



Differentiable daylight simulations using Mitsuba (?)

Wenzel Jakob
Mattéo Santini

Radiance &
HDR workshop

Aug 26, 2025

Mitsuba is a renderer

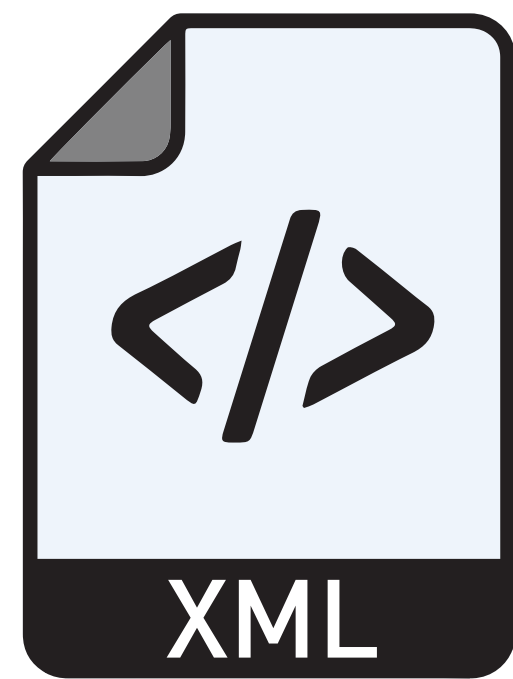
(.. but a rather strange one ..)



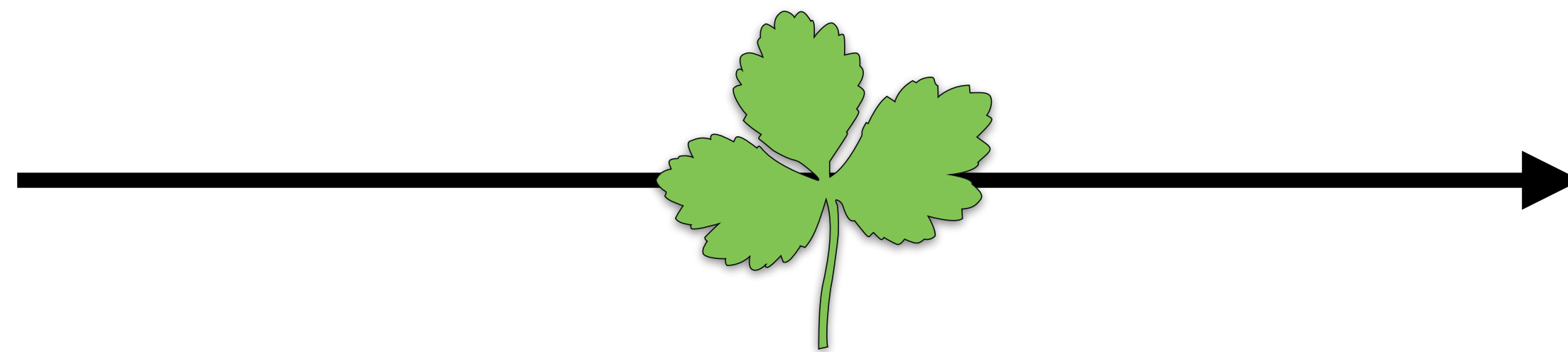
Scene file

Mitsuba is a renderer

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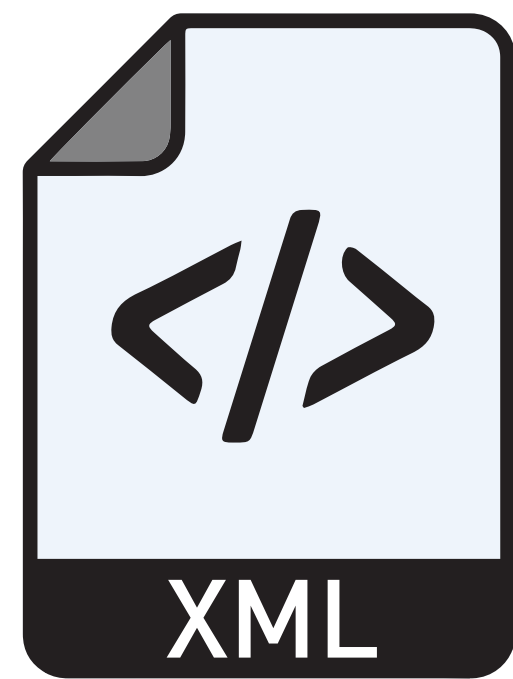
Scene file



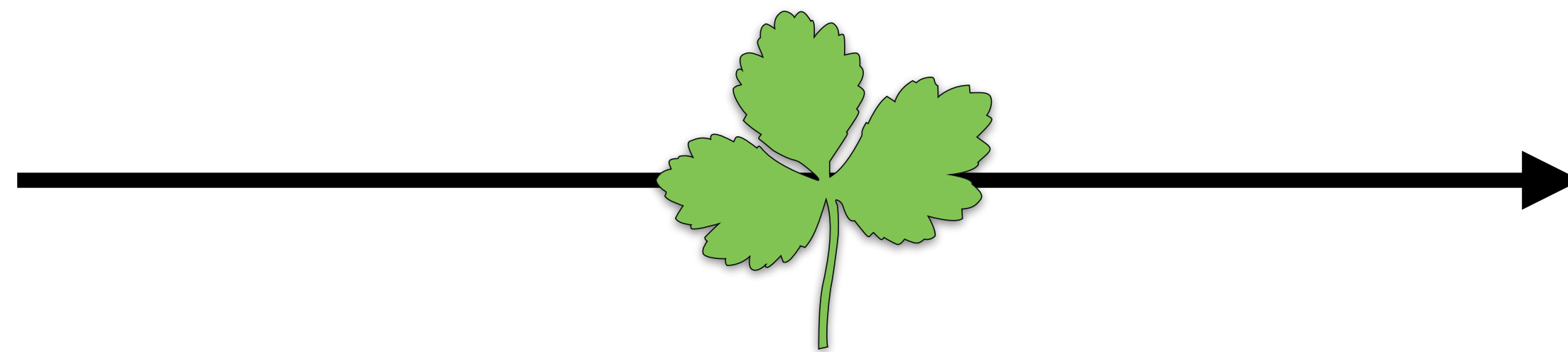
Image

Mitsuba is a renderer

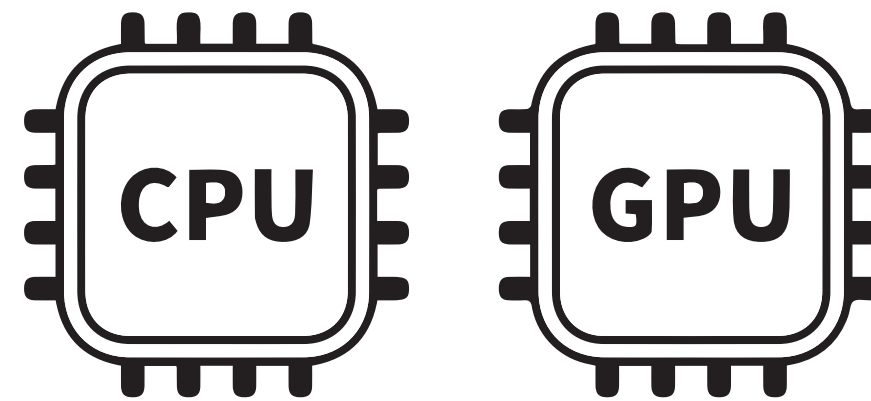
(.. but a rather strange one ..)



Scene file



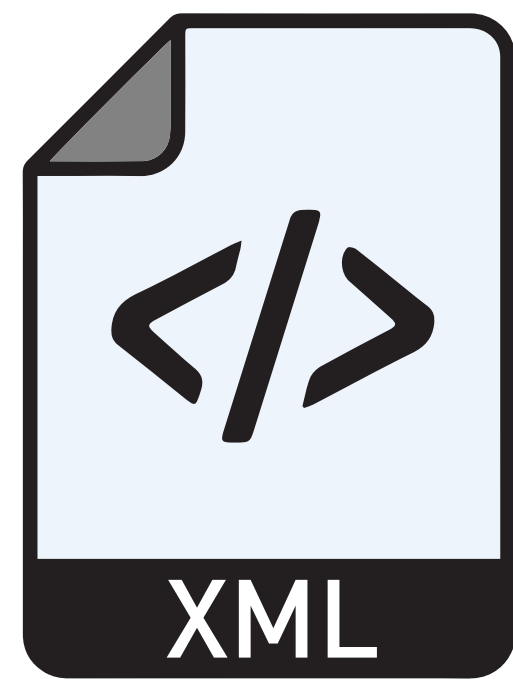
Image



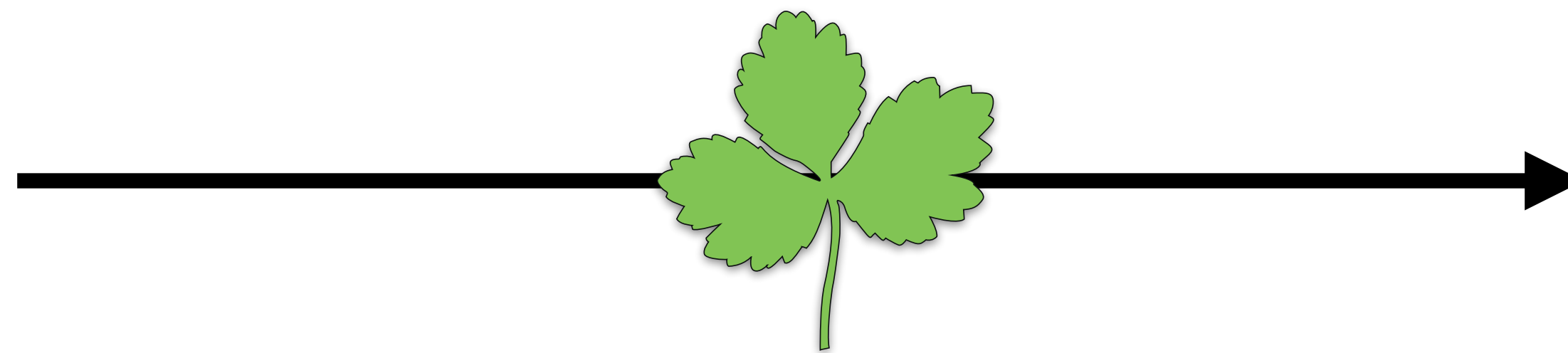
Mitsuba is a renderer

(.. but a rather strange one ..)

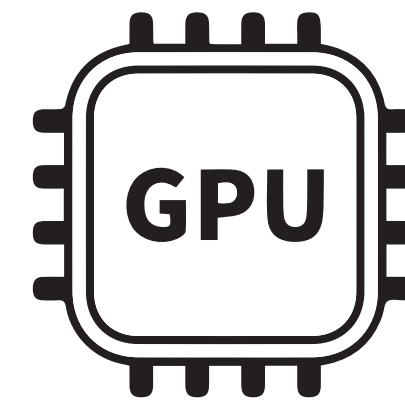
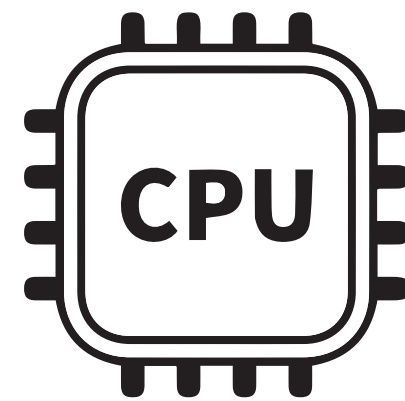
Mono/RGB/Spectral (optional: polarization)



Scene file

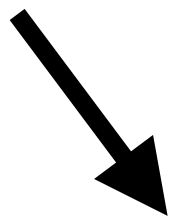


Image



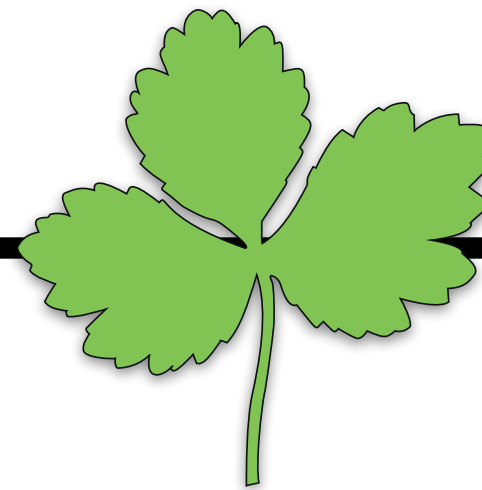
Mitsuba is a renderer

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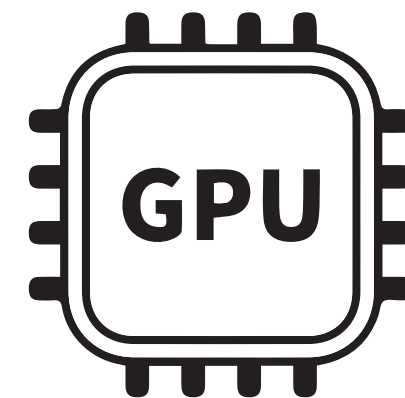
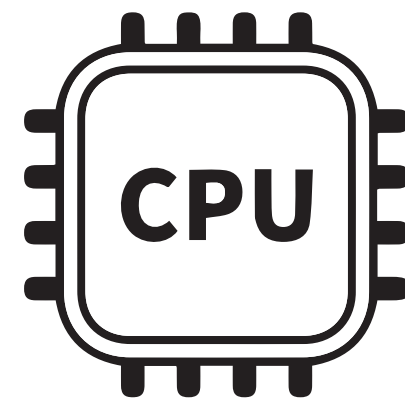


Scene file

Mono/RGB/Spectral (optional: polarization)

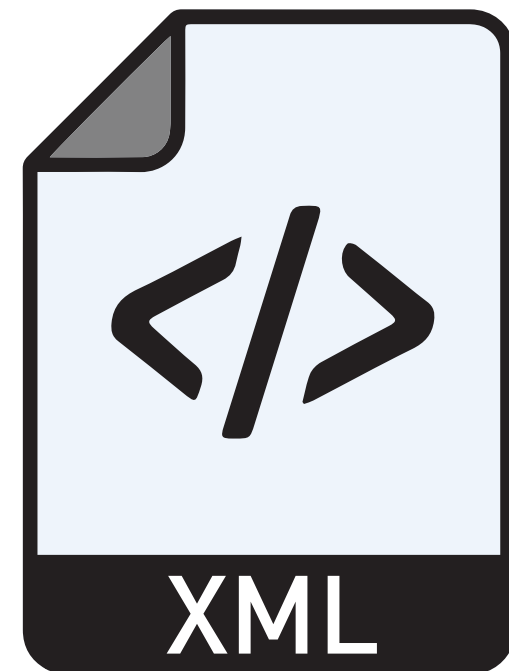
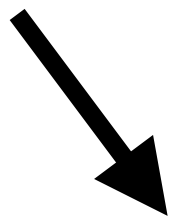


Image



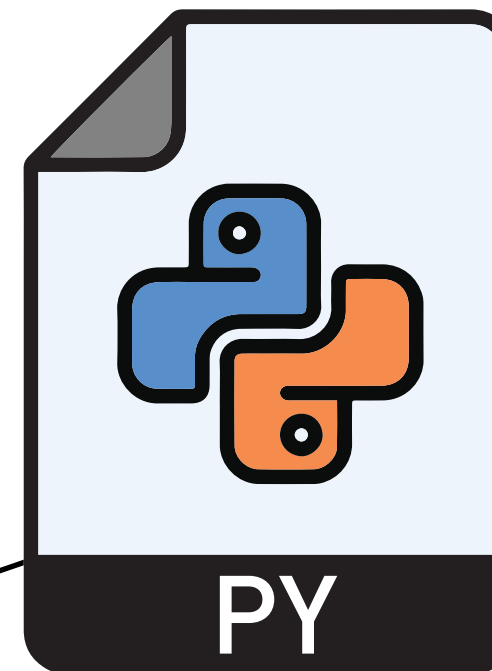
Mitsuba is a renderer

(.. but a rather strange one ..)



Scene file

Mono/RGB/Spectral (optional: polarization)

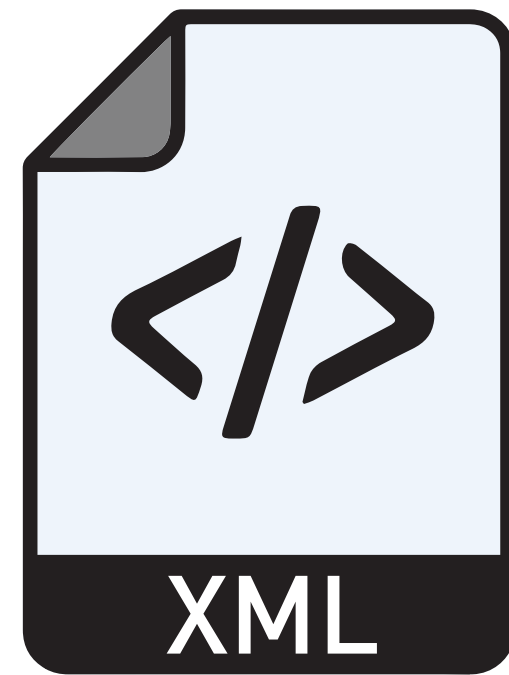
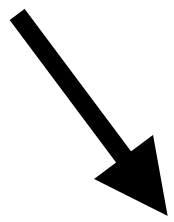


Image

```
import mitsuba as mi
scene = mi.load_file("scene.xml")
image = mi.render(scene)
```

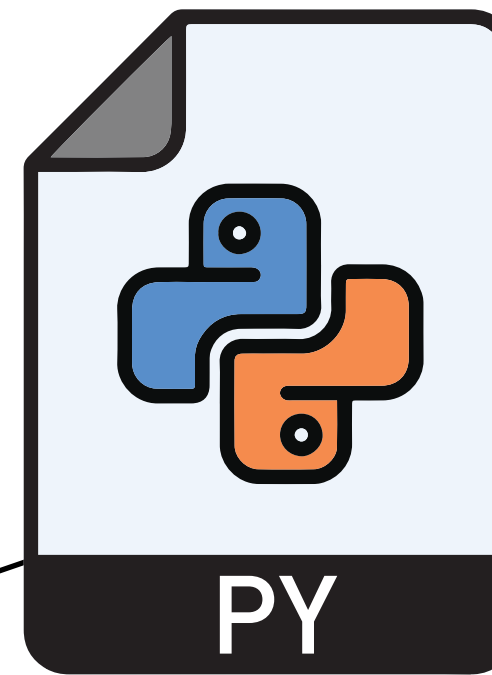

Mitsuba is a renderer

(.. but a rather strange one ..)



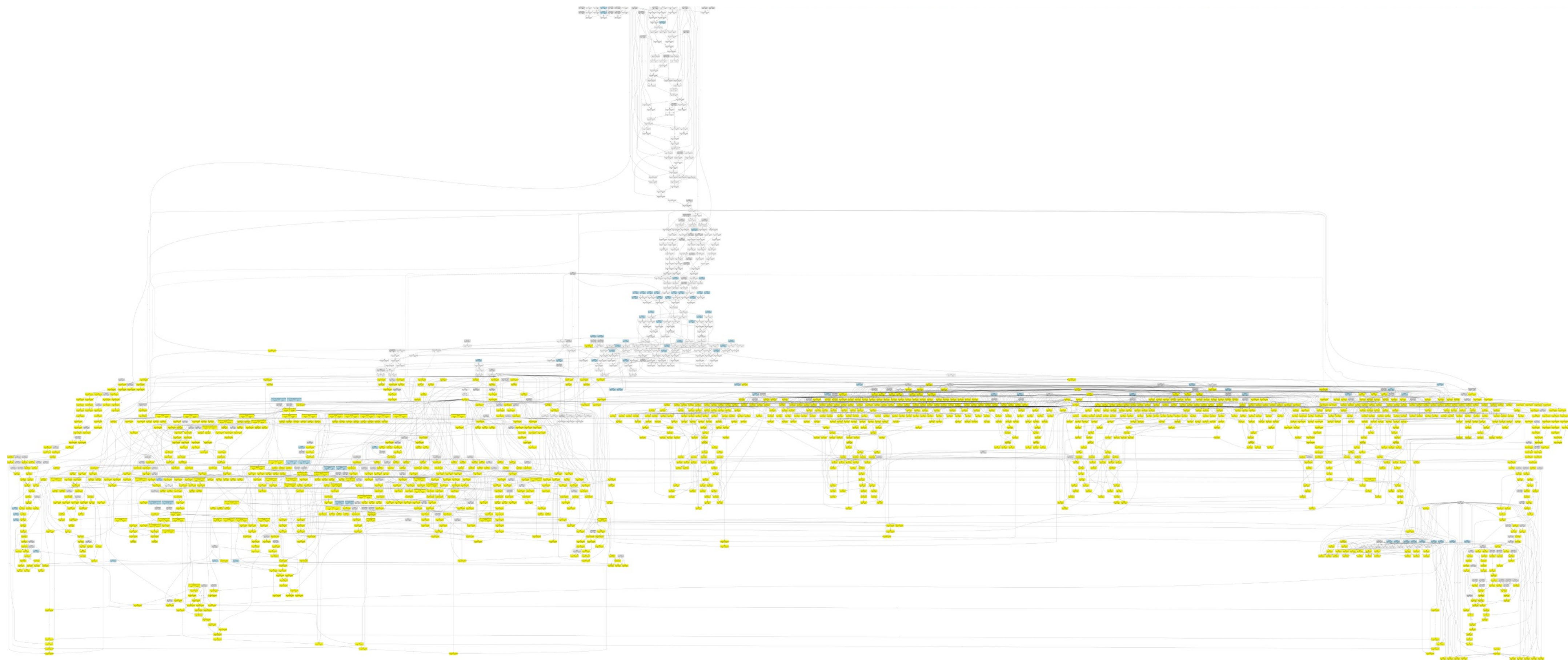
Scene file

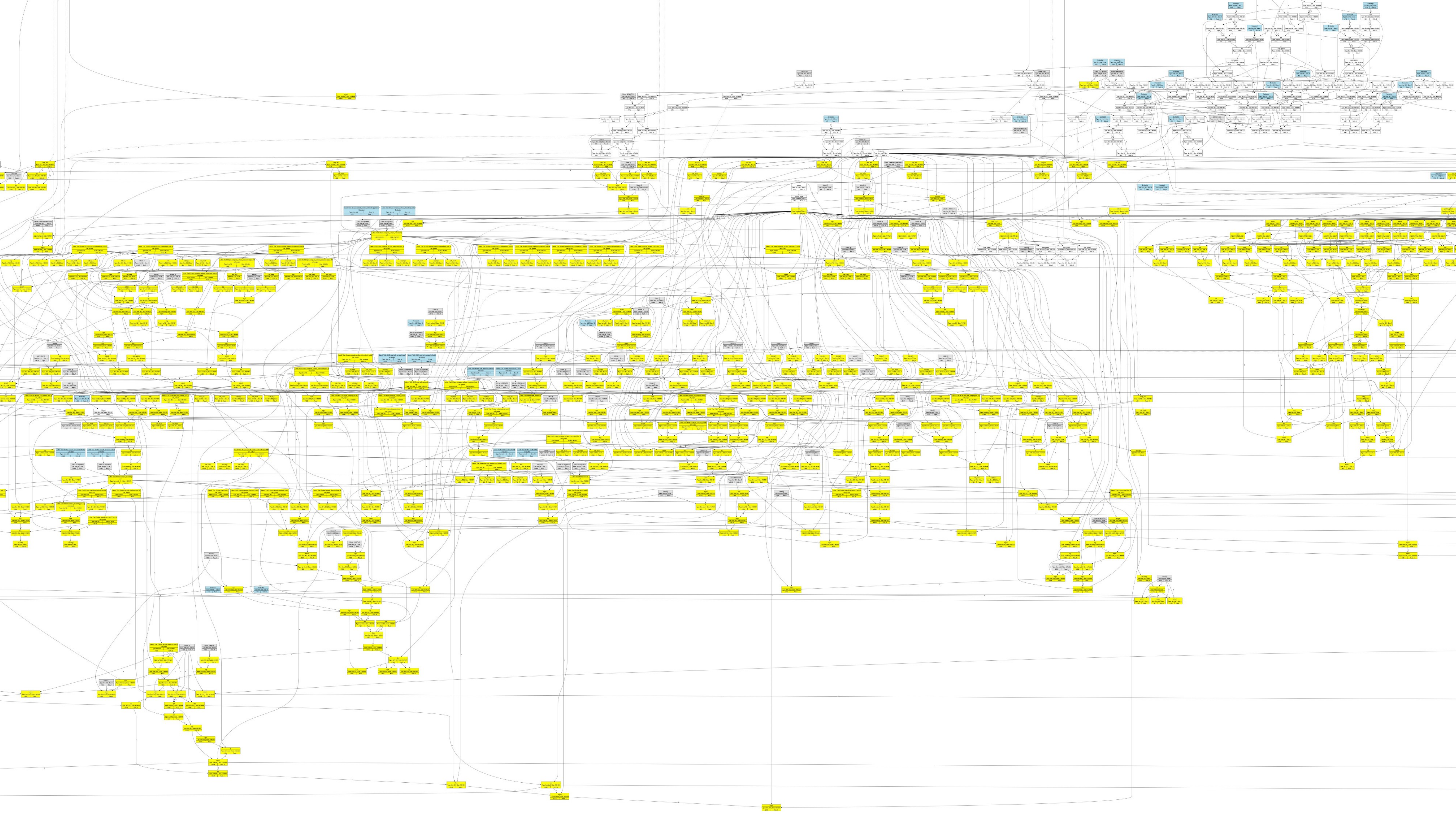
Mono/RGB/Spectral (optional: polarization)

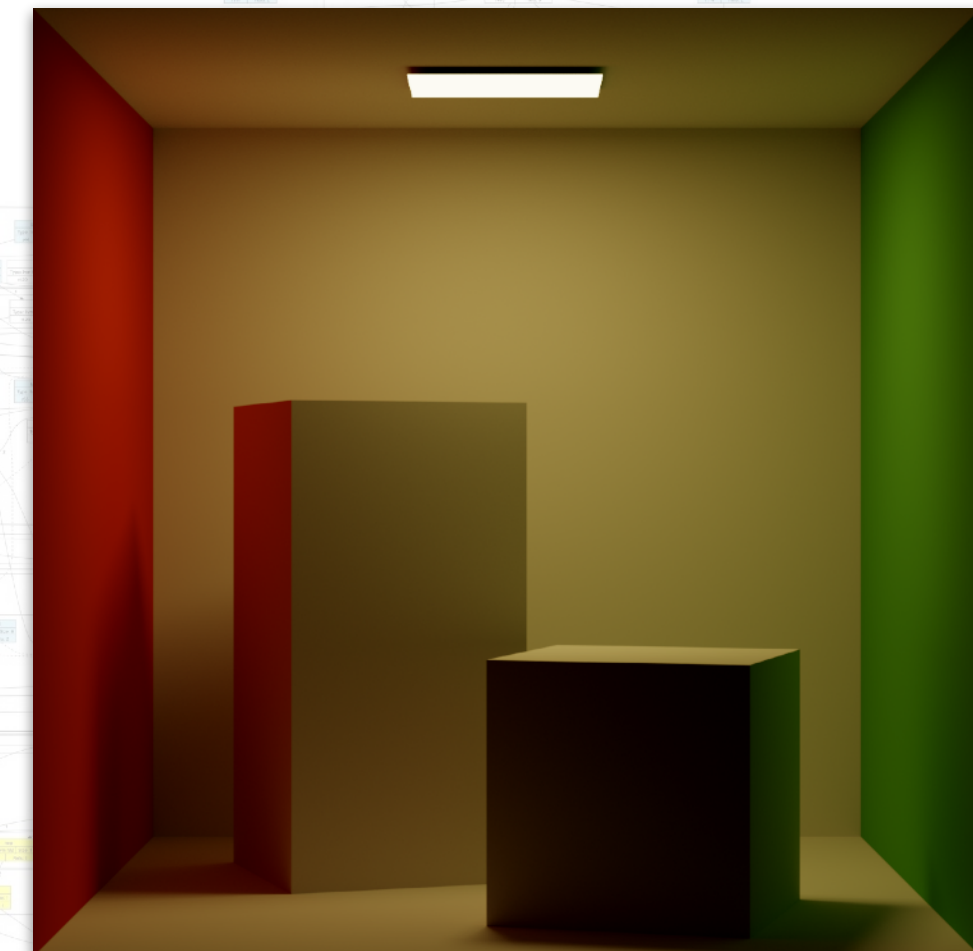
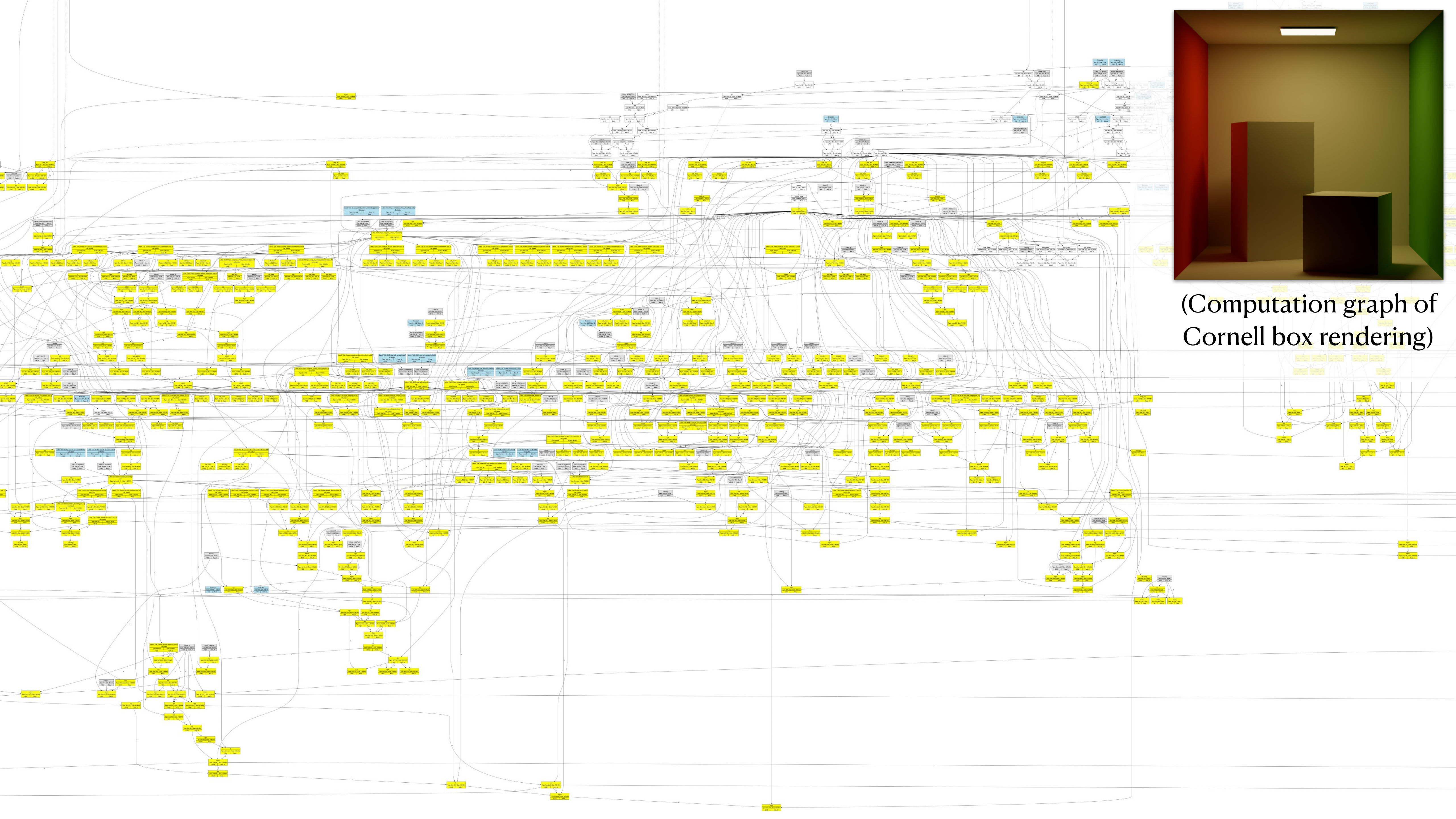


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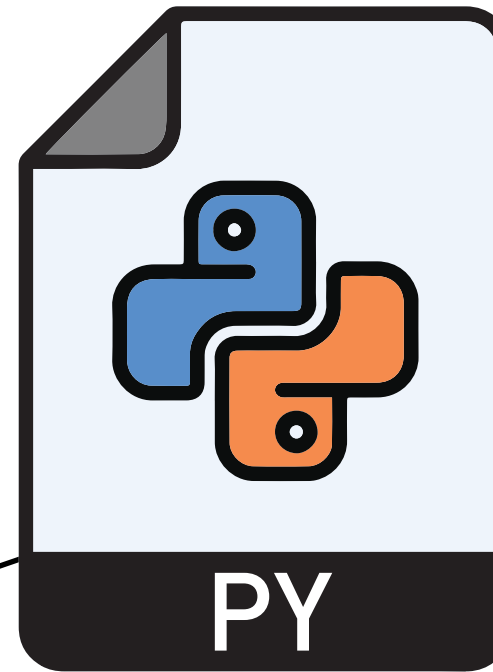
(Computation graph of
Cornell box rendering)

Mitsuba is a renderer

(.. but a rather strange one ..)



Scene file

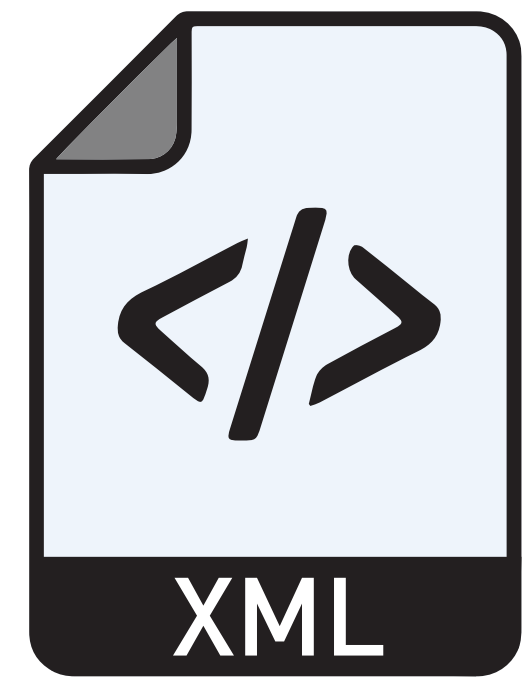


Image

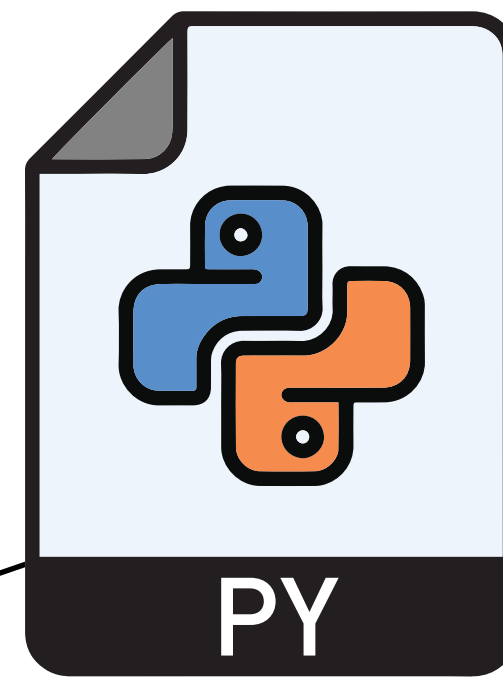
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Mitsuba is a renderer

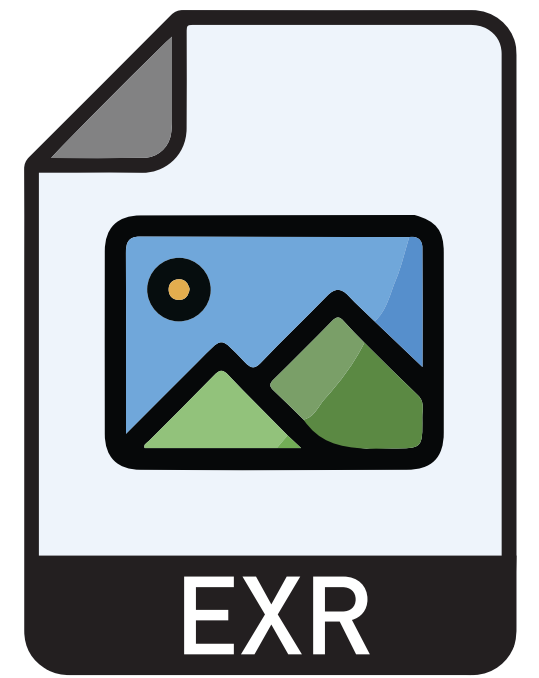
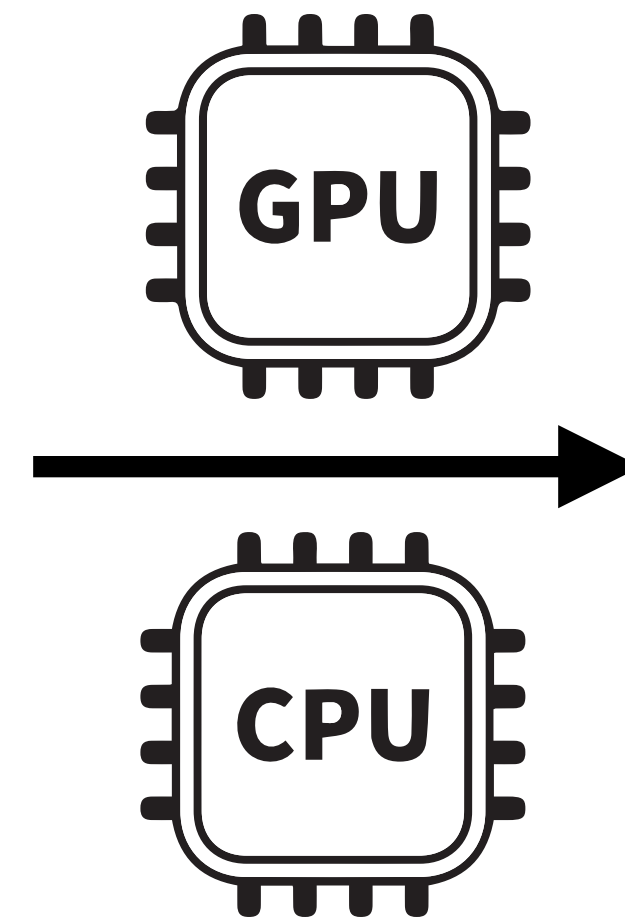
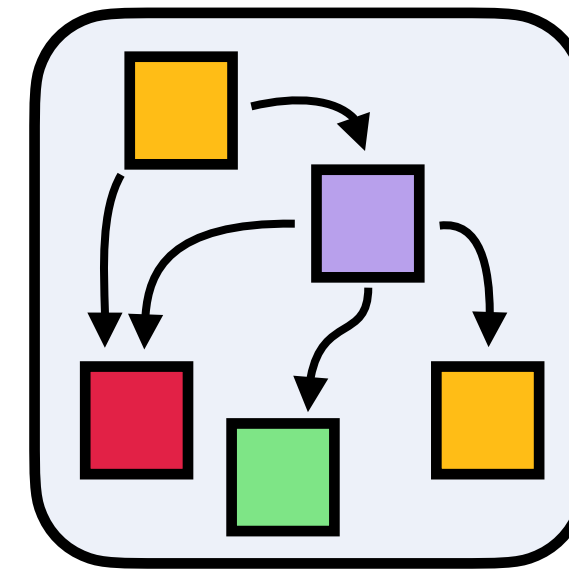
(.. but a rather strange one ..)



