TTK Installation Instructions

- TTK comes with Paraview, it can be downloaded here:
  - https://www.paraview.org/
- For those who want to follow along on your laptop during my presentation, you can find the same examples at:
  - https://topology-tool-kit.github.io/examples/index.html
- And while there are some direct links to individual datasets, if you want to download _all demos_ you would clone this repo (~1GB):
  - https://github.com/topology-tool-kit/ttk-data

An Introduction to the Topology ToolKit (TTK)

Joshua A. Levine and Julien Tierny
University of Arizona
Topological Data Visualizaton Workshop, May 2022

THE UNIVERSITY OF ARIZONA

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http://www.cs.arizona.edu/~josh

About Josh

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WYOMING
NEBRASKA
UTAH
COLORADO
ARIZONA
NEW MEXICO
OKLAHOMA
TEXAS
ARKANSAS
MISSISSIPPI
LOUISIANA
KENTUCKY
WEST VIRGINIA
VIRGINIA
NORTH CAROLINA
SOUTH CAROLINA
PENNSYLVANIA
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MD.
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MAINE
VT.
N.H.
MASS.
CONN.
R.I.
ALASKA
HAWAII
KAUAI
OAHU
MOLOKAI
MAUI
U.S. VIRGIN ISLANDS
PUERTO RICO
Yellowstone
Grand Teton
Wind Cave
Rocky Mountain
Great Basin
Arches
Capitol Reef
Bryce Canyon
Zion
Grand Canyon
Mesa Verde
Petrified Forest
Yosemite
Kings Canyon
Sequoia
Death Valley
Channel Islands
Carlsbad Caverns
Guadalupe Mountains
Big Bend
Hot Springs
Mammoth Cave
Shenandoah
Acadia
Kobuk Valley
Gates of the Arctic
Denali
Wrangell-St. Elias
Lake Clark
Katmai
Kenai Fjords
Glacier Bay
Haleakala
Hawaii Volcanoes
Virgin Islands
Everglades
Biscayne
Dry Tortugas
Where the Parks Are
North, South, East, Midwest, West—each section of the United States has at least one national park to call its own. You don't have to visit the parks to enjoy their splendors, for this book is filled with their sights and their sounds. But if a trip is in the offing, this map and the chart on the two following pages will serve as your guide.
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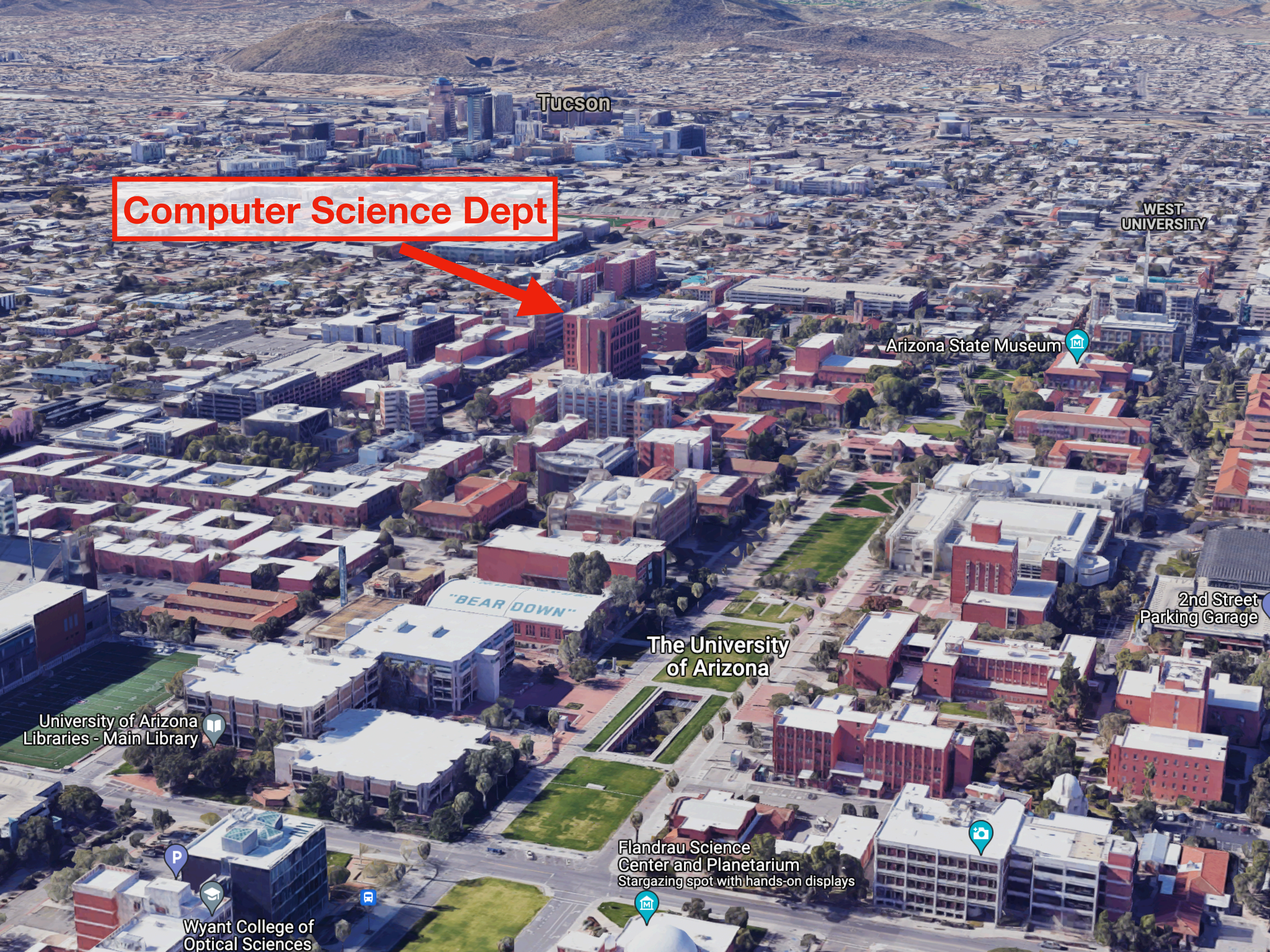
University of Arizona is in Tucson, AZ USA



Computer Science Dept
Tucson
WEST UNIVERSITY
Arizona State Museum
"BEAR DOWN"
The University of Arizona
2nd Street Parking Garage
University of Arizona Libraries - Main Library
Flandrau Science Center and Planetarium
Stargazing spot with hands-on displays
Wyant College of Optical Sciences

Tucson is in the Sonoran *Desert*
Average High Temperature in June/July: ~40°C
Annual rainfall: 270 mm / 10.61 inches

University of Arizona is in Tucson, AZ USA

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Collaborators and Credits

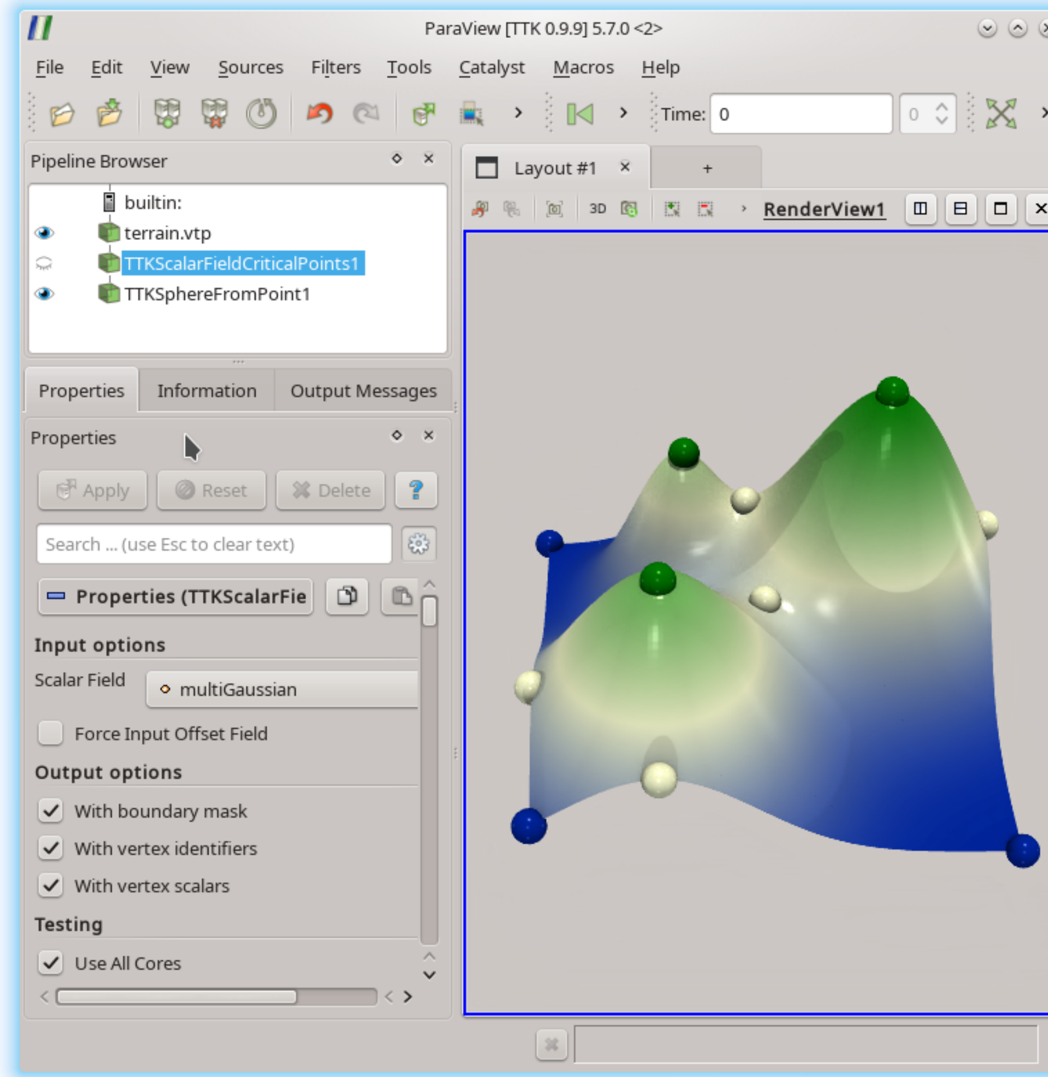
- Lead developer: Julien Tierny (Sorbonne / CNRS)
  - Public release in IEEE VIS 2017 involved Guillaume Favelier (Sorbonne), Charles Gueunet (Kitware), Michael Michaux (Sorbonne), and Josh
  - Dozens of international contributors to TTK since, mailing list: ttk-users@googlegroups.com

cnrs SORBONNE UNIVERSITÉ CRÉATEURS DE FUTURS DEPUIS 1257

Kitware

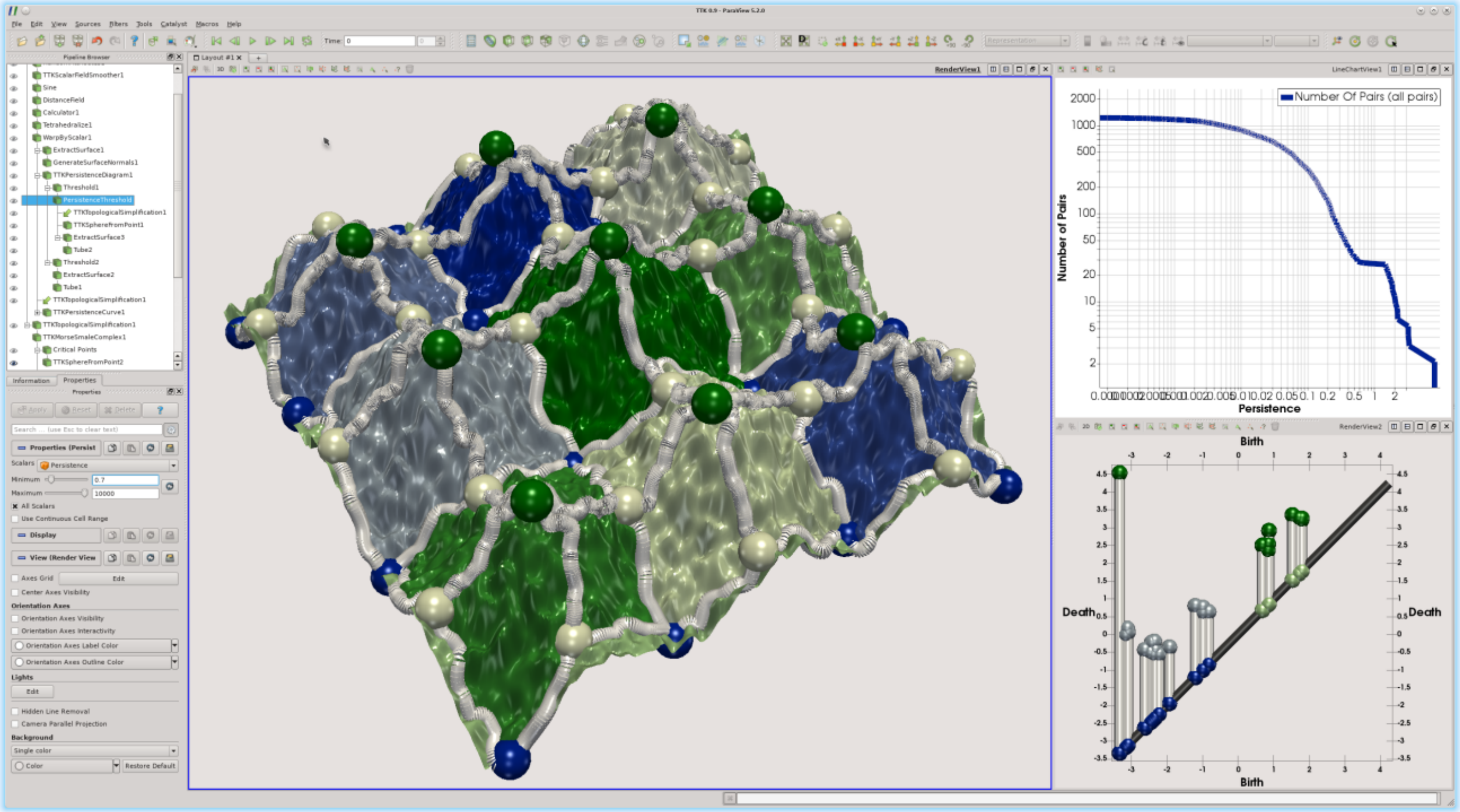
TTK is Built On Top of ParaView

- https://www.paraview.org/
- Provides many built-in features:
    - Rich IO support
    - Modern rendering
    - Advanced user interface
    - “Visual” programming
    - Python scripting



