CS6630 Realistic Image Synthesis

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Physics based rendering: a brief history

1968 Appel

1980s

- Ray Tracing
- Radiosity
- Microfacet model
- Rendering Equation

1990s

- Heyday of Radiosity
- Major Path Tracing variants emerge

2000s

- Material models
- Volumes, diffusion

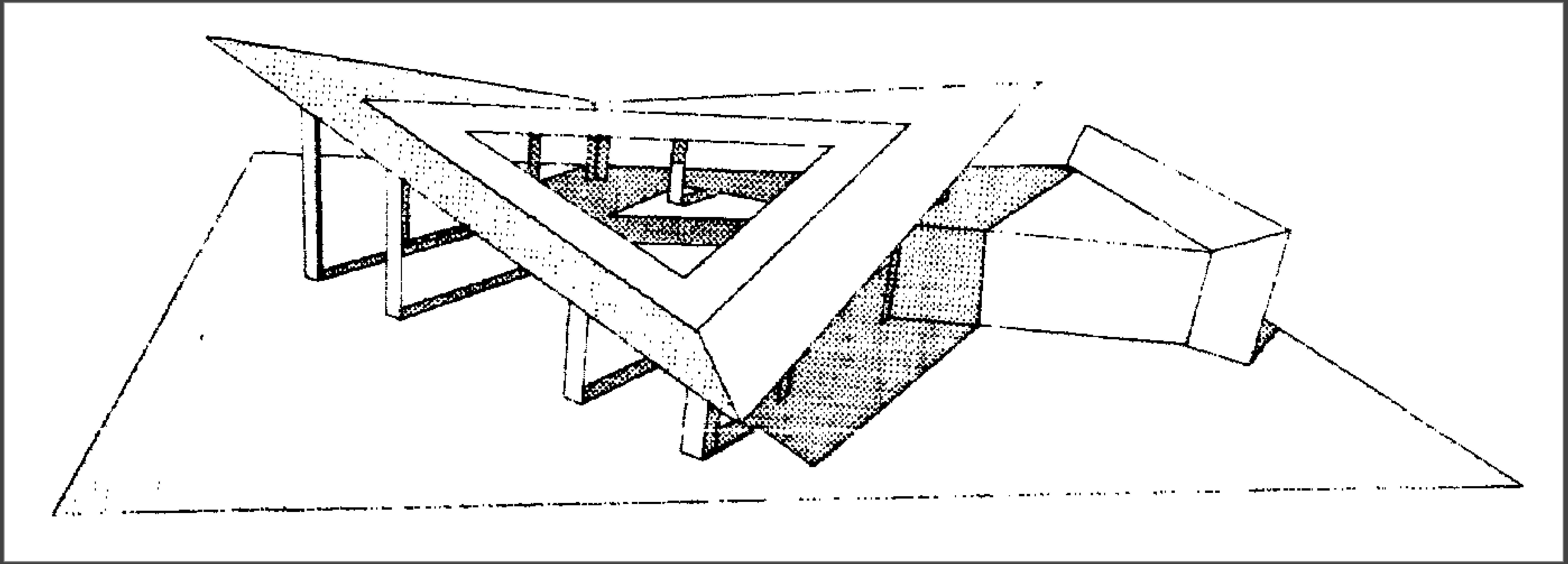
2010s

- GPU Ray Tracing
- Denoising
- Path Tracing refinements

2020s

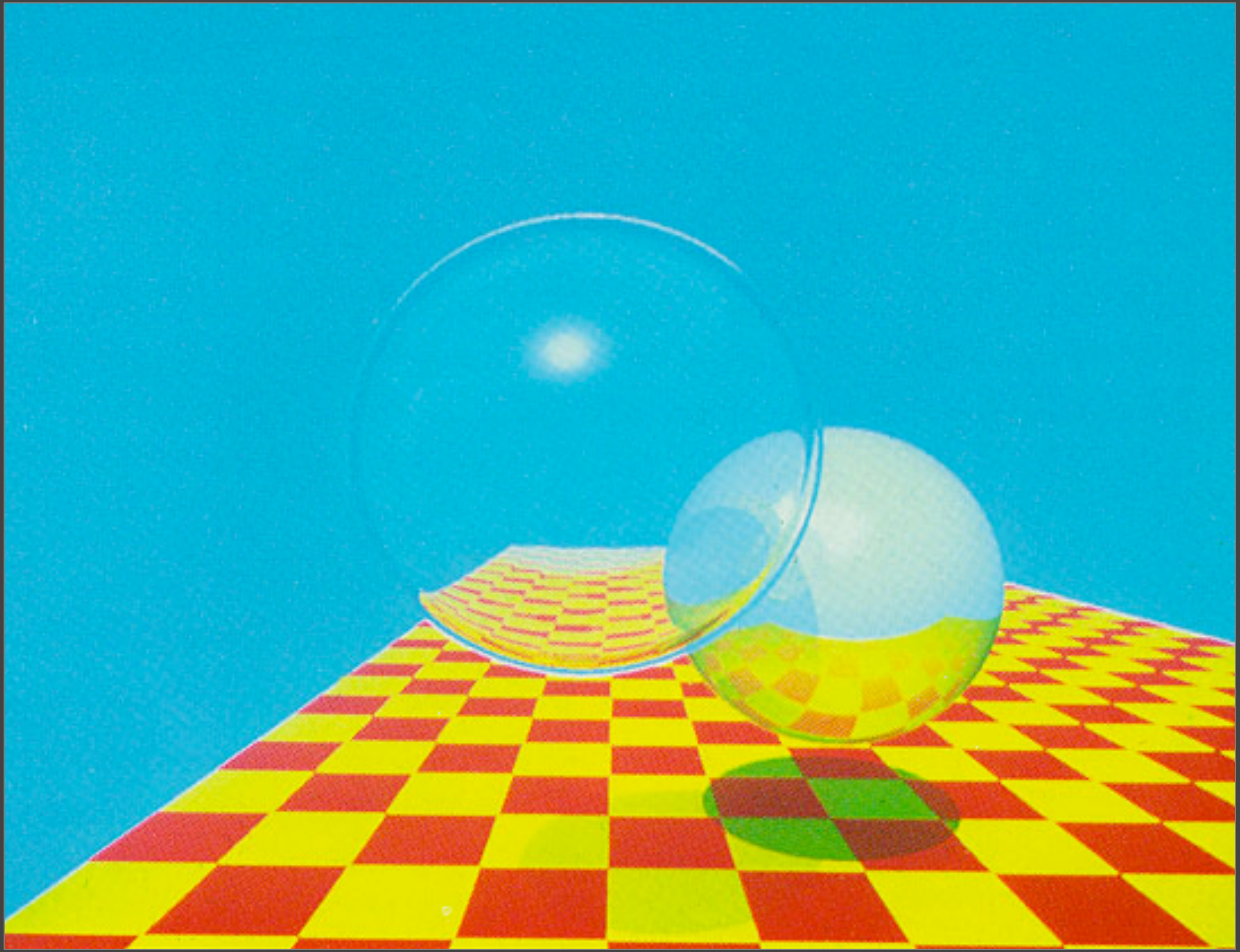
- Differentiable Rendering
- Real-time Path Tracing

