Scalable Virtual Ray Lights Rendering for Participating Media

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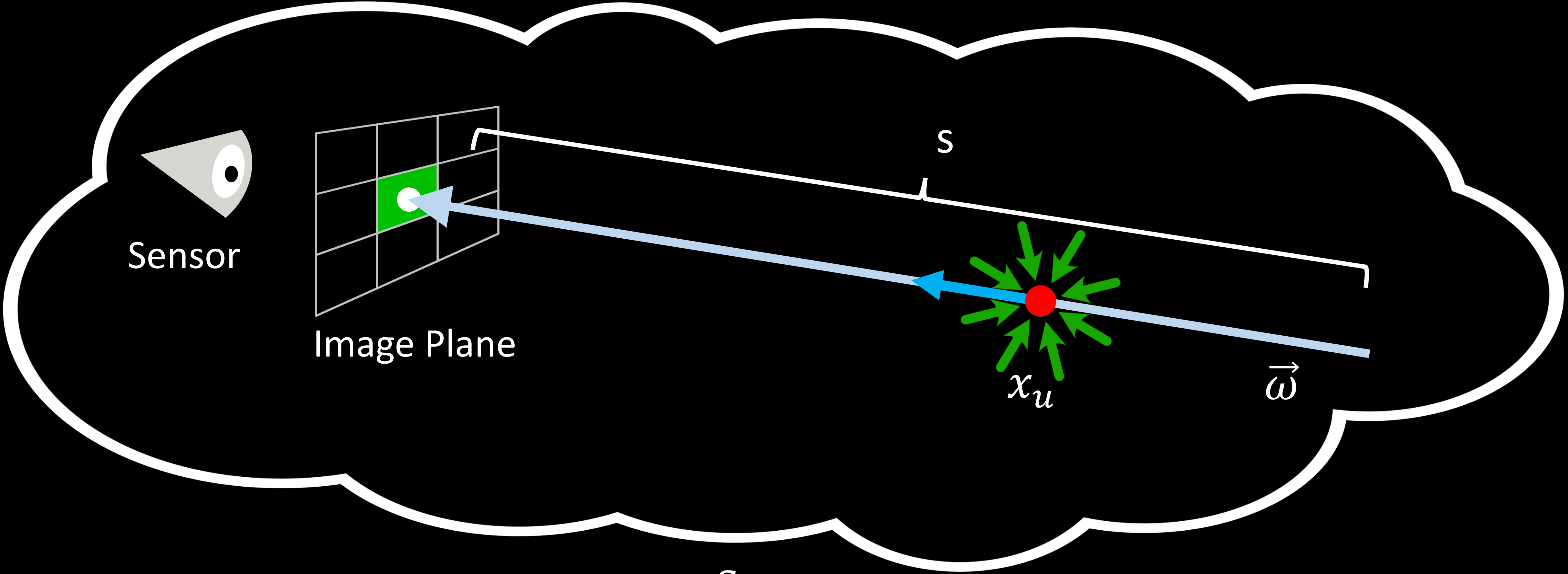
MOTIVATION: Surface and Volume interaction

MOTIVATION: Volume interaction only

VOLUMETRIC RENDERING



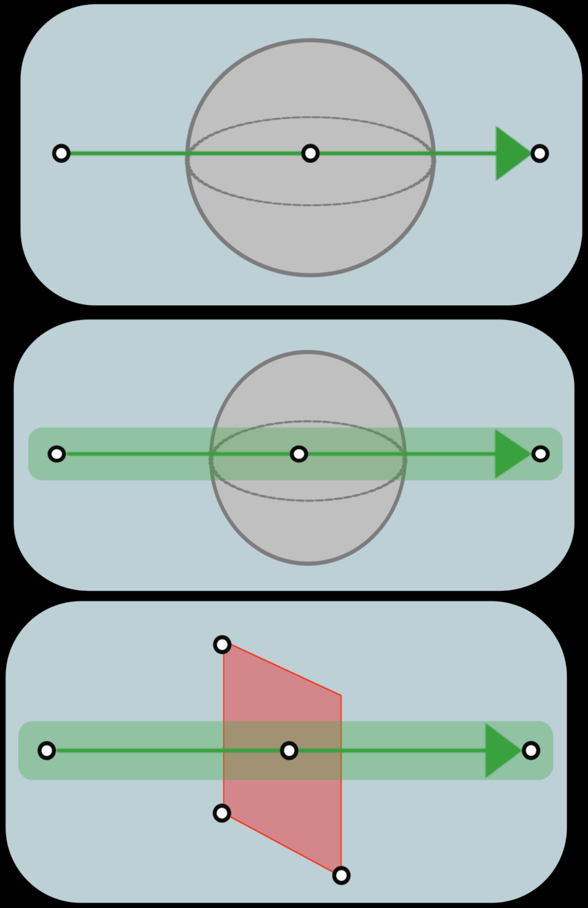
$$L_m(x,\vec{\omega}) = \int_0^s T_r(u) L_i(x_u,\vec{\omega})du$$

VOLUMETRIC RENDERING: Rendering techniques

- Path tracing / Bidirectional path tracing

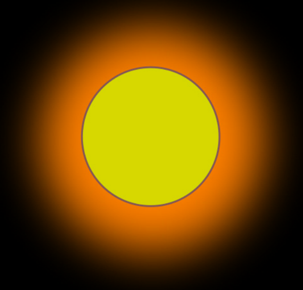
VOLUMETRIC RENDERING: Many techniques

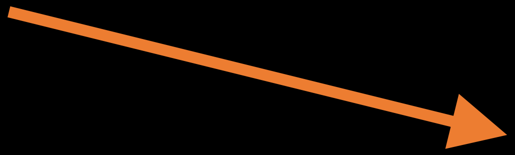
- Path tracing / Bidirectional path tracing
- Density estimation:
  - Volumetric Photon Mapping
  - Photon Beam
  - Photon Planes
  - “Higher-order geometric primitives”



VOLUMETRIC RENDERING: Many techniques

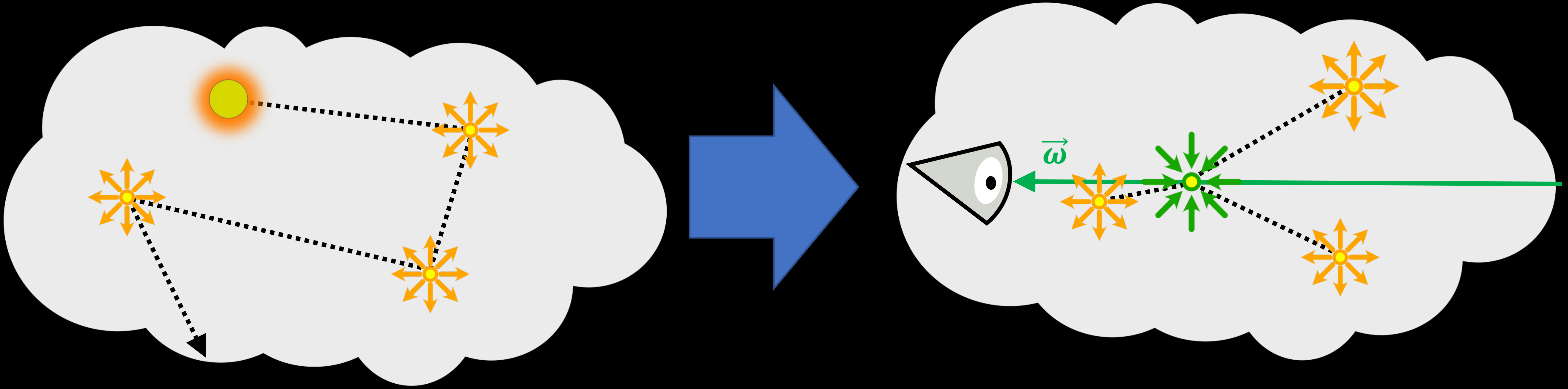
- Path tracing / Bidirectional path tracing
- Density estimation:
  - Volumetric Photon Mapping
  - Photon Beam
  - Photon Planes
  - “Higher-order geometric primitives”
- Many lights:
  - Virtual point lights
  - Virtual spherical lights
  - Virtual ray lights
  - “Higher-order geometric primitives”





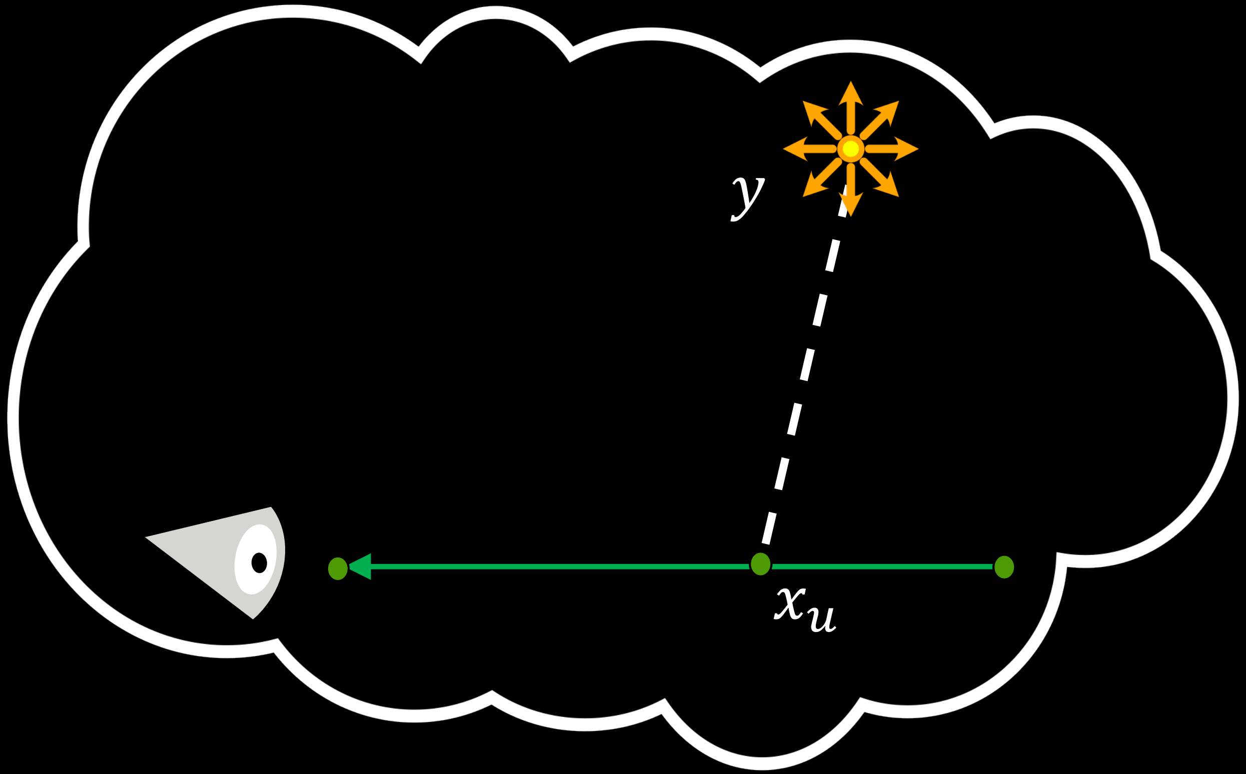
MANY LIGHTS

- Many-light techniques have been introduced in “instant radiosity” [Keller et al. 1997]
- Indirect illumination as a sum of direct illumination of virtual lights



