SCIENTIFIC COMPUTING AND IMAGING

INSTITUTE

www.sci.utah.edu

# Advanced Visualization of Magnetic Field Data

Allen R. Sanderson
Xavier Tricoche
Christoph Garth


UNIVERSITY OF UTAH

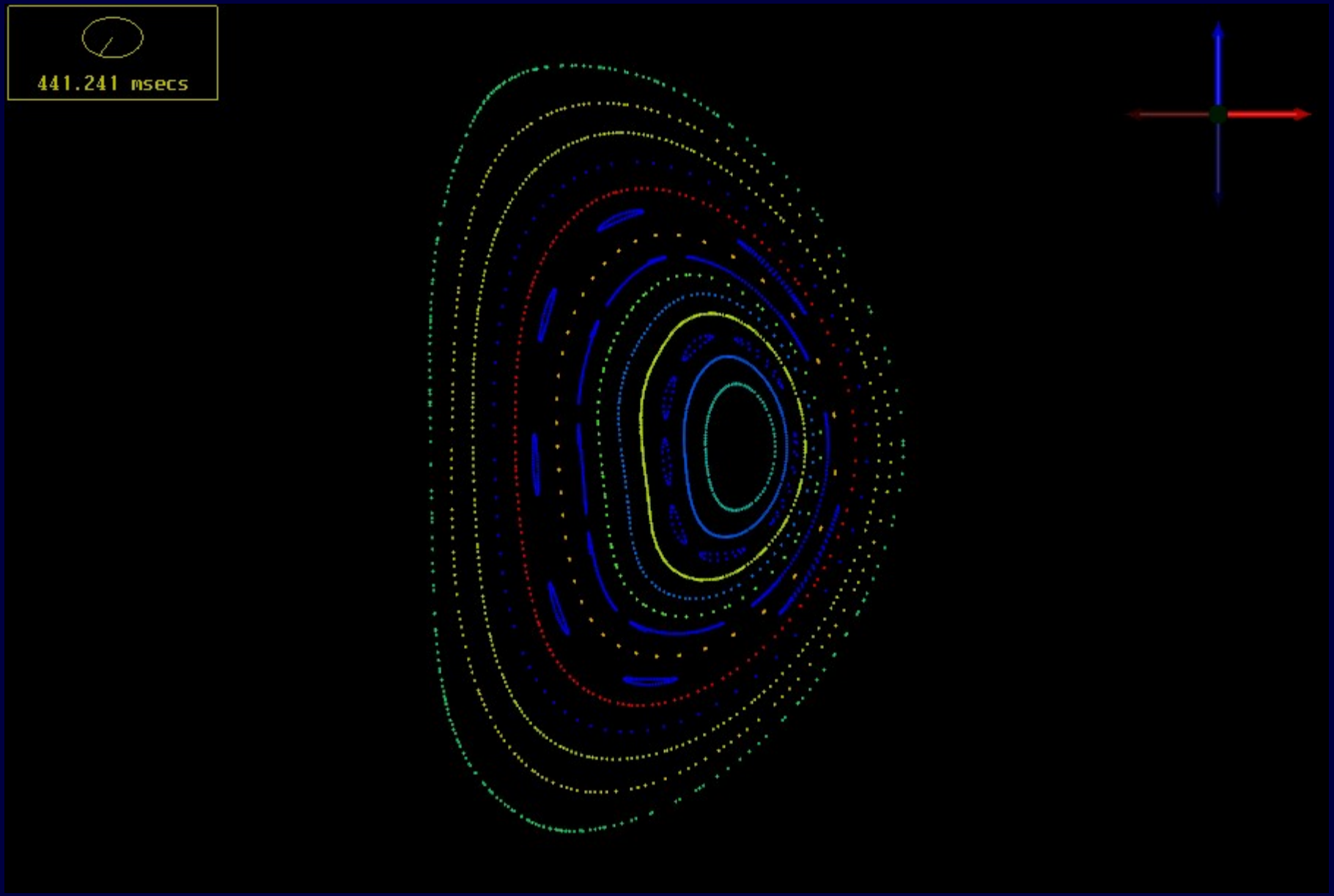

THE UNIVERSITY OF UTAH

# Research Focus

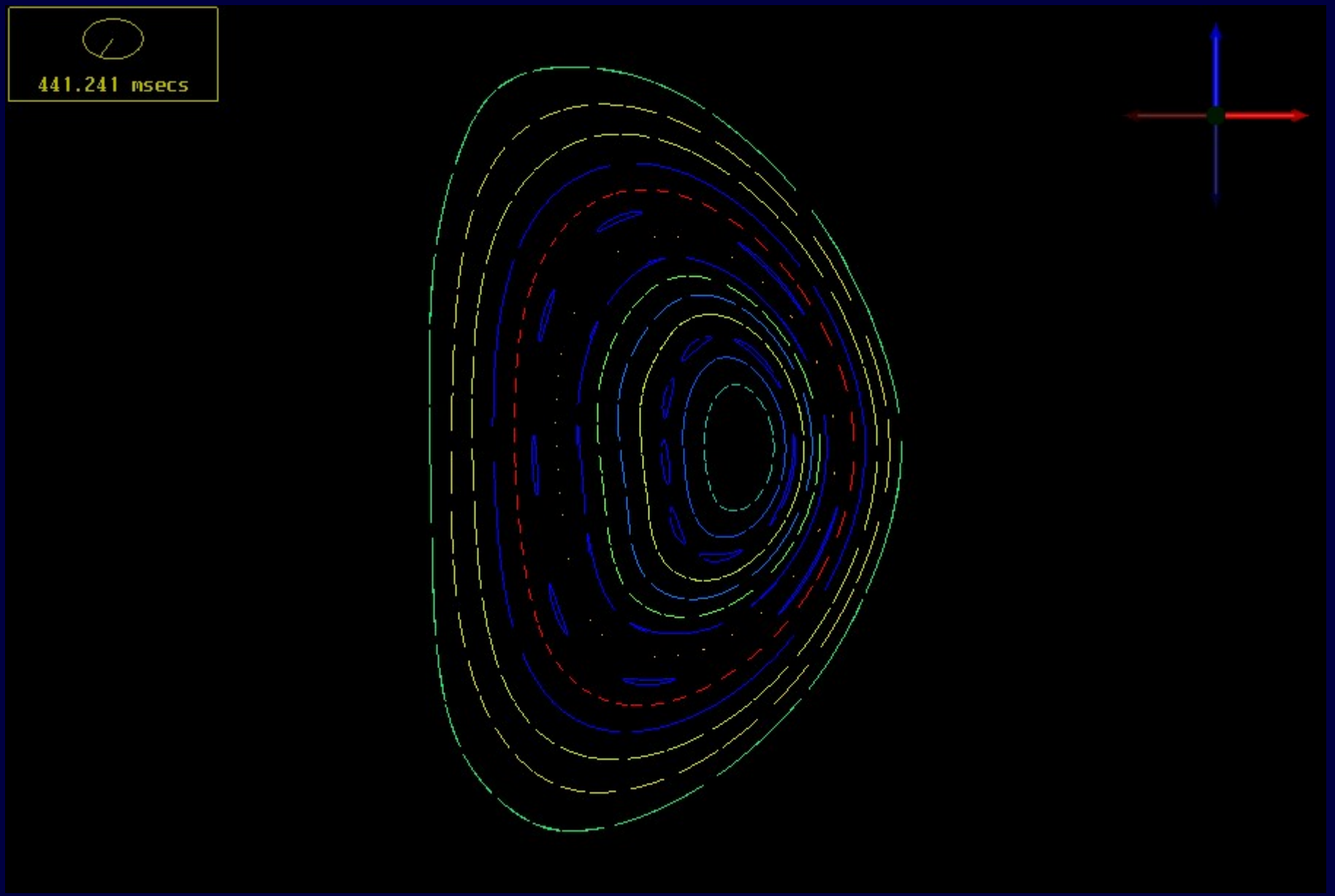
## Poincaré Based Techniques

- By definition Poincaré plots are discrete points with no explicit correspondence.
- This is really a loss in information when the safety factor is known or can be calculated.
- Safety factor provides connectivity between points.

