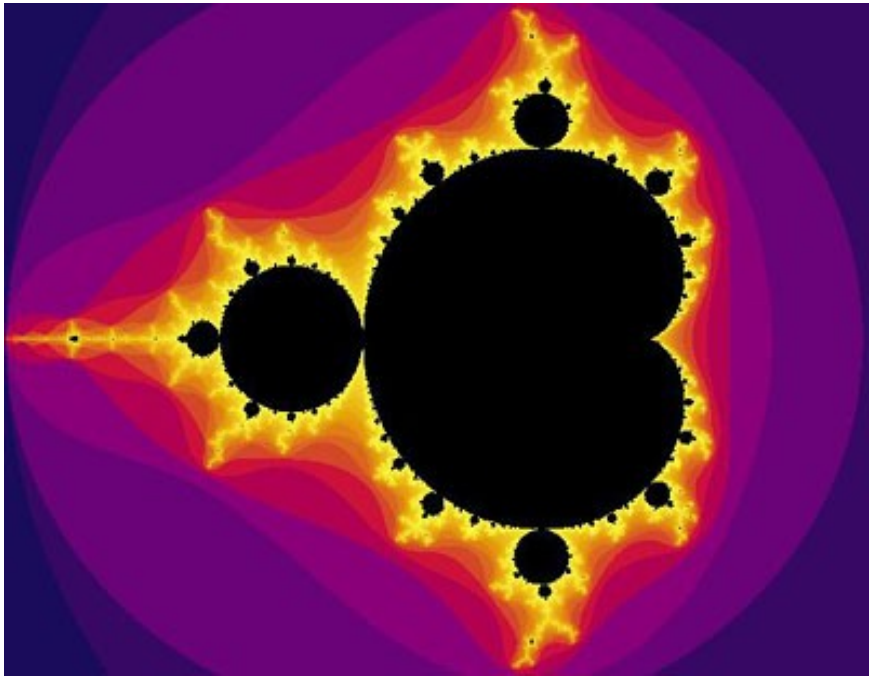
Ray Tracing: Mandelbulb and Ocean Simulation

