

Ray Tracing: Mandelbulb

CSCI 4239/5239

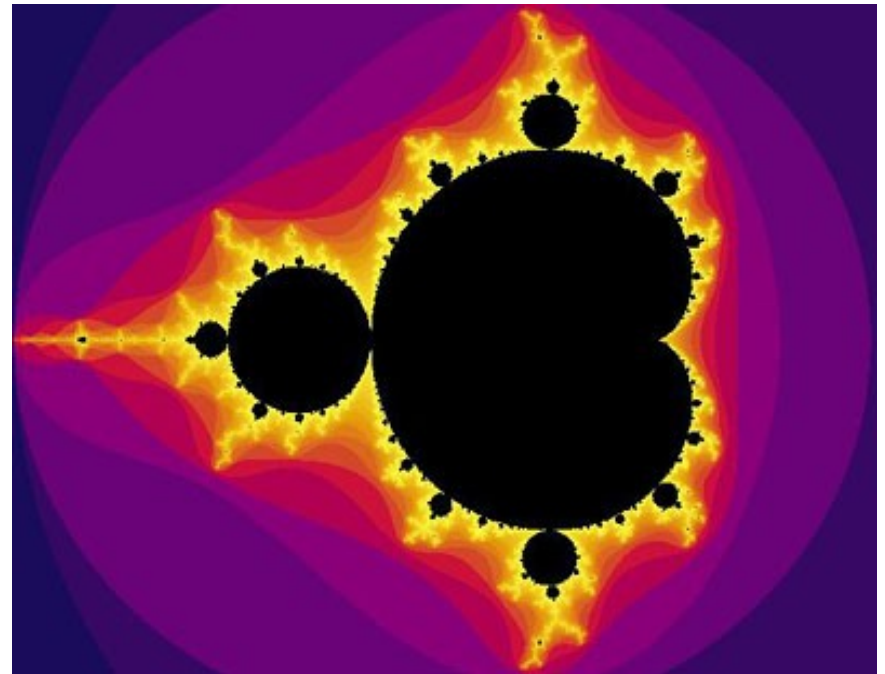
**Advanced Computer Graphics
Spring 2021**