# Poincaré plots - unconnected points



# Poincaré plots - connected points



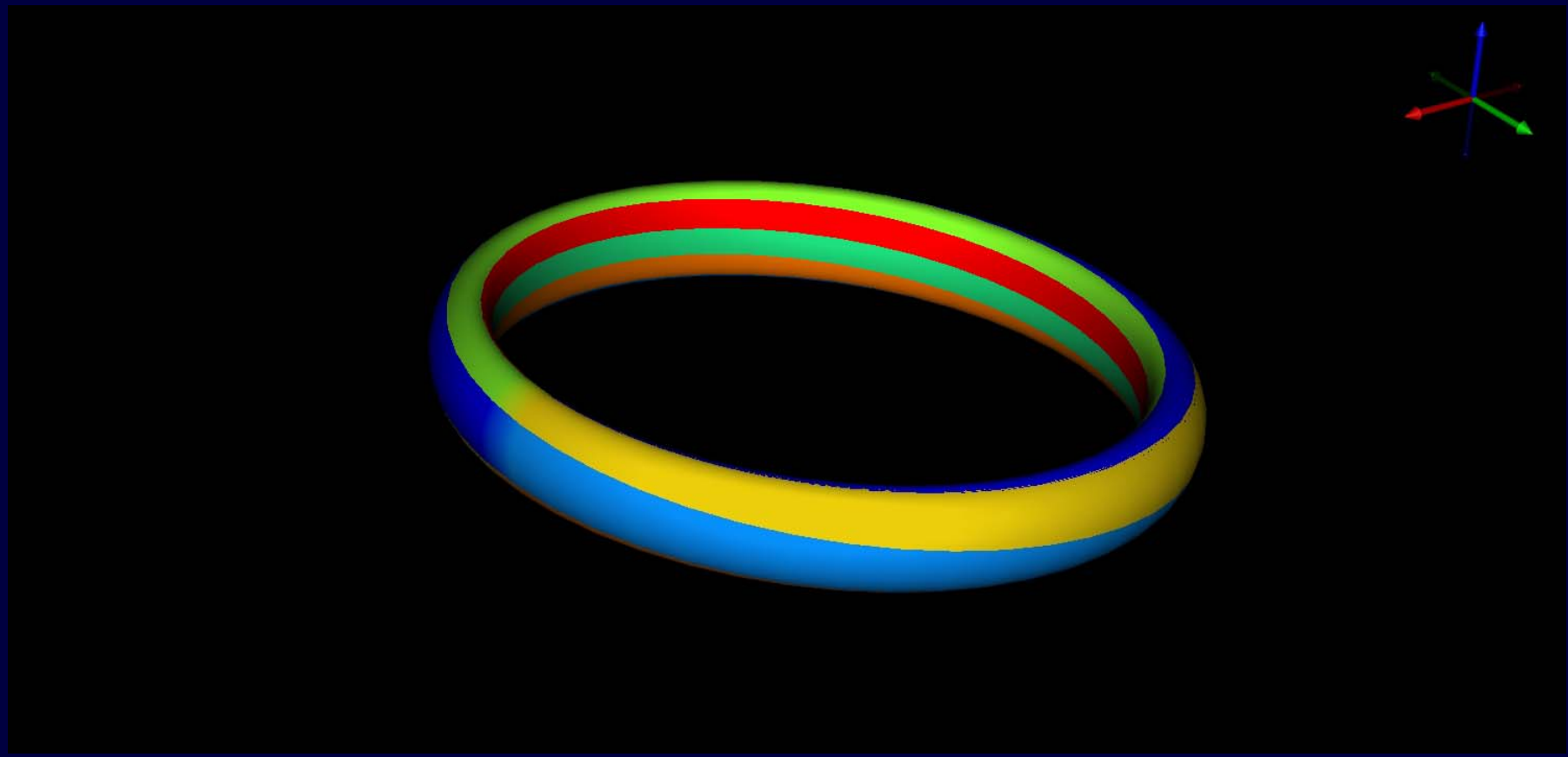
# Poincaré Plots

## Connected Points Benefits

- Fewer points are needed
  - Computationally more efficient
  - More accurate because less integration is needed
- Can see the number of windings of each surface
- Truer representation of the intersection of the flux surface and a poloidial plane
- Can reconstruct flux surfaces using the points
  - Can overlay color on the surfaces to visualize different features