CSCI 4239/5239
Advanced Computer Graphics
Spring 2025

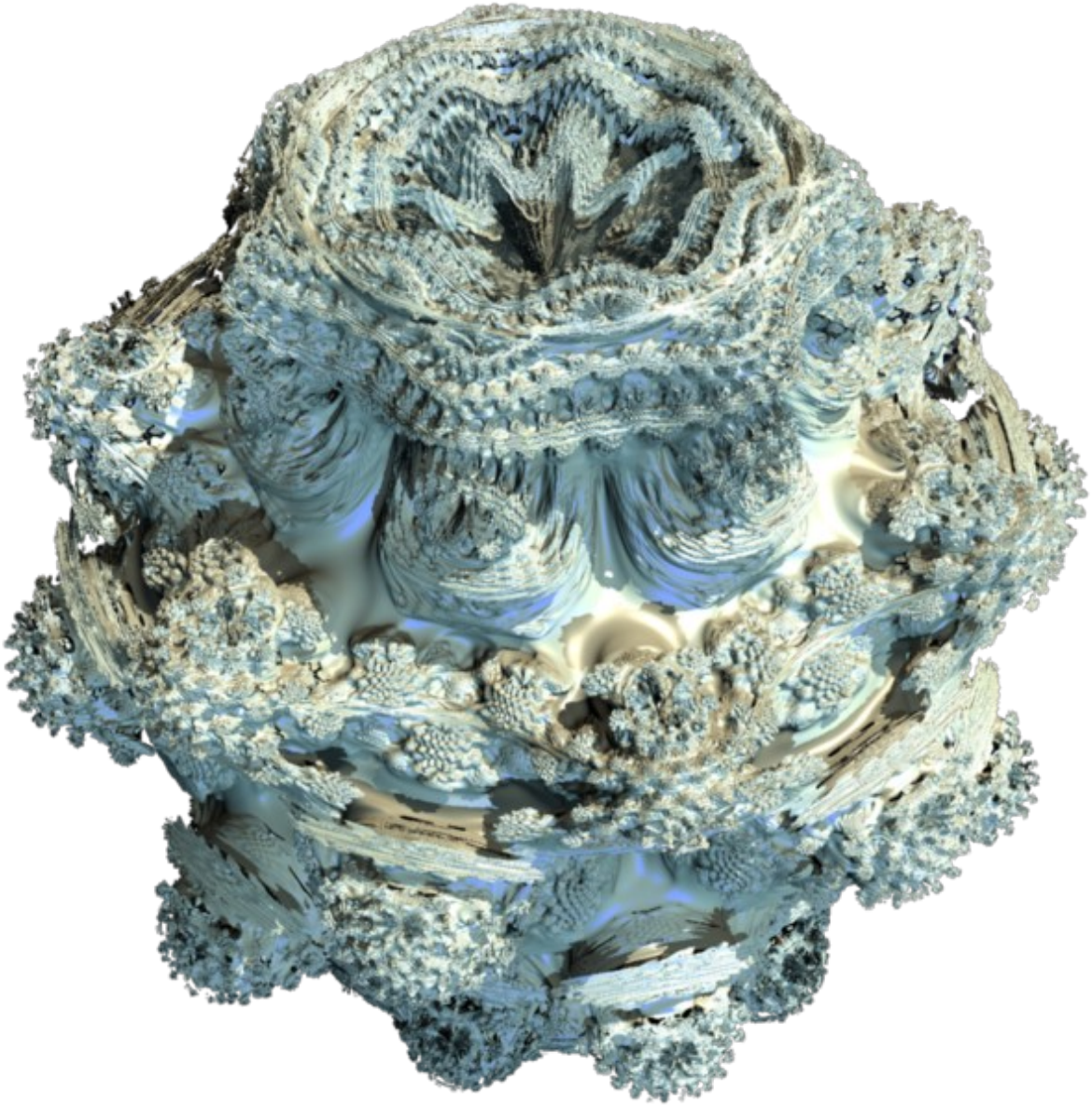
Mandelbrot Set

- Complex Quadratic Polynomial Sequence
  - $z_{n+1} = z_n^2 + c$
- For which values of c is the sequence bounded?
- This is a fractal set
  - Finite area
  - Boundary is infinite
  - Self-similar
  - 2D



Mandlebulb 3D Domain

- Defined mathematically
- Has appearance of Gothic architecure
- Shading needed to see details