Scene file



Computation graph

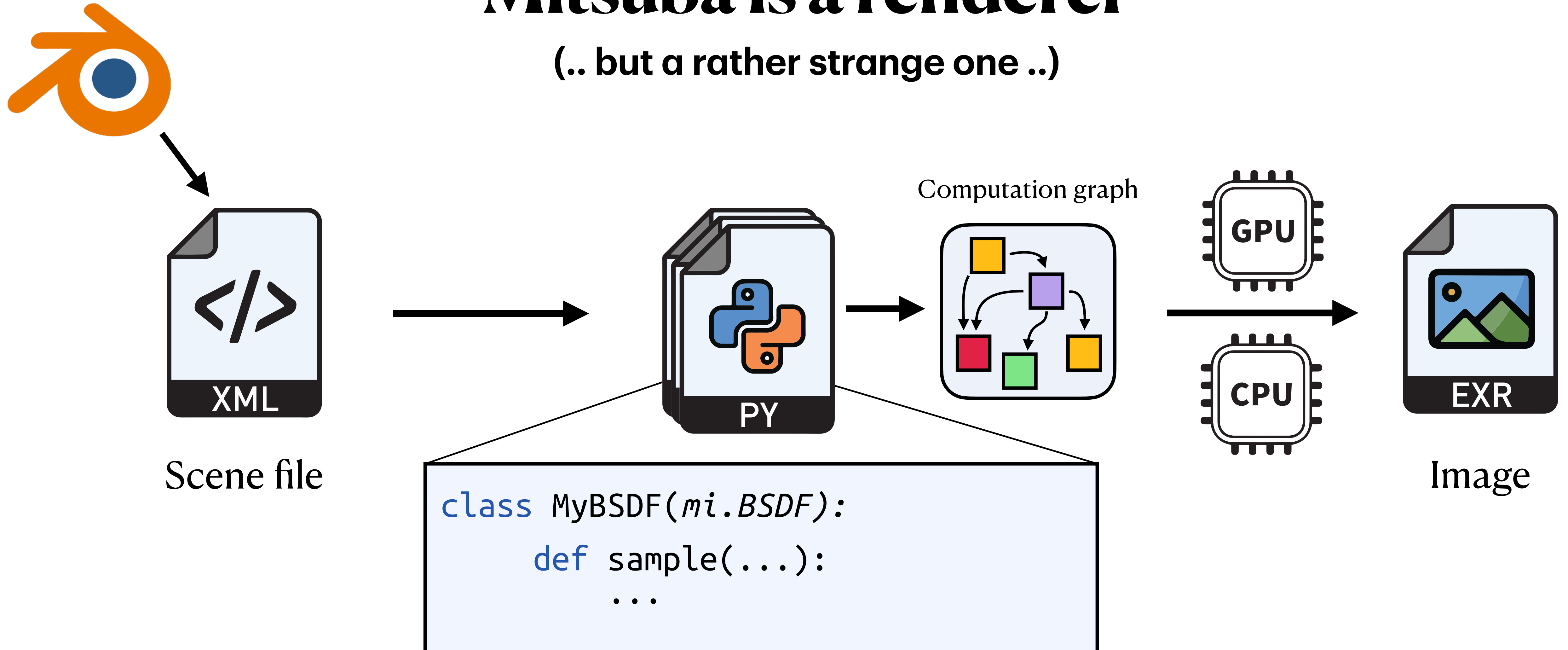


Image

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Mitsuba is a renderer

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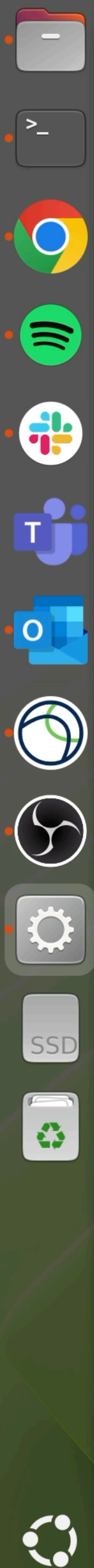
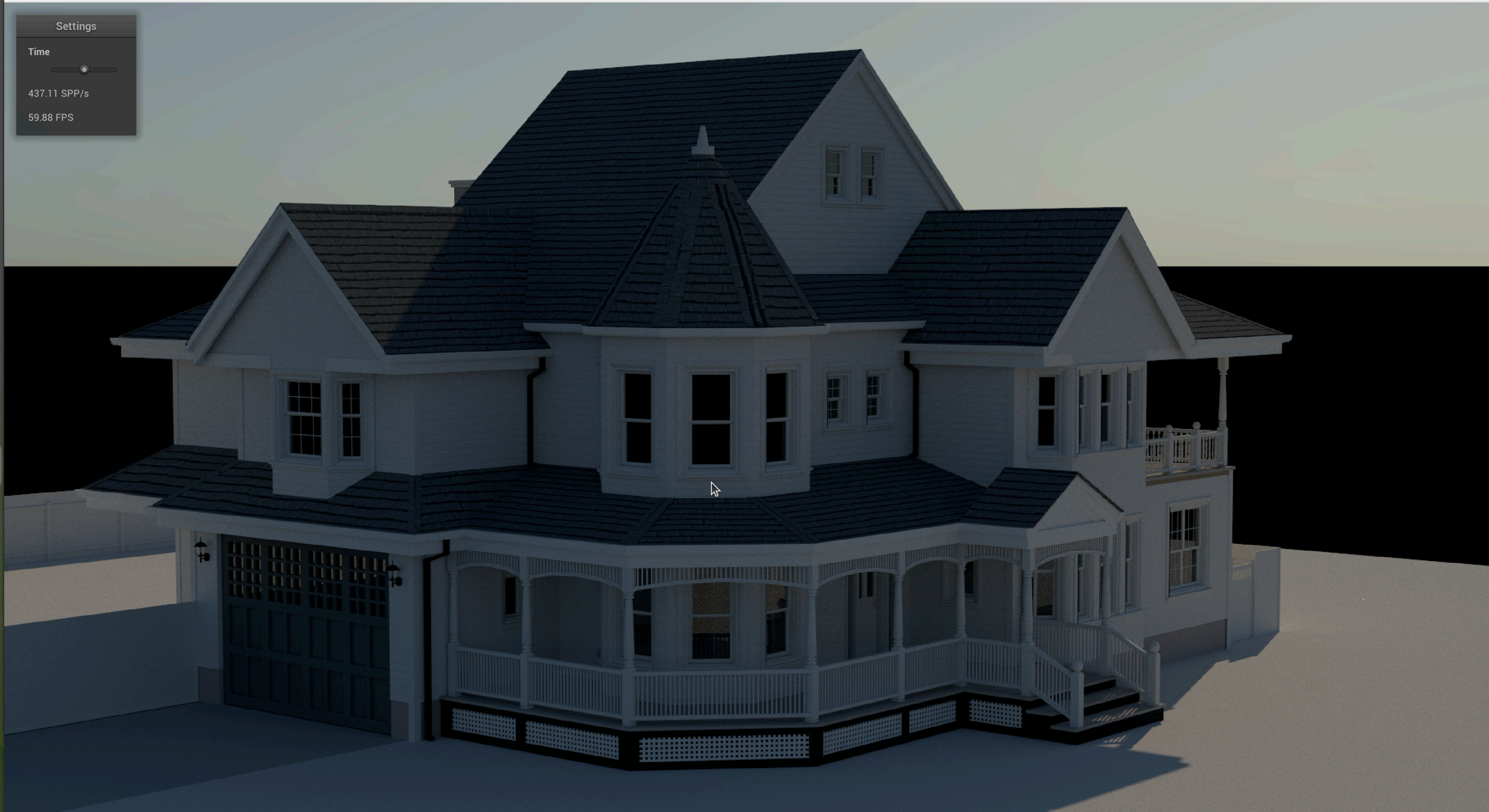
Settings

Time



437.11 SPP/s

59.88 FPS



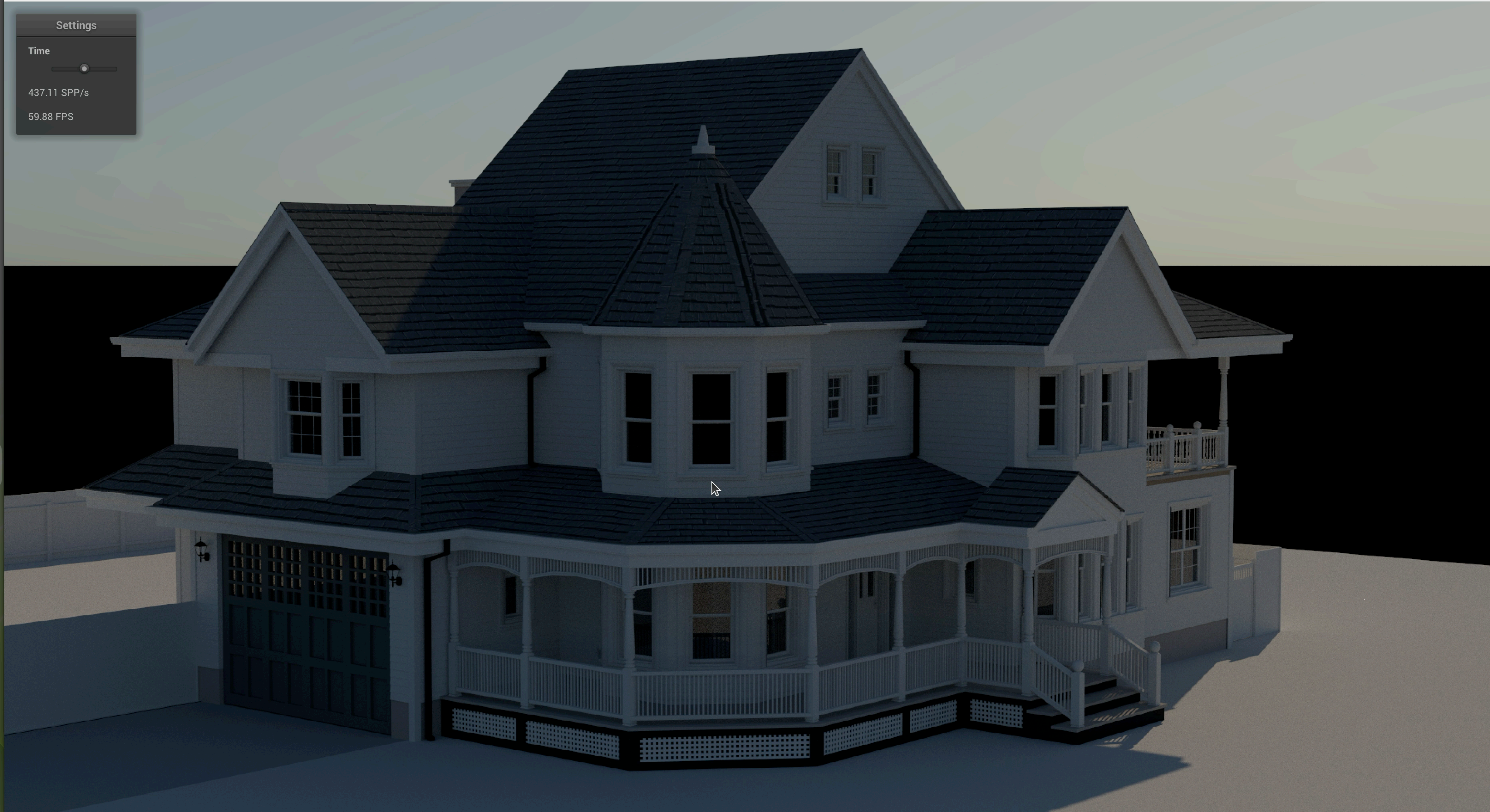
Settings

Time



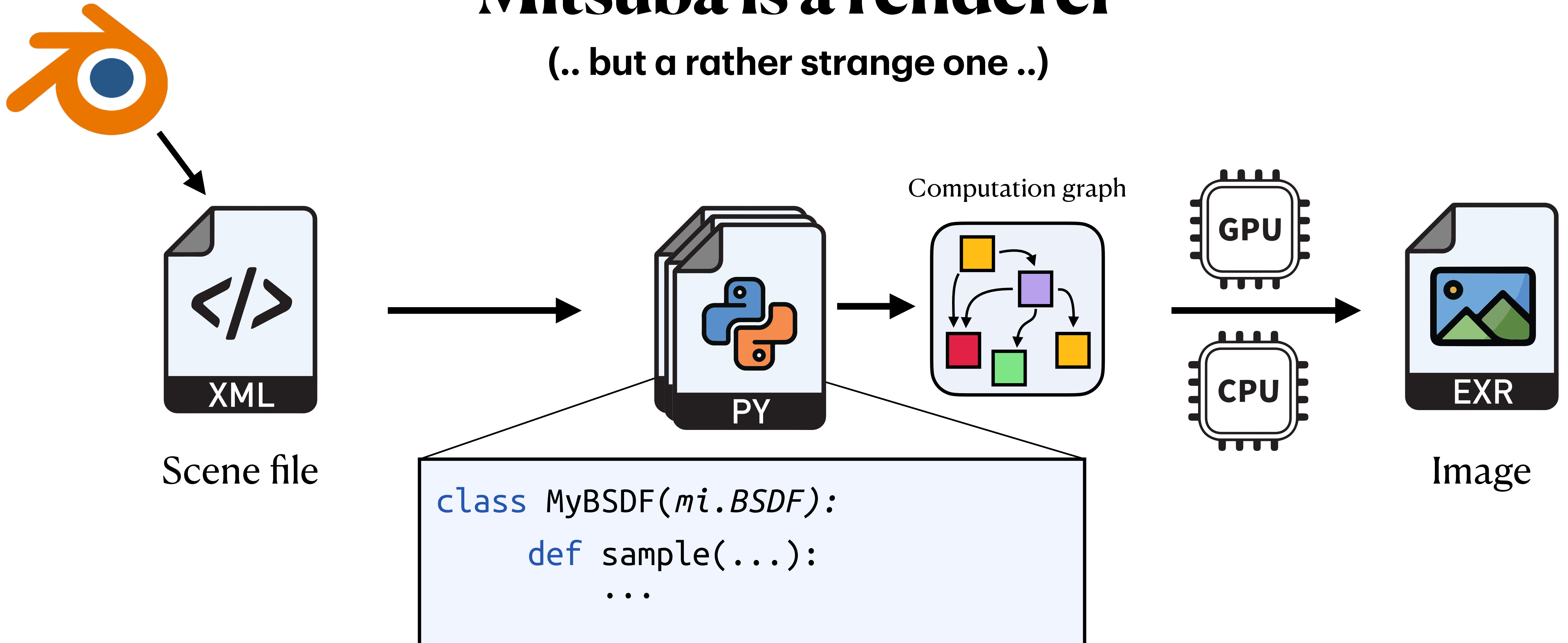
437.11 SPP/s

59.88 FPS



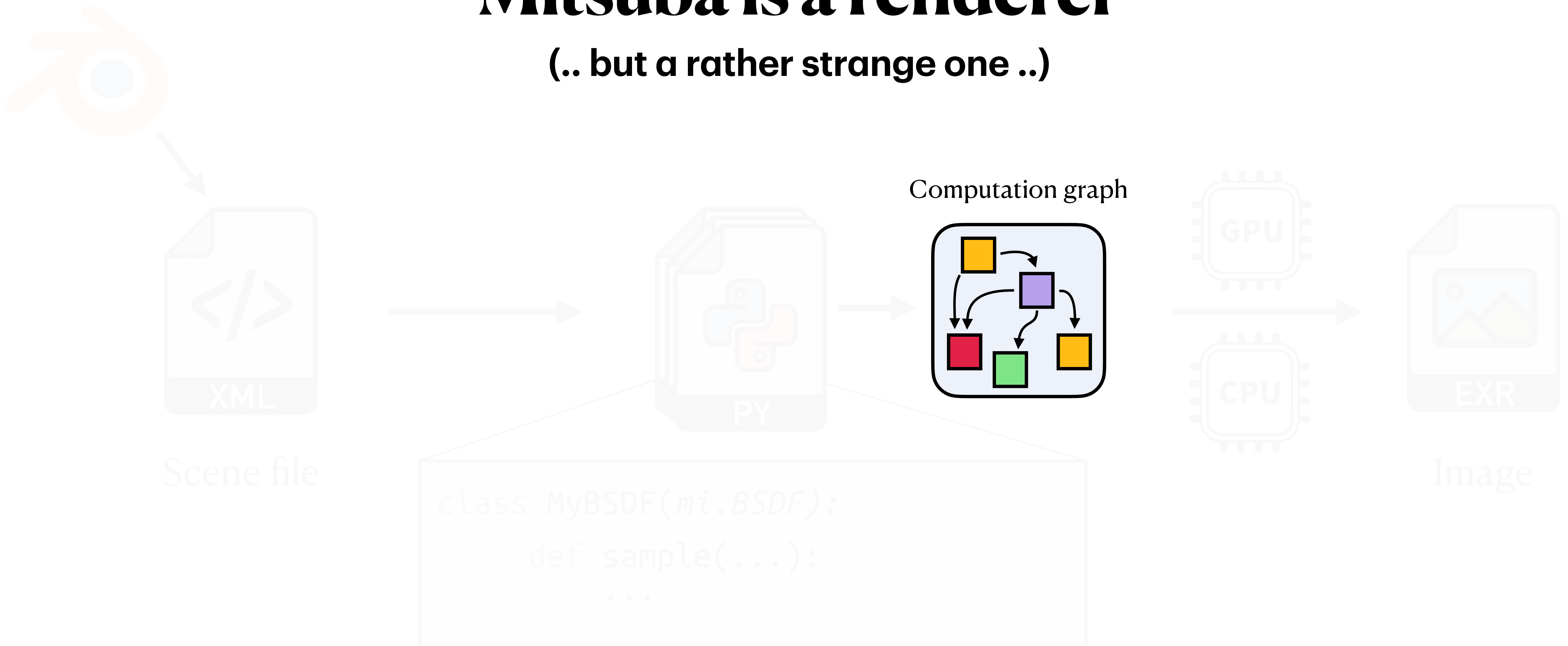
Mitsuba is a renderer

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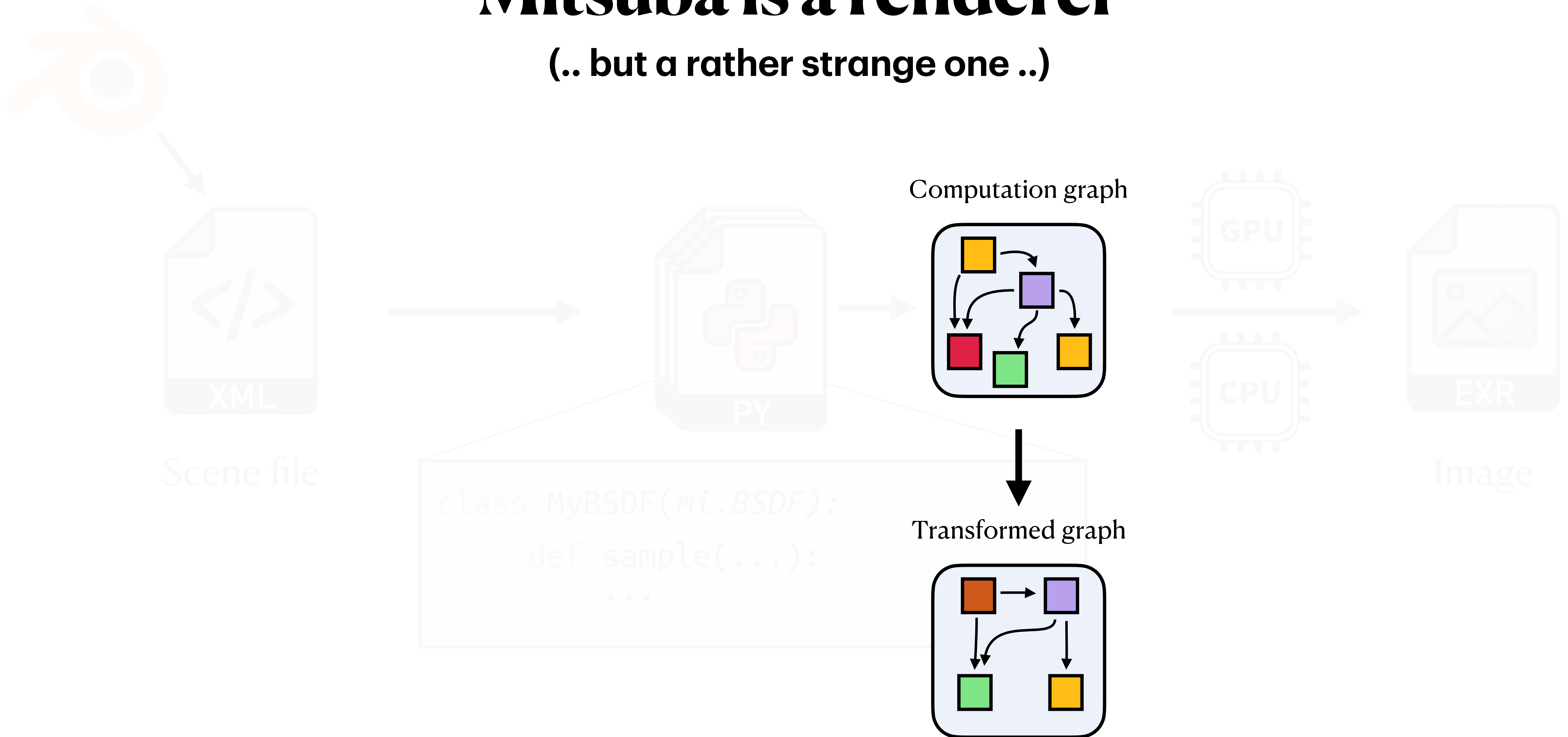
Mitsuba is a renderer

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Mitsuba is a renderer

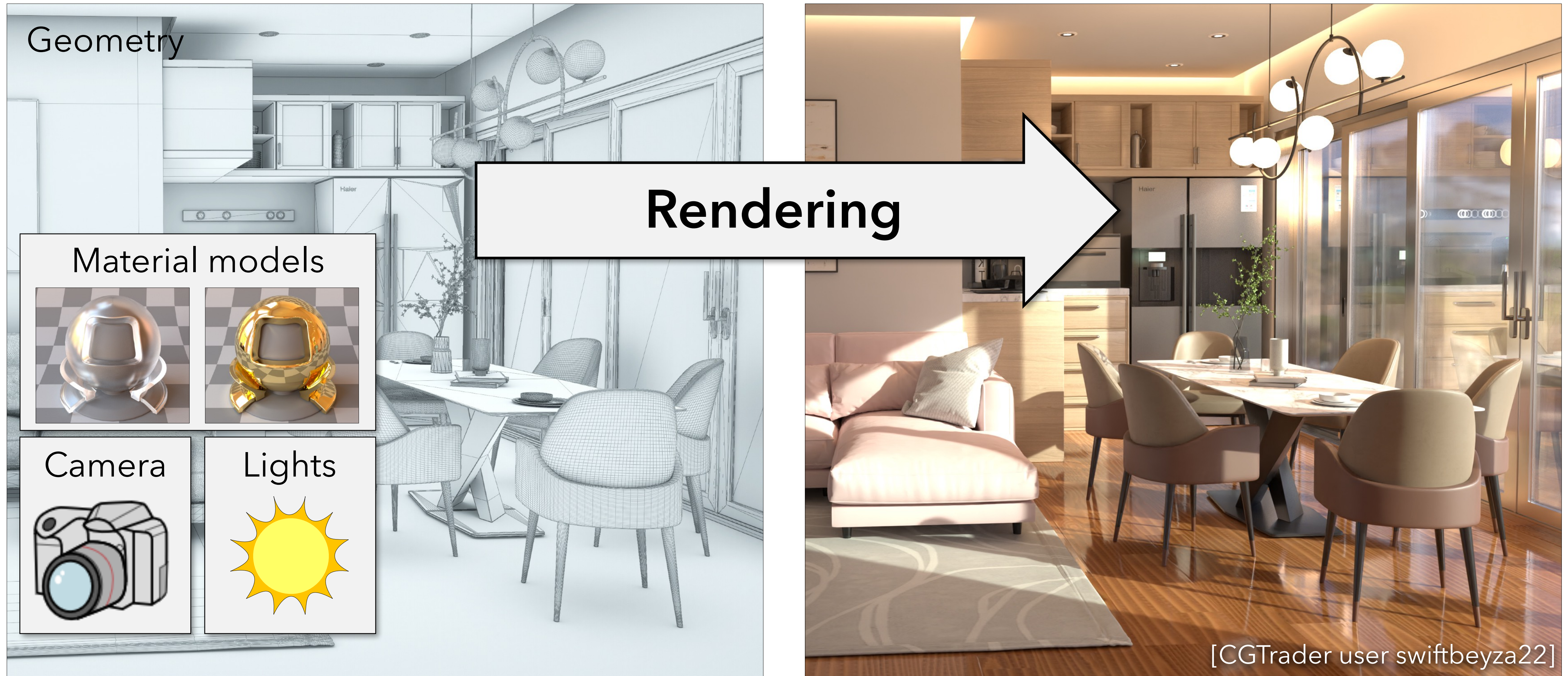
(.. but a rather strange one ..)



Mitsuba is also an *inverse* renderer

Input scene

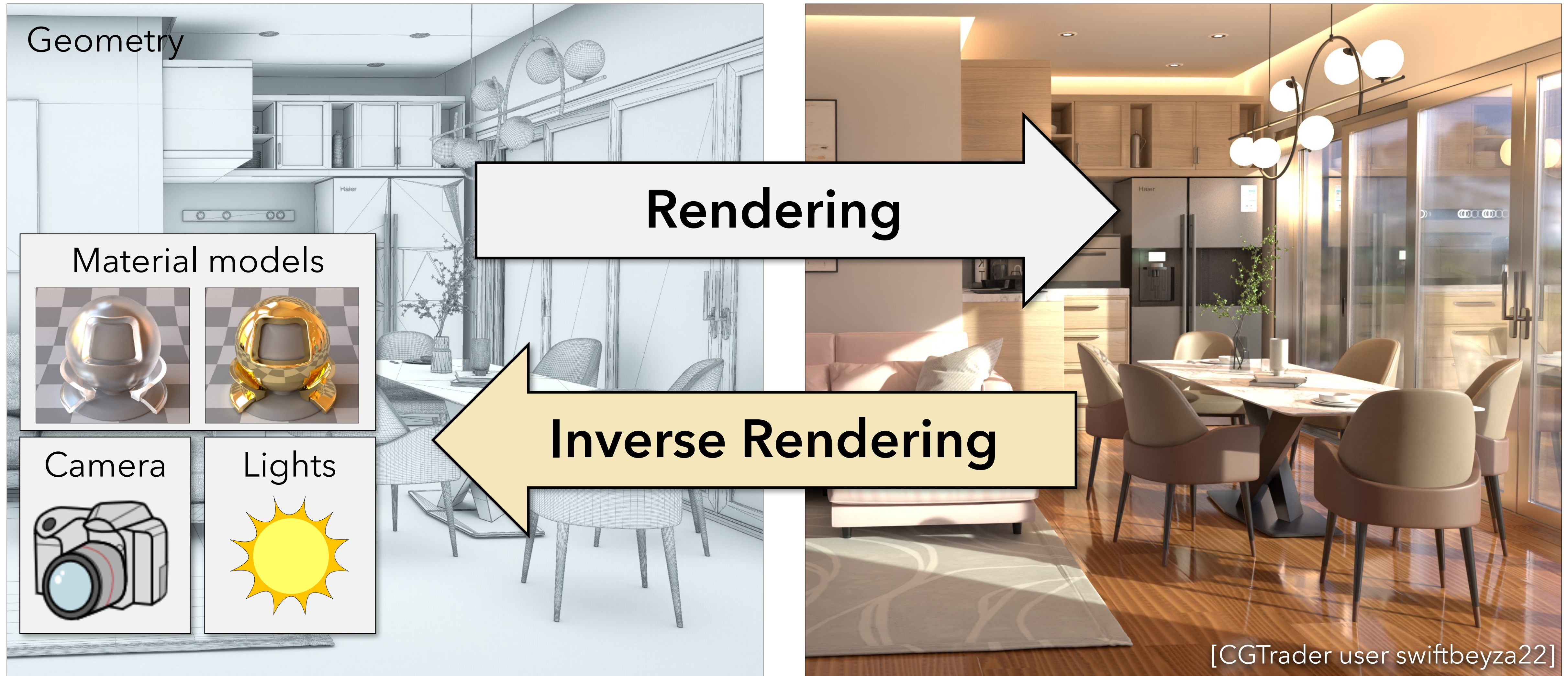
Rendered image



Mitsuba is also an *inverse* renderer

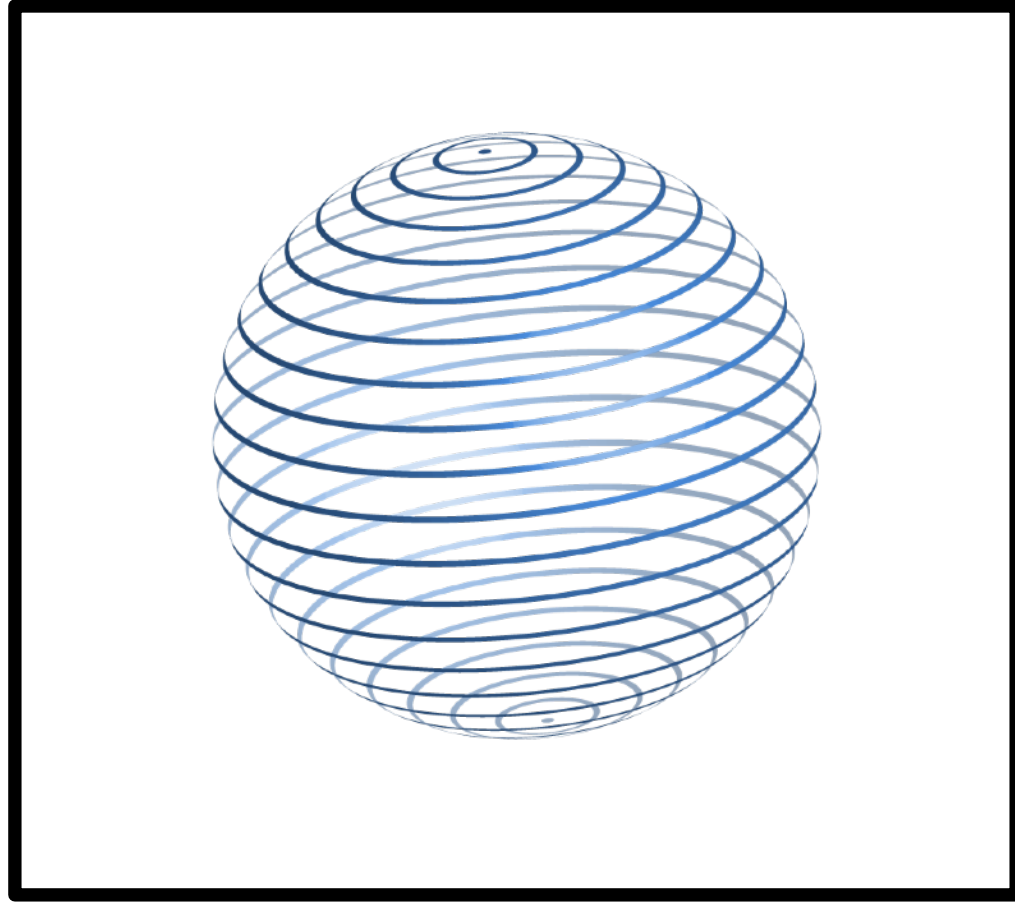
Input scene

Rendered image

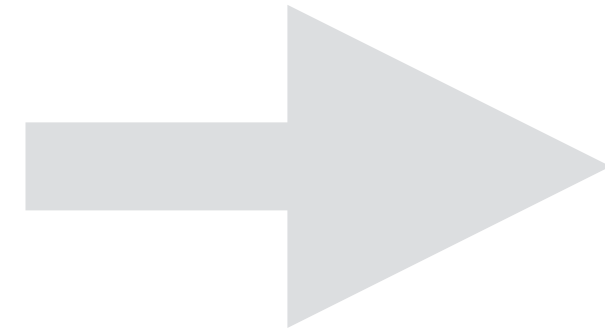
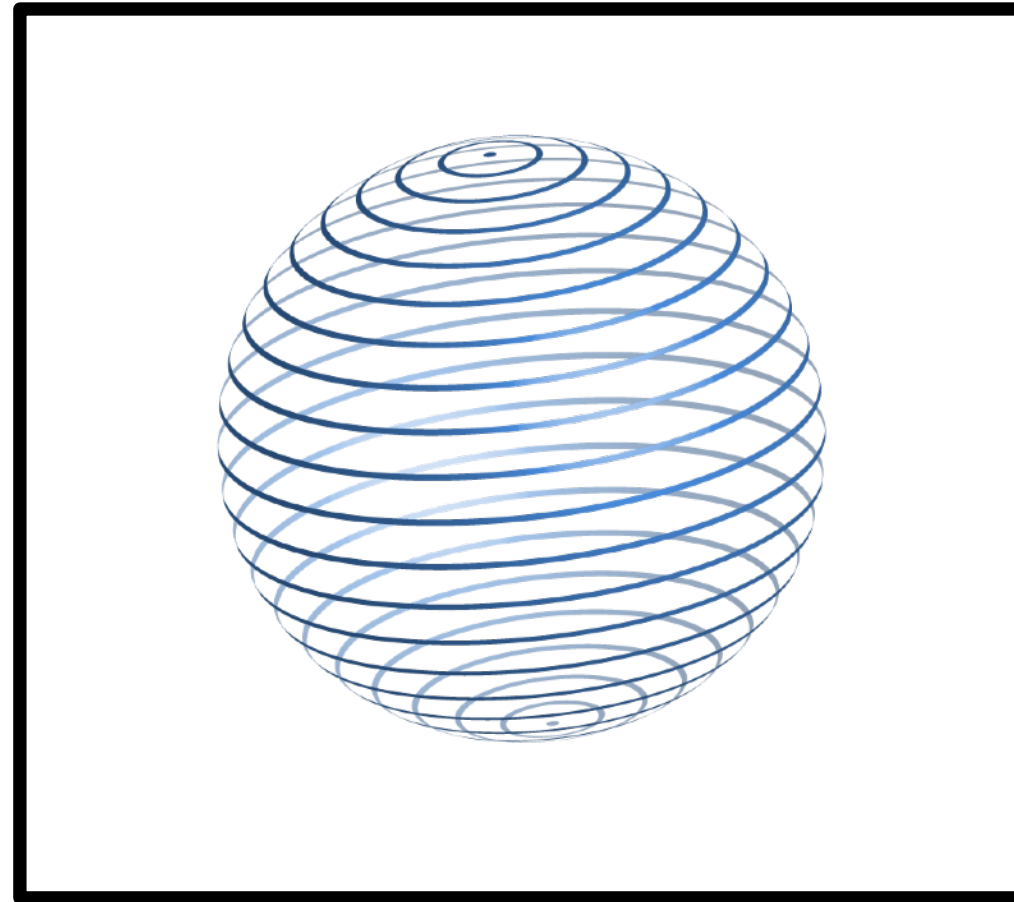


[Based on a slide by Delio Vicini]

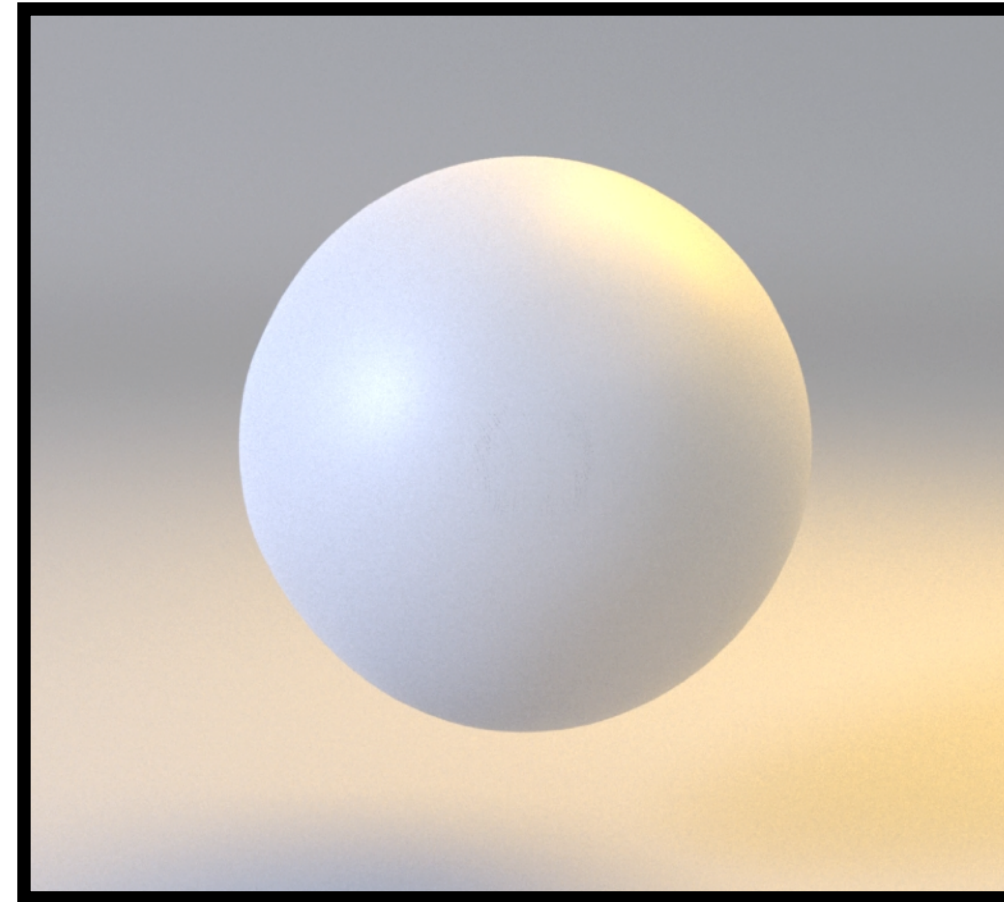
3D model



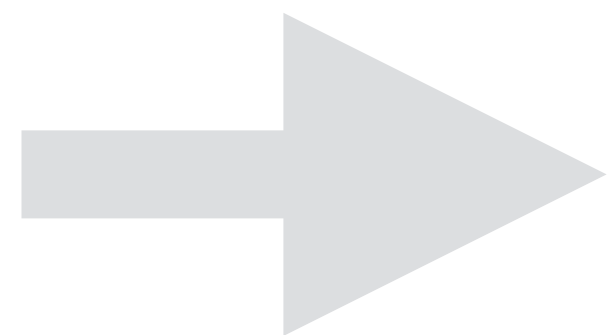
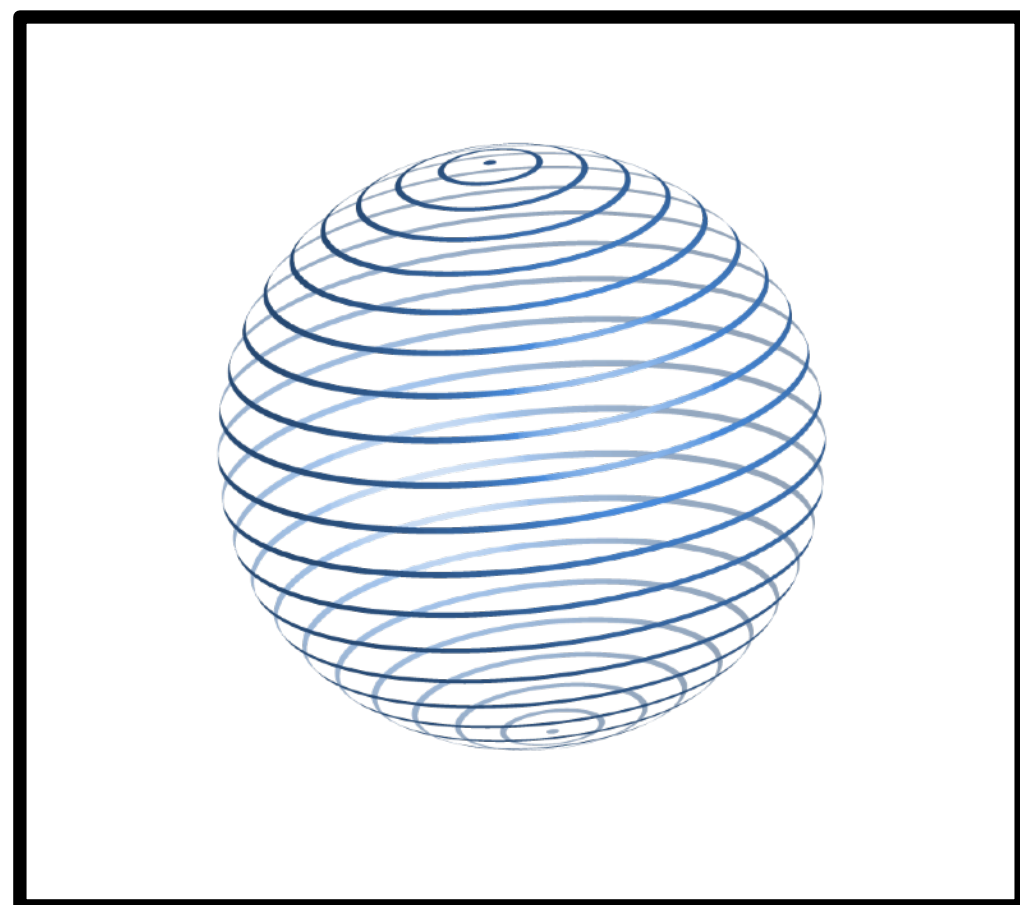
3D model