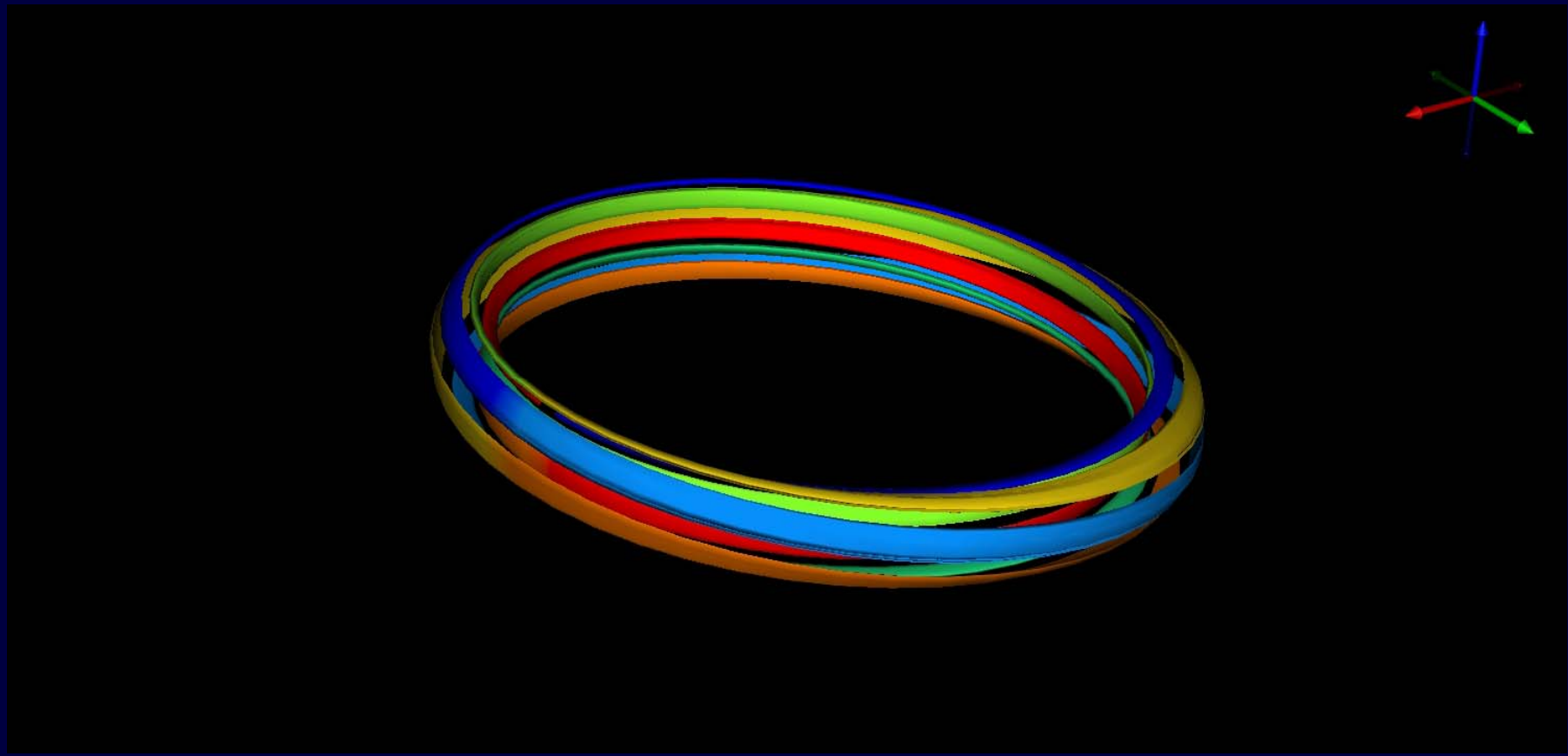
# Poincaré Plots - Connected Points

7:2 Flux Surface - color represents one rotation



# Poincaré Plots - Connected Points

## 7:2 Flux Surface as islands

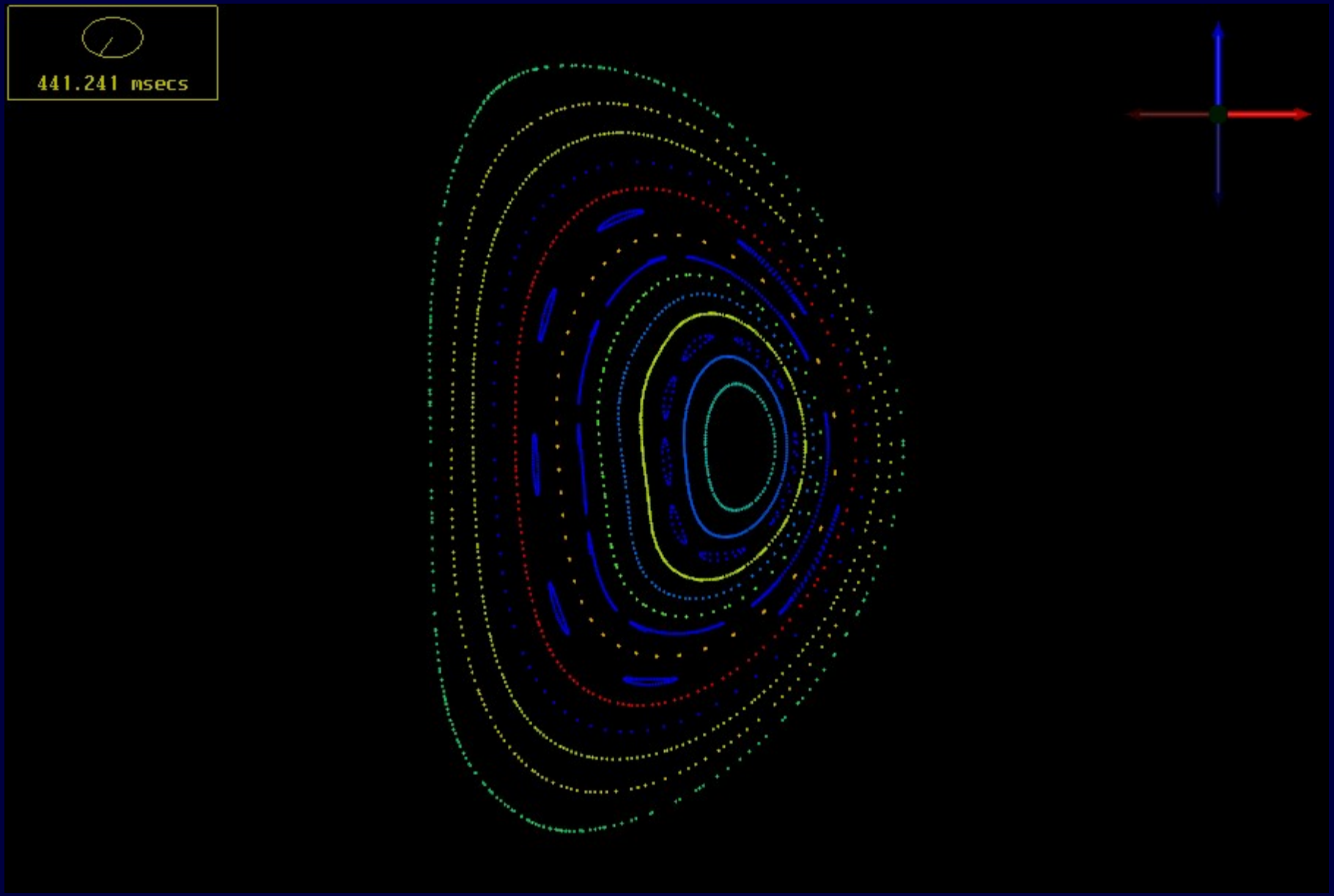


# Poincaré Plots

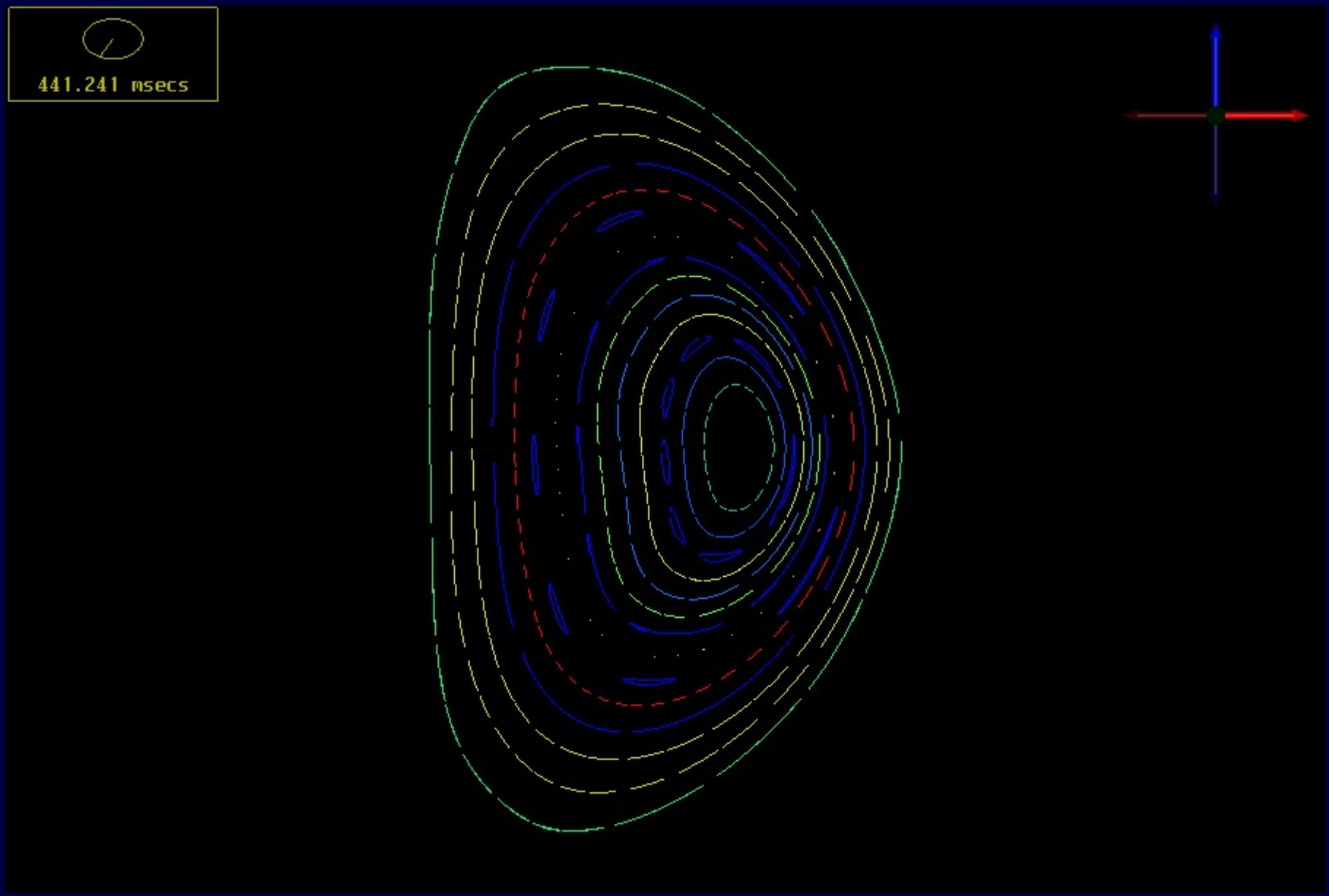
## Connected Points give geometry

- Geometric detection of islands
- Geometric detection of O Points
- Geometric detection of X Points (gross approximation)

