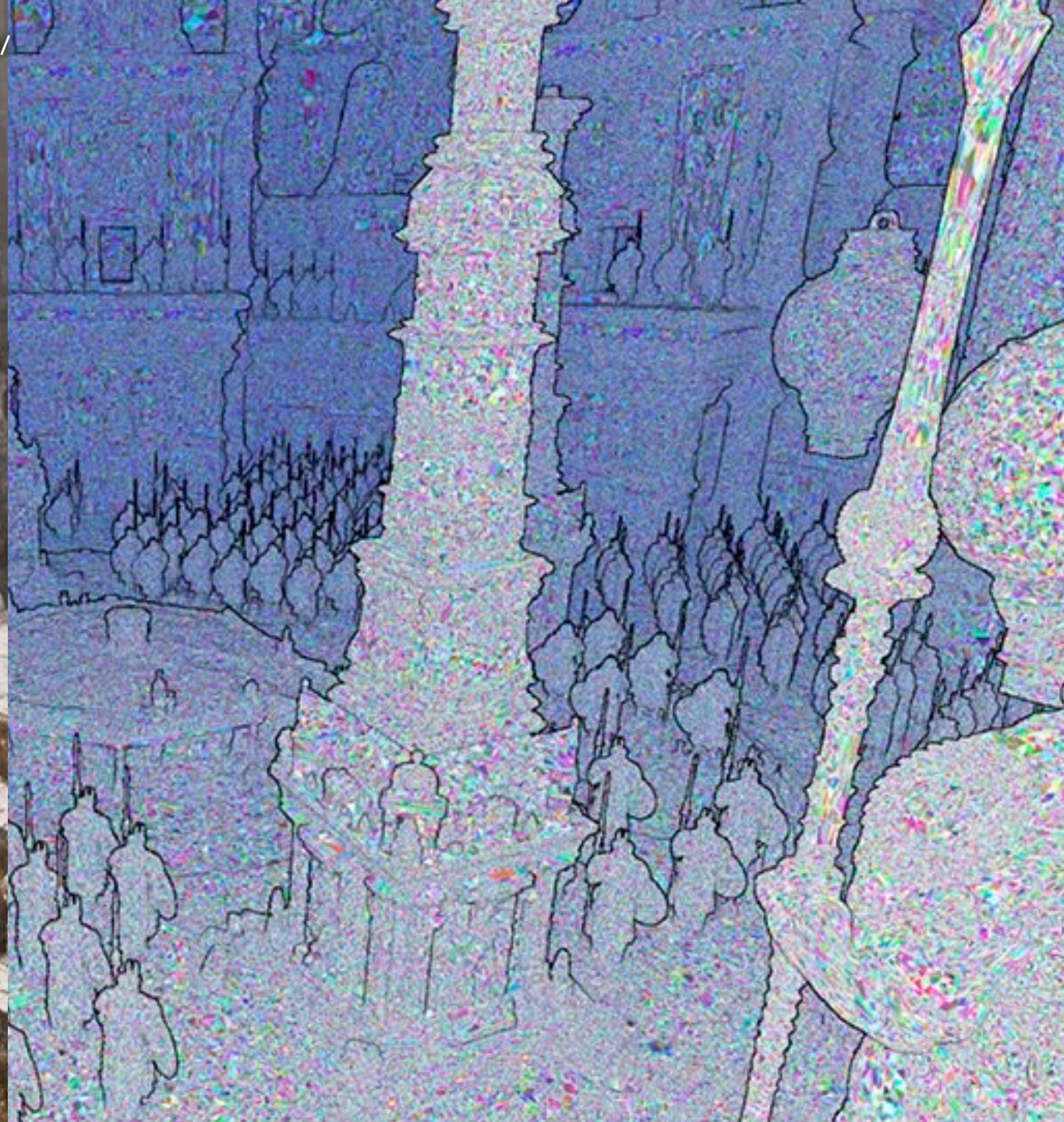
[1]DARTMOUTH COLLEGE, [2]NVIDIA

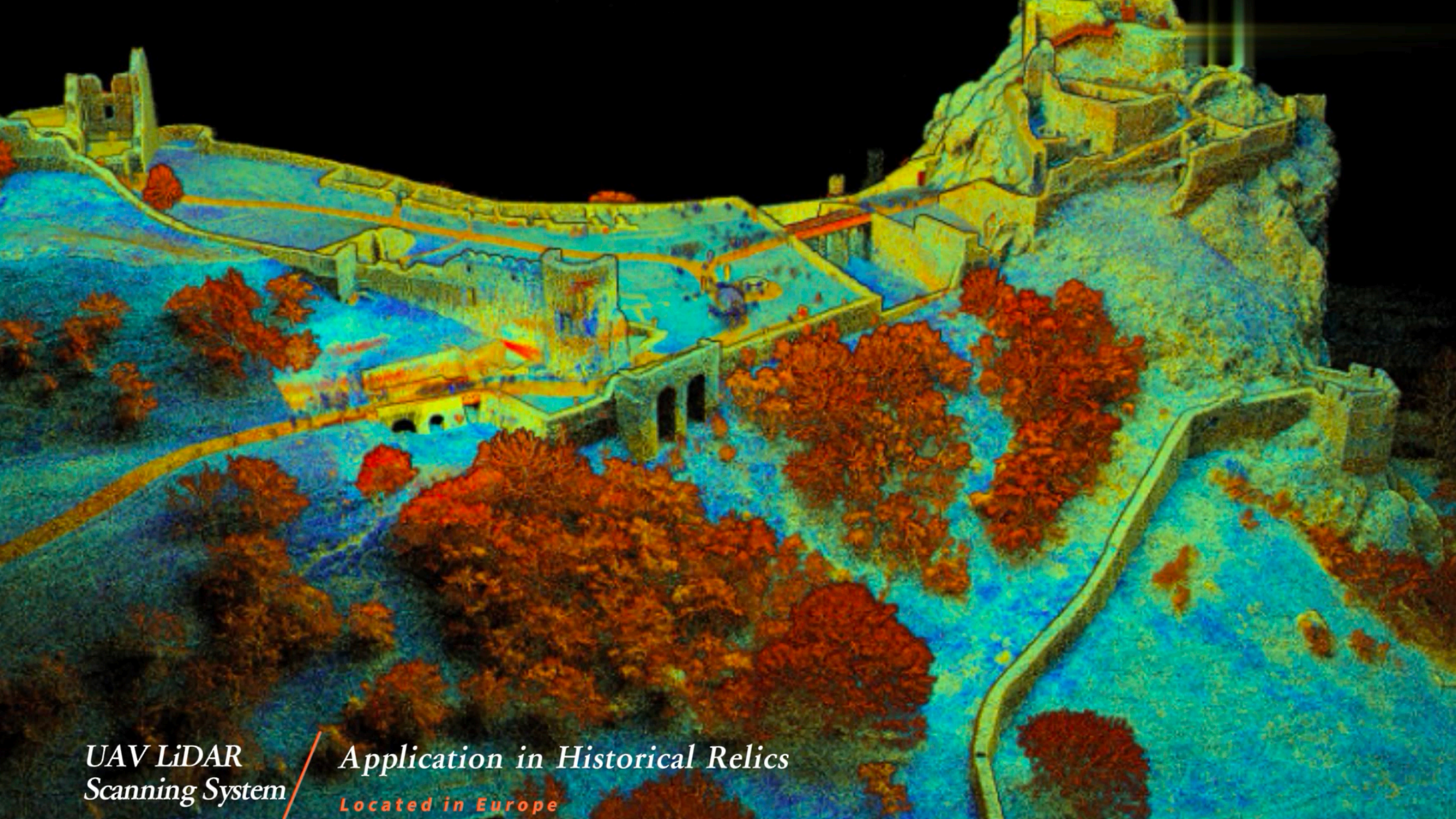


docs.unrealengine.com/5.0/en-US/nanite-virtualized-geometry-in-unreal-engine/



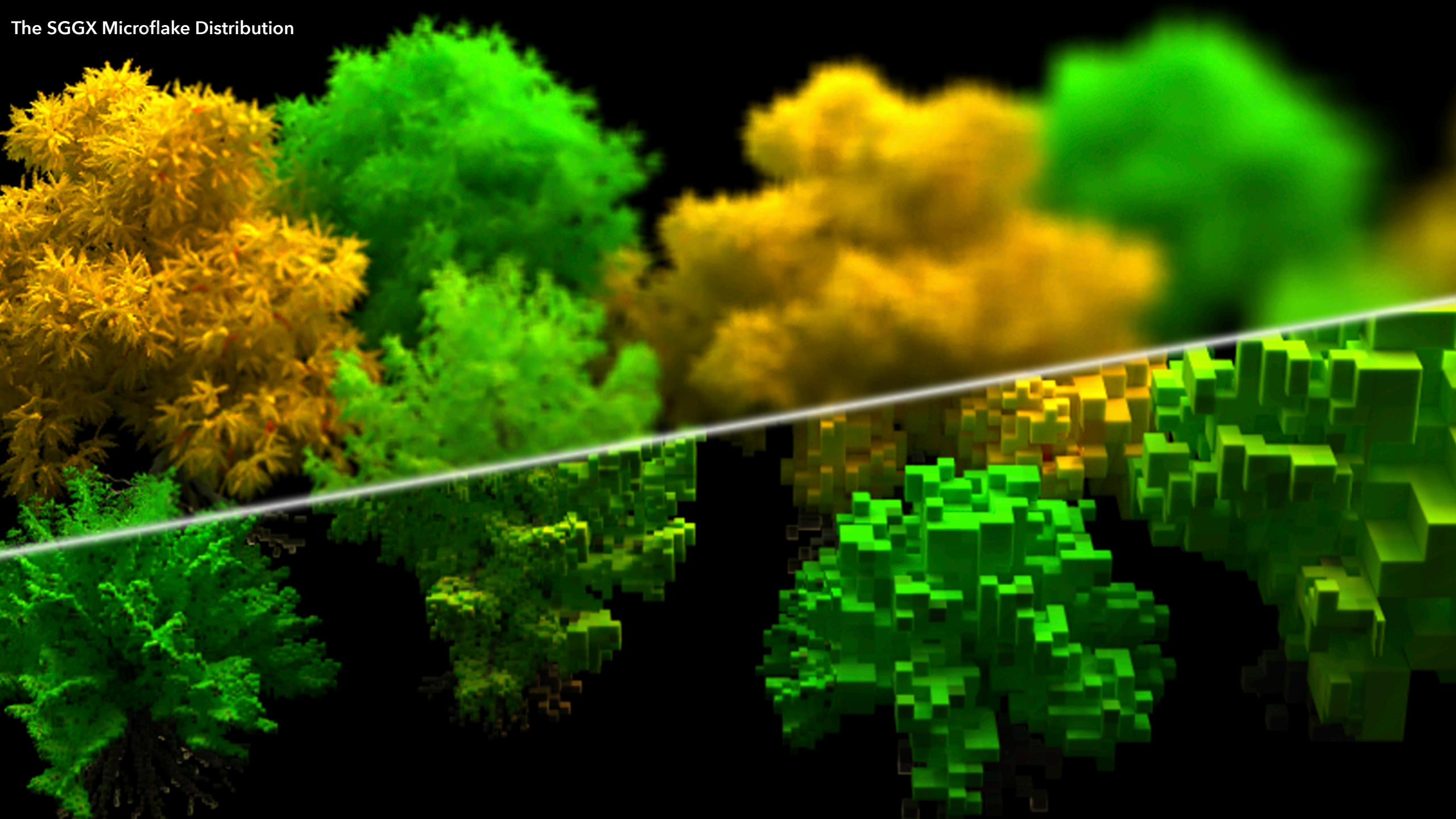

disneyanimation.com/data-sets/?drawer=/resources/clouds/


ospray.org


UAV LiDAR
Scanning System
Application in Historical Relics
Located in Europe

Pathtracing in Production: The Path of Water

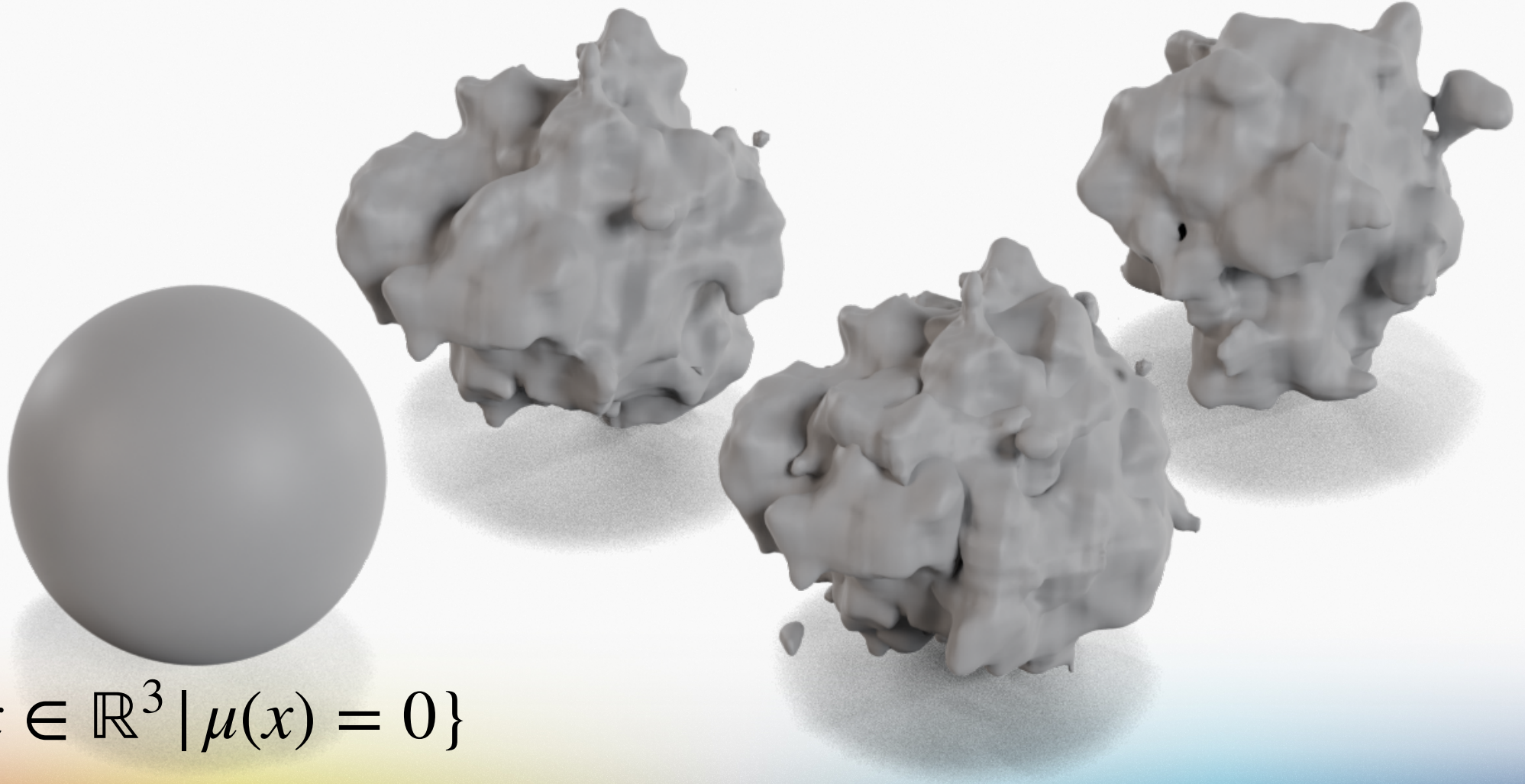
The SGGX Microflake Distribution



Lay the *foundations* for a new *geometry* representation for *surfaces and volumes*.