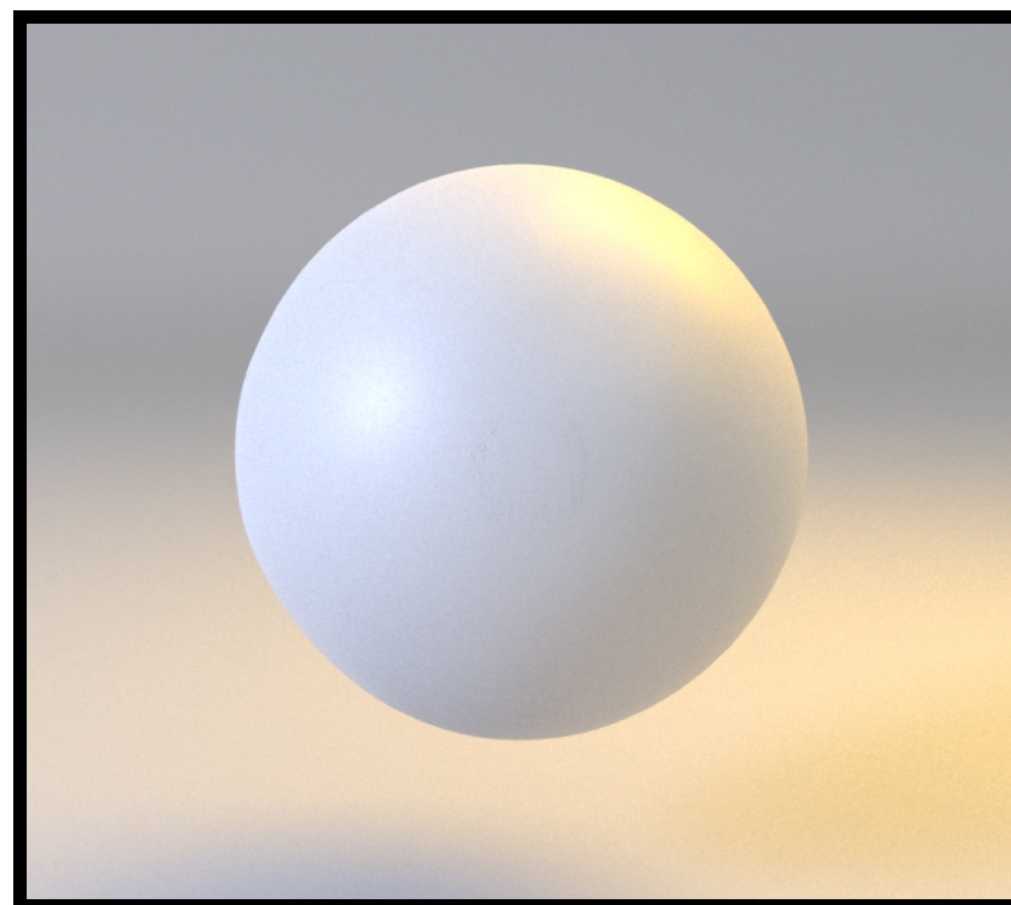
Rendering



3D model

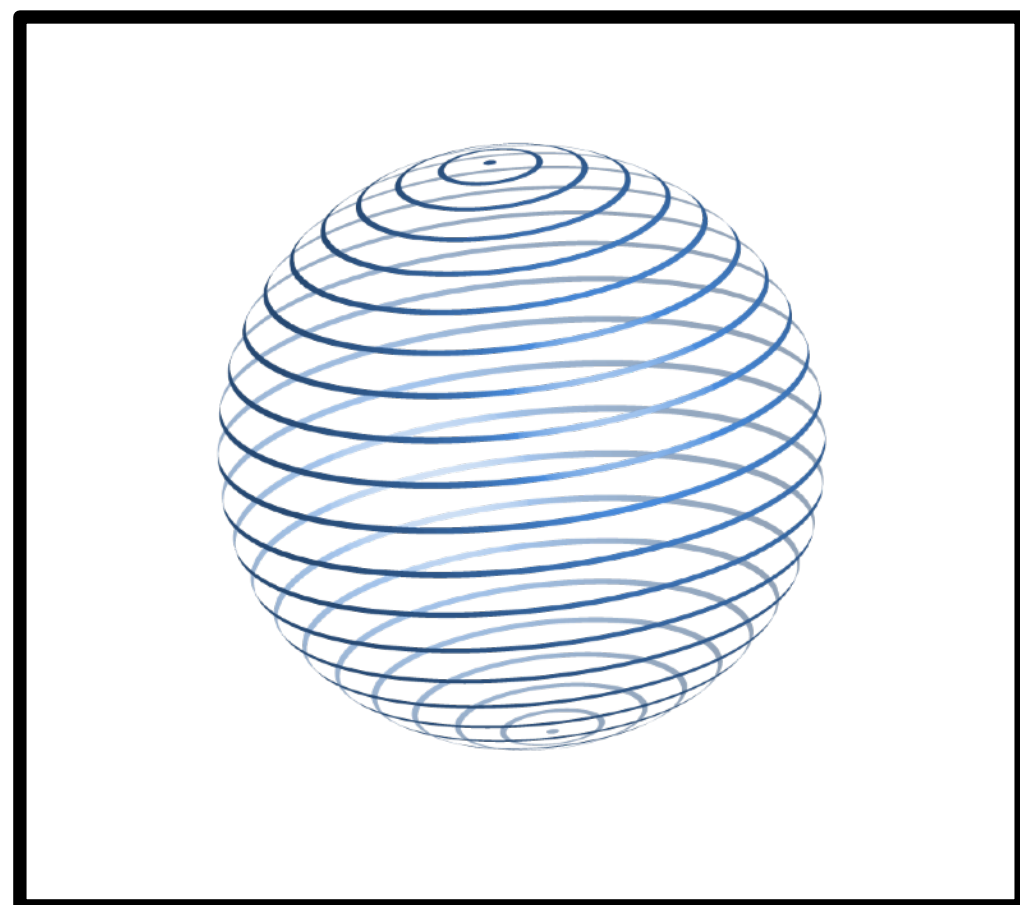


Rendering

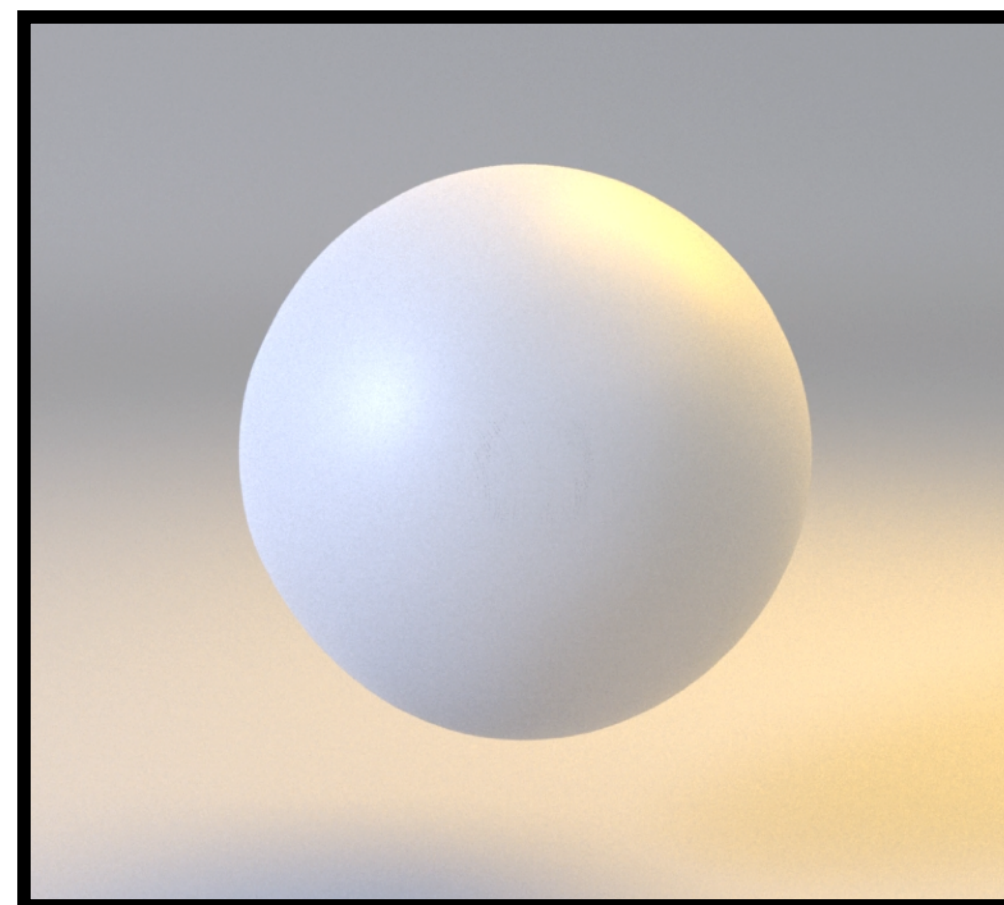


Reference

3D model



Rendering

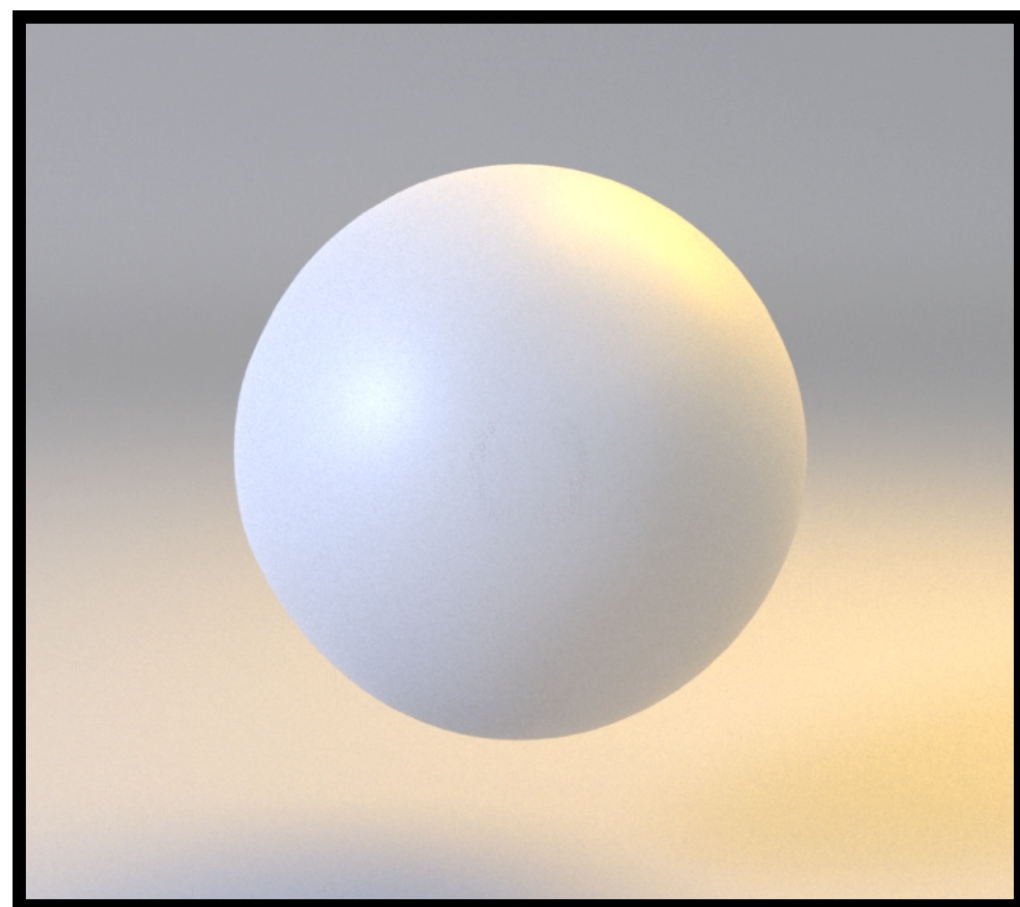


Reference

0.5231

Loss

Rendering



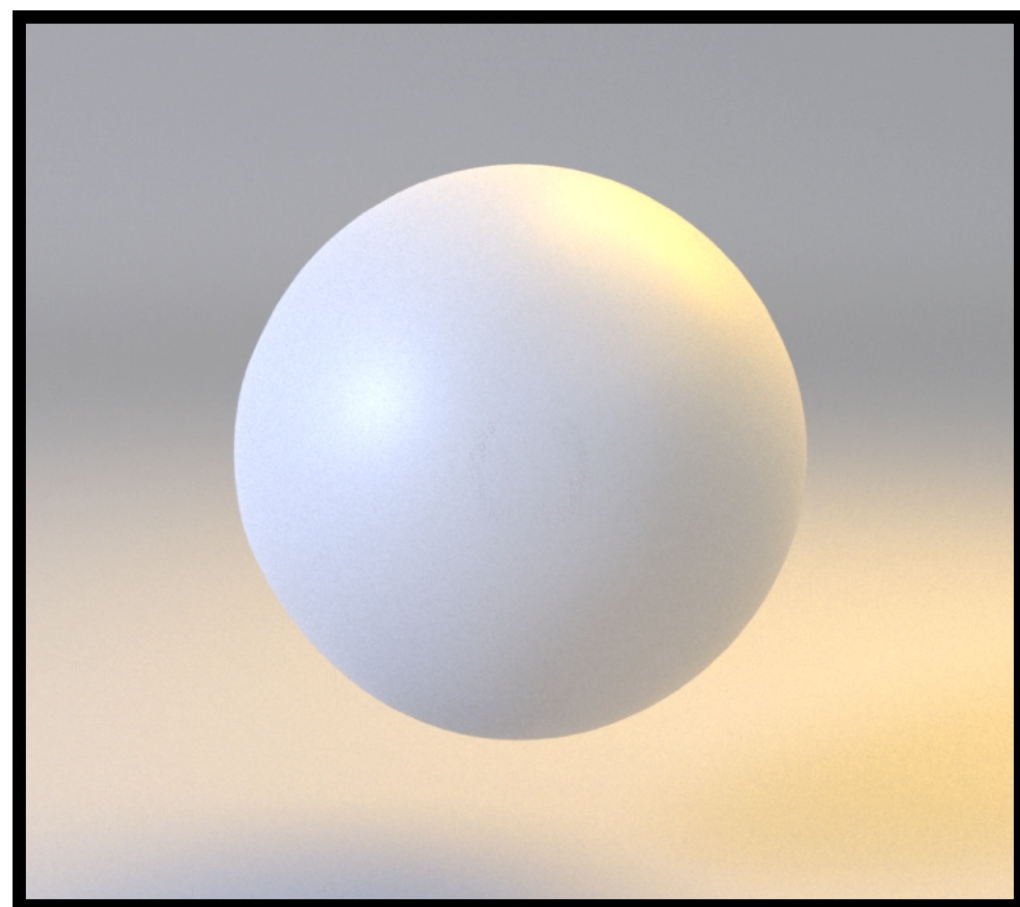
Reference



0.5231

Loss

Rendering

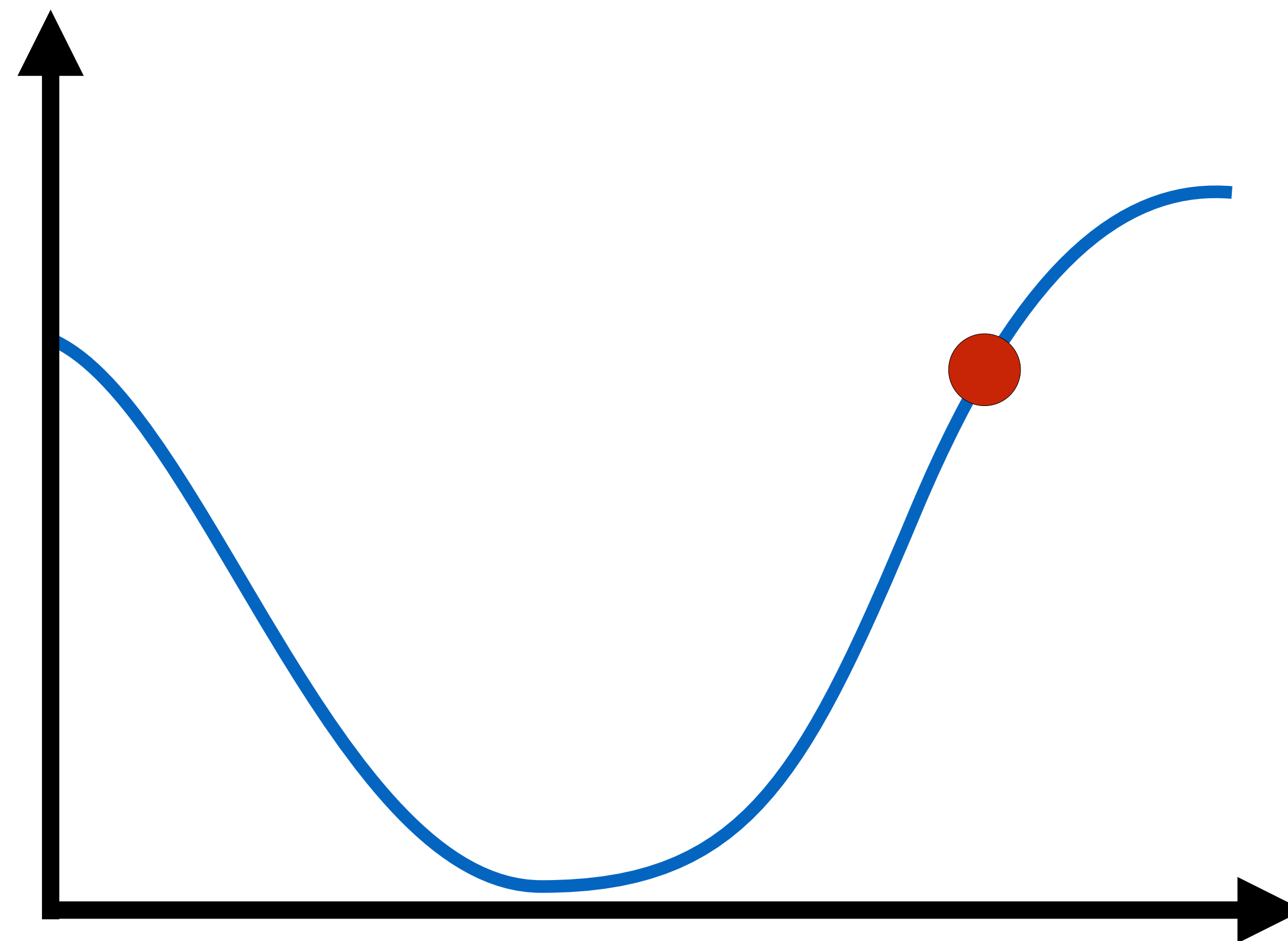


Reference



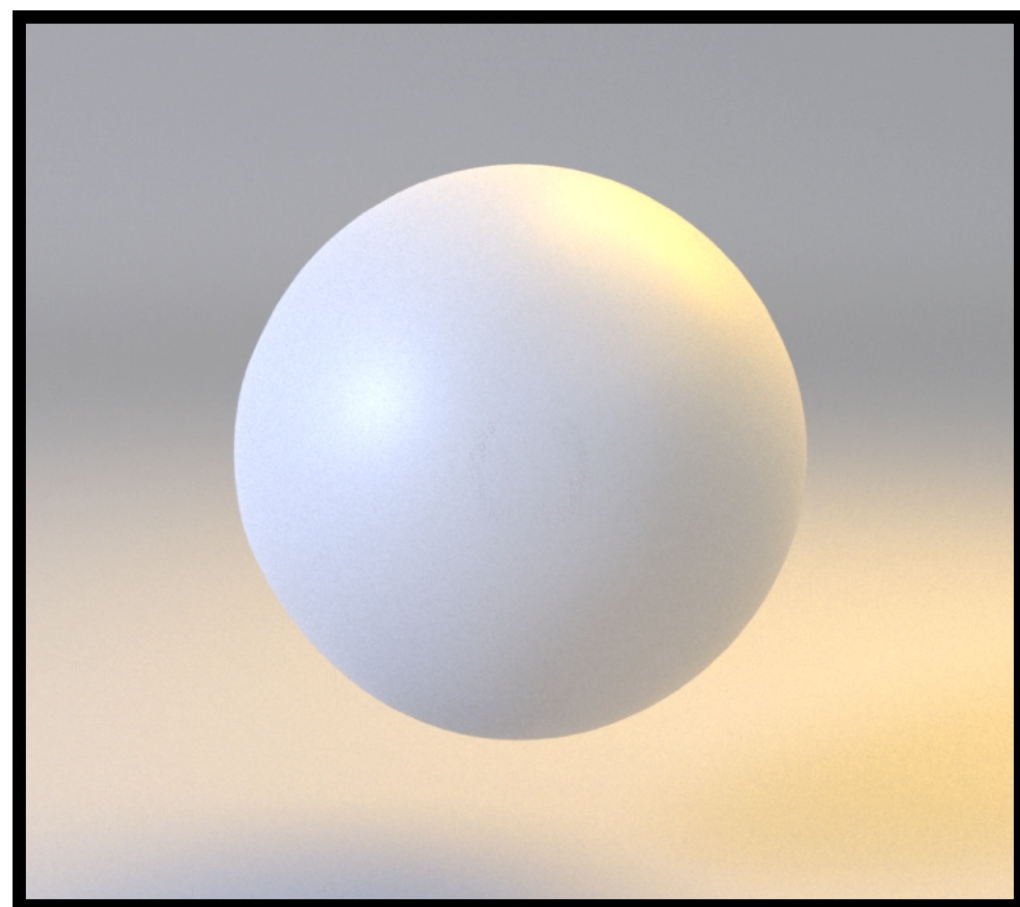
0.5231
Loss

Loss



Chair parameters

Rendering

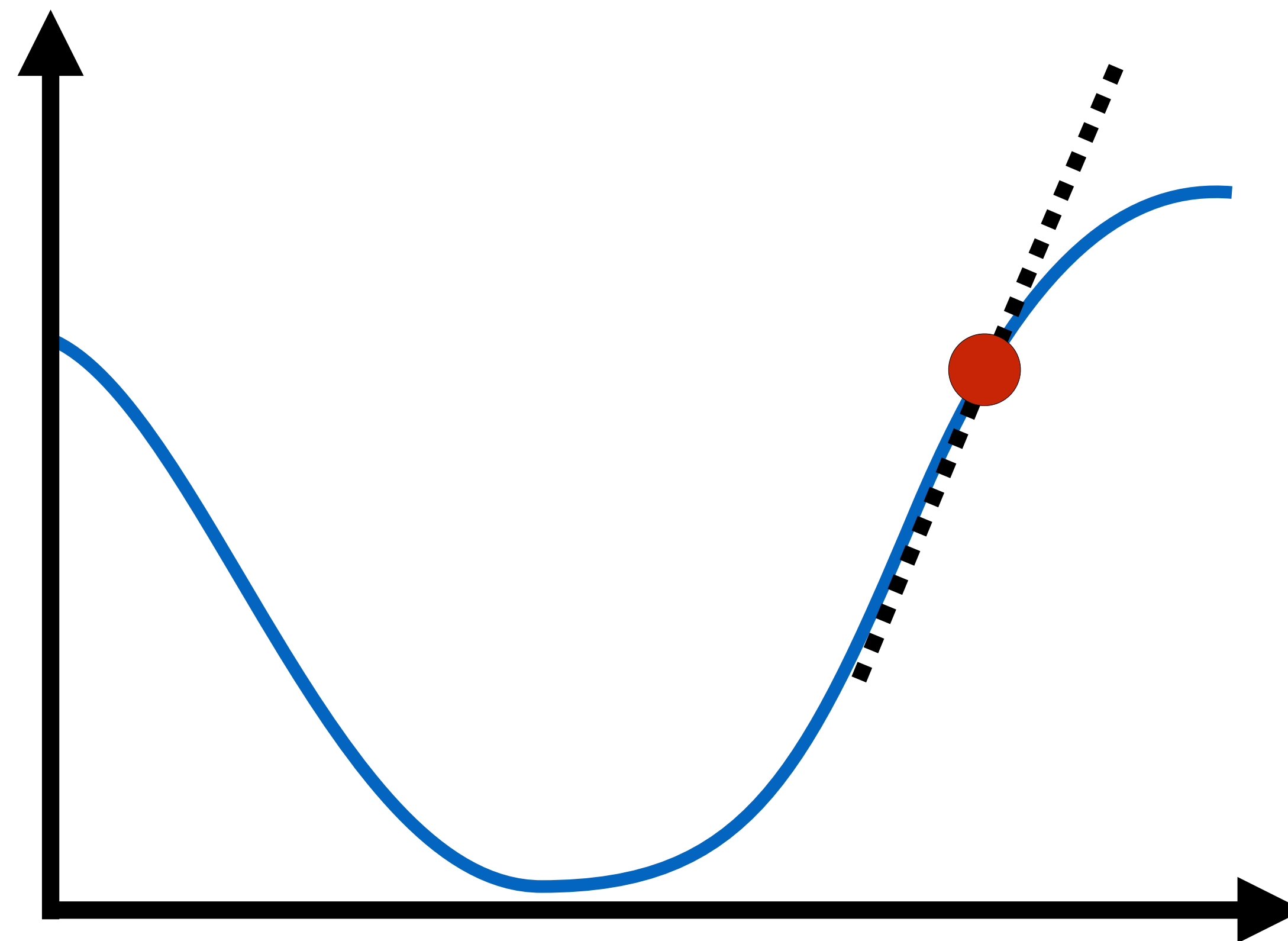


Reference



0.5231
Loss

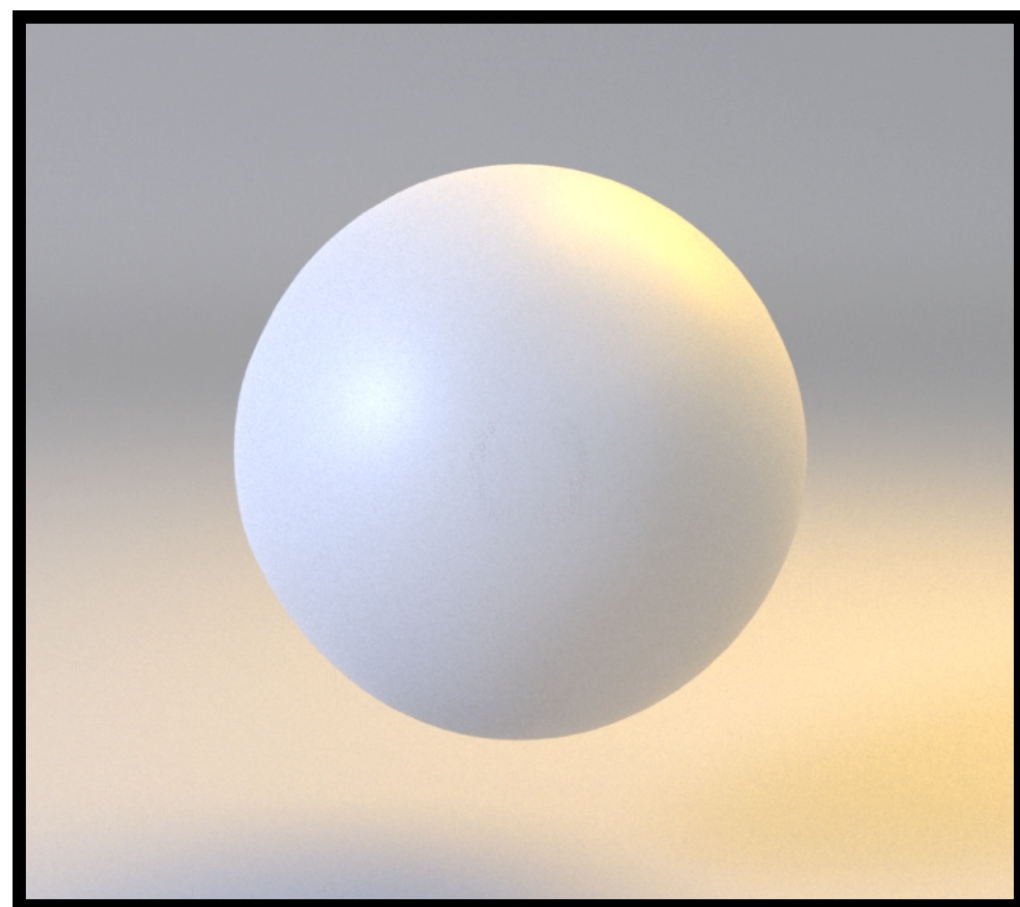
Loss



Chair parameters

[Inspired by a slide by Delio Vicini]

Rendering

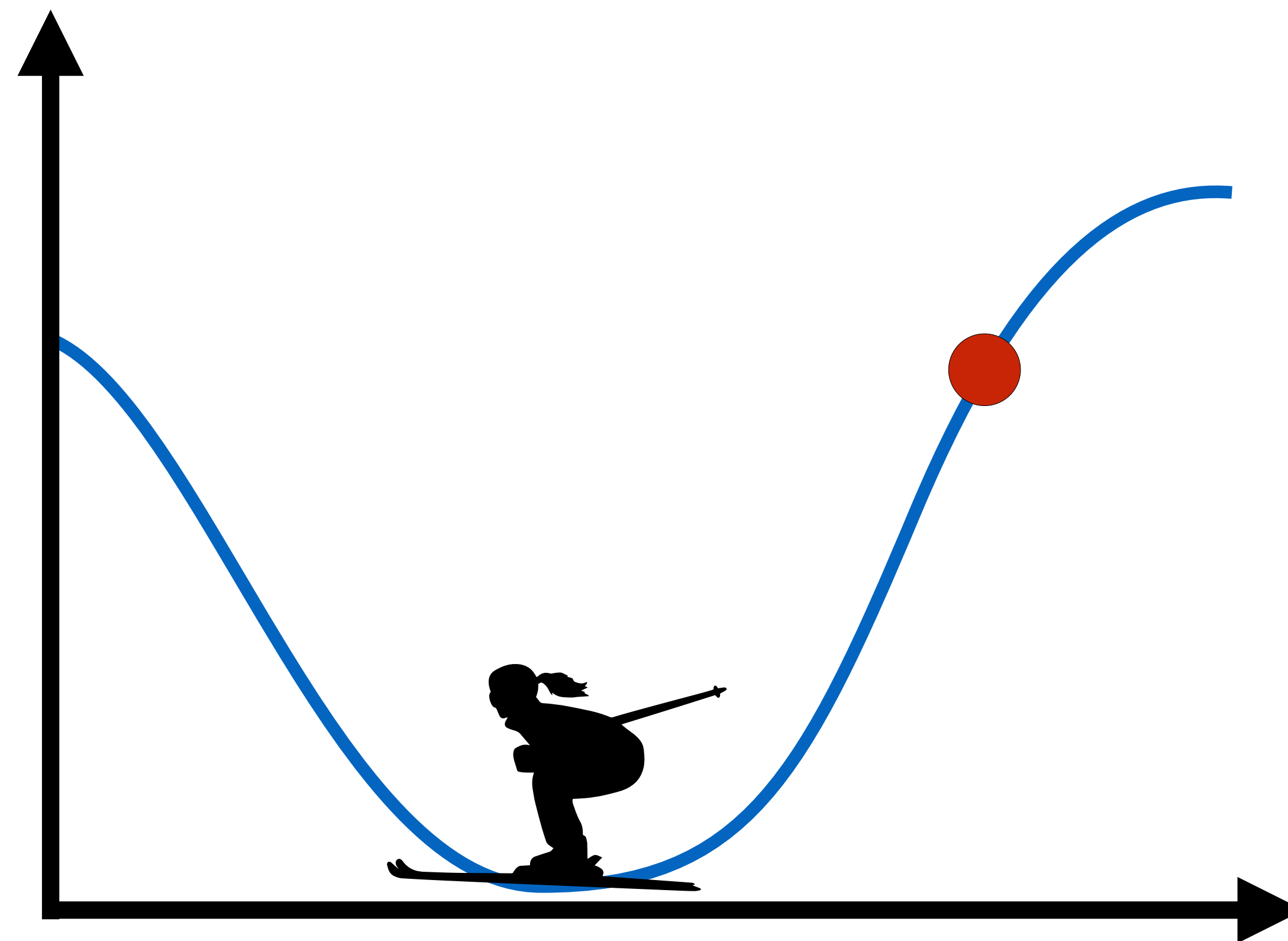


Reference



0.5231
Loss

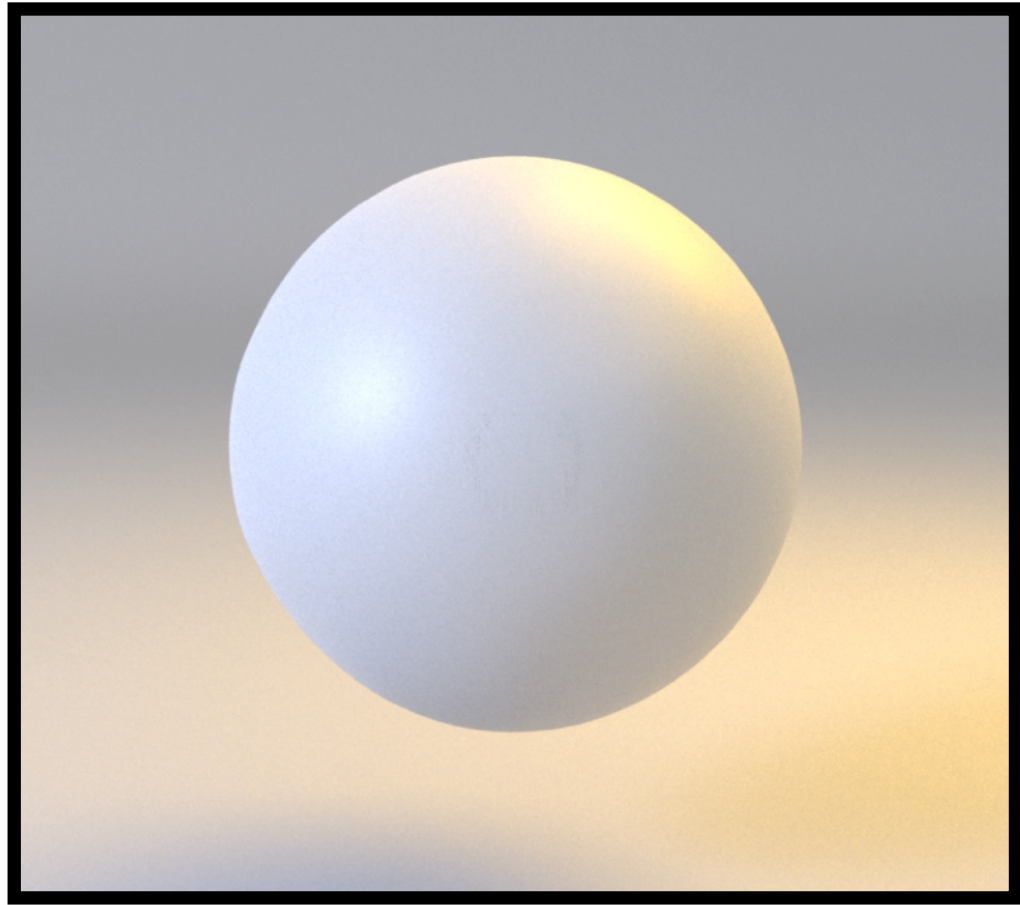
Loss



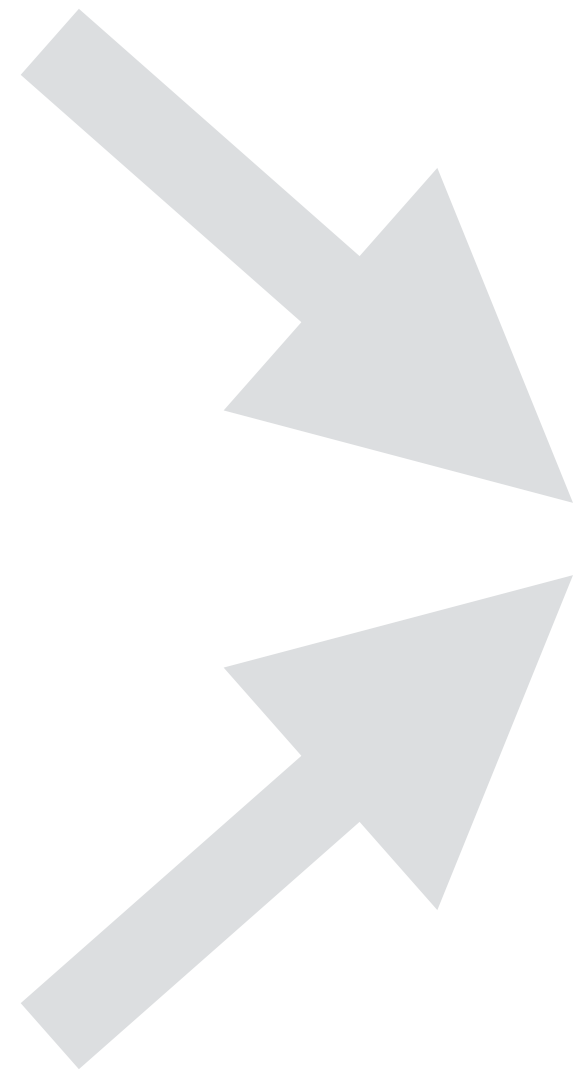
Chair parameters

[Inspired by a slide by Delio Vicini]

Rendering

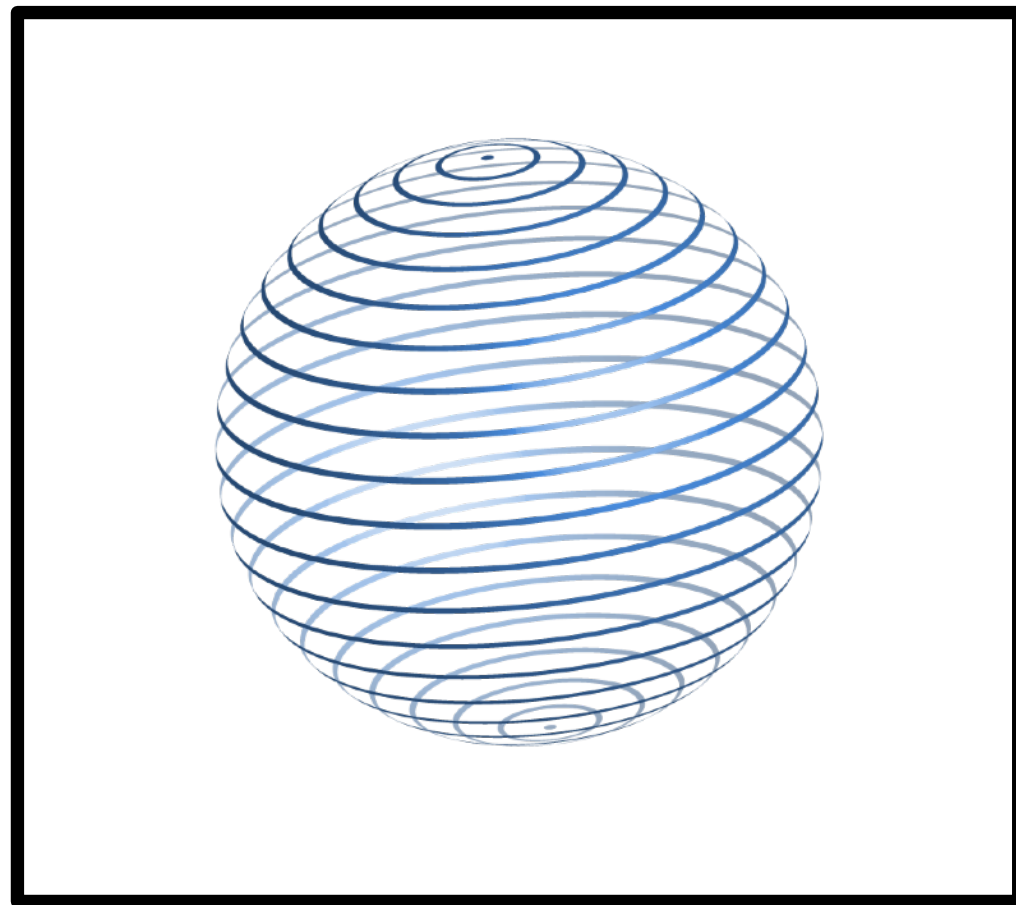


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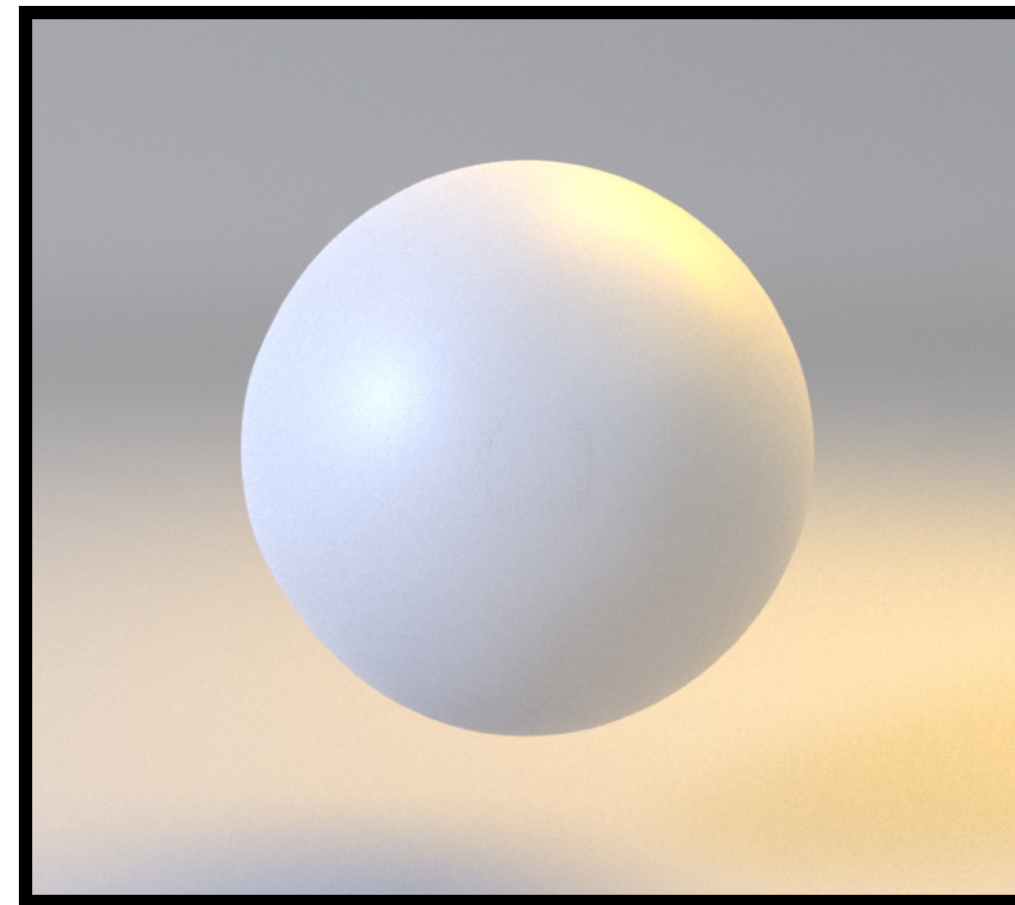


0.5231
Loss

3D model



Rendering

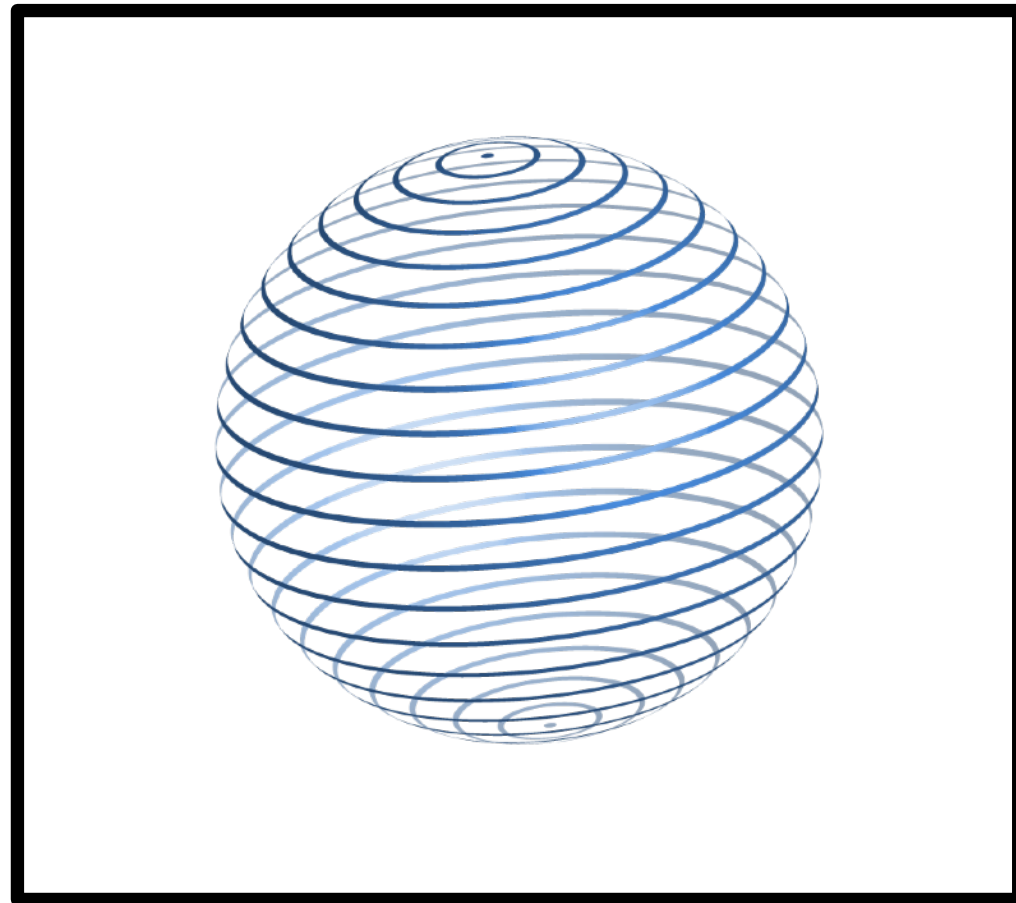


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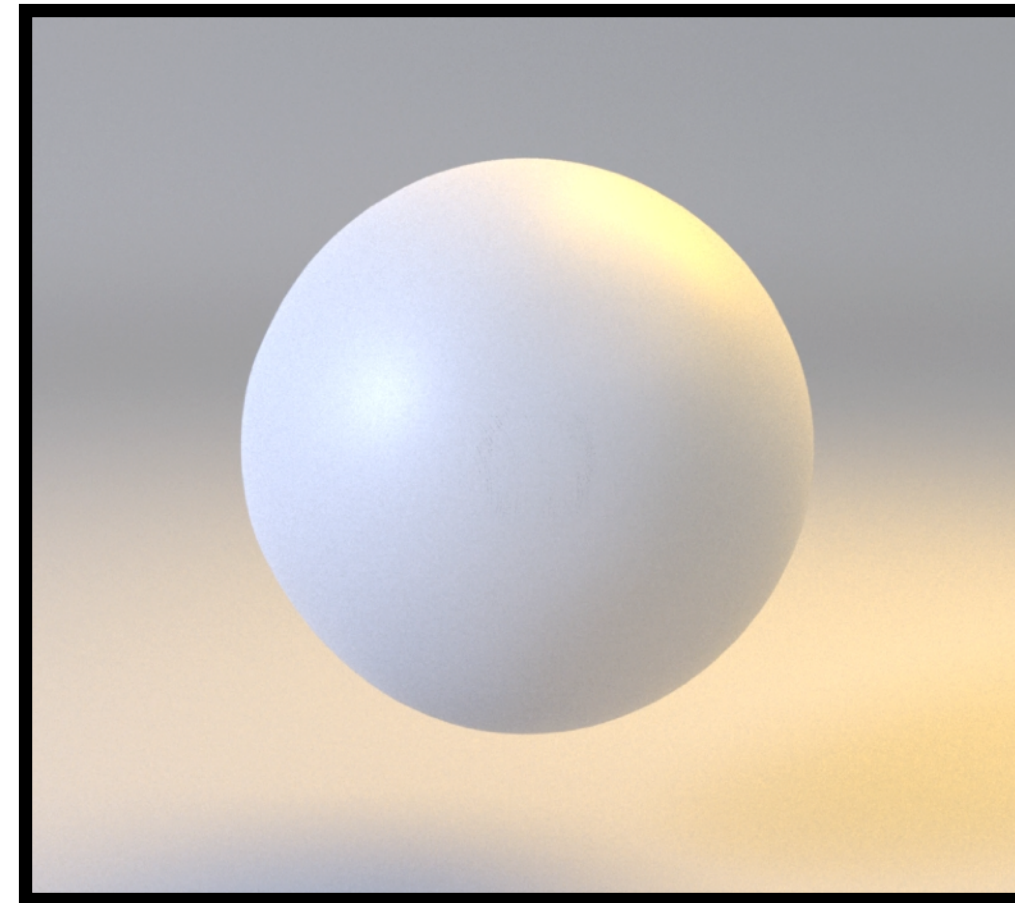
0.5231