ParaView

User experience



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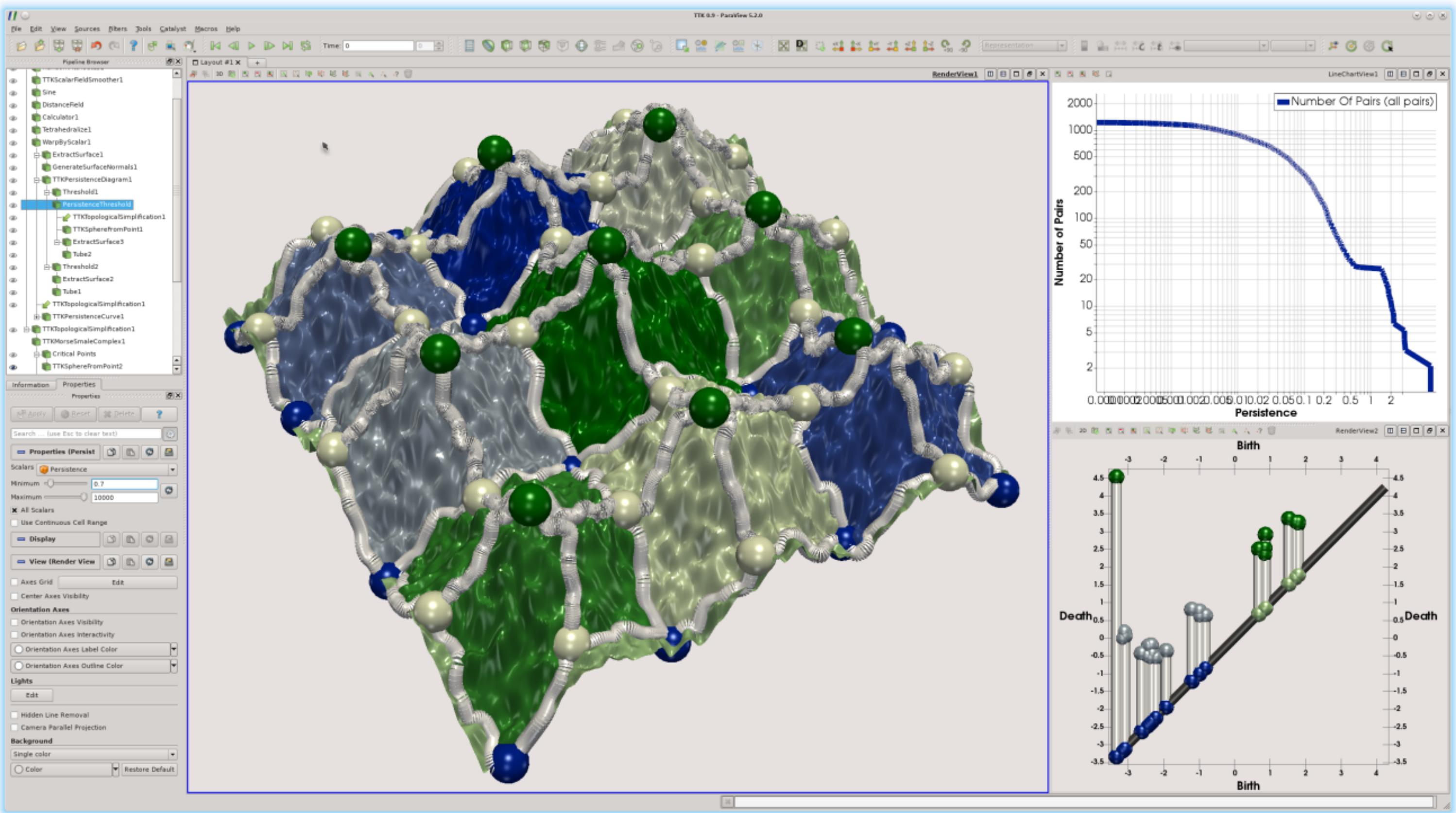

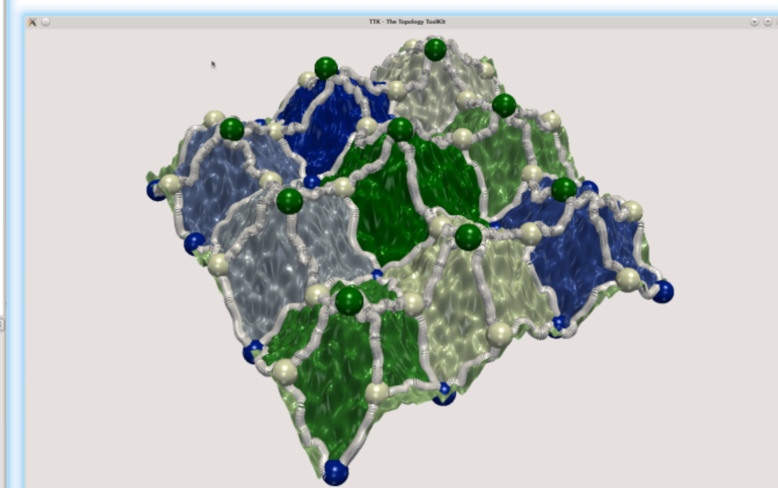

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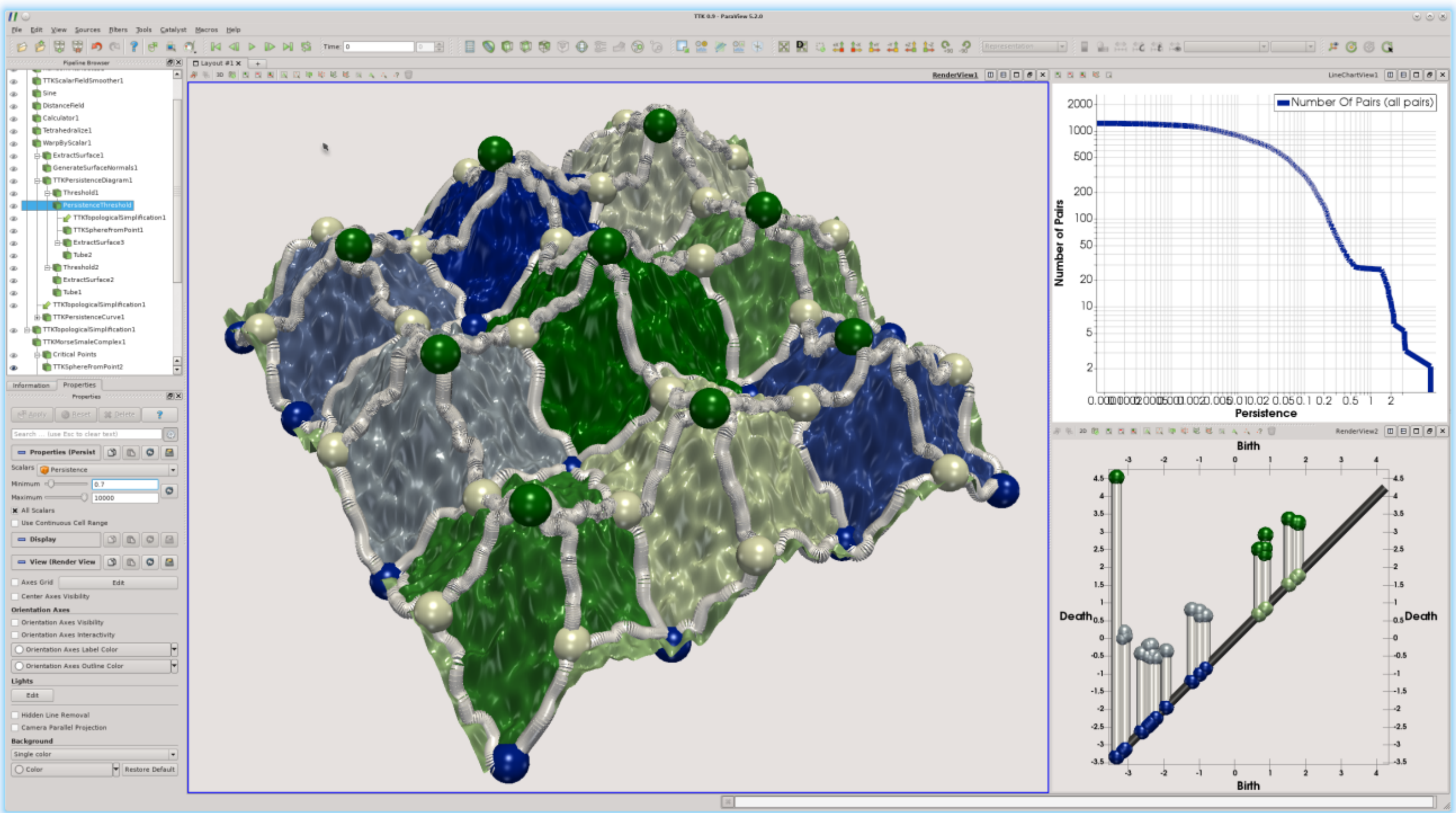

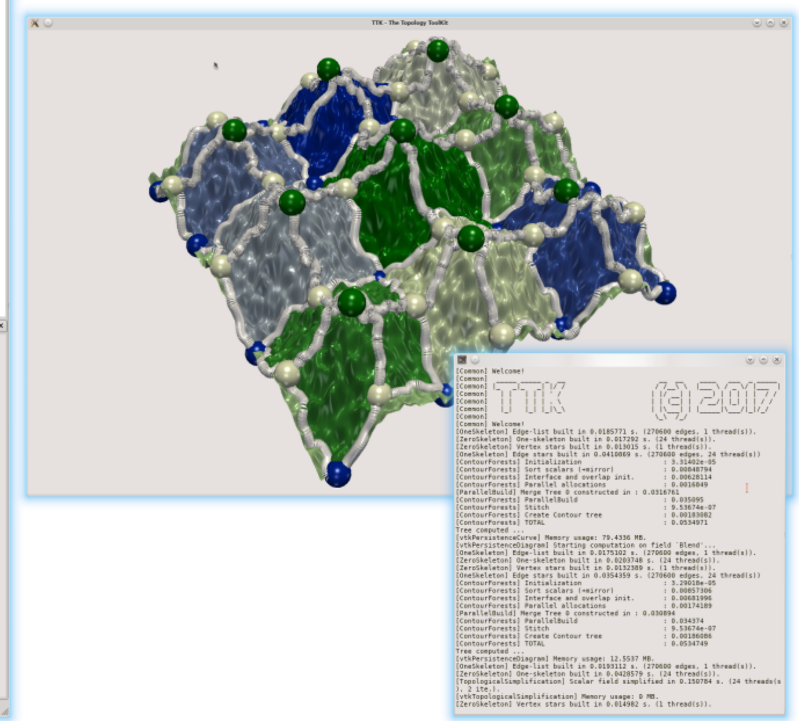

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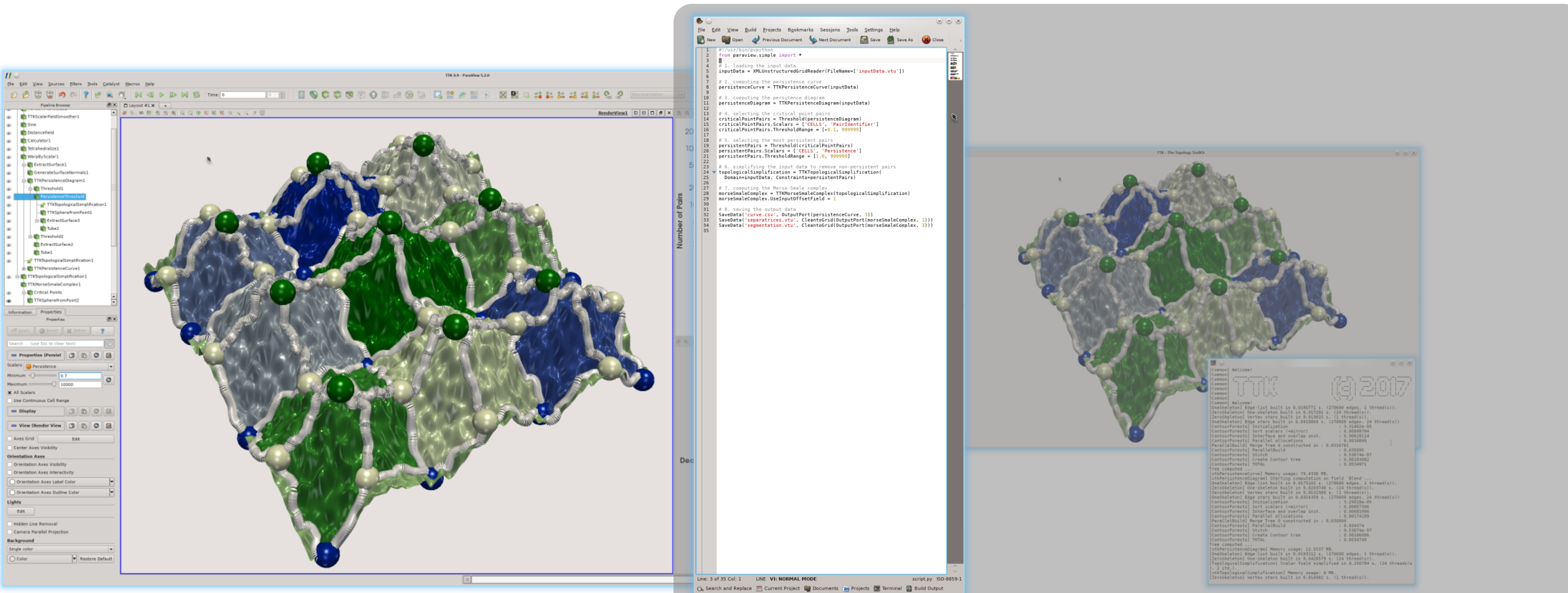
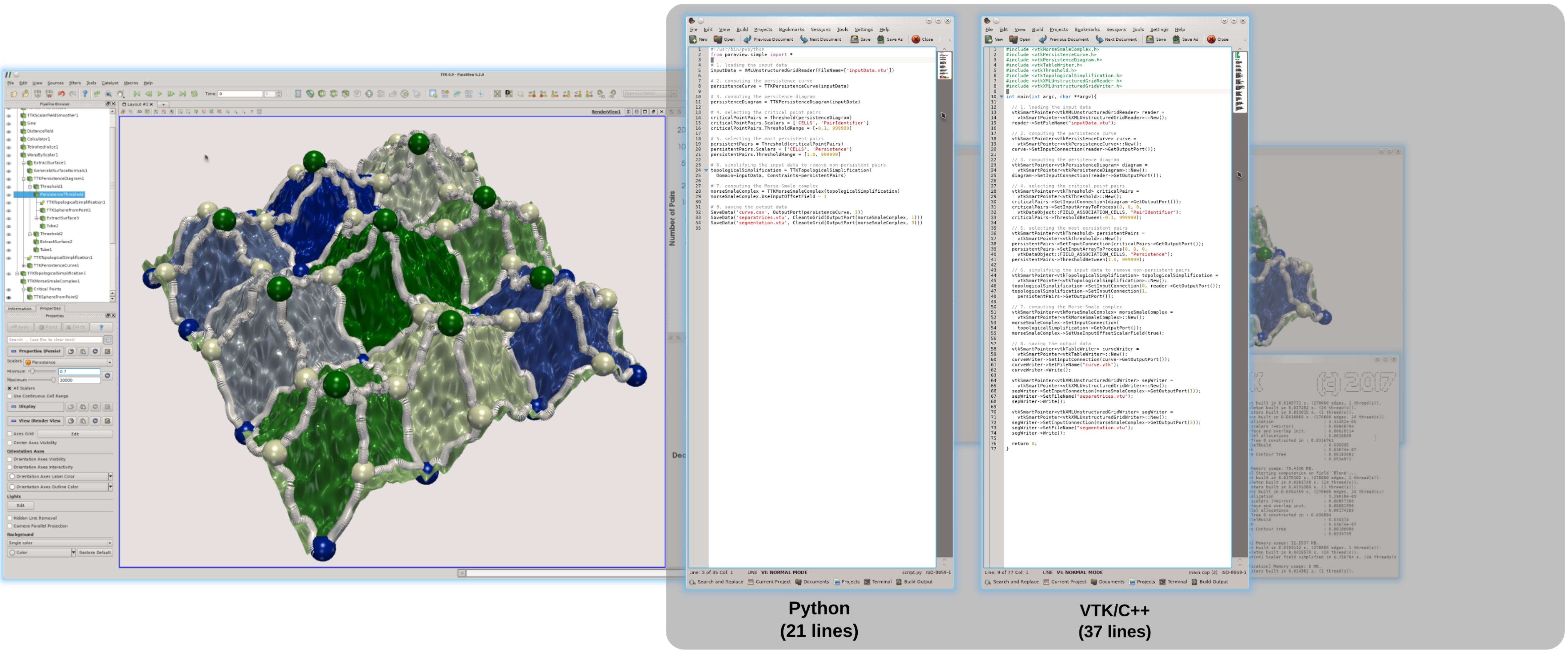