GAUSSIAN PROCESS IMPLICIT SURFACES (GPIS)

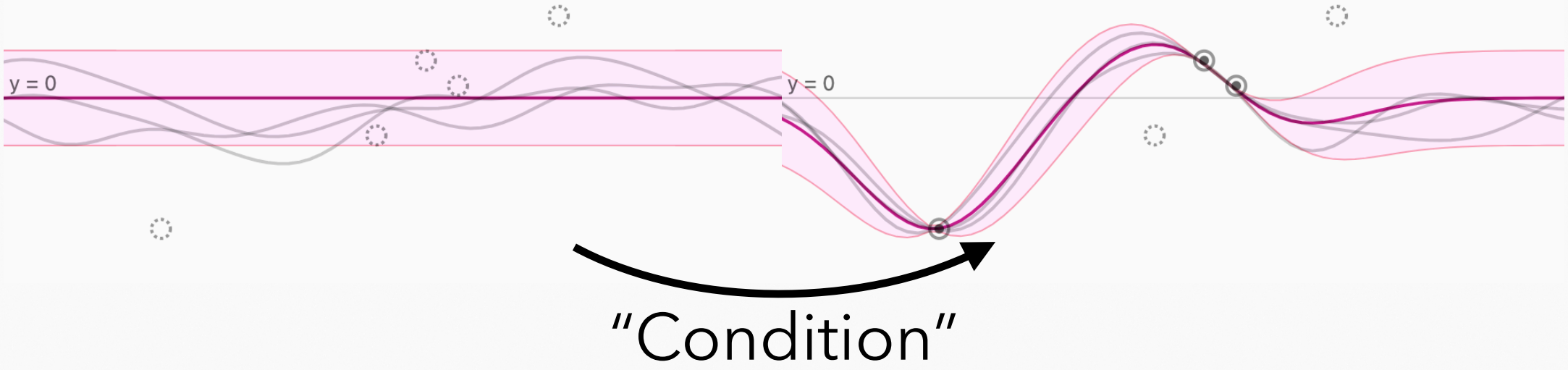
$$\{x \in \mathbb{R}^3 \,|\, f(x) = 0,\ f \sim \mathrm{GP}\}$$



$$\{x \in \mathbb{R}^3 \,|\, \mu(x) = 0\}$$

A SIDE NOTE ON GAUSSIAN PROCESSES (GPS)

A distribution over ***functions***



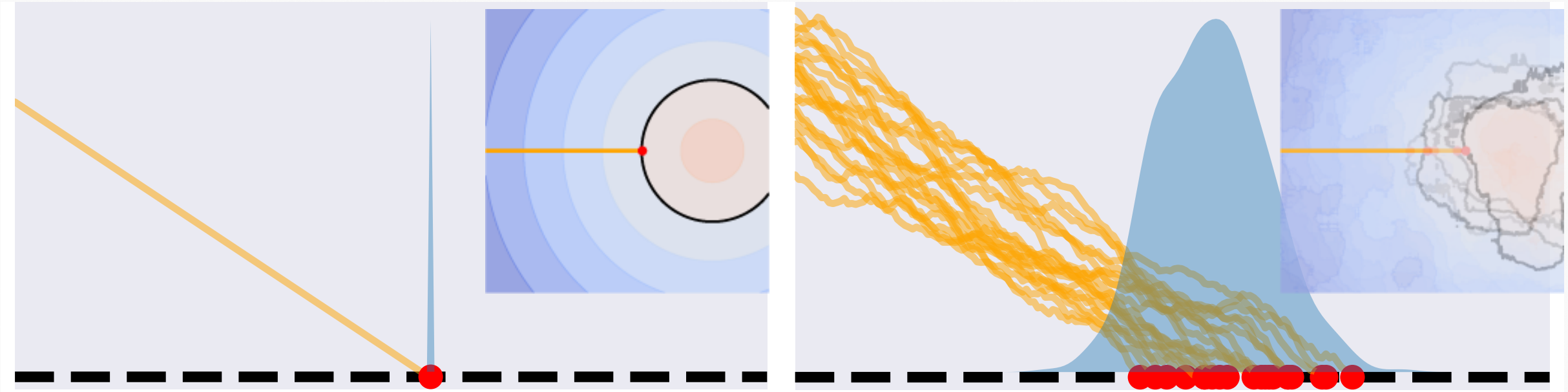
- Completely described by **mean function** and **covariance kernel**
- Closed under **linear transforms** (including derivatives)
- No relation to **Gaussian Splatting™**

distill.pub/2019/visual-exploration-gaussian-processes

GAUSSIAN PROCESS IMPLICIT SURFACES

Implicit Surface

Stochastic Implicit Surface

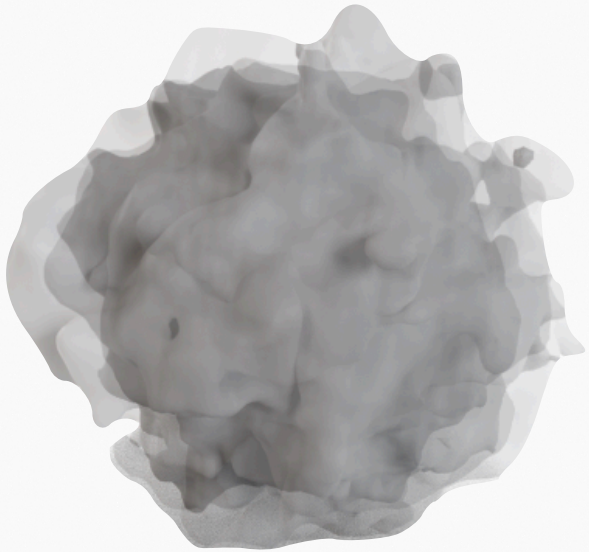


Special Case! $\sigma = 0$

ENSEMBLE AVERAGE LIGHT TRANSPORT

$\mathrm{E}[\mathscr{L}]u$

$\mathrm{E}[\mathscr{L}u]$



Remember: Light Transport is not linear in geometry!

LIGHT TRANSPORT IN STOCHASTIC IMPLICIT SURFACES

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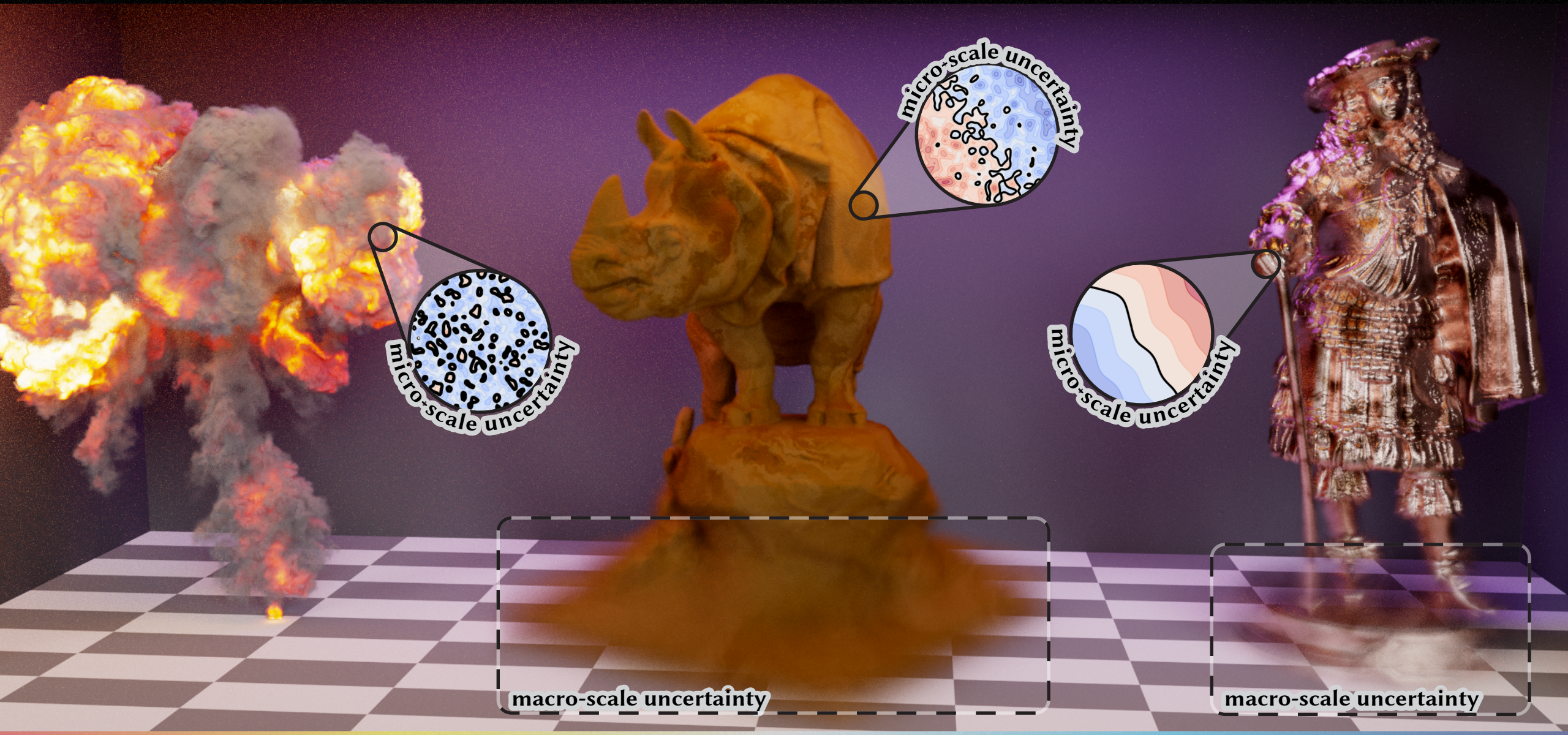

COMPUTING RADIANCE

$$L_i(x, \omega) = \int_{\Omega} L_i(x_s, \omega_s)\rho(x_s, \omega_s, n_s)\mathrm{d}\omega_s$$

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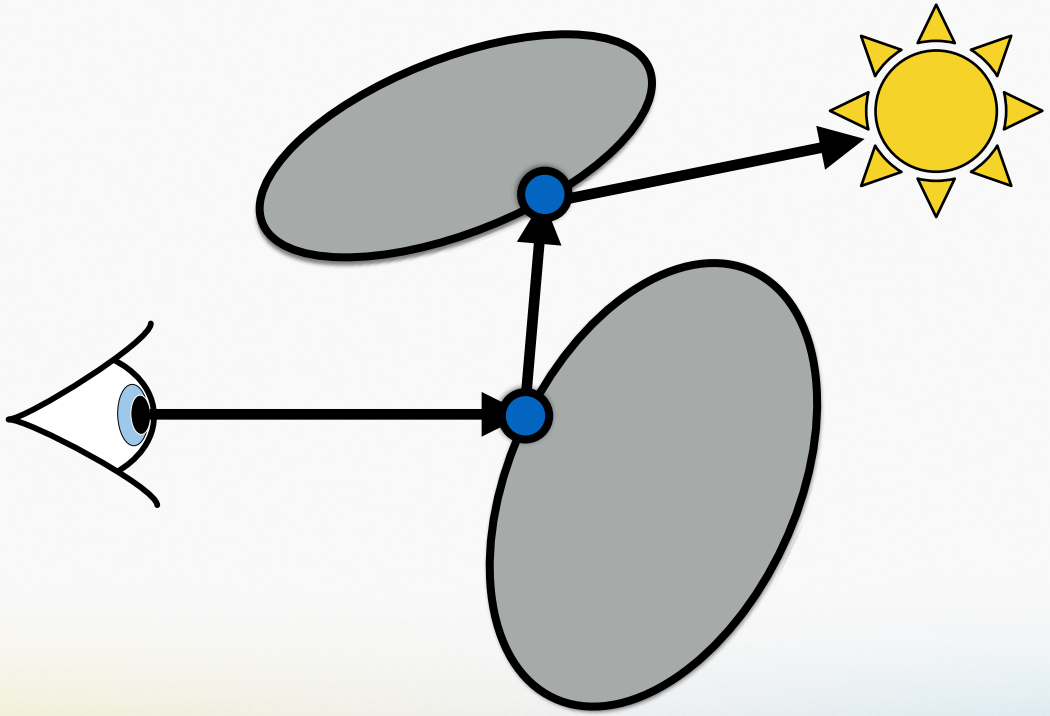
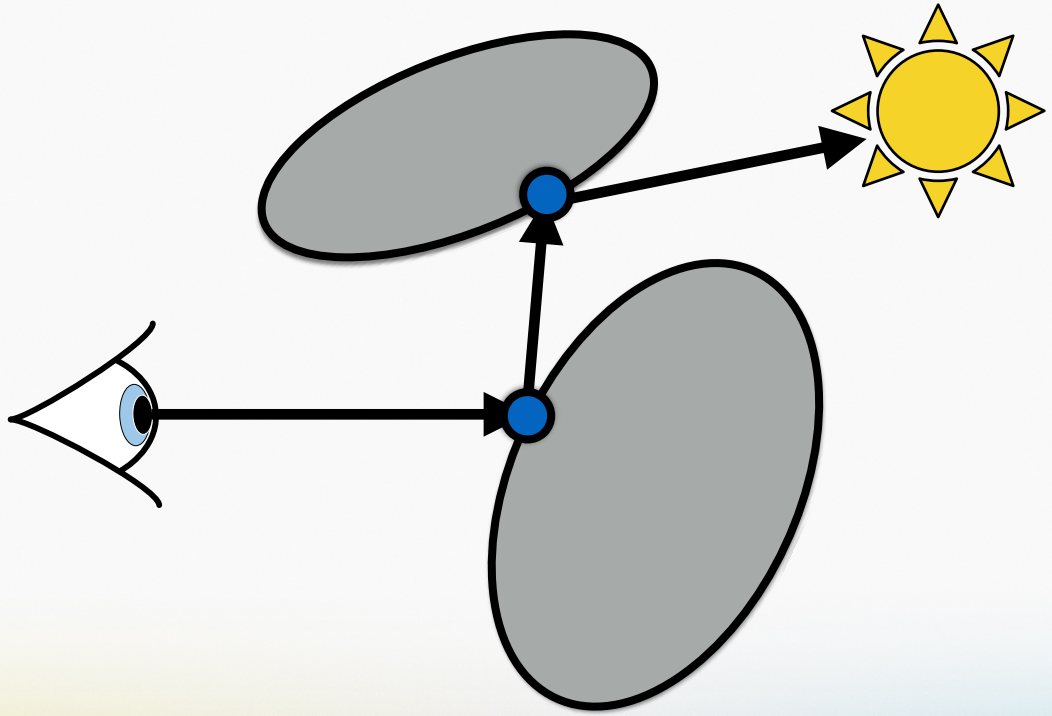


COMPUTING RADIANCE

$$\langle L_i(x,\omega)\rangle_{GP} = \int_{GP}\int_{\Omega} L_i(x_s^f,\omega_s)\rho(x_s^f,\omega_s,n_s^f)\mathrm{d}\omega_s\mathrm{d}\gamma(f)$$



COMPUTING *ENSAMBLE* RADIANCE

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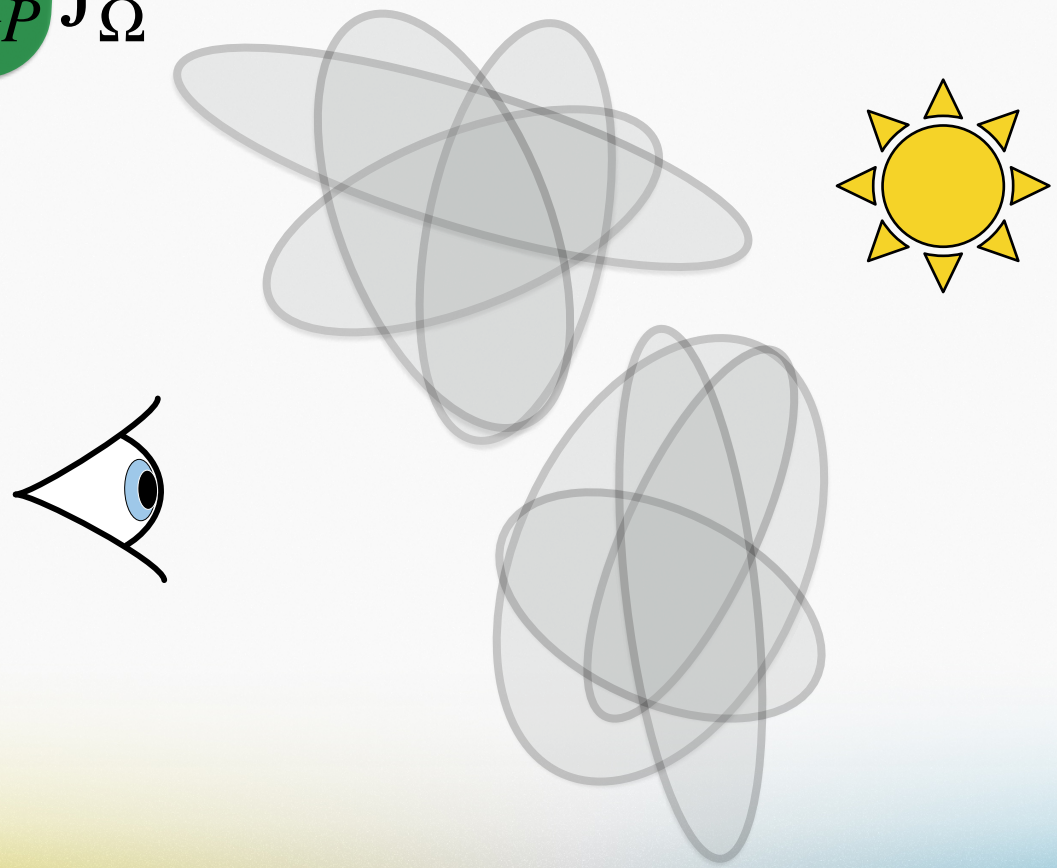

