King Abdullah University of Science and Technology

KAUST

# CS 247 – Scientific Visualization
# Lecture 14: Volume Visualization, Pt. 1

Markus Hadwiger, KAUST

# Reading Assignment #8 (until Mar 23)

Read (required):

- Real-Time Volume Graphics, Chapter 1
  (*Theoretical Background and Basic Approaches*),
  from beginning to 1.4.4 (inclusive)

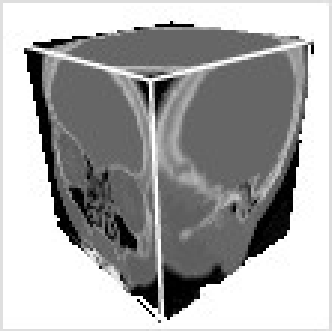
Read (optional):

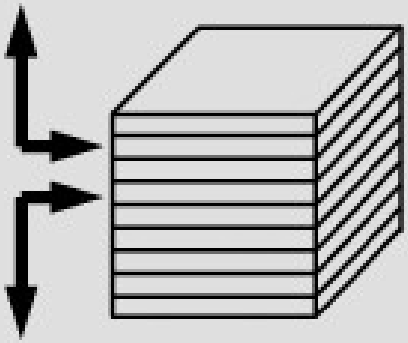
- Paper:
  *Nelson Max, Optical Models for Direct Volume Rendering,*
  *IEEE Transactions on Visualization and Computer Graphics, 1995*
  **`http://dx.doi.org/10.1109/2945.468400`**