Python
(21 lines)

User experience



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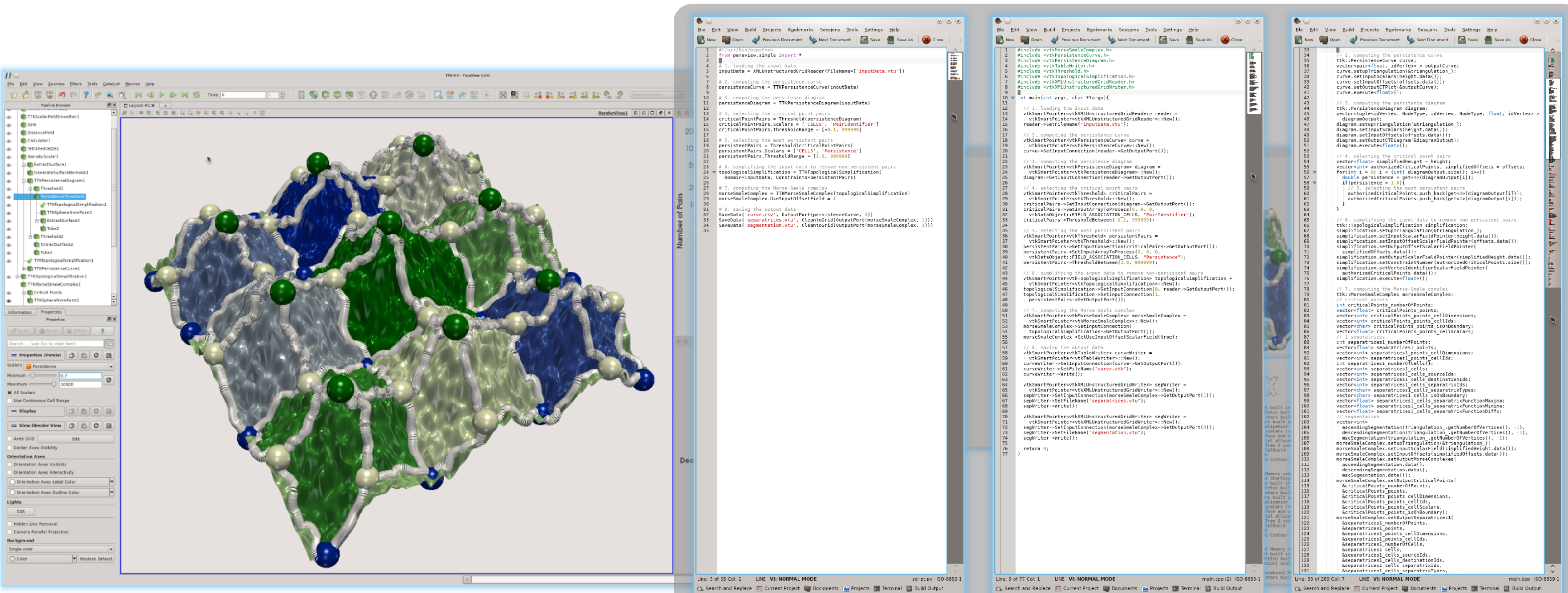


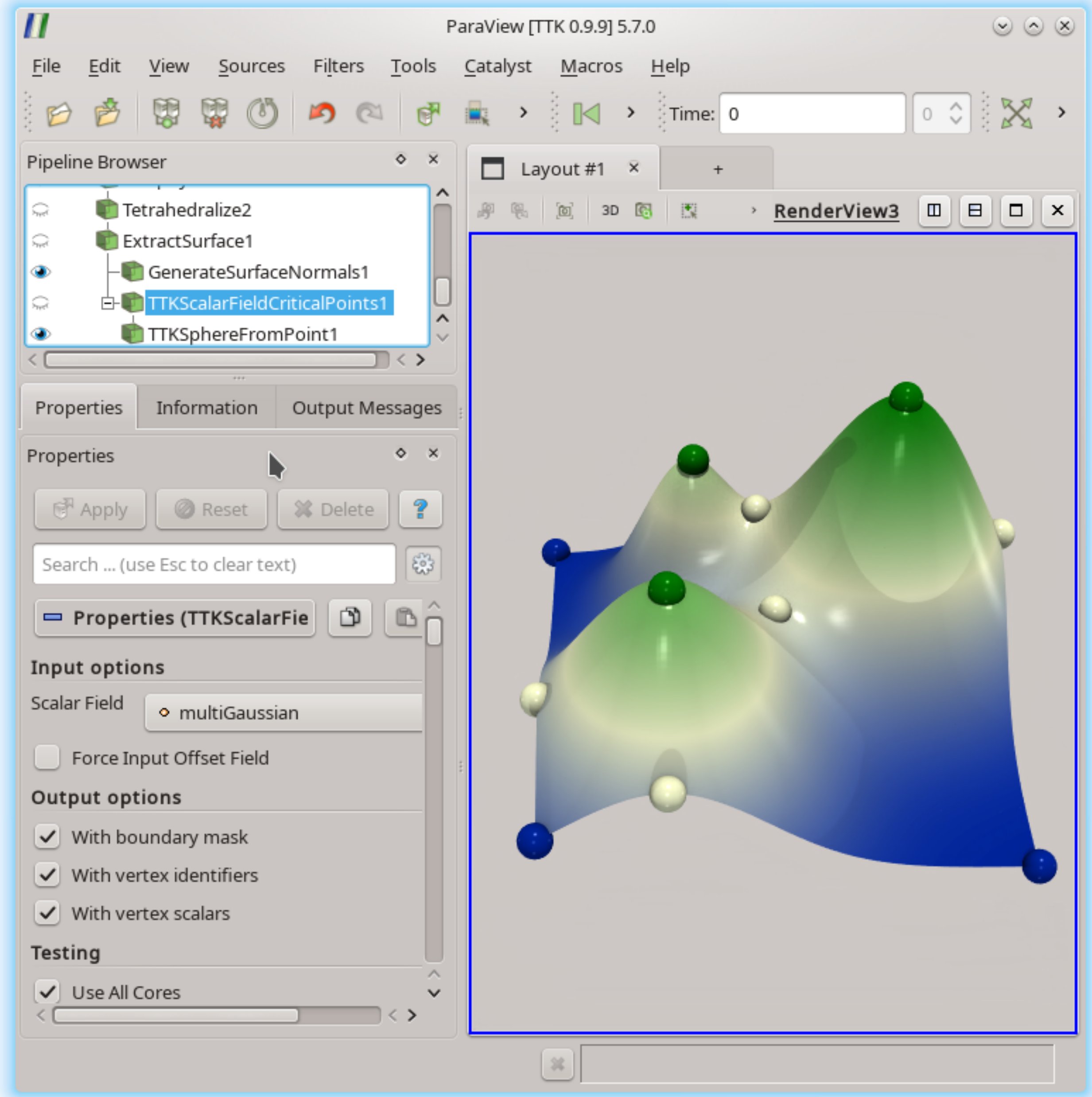
Python (21 lines) | VTK/C++ (37 lines) | Pure C++ (101 lines)

Part 2: A Tour of Topological Features of Scalar Data in TTK

https://topology-tool-kit.github.io/

Critical points

- Module
  - **`ScalarFieldCriticalPoints`**
  - Extract the singularities and their index
- Algorithm
  - Banchoff, J. Diff. Geom. 1967
  - Linear time, trivially parallel
- Output
  - Points with index and vertex IDs



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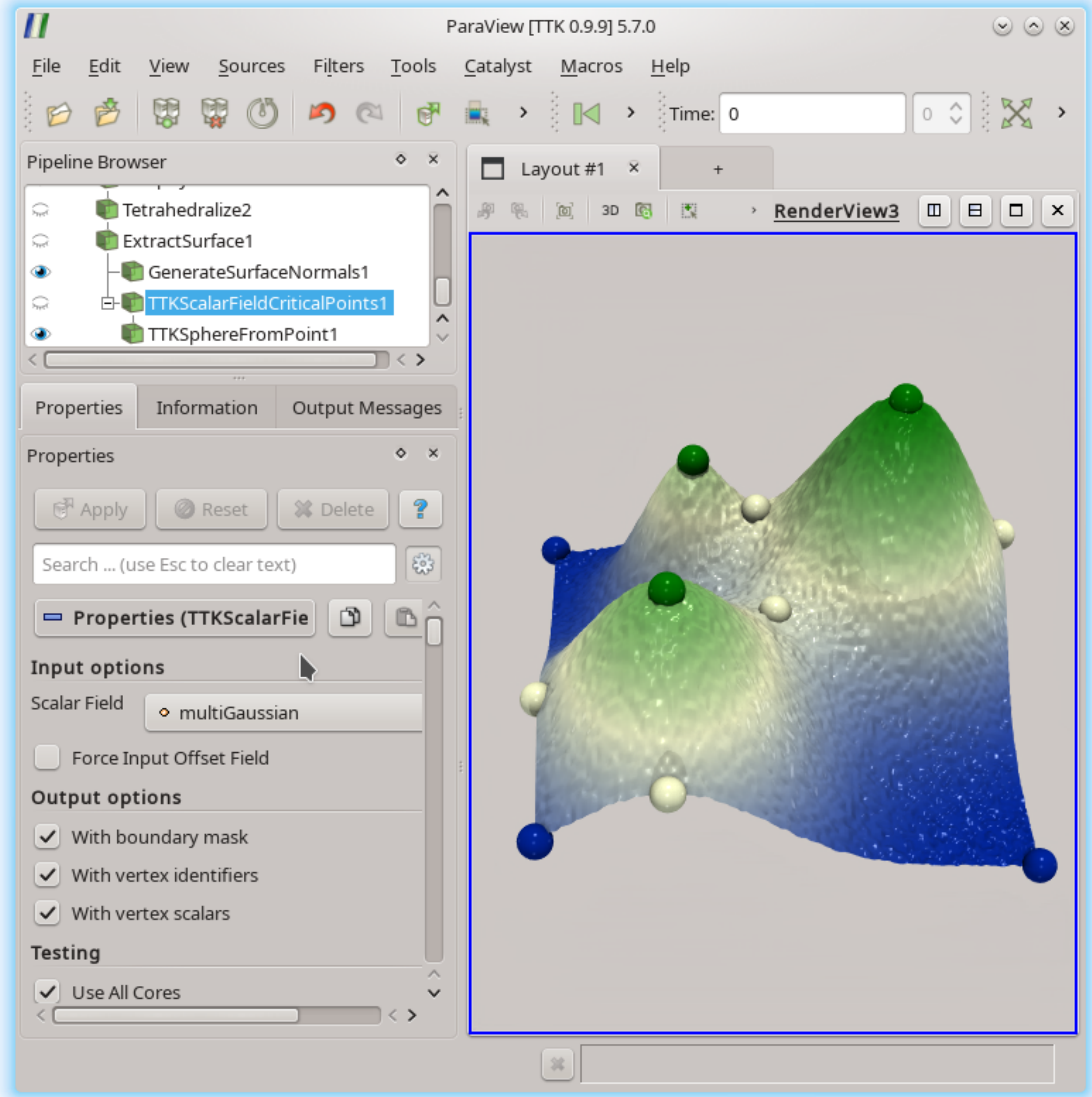

