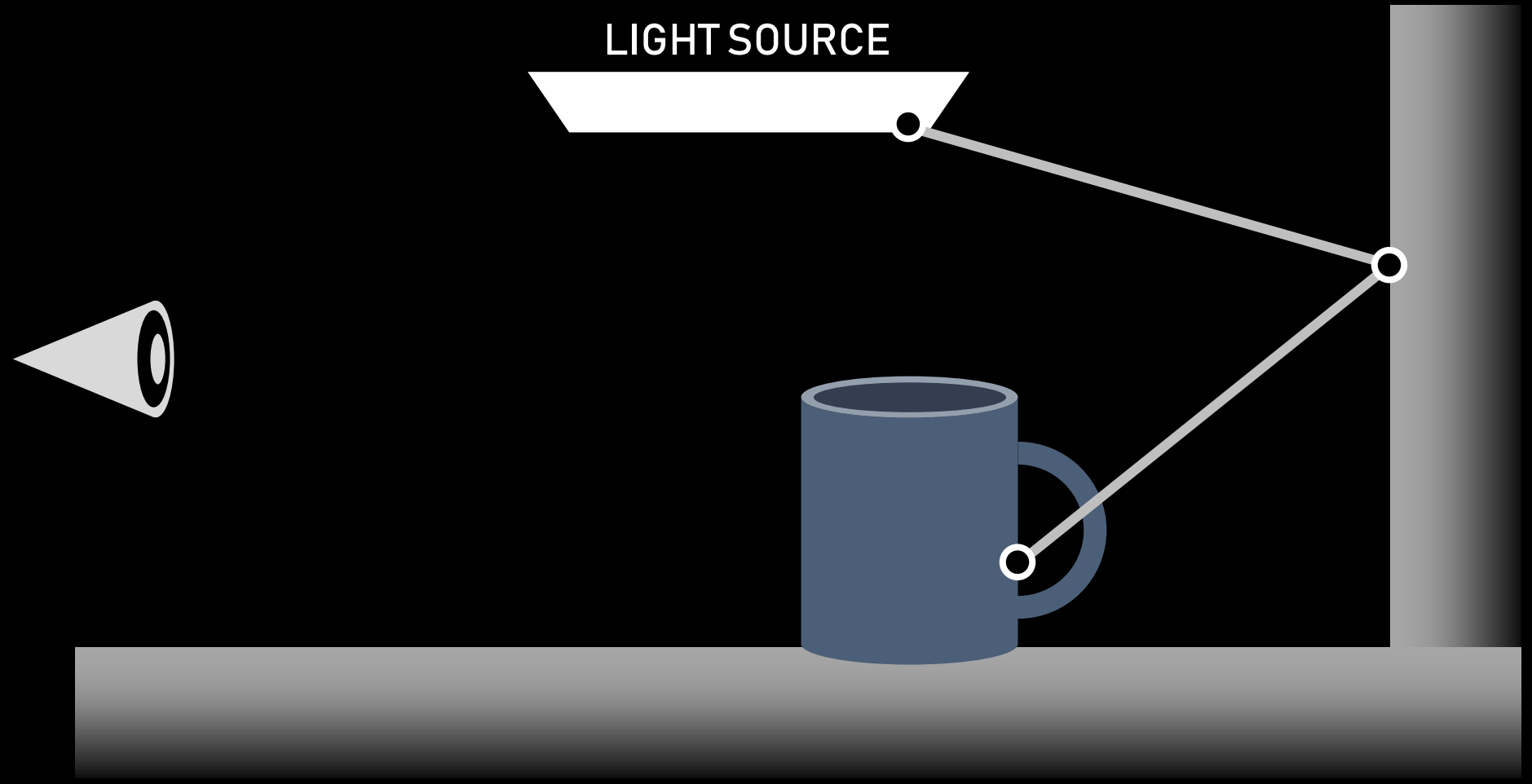
# Efficient Energy-Compensated VPLs using Photon Splatting

Jamorn Sriwasansak
The University of Tokyo

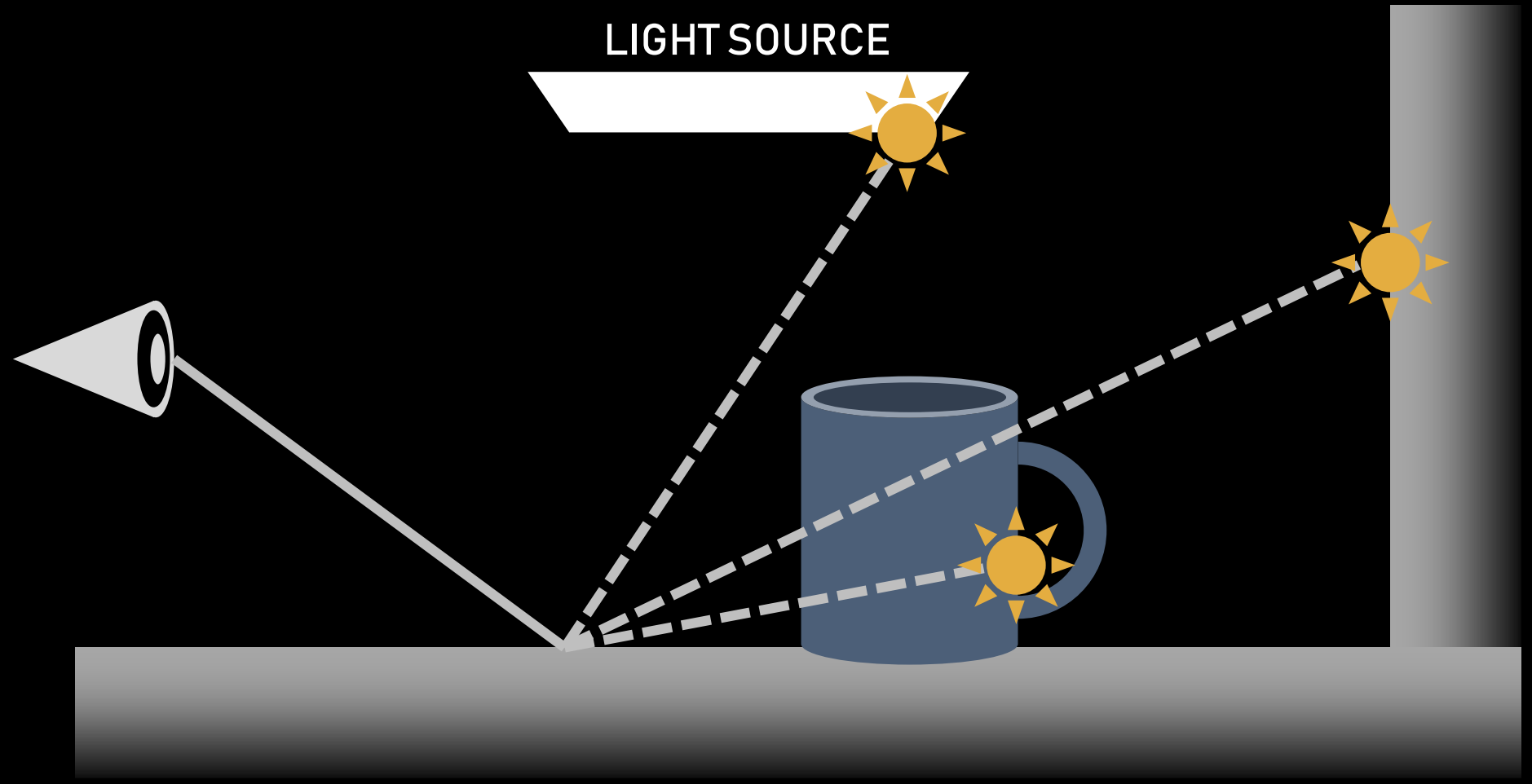
Adrien Gruson
The University of Tokyo
JFLI, CNRS, UMI 3527

Toshiya Hachisuka
The University of Tokyo

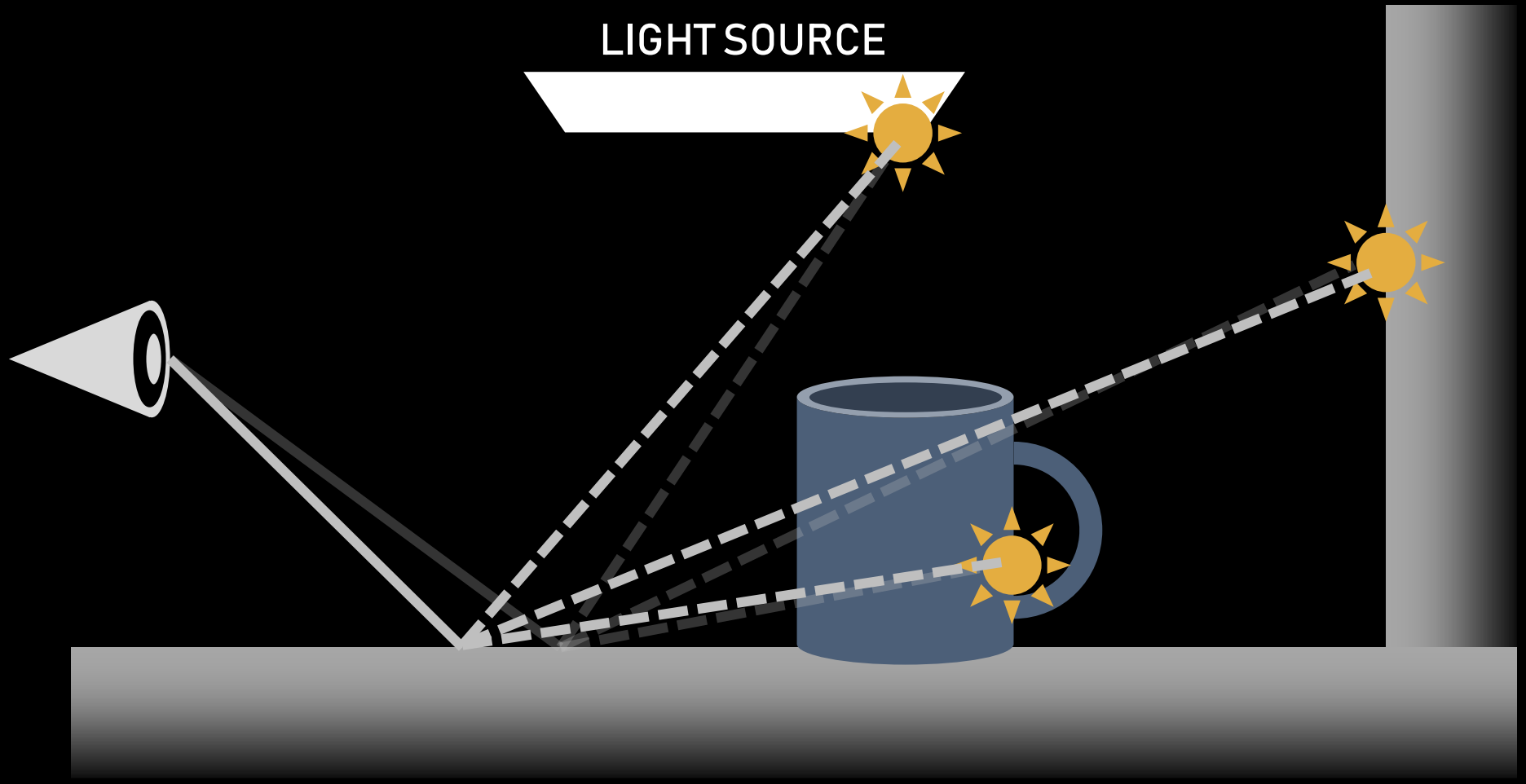
# Instant Radiosity with VPLs (Keller et al. 1997)



# Instant Radiosity with VPLs (Keller et al. 1997)



# Instant Radiosity with VPLs (Keller et al. 1997)



# Instant Radiosity with VPLs

## Advantages

- Reuses light subpaths across pixels efficiently
- Can be used with several scalable techniques
  (MRCS - Hašan et al. 2007, LightCuts - Walter et al. 2005, 2006, Ou and Pellacini 2011, …)

# Instant Radiosity with VPLs

## Advantages

- Reuses light subpaths across pixels efficiently
- Can be used with several scalable techniques
  (MRCS - Hašan et al. 2007, LightCuts - Walter et al. 2005, 2006, Ou and Pellacini 2011, …)

## Disadvantages

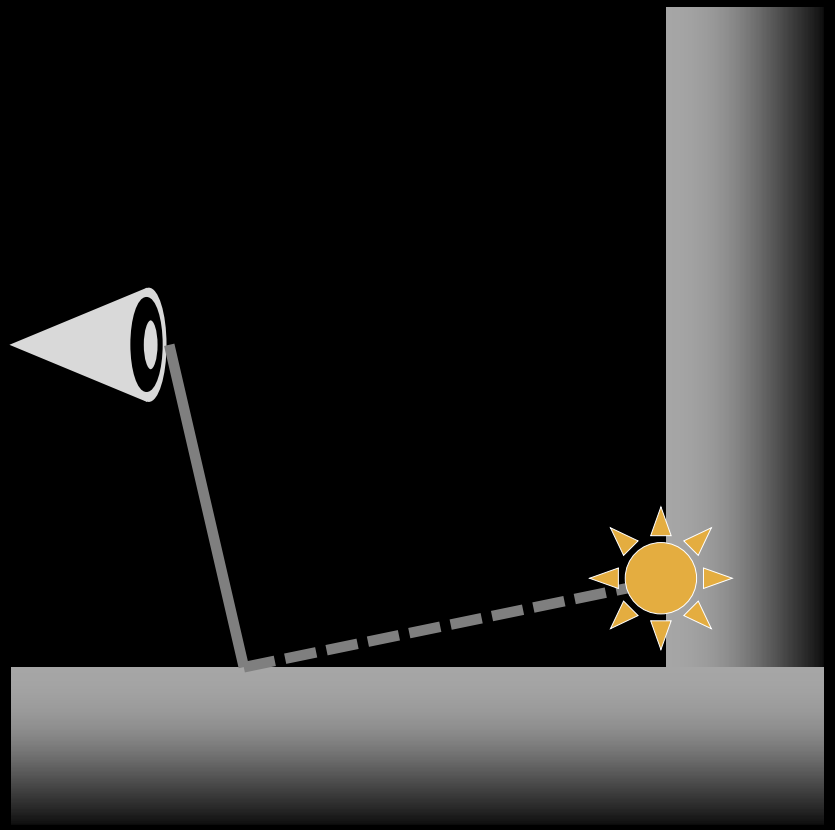
- Contains weak singularities

# Instant Radiosity with VPLs

RESULT
(500 light subpaths)

