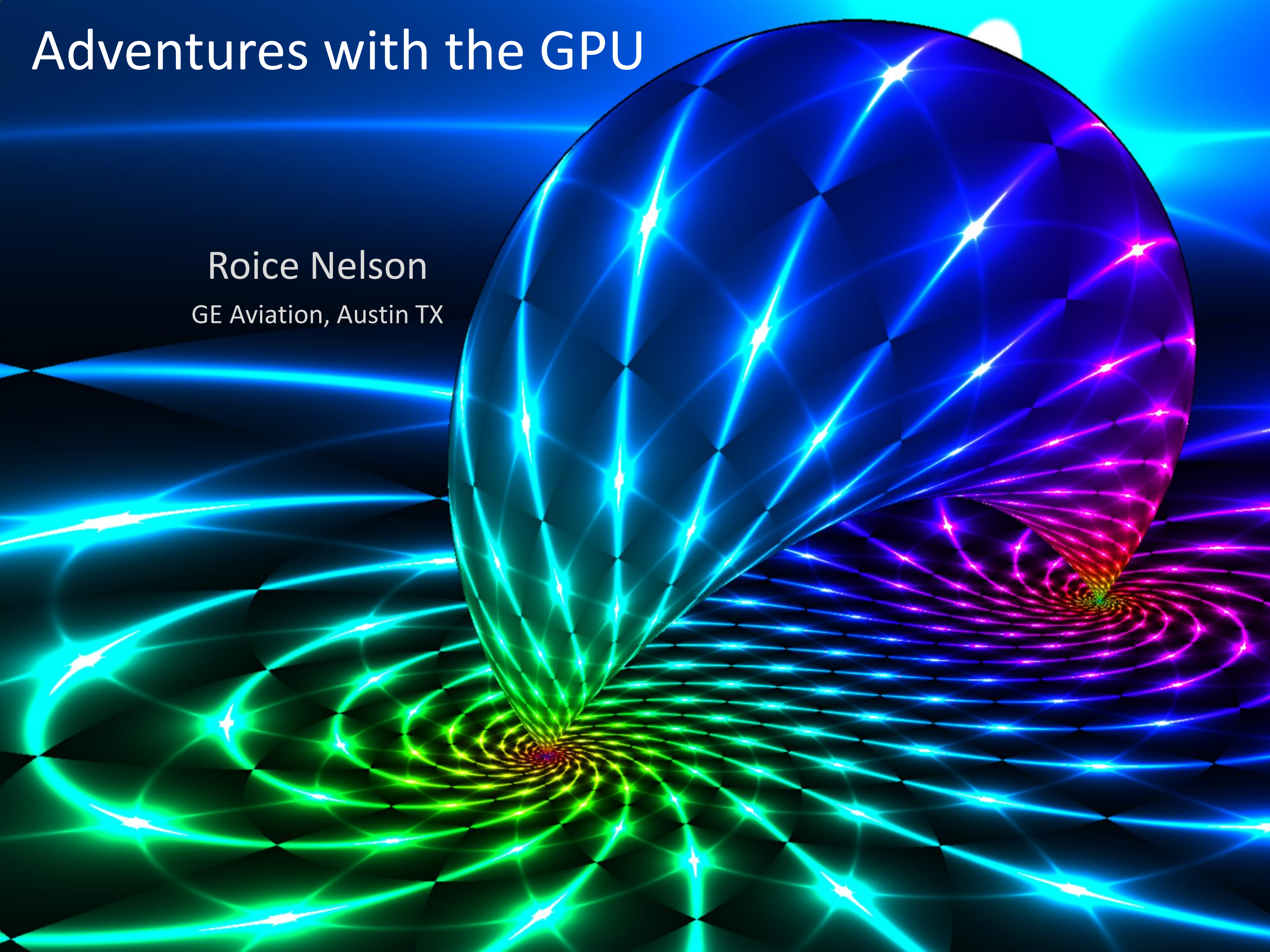
Adventures with the GPU

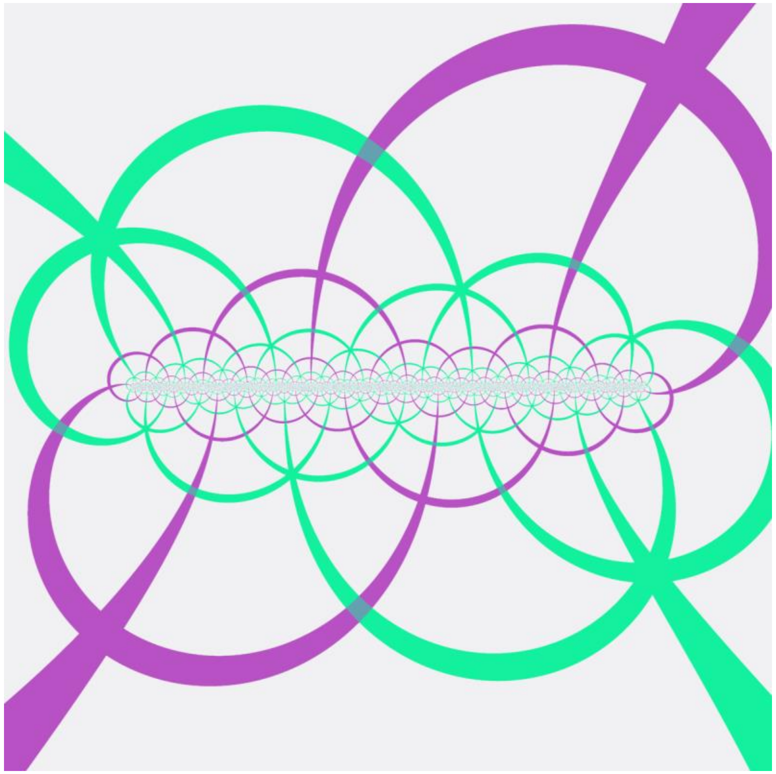
Roice Nelson

GE Aviation, Austin TX



My goals for this talk

- Provide resources and motivation to get started with shader programming
  roice3.org/icerm



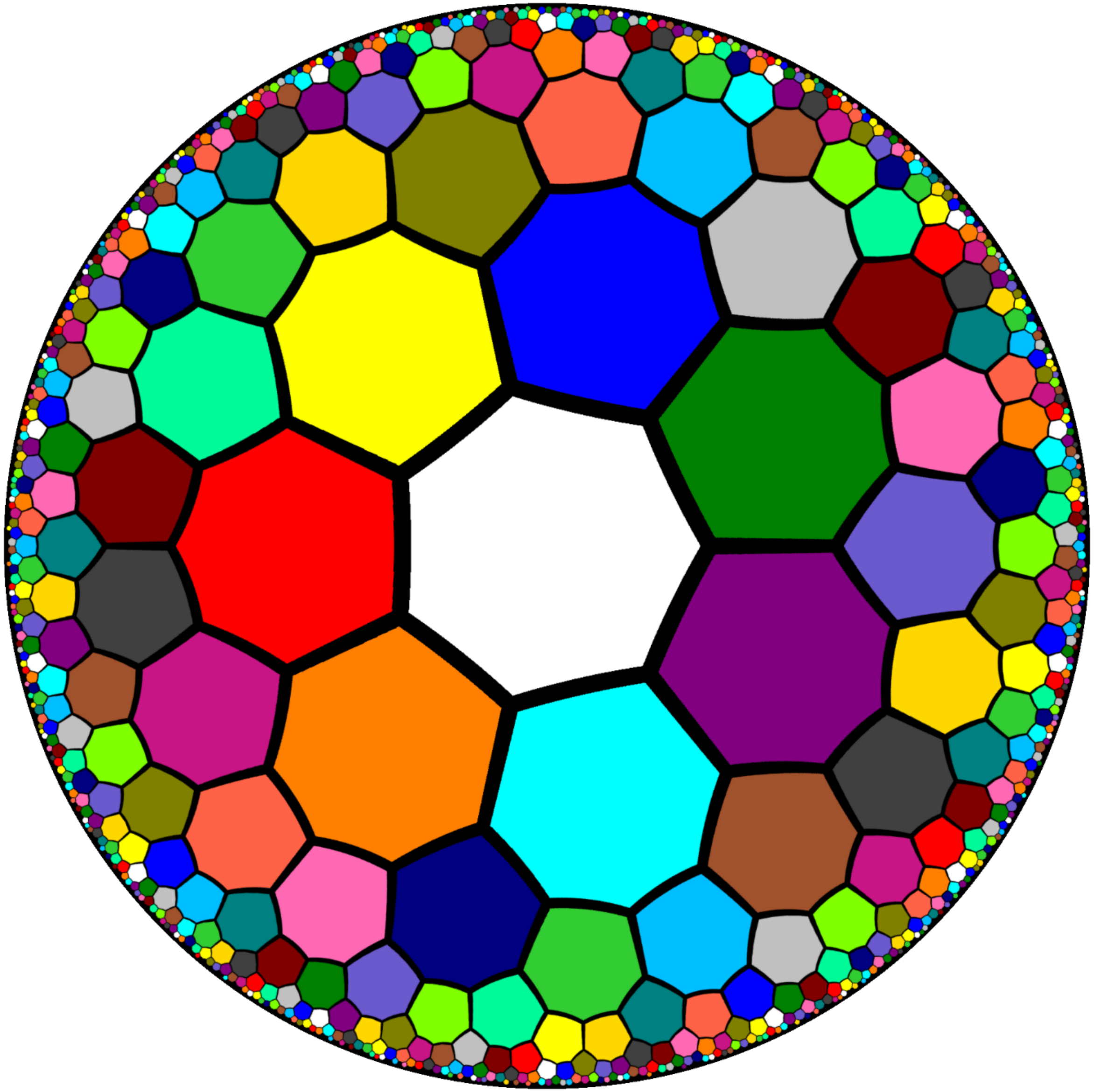
- A few mathematical detours
- Share fun with @TilingBot and a resulting art piece
- **Tons and tons of pictures and animations!** Maybe too many

What is a shader?

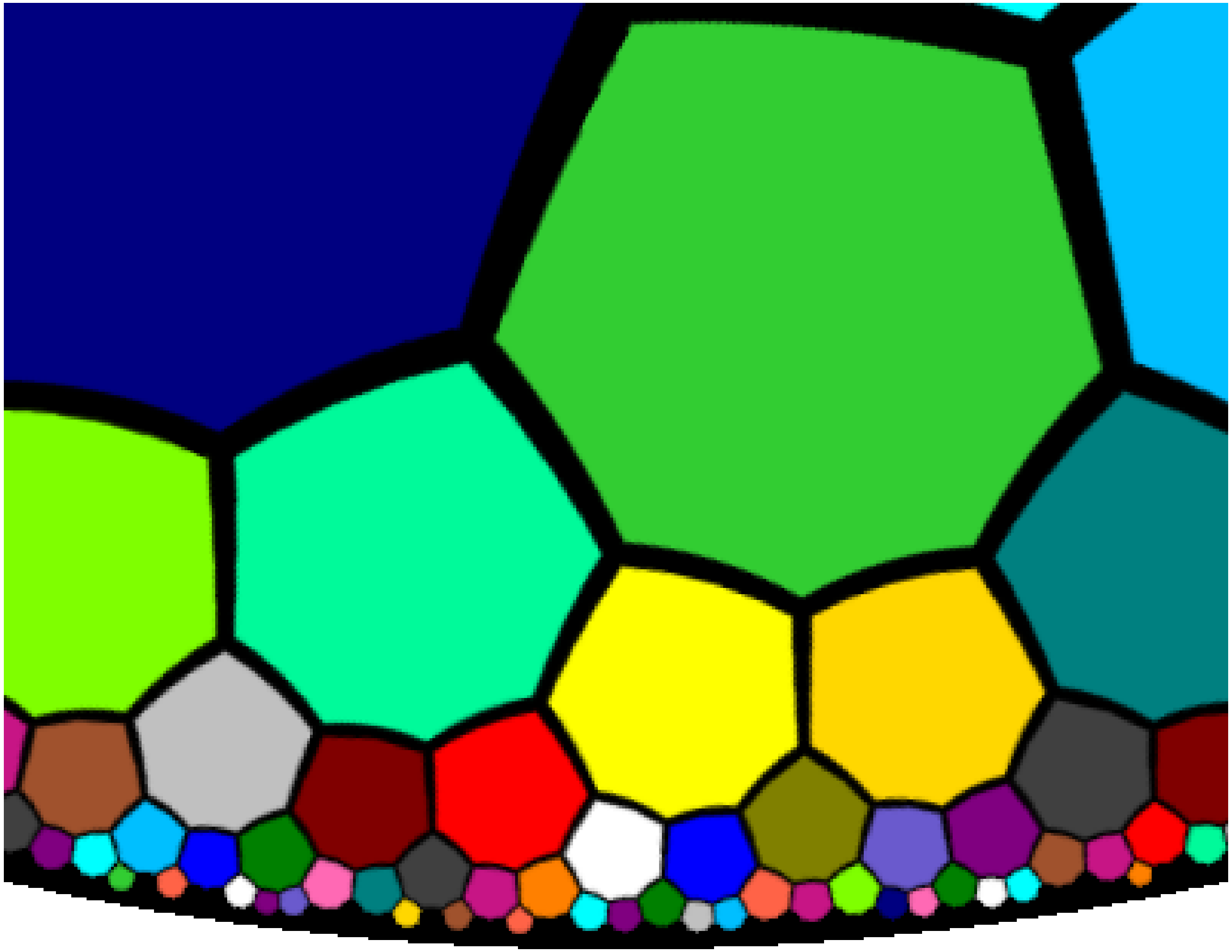
Shaders are little programs that run on the GPU.
These programs run at certain points of the graphics pipeline.

```
void mainImage( out vec4 fragColor, in vec2 fragCoord )
{
    // Normalized pixel coordinates (from 0 to 1)
    vec2 uv = fragCoord/iResolution.xy;

    // Time varying pixel color
    vec3 col = 0.5 + 0.5*cos(iTime+uv.xyx+vec3(0,2,4));

    // Output to screen
    fragColor = vec4(col,1.0);
}
```

