Computer Graphics (COMP0027) 2022/23

# Photon Mapping

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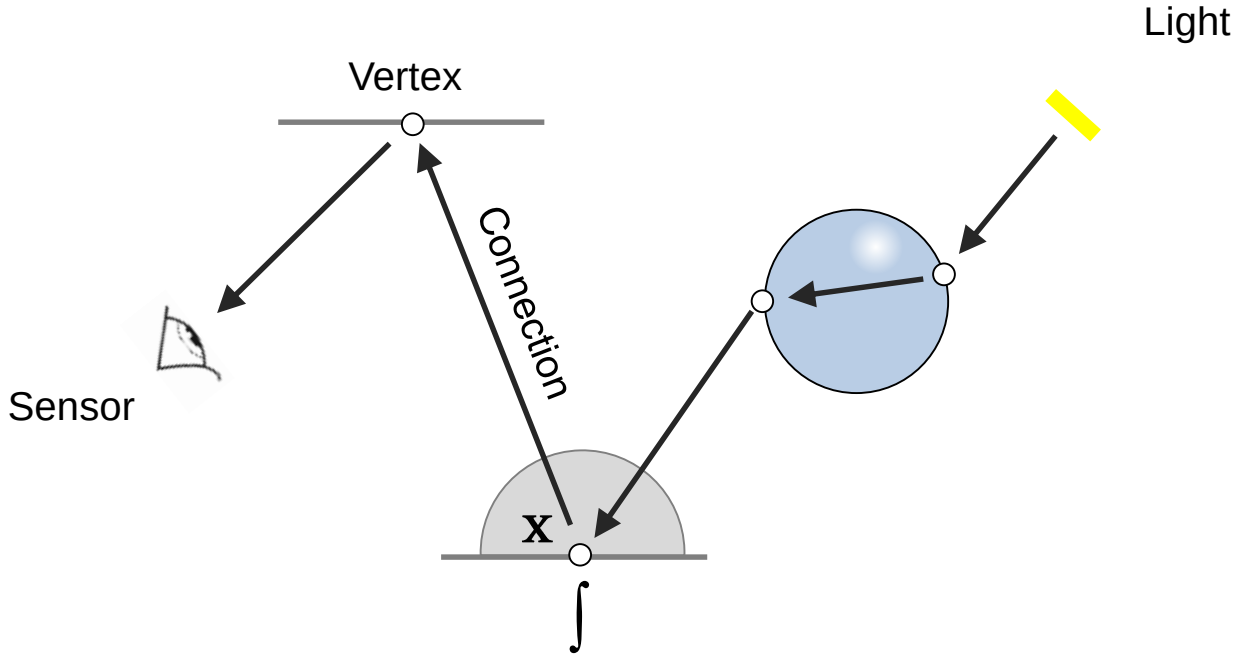
# Today

- Motivation
- Idea: Starting light paths at the light
- Methods
  - Light tracing
  - Bi-directional path tracing
  - Photon Mapping
  - Instant Radiosity

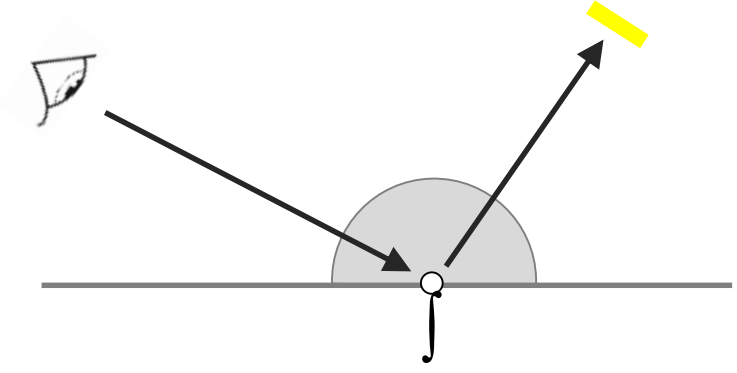
# Path space jargon

术语



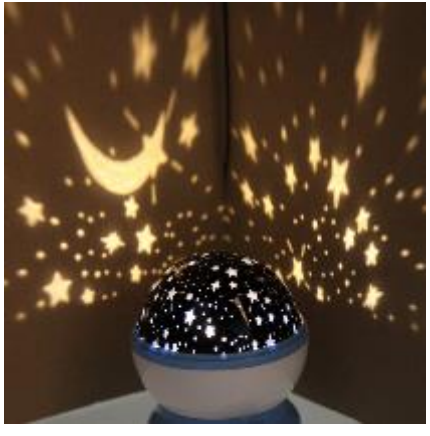
# Example 1: Small lights

- Small light sources imply a small hit chance
- Solution: Next-event estimation
- Pre-condition: We know what is a light



# What is hard for Path tracing

- Two examples:
  - Occlusion (key hole-like)
  - Specular (caustics)

