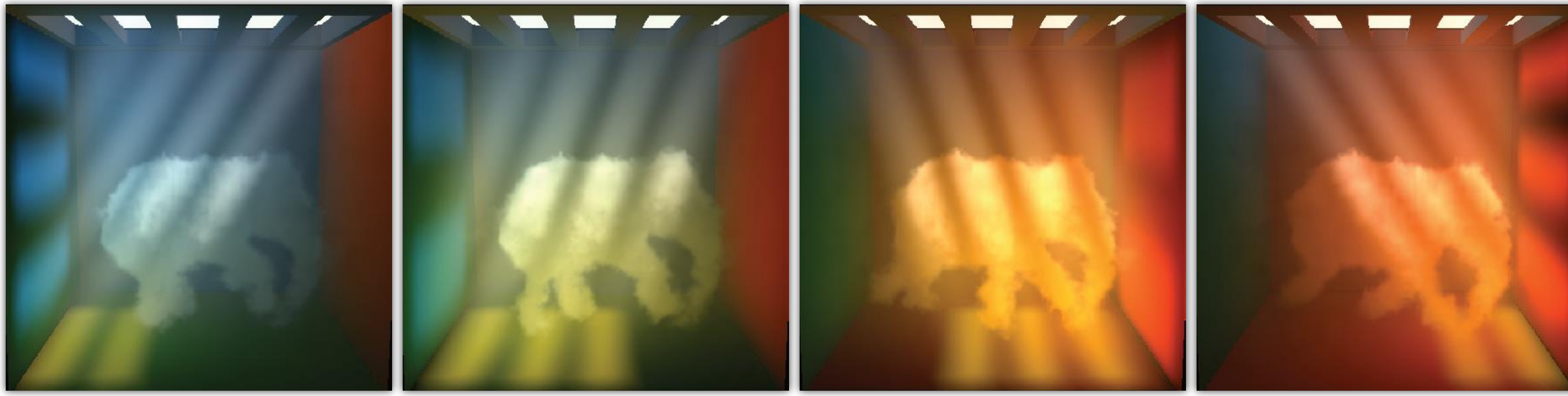
Graphics Interface 2014
May 7th to 9th, Montreal, Quebec, Canada



Interactive Light Scattering with Principal-Ordinate Propagation

Oskar Elek [1,2,3] Tobias Ritschel [1,2,3] Carsten Dachsbacher [4] Hans-Peter Seidel [1,3]

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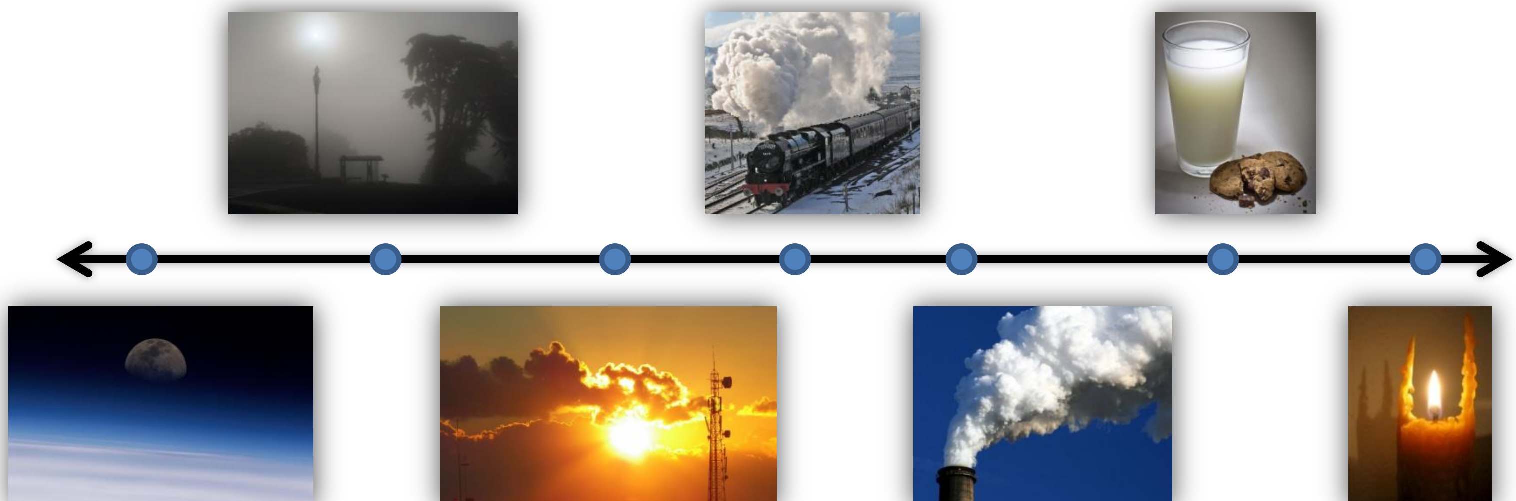
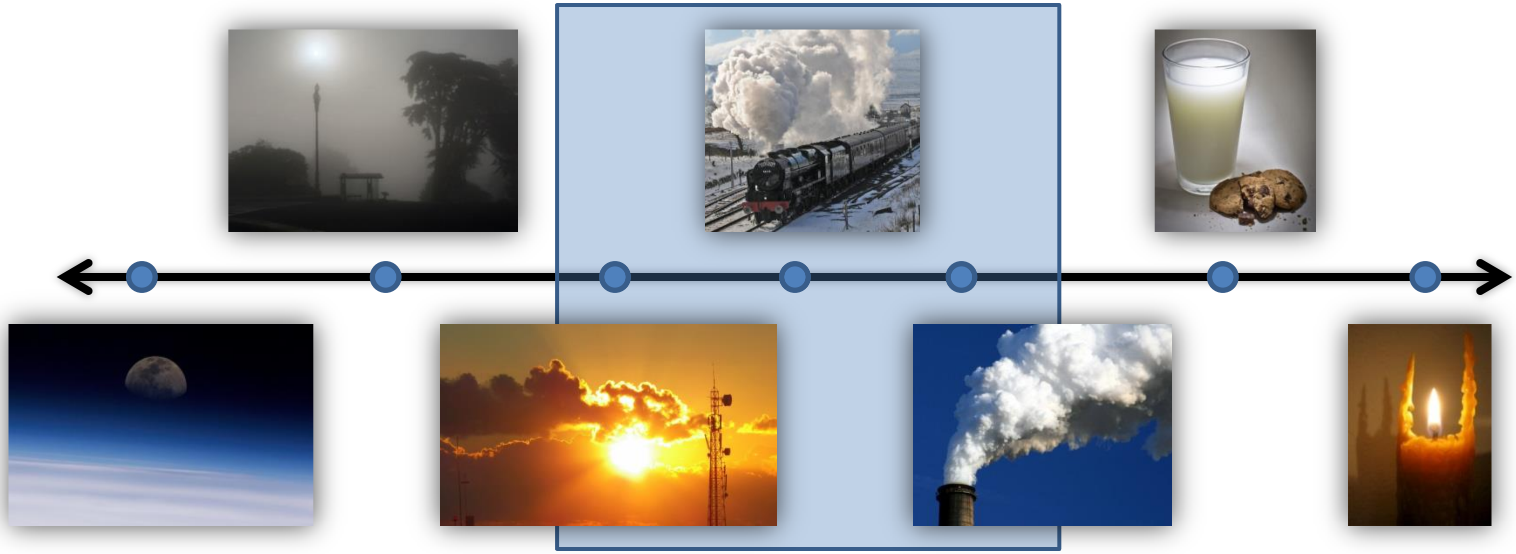
M2CI CLUSTER OF EXCELLENCE
UNIVERSITÄT DES SAARLANDES
KIT Karlsruher Institut für Technologie

PARTICIPATING MEDIA



Participating Media

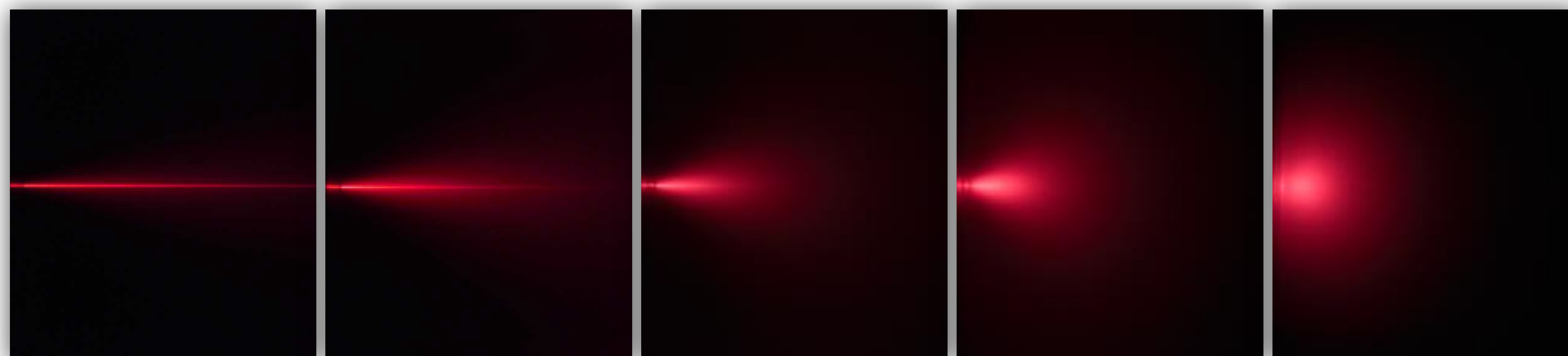


Light Scattering

Radiative Transfer Equation

$$\frac{dL(\vec{x},\vec{\omega})}{d\vec{x}} = -\sigma_t L(\vec{x},\vec{\omega}) + \sigma_s \int_{\Omega_{4\pi}} f(\vec{x},\vec{\omega}',\vec{\omega}) L(\vec{x},\vec{\omega}')\, d\vec{\omega}'$$

[Premoze, Ashikhmin, Ramamoorthi, Nayar: Practical Rendering of Multiple Scattering Effects in Participating Media, EGSR, 2004]



Medium density

WISHLIST

- Interactivity
- Dynamicity
- Physical plausibility
- Generality

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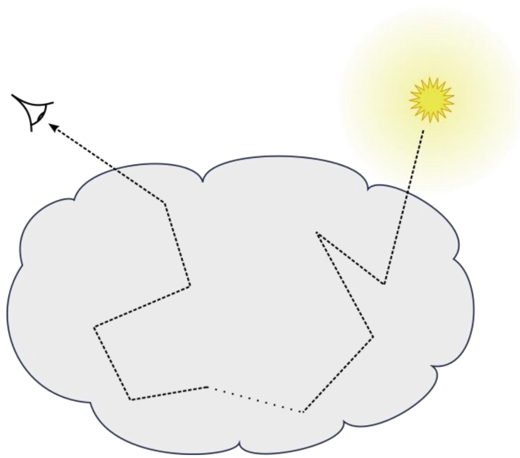
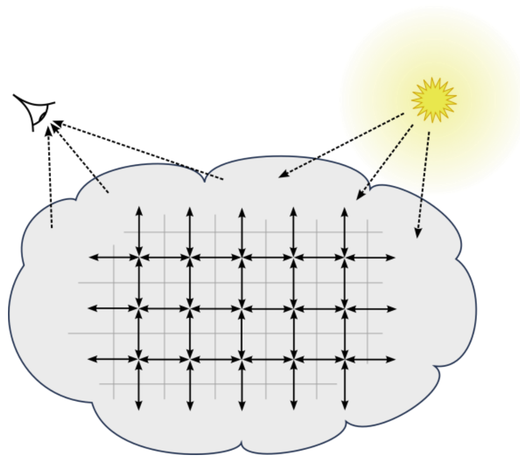


Monte-Carlo
(Path Tracing,
Photon Mapping…)



Finite-Elements
(Diffusion, Discrete-Ordinates,
Lattice-Boltzmann…)

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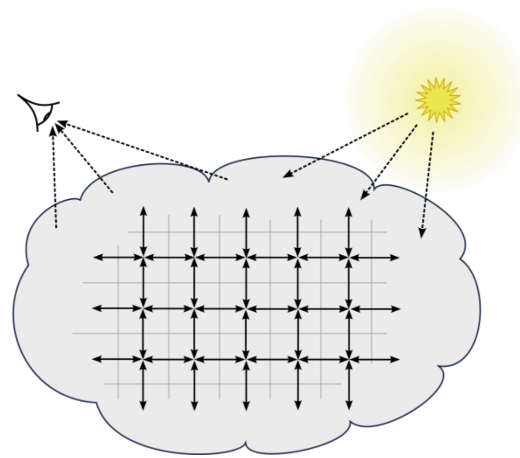

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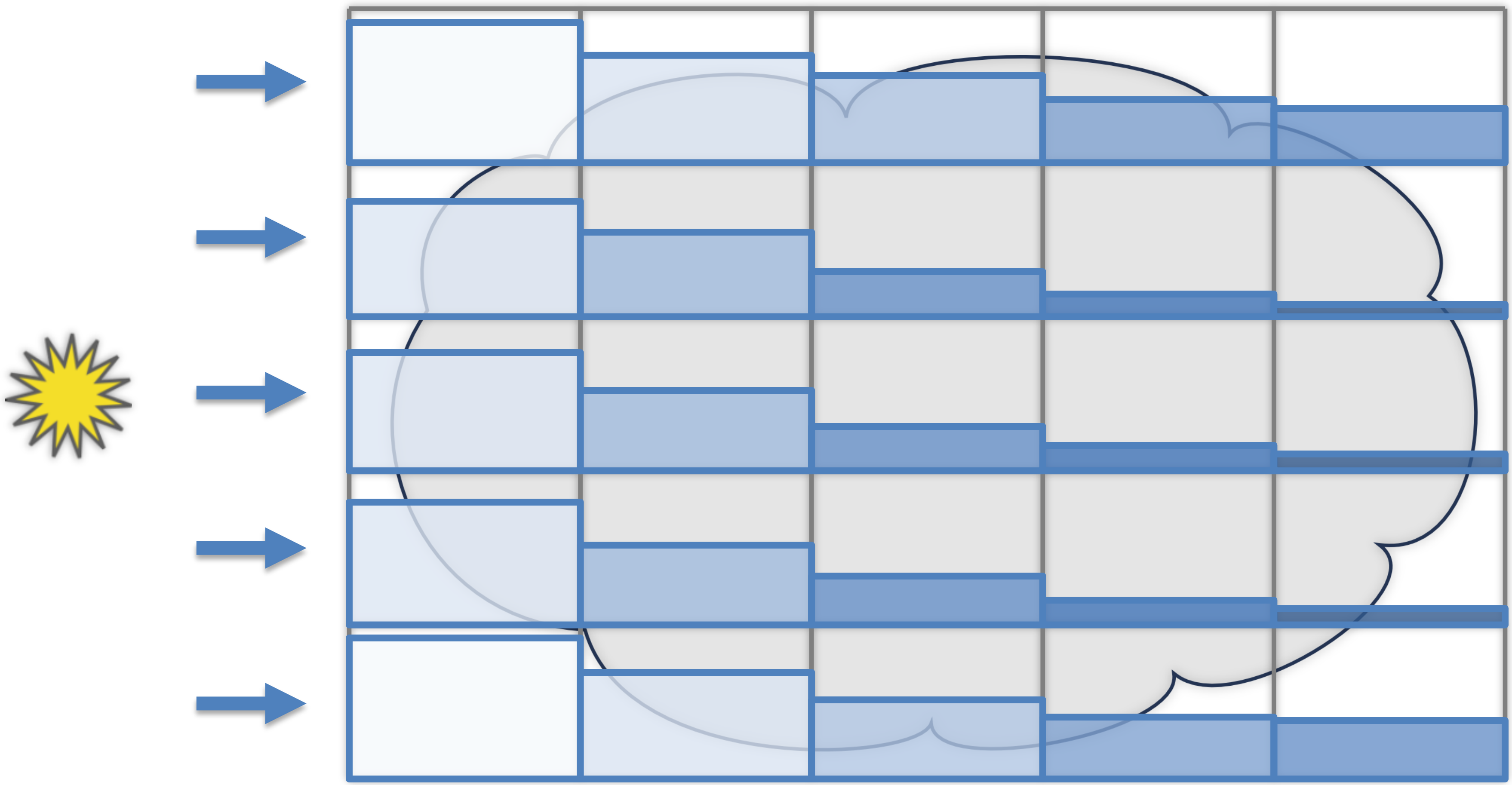
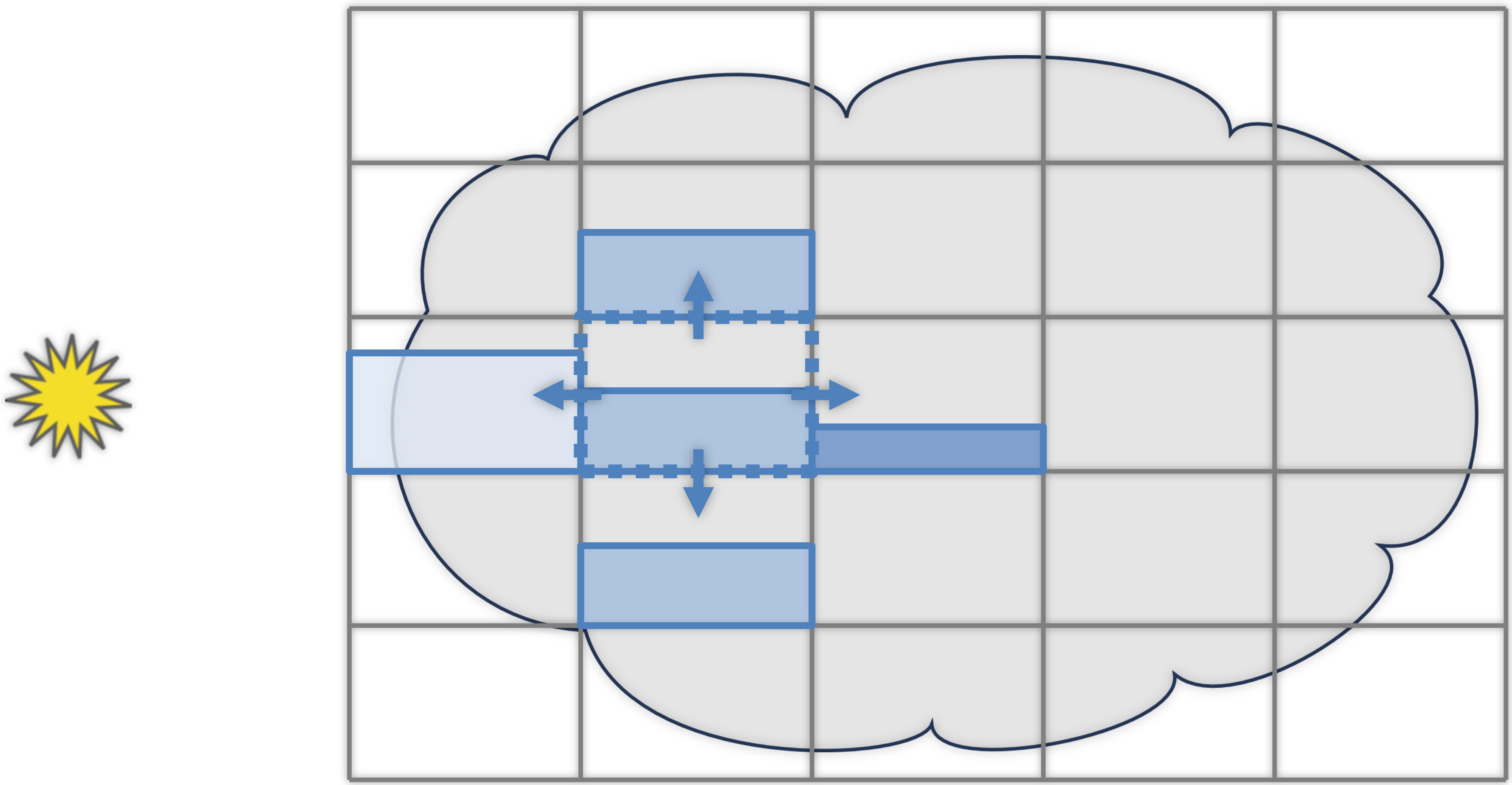
Finite Elements



