COMBINING VOLUMETRIC ESTIMATORS

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UNIFYING POINTS, BEAMS, AND PATHS IN VOLUMETRIC LIGHT TRANSPORT SIMULATION

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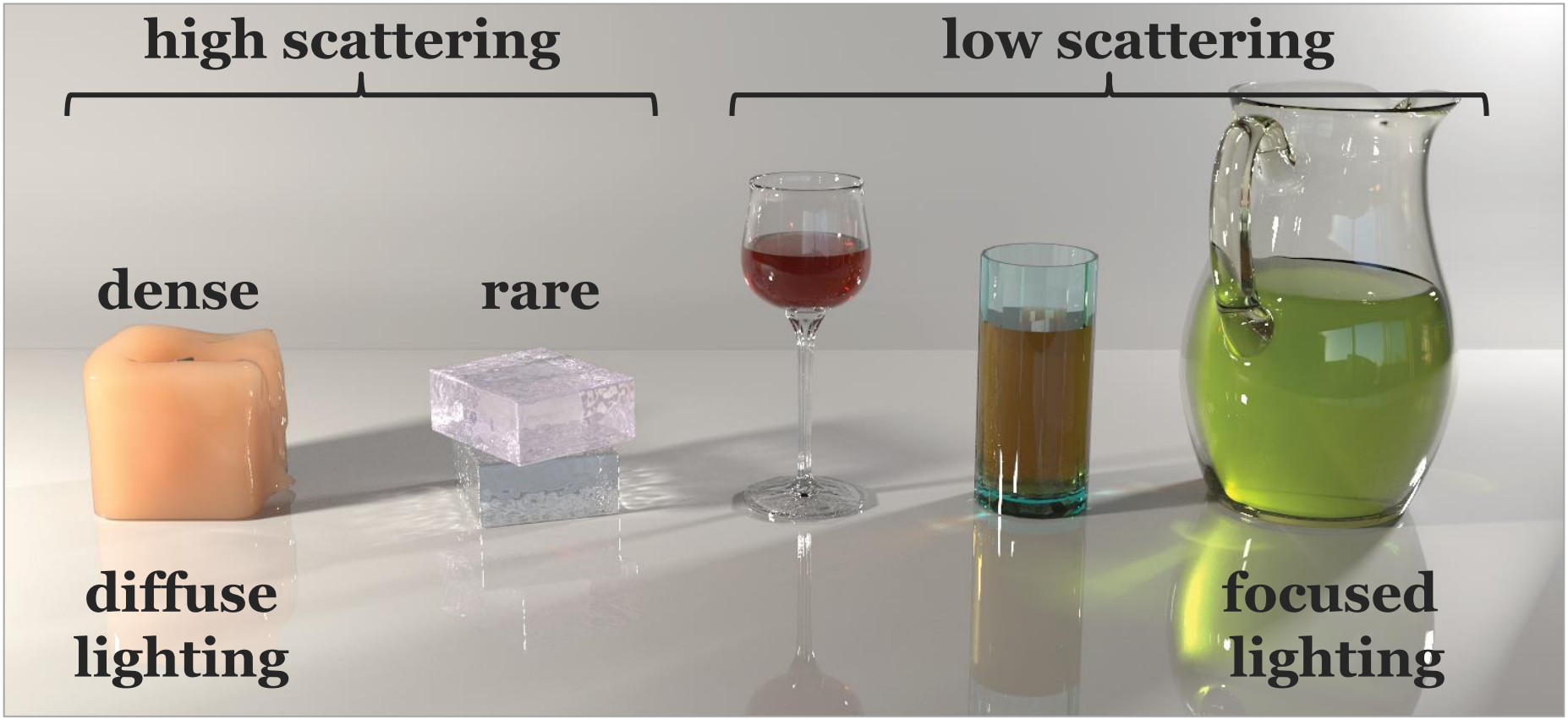
Disney Research, Zurich

Goal: Robust rendering of media

- Robust to: **media properties, lighting**



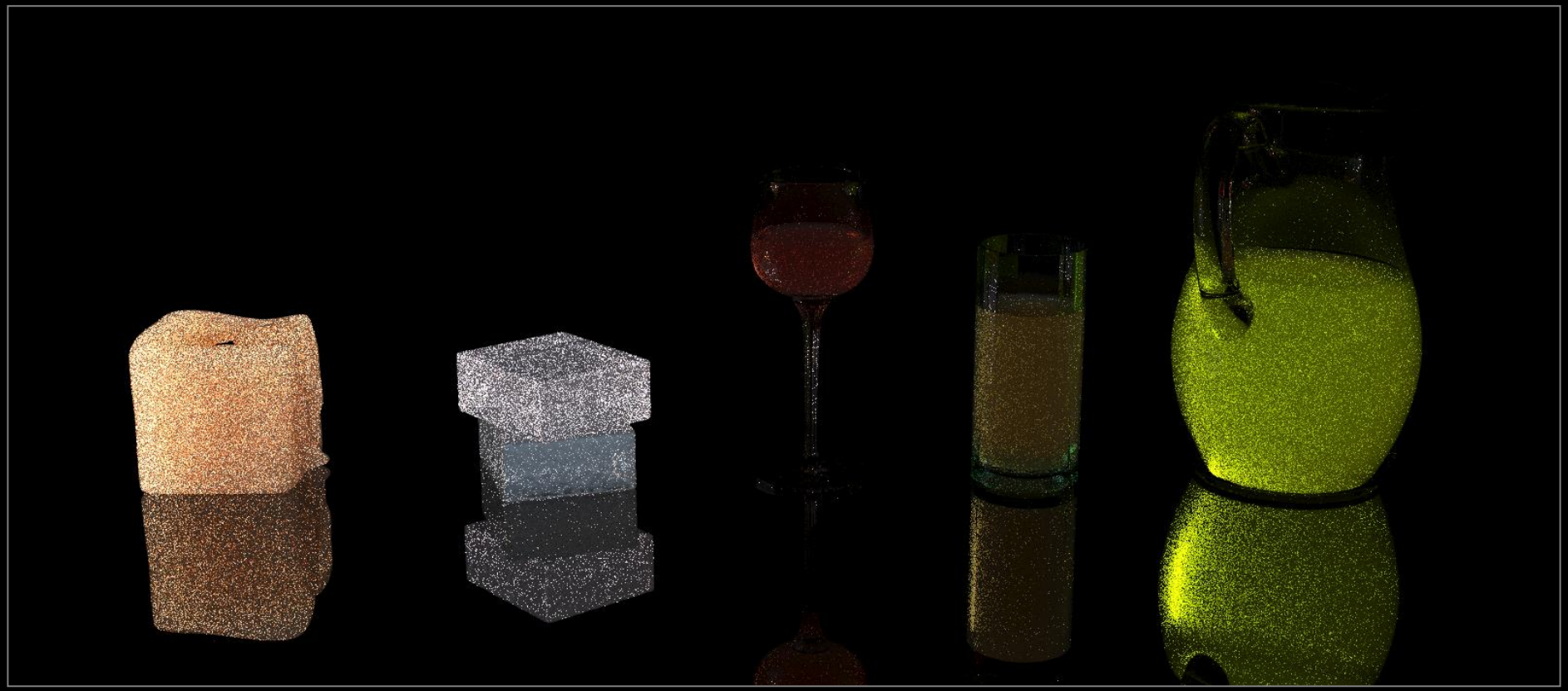
Existing volumetric rendering algorithms

- **MC path integration**
  - Path tracing [Kajiya '86, Rushmeier and Torrance '88]
  - Bidirectional path tracing [Lafortune and Willems '96]

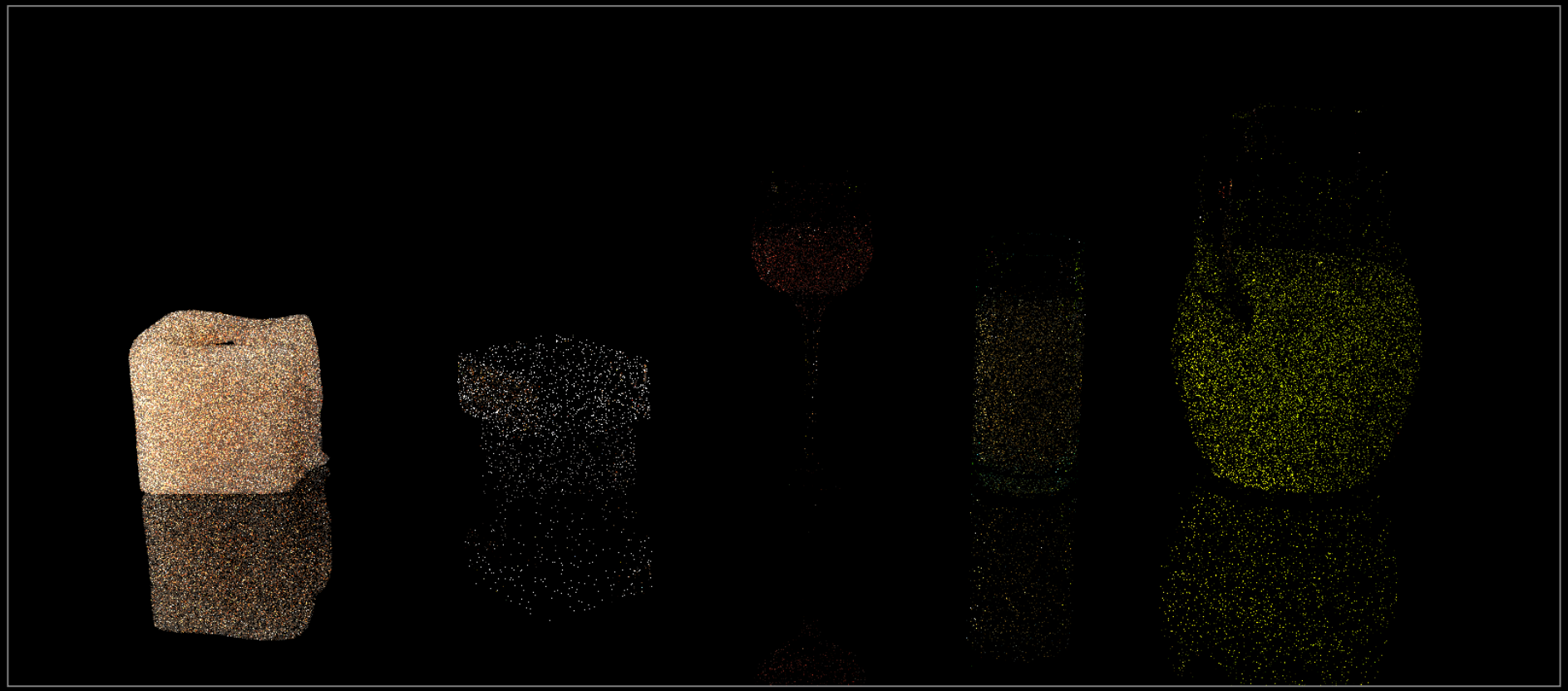
- **Photon density estimation**
  - Volumetric photon mapping [Jensen and Christensen '98]
  - Beam radiance estimate [Jarosz et al. '08]
  - Photon beams [Jarosz et al. '11]