REFERENCE

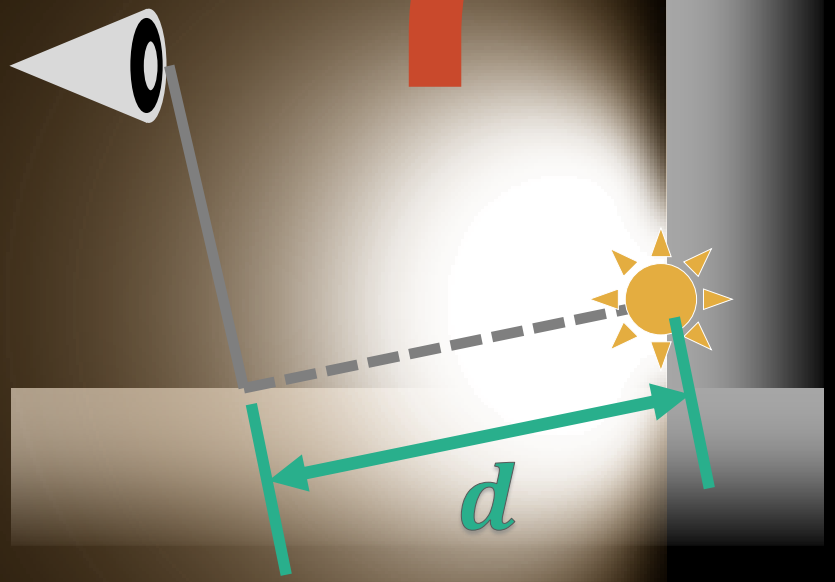
# Cause of weak singularities



# Cause of weak singularities

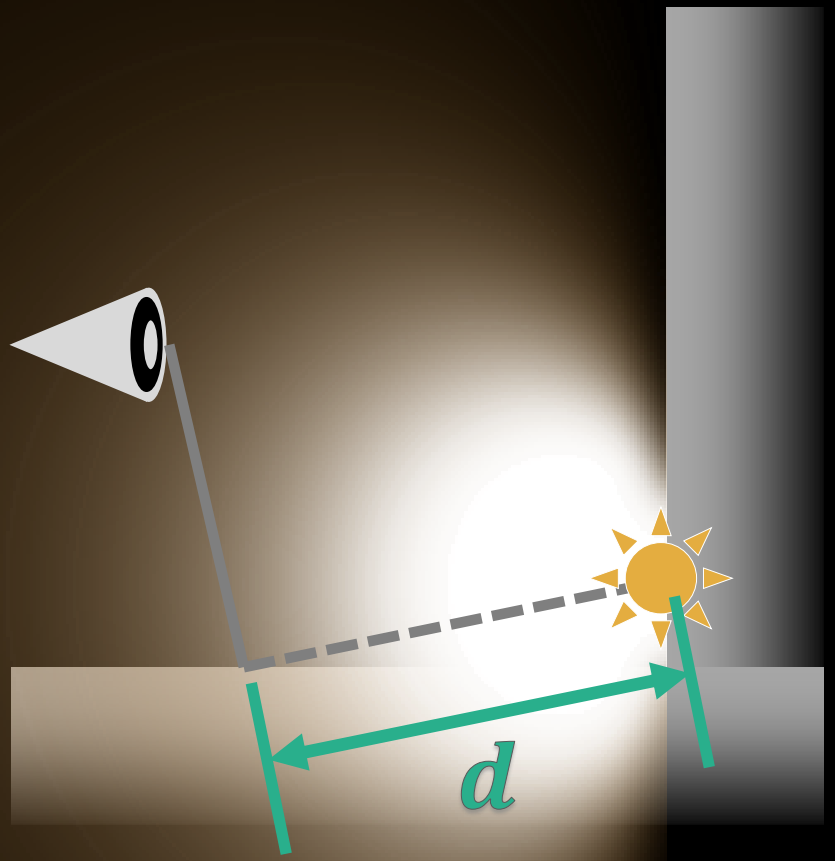
Geometry term

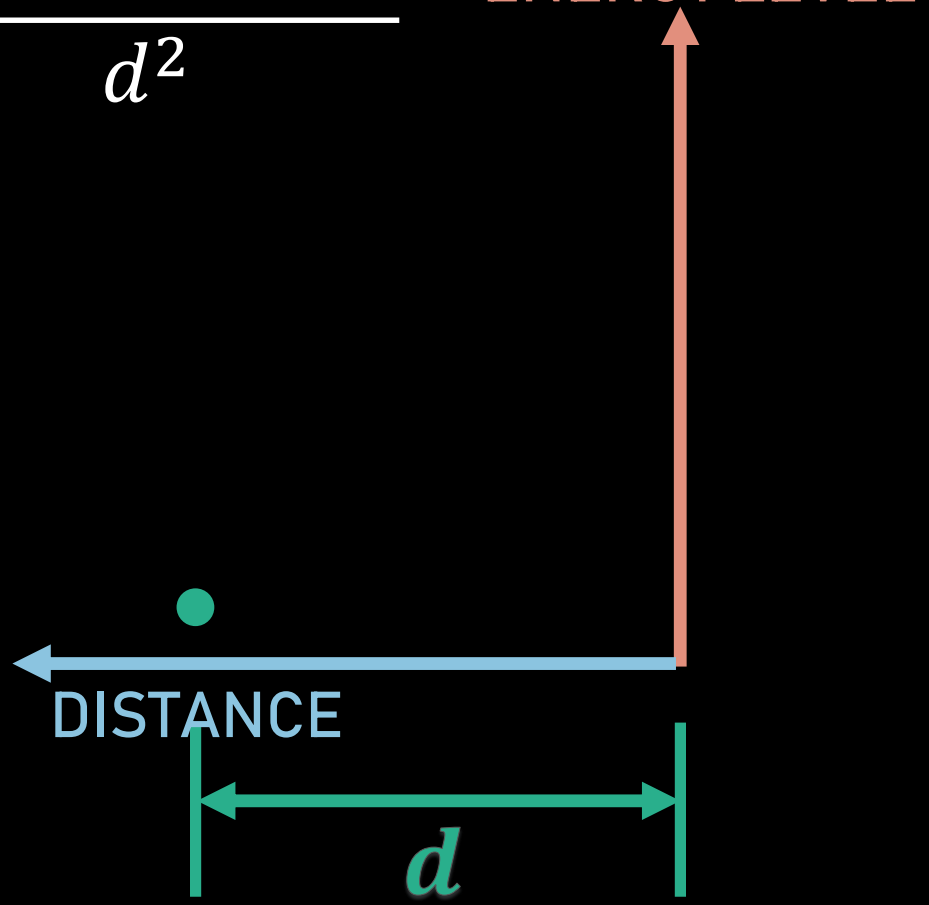
$$\frac{\cos(\theta)\cos(\phi)}{d^2}$$



# Cause of weak singularities

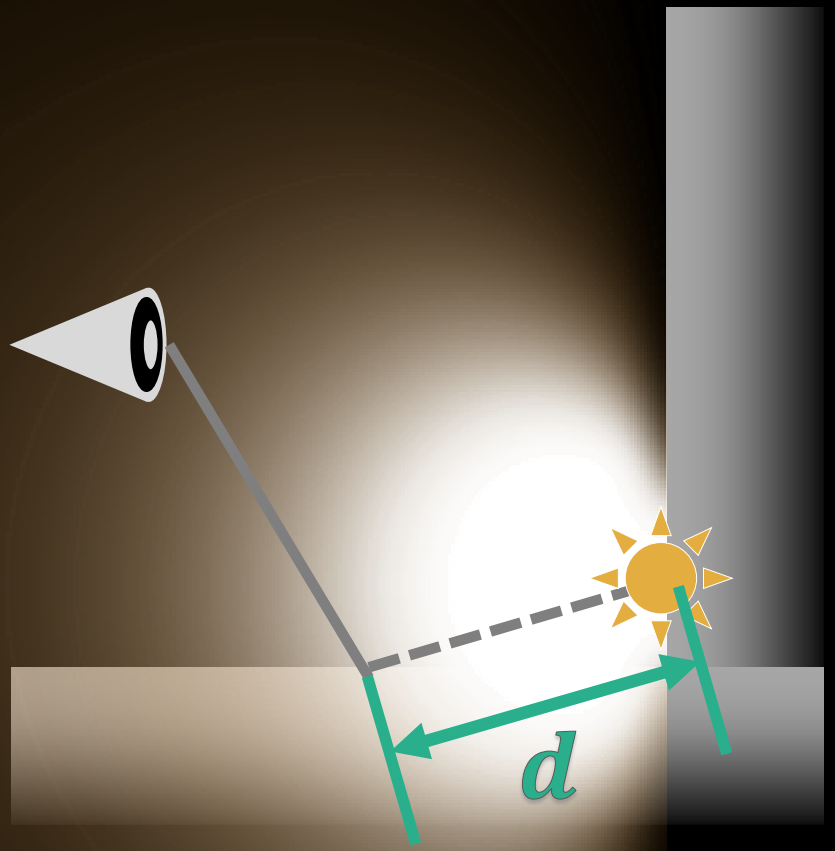
$$\frac{\cos(\theta)\cos(\phi)}{d^2}$$

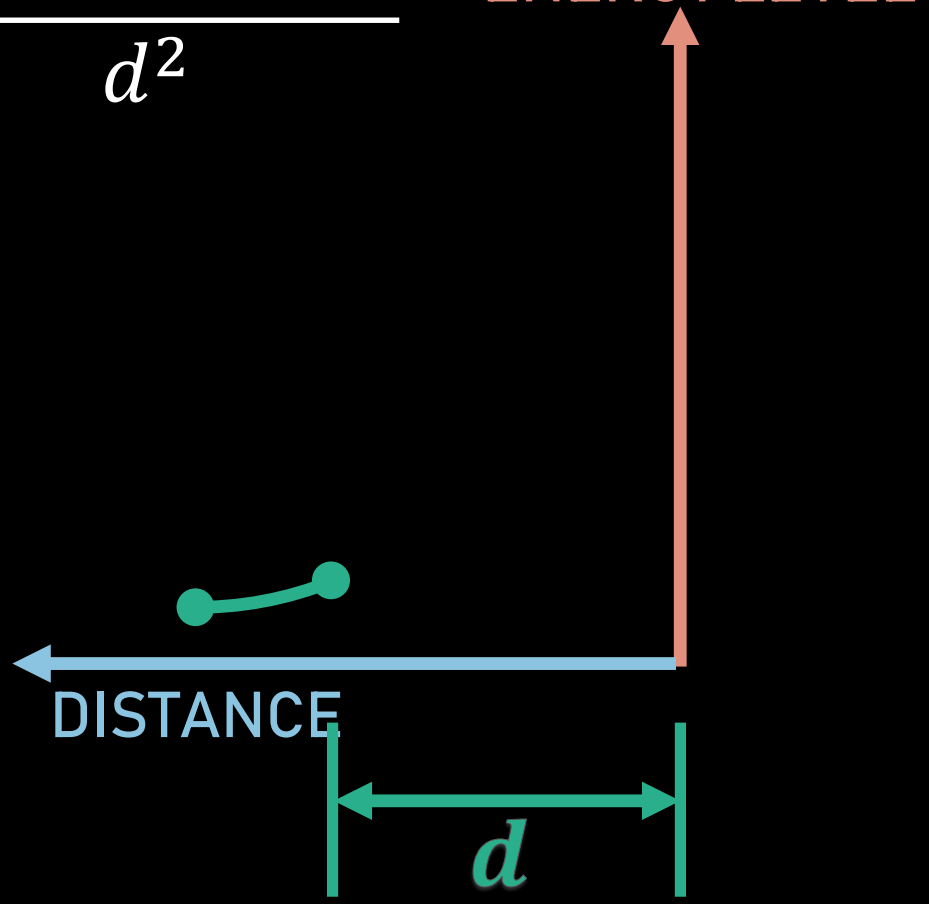


# Cause of weak singularities

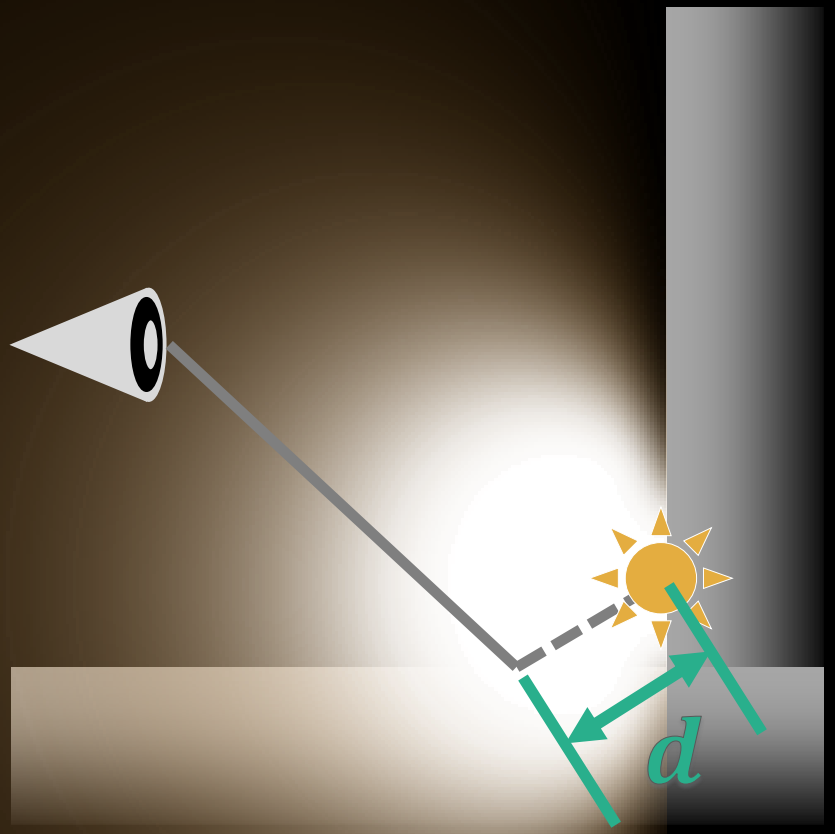
$$\frac{\cos(\theta)\cos(\phi)}{d^2}$$

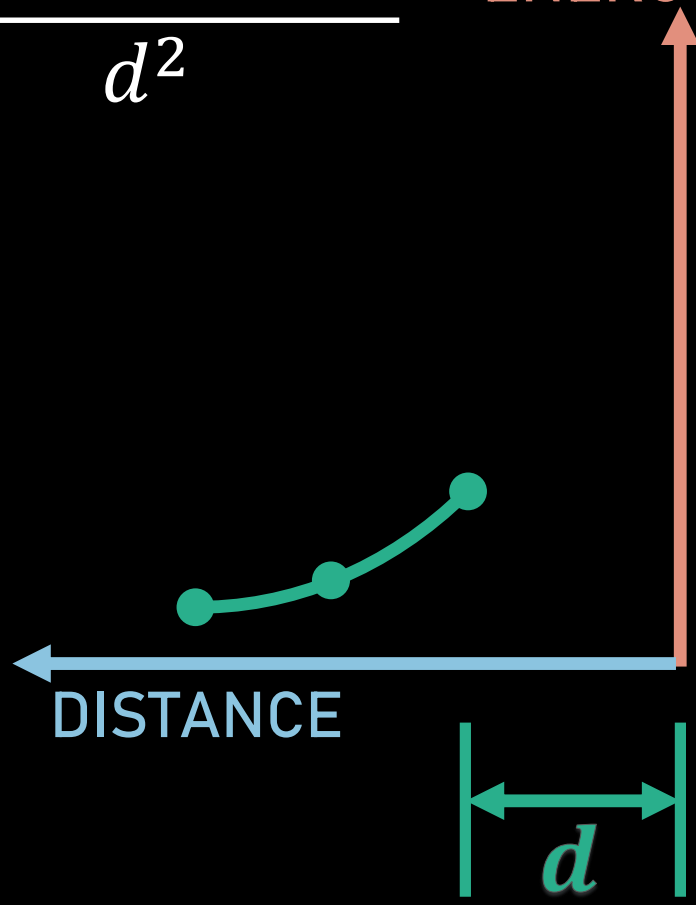


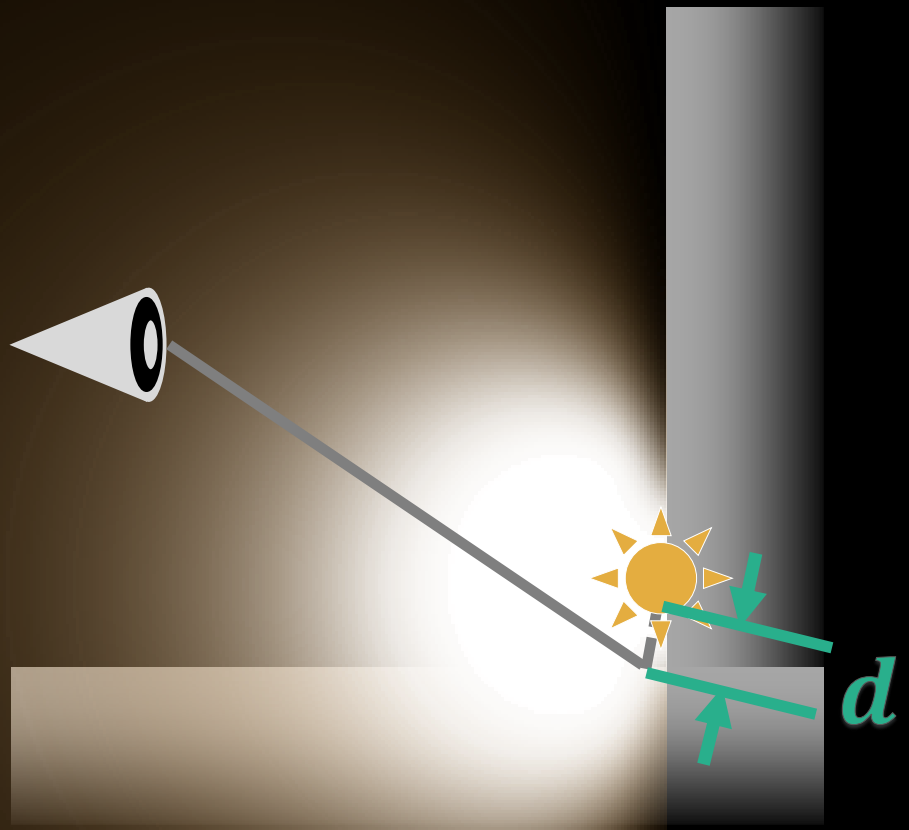
# Cause of weak singularities

$$\frac{\cos(\theta)\cos(\phi)}{d^2}$$

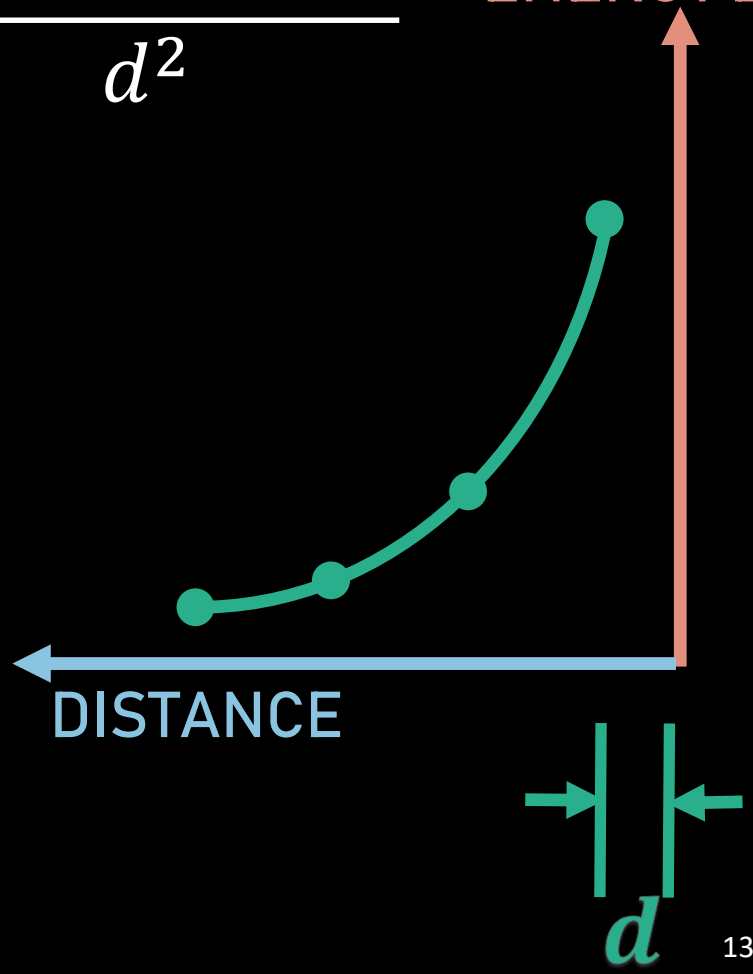


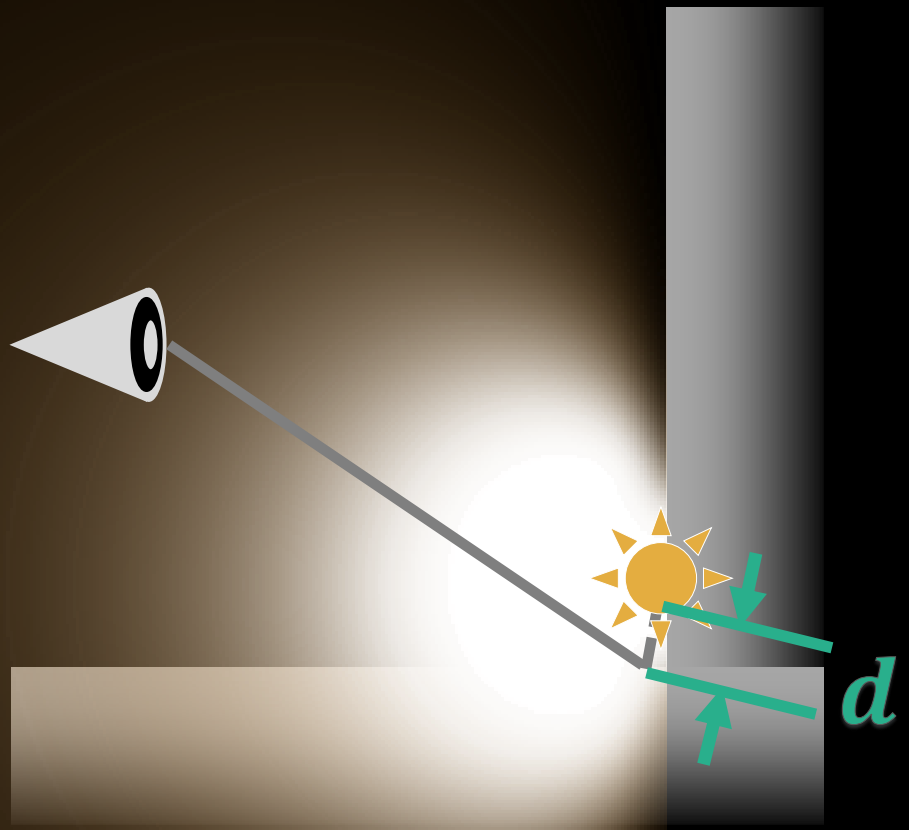
# Cause of weak singularities



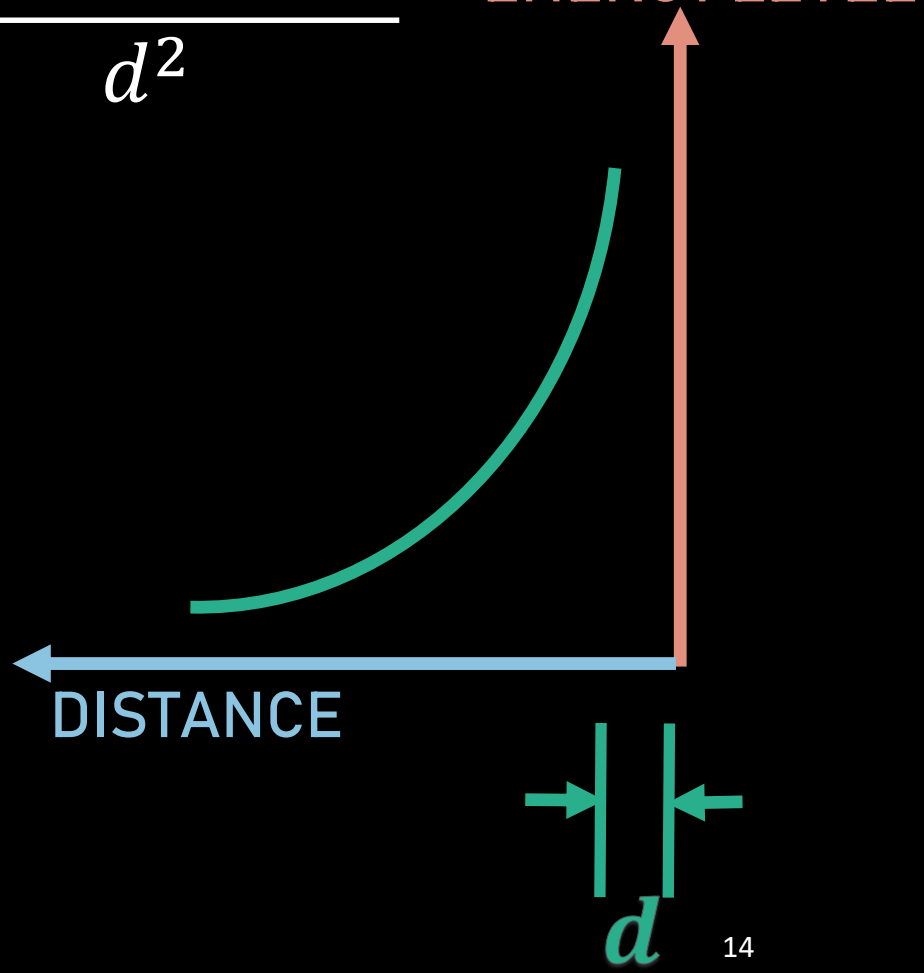