Finite Elements



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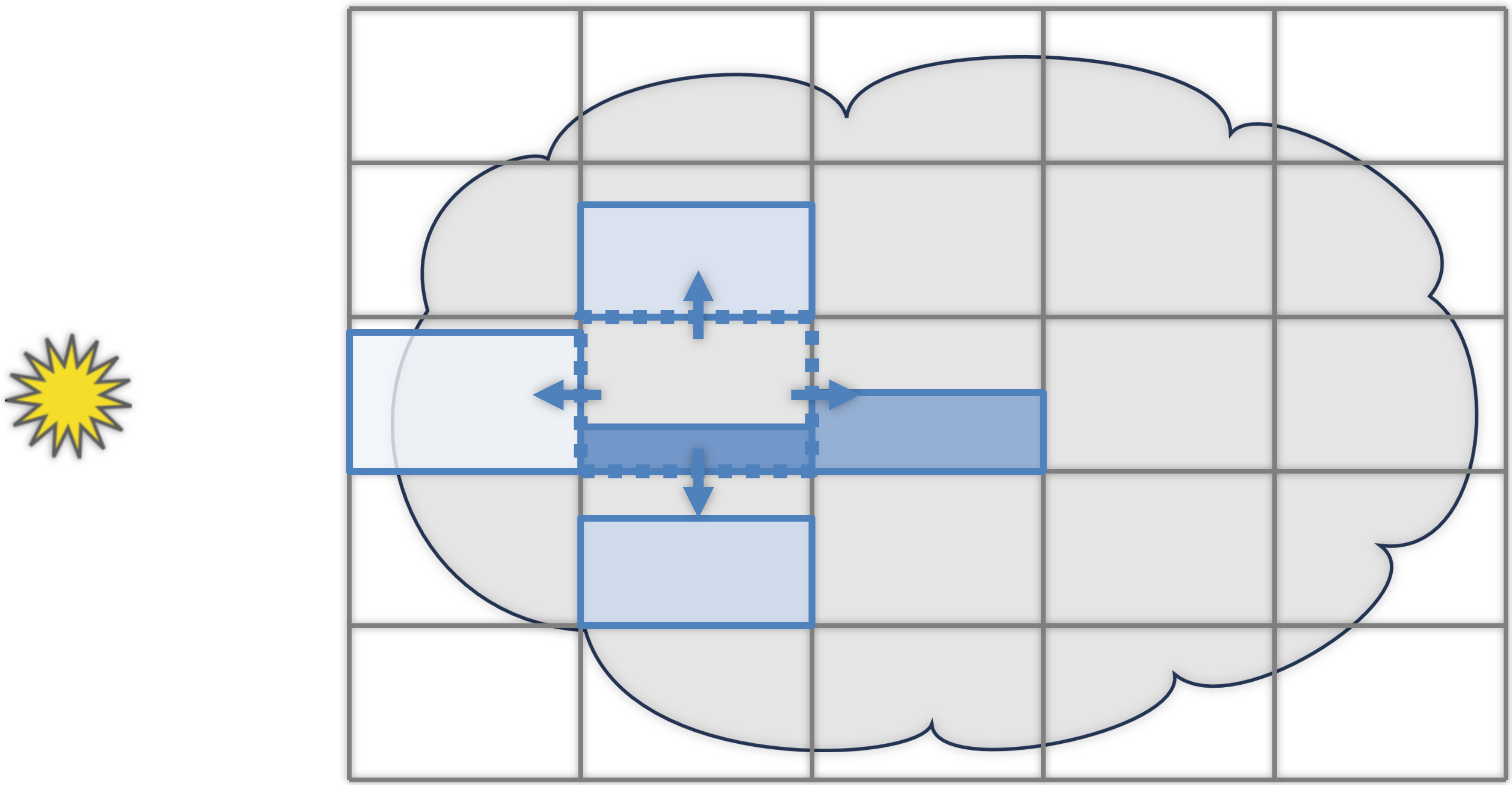

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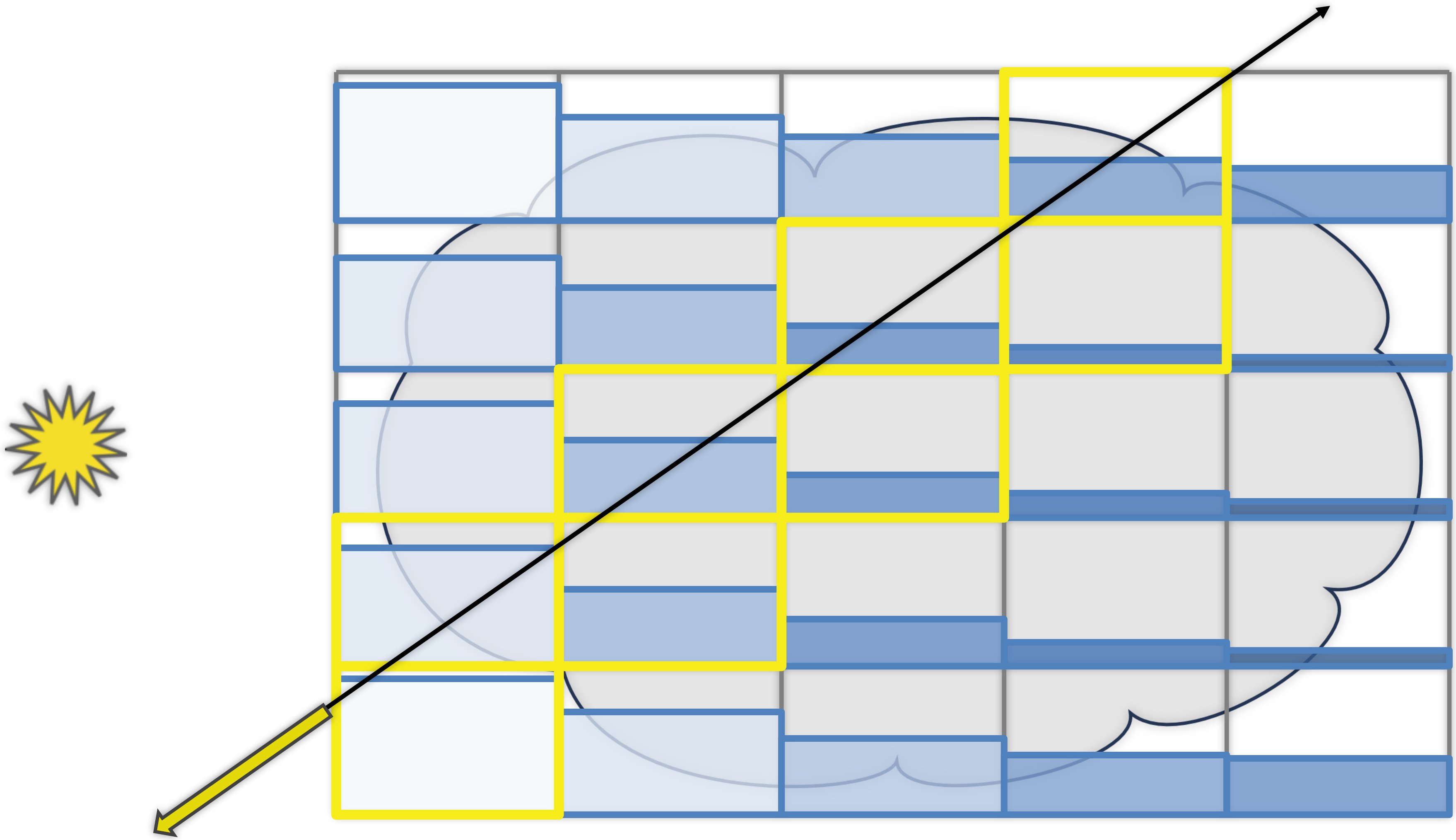
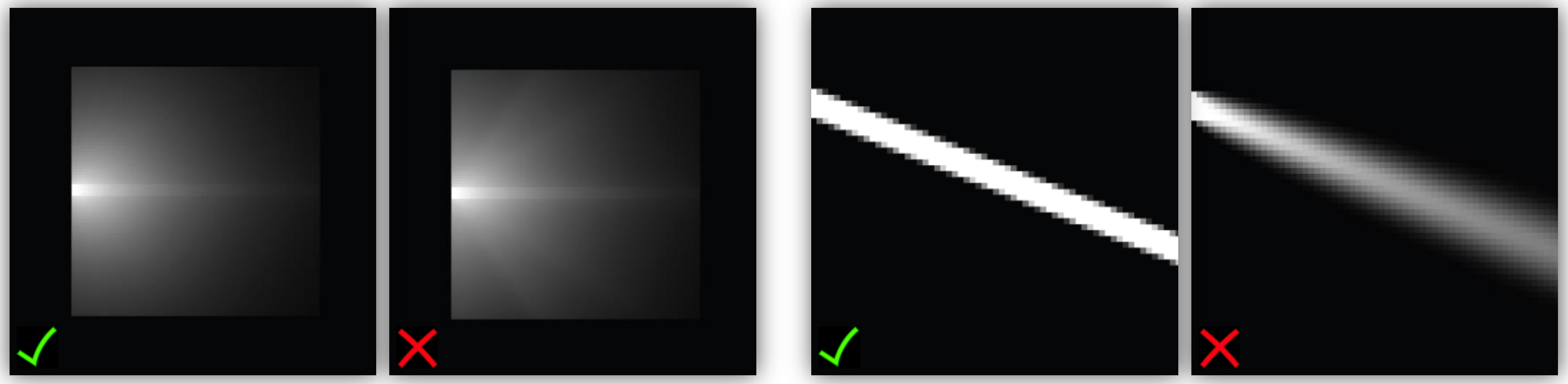


FINITE ELEMENTS

Problems

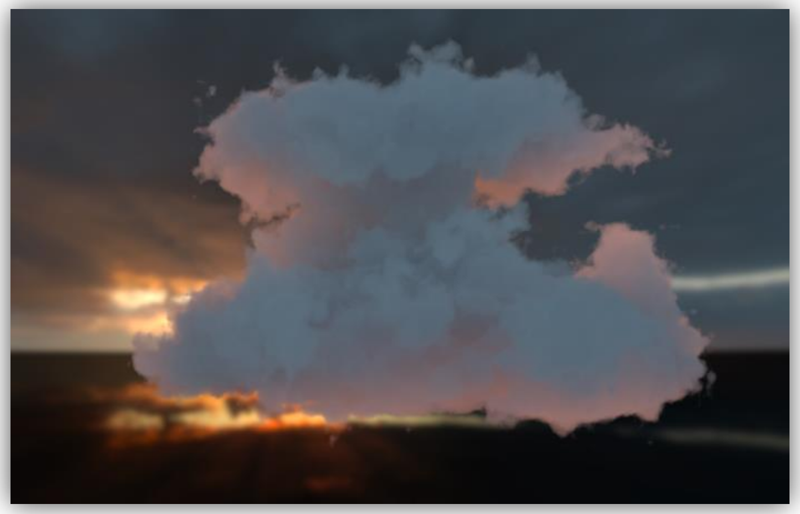
[Fattal: Participating Media Illumination Using Light Propagation Maps, ACM ToG, 2009]



Ray effect

False scattering

Scattering Anisotropy

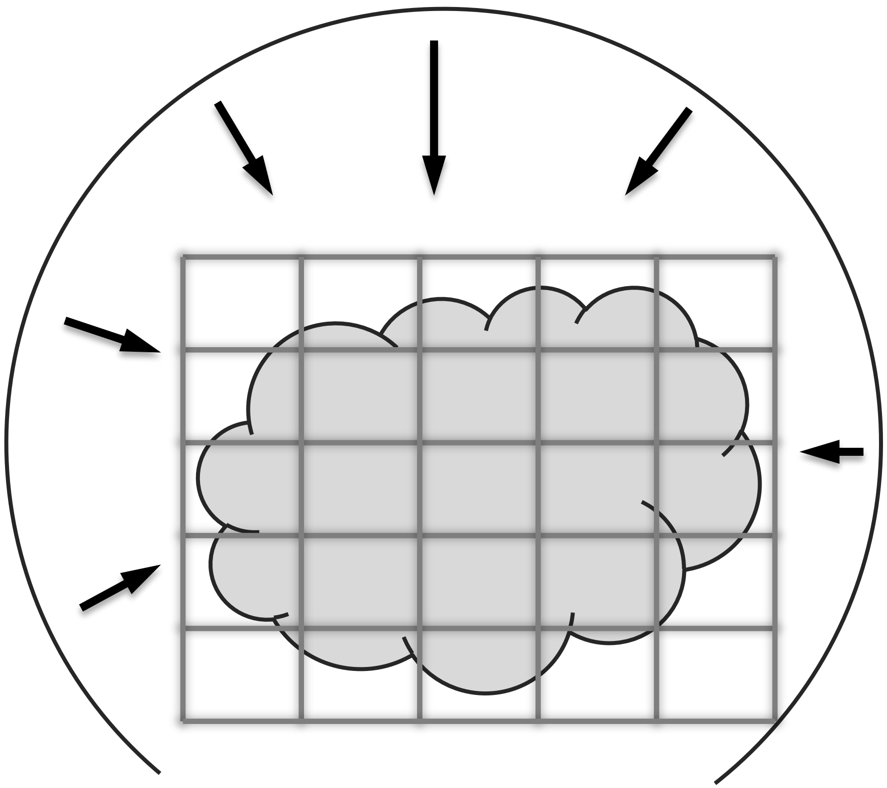


Isotropic scattering

Anisotropic scattering

Principal Ordinates

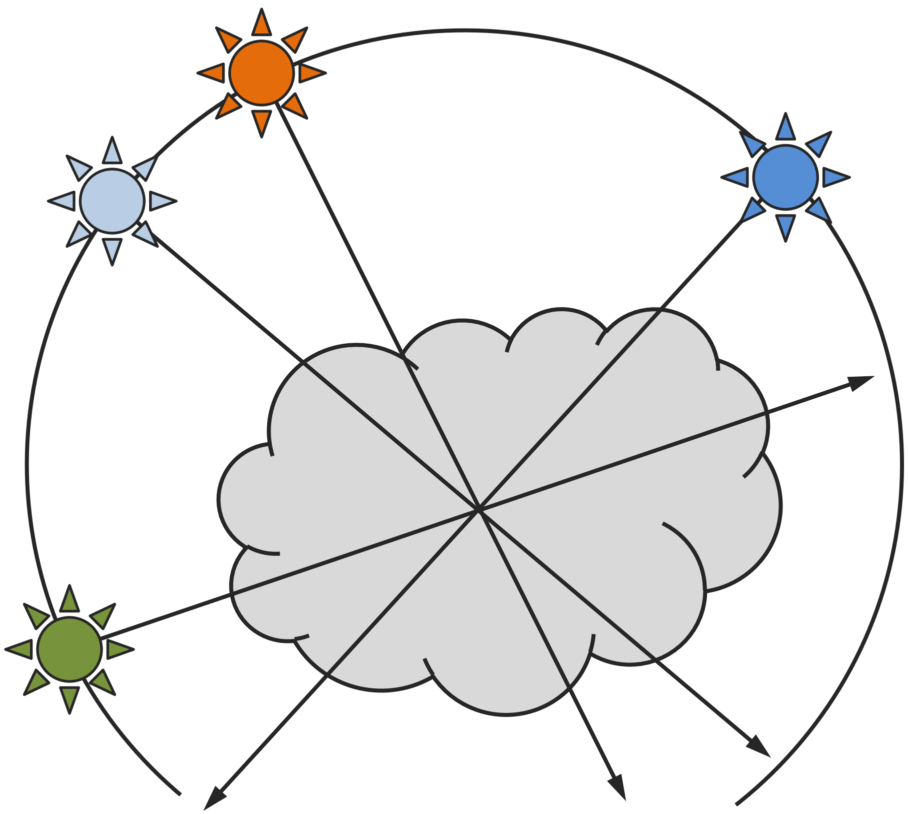
Idea: Instead of solving the transport globally…



Principal Ordinates

Idea: Instead of solving the transport globally…

…separate it, similar to Instant Radiosity



PRINCIPAL ORDINATES

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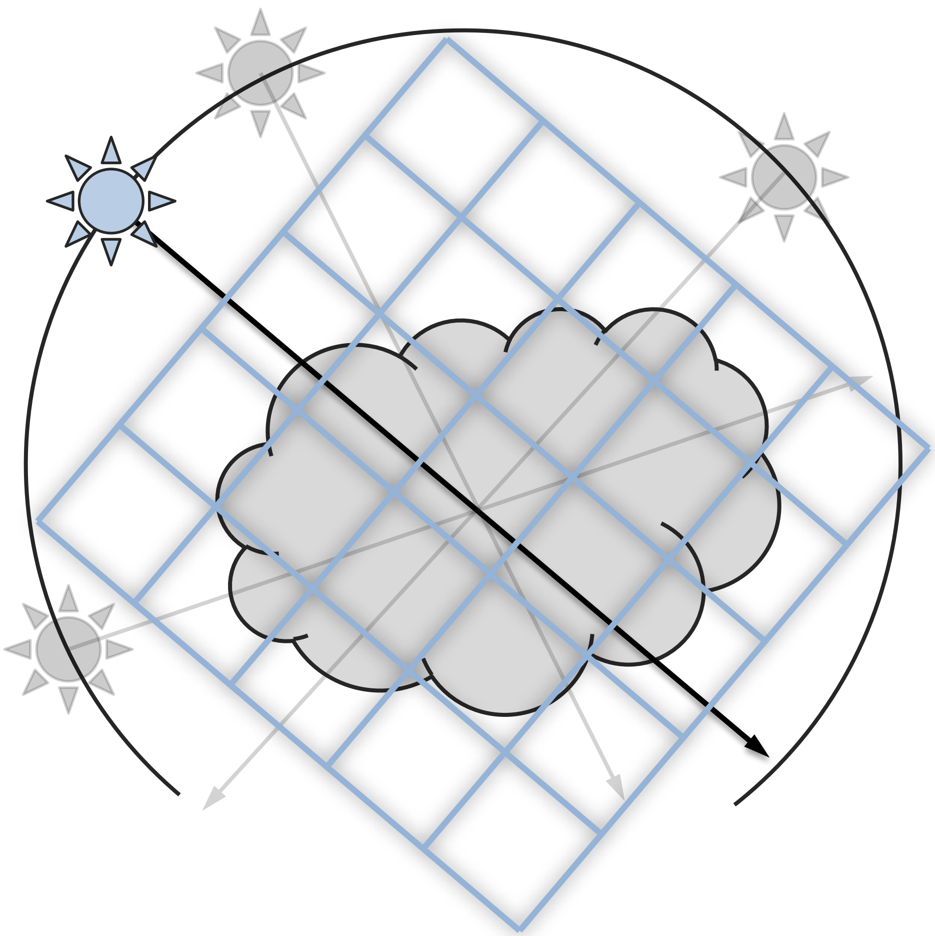

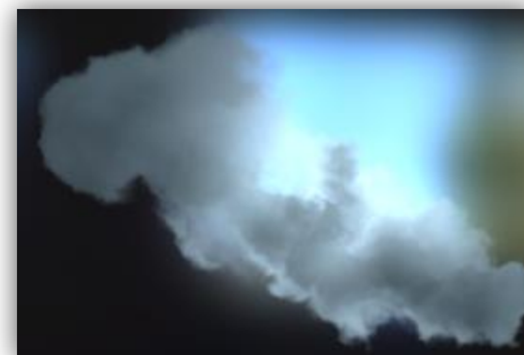

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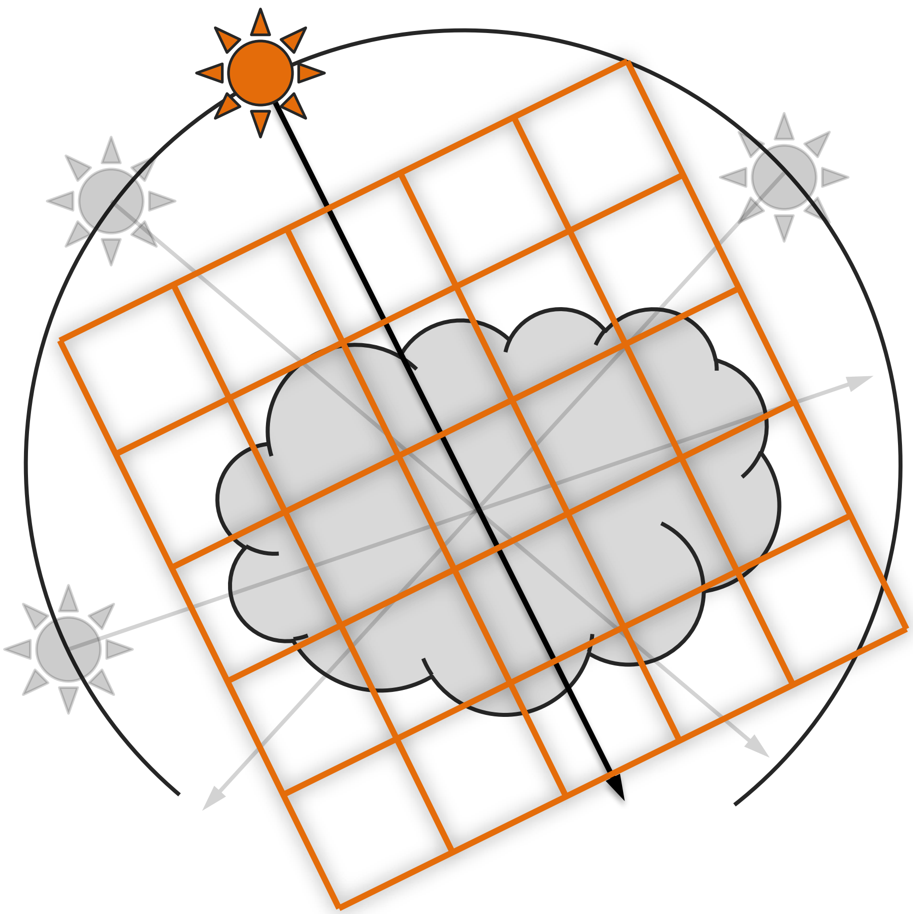