- No existing algorithm can handle all cases

Bidirectional path tracing
1 hour

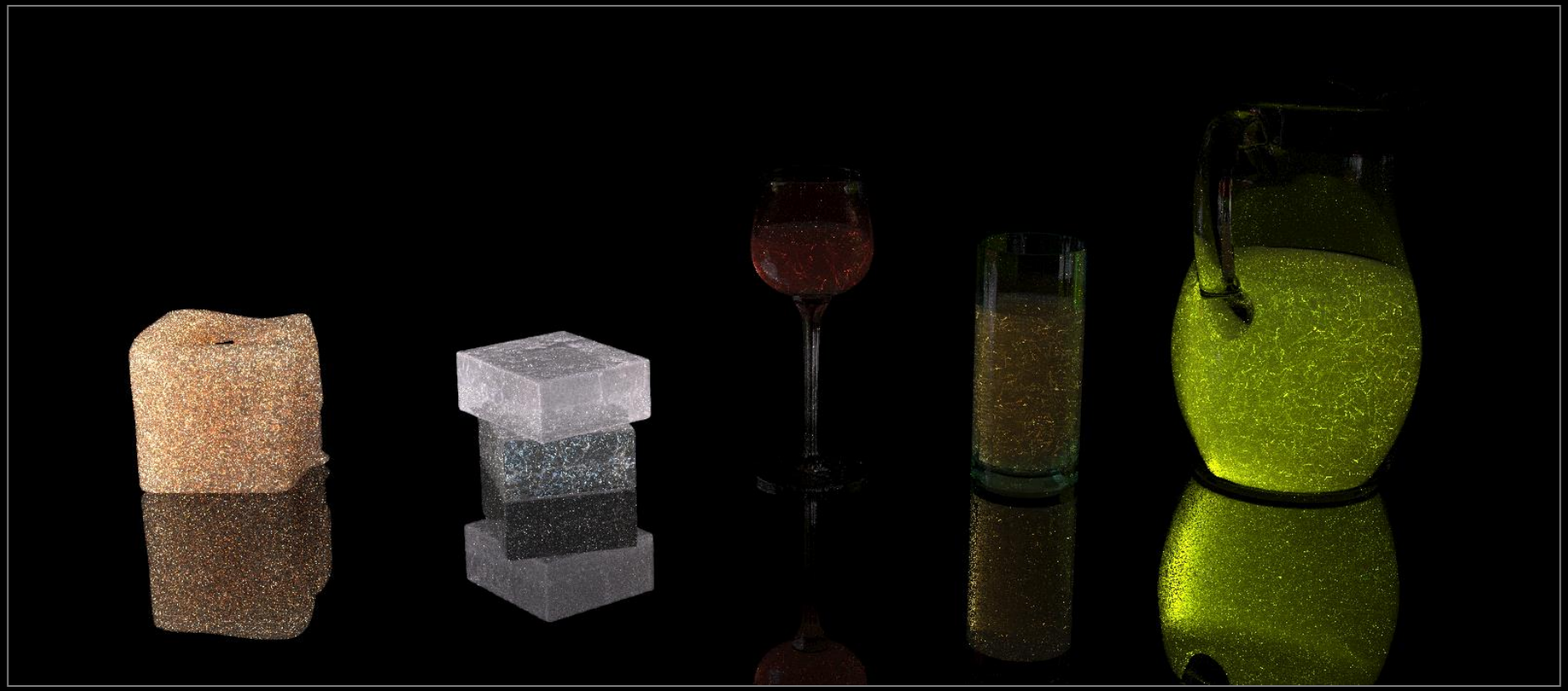


Volumetric photon mapping
1 hour



Beam radiance estimate
1 hour

Photon beams
1 hour



UPBP algorithm
1 hour

Approach: Combine estimators

- **Multiple Importance Sampling** [Veach and Guibas '95]
- **Previous work**
  - Bidirectional path tracing (**BPT**) [Veach and Guibas '95]
  - Vertex connection and merging (**VCM**) [Georgiev et al. '12]
  - Unified path sampling (**UPS**) [Hachisuka et al. '12]
- **Our algorithm**
  - **"Unified points beams and paths" (UPBP)**

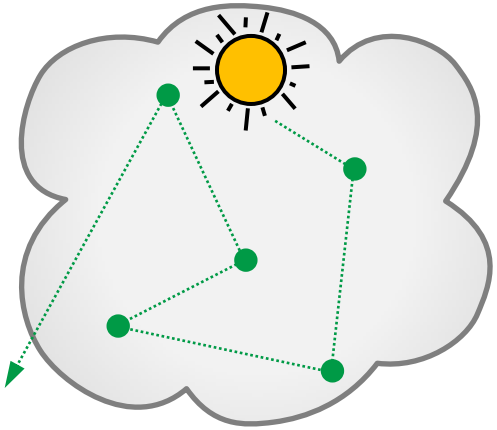
Contributions

- "Does it make sense to combine the estimators?"
  - **Variance analysis of estimators**
- "How can we combine the estimators?"
  - **Extended multiple importance sampling**
- "How do we make the method practical?"
  - **A combined volume rendering algorithm**

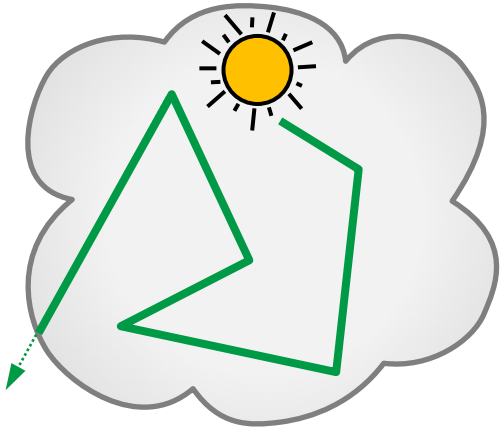
VOLUMETRIC PHOTON DENSITY ESTIMATORS

RADIANCE REP.:

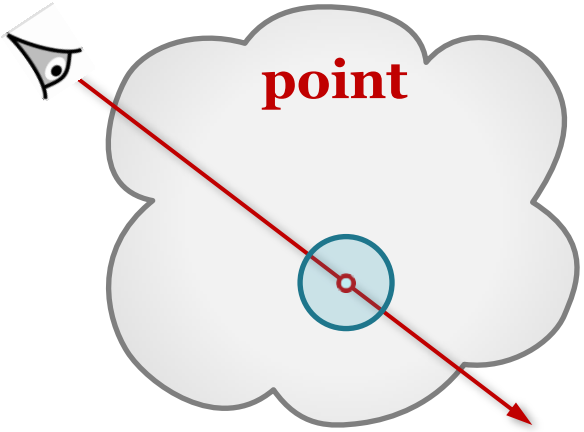
photon **points**



photon **beams**

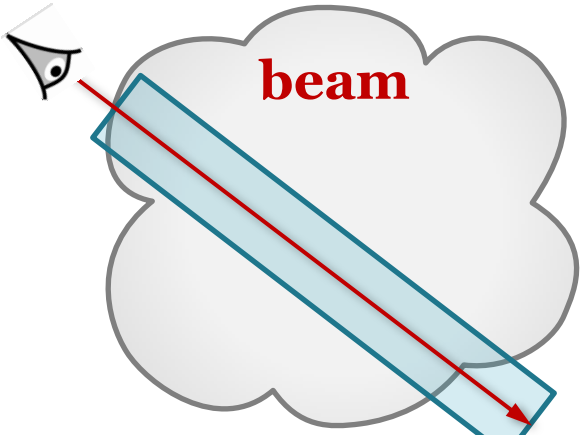


QUERY



Point - Point

Beam - Point



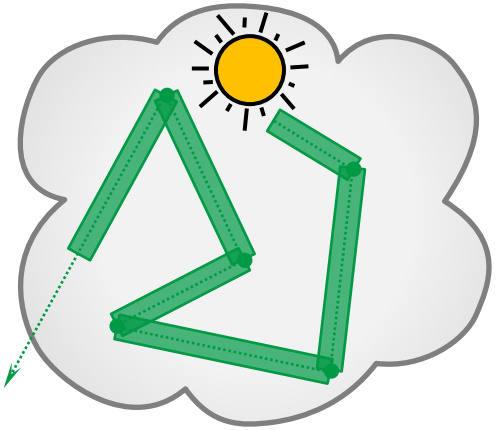
Point - Beam

Beam - Point

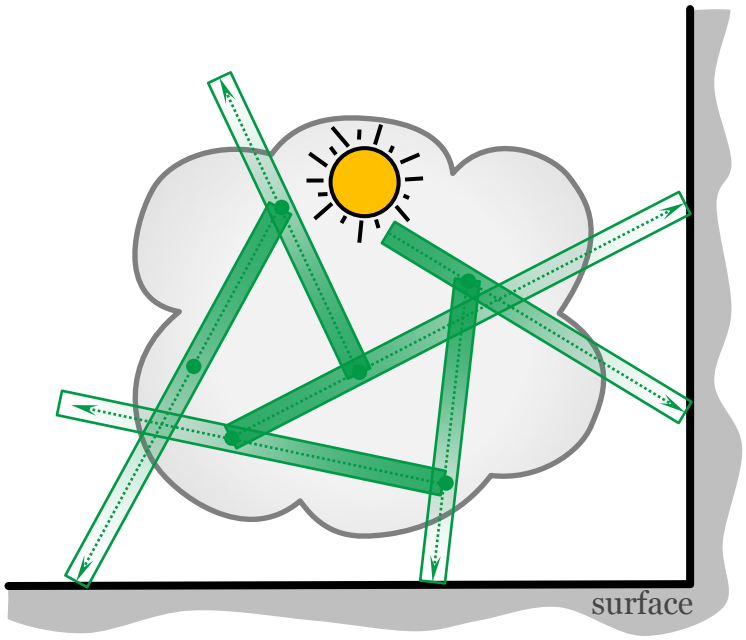
[Jarosz et al. '11a]

“Long” vs. “short” beams [Jarosz et al. ’11b]