$$\frac{\cos(\theta)\cos(\phi)}{d^2}$$



# Cause of weak singularities

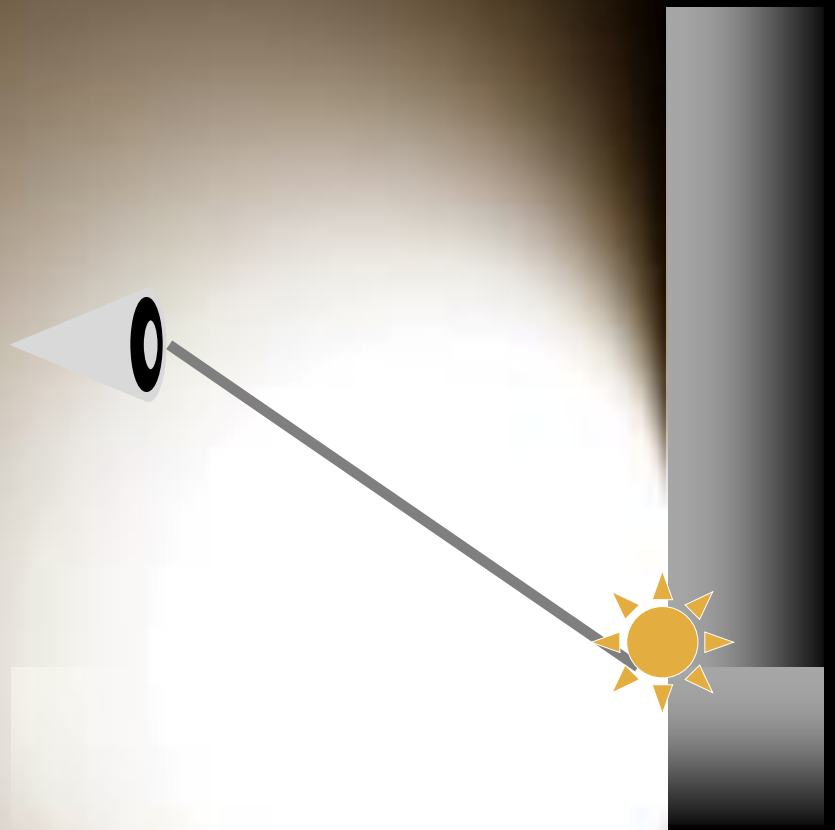


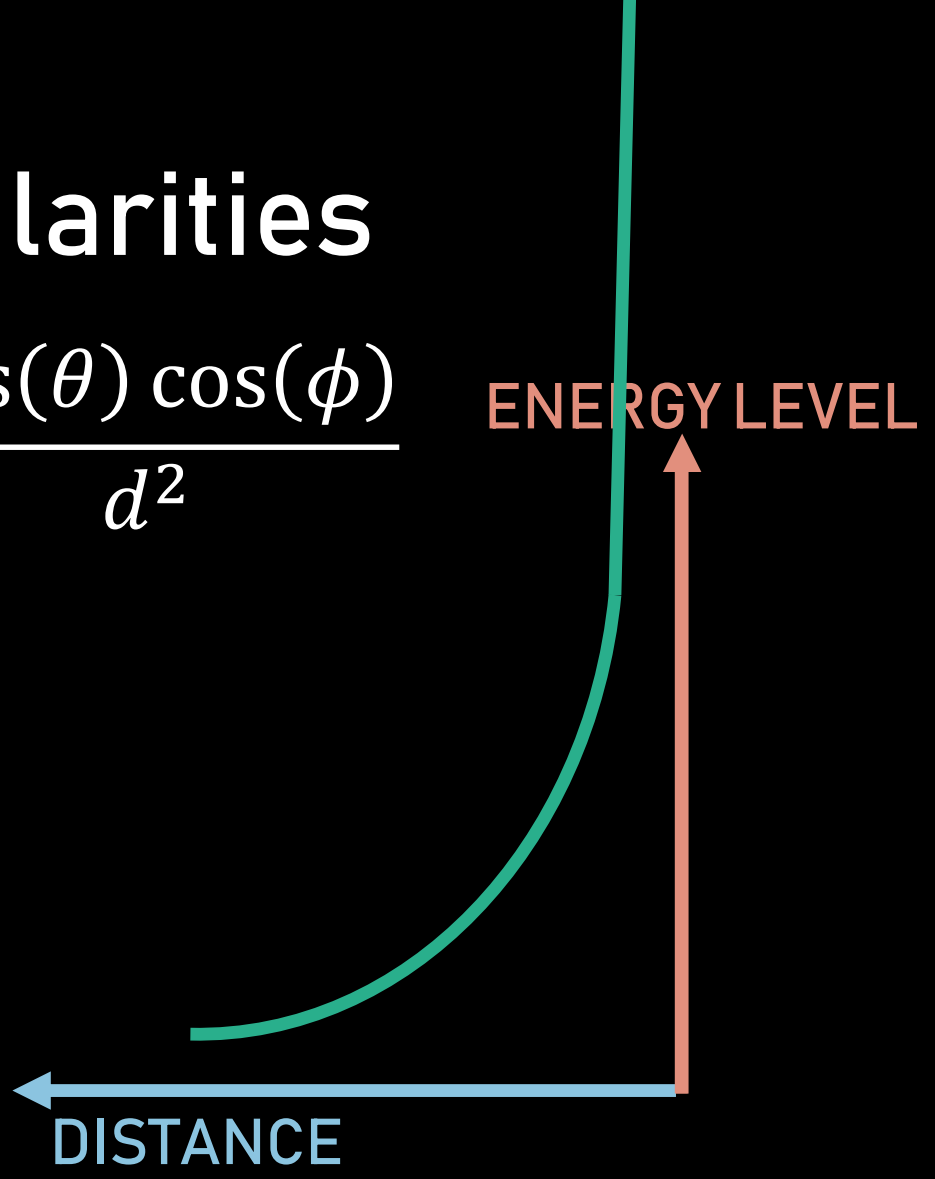

$$\frac{\cos(\theta)\cos(\phi)}{d^2}$$



# Cause of weak singularities

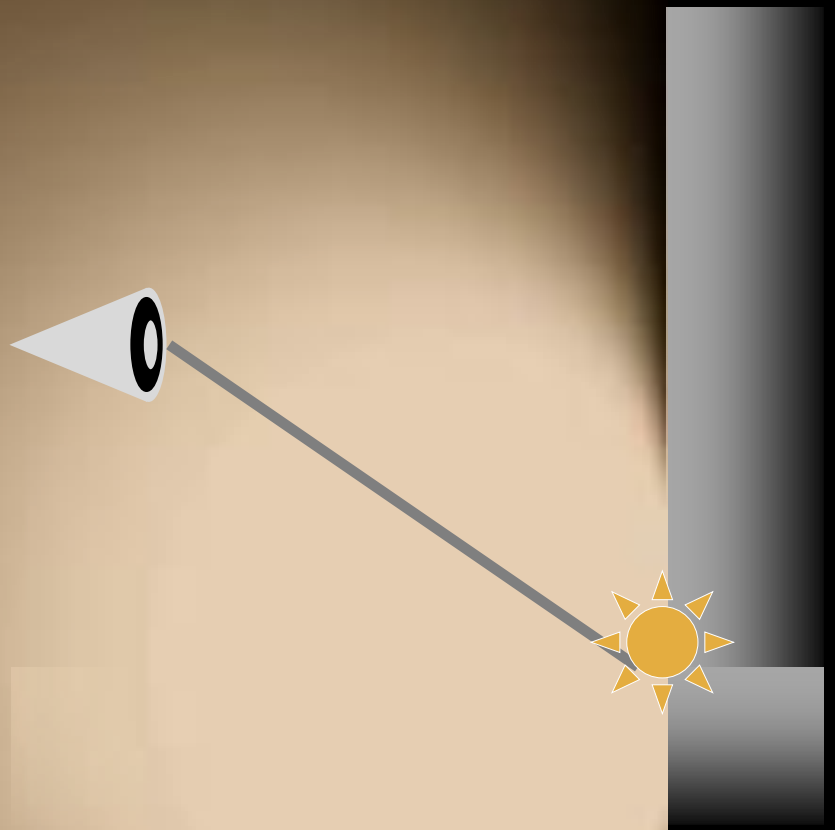
$$\frac{\cos(\theta)\cos(\phi)}{d^2}$$

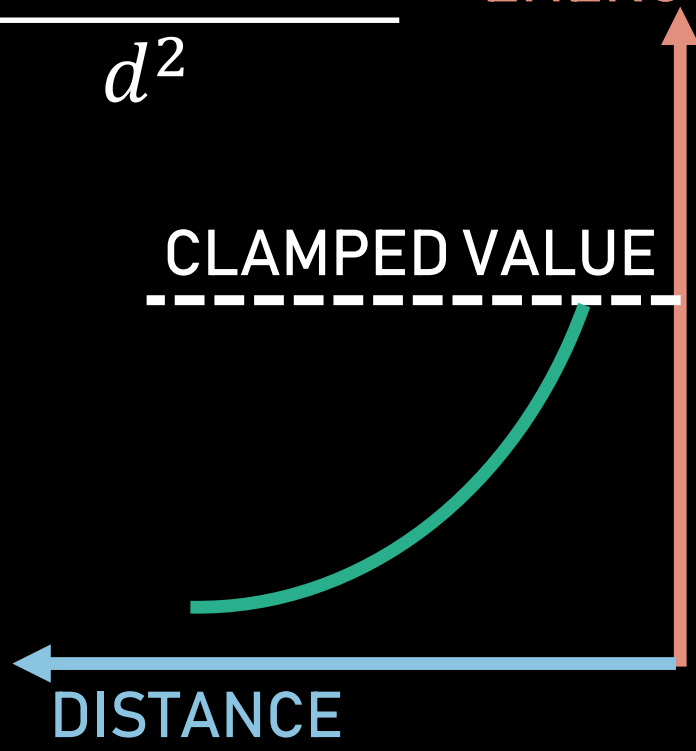




# Cause of weak singularities

$$\frac{\cos(\theta)\cos(\phi)}{d^2}$$



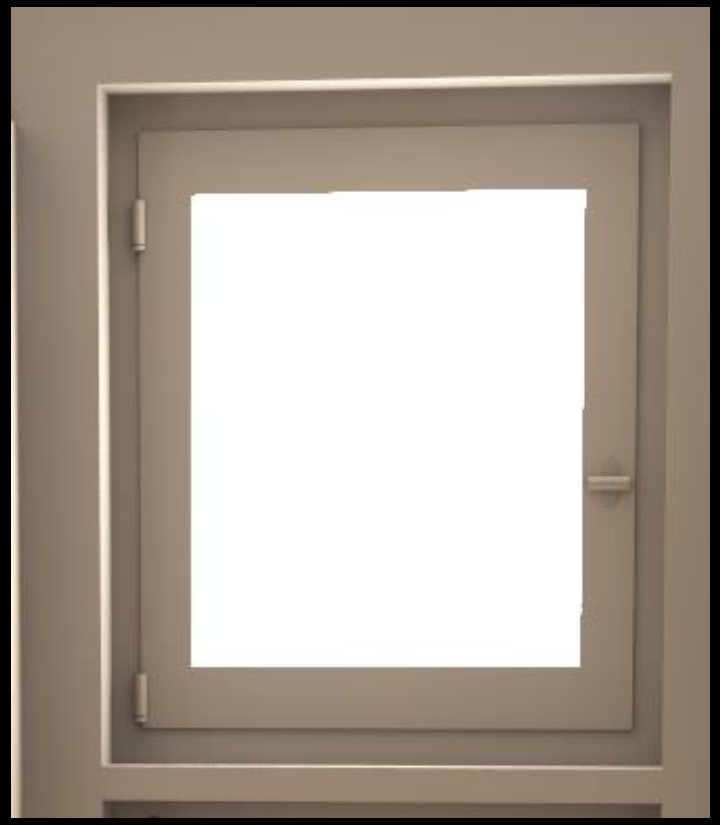


# Instant Radiosity with "clamped" VPLs

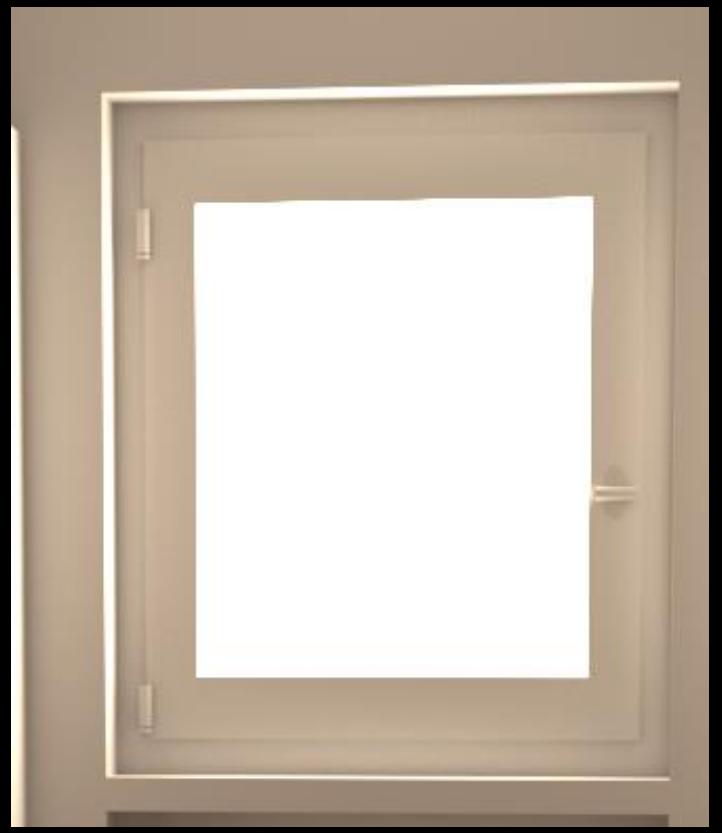
CLAMPED RESULT
(500 light subpaths)

REFERENCE

# Instant Radiosity with "clamped" VPLs

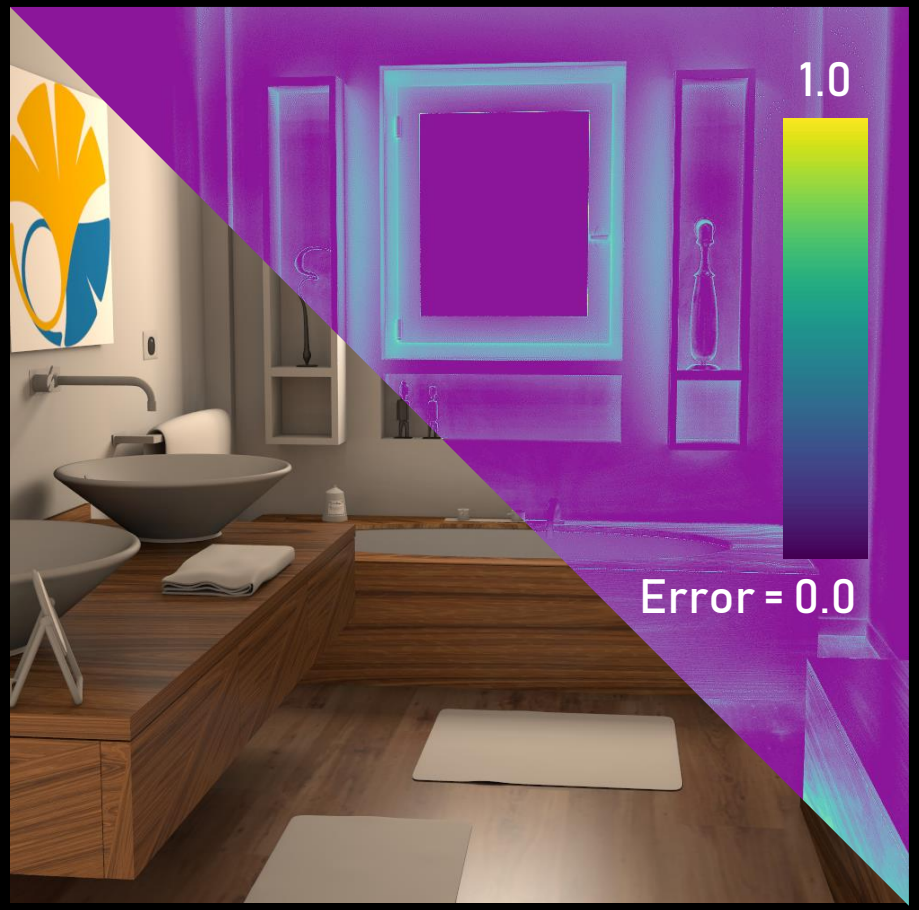


CLAMPED RESULT
(500 light subpaths)



REFERENCE

# Instant Radiosity with "clamped" VPLs

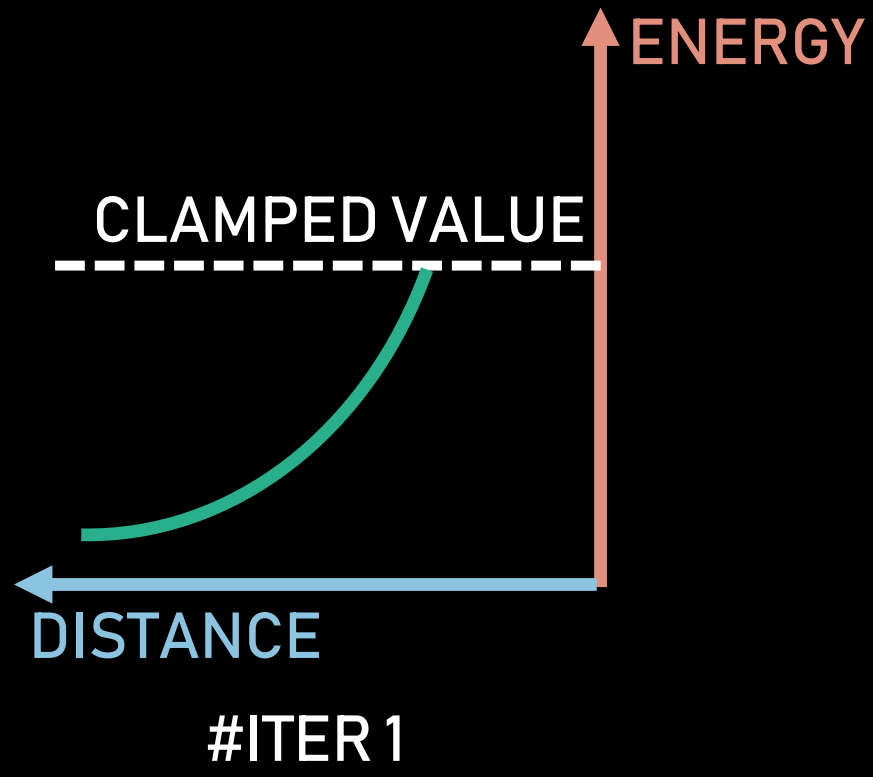



CLAMPED RESULT
(500 light subpaths)