MANY LIGHTS

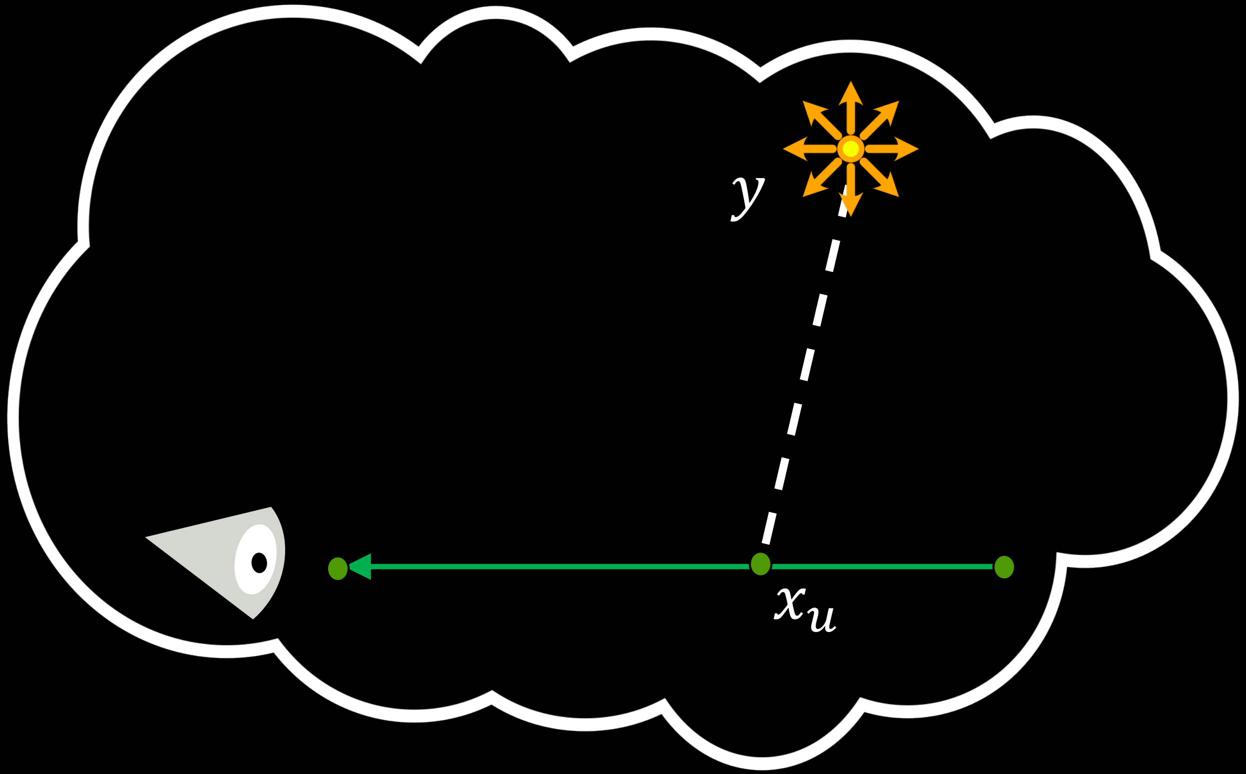
Virtual point light contribution



$$L_m^{VPL} = \frac{VPL(y, \mathrm{x}_u)}{|y - x_u|^2 p(\mathrm{x}_u)}$$

MANY LIGHTS

Virtual point light contribution

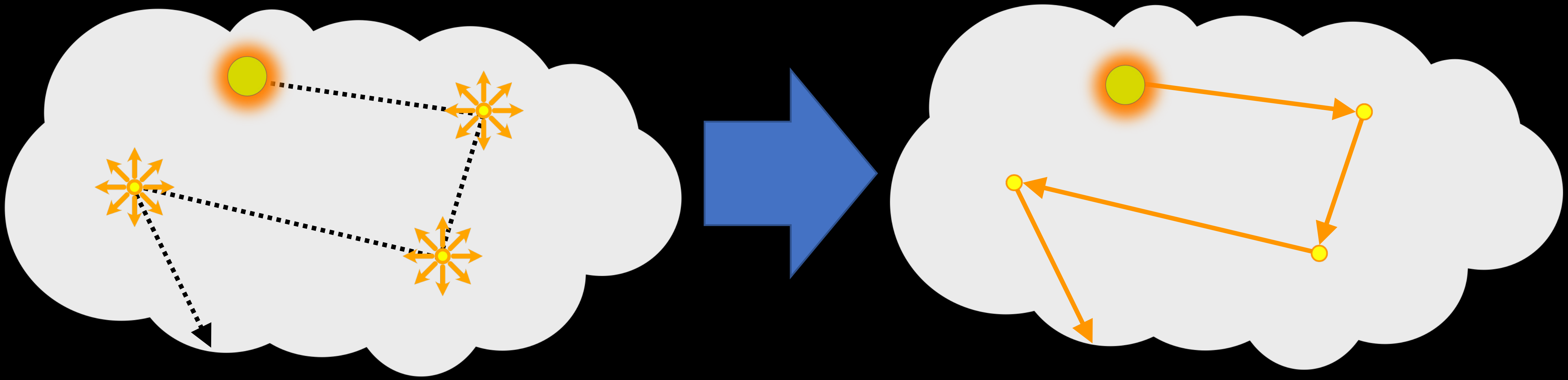


$$L_m^{VPL} = \frac{VPL(y, \mathrm{x}_u)}{|y - x_u|^2 p(\mathrm{x}_u)}$$

$$\propto \boxed{\frac{1}{|y - x_u|^2}}$$

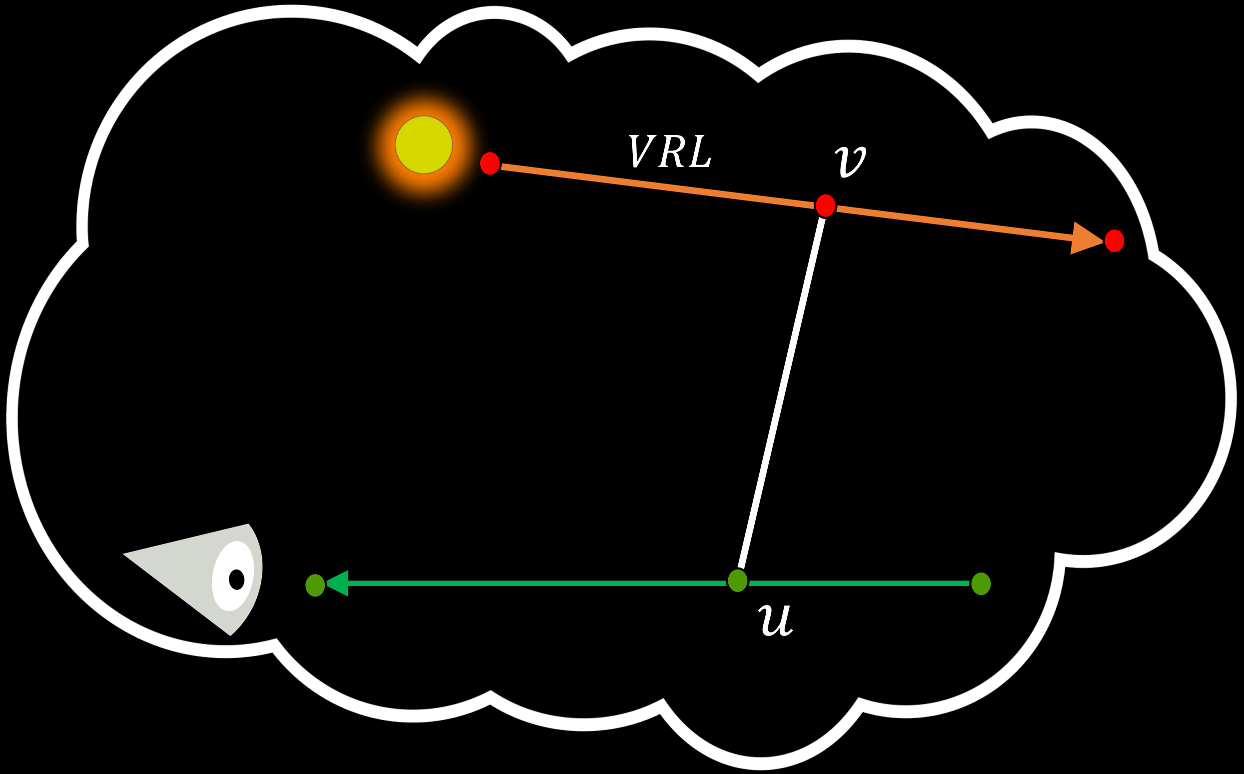
MANY LIGHTS

- VPL vs. short VRL



MANY LIGHTS: VRL

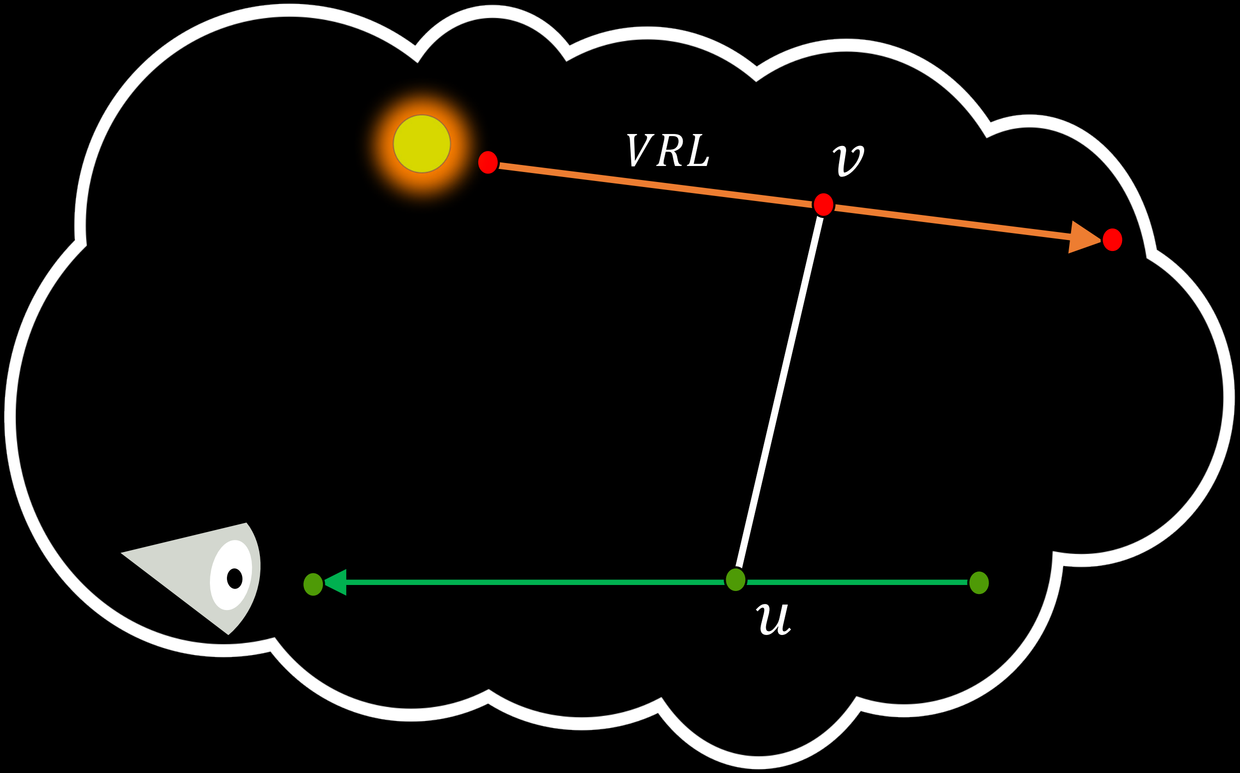
Virtual ray lights contribution



$$L_m^{VRL} = \int_0^s \int_0^t \frac{VRL(u,v)}{w(u,v)^2}\, dv\, du$$

MANY LIGHTS: VRL

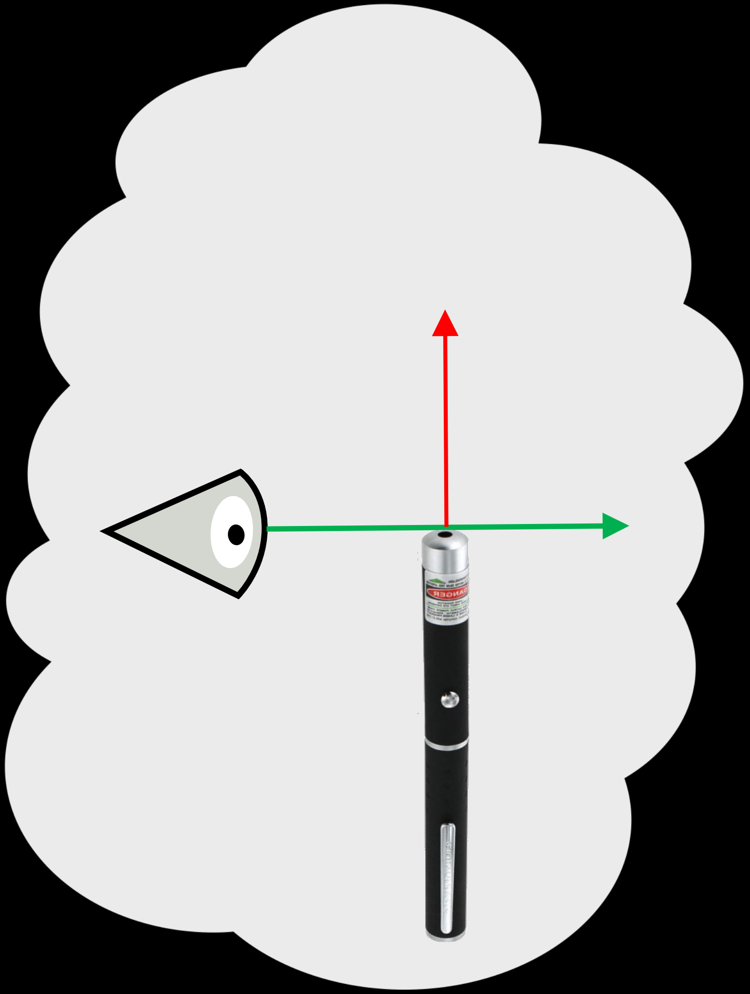
Virtual ray lights contribution



