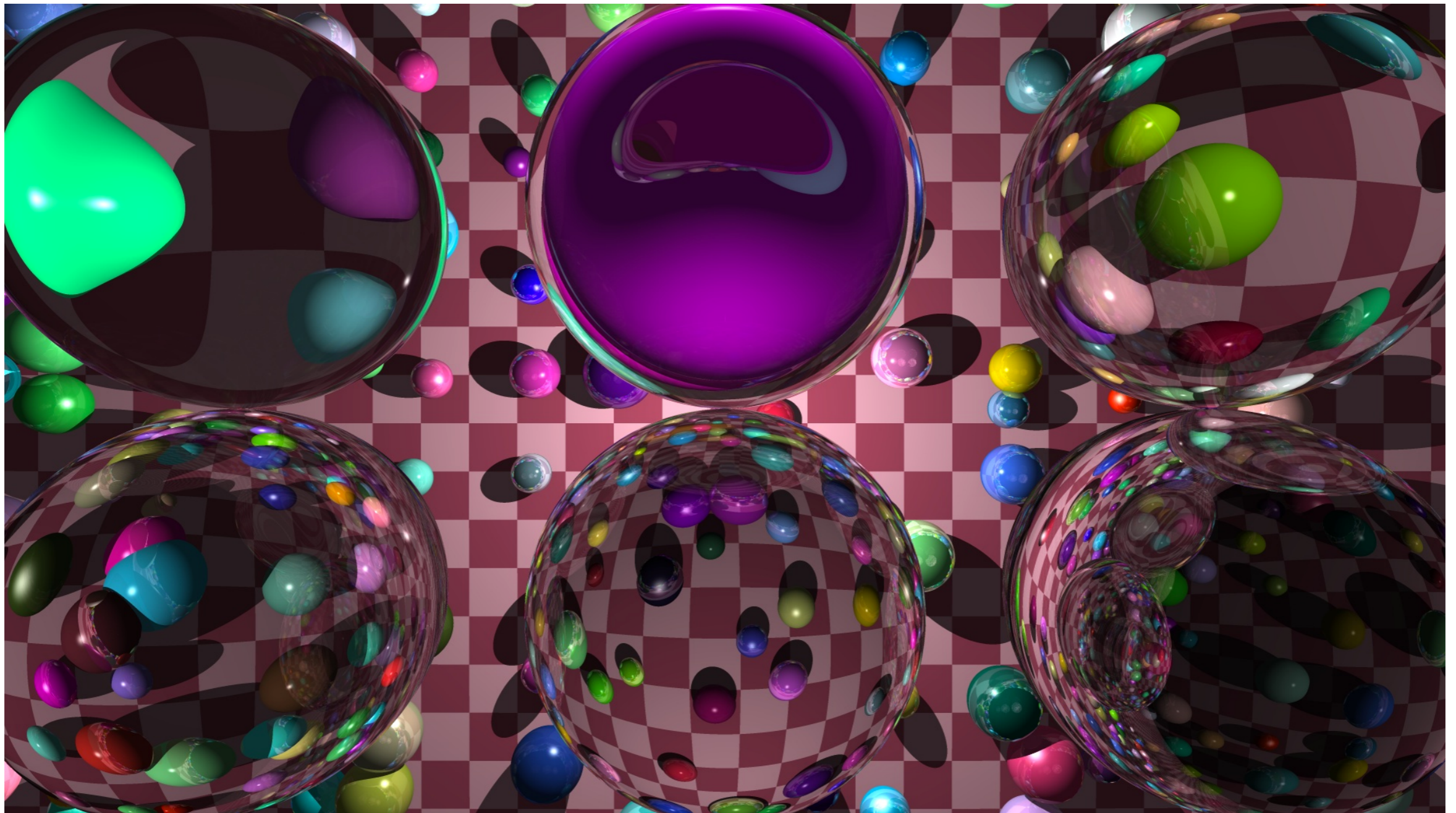


# ray tracer extensions

- refraction
- more complex geometry
  - instancing
  - CSG
- distribution ray tracing (Cook et al., 1984)
  - antialiasing
  - soft shadows
  - depth of field
  - fuzzy reflections
  - motion blur

# Transparency and Refraction



[marczych/github]