REFERENCE

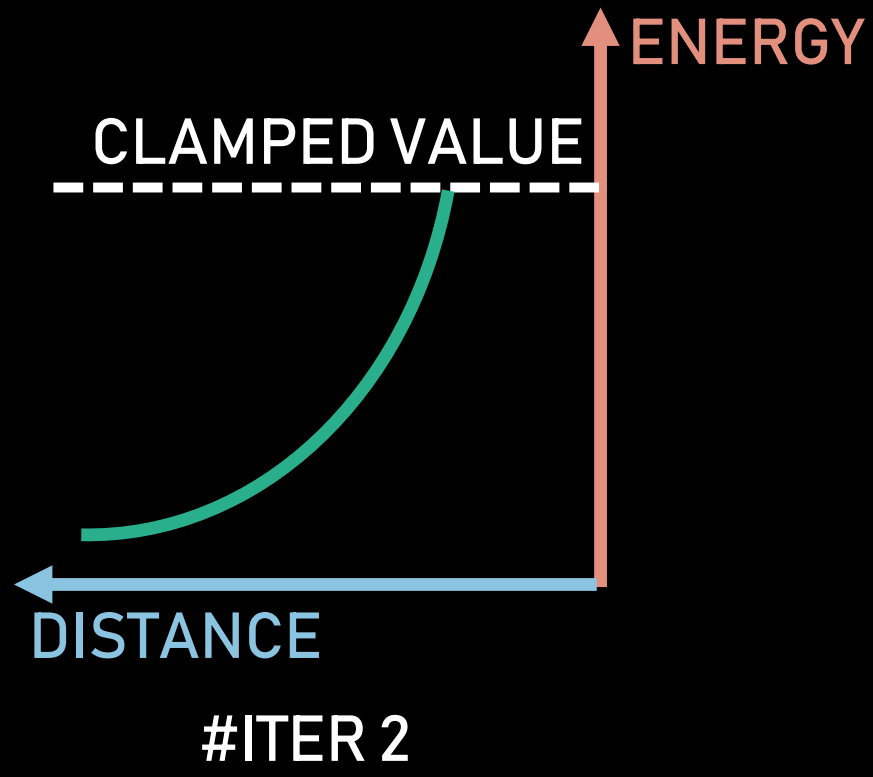
# Related work

## Progressive Lightcuts (Davidovič et al. 2012)



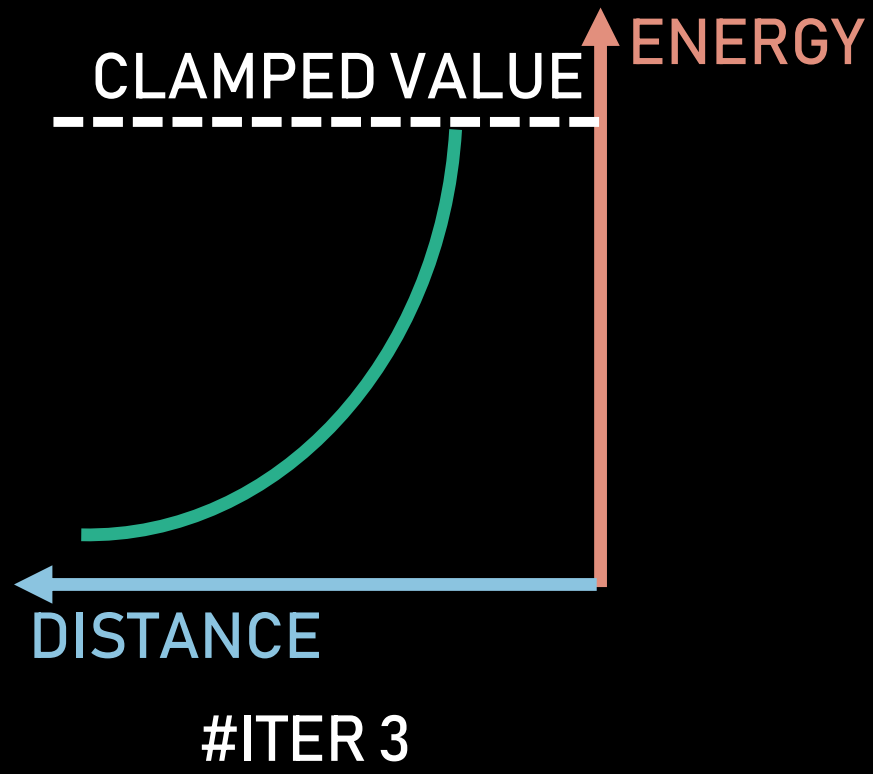
# Related work

## Progressive Lightcuts (Davidovič et al. 2012)



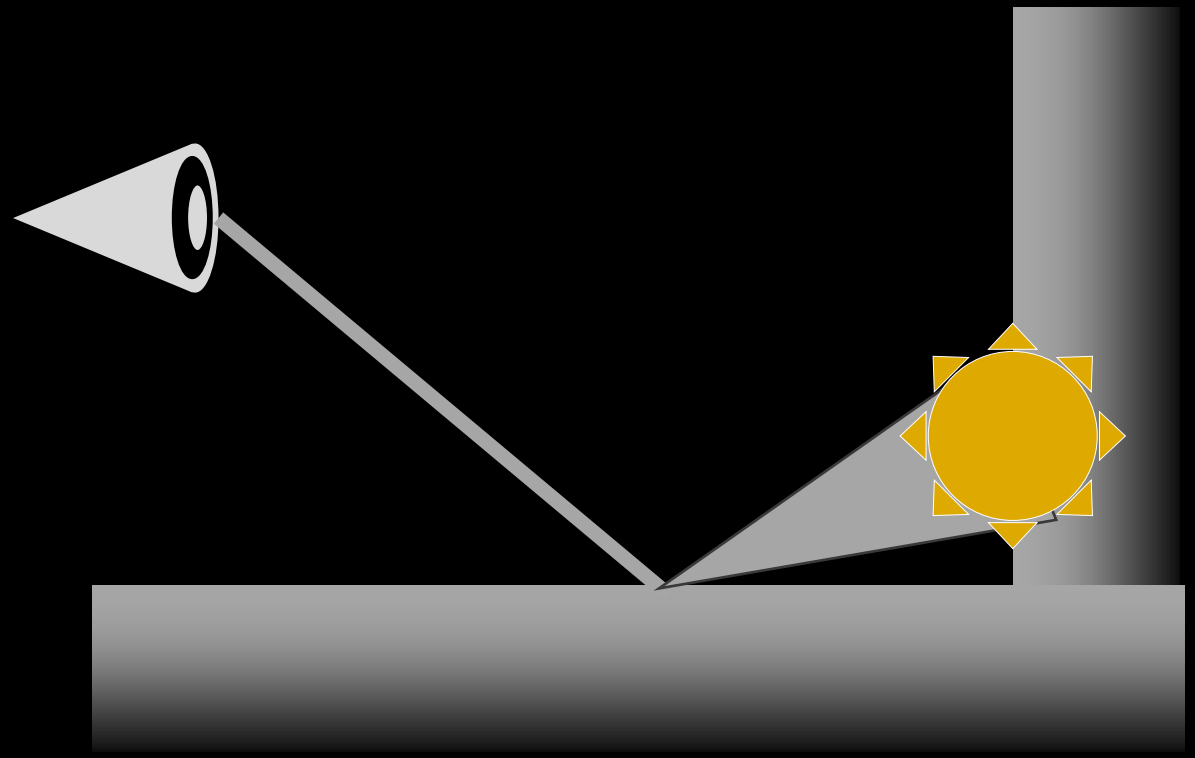
# Related work

## Progressive Lightcuts (Davidovič et al. 2012)



# Related work

## Virtual Spherical Lights (Hašan et al. 2009)



# Related work

## Illumination in the Presence of Weak Singularities (Kollig and Keller 2004)

# Related work

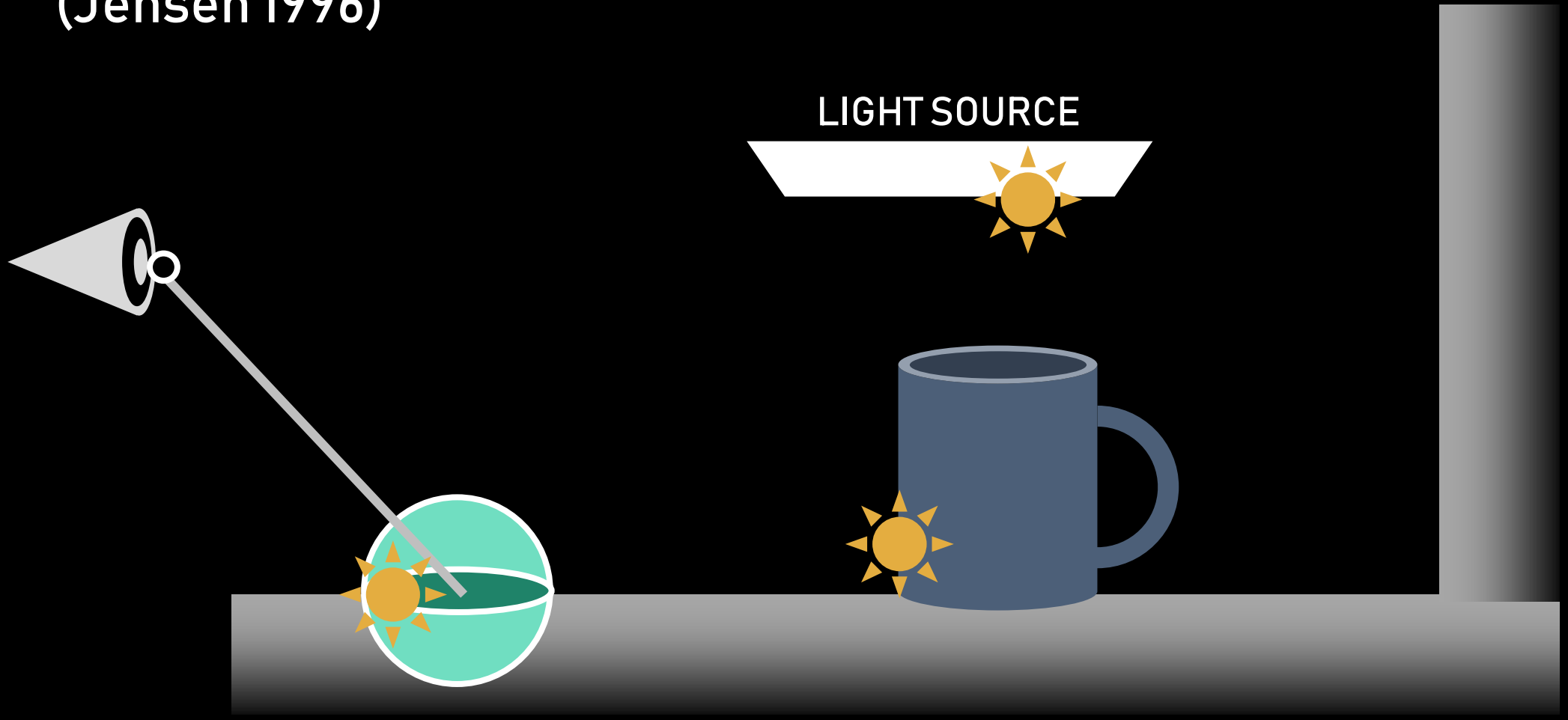
## Screen-Space Bias Compensation (SSBC), (Novák et al. 2011)

# Ours

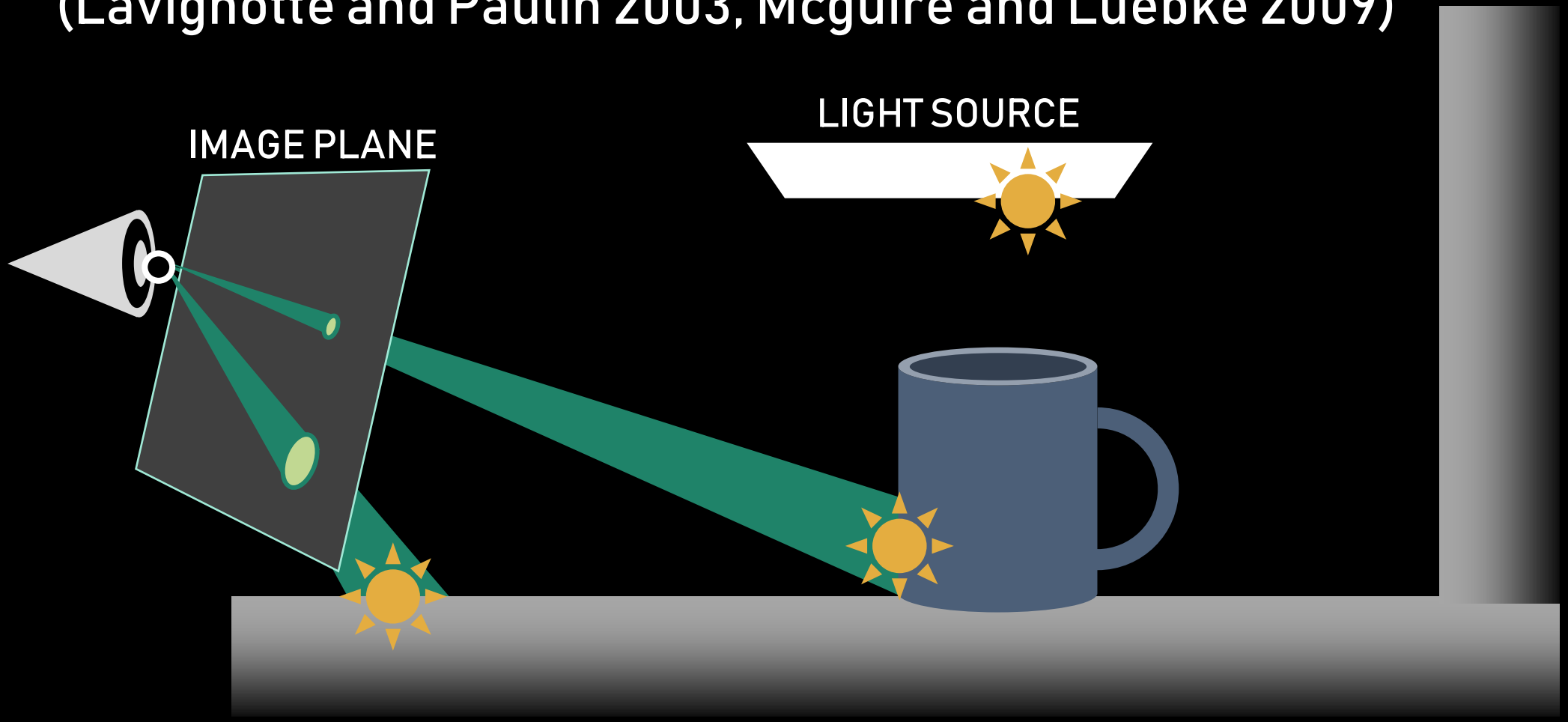
Based on these following observations:

- Light vertices can be used as VPLs or photons
- Photon density estimation is singularities free

# Global illumination using photon maps
(Jensen 1996)



# Image Space Photon Splatting
(Lavignotte and Paulin 2003, Mcguire and Luebke 2009)



# Ours

Based on these following observations:

- Light vertices can be used as VPLs or photons
- Photon Mapping is singularities free
- Instant Radiosity is efficient
- Photon Splatting is efficient

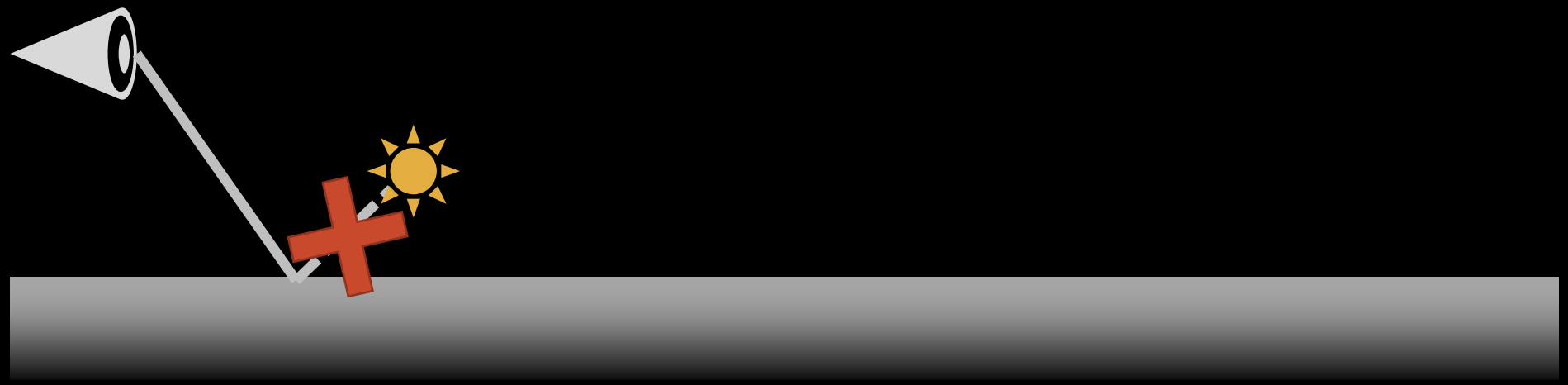
# Ours

Based on these following observations:

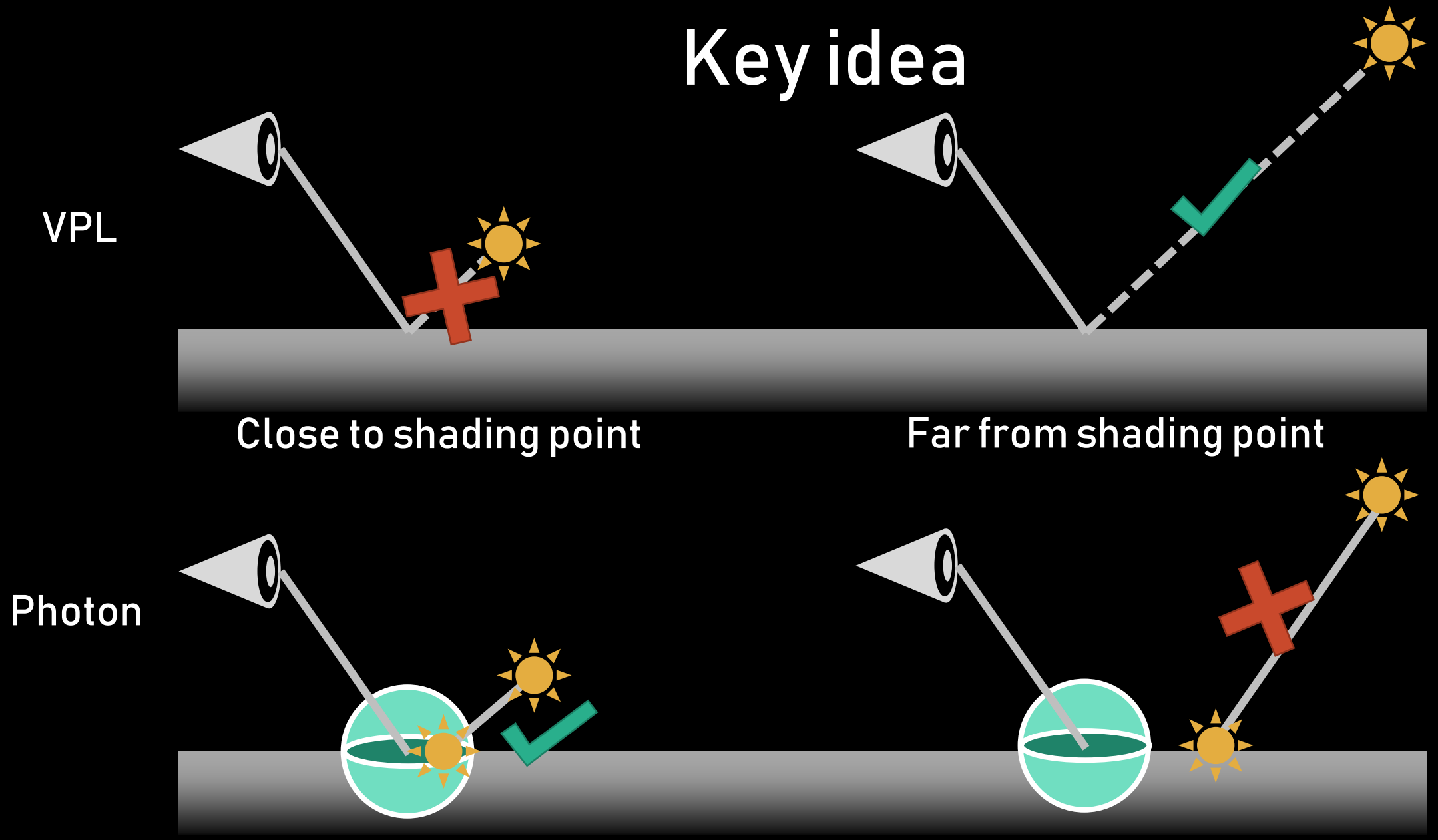
- Light vertices can be used as VPLs or photons
- Photon Mapping is singularities free
- Instant Radiosity is efficient
- Photon Splatting is efficient

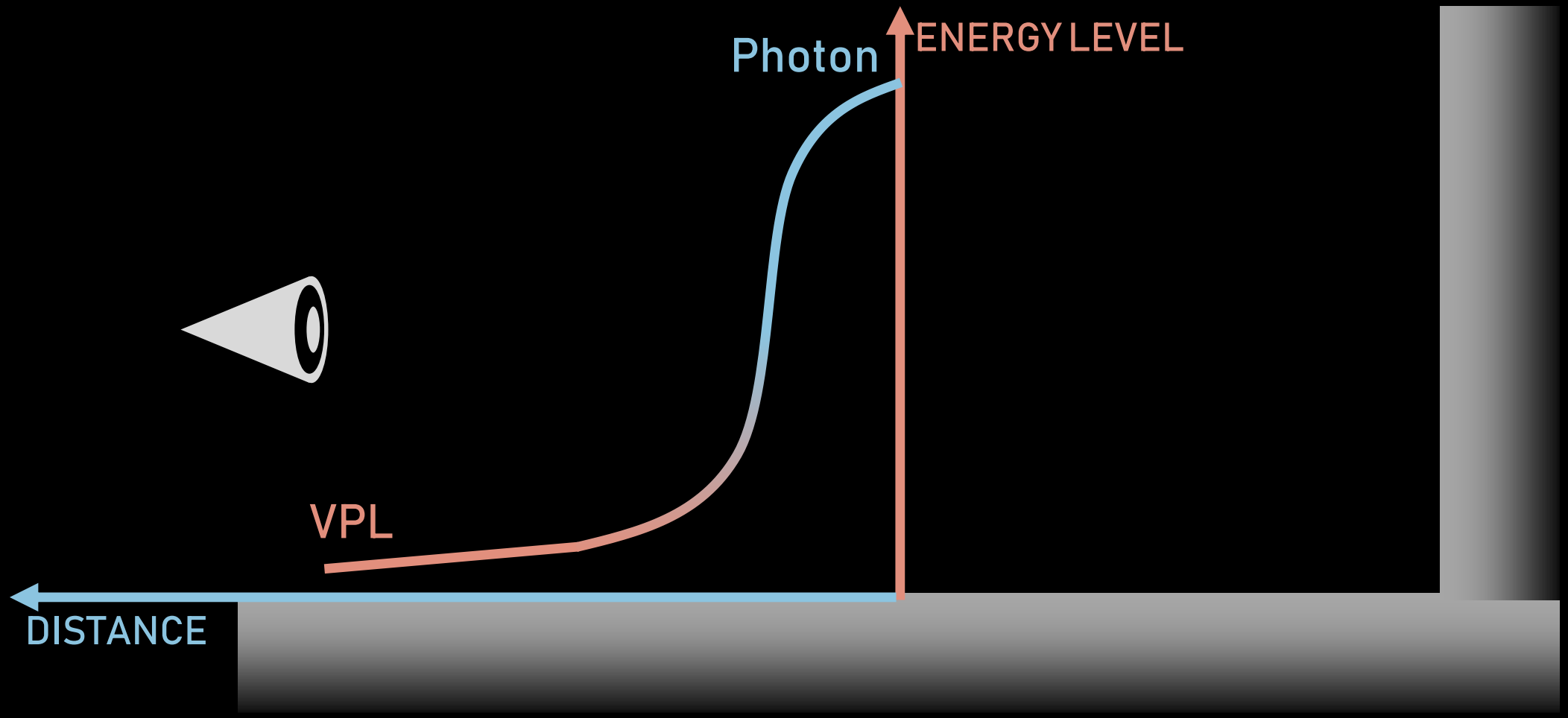
Key idea : switches between VPL and Photon when appropriate!