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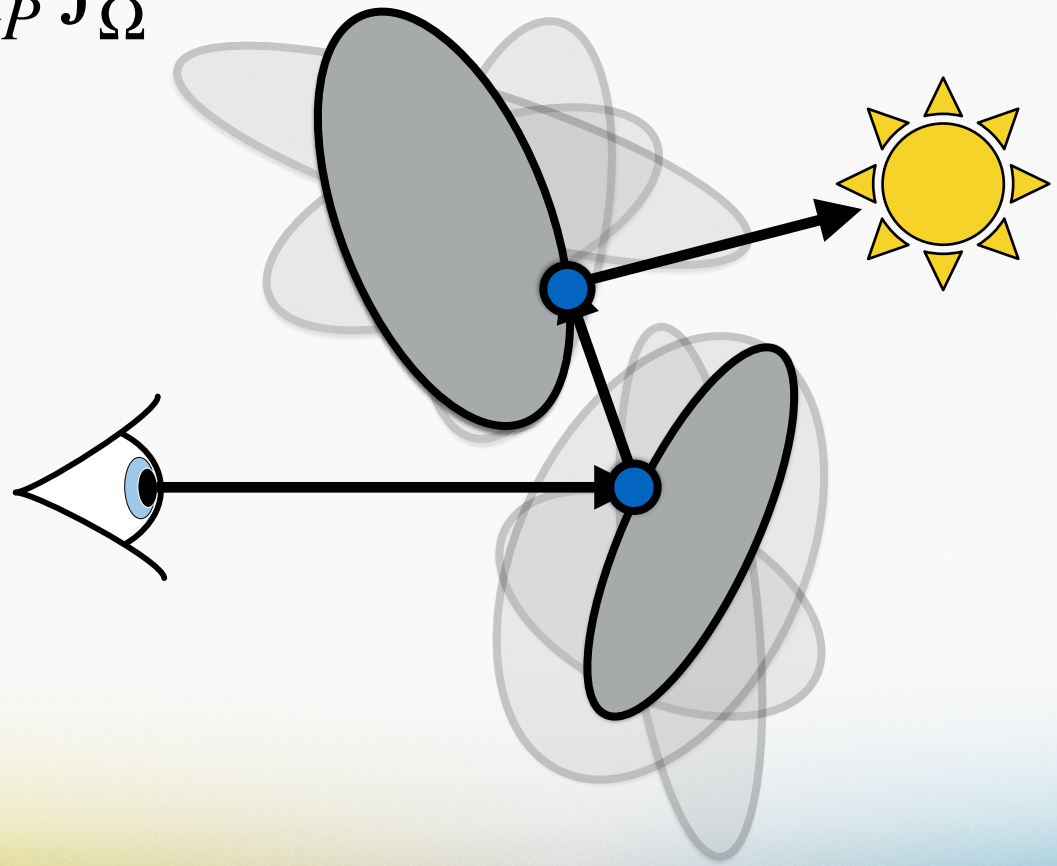

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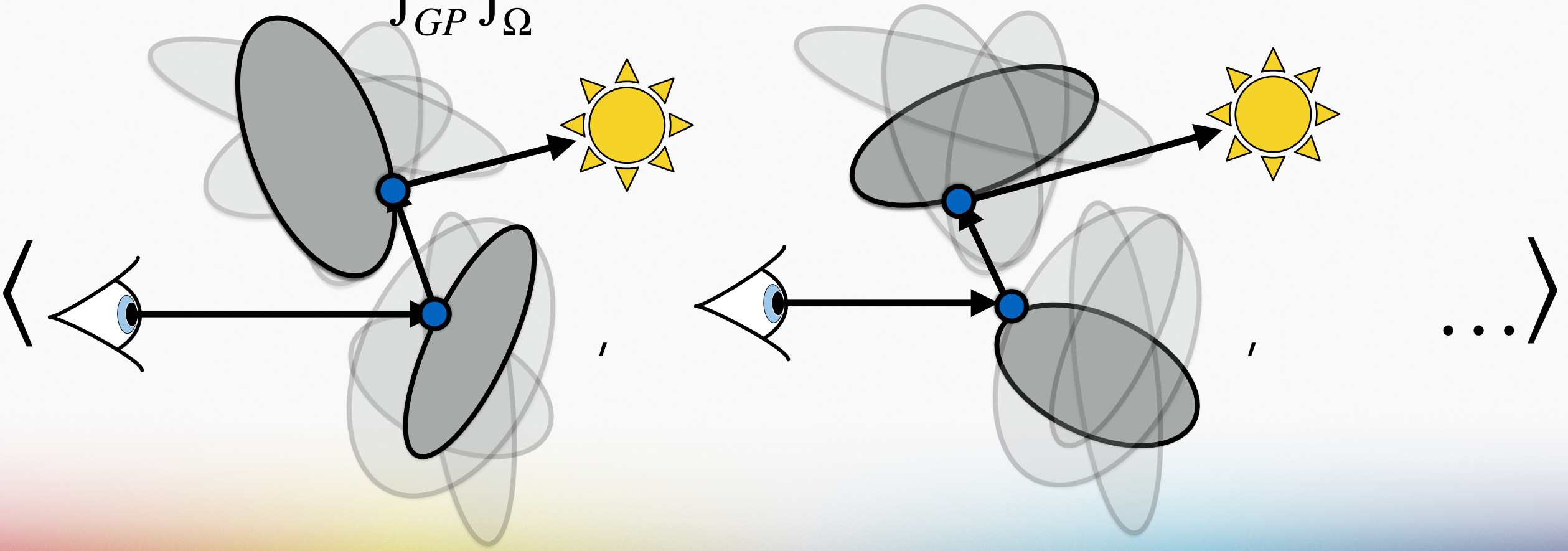

COMPUTING *ENSAMBLE* RADIANCE

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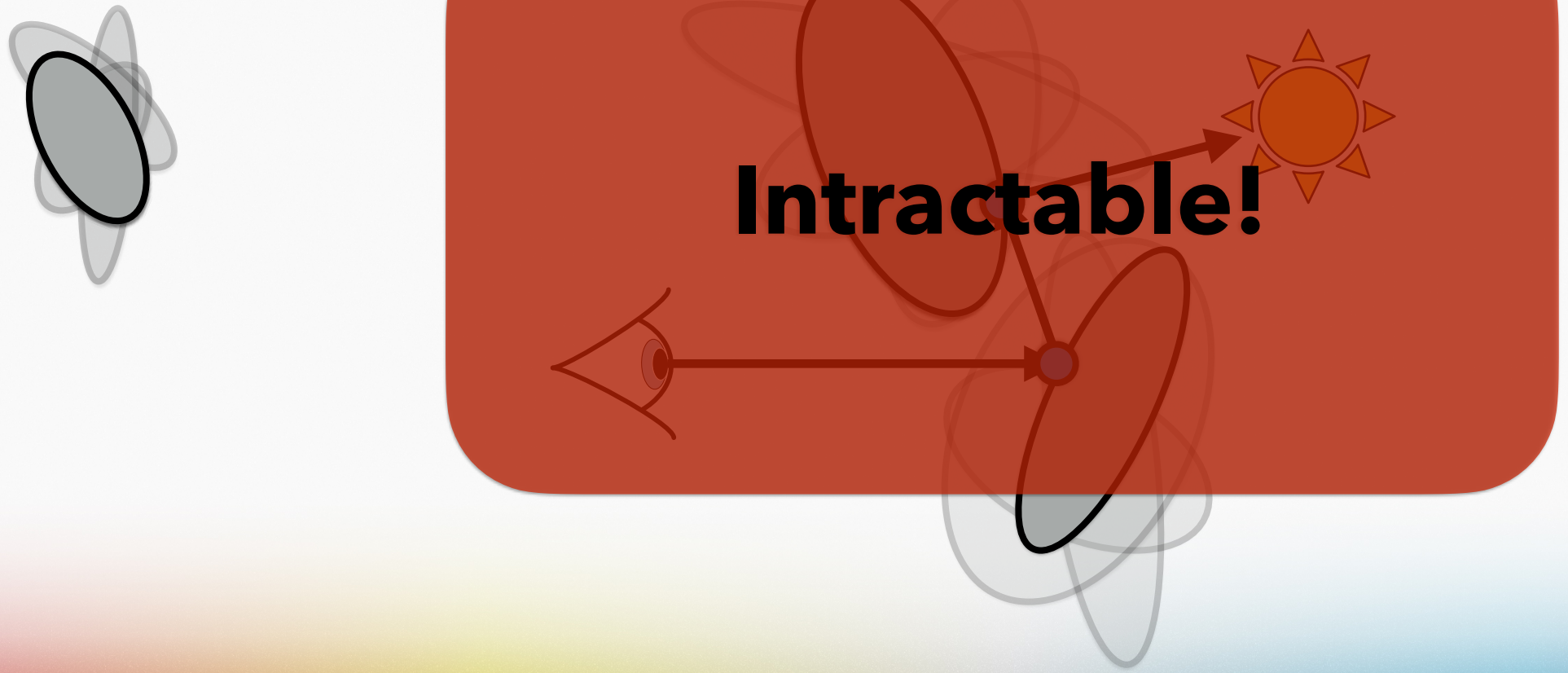
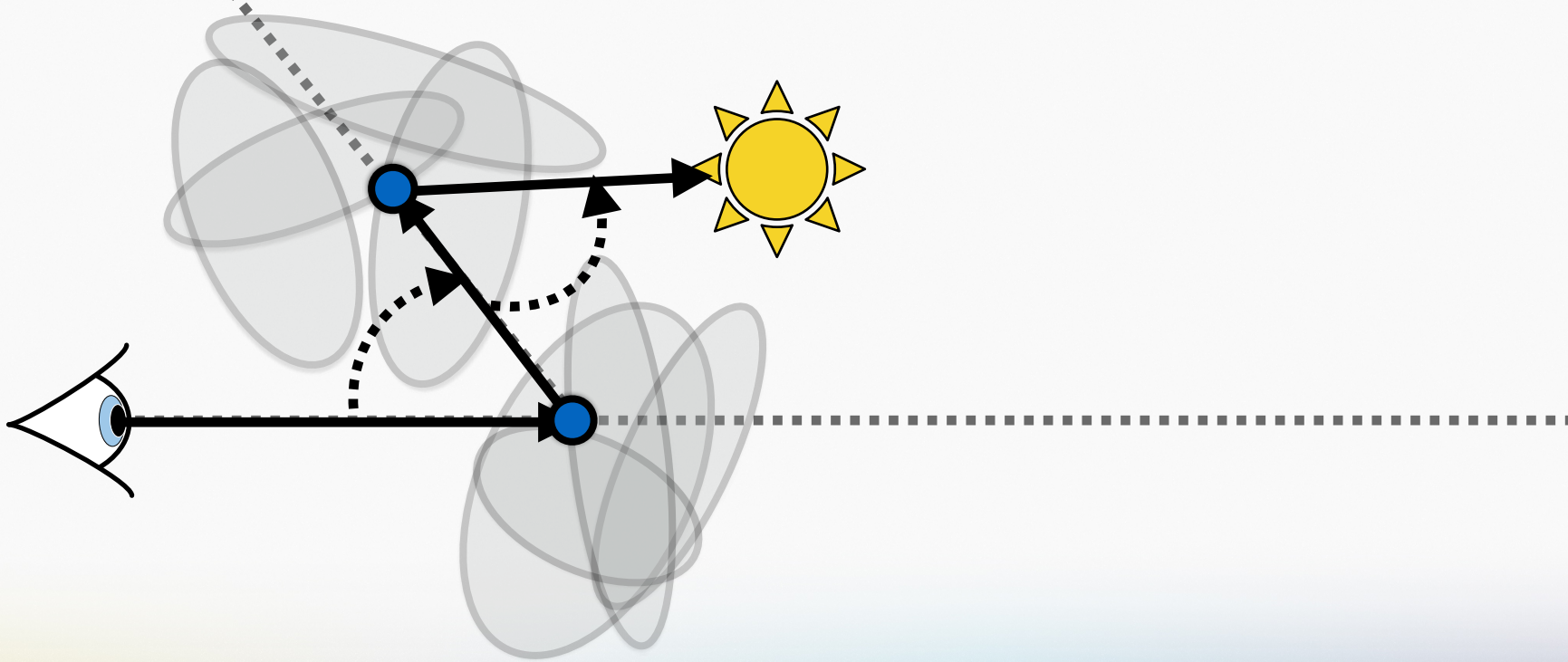
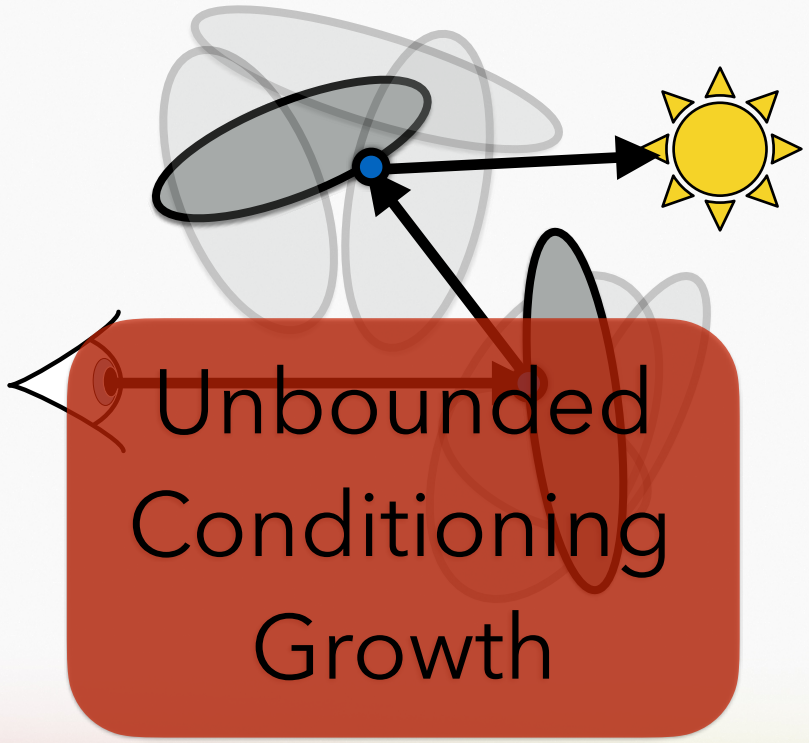


ENSAMBLE RADIANCE

$$\langle L_i(x,\omega)\rangle_{GP} = \int_0^\infty \iiint \langle L_i(x_s,\omega_s)\rangle_{|x_s n_s} \rho(x_s,\omega_s,n_s) p(x,\omega;x_s,n_s) \mathrm{d}\omega_s \mathrm{d}n_s \mathrm{d}s$$