# Volume Rendering

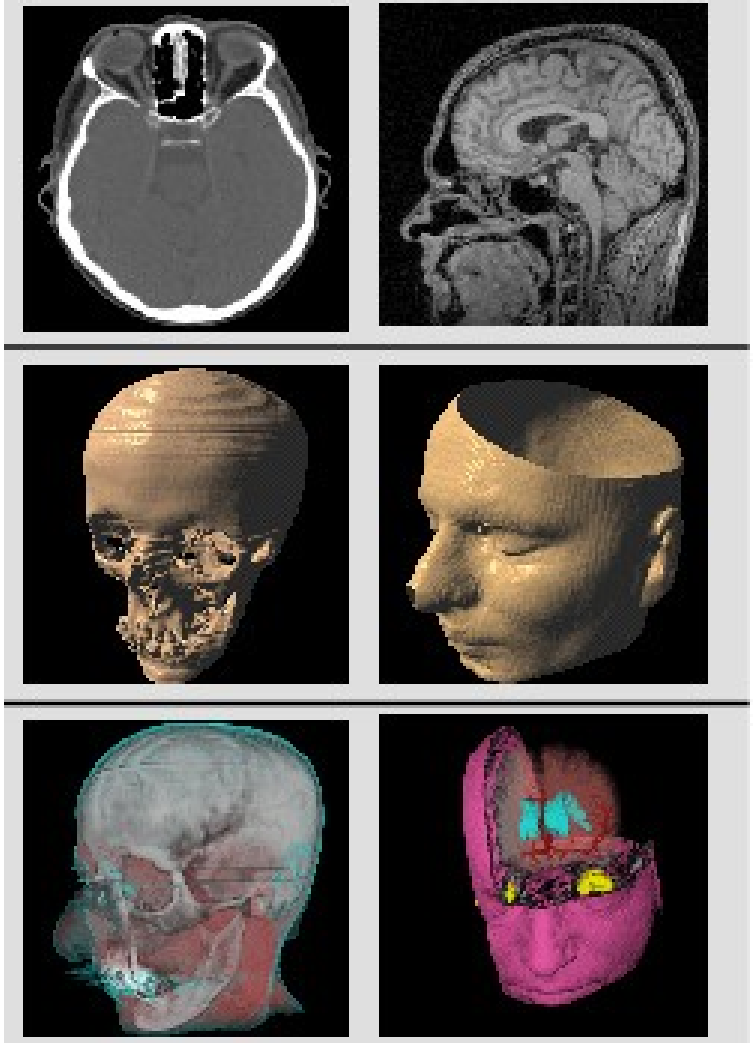
# Theory

# Volume Visualization

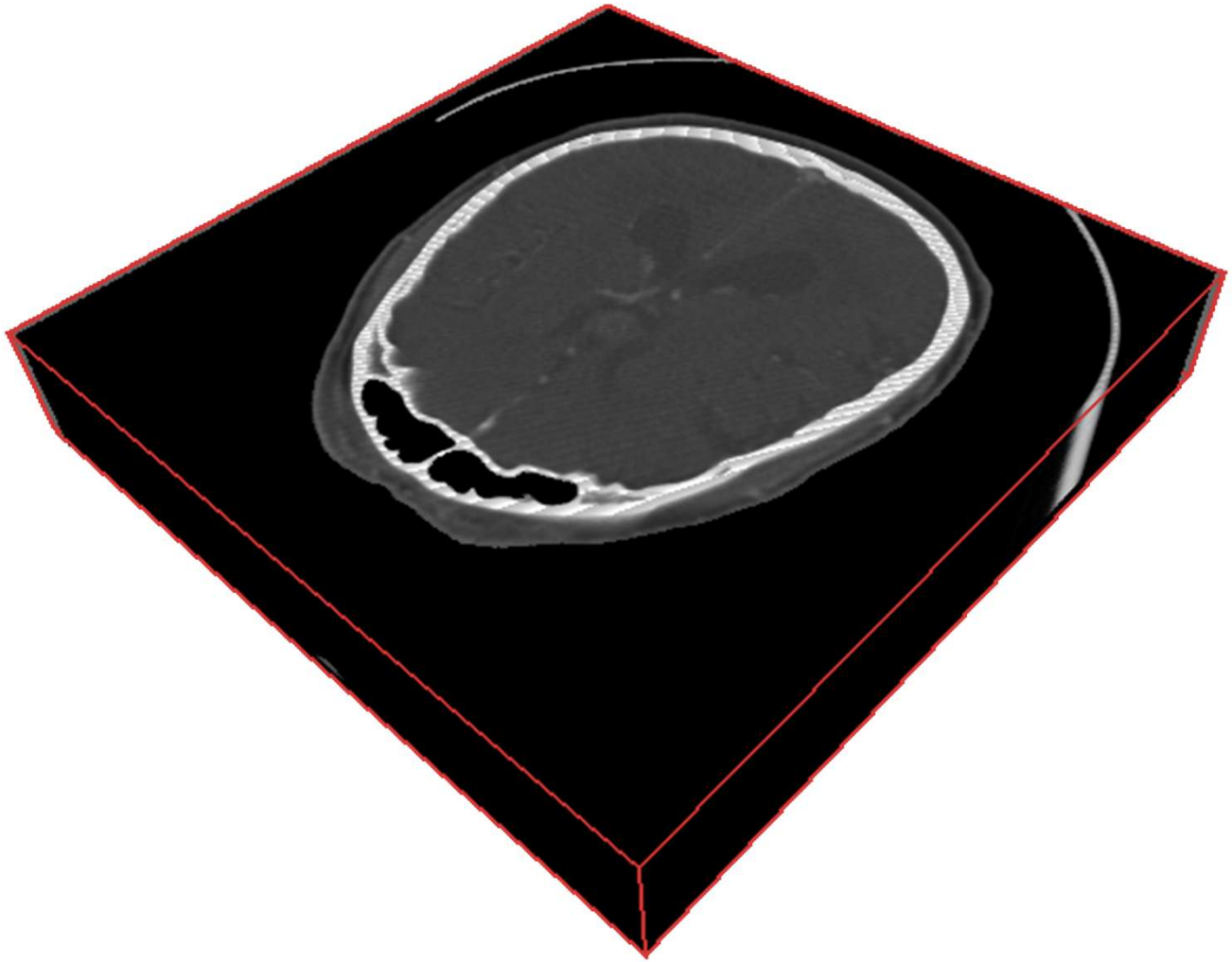




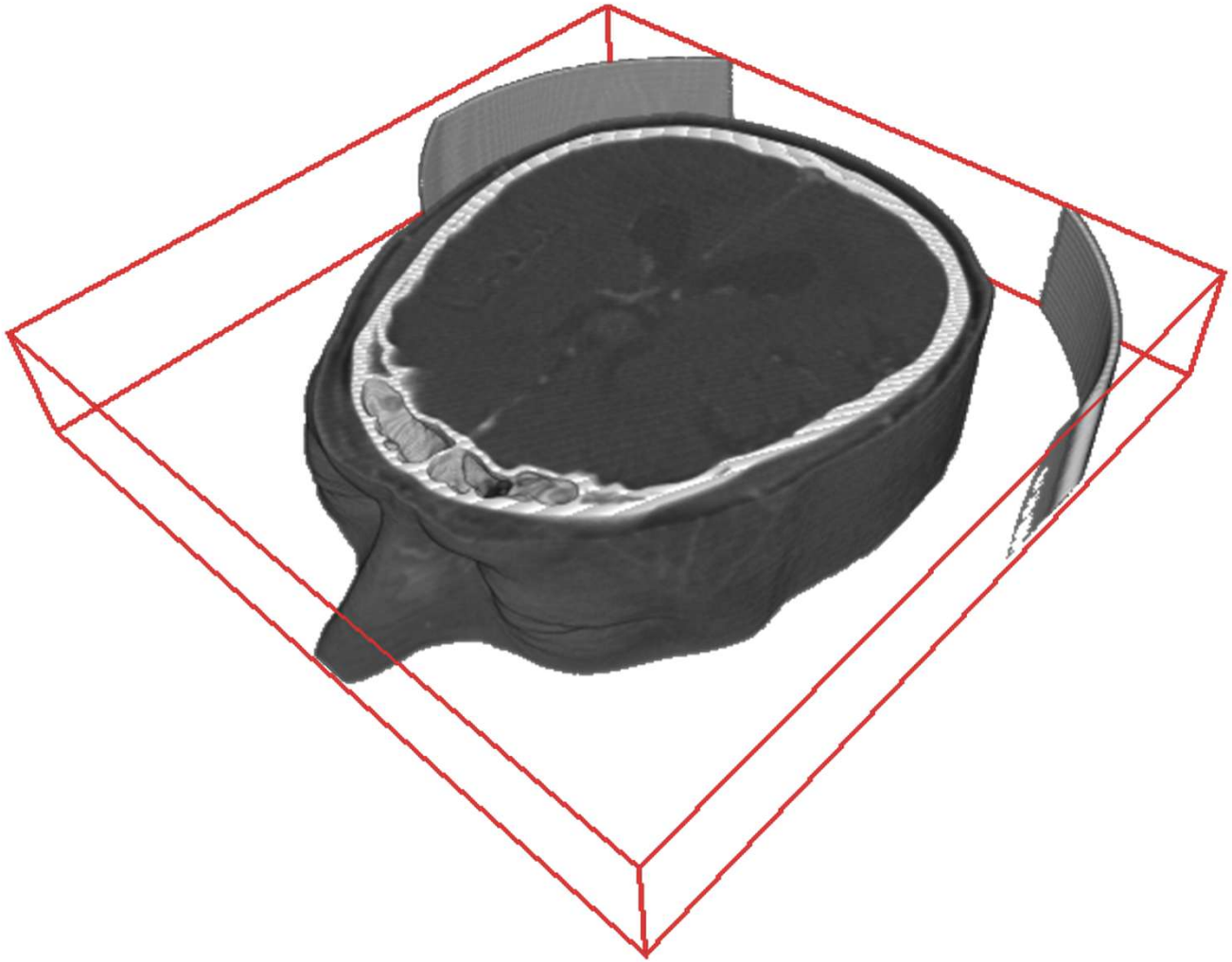
- 2D visualization
  slice images
  (or multi-planar
  reformatting MPR)
- *Indirect*
  3D visualization
  isosurfaces
  (or surface-shaded
  display: SSD)
- *Direct*
  3D visualization
  (direct volume
  rendering: DVR)