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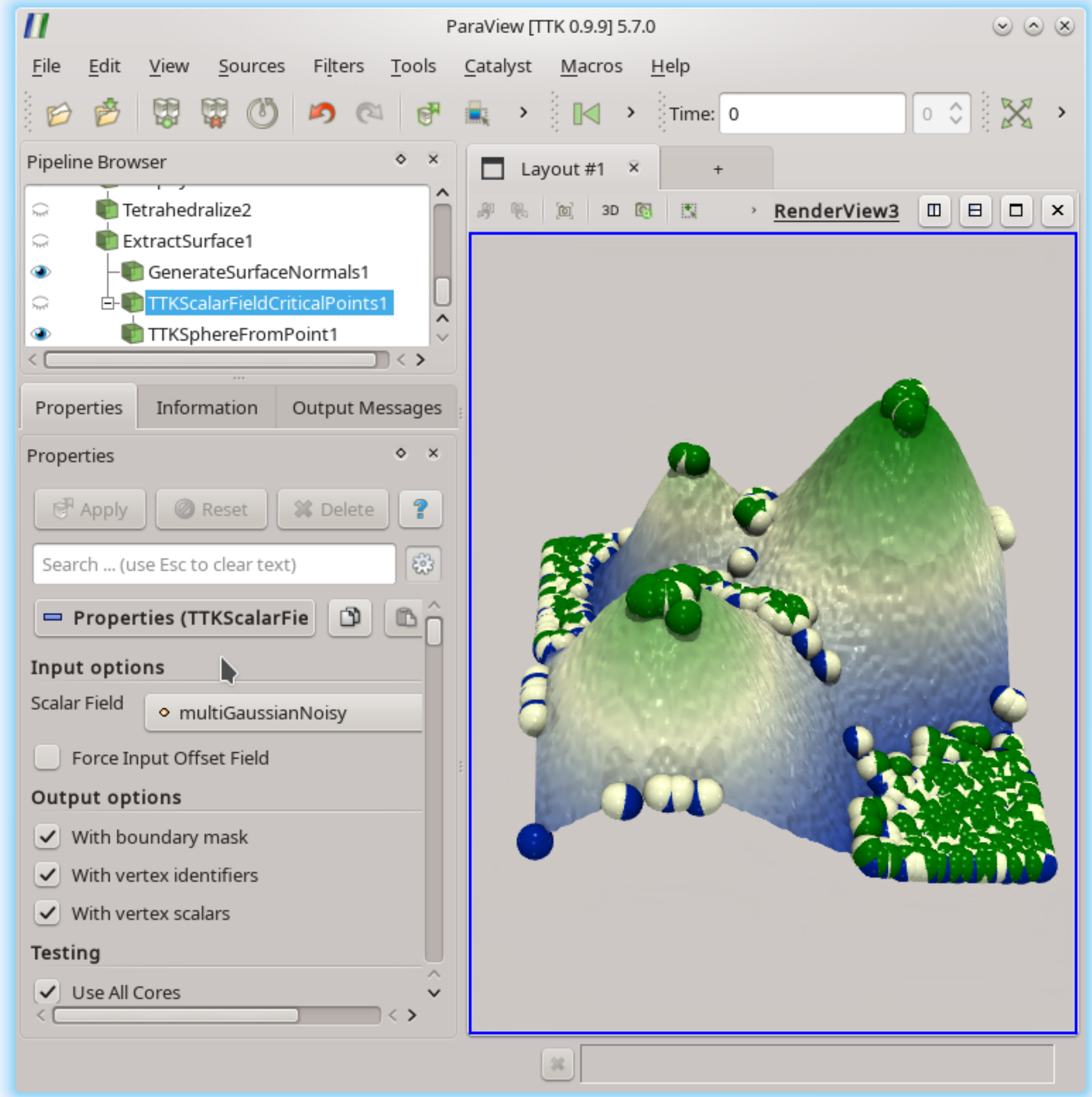
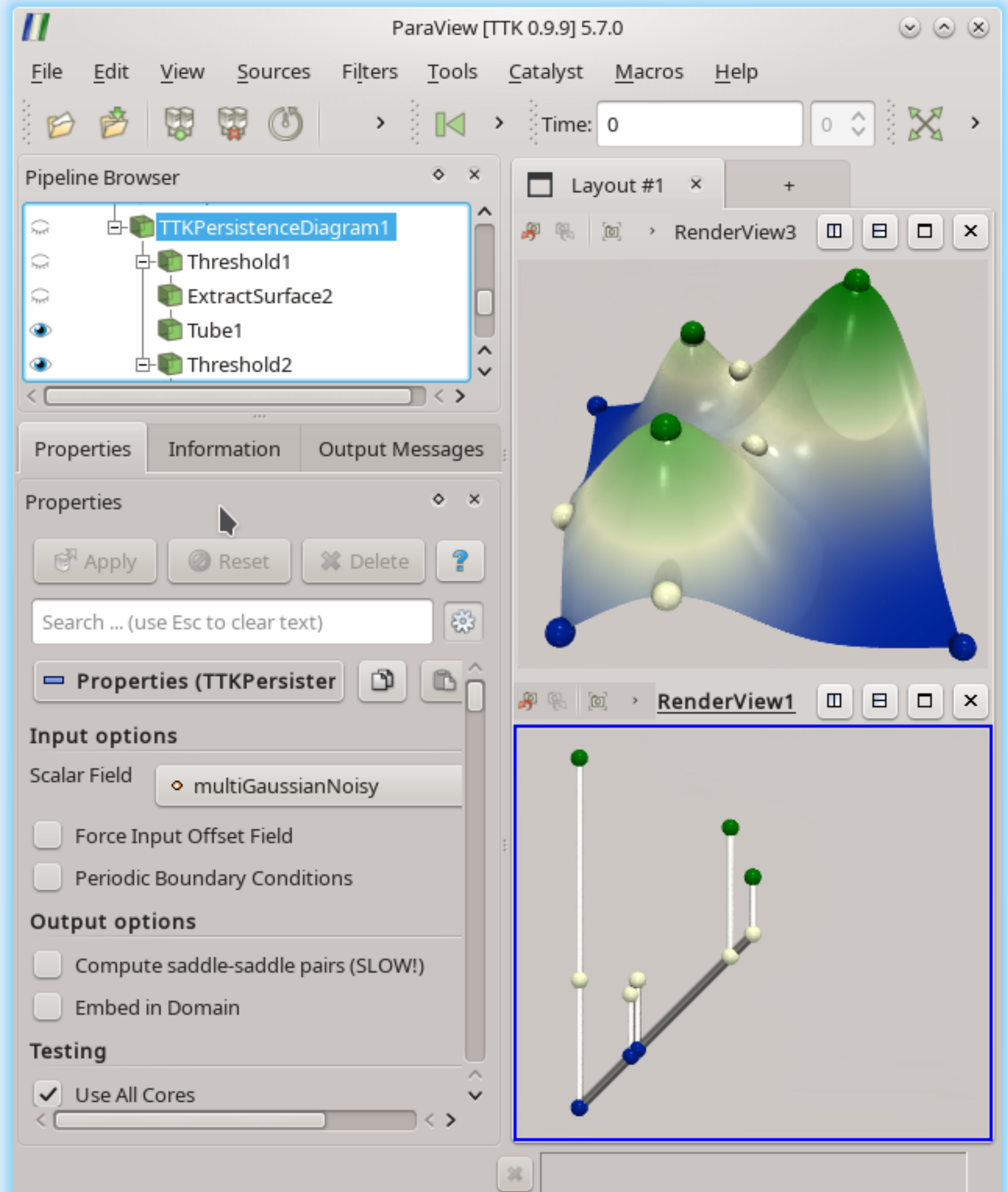


Persistence diagrams

- Module
  - `PersistenceDiagram`
  - `PersistenceCurve`
- Algorithms
  - Extremum/saddle pairs
    - Gueunet et al. IEEE TPDS 2019
    - Linearithmic time, efficient parallelization
  - Saddle/saddle pairs w/ saddle connectors
- Output
  - One curve per pair type



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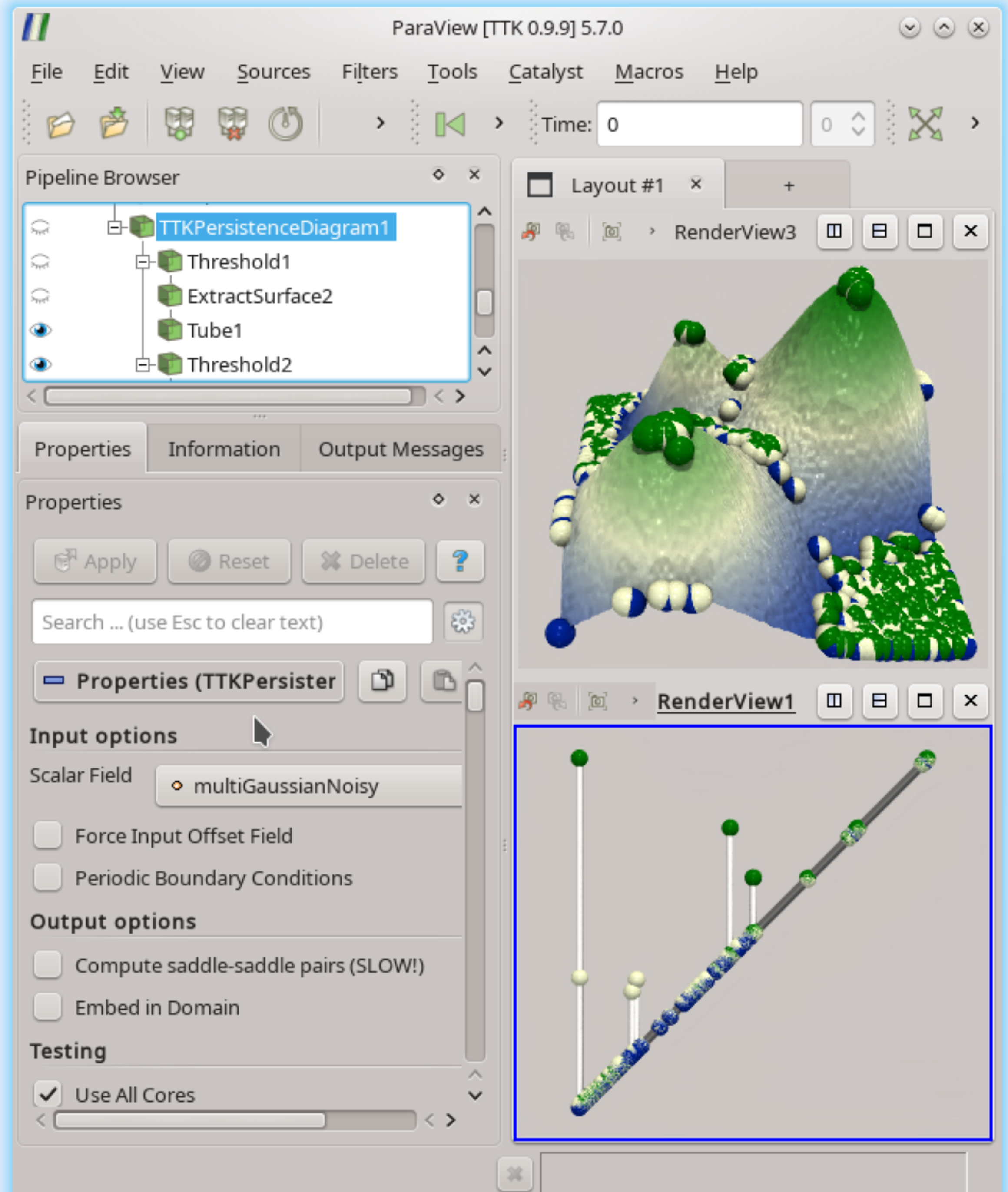

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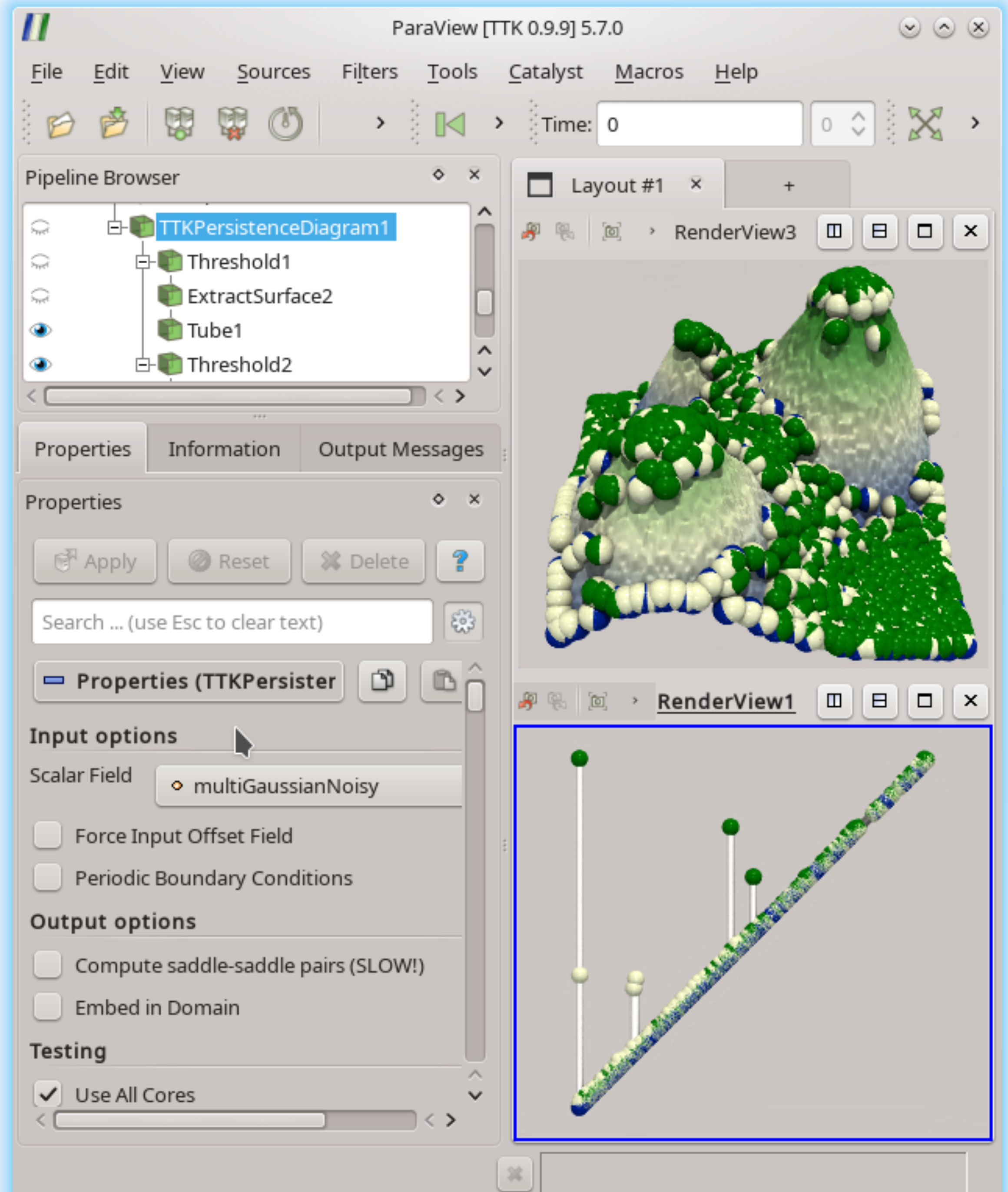

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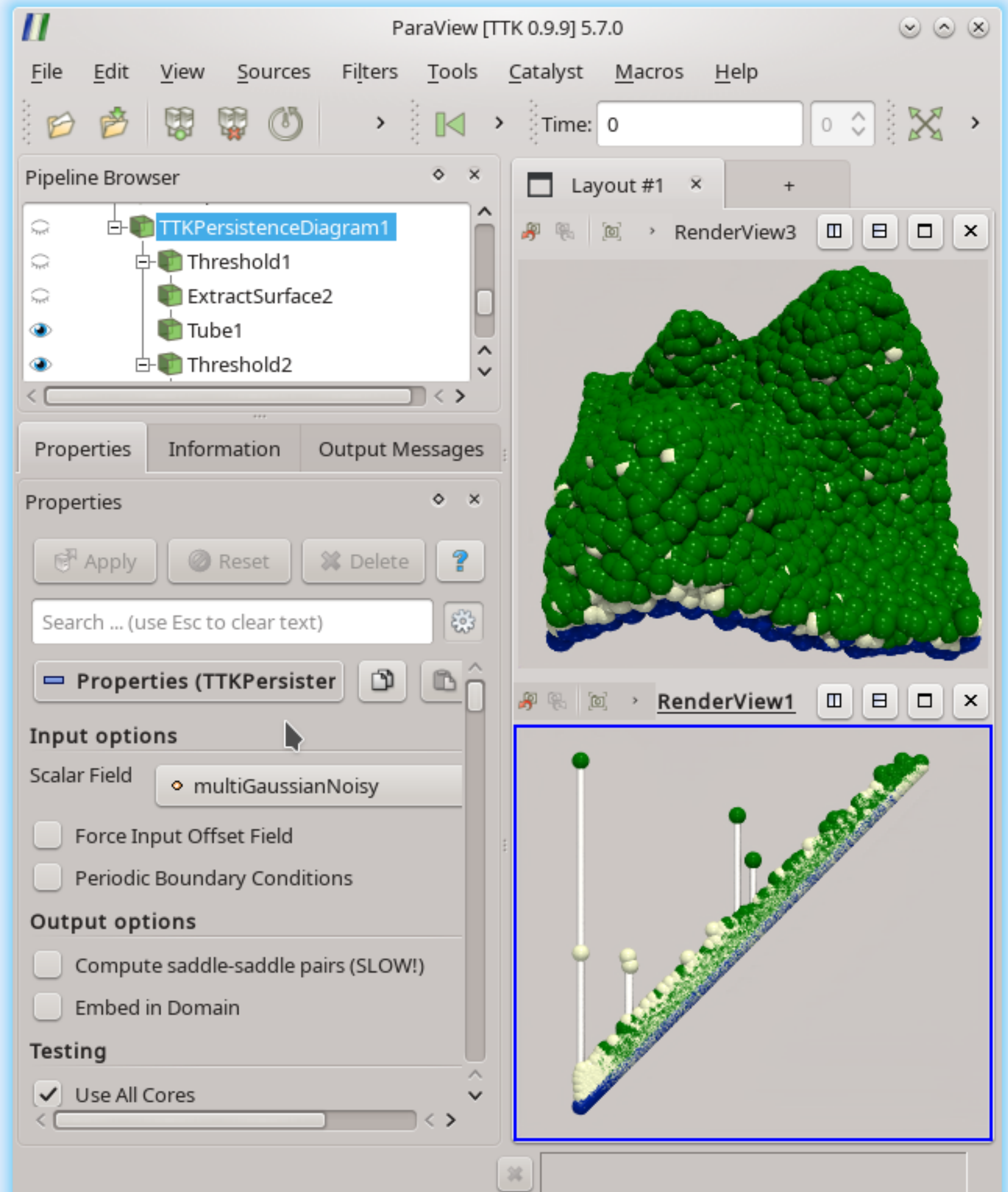