- **Photon beams**



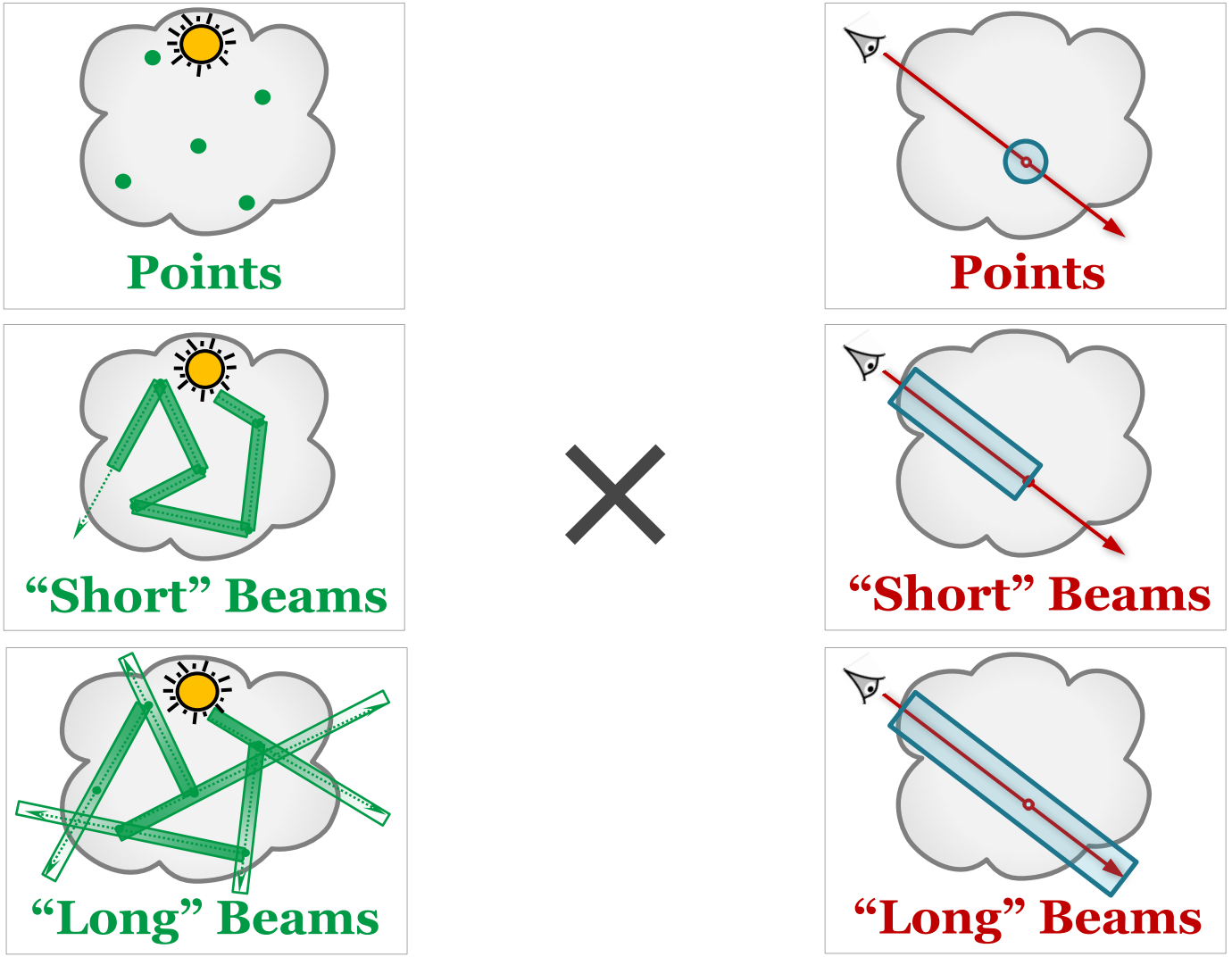
“Short” beams



“Long” beams

- **Query beams**
  - The same story

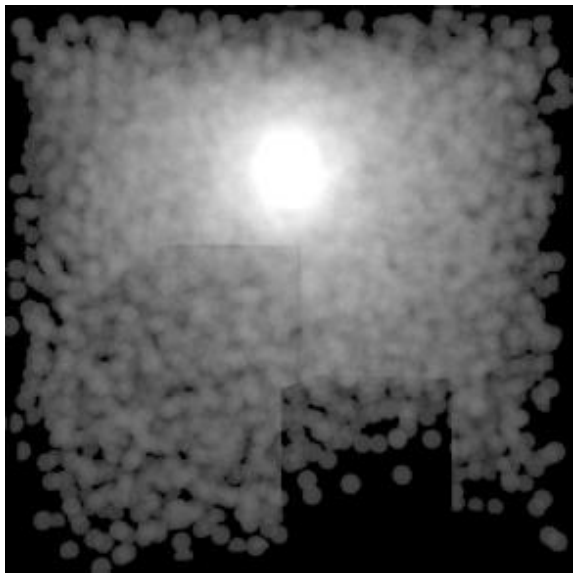
Bottom line: Many estimators

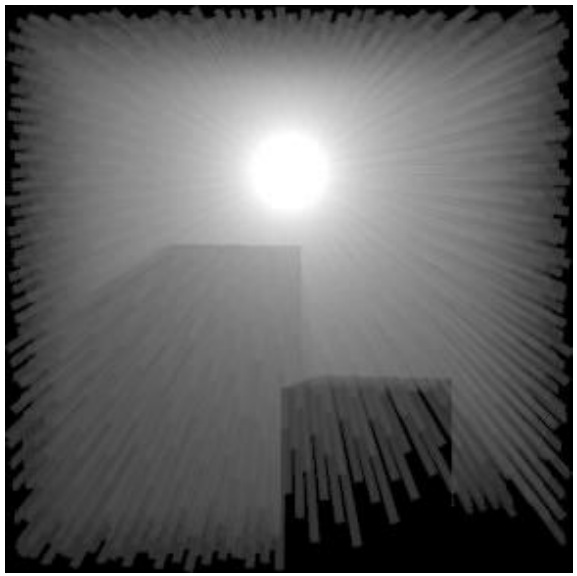


Why combine points and beams?

- Won't photon beams always outperform photon points?

100k photon **points** | reference | 5k photon **beams**

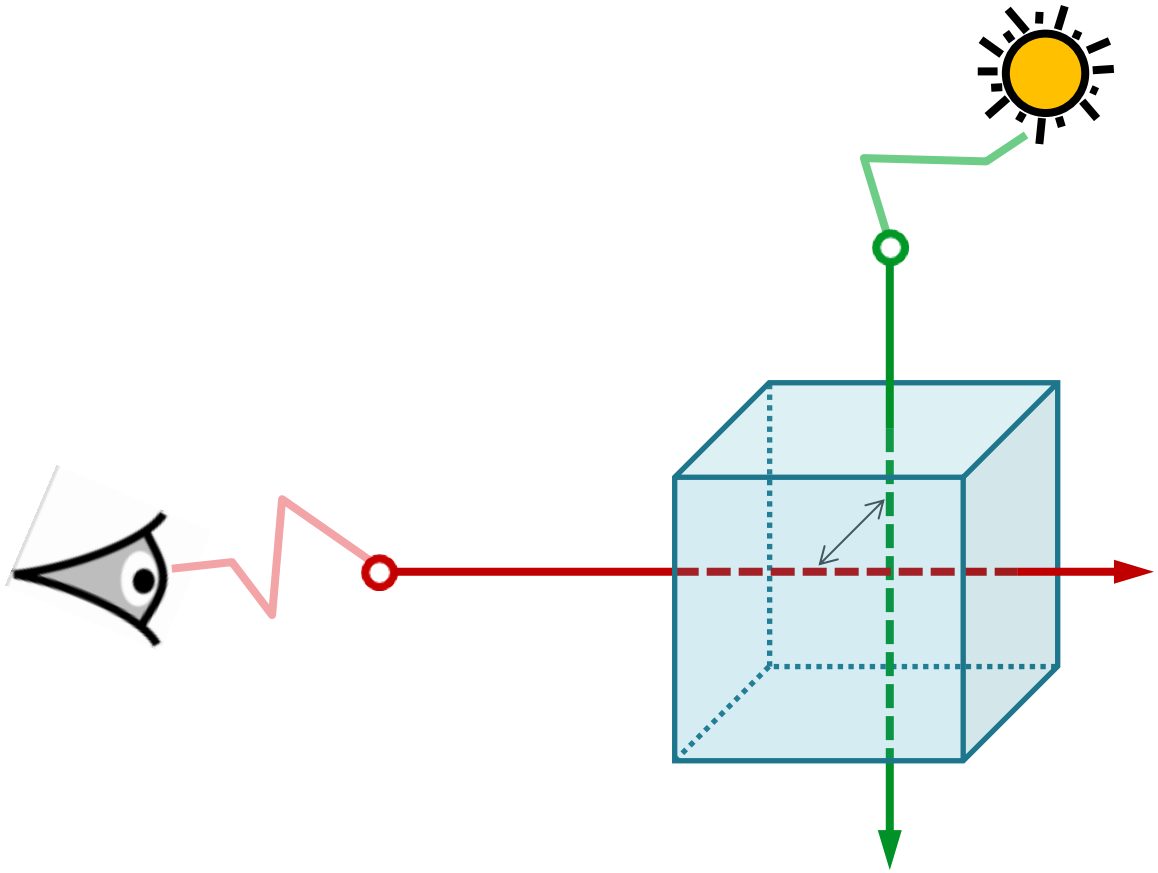




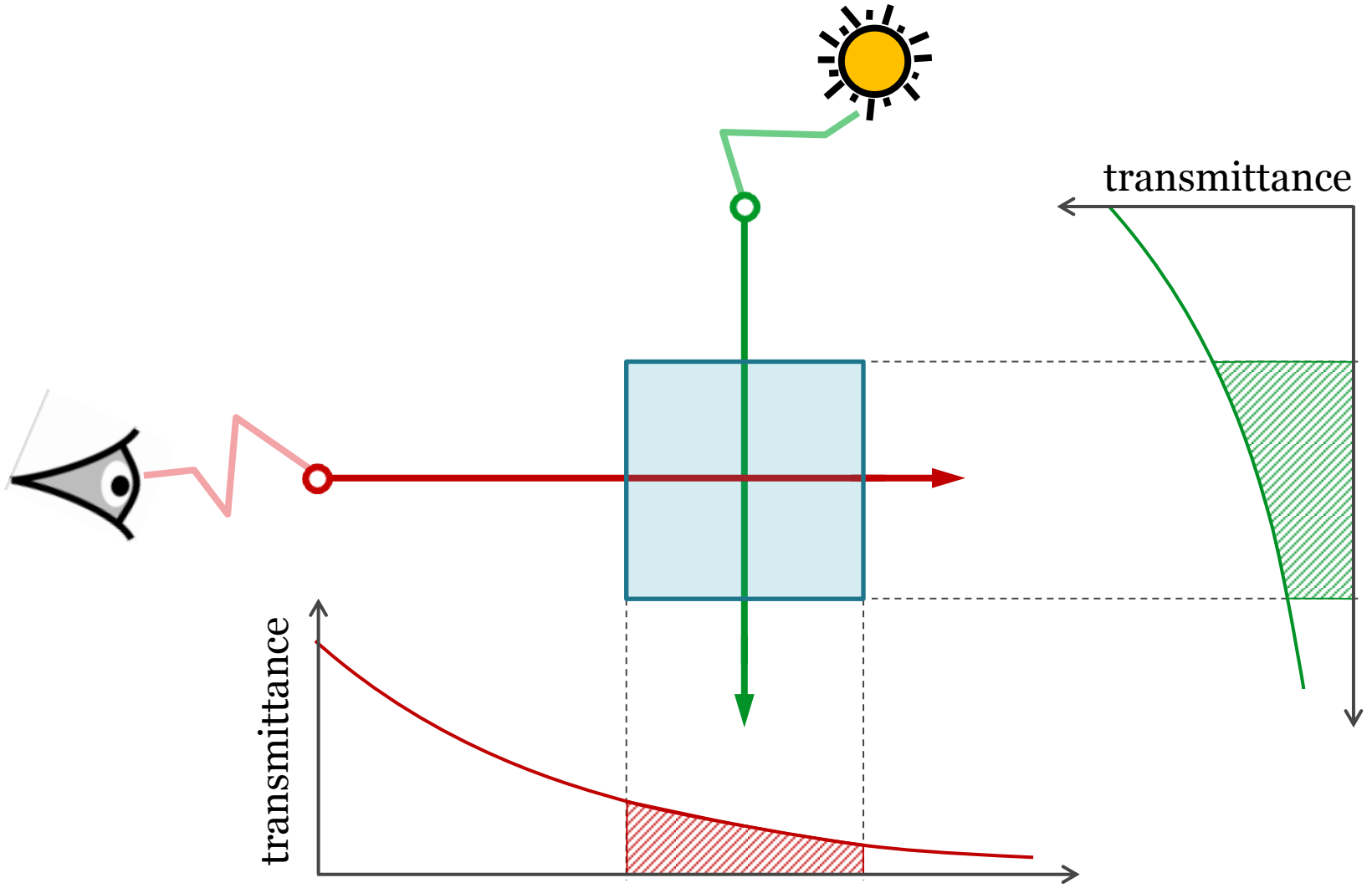
from [Jarosz et al. '11a]