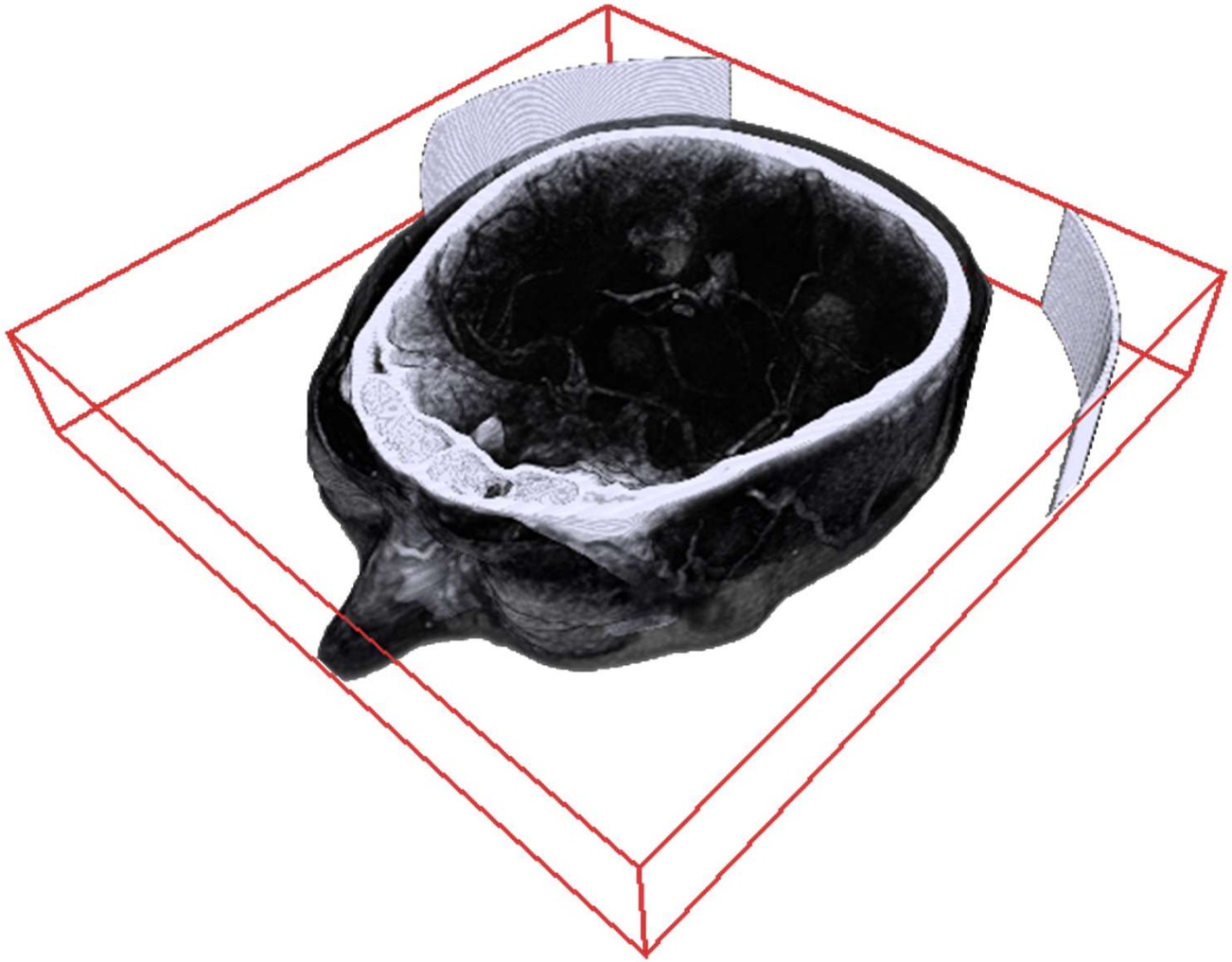
# Direct Volume Rendering



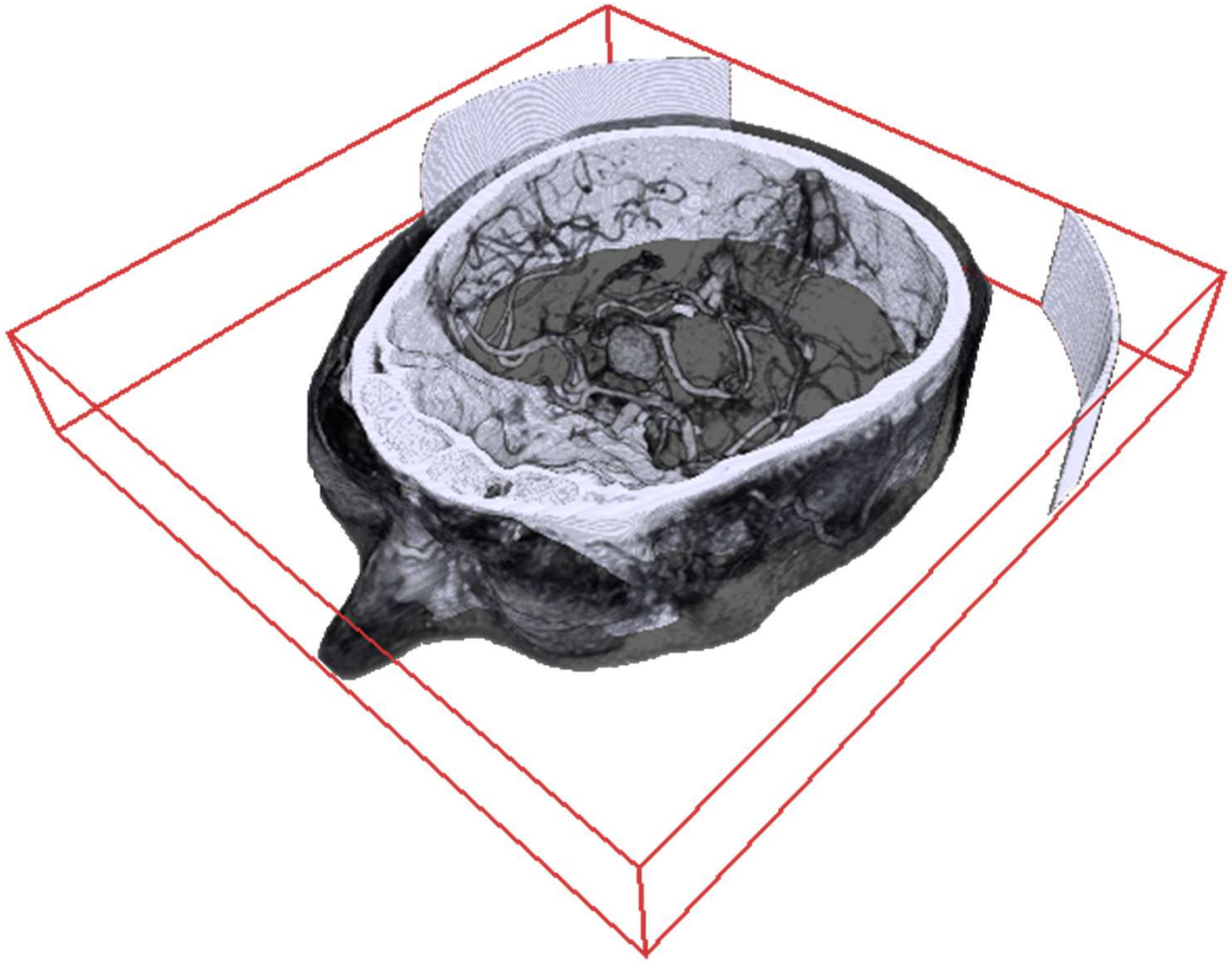
# Direct Volume Rendering