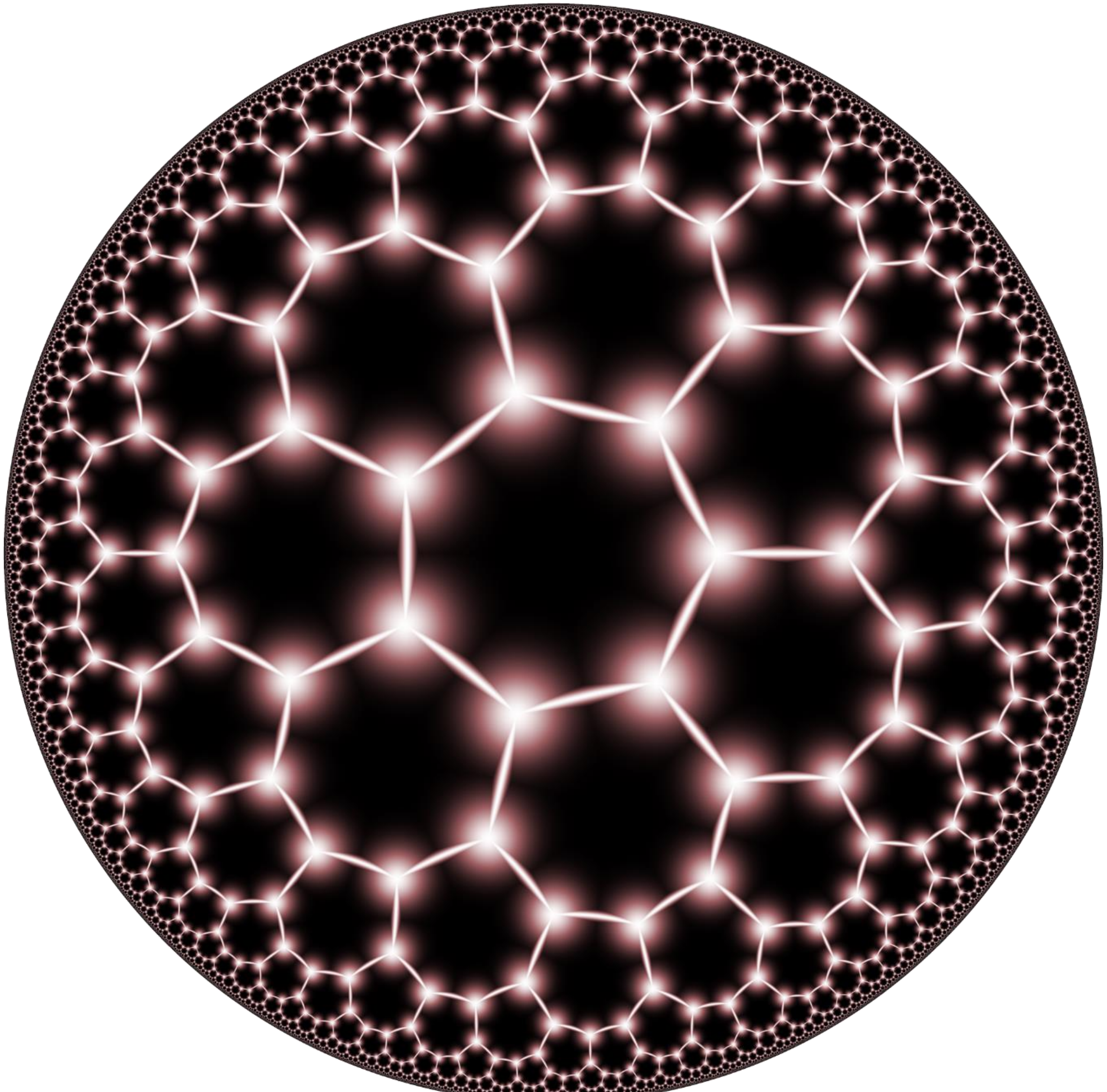
From **primitives** to shaders



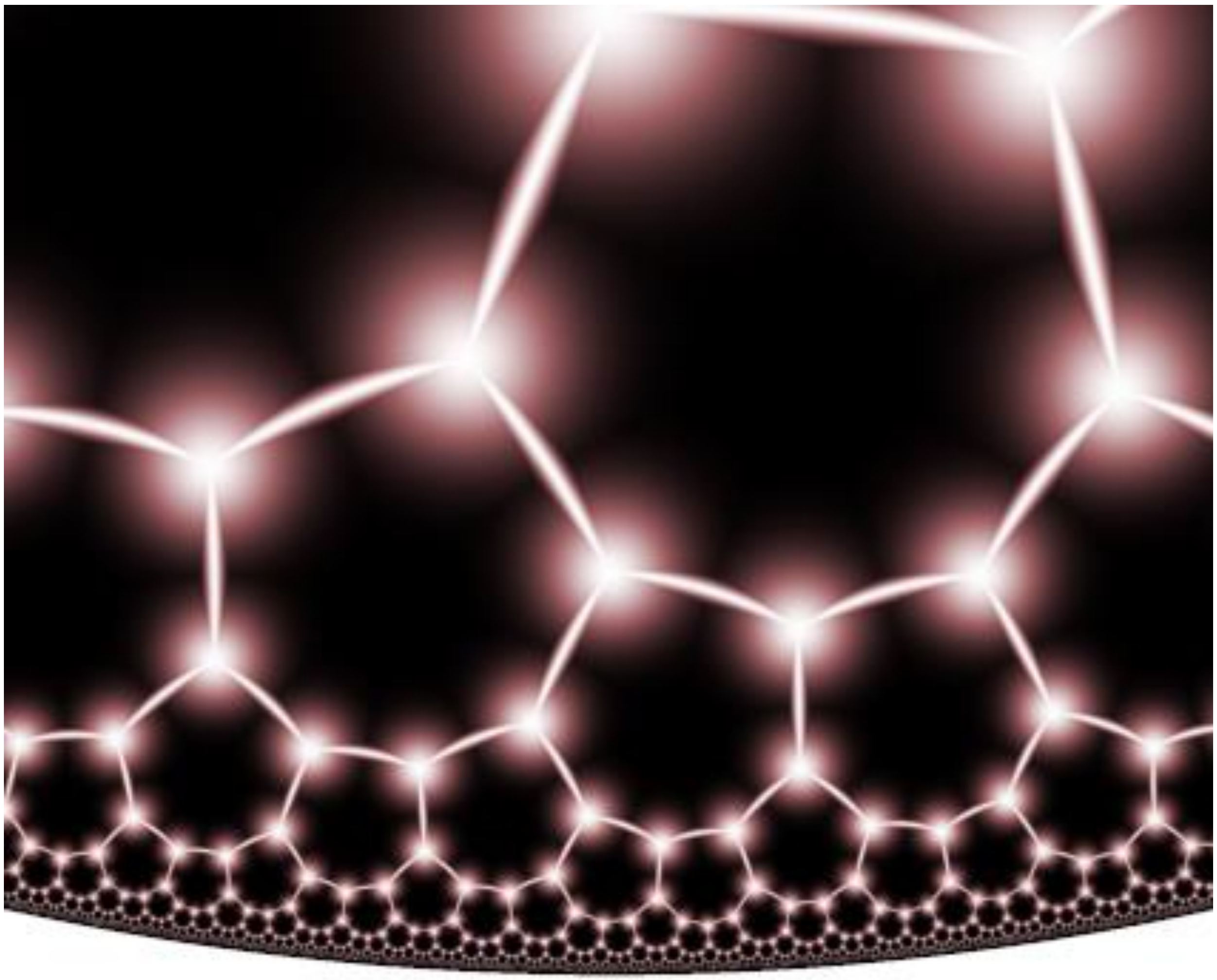
From **primitives** to shaders



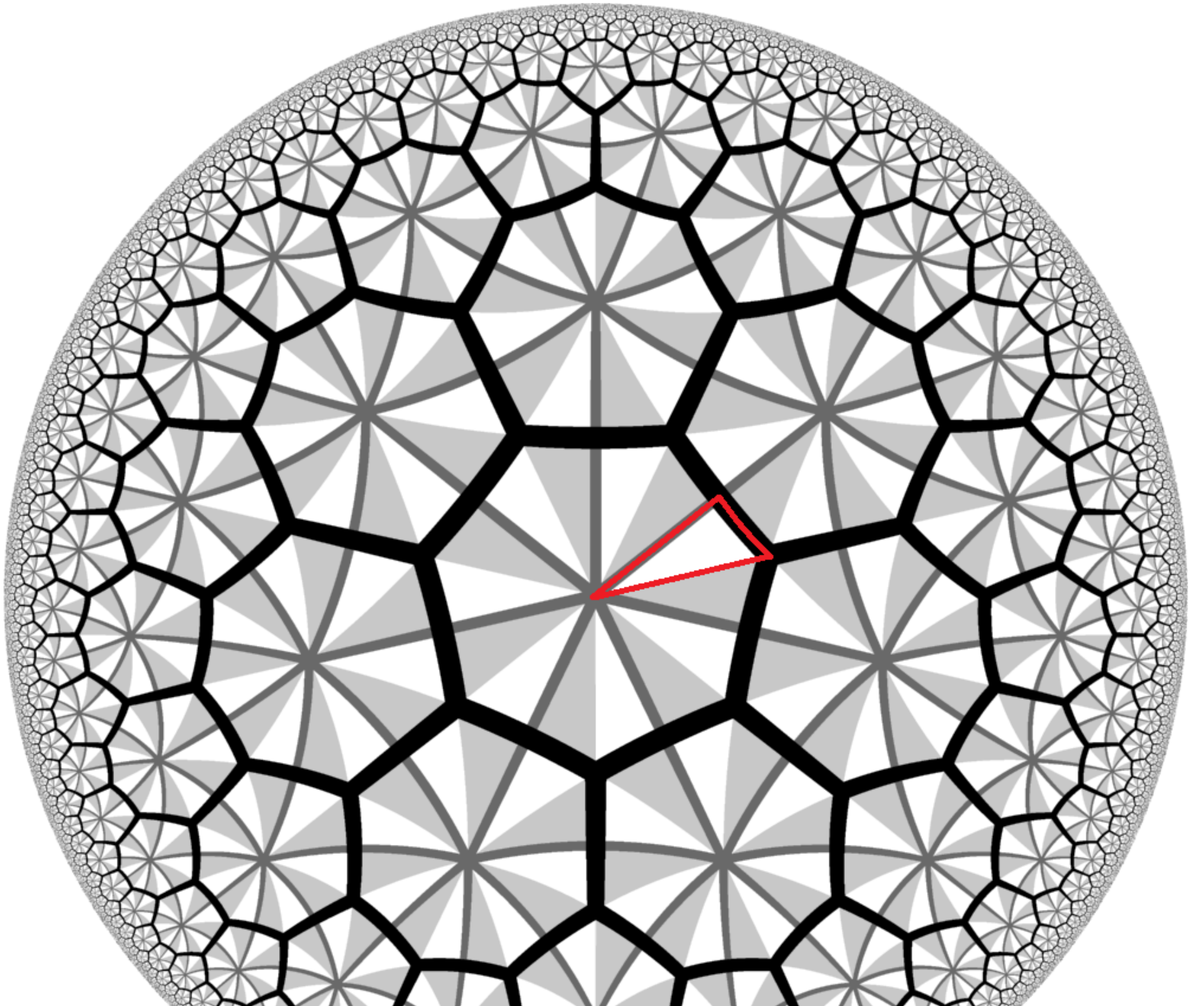
From primitives to **shaders**



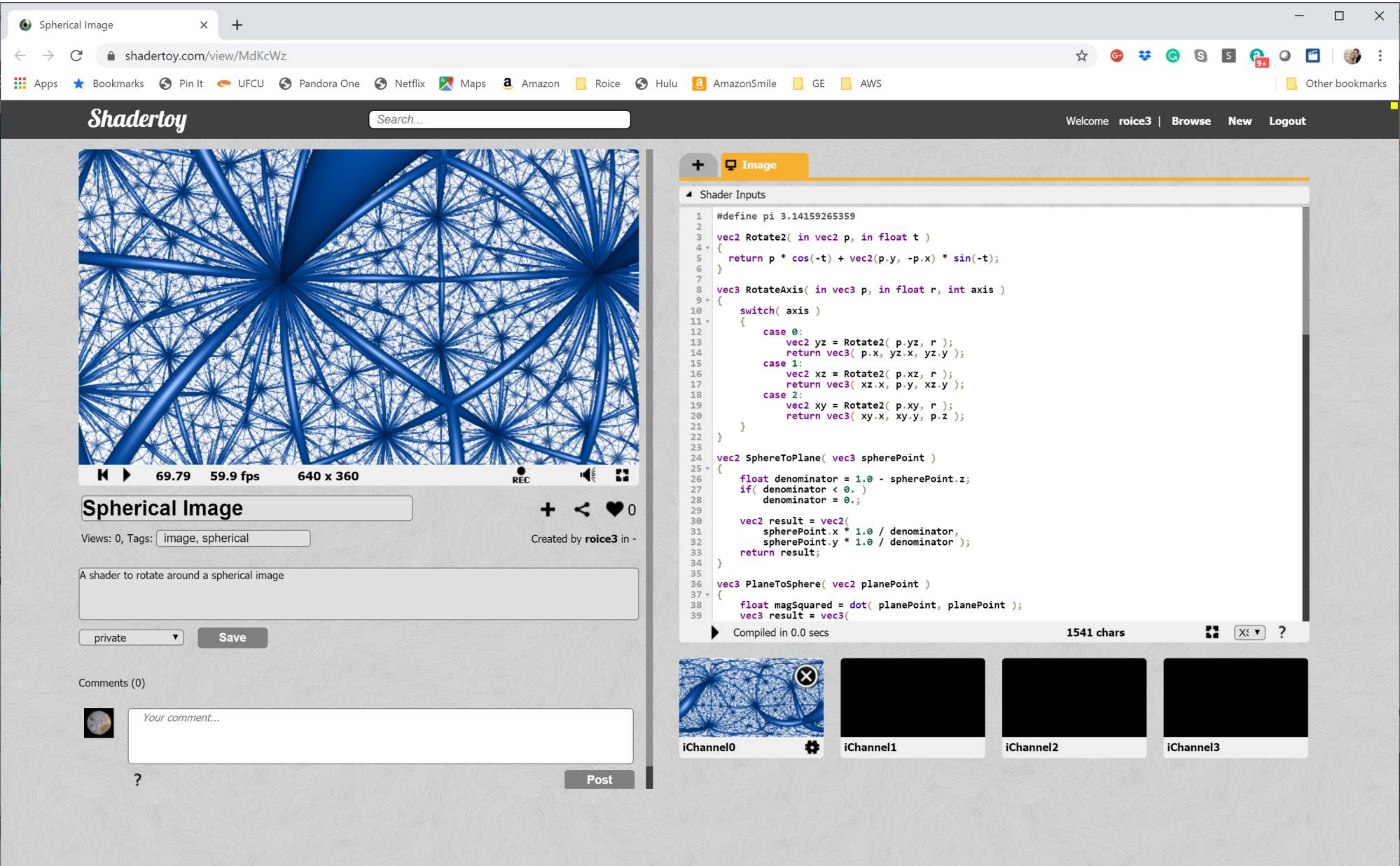
From primitives to **shaders**



“Folding”



www.shadertoy.com



Shader #2: Isometry classes of hyperbolic space

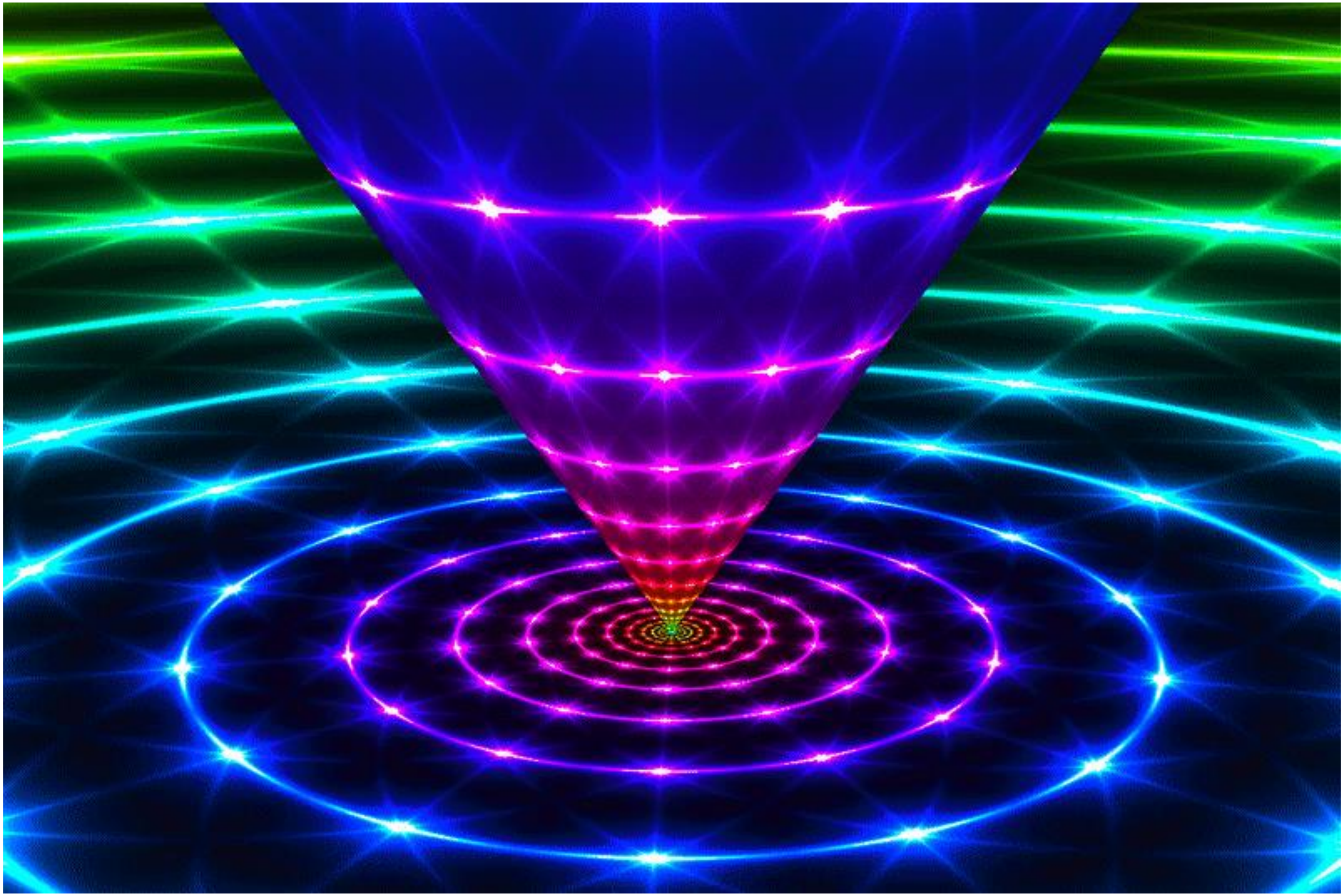
$$F(z) = \frac{az + b}{cz + d}$$

$$\widehat{\boldsymbol{C}} = \boldsymbol{C} \cup \{\infty\}$$

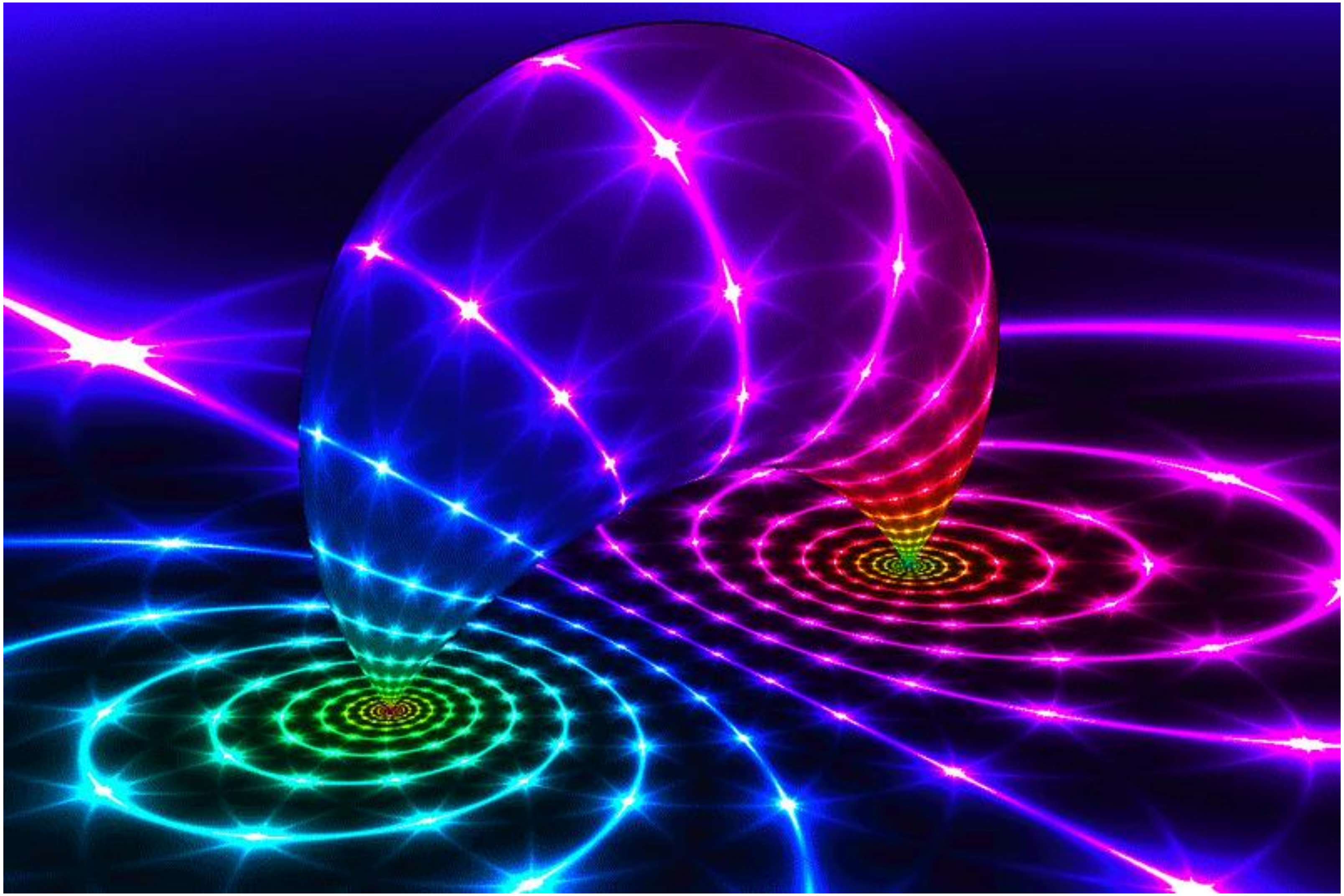
Group of Möbius Transformations

$$PSL(2, \boldsymbol{C}) \cong PGL(2, \boldsymbol{C})$$

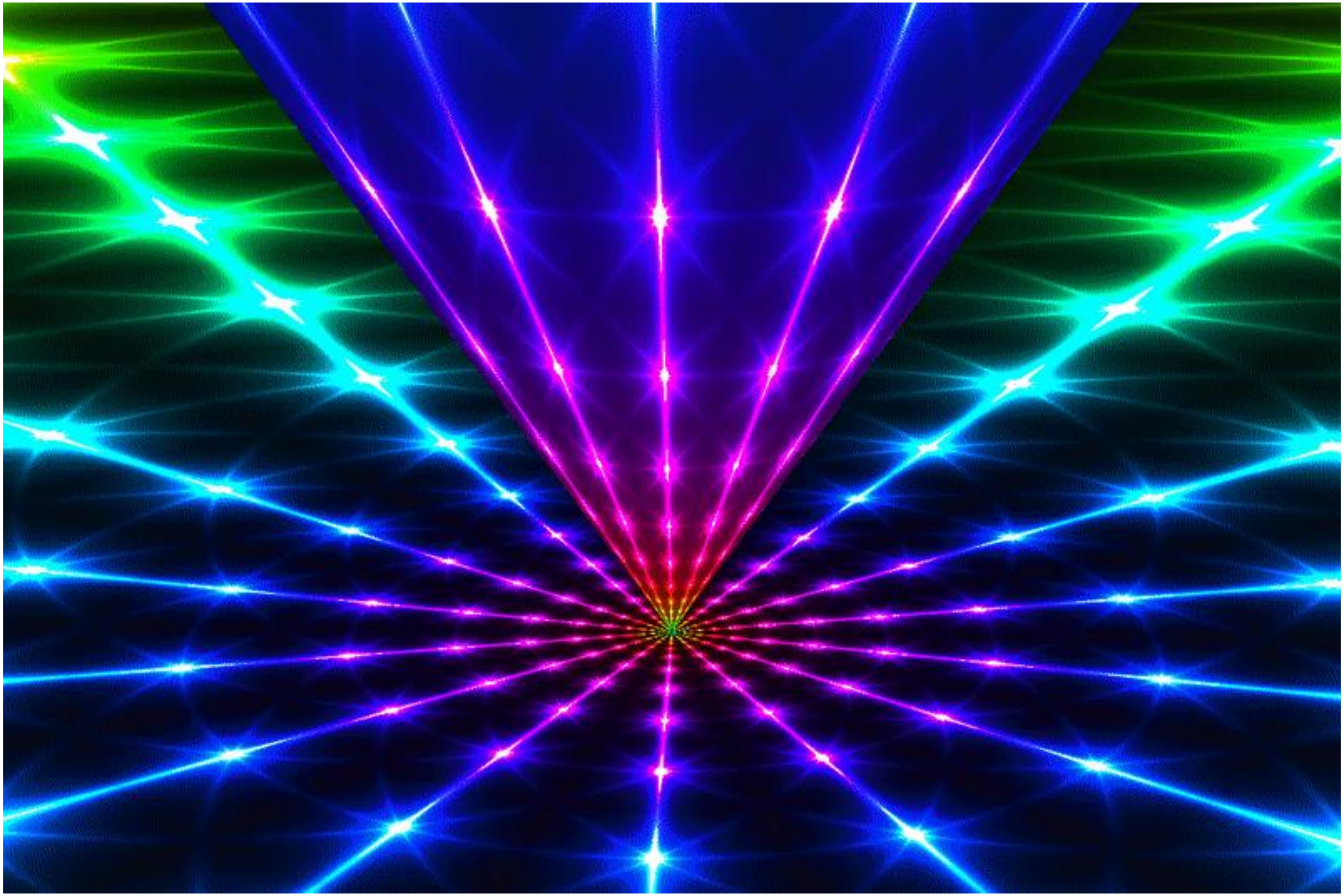
This is not a cone



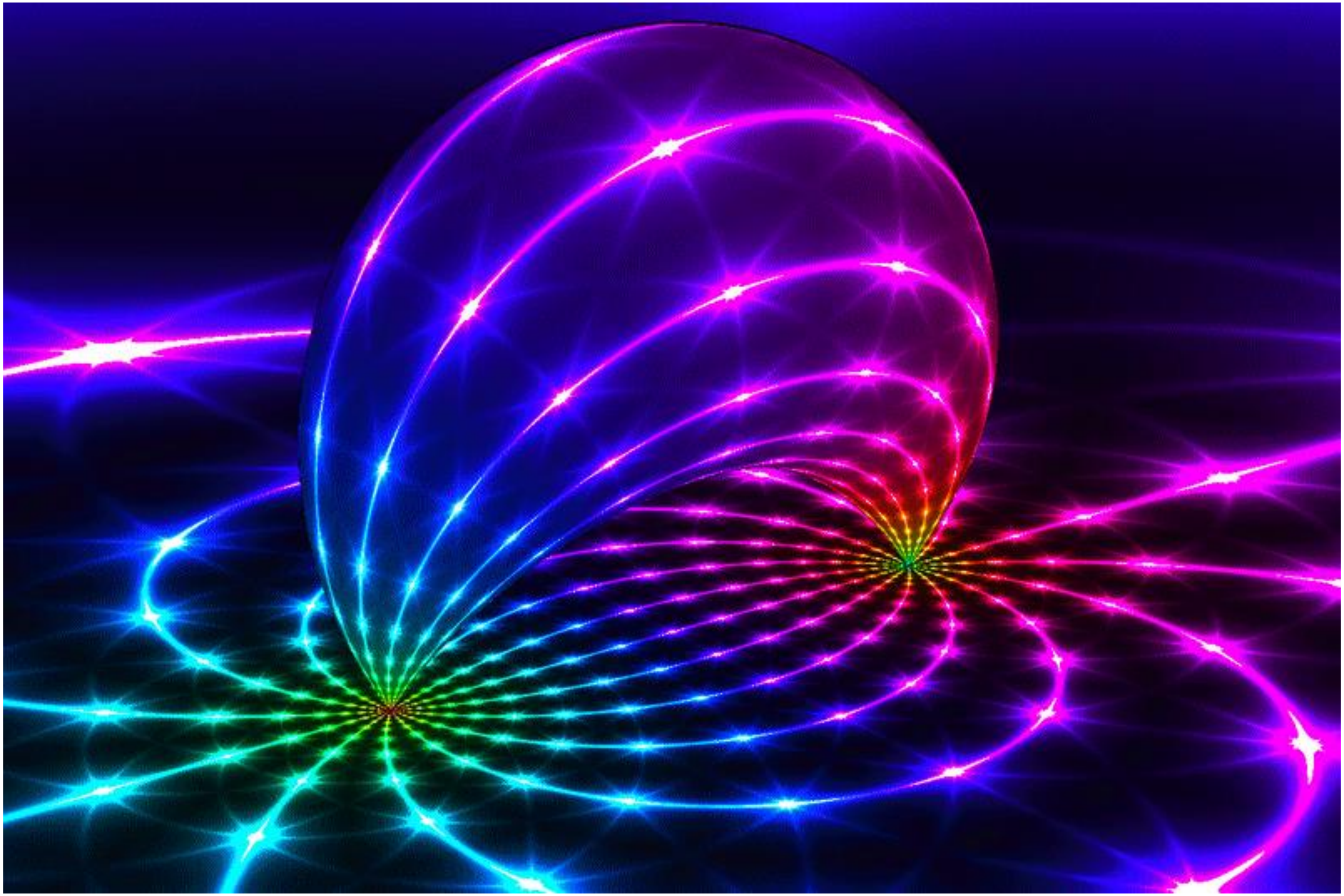
It’s a cylinder in UHS model: Elliptic Isometry