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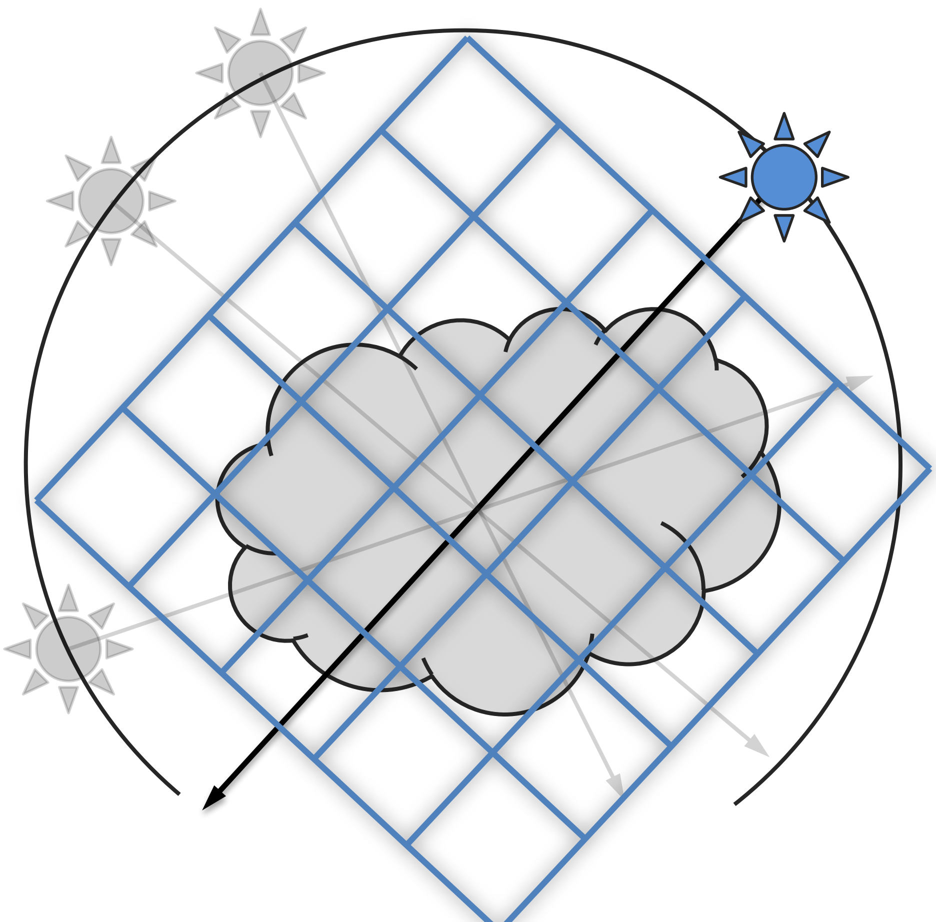

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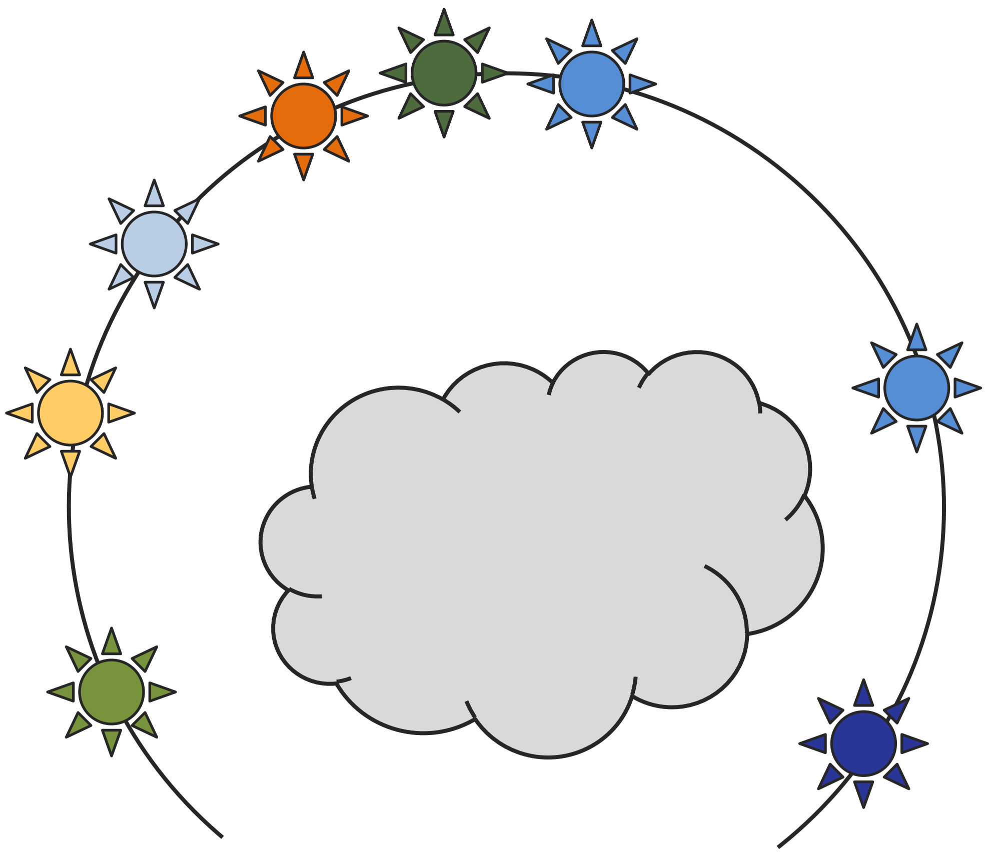

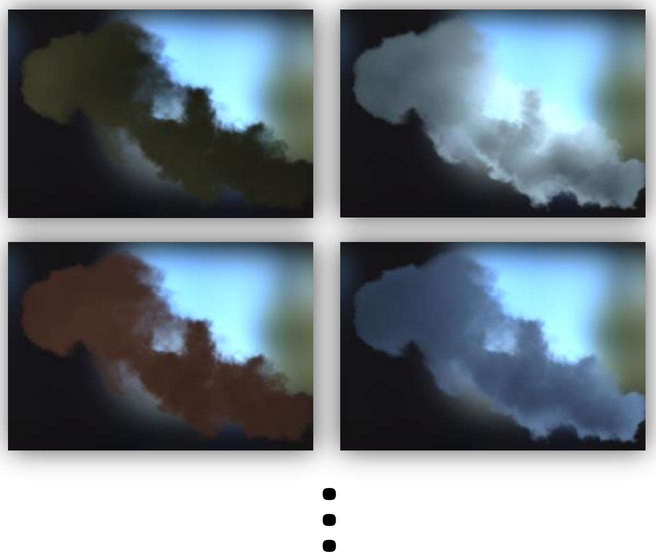

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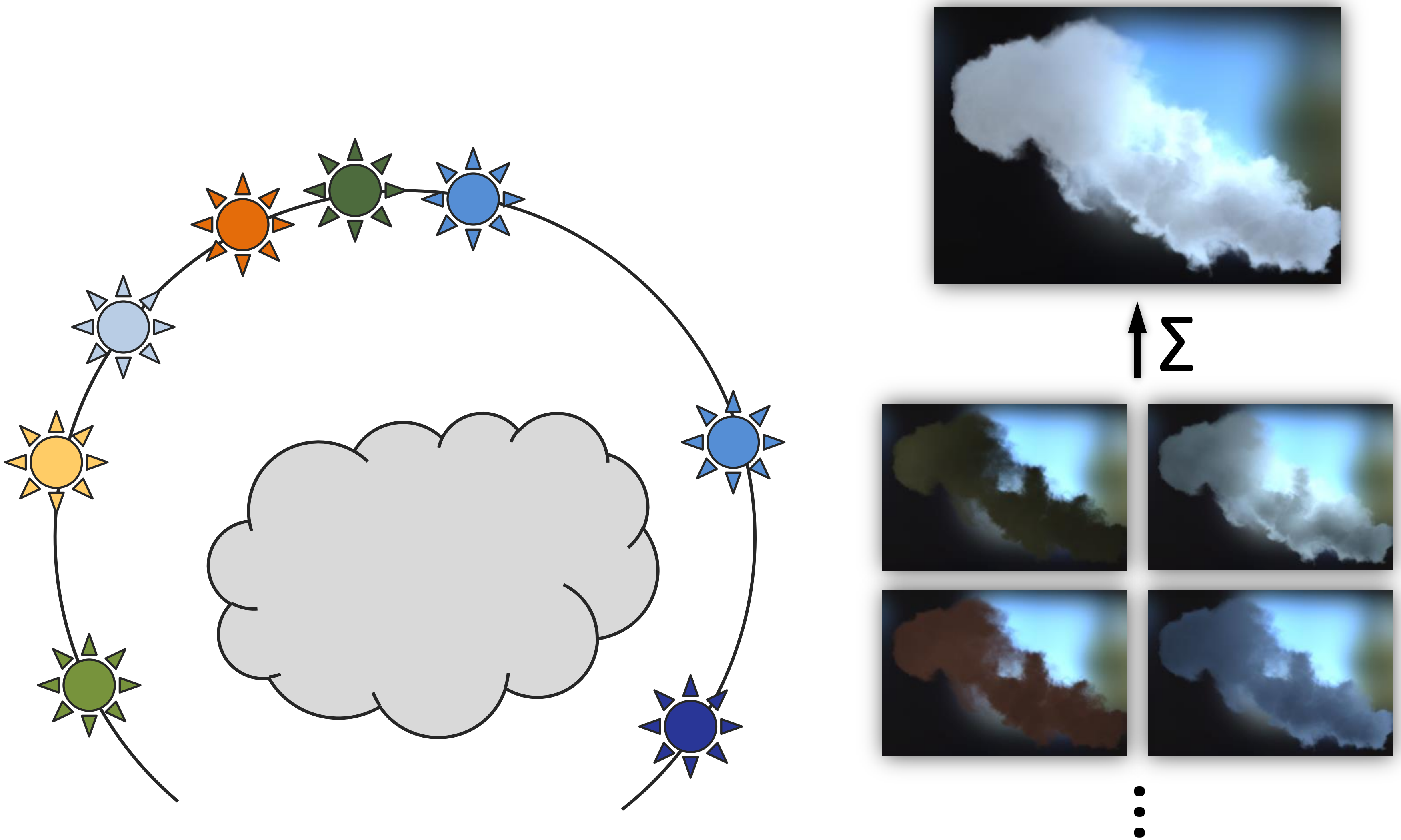
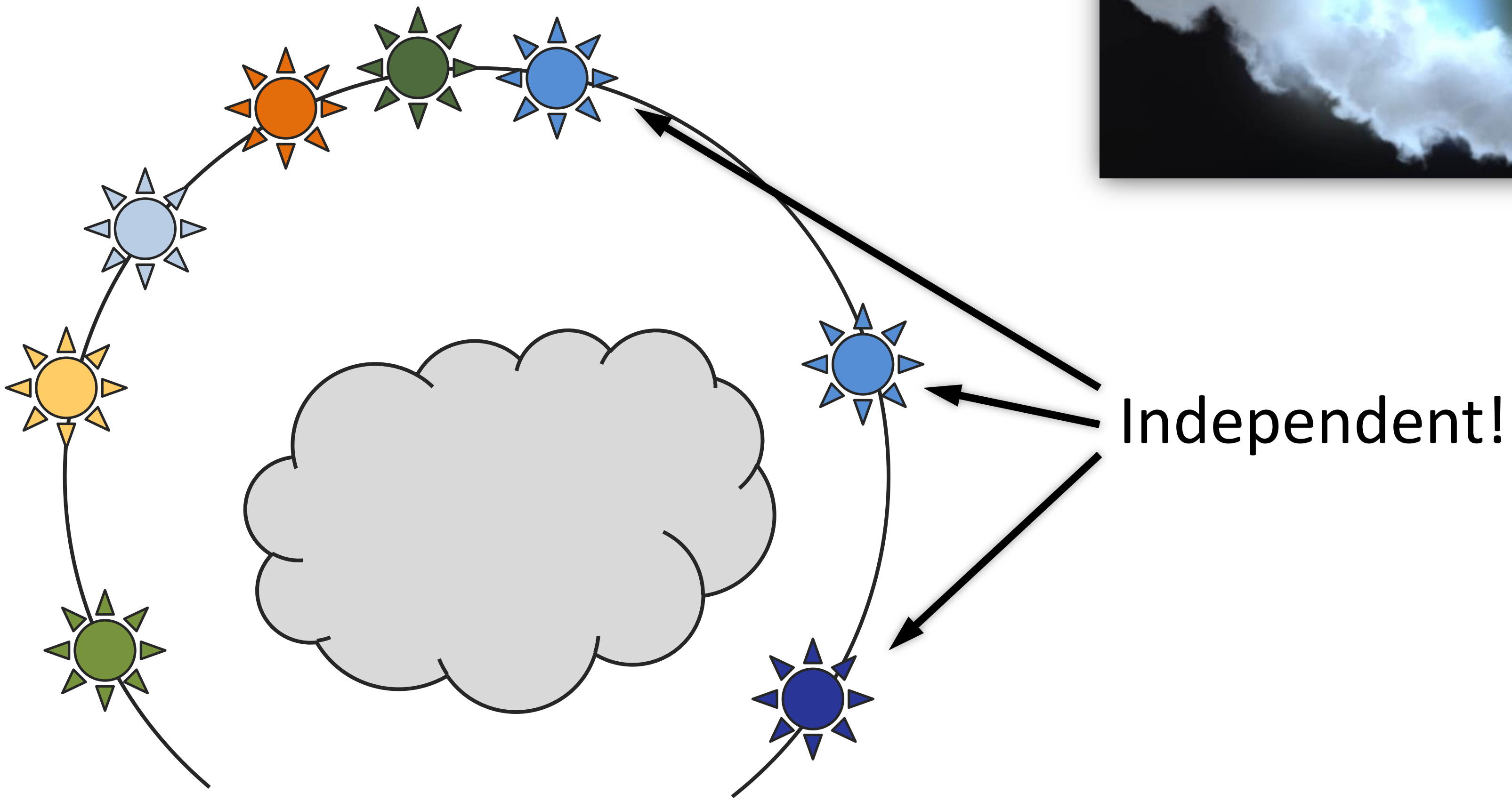


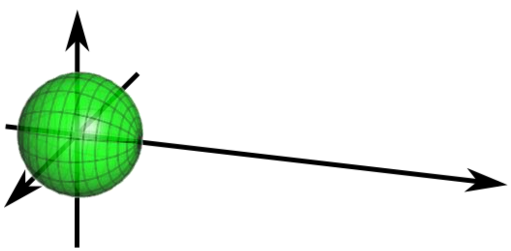
Principal Ordinates



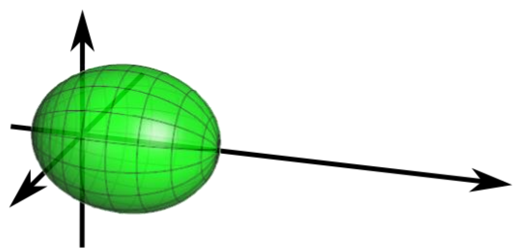
Propagation Basis

Henyey-Greenstein distribution

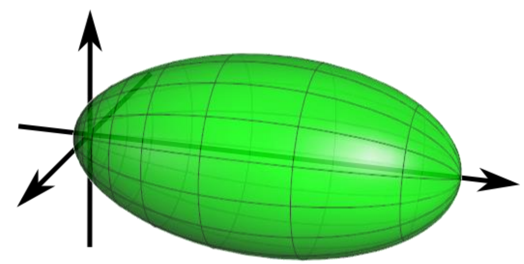
$$f_{\mathrm{HG}}(\theta, g) = \frac{1}{4\pi} \cdot \frac{1-g^2}{(1+g^2-2g\cos\theta)^{3/2}}$$



g=0

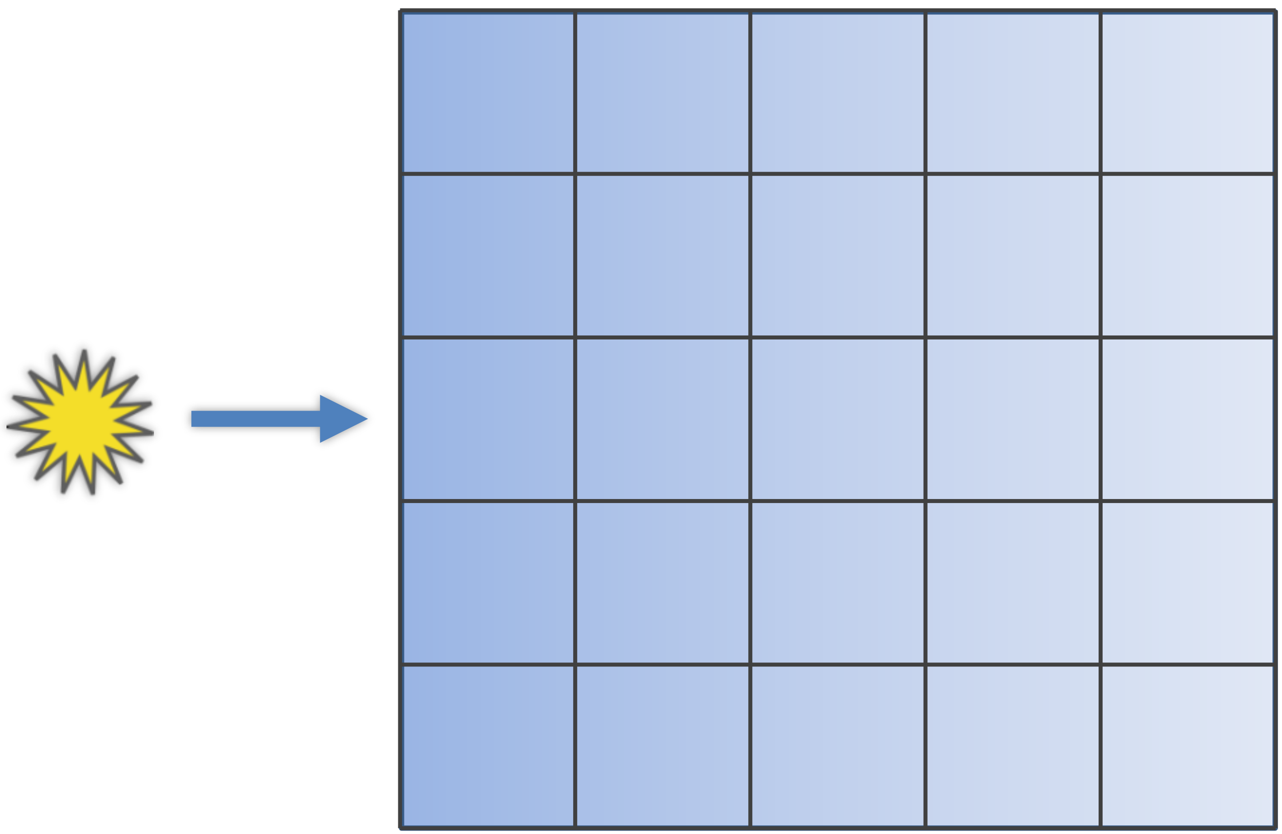


g=0.3



g=0.5

Light Propagation



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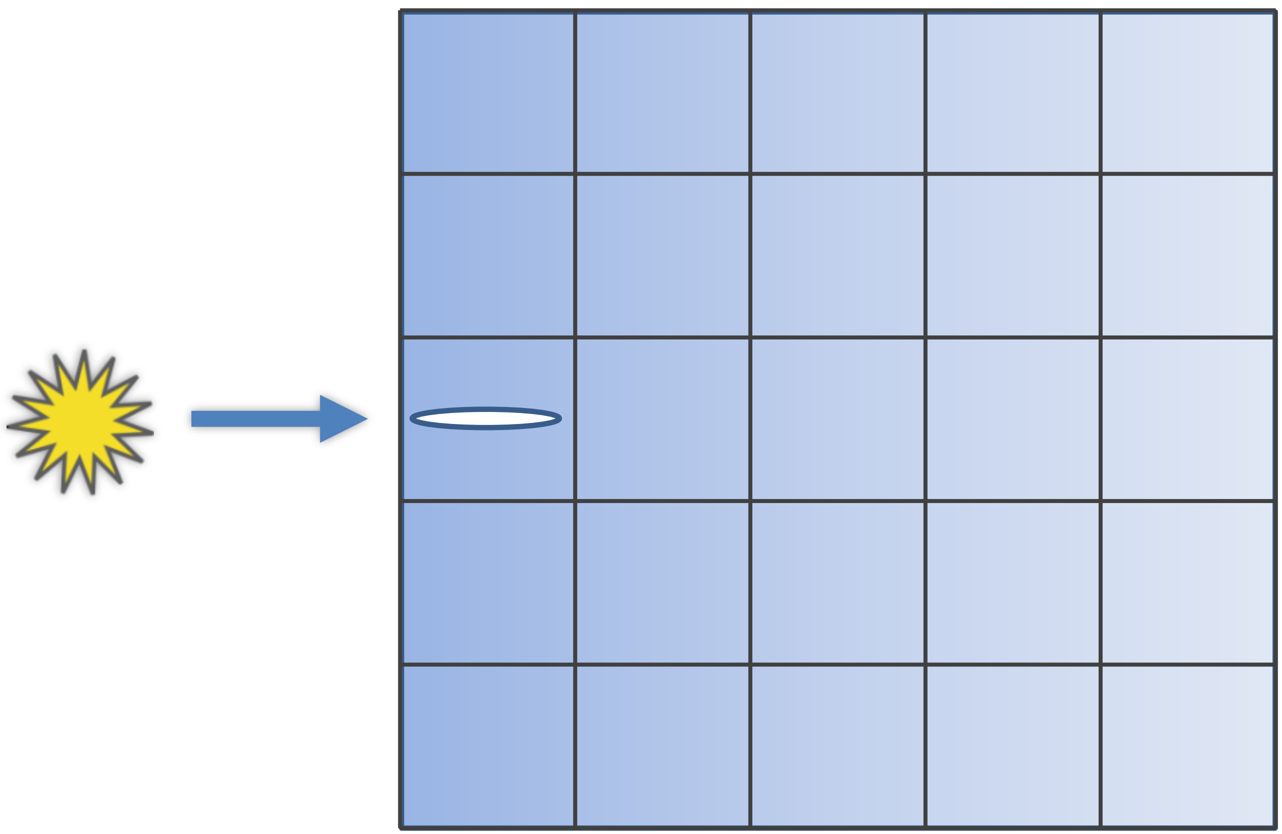