$$L_m^{VRL} = \frac{VRL(u,v)}{w(u,v)^2 p(u,v)}$$

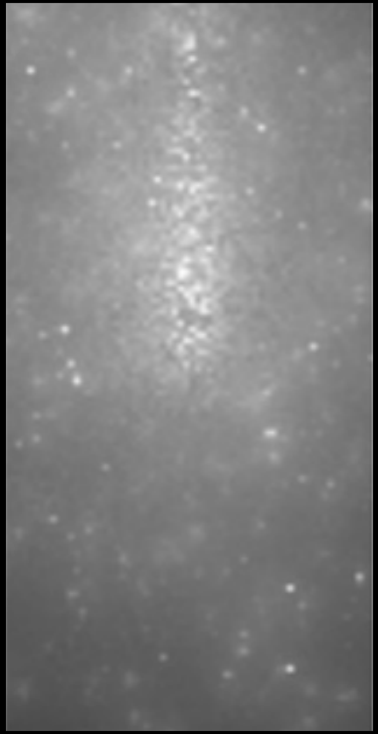
$$p(u,v) \propto w(u,v)^{-2}$$

MANY LIGHTS: VRL vs. VPL



VRL

VPL



Equal rendering time

MANY LIGHTS

Realistic rendering :

- Unmanageable amount of virtual lights
- Cost linear with lights

MANY LIGHTS

Realistic rendering:

- Unmanageable amount of virtual lights
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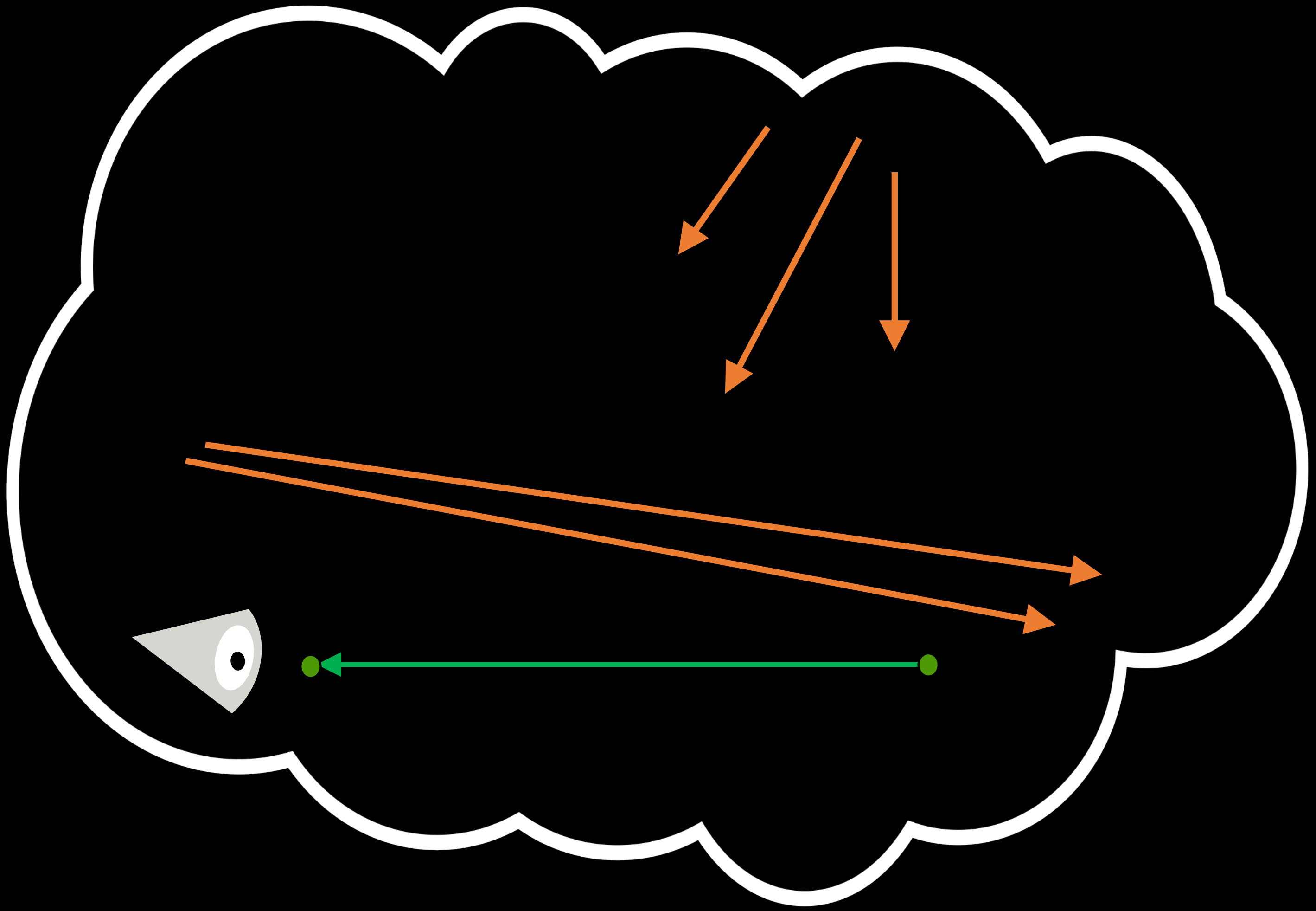
Aim:

- Sub-linear cost
- Scalable methods
  [Walter et al. 2005][Walter et al. 2006][Walter et al. 2012]
  [Hasan et al. 2007][Ou et al. 2011][Bus et al. 2015]

SCALABILITY



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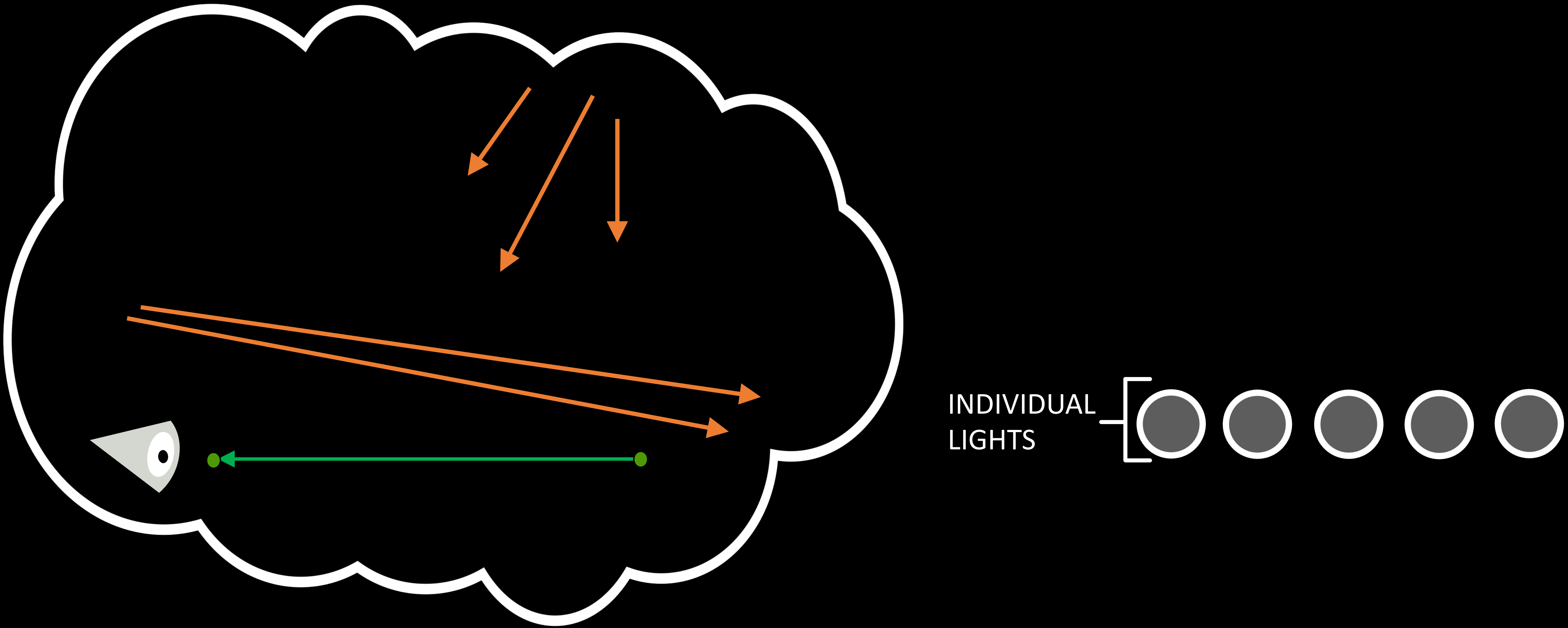