Loss

3D model



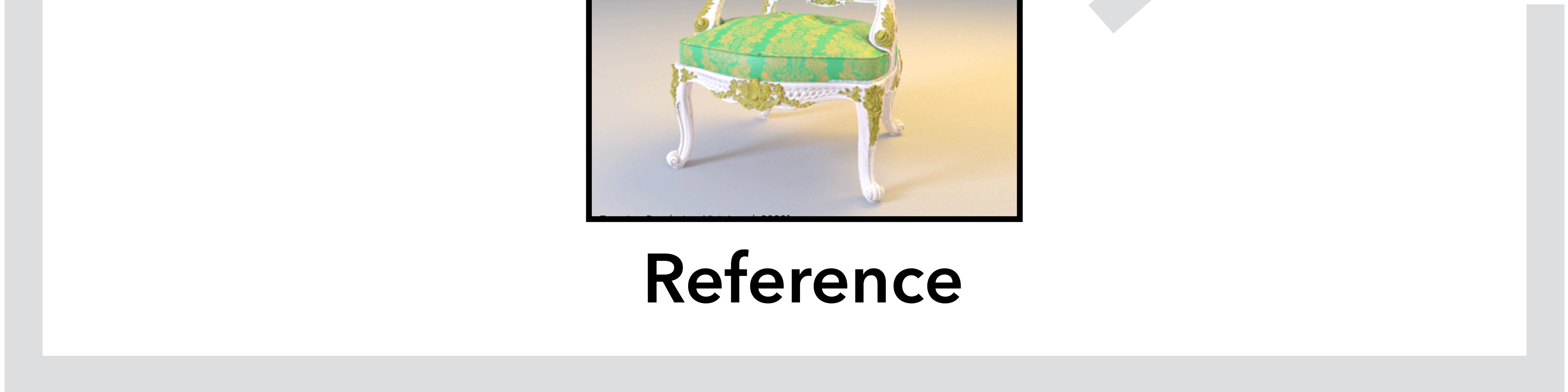
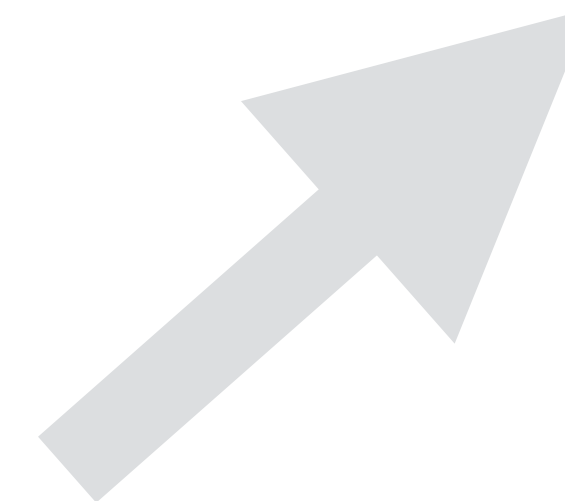
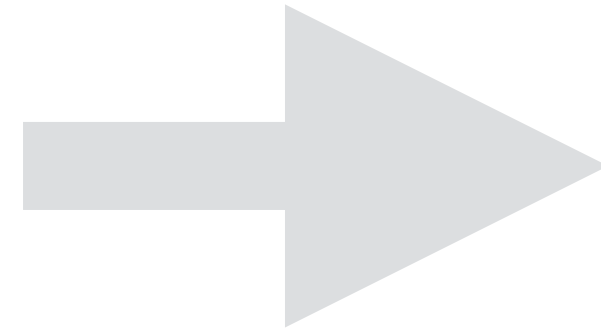
Rendering

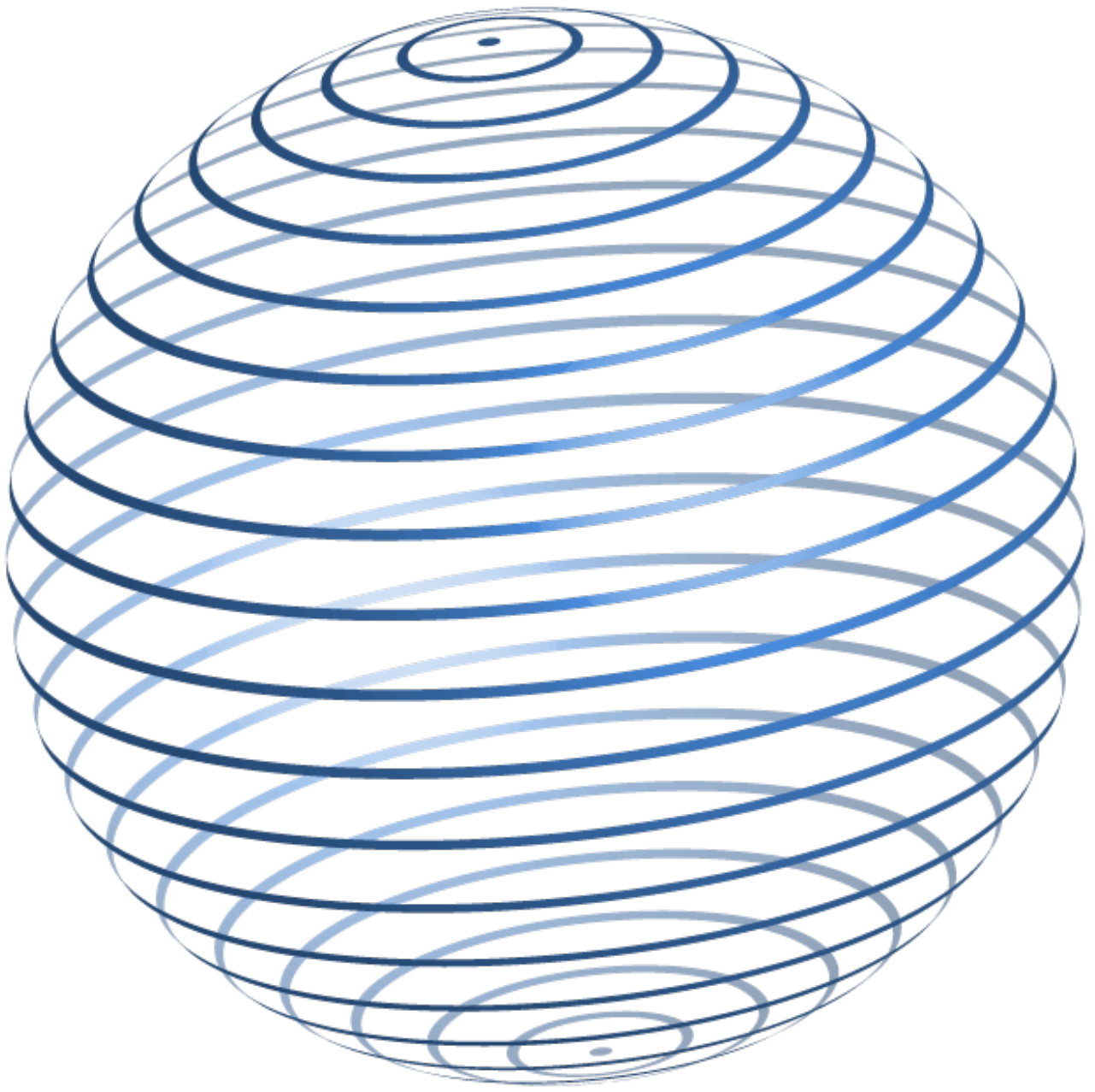


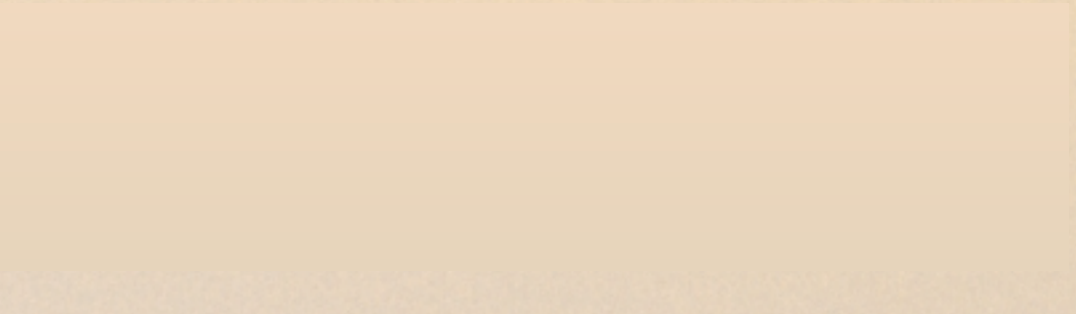
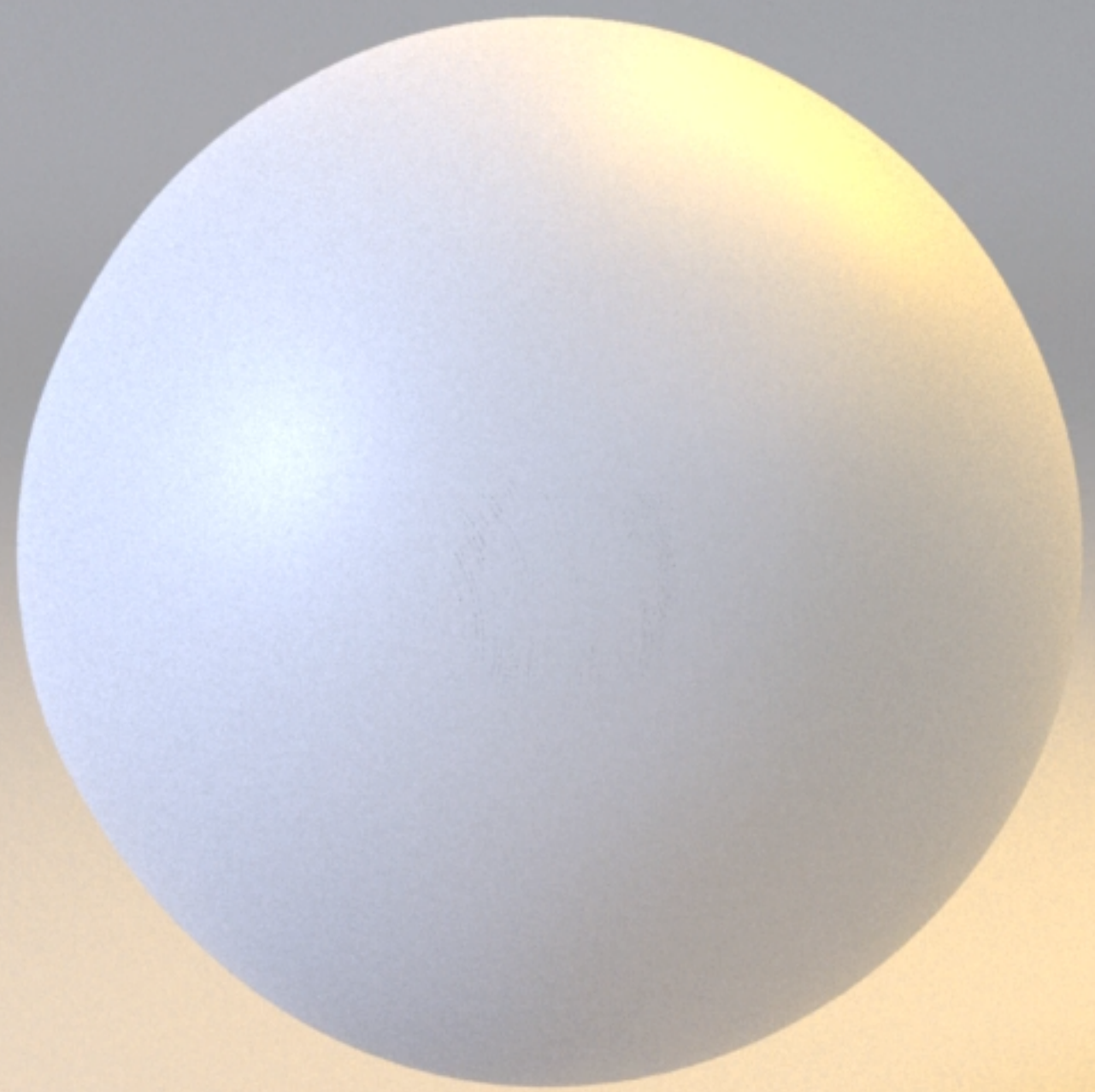
Reference

0.5231

Loss

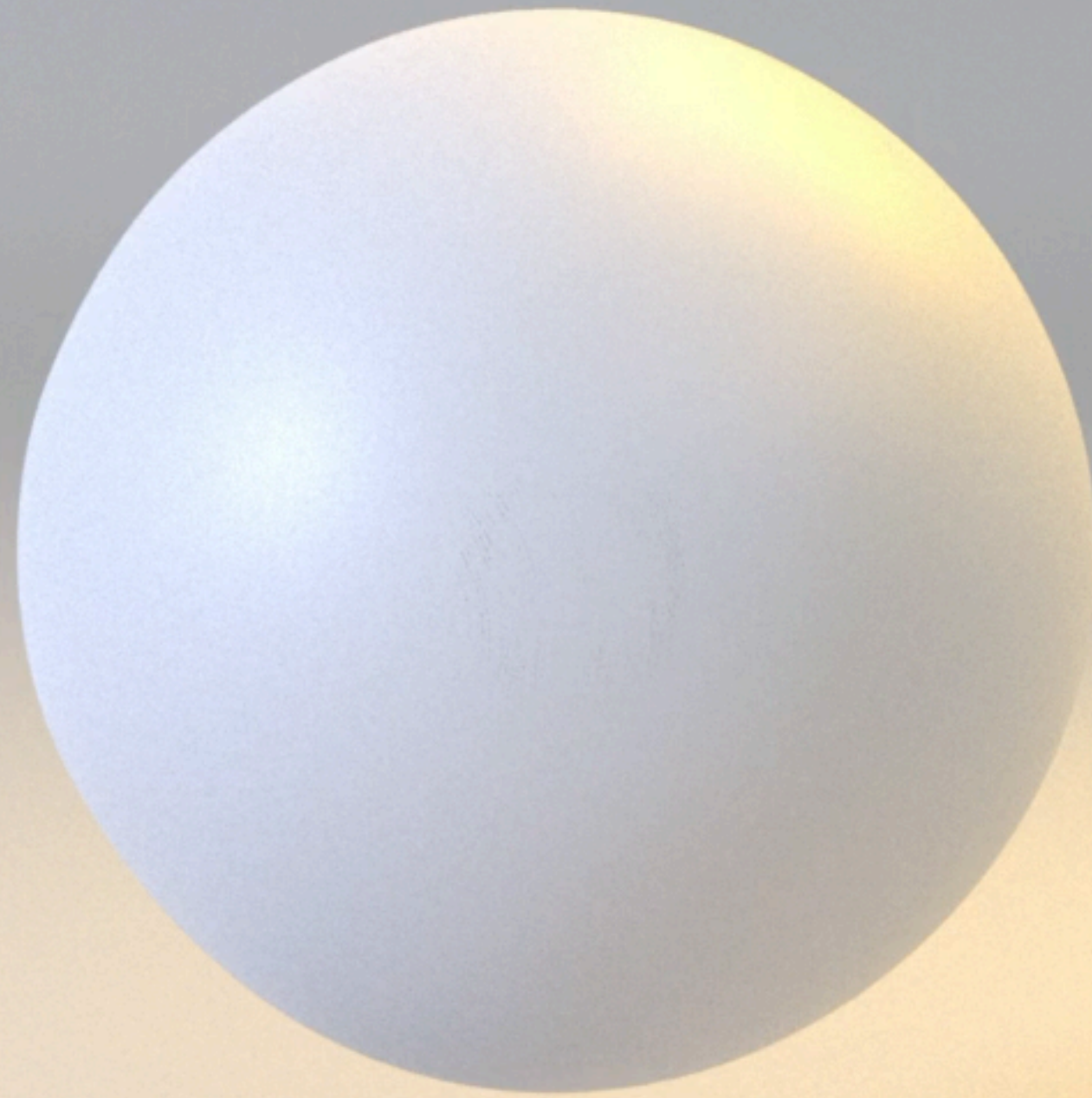






Optimization

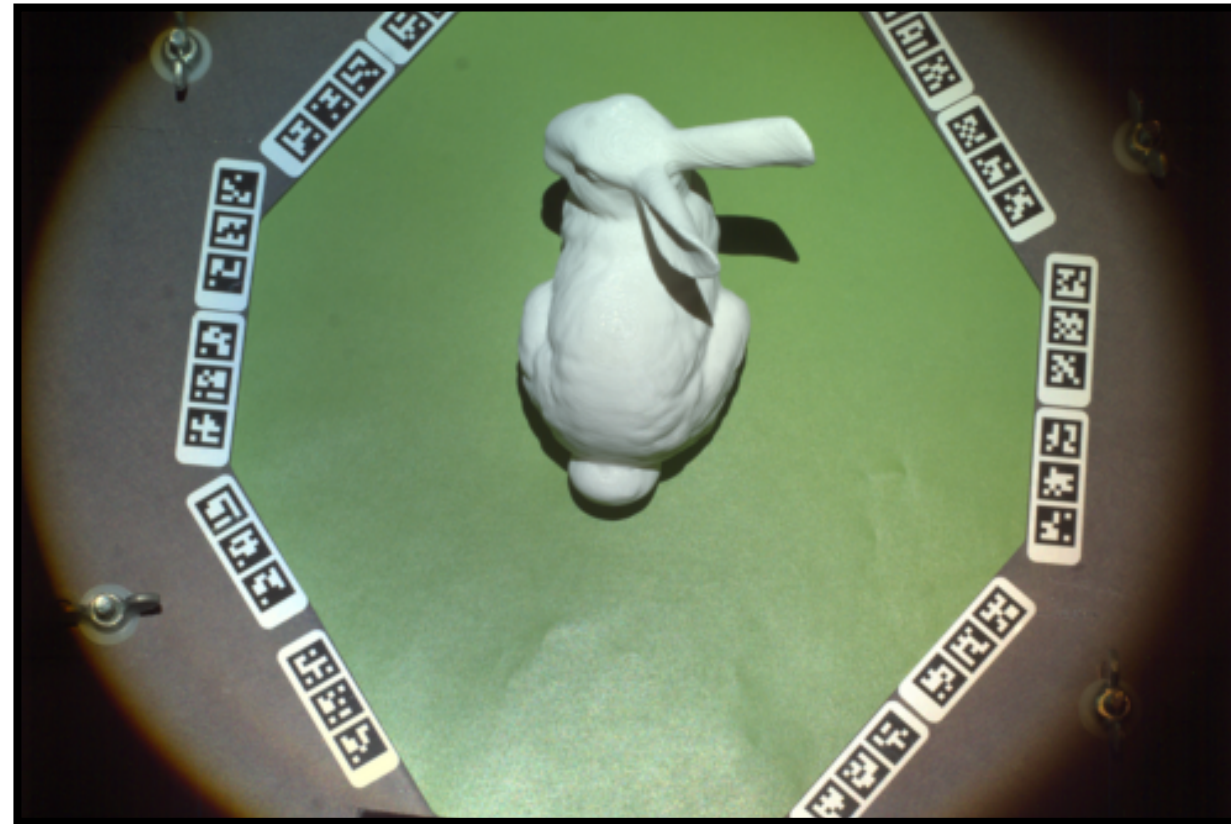
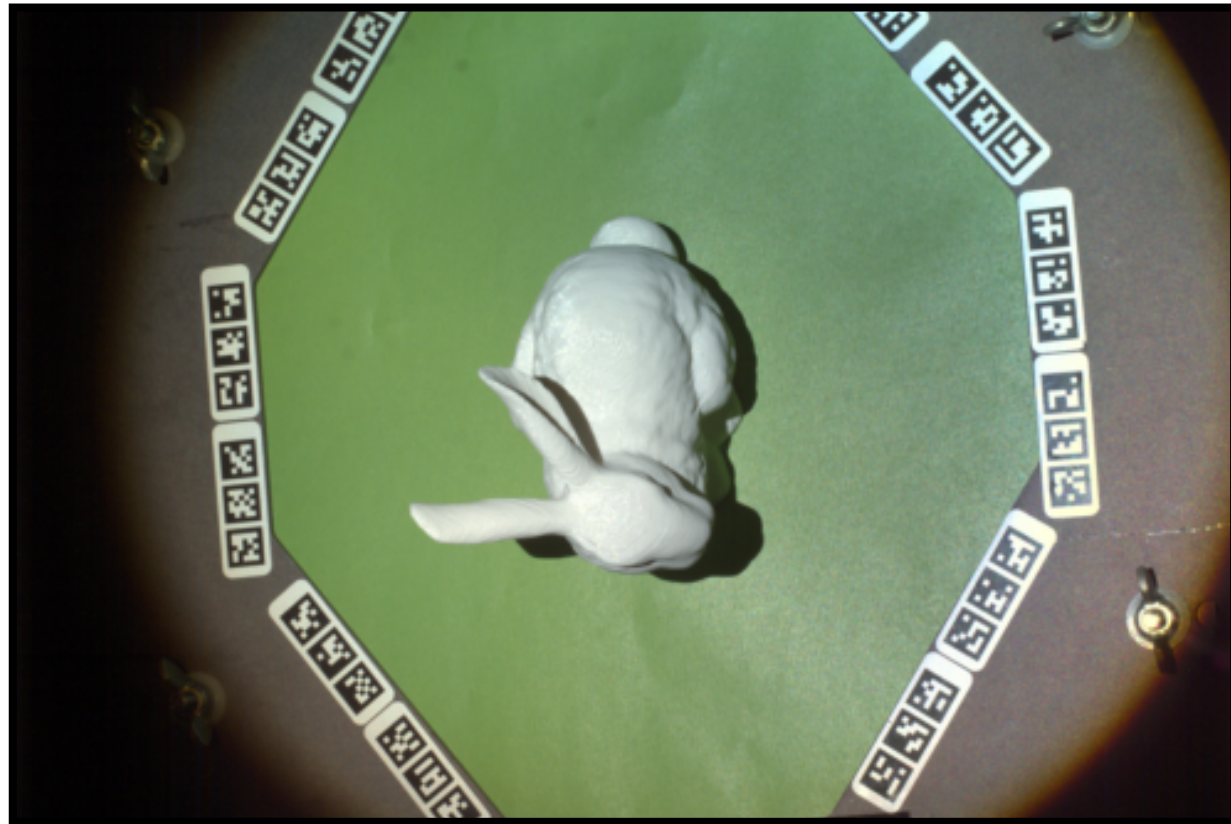
Optimizing shape, albedo
& roughness



Iteration 0

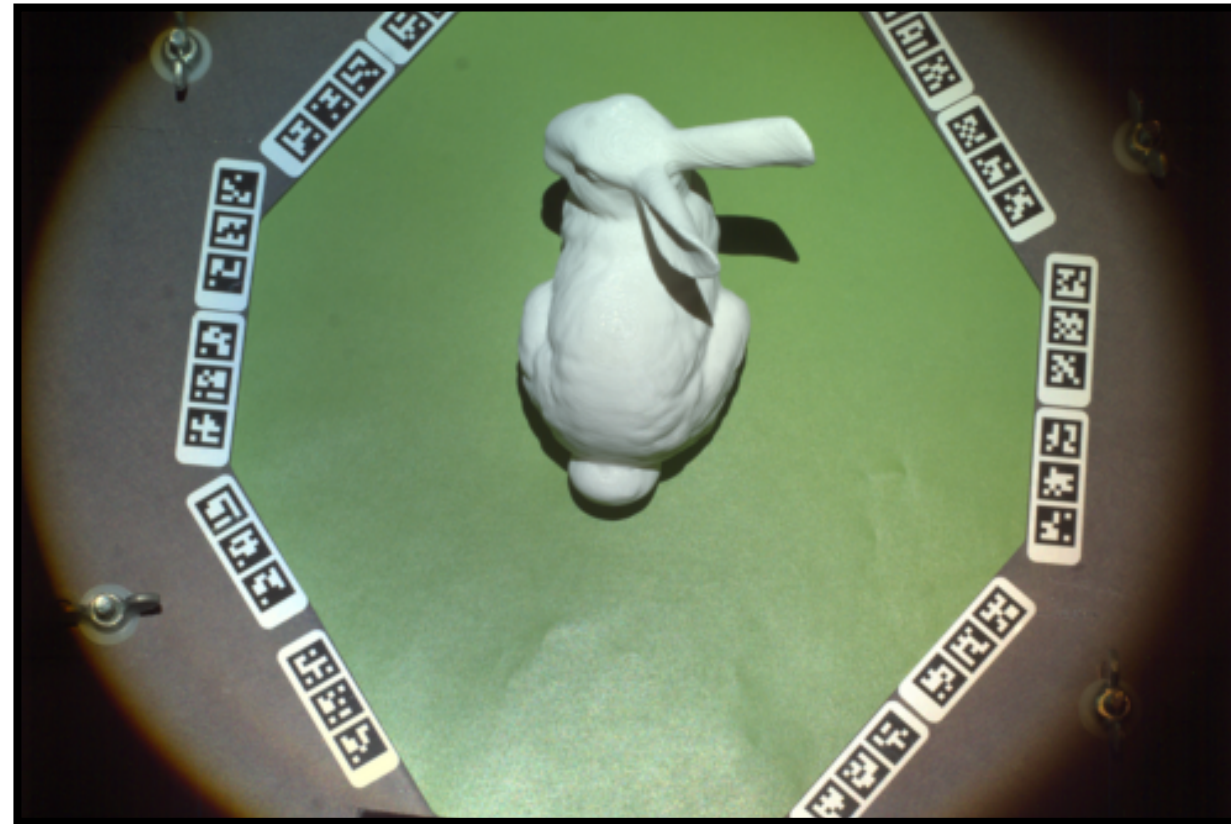
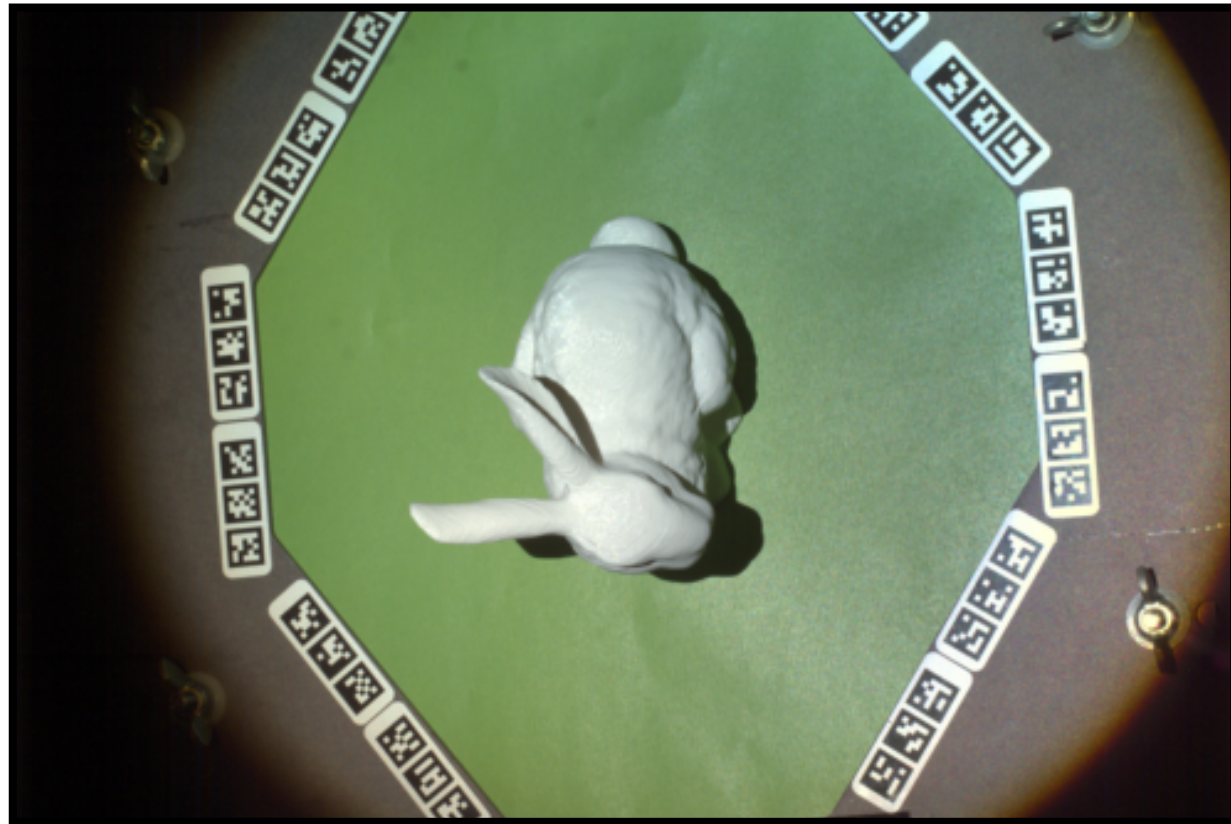
Reconstructing a shape from photos

Photos (4/14 views):



Reconstructing a shape from photos

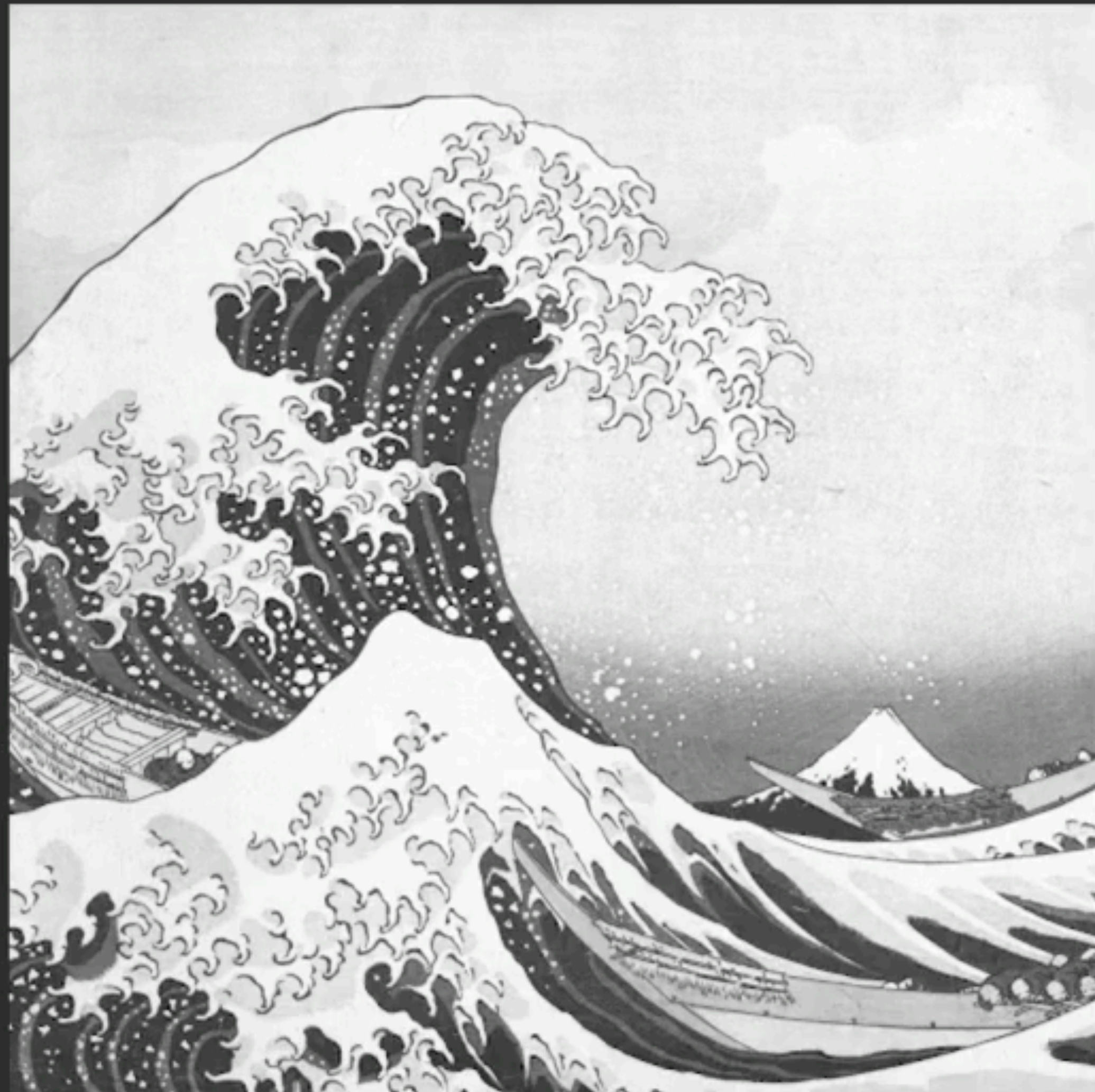
Photos (4/14 views):



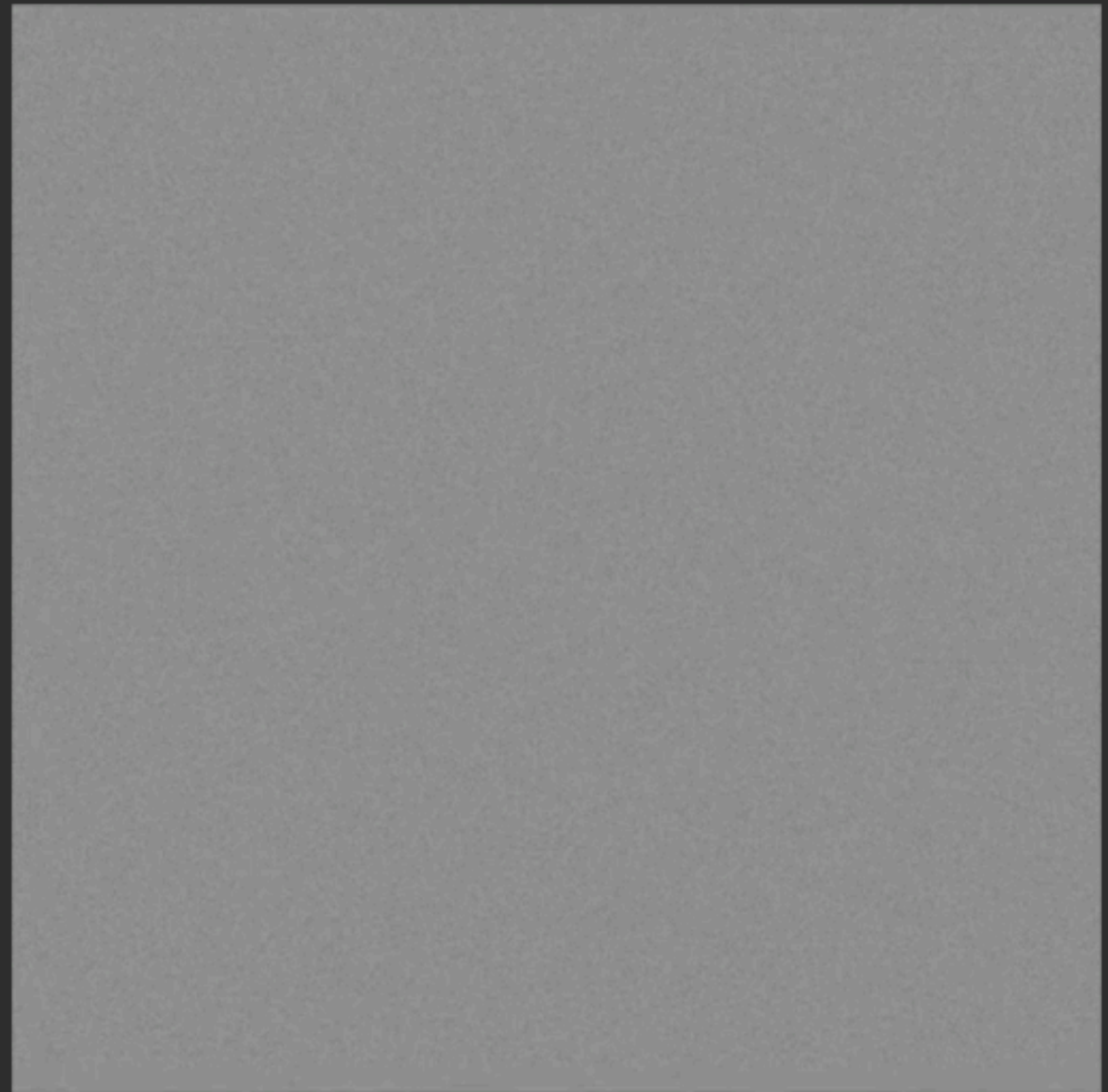
Reconstruction:



Target image

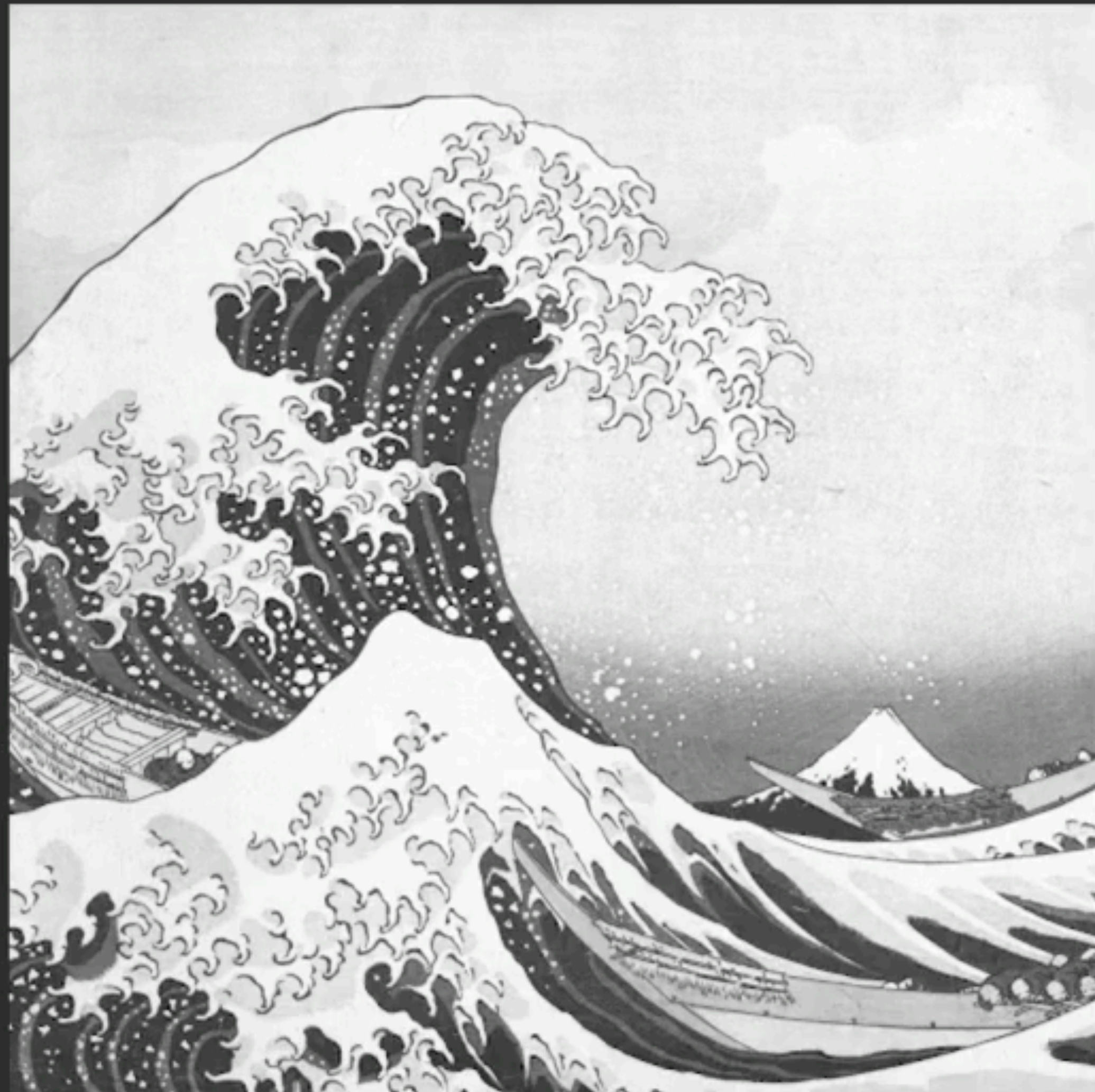


Initial state

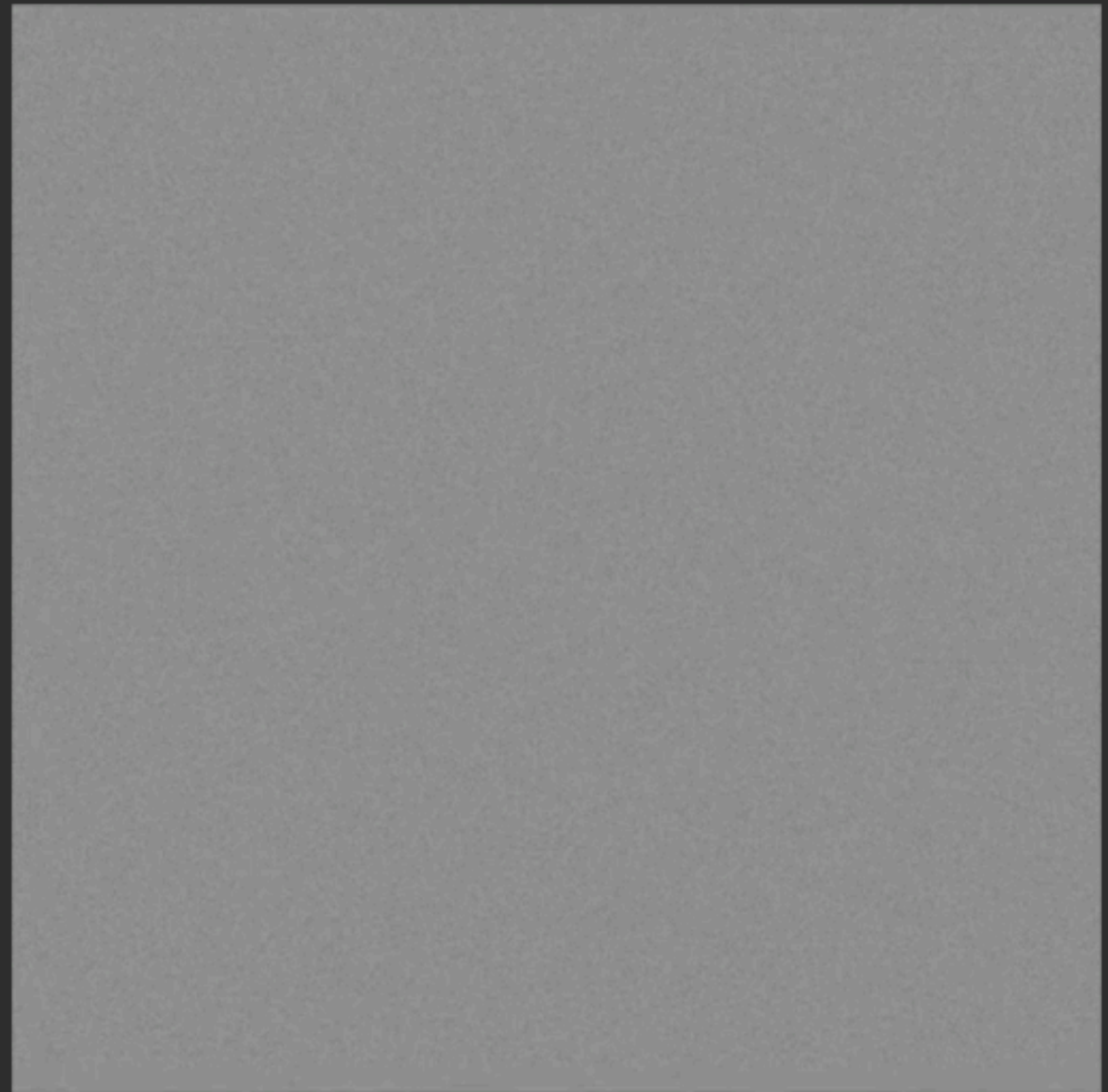


The Great Wave off Kanagawa by Katsushika Hokusai

Target image

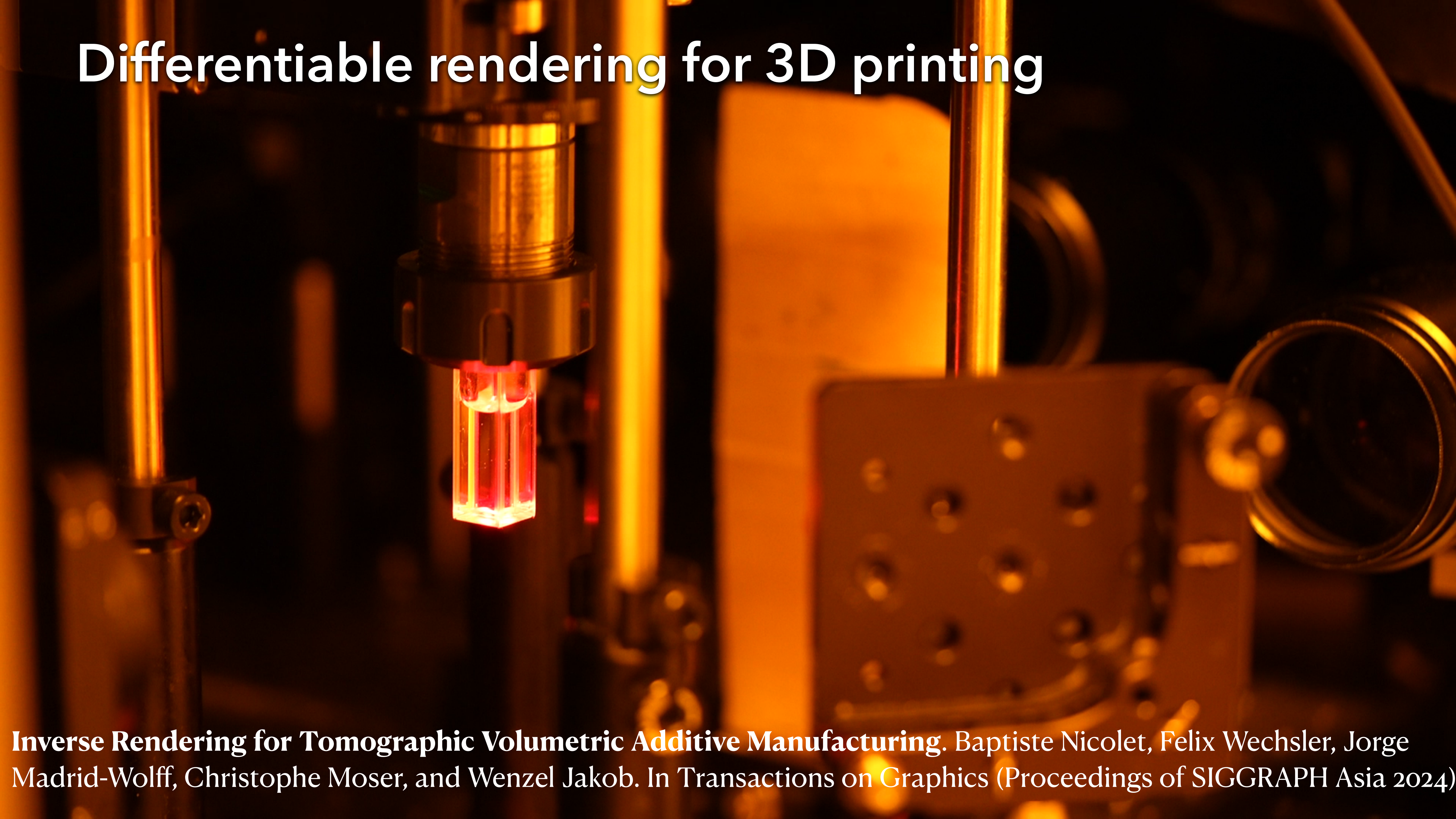


Initial state



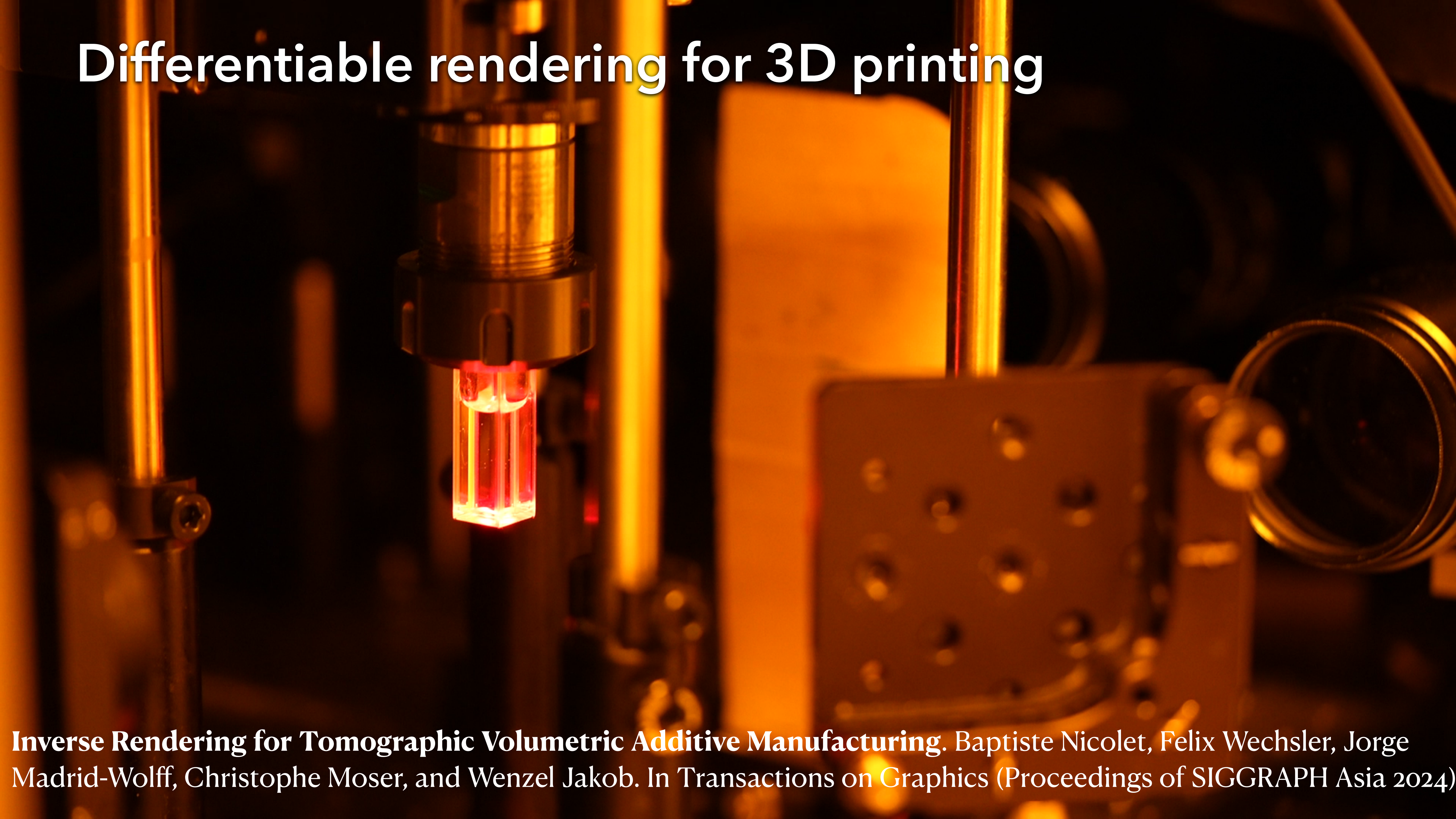
The Great Wave off Kanagawa by Katsushika Hokusai

Differentiable rendering for 3D printing



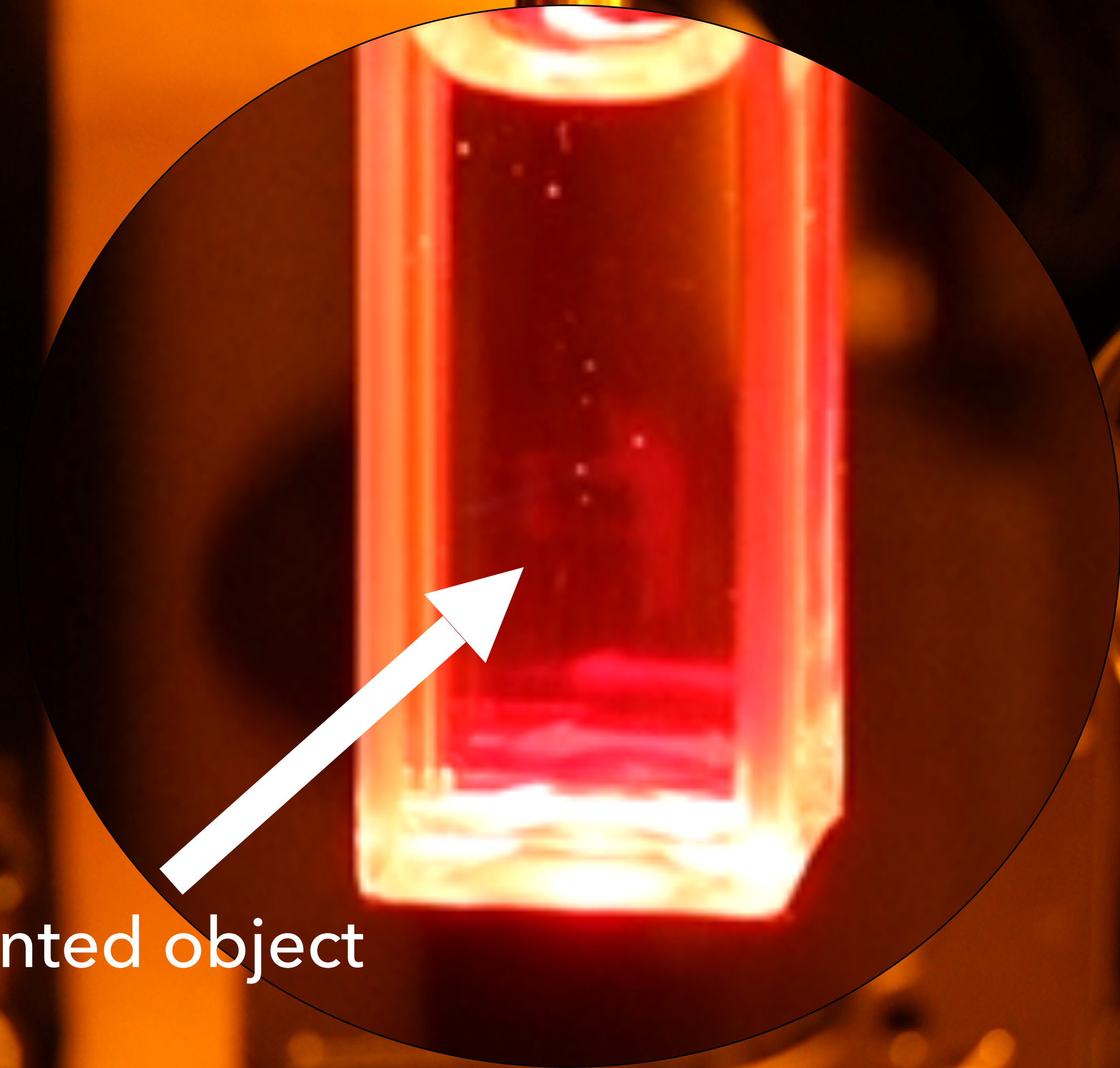
Inverse Rendering for Tomographic Volumetric Additive Manufacturing. Baptiste Nicolet, Felix Wechsler, Jorge Madrid-Wolff, Christophe Moser, and Wenzel Jakob. In Transactions on Graphics (Proceedings of SIGGRAPH Asia 2024)

Differentiable rendering for 3D printing



Inverse Rendering for Tomographic Volumetric Additive Manufacturing. Baptiste Nicolet, Felix Wechsler, Jorge Madrid-Wolff, Christophe Moser, and Wenzel Jakob. In Transactions on Graphics (Proceedings of SIGGRAPH Asia 2024)

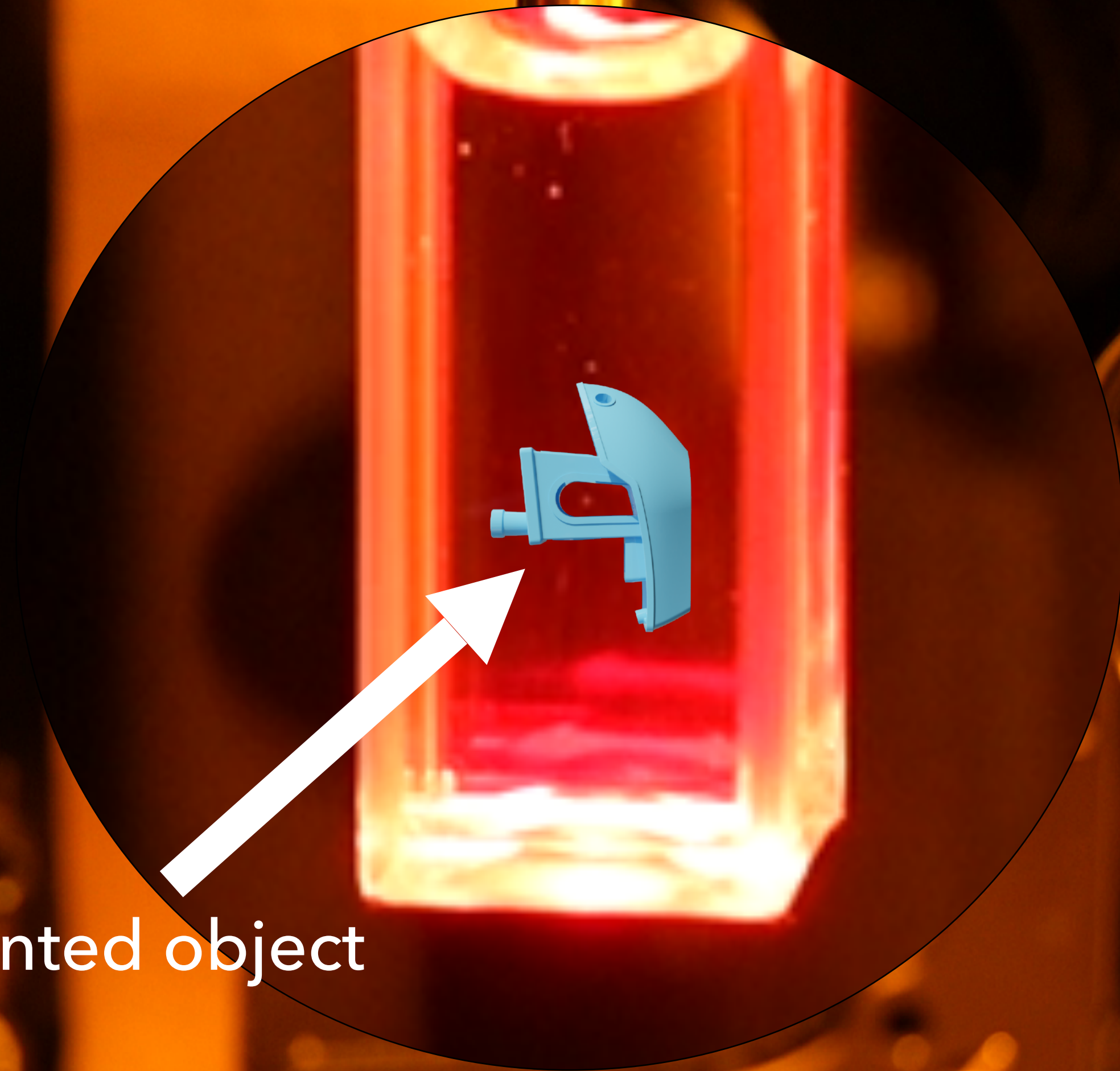
Differentiable rendering for 3D printing



Printed object

Inverse Rendering for Tomographic Volumetric Additive Manufacturing. Baptiste Nicolet, Felix Wechsler, Jorge Madrid-Wolff, Christophe Moser, and Wenzel Jakob. In Transactions on Graphics (Proceedings of SIGGRAPH Asia 2024)

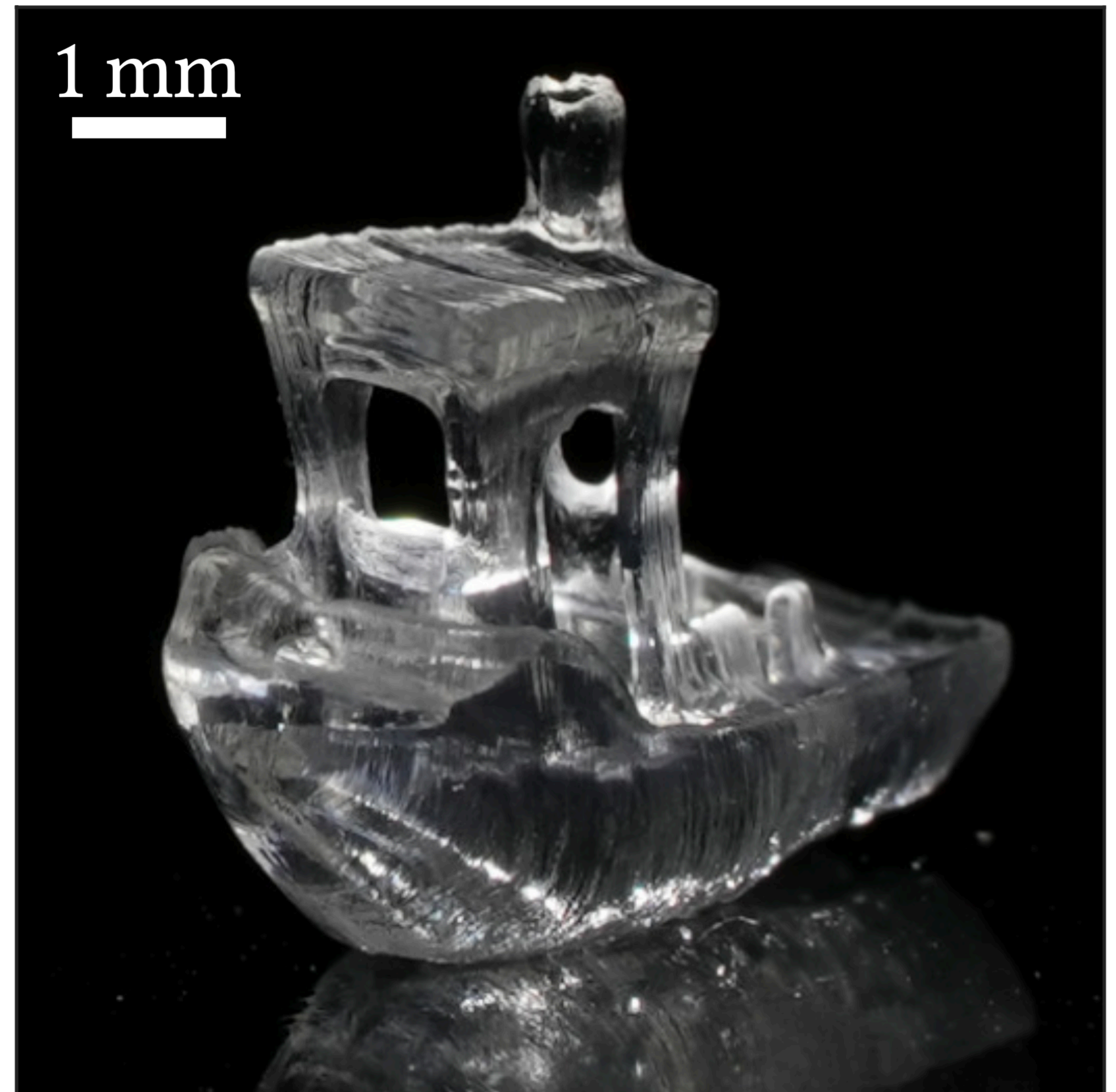
Differentiable rendering for 3D printing



Printed object

Inverse Rendering for Tomographic Volumetric Additive Manufacturing. Baptiste Nicolet, Felix Wechsler, Jorge Madrid-Wolff, Christophe Moser, and Wenzel Jakob. In Transactions on Graphics (Proceedings of SIGGRAPH Asia 2024)

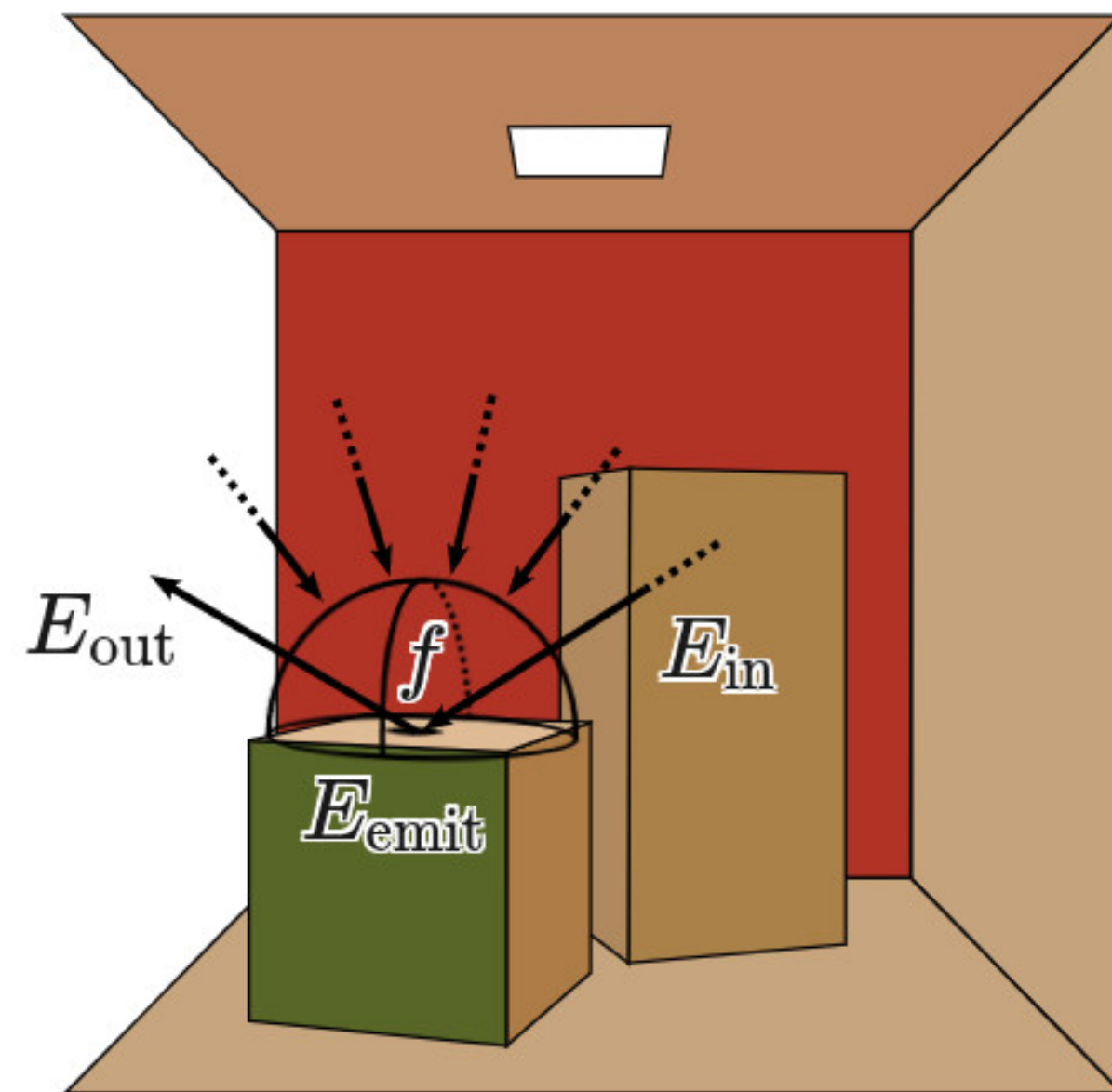
Tomographic print



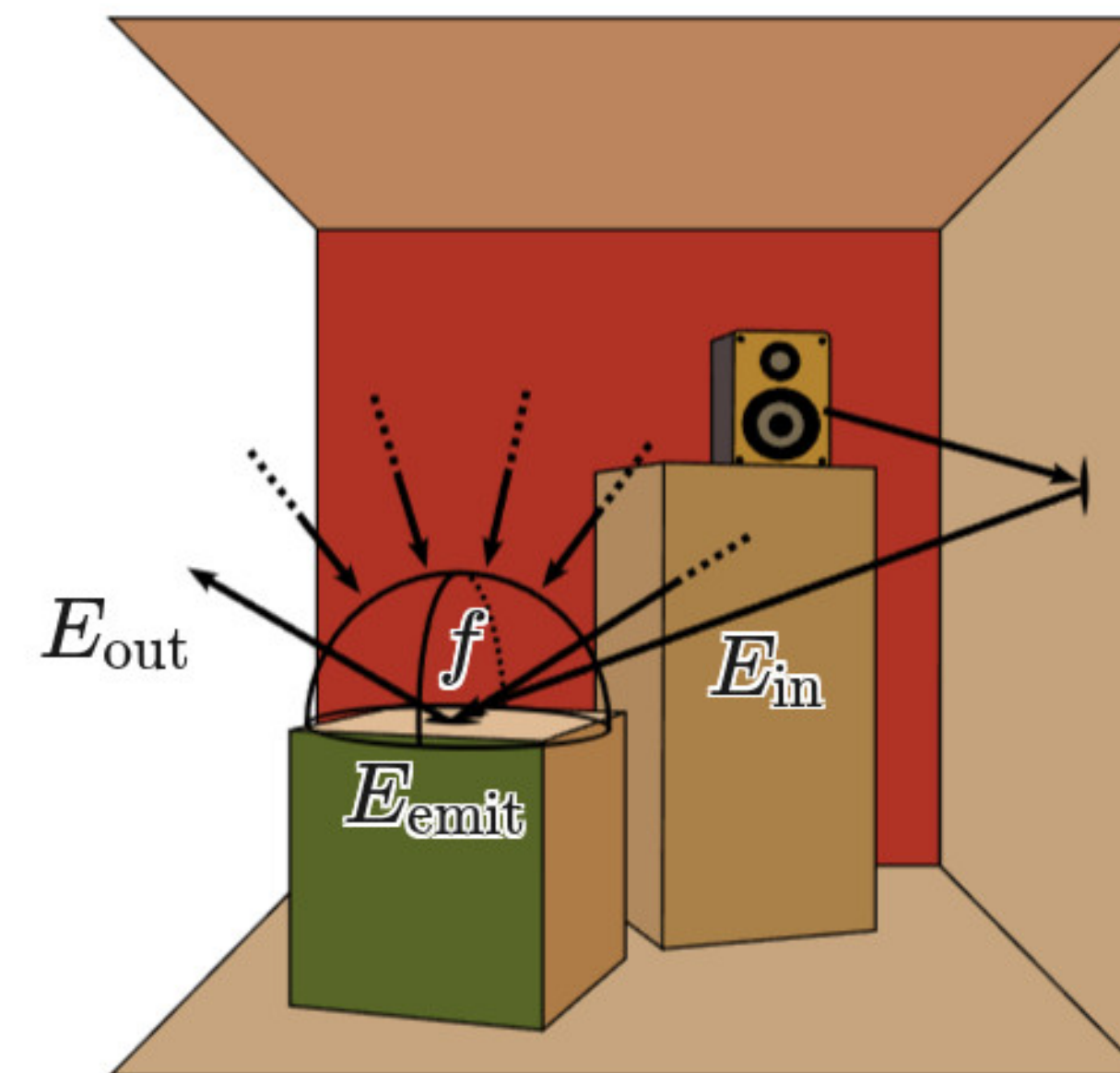
Differentiable rendering for acoustics

Rendering Equations

Light



Sound



Differentiable rendering for acoustics

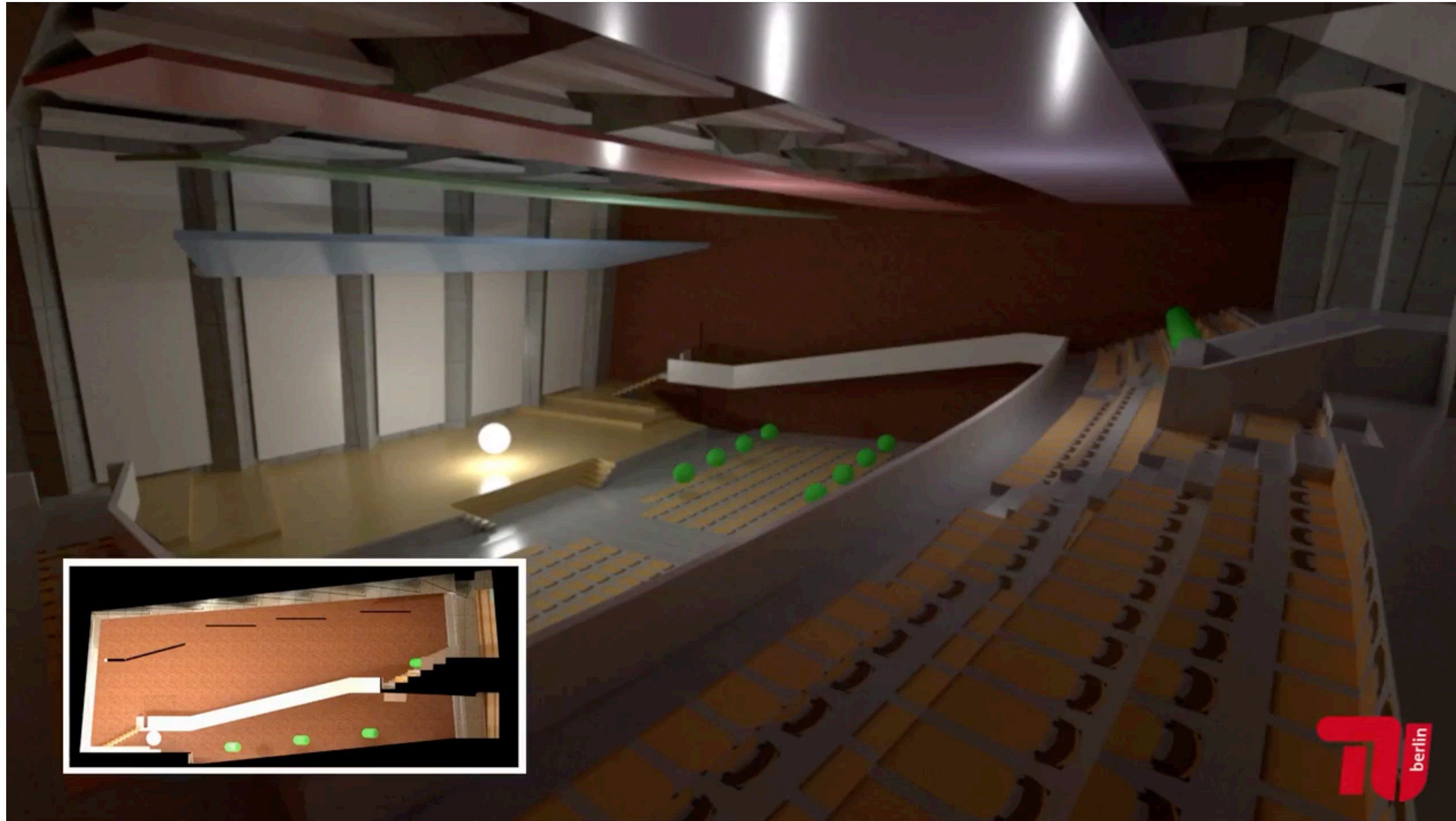


Simulation



Derivative

Differentiable rendering for acoustics



Differentiable geometric acoustic path tracing using time-resolved path replay backpropagation. Finnendahl, U., Worchel, M., Jüterbock, T., Wujecki, D., Brinkmann, F., Weinzierl, S., & Alexa, M. (2025). ACM Transactions on Graphics, 44(4). <https://doi.org/10.1145/3730900>

**Mitsuba for architectural
daylighting?**

▼ Mitsuba Controls

▼ Scene

Reload Scene

Current: scene.xml

▼ Rendering

Render

FPS: 60.0 (16.67 ms)

Samples: 2304/8192

32

SPP per frame

8192

Max SPP

✓

Use Optix Denoiser

✓

Render Irradiance Meter

Render Derivatives

Reset

Irradiance screenshot

▼ Sun-sky model

480

Time (8:00)

▼ Camera

Turntable

▼ Navigation Style

Reset Camera

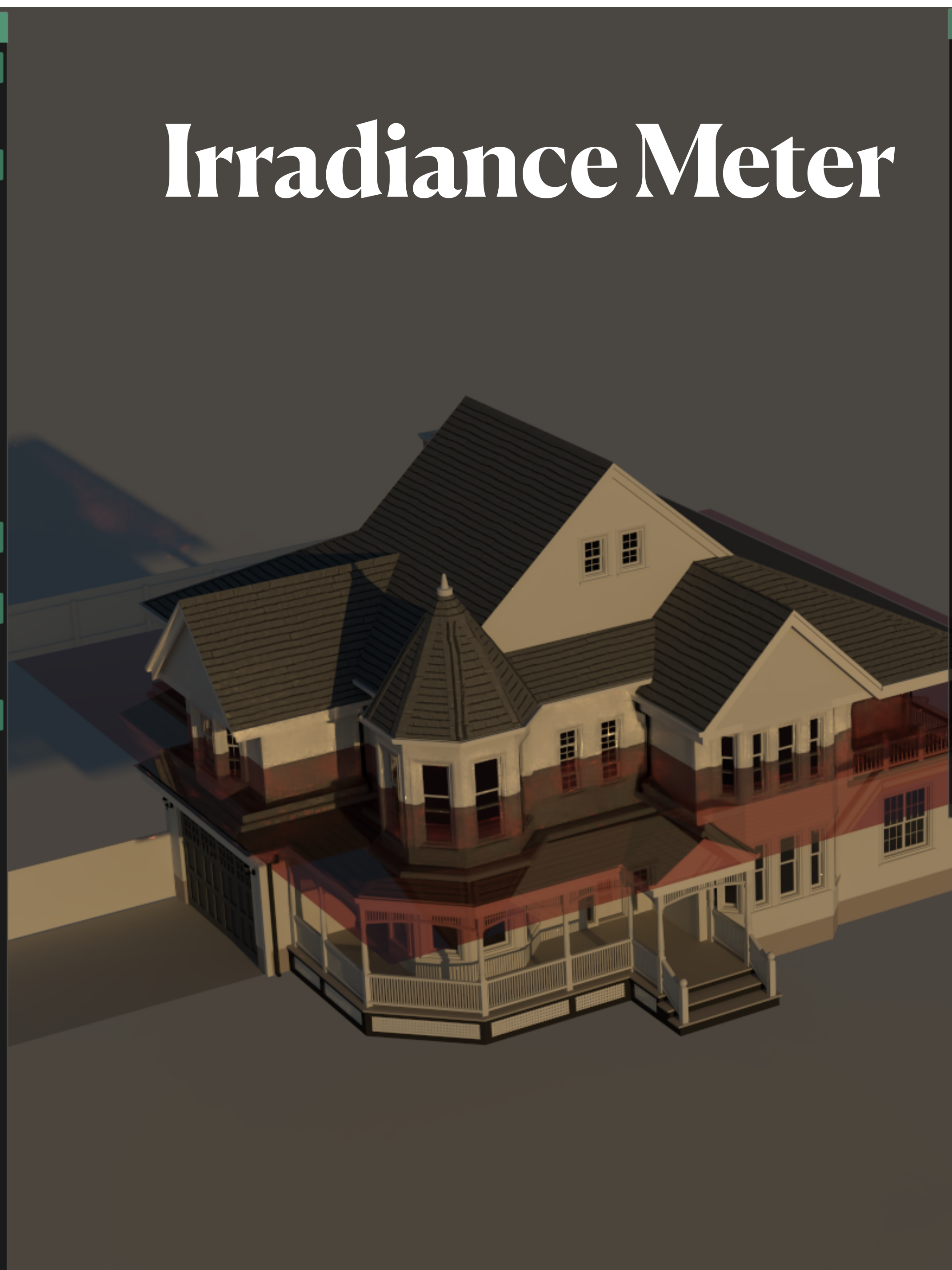
▼ Render Info

Resolution: 1920x1080

GPU Interop: Disabled

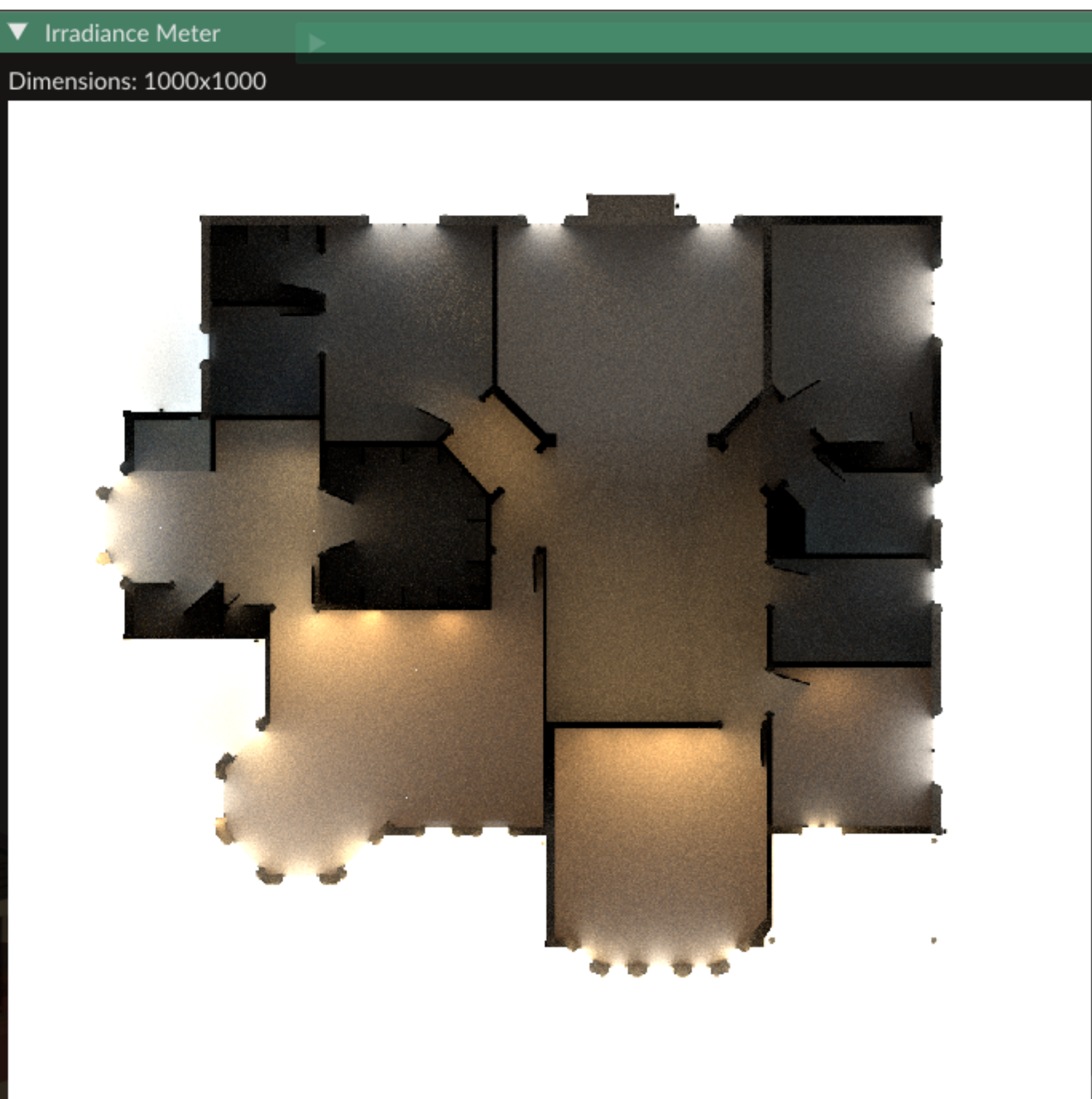
Scene: scene.xml

Irradiance Meter



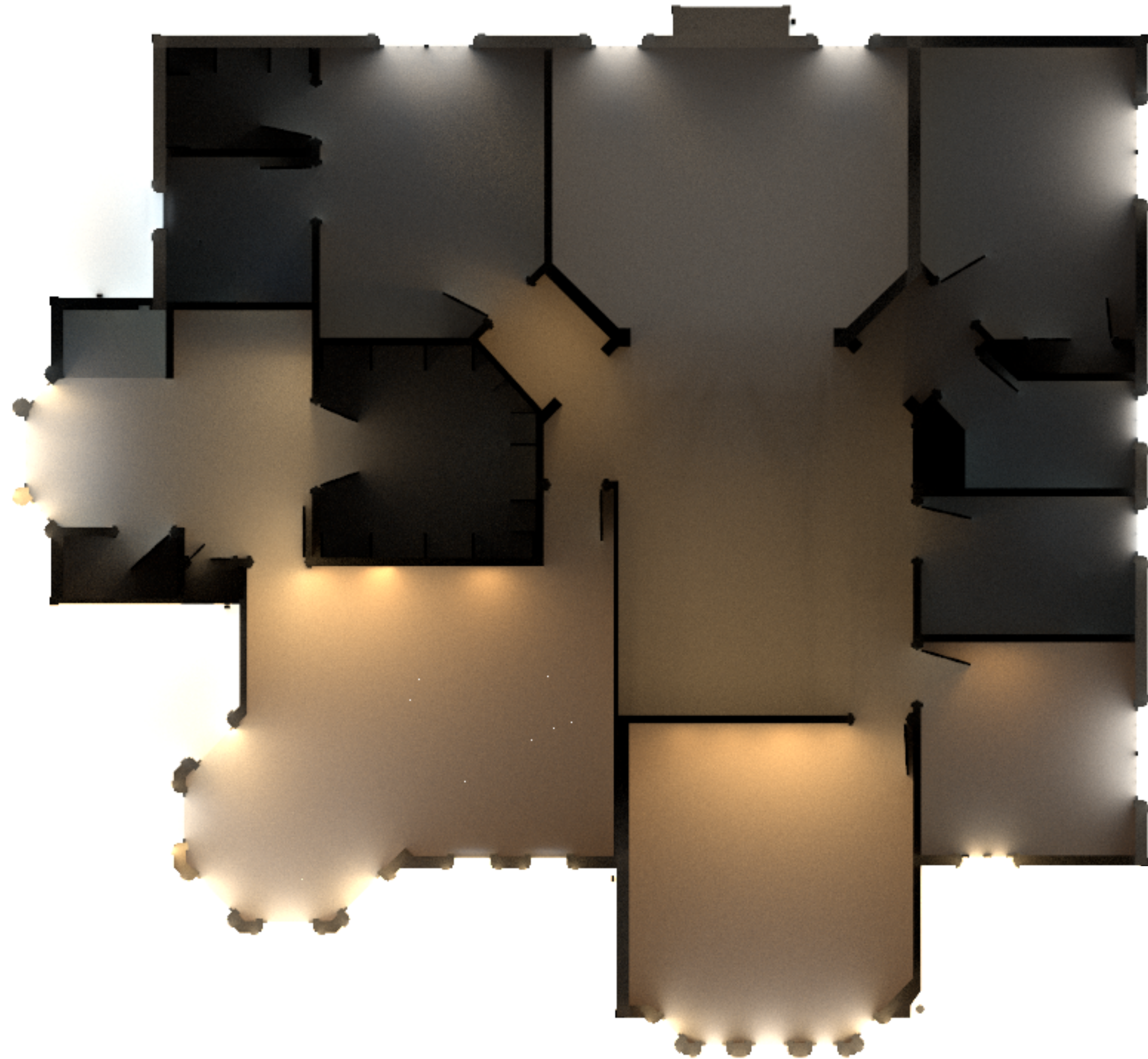
▼ Irradiance Meter

Dimensions: 1000x1000



[provided by Ziyi Zhang]