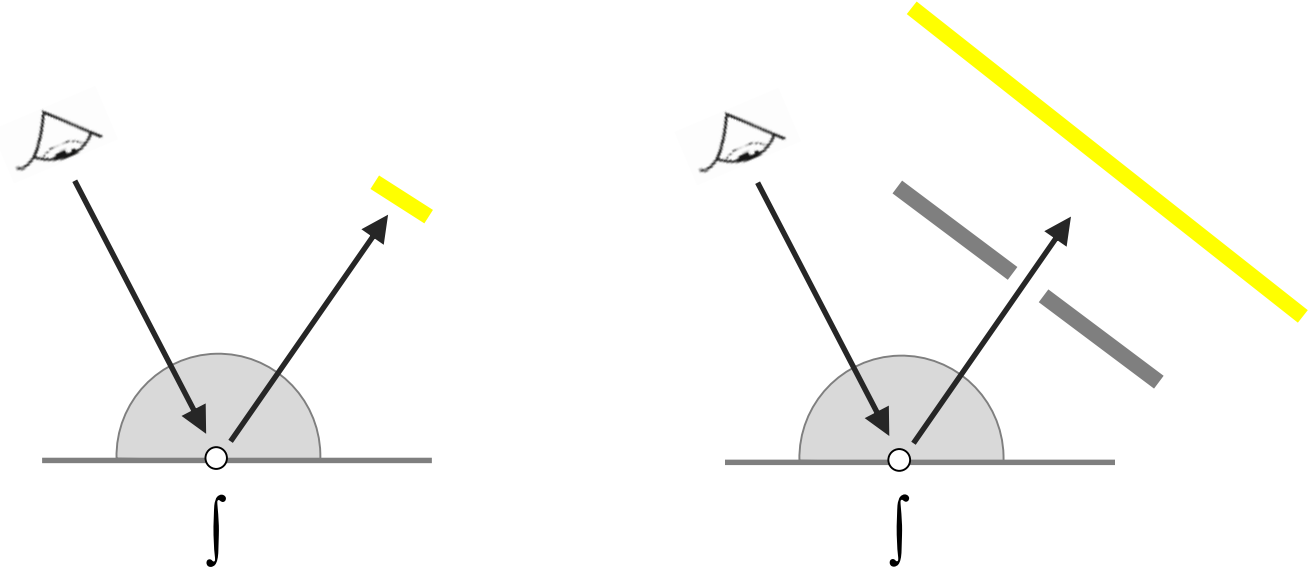


# Small lights

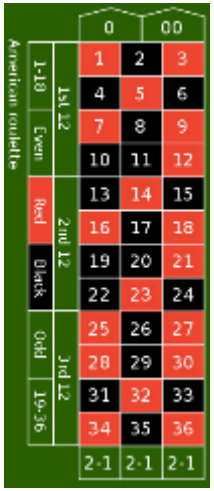
# Limits of next-event estimation

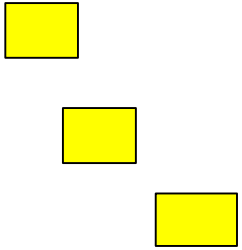
Small light: Fine!

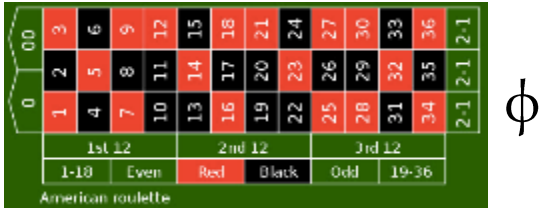
Large light, small holes, now what?

