matfyz

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Distributed Ray Tracing

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Distributed ray tracing

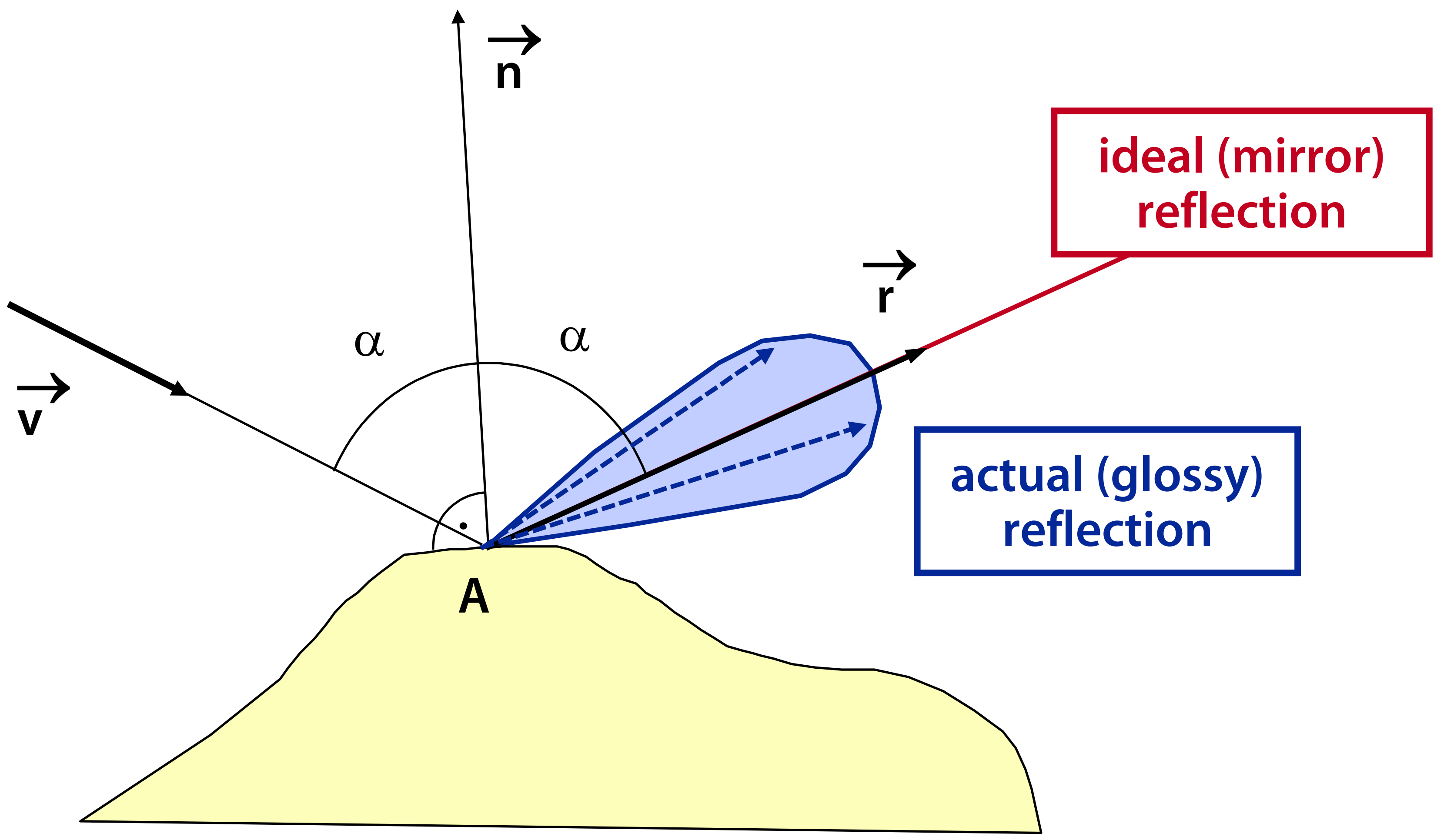
Better image quality (fidelity)

- soft shadows, glossy reflections, soft refractions
- motion blur
- depth of field imitation
- light dispersion (index of refraction depends on λ)

Introducing **new variables** to an image function

- reflection or refraction angle, wavelength, light source point, lens entry point, time…

Glossy reflection



Glossy reflection computation

Sharp reflection

$$I(V) = I(R)$$

(one reflected ray)