Ray Tracing

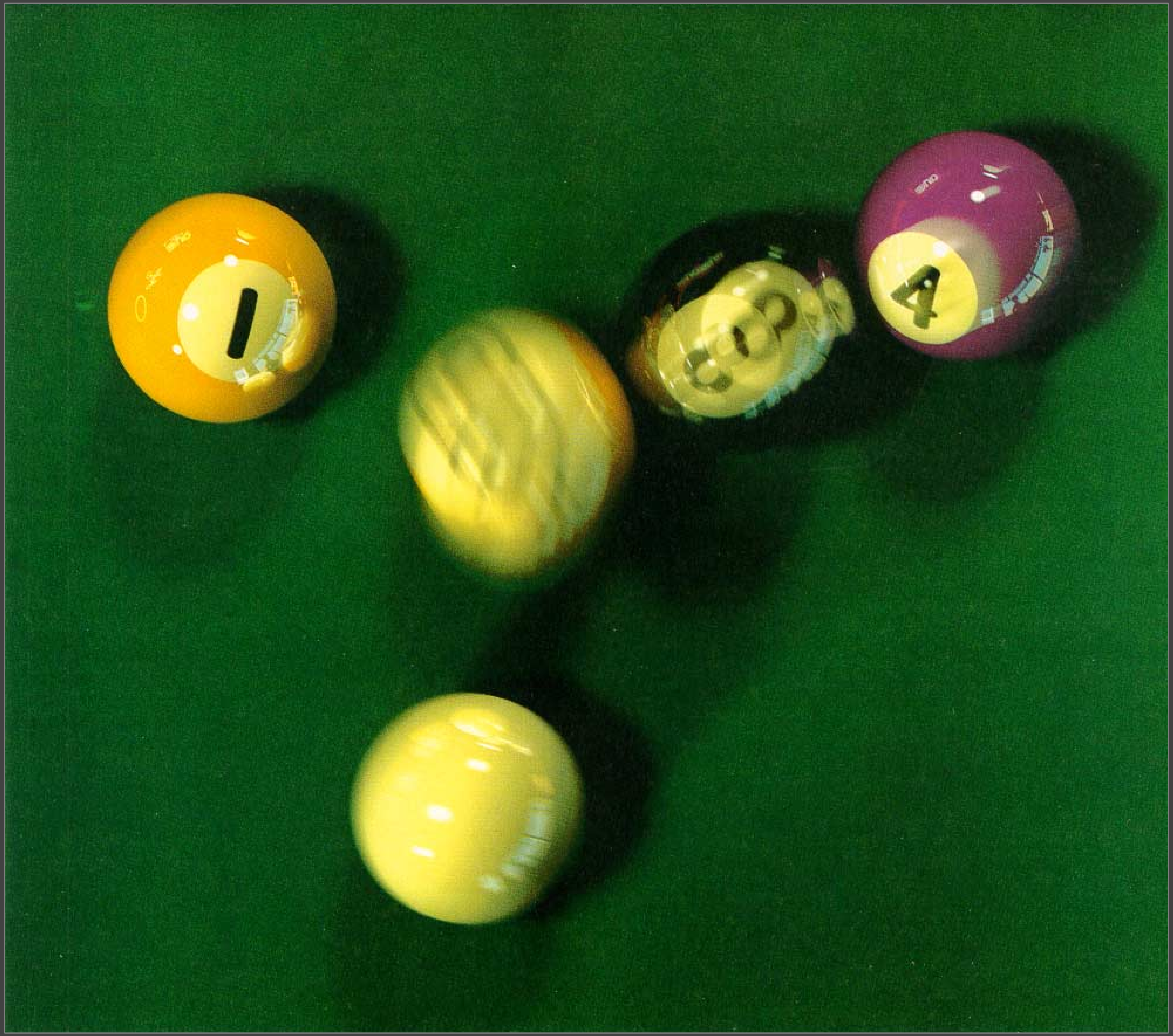


Appel 1968

Ray Tracing for shadows



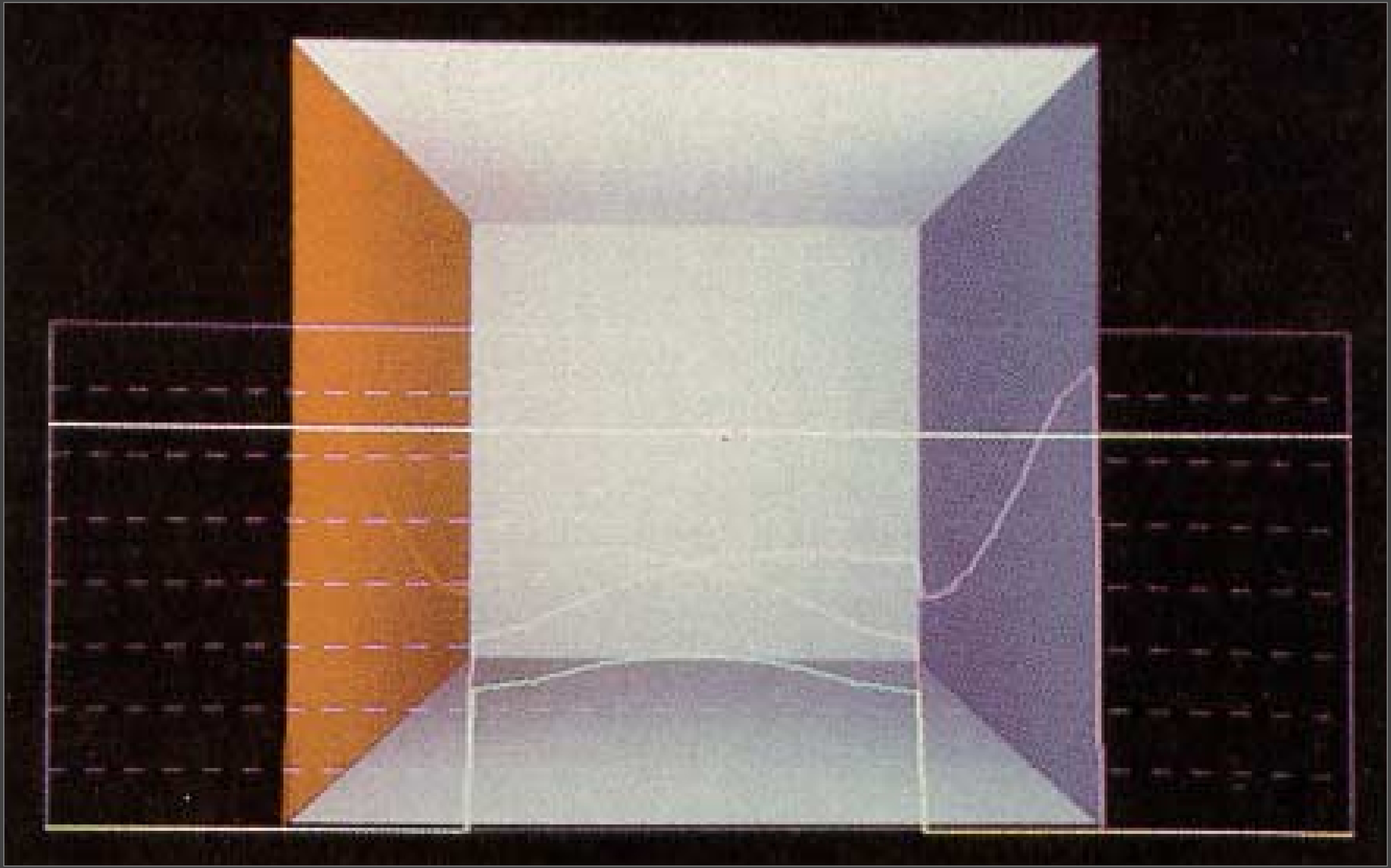
Whitted 1980
Recursive ray tracing



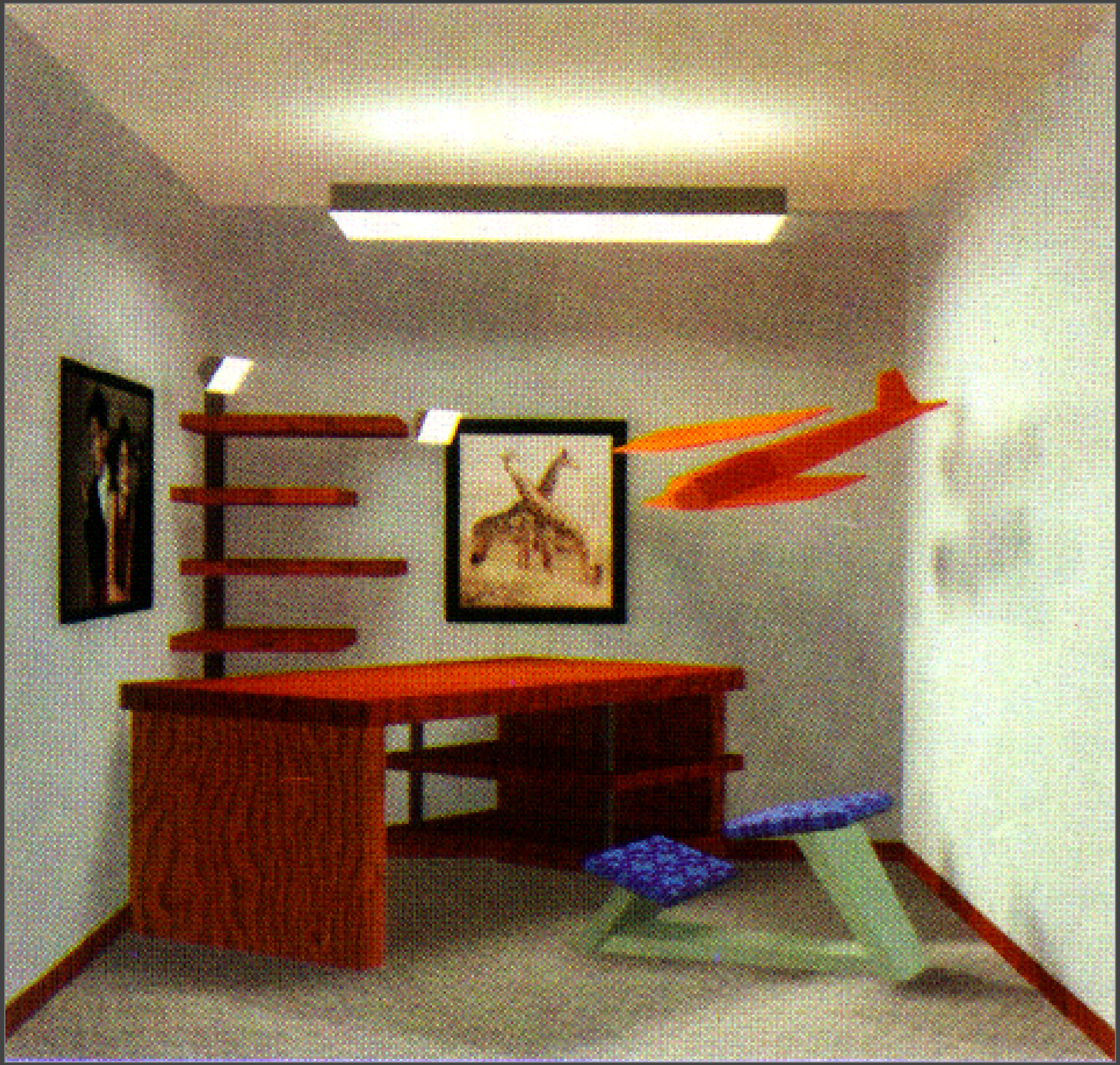
Cook, Porter, Carpenter 1984

Distribution Ray Tracing

Radiosity



Goral et al. 1984
Radiosity method



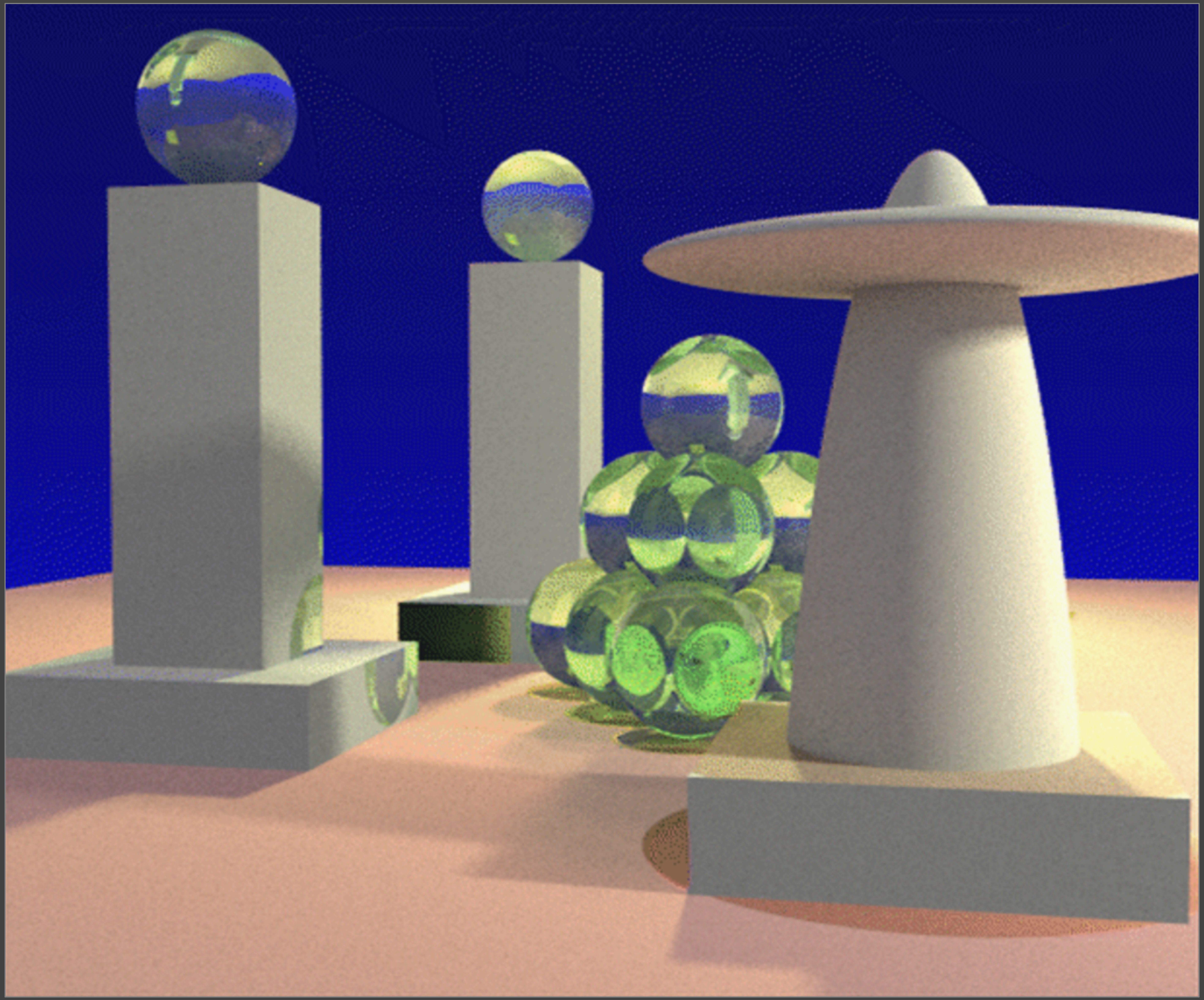
Hanrahan et al. 1991
Hierarchical radiosity