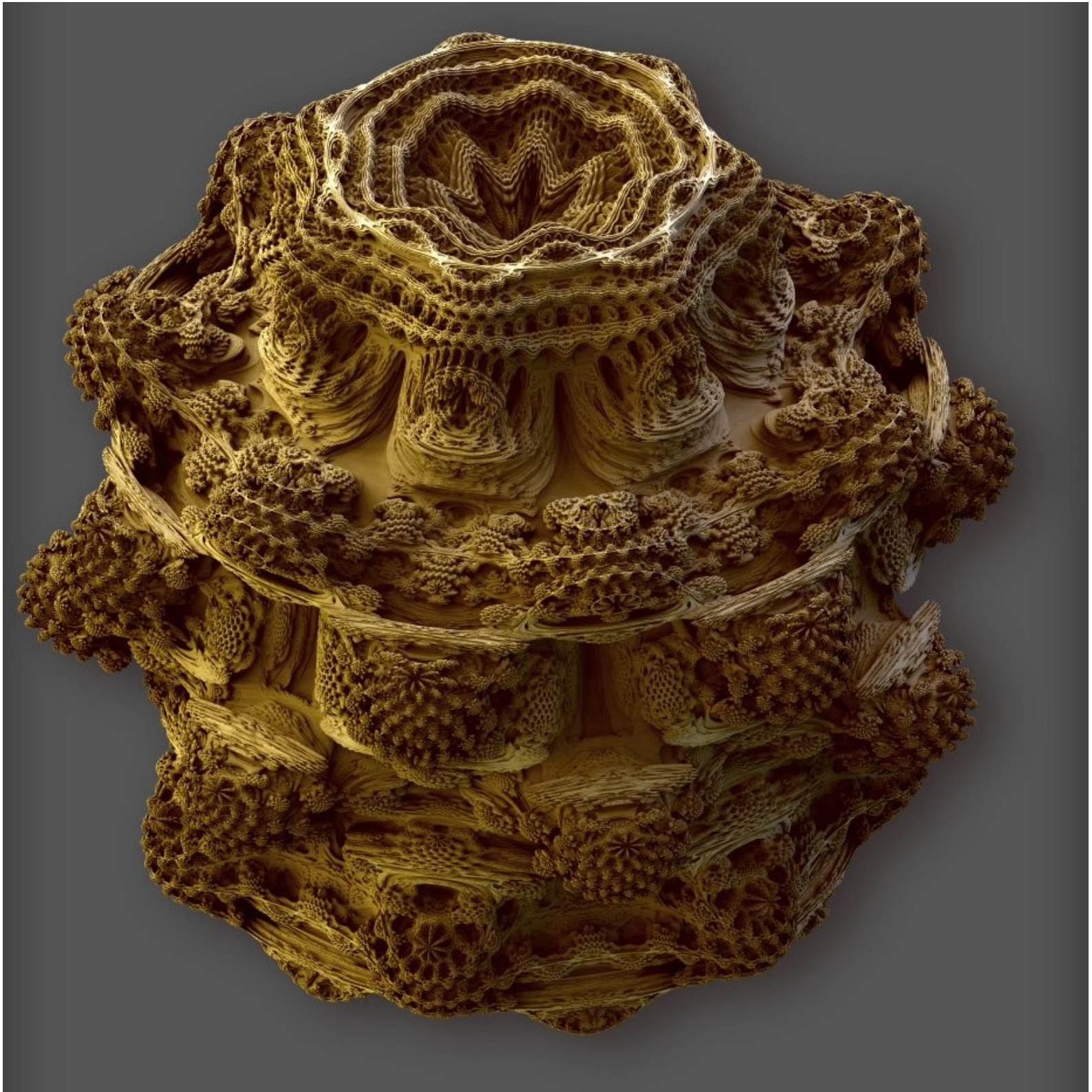
Mandelbulb Equation

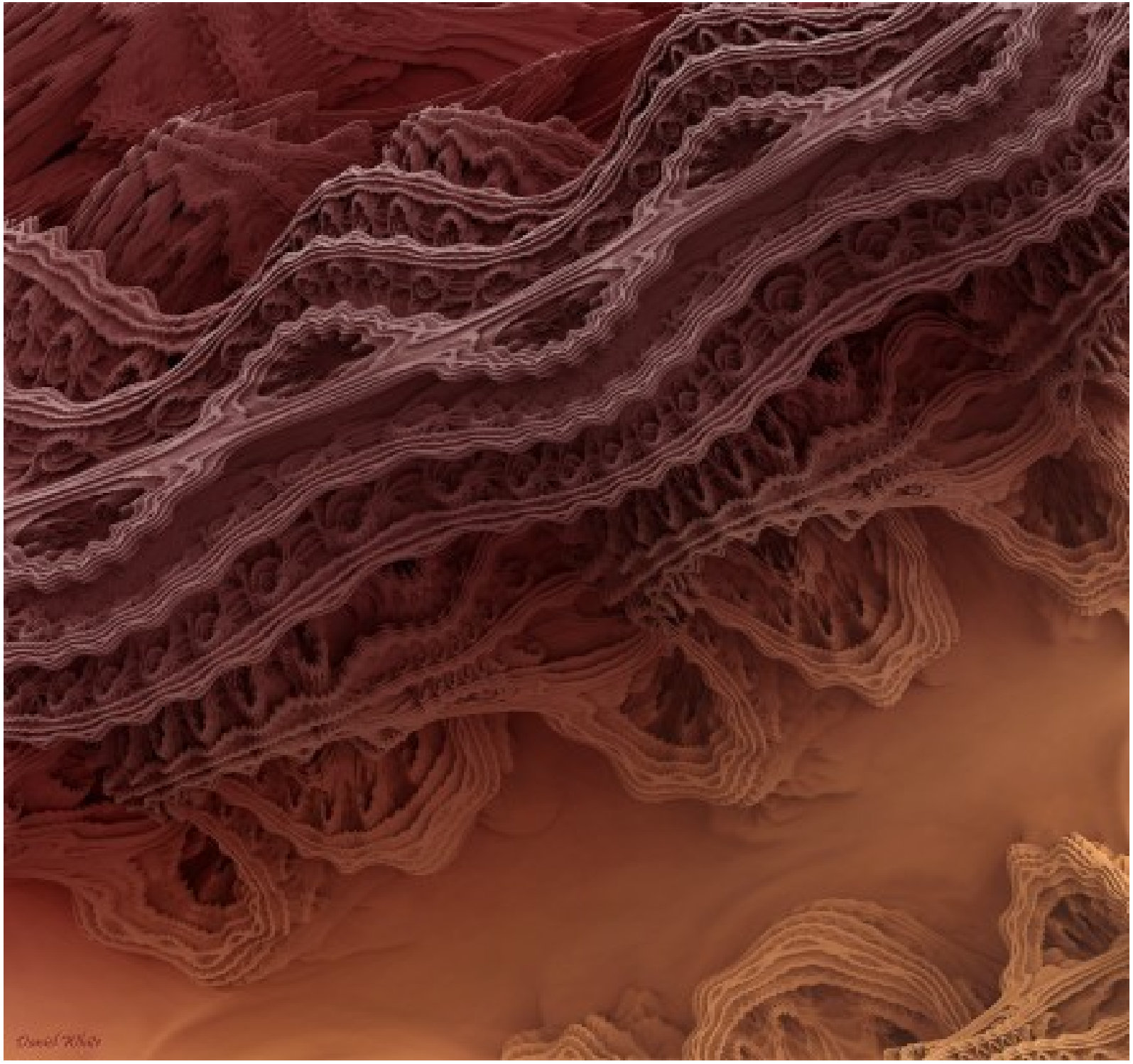
- $z_{n+1} = z_n^2 + c$
- Domain for this equation converges
- No direct equivalent to complex for 2D
- White and Nylander spherical coordinates
- How do you render this set?
  - POVray used for many images
  - ex24 is primitive but real time
- *See handout for details*