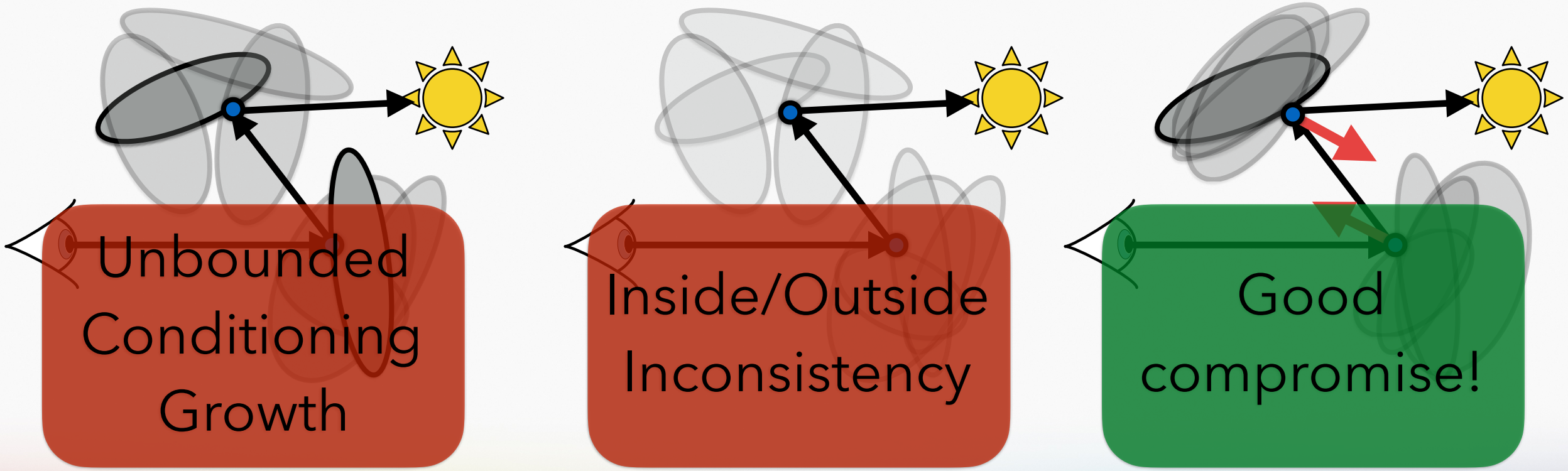


Globally Consistent

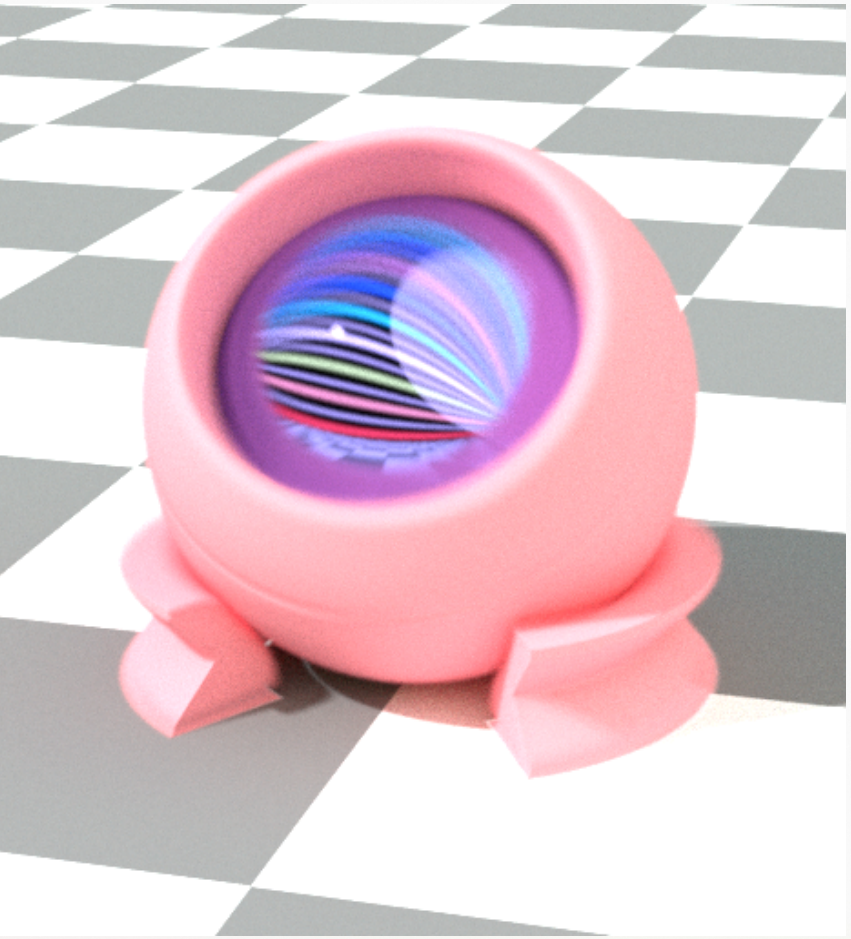


PROCESS MEMORY MODELS

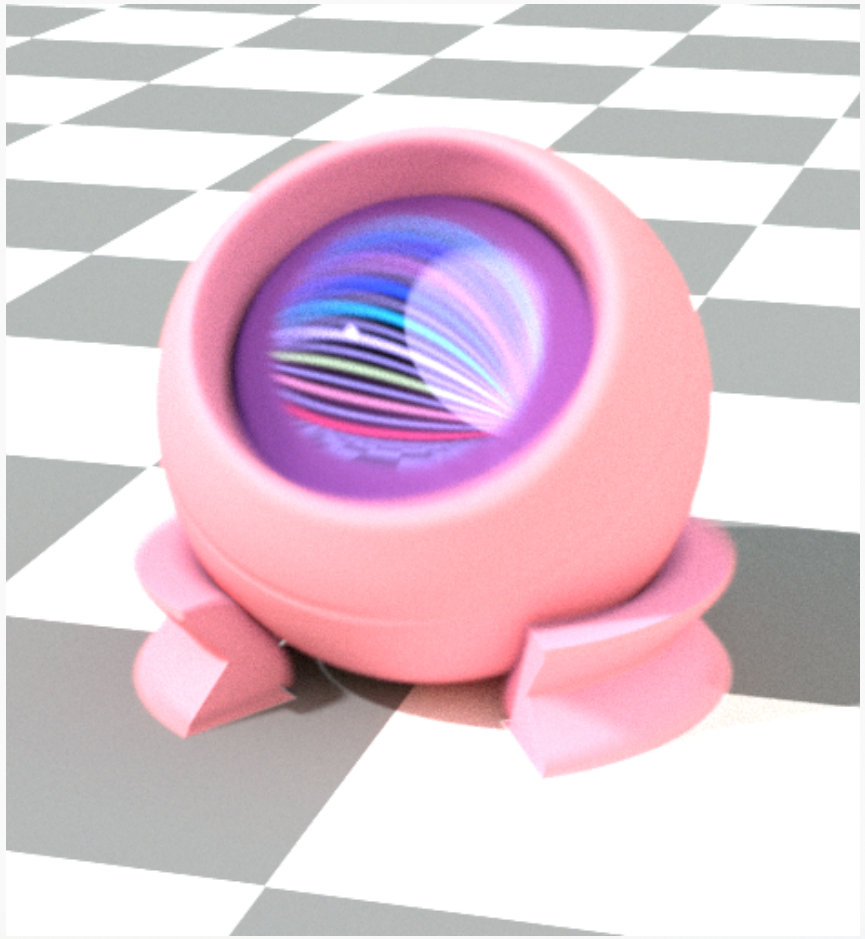
Globally Consistent Position Consistent +Normal Consistent



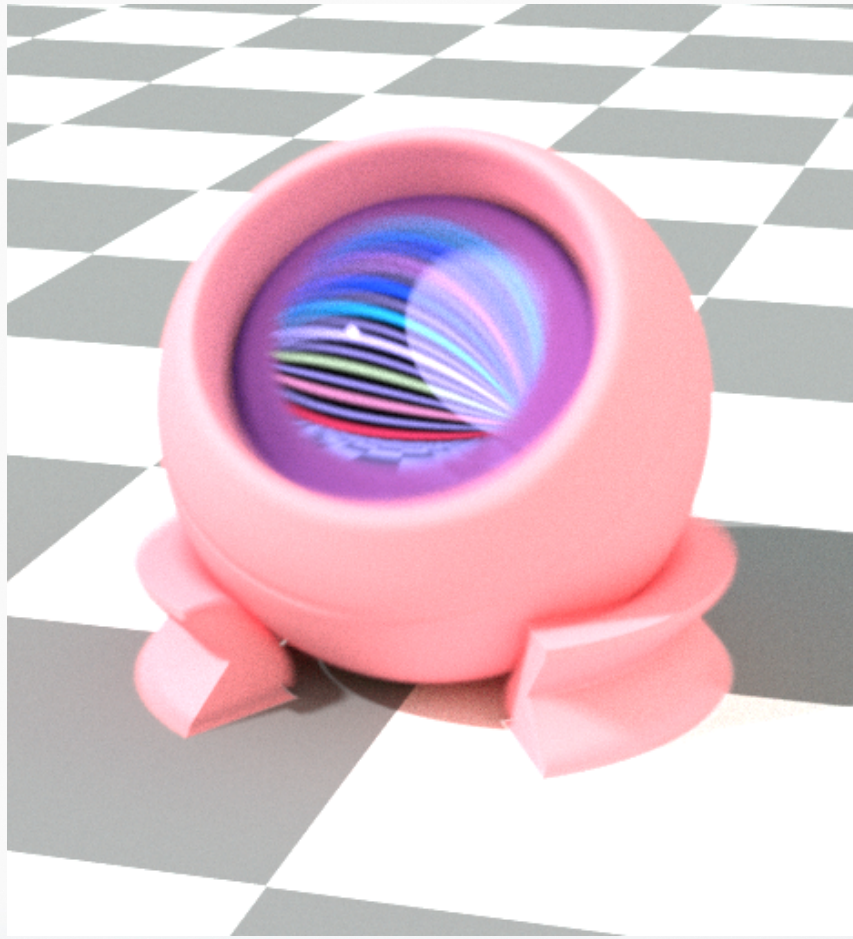
PROCESS MEMORY MODELS



Global



Position



Position+Normal

PROCESS MEMORY MODELS

Global

Position

Position+Normal

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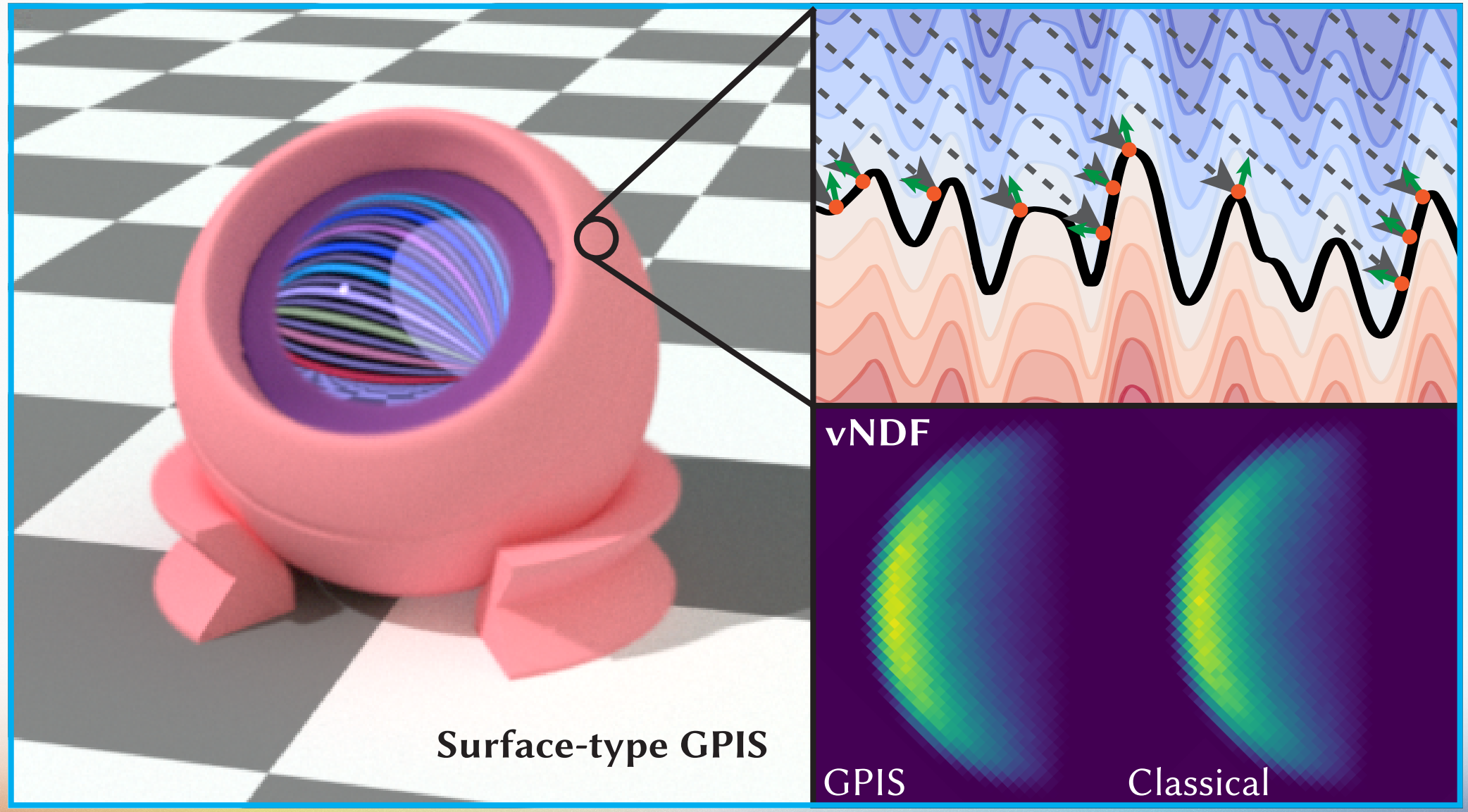
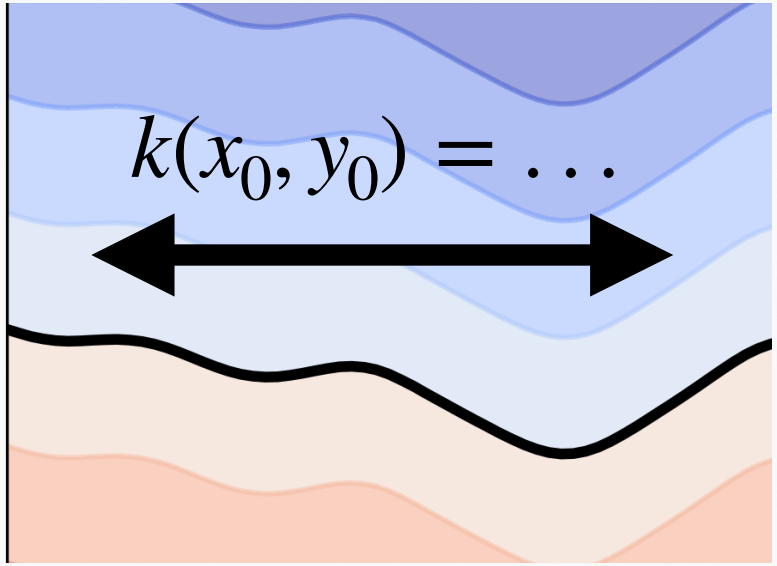
APPEARANCE SPACE OF STOCHASTIC IMPLICITS

SURFACE-TYPE GPISES INCLUDE MICROFACET SURFACES



2D heightfields are the special case!