Lischinski et al. 1993
Discontinuity meshing

Sillion et al. 1991

Nondiffuse radiosity

Path Tracing

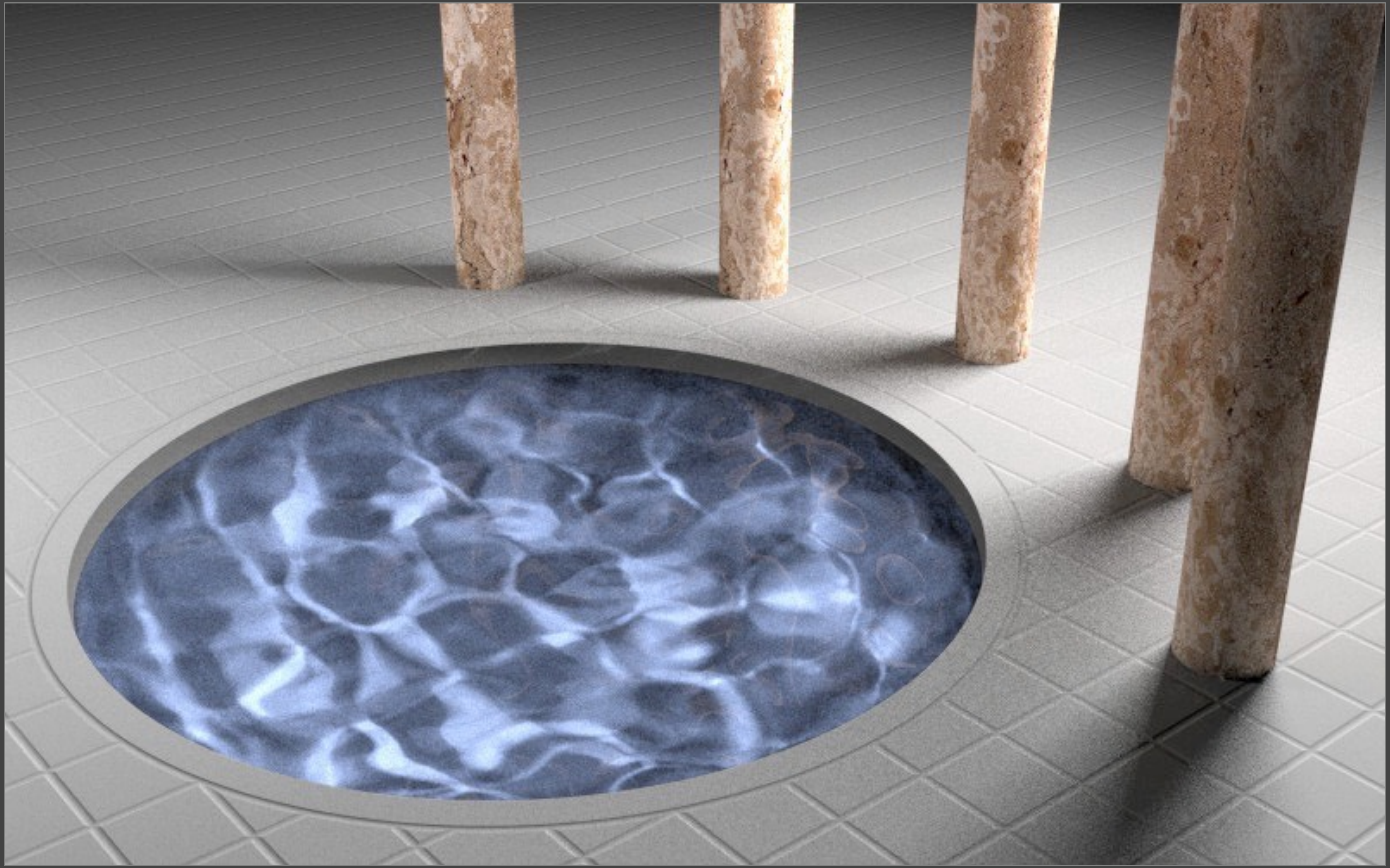


Kajiya 1986

The Rendering Equation; path tracing

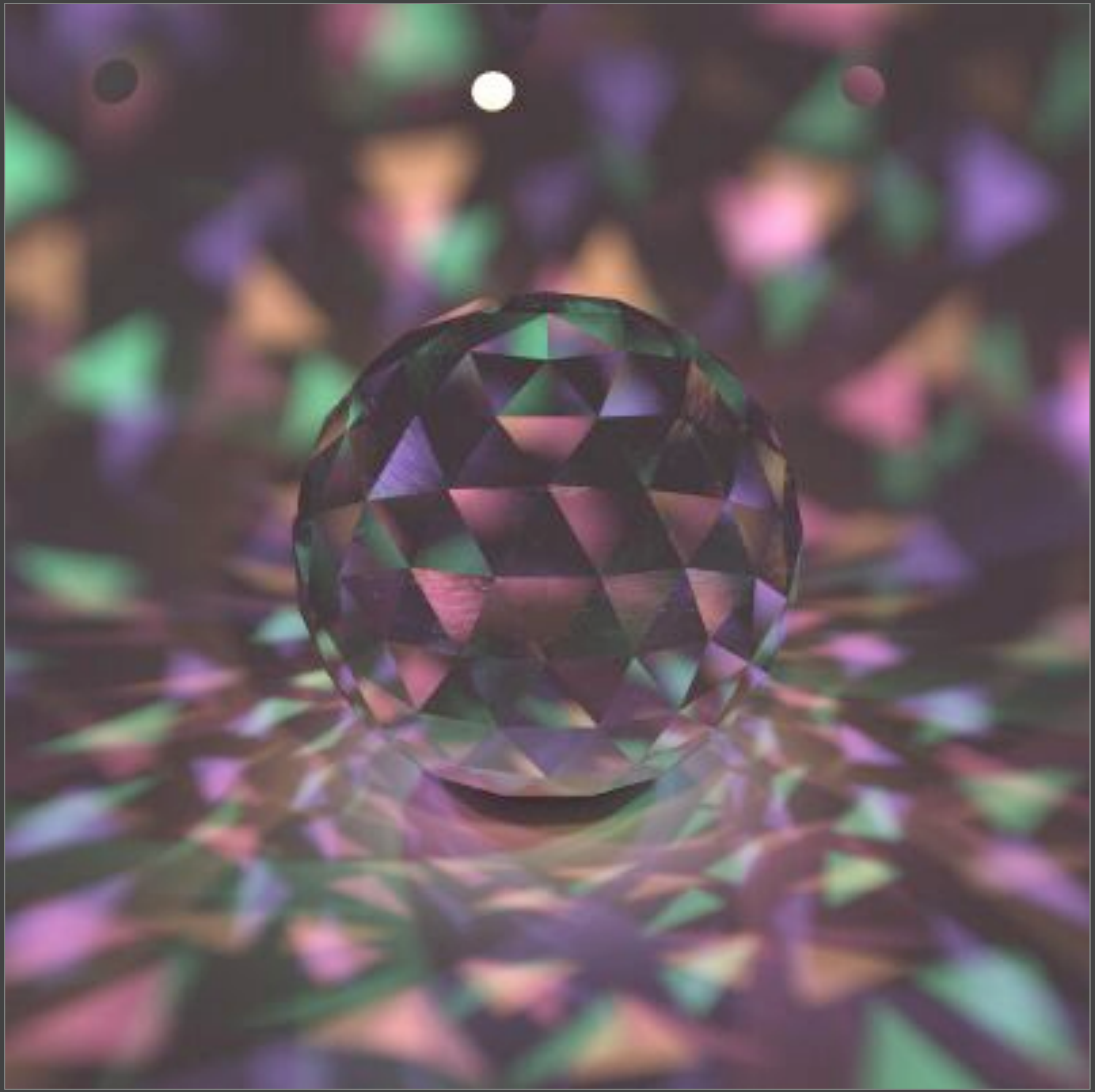
Lafortune and Willems 1993 • Veach and Guibas 1994