# Key idea

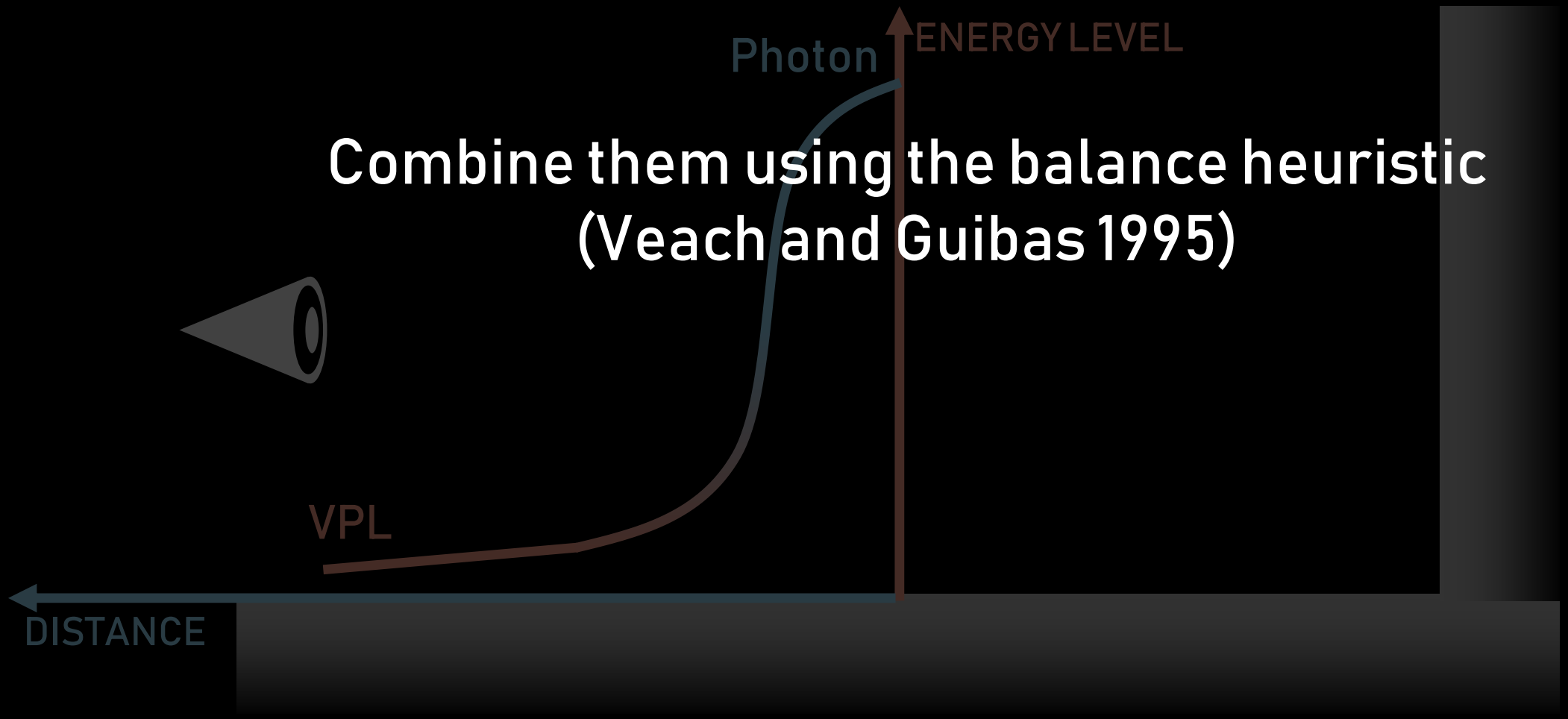



# Key idea



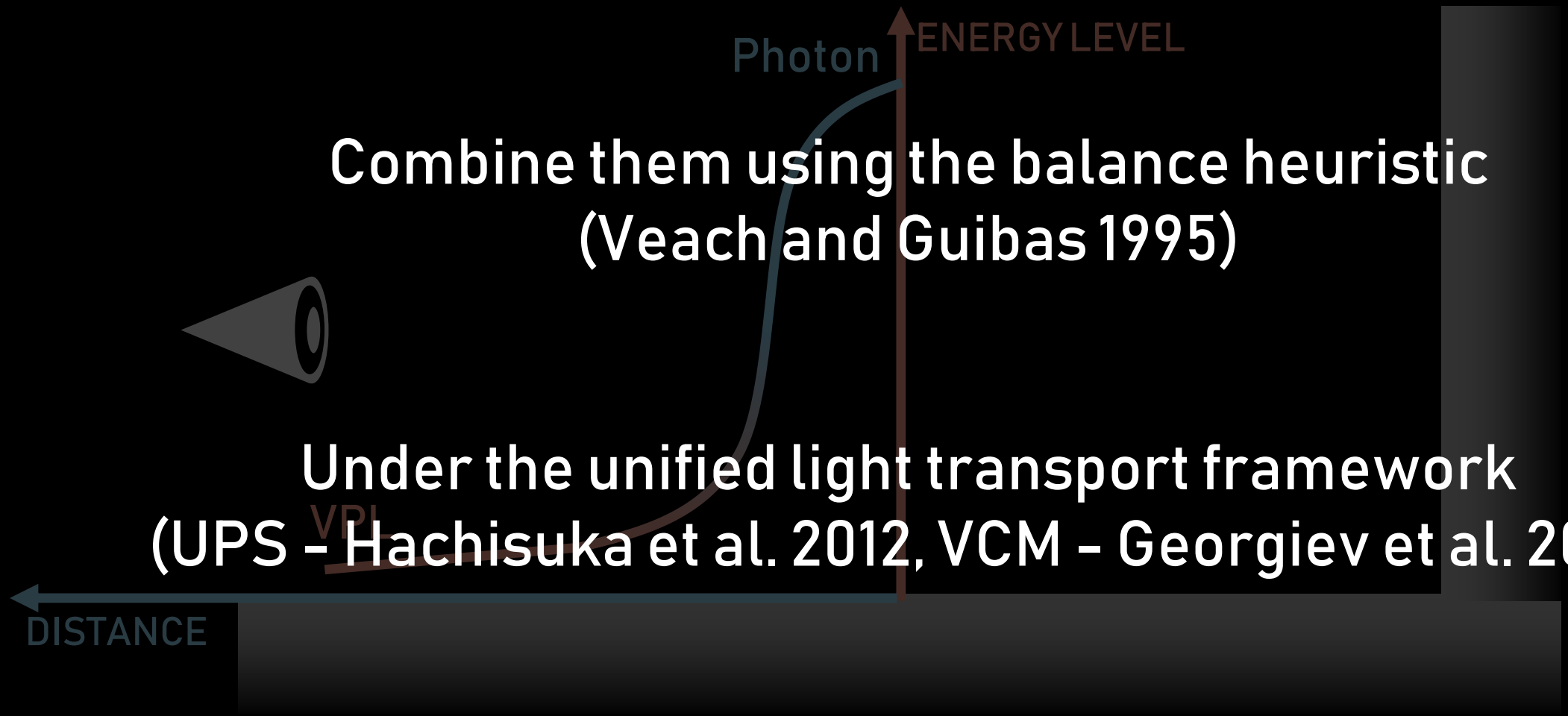

Photon
ENERGY LEVEL
VPL
DISTANCE

# Ours




Combine them using the balance heuristic
(Veach and Guibas 1995)

# Ours

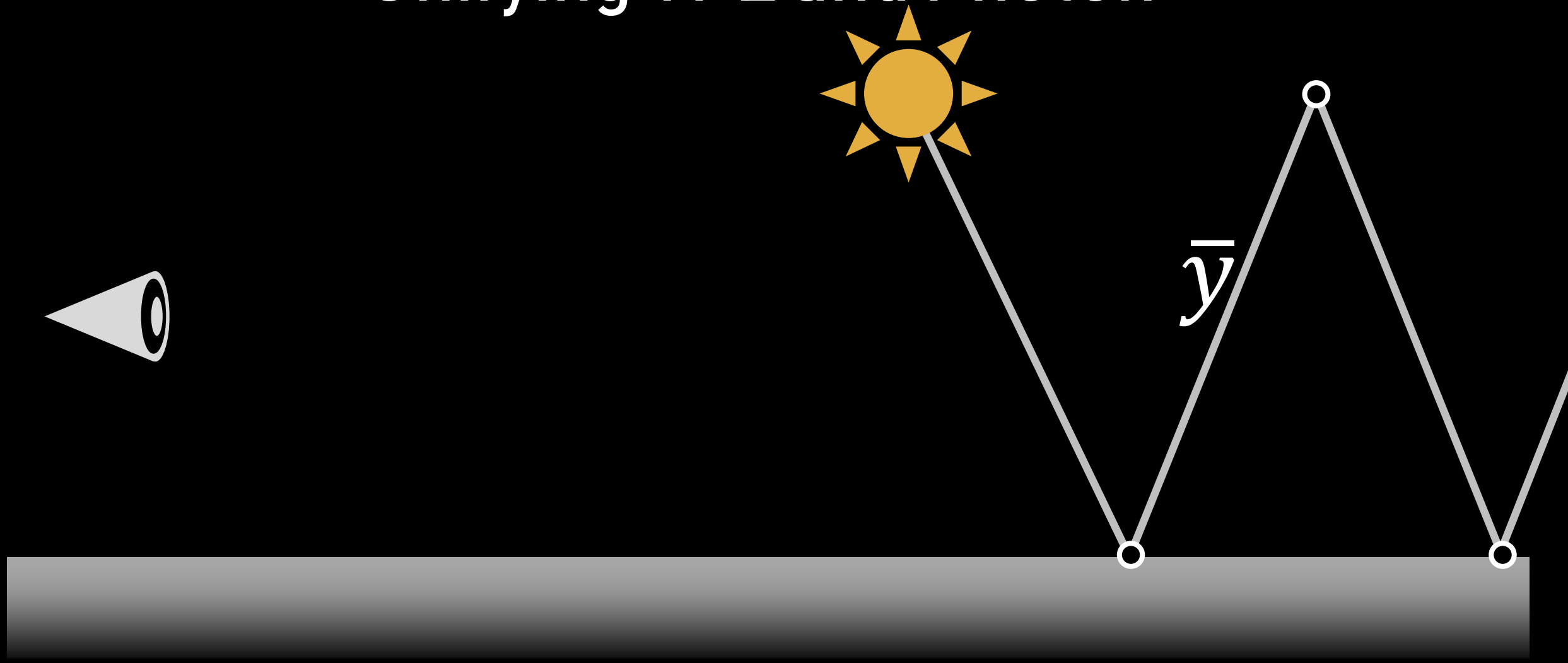



Combine them using the balance heuristic
(Veach and Guibas 1995)

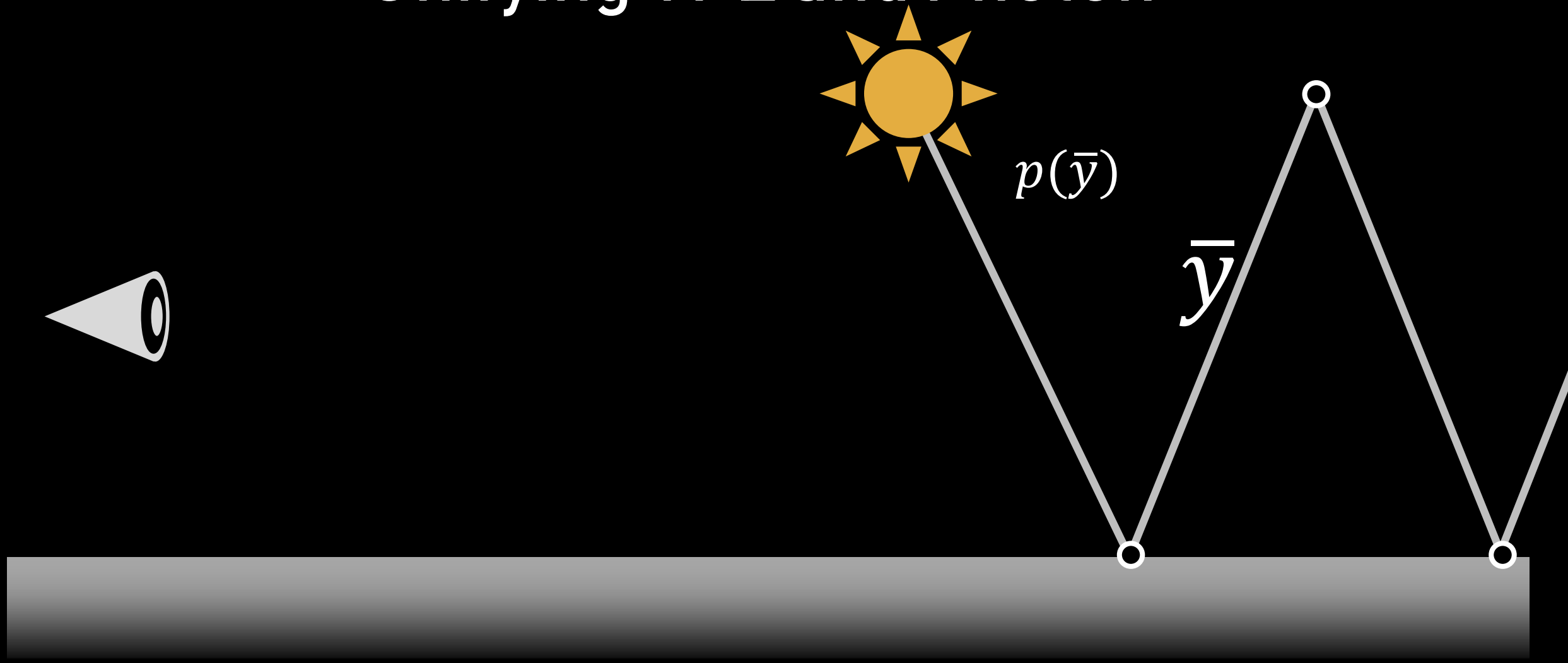
Under the unified light transport framework
(UPS – Hachisuka et al. 2012, VCM – Georgiev et al. 2012)