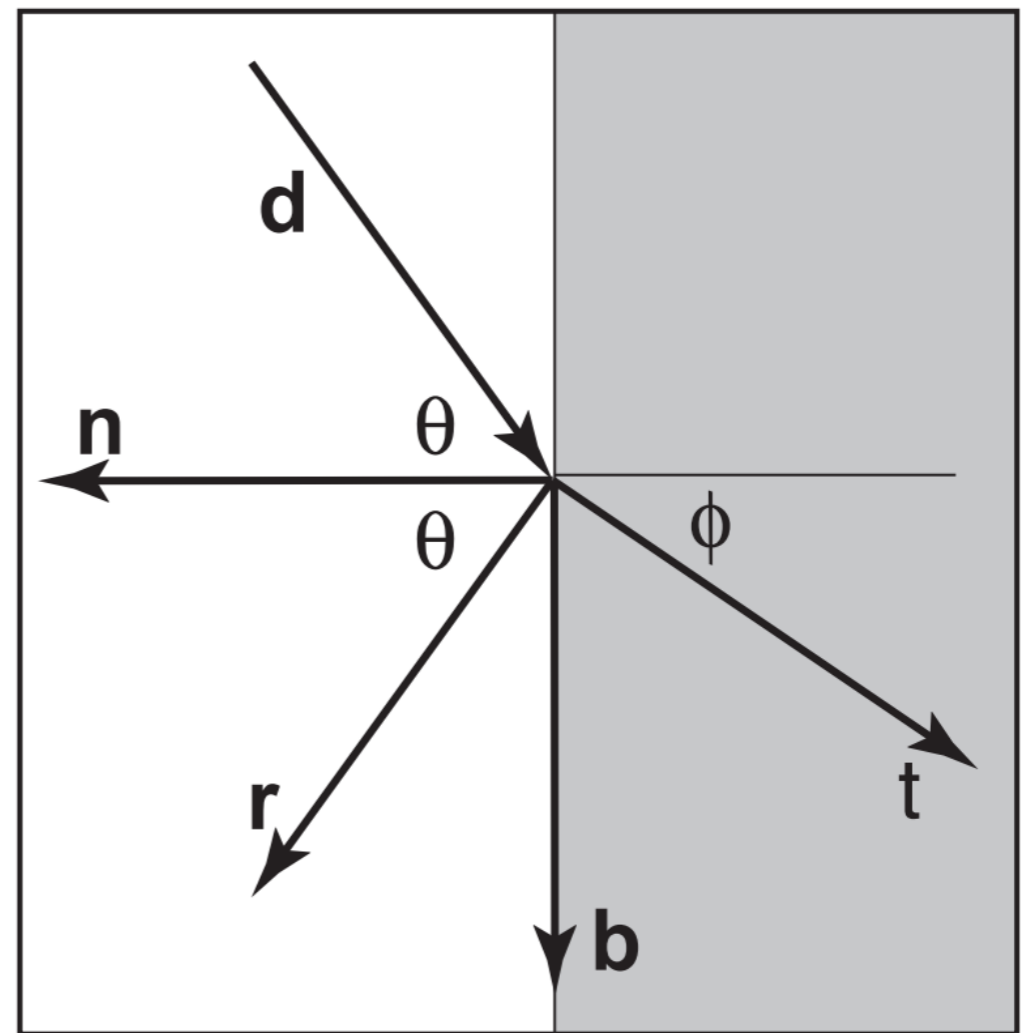
# Transparency and Refraction

Snell's Law

$$n_1 \sin\theta = n_2 \sin\phi$$

Example values of  $n$ :  
air: 1.00;  
water: 1.33–1.34;  
window glass: 1.51;  
optical glass: 1.49–1.92;  
diamond: 2.42.