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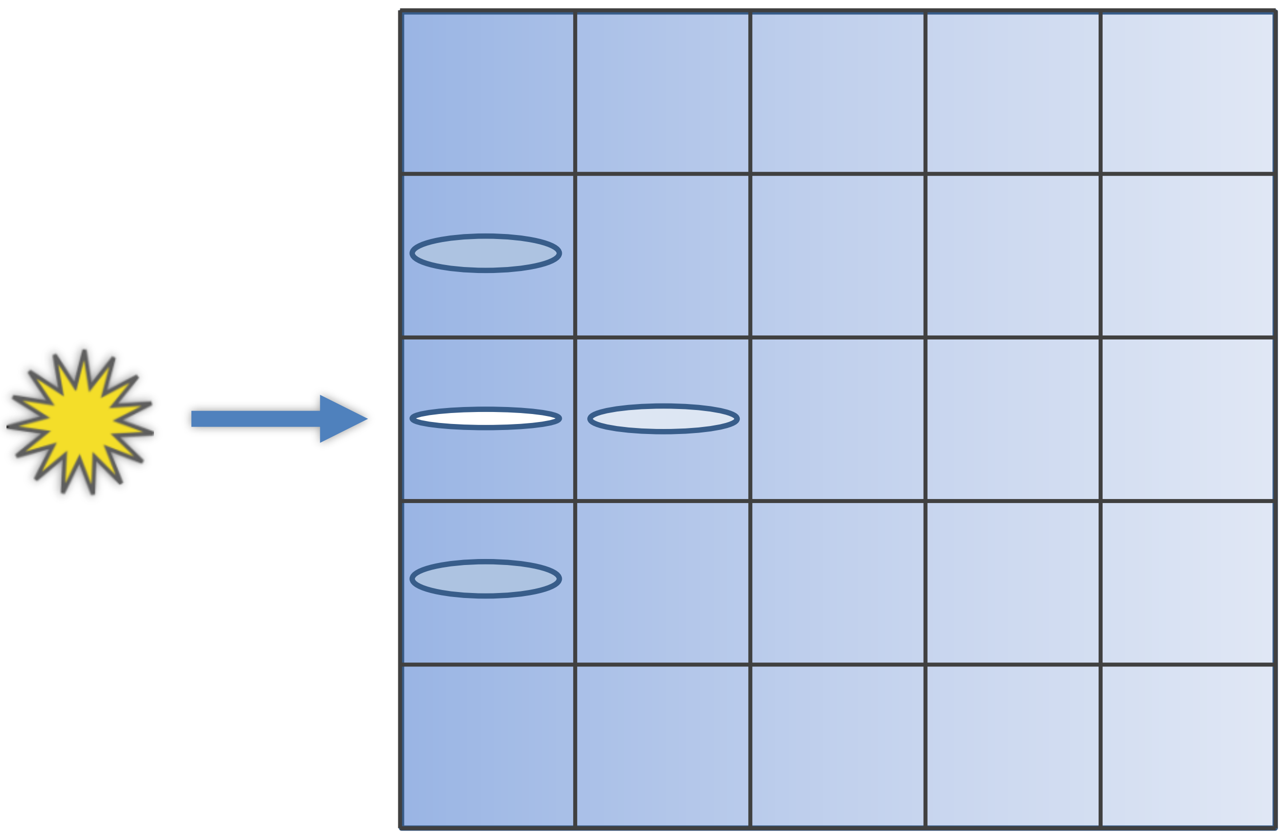

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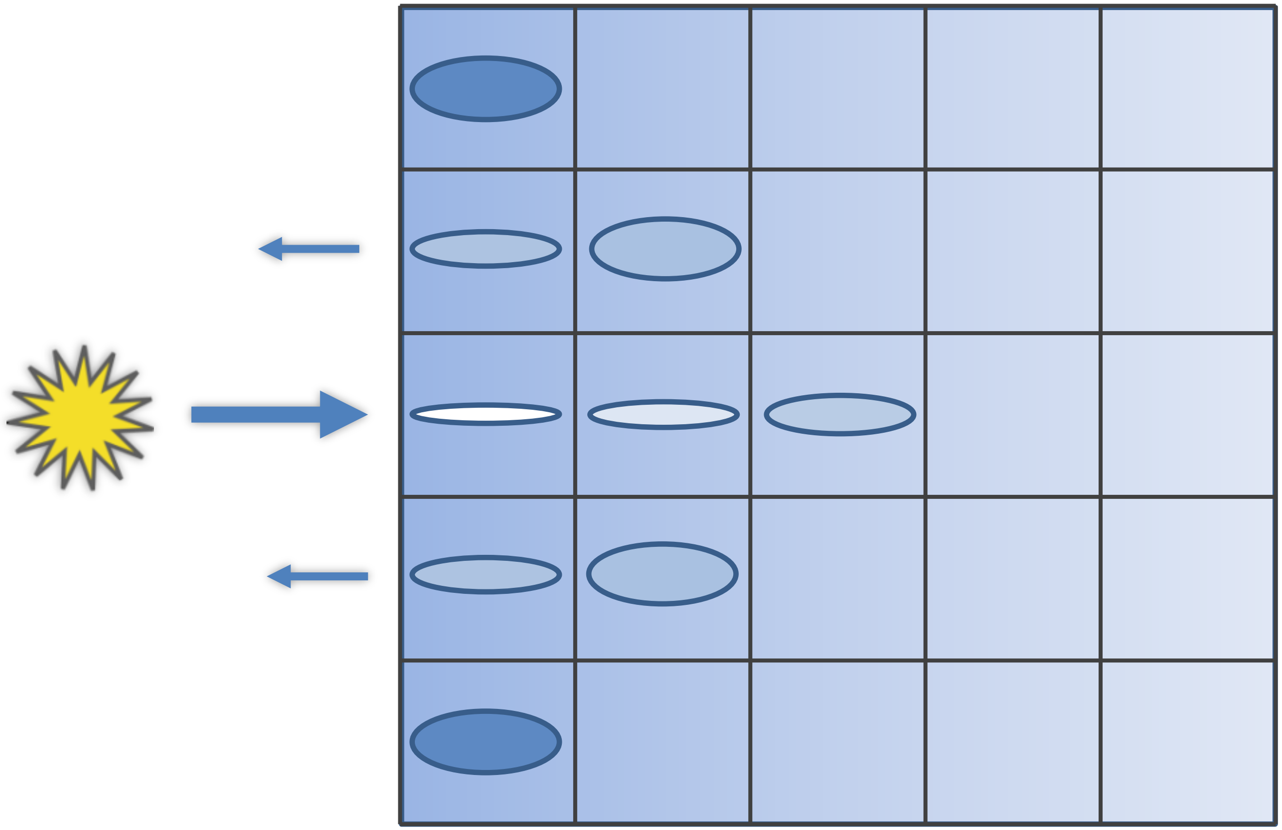

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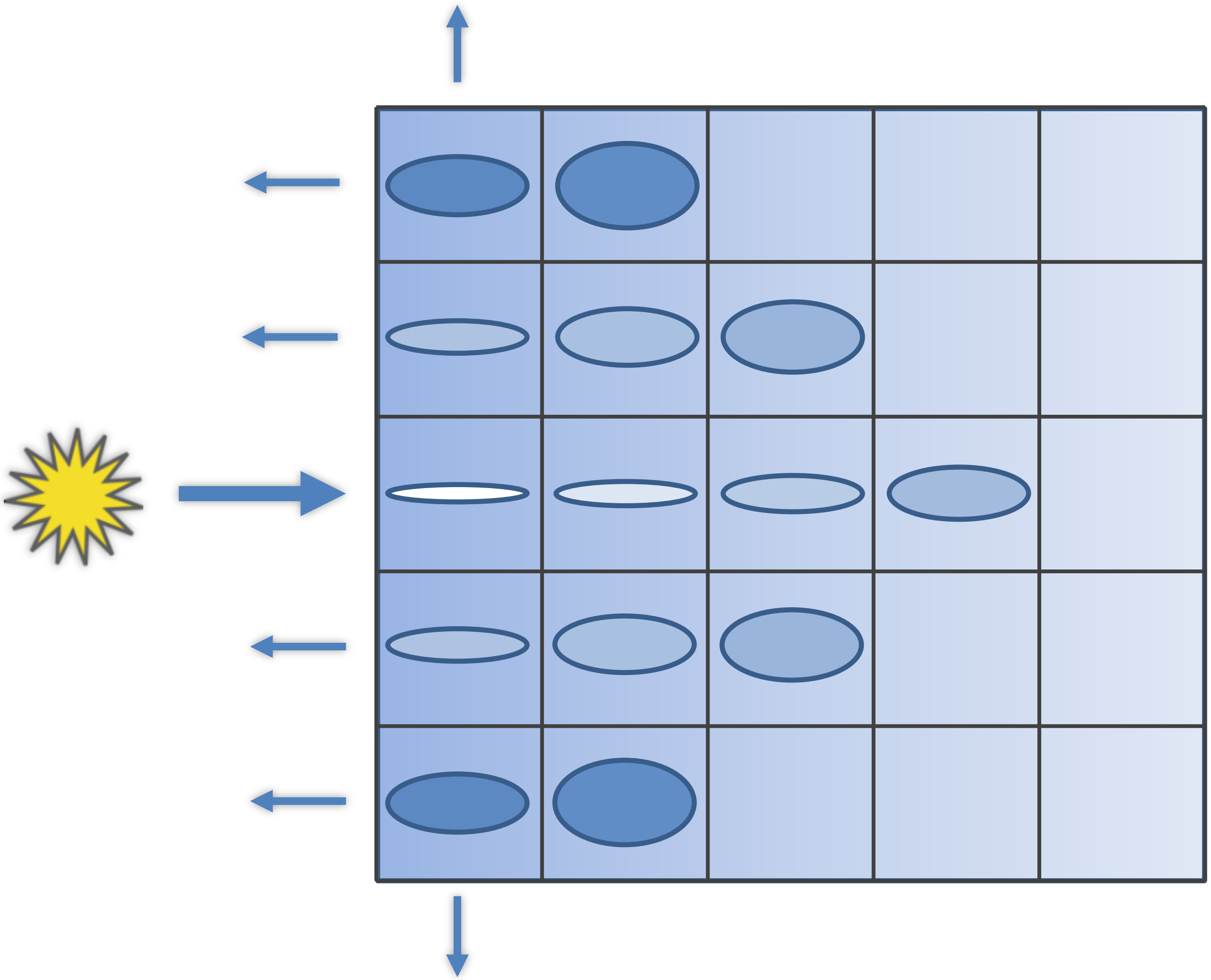
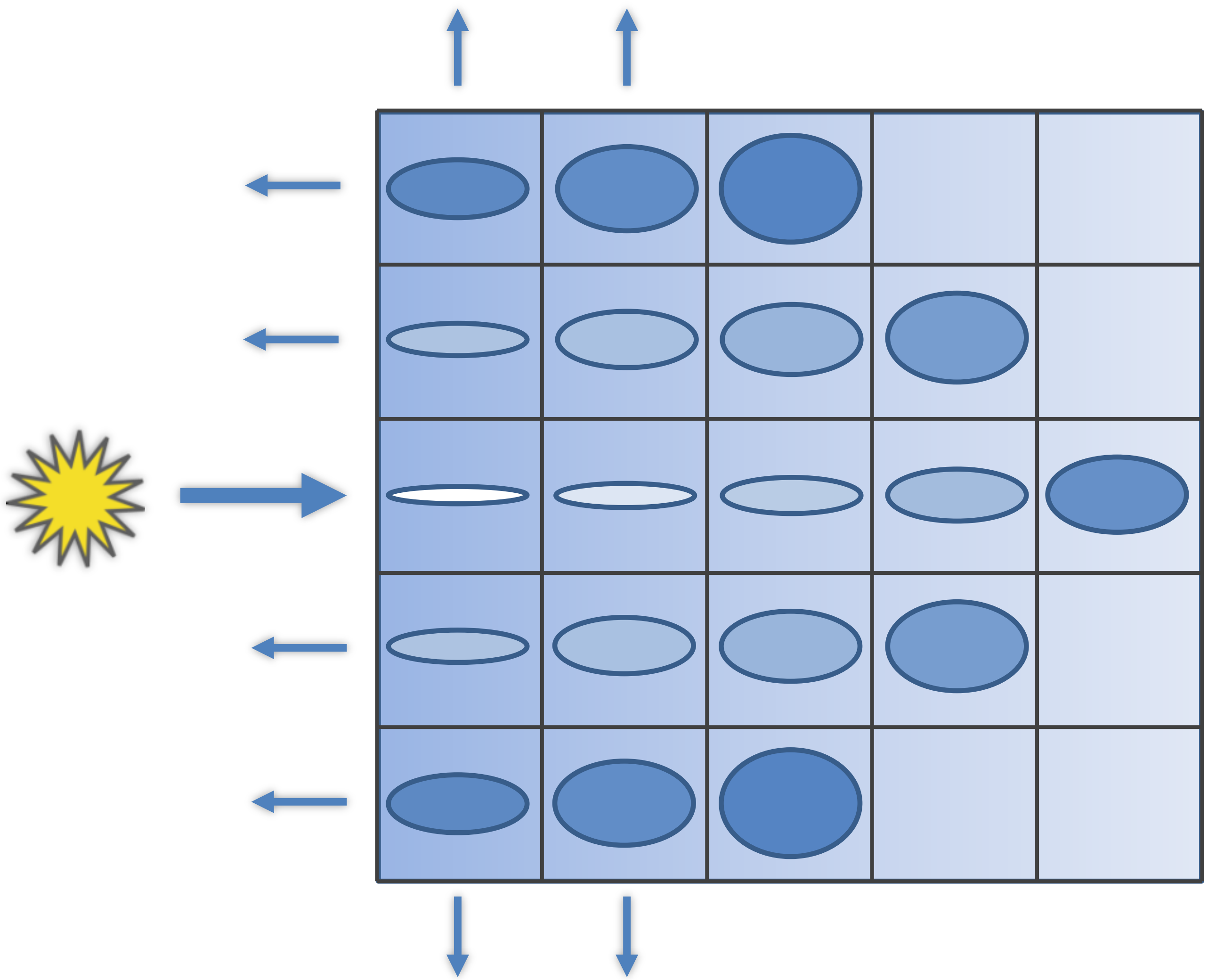


LIGHT PROPAGATION



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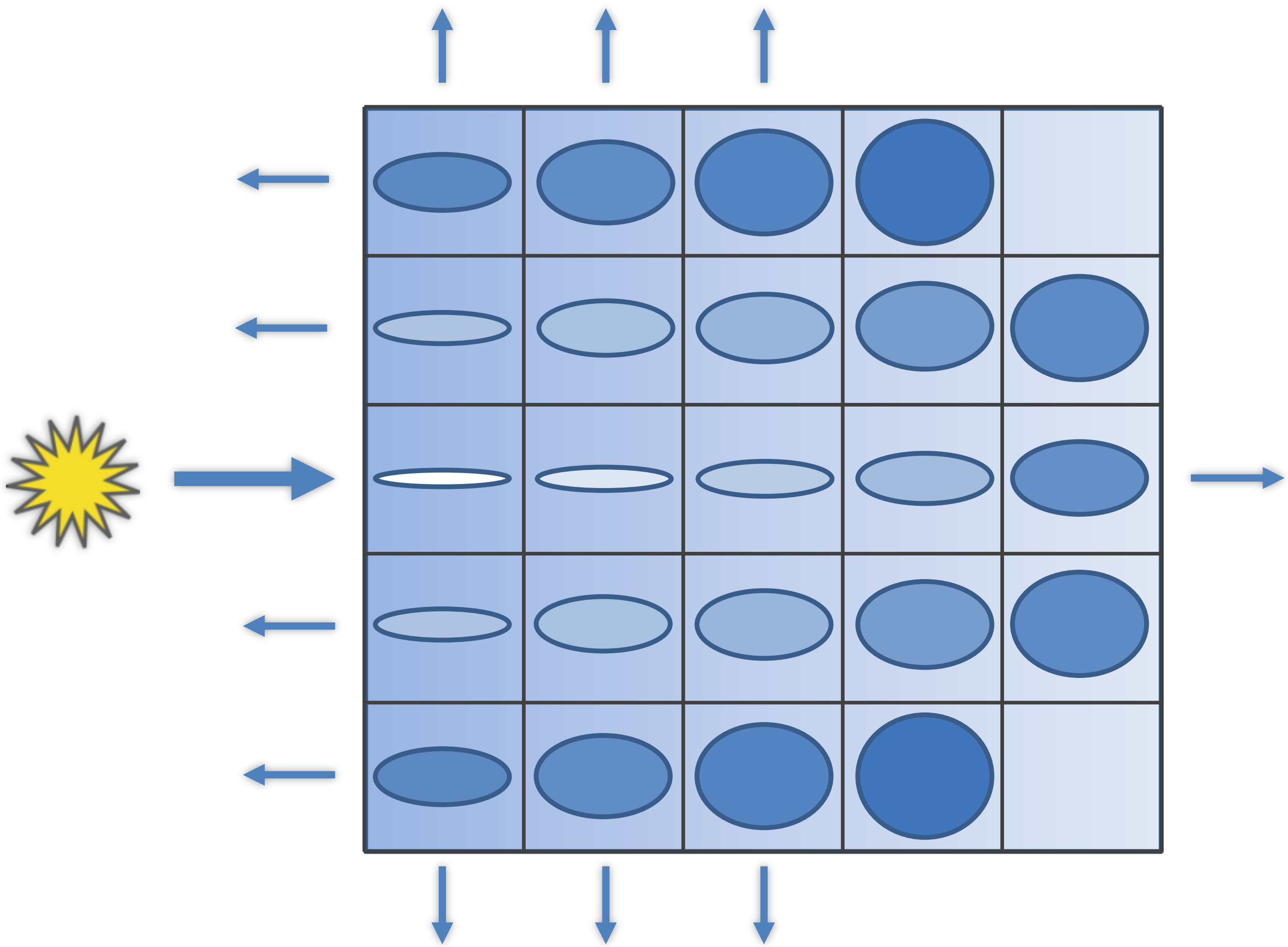

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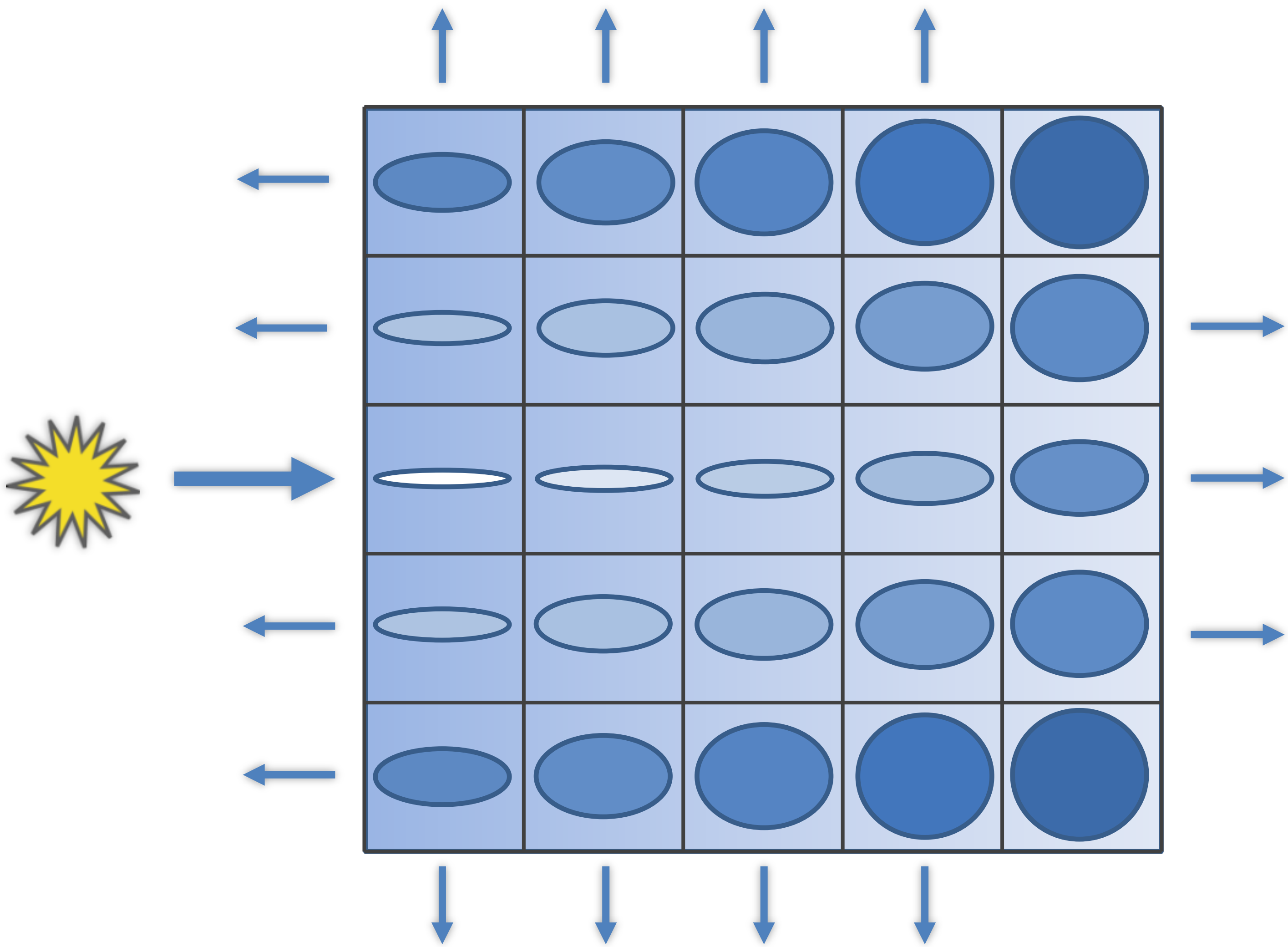