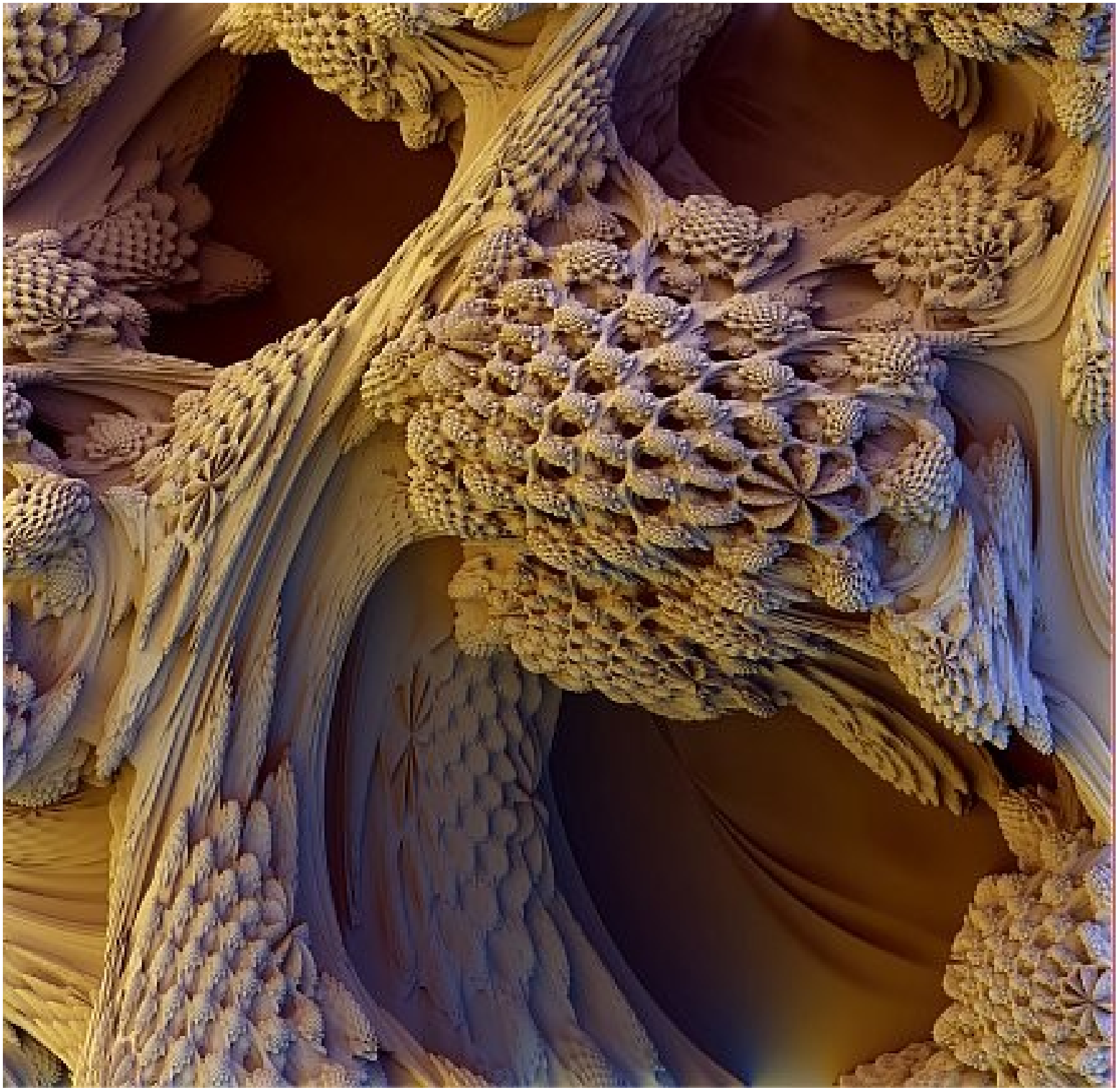
Gallery of Daniel White

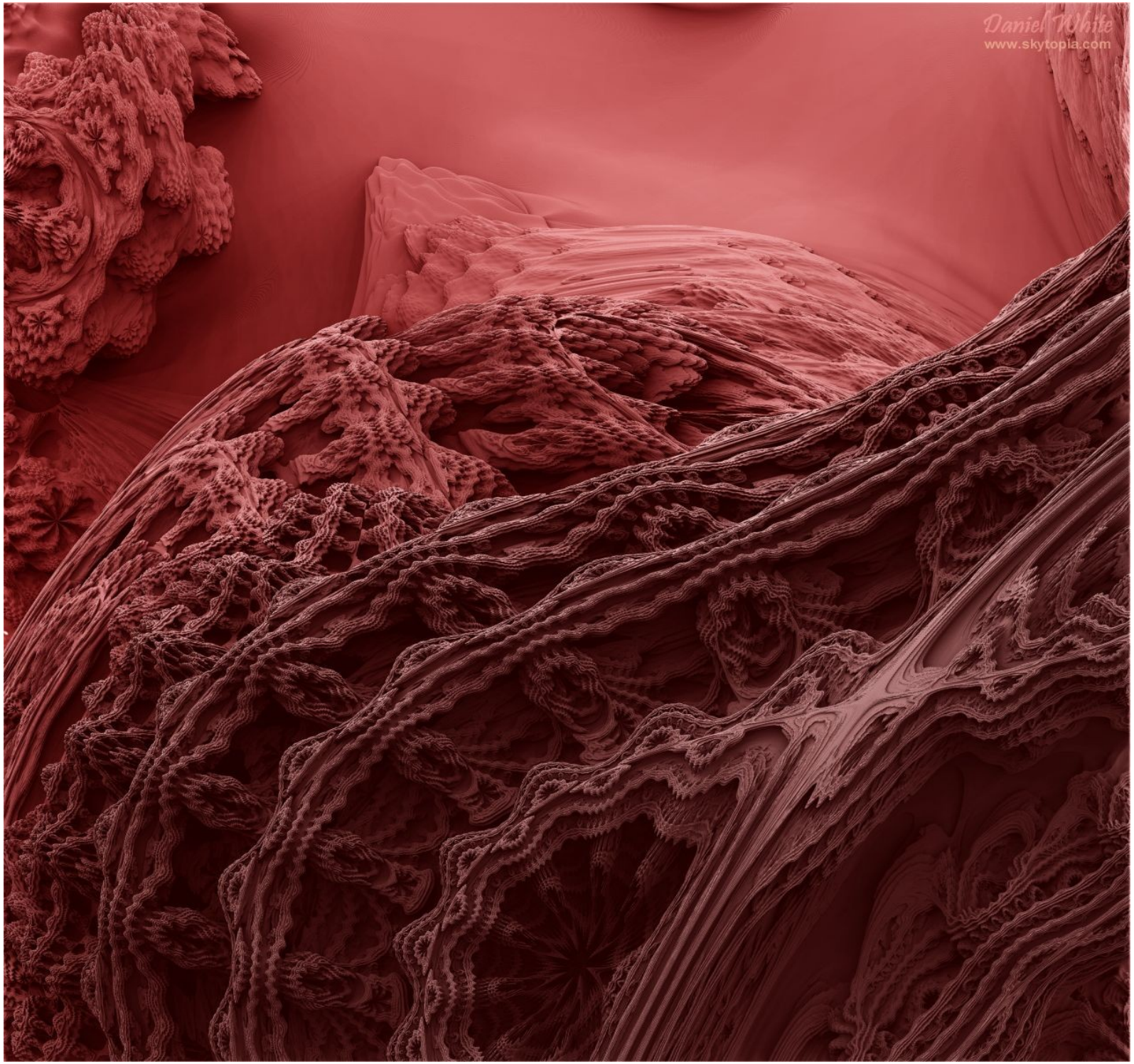
- The Unravelling the Real 3D Mandelbulb