<whiteboard>

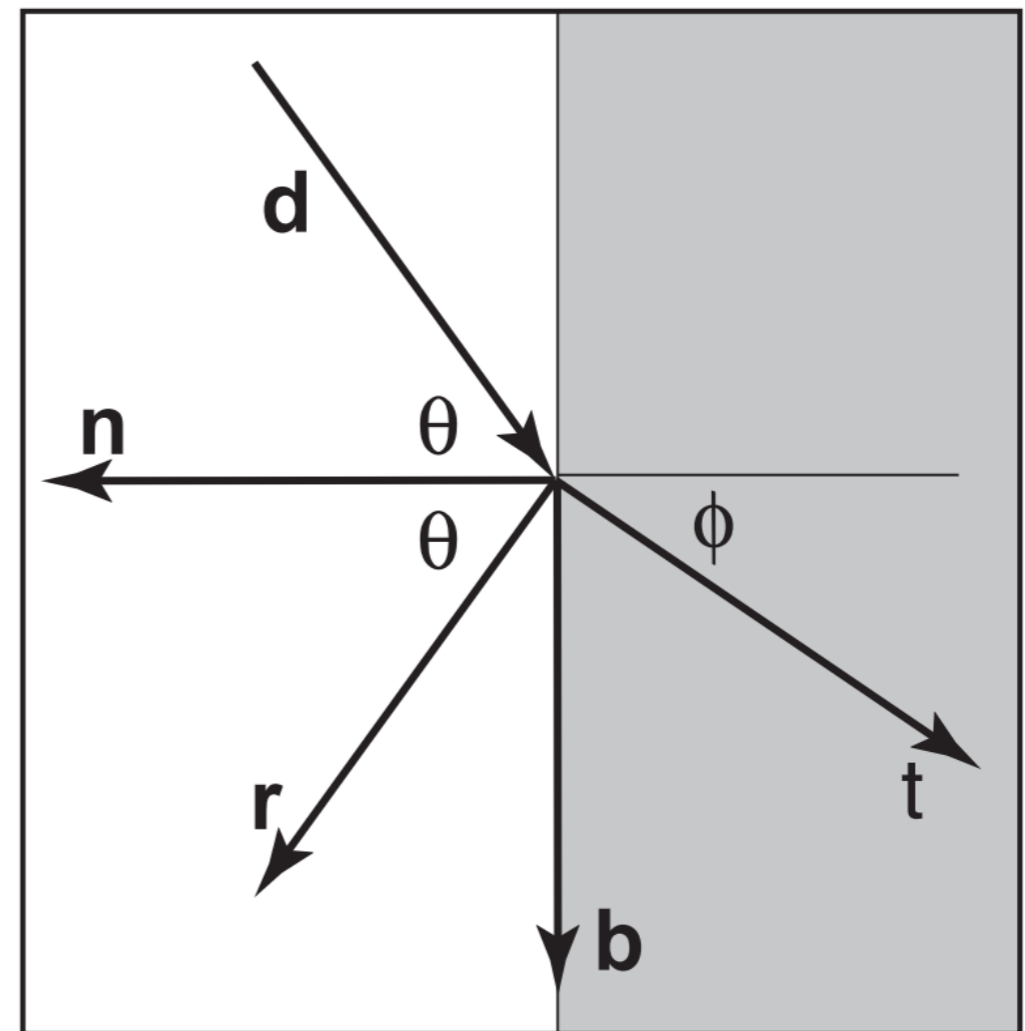


# Transparency and Refraction

## Snell's Law

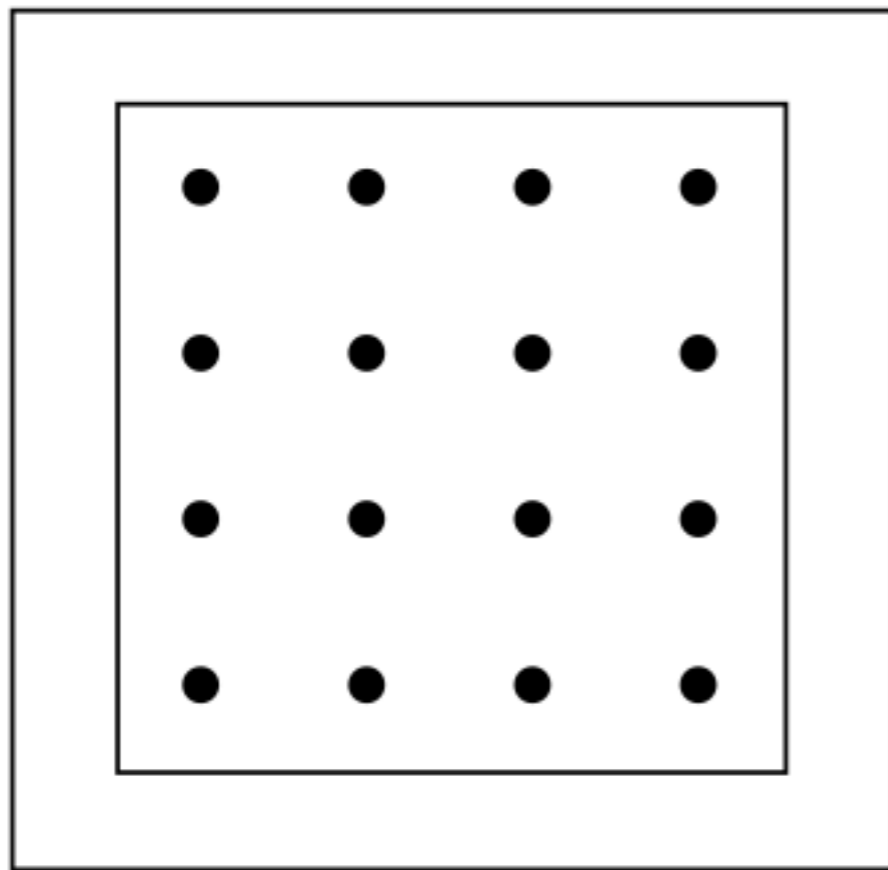
### Additional effects

- varying reflectivity  
*Fresnel equations*
- attenuation of light intensity  
*Beer's Law*