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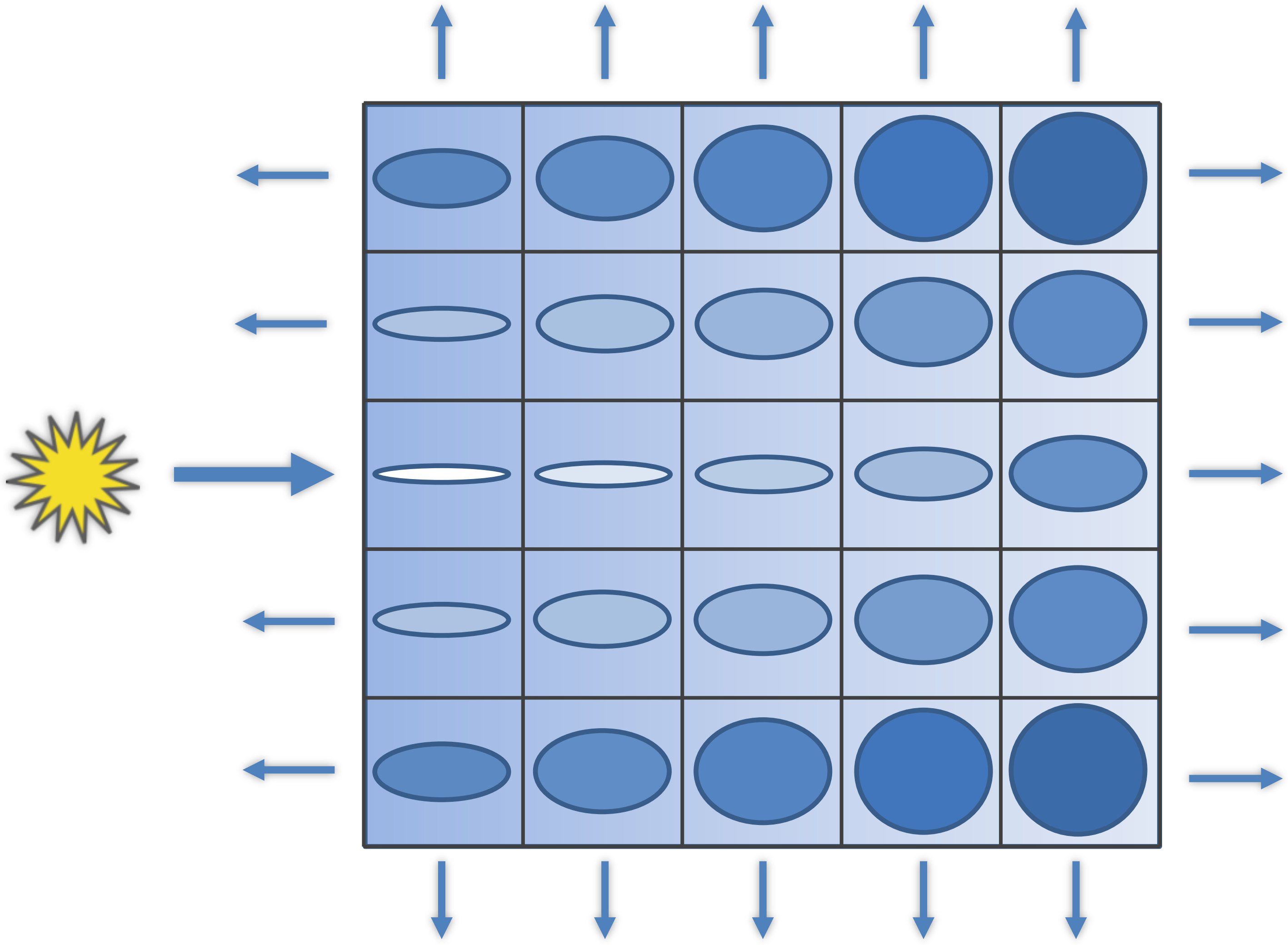

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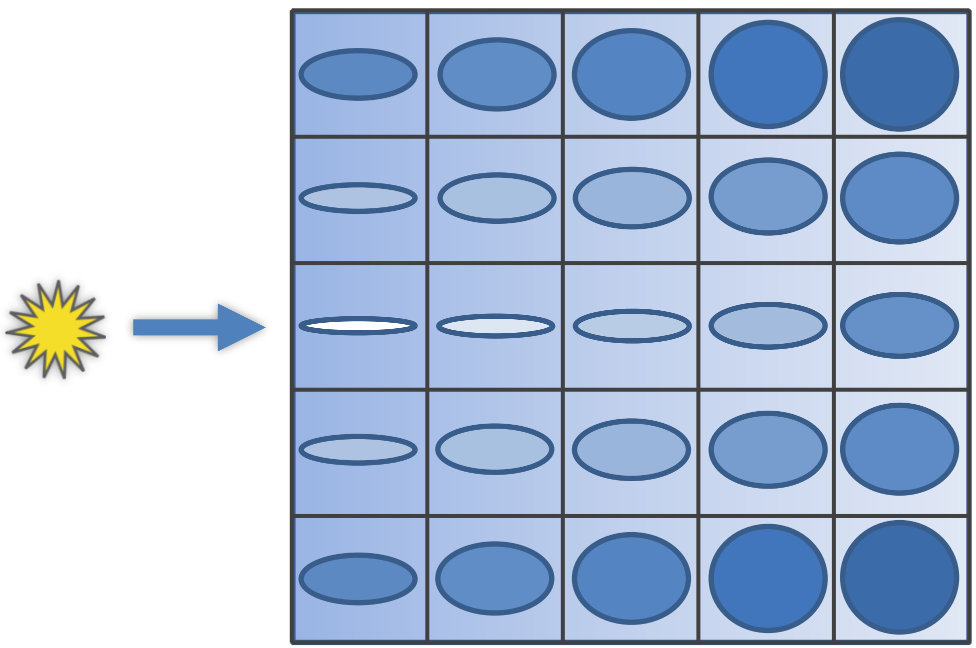

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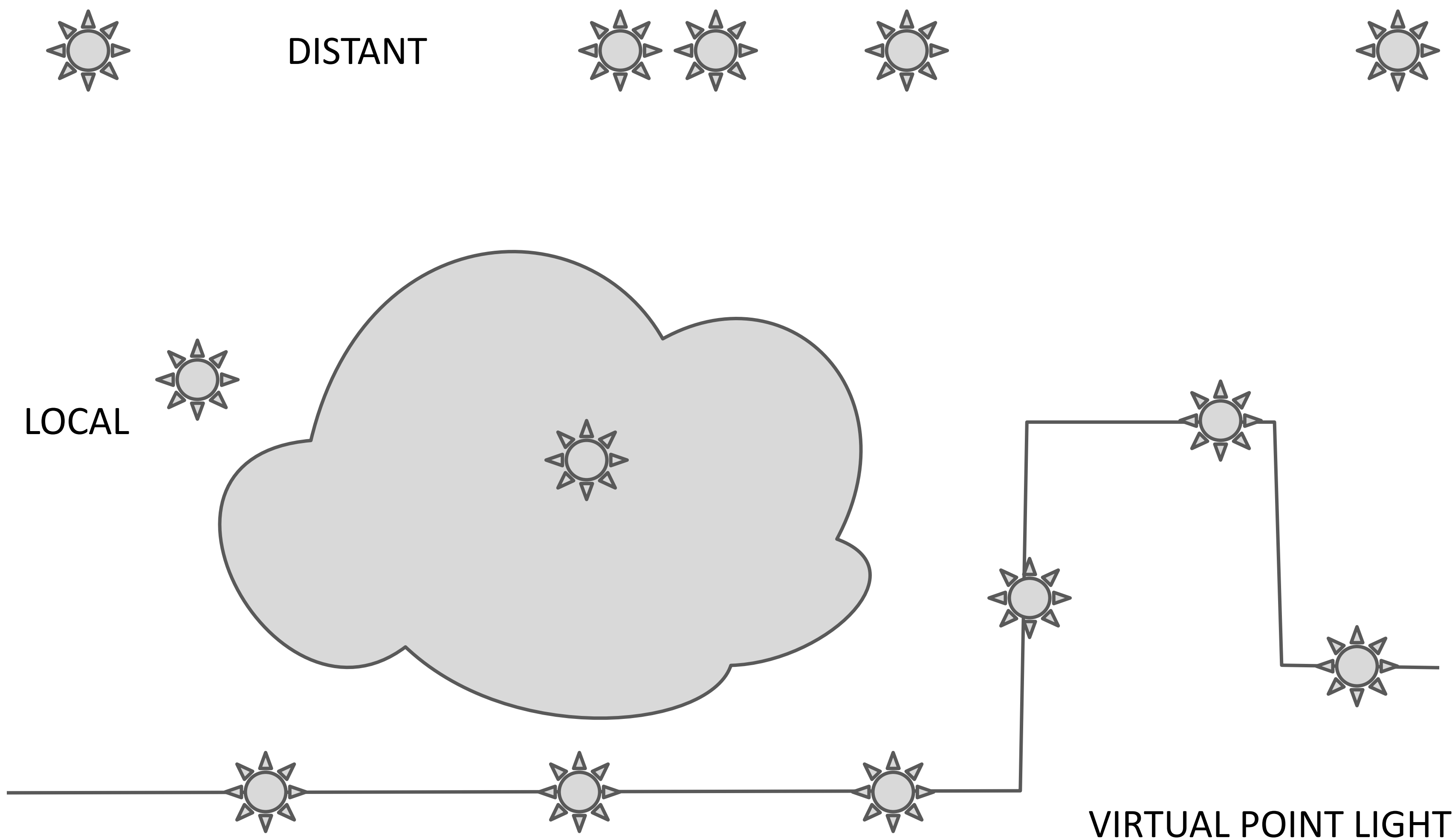
[Premoze, Ashikhmin, Ramamoorthi, Nayar: Practical Rendering of Multiple Scattering Effects in Participating Media, EGSR, 2004]

LATTICE ZOO



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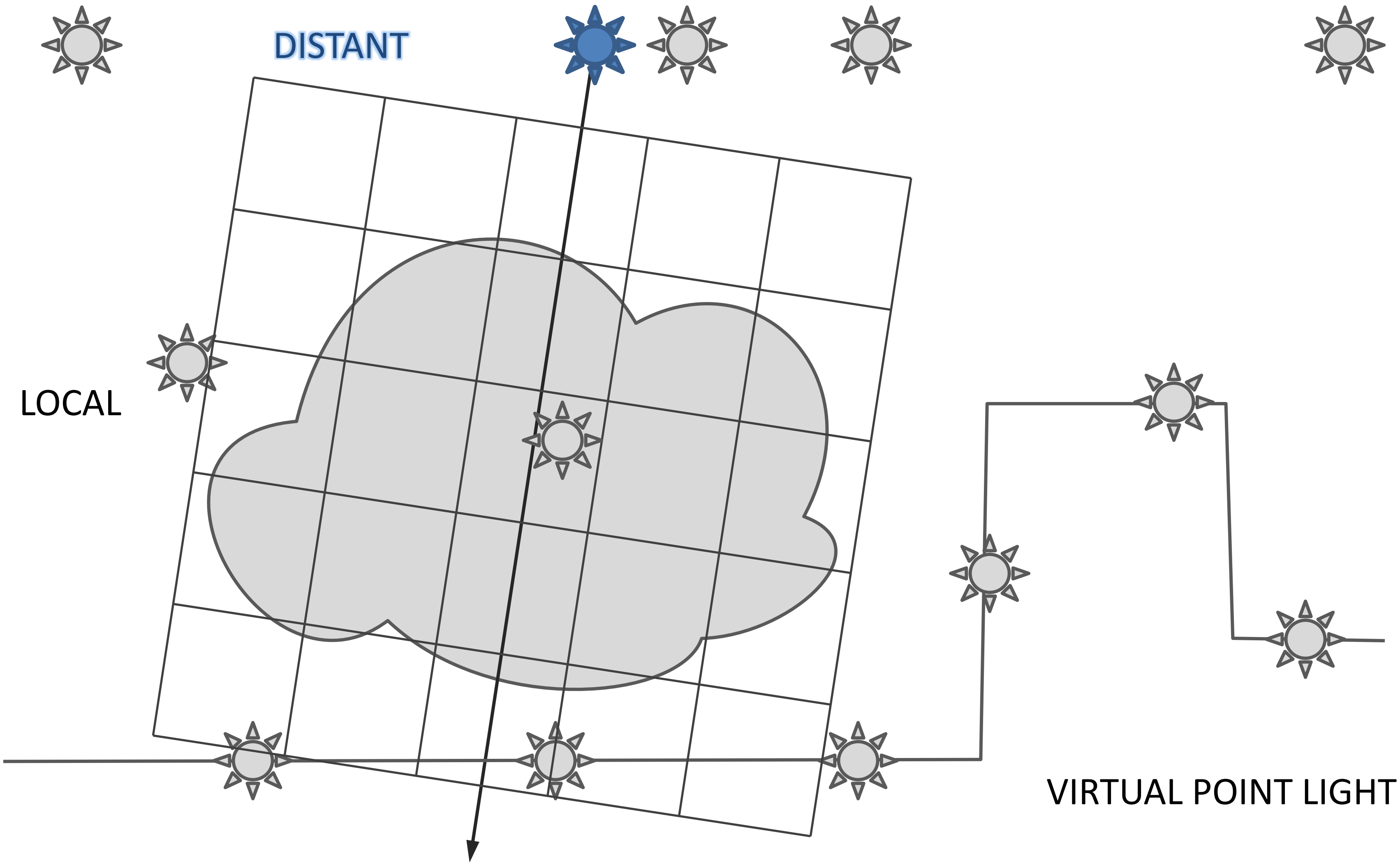
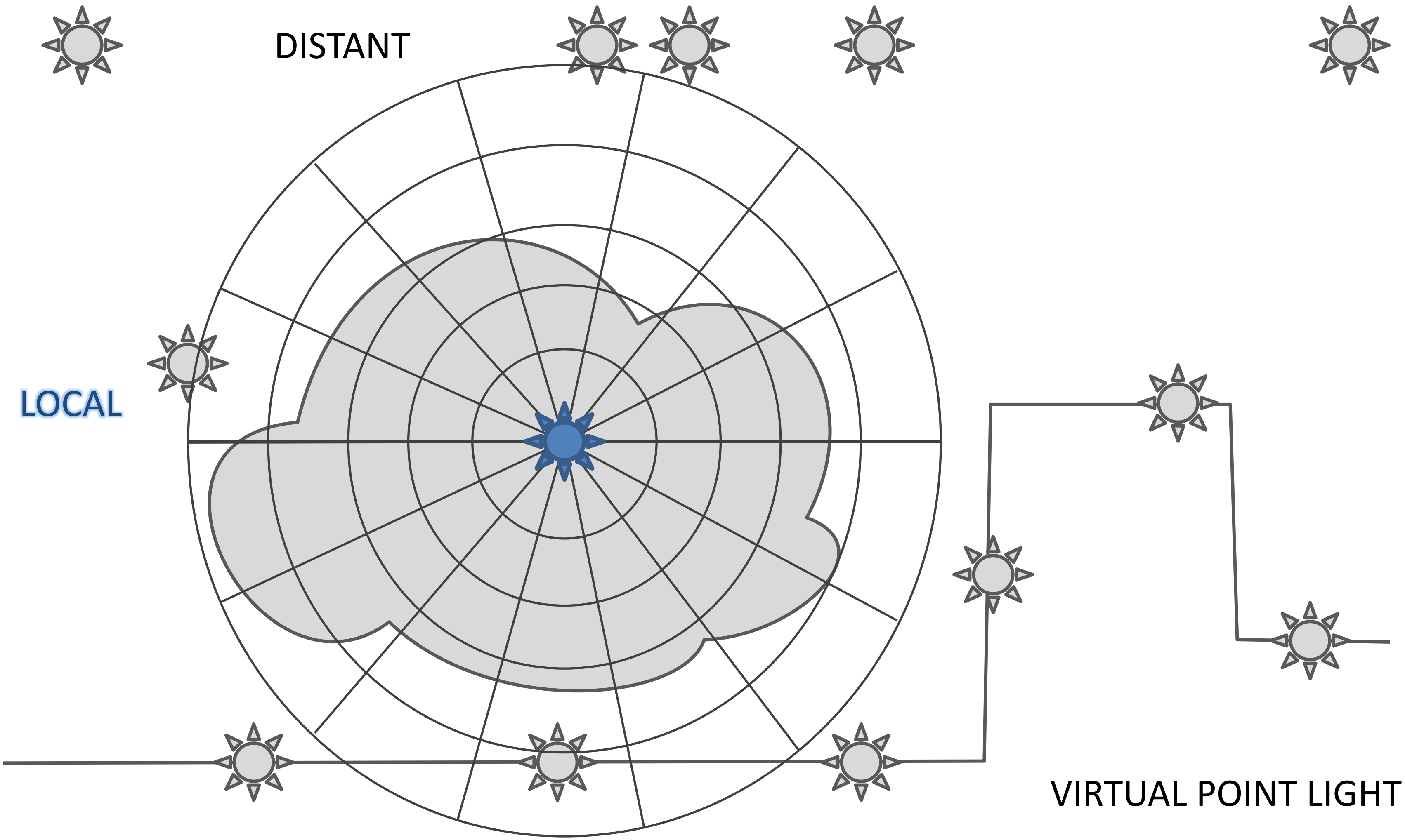


Lattice Zoo



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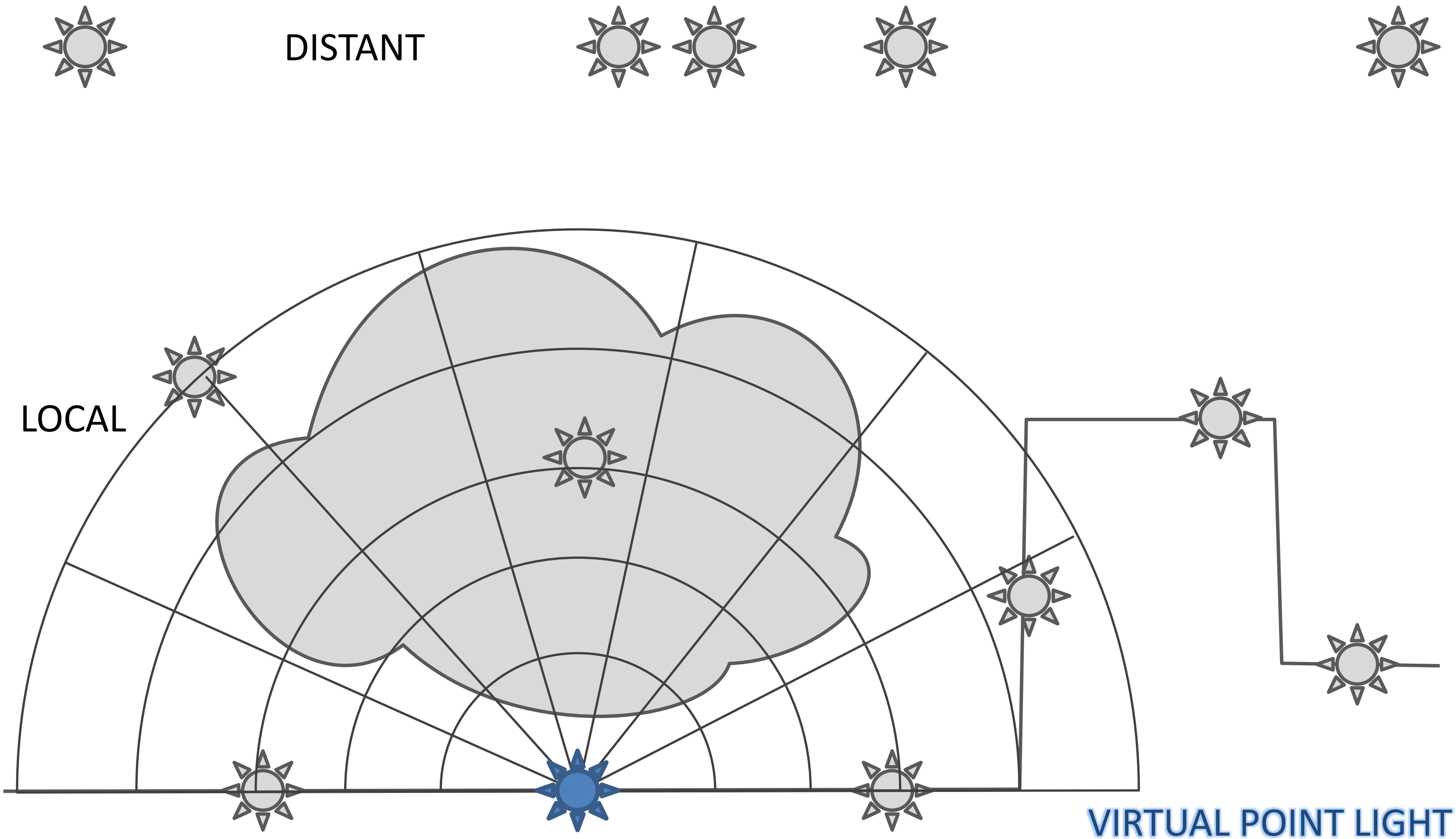
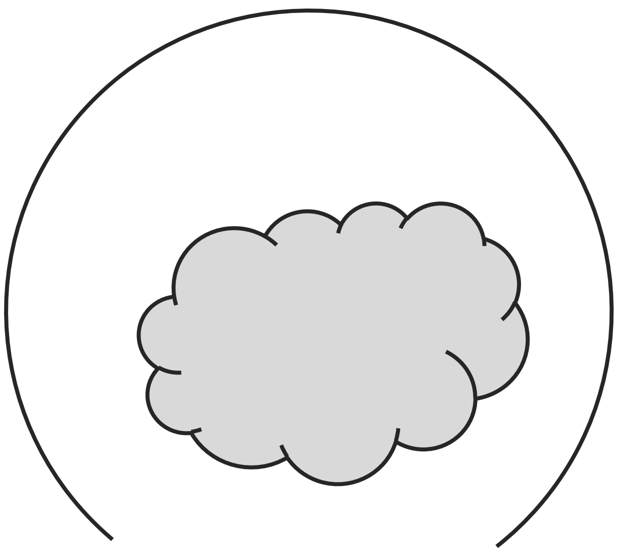