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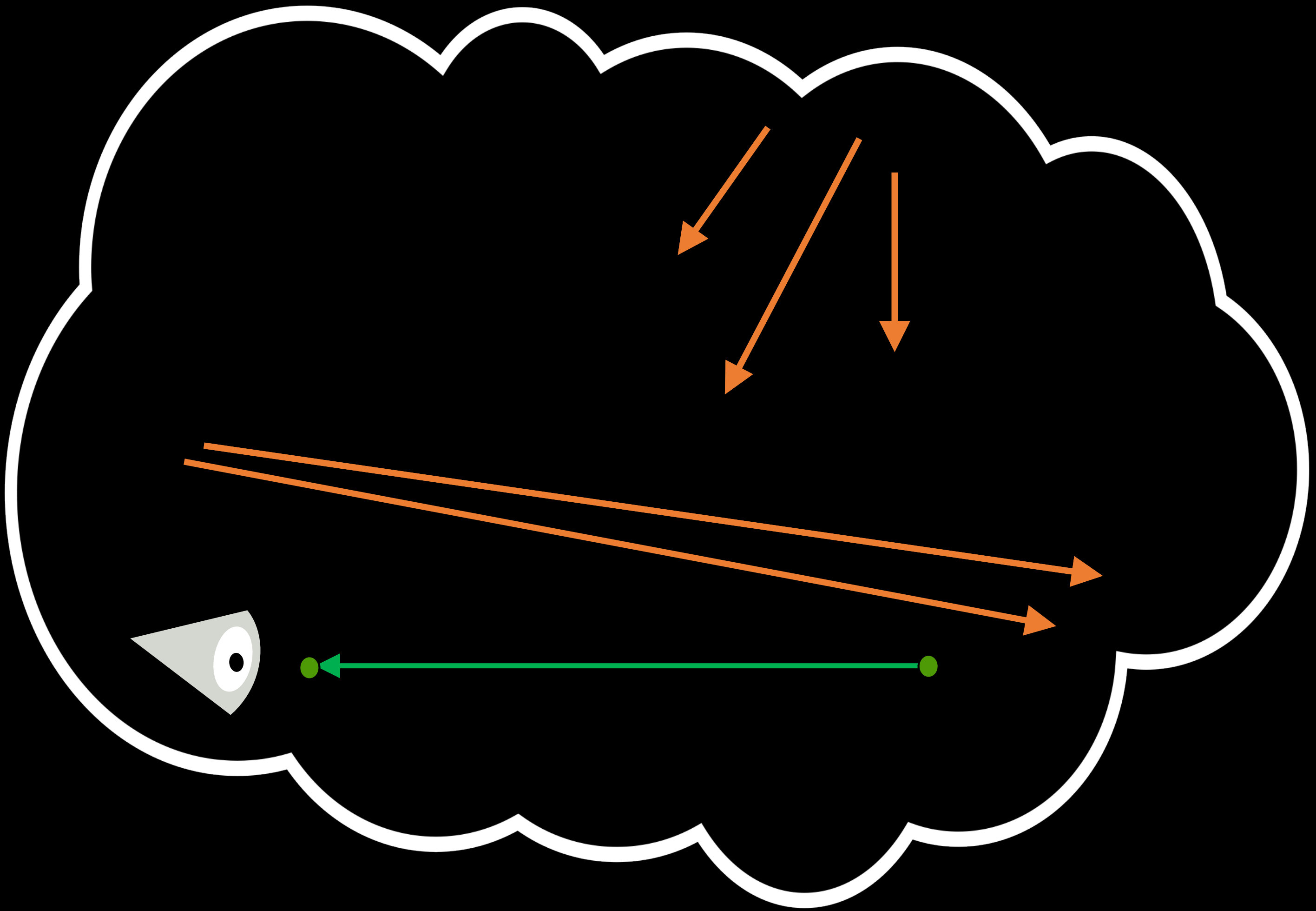
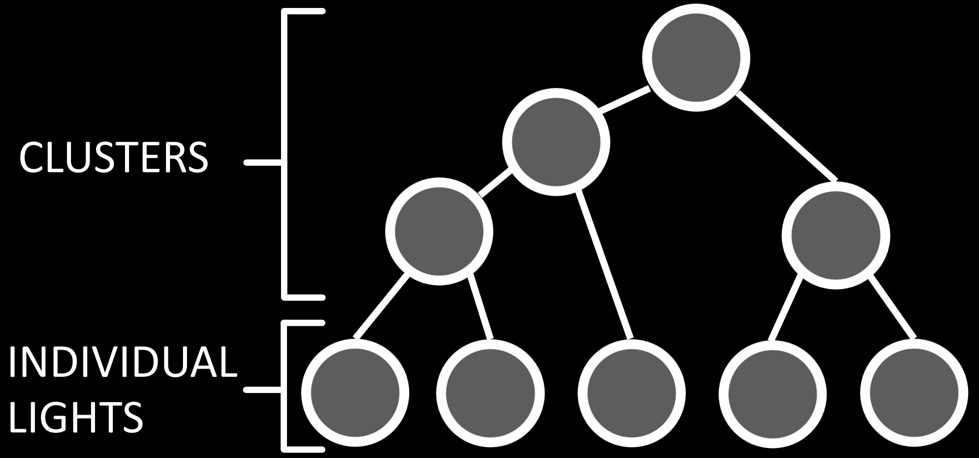
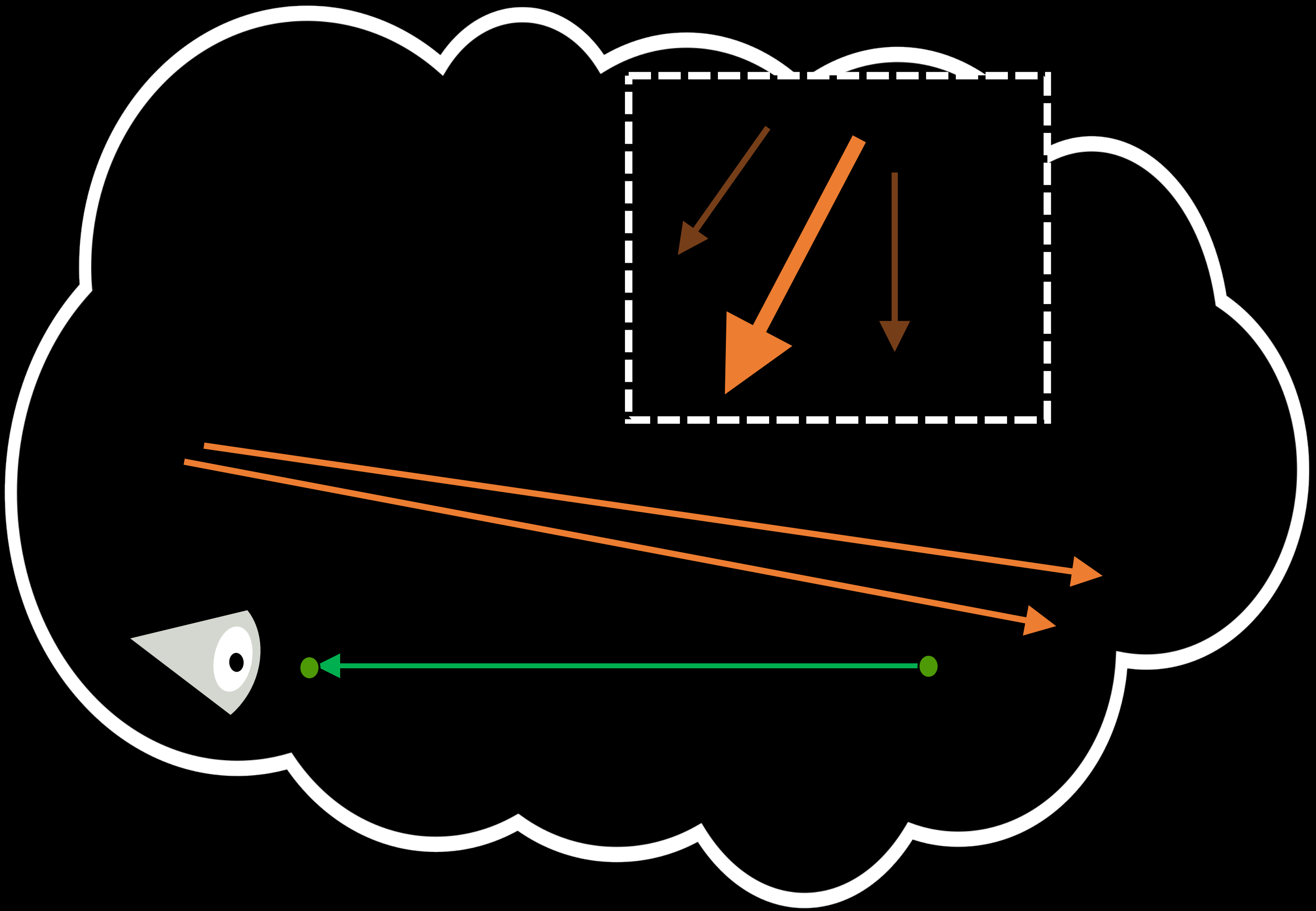
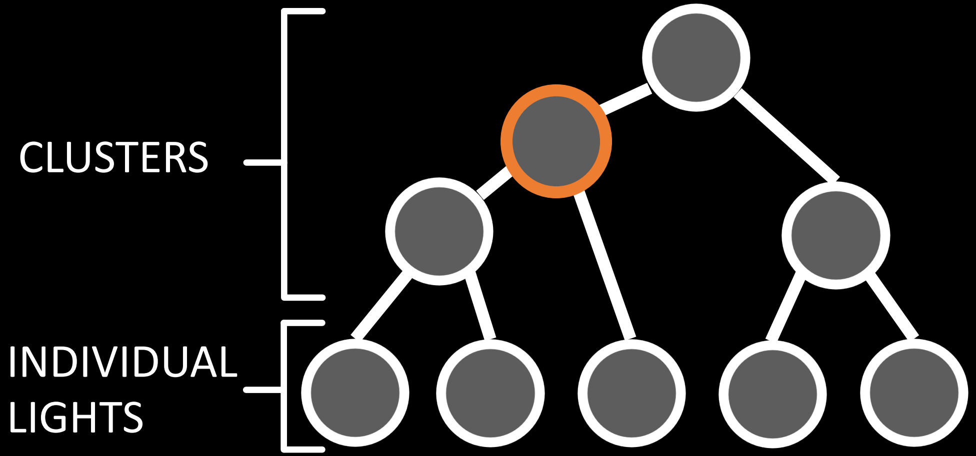




SCALABILITY





RELATED WORKS

Previous works have already explored a combination of VRLs with scalable techniques:

- Adaptive light-slice for virtual ray light [Frederickx al. 2015]
- Adaptive matrix column sampling and completion for rendering participating media [Huo et al. 2016]

Our solution: Upper bound

$$\frac{VRL(u,v)}{w(u,v)^2 p(u,v)} < \mathrm{B}$$

B=?

Our solution: Upper bound

$$\frac{\Phi f(u,v) T_r(u) T_r(w(u,v))}{w(u,v)^2 p(u,v)} < \mathrm{B}$$

$\Phi f(u, v)$: Constant within the VRL cluster

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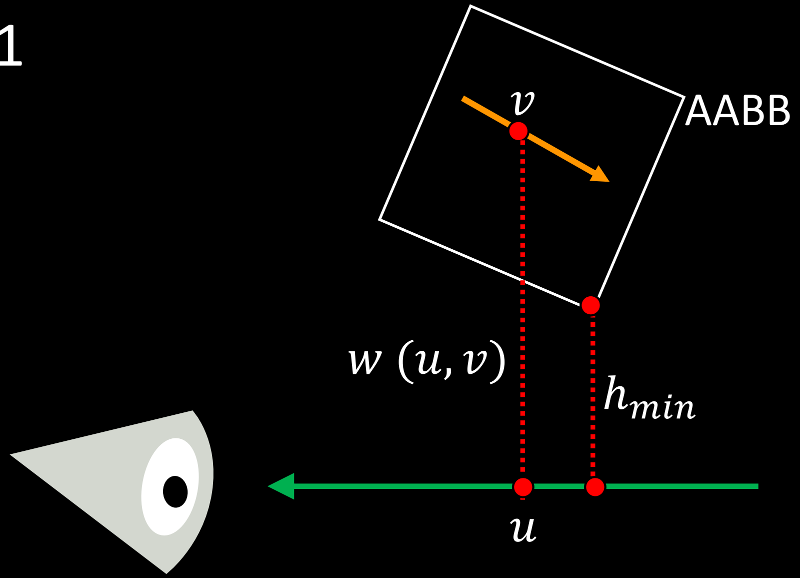
$T_r(w(u,v))$: Based on the min distance

=> $h_{min} \leq w_k(u,v)$

=> $T_r(w\,(u,v)) < \boxed{T_r(h_{min})}$



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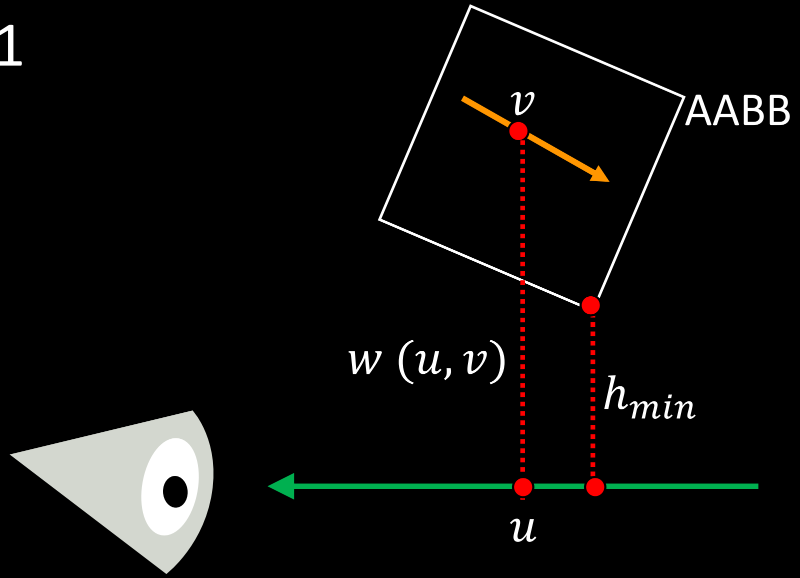

Our solution: Upper bound

$$w_k(u,v)^2 p(u,v)$$
$$= w_k(u,v)^2 p(u|v)p(v)$$

Our solution: Upper bound

$$\begin{aligned} & w_k(u,v)^2 p(u,v) \\ =& w_k(u,v)^2 p(u|v) p(v) \end{aligned}$$

Worst case when VRL and sensor ray are parallel.