VARIANCE ANALYSIS

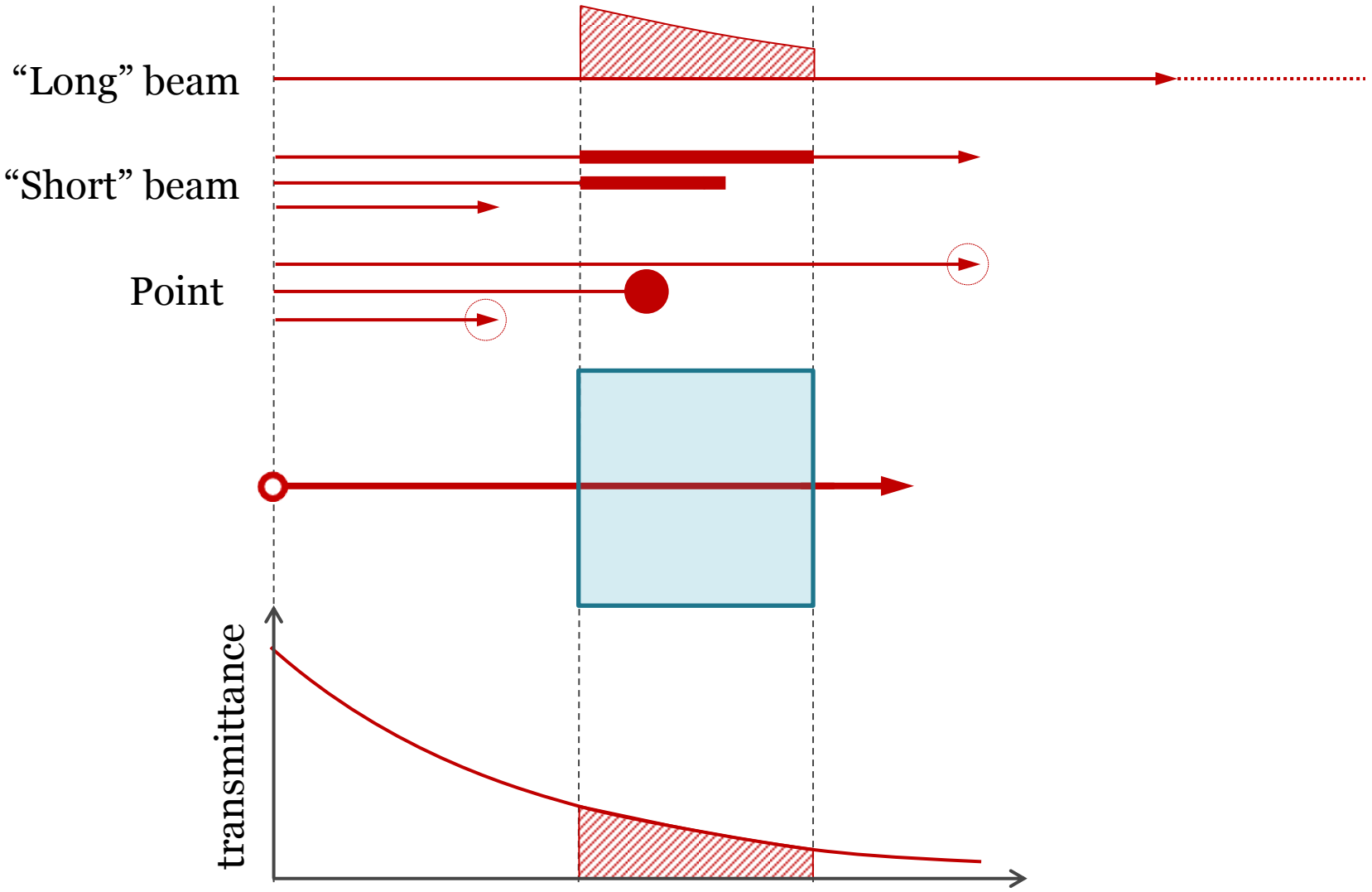
Variance analysis – Canonical setup



Variance analysis – Expected value

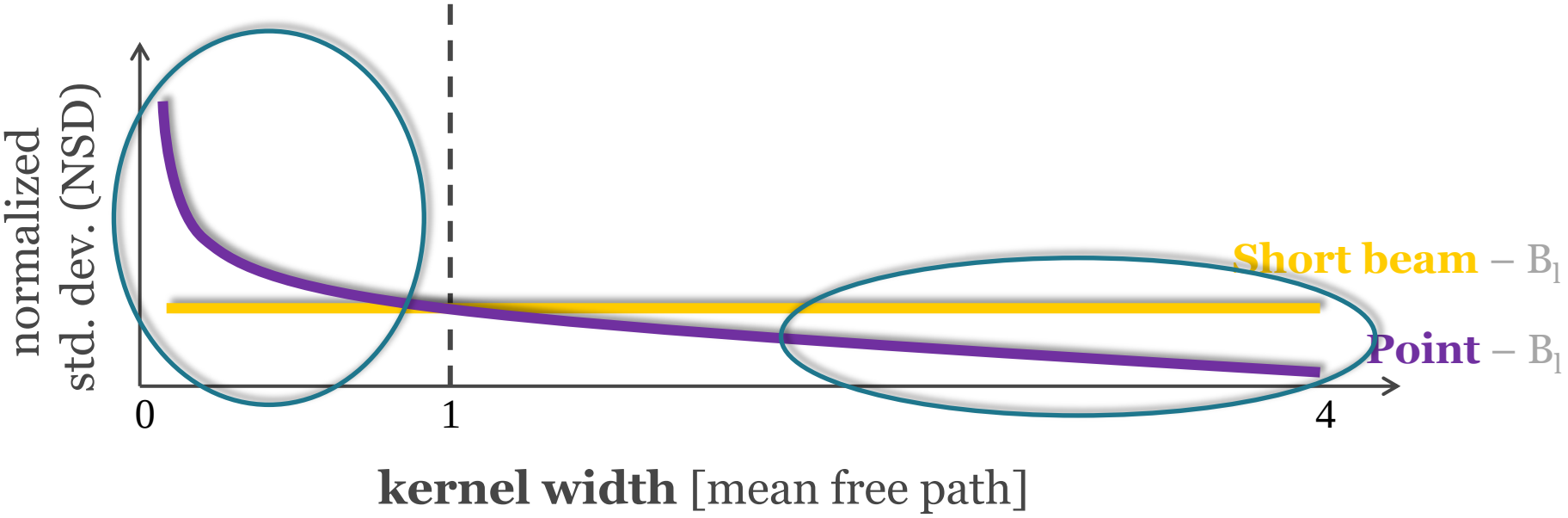


Variance analysis – Estimators



Variance analysis results

rare media ⟷ dense media



Variance analysis results

rare media

dense media

beams:		
points:		

“HOW TO COMBINE?”

EXTENDED MIS

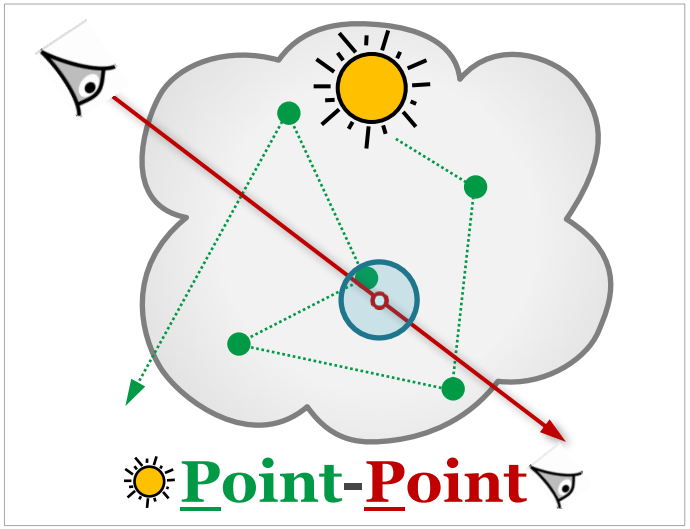
Our MIS extension

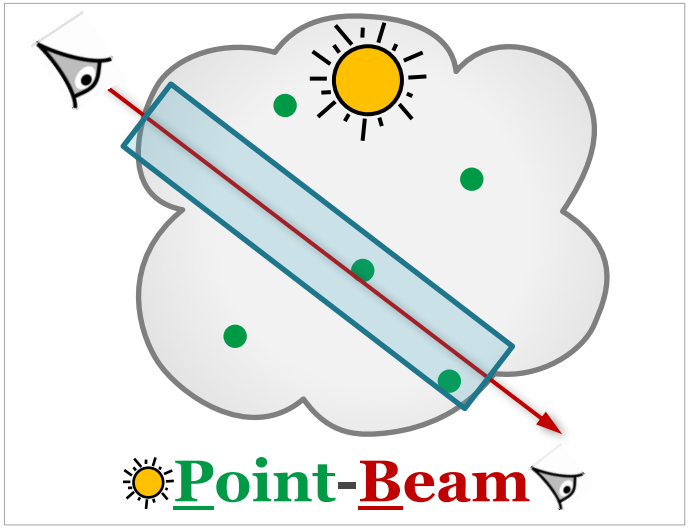
- Extended MIS – accommodate all the different estimators
- Compatible with RR interpretation of density estimation kernels (like VCM [Georgiev et al. '12])
- Alternative view: extended path space [Hachisuka et al. '12, Hachisuka et al. '17]

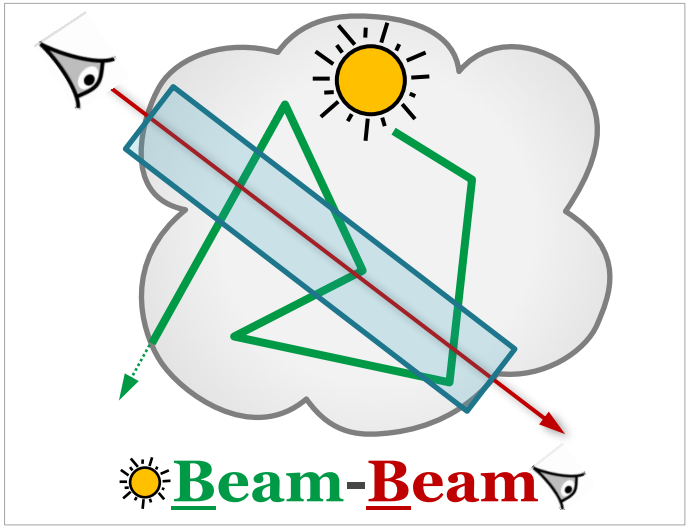
“HOW TO IMPLEMENT IT?”

THE COMBINED ALGORITHM

Estimator choice

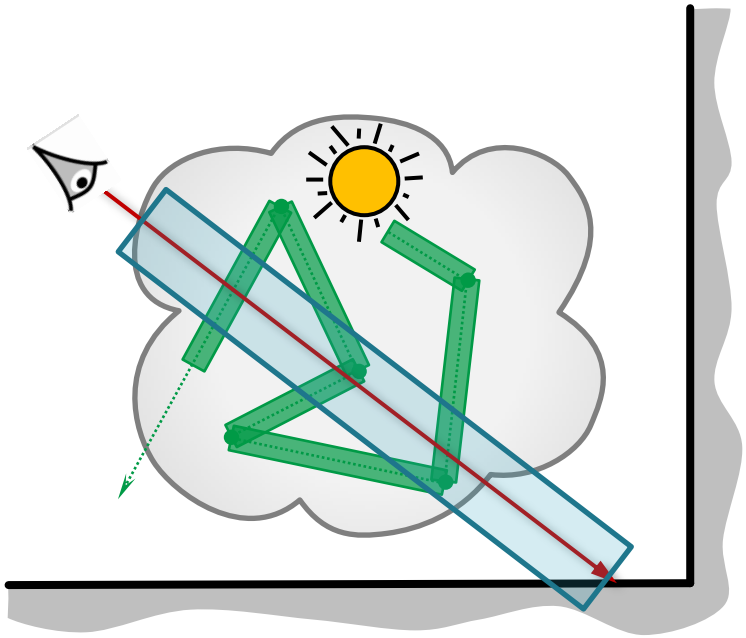






“Long” vs. “short” beams

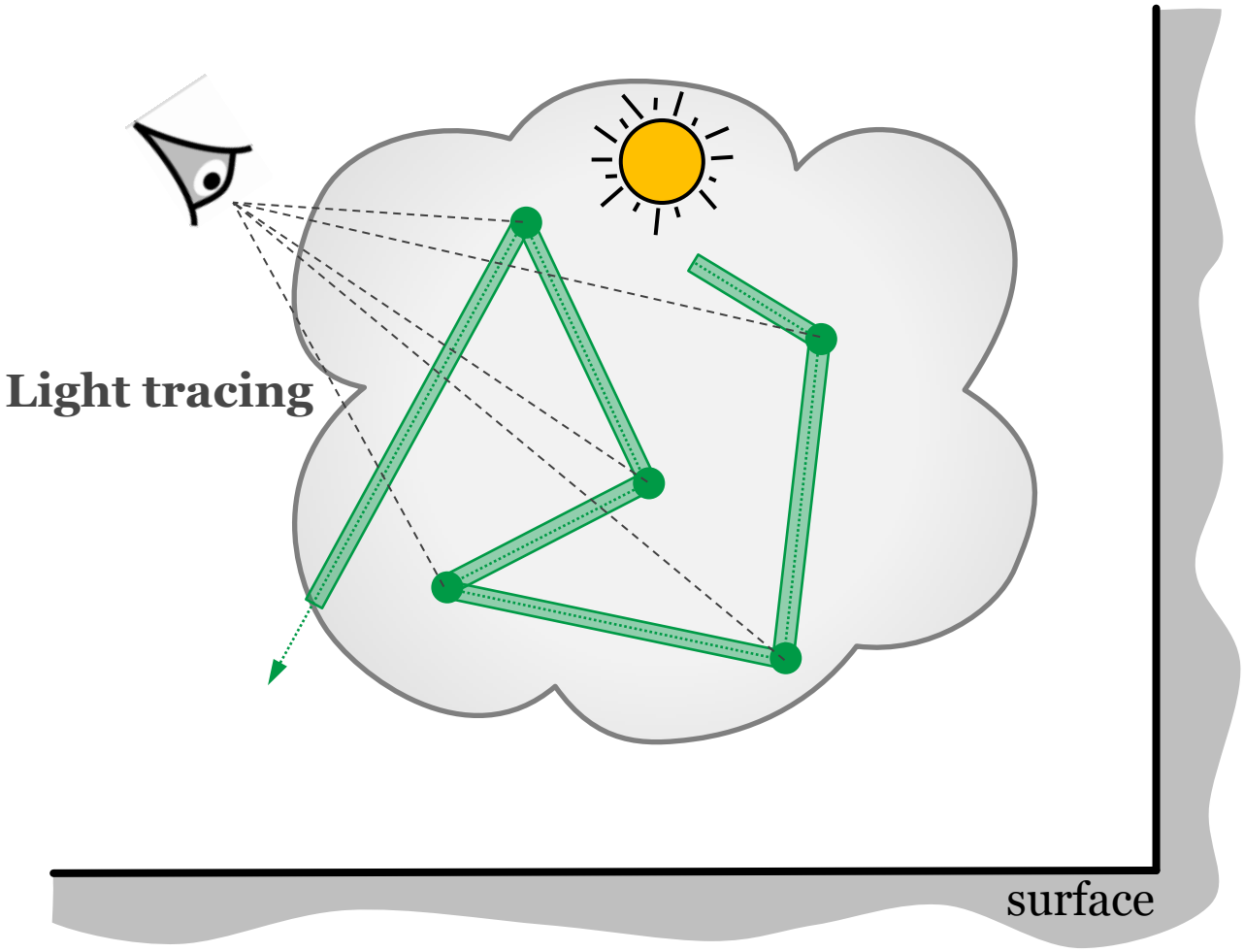
- **“Short” photon beams**
- **“Long” query beams**