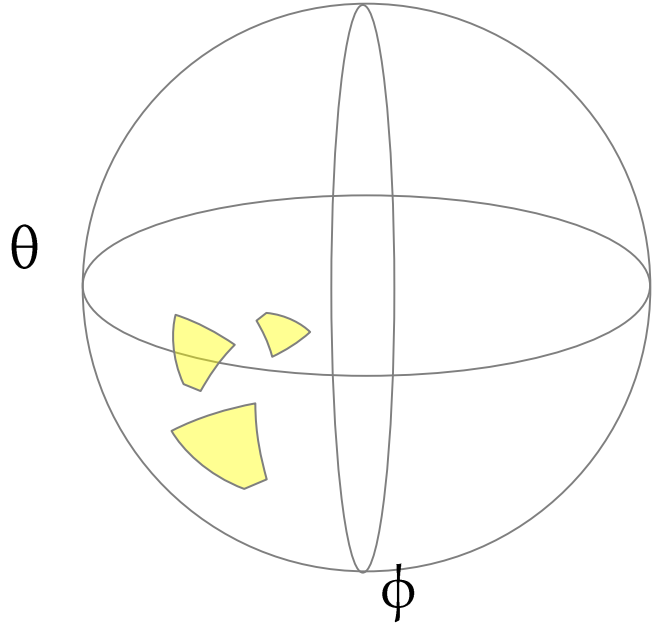


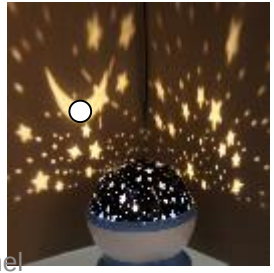
# Roulette in spherical domain





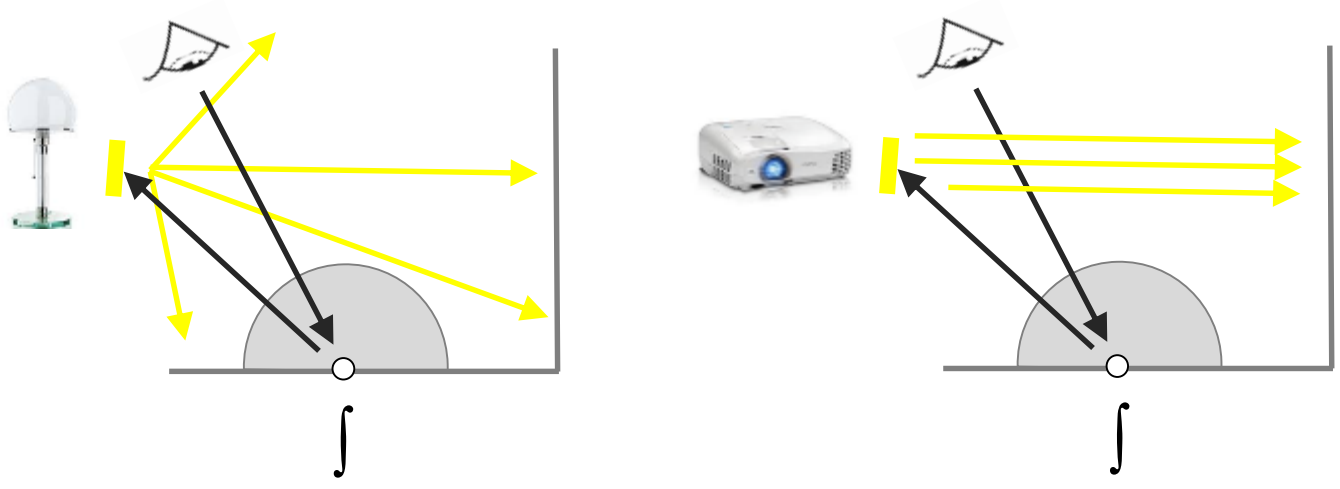



# Projector

# Next-event can *not* help

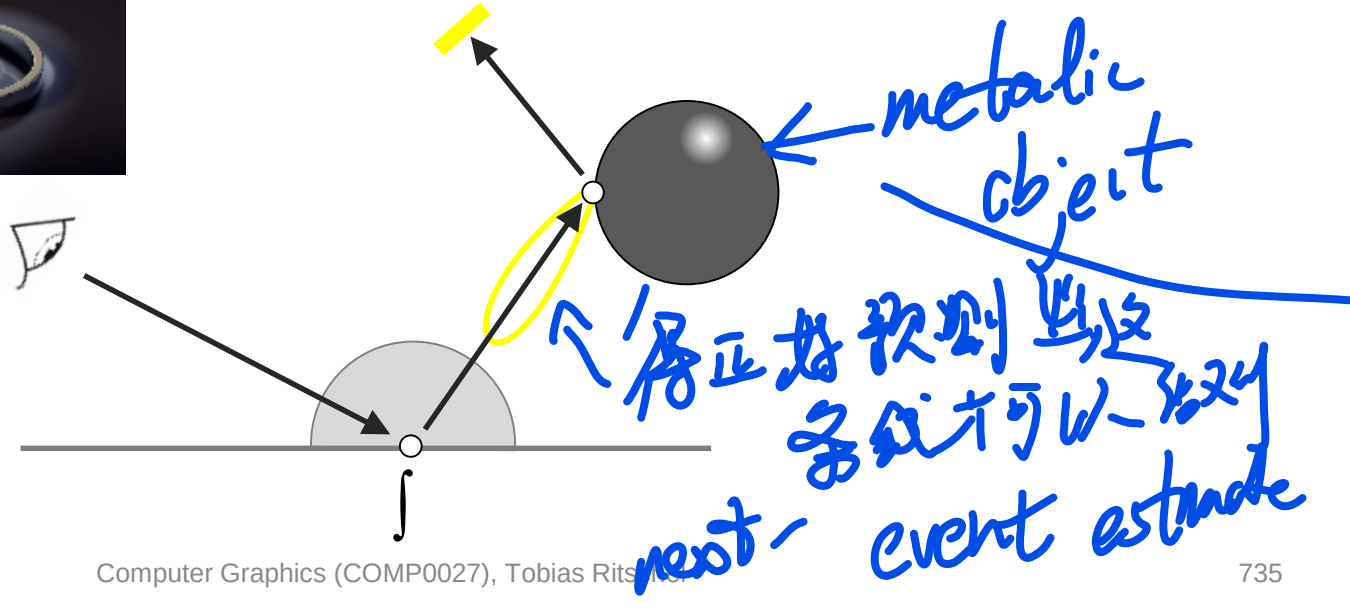
- The projector sends light into very few directions only
- Connecting to it is useless most of the time