Bidirectional path tracing



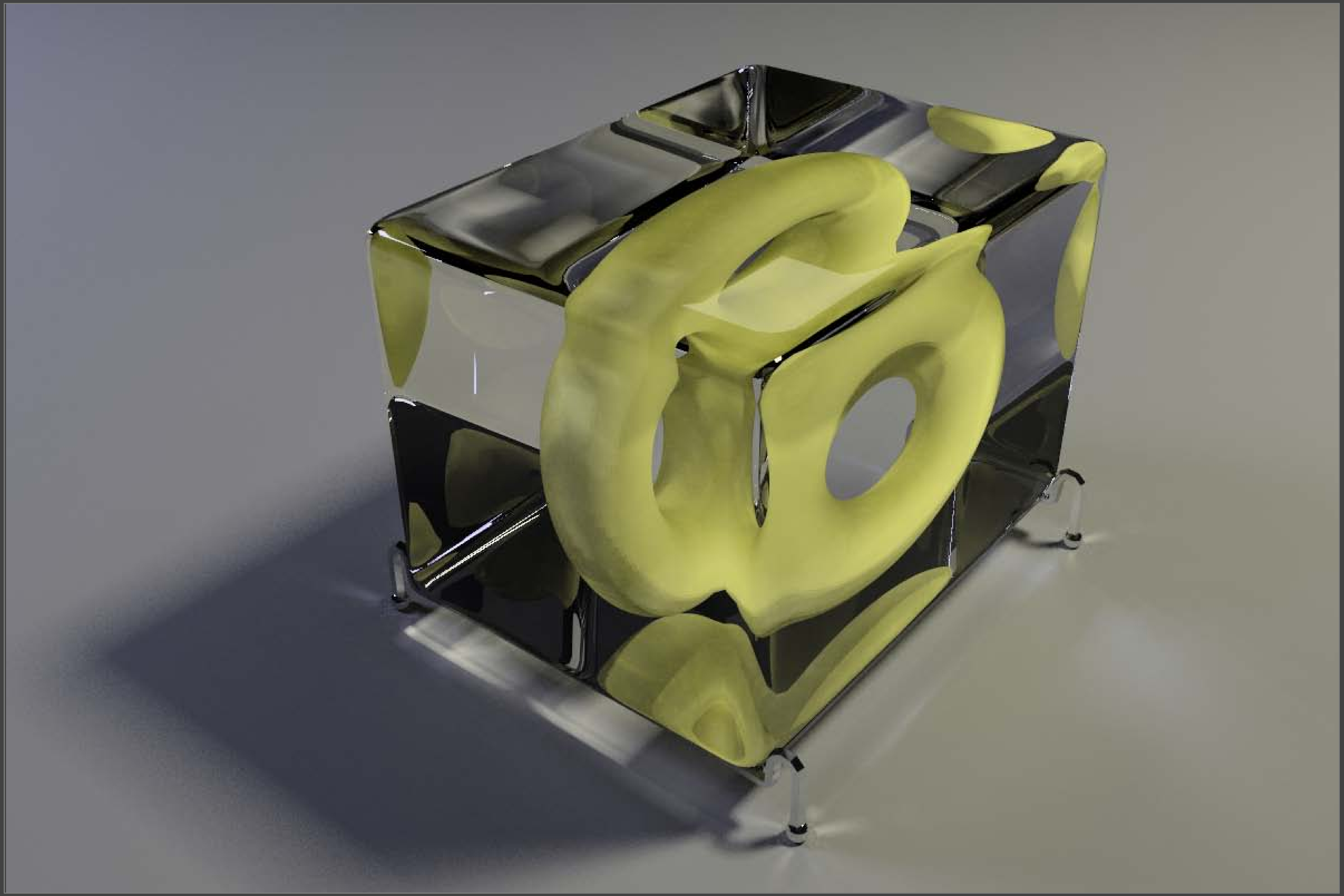
Veach and Guibas 1997

Markov Chain Monte Carlo (Metropolis Light Transport)



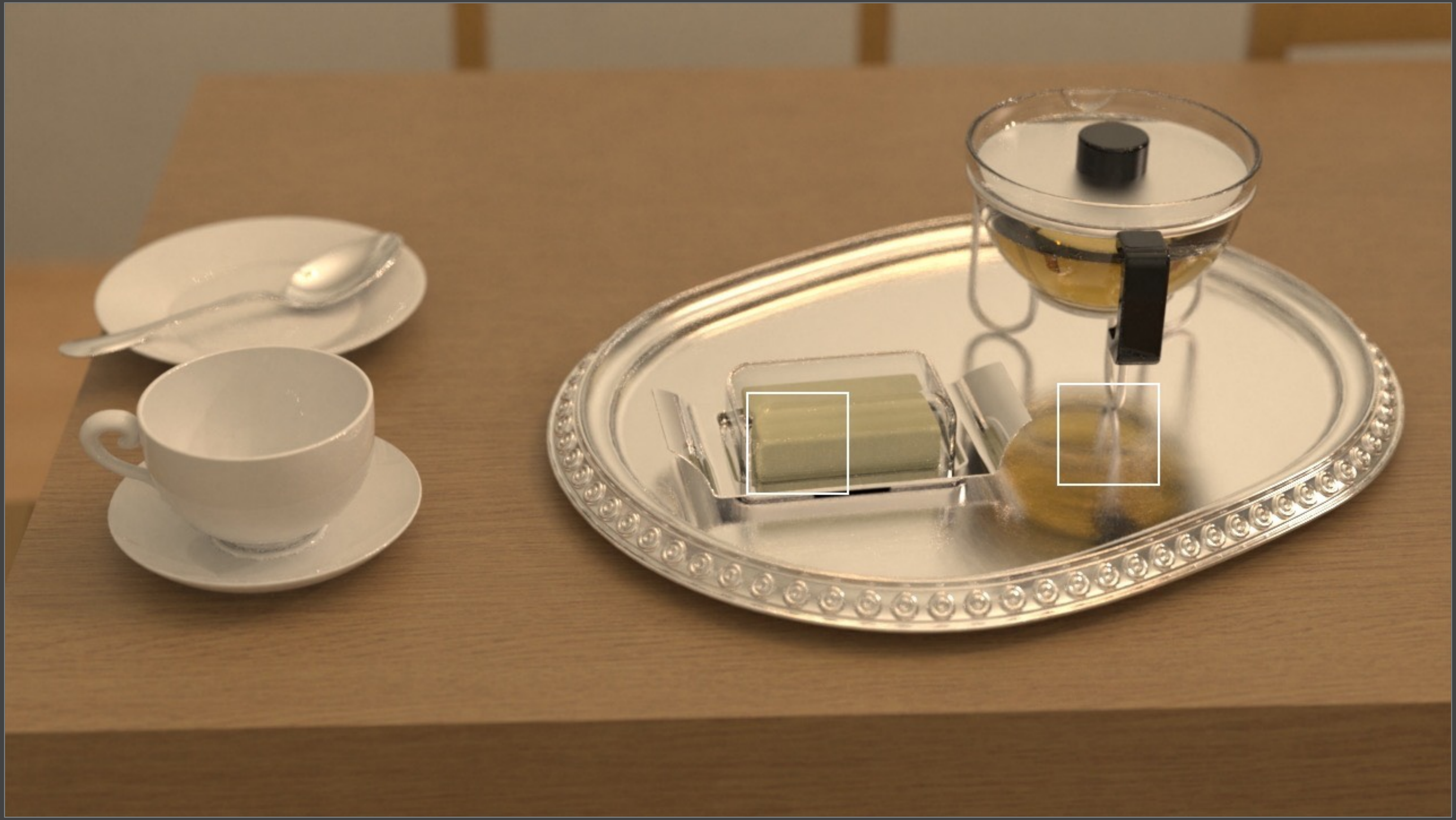
Kelemen et al. 2002

Primary sample space MCMC



Cline et al. 2005

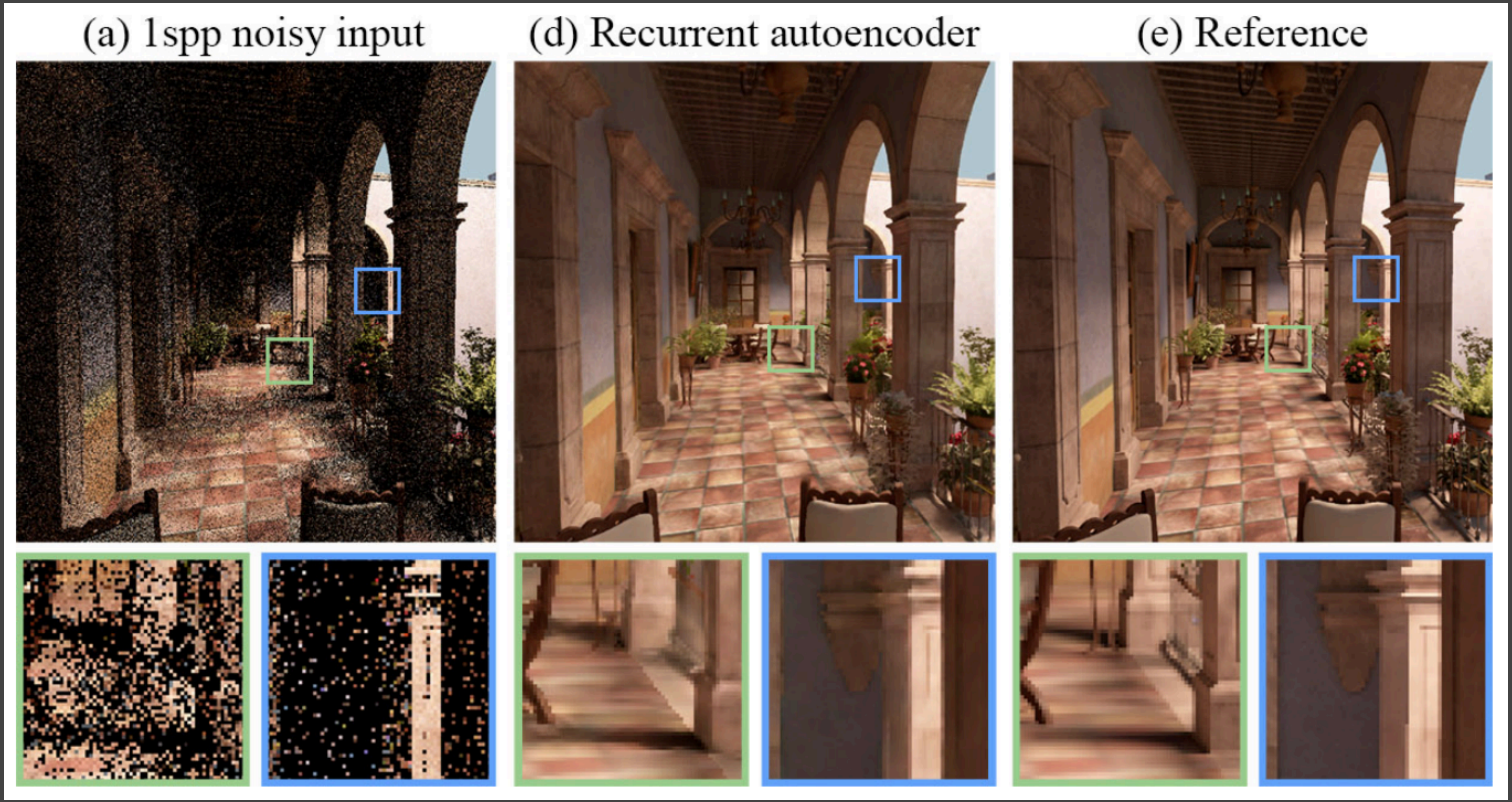
“Energy Redistribution” with non-ergodic MCMC