Mandelbrot Set

- Complex Quadratic Polynomial Sequence

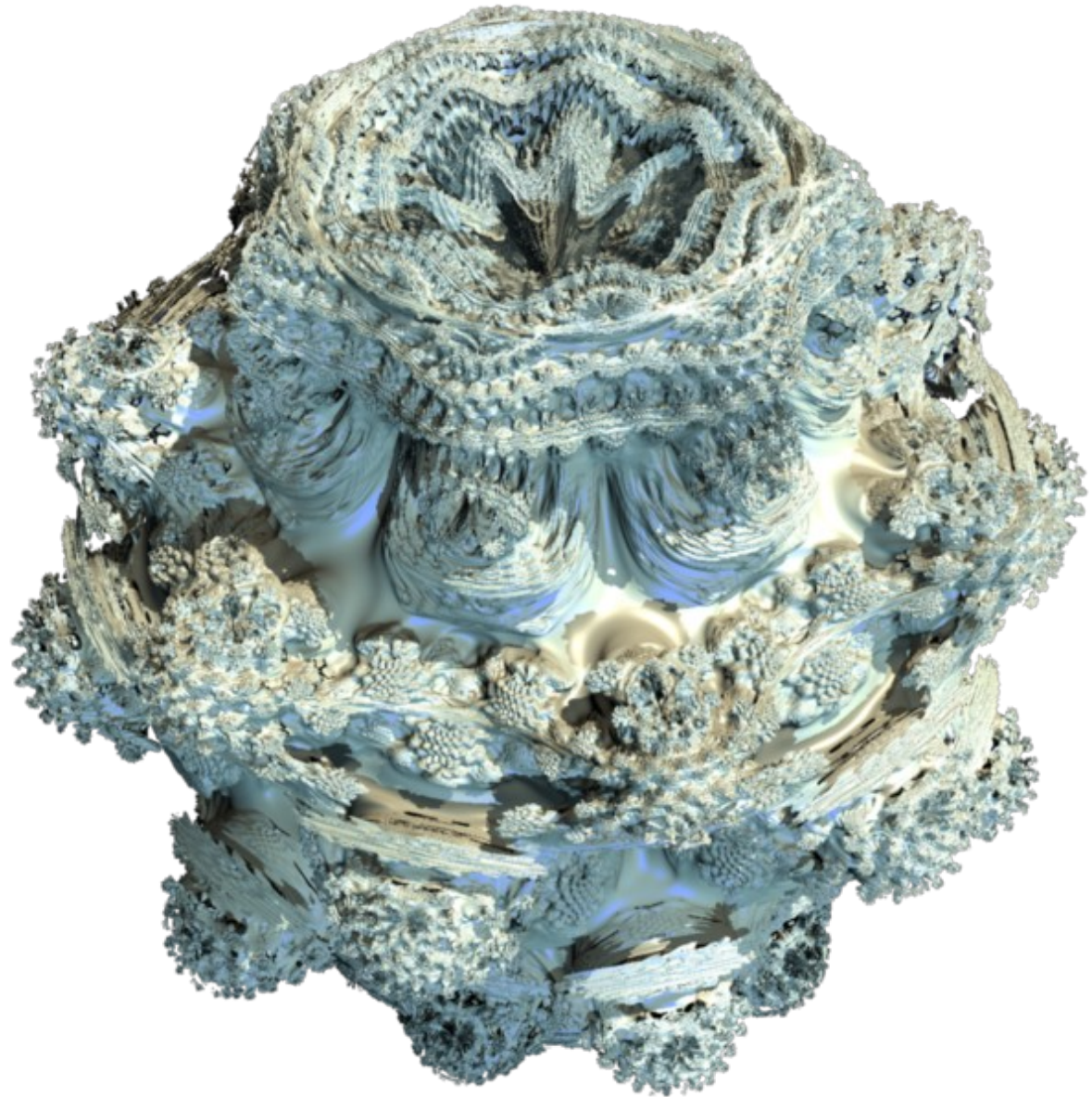
$$- z_{n+1} = z_n^2 + c$$

- 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 architecture
- Shading needed to see details