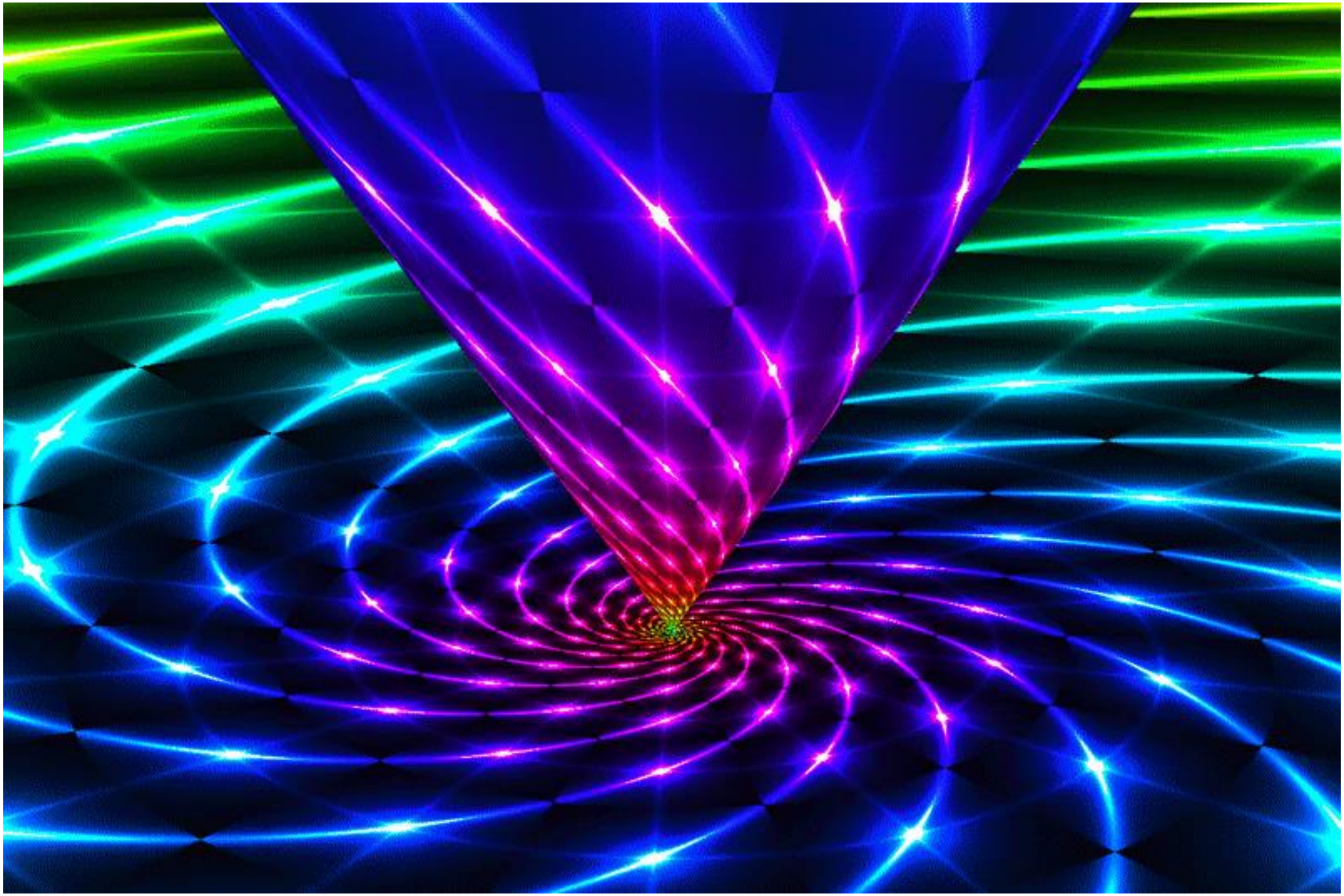
Hyperbolic Isometry



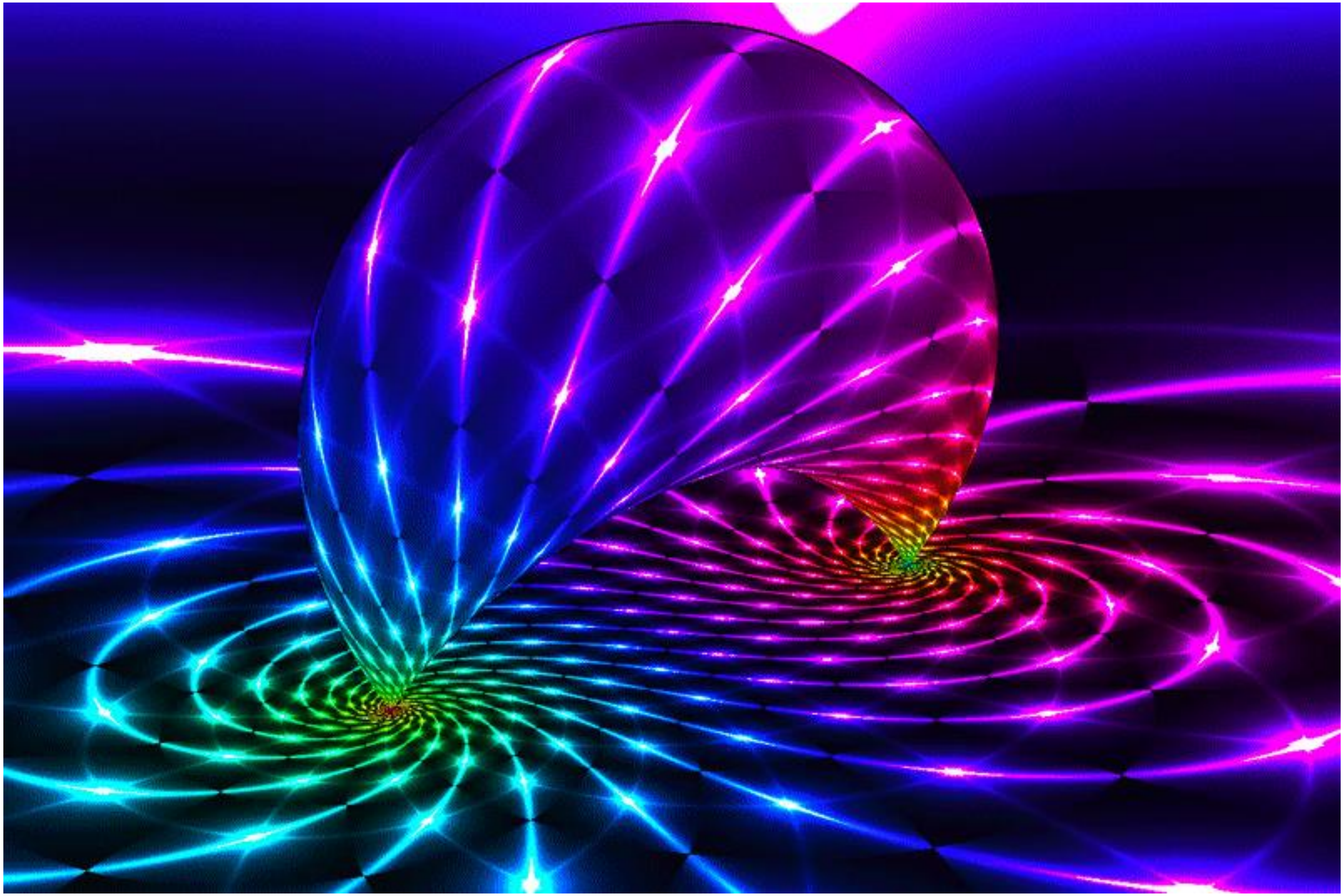
Hyperbolic Isometry



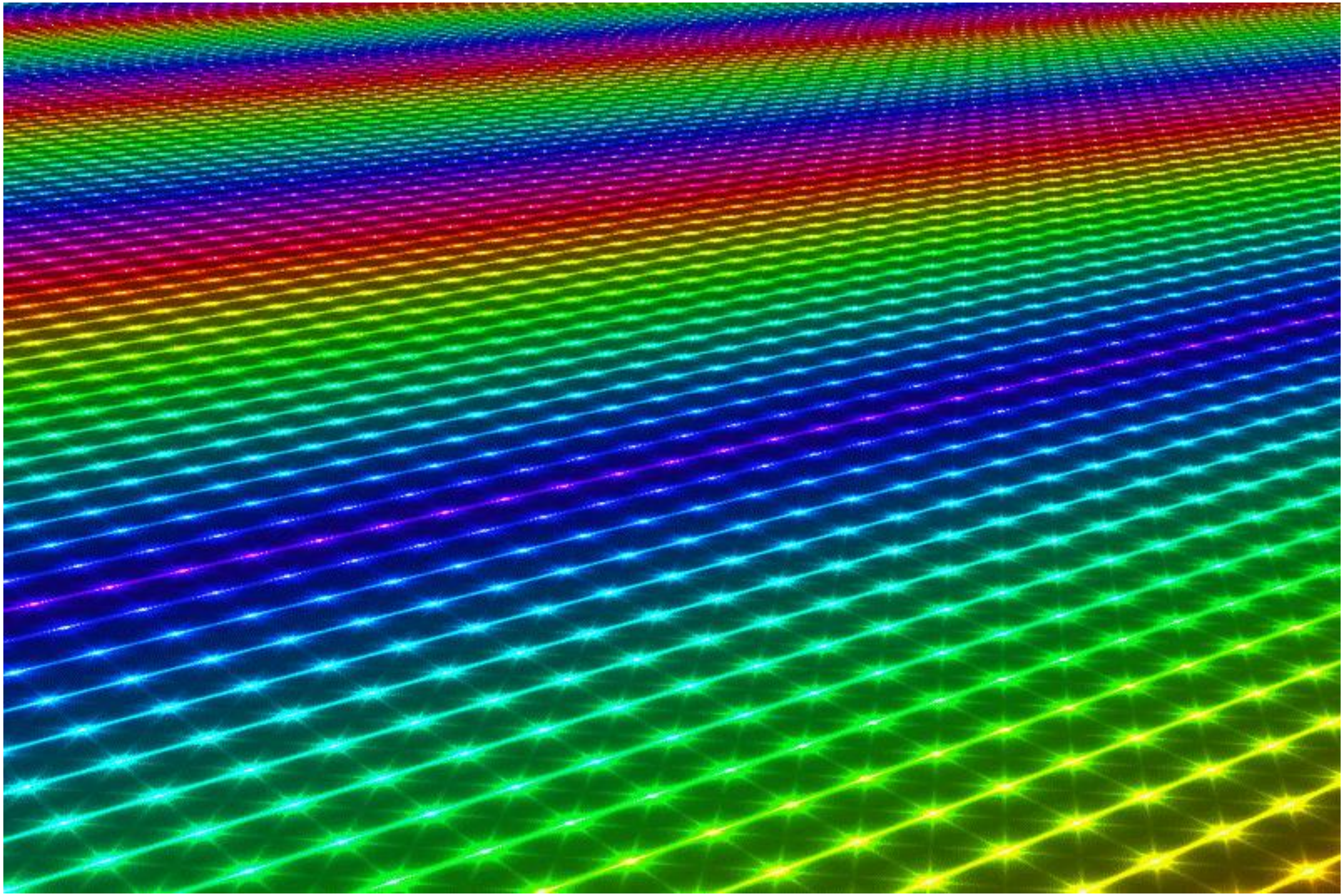
Loxodromic Isometry



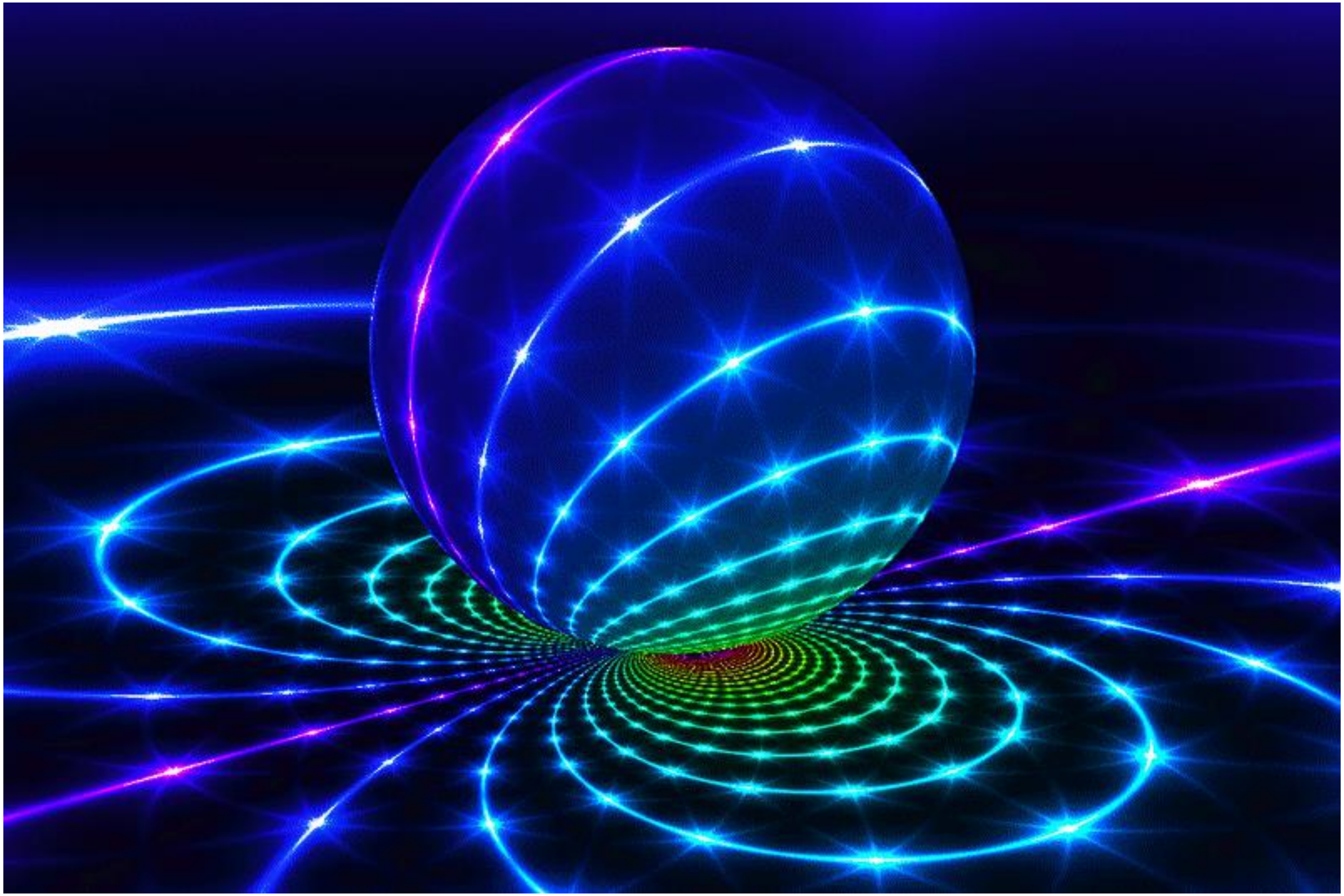
Loxodromic Isometry



This is not a plane

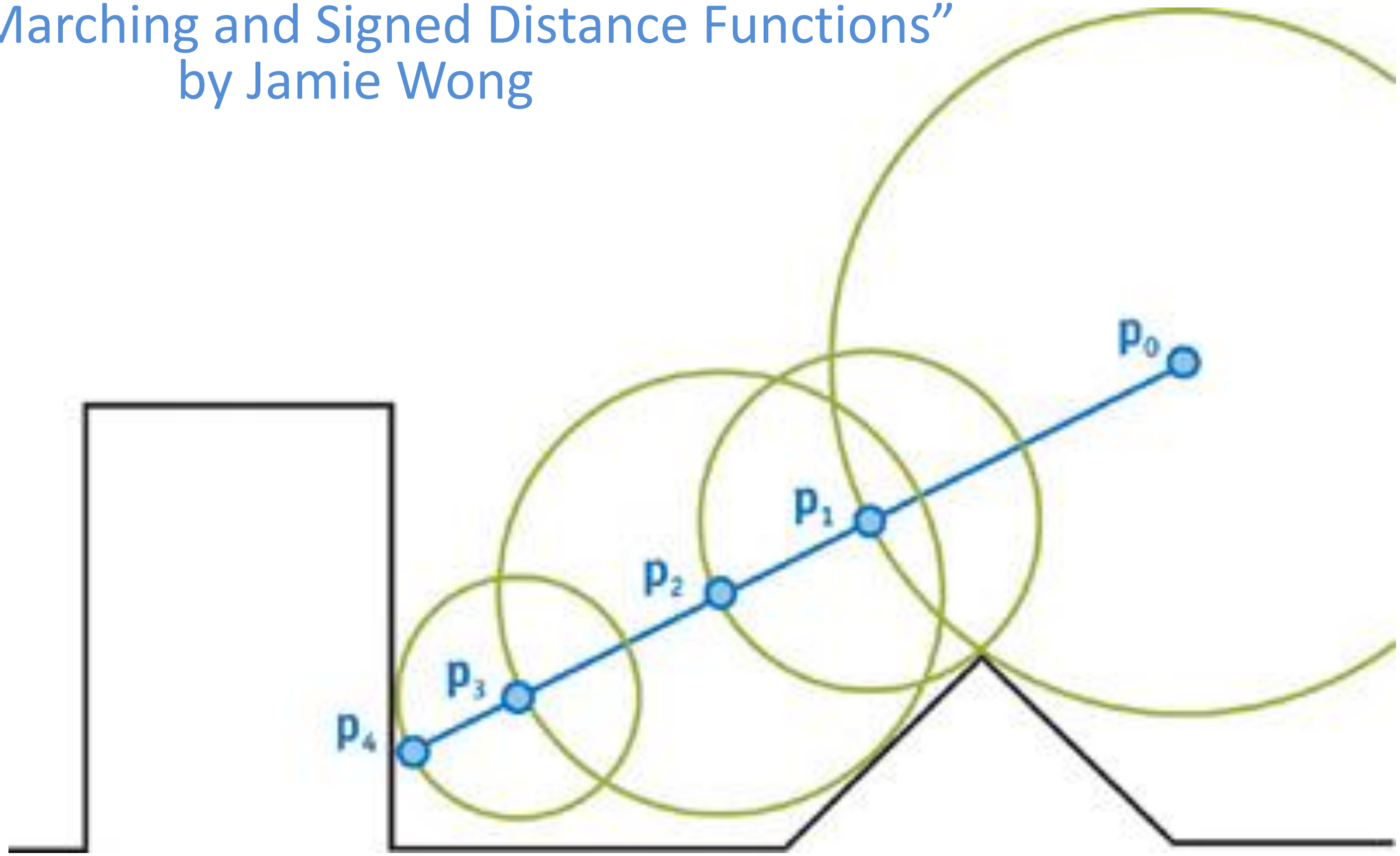


It’s a horosphere: Parabolic Isometry



Raymarching

See “Ray Marching and Signed Distance Functions”
by Jamie Wong



Credit: GPU Gems 2: Chapter 8

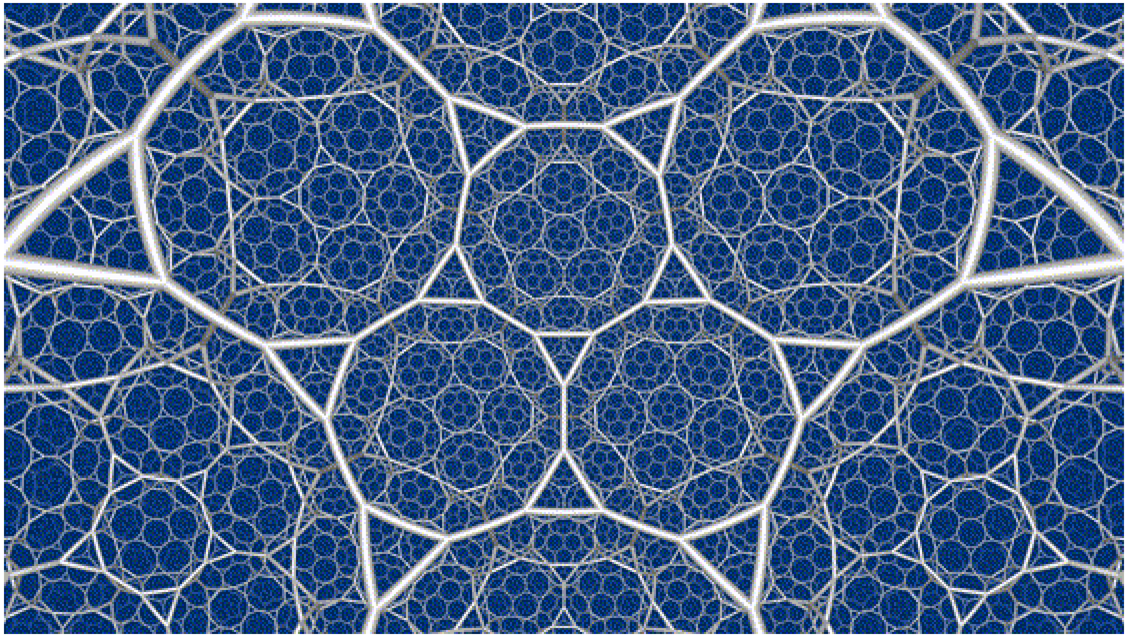
Quaternions!

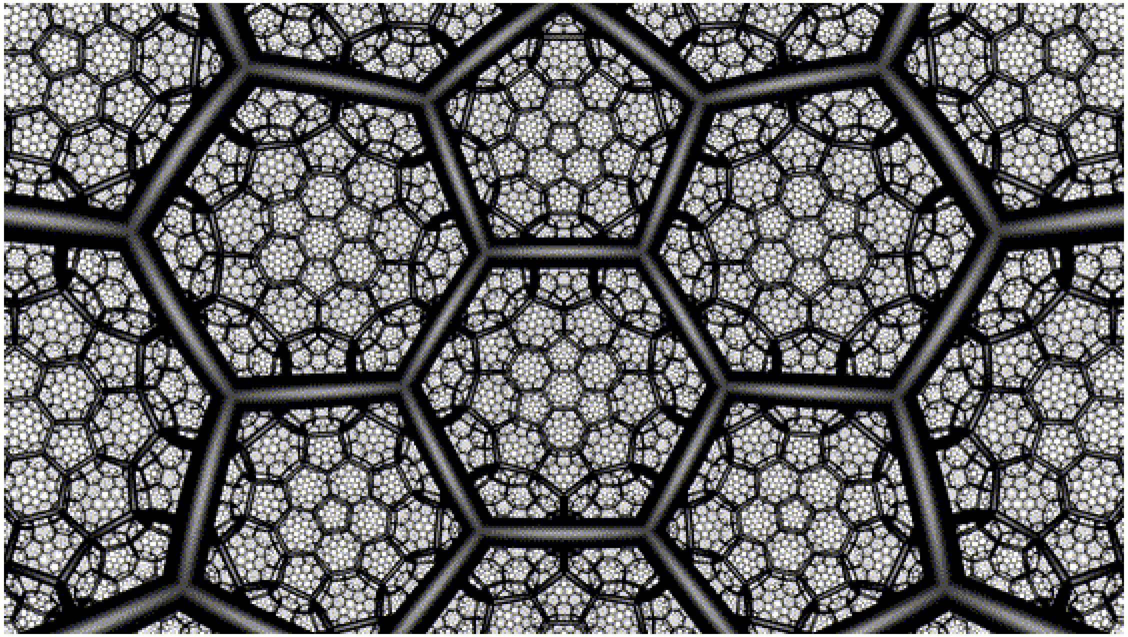
$$z \mapsto \frac{az+b}{cz+d}, z \in \widehat{\boldsymbol{C}}$$

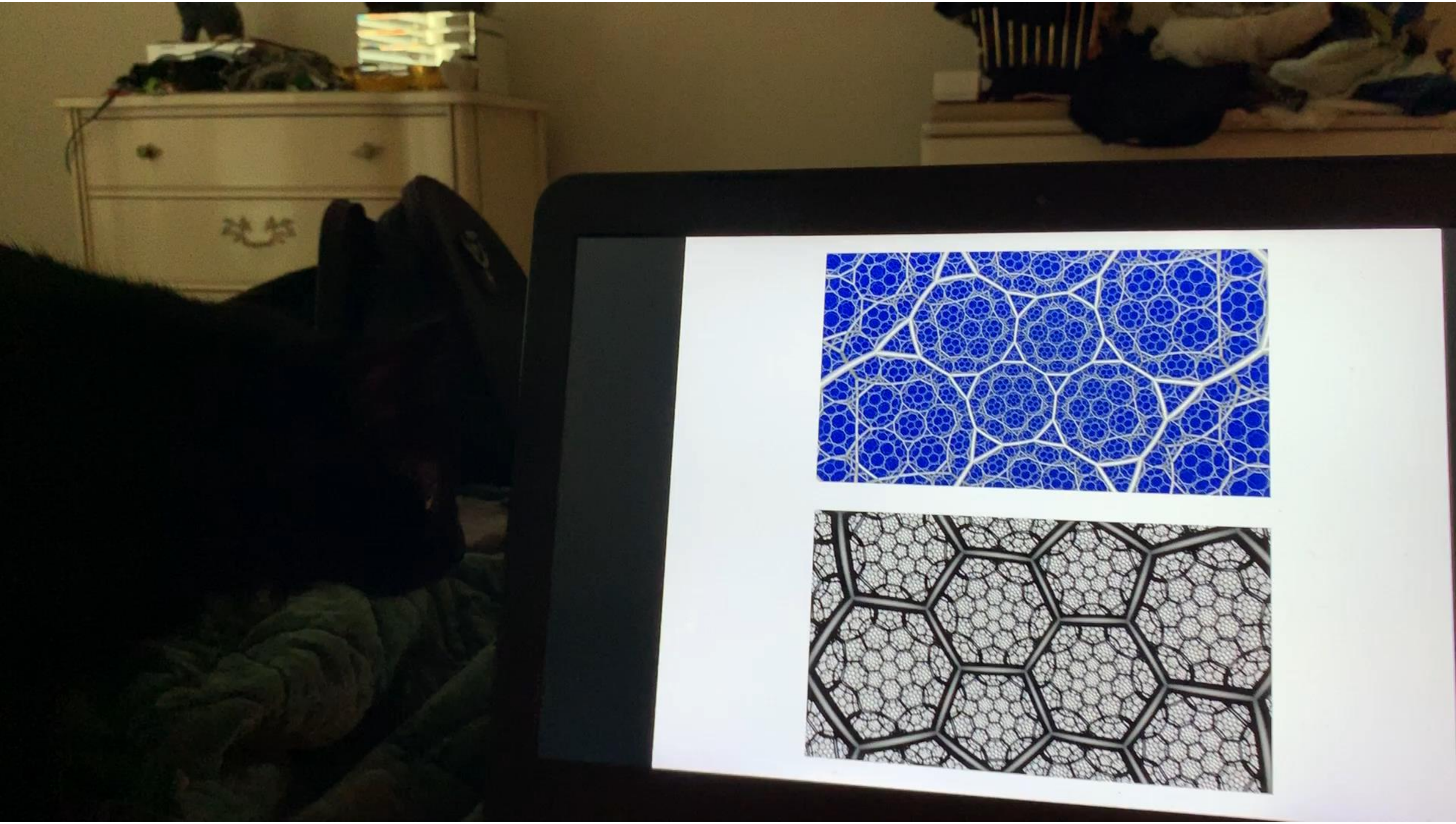
$$w = z + y\boldsymbol{j}, y \in \boldsymbol{R}^{+}$$

$$w \mapsto \frac{aw+b}{cw+d}$$

Shader #3: Spherical Images

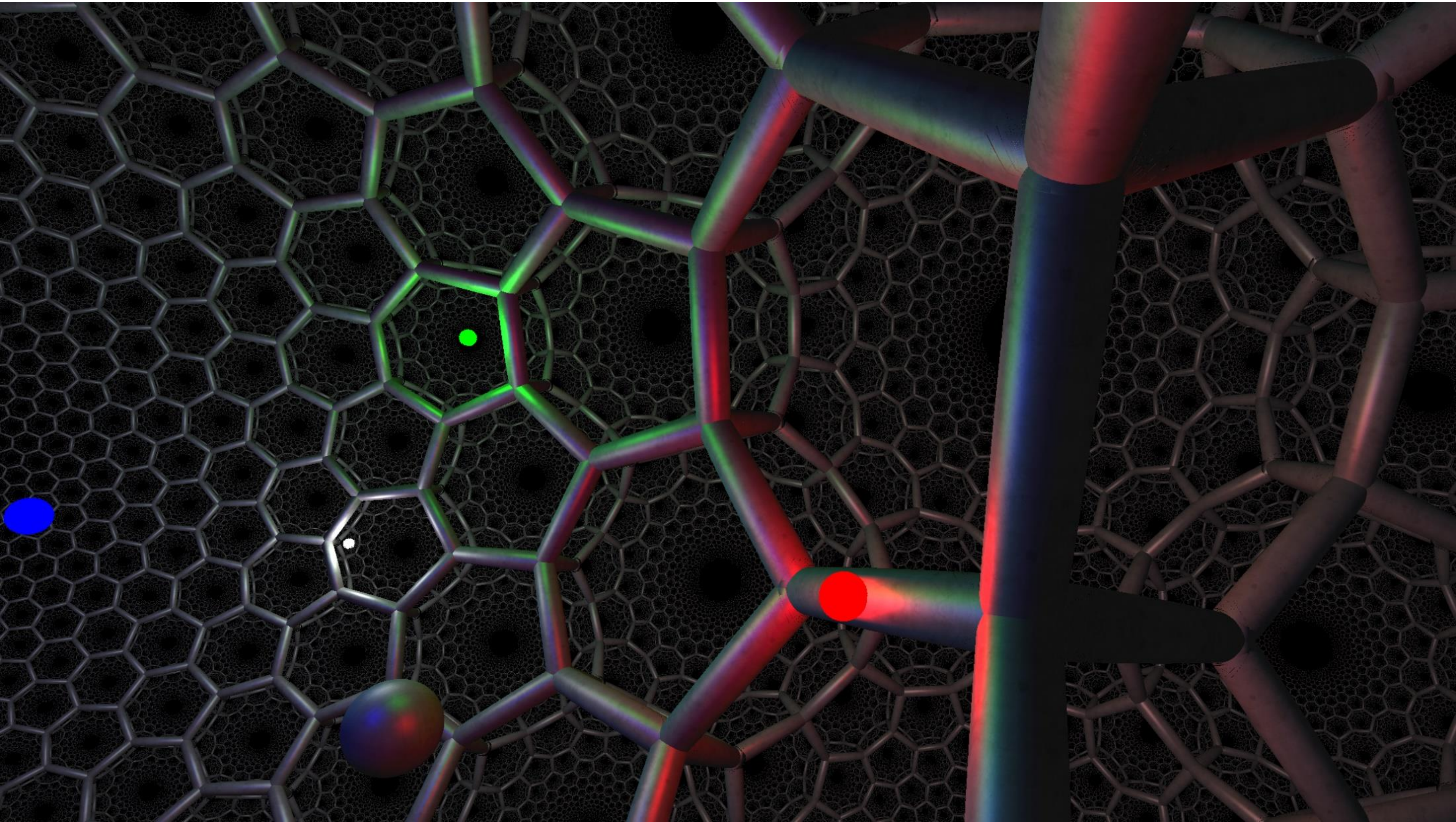






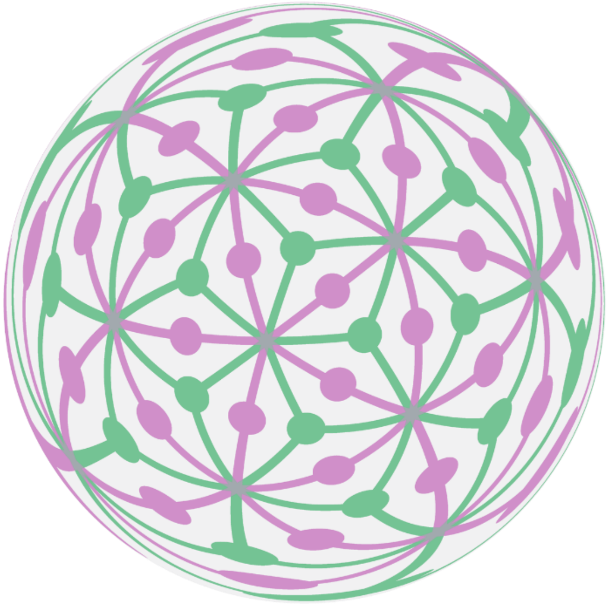
Shader #4: Hyperbolic VR using Raymarching

Folding AND Raymarching, see Henry's NSF video!



Utilities

- Shadertoy-render
- ffmpeg
- Pov-Ray
- LinqToTwitter



Again, links (and scripts) at: roice3.org/icerm

In my experience…

Advantages

- Fast!
- Motion
- Quality
- Fractals
- WebGL
- Lots of Examples

Disadvantages

- Hardware
- Debugging
- Optimization
- Low-level
- Code libraries

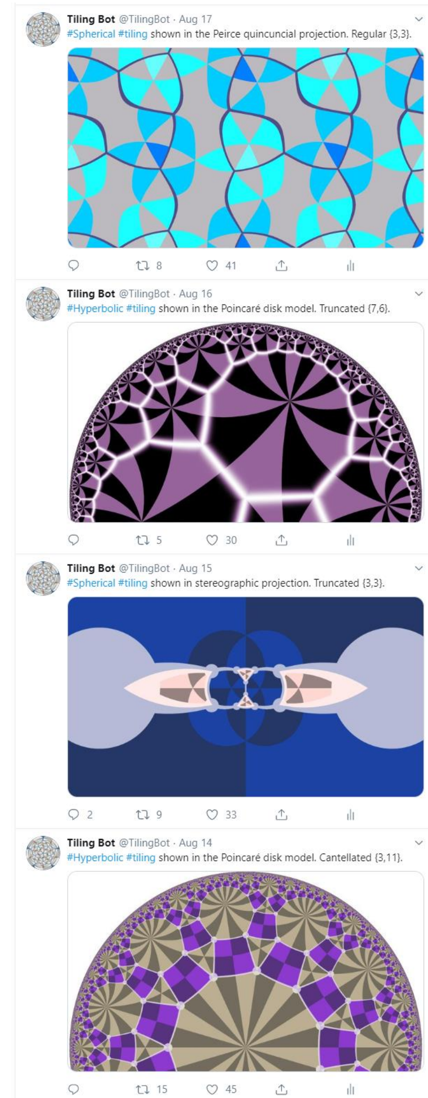
“The explorer who will not come back or send back his ships to tell his tale is not an explorer, only an adventurer.”

-Ursula K. Le Guin, *The Dispossessed: An Ambiguous Utopia*