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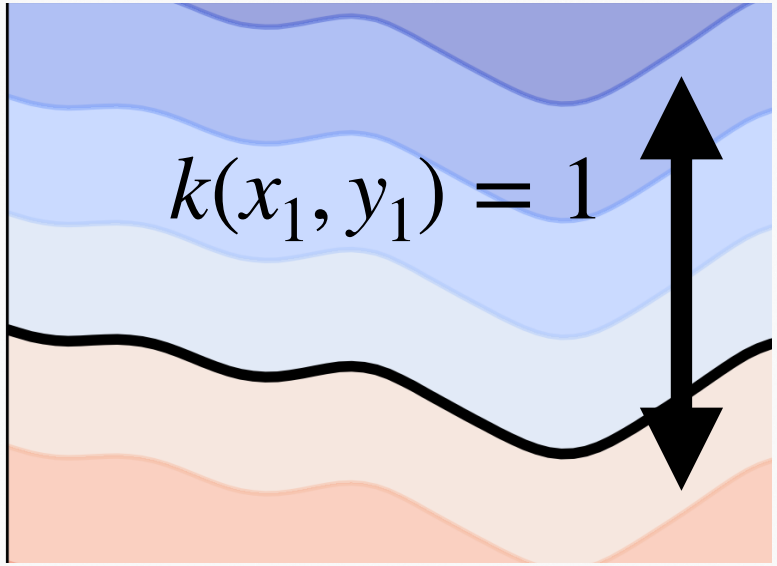
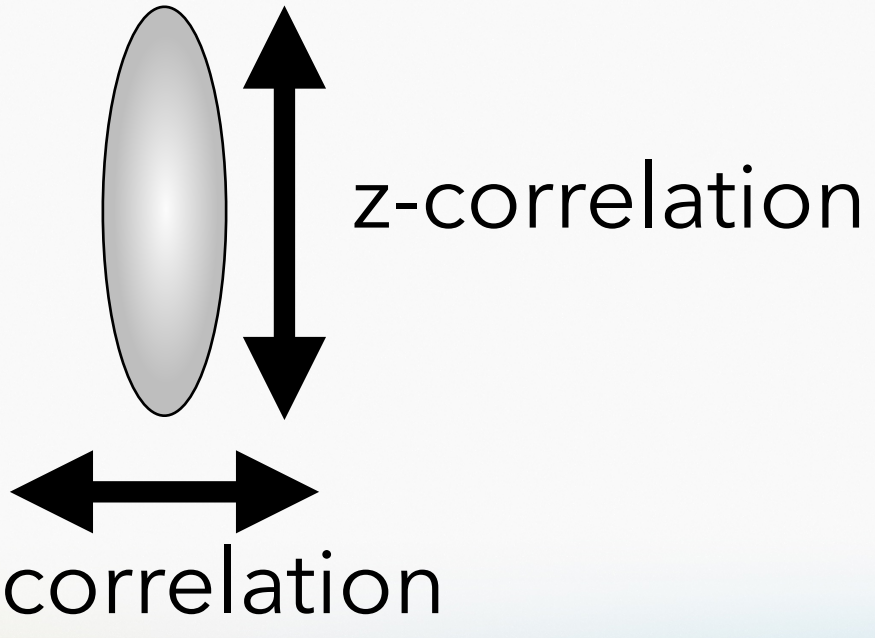
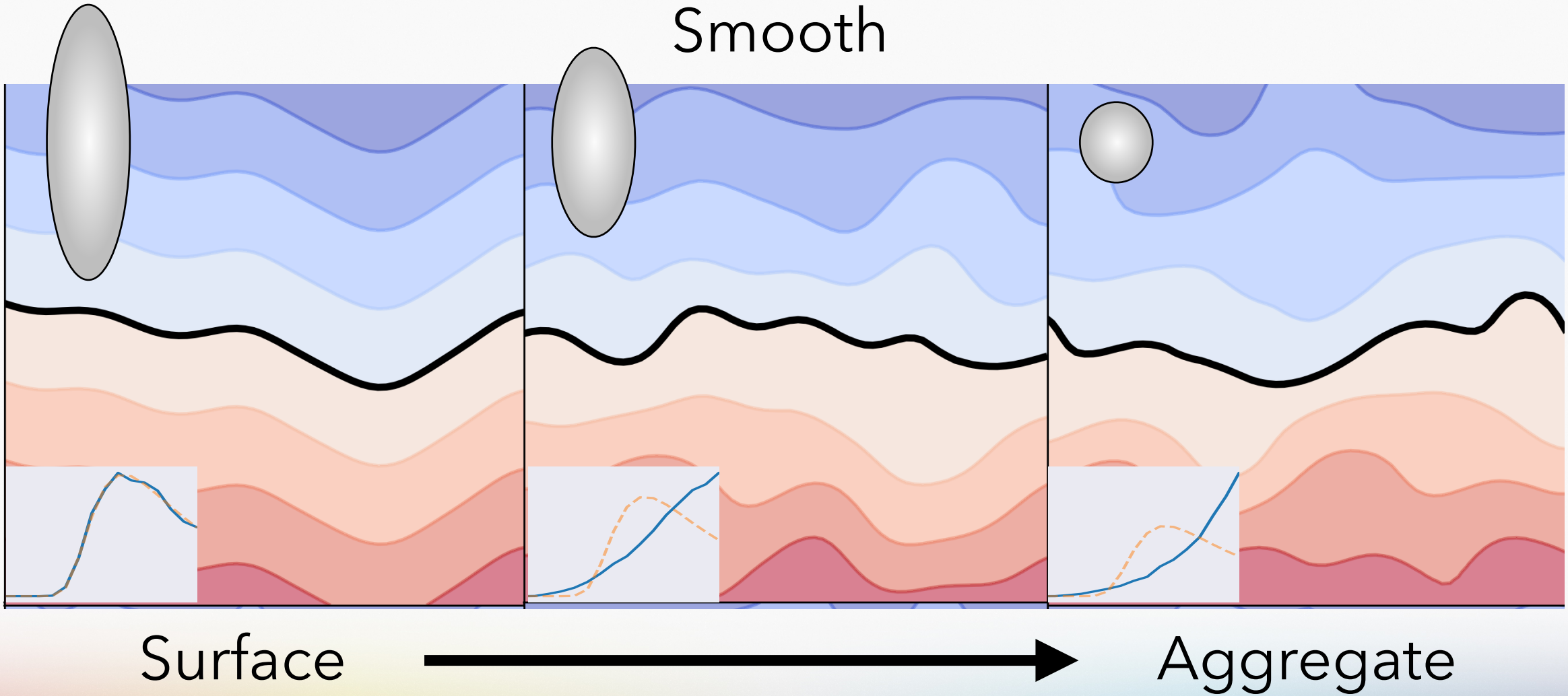
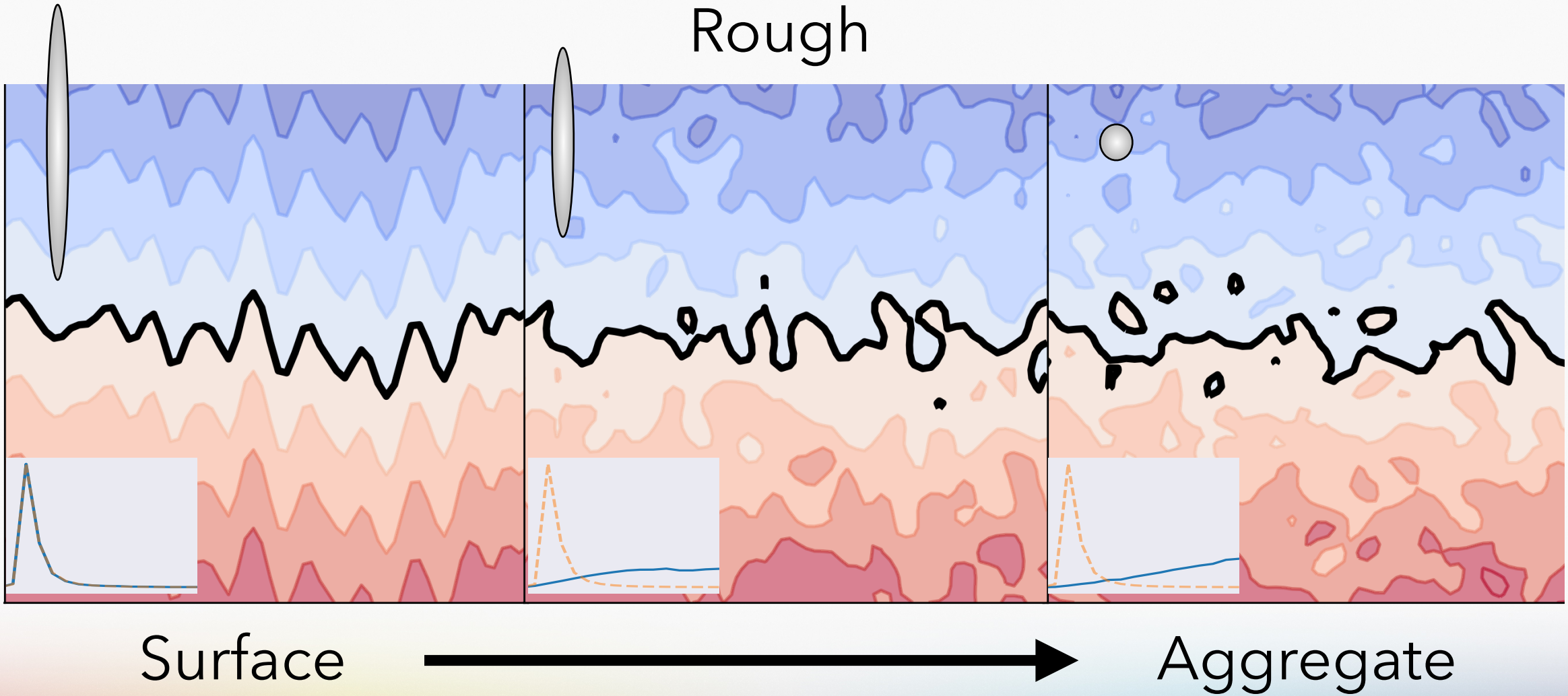