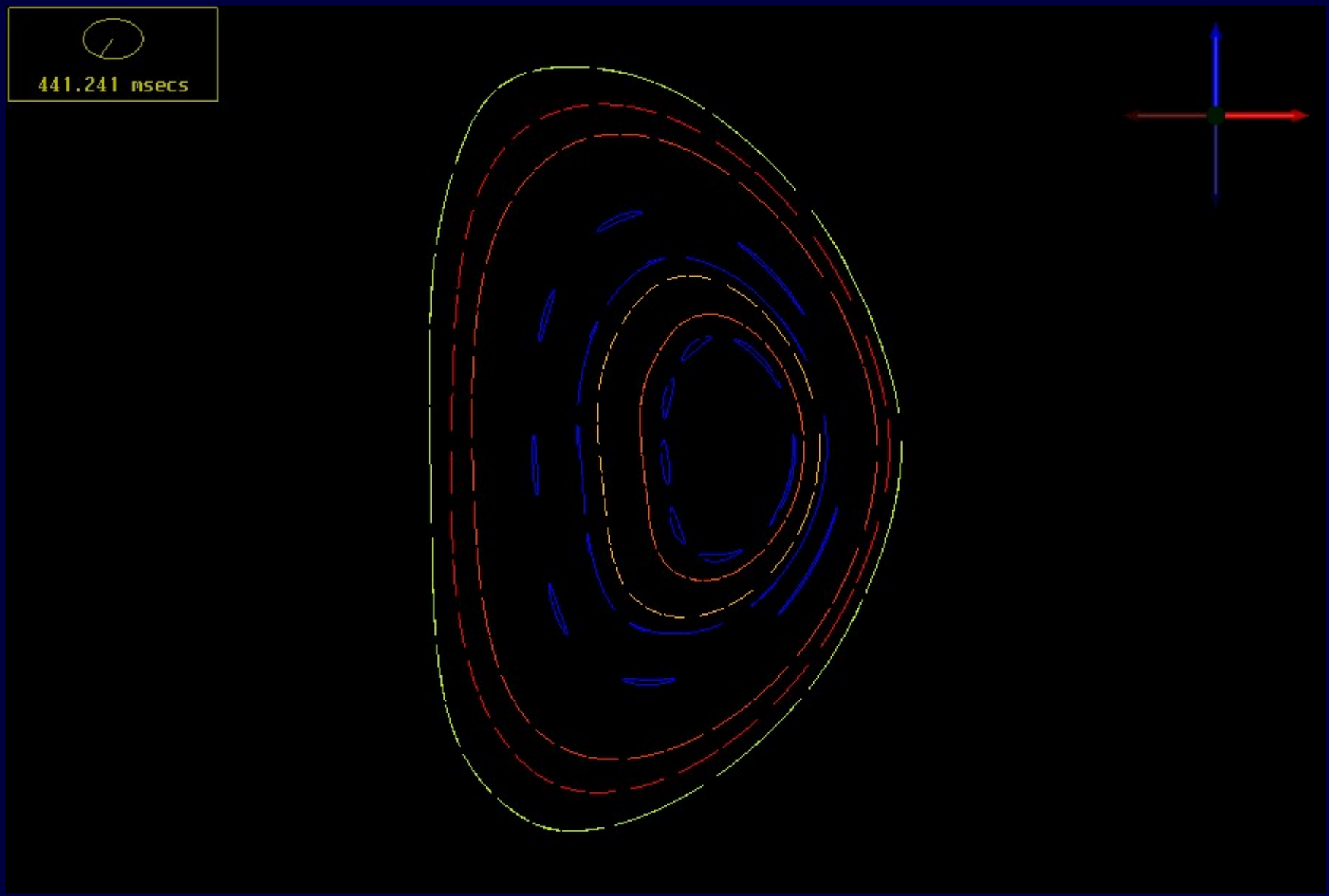
# Poincaré plots - Points



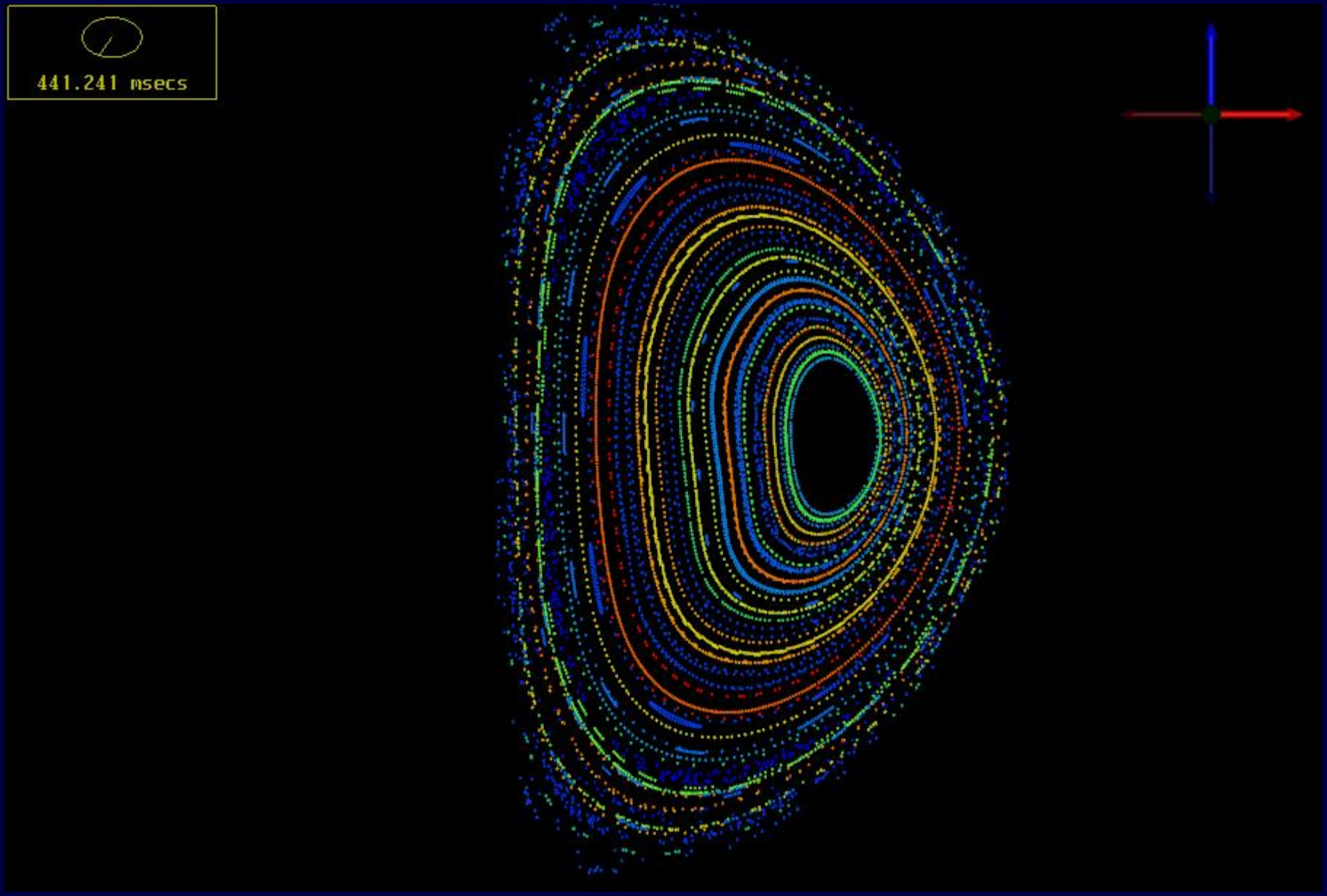
# Poincaré plots - Edges



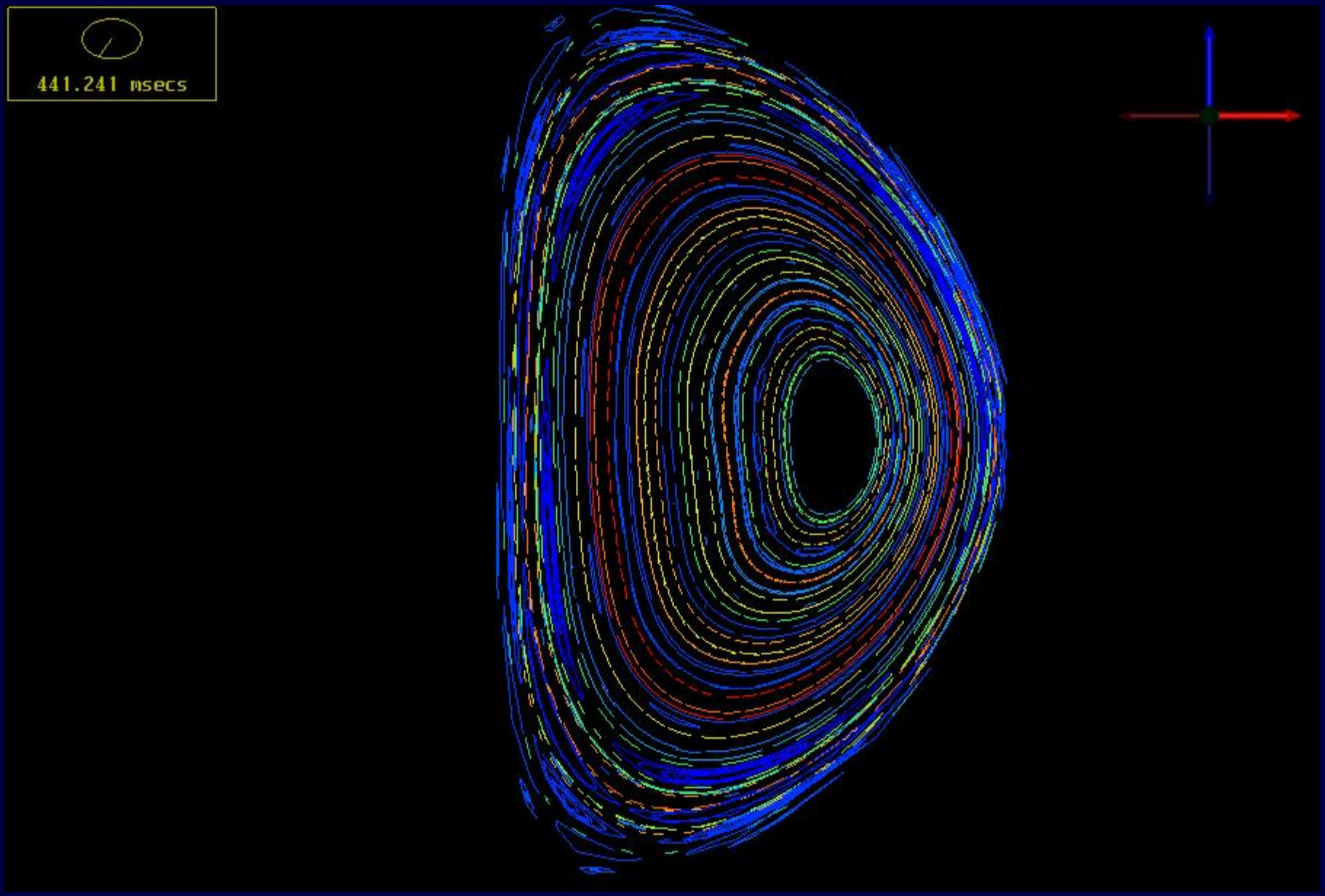
# Poincaré plots - Inlands Only



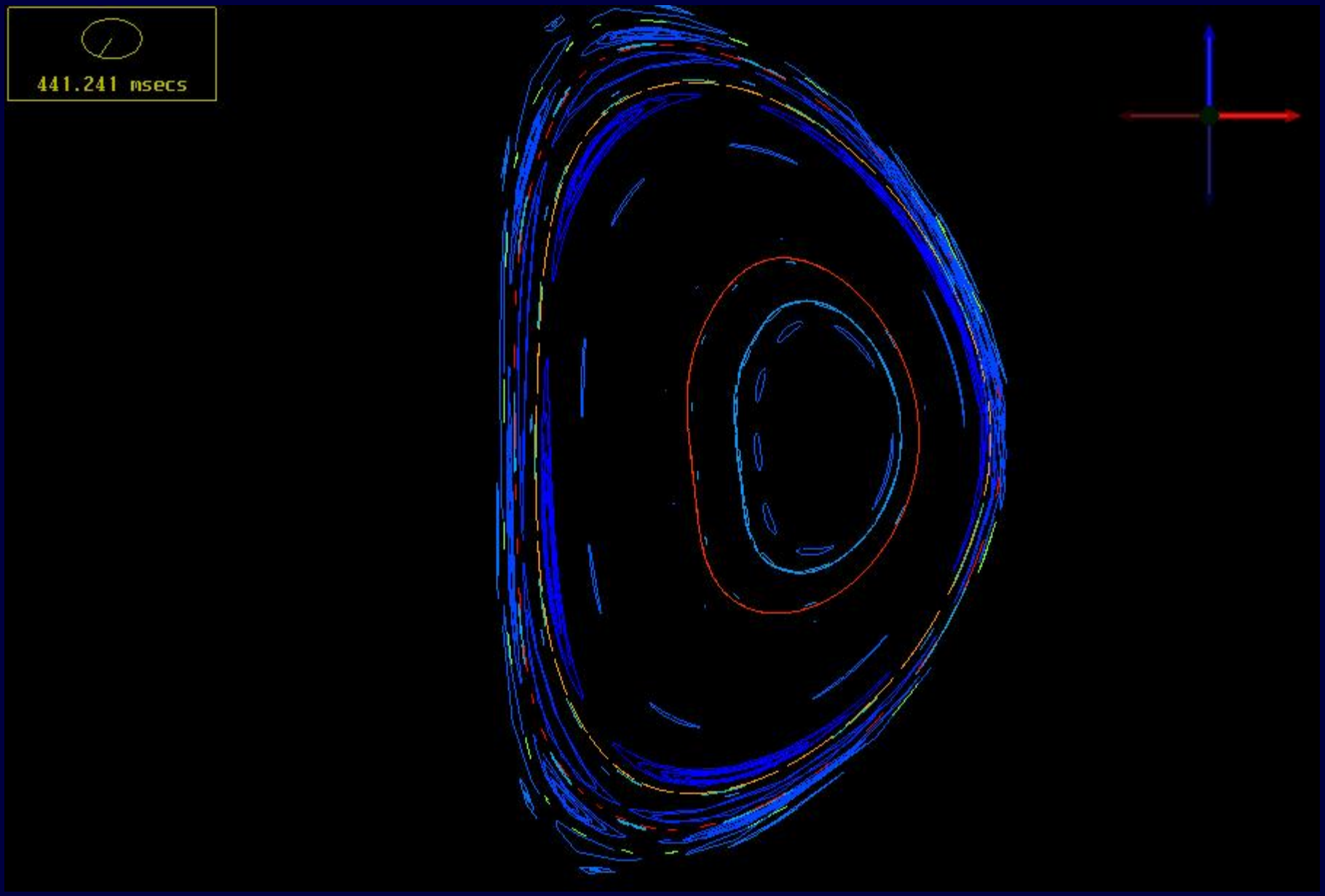
# Poincaré Plot - Points



# Poincaré Plot - Edges

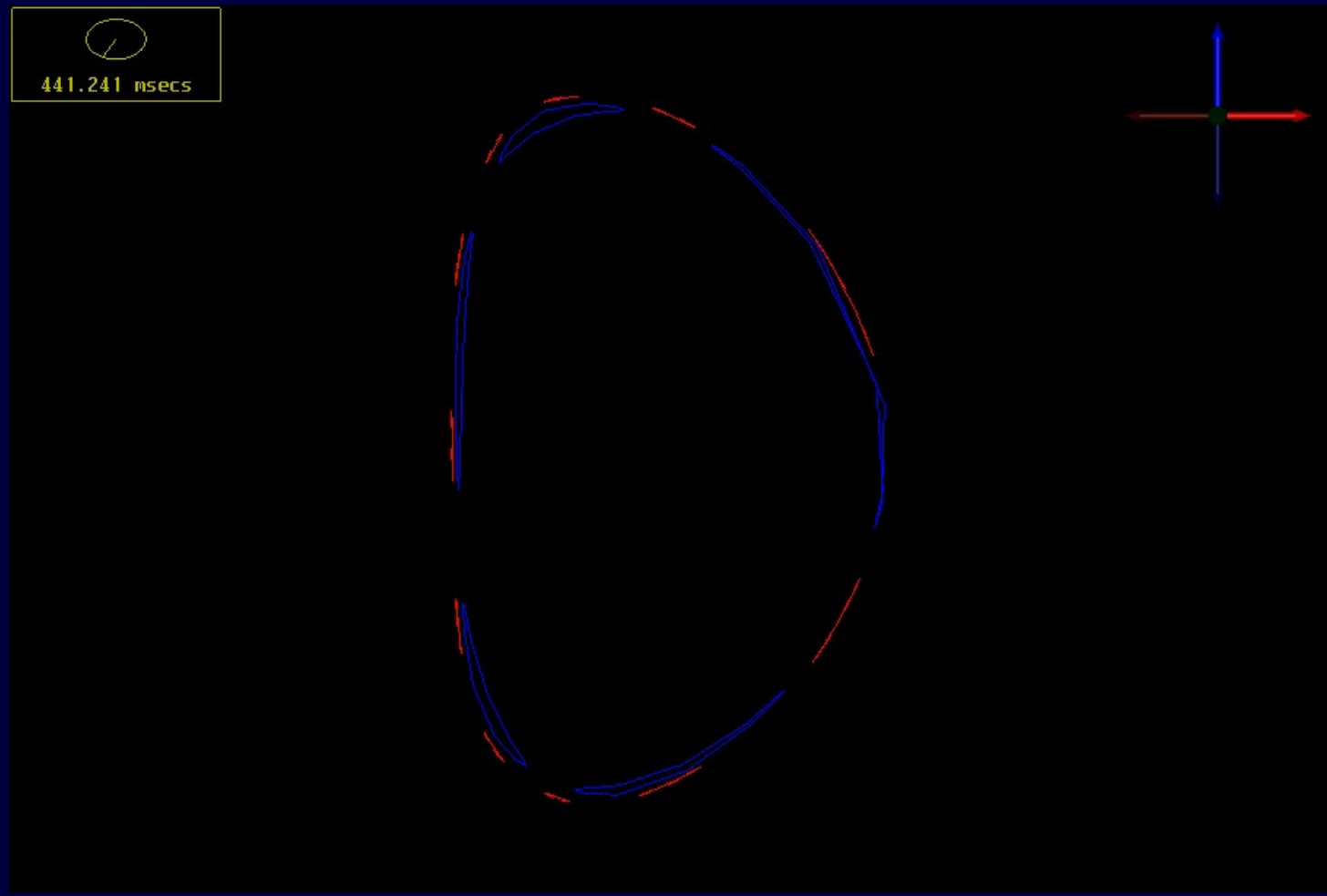


# Poincaré Plot - Islands only



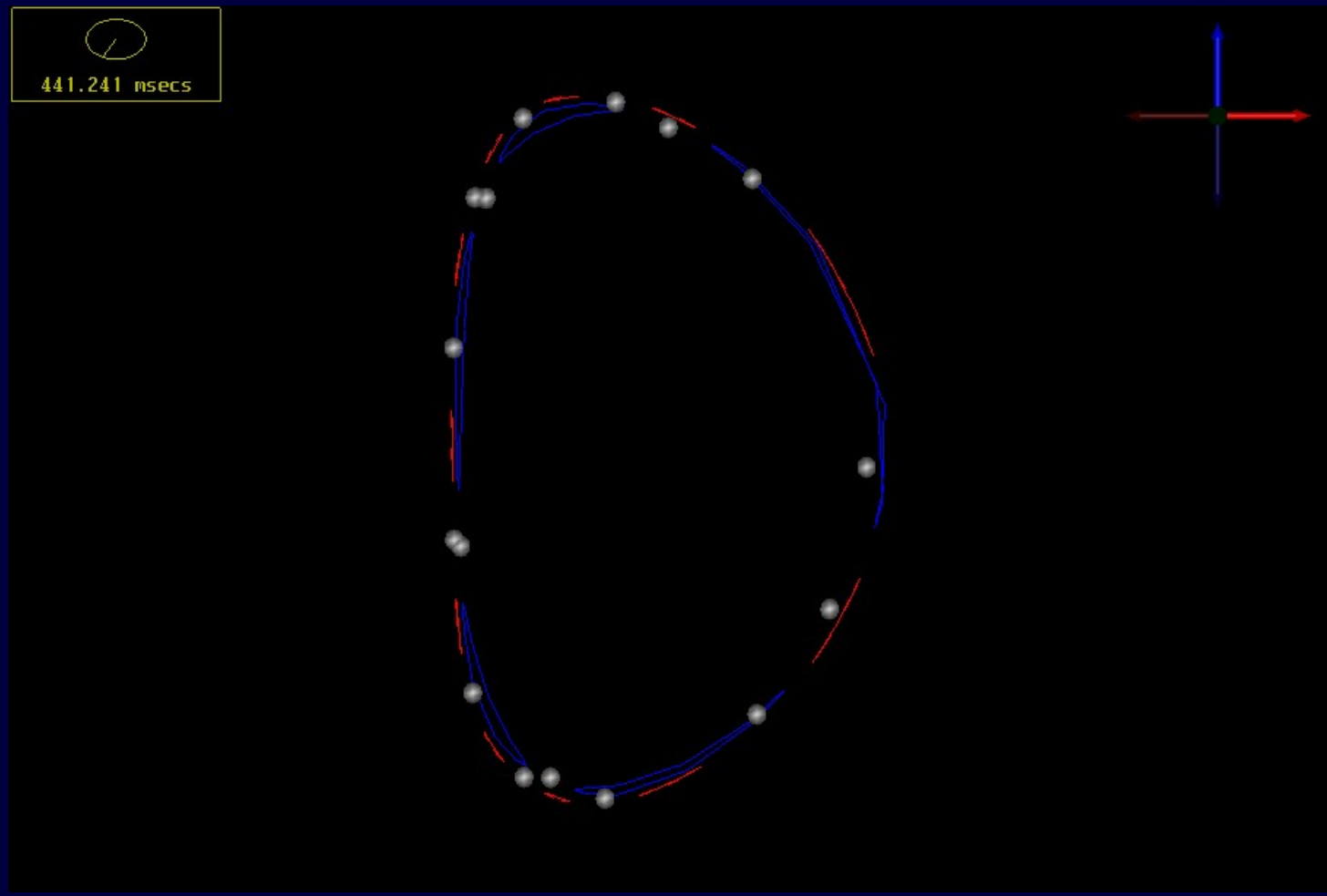