@Tilingbot

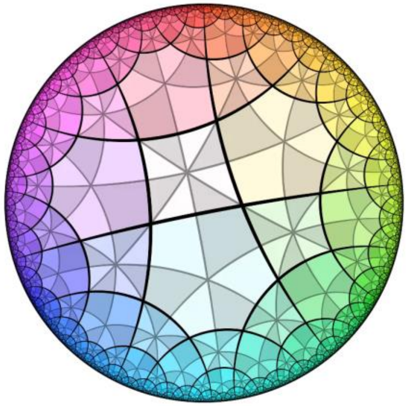

Tiling Bot
723 Tweets
Edit profile
Tiling Bot
@TilingBot
A twitter bot creating a random 2-dimensional tiling once a day, by @roice713.
github.com/roice3/TilingB...
Joined April 2018
1 Following 3,354 Followers
Tweets
Tweets & replies
Media
Likes
Tiling Bot @TilingBot · 16h
#Euclidean #tiling shown in the plane model. Rectified {3,6}.
4
37
Tiling Bot @TilingBot · Sep 6
#Spherical #tiling shown in the equirectangular projection. Regular {4,3}.
2
4
21
Tiling Bot @TilingBot · Sep 5
#Hyperbolic #tiling shown in the Poincaré disk model. Bitruncated {9,11}.
11
34

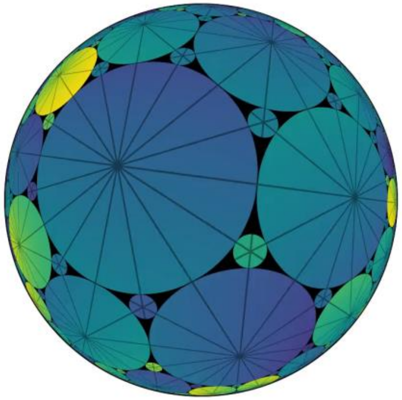

Tiling Bot @TilingBot · Sep 3
#Hyperbolic #tiling shown in the Poincaré disk model. Omnitruncated {14,3}.
13
63
Tiling Bot @TilingBot · Sep 2
#Hyperbolic #tiling shown in the Joukowsky projection. Catalan tiling dual to truncated {9,3}.
1
16
67
Tiling Bot @TilingBot · Sep 1
#Hyperbolic #tiling shown in the Klein model. Cantellated {6,6}.
2
7
26

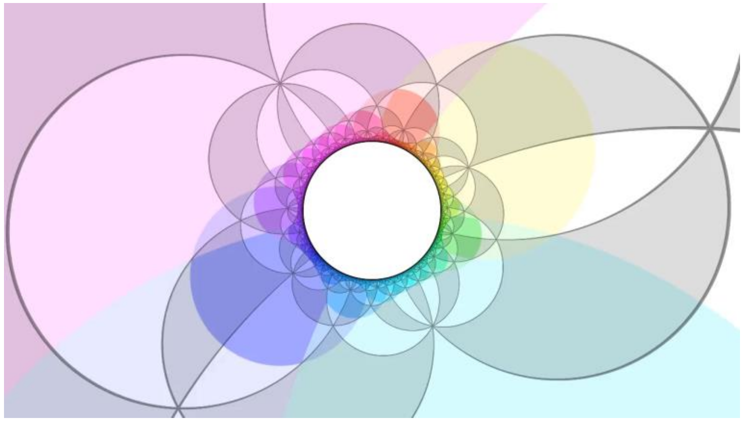

Tiling Bot @TilingBot · Aug 17
#Spherical #tiling shown in the Peirce quincuncial projection. Regular {3,3}.
8
41
Tiling Bot @TilingBot · Aug 16
#Hyperbolic #tiling shown in the Poincaré disk model. Truncated {7,6}.
5
30
Tiling Bot @TilingBot · Aug 15
#Spherical #tiling shown in stereographic projection. Truncated {3,3}.
2
9
33
Tiling Bot @TilingBot · Aug 14
#Hyperbolic #tiling shown in the Poincaré disk model. Cantellated {3,11}.
15
45