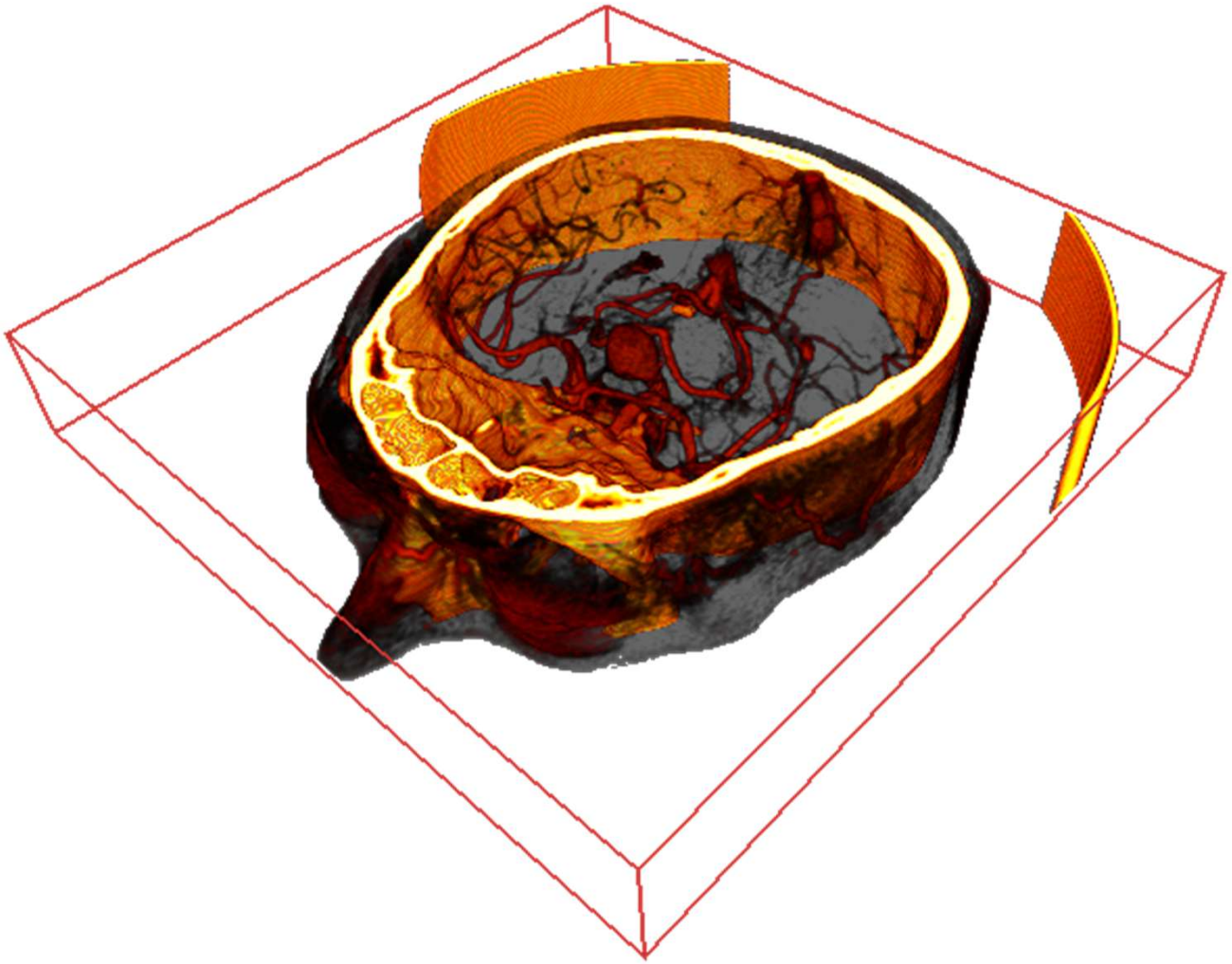
# Direct Volume Rendering



# Direct Volume Rendering



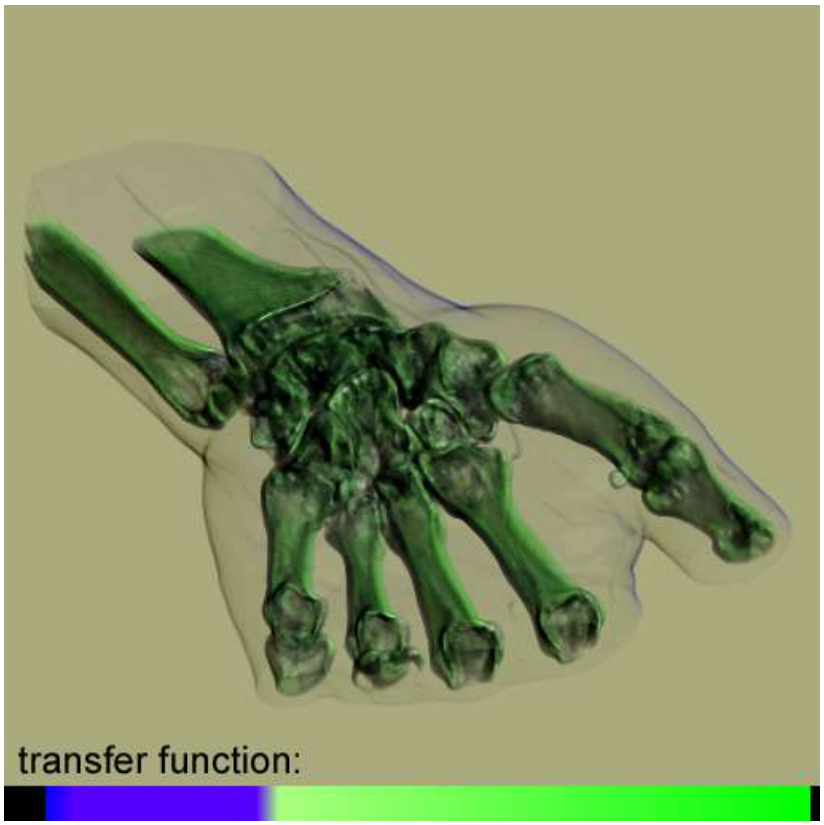