$p(v) < \frac{1}{L_{max}}$, with L_{max} the maximum length inside the cluster.

Our solution: Upper bound

$$
\begin{aligned}
&w_k(u,v)^2 p(u,v)\\
&= w_k(u,v)^2 p(u|v)\, p(v)
\end{aligned}
$$

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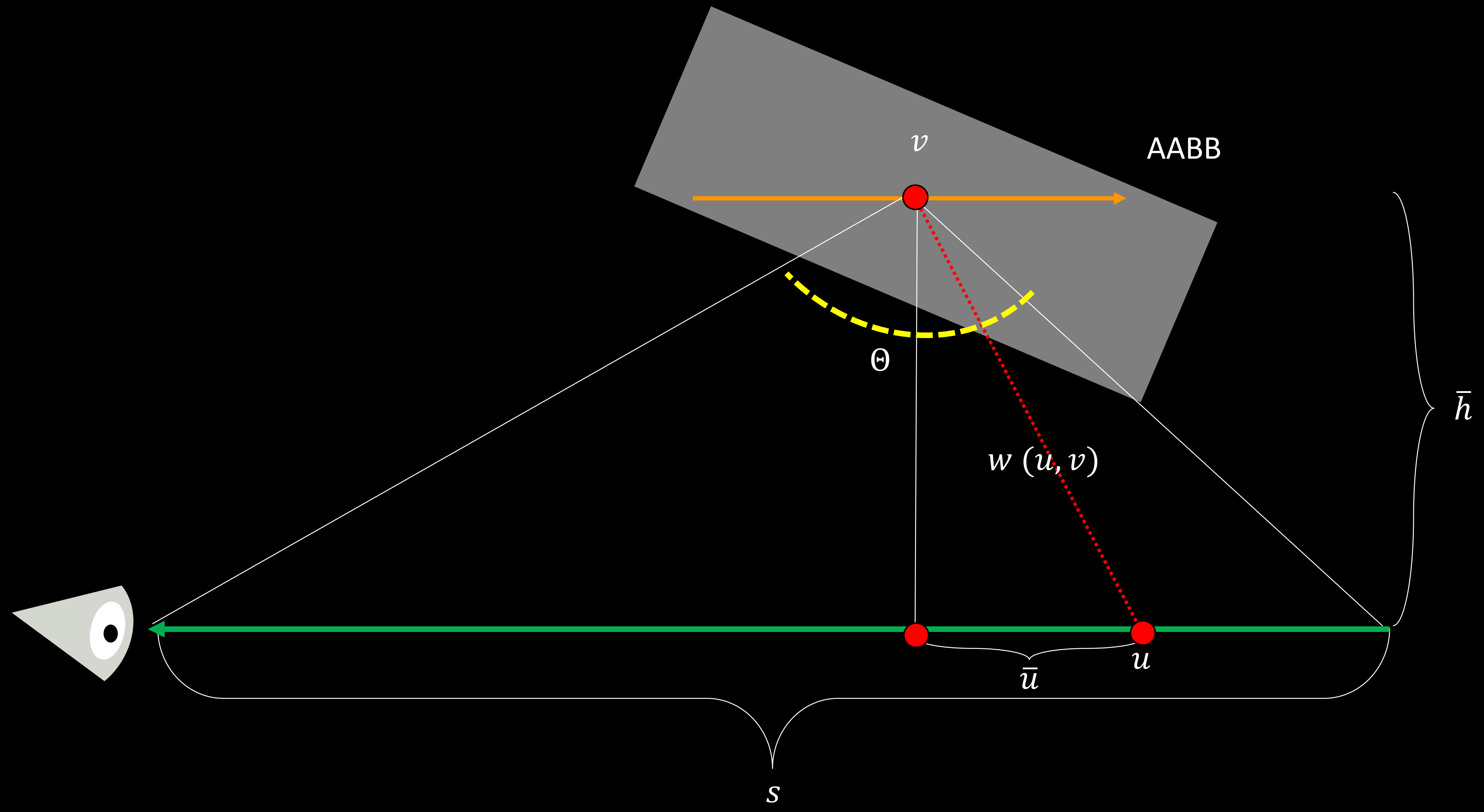
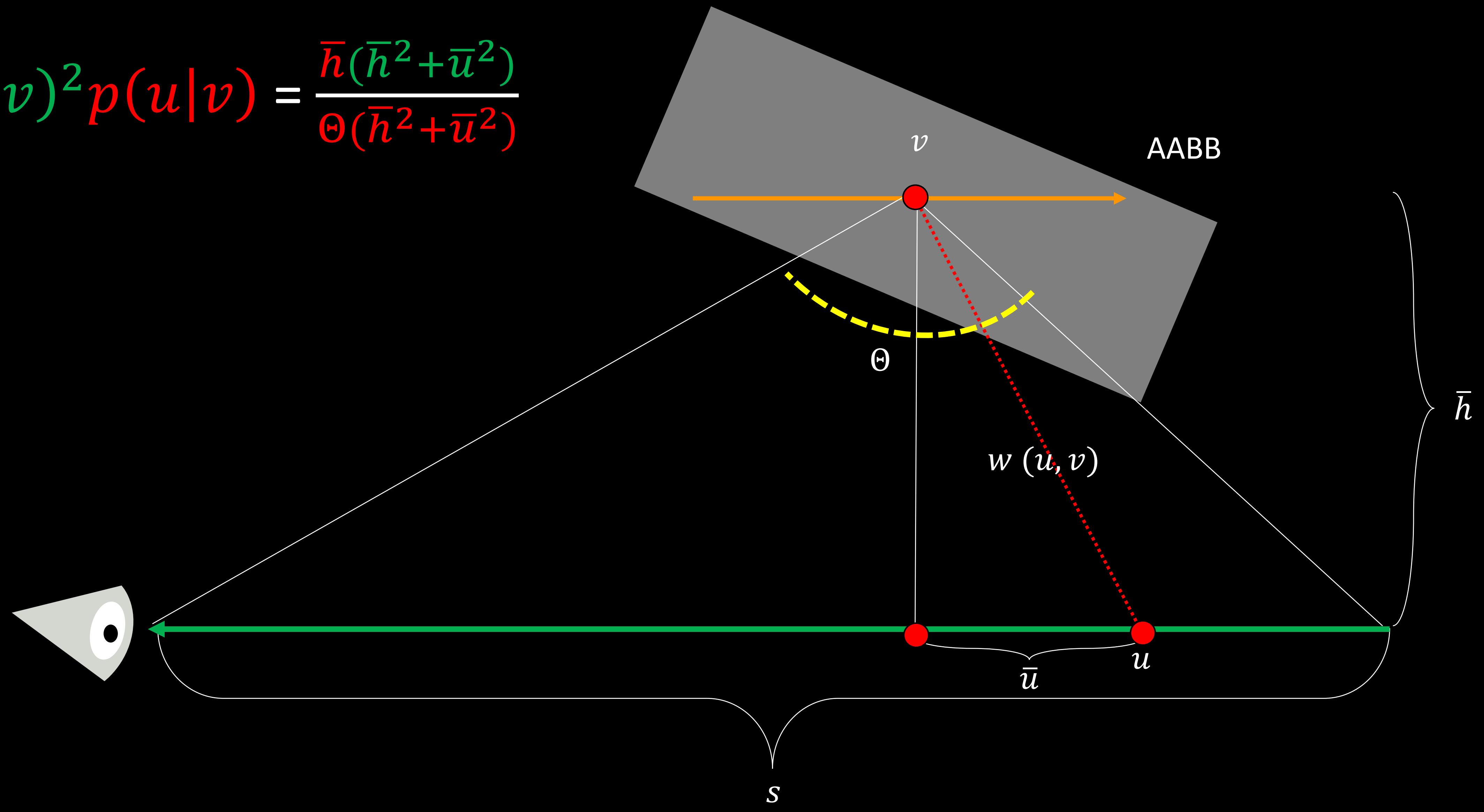


Our solution: Upper bound

$$w(u,v)^2 p(u|v) = \frac{\bar{h}(\bar{h}^2+\bar{u}^2)}{\Theta(\bar{h}^2+\bar{u}^2)}$$



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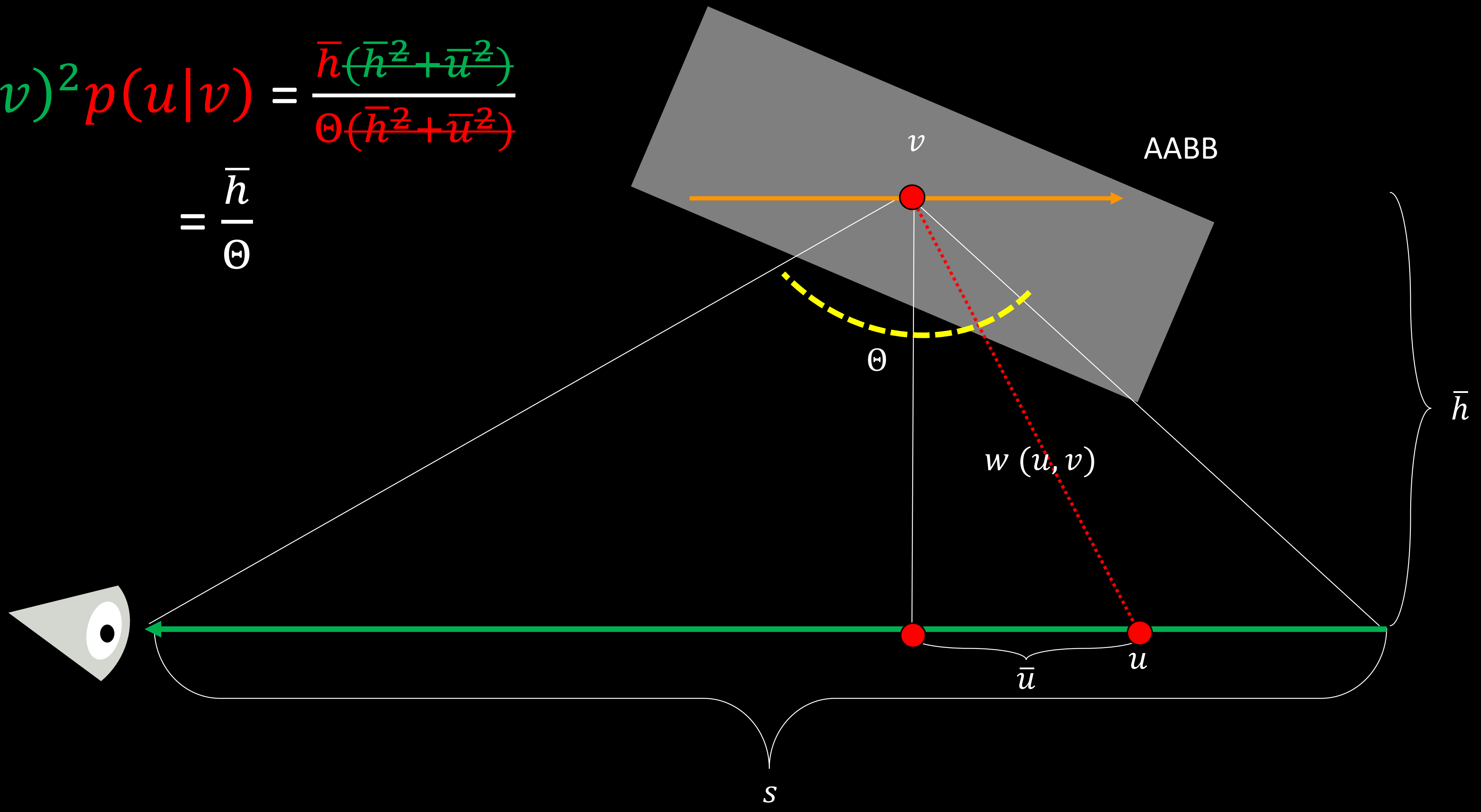
$$= \frac{\bar{h}}{\Theta}$$