# Poincaré Plots - Islands

## Islands Detection - 5:1 (blue) and 11:2 (red) Surfaces



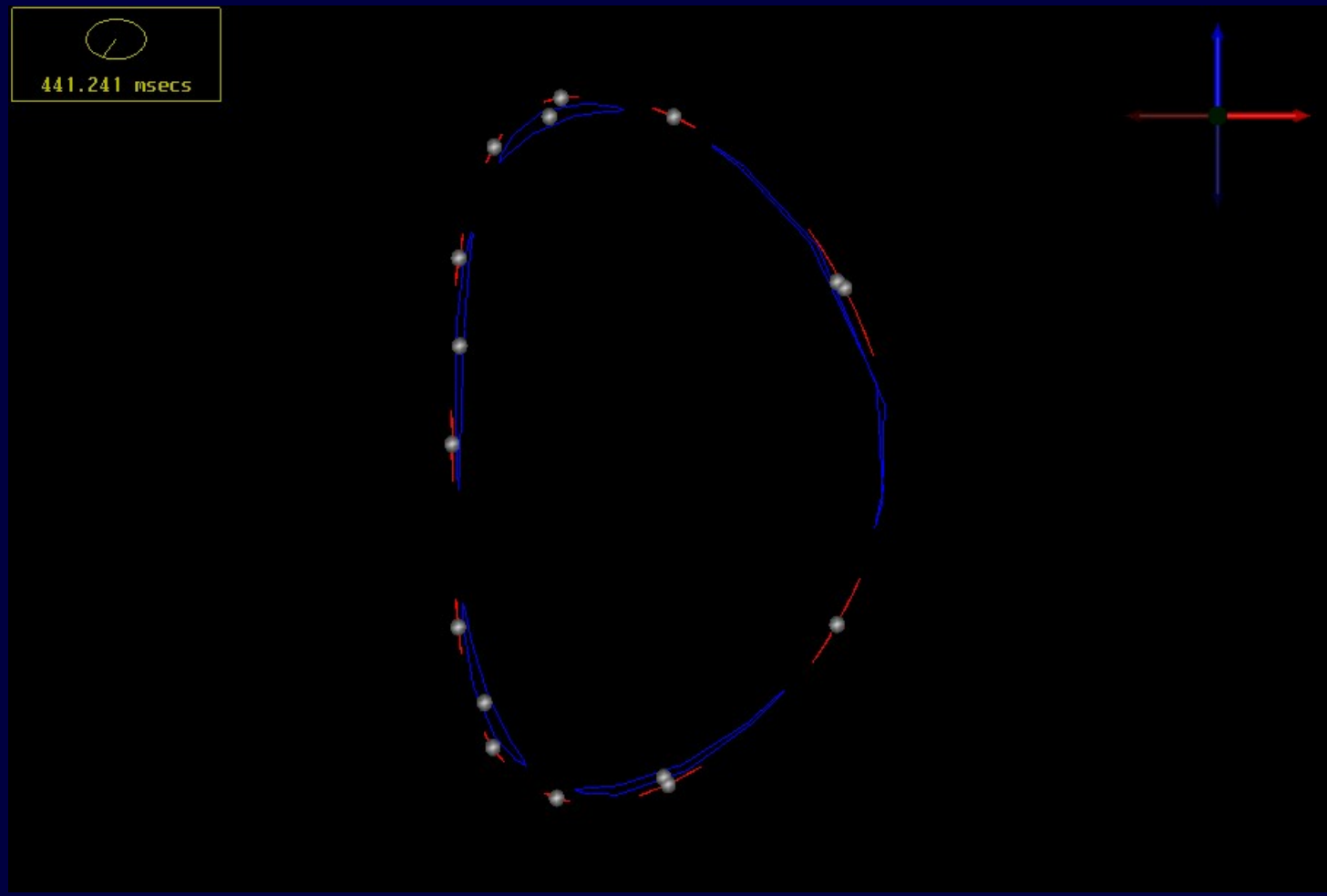
# Poincaré Plots - X Points

Islands to X Points - via mid point of the island extrema



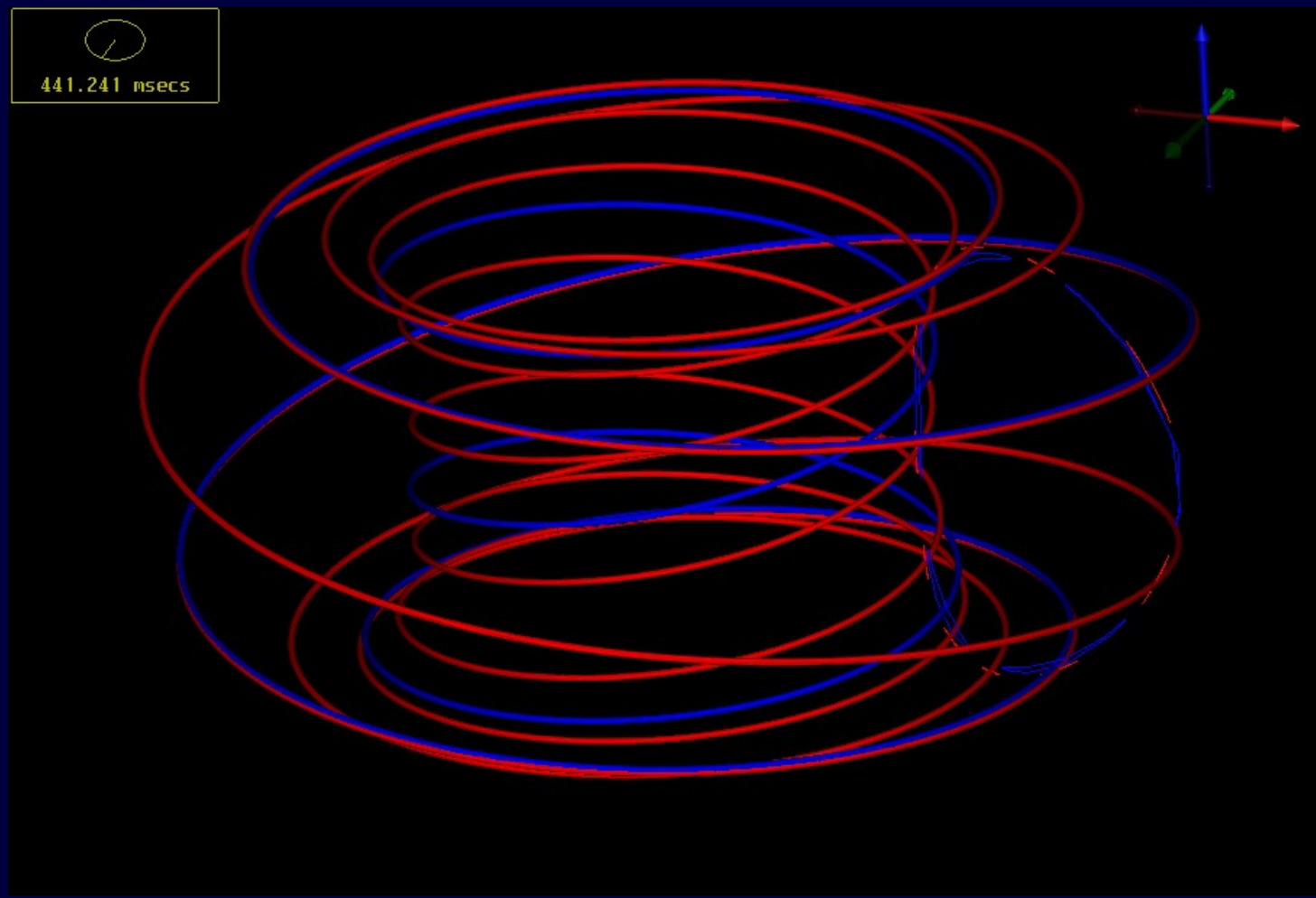
# Poincaré Plots - O Points

## Islands to O Points - iterative technique



# Poincaré Plots - O Points

O points as seeds for fieldlines