# Direct Volume Rendering



# Transparent Volumes vs. Isosurfaces

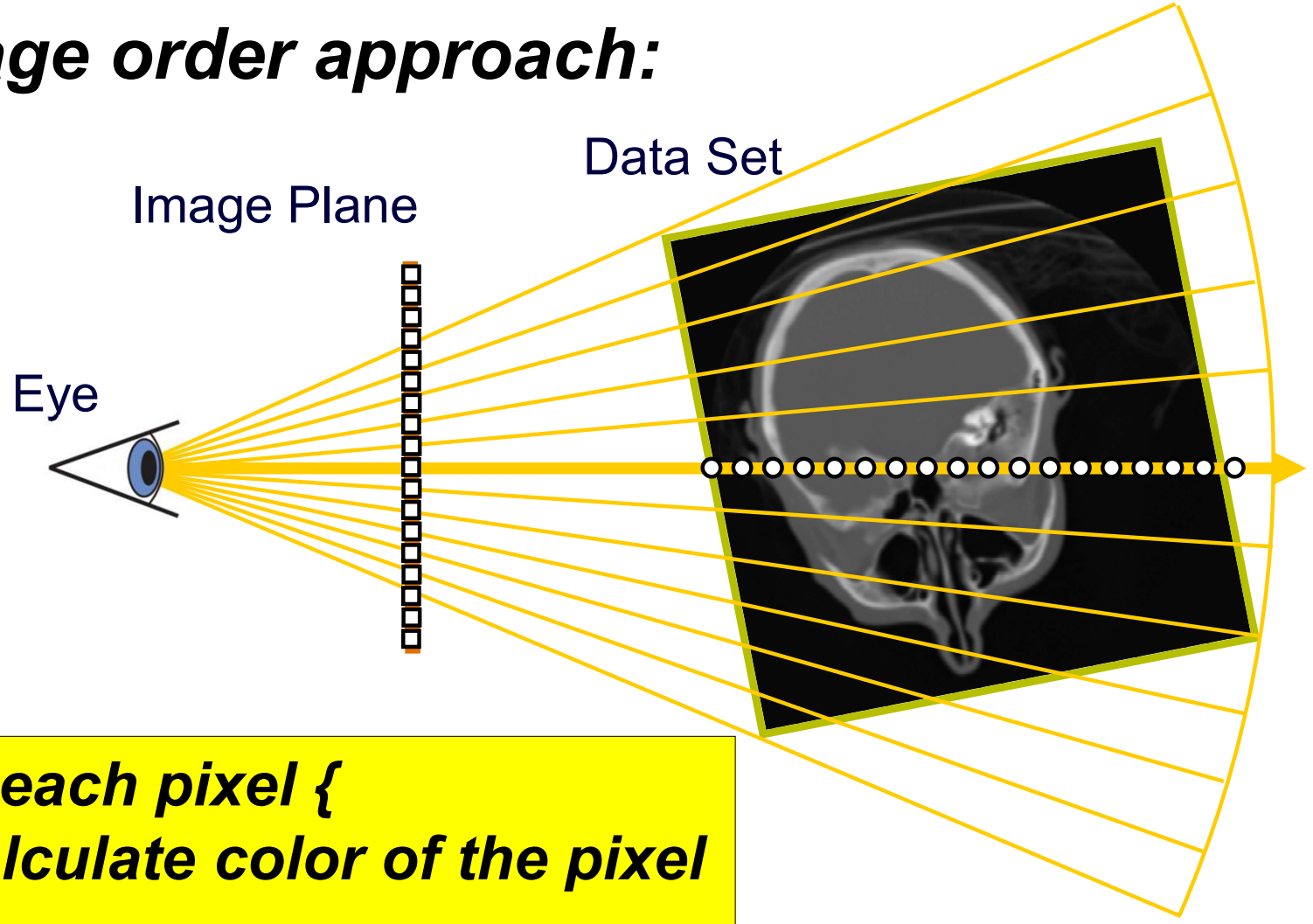
The *transfer function* assigns *optical properties* to data