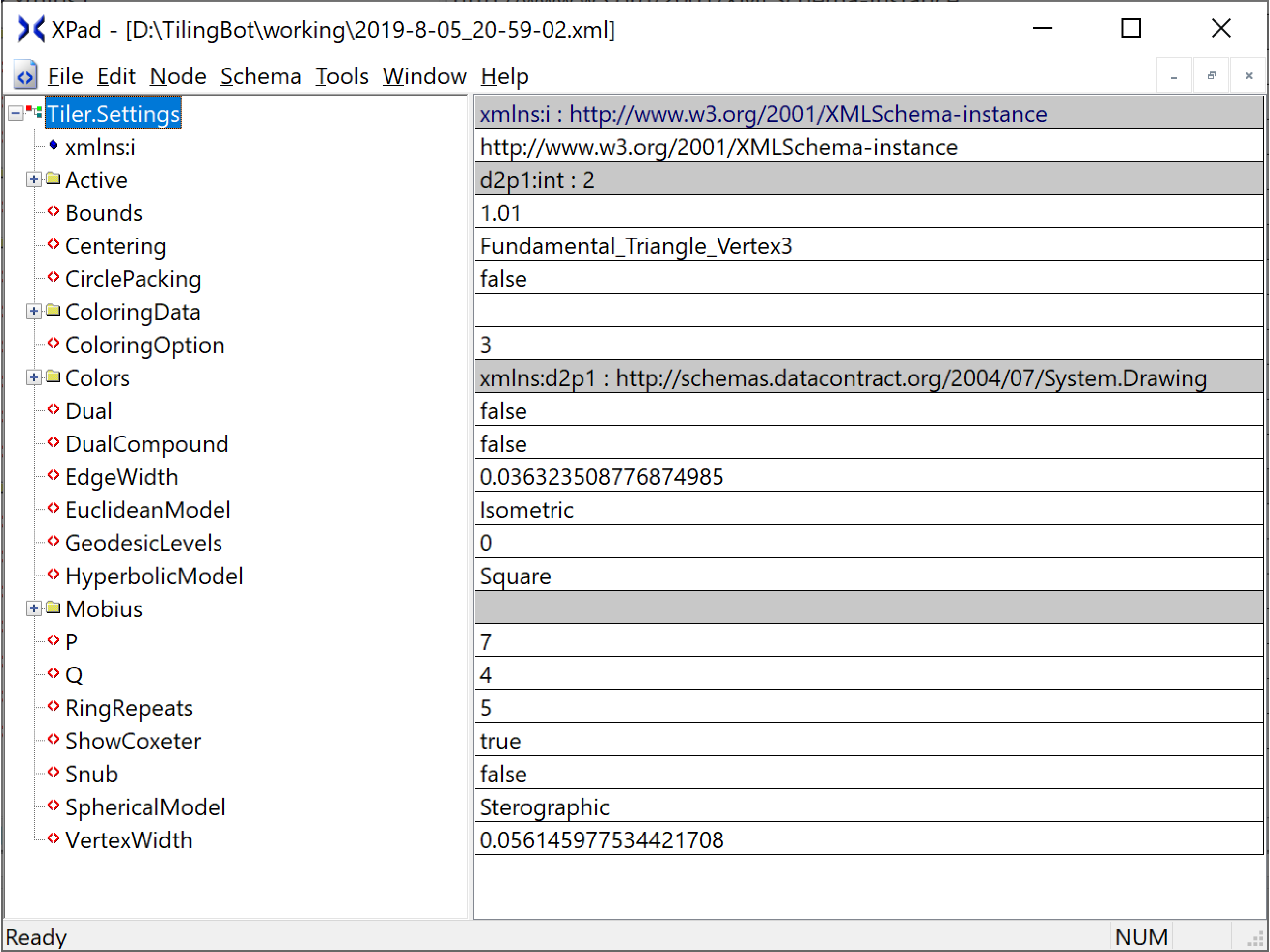
The Real Shader #1: Hyperbolic Wythoff explorer

by Matt Zucker, mzucker.github.io








XPad - [D:\TilingBot\working\2019-8-05_20-59-02.xml]
File Edit Node Schema Tools Window Help
Tiler.Settings
xmlns:i : http://www.w3.org/2001/XMLSchema-instance
xmlns:i
http://www.w3.org/2001/XMLSchema-instance
Active
d2p1:int : 2
Bounds
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Centering
Fundamental_Triangle_Vertex3
CirclePacking
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ColoringData
ColoringOption
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Colors
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Dual
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DualCompound
false
EdgeWidth
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EuclideanModel
Isometric
GeodesicLevels
0
HyperbolicModel
Square
Mobius
P
7
Q
4
RingRepeats
5
ShowCoxeter
true
Snub
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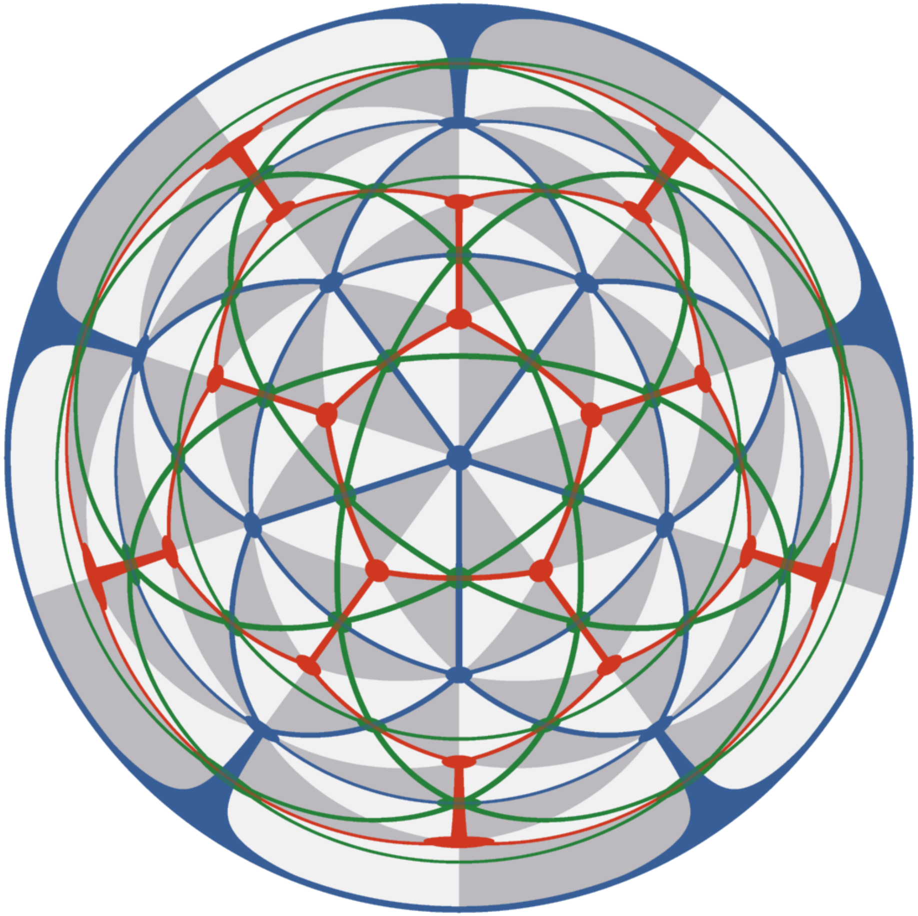
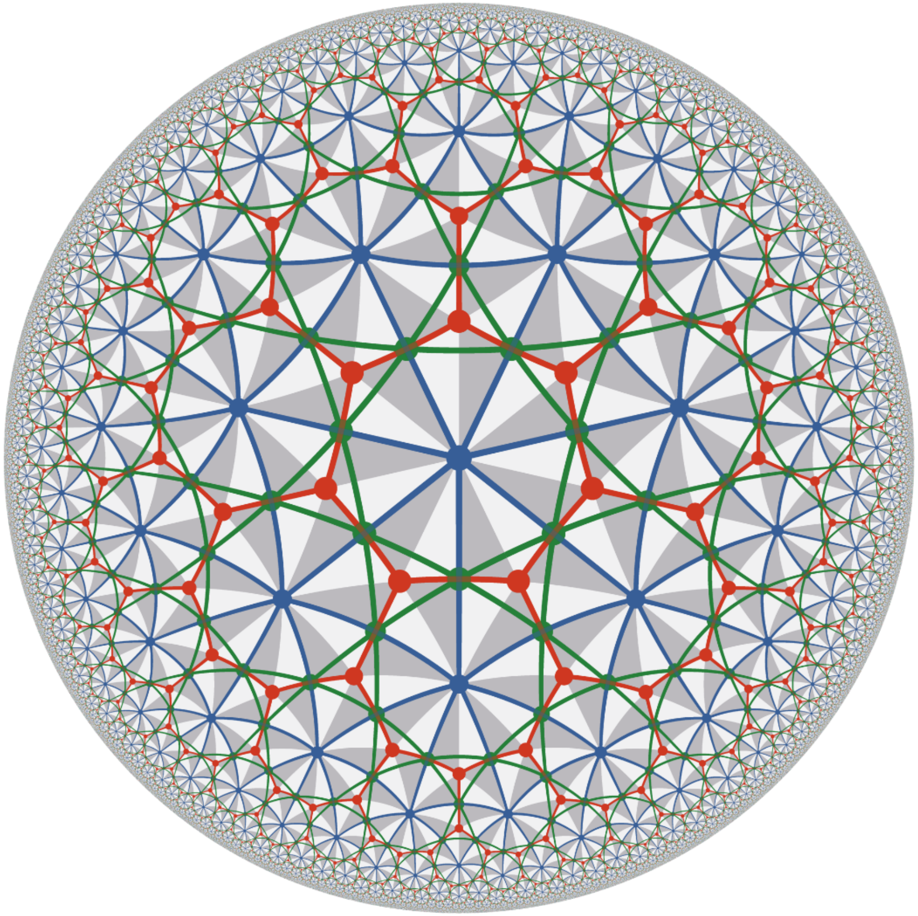
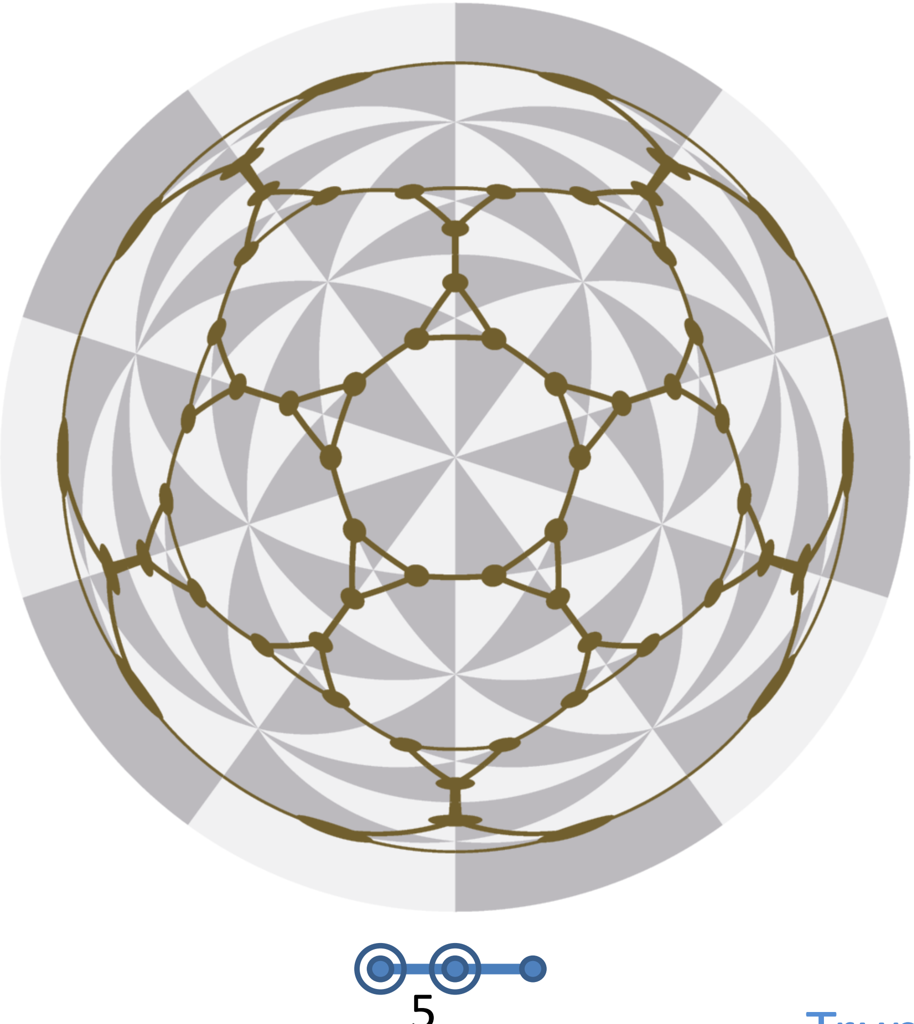
SphericalModel
Sterographic
VertexWidth
0.056145977534421708
Ready
NUM