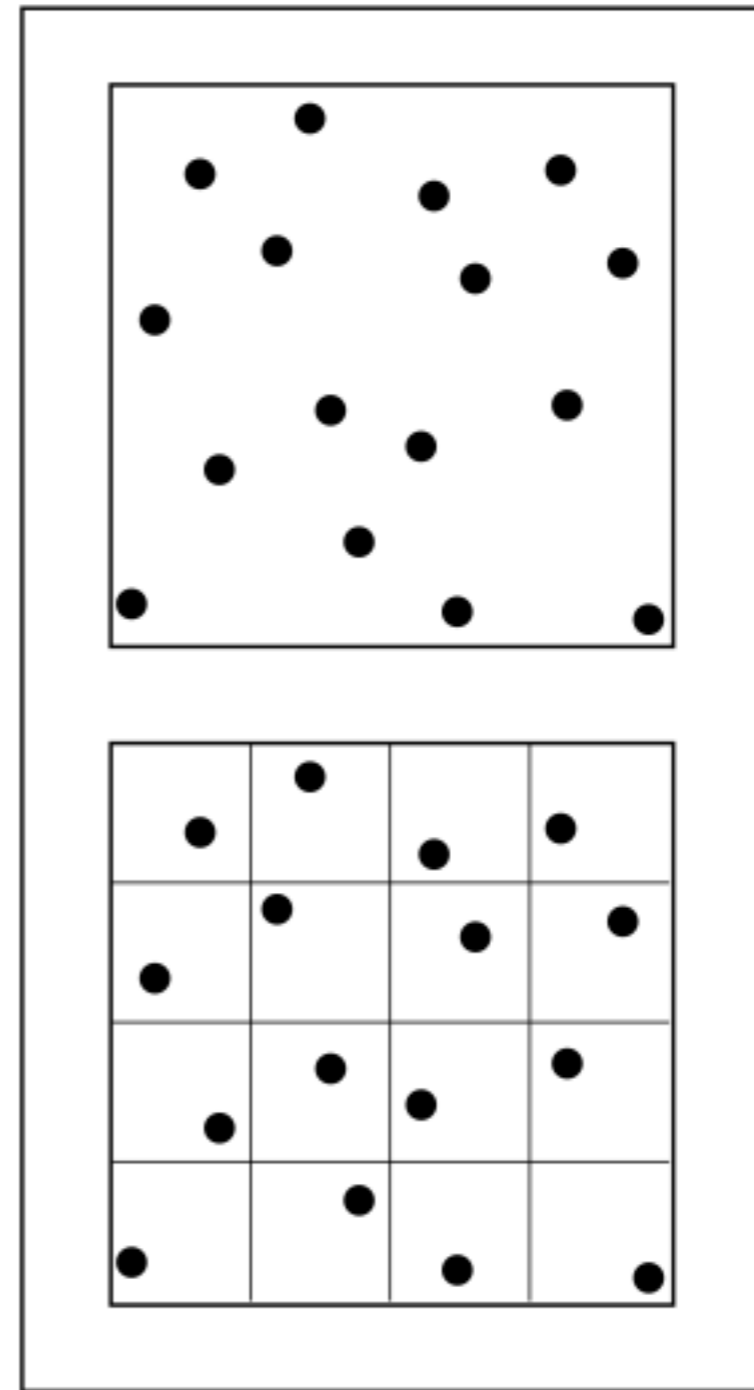


# Distribution Ray Tracing

# Anti-aliasing

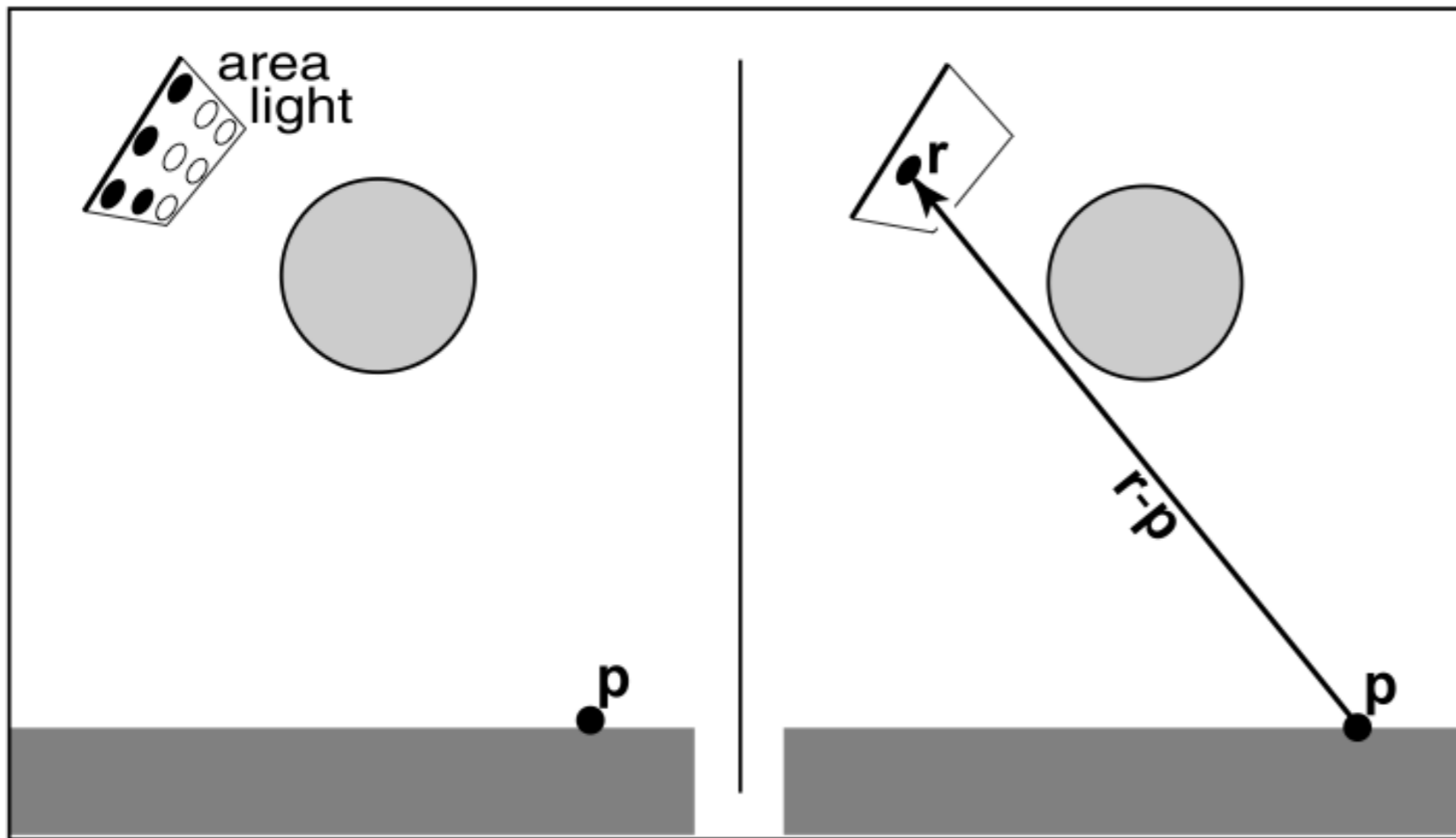