# Reflective caustic

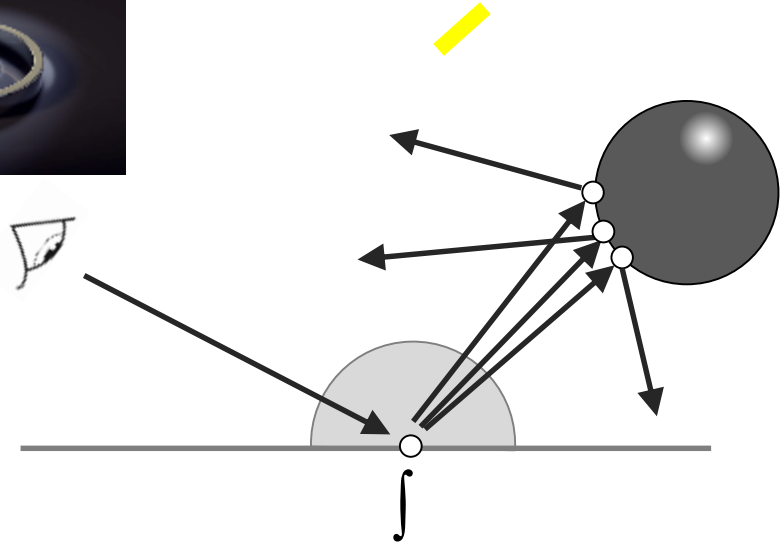
# Example 2: Caustics

- A **caustic** is similar to a small light sources
- No obvious way to find it

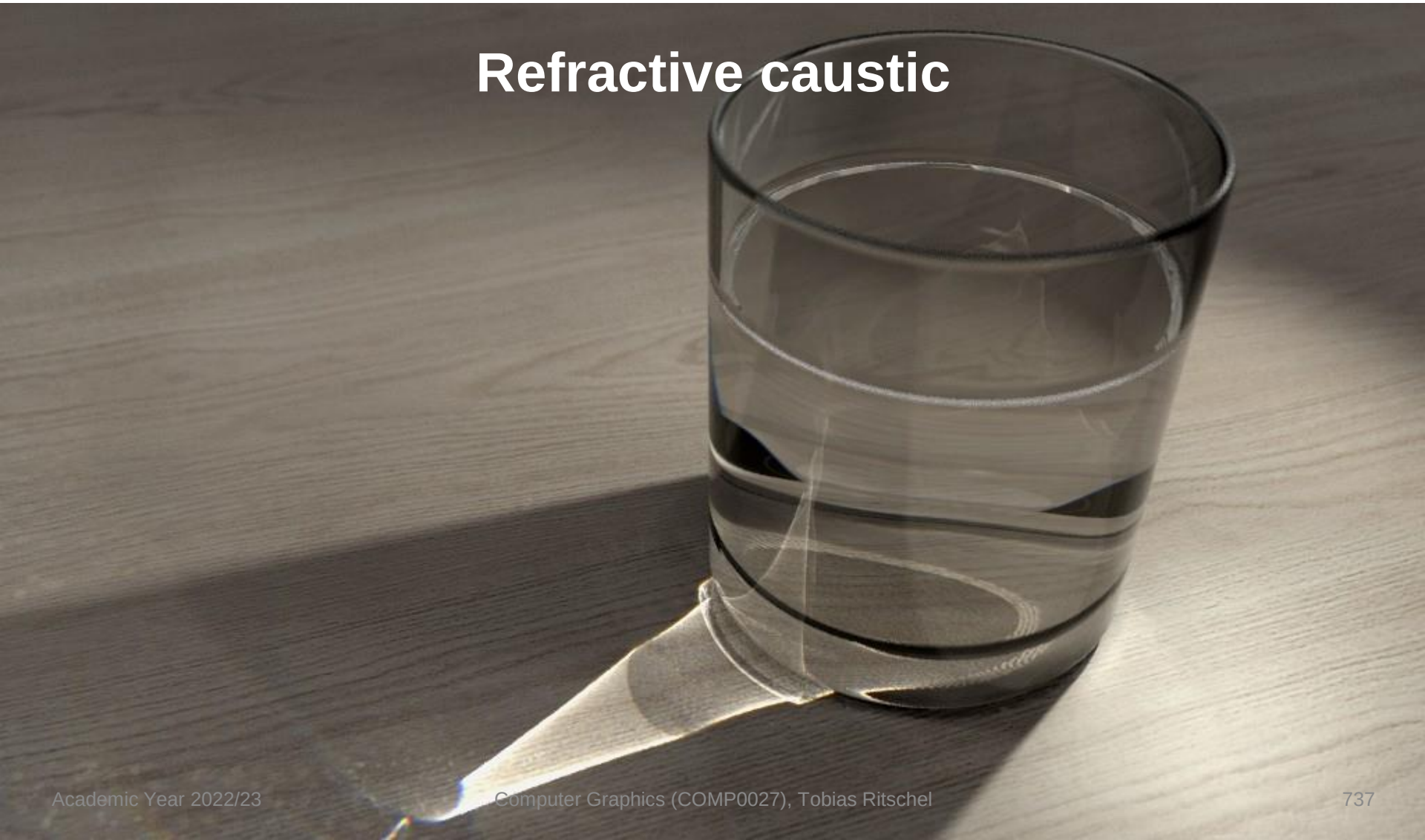


# Example 2: Caustics

- This can be wronh in a million of ways
- Needs luck twice
- Three examples

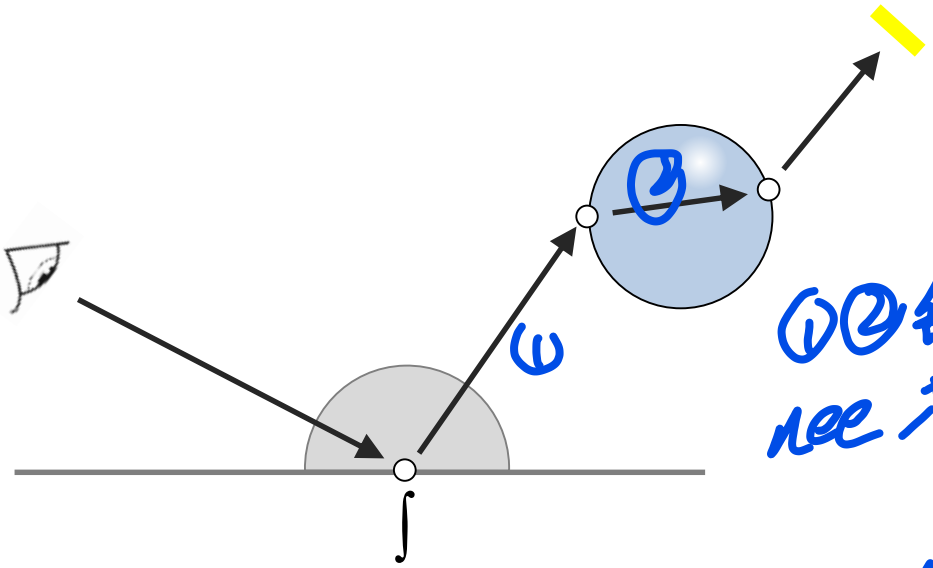


# Refractive caustic



# Example 2: Caustics

- A **caustic** is similar to a small light sources
- No obvious solution
- Refractive even harder: Two angles!