Illumination Sampling



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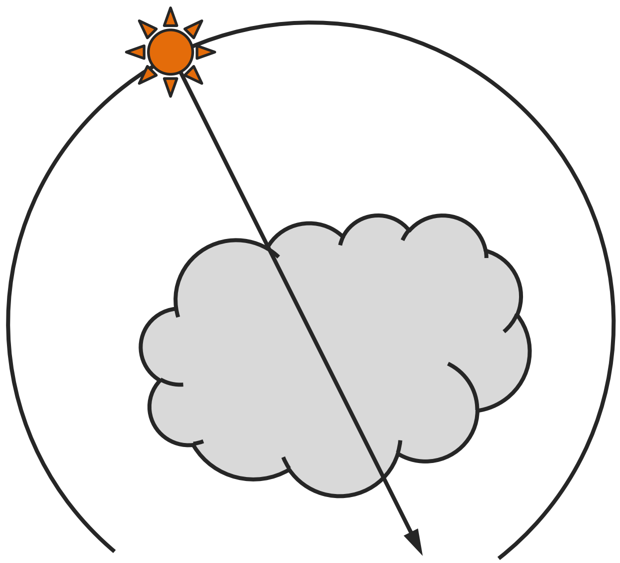

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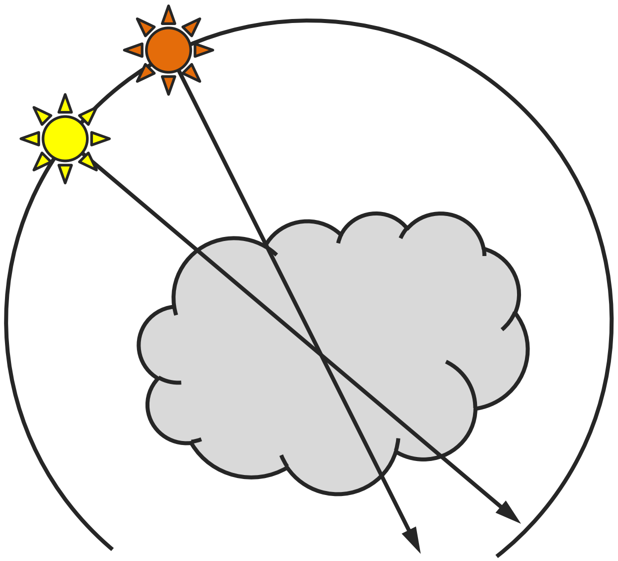

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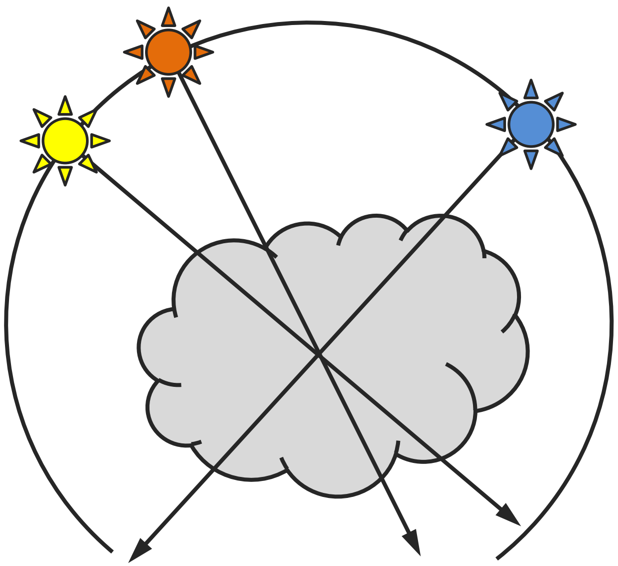

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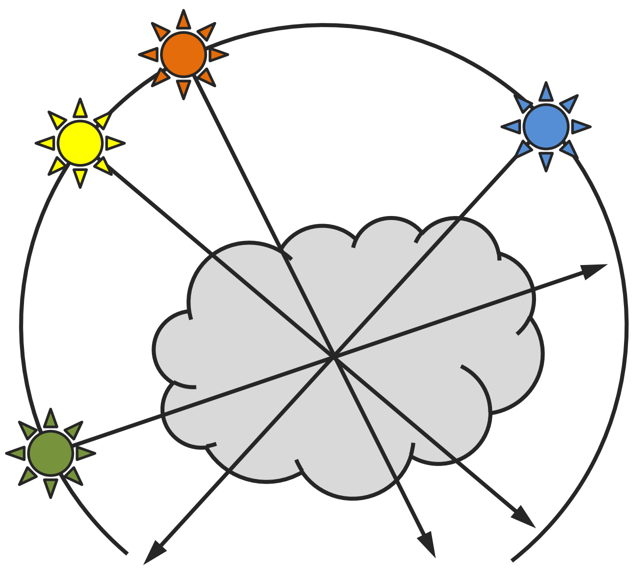

PIPELINE

Input:

- Medium parametrization
- Scene definition

Single directional light

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Output:

- Final image

Single directional light

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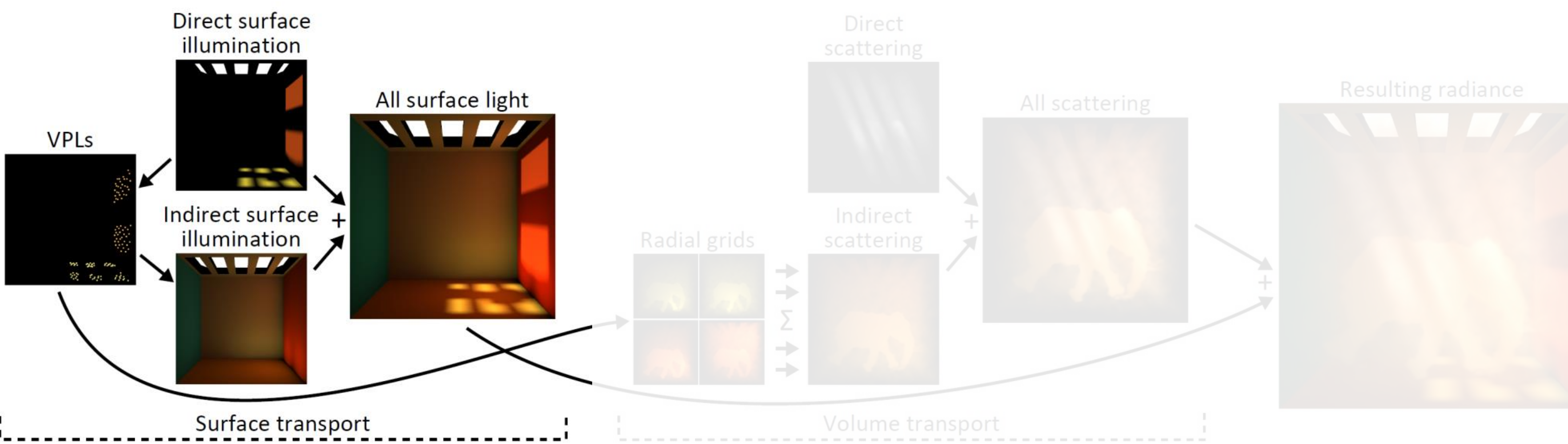

Single directional light

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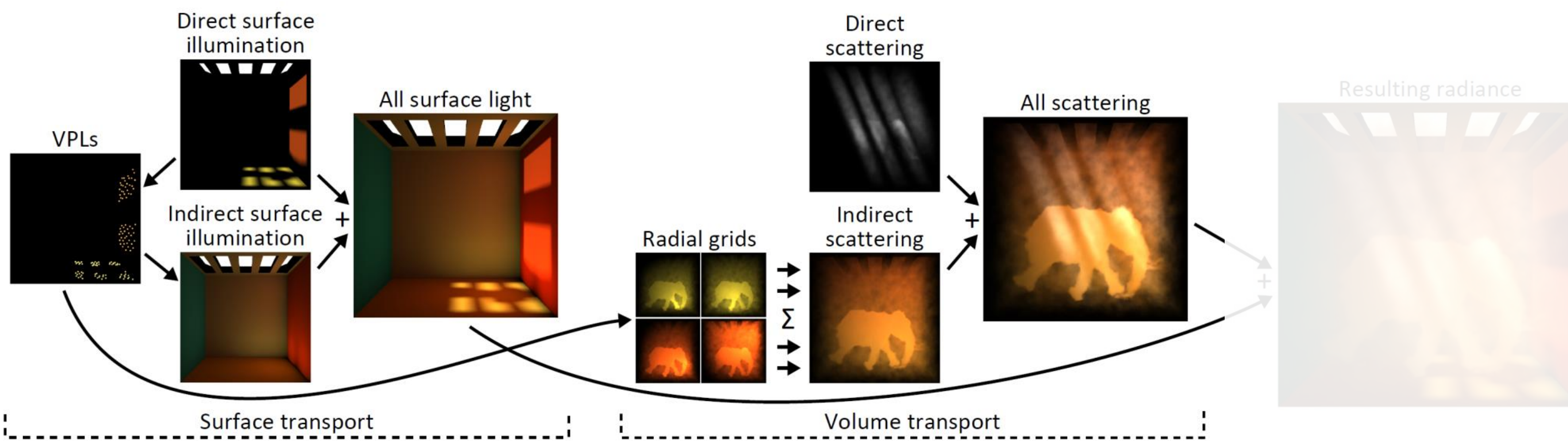

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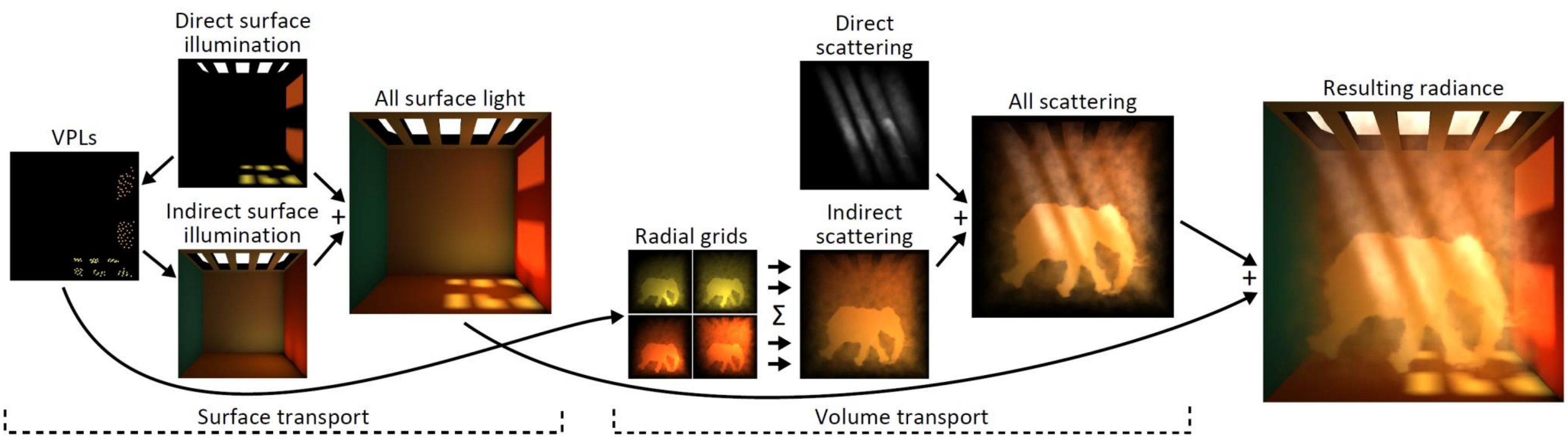
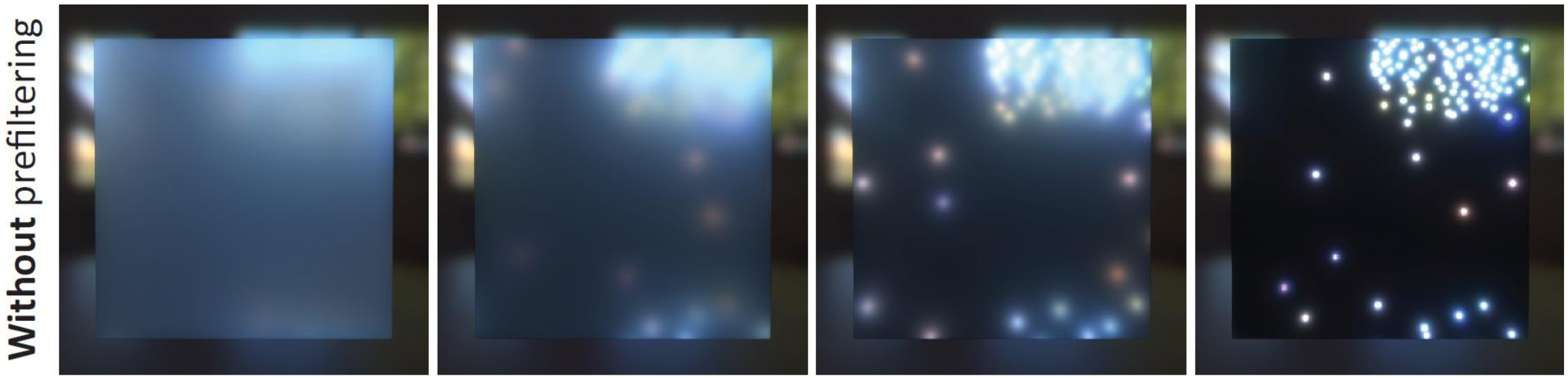


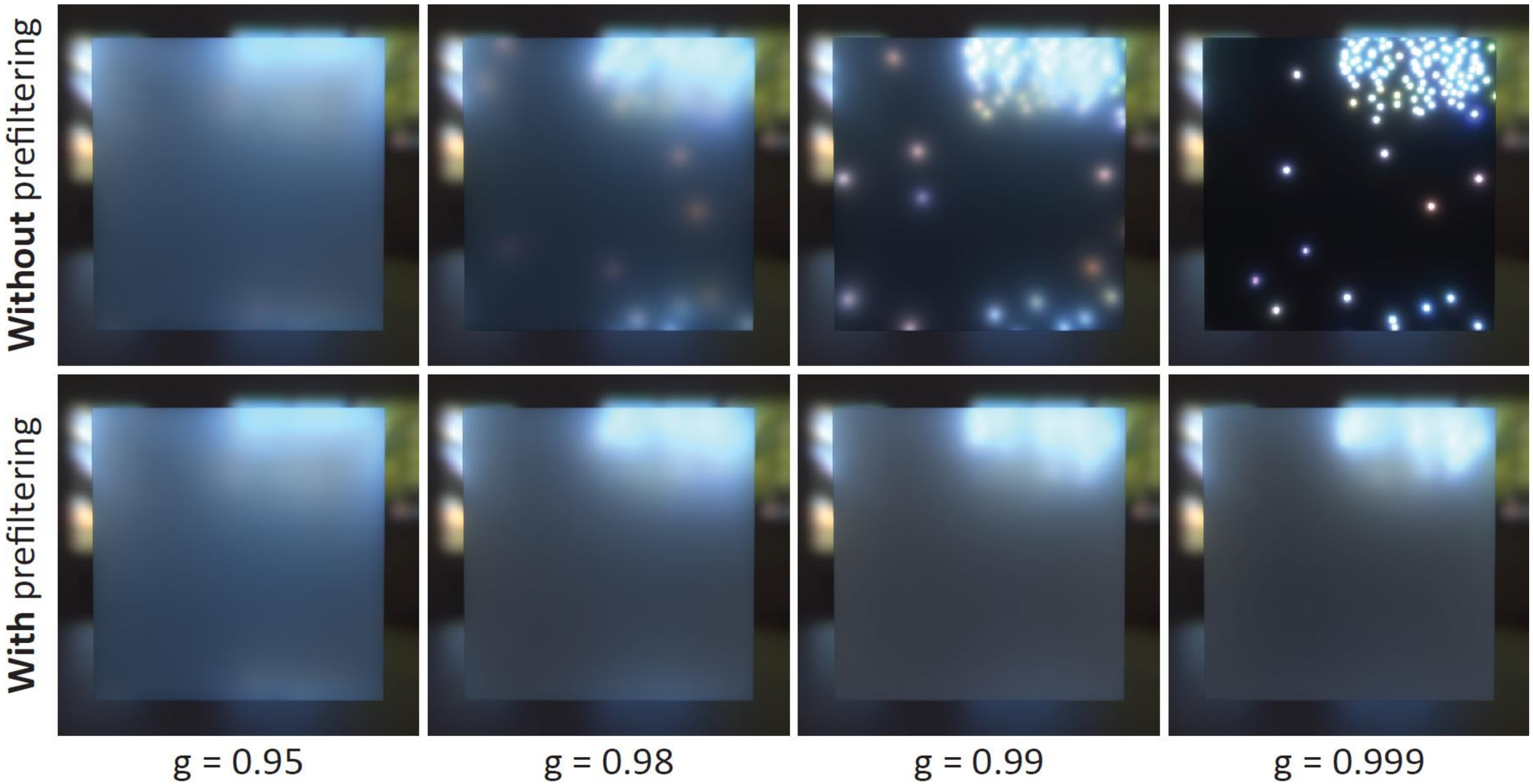
Single directional light

PRE-FILTERING

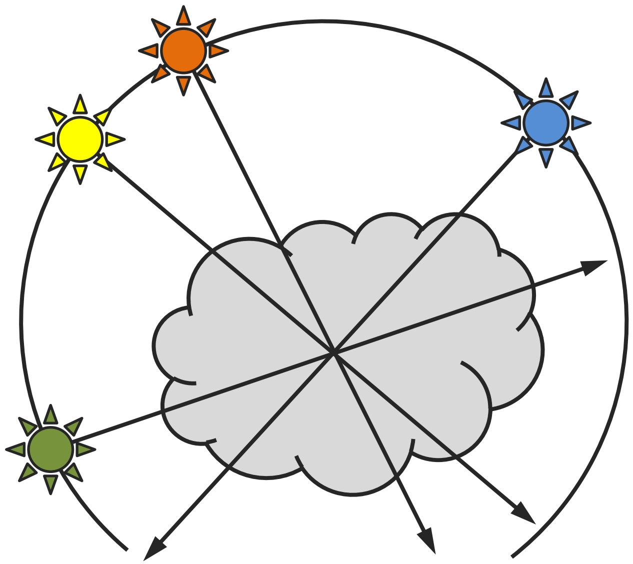


g = 0.95 g = 0.98 g = 0.99 g = 0.999

PRE-FILTERING



BI-DIRECTIONALITY



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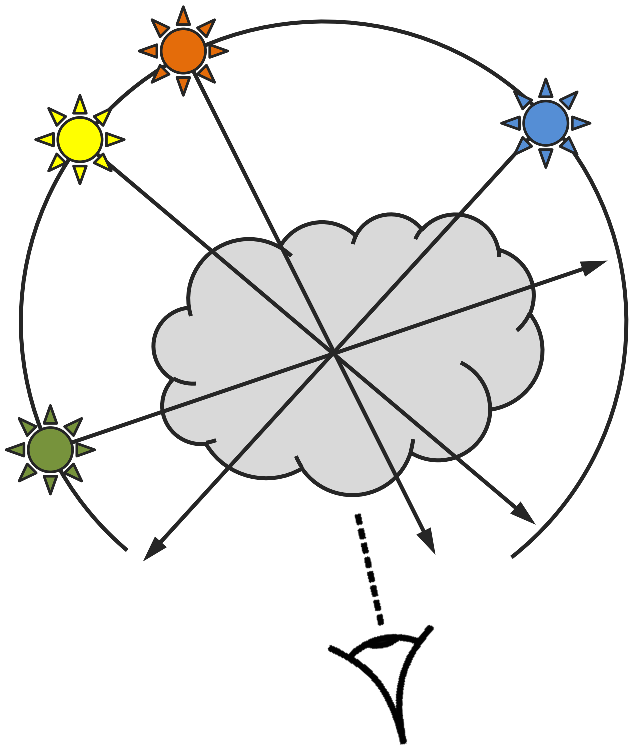
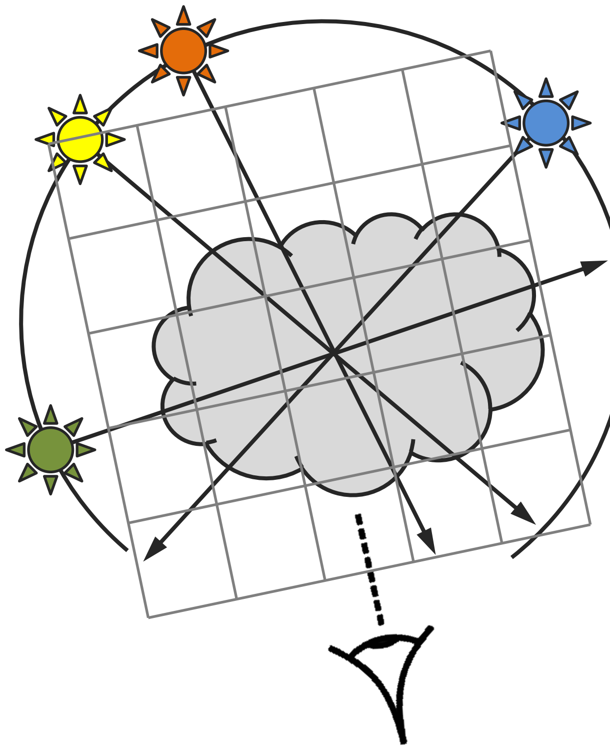