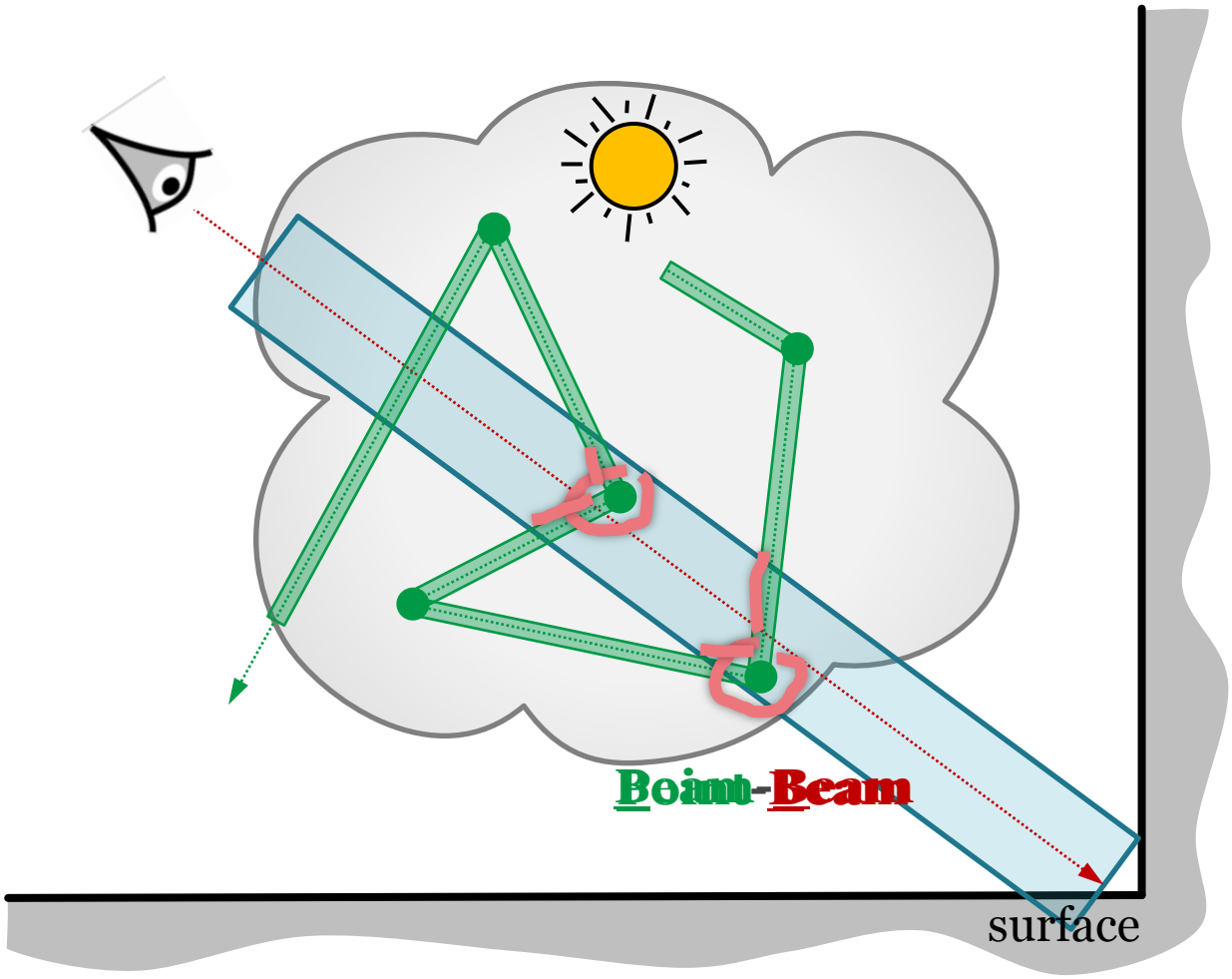
Family of estimators

- **+ Bidirectional path tracing**

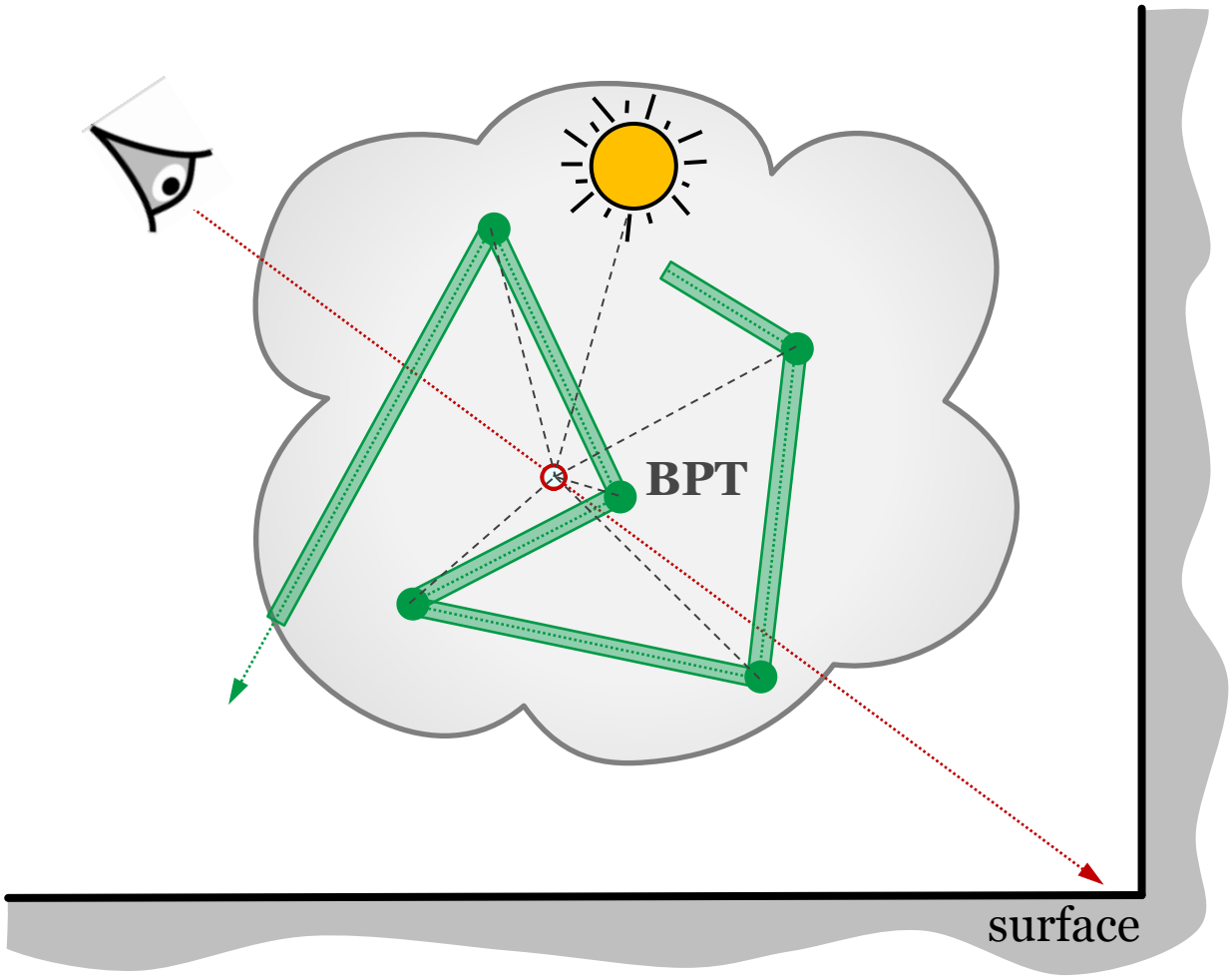
UPBP – Algorithm overview



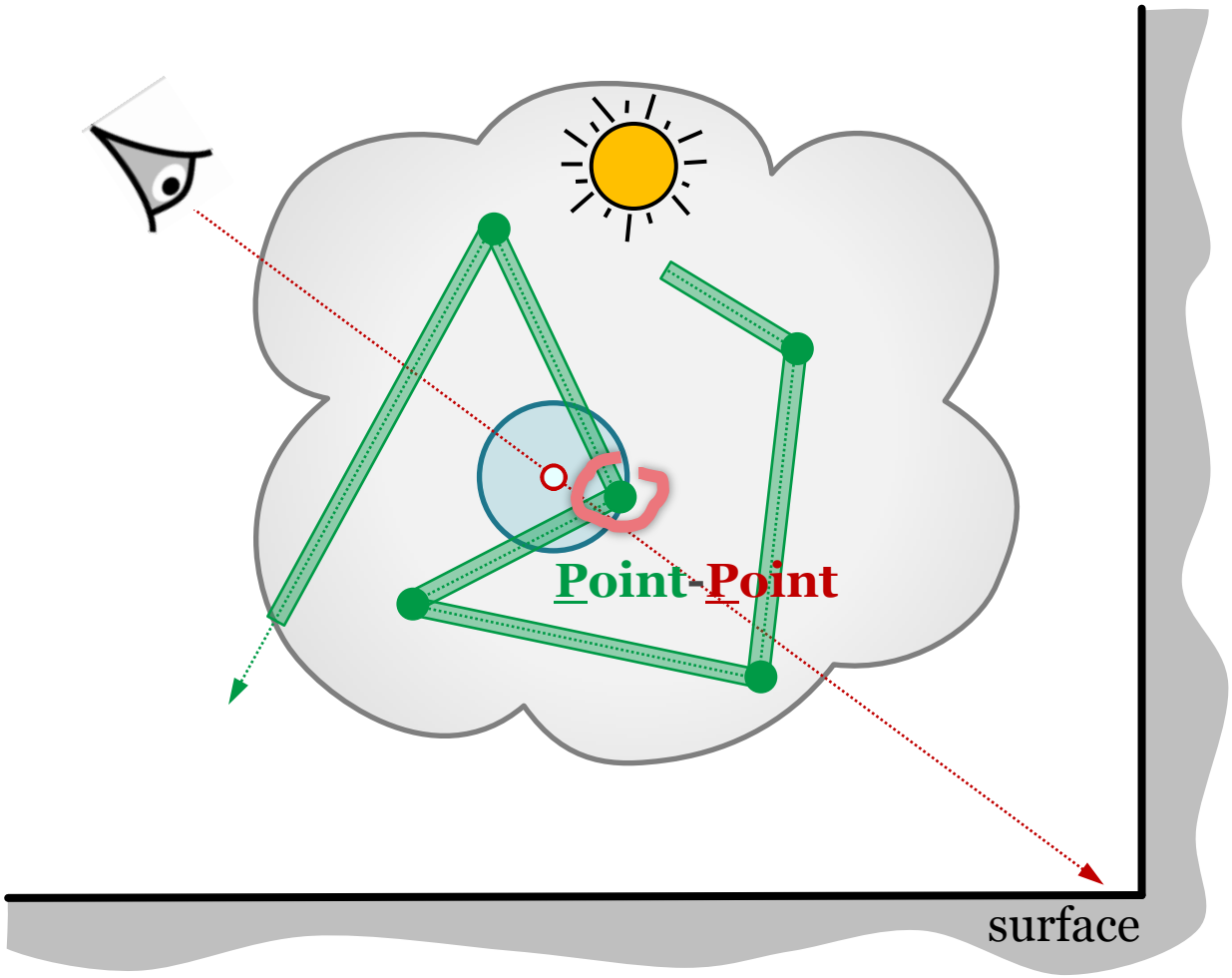
UPBP – Algorithm overview



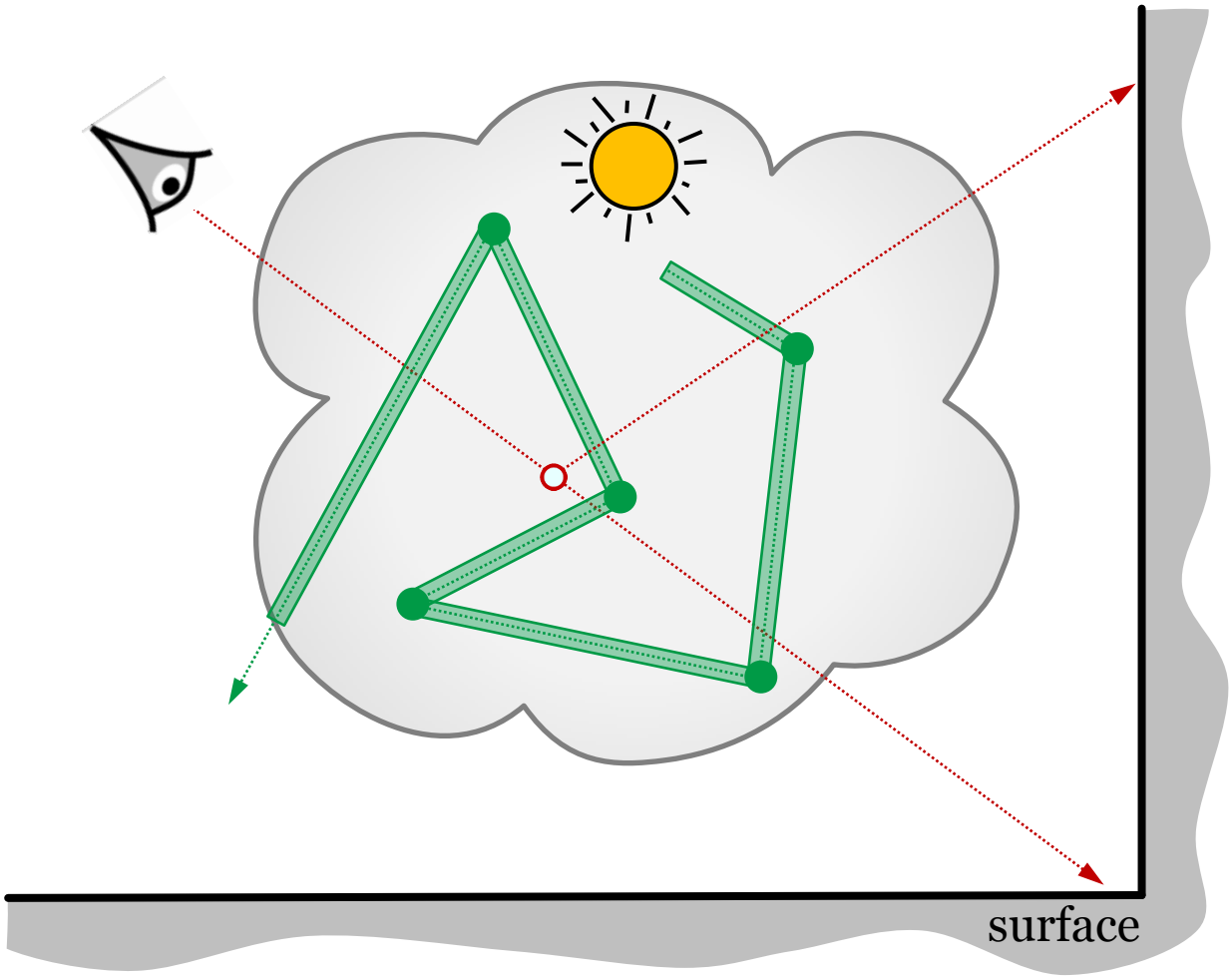
UPBP – Algorithm overview