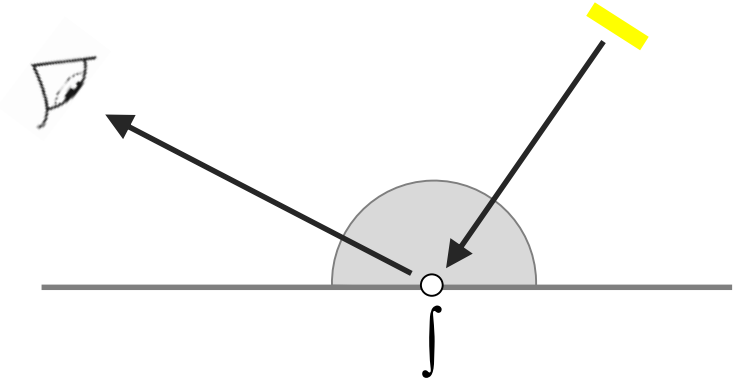


# What is hard for path tracing?

- Paths of the form LSDE, LSSDE, etc
- Light that undergoes one or more specular reflections, then a diffuse bounce
- Reflective or refractive caustics

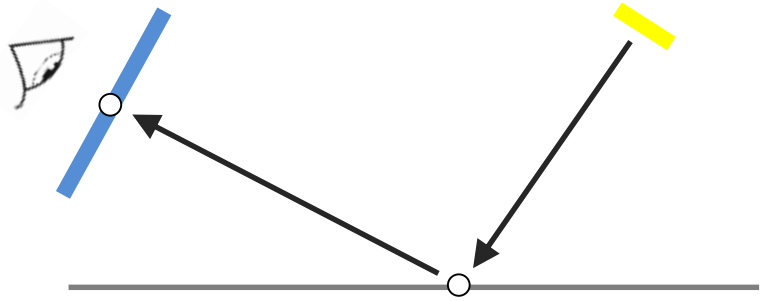
# Solution: Light tracing method

- Start path at the light
- Trace rays through the scene
- In the end **project** onto sensor



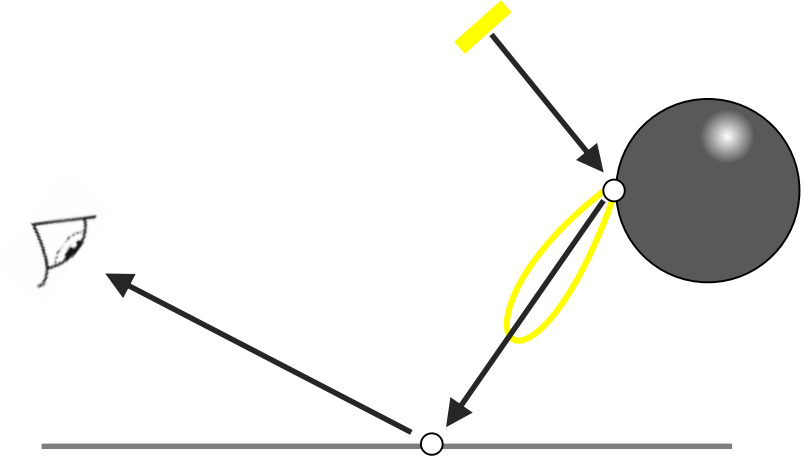
# Light tracing

- Need next-event estimation at final vertex
- Sensor is even smaller than light
- Finding it by chance even less likely



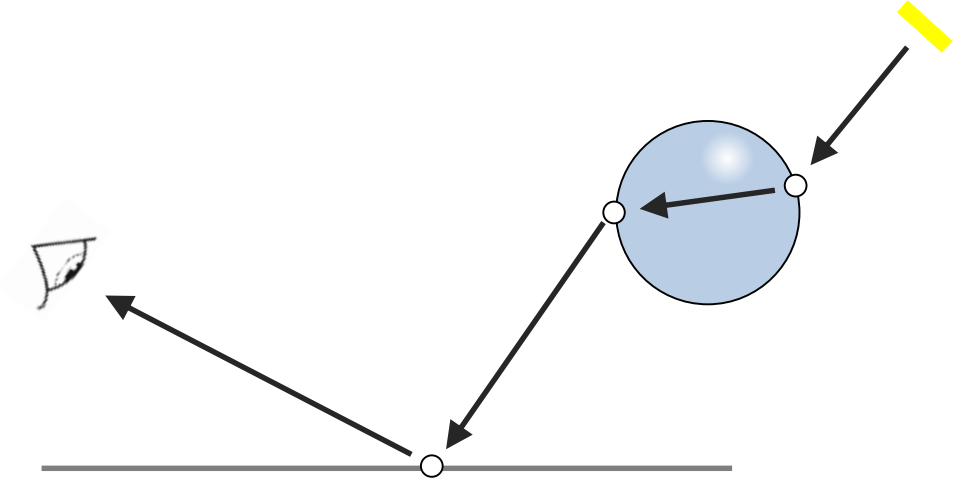
# Light tracing for a reflective caustic