Bi-Directionality



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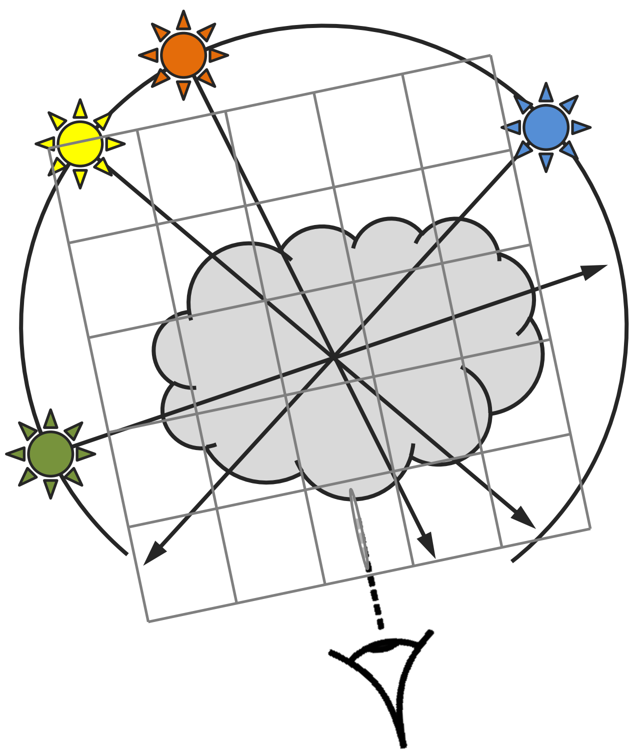

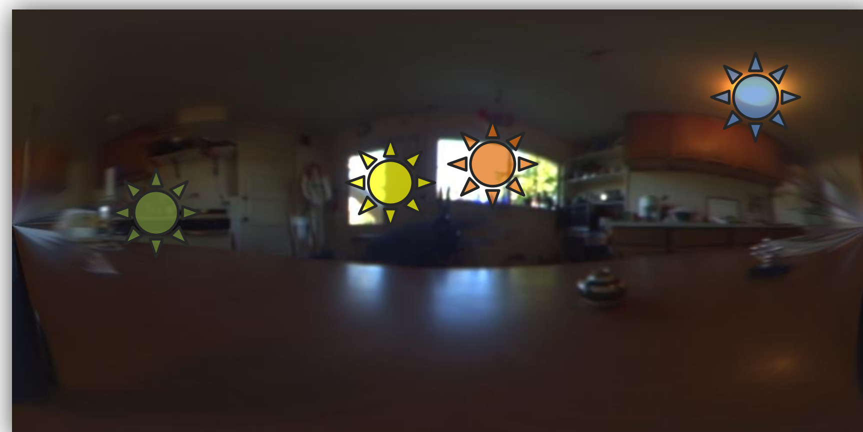

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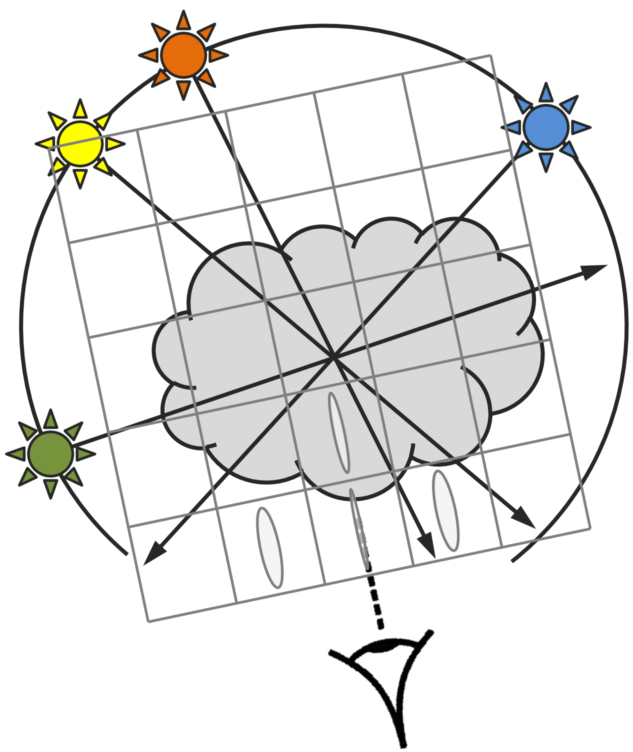

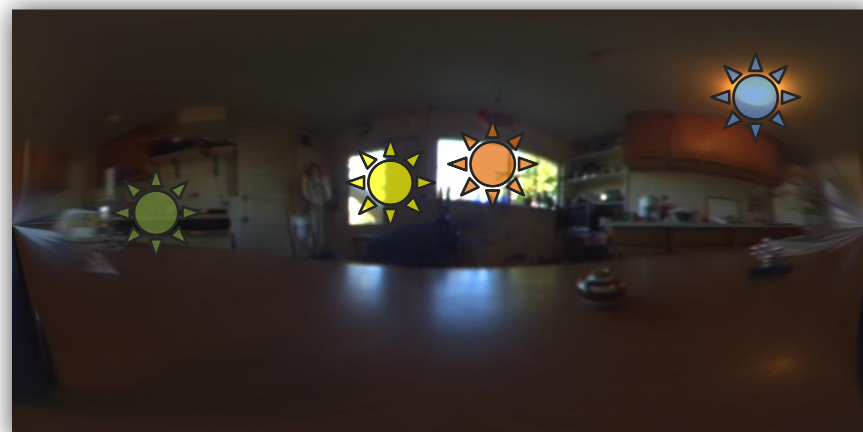

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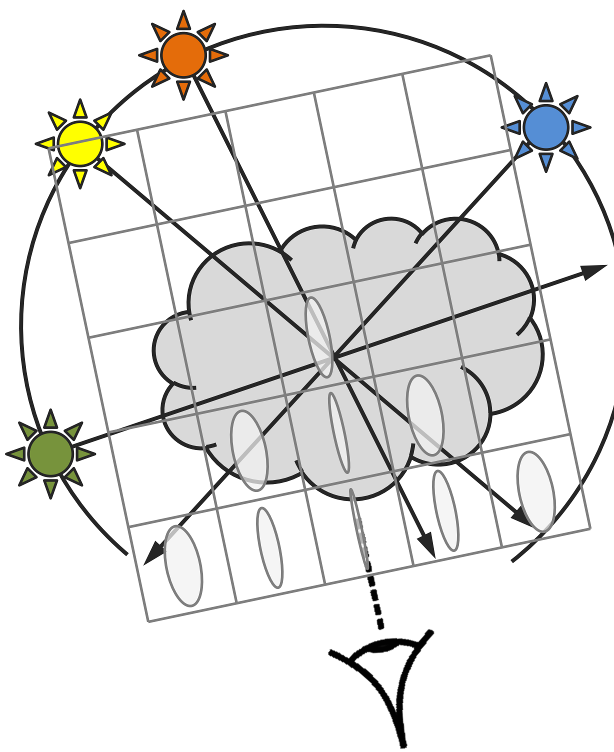

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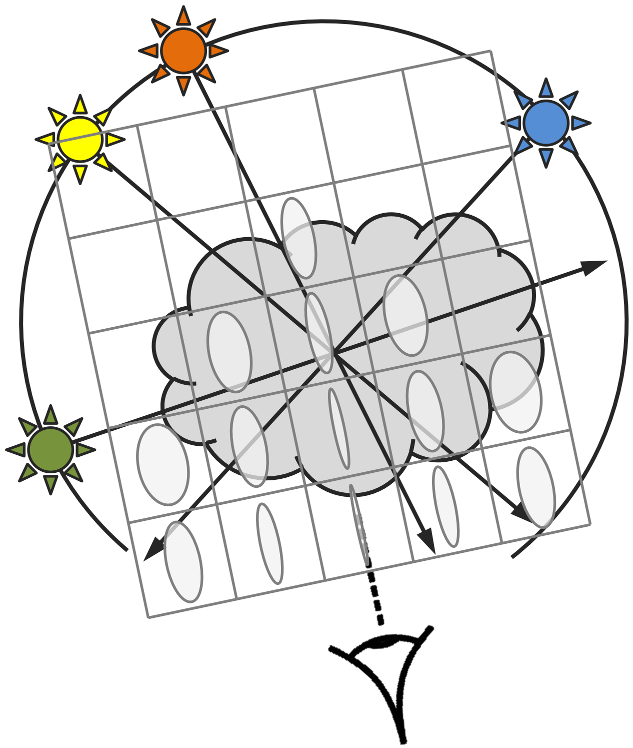

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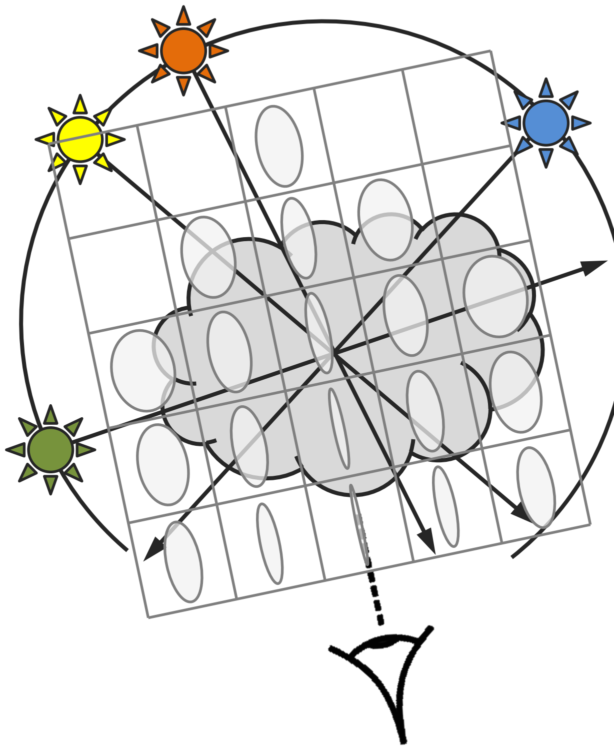

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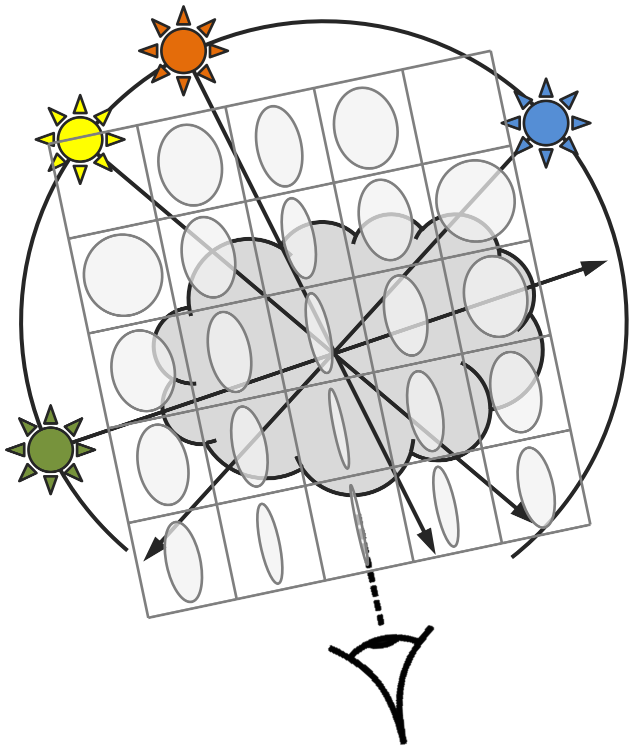

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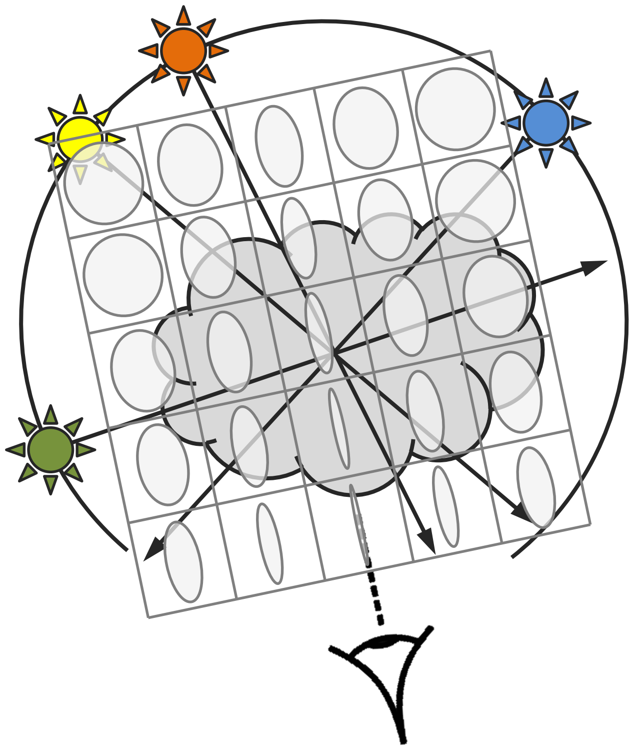

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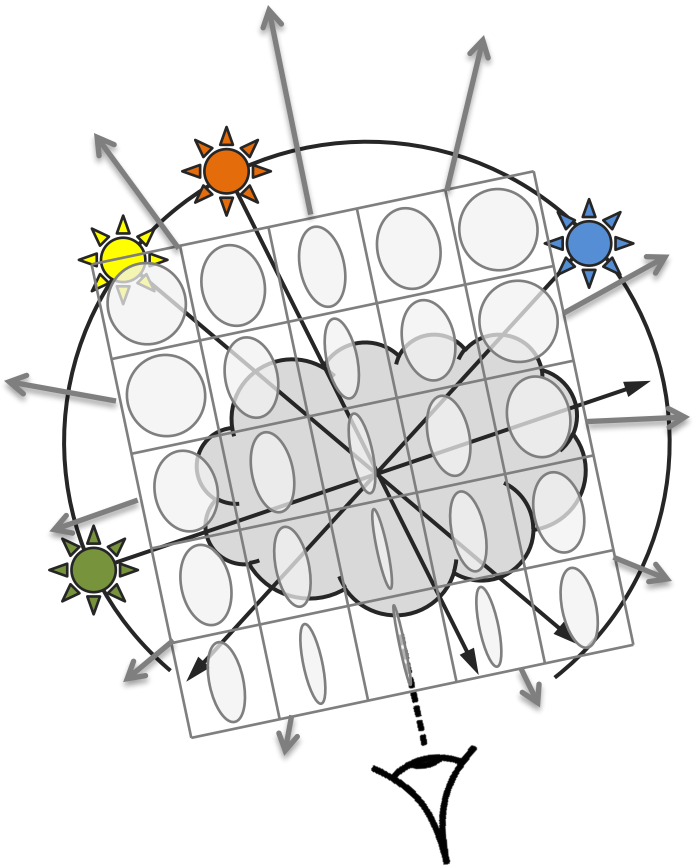

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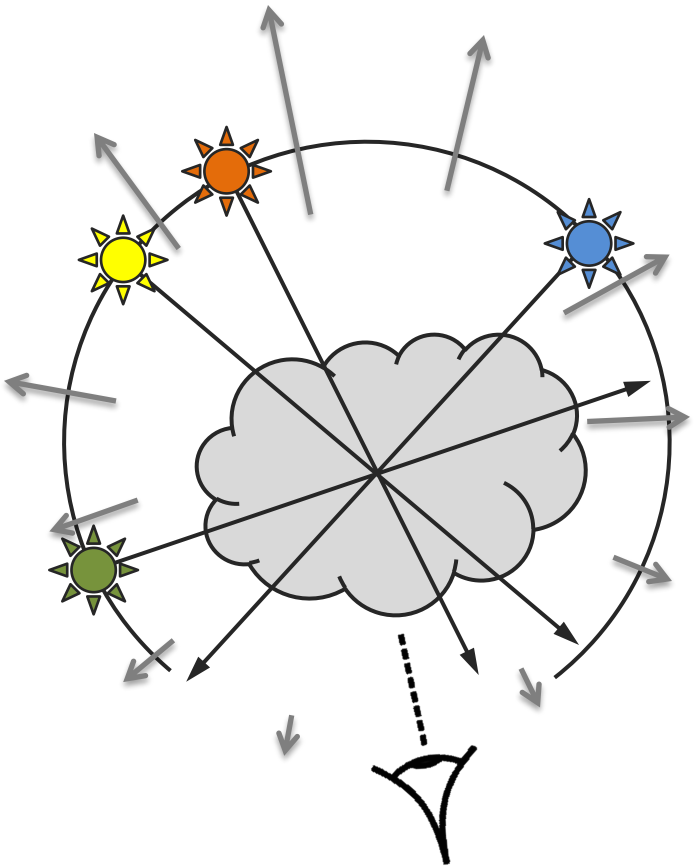