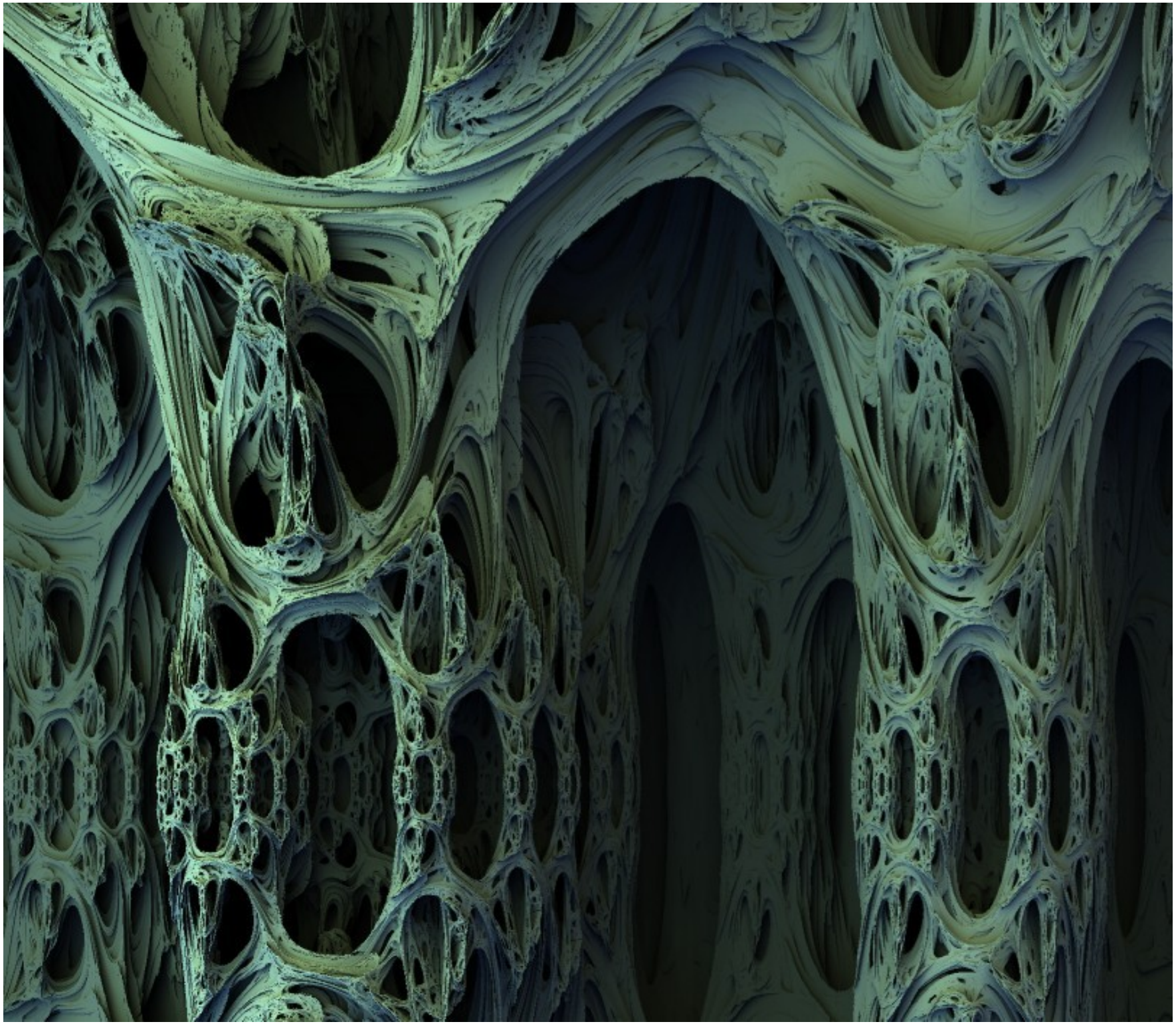
  http://www.skytopia.com/project/fractal/mandelbulb.html
- Explores and zooms into the mandelbulb
- Ray traced using colored lights
- Most are the n=8 mandelbulb