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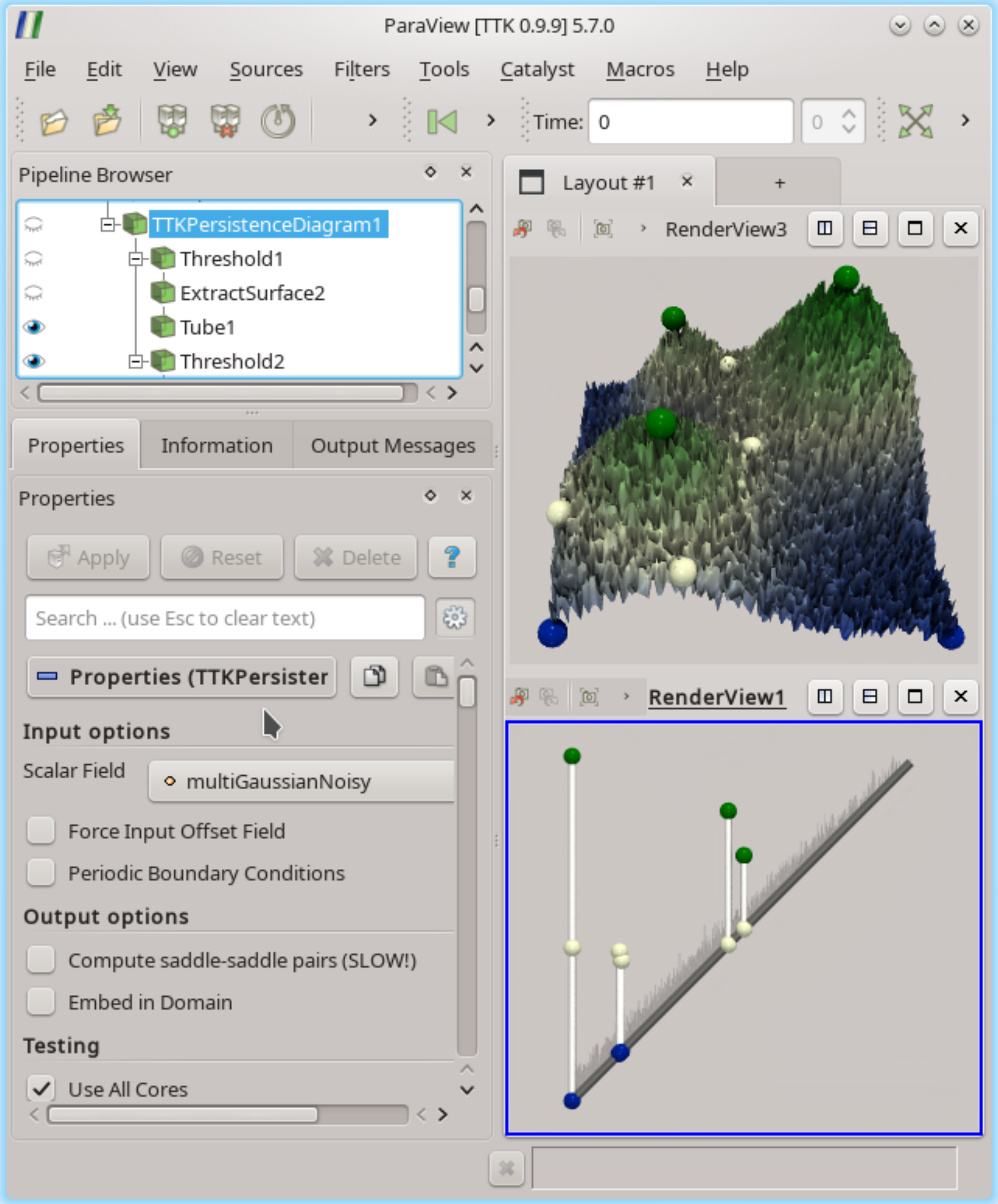

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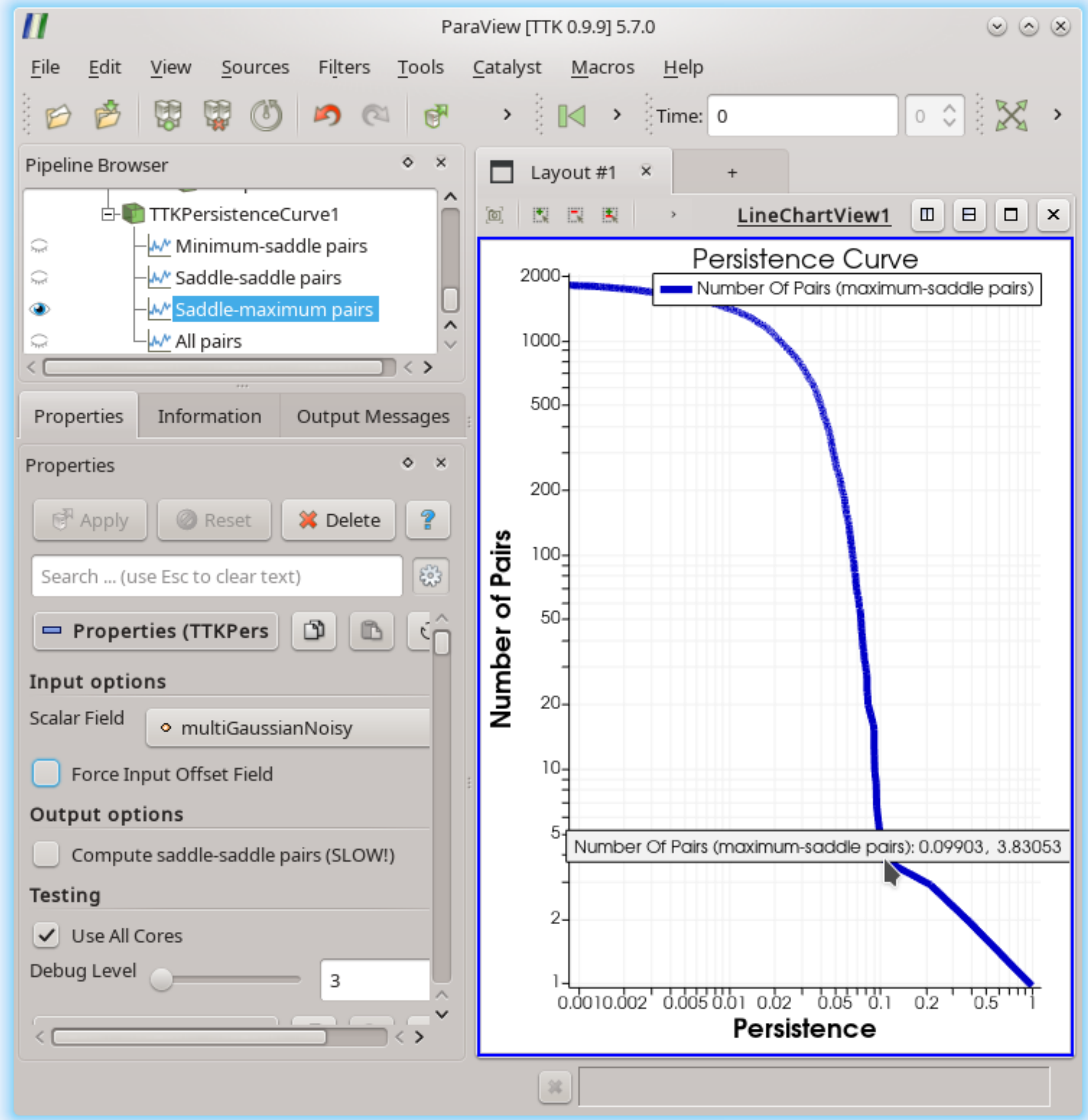
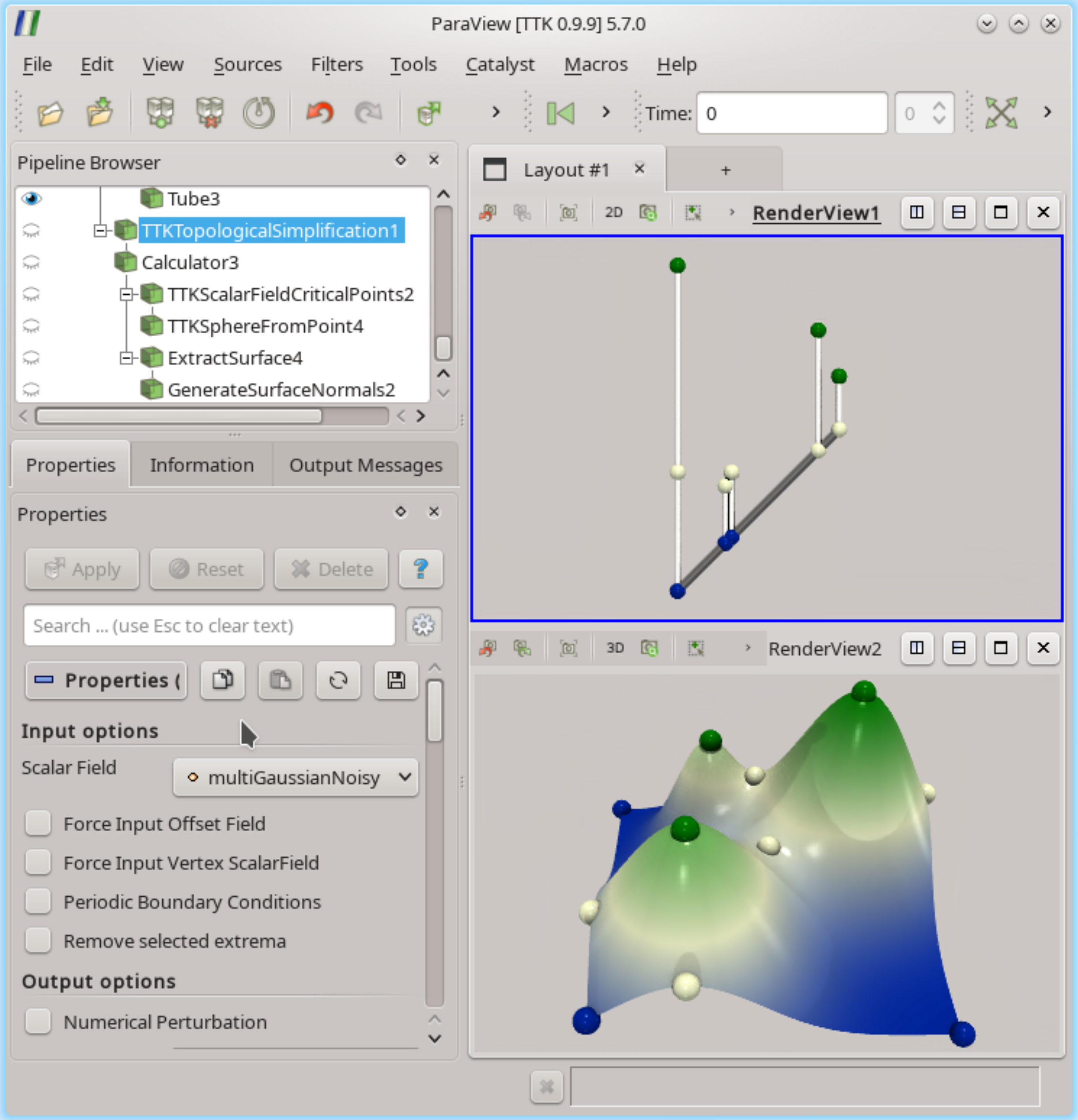


Topological data simplification

- Module
  - `TopologicalSimplification`
  - Extremum removal
  - Default multiscale mechanism
- Algorithm
  - Tierny & Pascucci IEEE TVCG 2012
  - Linearithmic time
- Output
  - “Flattened” data



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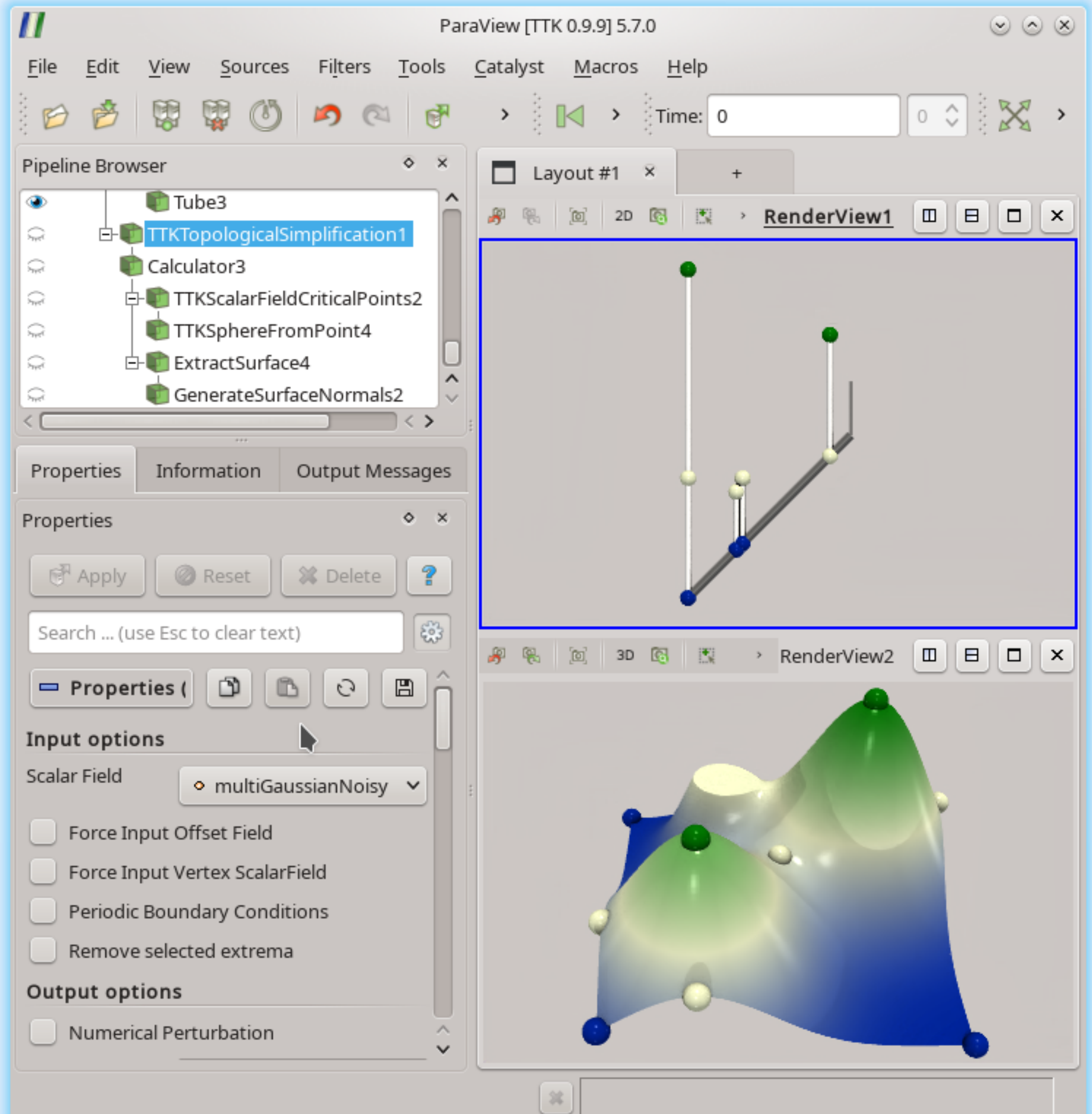