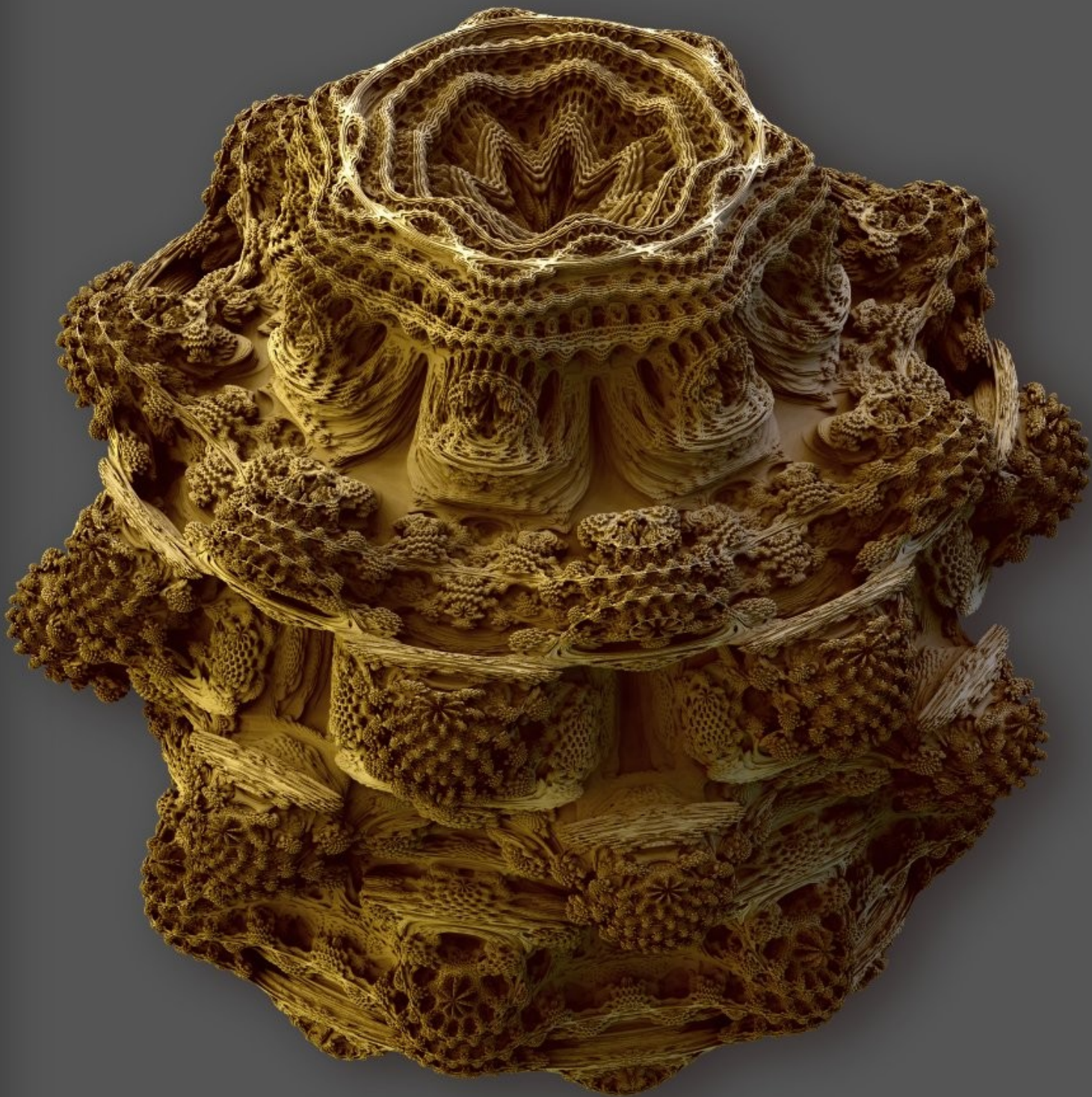


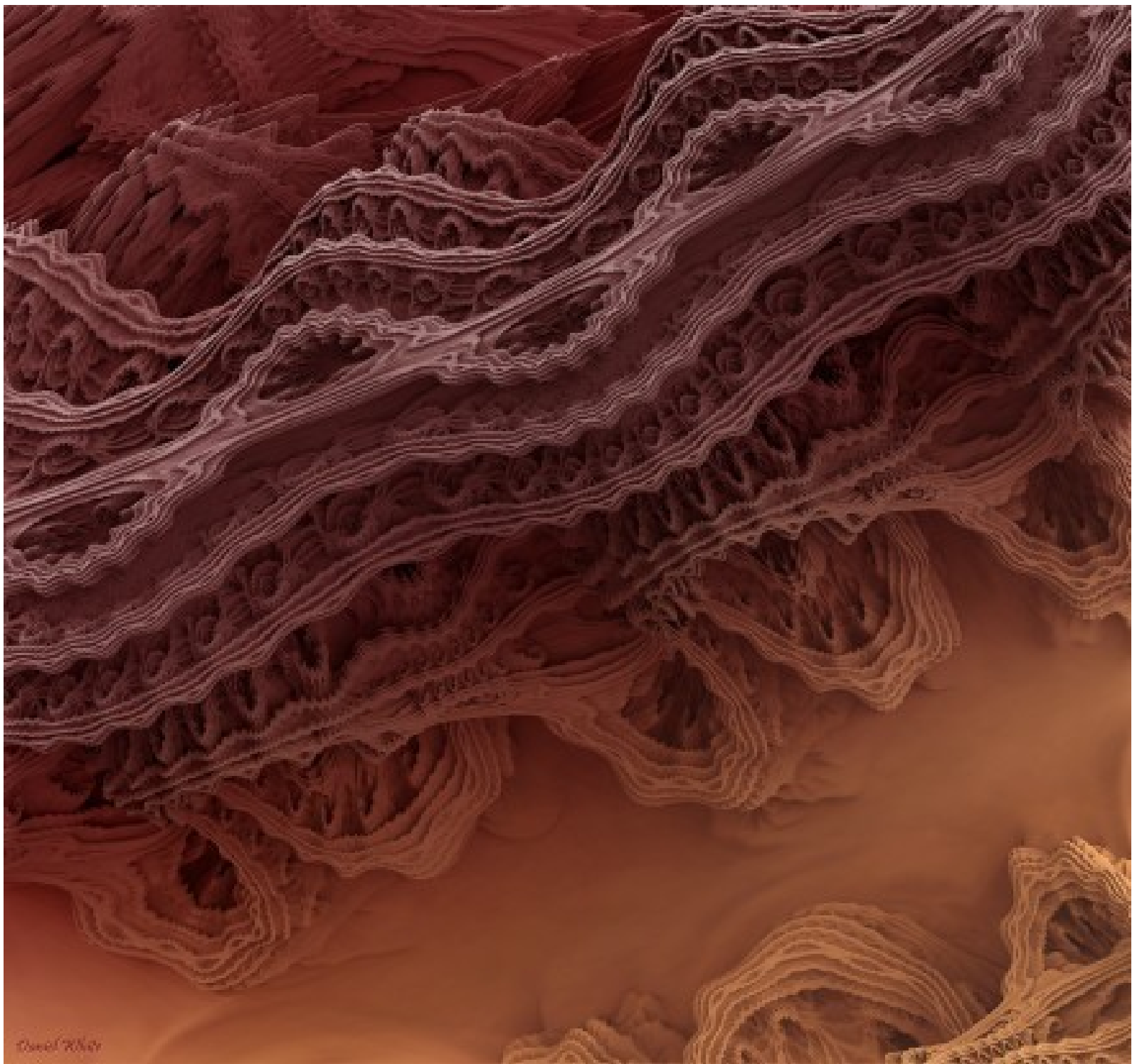
Mandelbulb Equation

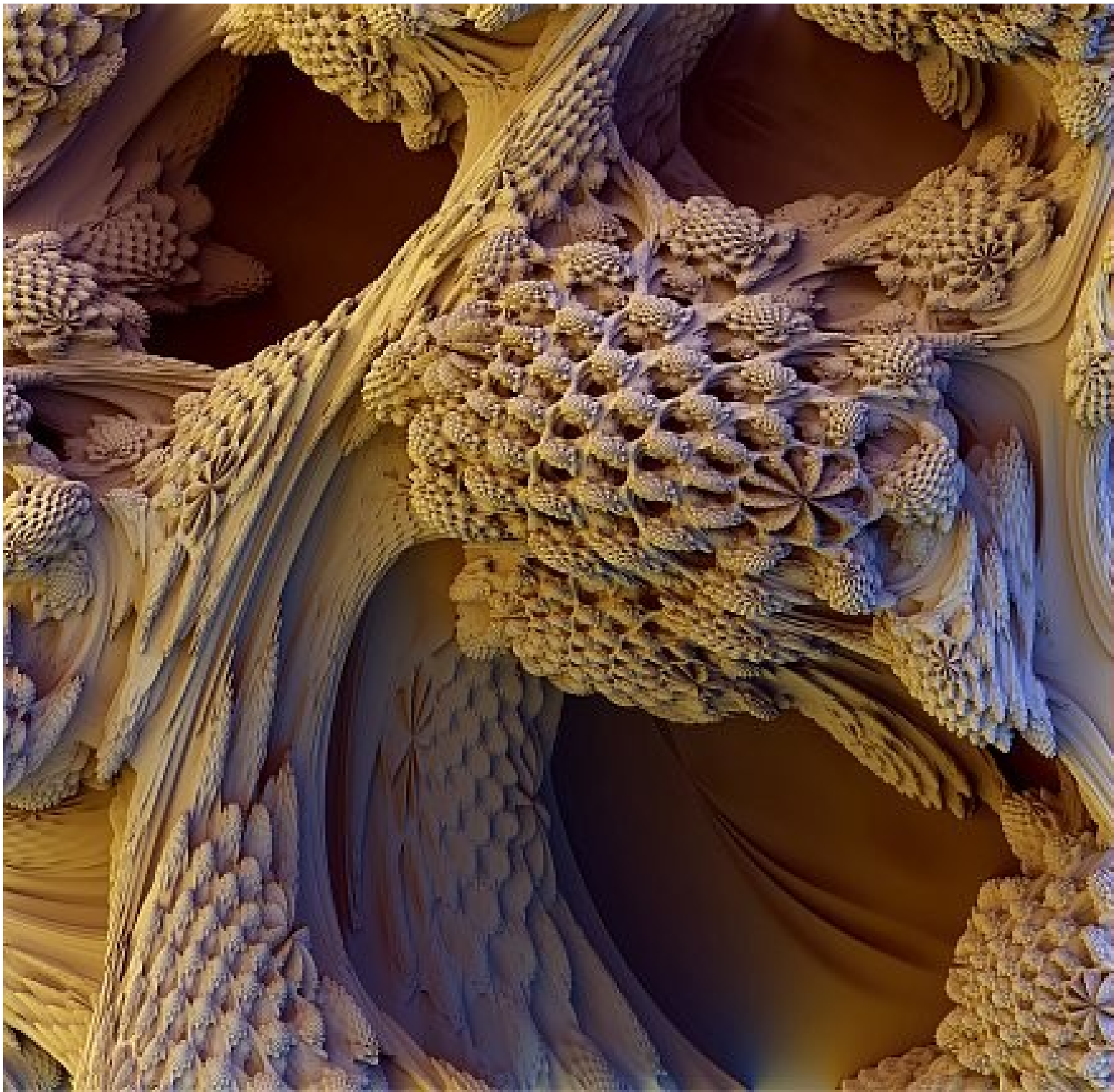
- $z_{n+1} = z_n^2 + c$
- Domain for this equation converges
- No direct equivalent to complex for 2D
- White and Nylander spherical coordinates
- How do you render this set?
 - POVray used for many images
 - ex24 is primitive but real time
- *See handout for details*