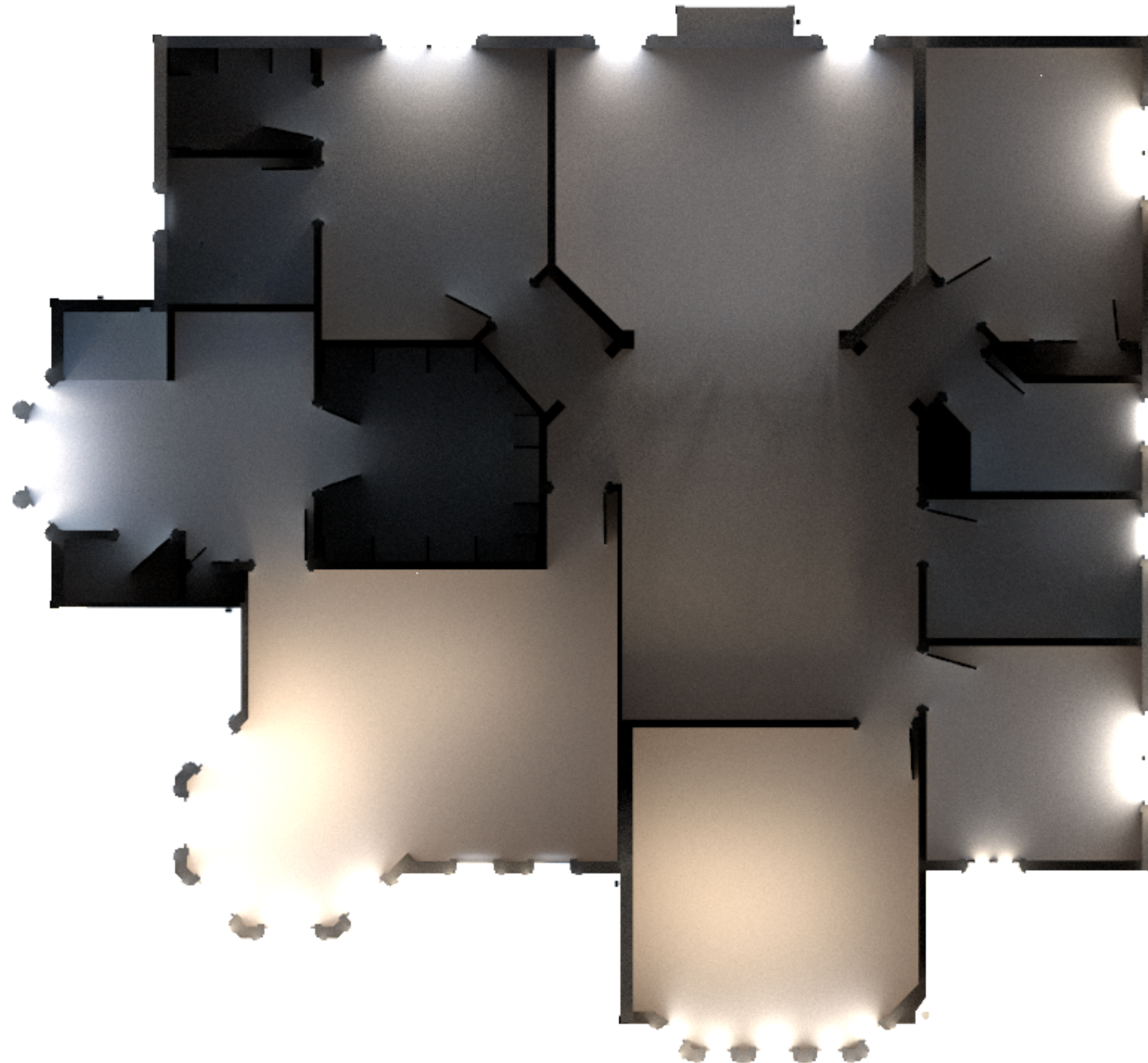
Irradiance Meter



8:00

[provided by Ziyi Zhang]

Irradiance Meter

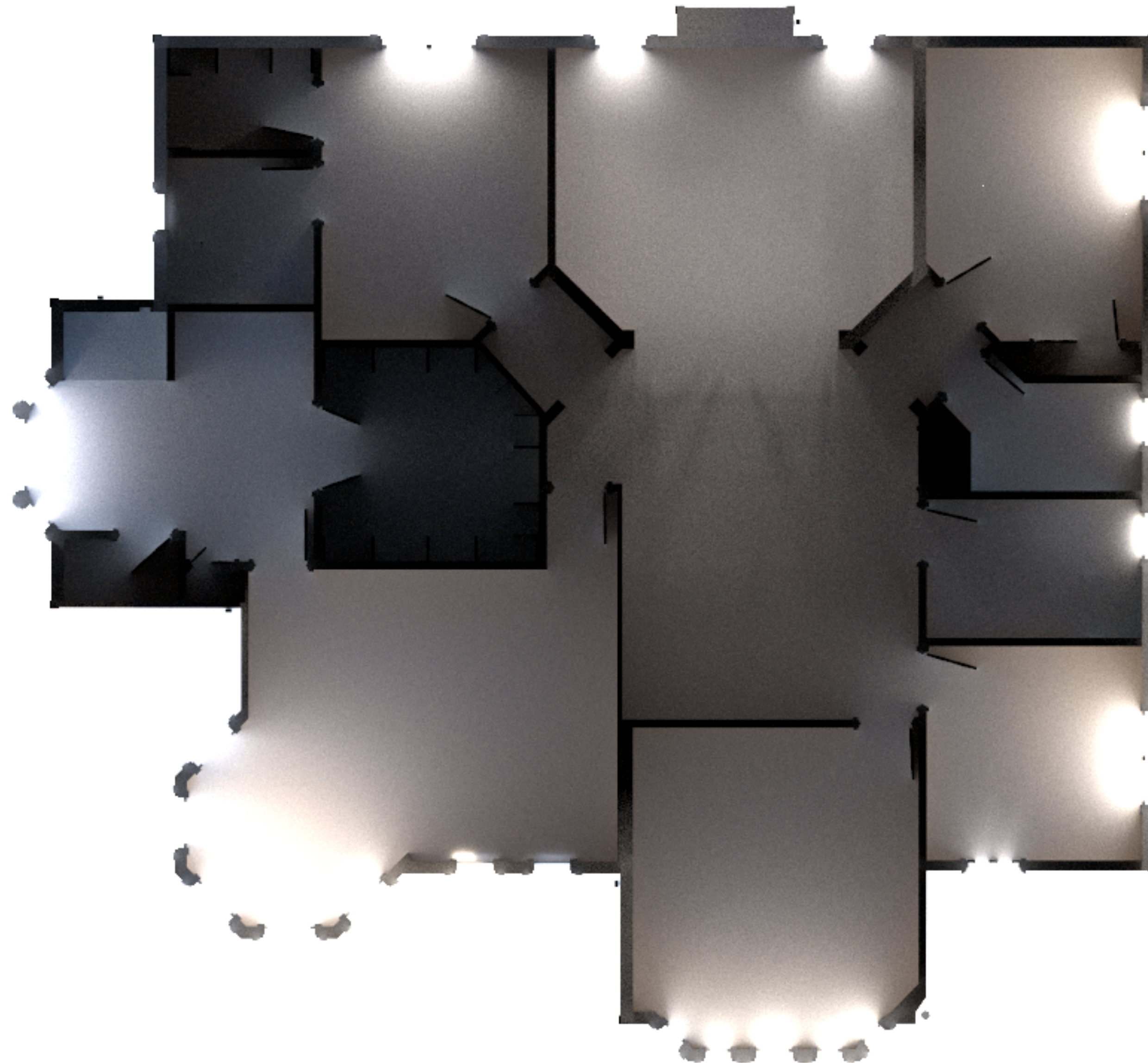


8:00

10:00

[provided by Ziyi Zhang]

Irradiance Meter



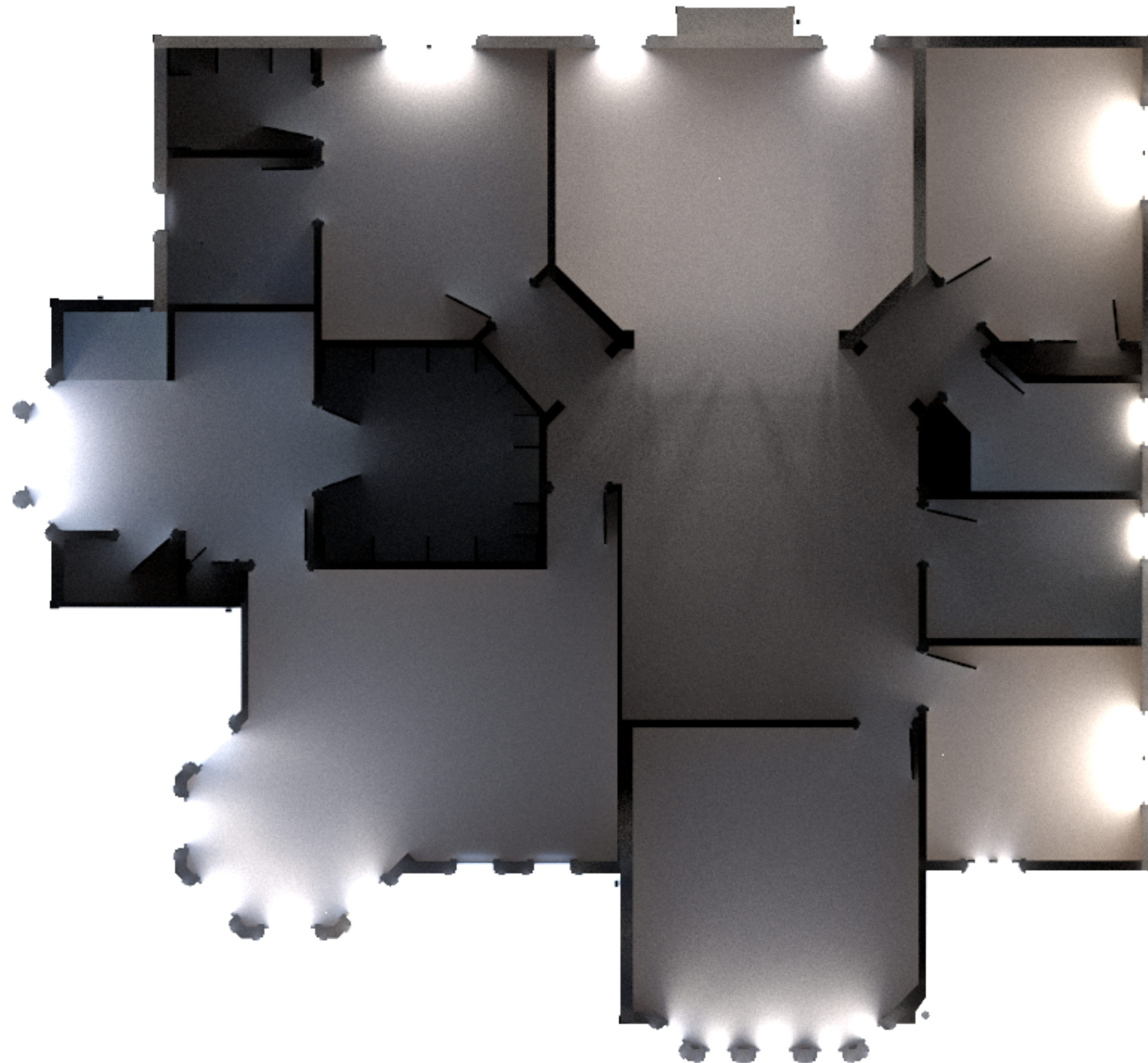
8:00

10:00

12:00

[provided by Ziyi Zhang]

Irradiance Meter



8:00

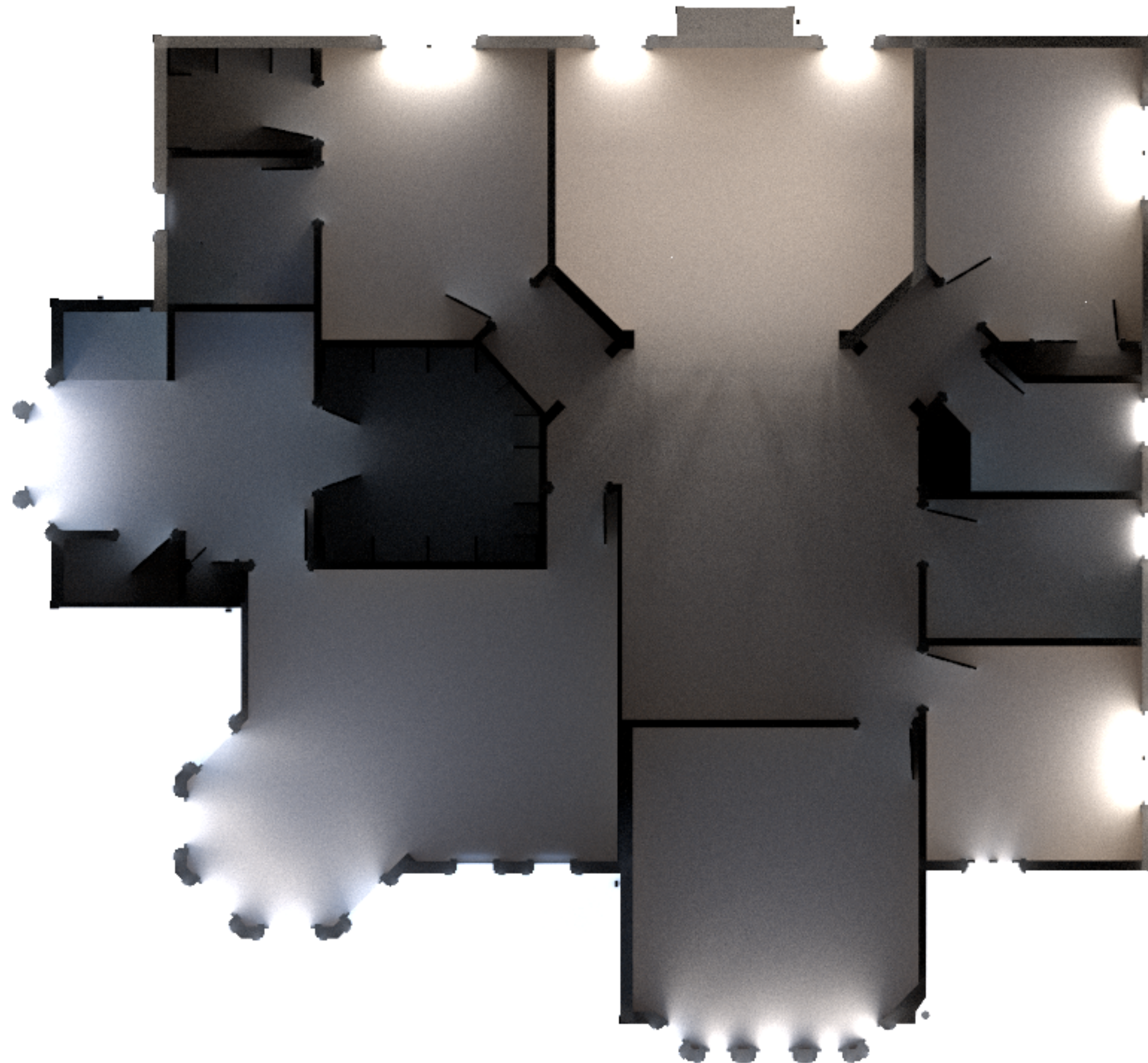
10:00

12:00

14:00

[provided by Ziyi Zhang]

Irradiance Meter



8:00

10:00

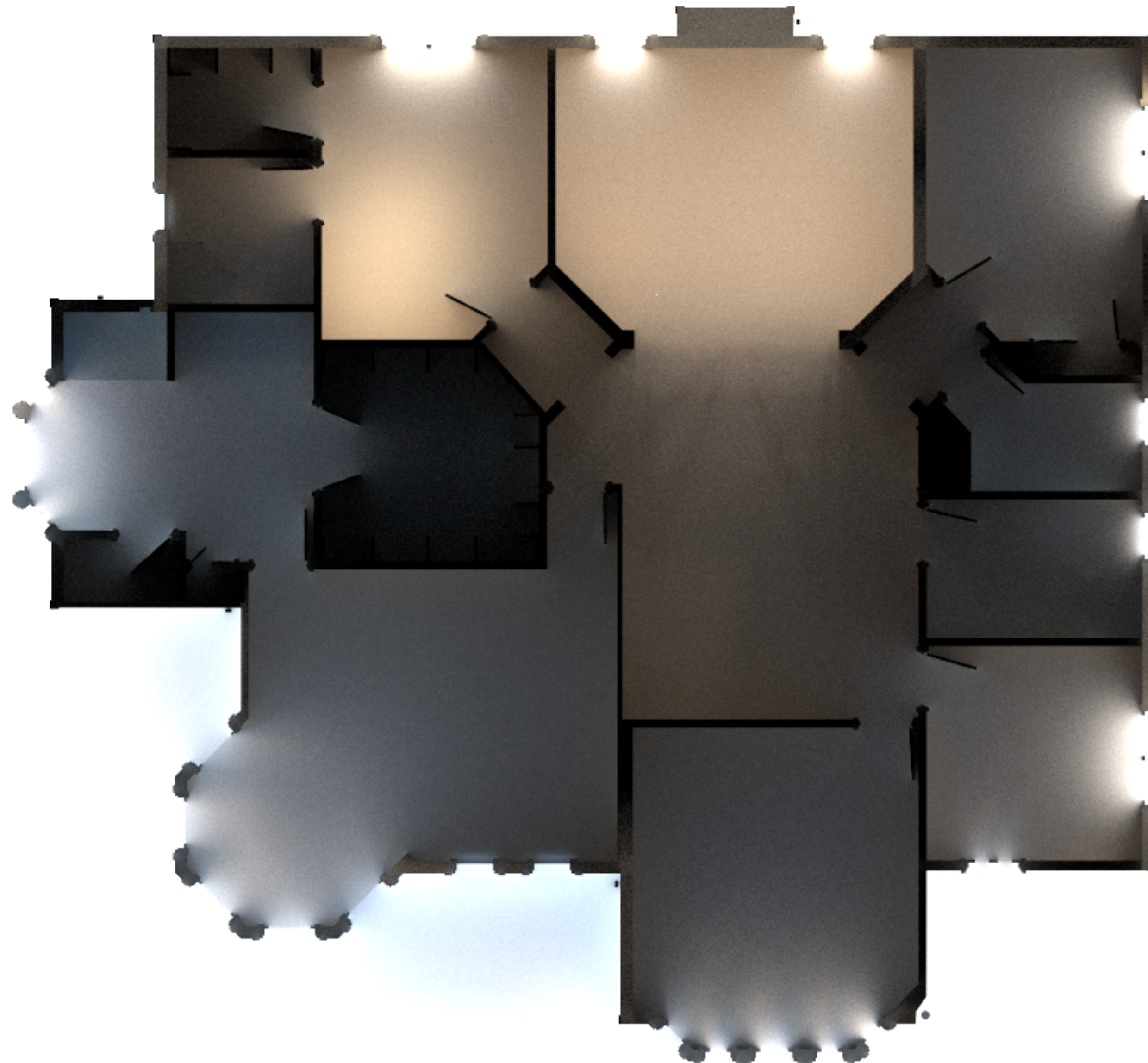
12:00

14:00

16:00

[provided by Ziyi Zhang]

Irradiance Meter



8:00

10:00

12:00

14:00

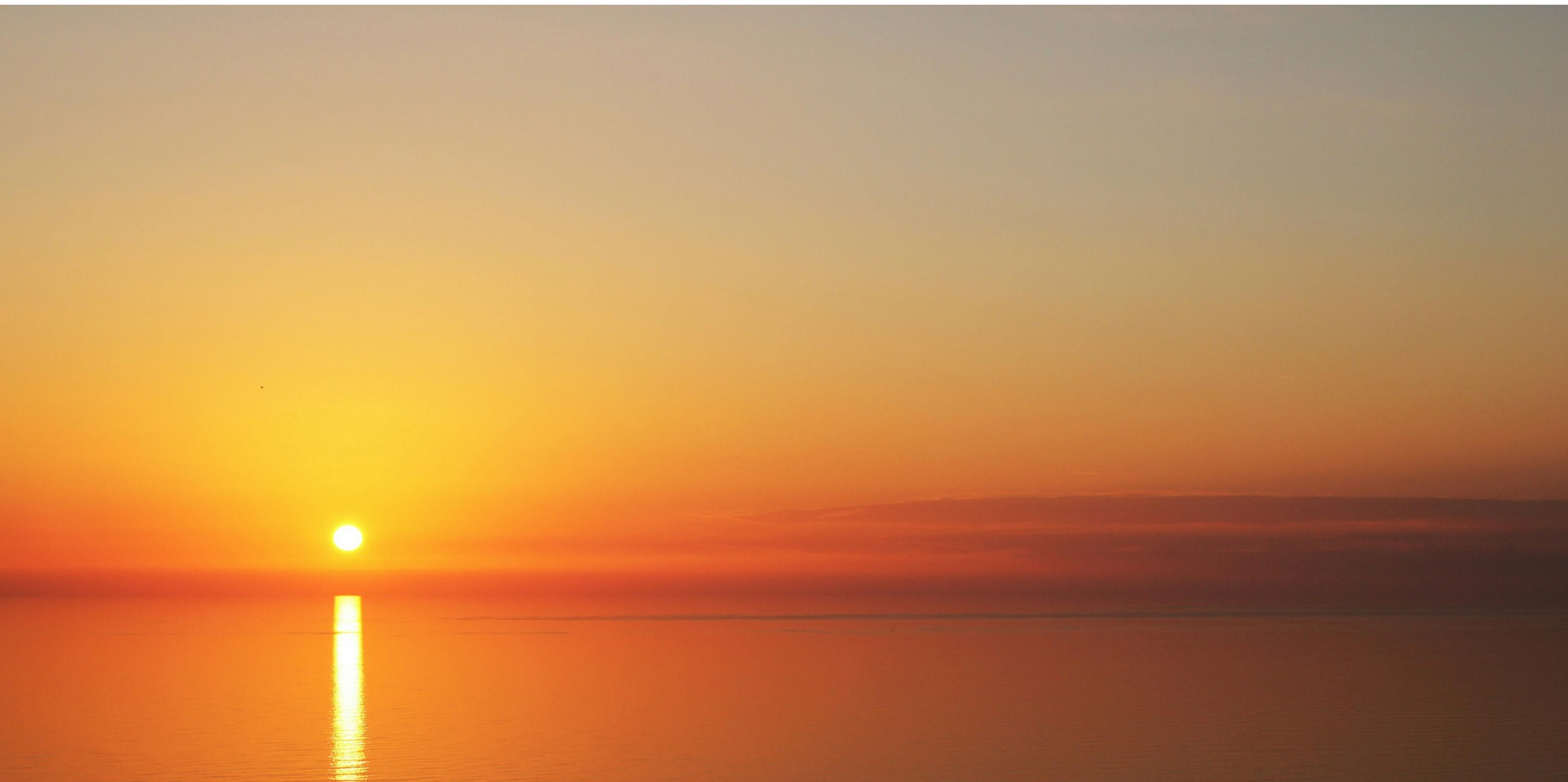
16:00

18:00

[provided by Ziyi Zhang]

Daylight illumination in Mitsuba 3

Mattéo Santini, EPFL Bachelor Graduate in Computer Science



Illustrative photo from [pexels.com](https://www.pexels.com)

How do we compute daylight?

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A sun and sky analytical model

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- Set of equations that approximate the sky's appearance

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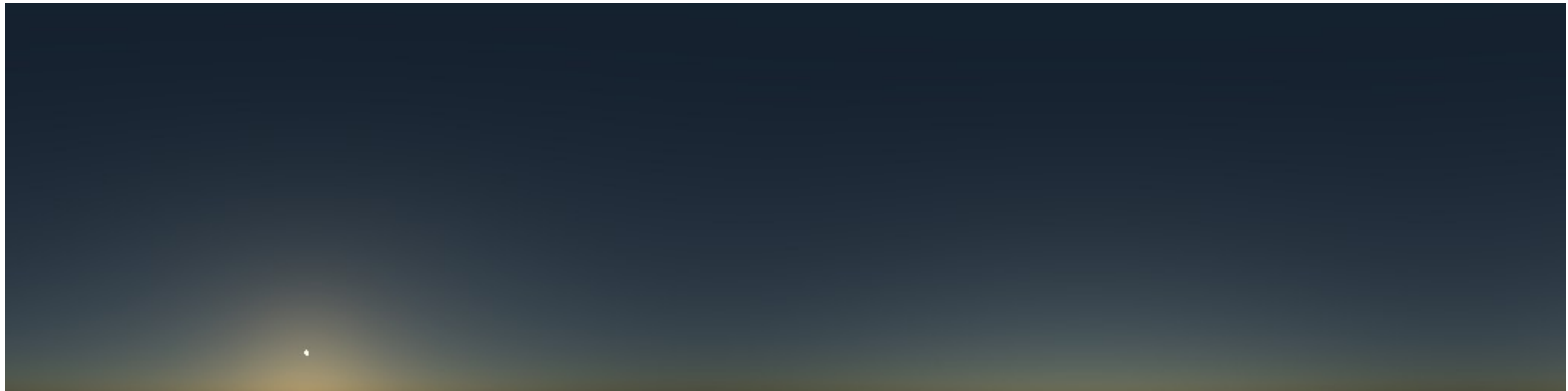
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Rendered in Mitsuba 3

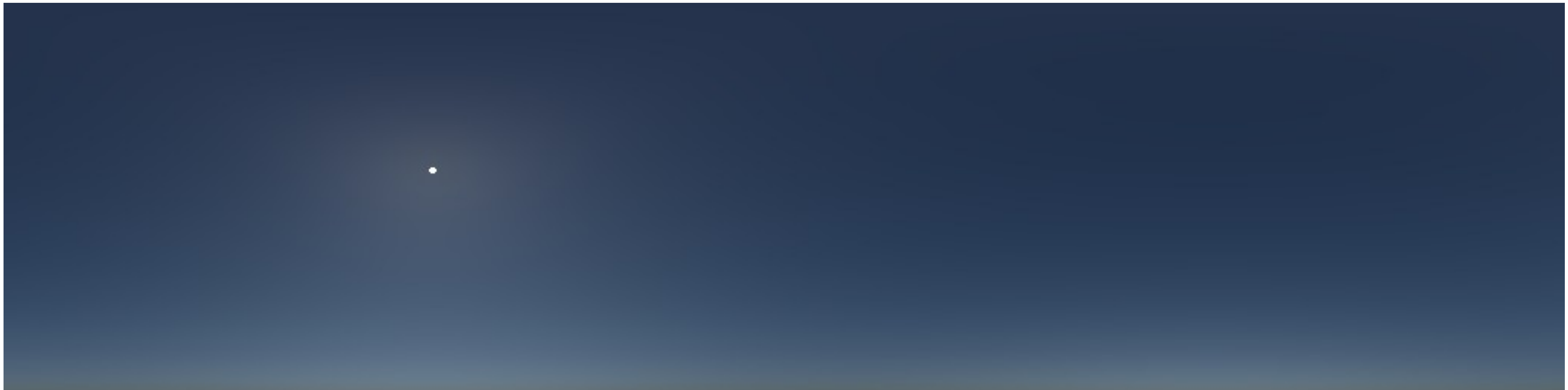


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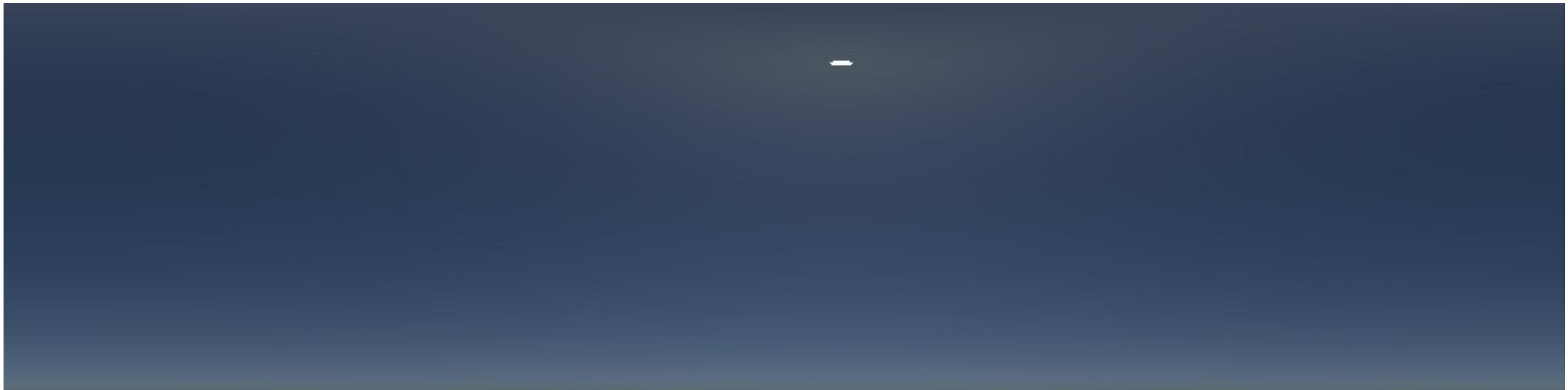


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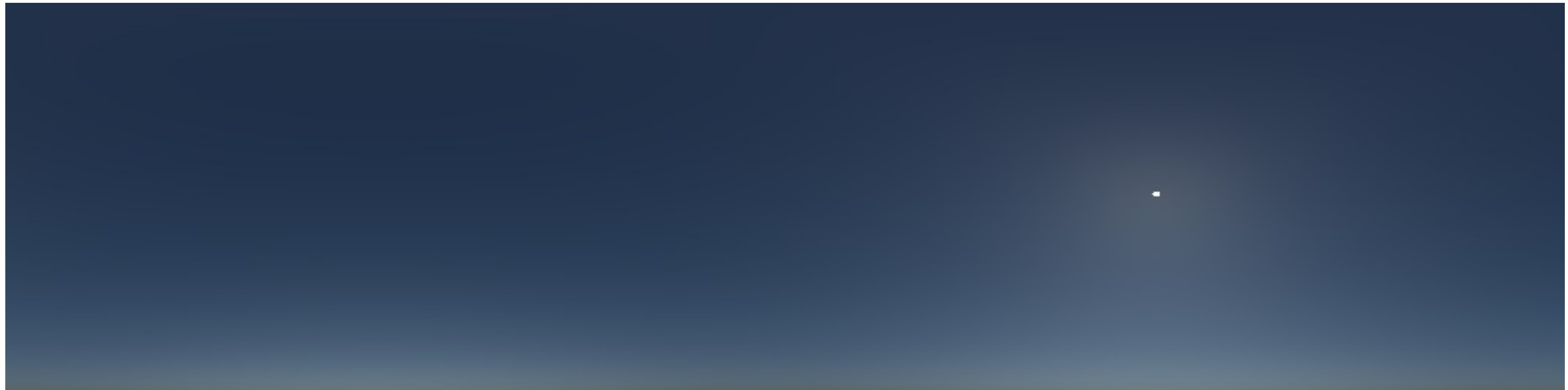


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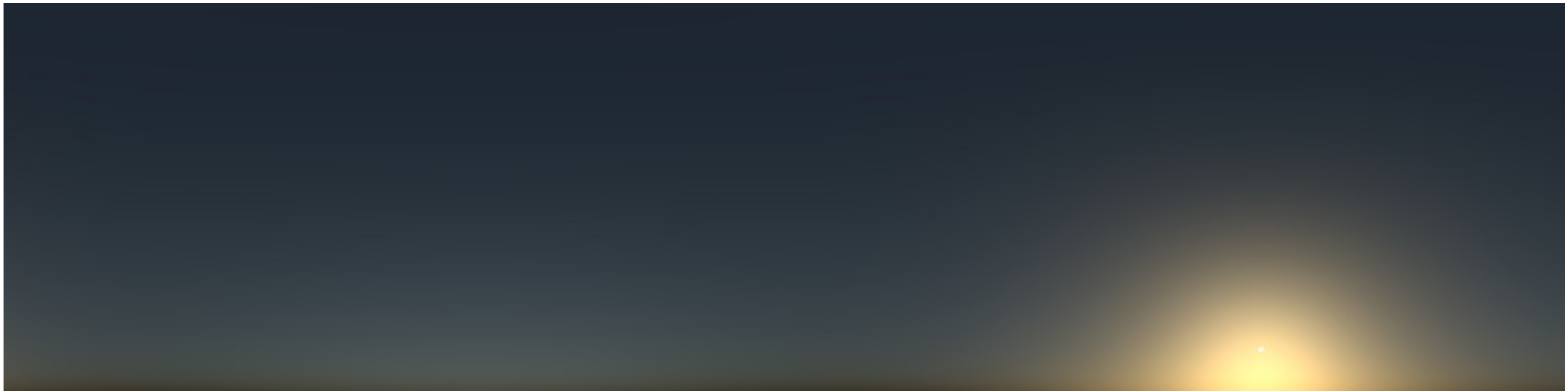


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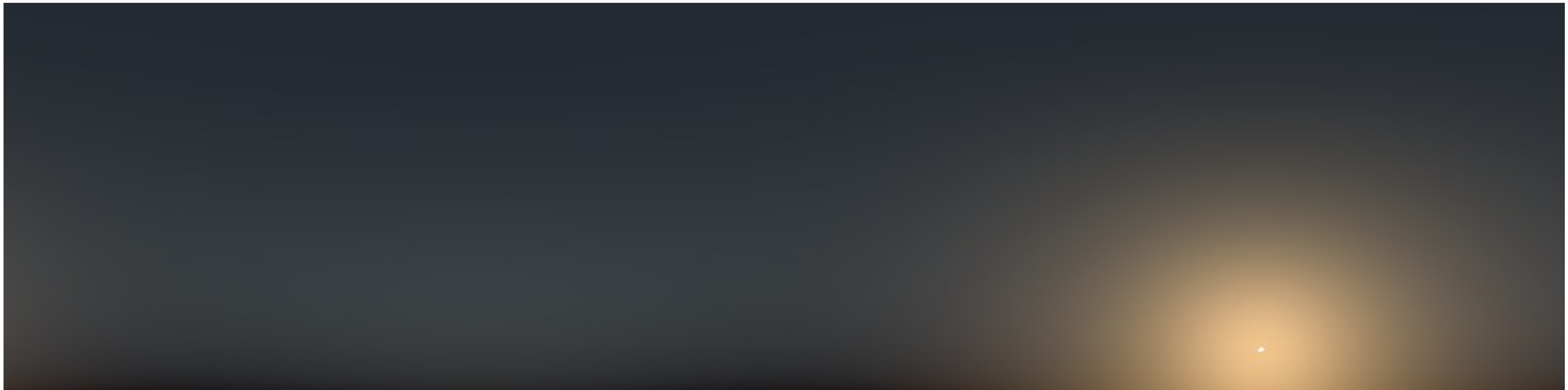


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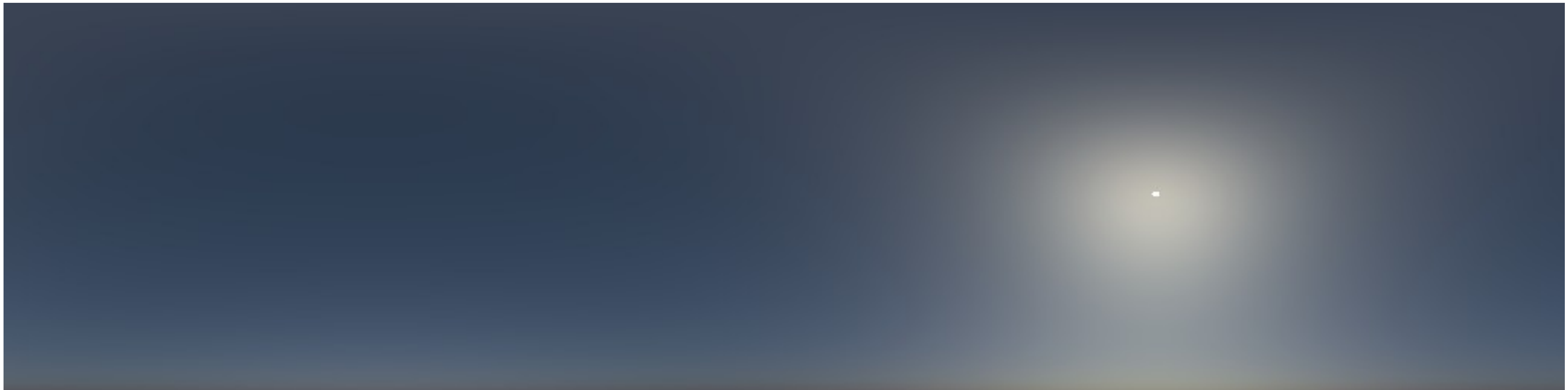


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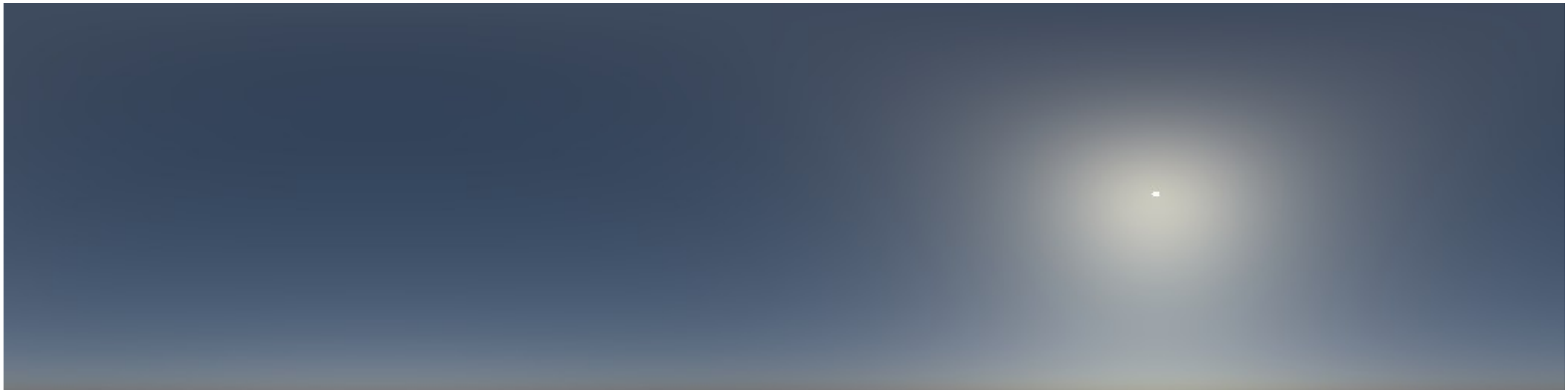


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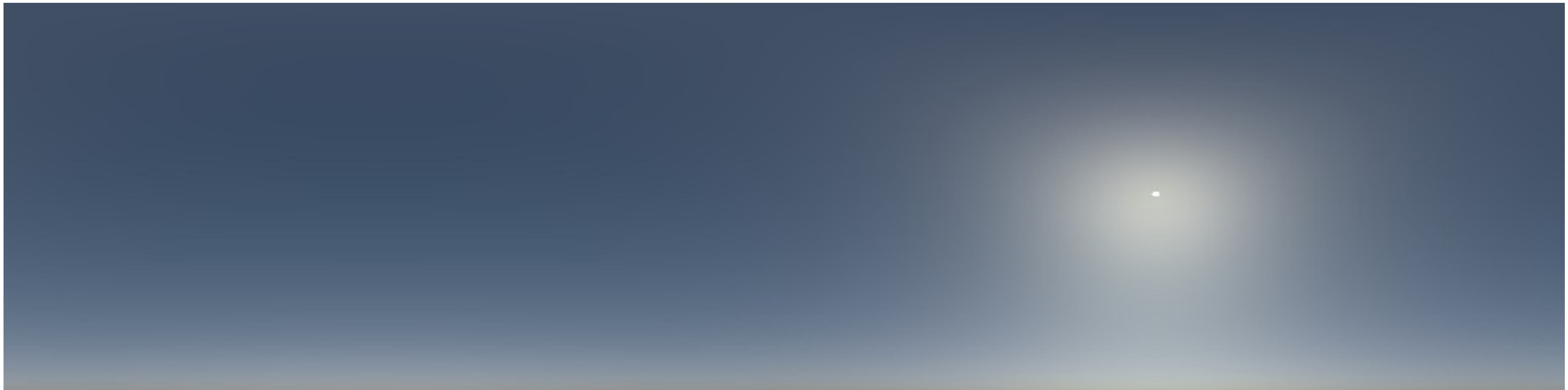


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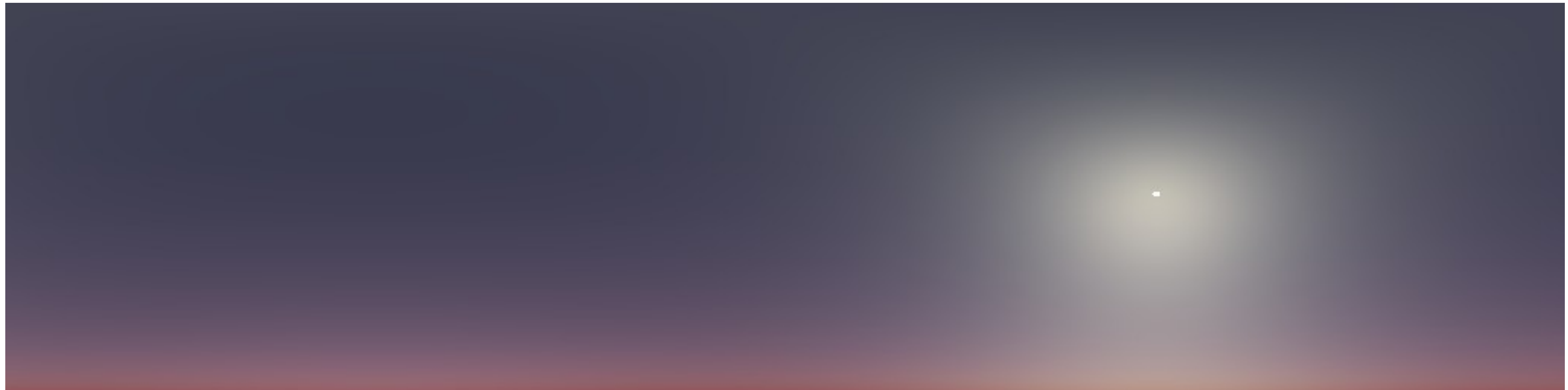