- Works quite well

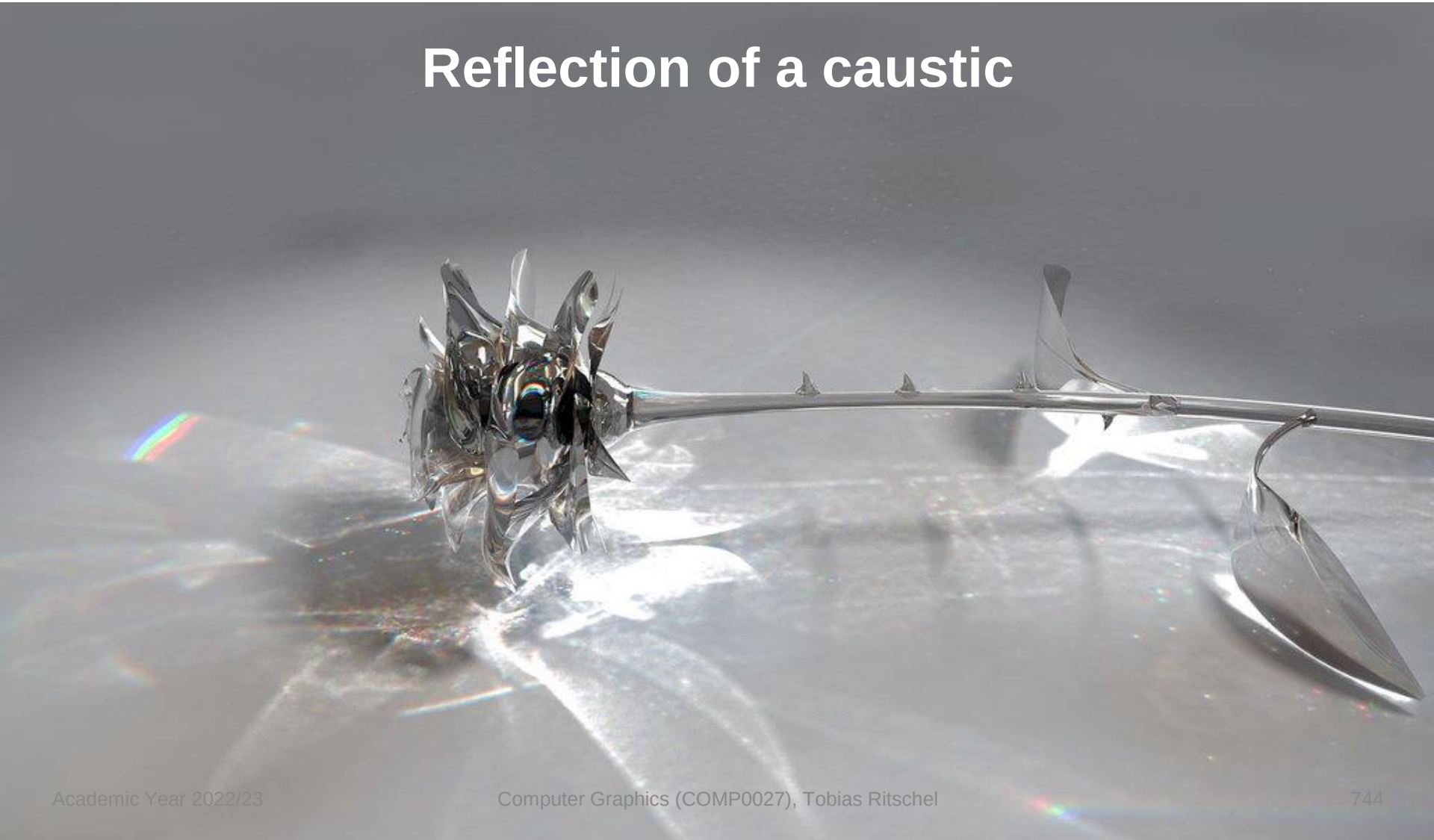


# Light tracing for a refractive caustic

- Works quite well

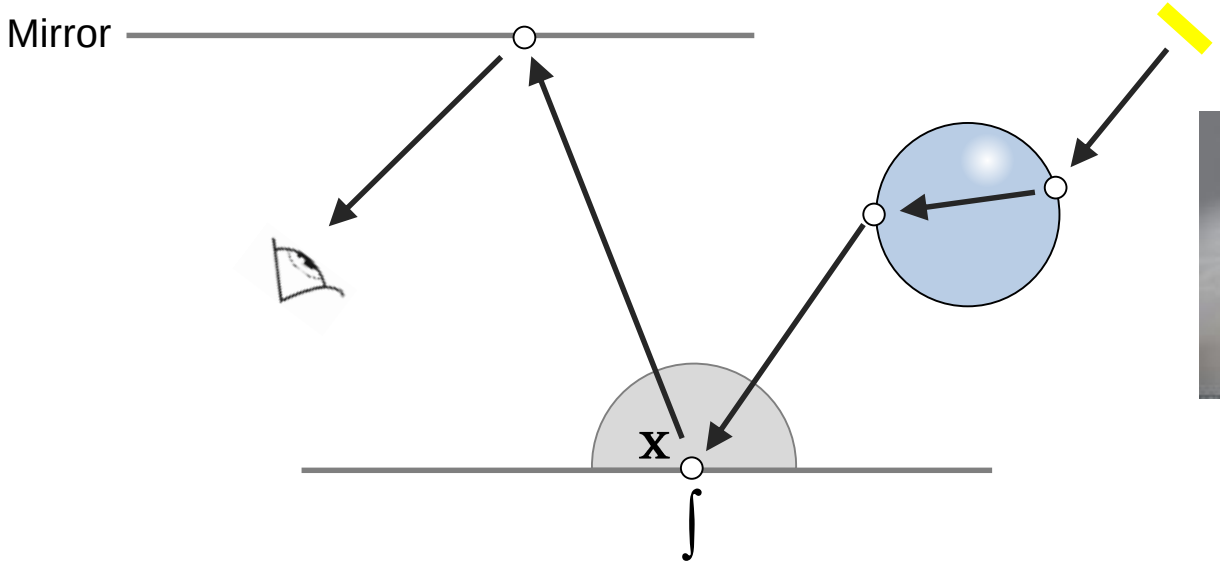


# Reflection of a caustic



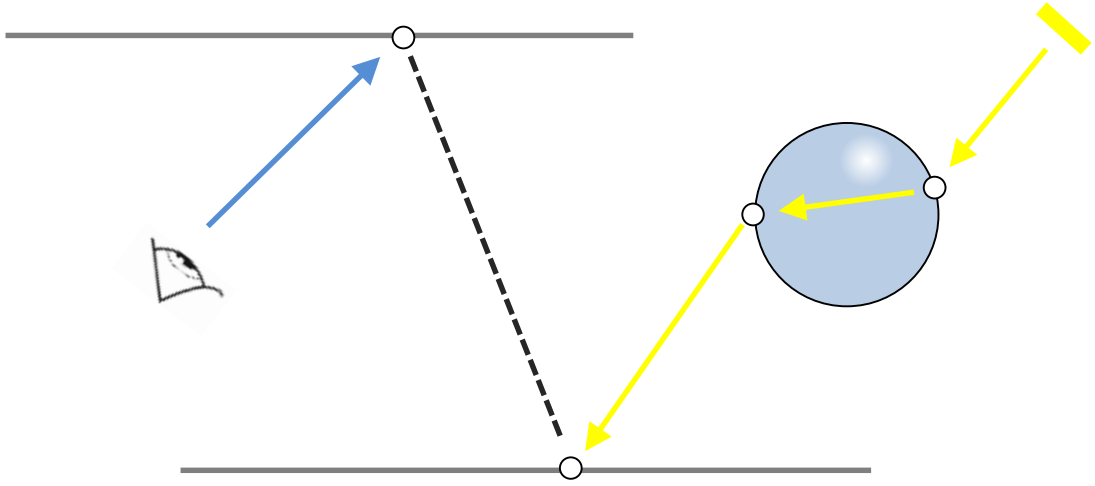
# Caustics in a mirror

- Very hard!