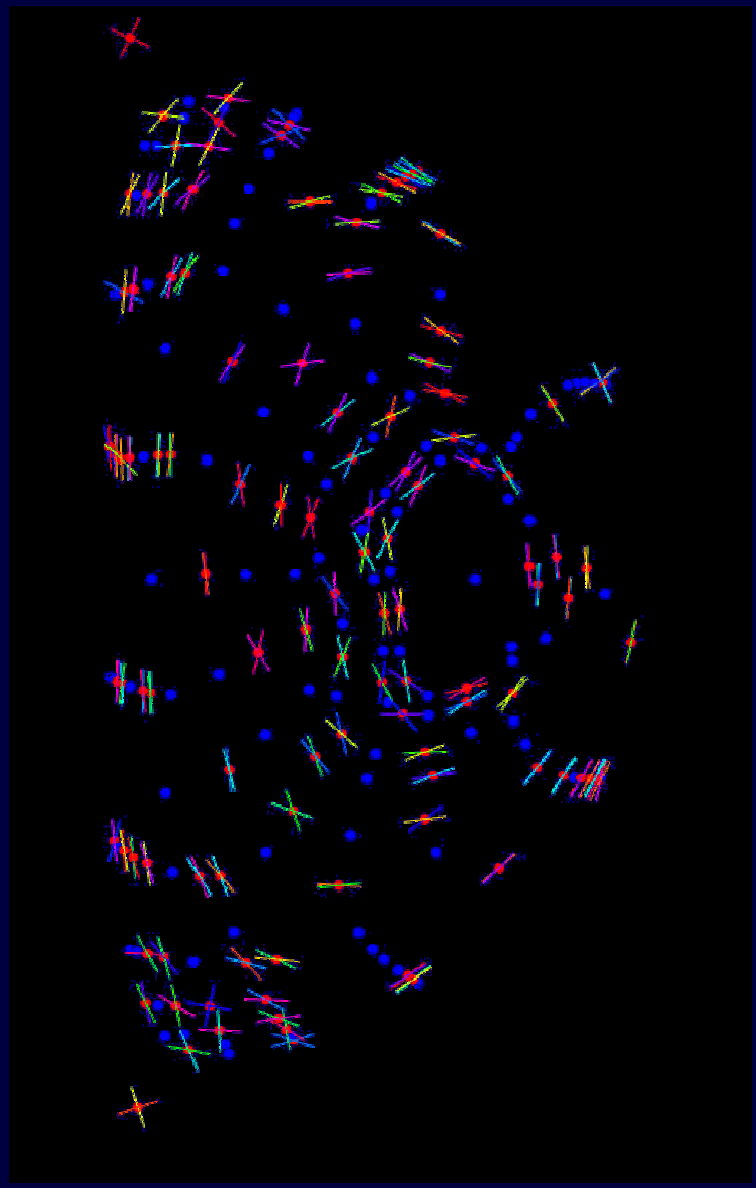


# Poincaré Plots - X and O Points

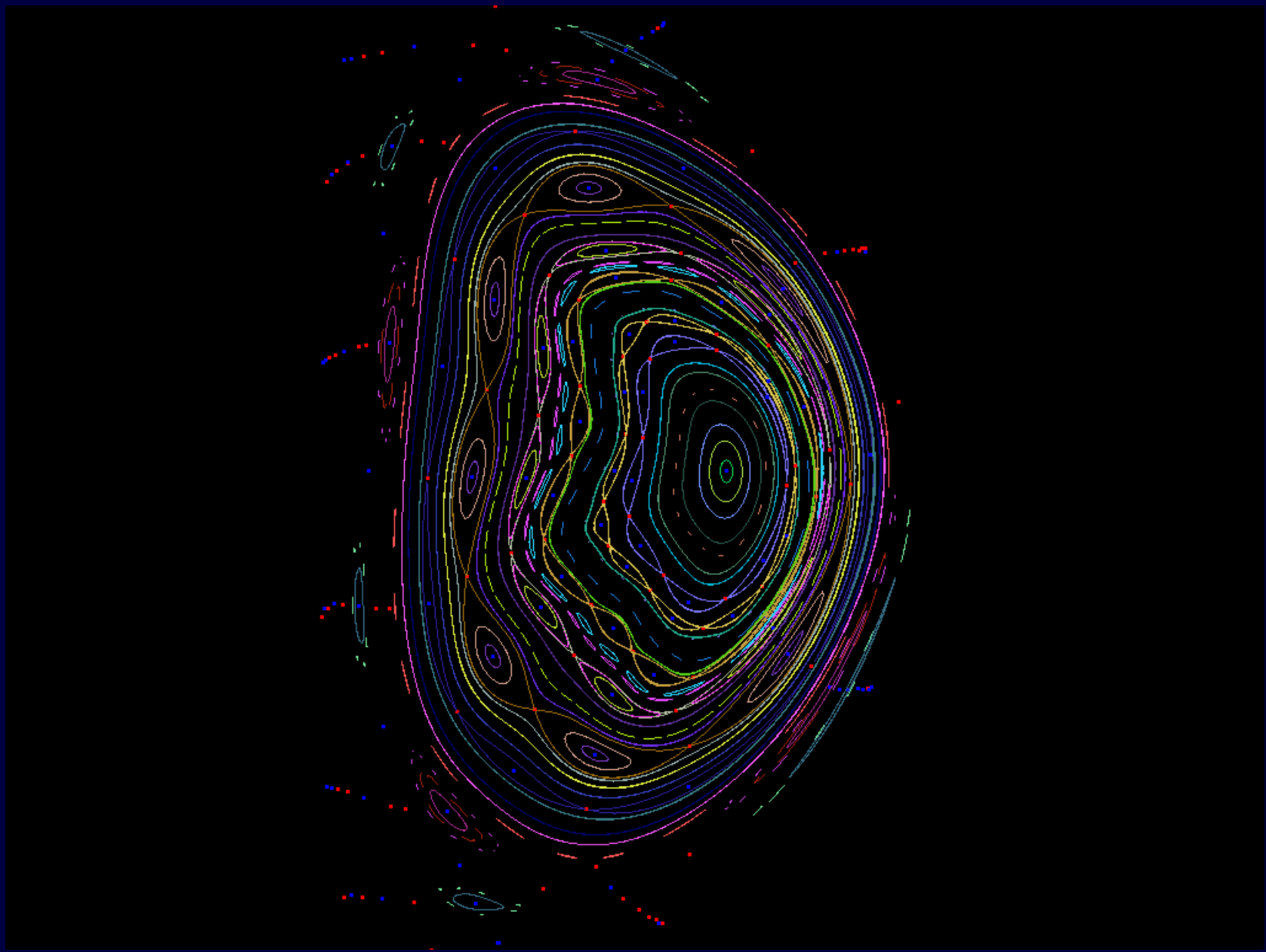
## Brut force numerical search

- Coarse Delaunay triangulation with ~1,500 points
- Assume a winding k=[1,10]
- Calculate the distance from the starting point to final point for each fieldline for a given winding.
- Look for a local minimum based on the grid connectivity