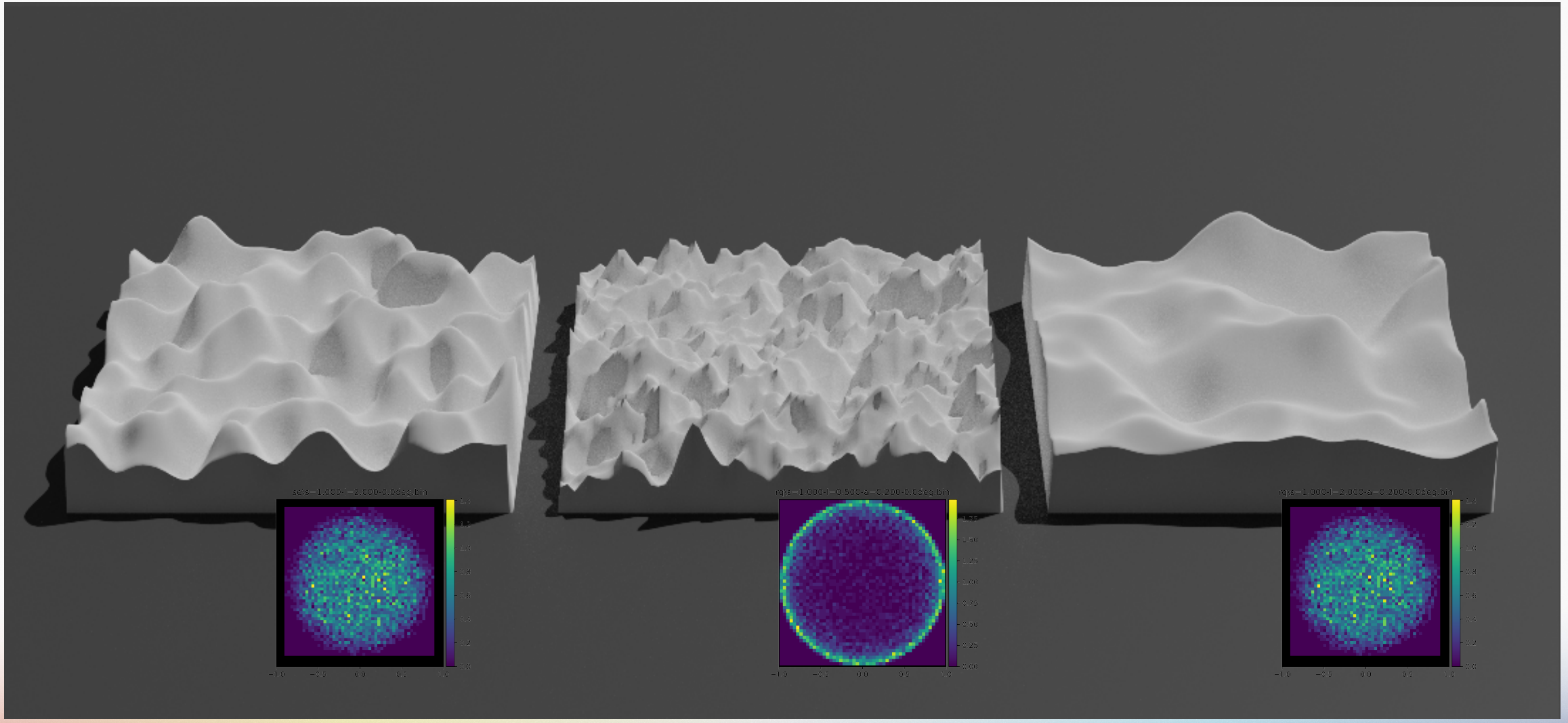
CONNECTIONS TO MICROFACET THEORY



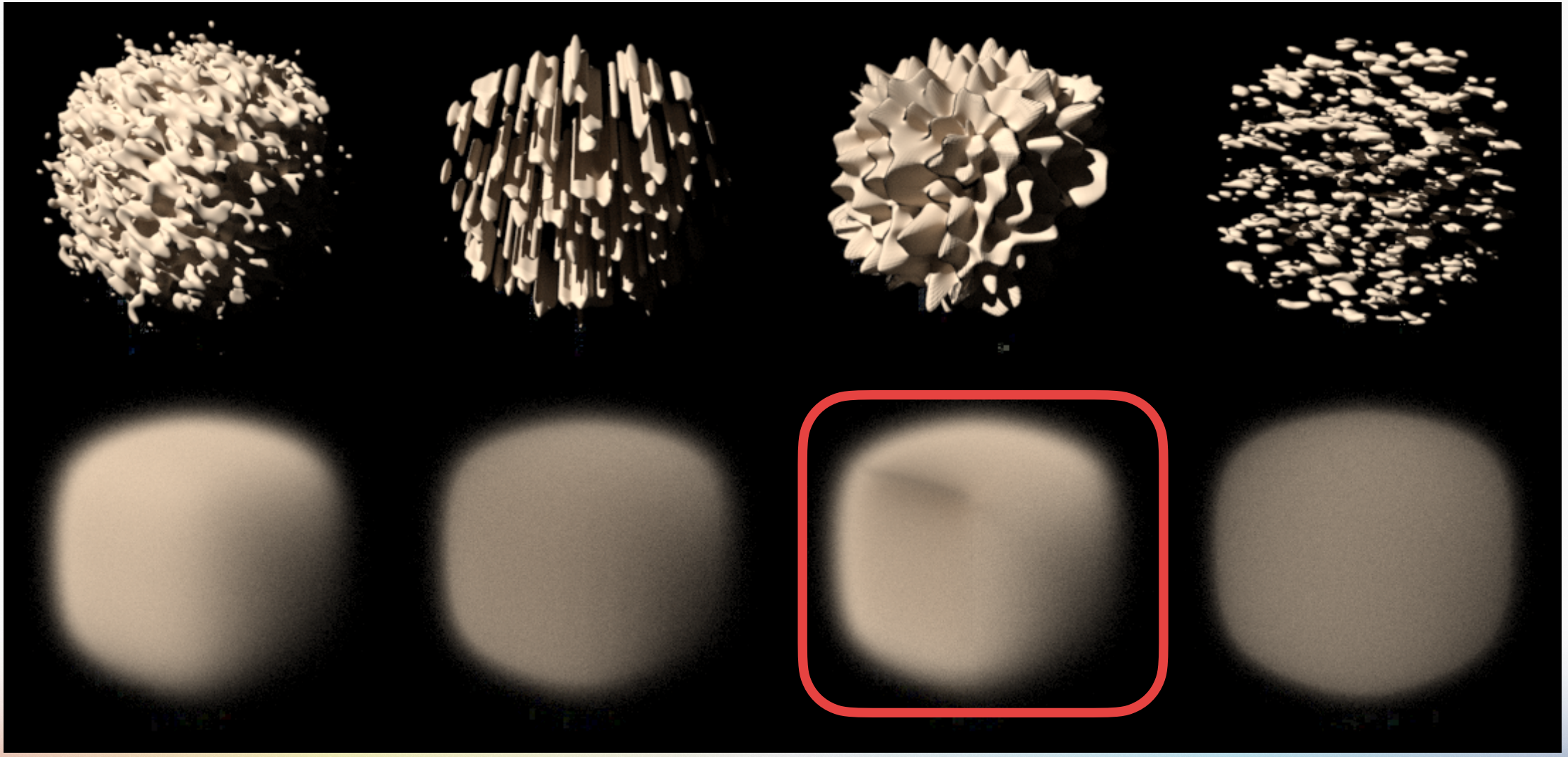
CONNECTIONS TO MICROFACET THEORY



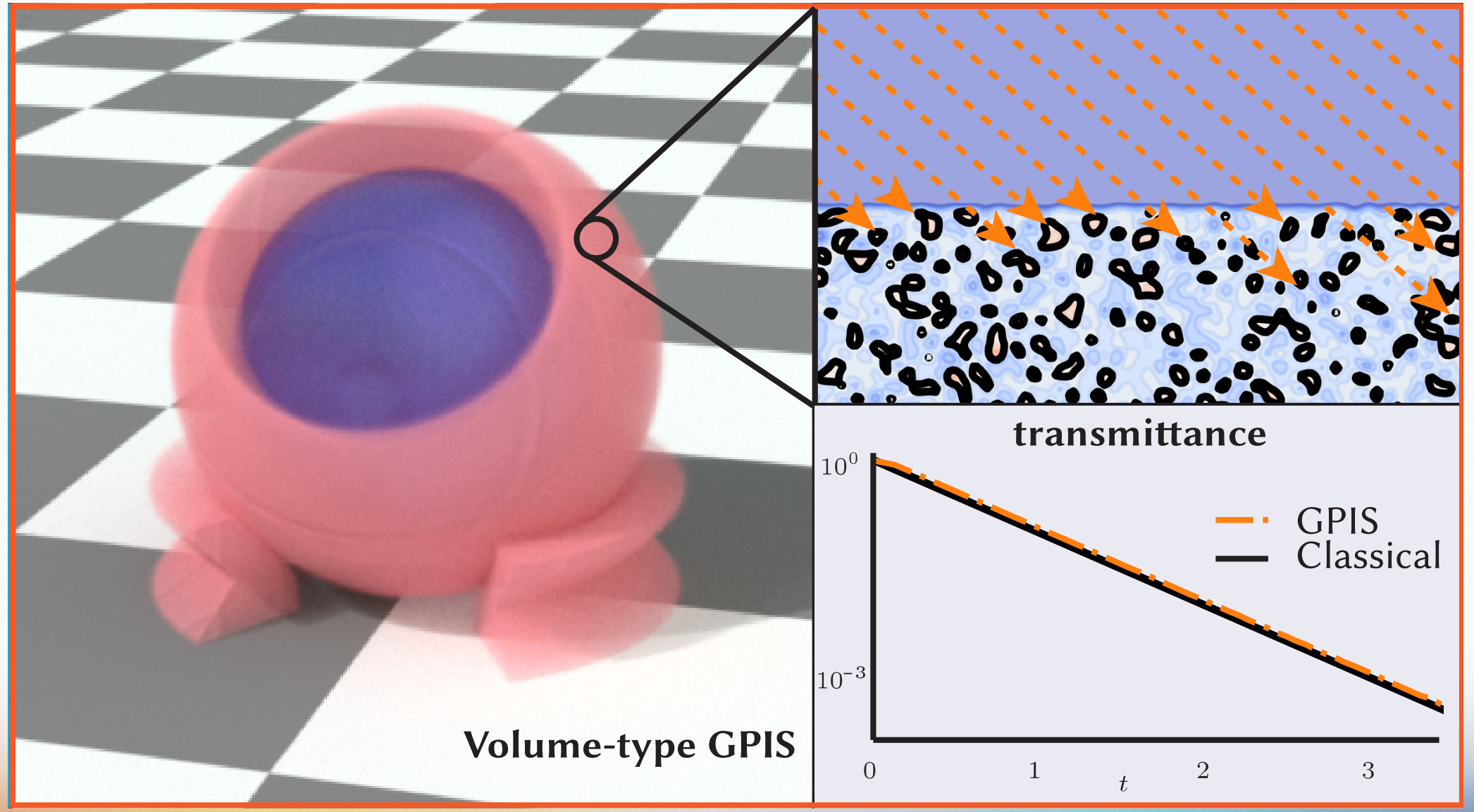
GENERATE SURFACES WITH GIVEN NDFS



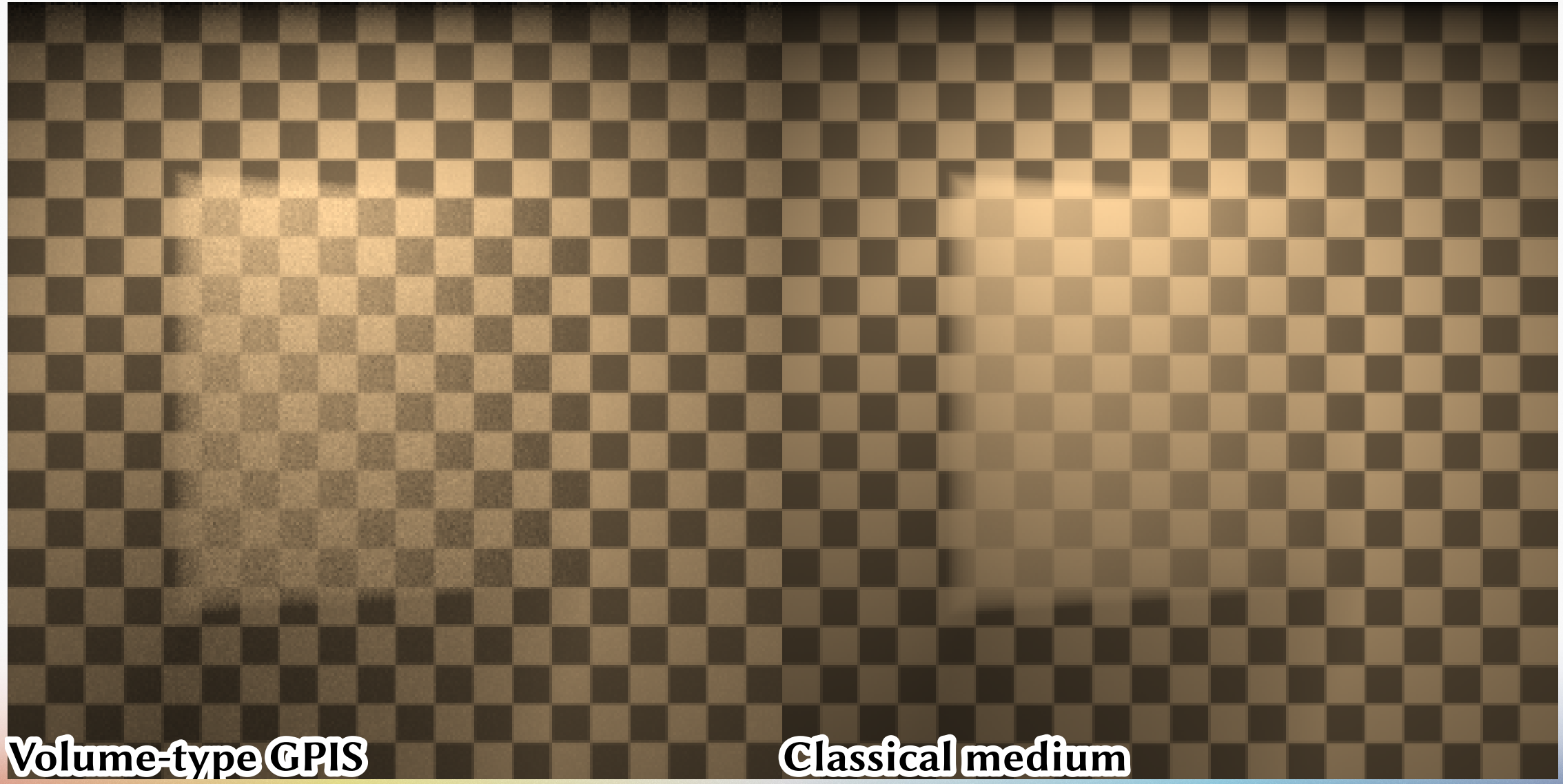
OR LOOK AT MORE GENERAL GEOMETRY!



VOLUME-TYPE GPIS APPROXIMATE CLASSICAL MEDIA



CONNECTIONS TO PARTICIPATING MEDIA



A NON-STATIONARY GPIS MODEL

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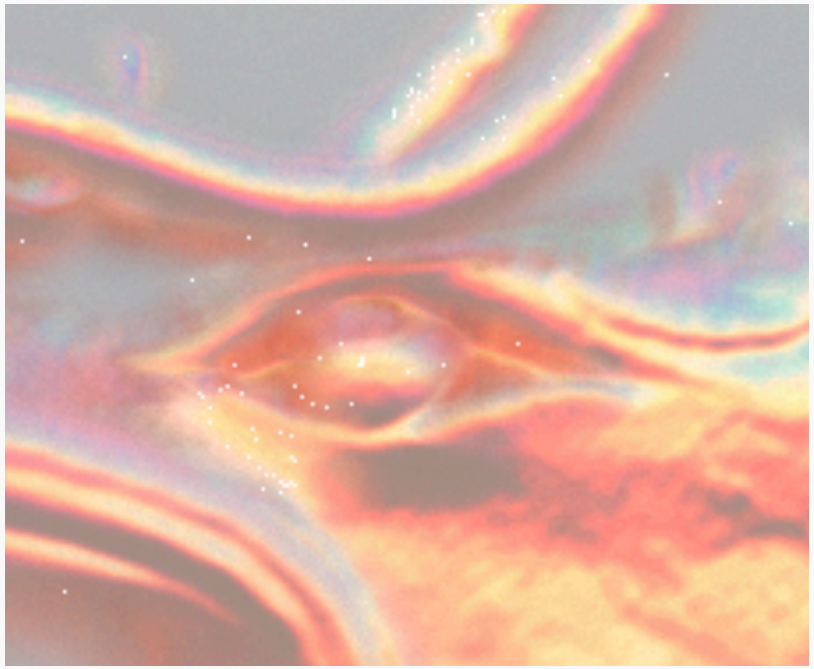
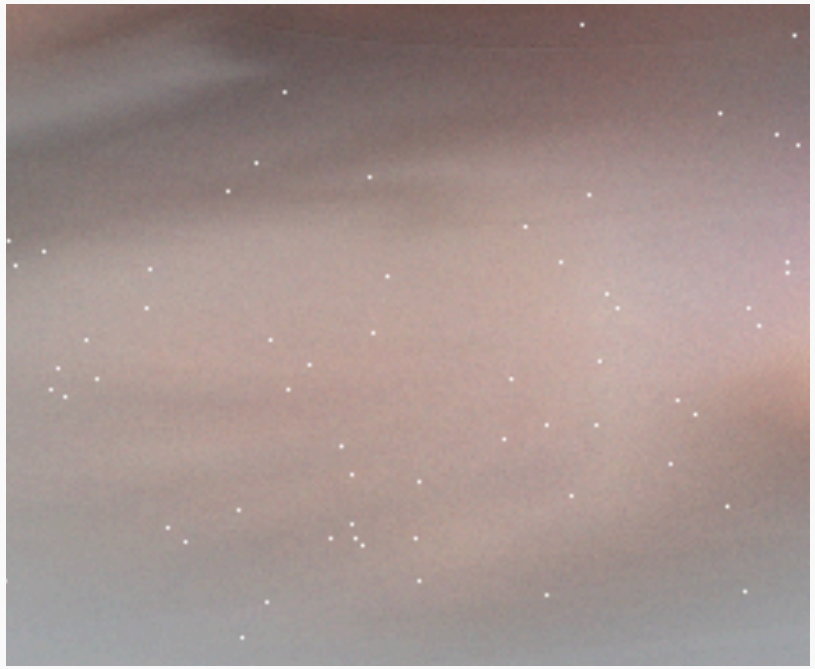


Surface

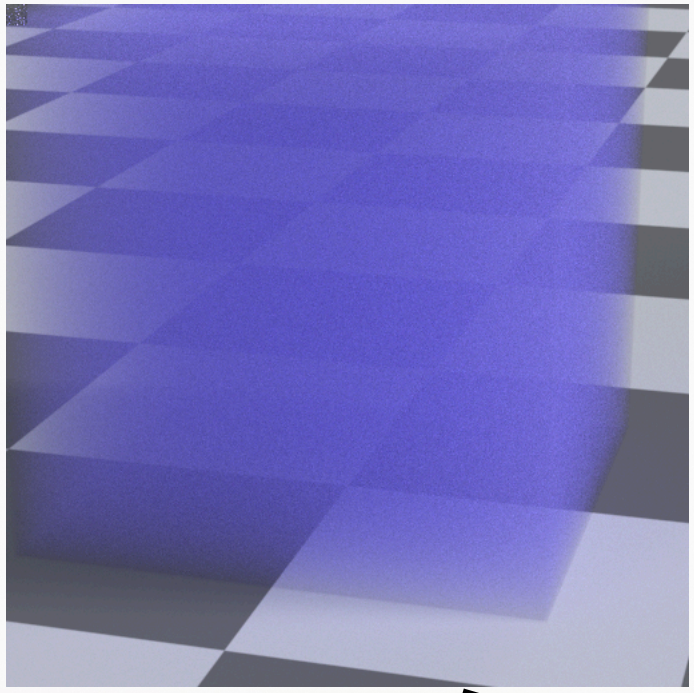


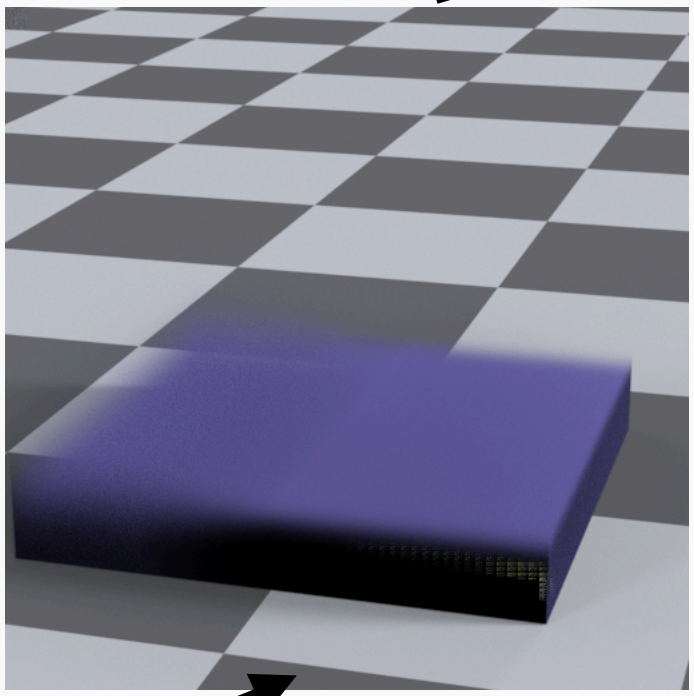
Volume

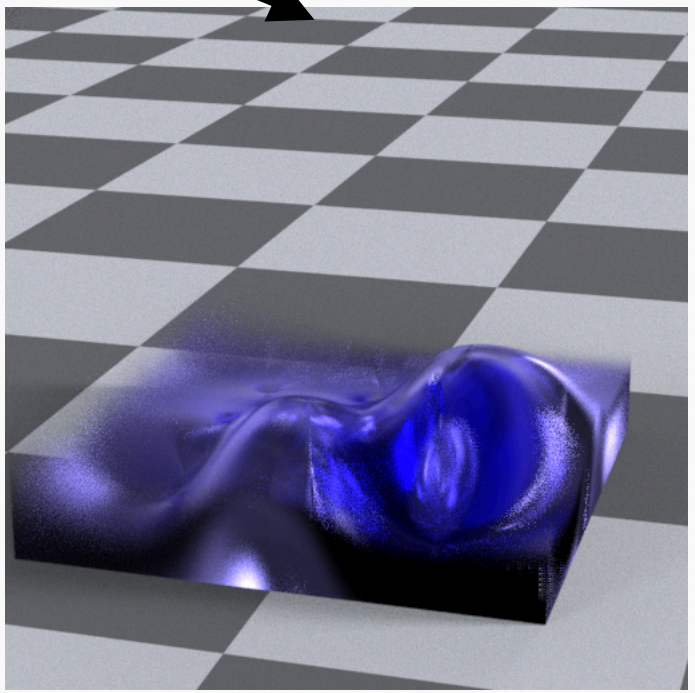
“Motion Blur”

MANUAL EDITING

"posterior editing"