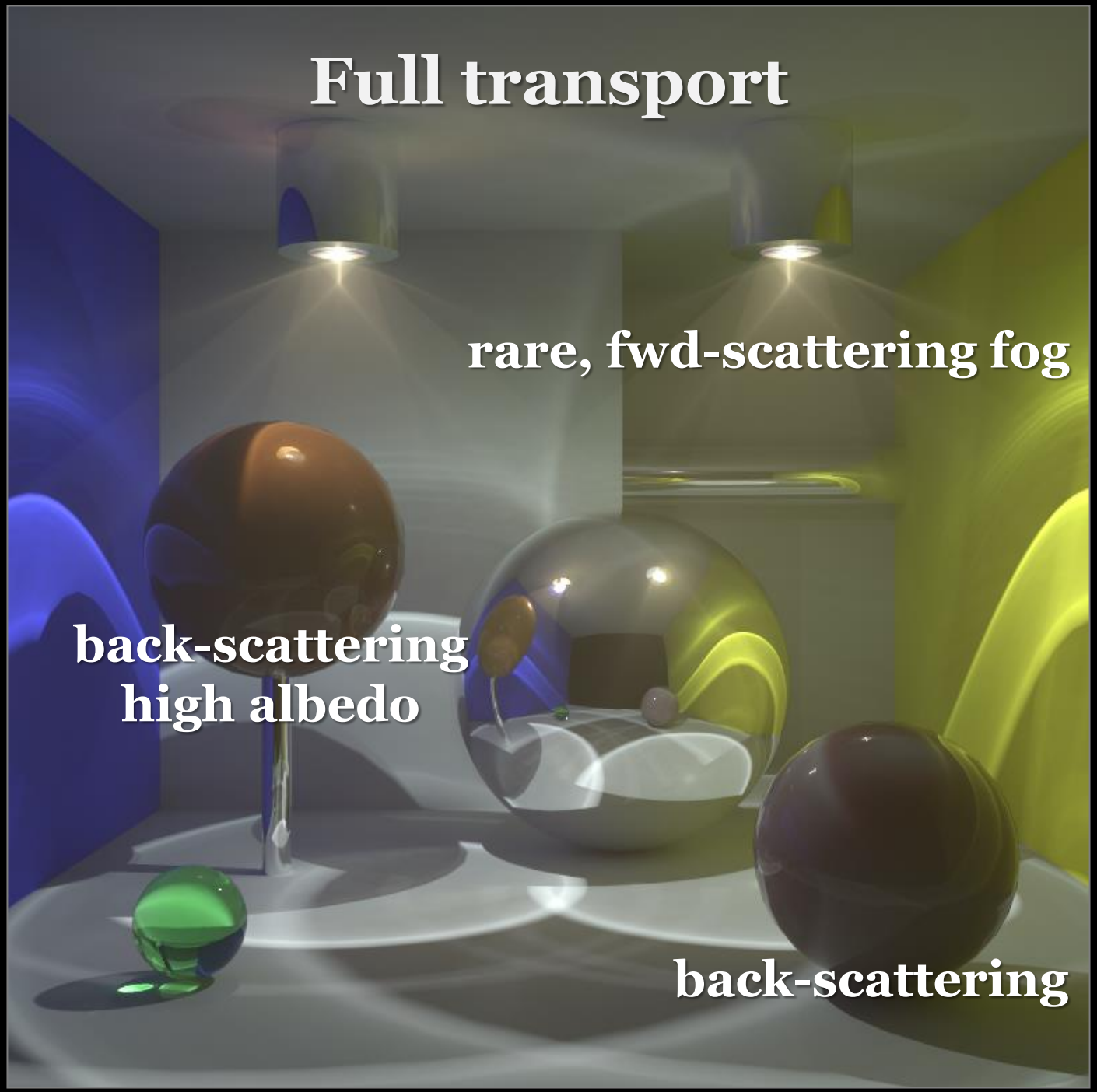
UPBP – Algorithm overview



UPBP – Algorithm overview

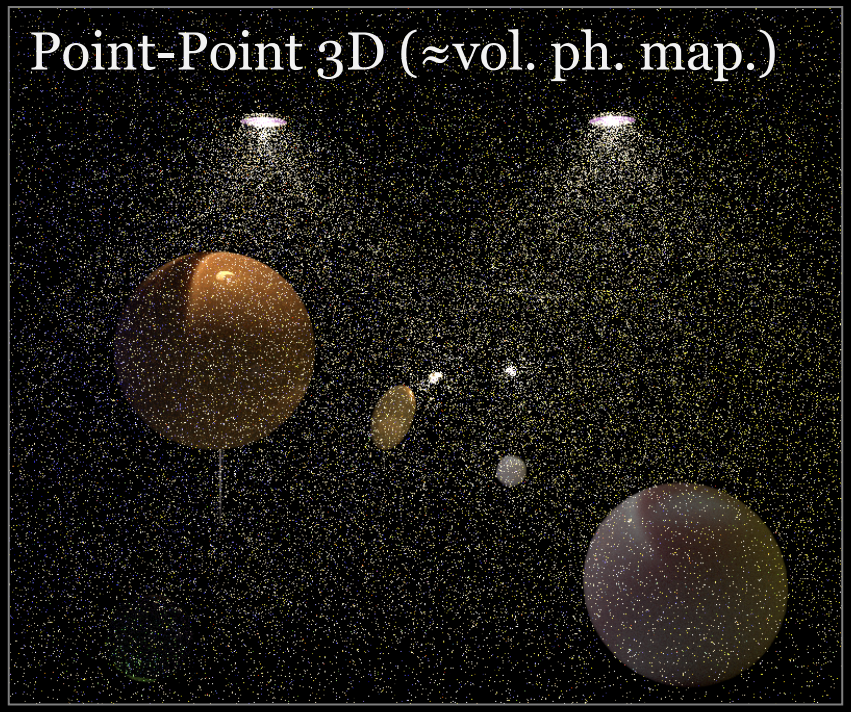


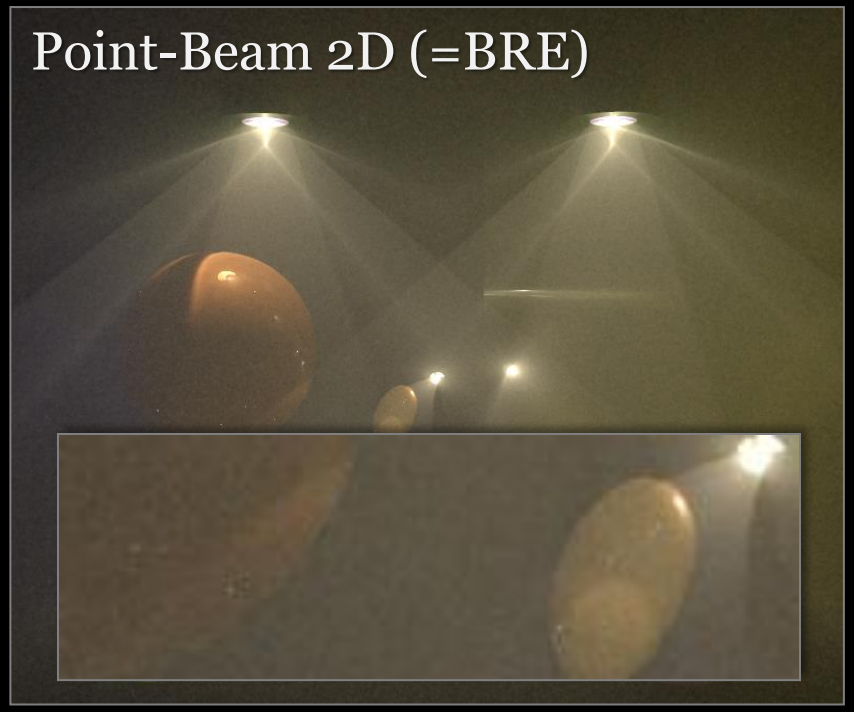
RESULTS

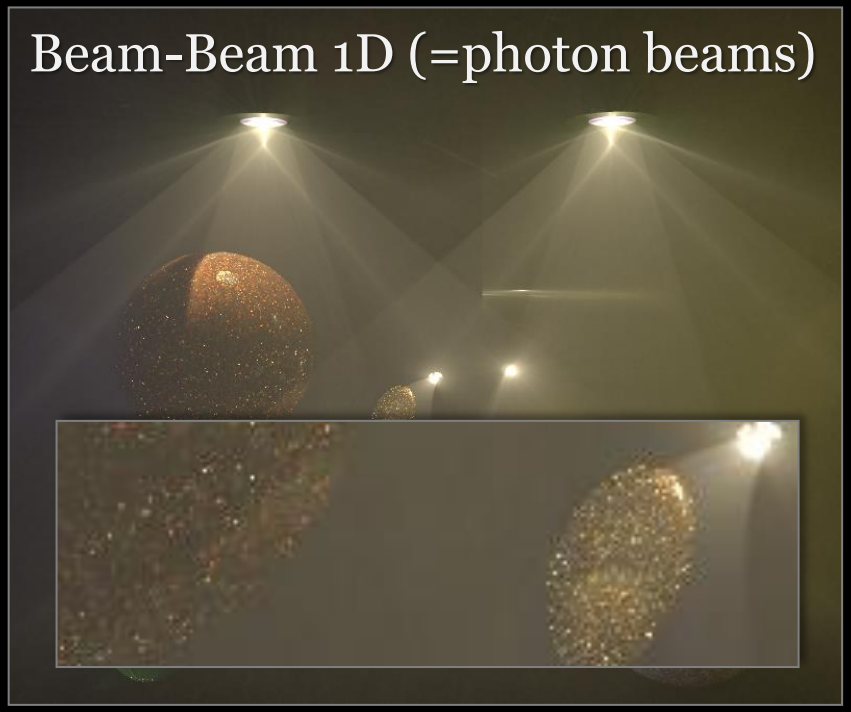

Full transport
rare, fwd-scattering fog
back-scattering
high albedo
back-scattering