- How could we know at $\mathbf{x}$ how to go on?




# Bi-directional path tracing

- Start a path both at the eye and the light
- Connect the ends



# Bi-directional path tracing

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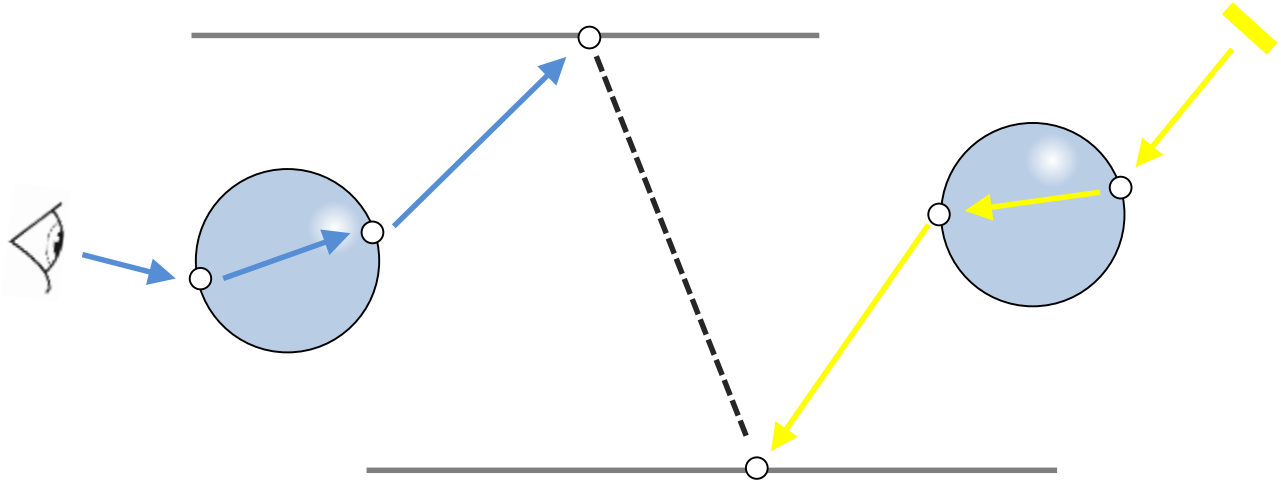
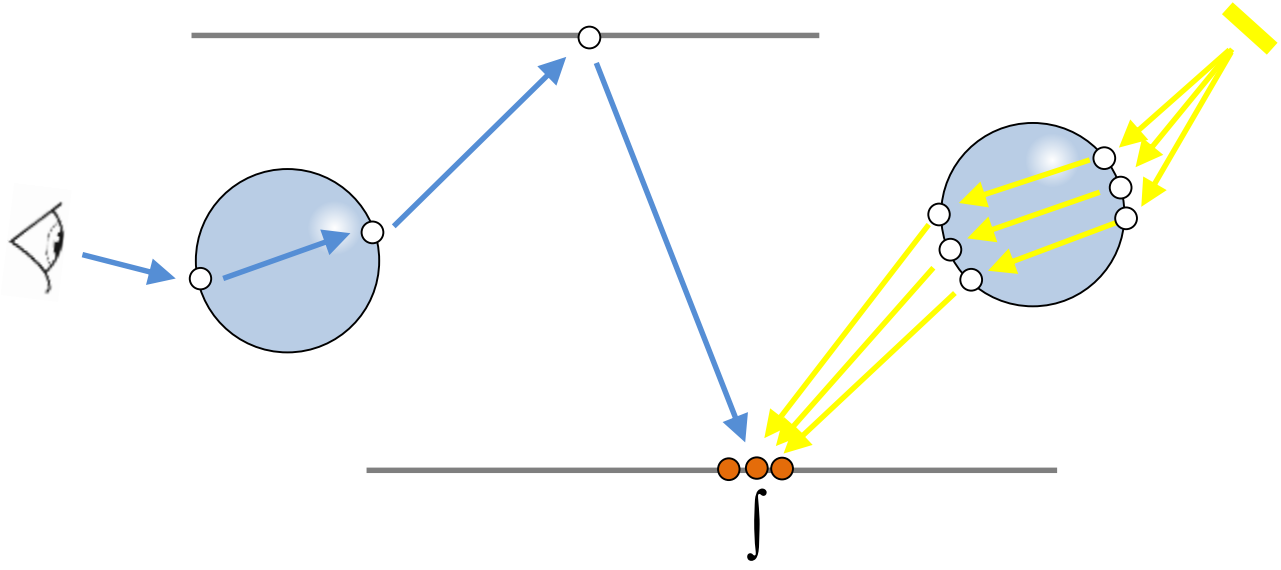