- Numerical search using a combination of Newton-Rasphson and Broyden to find exact location where the distance from the starting point to final point for a fieldline is approximately zero.

# Poincaré Plots - X and O Points



# Poincaré Plots - Separatrices



# Poincaré Plots

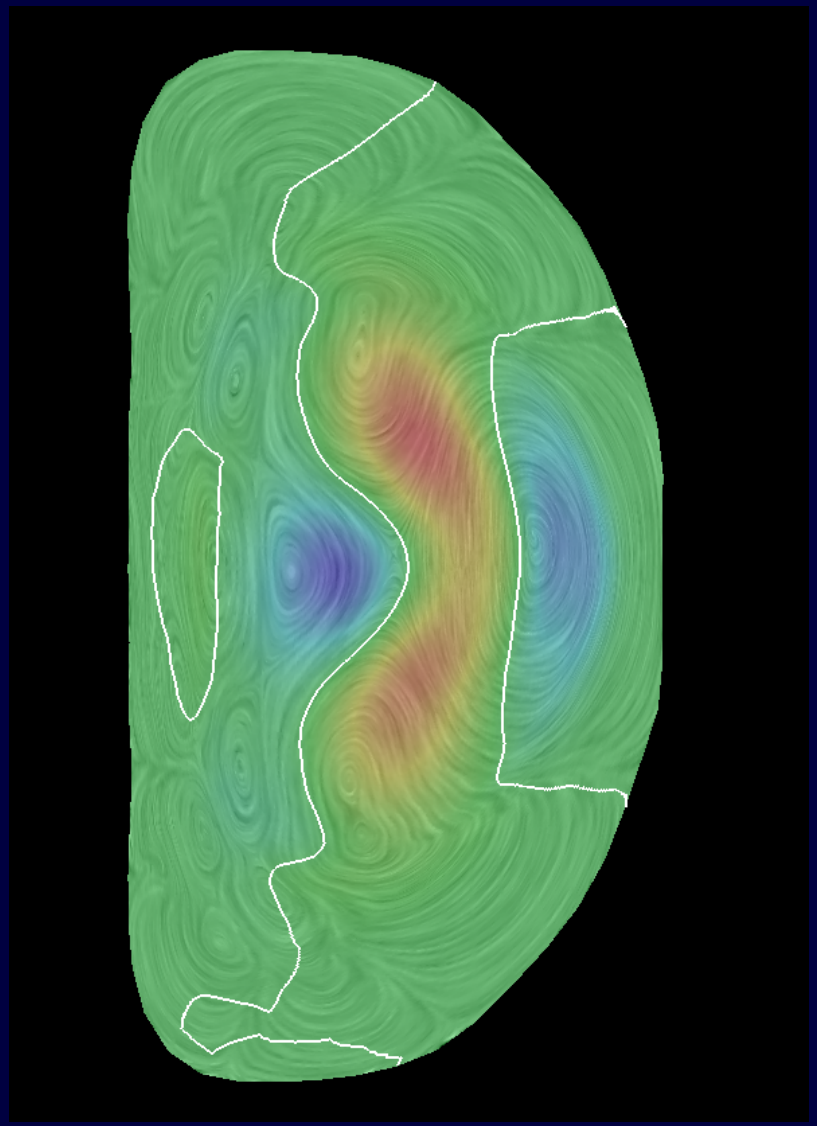
## Current

- Discrete but coarse representation
- Gives adequate results
- May miss features (islands)