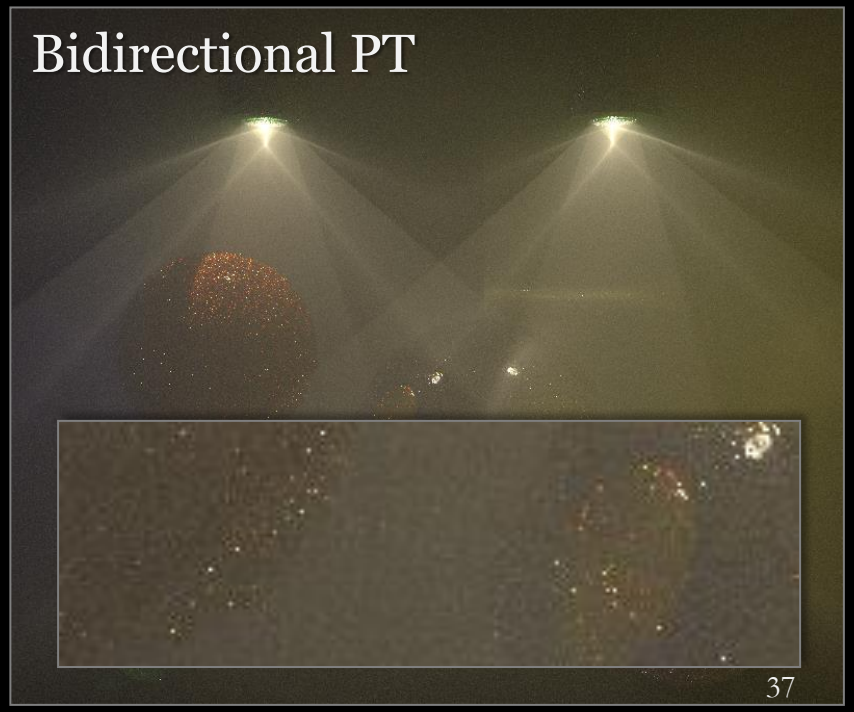
Medium transport only

Previous work comparison, 1 hr

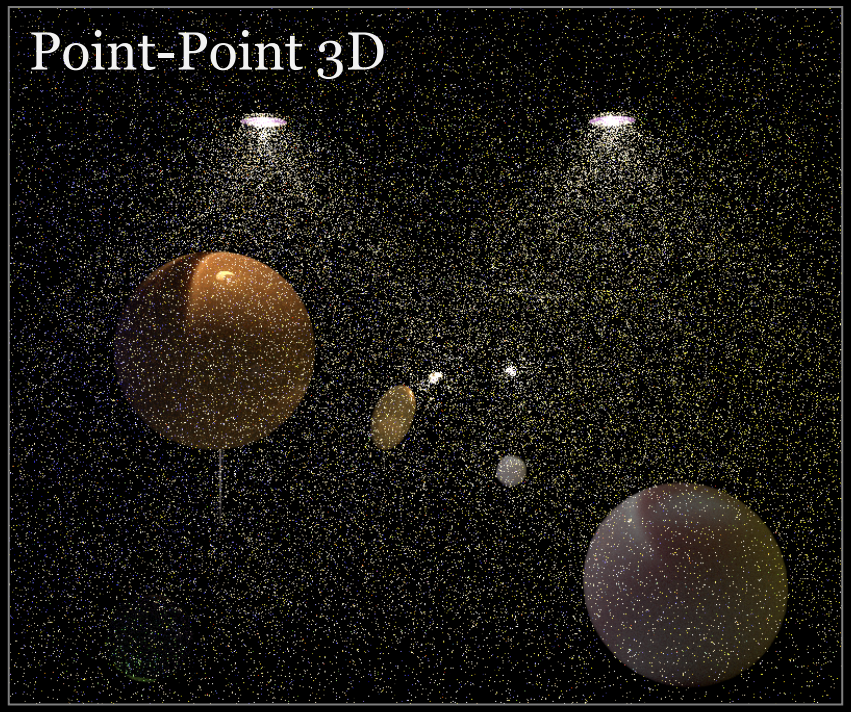


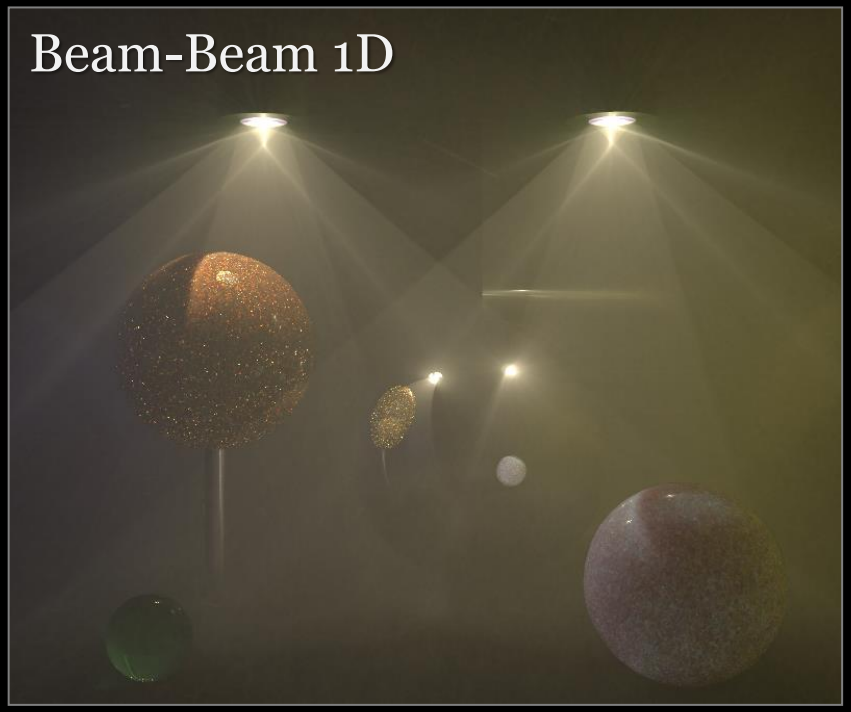


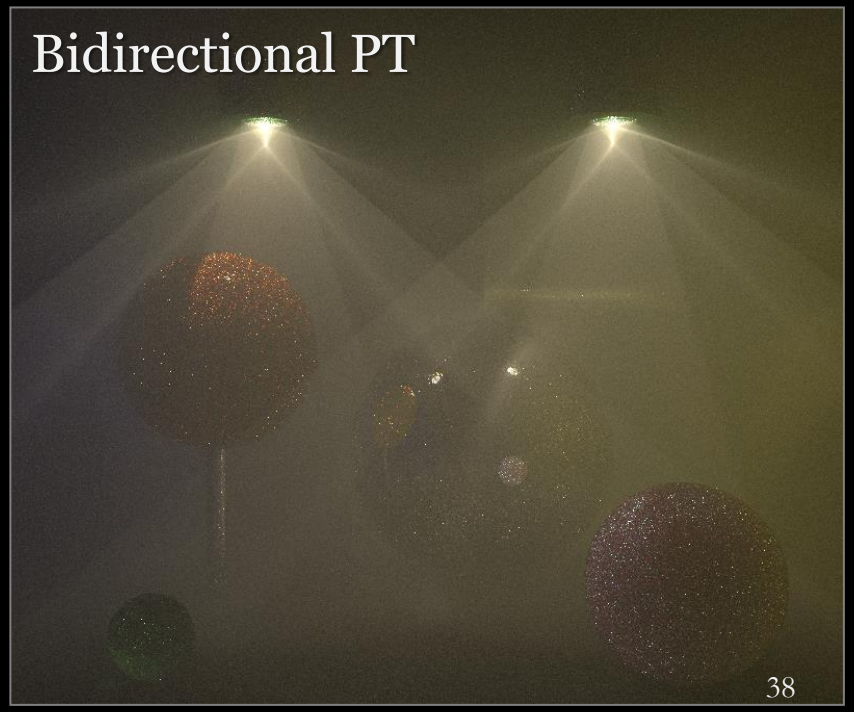




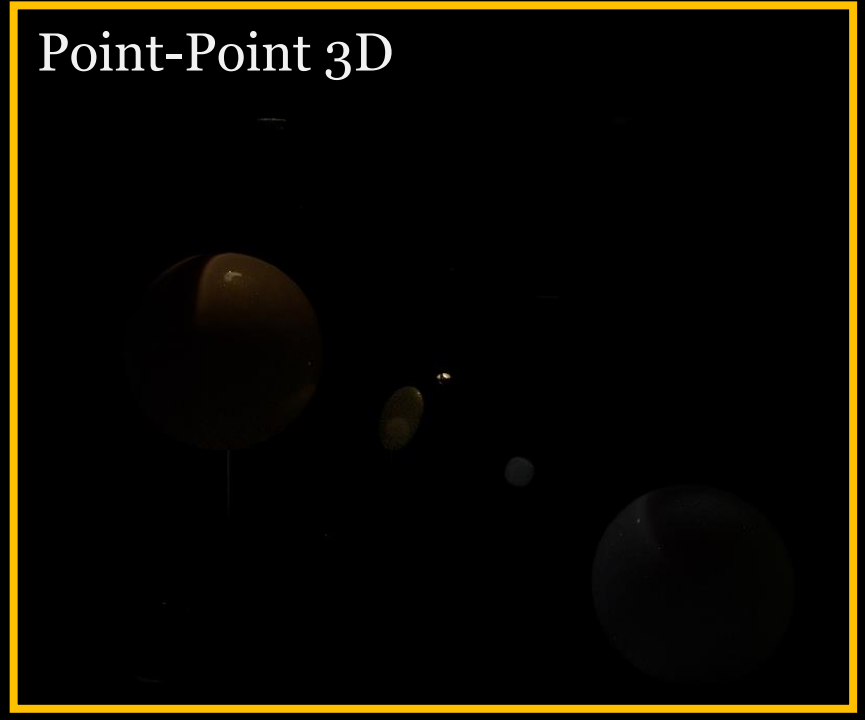
Previous work comparison, 1 hr

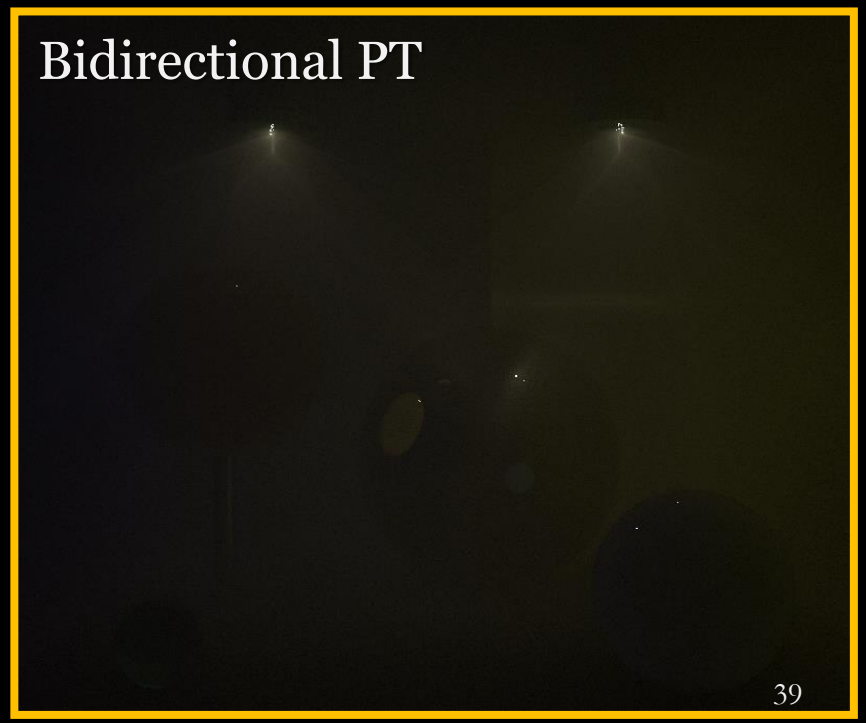




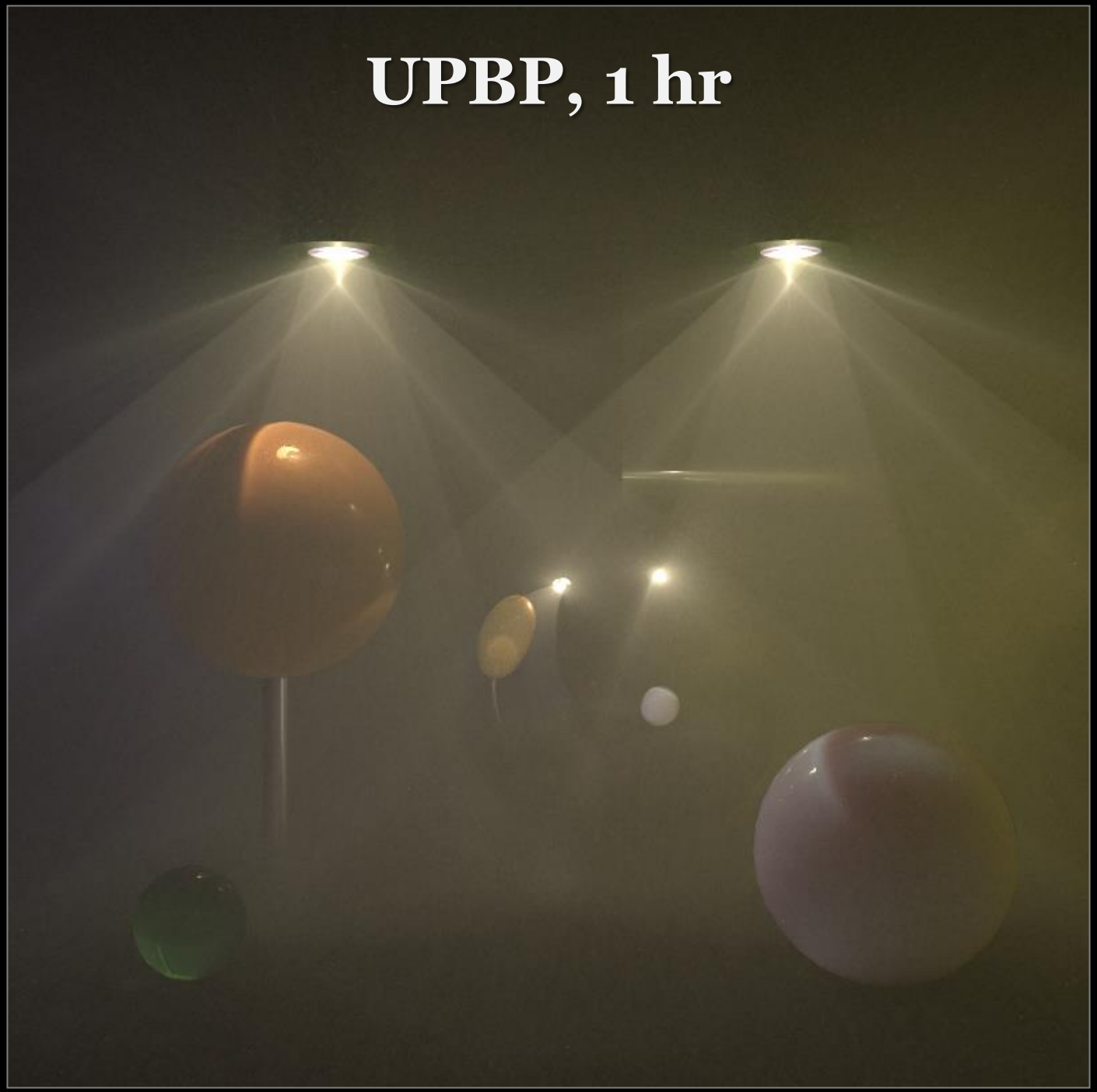


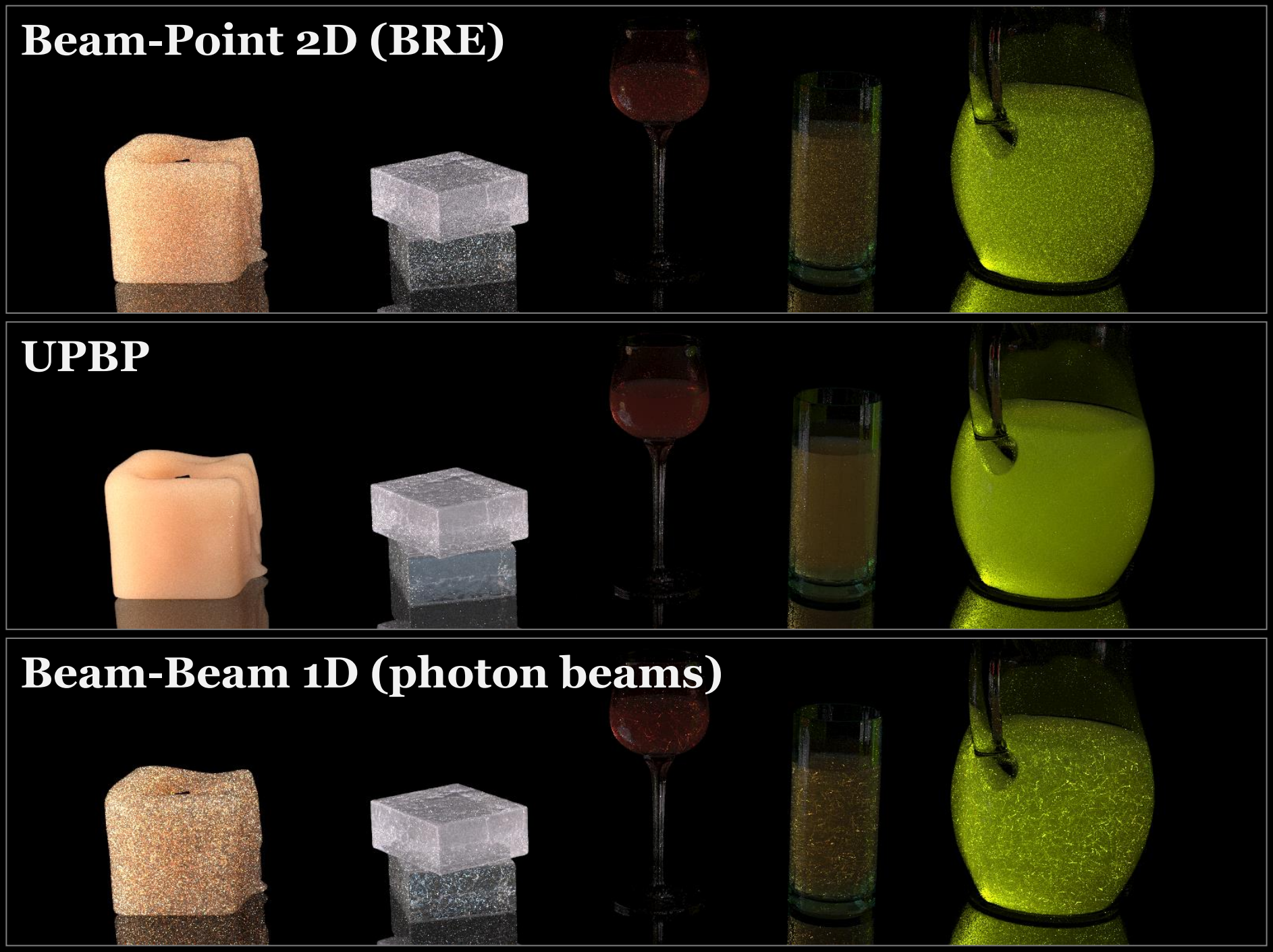