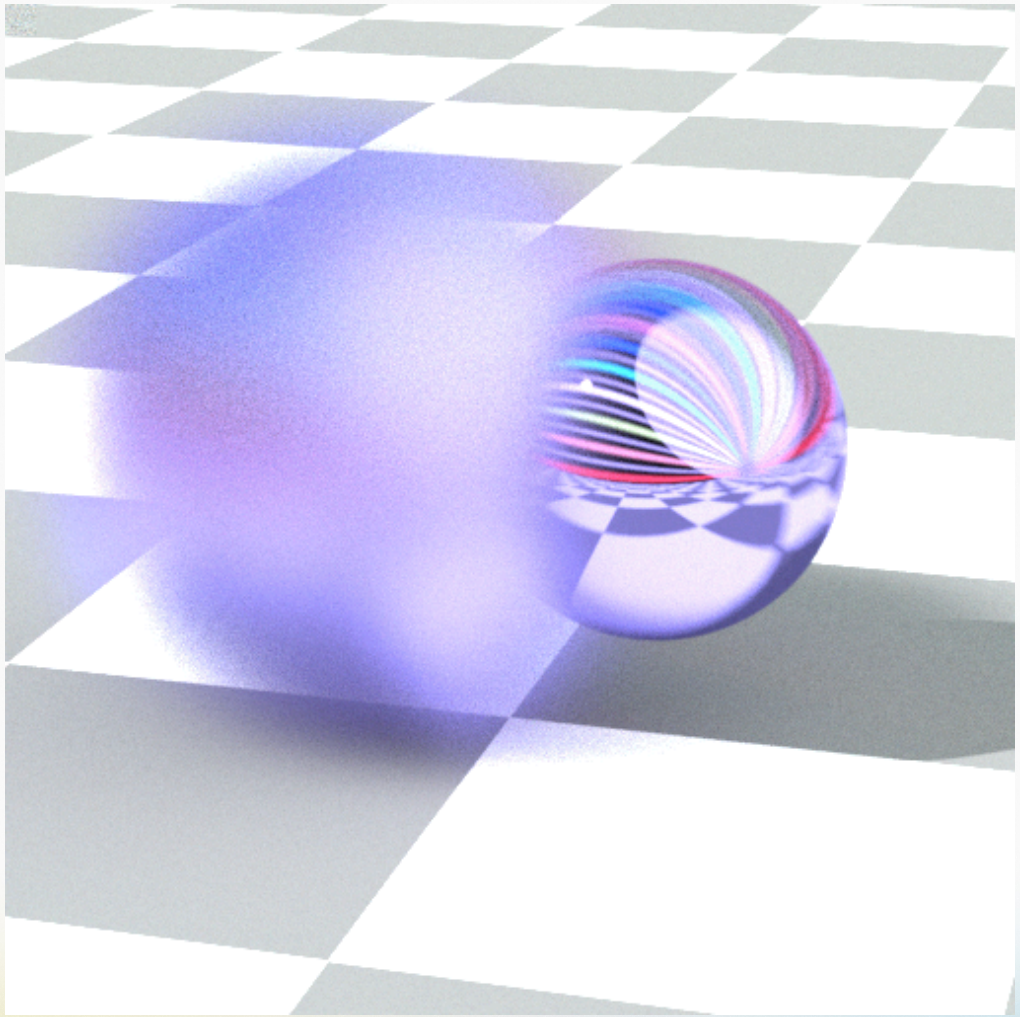




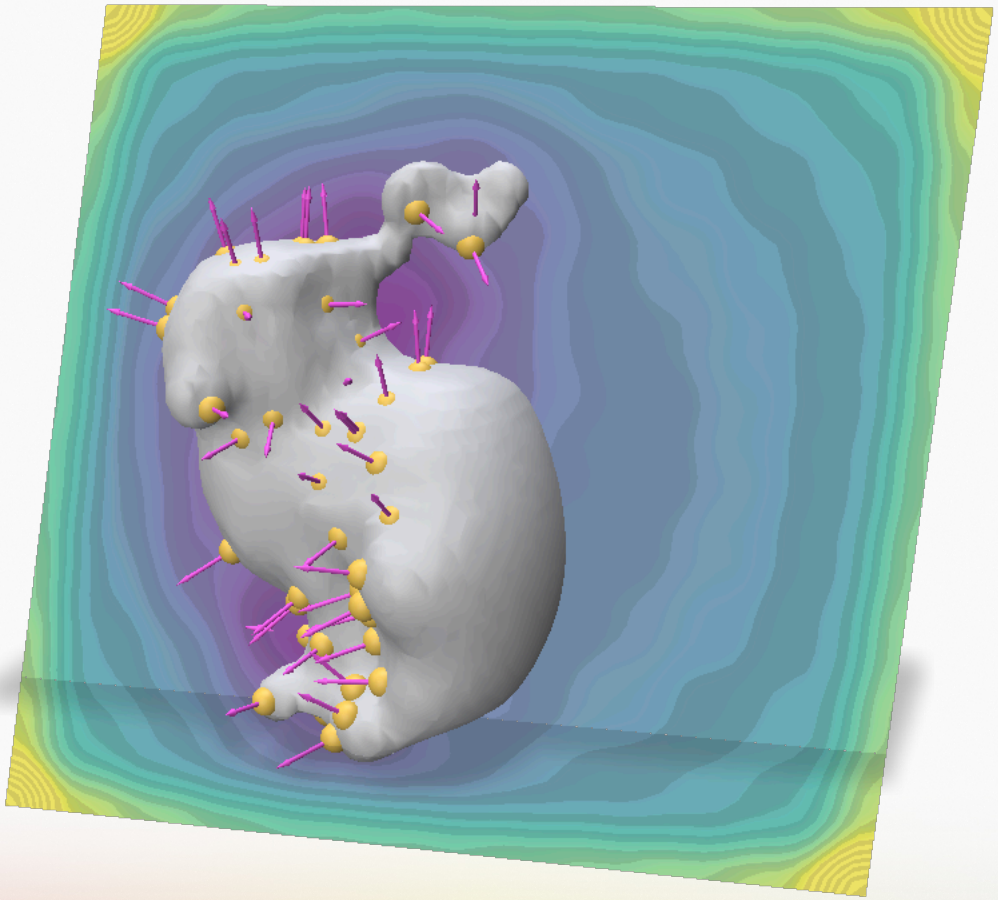


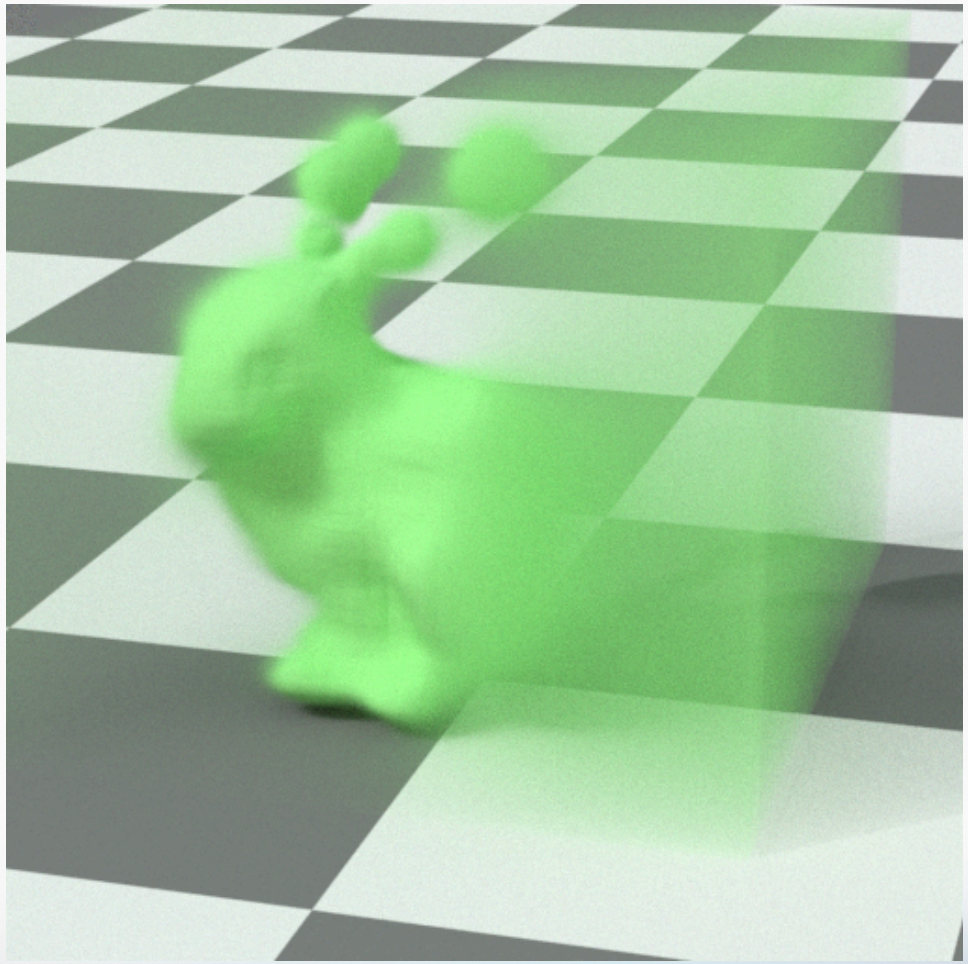
"prior editing"

STOCHASTIC CONSTRUCTIVE SOLID GEOMETRY



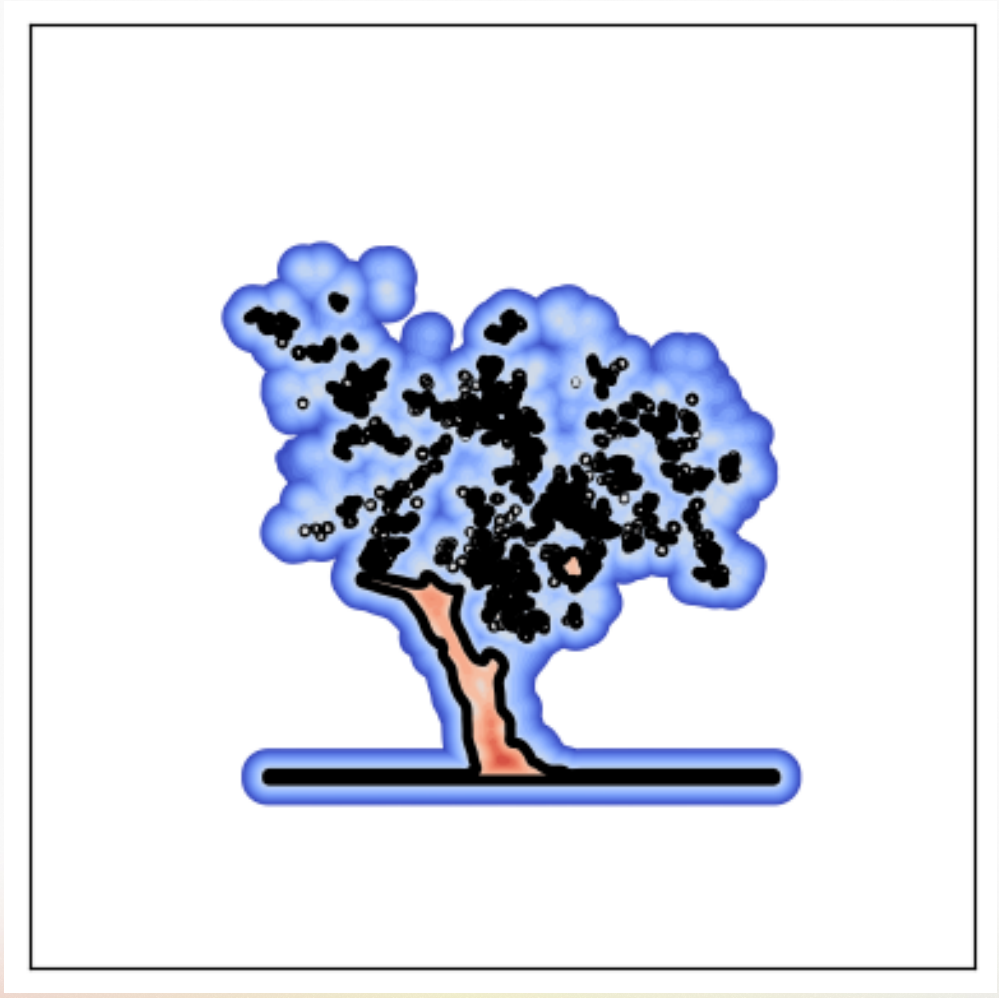
STOCHASTIC POISSON SURFACE RECONSTRUCTION