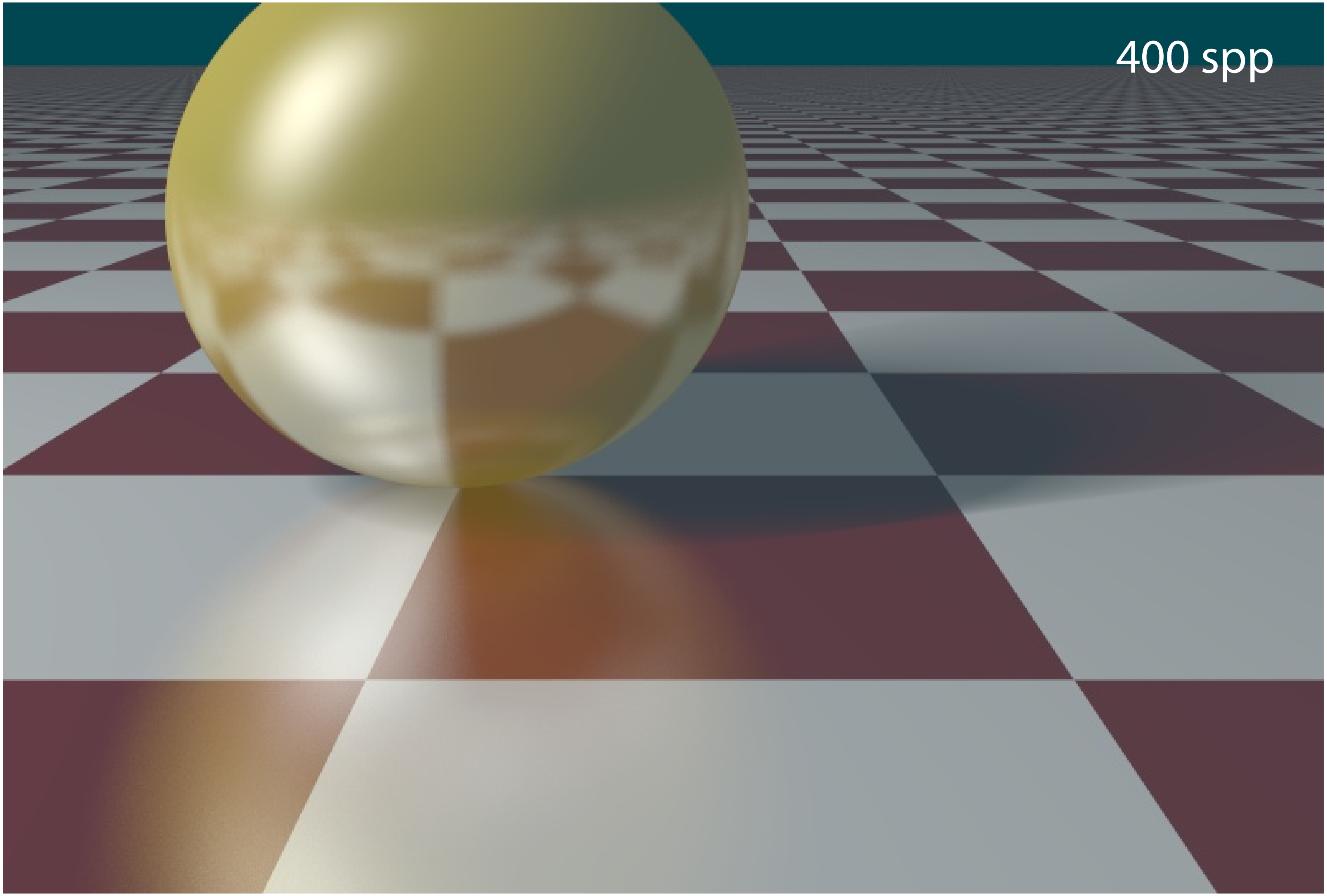
Glossy reflection

$$I(V) = \iint_{sphere} I(R(\varphi,\theta)) \cdot \underline{BRDF(\alpha,\beta,\varphi,\theta)}\, d\varphi\, d\theta$$

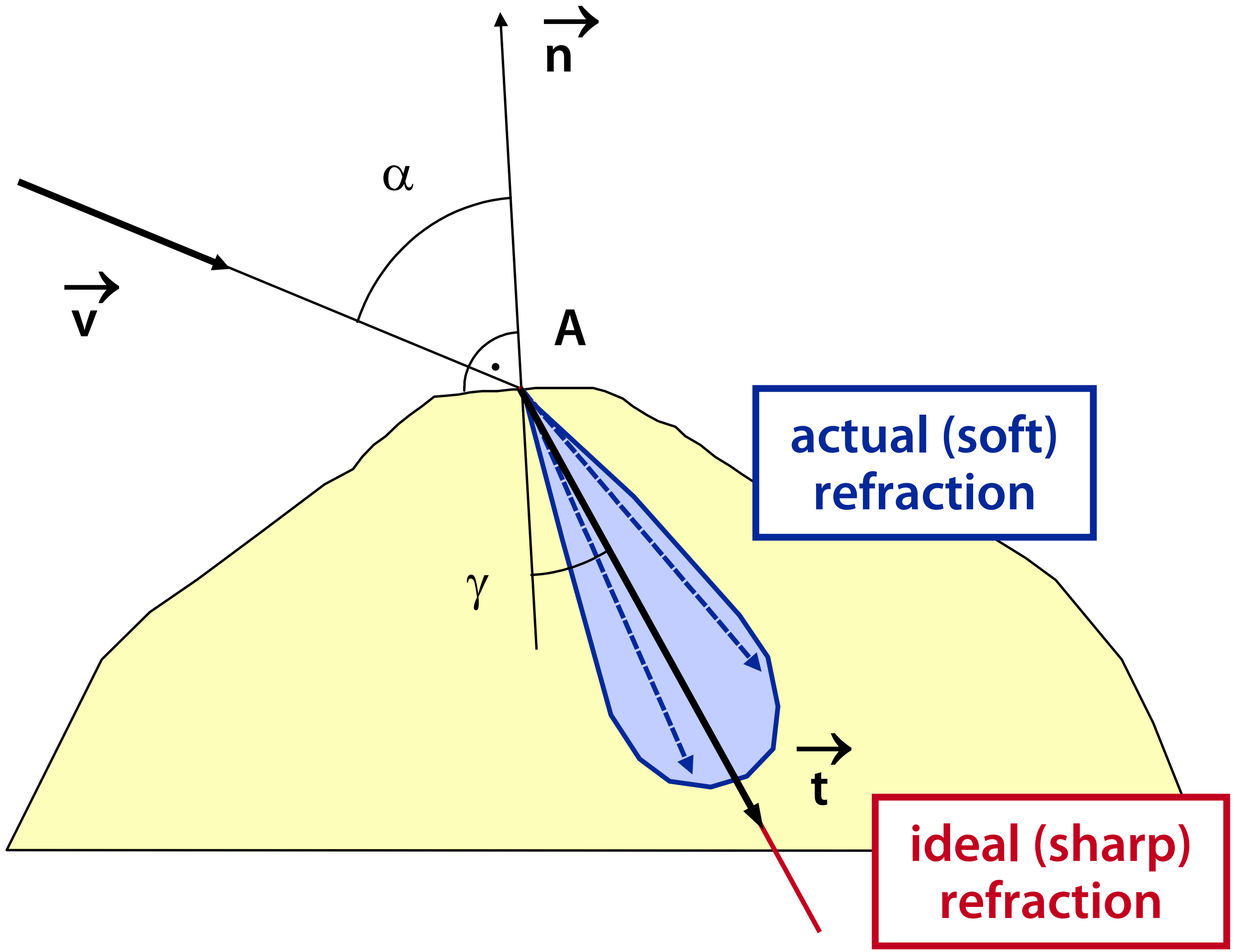
reflectance function

(weighted integral average … over all reflection angles)