- Translucent volumes
- But also: isosurface rendering using step function as transfer function




# Direct Volume Rendering: Image Order

***Image order approach:***

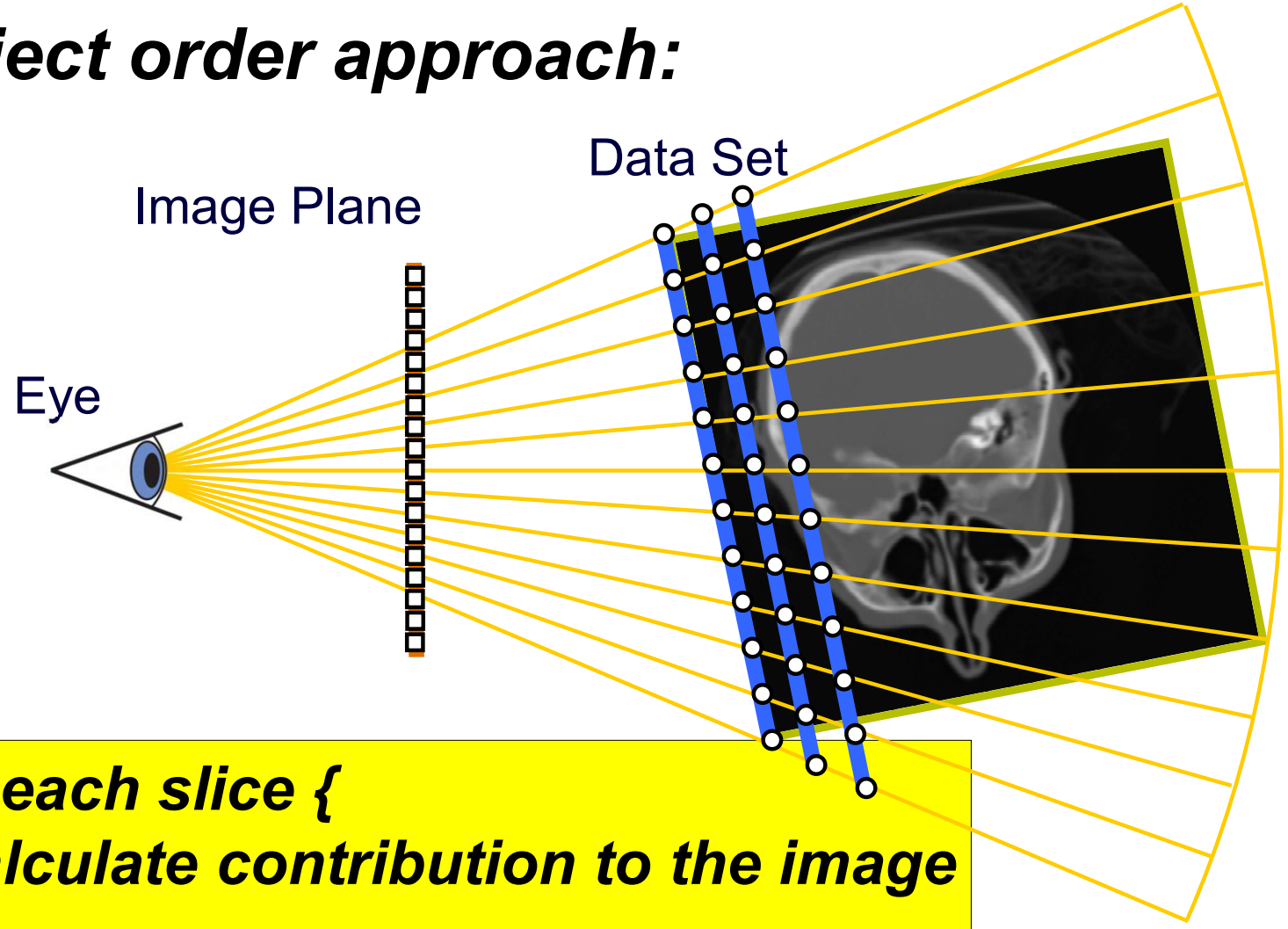



***For each pixel {***
***calculate color of the pixel***
***}***

# Direct Volume Rendering: Object Order

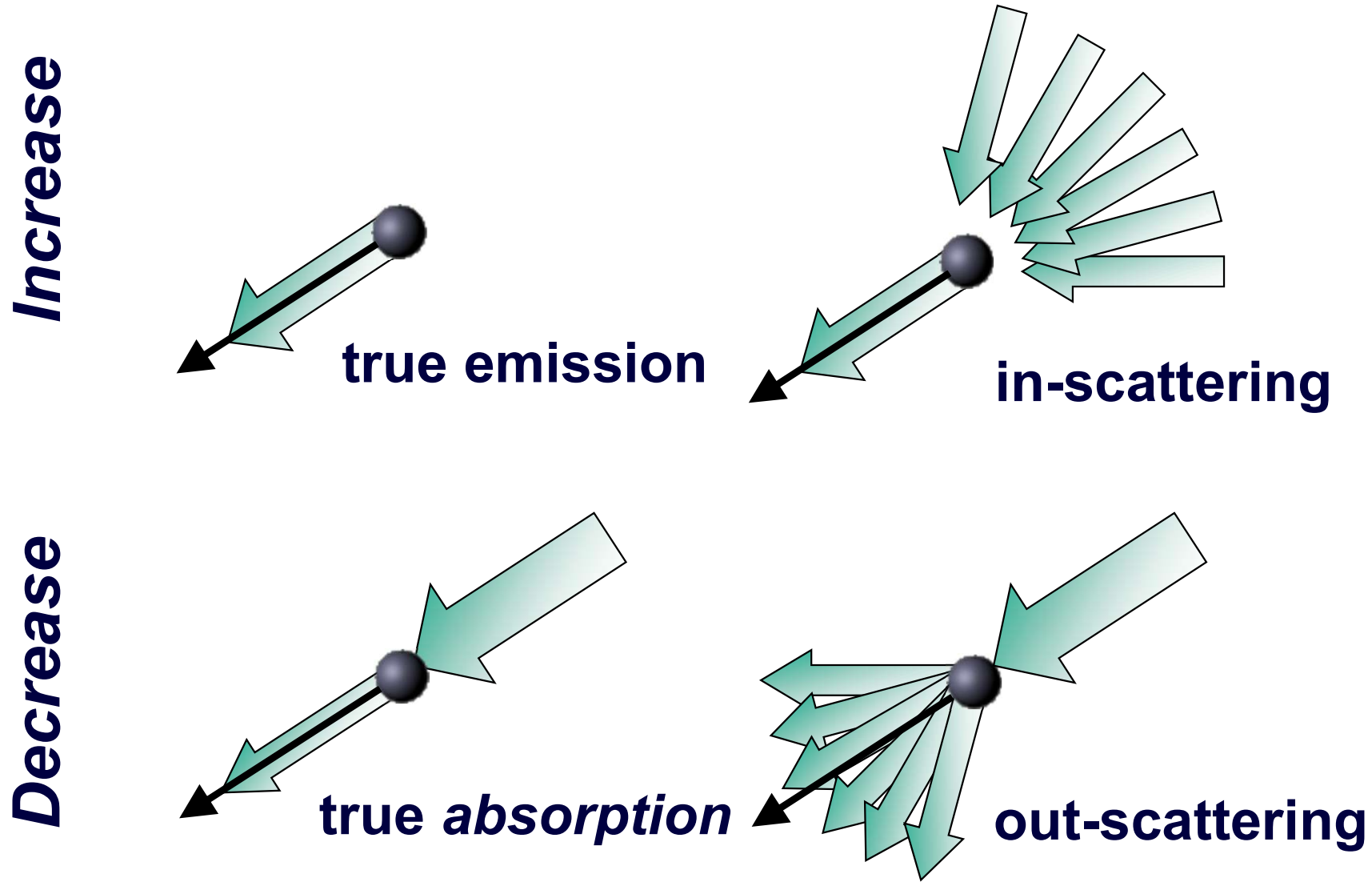


***Object order approach:***

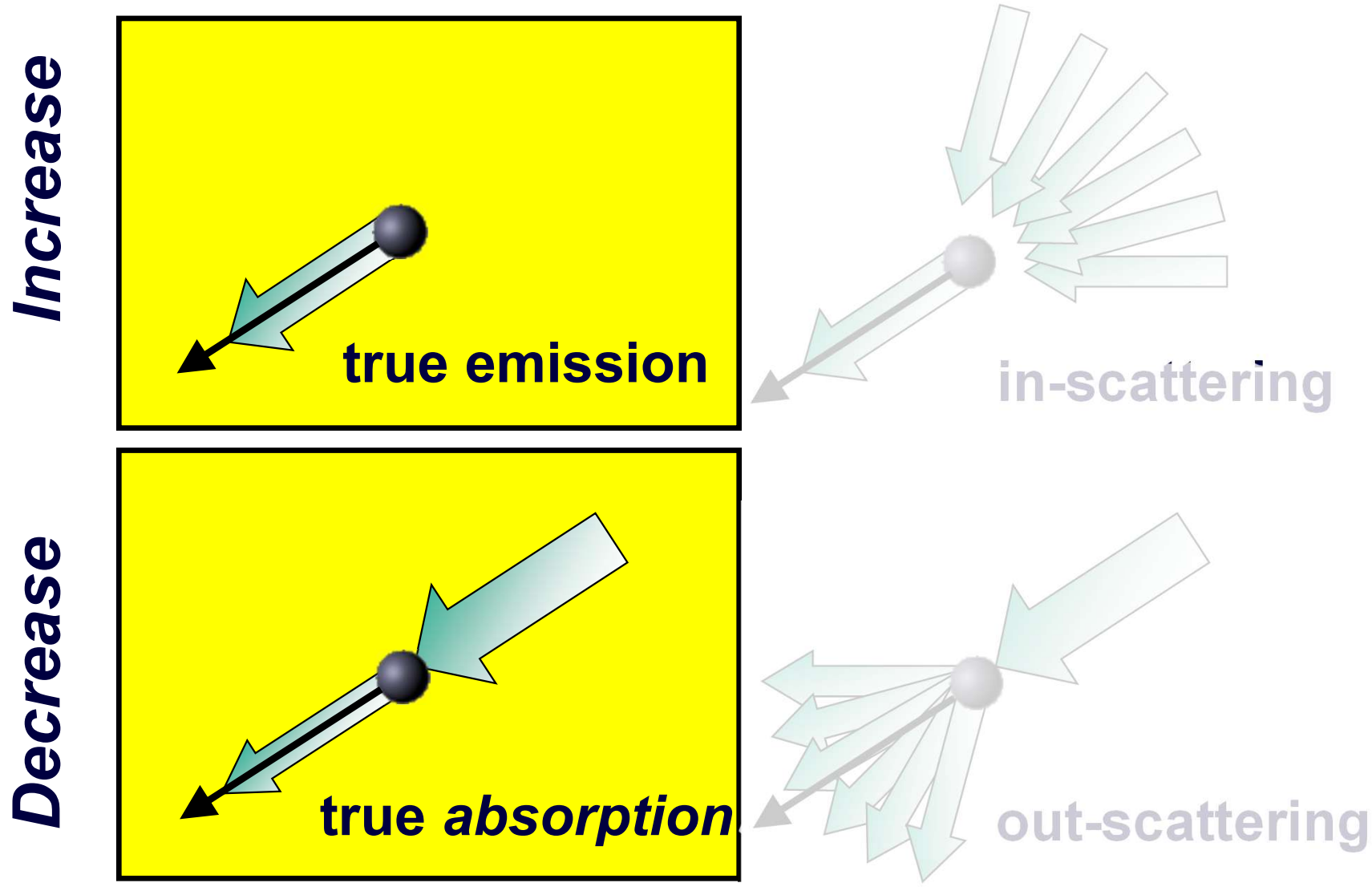



***For each slice {***
***calculate contribution to the image***
***}***

# Physical Model of Radiative Transfer



# Physical Model