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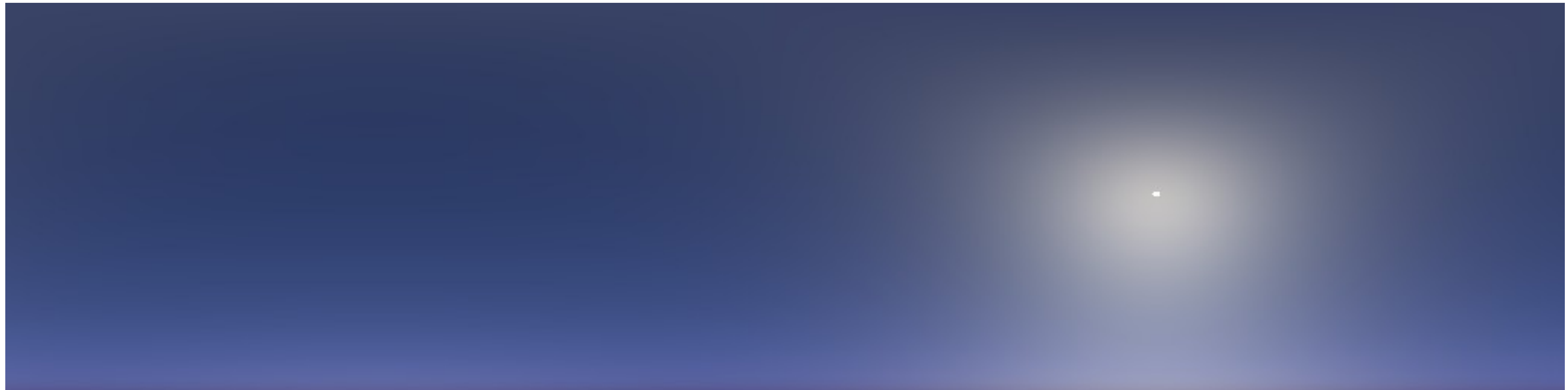


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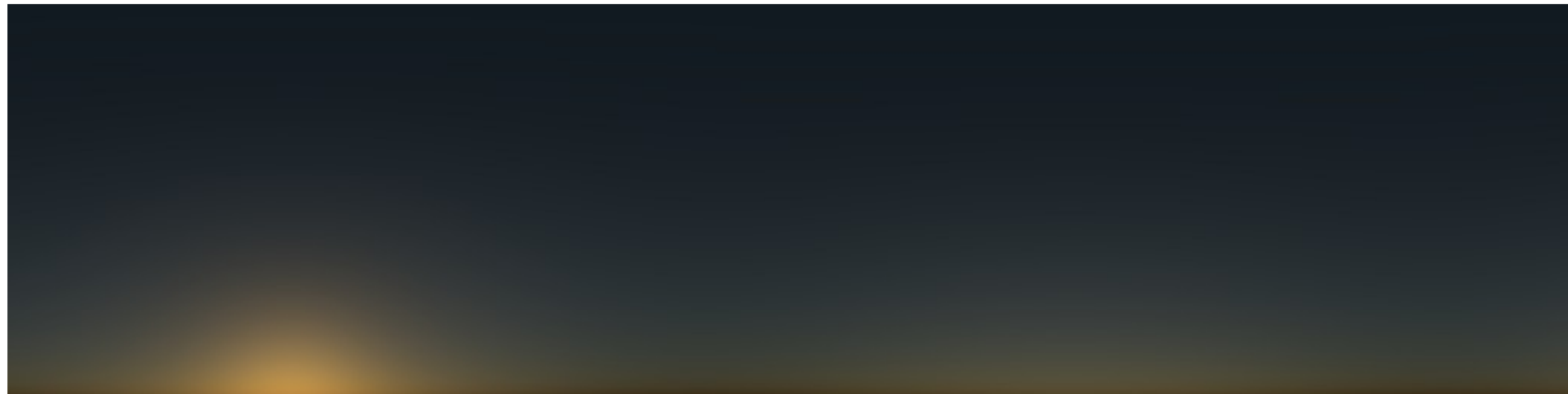
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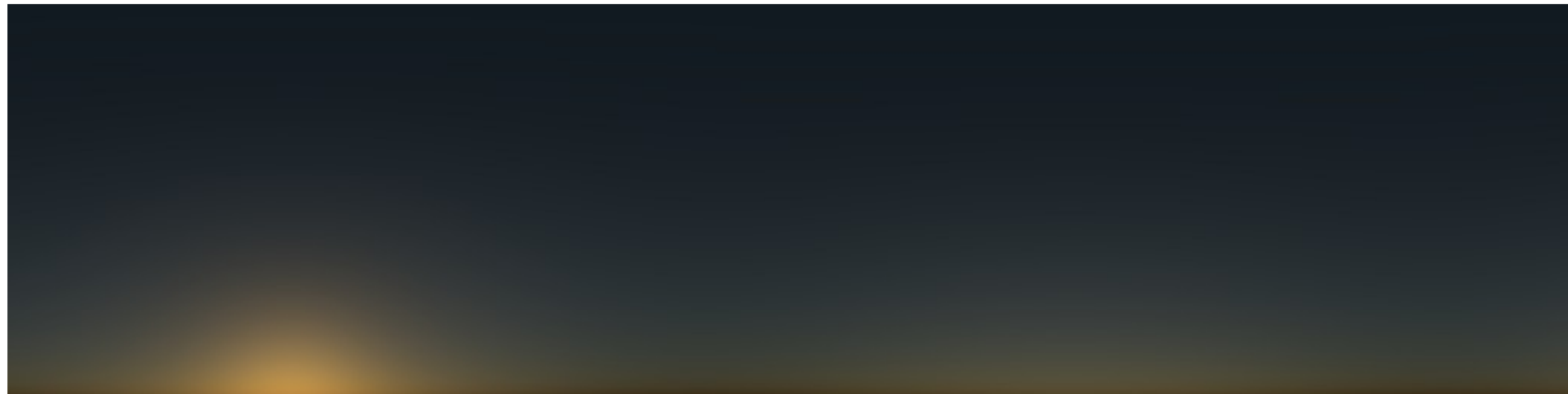
Hošek-Wilkie Sky model

Hošek-Wilkie Sky model

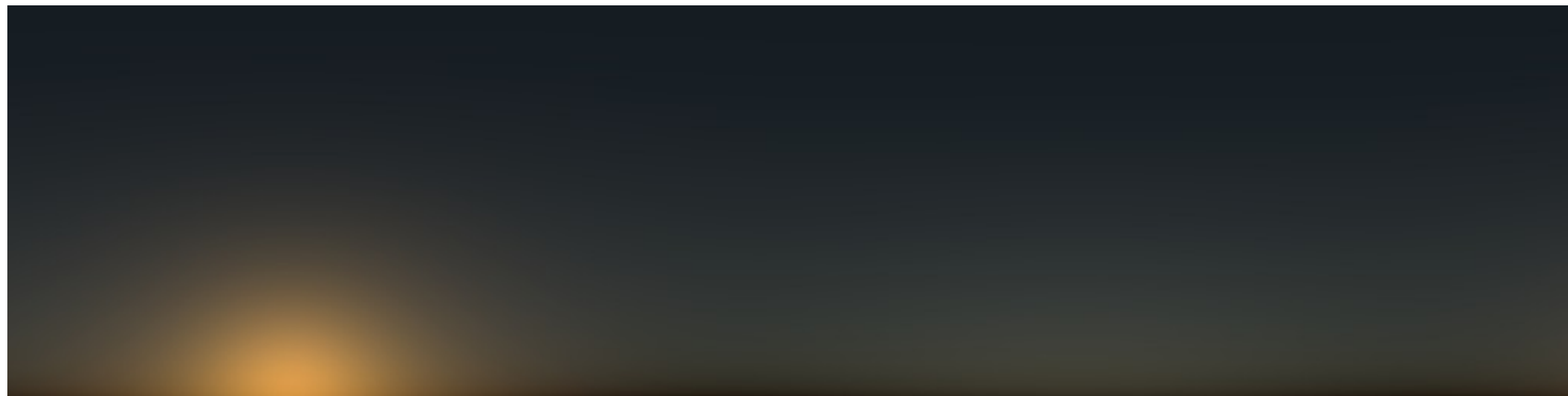


Early morning sky, $t=3$, $a=0$

Hošek-Wilkie Sky model

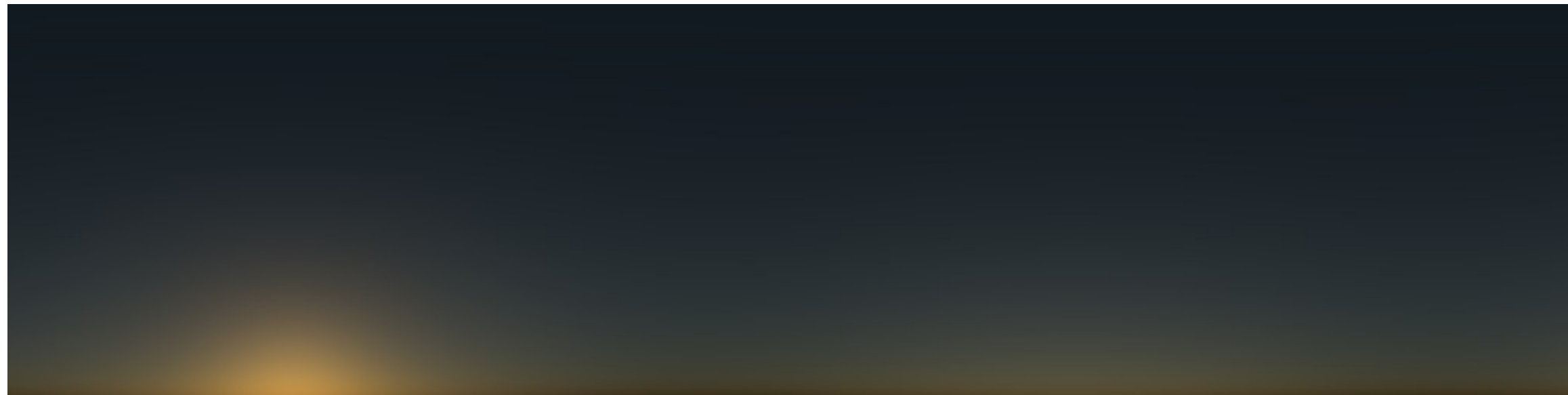


Early morning sky, $t=3$, $a=0$

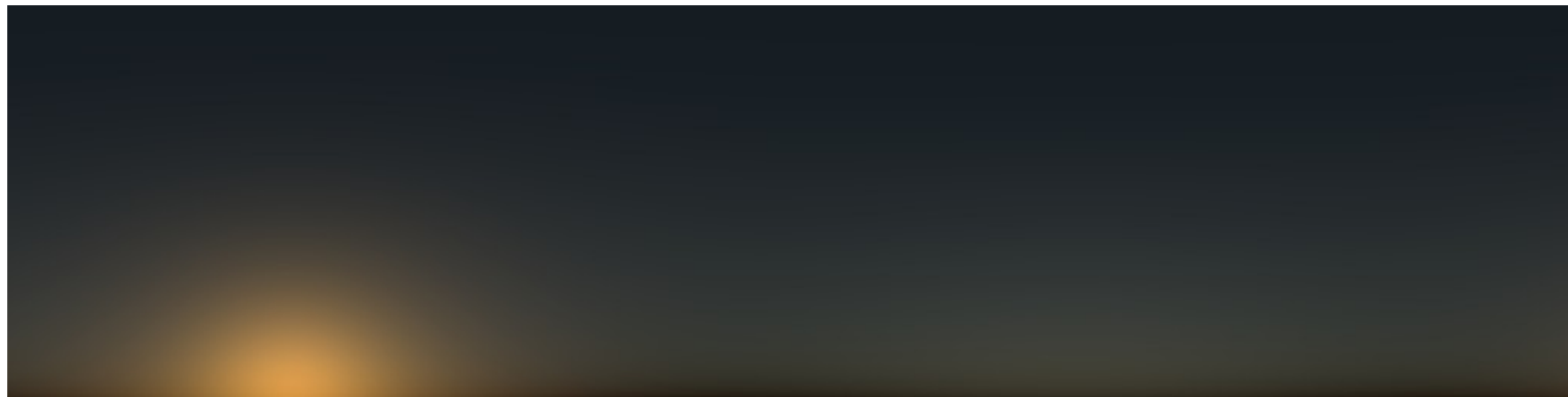


Early morning sky, $t=7$, $a=0$

Hošek-Wilkie Sky model



Early morning sky, $t=3$, $a=0$

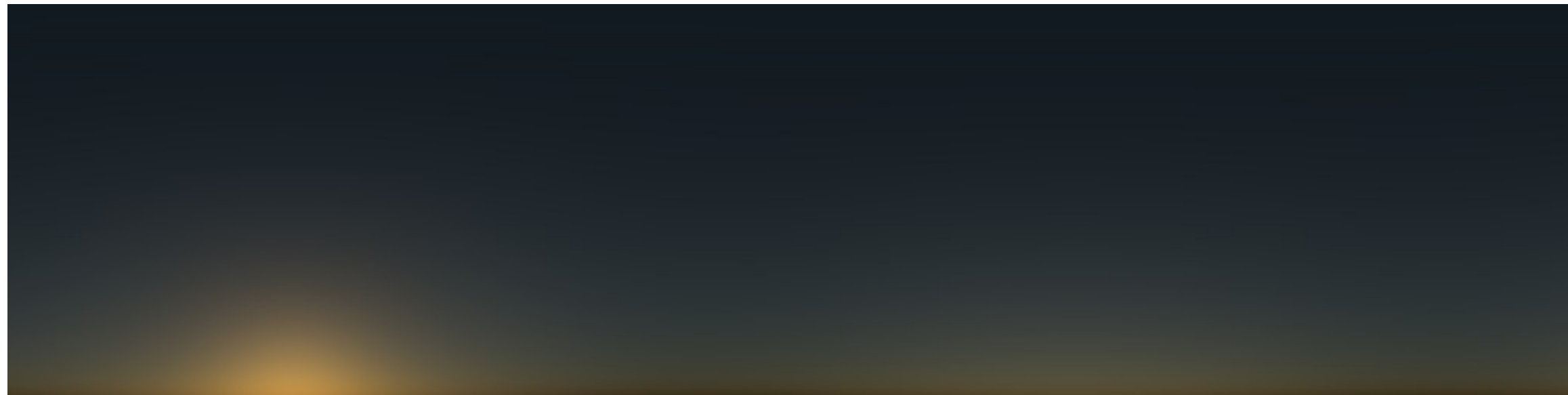


Early morning sky, $t=7$, $a=0$

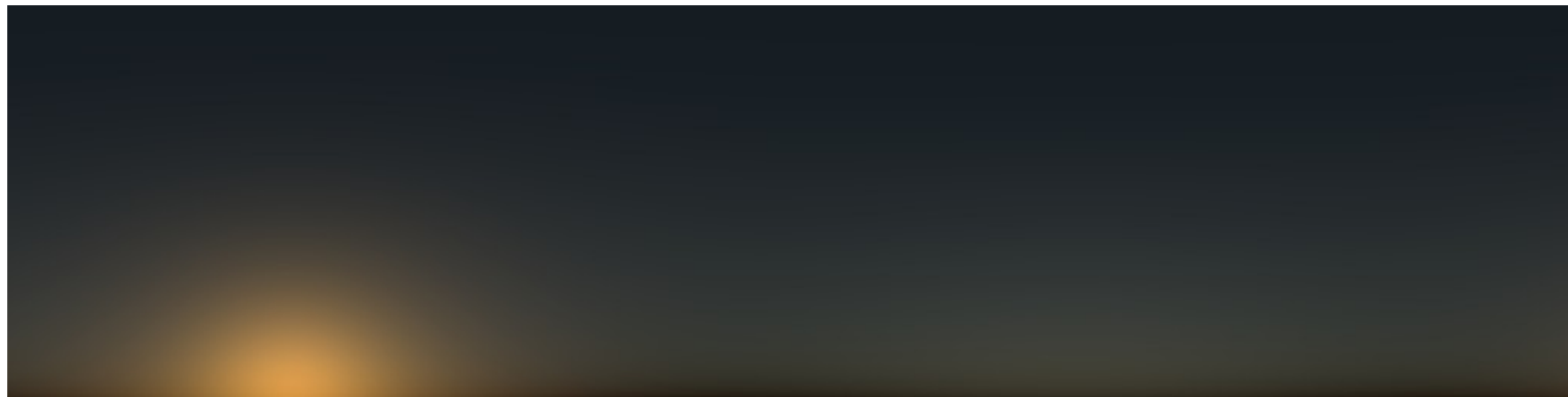
Extension of the Perez daylight formula with revisited parameters.

Supports:

Hošek-Wilkie Sky model



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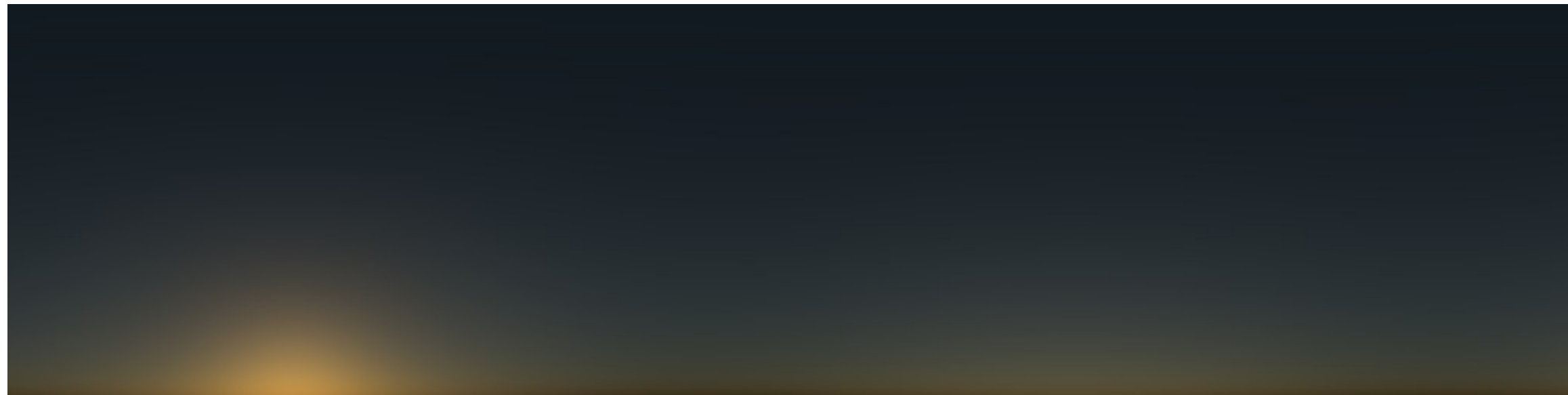
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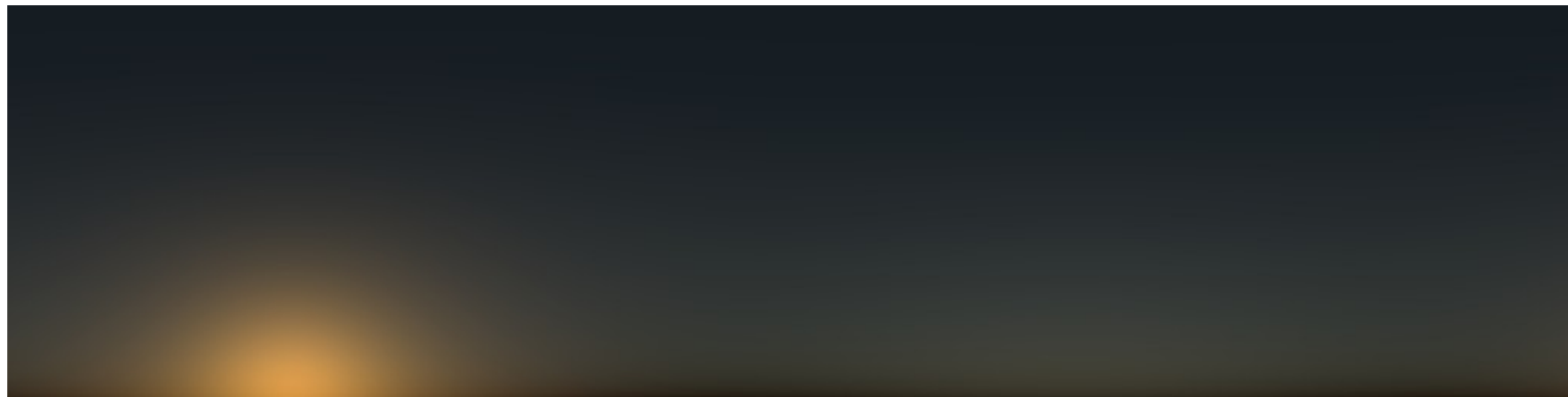
Supports:

- Turbidity values in $[1, 10]$

Hošek-Wilkie Sky model



Early morning sky, $t=3$, $a=0$



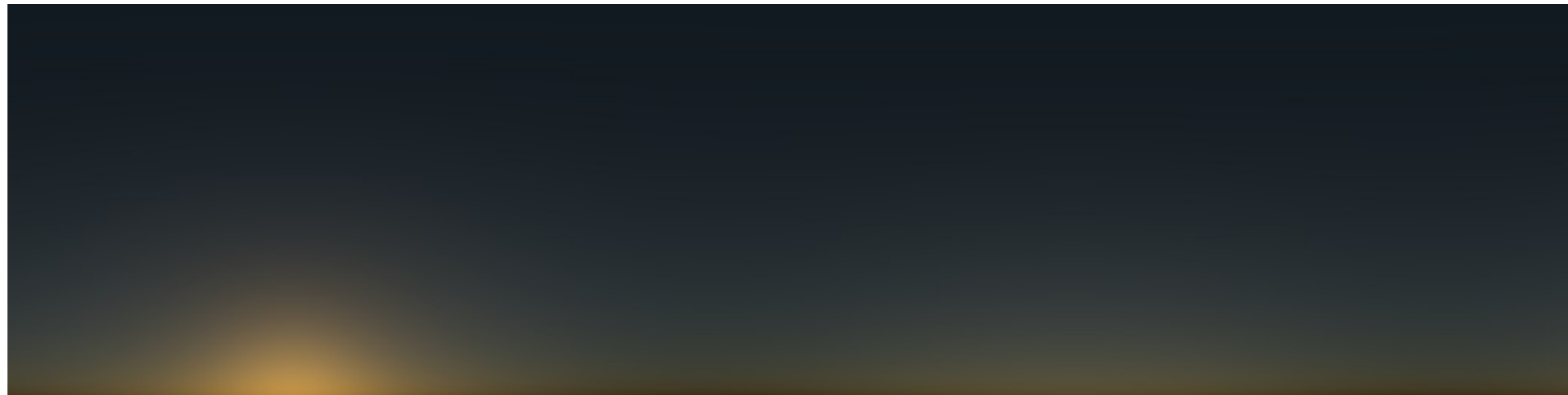
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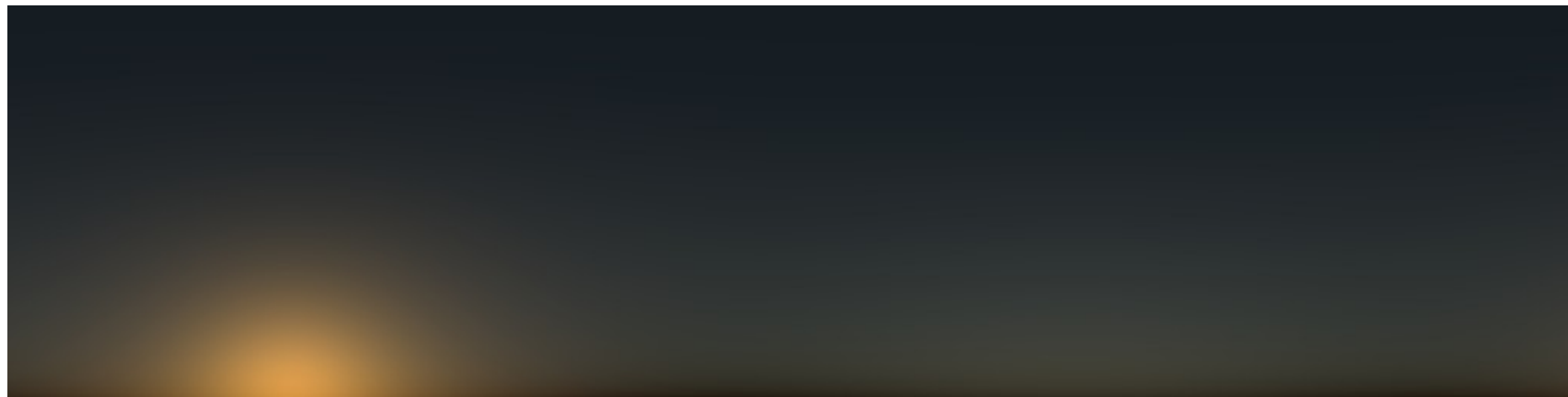
Supports:

- Turbidity values in $[1, 10]$
- Spectral albedo in $[0, 1]$

Hošek-Wilkie Sky model



Early morning sky, $t=3$, $a=0$



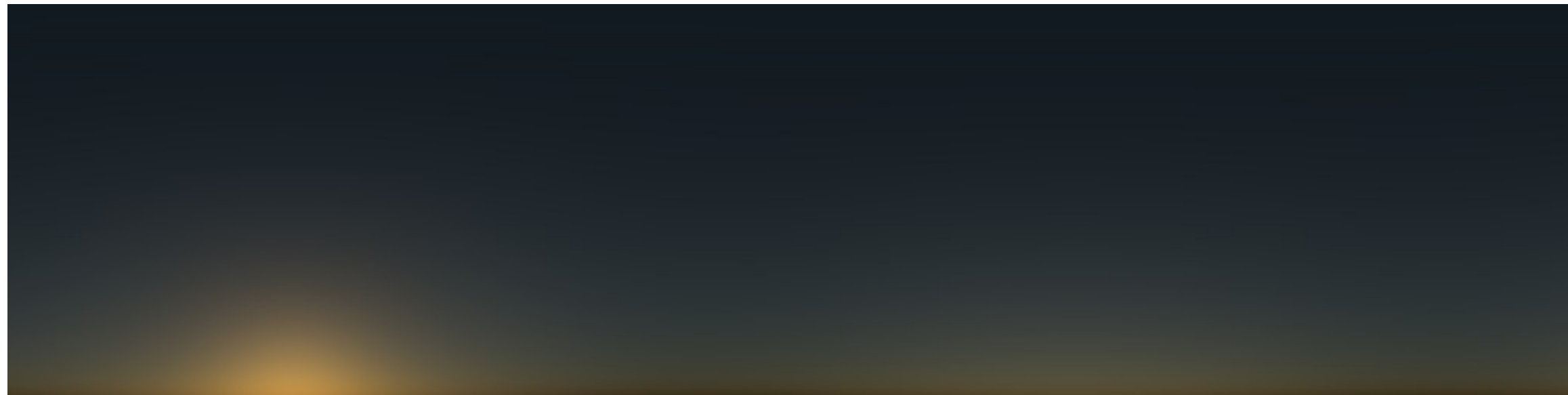
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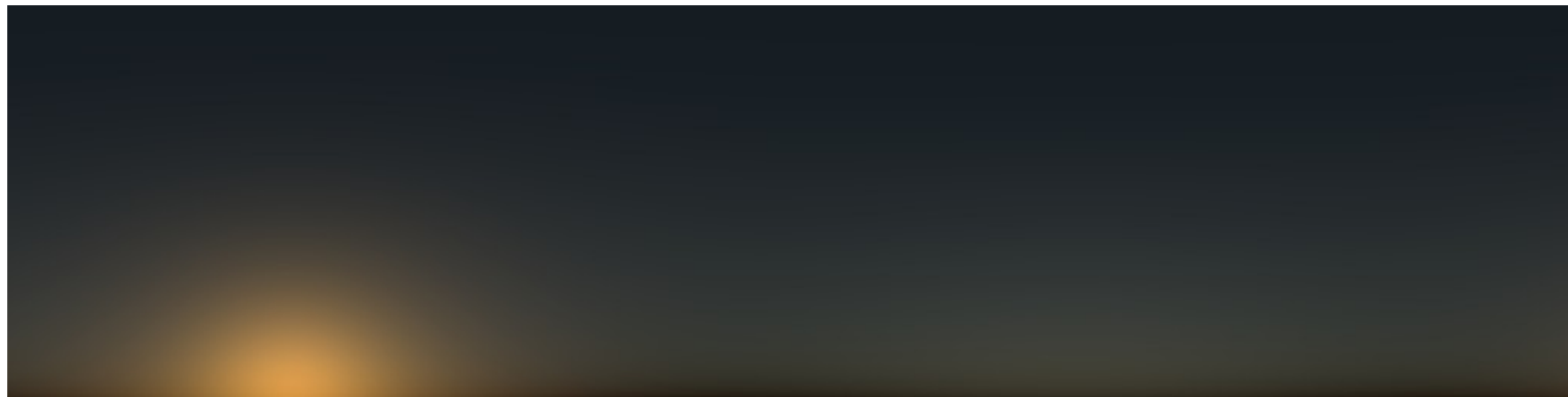
Supports:

- Turbidity values in $[1, 10]$
- Spectral albedo in $[0, 1]$
- All sun positions above the horizon

Hošek-Wilkie Sky model



Early morning sky, $t=3$, $a=0$



Early morning sky, $t=7$, $a=0$

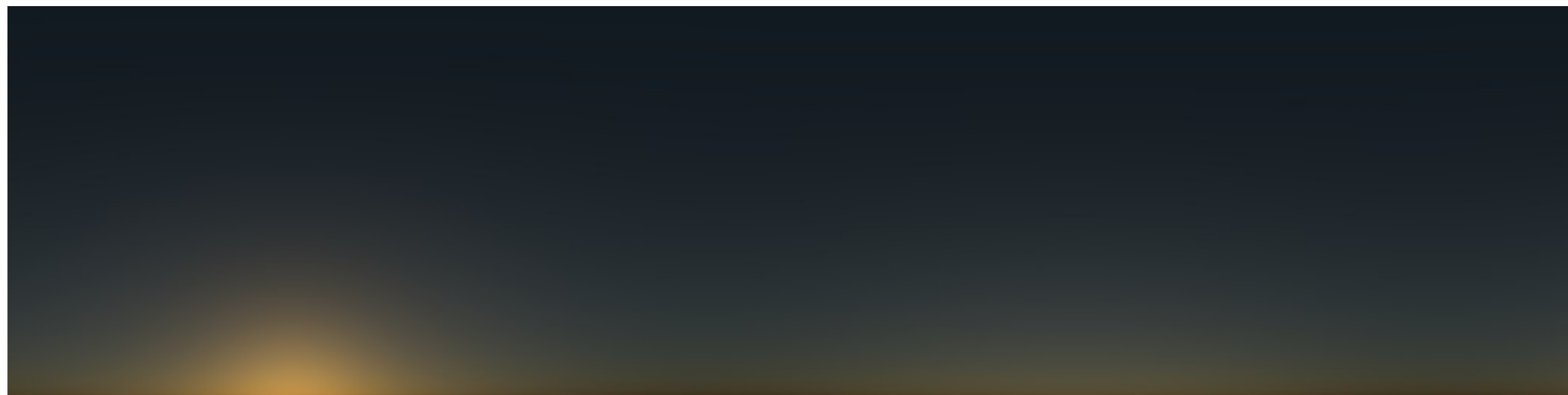
Extension of the Perez daylight formula with revisited parameters.

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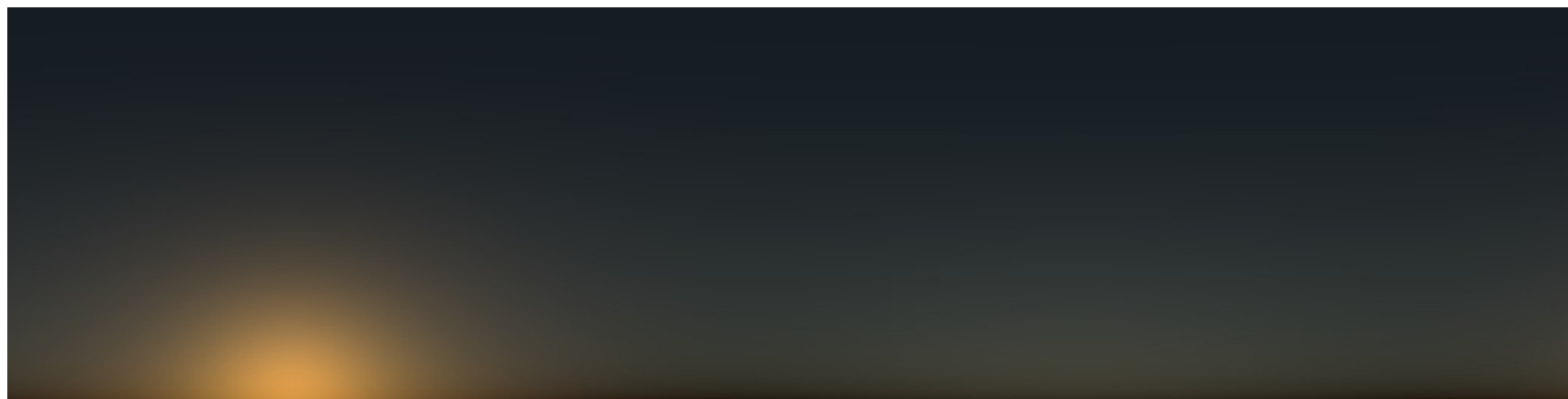
- Turbidity values in $[1, 10]$
- Spectral albedo in $[0, 1]$
- All sun positions above the horizon

Outputs radiance for:

Hošek-Wilkie Sky model



Early morning sky, $t=3$, $a=0$



Early morning sky, $t=7$, $a=0$

Extension of the Perez daylight formula with revisited parameters.

Supports:

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- All sun positions above the horizon

Outputs radiance for:

- Wavelengths in $[320, 720]$ nm

Hošek-Wilkie's Solar Radiance Function

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- Same capabilities as the sky model

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Two visible gradients:

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Vertical



Hošek-Wilkie's Solar Radiance Function

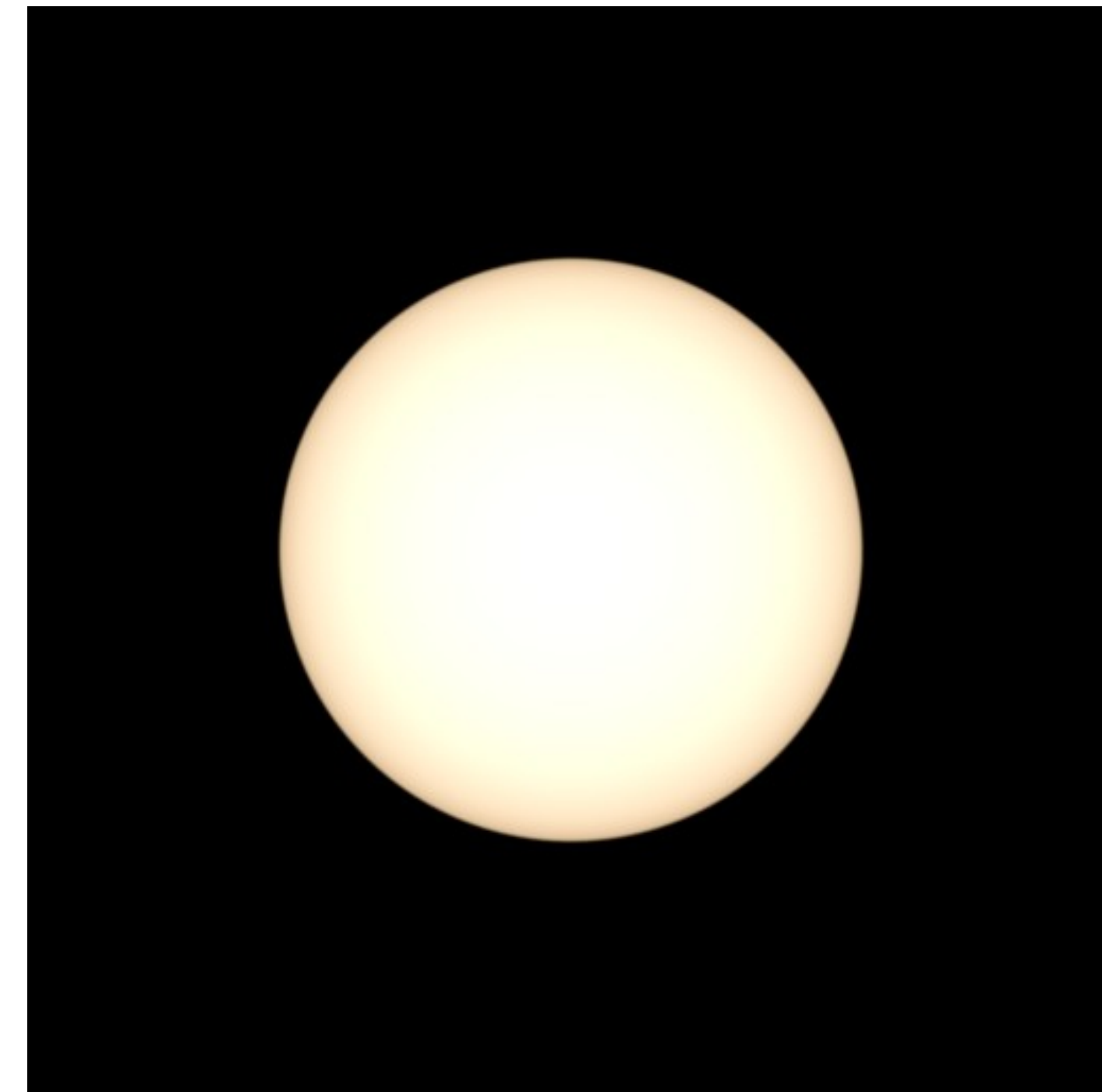
Two visible gradients:

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Vertical



Radial (limb darkening)



Hošek-Wilkie's Solar Radiance Function

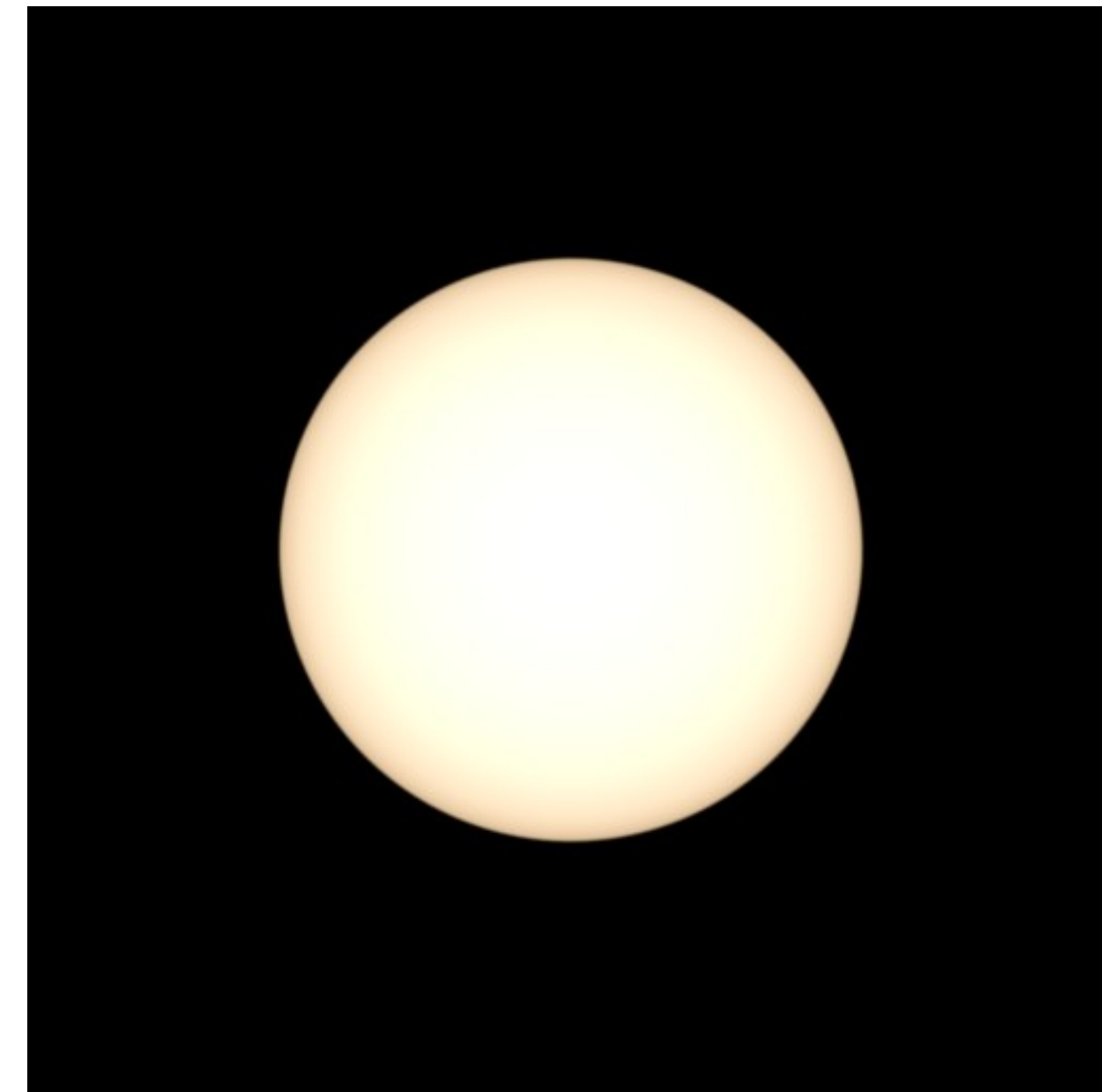
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Radial (limb darkening)



Sunsky emitter

Sunsky emitter

Initialized with turbidity, albedo
and time

Sunsky emitter

Initialized with turbidity, albedo
and time

Queried with view direction

Sunsky emitter

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Queried with view direction

✓ Efficient

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Initialized with turbidity, albedo
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✓ Photo-realistic renders