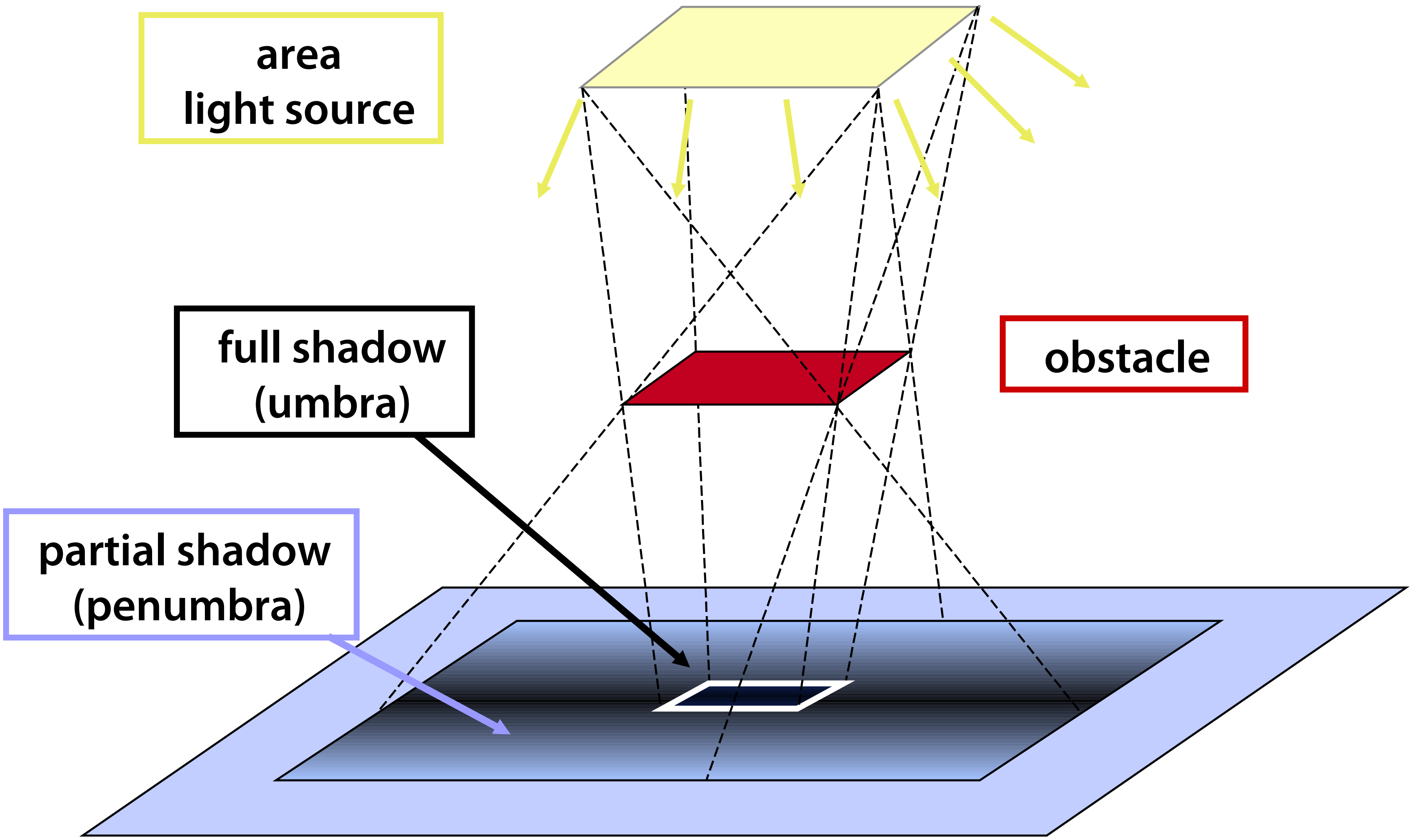
Glossy reflection – example



Soft refraction



Soft shadow



area
light source
full shadow
(umbra)
obstacle
partial shadow
(penumbra)

Soft shadow computation

Contribution of a point light source

$$I(A) = \begin{cases} I_L & \text{if source is visible from A} \\ 0 & \text{else} \end{cases}$$

Contribution of an area light source

$$I(A) = I_L \cdot S[\%]$$

$S[\%]$ → visible portion of a light source

Soft shadow computation

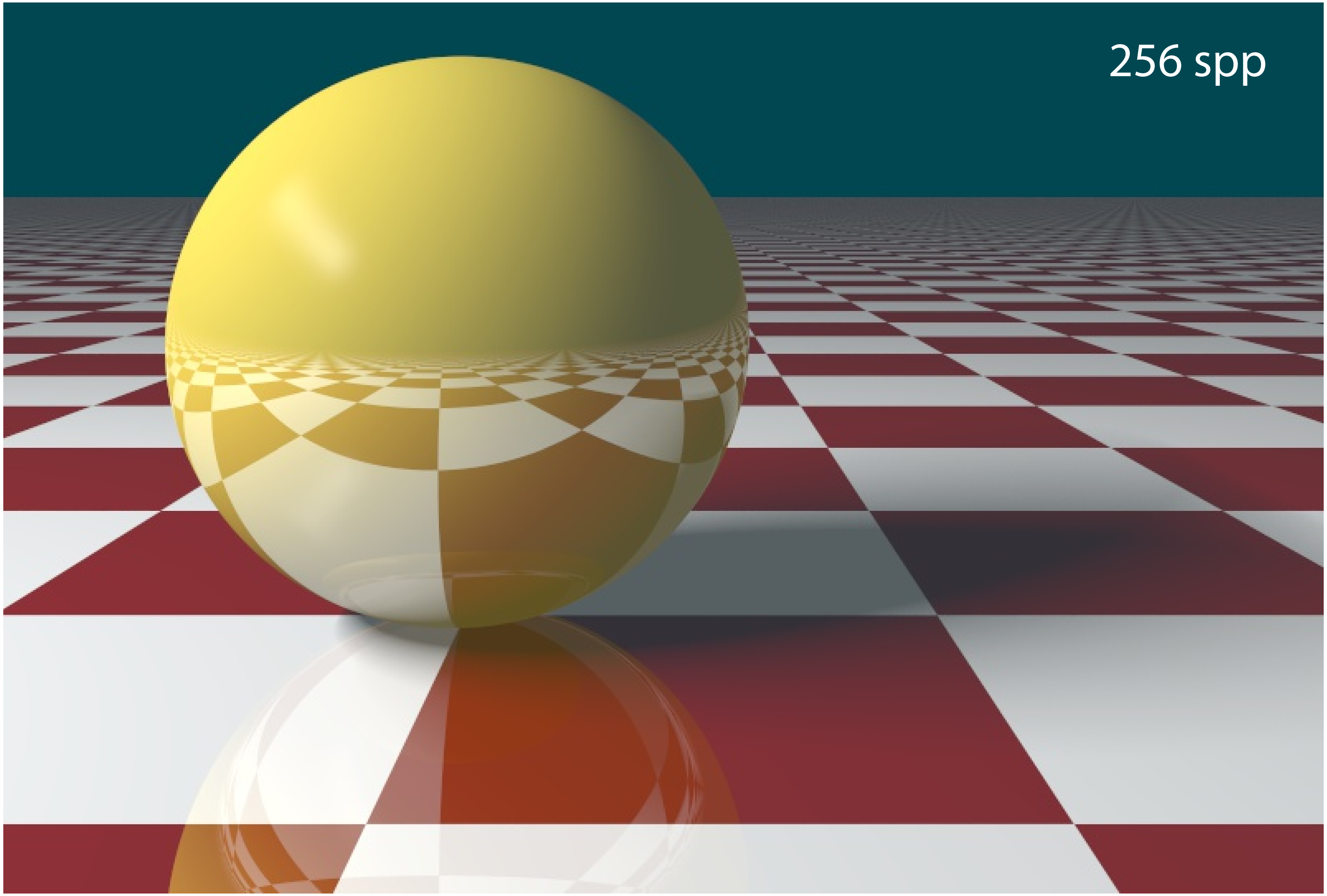
Contribution of an inhomogenous light source

$$I(A) = \iint_{\text{light source area}} I_L(u,v) \cdot \underline{vis(A,u,v)}\, du\, dv$$