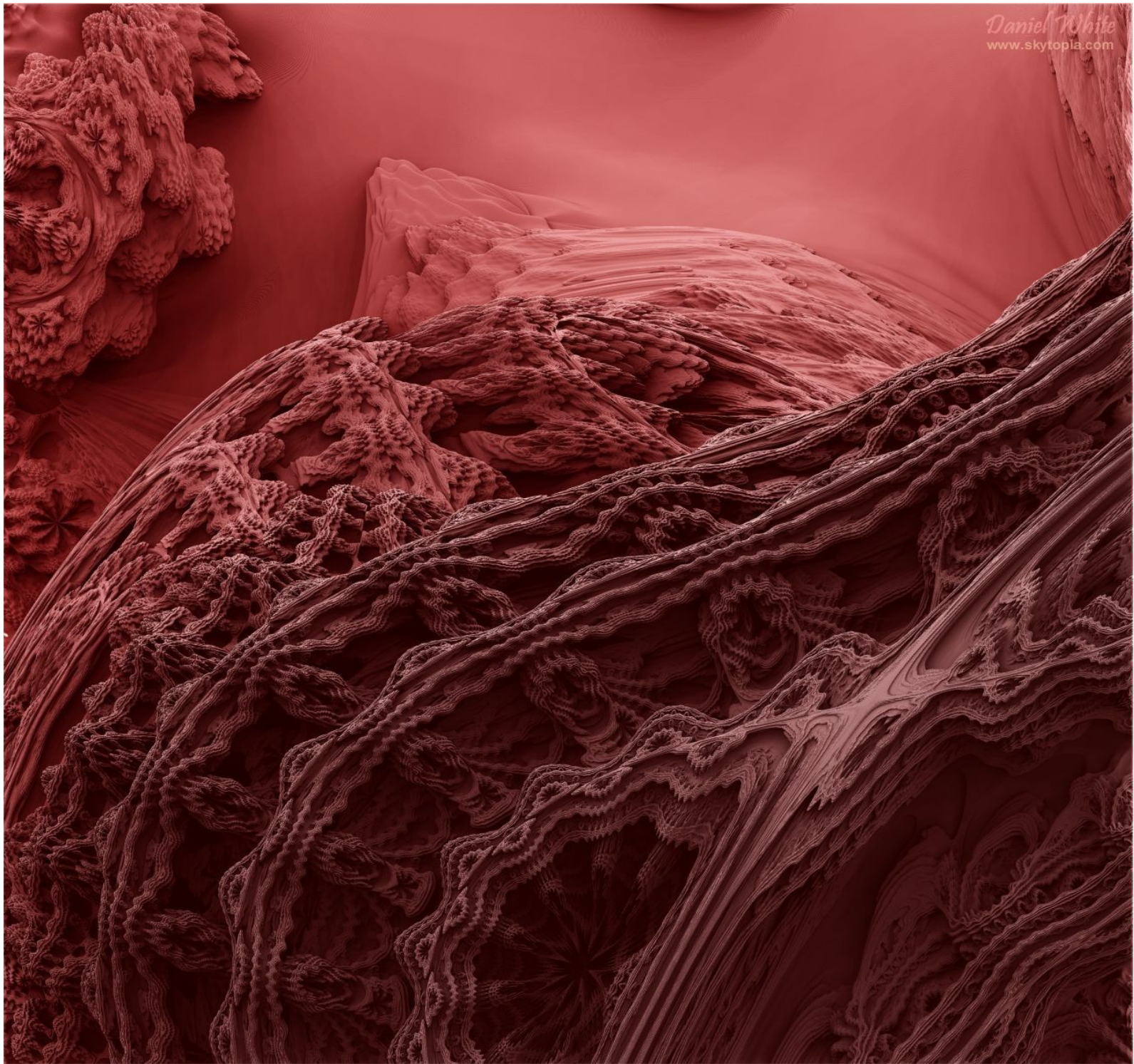
Gallery of Daniel White

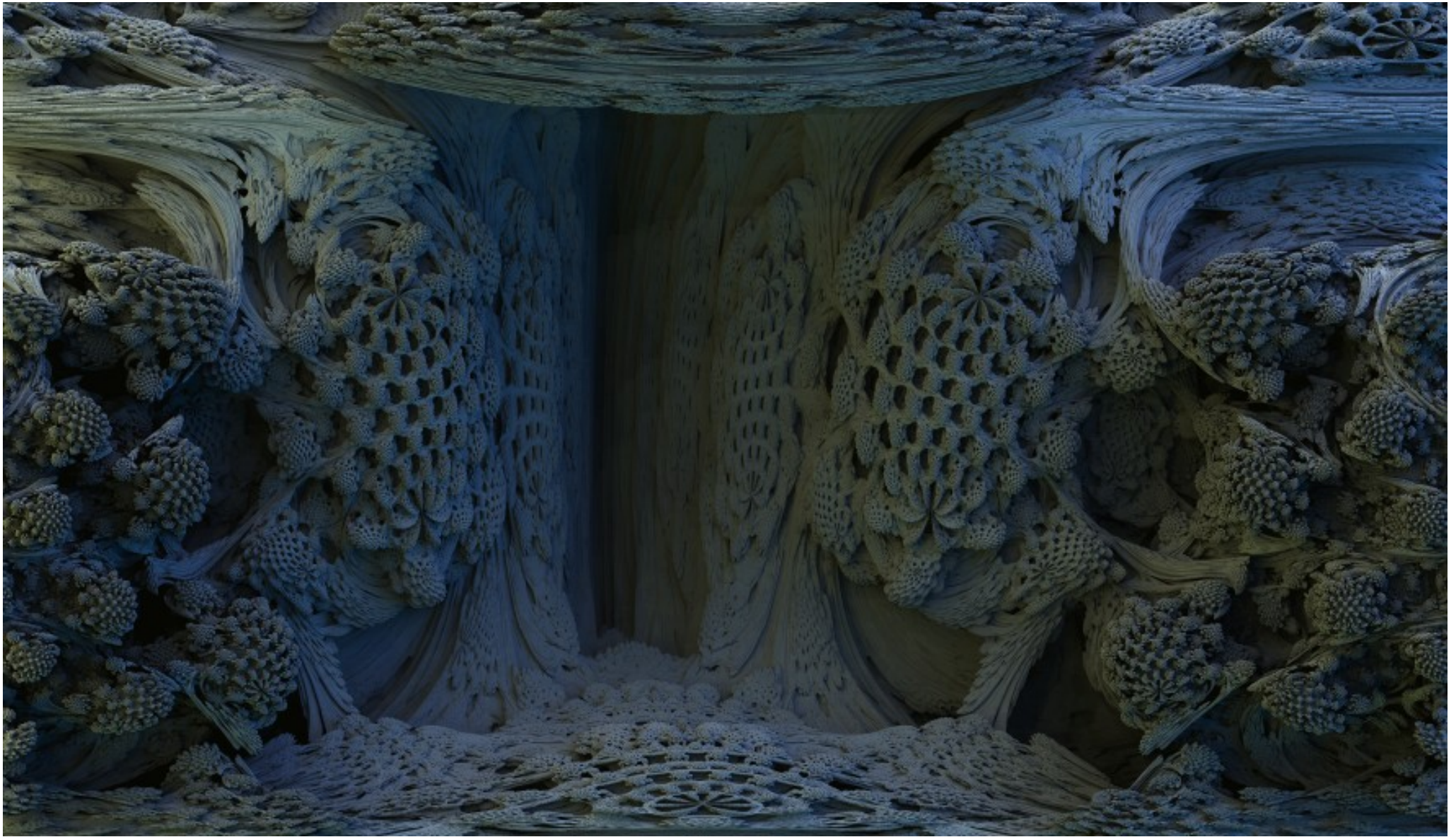
- The Unravelling the Real 3D Mandelbulb
<http://www.skytopia.com/project/fractal/mandelbulb.html>
- Explores and zooms into the mandelbulb
- Ray traced using colored lights
- Most are the $n=8$ mandelbulb