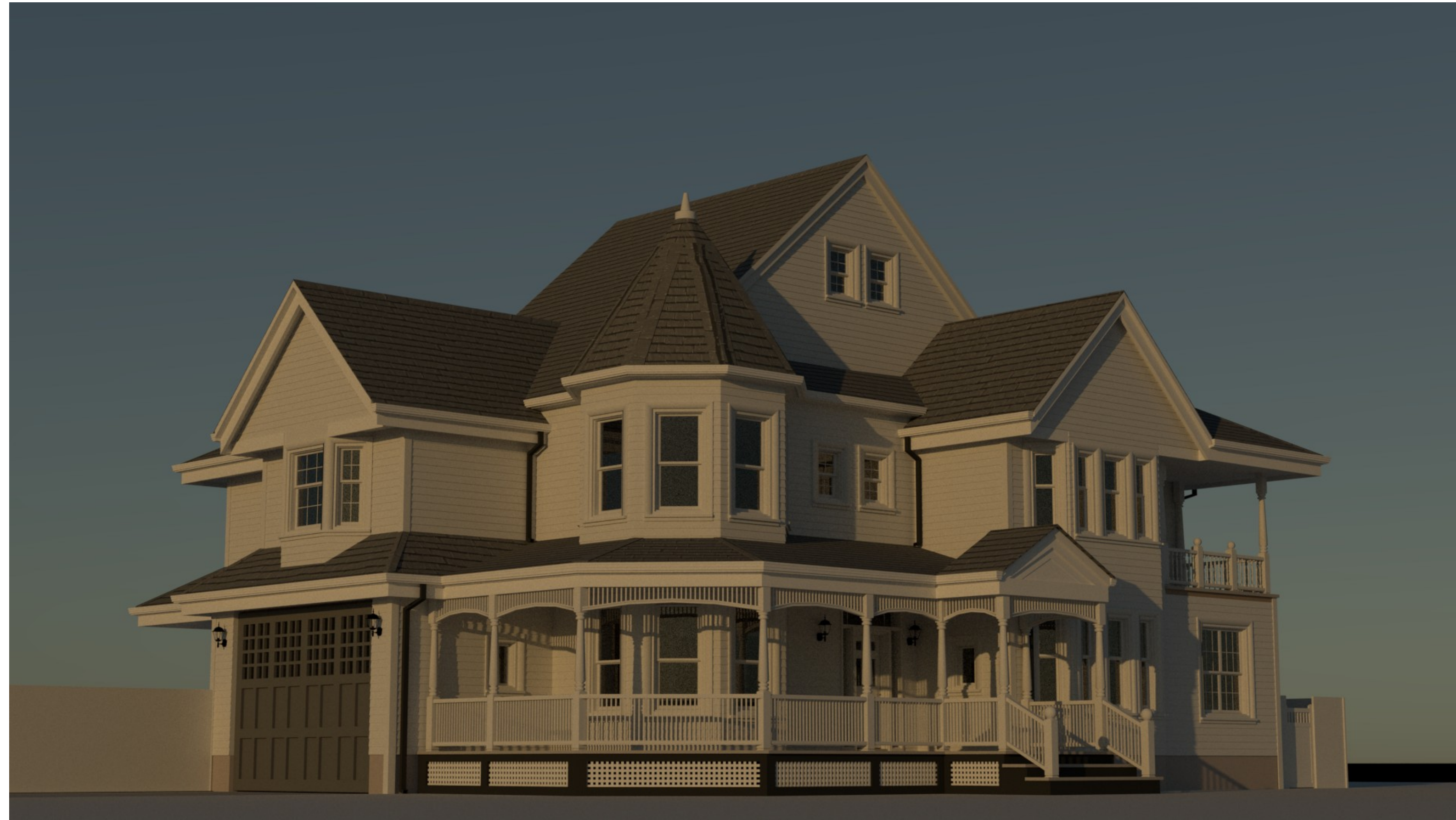
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Victorian Style House at 6pm

Sunsky emitter

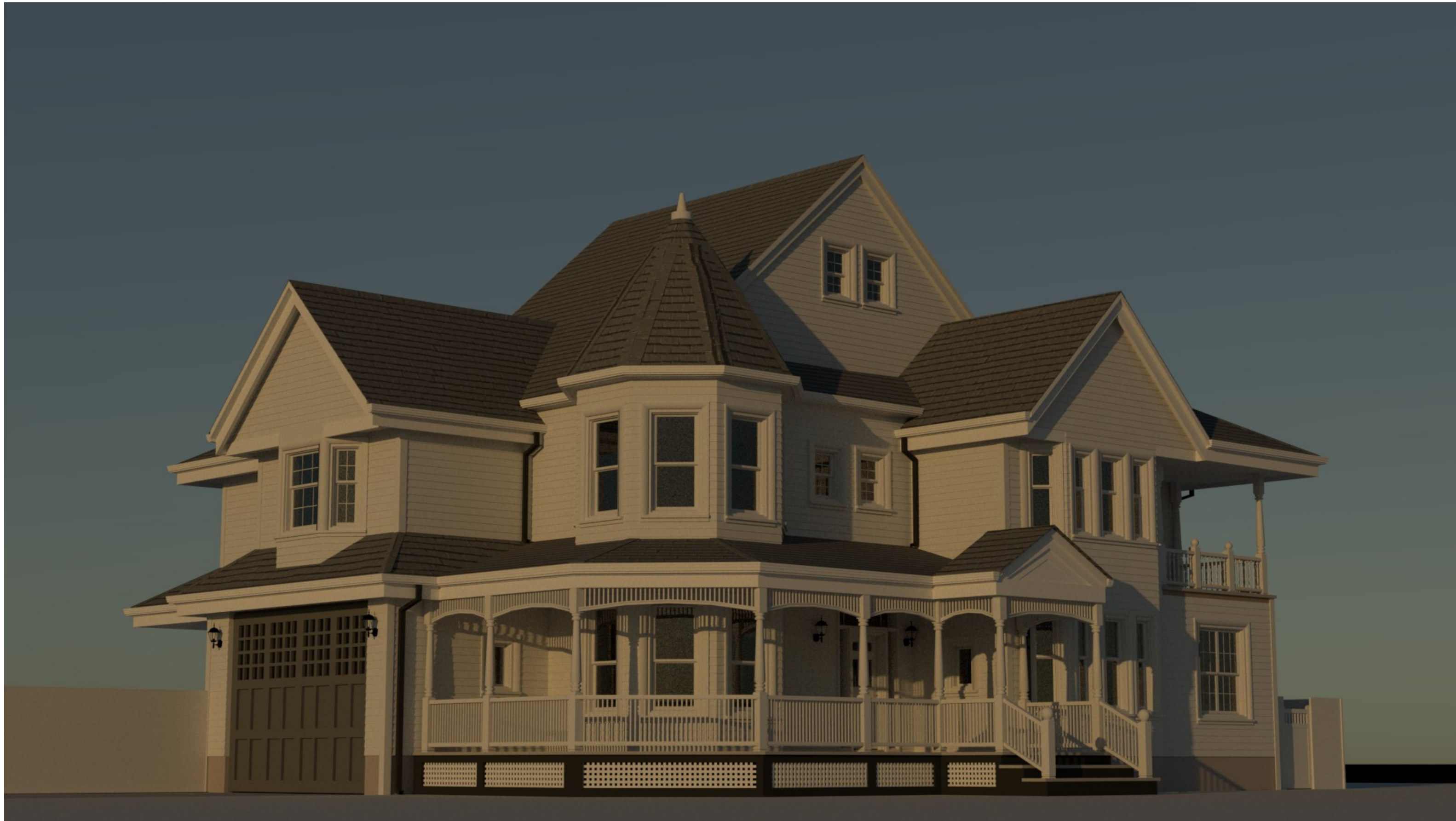
Initialized with turbidity, albedo
and time

Queried with view direction

✓ Efficient

✓ Photo-realistic renders

✗ No measures depending on time



Victorian Style House at 6pm

TimedSunsy emitter

TimedSunsy emitter

Initialized with turbidity, albedo

TimedSunsy emitter

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Queried with view direction and
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✓ More versatile

TimedSunsy emitter

Initialized with turbidity, albedo
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- ✓ More versatile
- ✓ Time dependent measures:
 - Useful Daylight Illuminance
 - Spatial Daylight Autonomy
 - Glare
 - and more

TimedSunsy emitter

Initialized with turbidity, albedo
Queried with view direction and
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✓ More versatile

✓ Time dependent measures:

- Useful Daylight Illuminance
- Spatial Daylight Autonomy
- Glare
- and more

✗ Extra dimension to integrate



Victorian Style House averaged over a year (7am to 7pm)

Future work

- Improve sensor suite (currently only average)

Average irradiance of Victorian style house over a year



Future work

- Improve sensor suite (currently only average)
- Optimize indoor renders (path guiding)

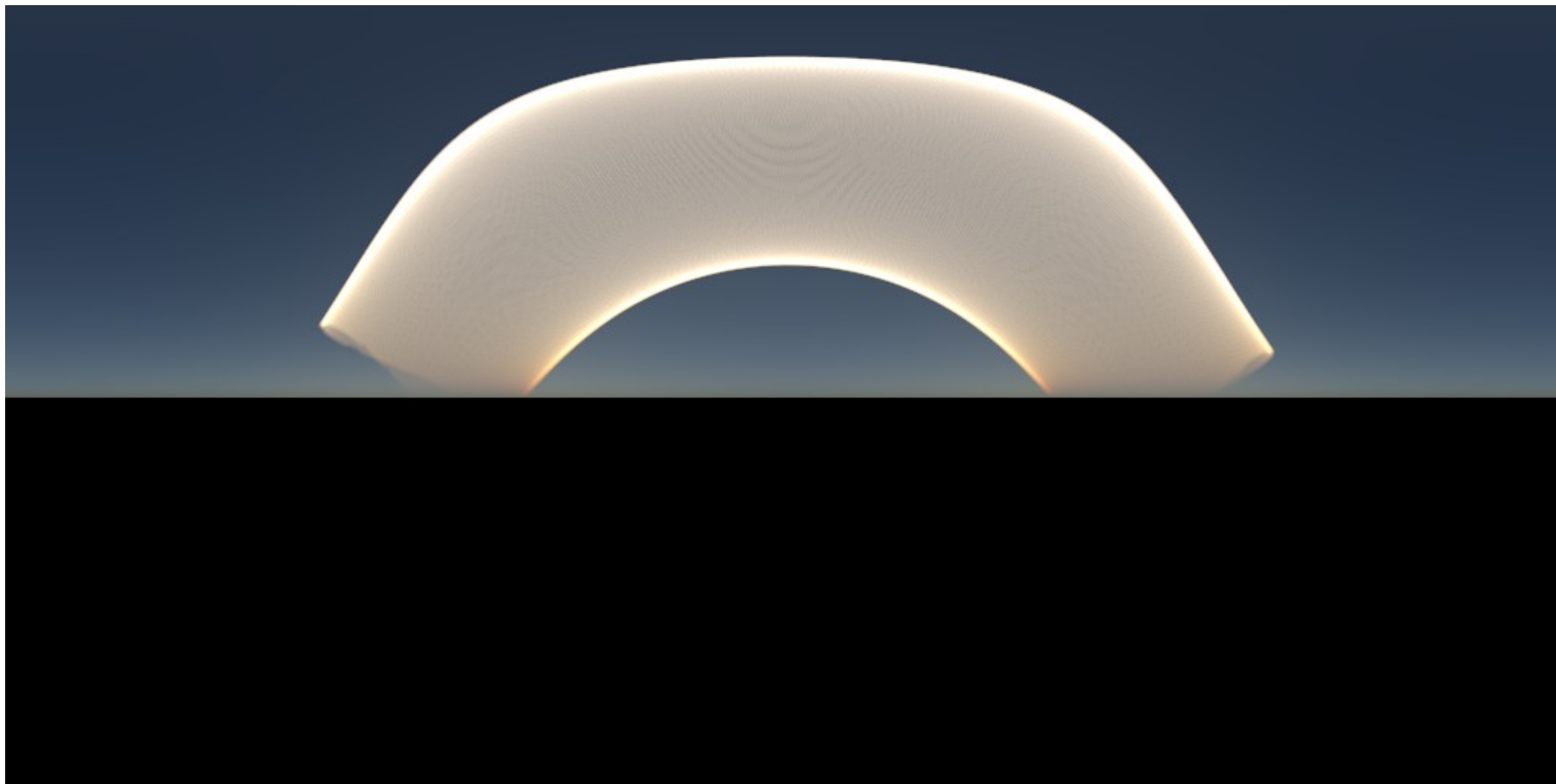
Average irradiance of Victorian style house over a year



Future work

- Improve sensor suite (currently only average)
- Optimize indoor renders (path guiding)
- Better interface to generate environment maps

Average radiance over a year in Tokyo



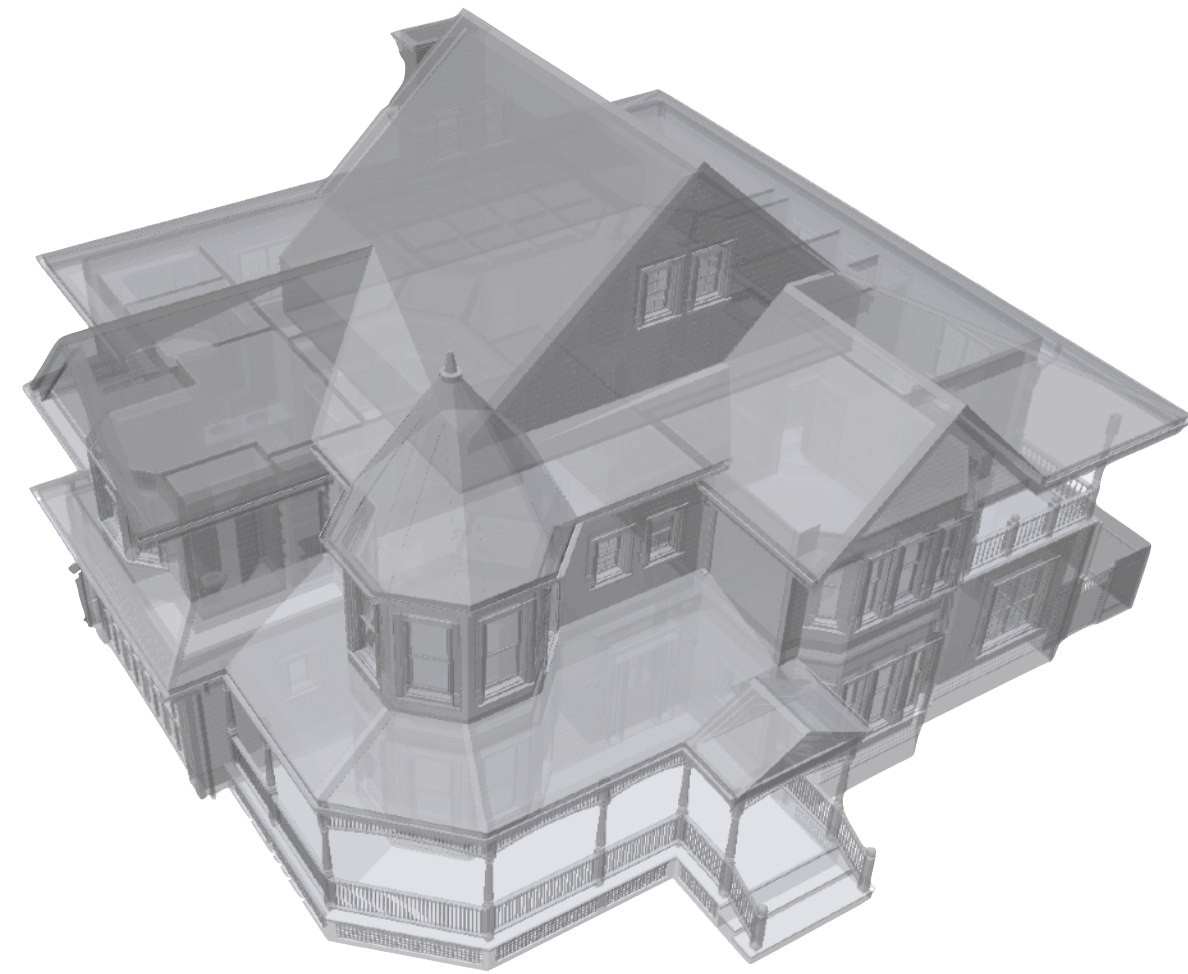
Average irradiance of Victorian style house over a year



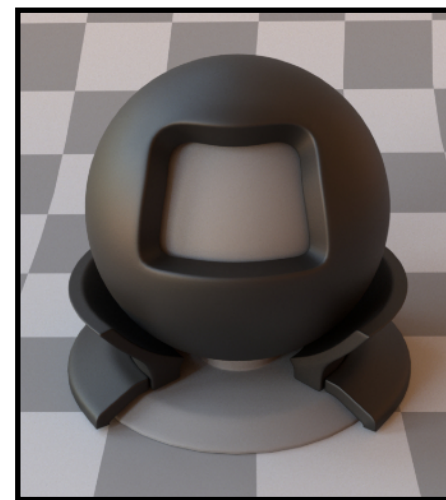
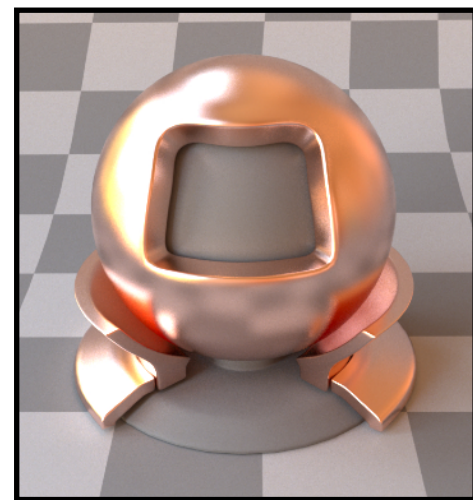
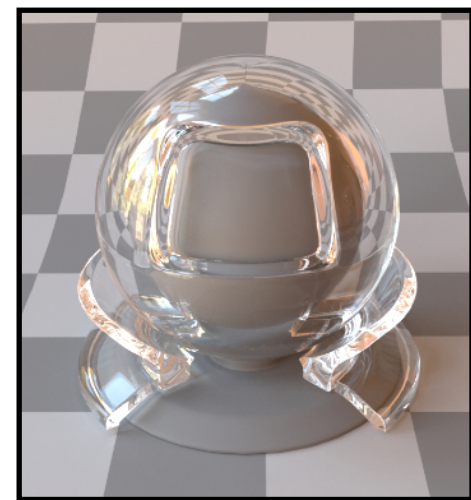
Daylight metrics

- Daylight / glare metrics:
 - Daylight factor (DF)
 - Useful Daylight Illuminance (UDI)
 - Annual Sunlight Exposure (ASE)
 - Daylight Autonomy (sDA)
 - Daylight Glare Probability (DGP)
 - ...?

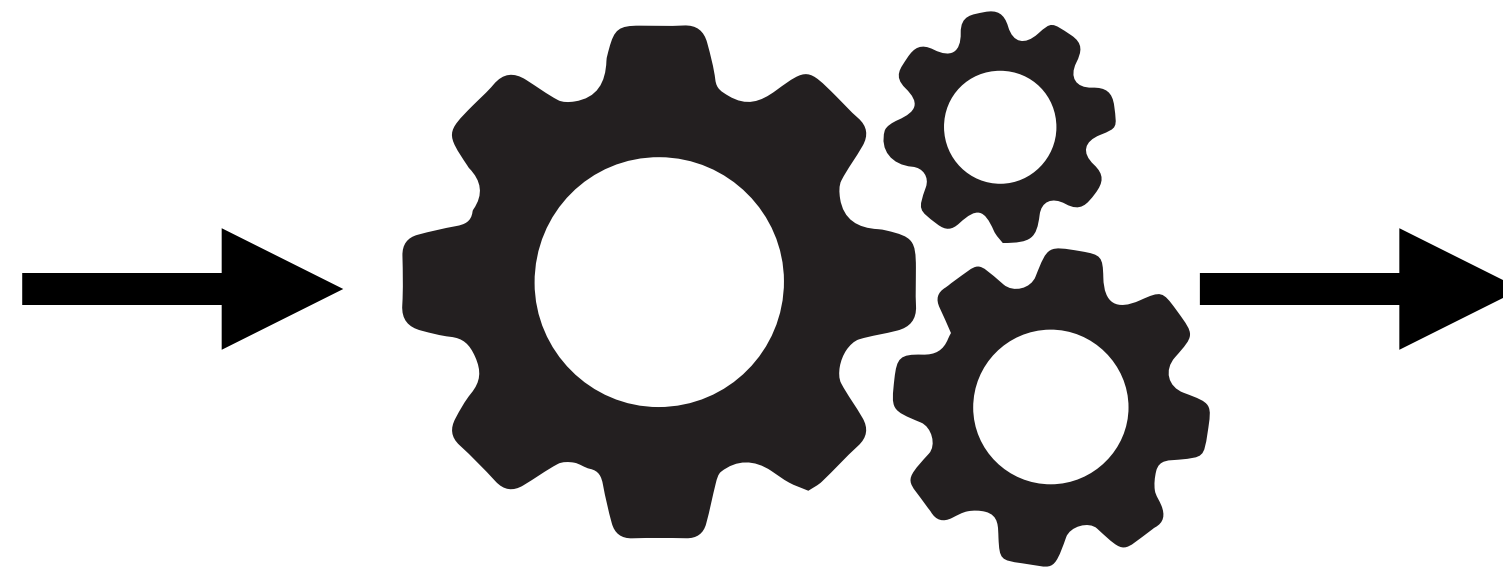
Differentiable daylight metrics?



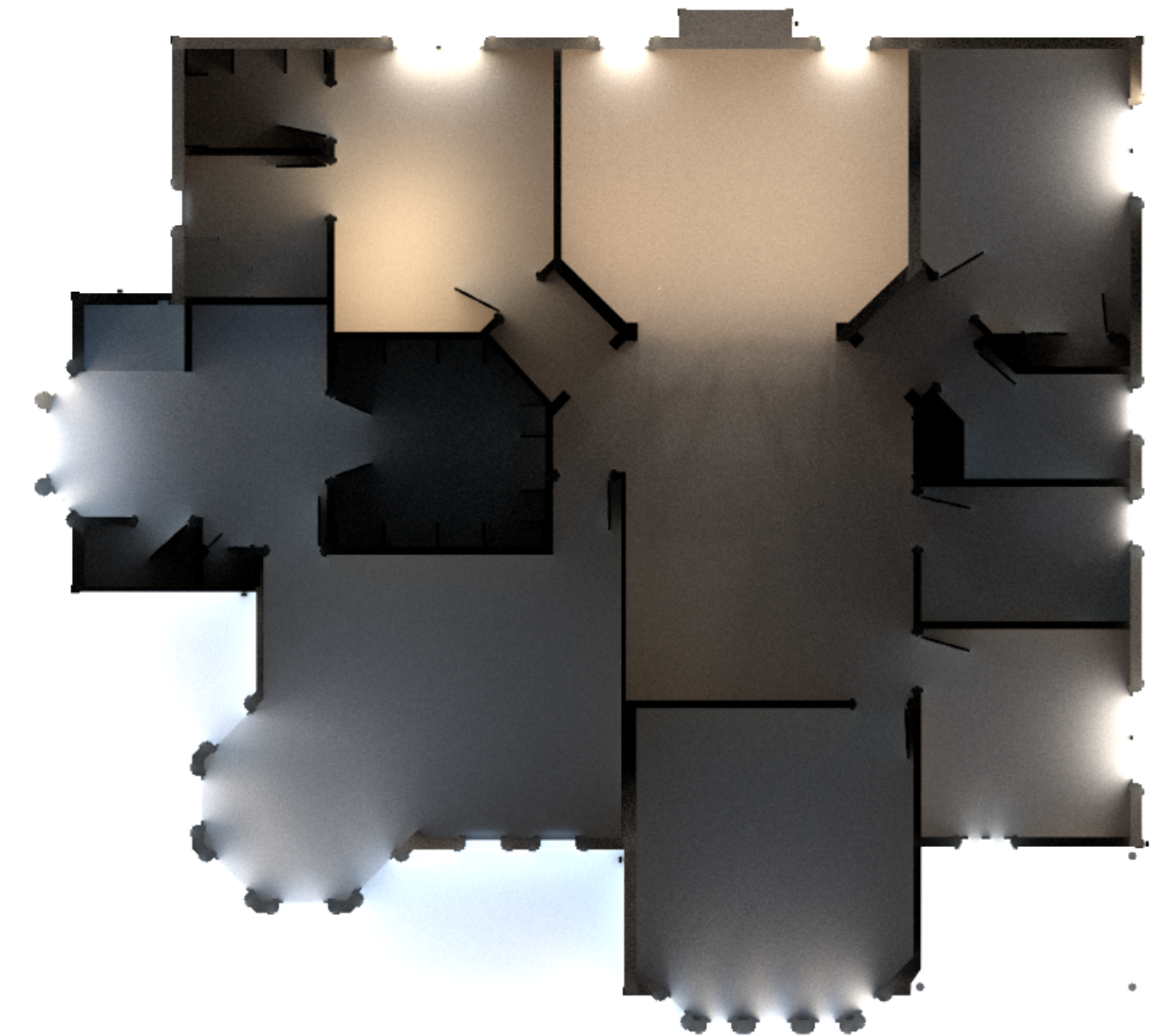
3D geometry



Materials

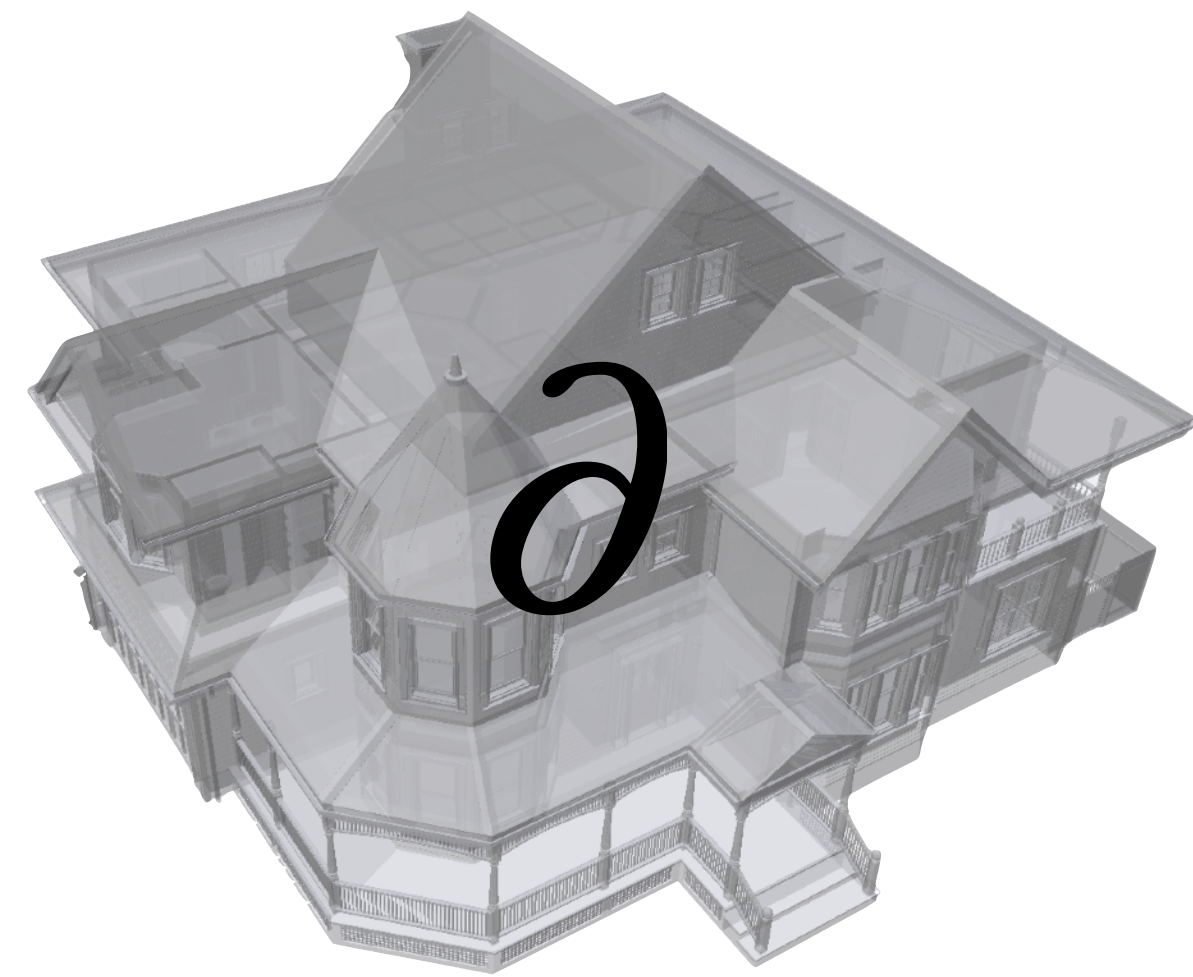


Simulation

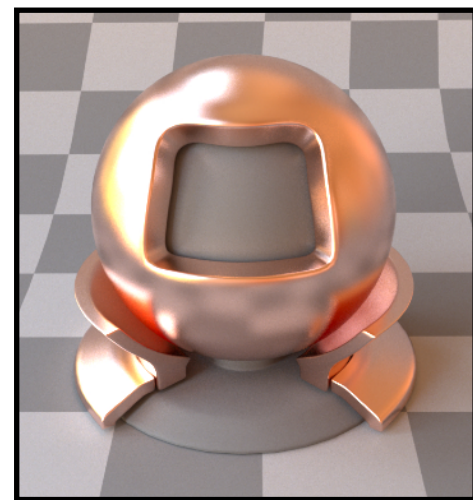
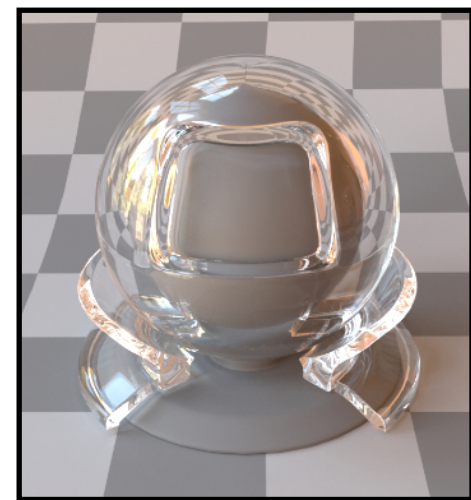


Metrics

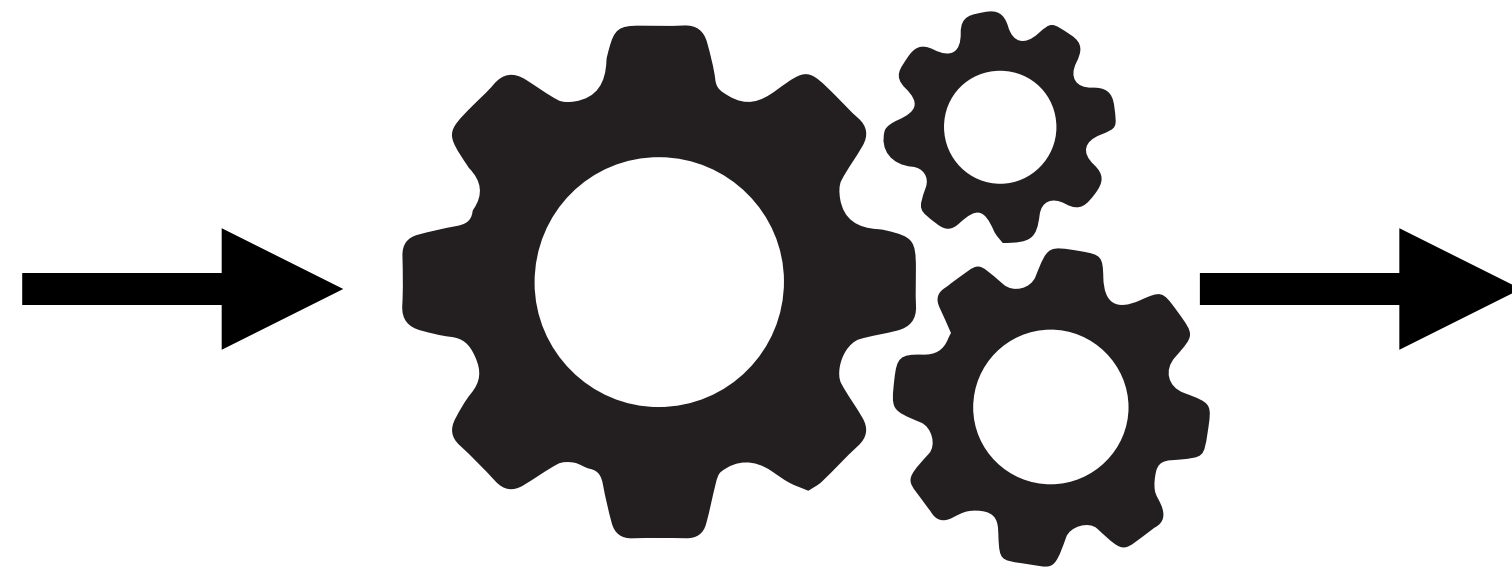
Differentiable daylight metrics?



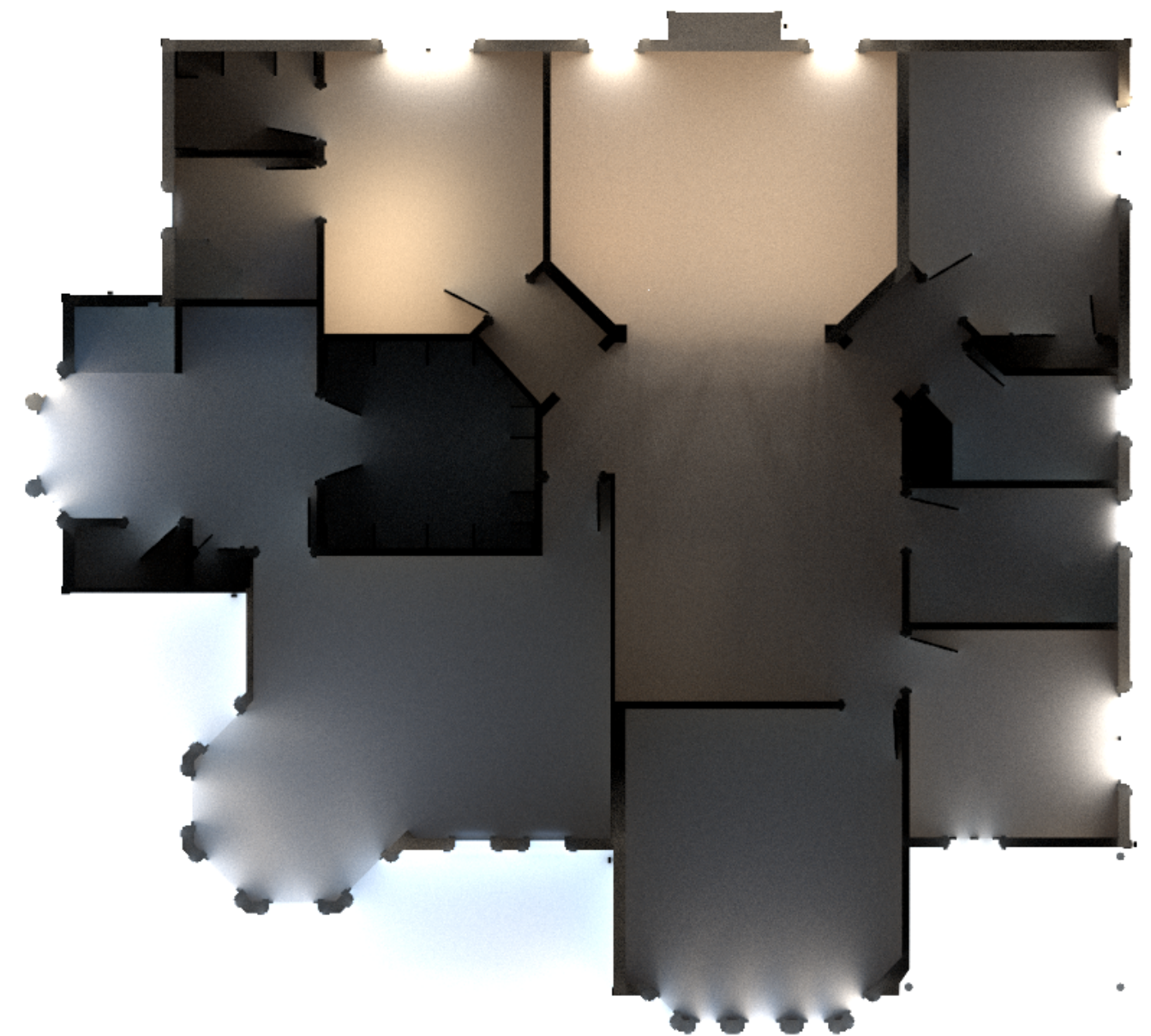
3D geometry



Materials

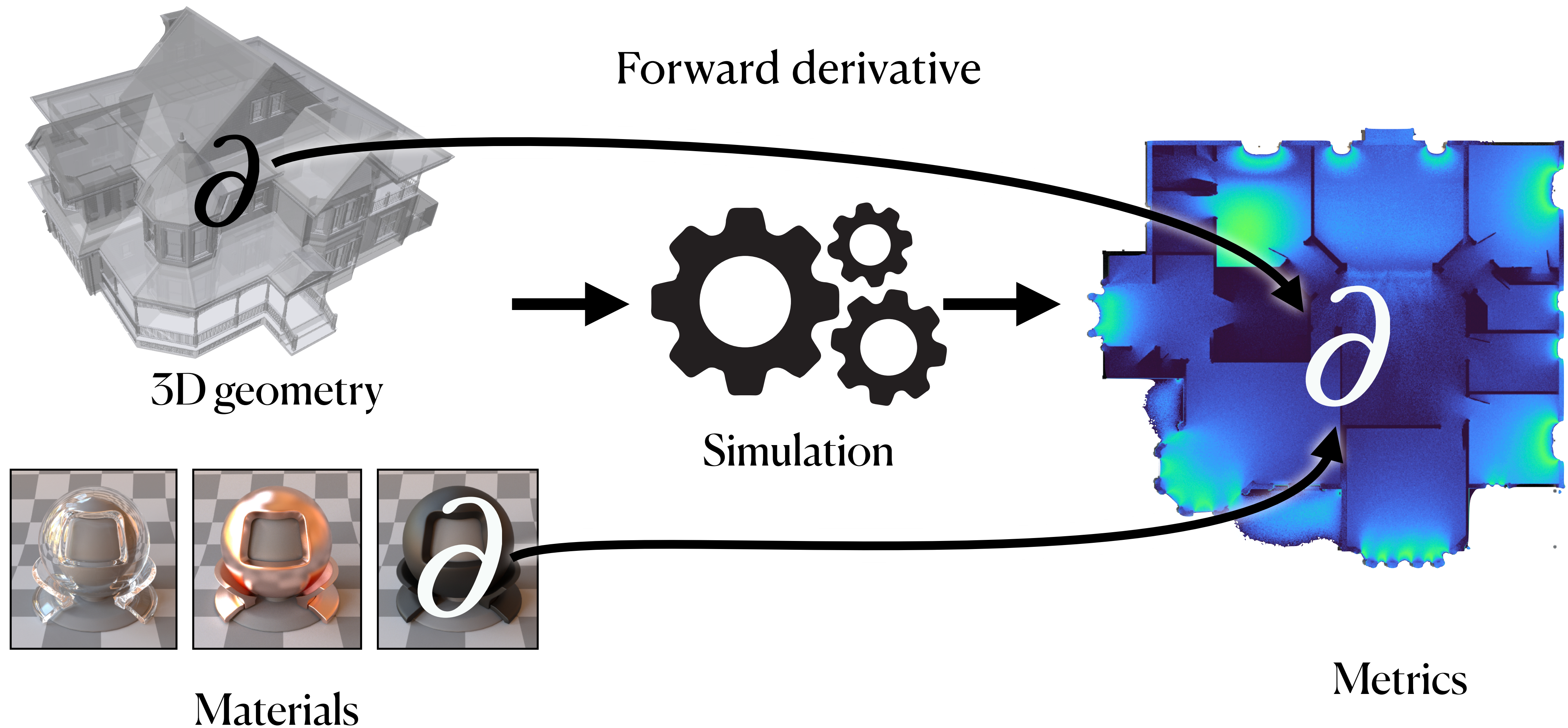


Simulation

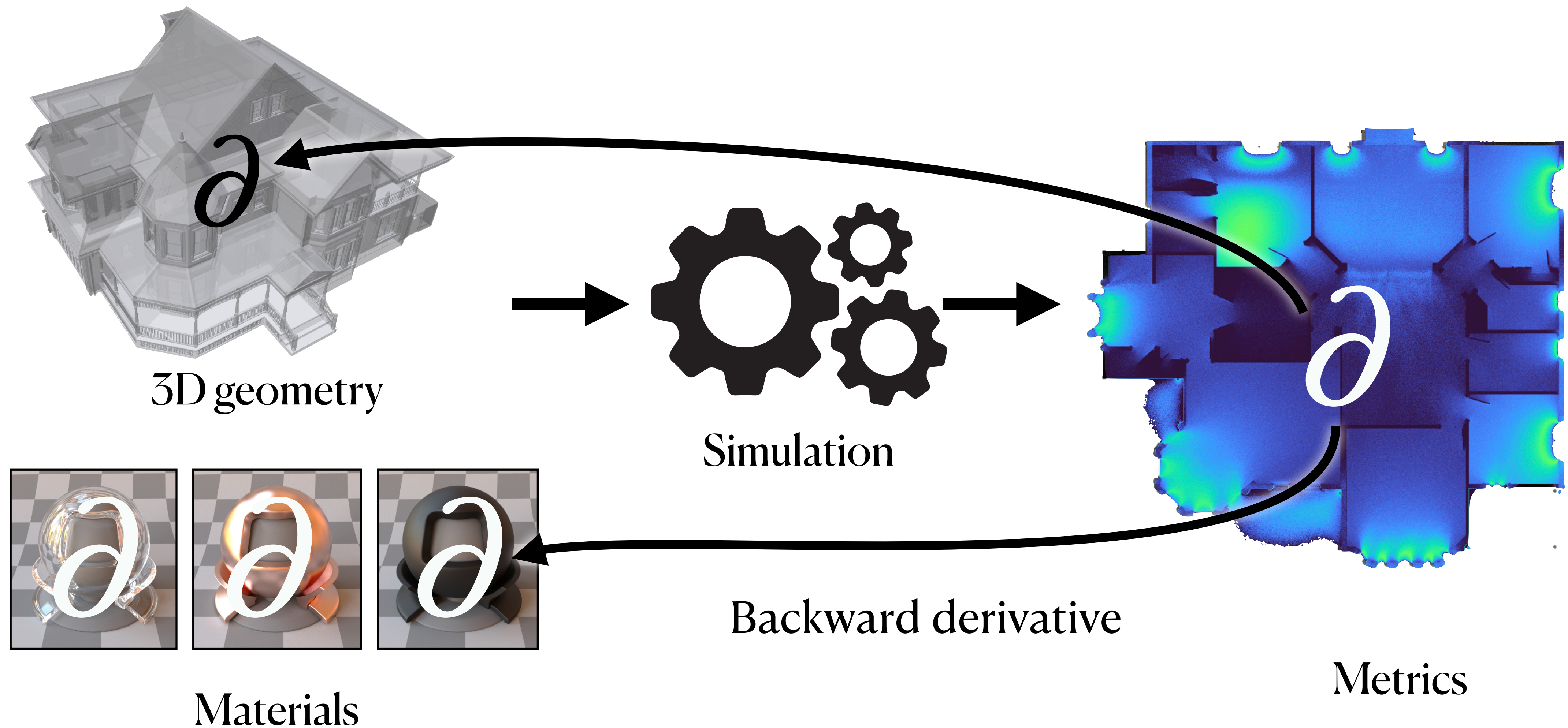


Metrics

Differentiable daylight metrics?



Differentiable daylight metrics?



A call for help and collaborators

- General question: is this actually useful? Is there a breakthrough application enabled by high performance / large-scale differentiable daylight simulation?
- Interested in exploring this space!
- **But:** we have no experience in architecture/daylighting and need help & experienced collaborators.