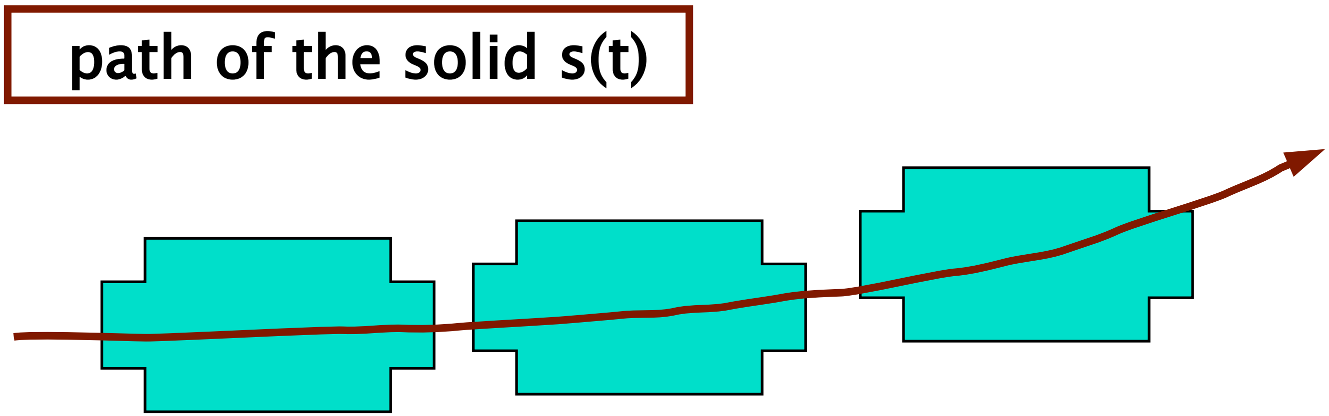
visibility function

$$\underline{vis(A,u,v)} = \begin{cases} 1 & \text{if } S(u,v) \text{ is visible from } A \\ 0 & \text{else} \end{cases}$$

Soft shadow – example



Motion blur



Rendered interval (shutter open time) $[t_1, t_2]$

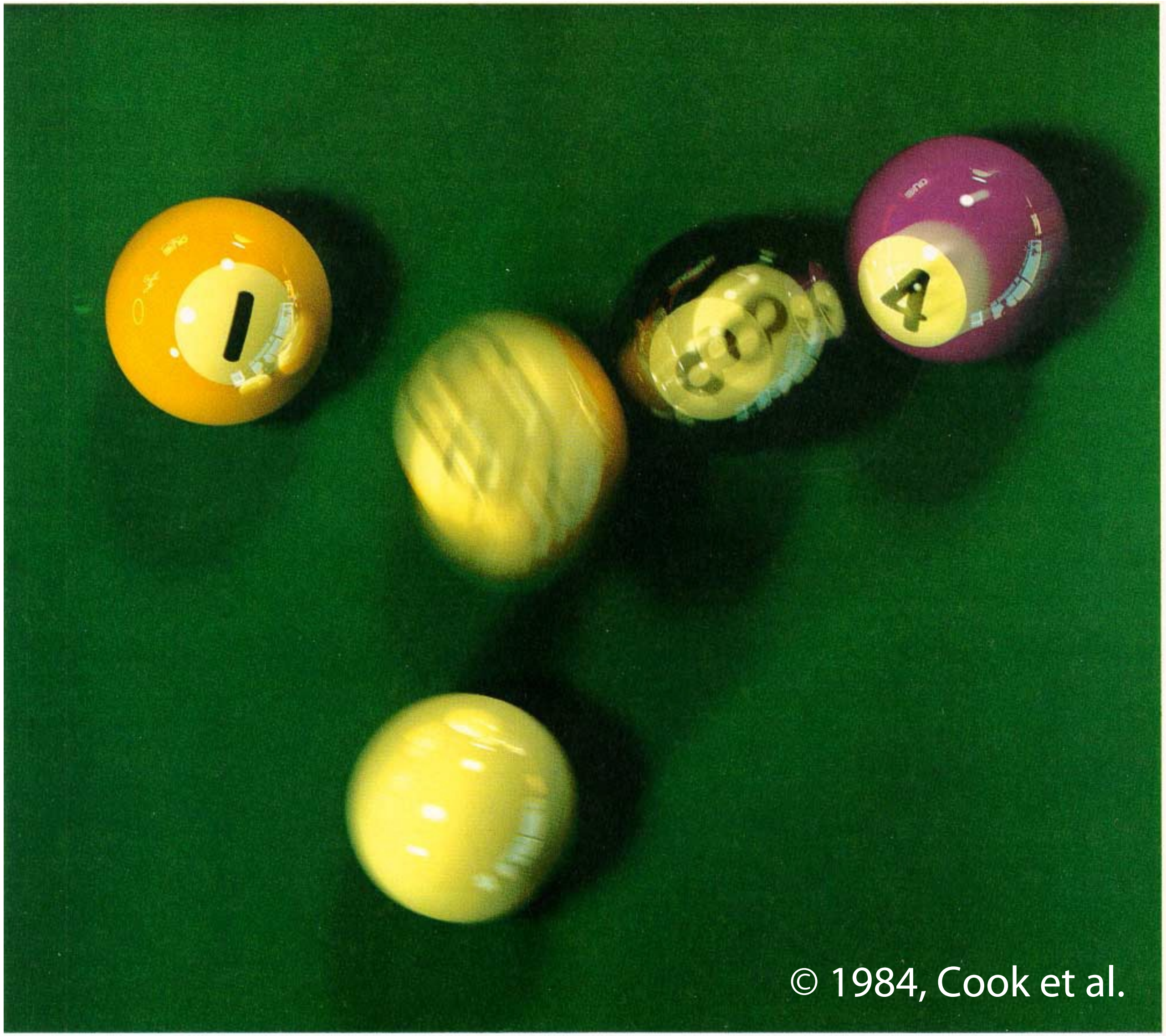
Scene rendering in time t $f(t) = f(x,y,t)$