of Radiative Transfer



# Optical Models: Physical Model gives ODE

Optical Models for Direct Volume Rendering, Nelson Max

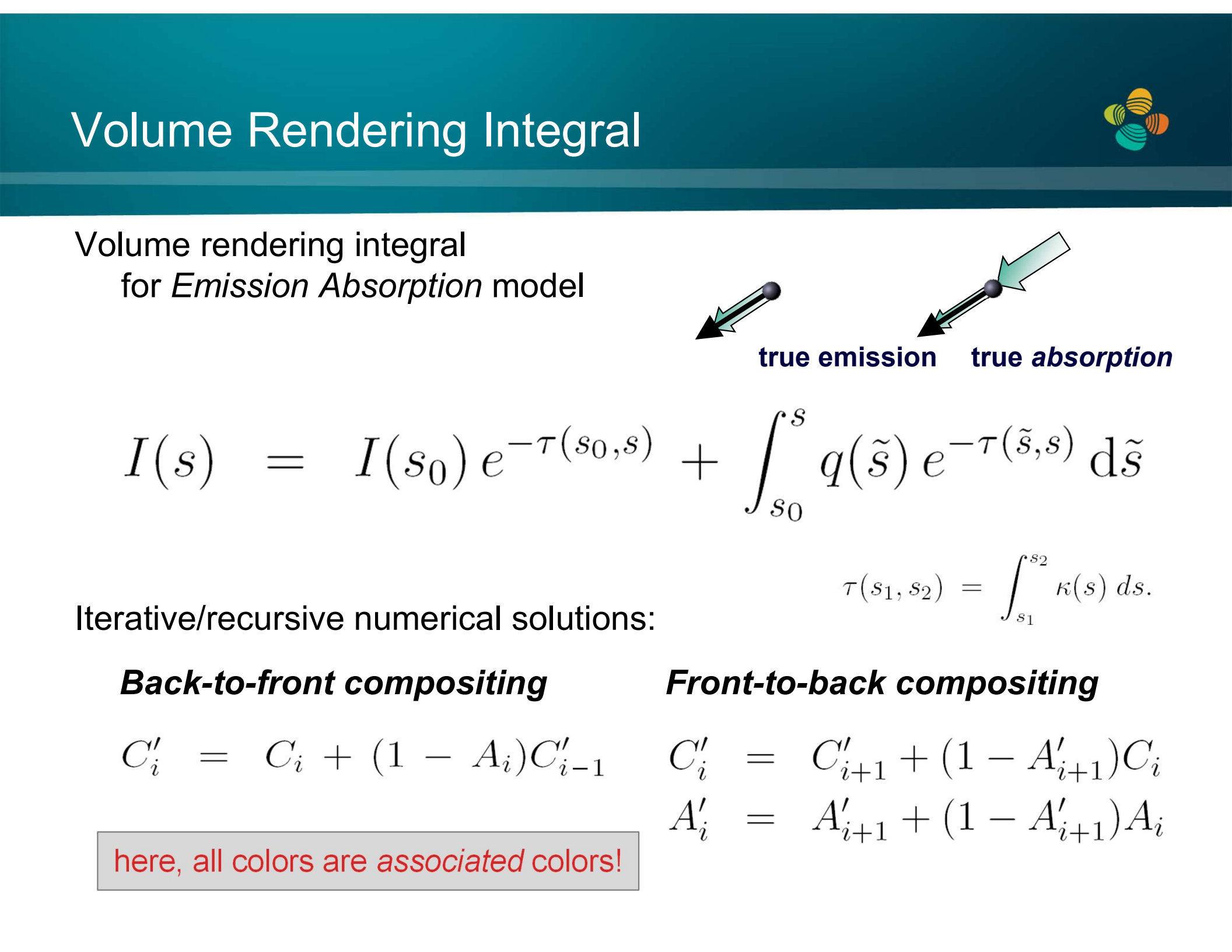
Emission-Absorption optical model

$$\frac{dI}{ds}(s) = q(s) - \kappa(s)\, I(s)$$


Right-hand side: *Rates of change* (derivatives) of light intensity along ray

Absorption rate is proportional to light intensity: Solution is exponential

# Volume Rendering Integral



Volume rendering integral
for *Emission Absorption* model



**true emission** **true *absorption***

$$I(s) = I(s_0)\, e^{-\tau(s_0,s)} + \int_{s_0}^{s} q(\tilde{s})\, e^{-\tau(\tilde{s},s)}\, \mathrm{d}\tilde{s}$$

$$\tau(s_1, s_2) = \int_{s_1}^{s_2} \kappa(s)\, ds.$$

Iterative/recursive numerical solutions:

***Back-to-front compositing***

$$C'_i = C_i + (1 - A_i)C'_{i-1}$$

***Front-to-back compositing***

$$C'_i = C'_{i+1} + (1 - A'_{i+1})C_i$$
$$A'_i = A'_{i+1} + (1 - A'_{i+1})A_i$$

here, all colors are *associated* colors!

# Thank you.

Thanks for material

- Helwig Hauser
- Eduard Gröller
- Daniel Weiskopf
- Torsten Möller
- Ronny Peikert
- Philipp Muigg
- Christof Rezk-Salama