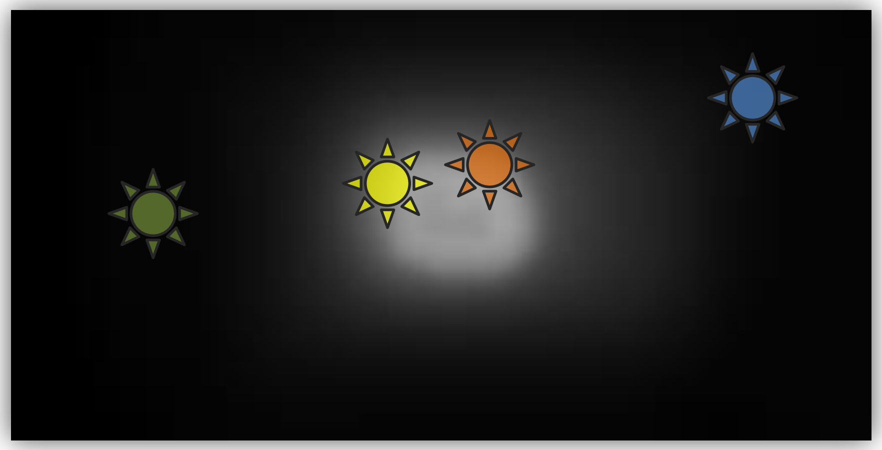

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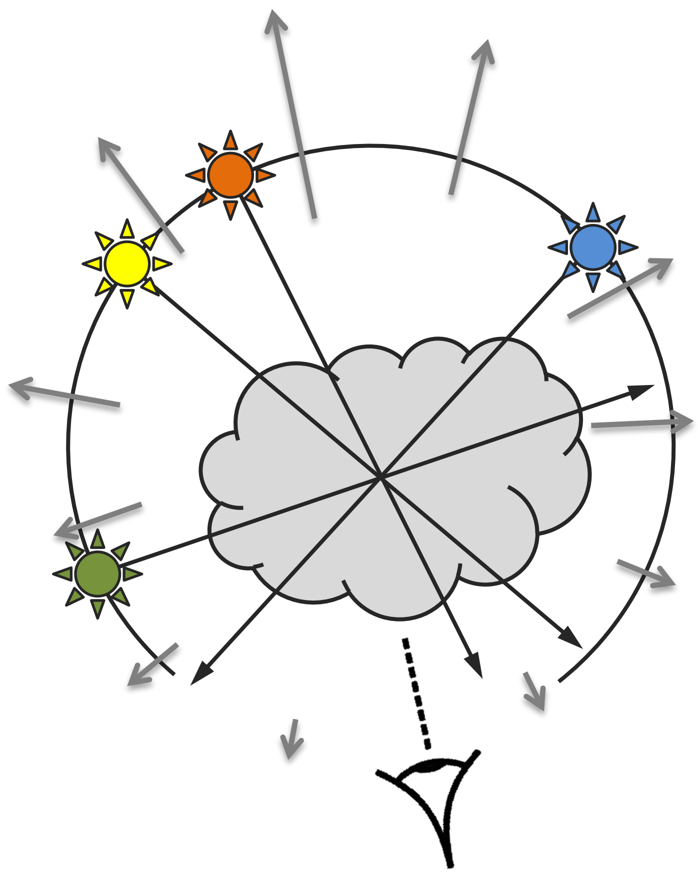
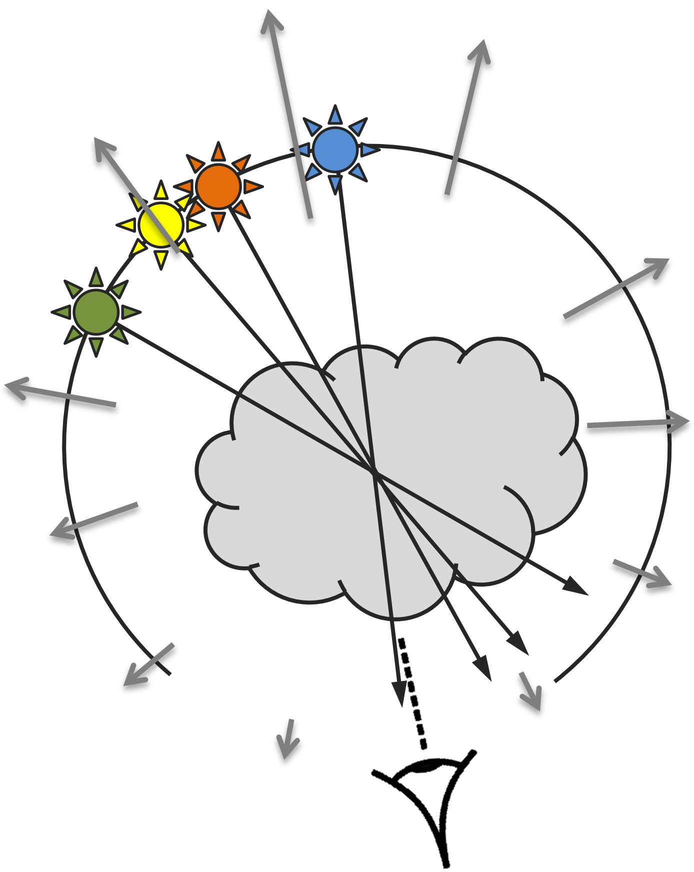
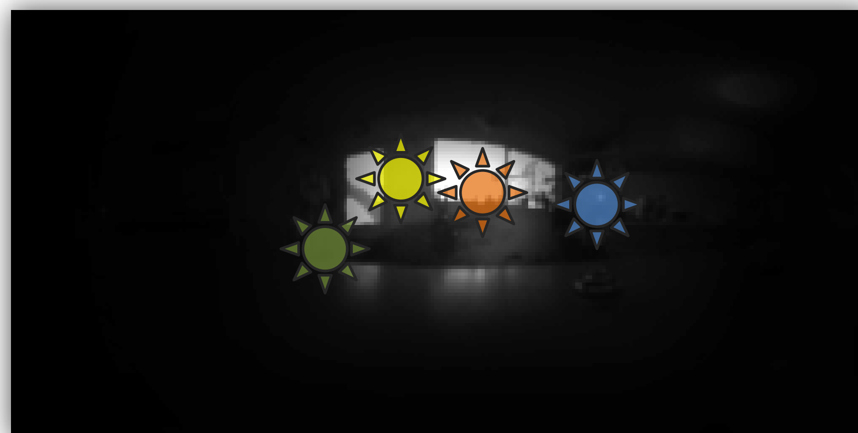


Bi-Directionality





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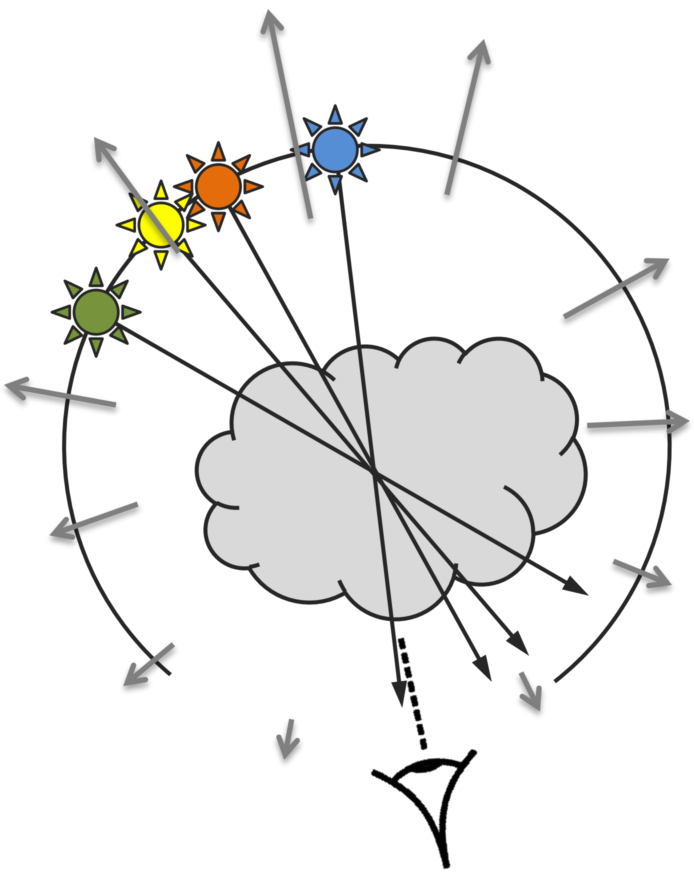
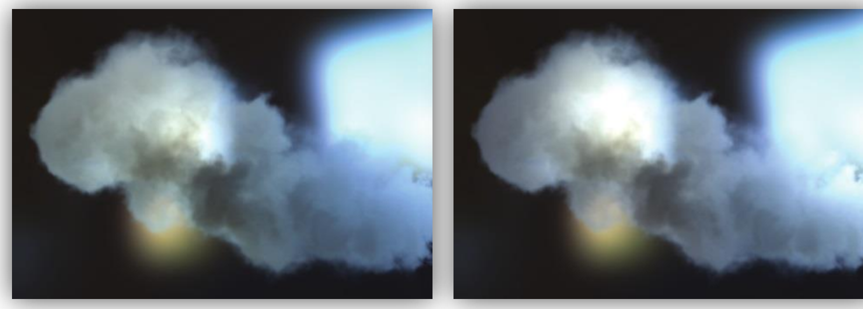
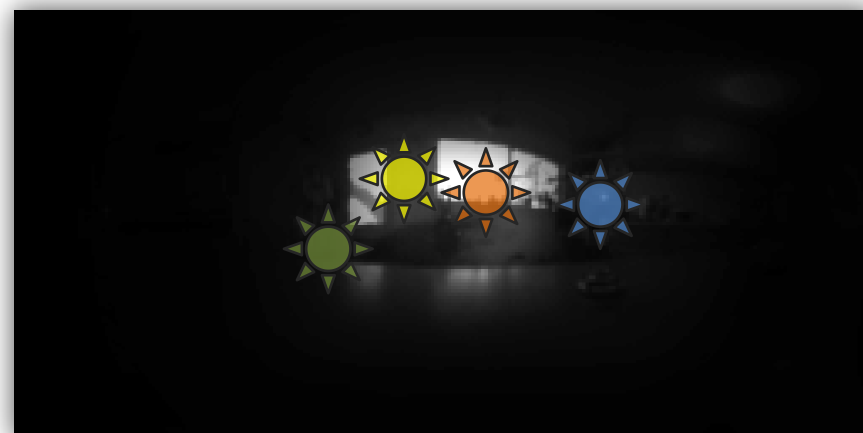
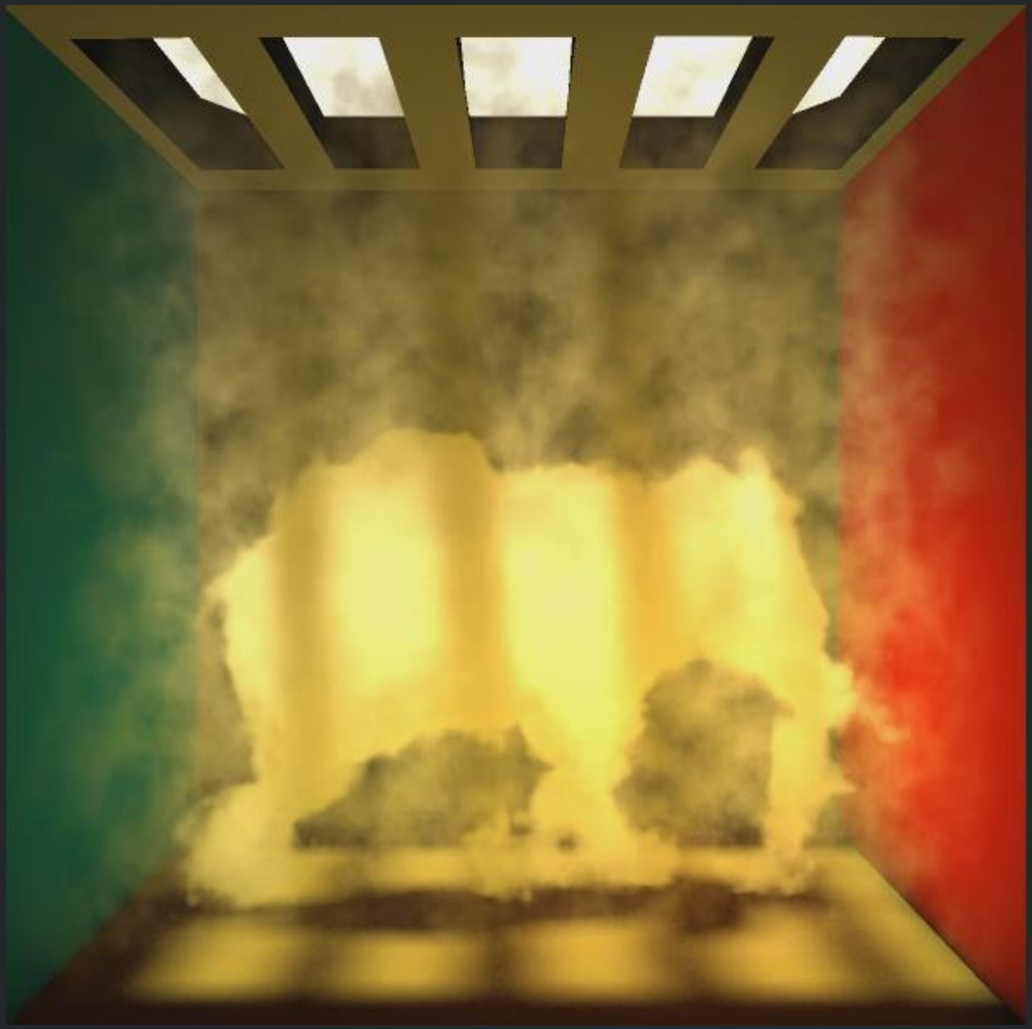






Results

Captured at 9-12 Hz on NVIDIA GeForce GTX 485 Mobile



$128^2 \times 16$ direct scattering grid and 128 VPLs × 8^3 radial grid each

RESULTS

Captured at 9-12 Hz on NVIDIA GeForce GTX 485 Mobile

125 principal directions × 16^3 grid each

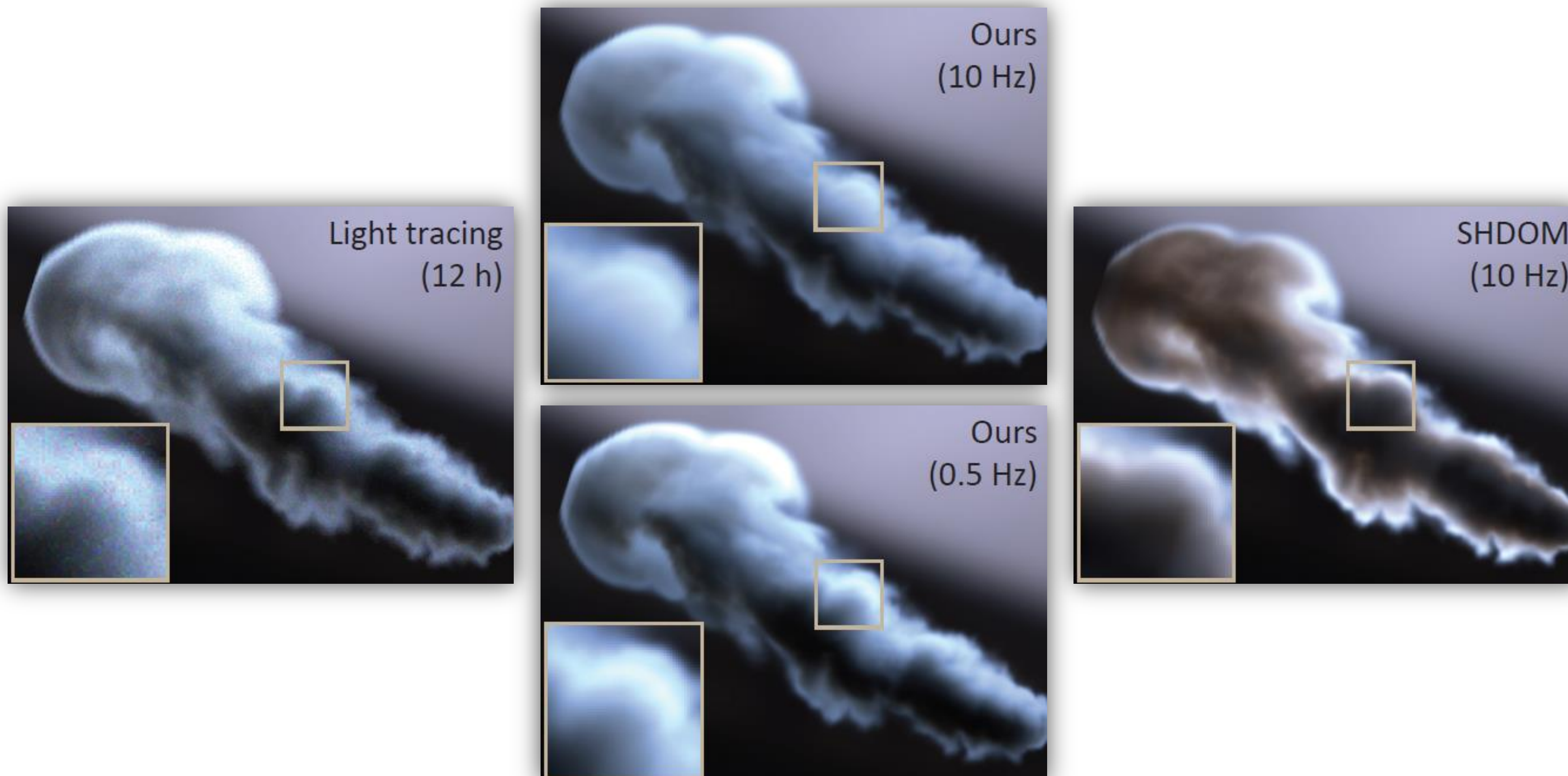
Results

Captured at 9-12 Hz on NVIDIA GeForce GTX 485 Mobile

64 principal directions × 20^3 grid each

COMPARISON

Reference and SHDOM



COMPARISON

Light Propagation Volumes

[Kaplanyan and Dachsbacher: Cascaded Light Propagation Volumes for Real-Time Indirect Illumination, I3D, 2010]

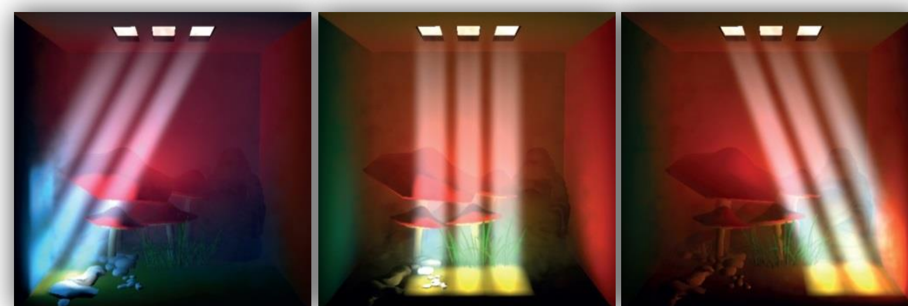
[Billeter, Sintorn, Assarsson: Real-Time Multiple Scattering Using Light Propagation Volumes, I3D, 2012]

Future Work

- Temporal coherence

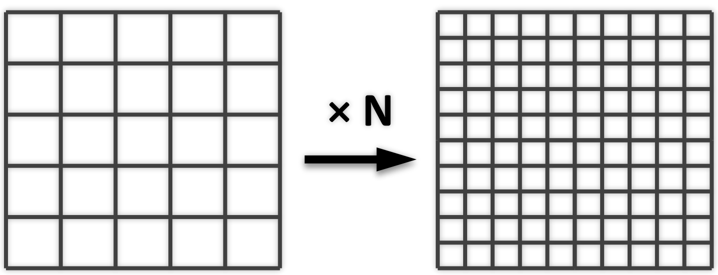
FUTURE WORK

- Temporal coherence
- Surface interaction



Future Work

- Temporal coherence
- Surface interaction
- Convergence



INTERACTIVE LIGHT SCATTERING WITH **PRINCIPAL-ORDINATE PROPAGATION**

Oskar Elek (1,2,3) Tobias Ritschel (1,2,3) Carsten Dachsbacher (4) Hans-Peter Seidel (1,3)

max planck institut informatik
M2CI CLUSTER OF EXCELLENCE
UNIVERSITÄT DES SAARLANDES
KIT Karlsruher Institut für Technologie

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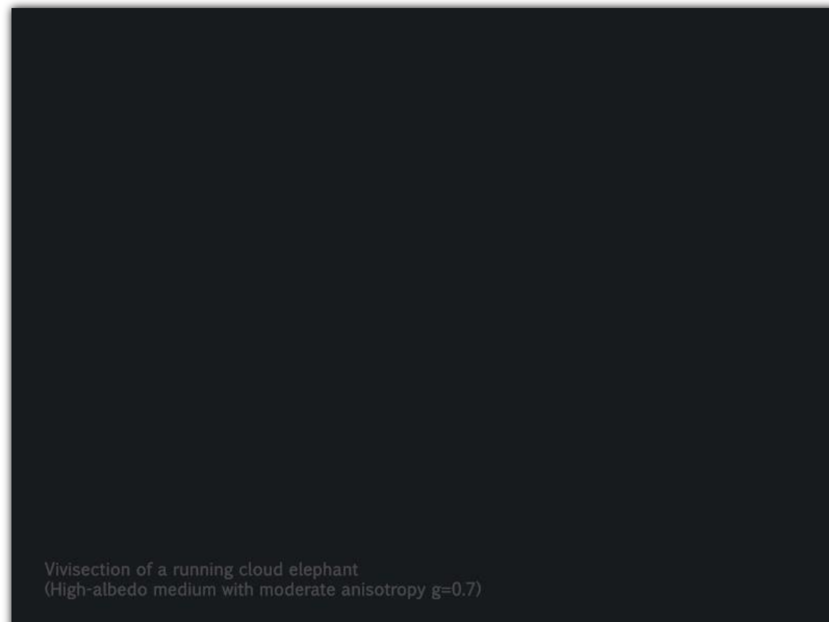
- Chuong Nguyen, Peter Vangorp, Yulia Gryaditskaya, Anton Kaplanyan
- Anonymous reviewers
- You!

More info

- tinyurl.com/**ScatteringPOP**
- Google “Principal Ordinate Propagation”



RTE + MPP

$$\left(\frac{\partial}{\partial s} + \vec{\omega}\cdot\nabla + c(\mathbf{x})\right) L(s,\mathbf{x},\vec{\omega}) =$$

$$b(\mathbf{x}) \int_{4\pi} P(\vec{\omega},\vec{\omega}') L(s,\mathbf{x},\vec{\omega}') d\omega'$$

$$\left(\frac{\partial}{\partial s} + \vec{\omega}\cdot\nabla + c(\mathbf{x})\right) G(s,\mathbf{x},\vec{\omega},\mathbf{x}',\vec{\omega}') =$$

$$b(\mathbf{x}) \int_{4\pi} P(\vec{\omega},\vec{\omega}'') G(s,\mathbf{x},\vec{\omega}'',\mathbf{x}',\vec{\omega}') d\omega''$$

$$L(s,\mathbf{x},\vec{\omega}) = \int G(s,\mathbf{x}-\mathbf{x}',\vec{\omega},\vec{\omega}') L_0(\mathbf{x}',\vec{\omega}') dx' d\omega'$$

$$G(t,\mathbf{x}_i,\mathbf{x}_f) =$$

$$\lim_{N\to\infty} \int \cdots \int G(t/N,\mathbf{x}_i,\mathbf{x}_1) \cdots G(t/N,\mathbf{x}_{N-1},\mathbf{x}_f) d\mathbf{x}_1 \cdots d\mathbf{x}_{N-1}$$