Motion blur

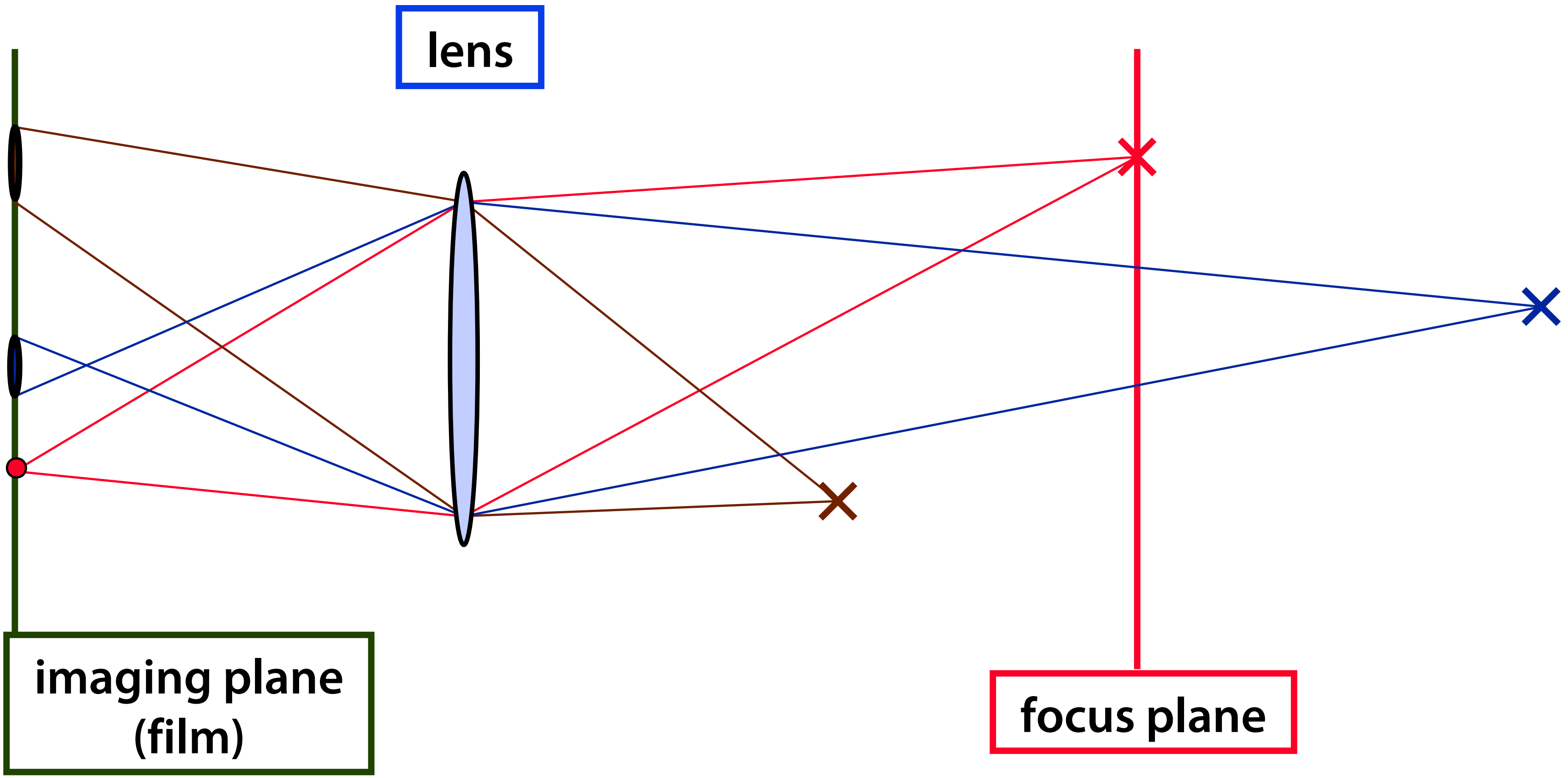
General motion blur

$$f_{blurr} = \int_{t_1}^{t_2} f(t)\, dt$$

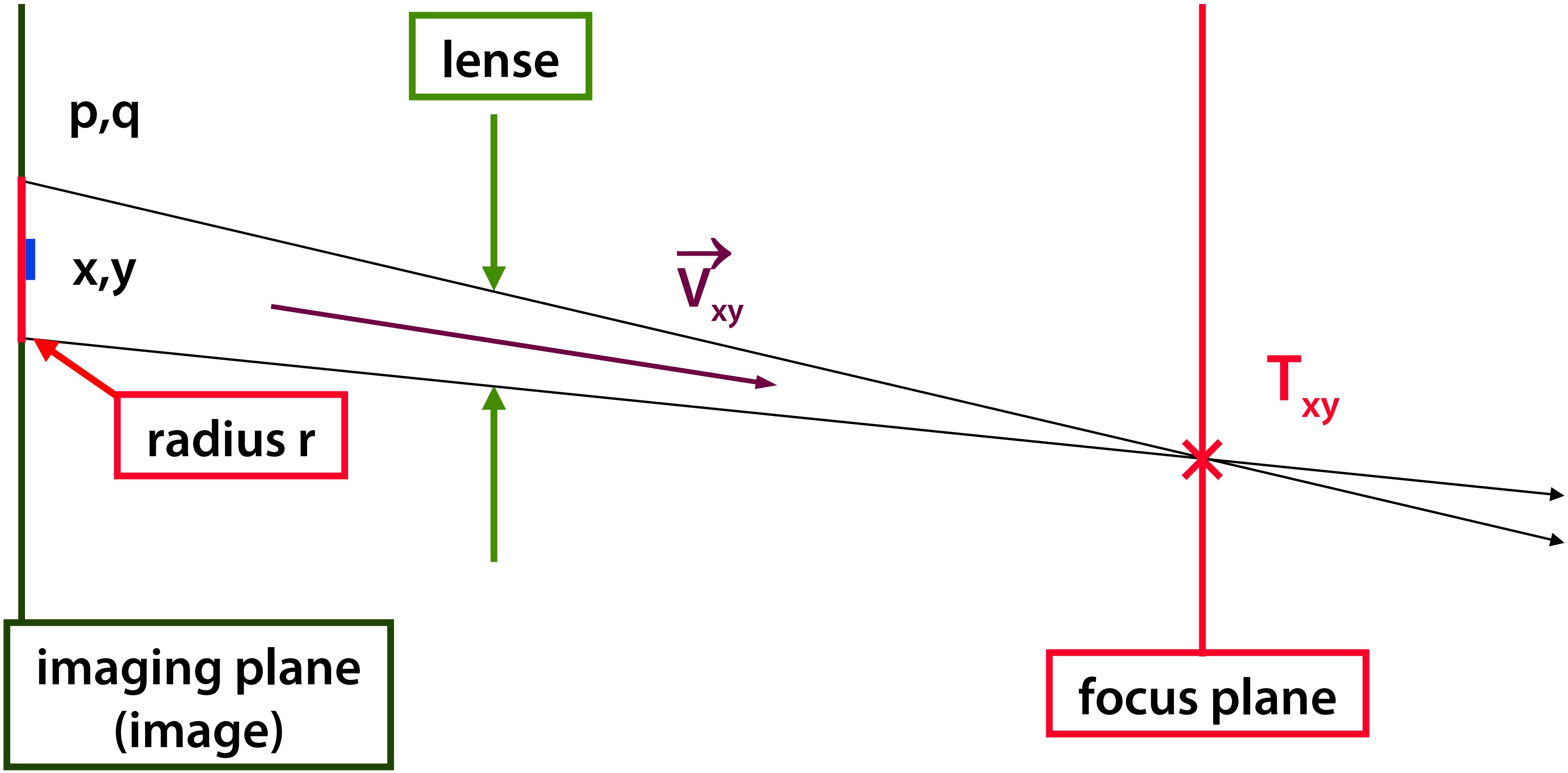
Motion blur – famous example



Depth of field



Geometric simplification



Depth of field computation

Pinhole camera model

$$f(x,y) = I(V_{xy})$$

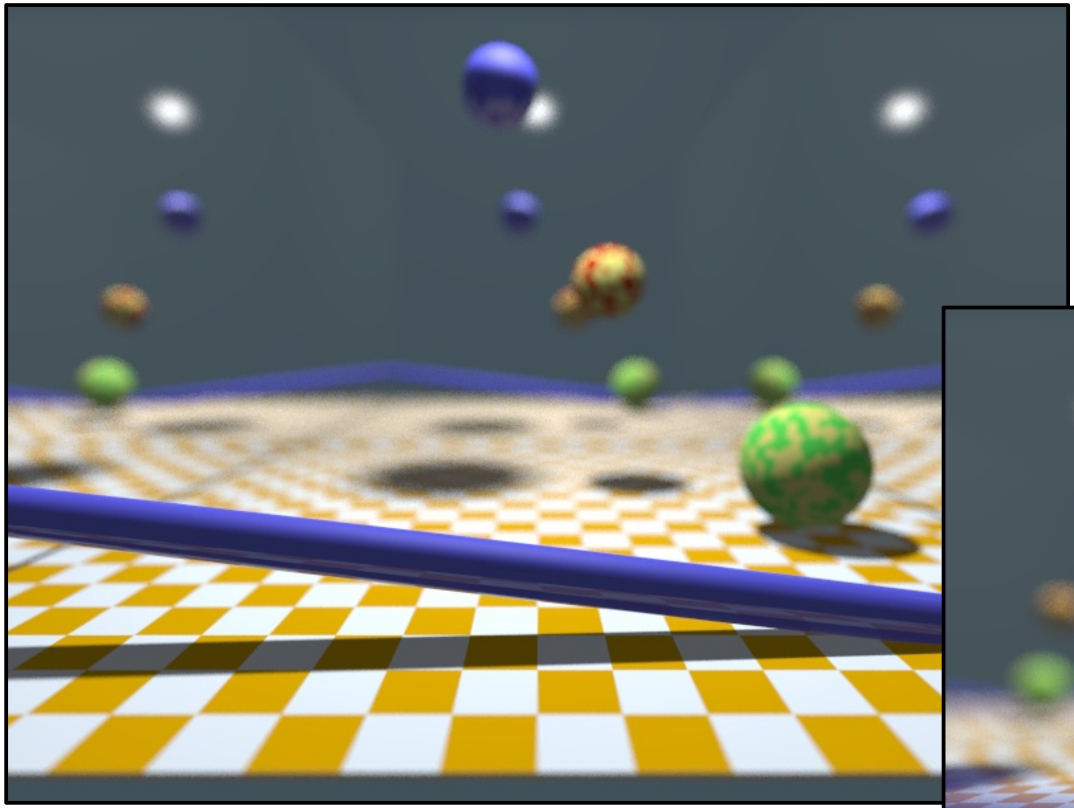
$$V_{xy} = T_{xy} - [x, y, 0]$$

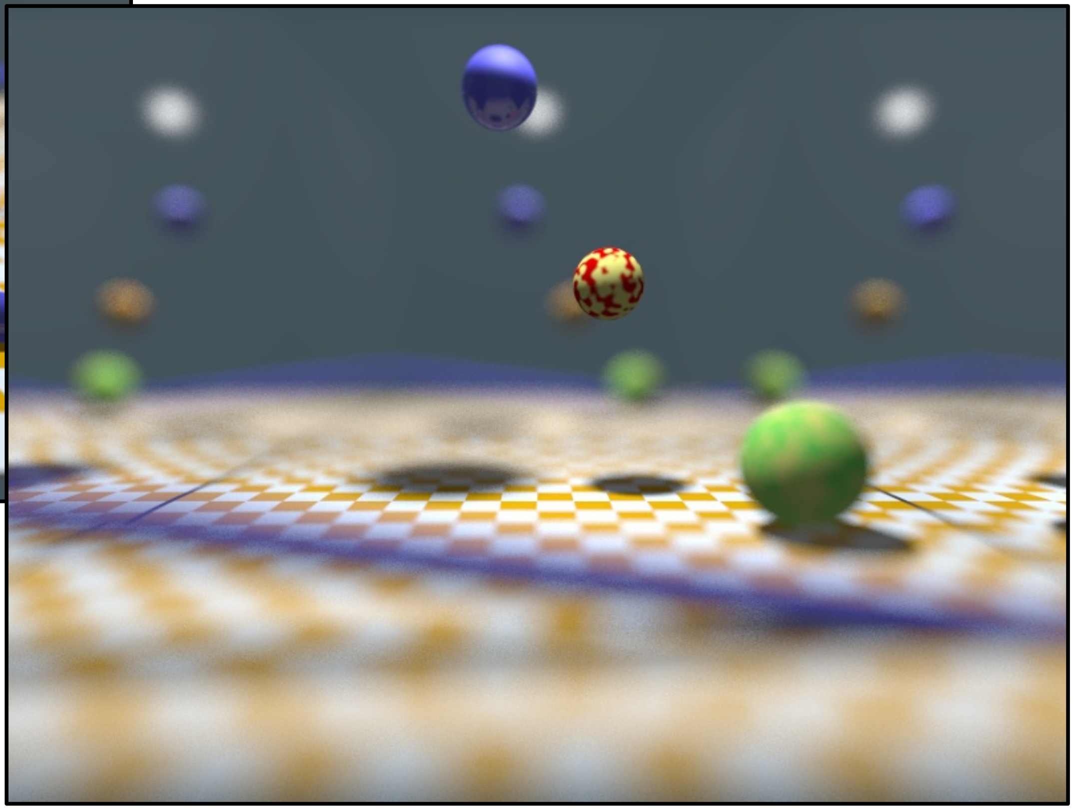
$$V_{pq} = T_{xy} - [p, q, 0]$$

Lens with finite aperture

$$f(x,y) = \int_{\text{circle around } [x,y]} I(V_{pq})\, dp\, dq$$