16 regular samples /  
pixel

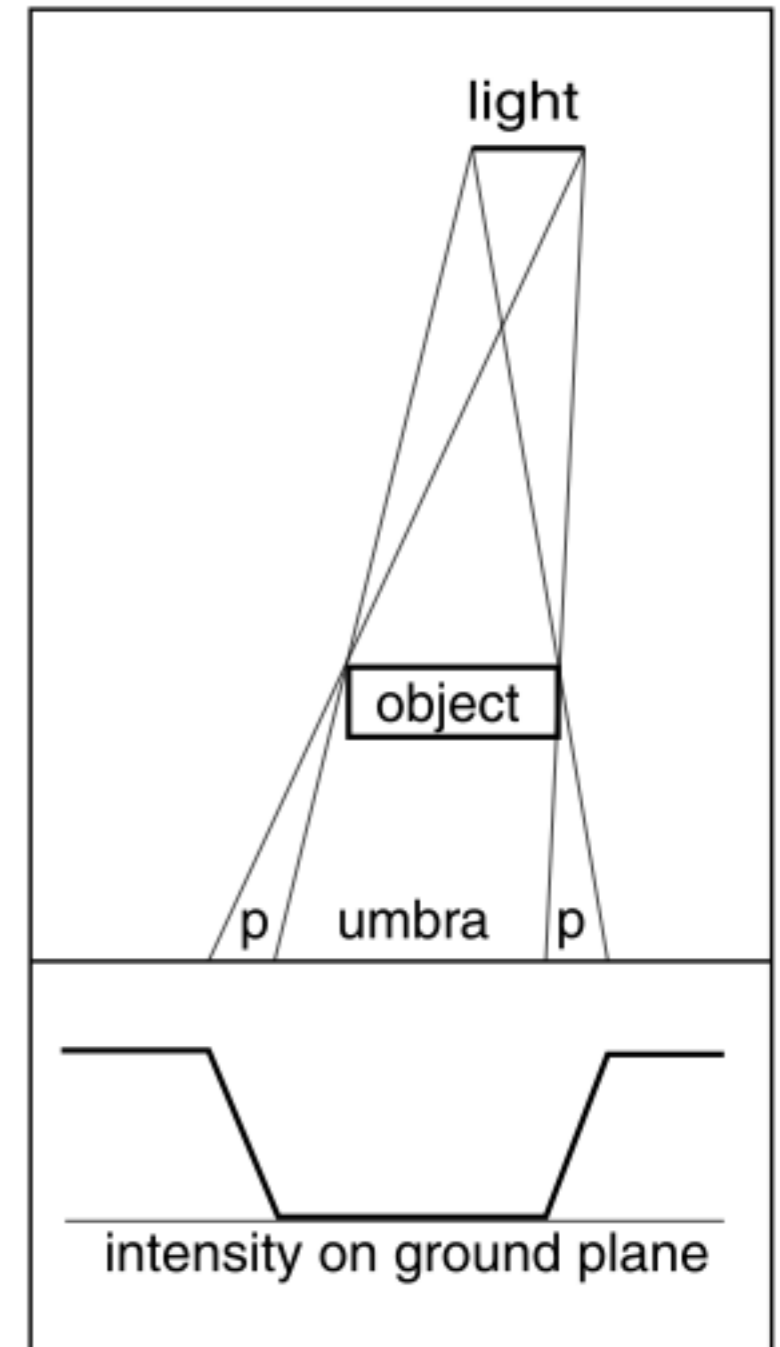


jittered samples

# Soft Shadows

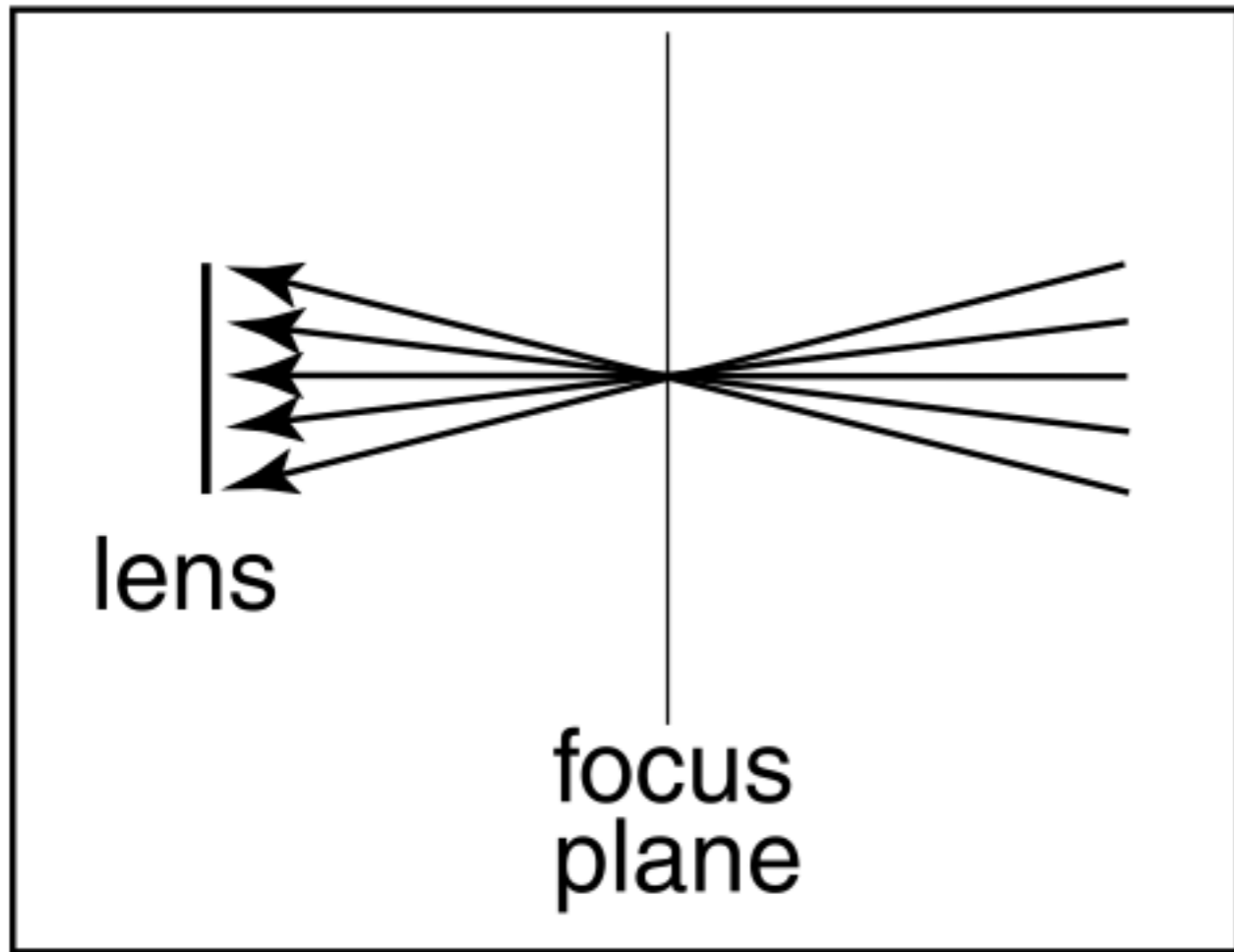