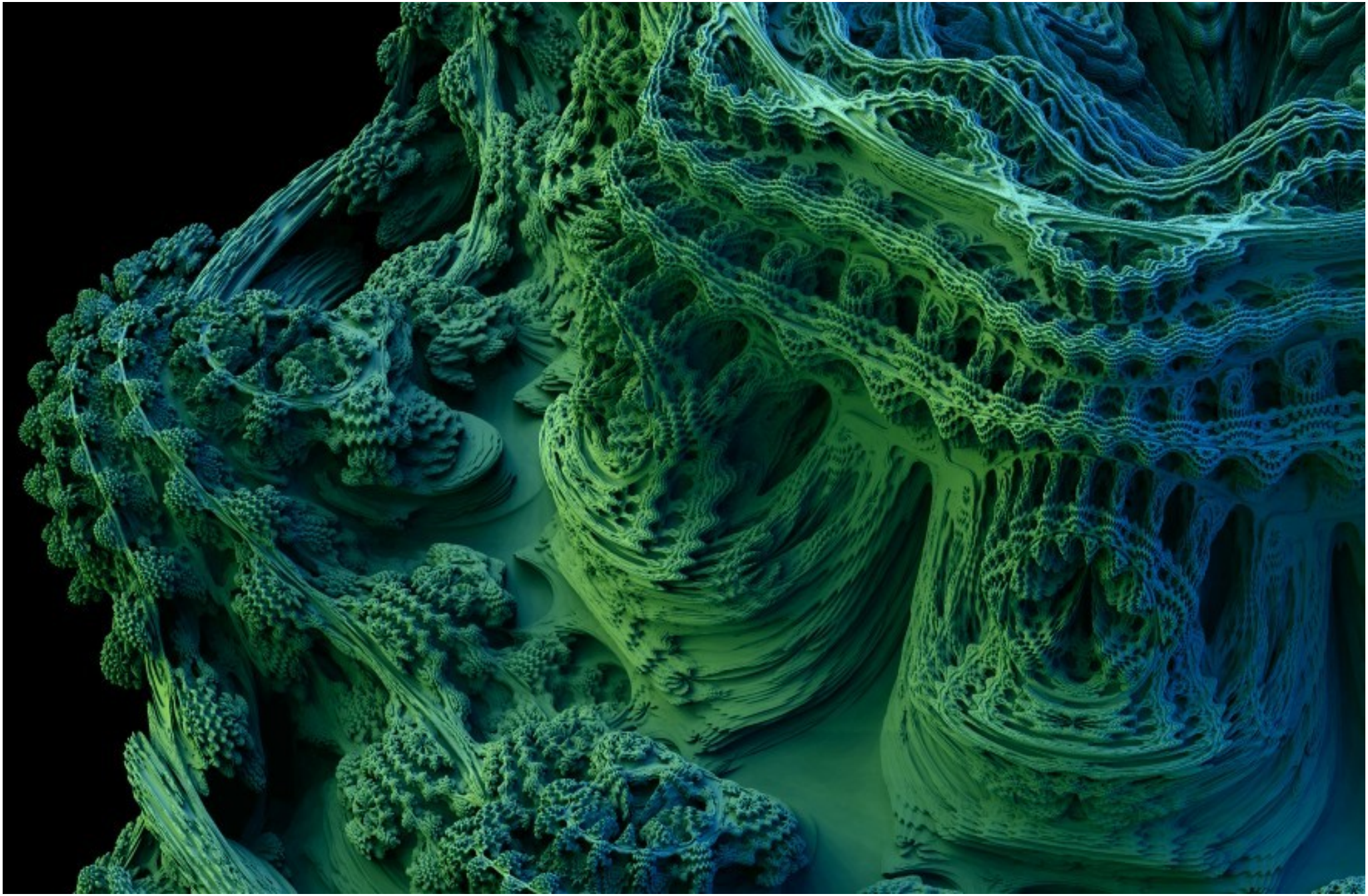






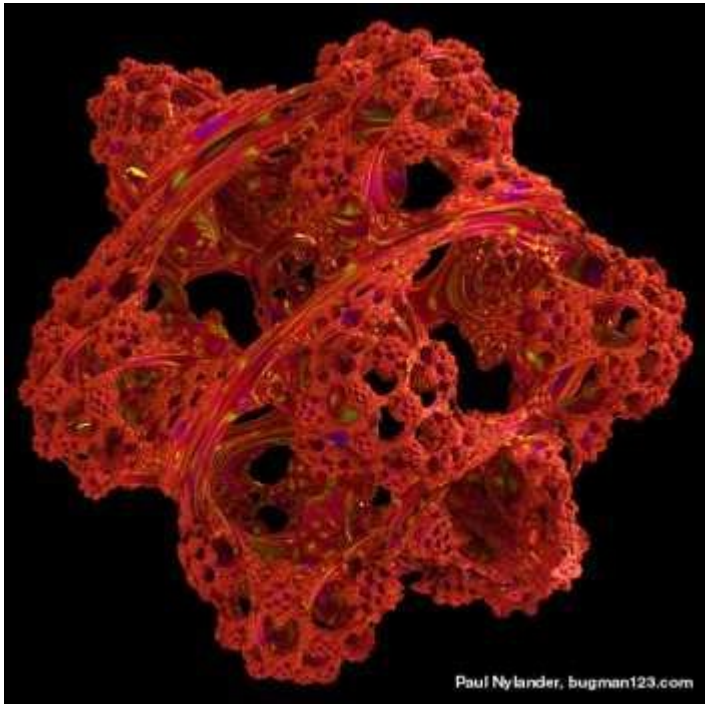

Daniel White
www.skytopia.com





Other Fractal Sets

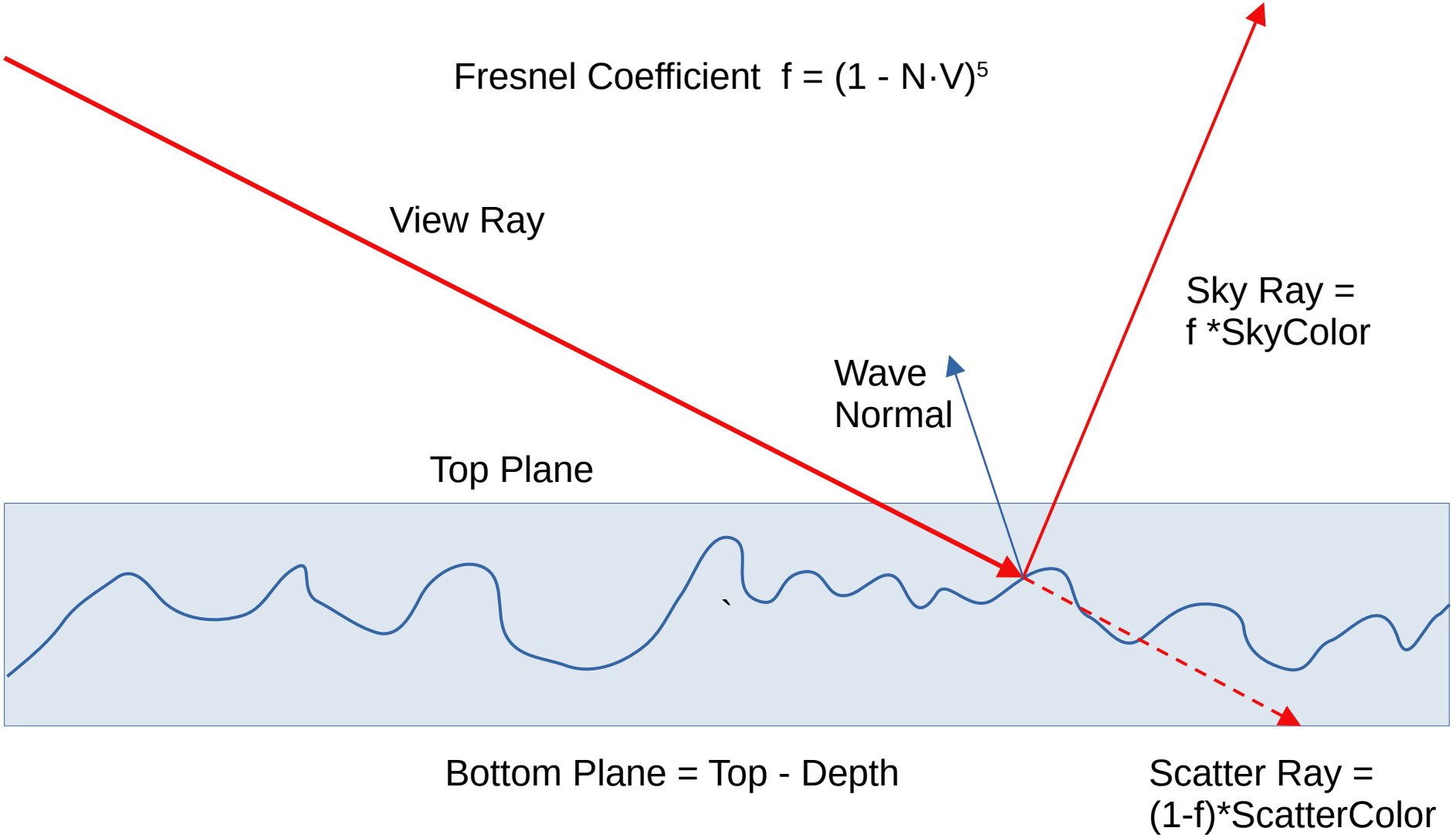
- Mandelbrot set is just one of many 2D fractal sets
  - Julia
  - Lyapunov
  - Sierpinski triangle
- Many extensions to 3D



Ex26: Real Time Ray Tracer

- Draws monochrome mandelbulb
  - Single light
  - No secondary rays
  - Shadows
- Iterative solver for ray marching
  - OpenMP on CPU
  - CUDA on GPU
- Why not use GLSL?
  - Perhaps a compute shader?
  - Vulkan Ray Shaders

Ex27: Ocean by afl_ext

- ShaderToy example https://www.shadertoy.com/view/MdXyzX
- Ray marched ocean waves
  - Summation of noisy sines
  - Similar to noise calculations
- Entirely implemented in frag shader

Ocean Shader