Depth of field – examples





Light dispersion

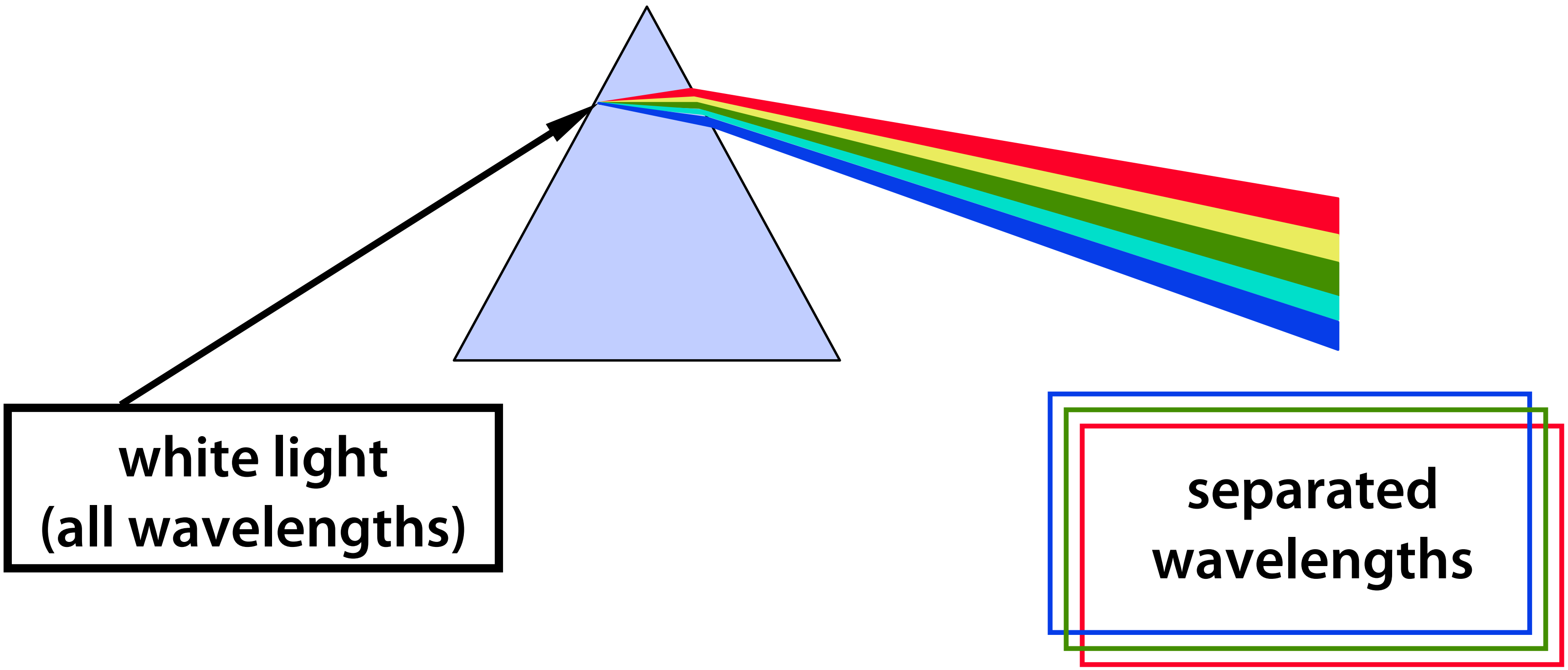


image function $f(\lambda) = f(x,y,\lambda)$

Light dispersion computation

Pixel RGB color from spectral dristribution

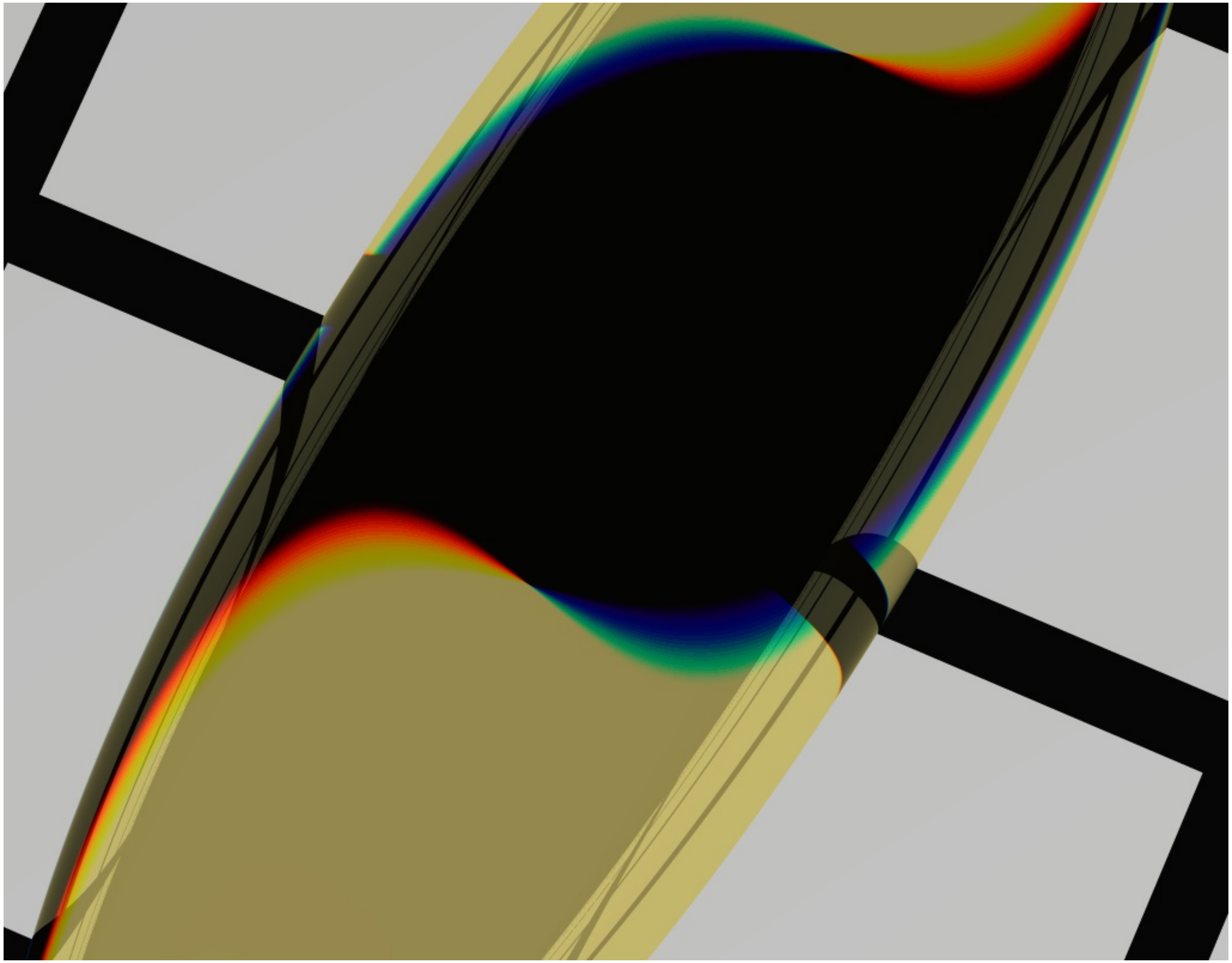
$$R(x,y) = \int_{\text{spectrum}} f(x,y,\lambda) \cdot R(\lambda)\; d\lambda$$

$$G(x,y) = \int_{\text{spectrum}} f(x,y,\lambda) \cdot G(\lambda)\; d\lambda$$

$$B(x,y) = \int_{\text{spectrum}} f(x,y,\lambda) \cdot B(\lambda)\; d\lambda$$

trichromatic spectral coefficients

Light dispersion – example



Implementation