Jakob & Marschner 2012
Manifold Exploration MCMC

Kettunen et al. 2015

Gradient Domain Path Tracing



Chakravarty et al. 2017

Recurrent Denoising Autoencoder

frame times 20-30ms

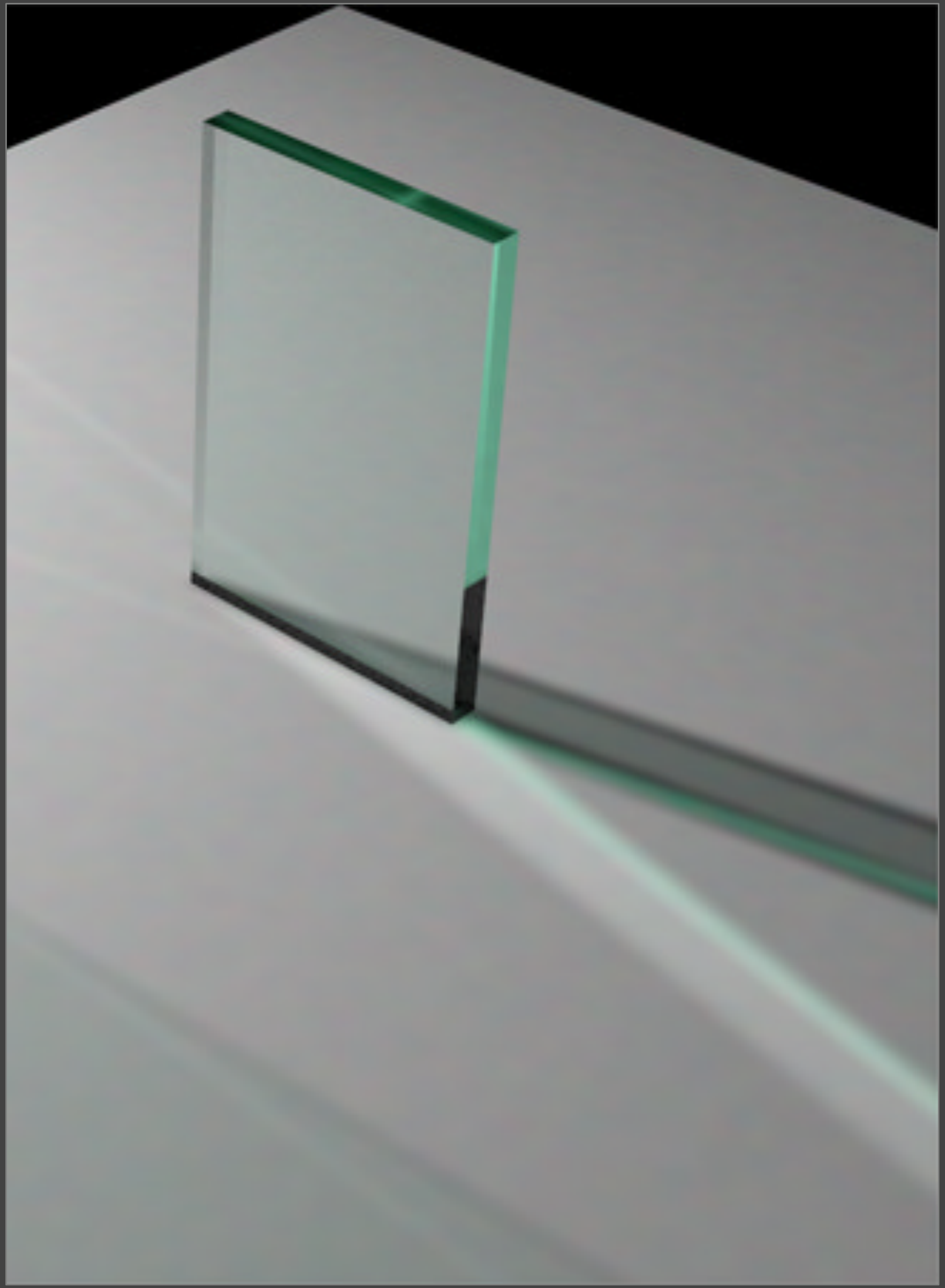
Bitterli et al. 2020

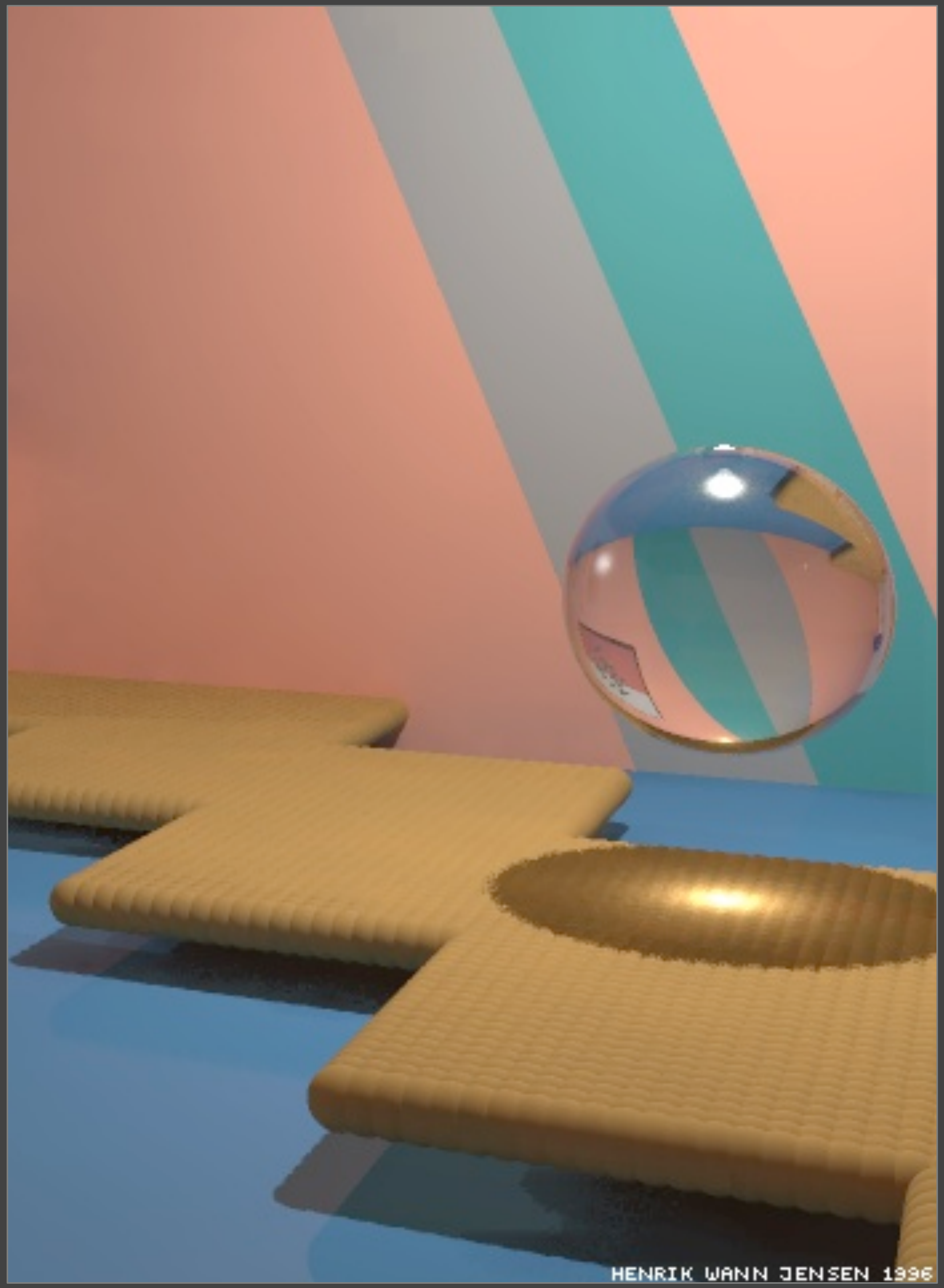
Spatiotemporal reservoir sampling

Real time path tracing — NVIDIA / Omniverse RTX tech demo (2020) (YouTube) (SIGGRAPH presentation)

Real time path tracing — NVIDIA / Omniverse RTX tech demo (2020) (YouTube) (SIGGRAPH presentation)