$$\mathbf{r} = \mathbf{c} + \xi_1 \mathbf{a} + \xi_2 \mathbf{b},$$

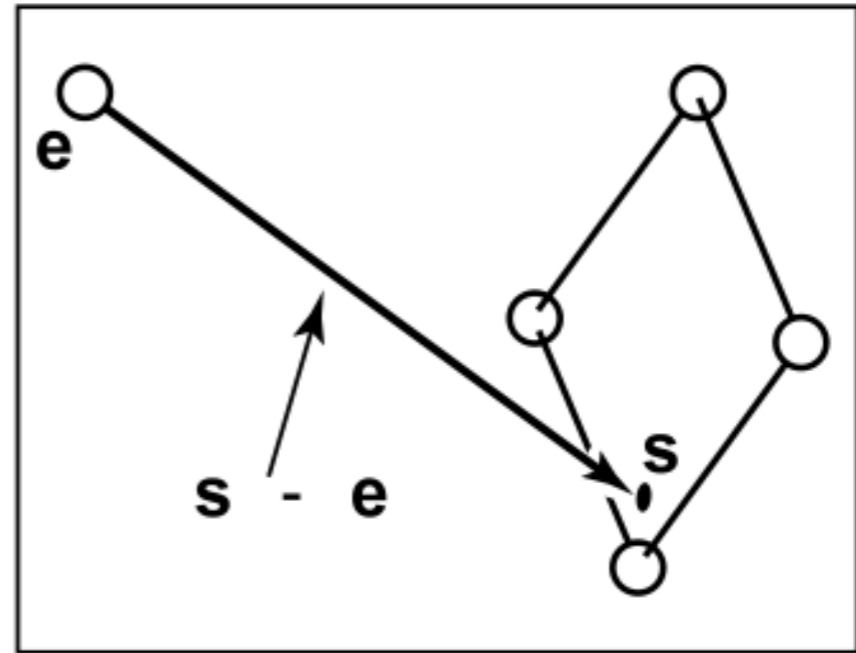


[Shirley and Marschner]