Integral averaging is done **stochastically** (Monte-Carlo methods)

- finite number of point samples (rays)
- integral is estimated by a [weighted] sum

Weighted integral average

- uniform sampling and appropriate weight function
- nonuniform sampling (using the right density/PDF)

Combining methods

Any methods can be **combined**

- with anti-aliasing as well
- higher order integrals – e.g. dimension 10:

  anti-aliasing (2), depth of field (2), glossy reflection (2),
  soft shadows (2), motion blur (1), light dispersion (1)

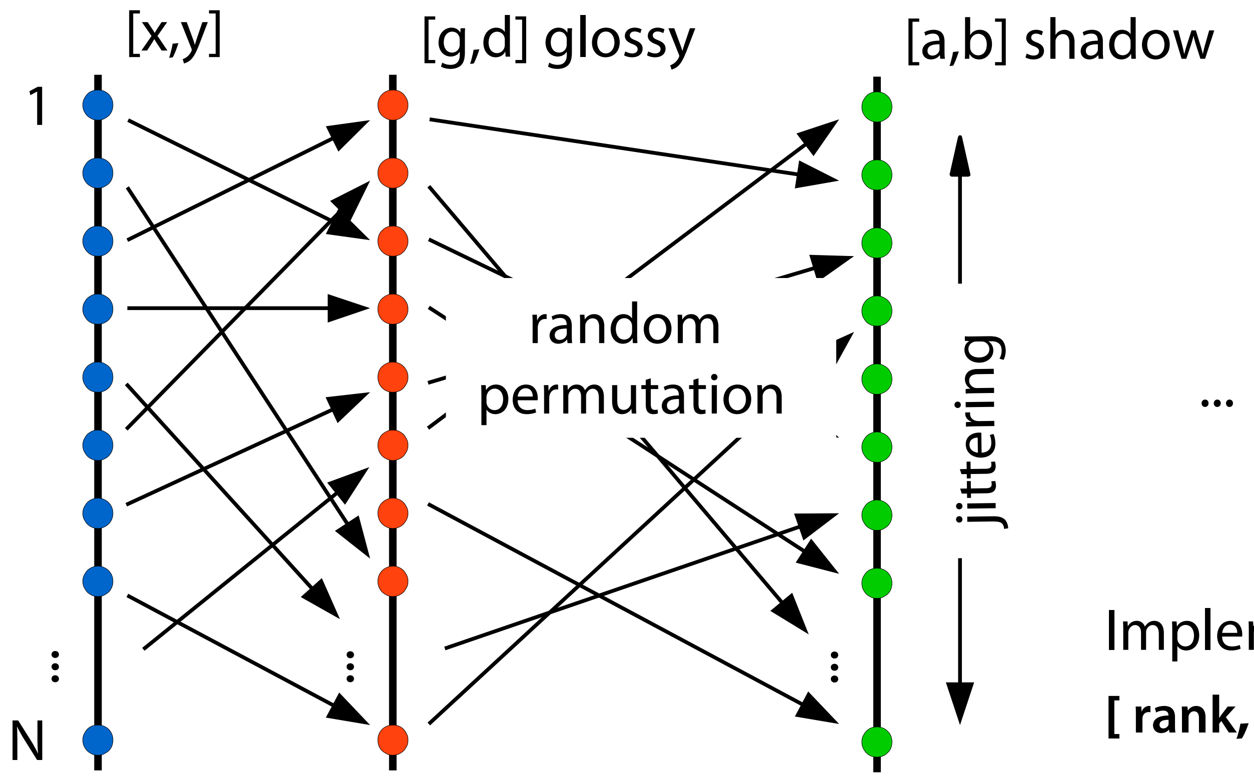
Sampling method

- jittering
- independent jittering ("N rooks") in form of **hidden sampling**
- adaptive sampling

Hidden sampling

Number of **samples per pix** (primary rays) is defined

- every inner component is sampling independently
- arbitrary number of additional (sampled) dimensions



Implementation:

[rank, total]

Literature

A. Glassner: ***An Introduction to Ray Tracing***, Academic Press, London 1989, 171-199

A. Watt, M. Watt: ***Advanced Animation and Rendering Techniques***, Addison-Wesley, Wokingham 1992, 262-265