# Unifying VPL and Photon

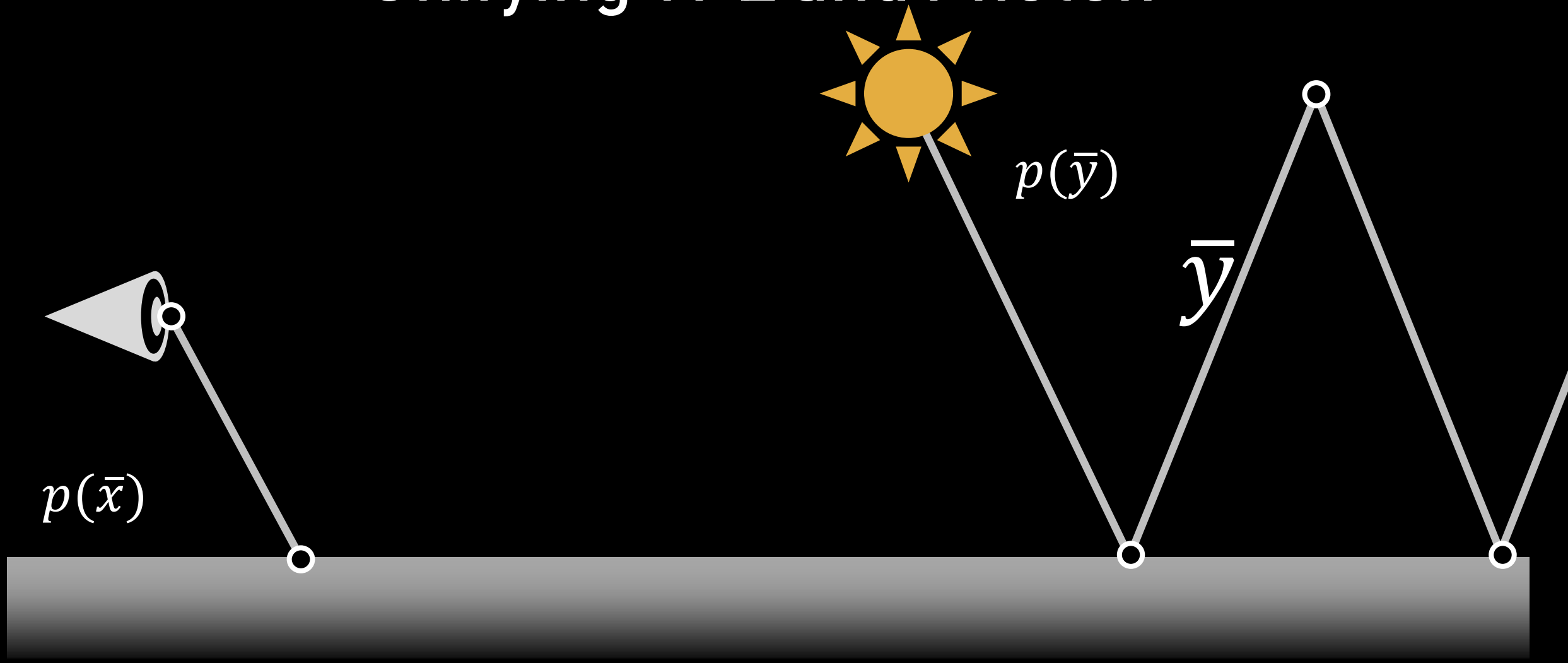
# Unifying VPL and Photon - VPL



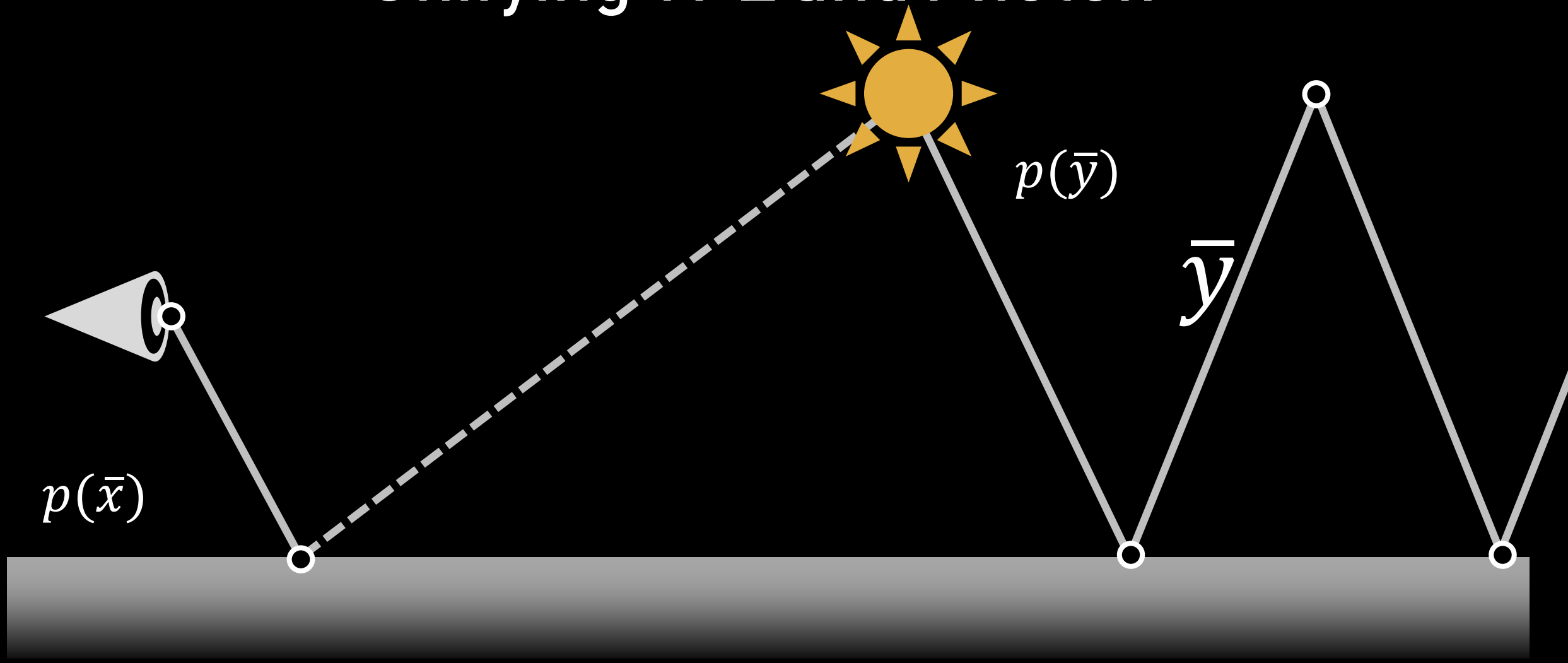
# Unifying VPL and Photon - VPL



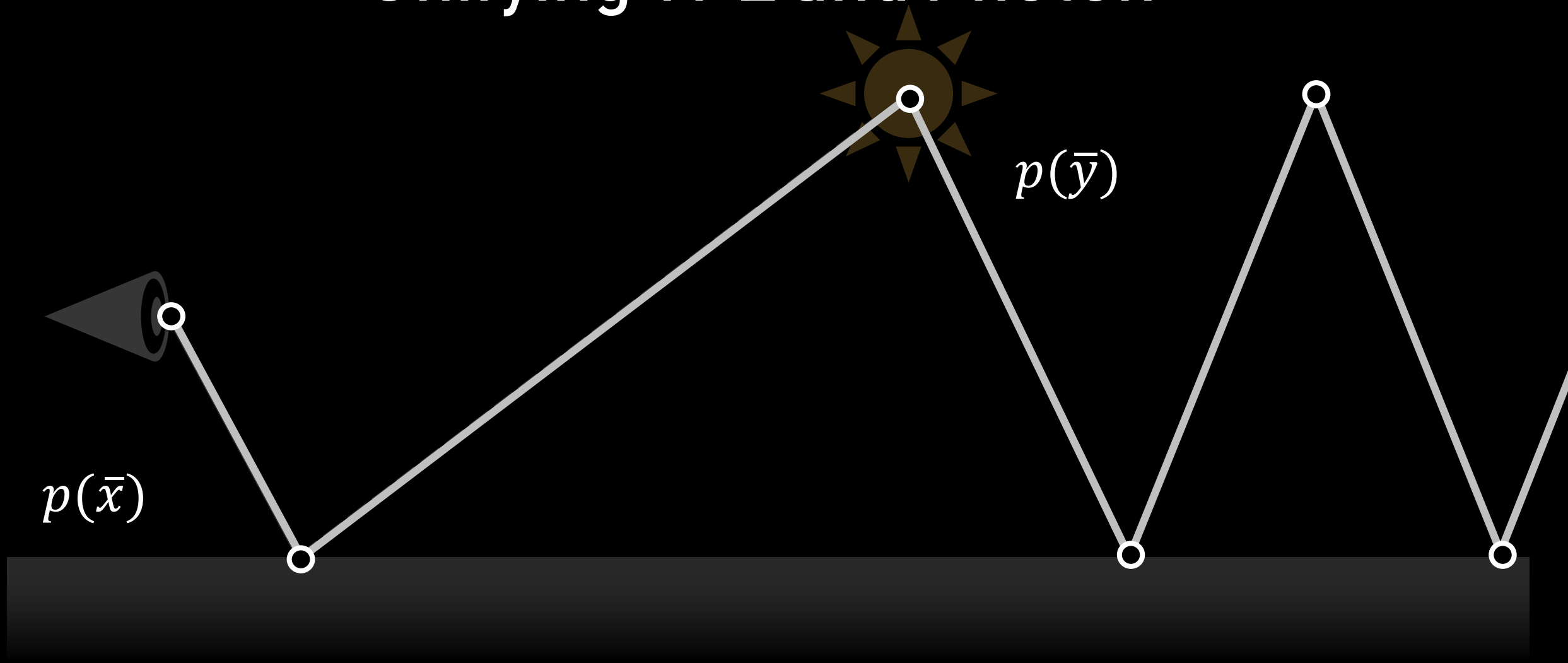
# Unifying VPL and Photon - VPL



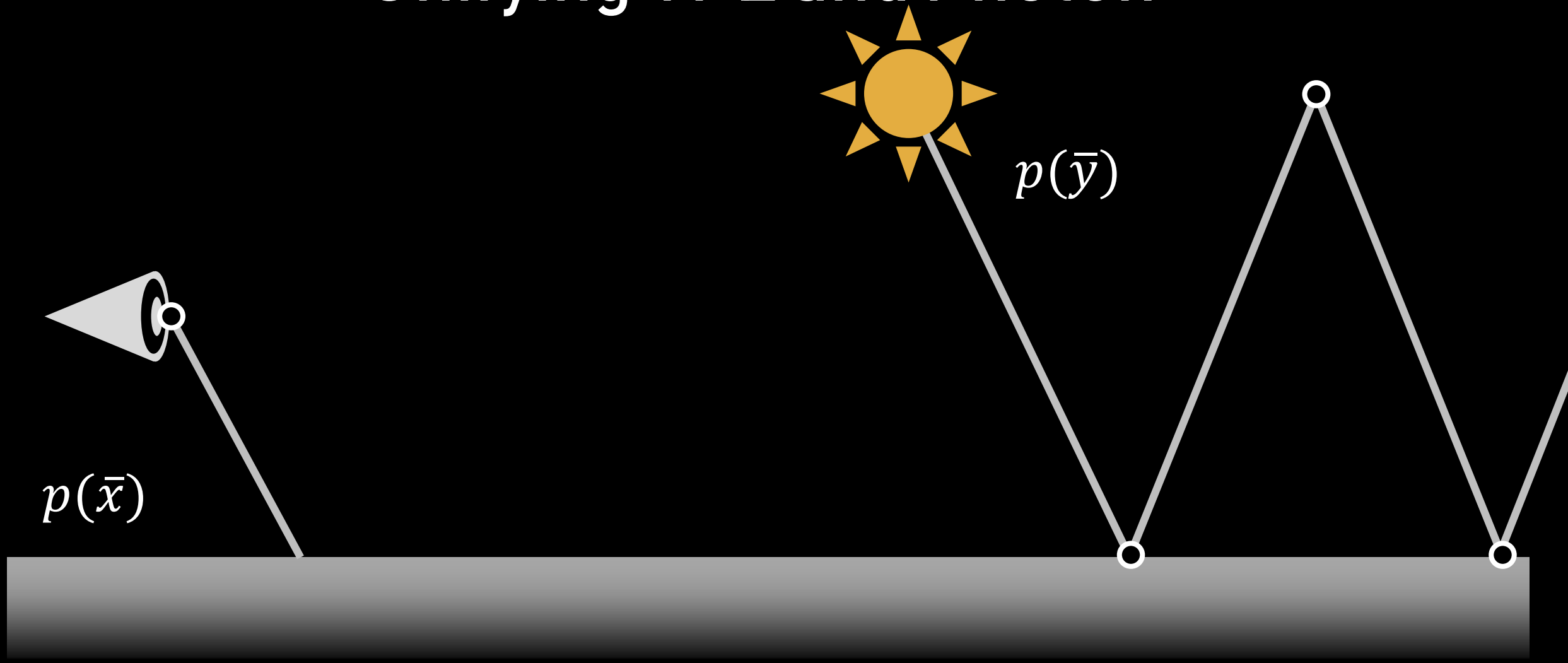
# Unifying VPL and Photon - VPL



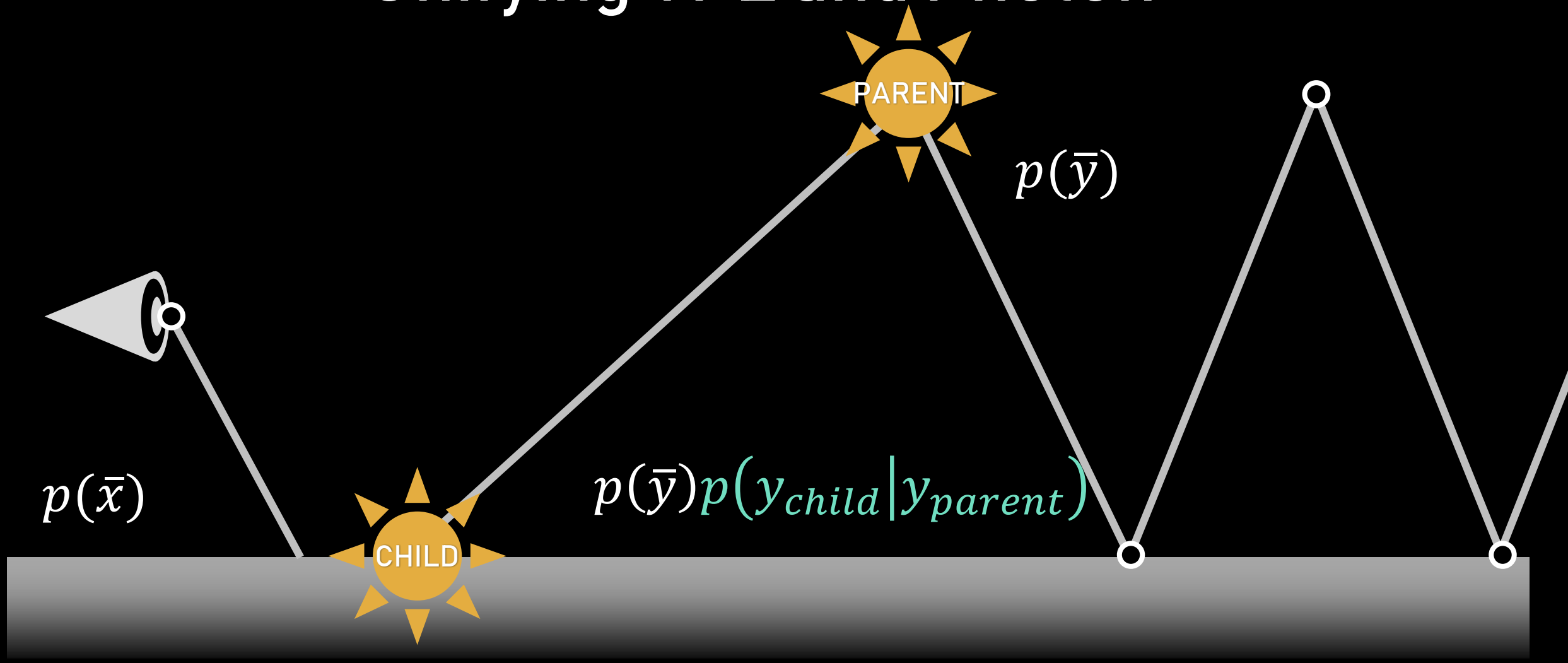
# Unifying VPL and Photon - VPL



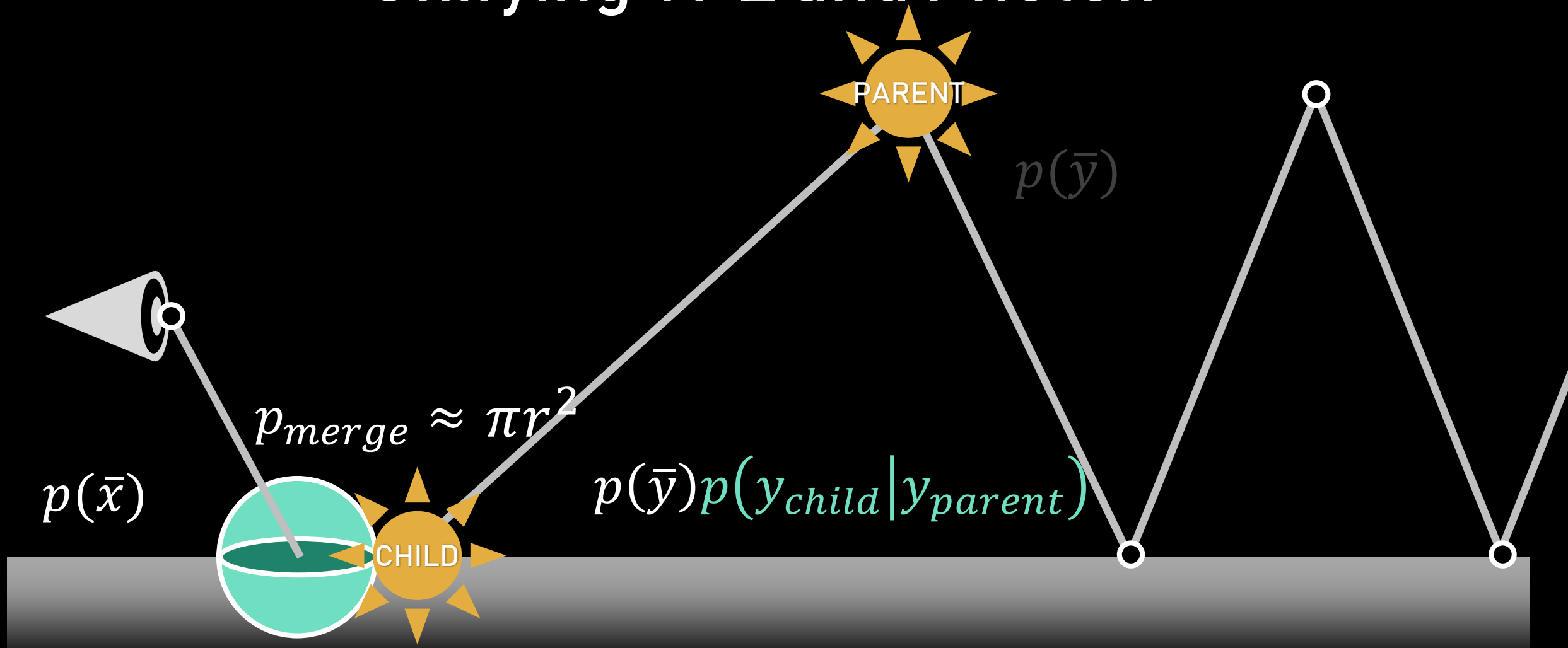
# Unifying VPL and Photon - Photon



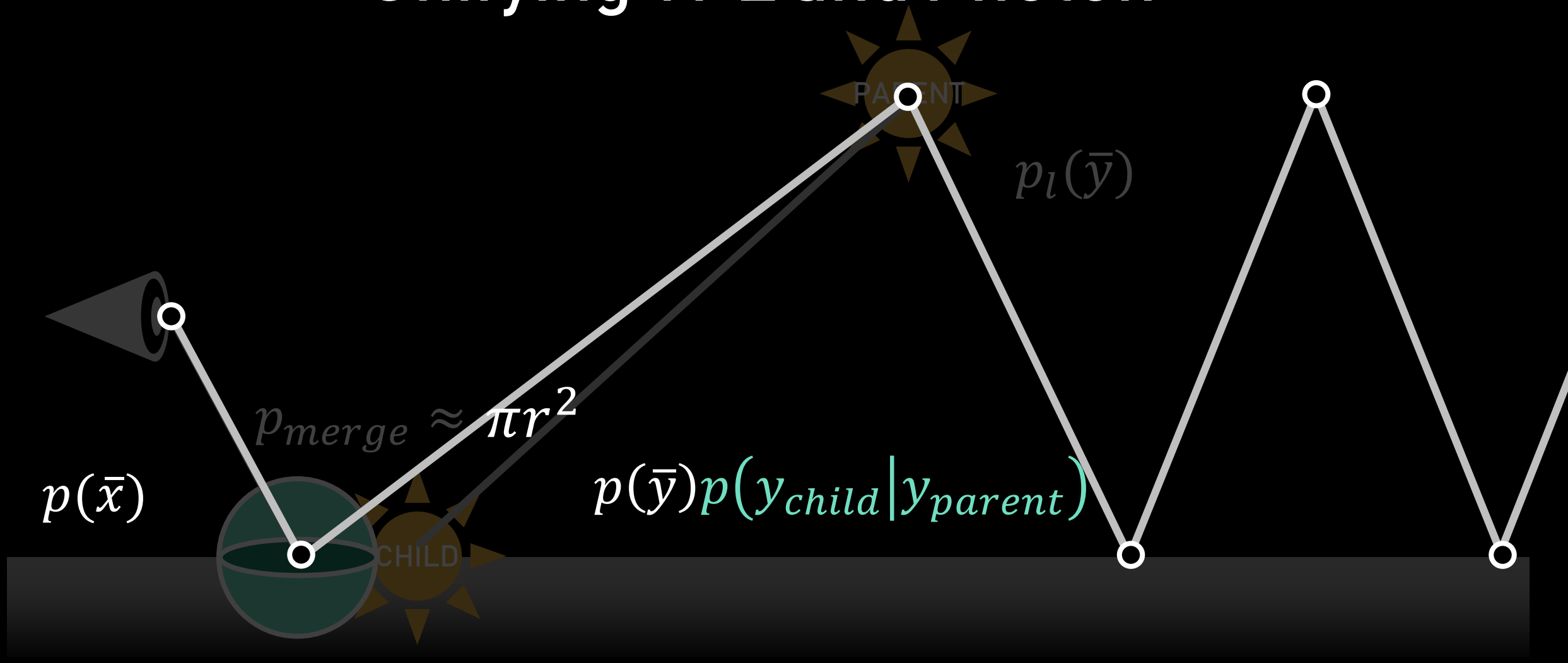
# Unifying VPL and Photon - Photon



# Unifying VPL and Photon - Photon



# Unifying VPL and Photon - Photon



# Mixture of VPLs and Photons

$$w_{vpl}(\overline{xy}) = \frac{N_{vpl}\, p_{vpl}(\overline{xy})}{N_{vpl}\, p_{vpl}(\overline{xy}) + N_{pm}\, p_{pm}(\overline{xy})}$$

# Mixture of VPLs and Photons

$$w_{vpl}(\overline{xy}) = \frac{N_{vpl}\, p_{vpl}(\overline{xy})}{N_{vpl}\, p_{vpl}(\overline{xy}) + N_{pm}\, p_{pm}(\overline{xy})}$$

$$= \frac{N_{vpl}}{N_{vpl} + N_{pm}\pi r^2 p\left(y_{child} \middle| y_{parent}\right)}$$

# Mixture of VPLs and Photons

$$w_{vpl}(\overline{xy}) = \frac{N_{vpl}\, p_{vpl}(\overline{xy})}{N_{vpl}\, p_{vpl}(\overline{xy}) + N_{pm}\, p_{pm}(\overline{xy})}$$

$$= \frac{N_{vpl}}{N_{vpl} + N_{pm}\pi r^2 p\left(y_{child} \middle| y_{parent}\right)}$$