## Can do better?

- Continuous representation
- Better visual representation
- Smaller features should be more apparent

# Poincaré Plots



# Poincaré Plots - Safety Factor

Depends on having the correct safety factor

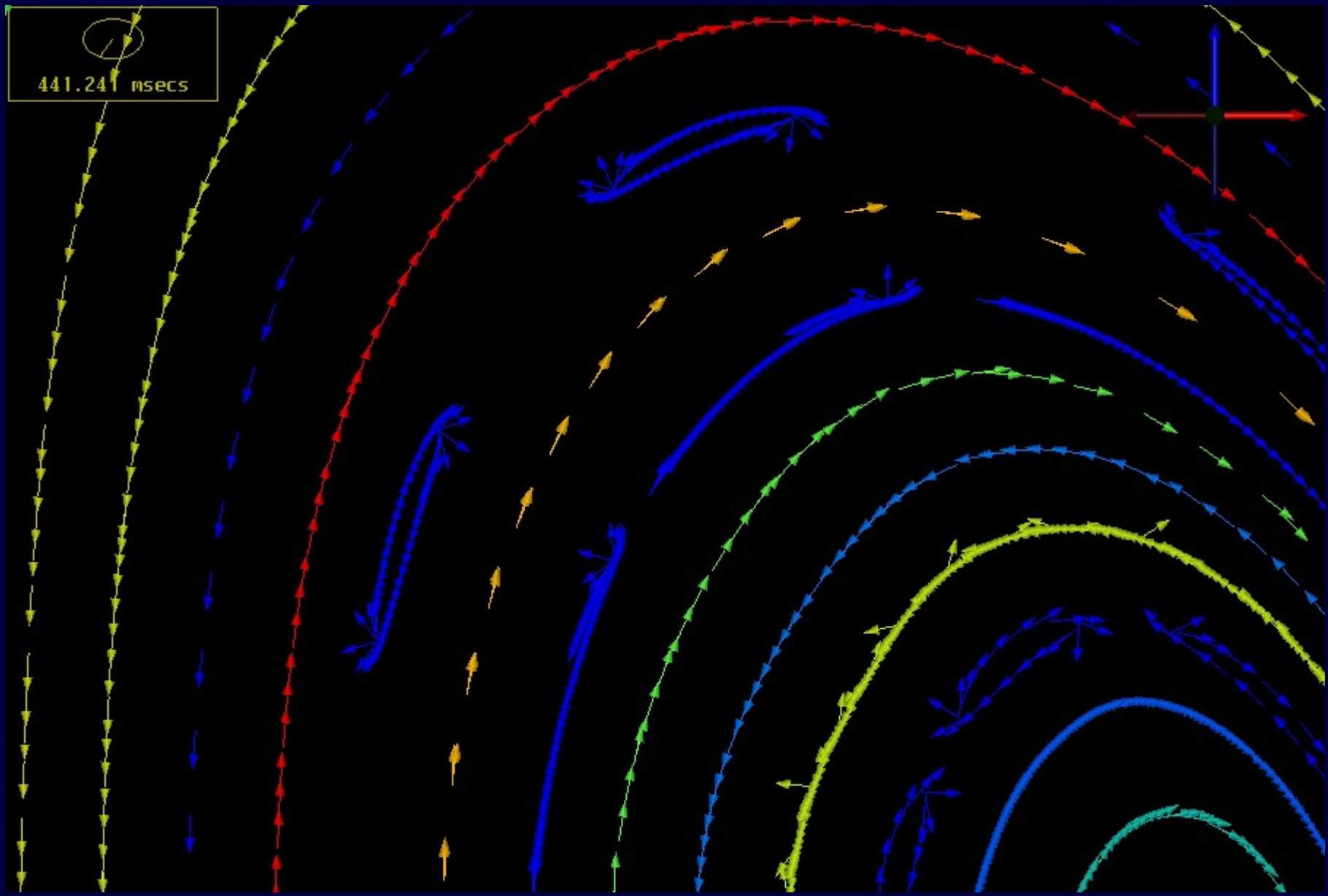
(or really the number of windings)

Currently the safety factor is determined geometrically using several different techniques.

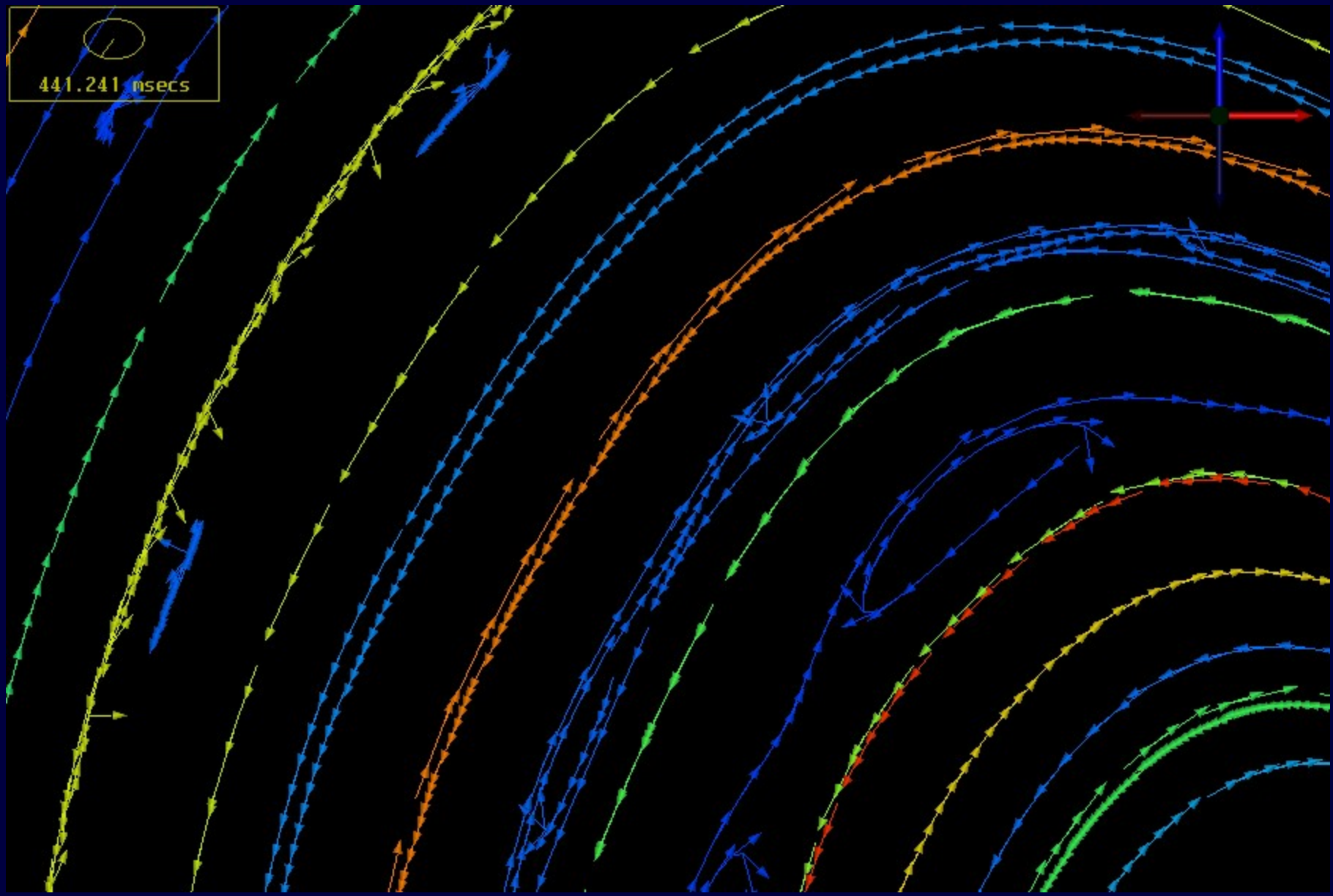
- Closest return the starting point.
- Closest return to an integer number of twists

Does not always give consistent results.

# Poincaré Plots - Safety Factor



# Poincaré Plots - Safety Factor



# Summary

- Geometric Based Techniques
- Detection of
  - Islands
  - X Points (approximation)
  - O Points
- Can show separatrices
- Future
  - Continuous Representation
  - Need accurate safety factor (windings)