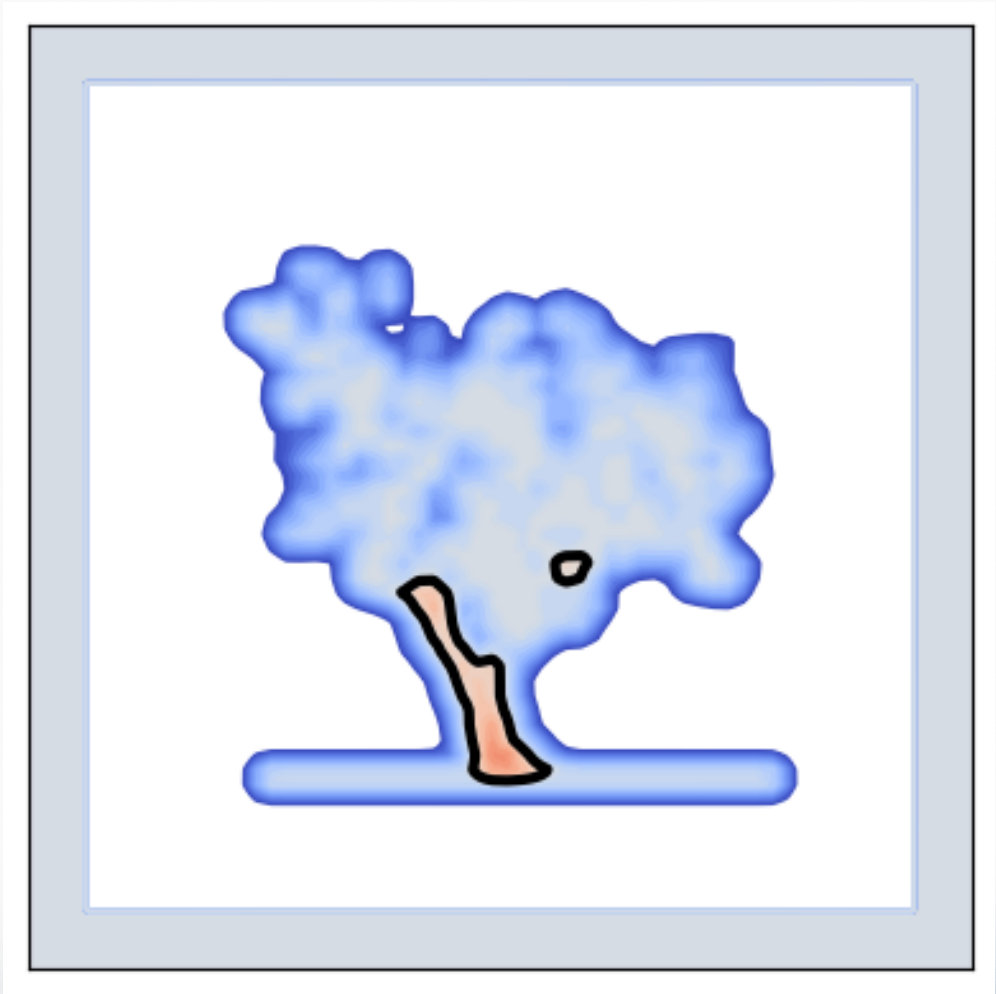




FILTERING IMPLICIT SURFACES

FILTERING IMPLICIT SURFACES





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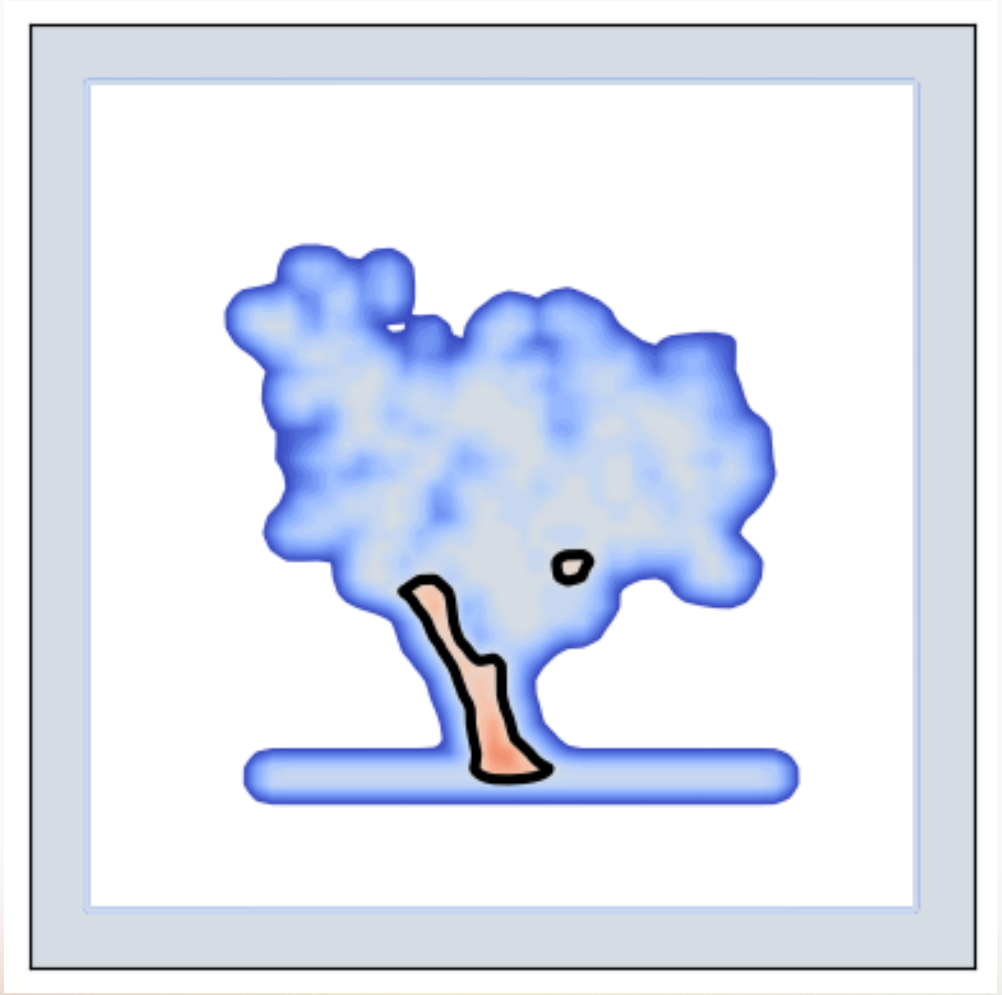
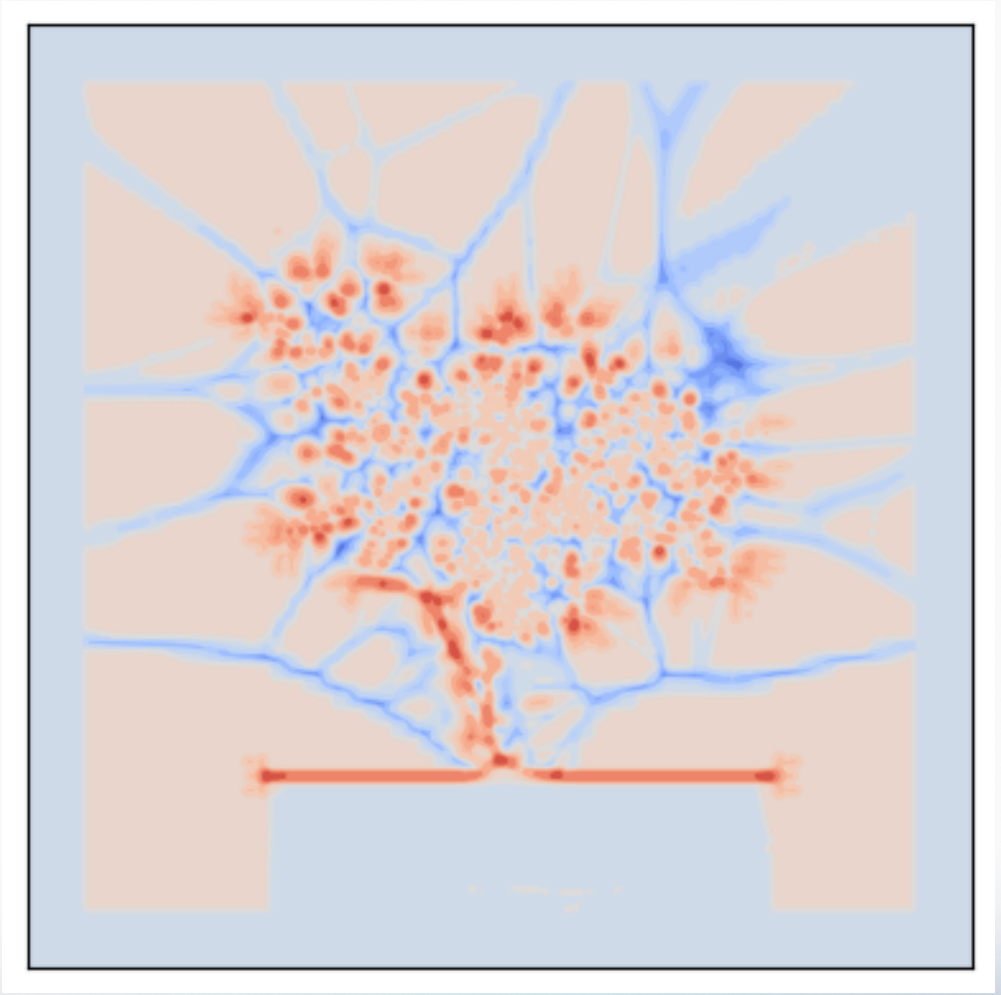
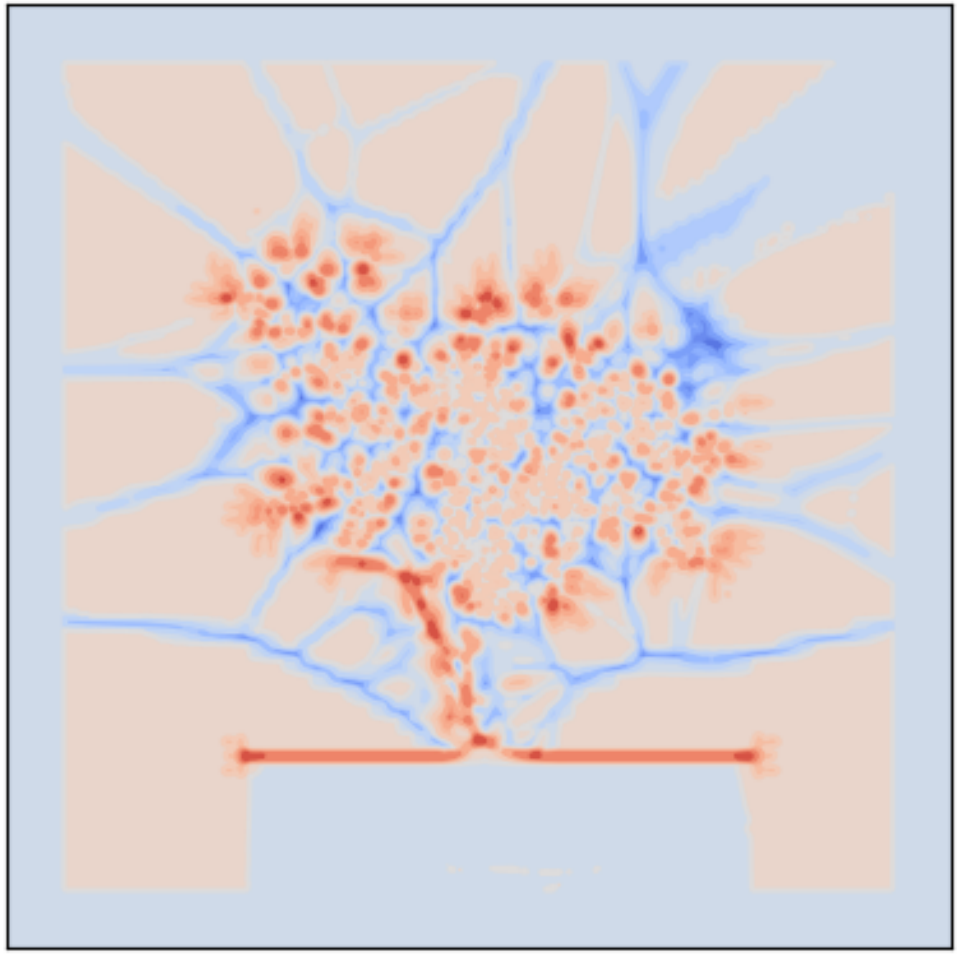
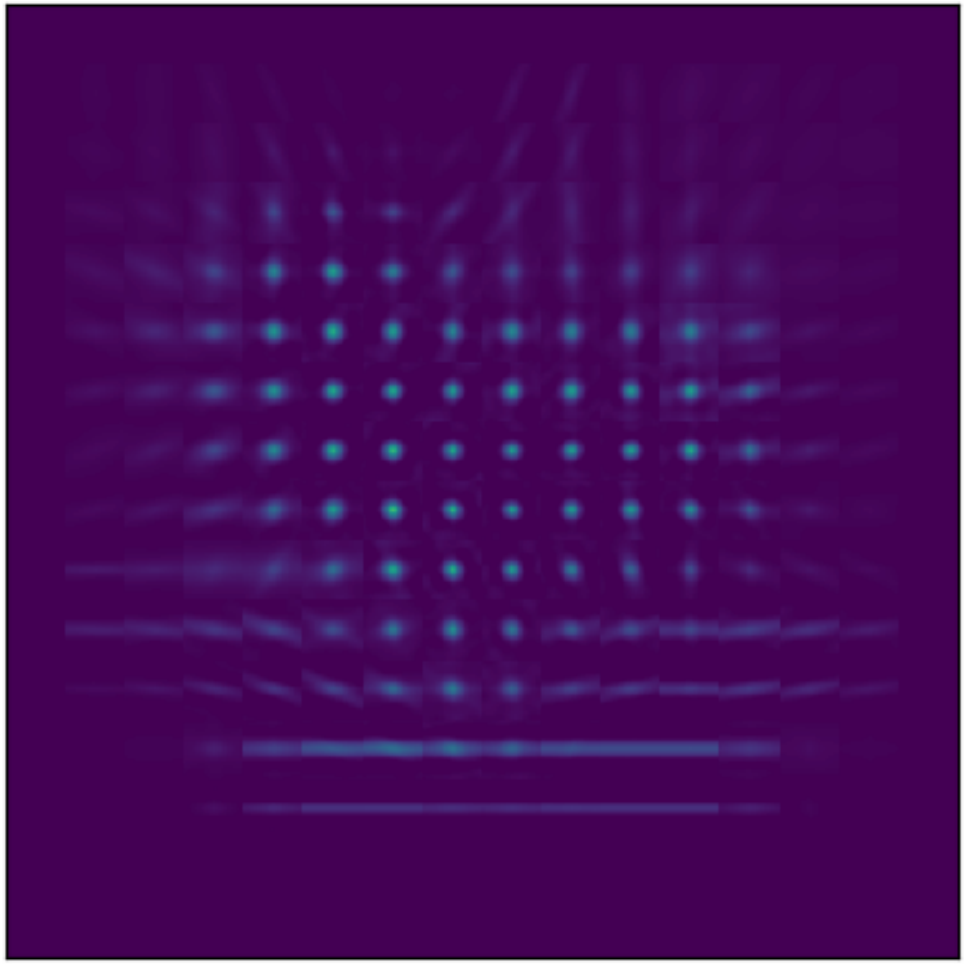




FILTERING IMPLICIT SURFACES

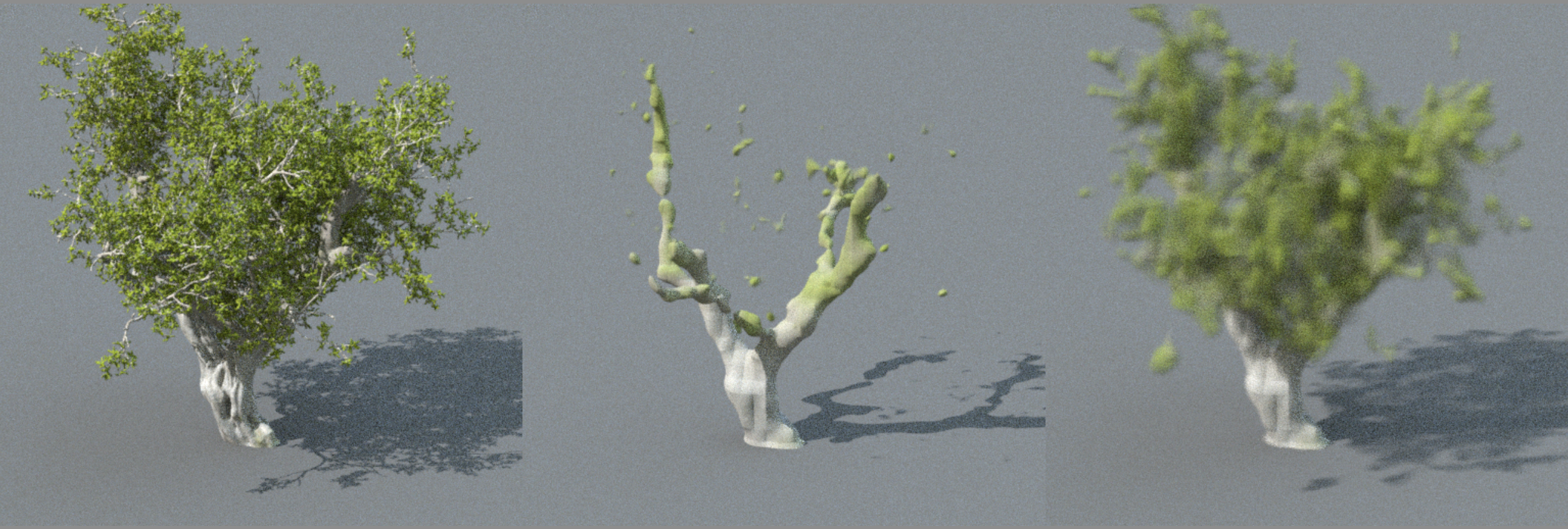




Original

Downsampled

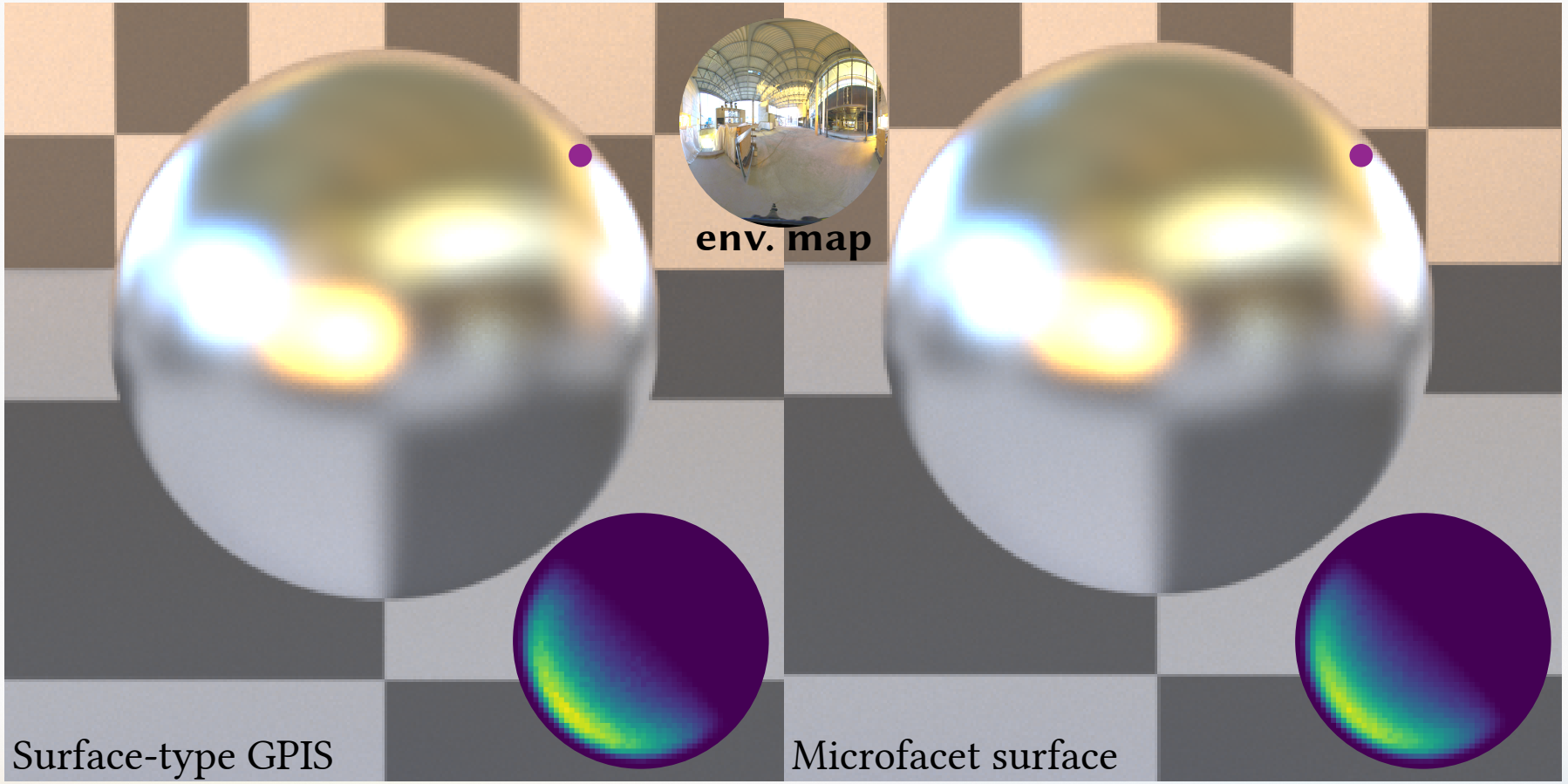
Ours



LIMITATIONS

Ours

Classical



~100x slower…

FUTURE WORK

- Find closed-form approximations for transmittance.
- Differentiable rendering algorithm
- Wider range of stochastic processes
- Apply to Monte Carlo PDE solvers

Project Page/Code

THANK YOU!

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Eugene d’Eon

Benedikt Bitterli

Wojciech Jarosz