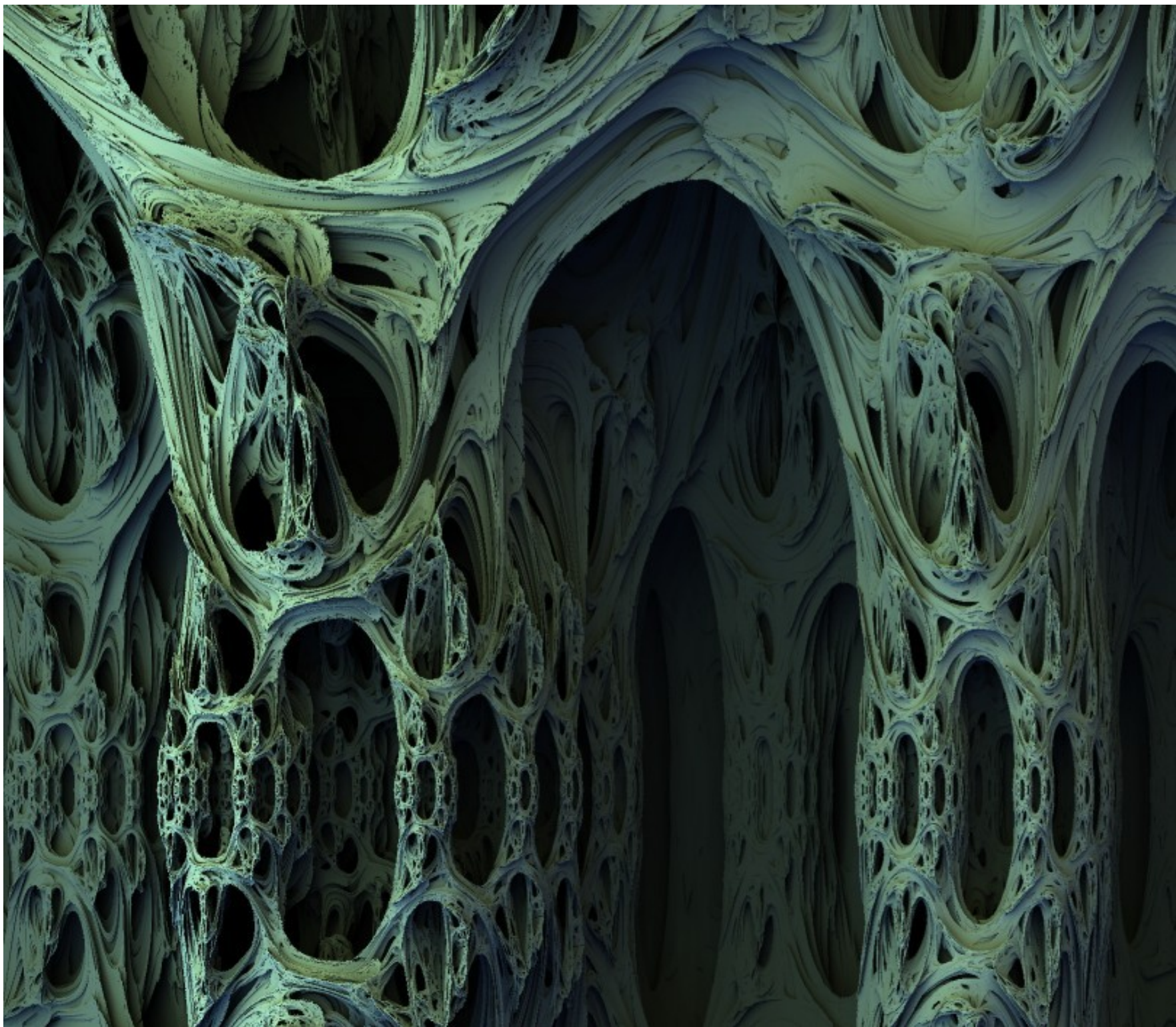


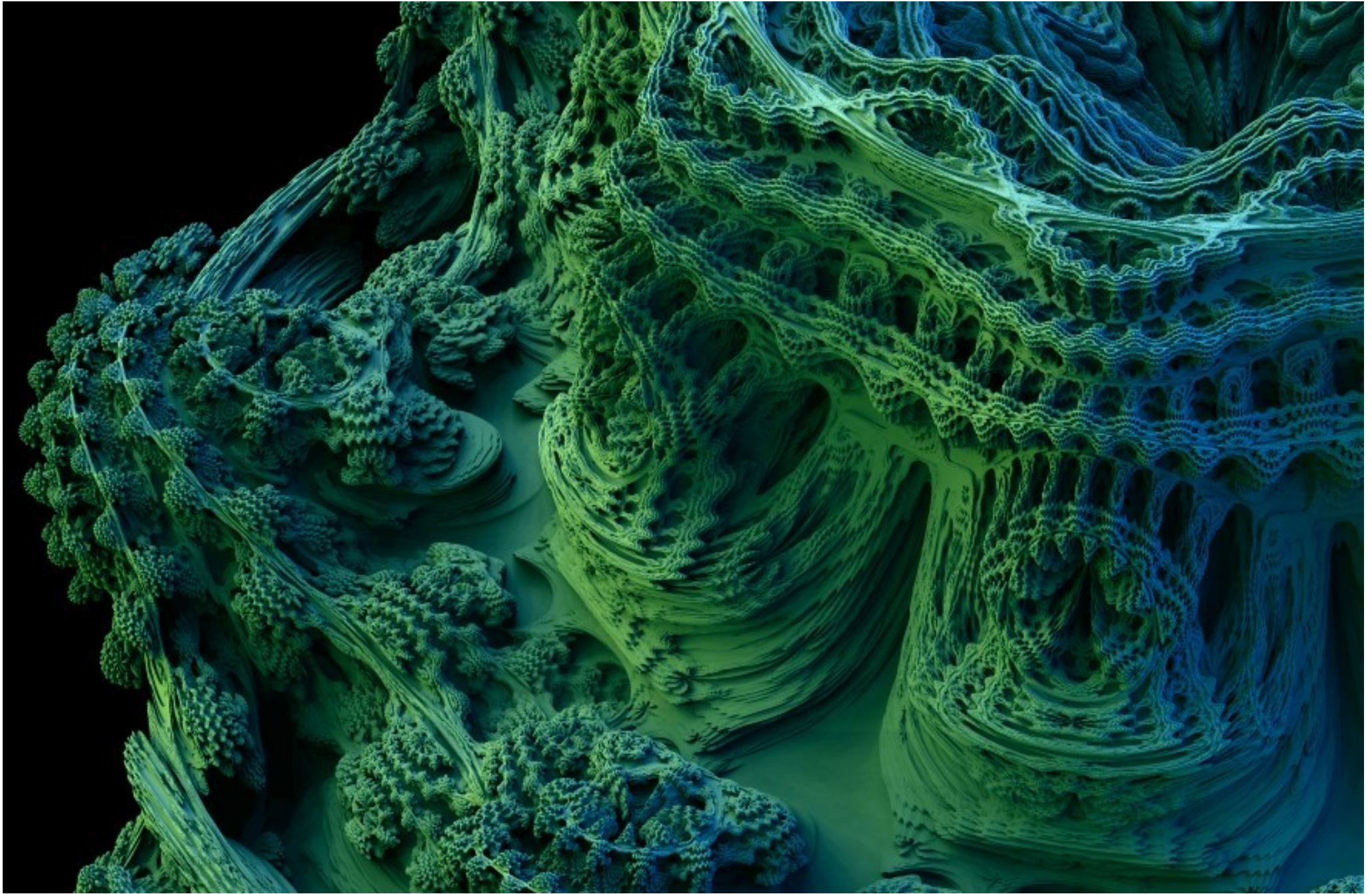












Other Fractal Sets

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



ex24: 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