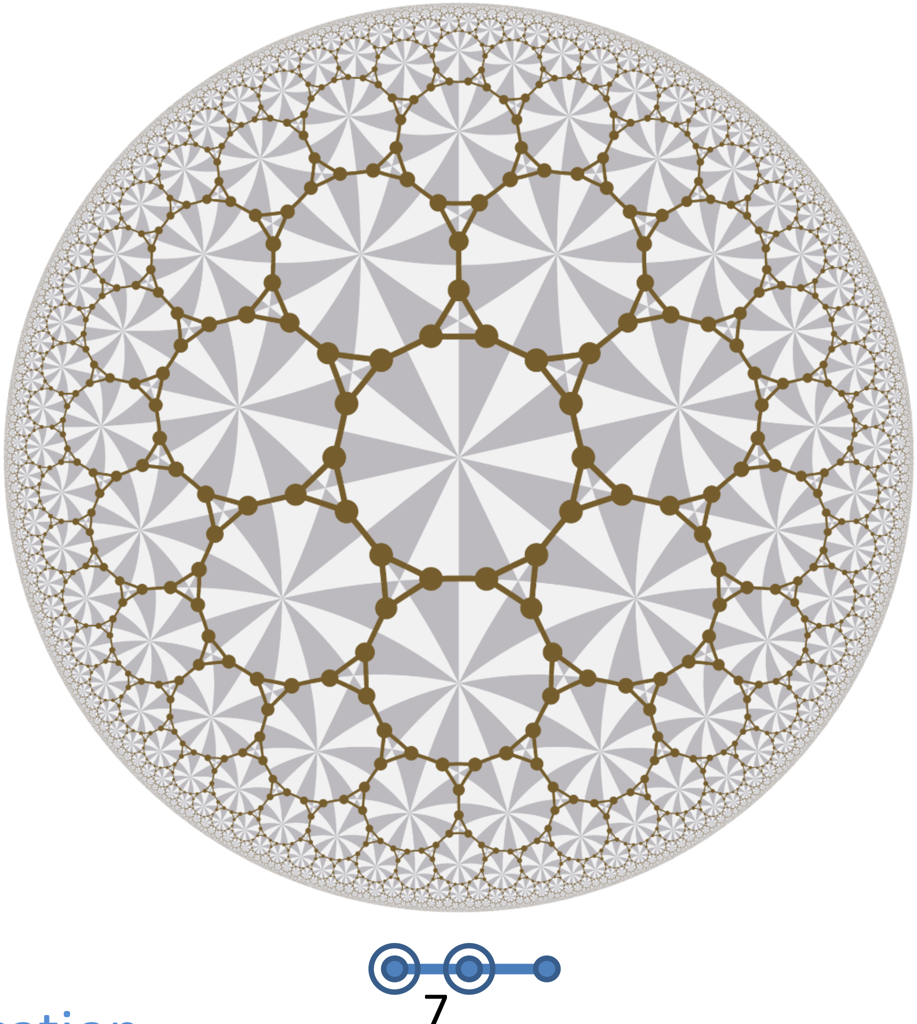
Regular and Rectified





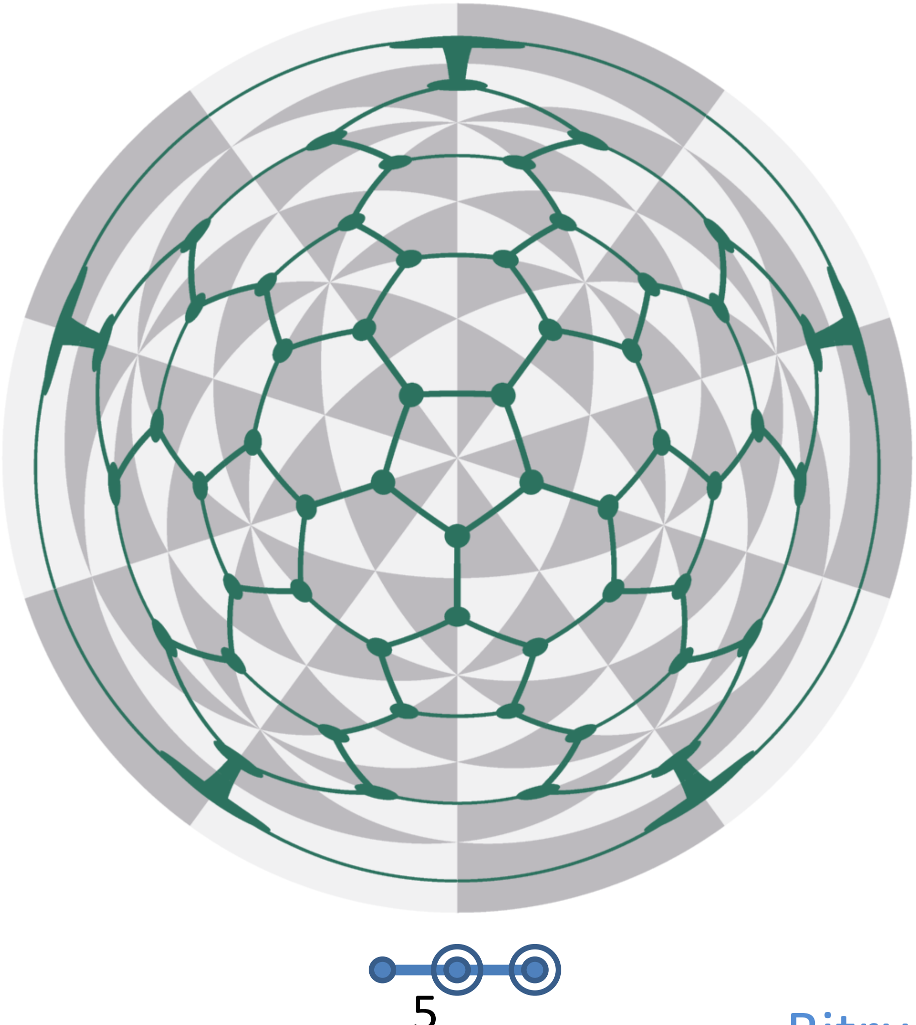
Uniform Tilings

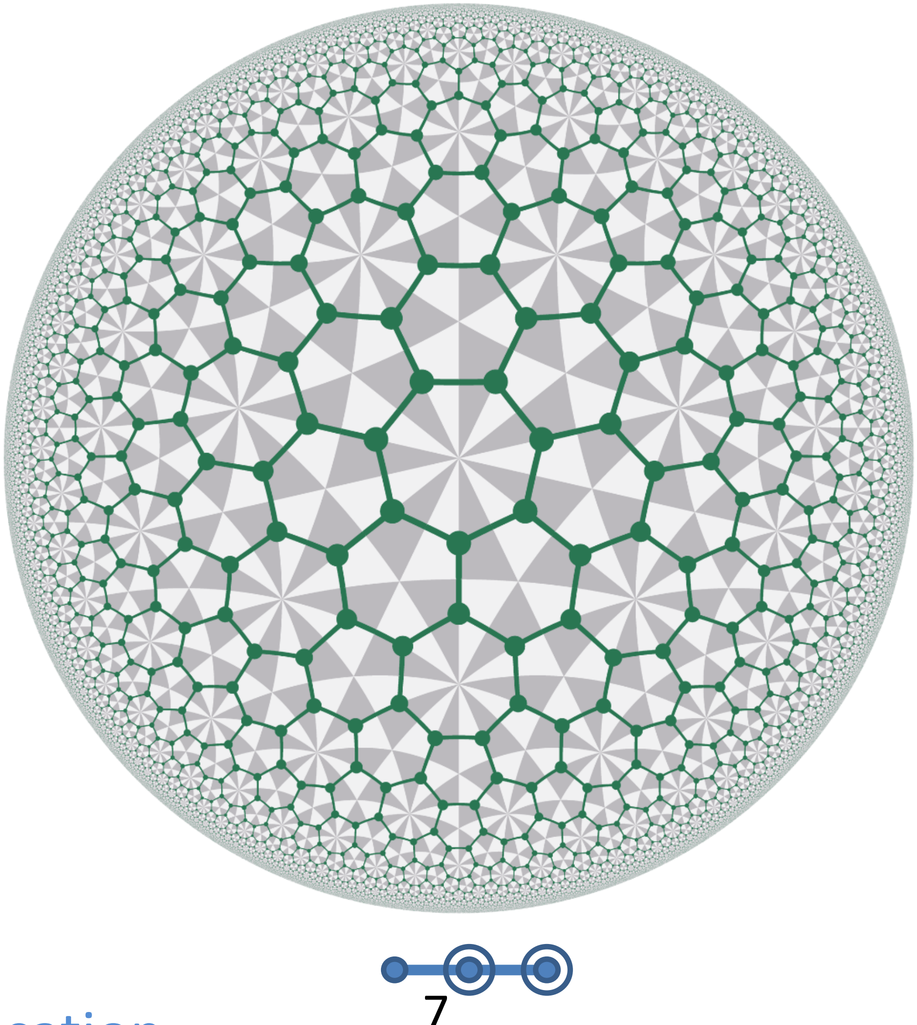




Truncation

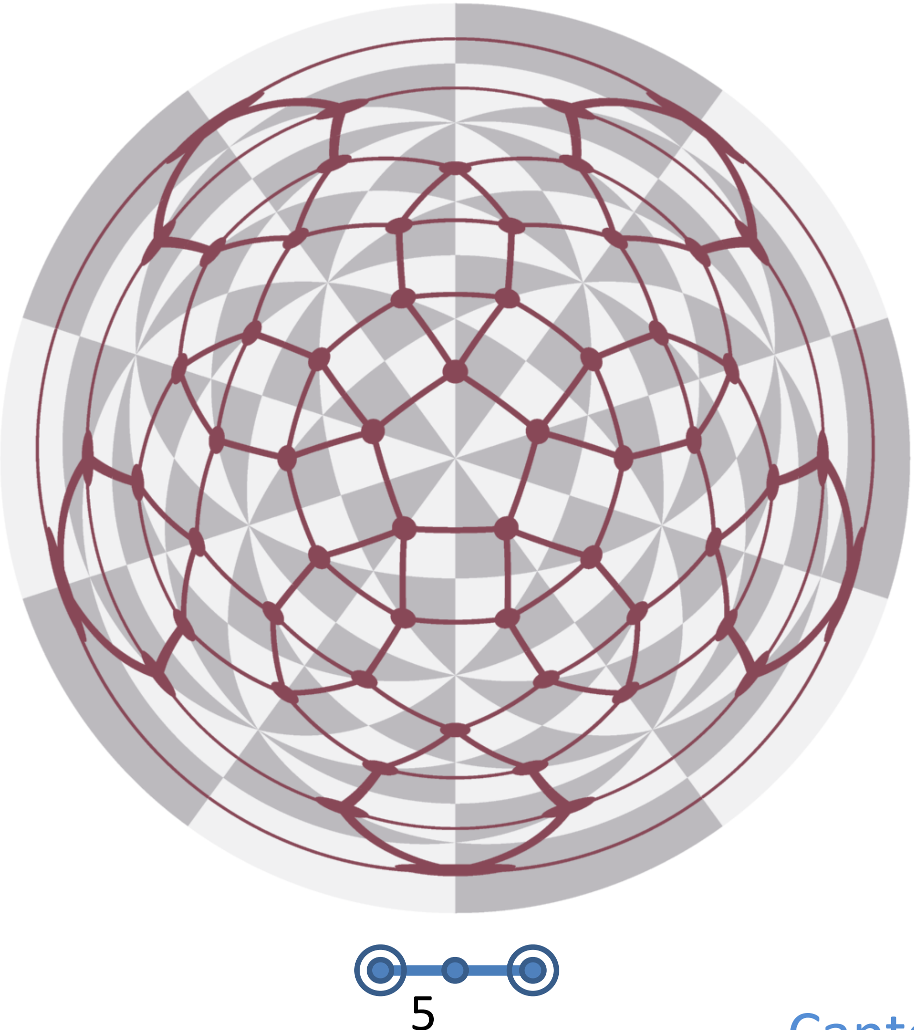
Uniform Tilings

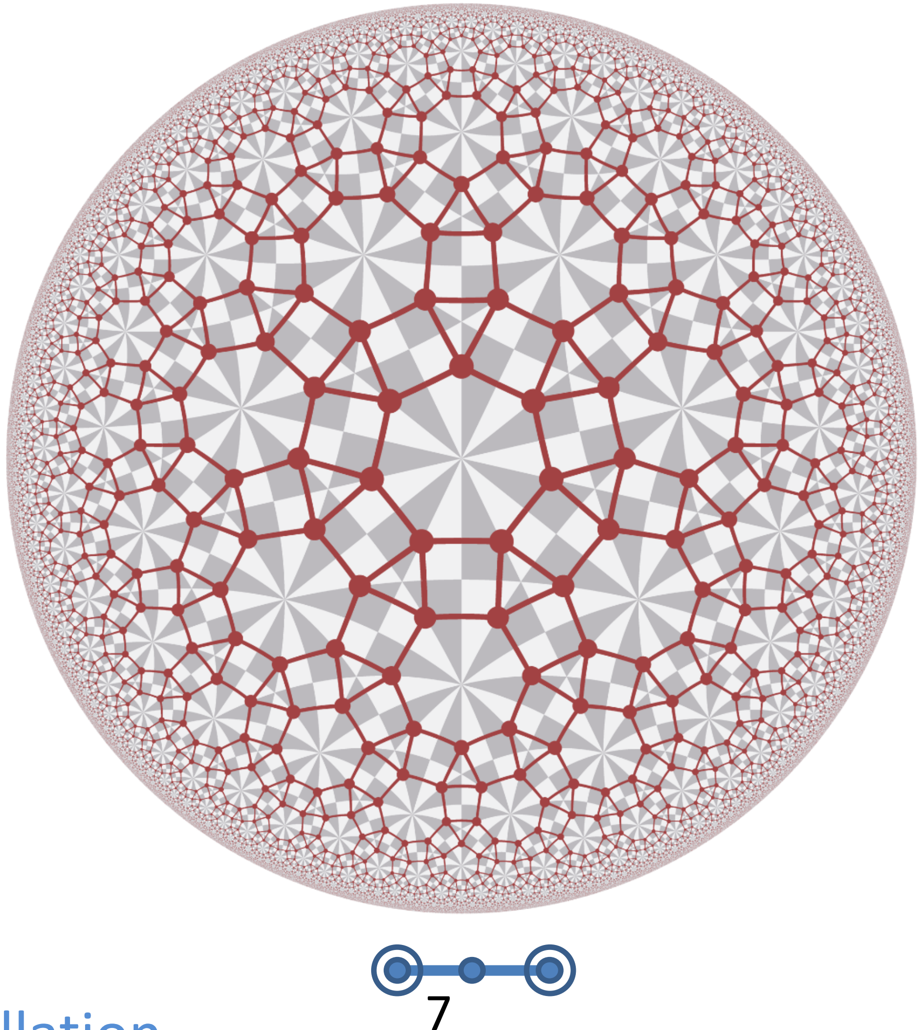




Bitruncation

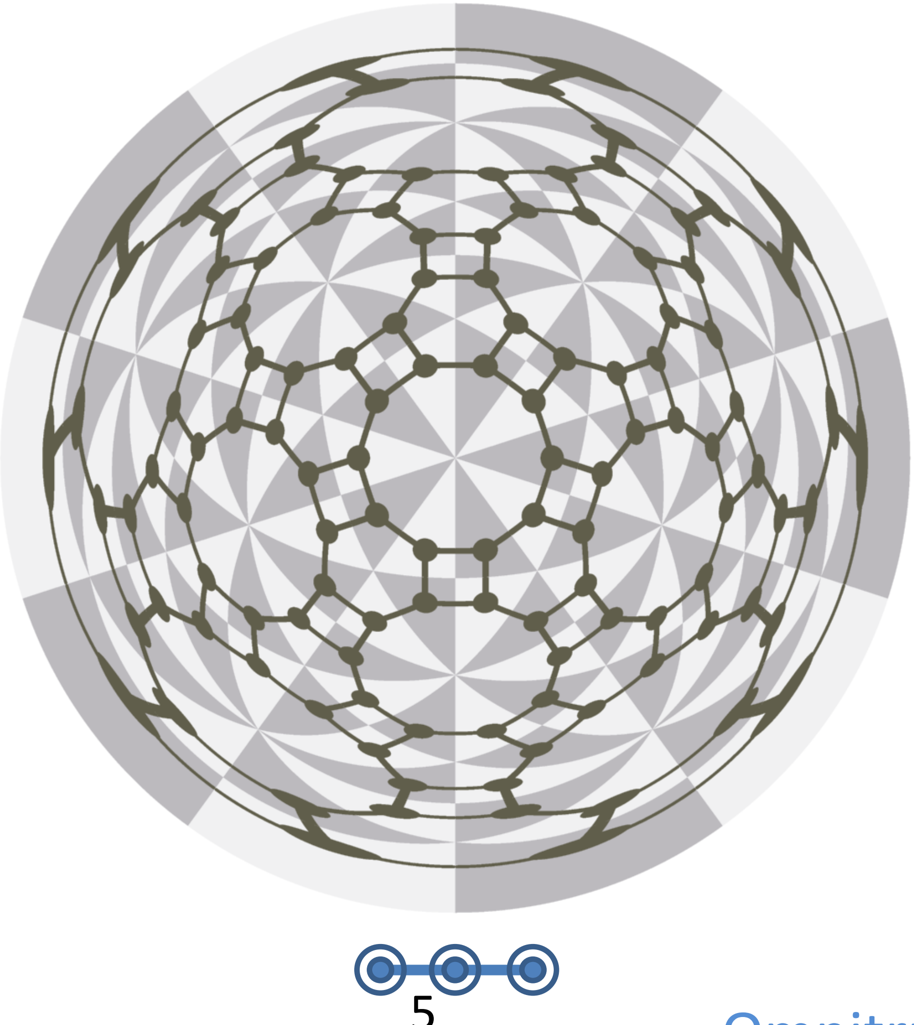
Uniform Tilings

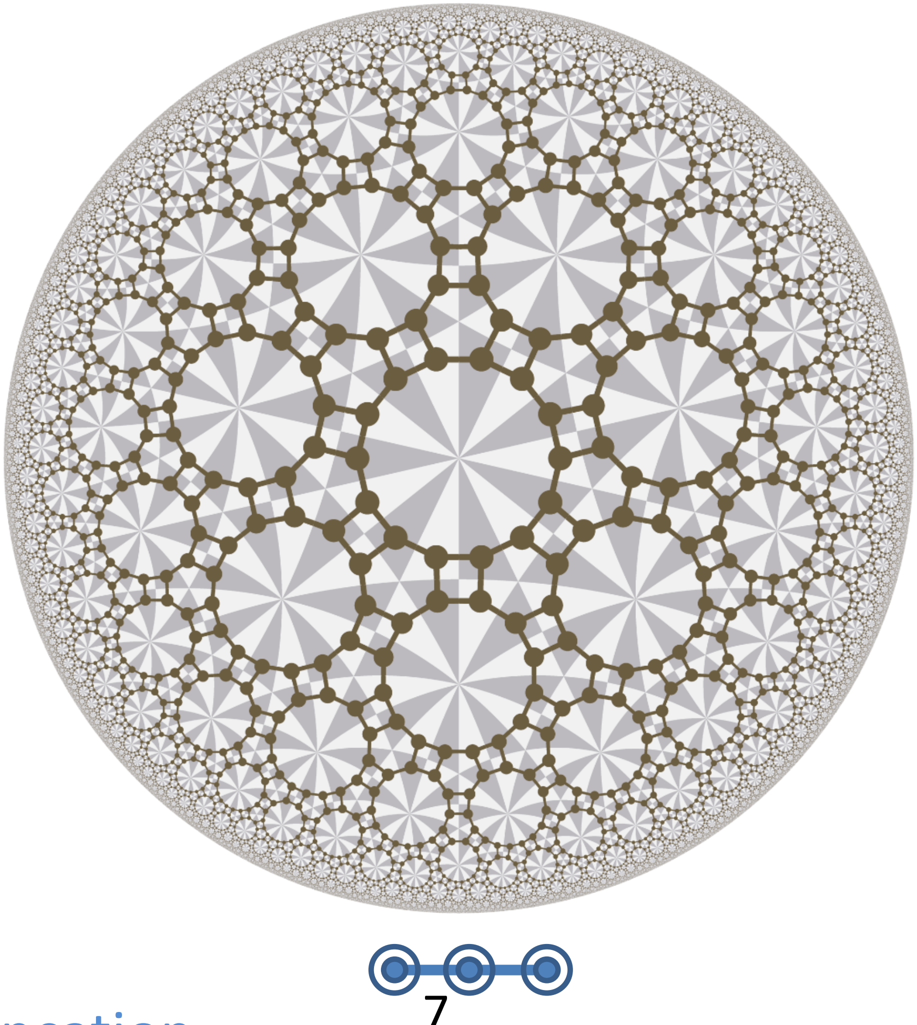




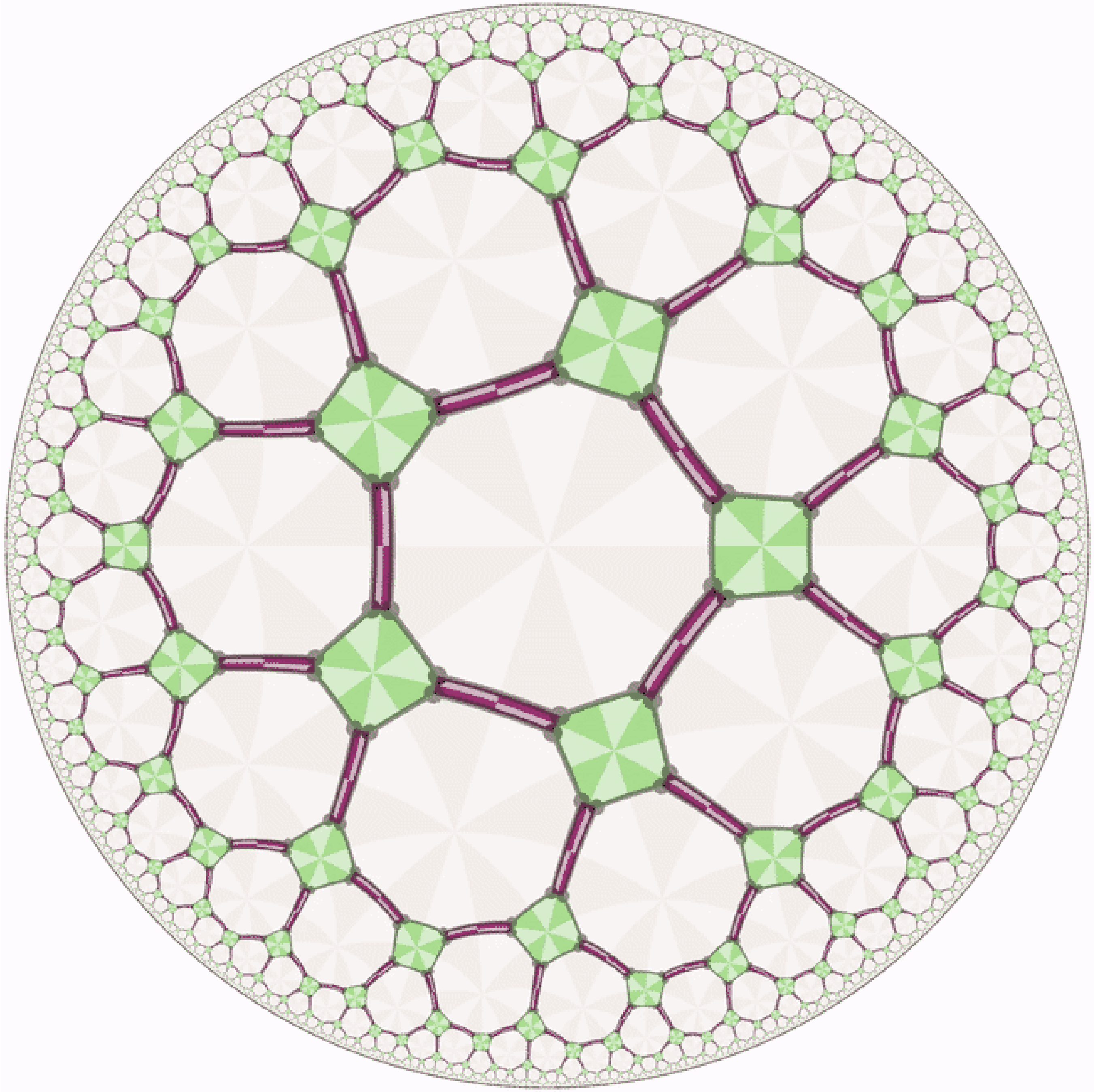
Cantellation

Uniform Tilings

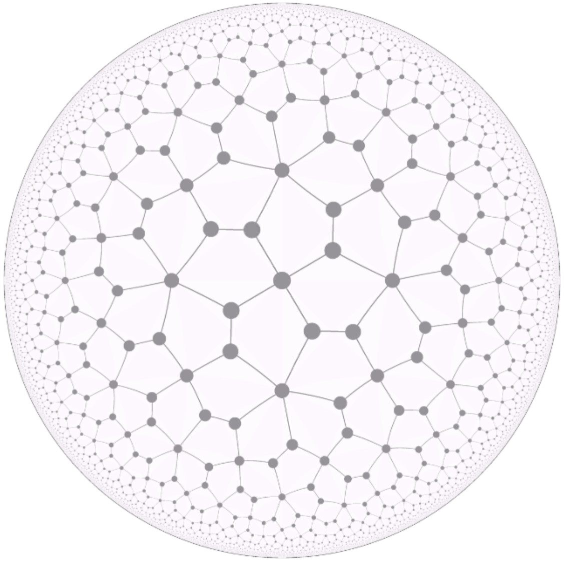
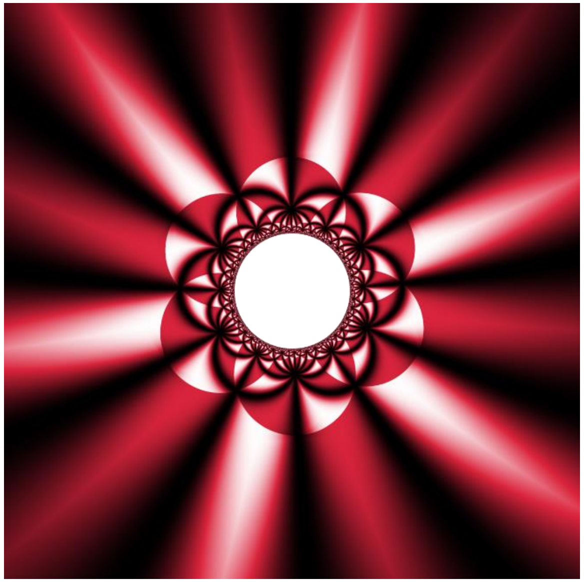
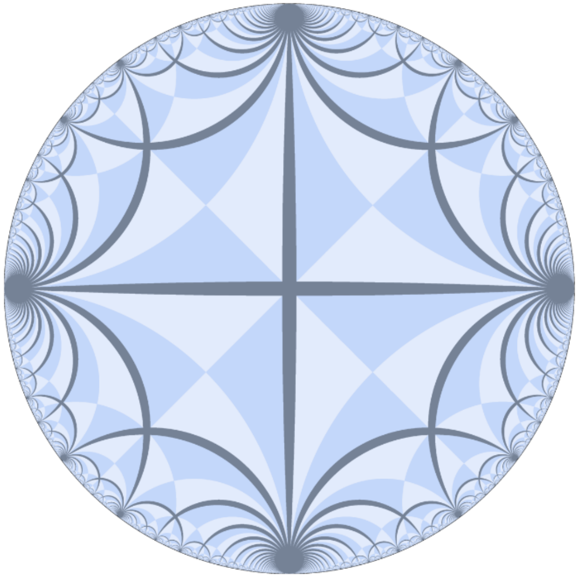
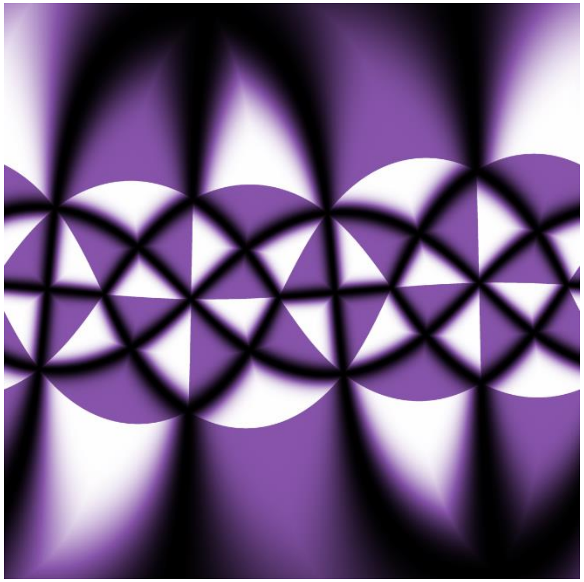
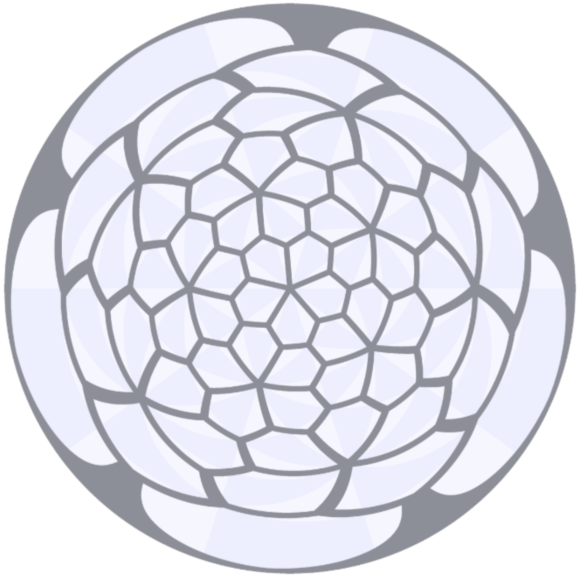
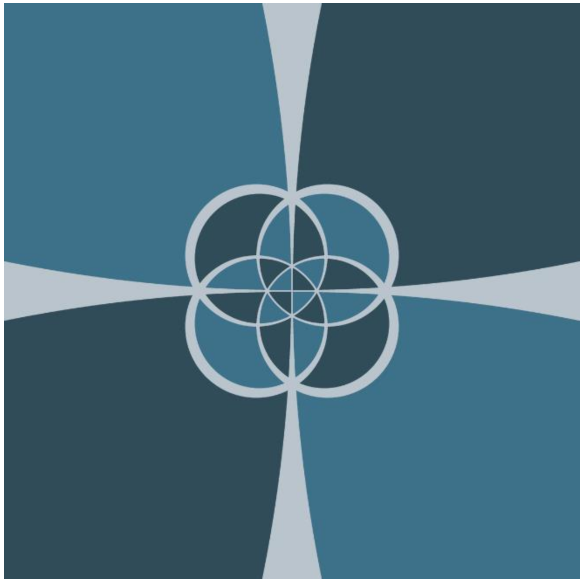