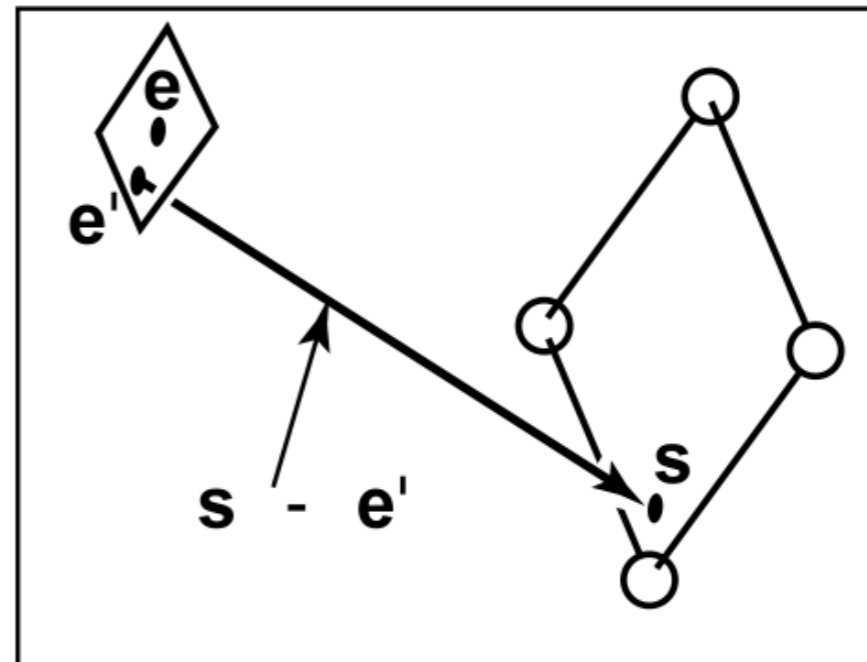
# Soft Focus (depth of field)