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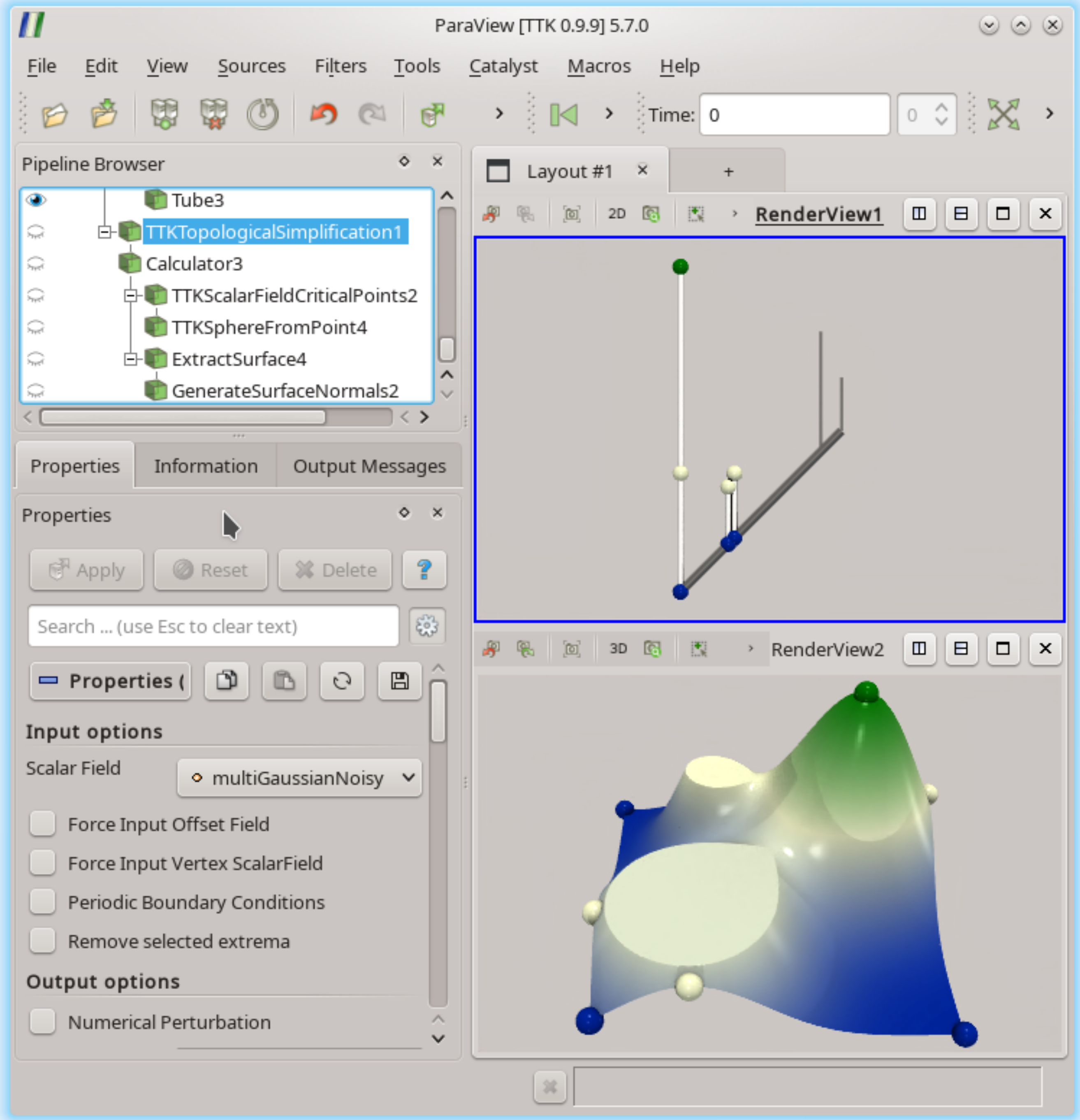
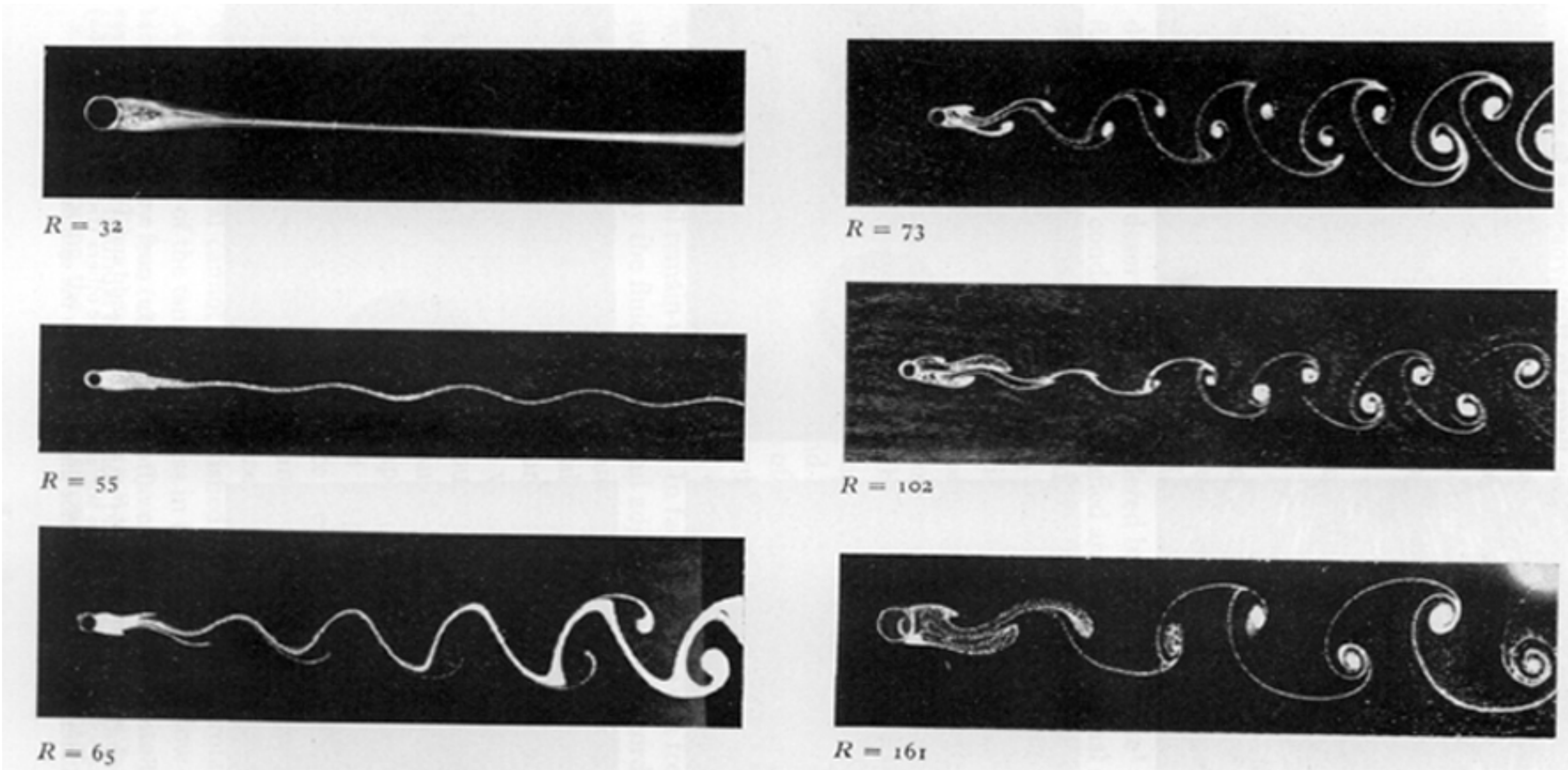
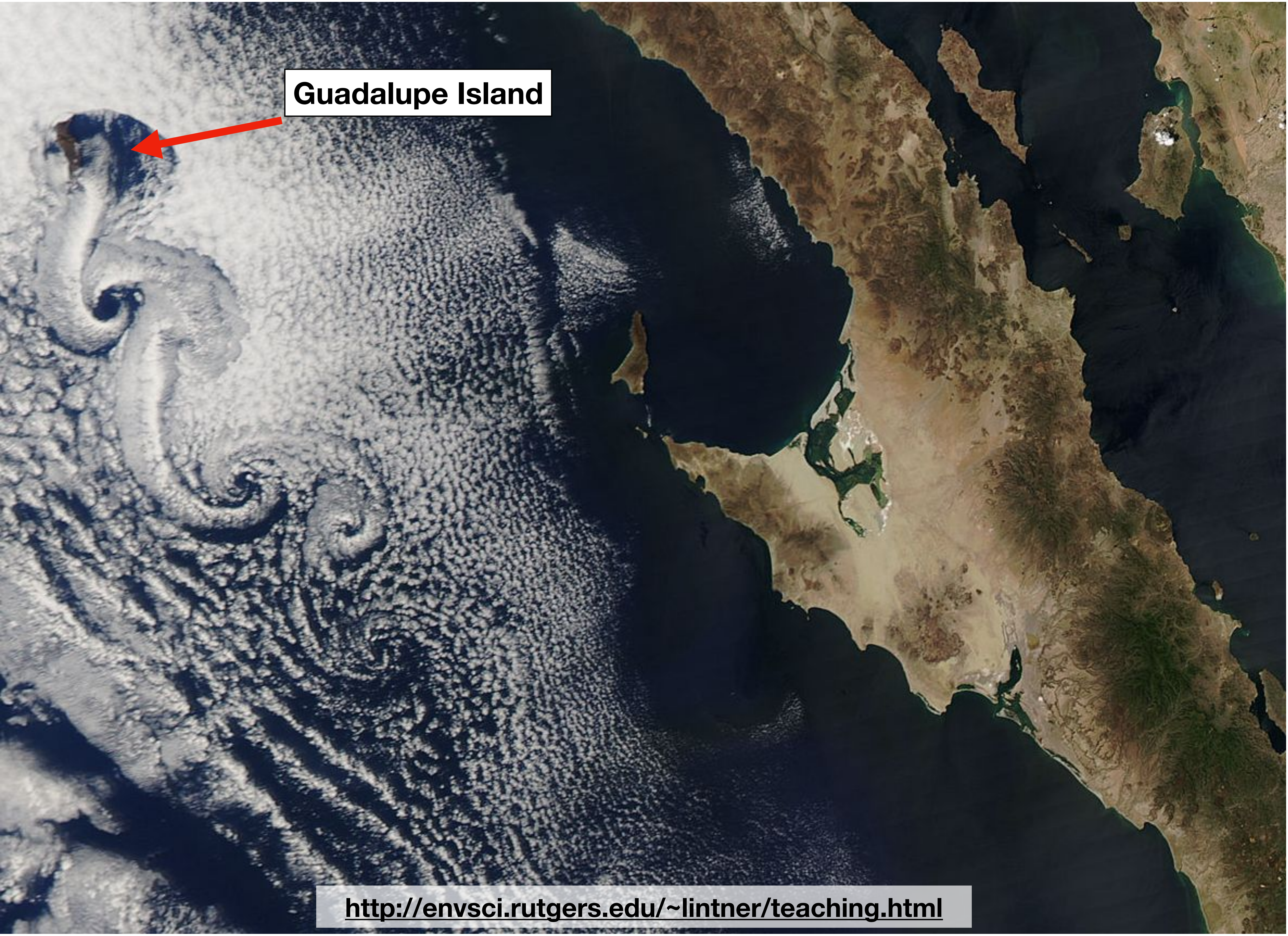