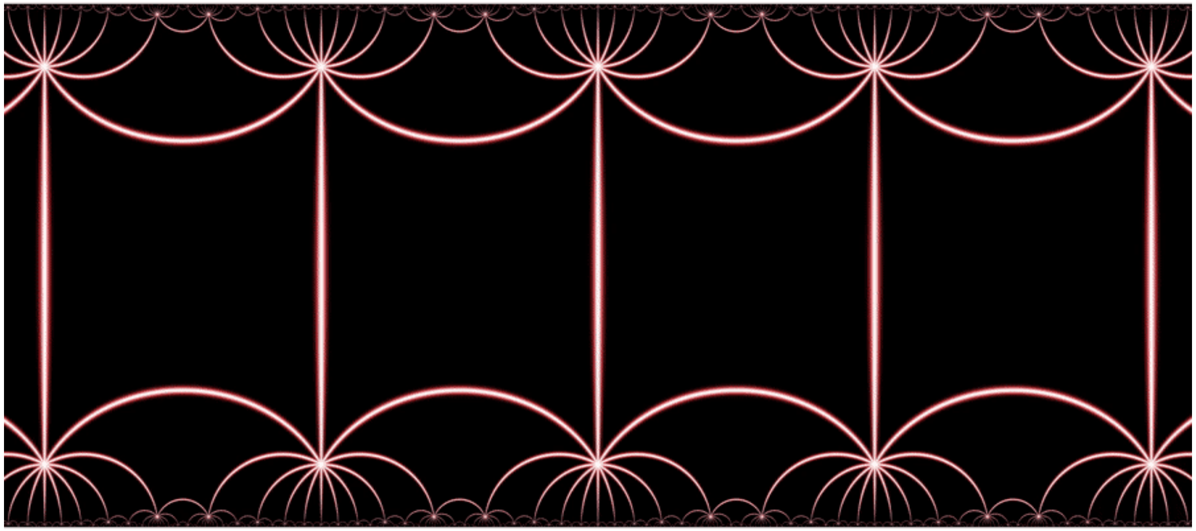
Omnitruncation

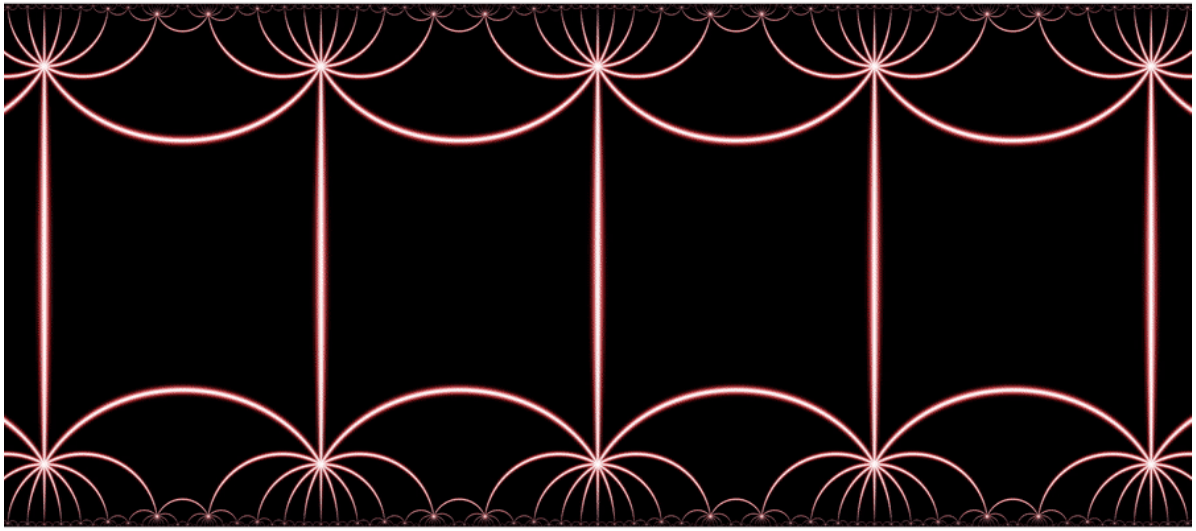


Duals to Uniform (Catalan Tilings)