lens (eye location) averages  
over a cone of directions



without depth of field

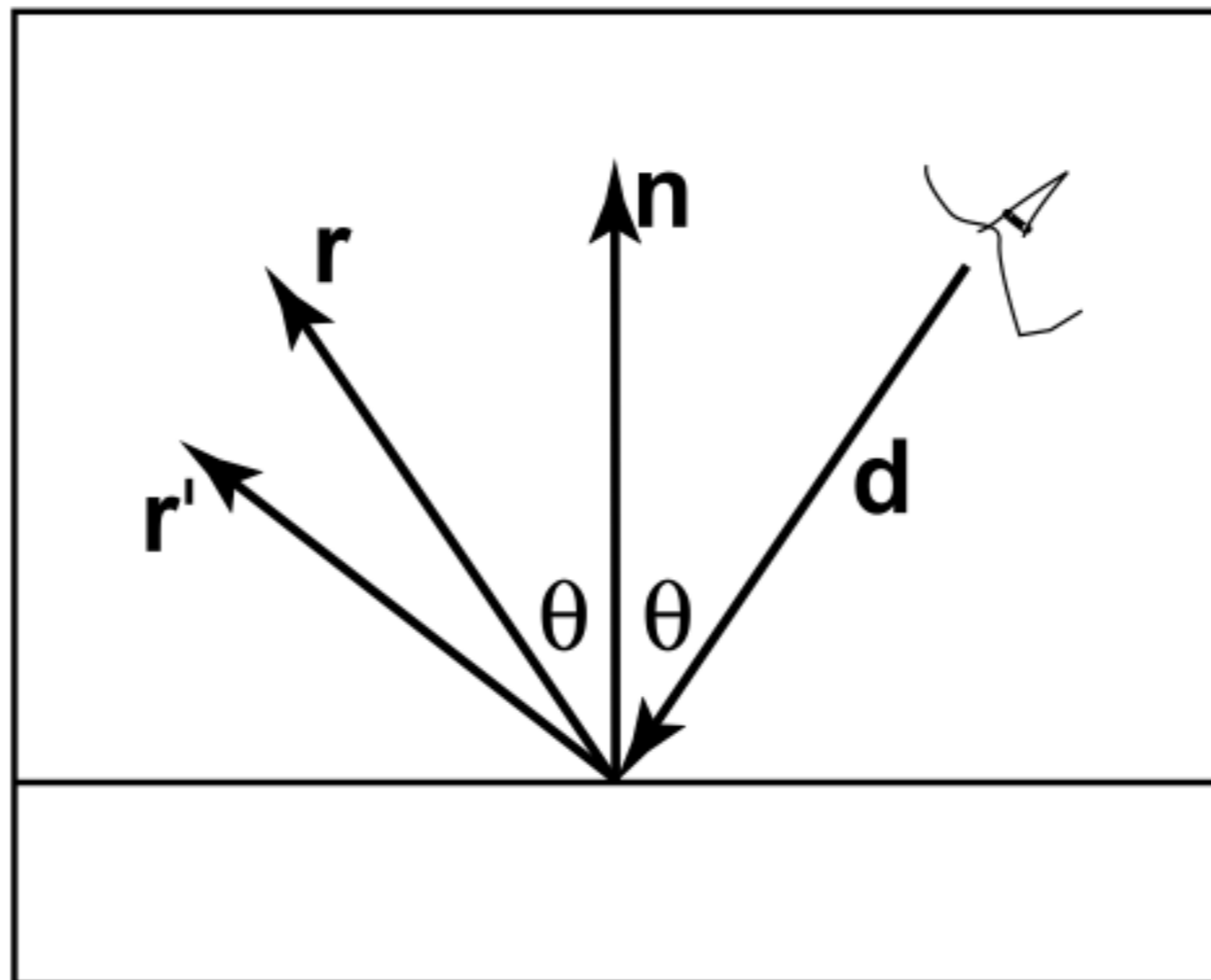


with depth of field



image using 25 samples per pixel

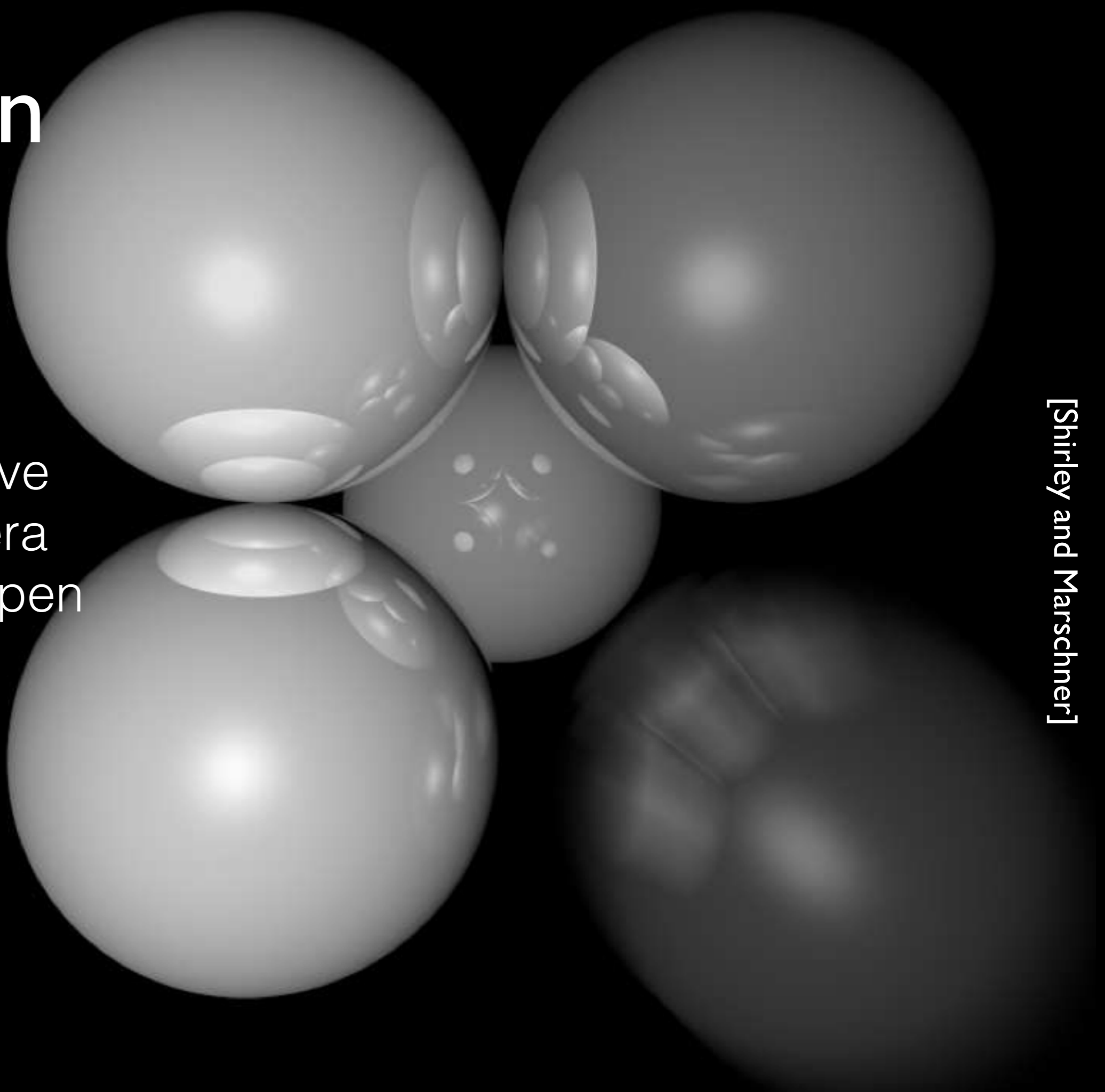
# Fuzzy Reflections



randomly perturb ideal  
specular reflection rays

# Motion Blur

objects move  
while camera  
aperture is open



[Shirley and Marschner]

# Motion Blur

to simulate,  
choose random  
time within open  
aperture interval  
for each view ray

[Shirley and Marschner]