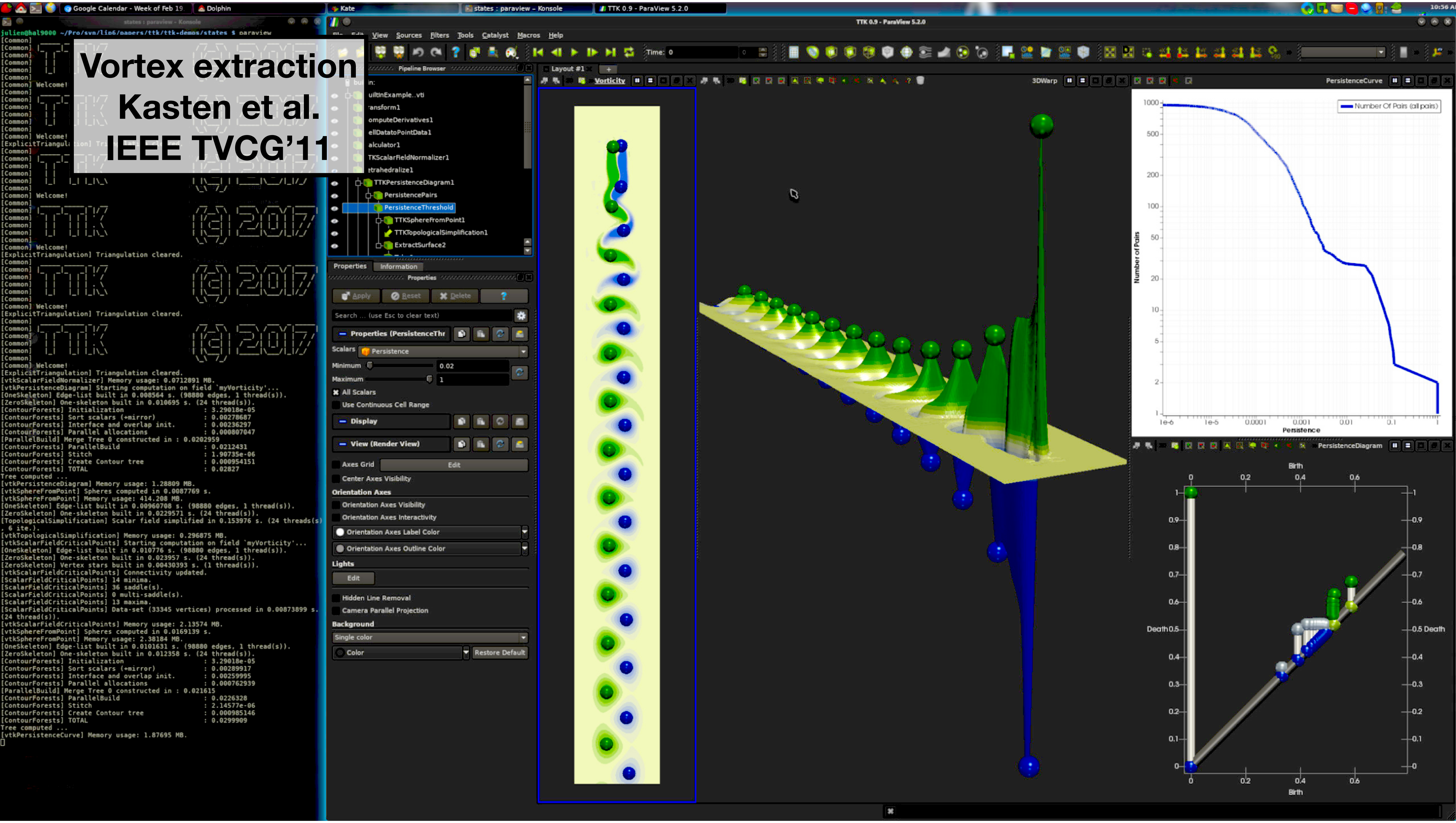
Experimental Flow Vis



von Kármán vortex street, depending on Reynolds number


Guadalupe Island
http://envsci.rutgers.edu/~lintner/teaching.html

TDA Apps in Visualization



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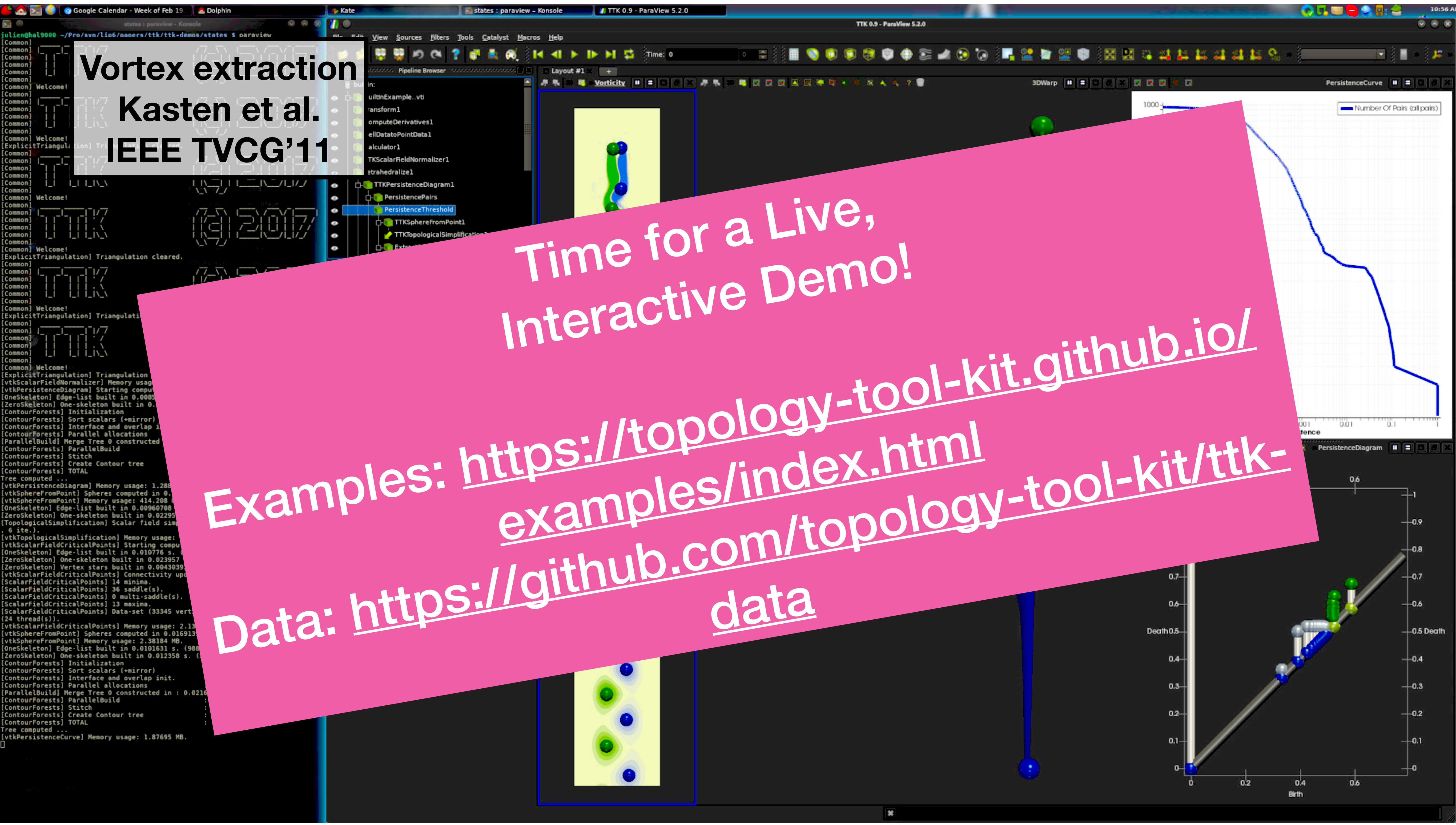


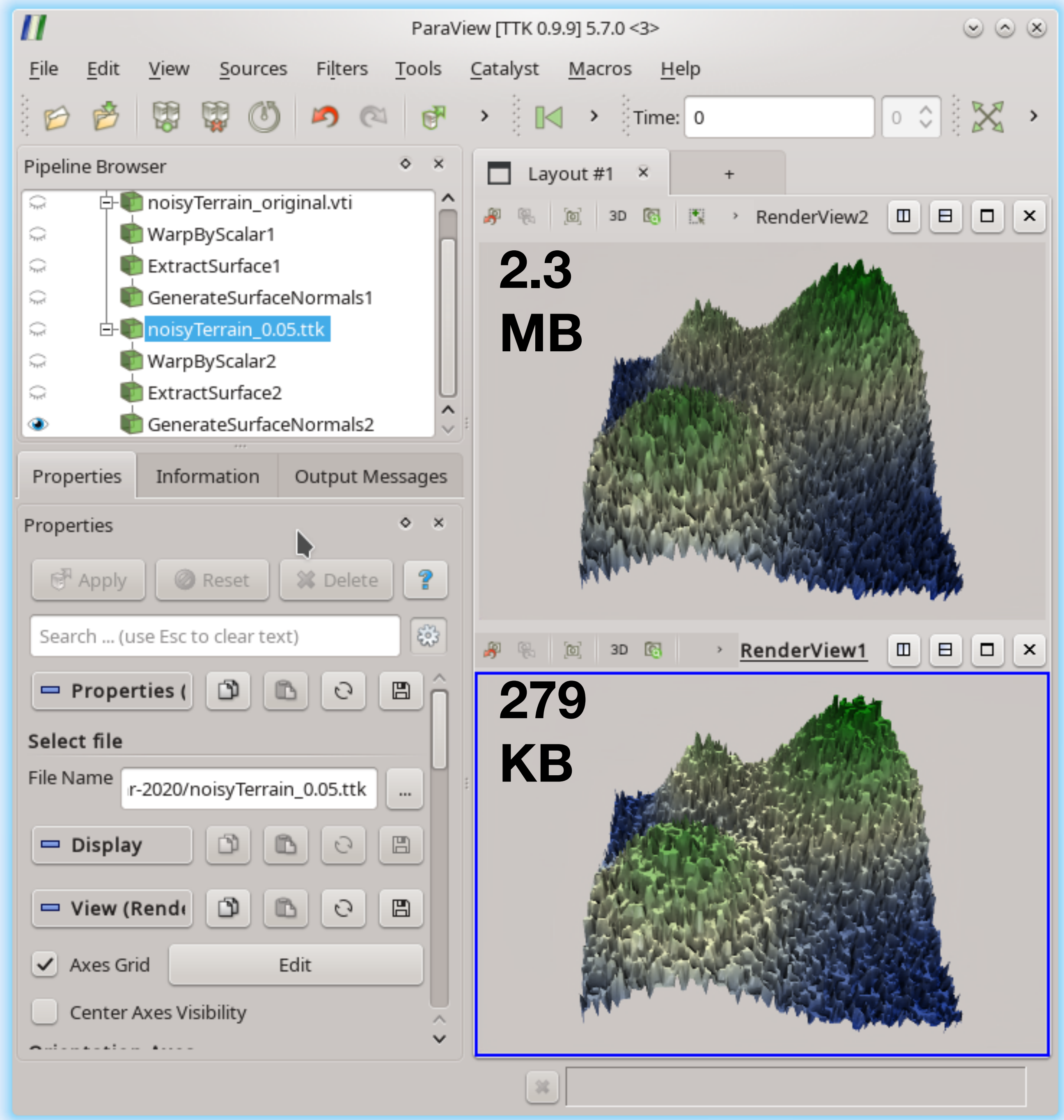
Time for a Live, Interactive Demo!

Examples: https://topology-tool-kit.github.io/examples/index.html

Data: https://github.com/topology-tool-kit/ttk-data

Topology aware compression

- Module
  - `TopologicalCompression` (IO)
  - Preserves the persistence diagram
    - Dimension 0 or (d-1)
- Algorithm
  - Soler et al. PacificViz 2018
  - Linearithmic time
- Output
  - Compressed image data
  - Geometry improvement with ZFP
    - Lindstrom IEEE TVCG 2014



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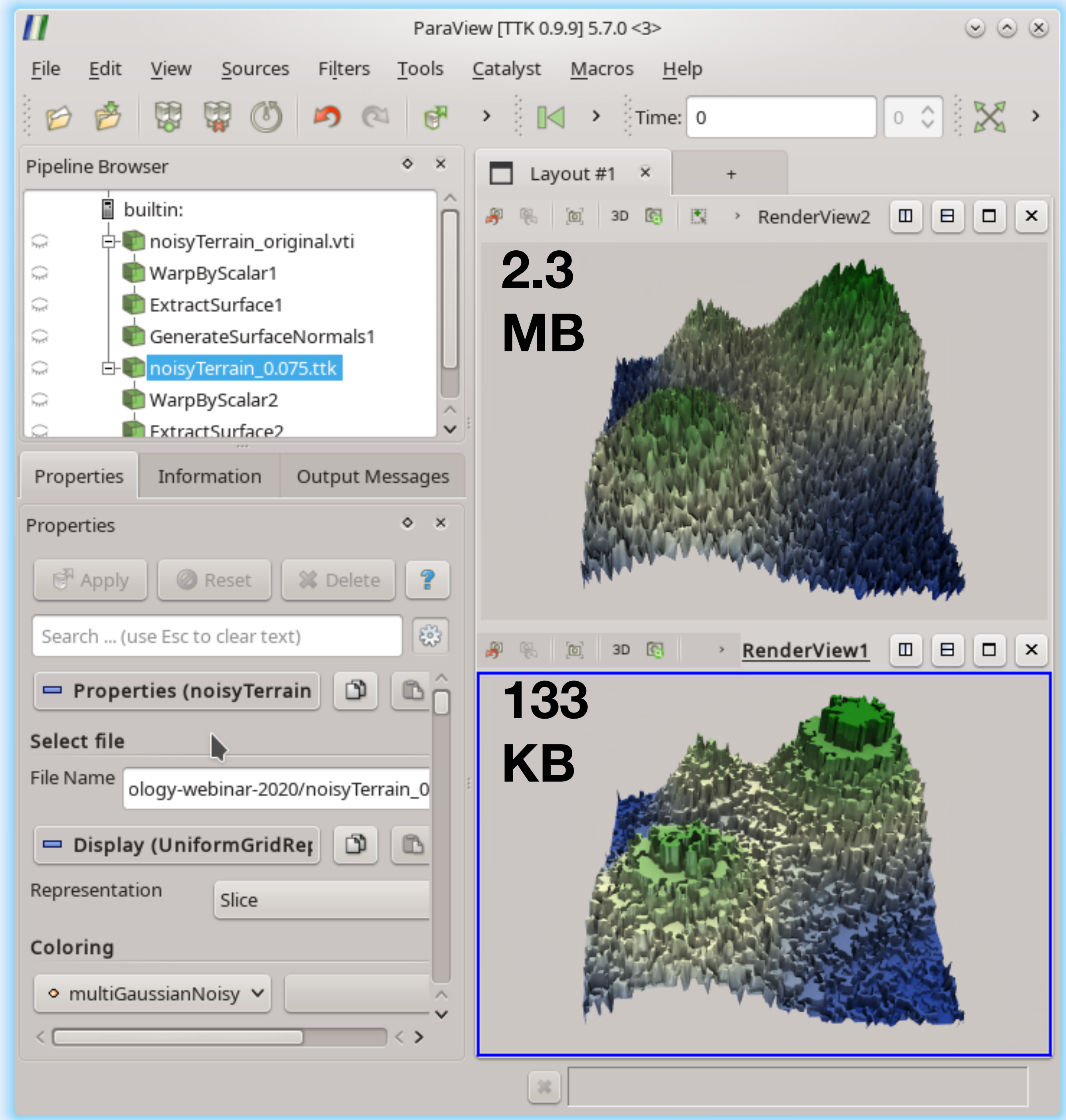

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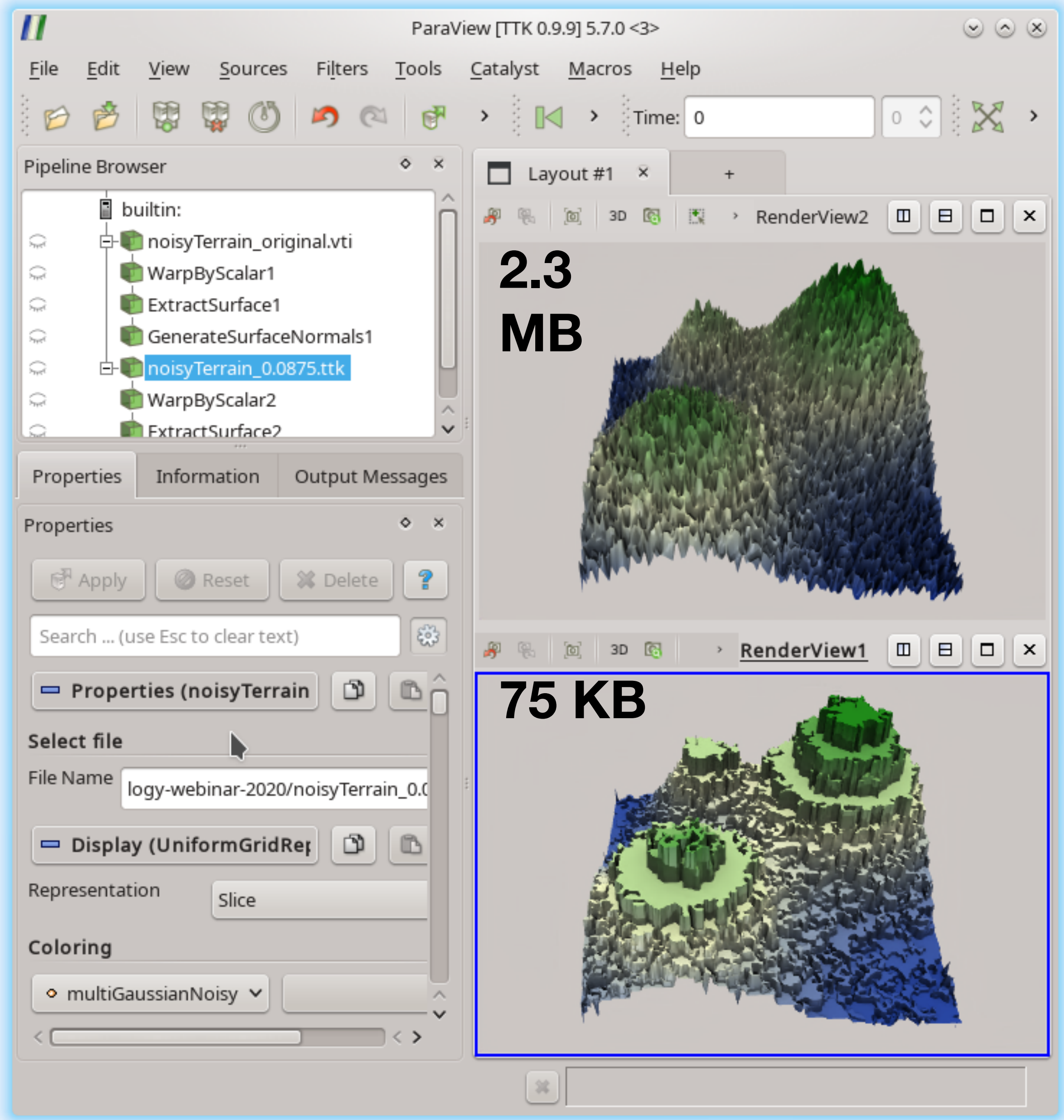