Two-Pass Methods





Walter et al. 1997 • Jensen 1996

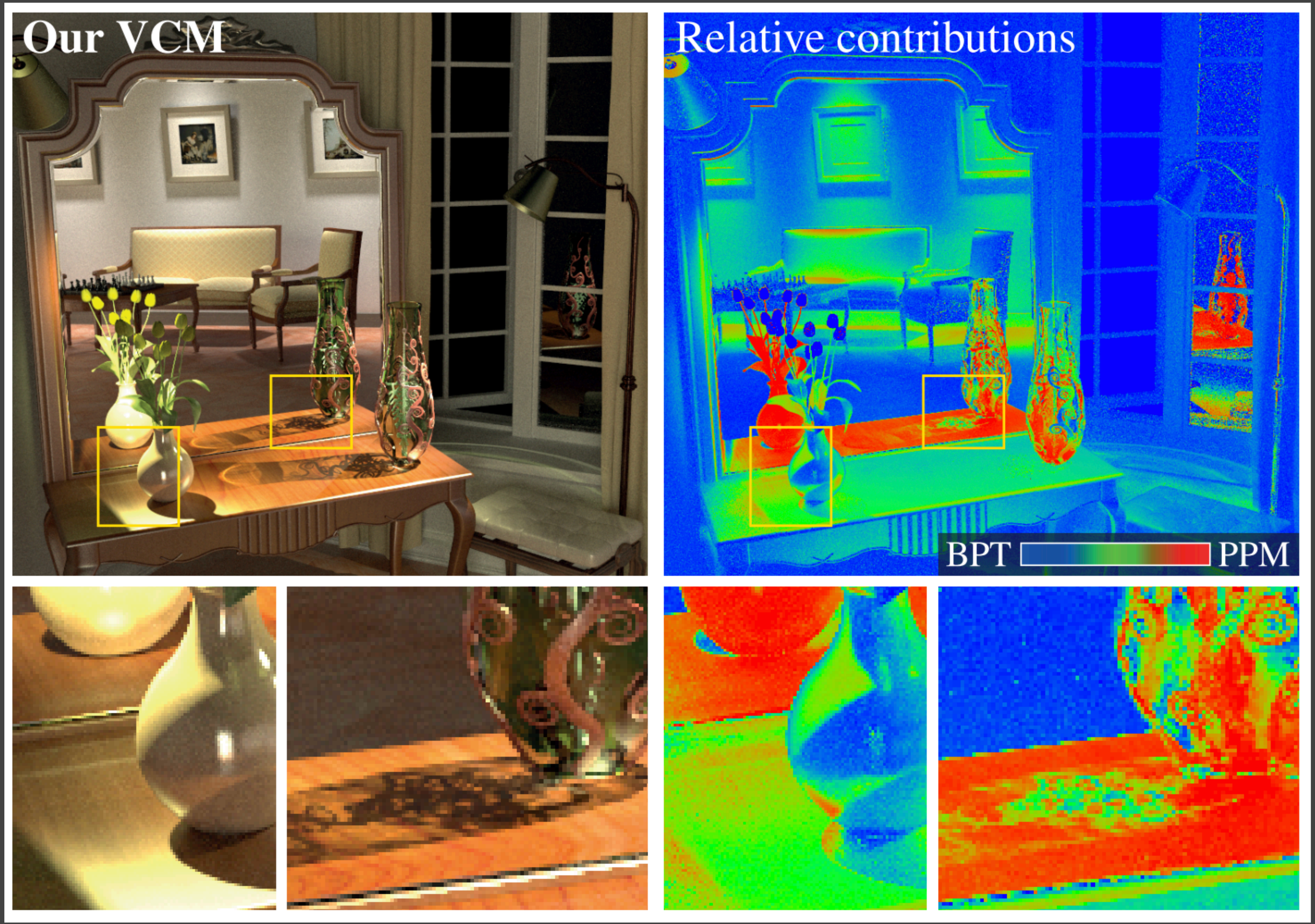
Density estimation (Photon Mapping)

Henrik Wann Jensen

Keller 1997

Virtual point lights (Instant Radiosity)