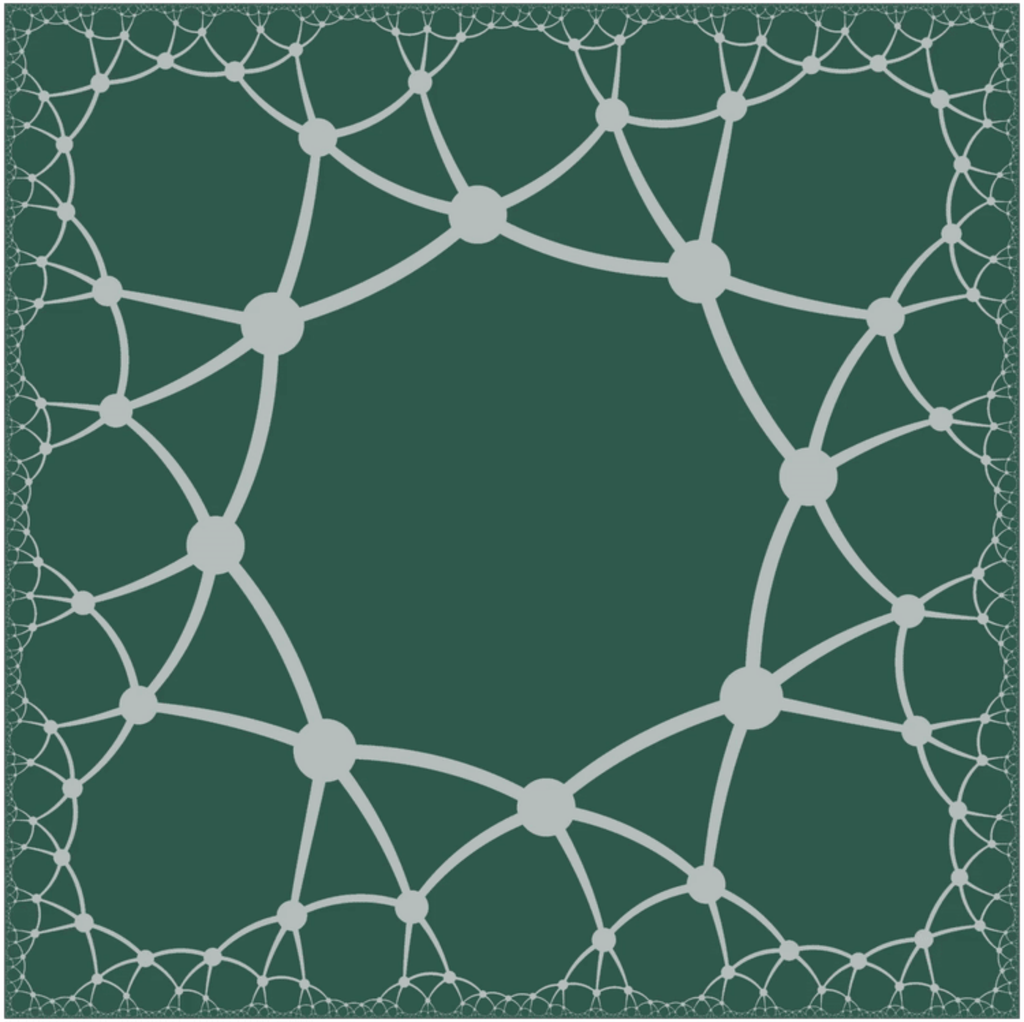







The Same But Different



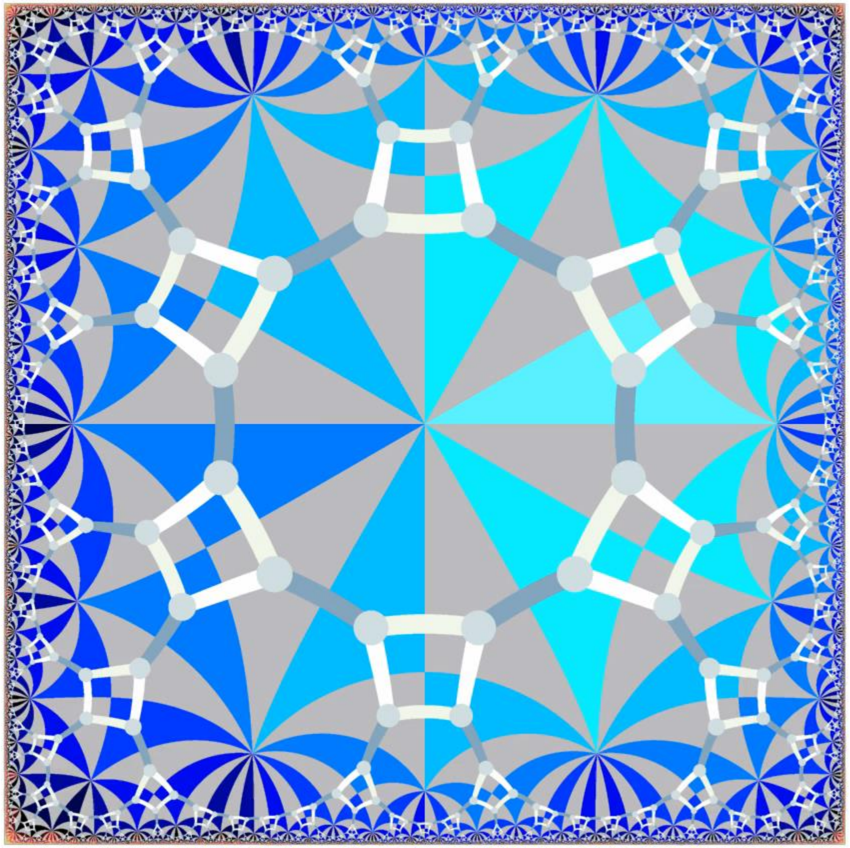


Rotating in a conformal square

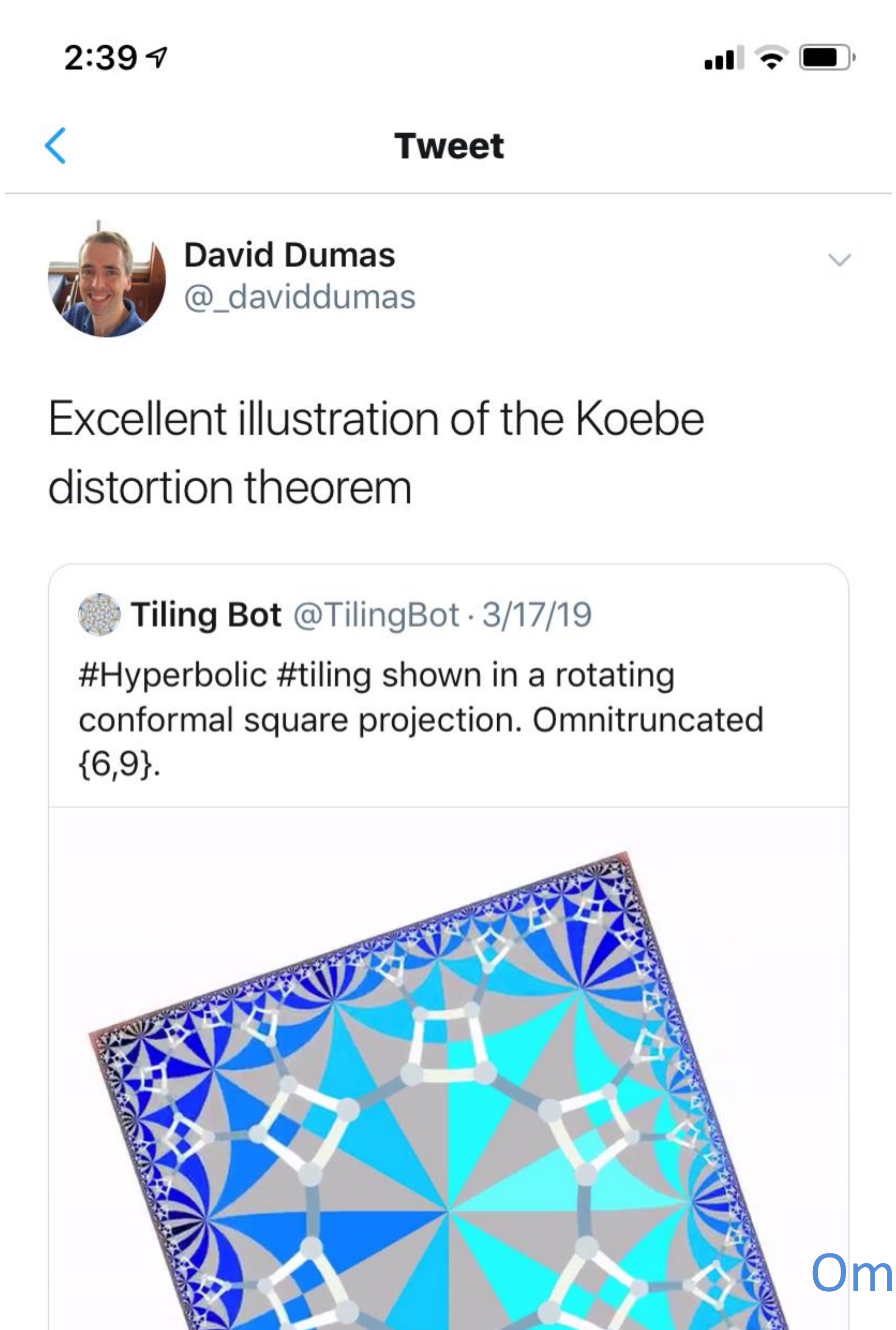


Snub {8,8}

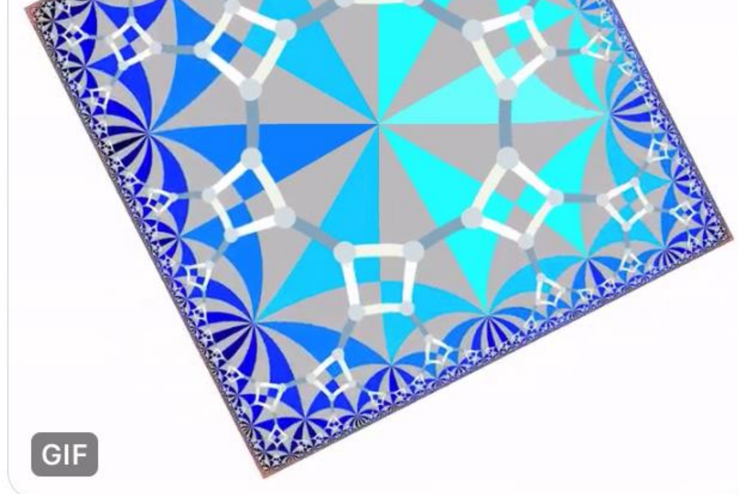
In a rotating conformal square



Omnitruncated {6,9}



Omnitruncated {6,9}



6 151 476

Liquid Plutonium
@LiquidPlutonium

Replying to @TilingBot

Lol 69

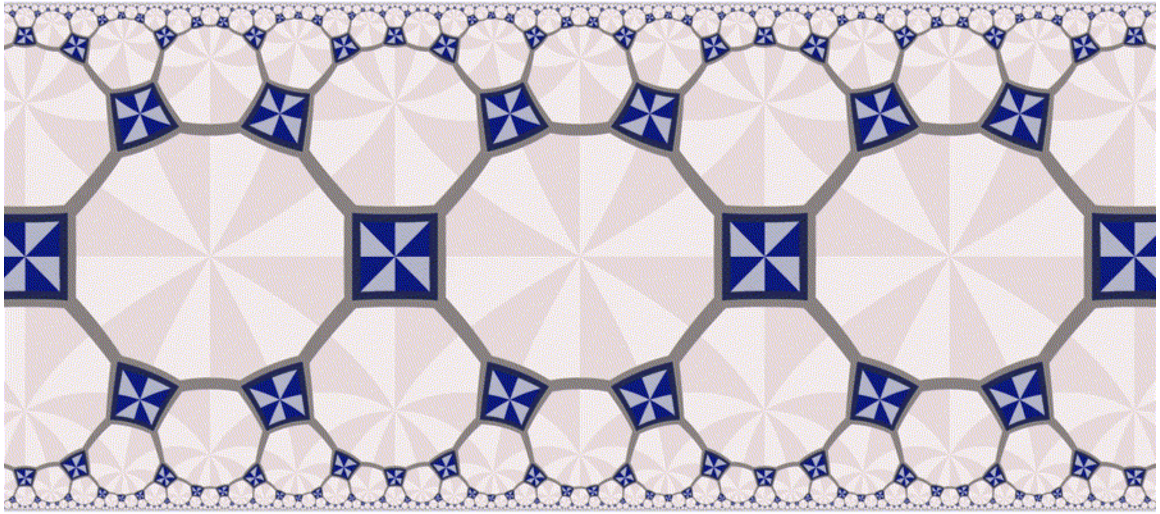
4:21 PM · 3/17/19 · Twitter for Android

Tweet your reply

4

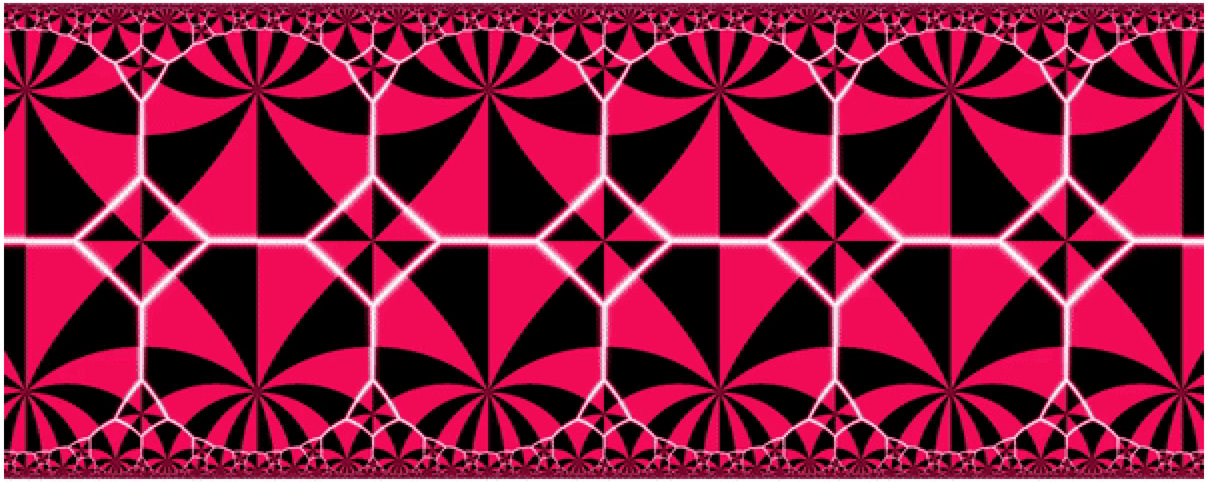
Omnitruncated {6,9}

Rotating in the band model



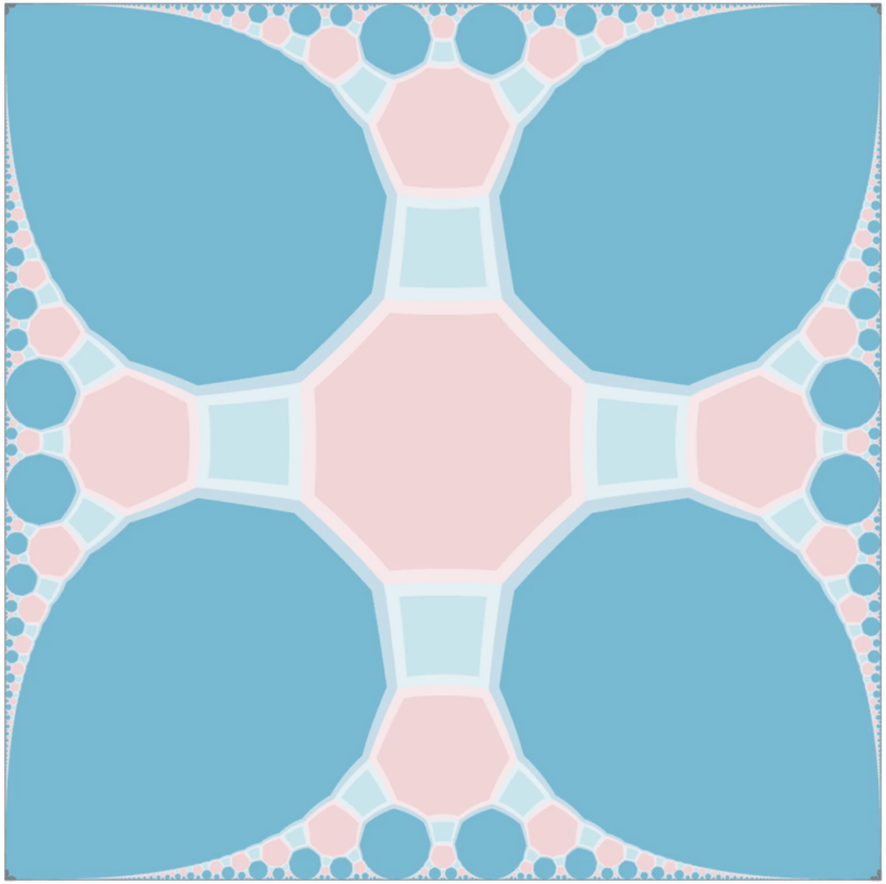
Truncated {6,4}

In a rotating band model

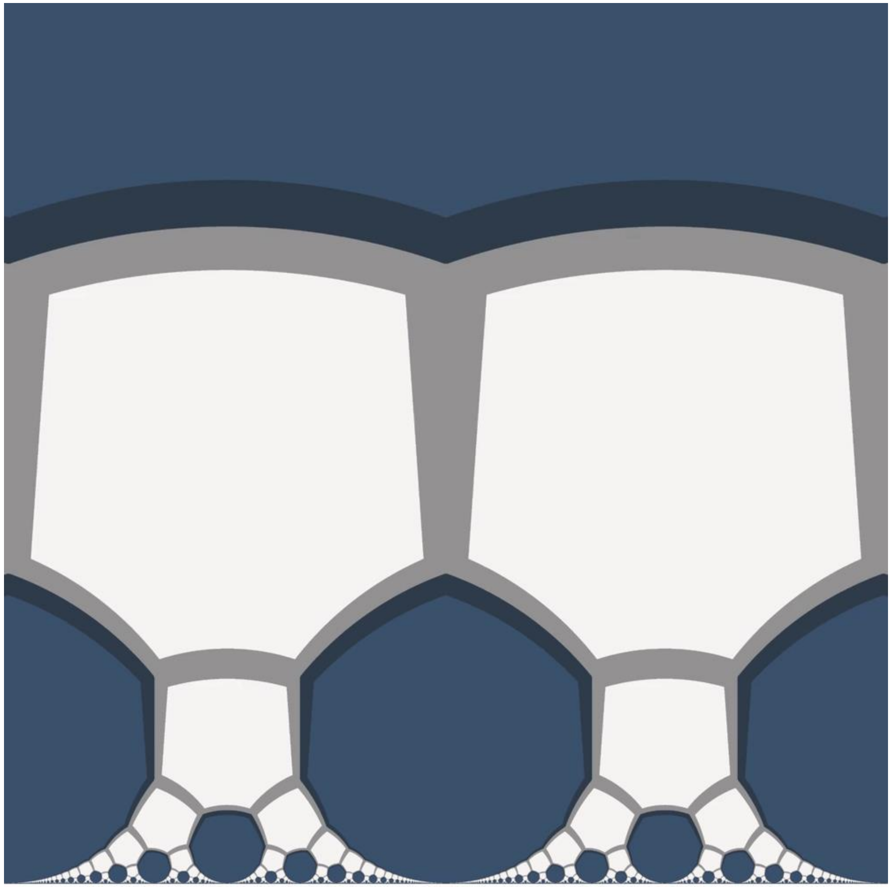


Truncated {8,4}

Limit Rotations



Omnitruncated {4,∞}

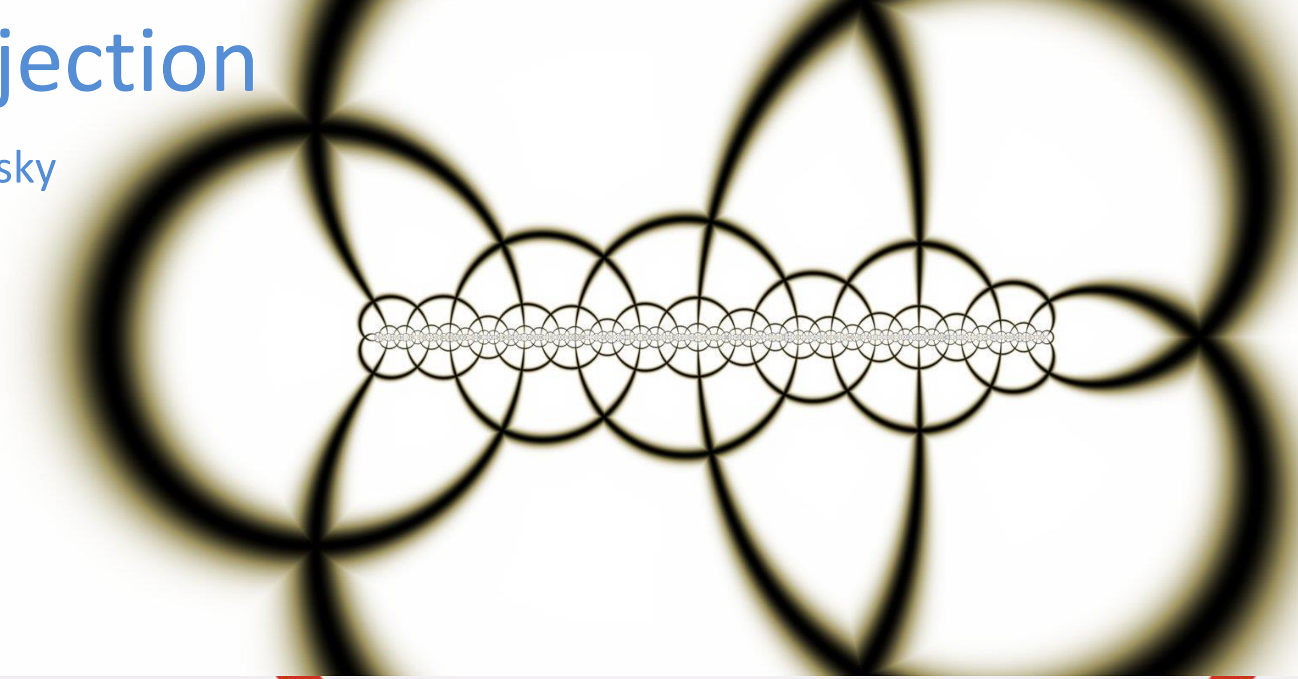


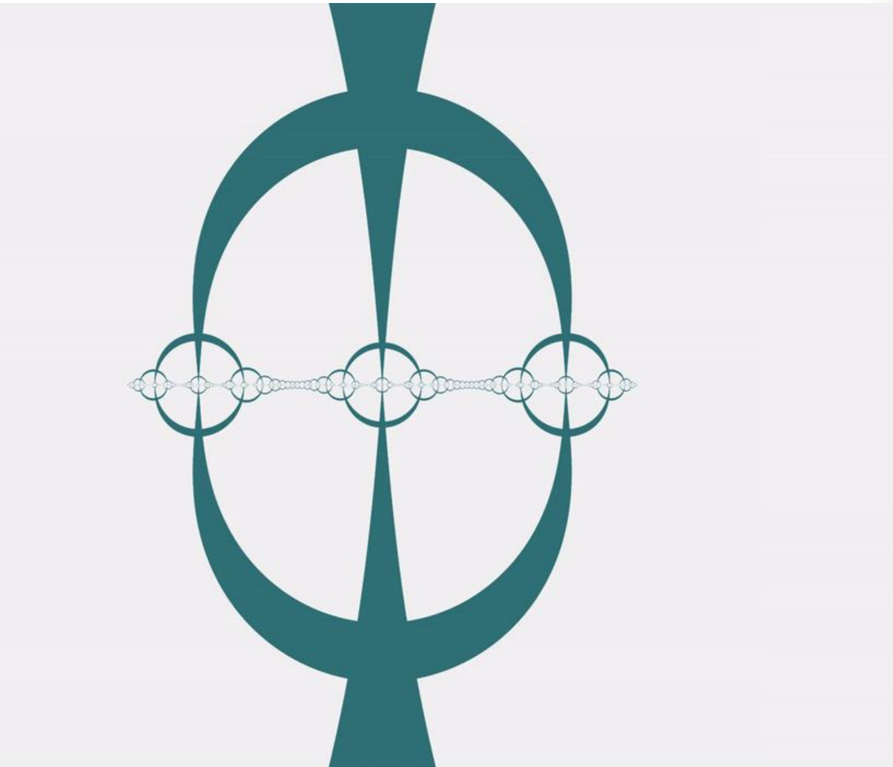
Truncated {3,∞}

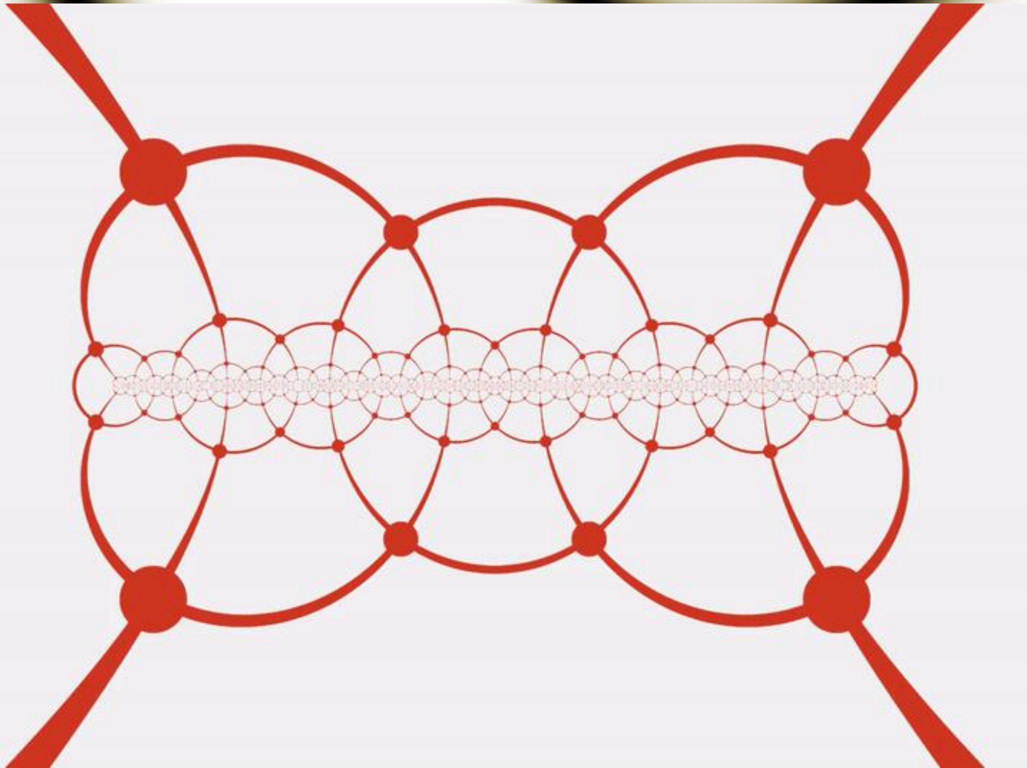
Joukowsky projection

named after Nikoli Zhukovsky

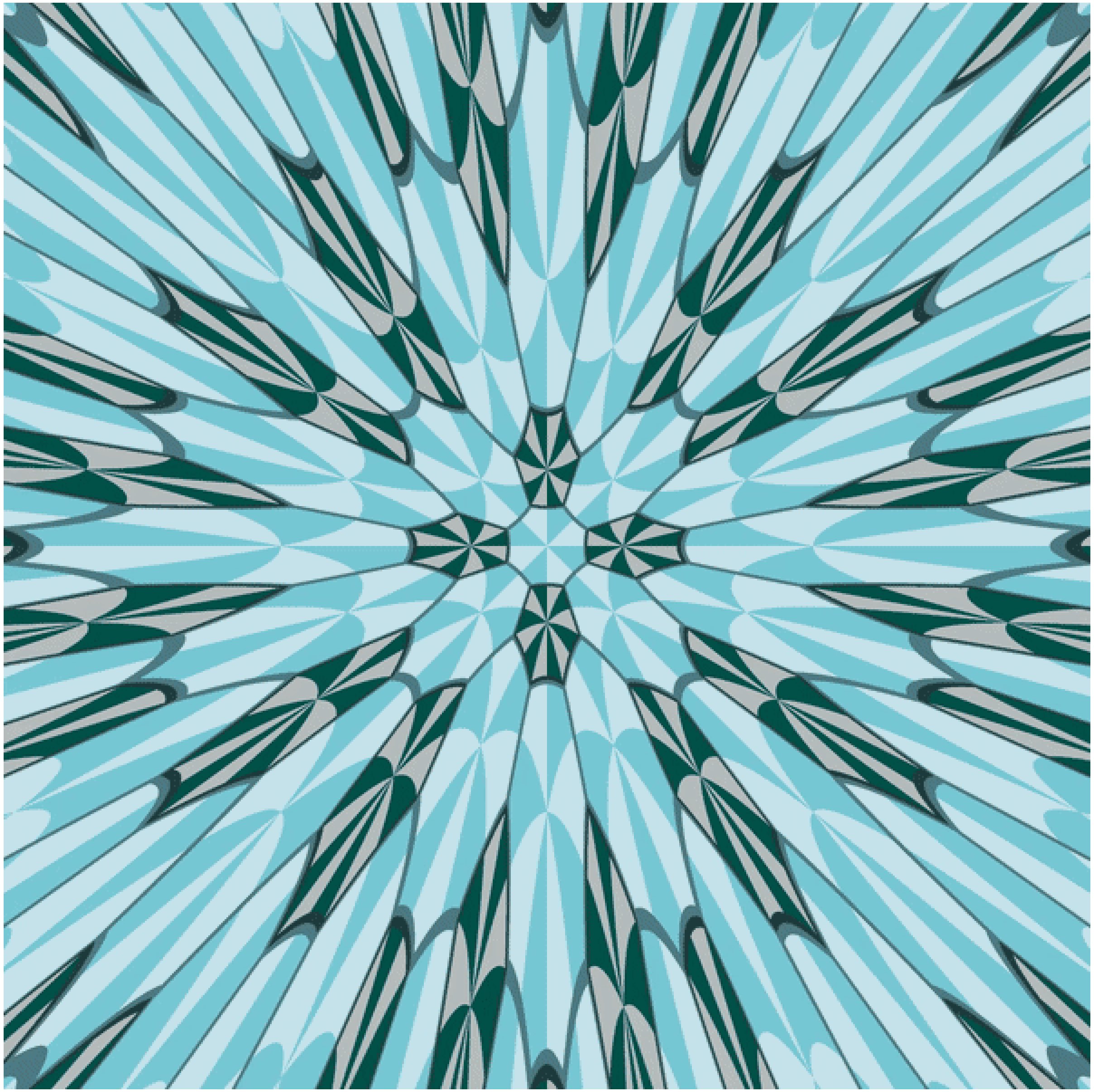
$$z = \frac{1}{2}\left(\zeta + \frac{1}{\zeta}\right)$$

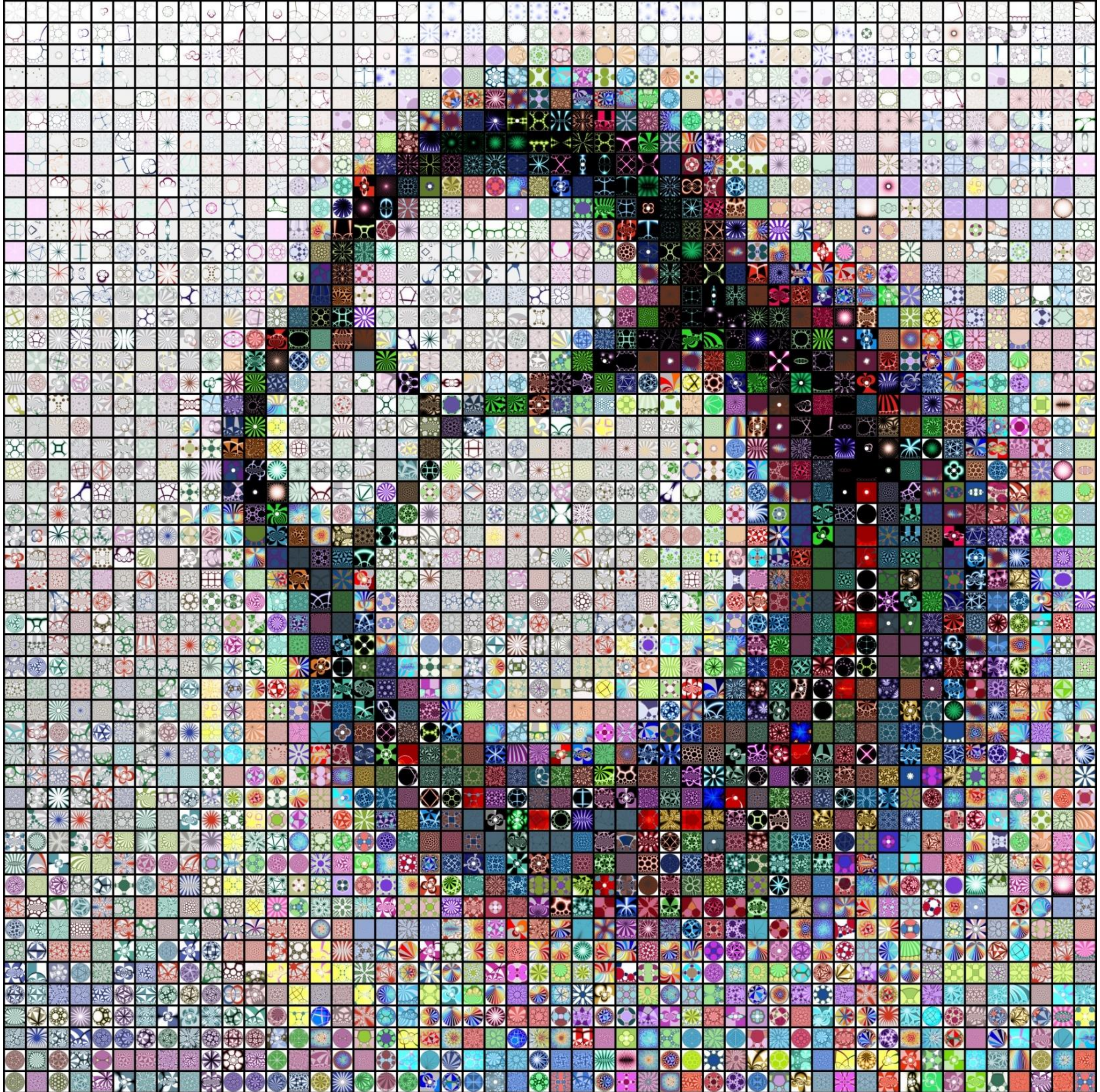






The best internal representation?





roice3.org/icerm

Thank you!