Geometry term $\frac{\cos(\theta)\cos(\phi)}{d^2}$

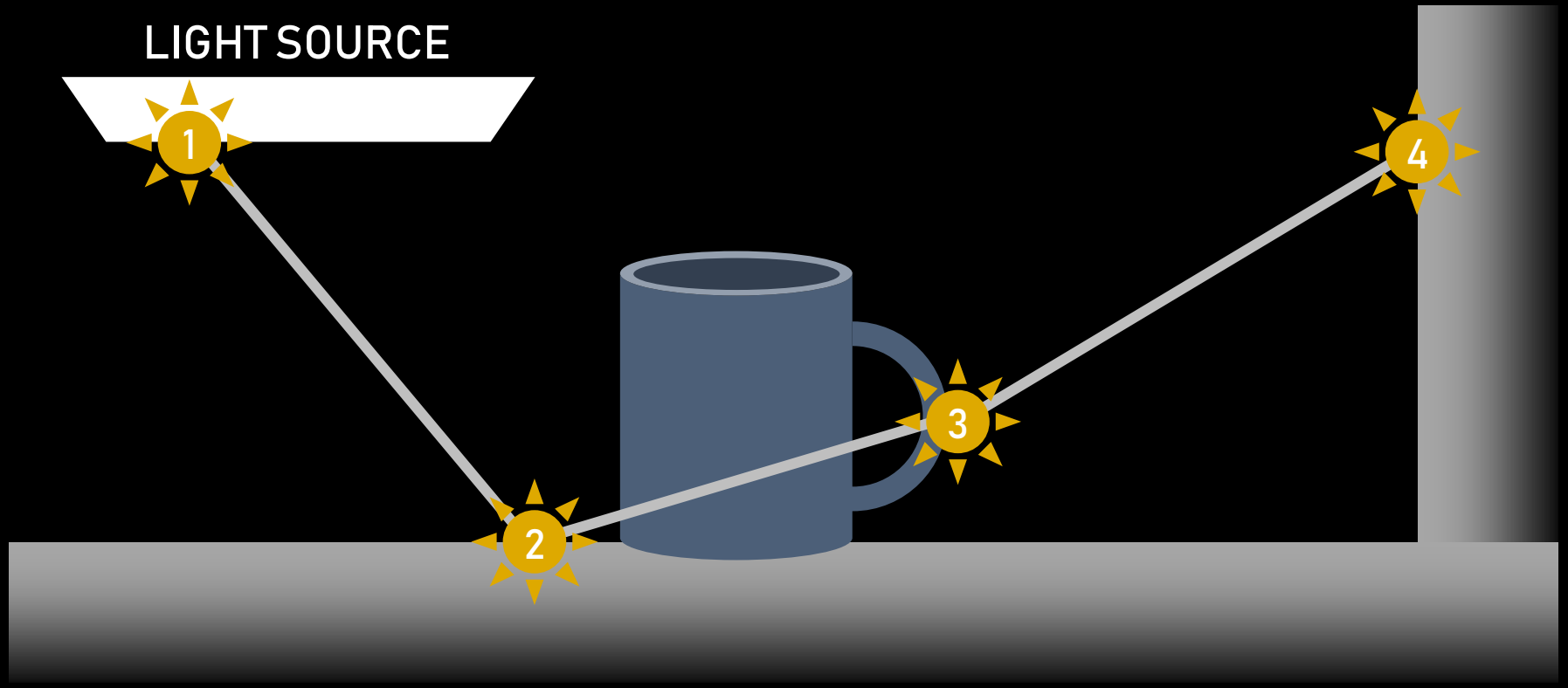
# Progressive

$$w_{vpl}(\overline{xy}) = \frac{N_{vpl}\, p_{vpl}(\overline{xy})}{N_{vpl}\, p_{vpl}(\overline{xy}) + N_{pm}\, p_{pm}(\overline{xy})}$$

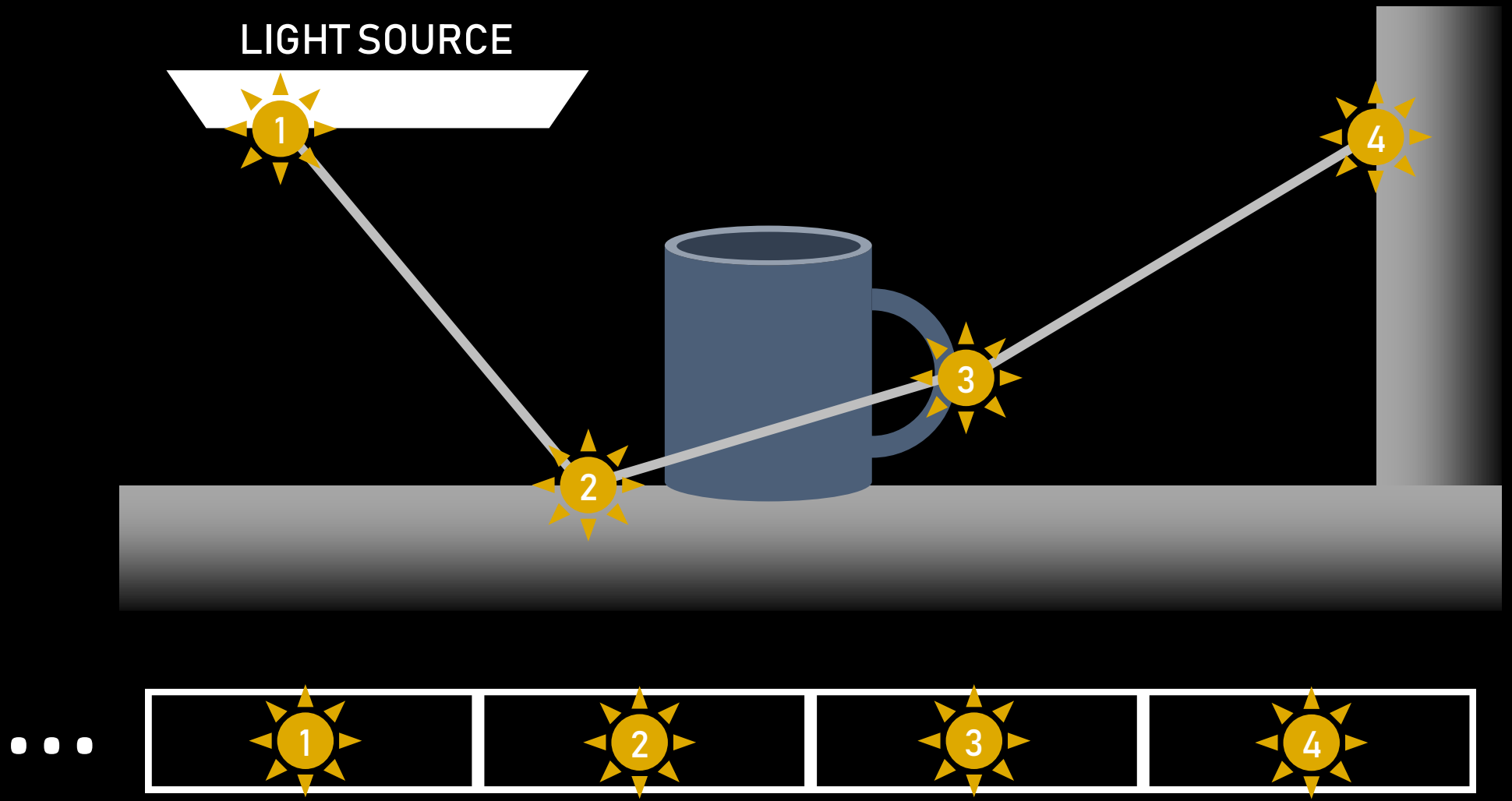
$$= \frac{N_{vpl}}{N_{vpl} + N_{pm}\, \pi r^2 p\left(y_{child} \middle| y_{parent}\right)}$$

(Hachisuka et al. 2008, Hachisuka et al. 2009, Knaus and Zwicker 2011)

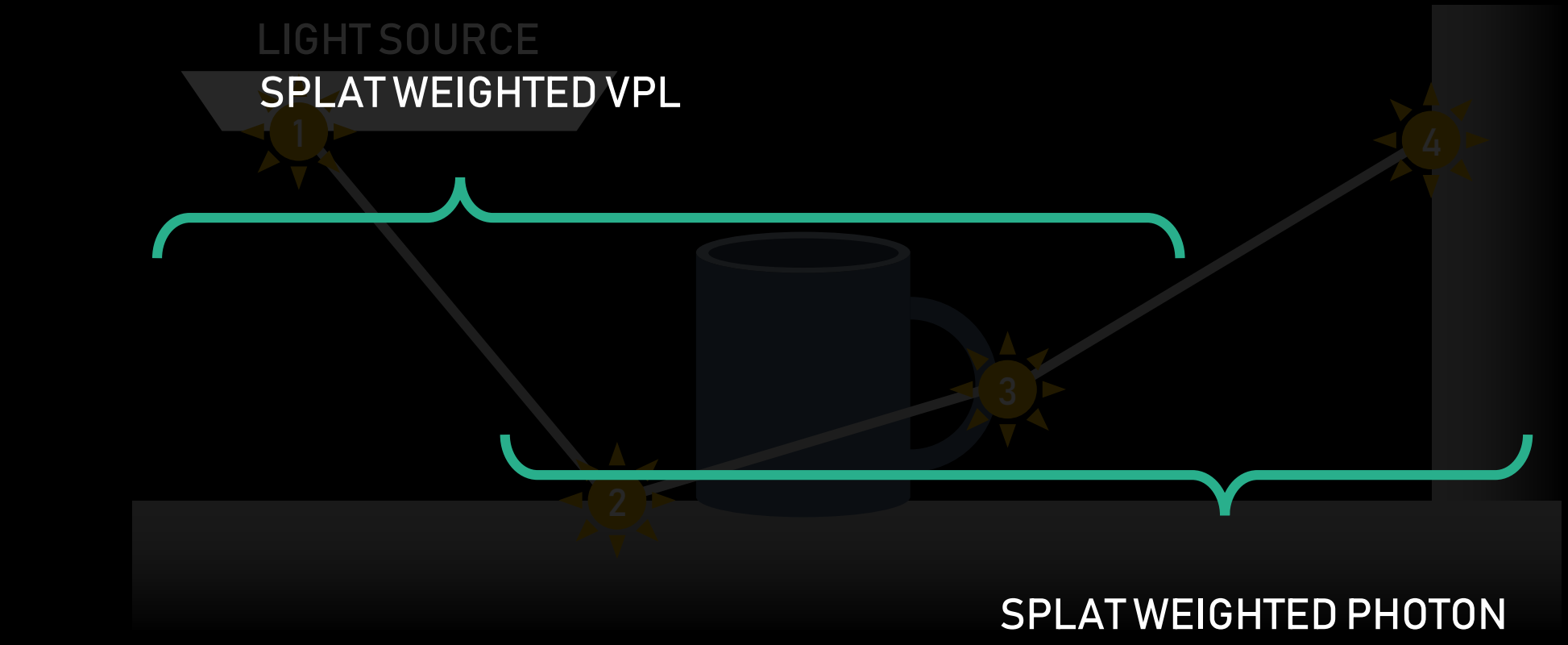
# Implementation

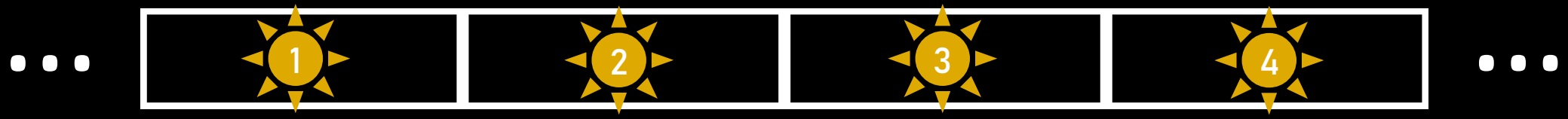


# Implementation



# Implementation

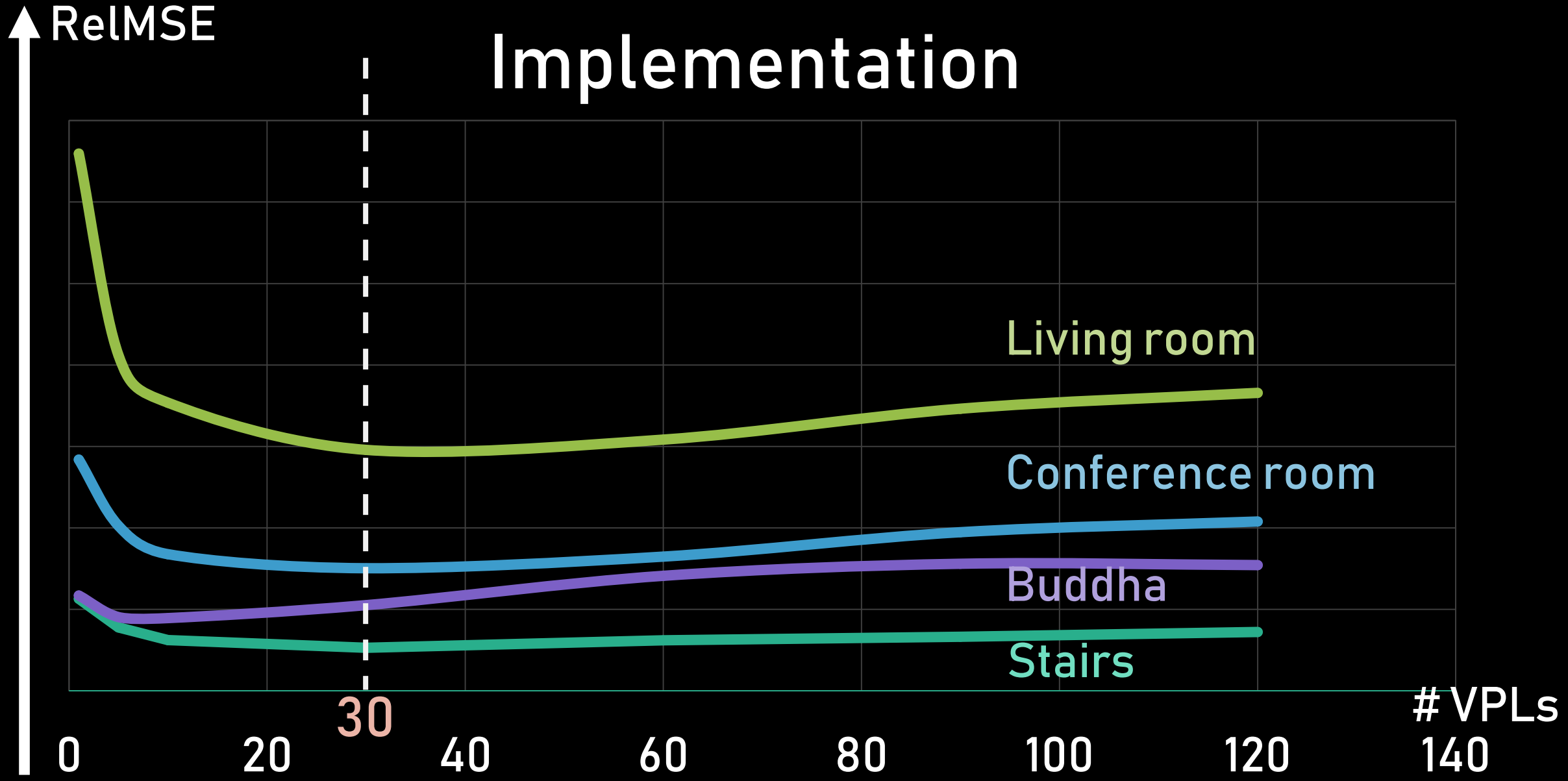


# Implementation

| | |
|---|---|
| $\frac{\text{Splat weighted VPLs}}{\text{light subpath}}$ | 2.83 ms |
| $\frac{\text{Splat weighted Photons}}{\text{light subpath}}$ | $1.71 \times 10^{-4}$ ms |

# Implementation



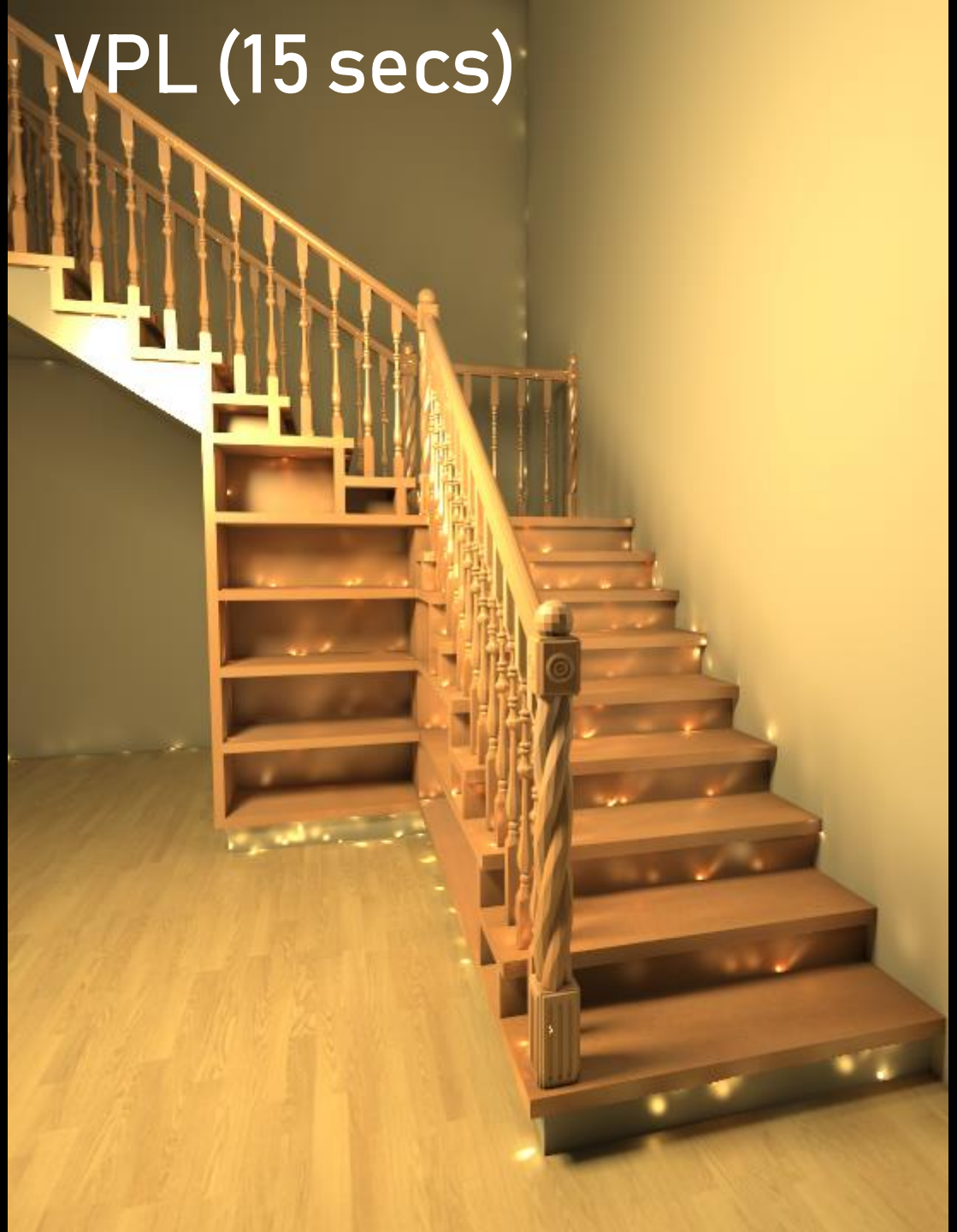
# Implementation

$$\frac{\text{Splat weighted VPLs}}{\text{light subpath}} \quad 2.83 \quad \text{ms}$$