# Photon mapping

- When eye paths connect to light paths we don’t care about their path, only about the vertex
- Idea:
  - Store end-vertices from the light
  - Re-use from the eye

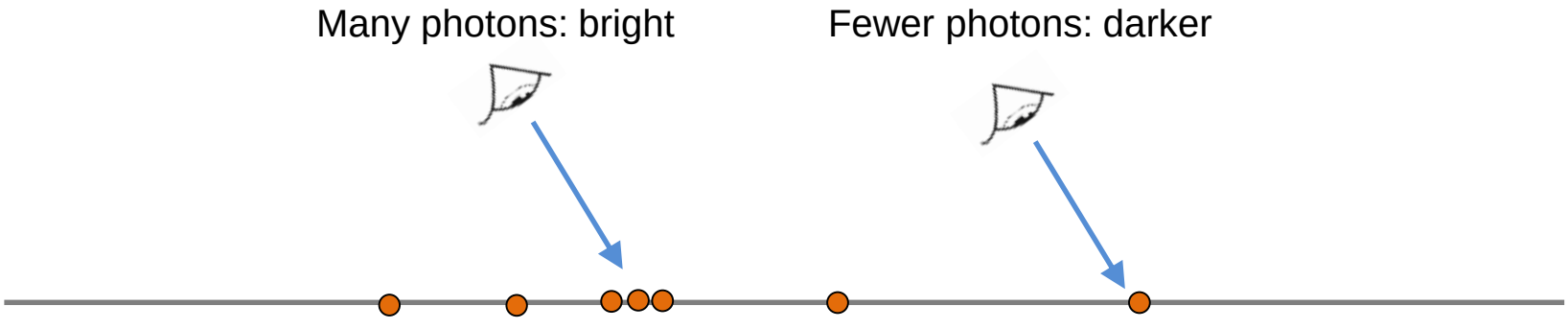
# Photon mapping

- Start many rays at the light, store last vertex
- Re-use form the eye



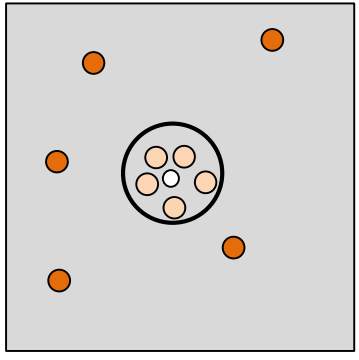
# Density estimation

- Photon are just a list of 3D points
- How to convert into $L_i(\mathbf{x}, \omega)$ ?
- Find how many are nearby!



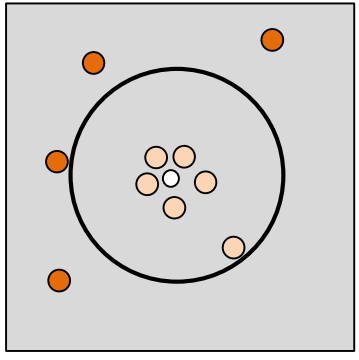
# Two options: Option 1

- Find the nearest $k$
- See how large their radius $r$ is
- Large a is small density and low $L$



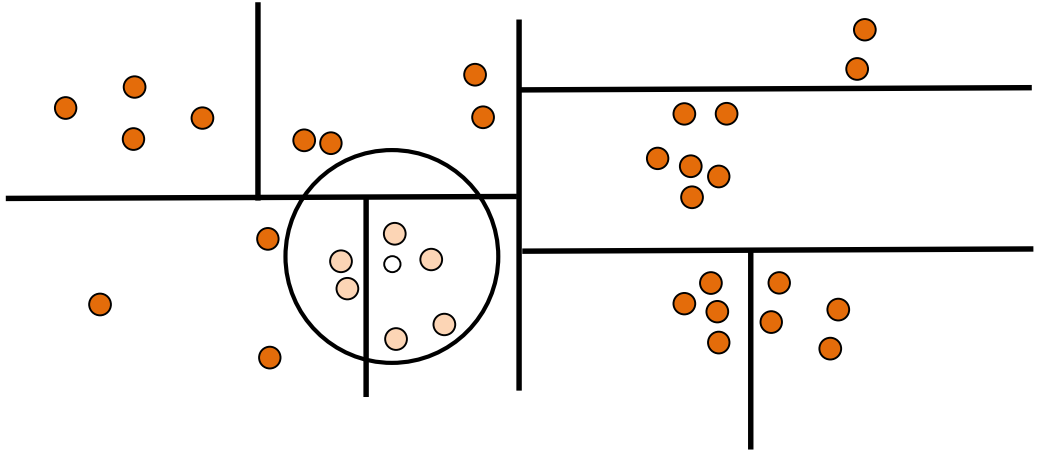
# Two options: Option 2

- Fix a radius $r$
- Count how many $k$ are in this radius
- Large $k$ is high density and high $L$



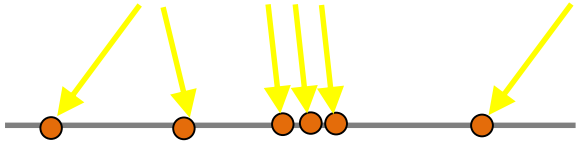
# How to find $k$ nearest?

- Spatial bounding structures
- $k$-$d$ tree
- Can find $k$ NN in $\log(n)+k$ time for $n$ points



# BRDF in PM

- The light also depends on the direction
- Photons also store from where they came
- Like this, can take direction into account



# Recap

- Can also start from the light
- Sometimes better
- Three ways to to this
  - Light tracing
  - Bi-dir raytracing
  - Photonmapping