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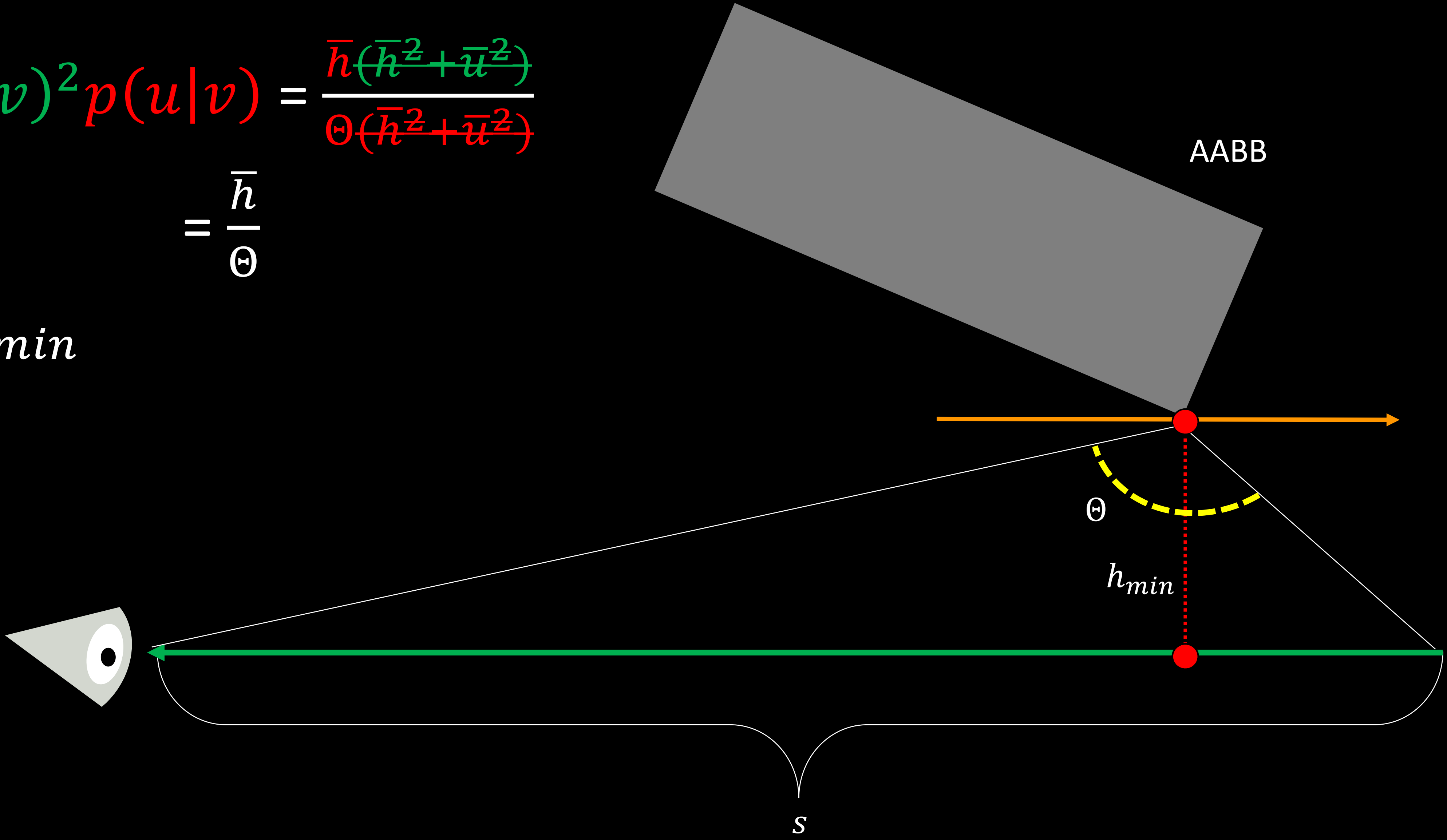
$$\bar{h} > h_{min}$$



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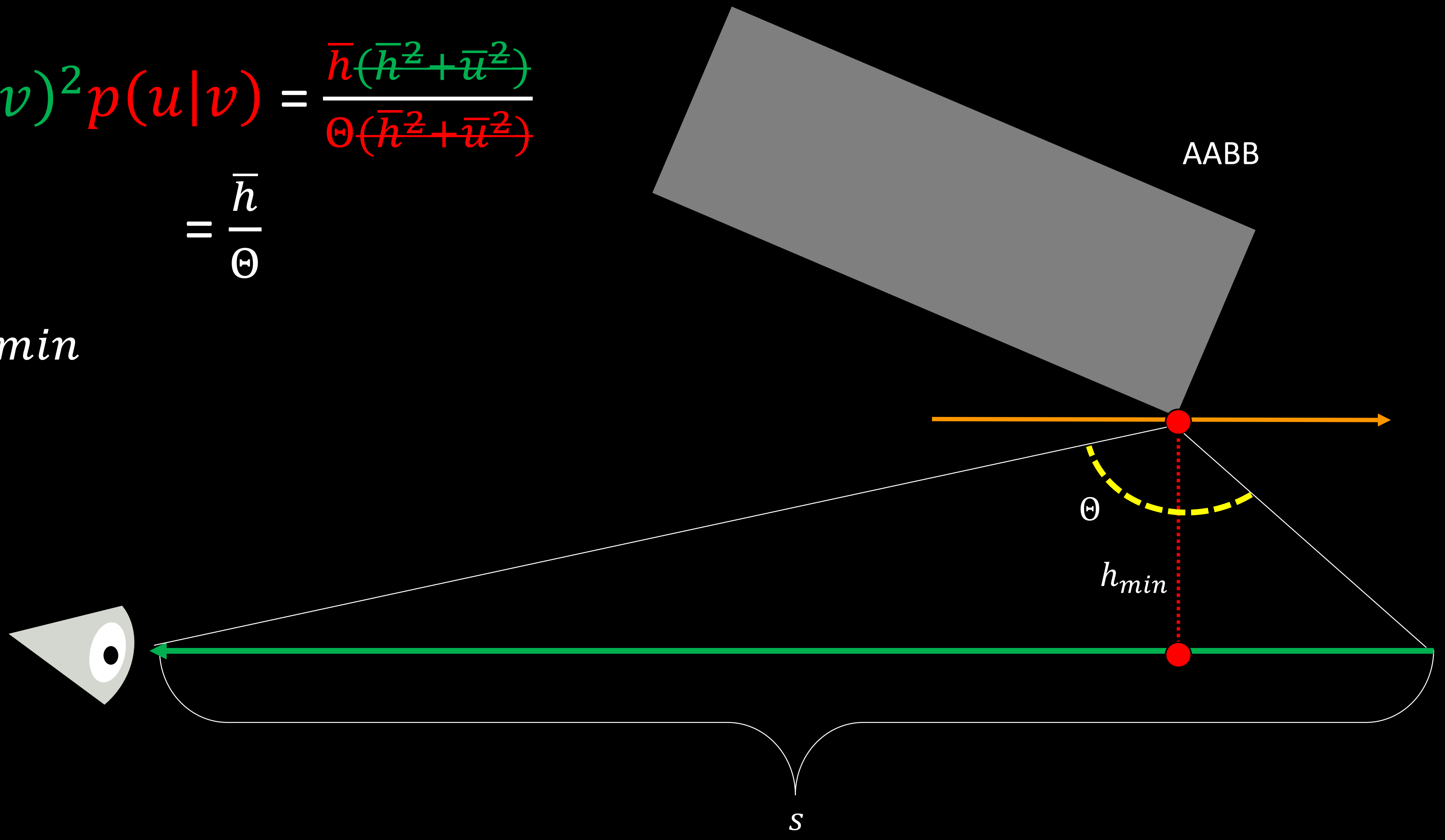

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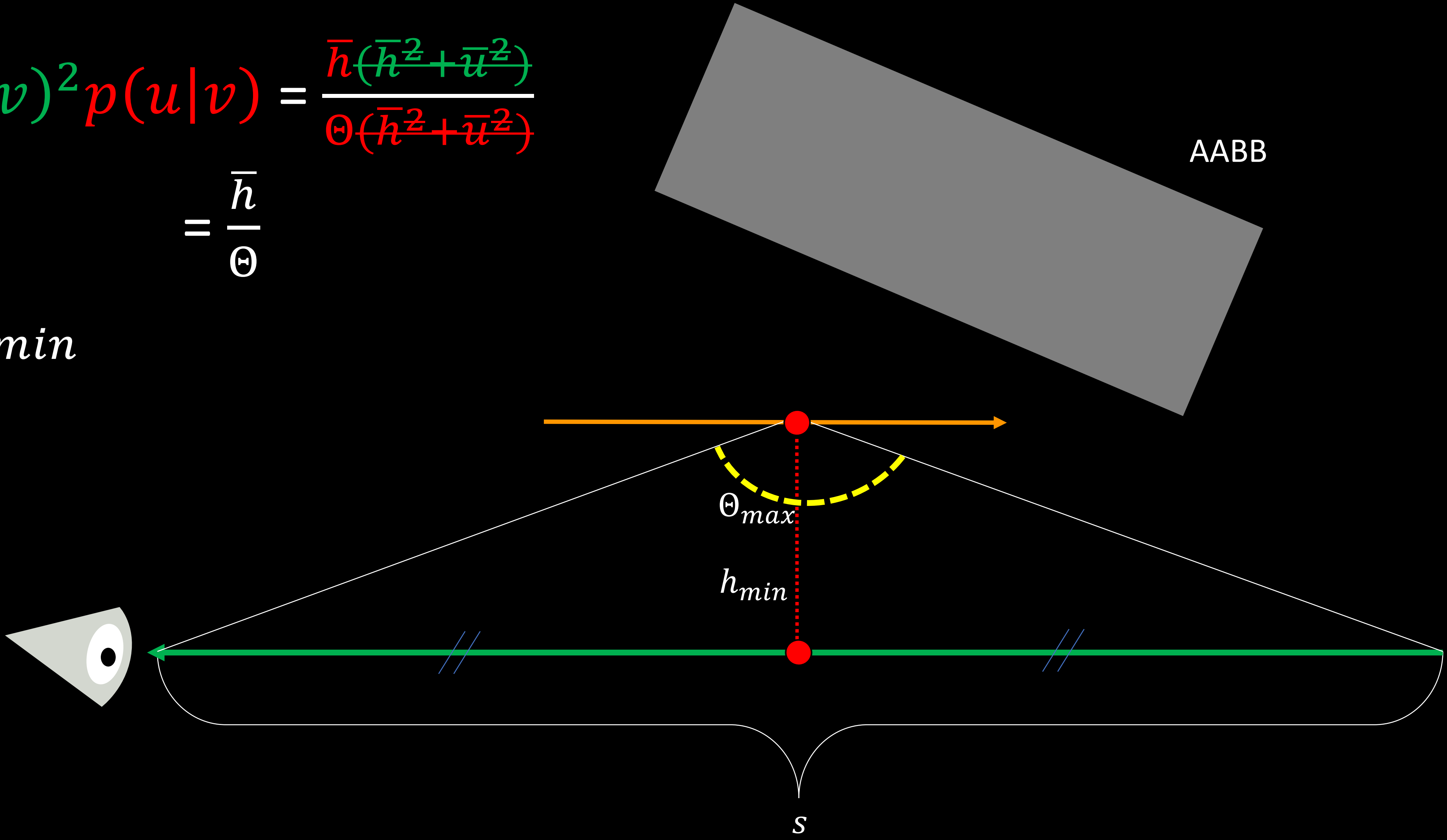