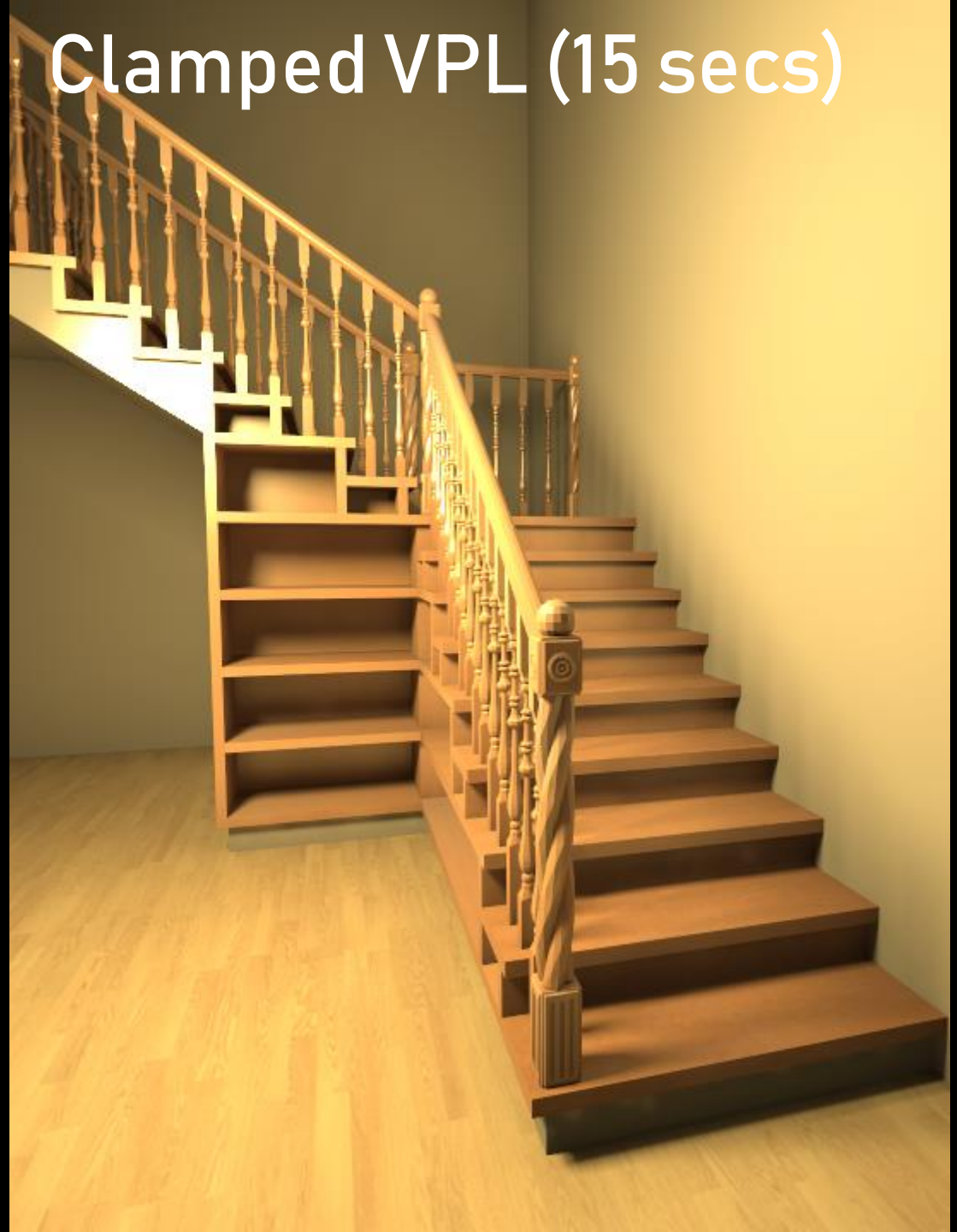
$$\frac{\text{Splat weighted Photons}}{\text{light subpath}} \quad 1.71 \times 10^{-4} \quad \text{ms}$$

$$\frac{\text{Splat } 300000 \text{ Photons : } 30 \text{ VPLs}}{1 \text{ iteration}}$$

# Result

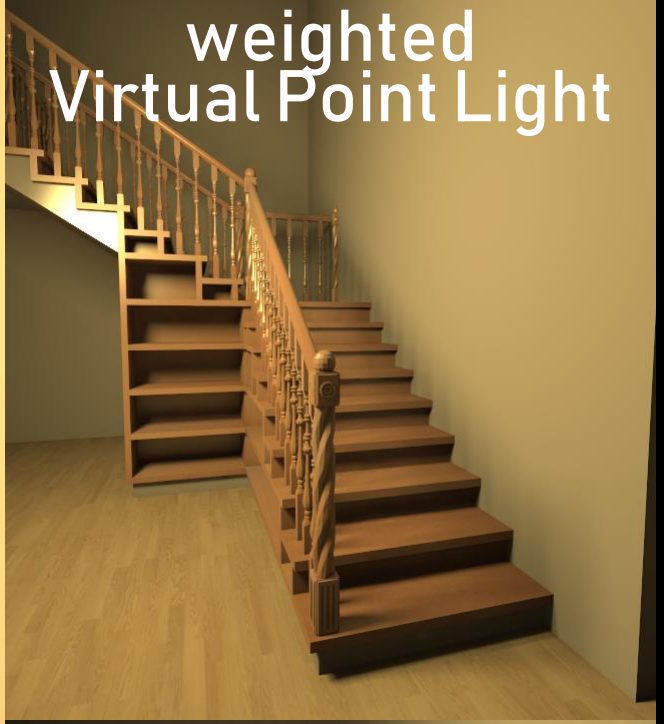

VPL (15 secs)

# Clamped VPL (15 secs)



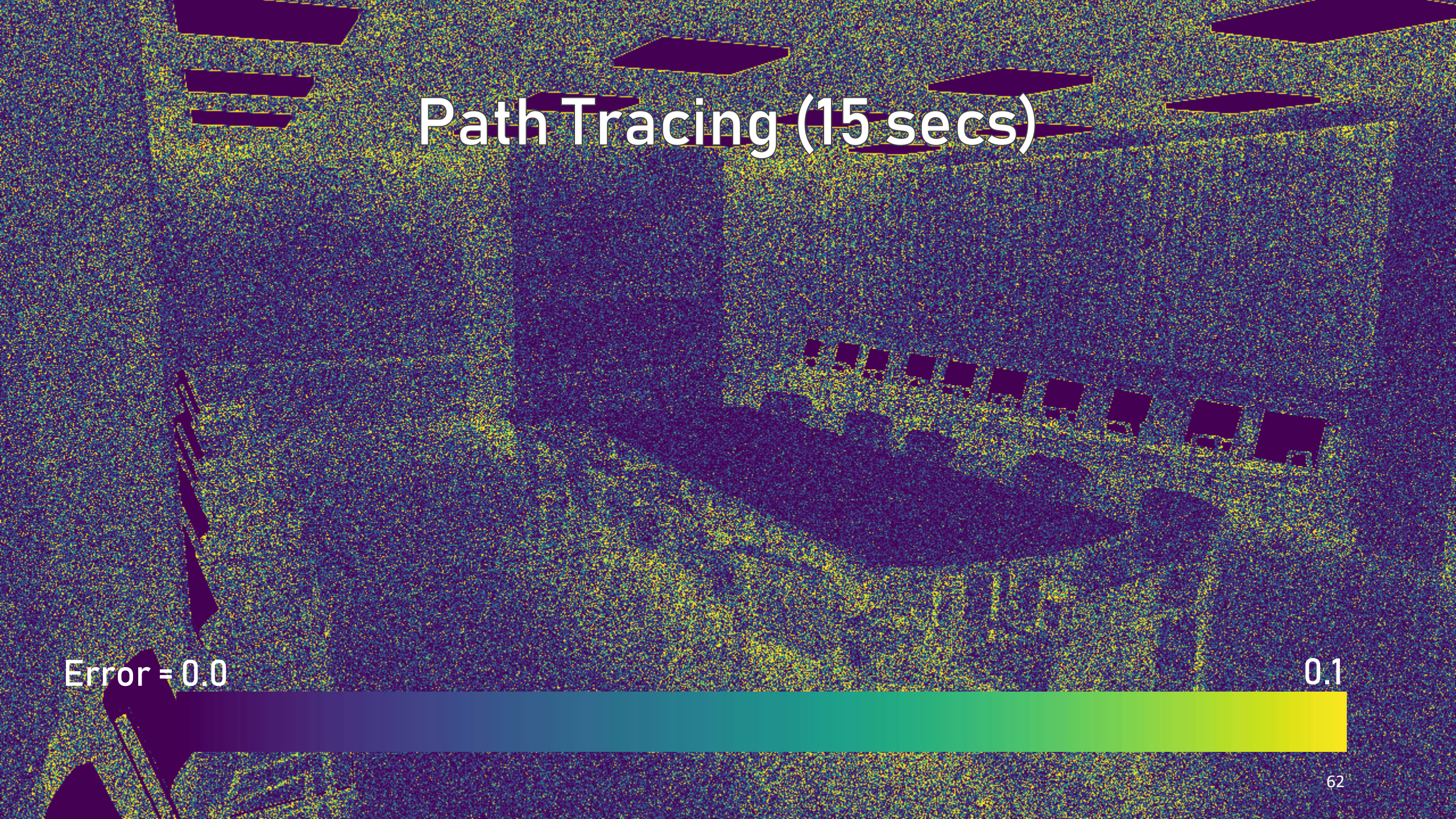

Ours (15 secs)


Ours (15 secs)


weighted
Virtual Point Light


weighted
Photon Splatting


Path Tracing (15 secs)


Path Tracing (15 secs)
Error = 0.0
0.1


Virtual Point Light (15 secs)

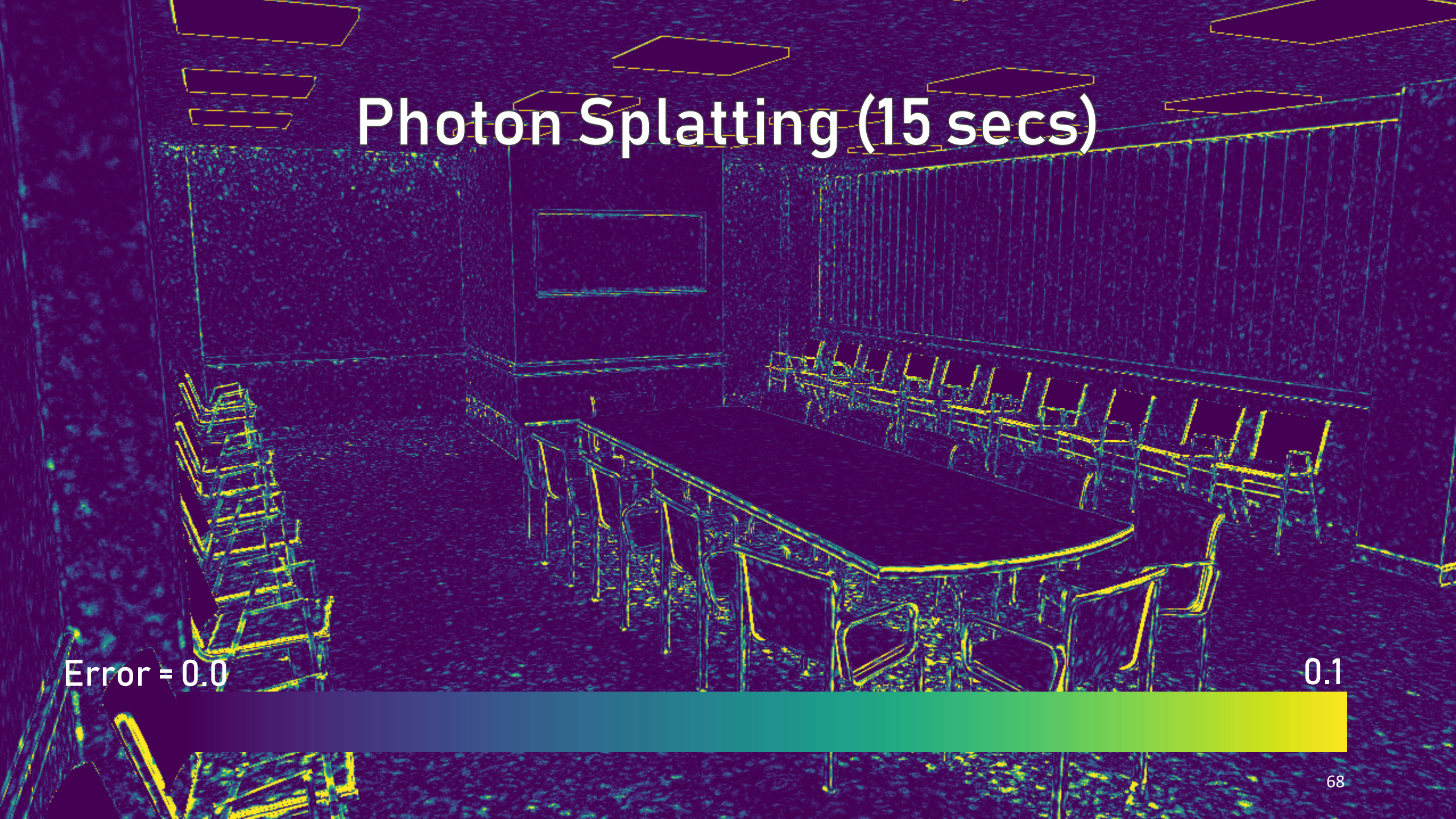
# Virtual Point Light (15 secs)


Virtual Spherical Light (15 secs)

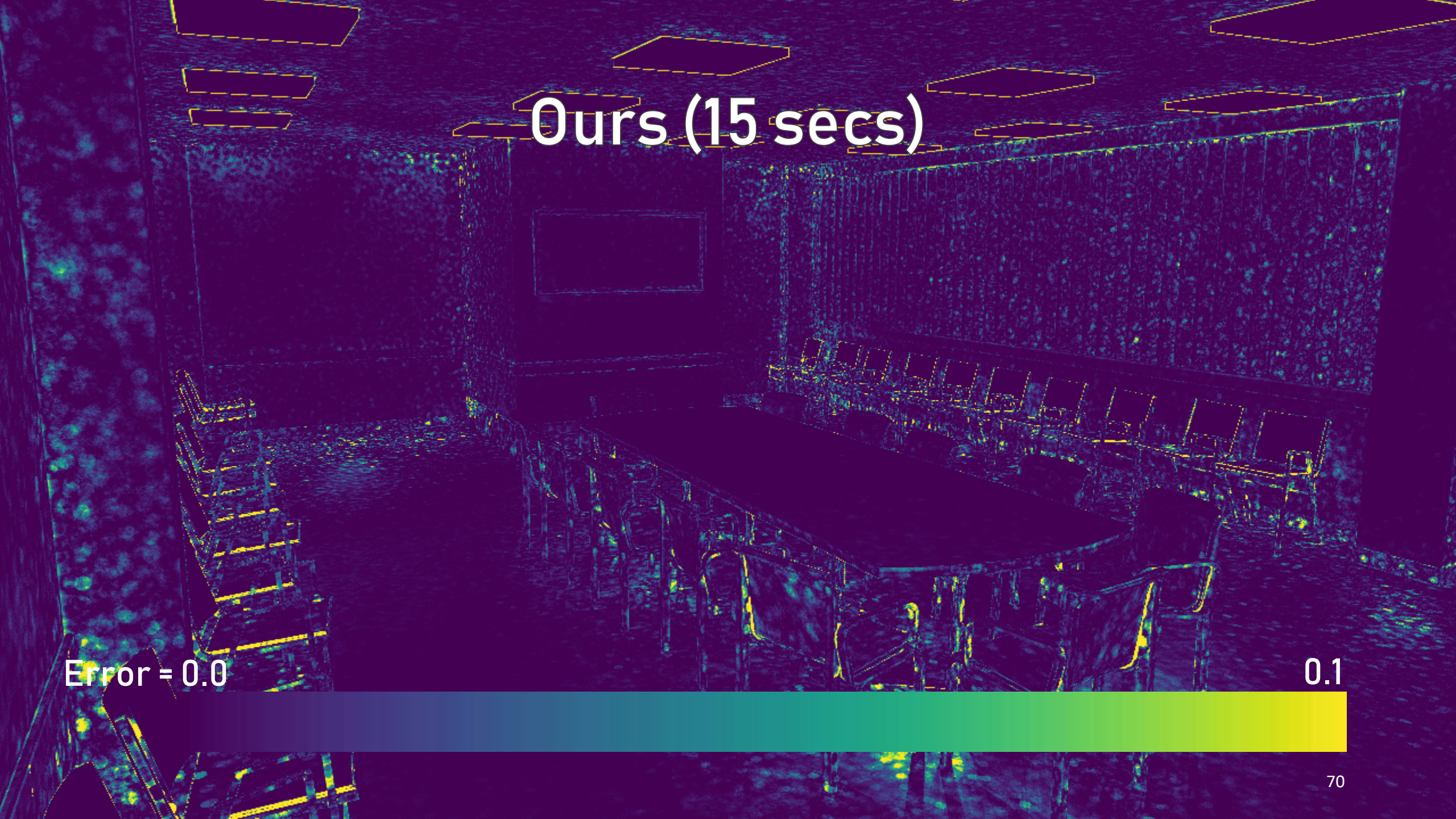
# Virtual Spherical Light (15 secs)


Photon Splatting (15 secs)

# Photon Splatting (15 secs)




Ours (15 secs)


Ours (15 secs)
Error = 0.0
0.1

# Reference

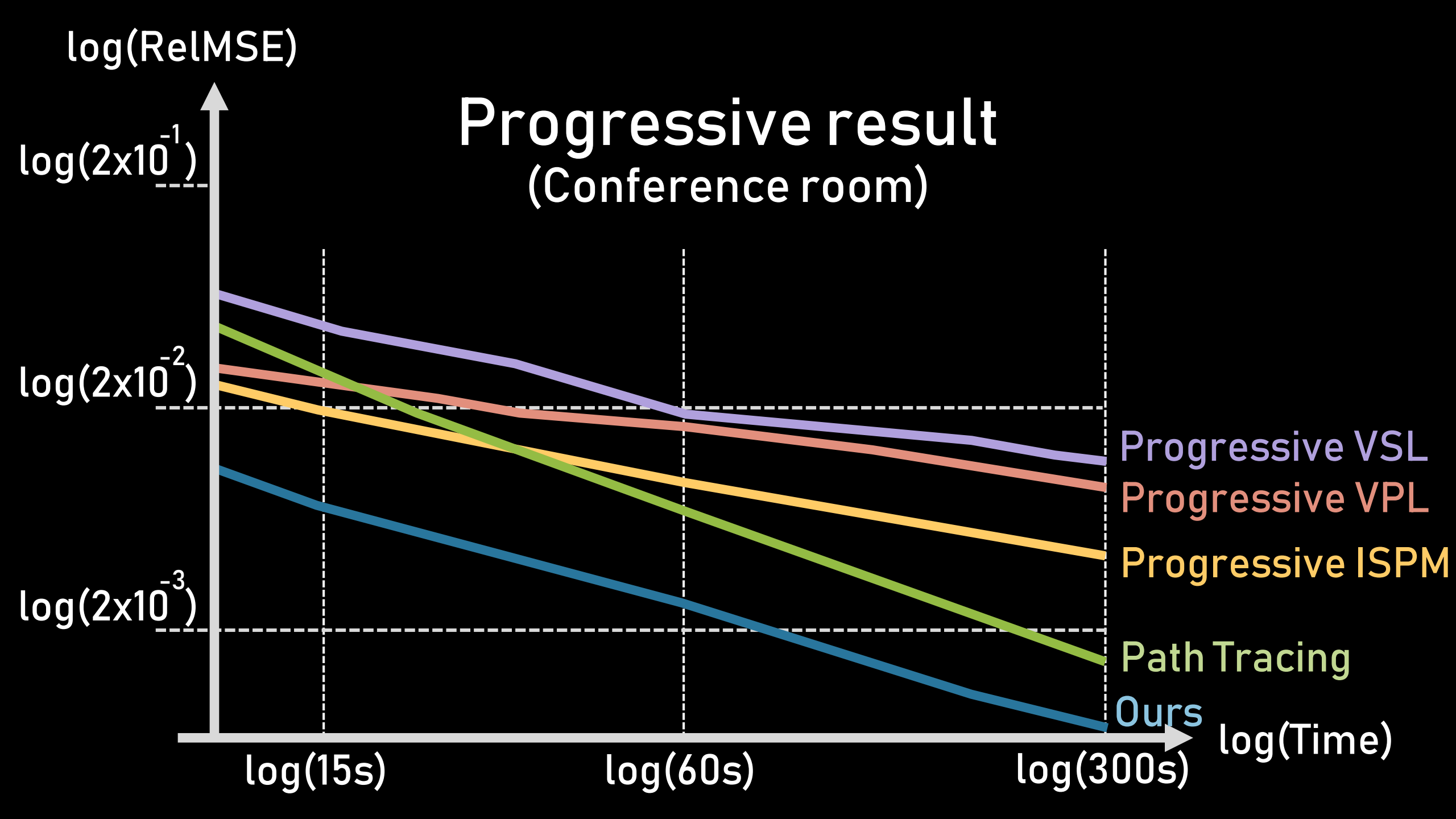

VPL
VSL
ISPM
Ours


VPL
VSL
ISPM
Ours


VPL
VSL
ISPM
Ours


VPL
VSL
ISPM
Ours

# Progressive result


log(RelMSE)
Progressive result
(Conference room)
log(2x10^-1)
log(2x10^-2)
log(2x10^-3)
Progressive VSL
Progressive VPL
Progressive ISPM
Path Tracing
Ours
log(Time)
log(15s)
log(60s)
log(300s)

# Limitations

- Is not efficient at rendering camera-visible glossy surfaces
- Is not trivial to find tight error bound and compute optimal weight with LightCuts (but still usable)
- Competitive to PT-NEE in the scene that
  - Has high frequency textures (limitation of VPL)
  - Has the light sources are visible to much of the geometry

# Future work

- Improves the light vertices distribution
- Investigate if it is applicable to volume rendering (VRL – Novák et al. 2012, Photon Beam – Jarosz et al. 2011)

# Thank you

We would like to acknowledge:
- Anonymous reviewers
- JSPS KAKENHI program
- Monbukagakusho – MEXT scholarship

- All materials will be available at www.jamorn.me/evplp