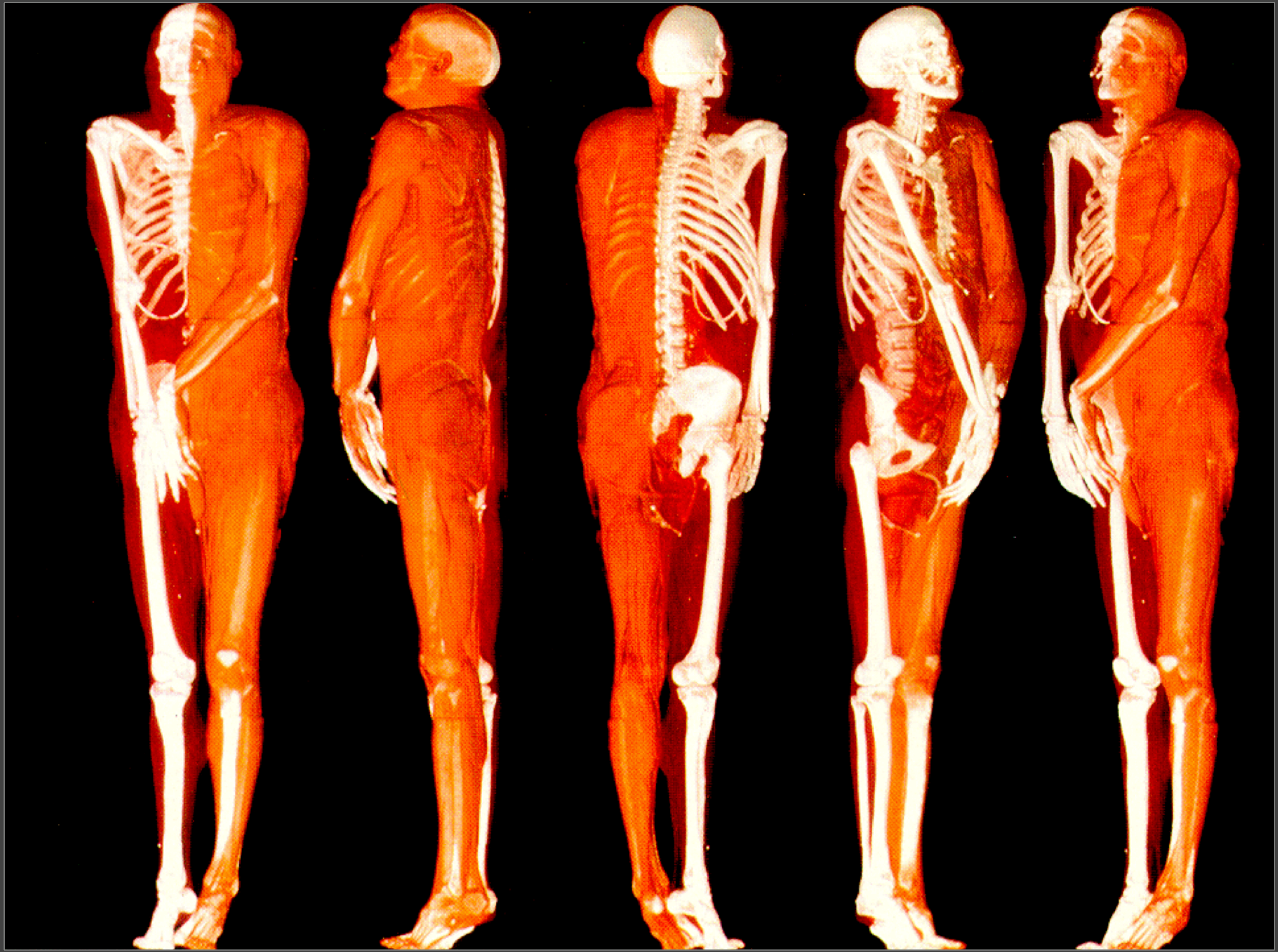
Walter et al. 2005
LightCuts



Georgiev et al. 2013

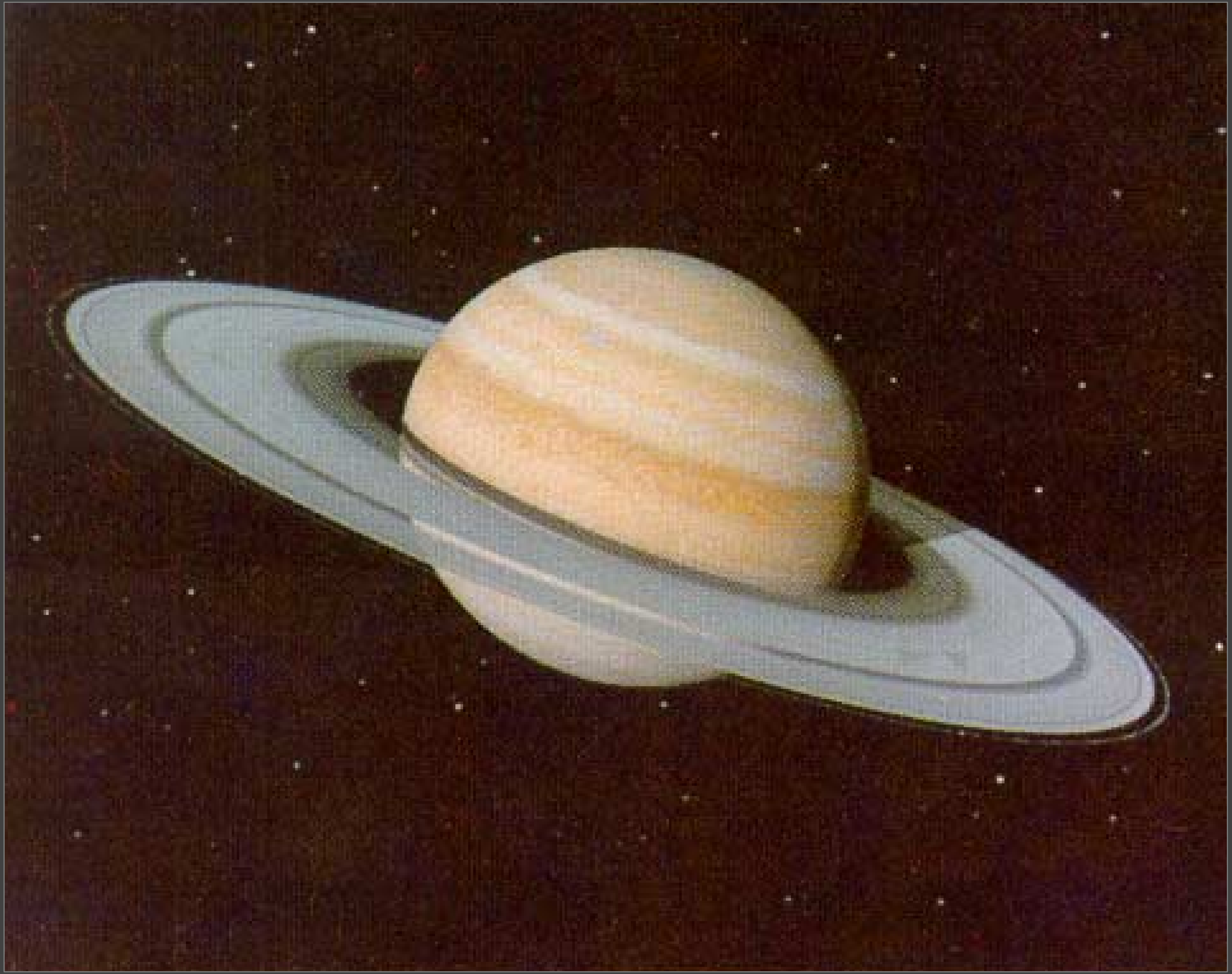
Vertex Connection and Merging

Radiative Transport



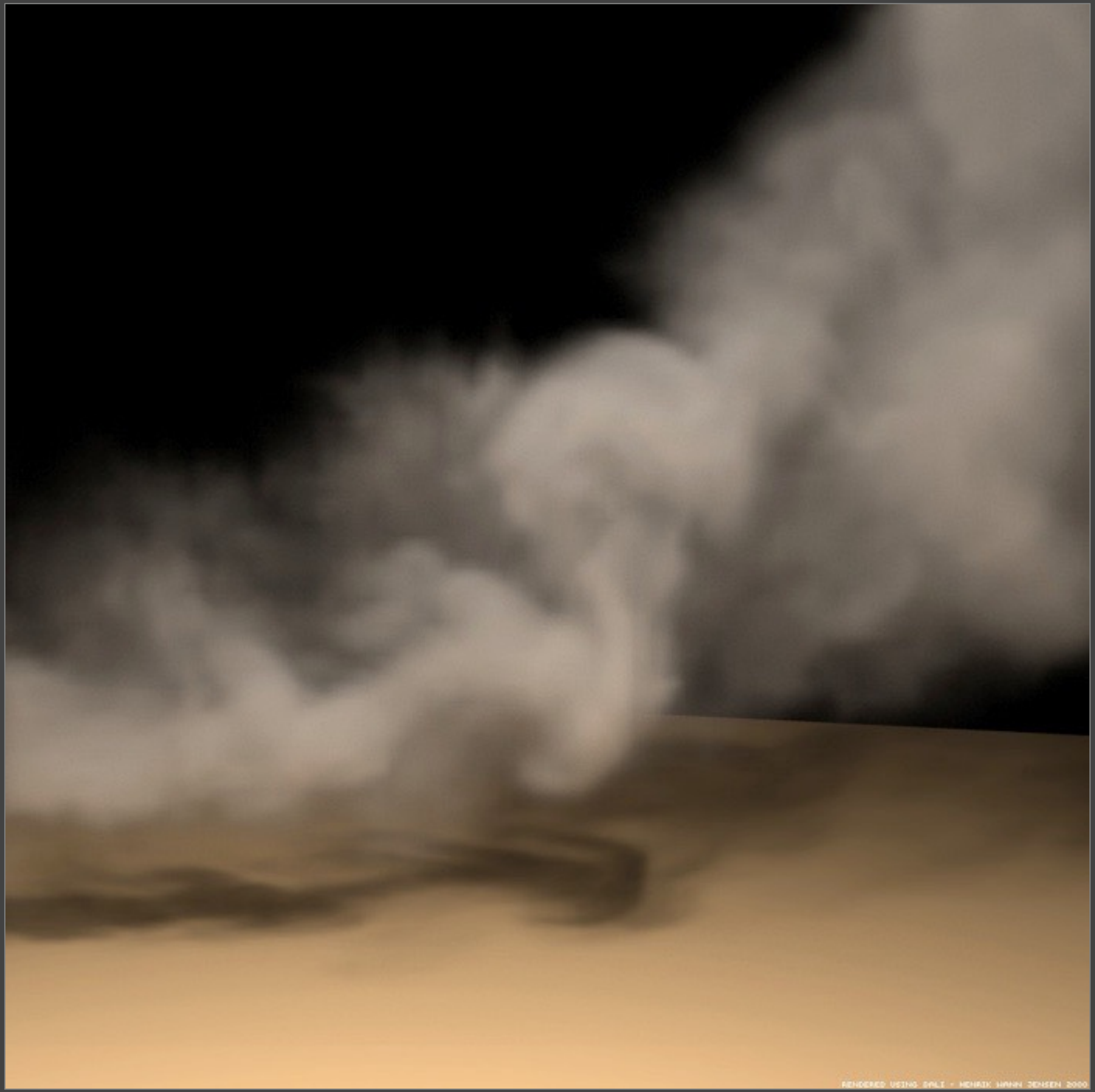
Drebin et al. 1988

Direct volume rendering



Blinn 1982

Volume scattering



(this image is later)