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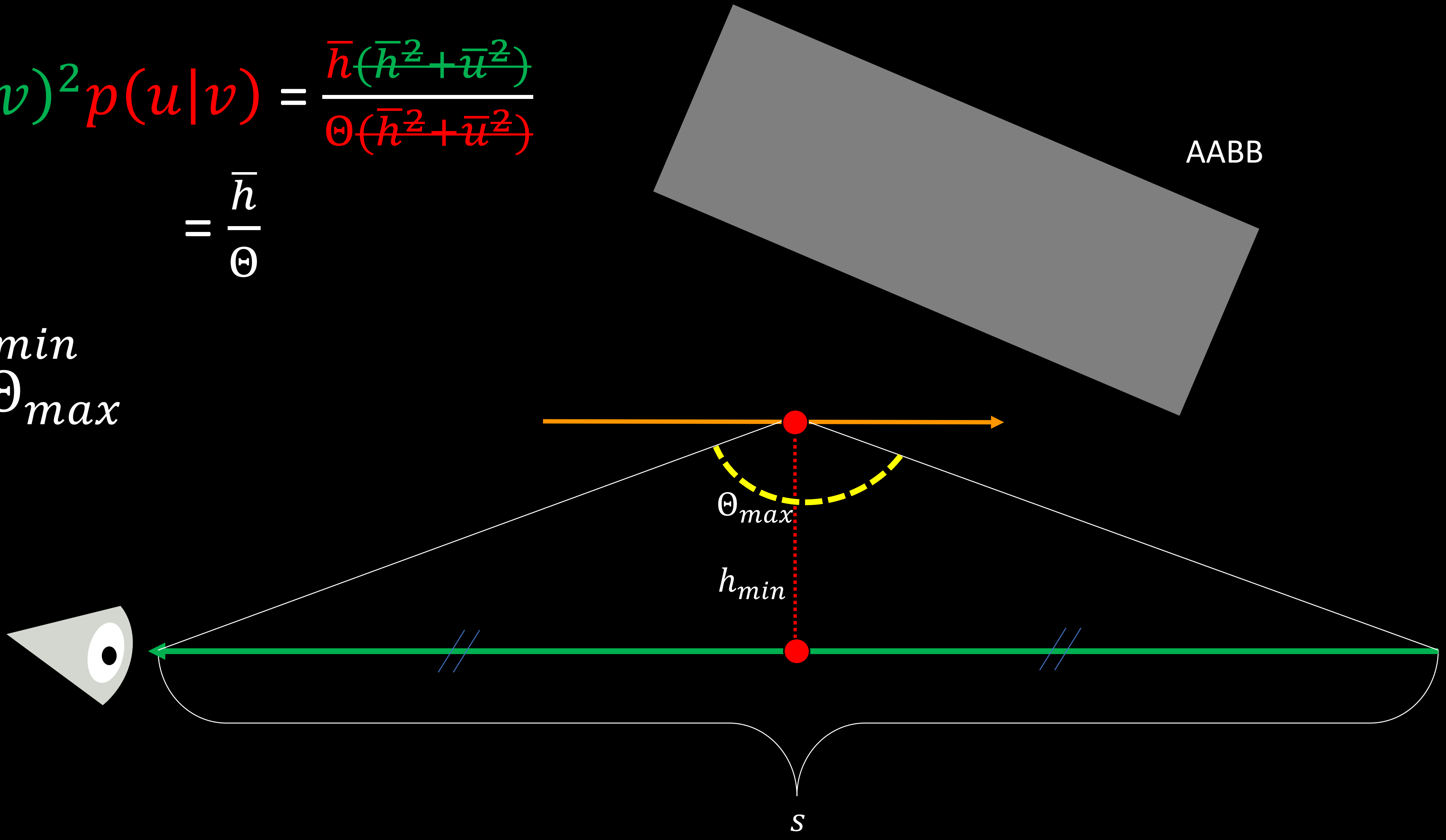
$$\Theta < \Theta_{max}$$



Our solution: Upper bound

$$\mathrm{B} = \frac{\Phi f(u,v) T_r(\mathrm{h_{min}}) \Theta_{\mathrm{max}} \mathrm{L_{max}}}{h_{min}}$$

Our solution: Light tree

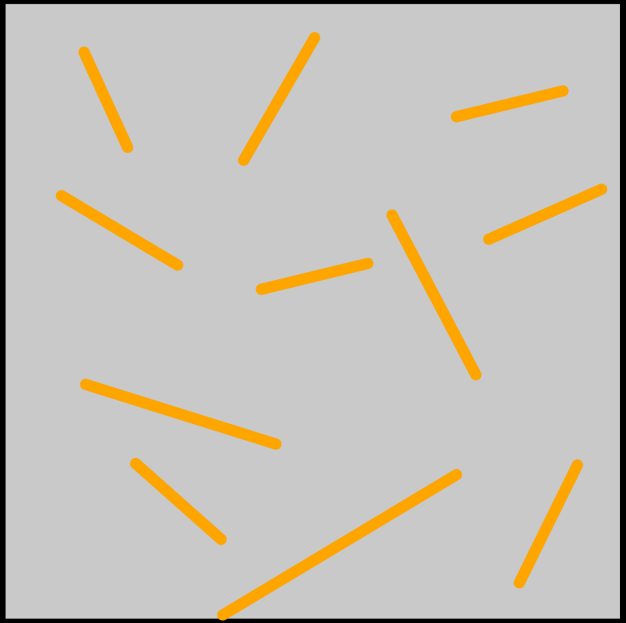
Agglomerative approach [Walter et al. 2008]:

- Not multithreaded
- Does not scale with high node overlapping $O(N^2)$

What we need:

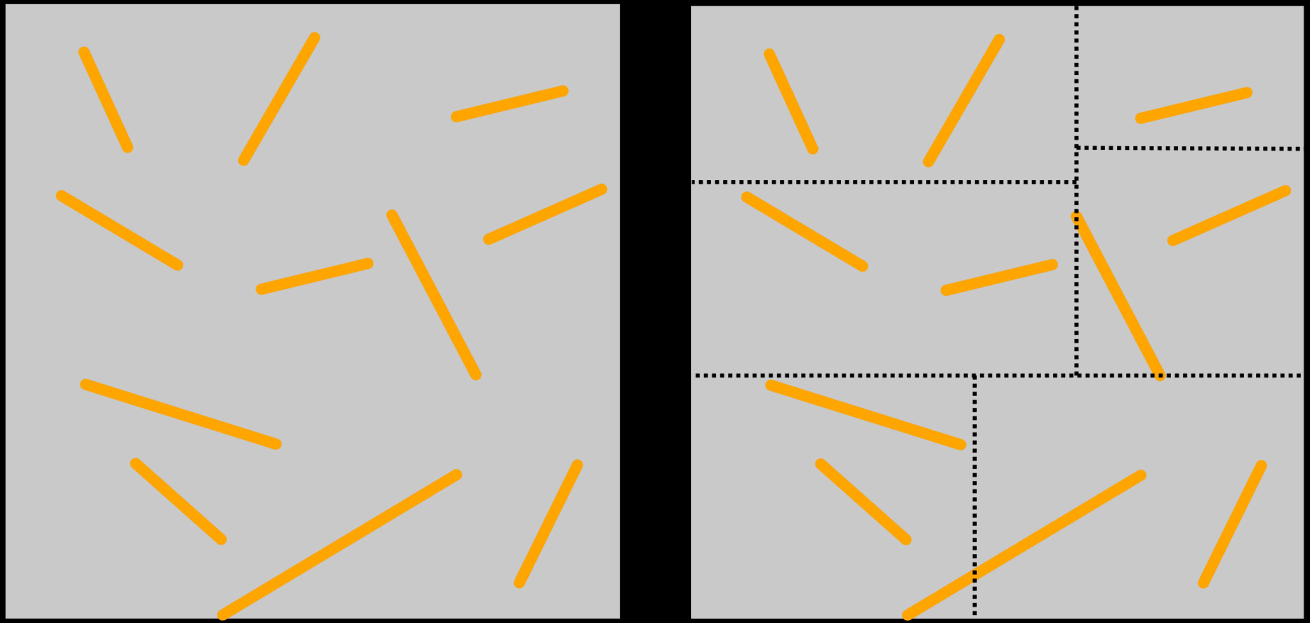
- Fast/Parallelizable
- Agglomerative principal