Weighted contributions





UPBP, 1 hr




Beam-Point 2D (BRE)
UPBP
Beam-Beam 1D (photon beams)

Limitations & future work

- **Efficiency-based combination**
- **Overhead**
  - Number of samples from different estimators

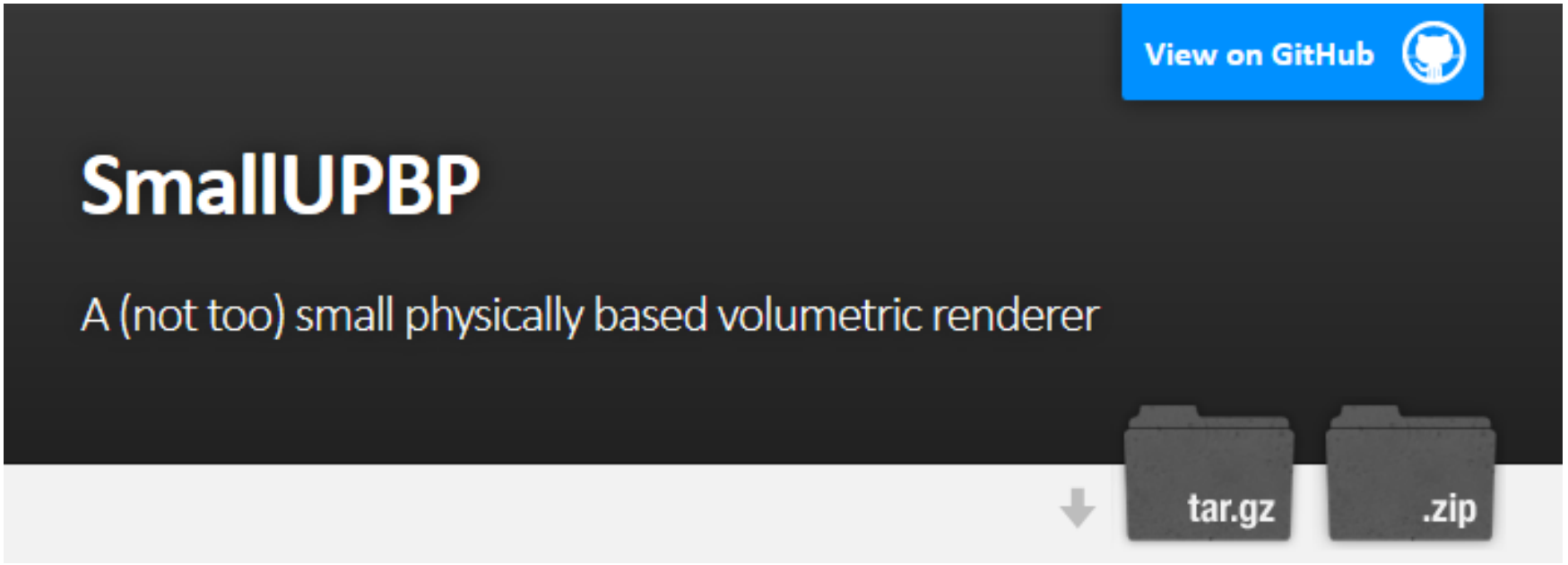
Take-home message

rare media

dense media

beams:		
points:		

Source code



http://www.smallupbp.com/

Acknowledgment

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