Jensen and Christensen 1998

Volumetric photon mapping

Jarosz et al. 2008

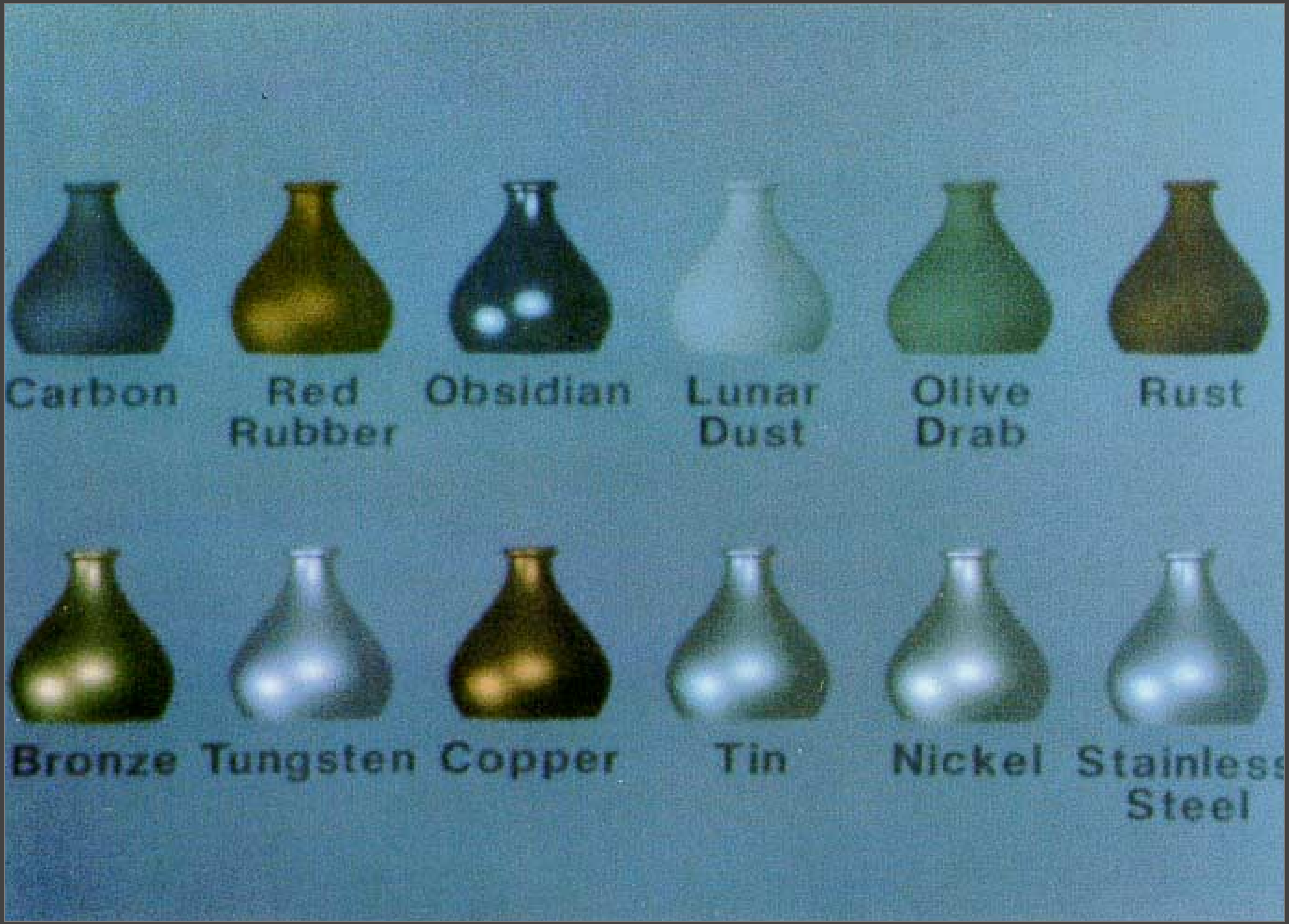
Beam Radiance Estimate

Křivánek et al. 2014
Unifying Points, Beams, and Paths

Pauly et al. 2000

Metropolis in volumes

Scattering Models

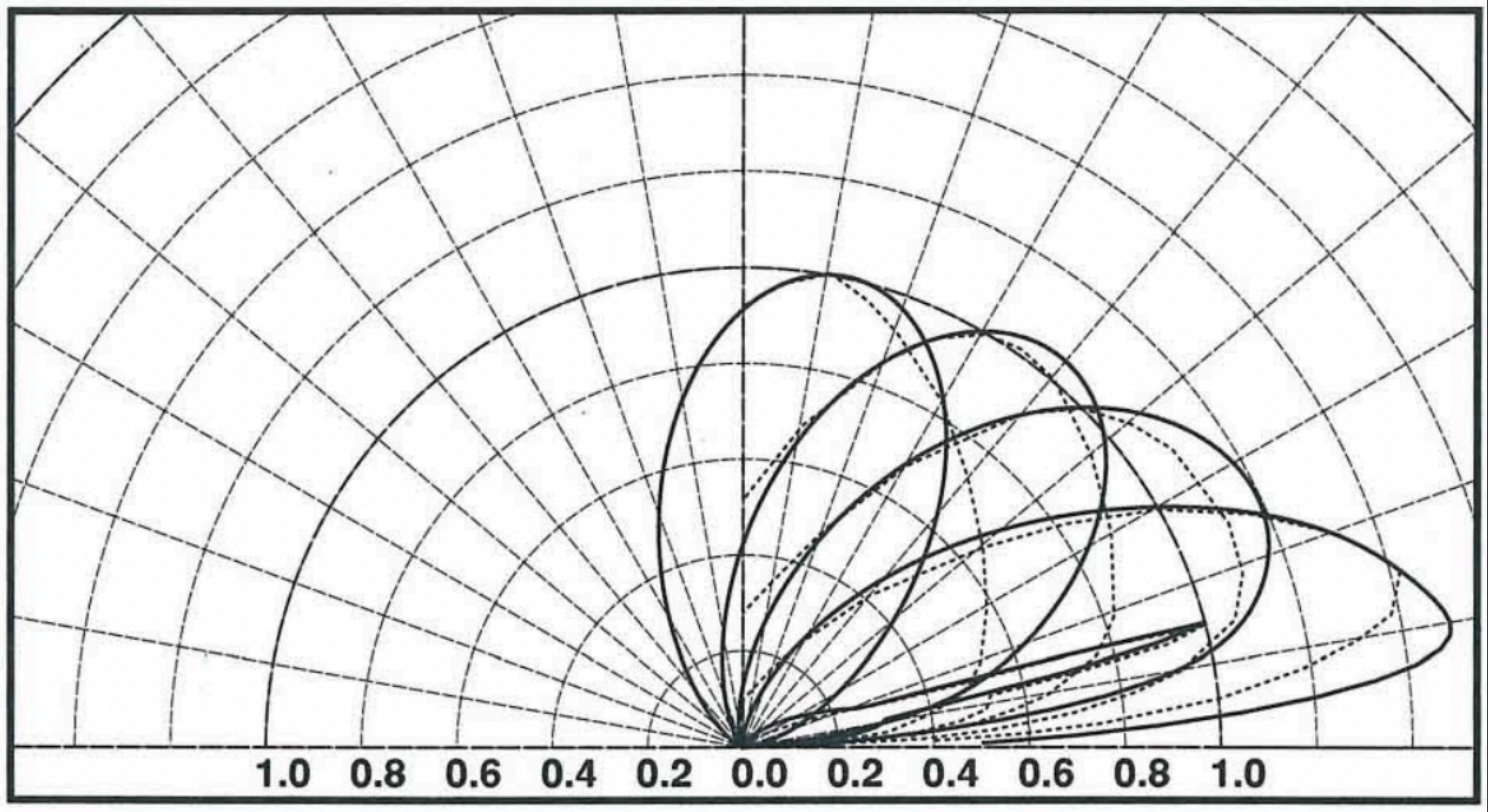


Cook and Torrance 1981

Microfacet reflection models

Walter et al. 2007

Microfacet transmission model



Xiao D. He et al. 1991

Comprehensive physical (wave) model for light reflection

Stam 1999

Fourier-based diffraction model

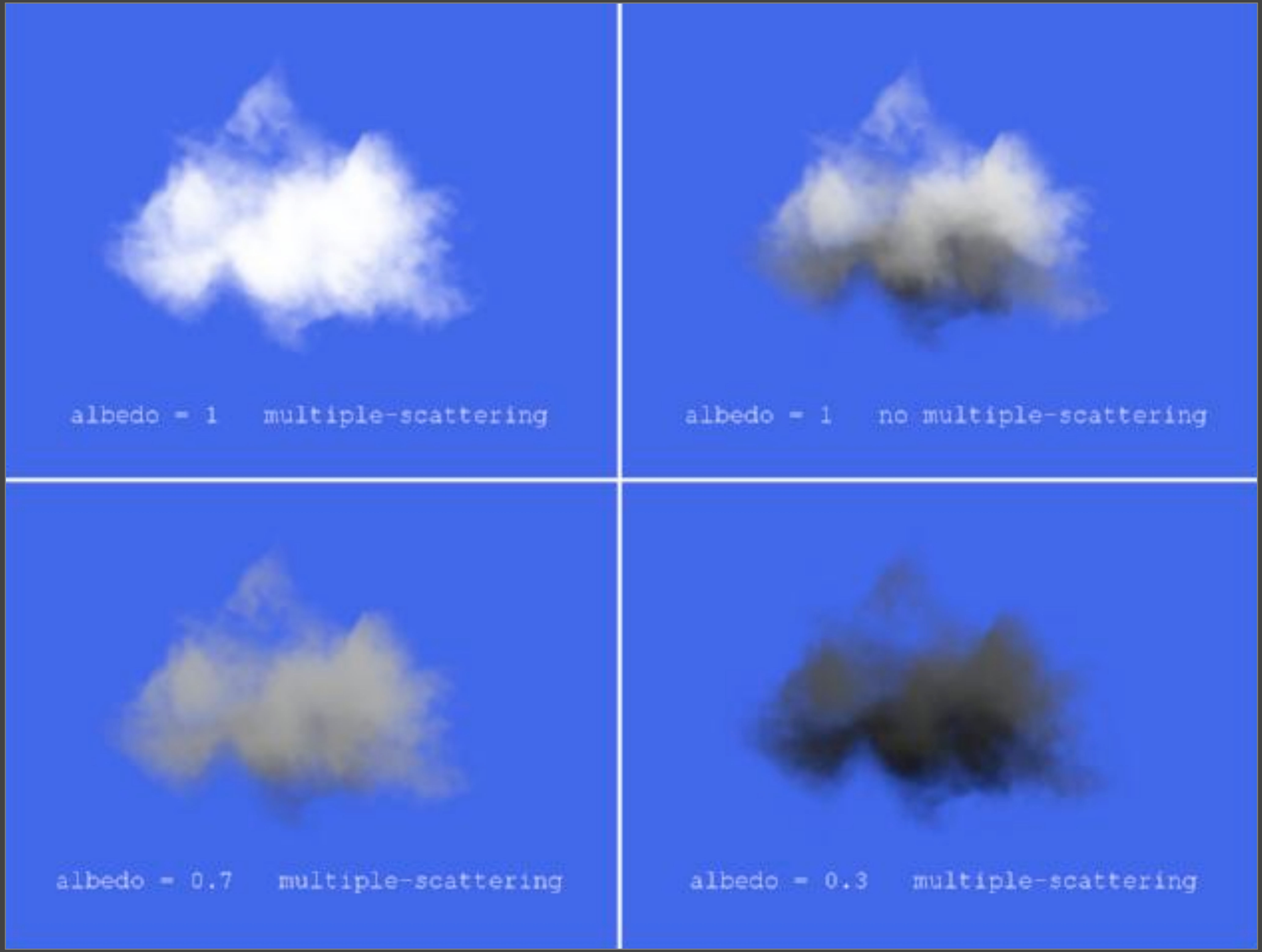
Belcour et al. 2017
Microfacet iridescence model

Jakob et al. 2014

Layered surface model

Jakob et al. 2010
Anisotropic volume media

Diffusion and Translucency



Stam 1995

Diffusion for light transport

[Niniane Wang]

Jensen, Marschner, Levoy, and Hanrahan 2001
Subsurface scattering

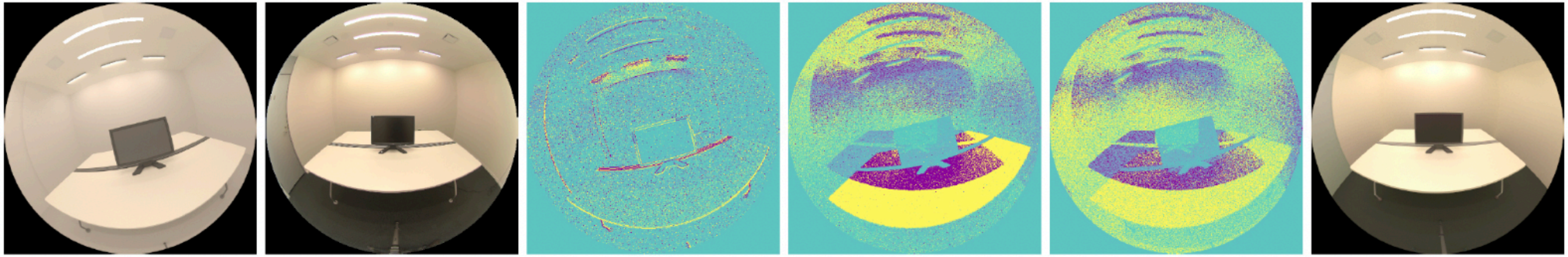
d’Eon and Irving 2011

Advanced diffusion models

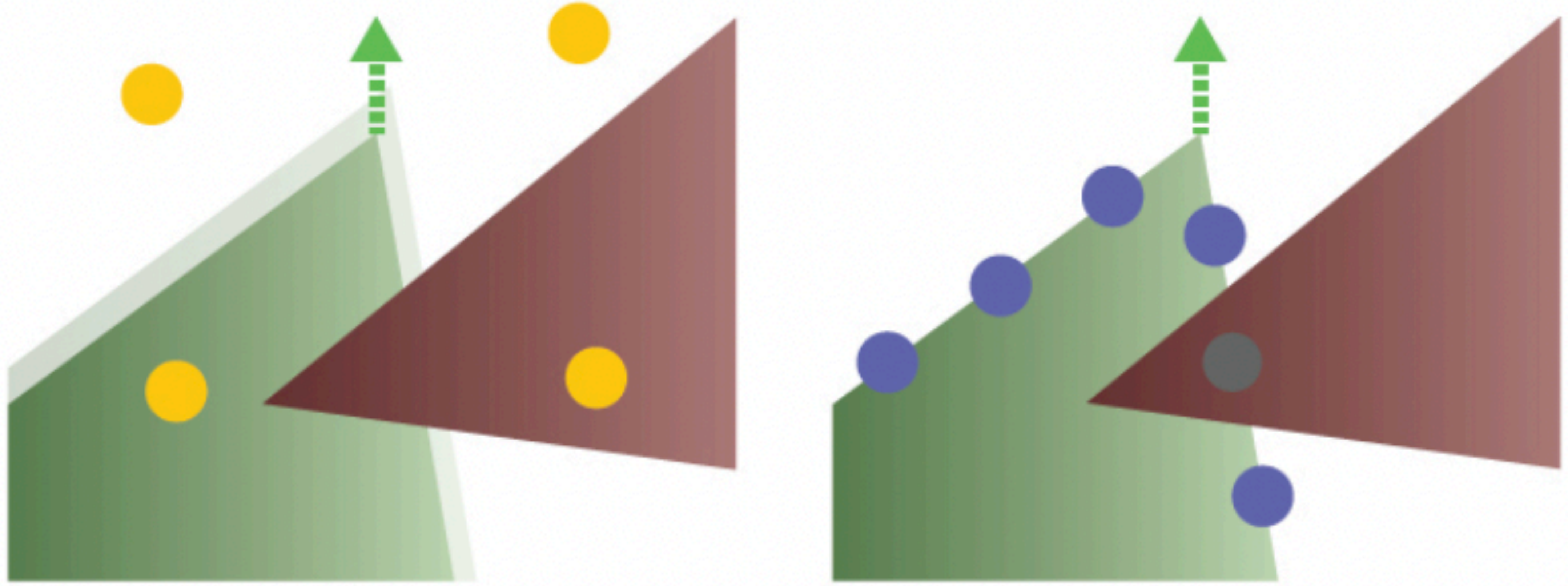

NVIDIA


NVIDIA

Differentiable rendering



(a) initial guess (b) real photograph (c) camera gradient (per-pixel contribution) (d) table albedo gradient (per-pixel contribution) (e) light gradient (per-pixel contribution) (f) our fitted result



(a) area sampling (b) edge sampling

Tzu-Mao Li et al. 2018

Differentiable ray tracing

Original | **Derivative** with respect to sun location

Cheng Zhang et al. 2020

Path-space differentiable rendering

Nimier-David et al. 2020

Radiative backpropagation