Our solution: Light tree



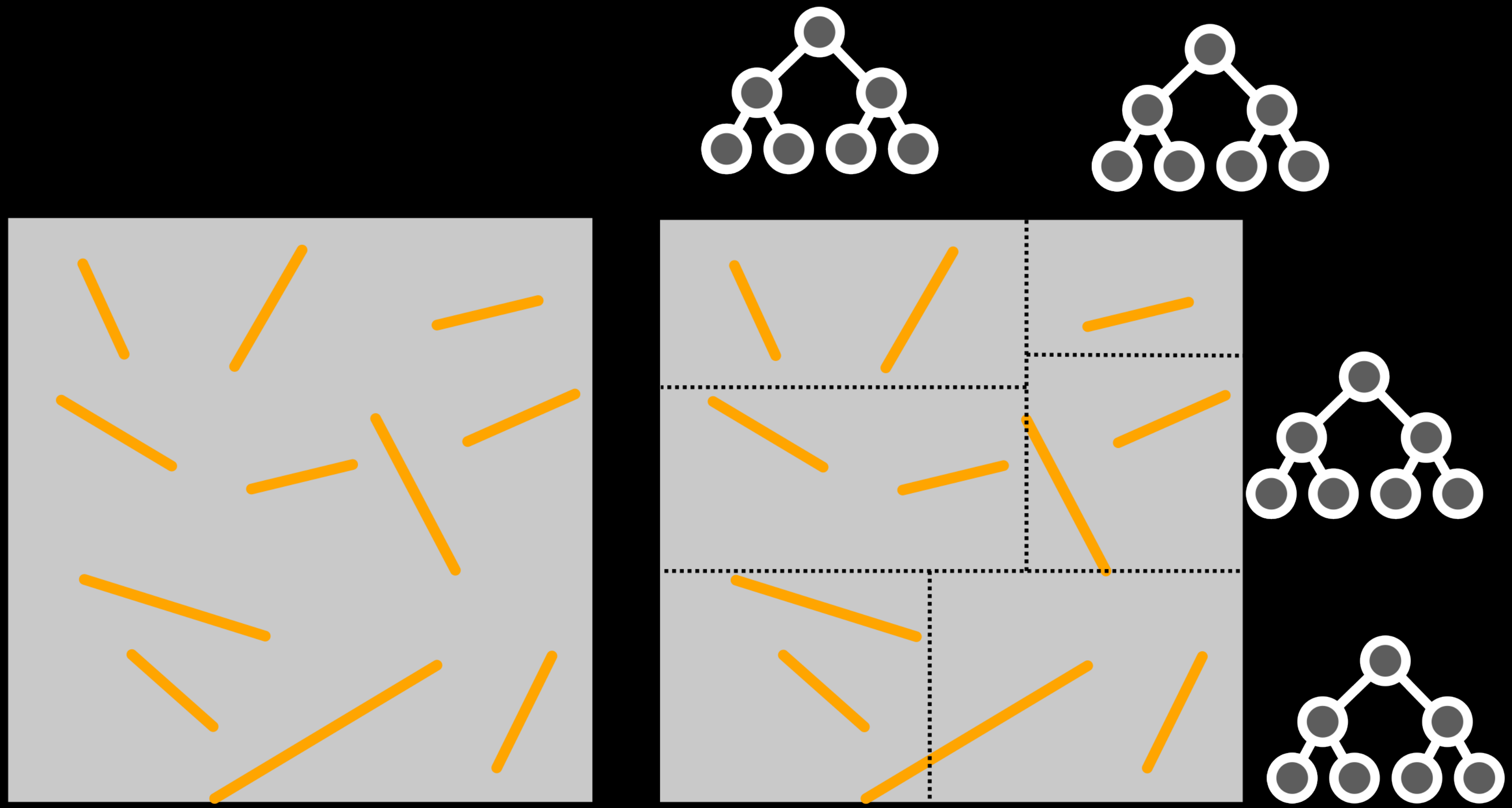
Our solution: Light tree

Step 1: Partition the space with sorting



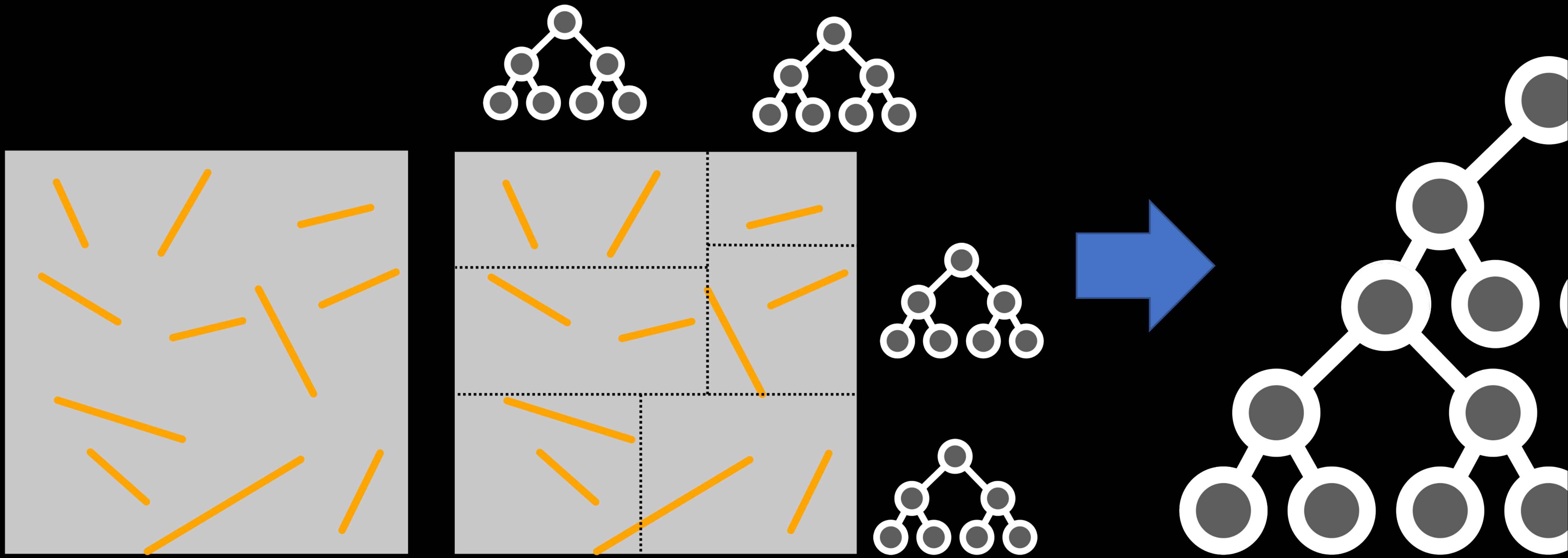
Our solution: Light tree

Step 2: Build local light tree that minimize the metric



Our solution: Light tree

Step 3: Build final tree with agglomerative process



Results

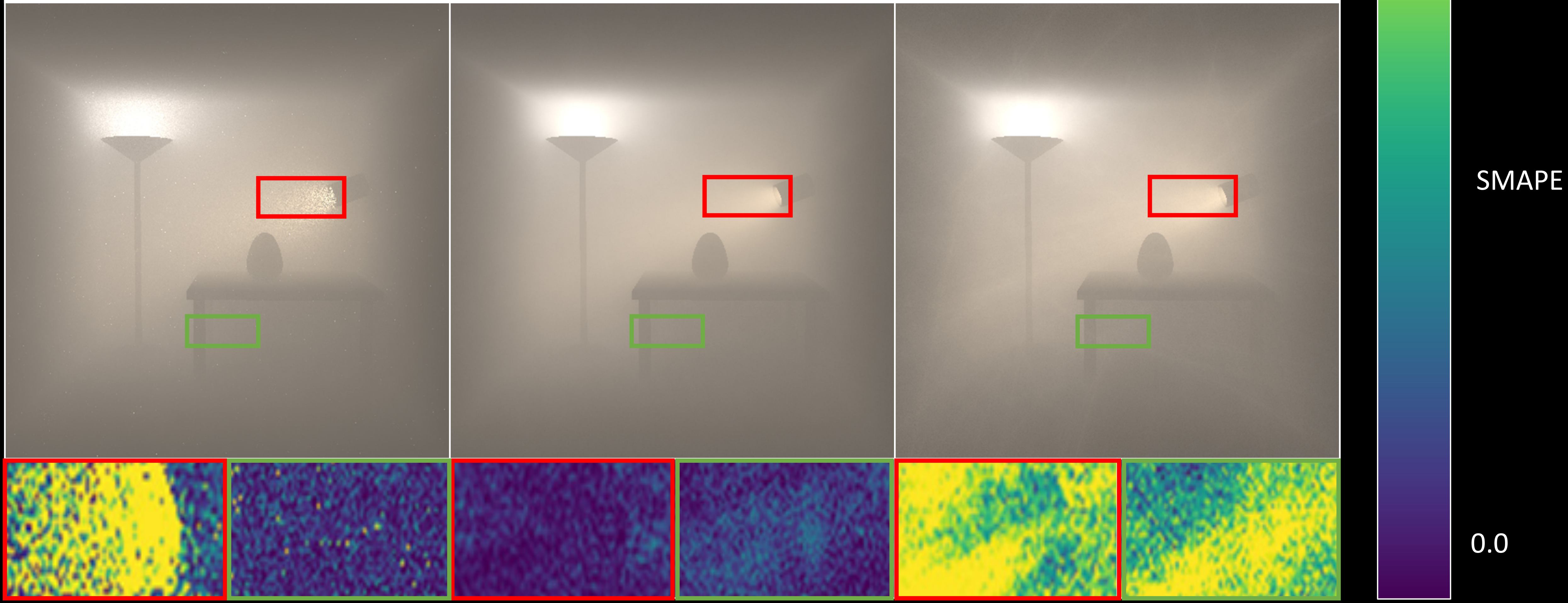
- Equal time comparison
  - VPL with LC
  - VRL
- Two metrics
  - RMSE: sensitive to fireflies
  - SMAPE: robust to fireflies
- Isotropic medium, only medium-medium interactions

Results

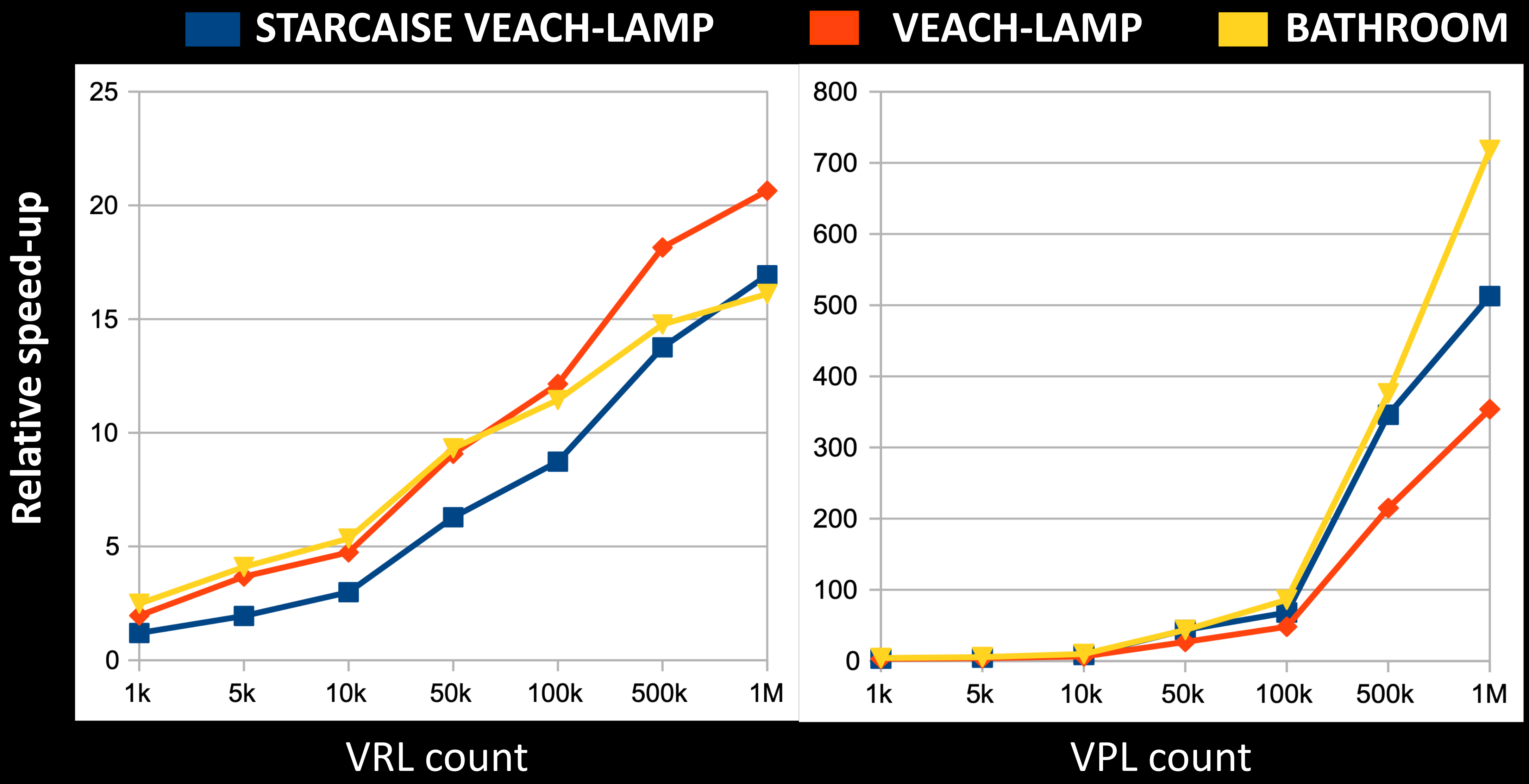
Reference	VPL LC (1M) 344 secs RMSE: 9.01 SMAPE: 3.25	VRL LC (100k) 370 secs RMSE: 2.70 SMAPE: 4.31	VRL (10k) 323 secs RMSE: 5.46 SMAPE: 9.93
			

Results

VPL LC (1M) - 147 secs RMSE: 0.33 SMAPE: 2.44	VRL LC (100k) - 121 secs RMSE: 0.01 SMAPE 1.88	VRL (10k) - 147 secs RMSE: 0.05 SMAPE 9.11



Results


STARCAISE VEACH-LAMP
VEACH-LAMP
BATHROOM
Relative speed-up
25
20
15
10
5
0
1k
5k
10k
50k
100k
500k
1M
VRL count
800
700
600
500
400
300
200
100
0
1k
5k
10k
50k
100k
500k
1M
VPL count

Summary

Contributions:

- New bound for VRL cluster
- Efficient tree construction
- X10 Speedup

Questions ?