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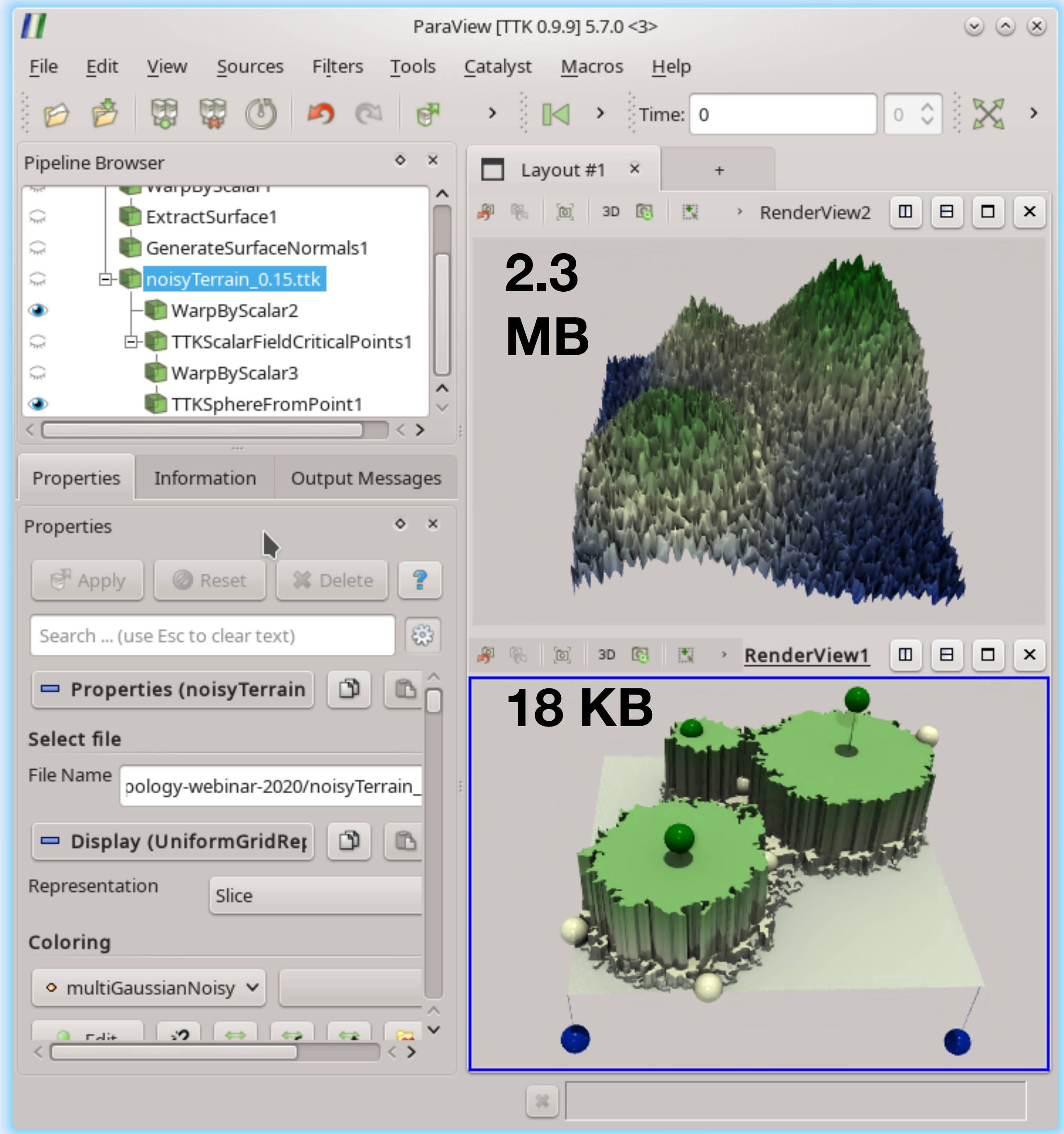

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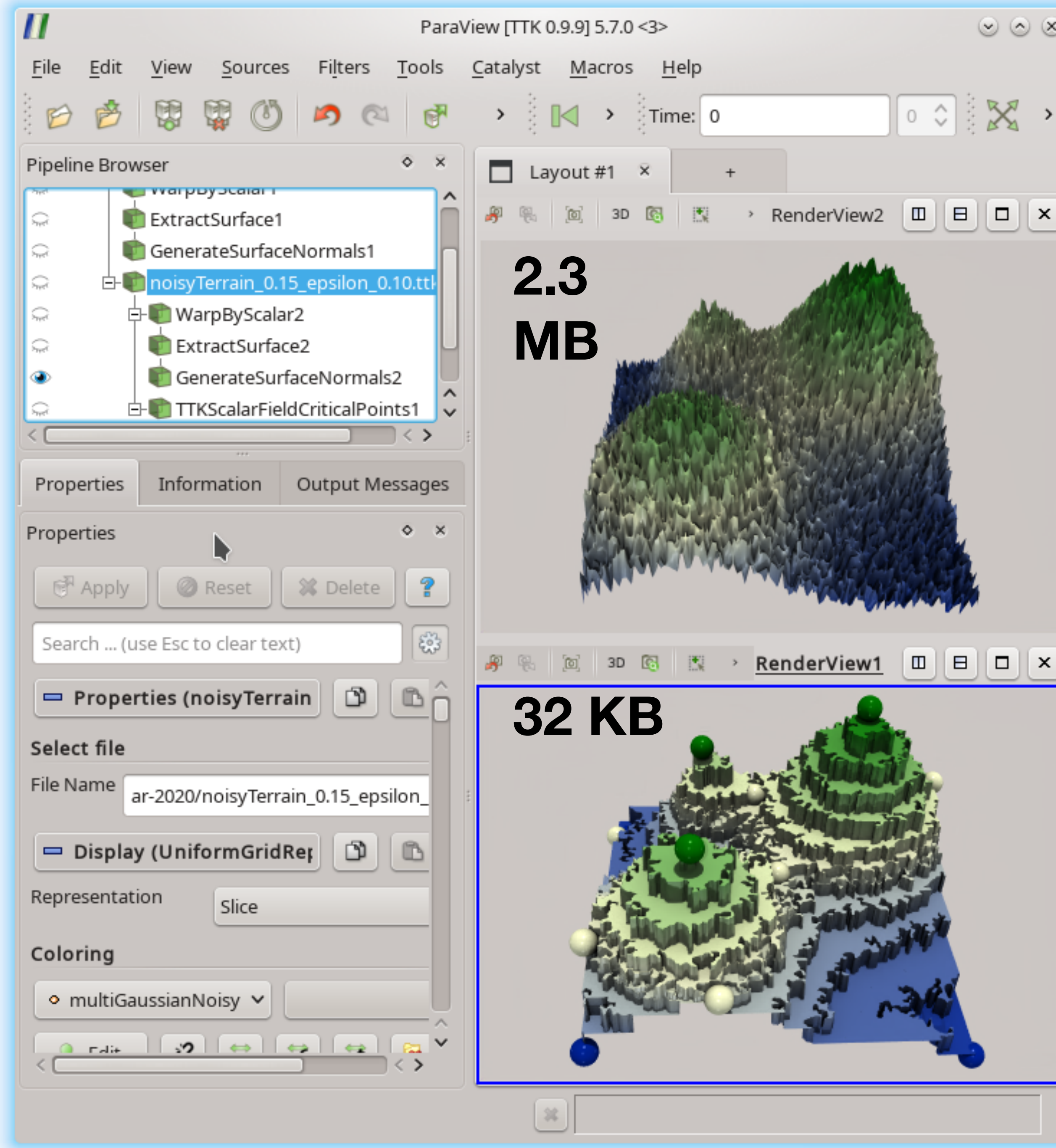

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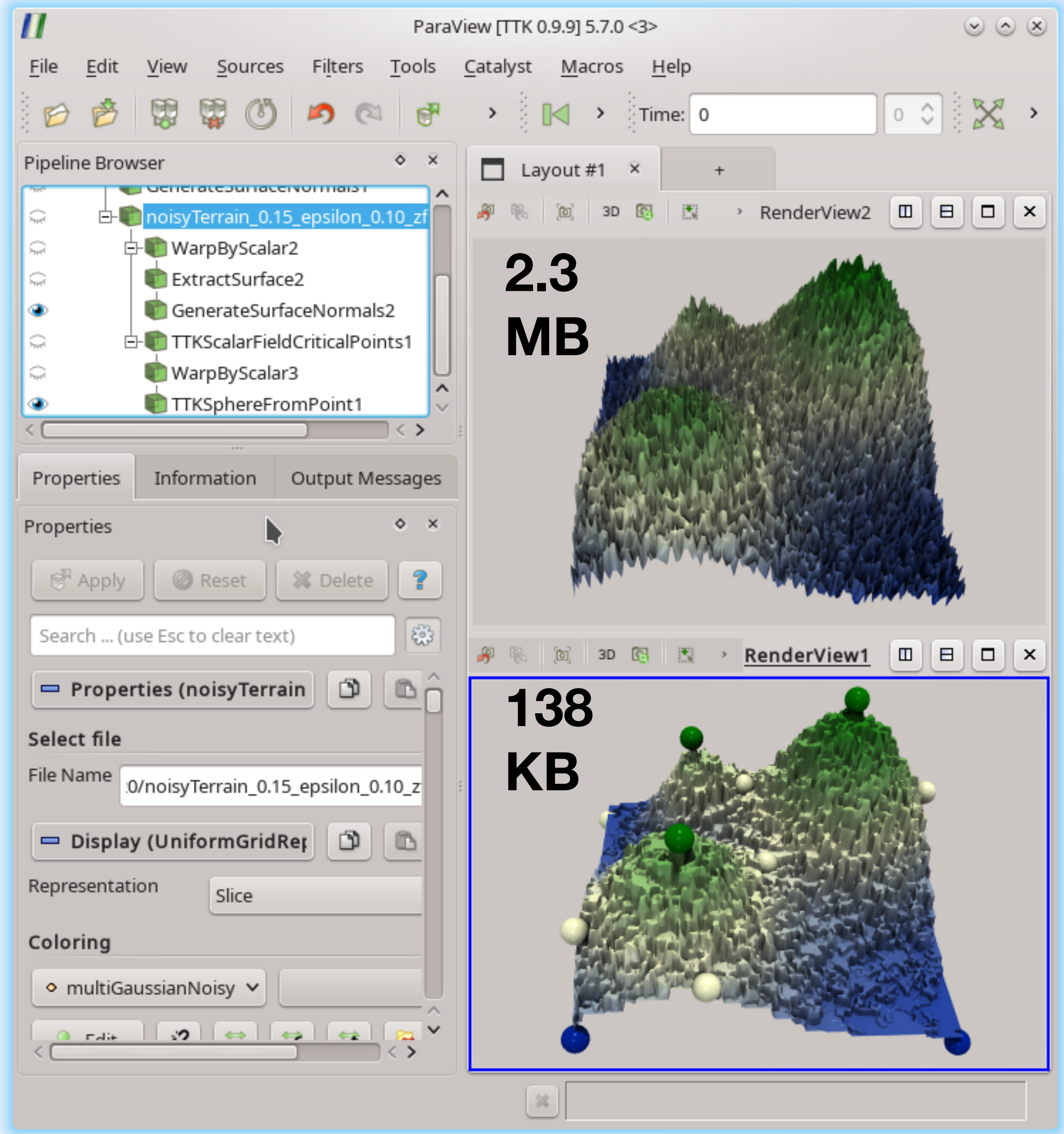
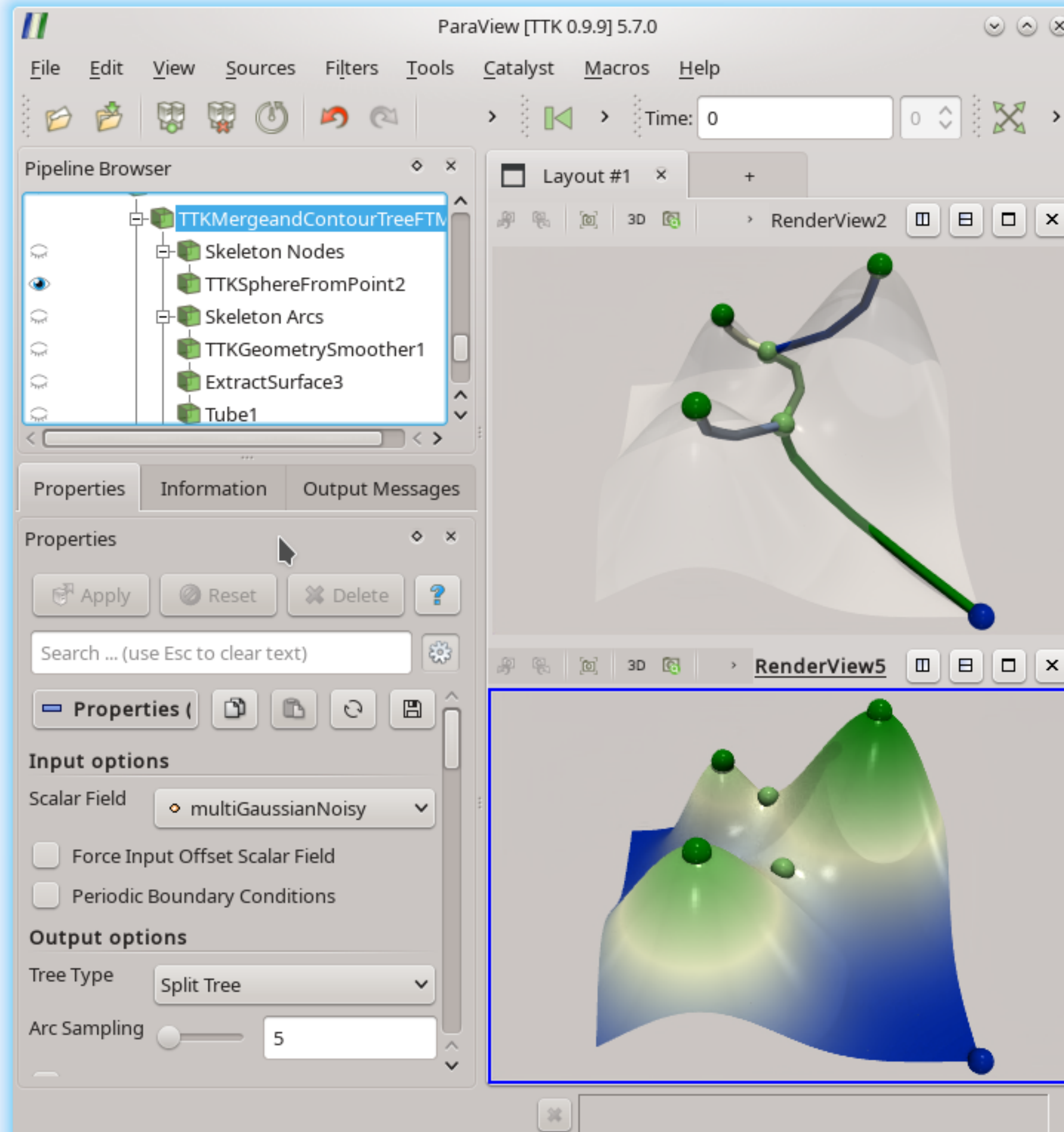


Merge & contour trees

- Module
  - `FTMTree`
  - Skeleton extraction
  - Level-set based segmentation
- Algorithm
  - Gueunet et al. IEEE TPDS 2019
  - Linearithmic time, efficient parallelization
- Output
  - Nodes of the trees
  - Arcs
  - Data segmentation



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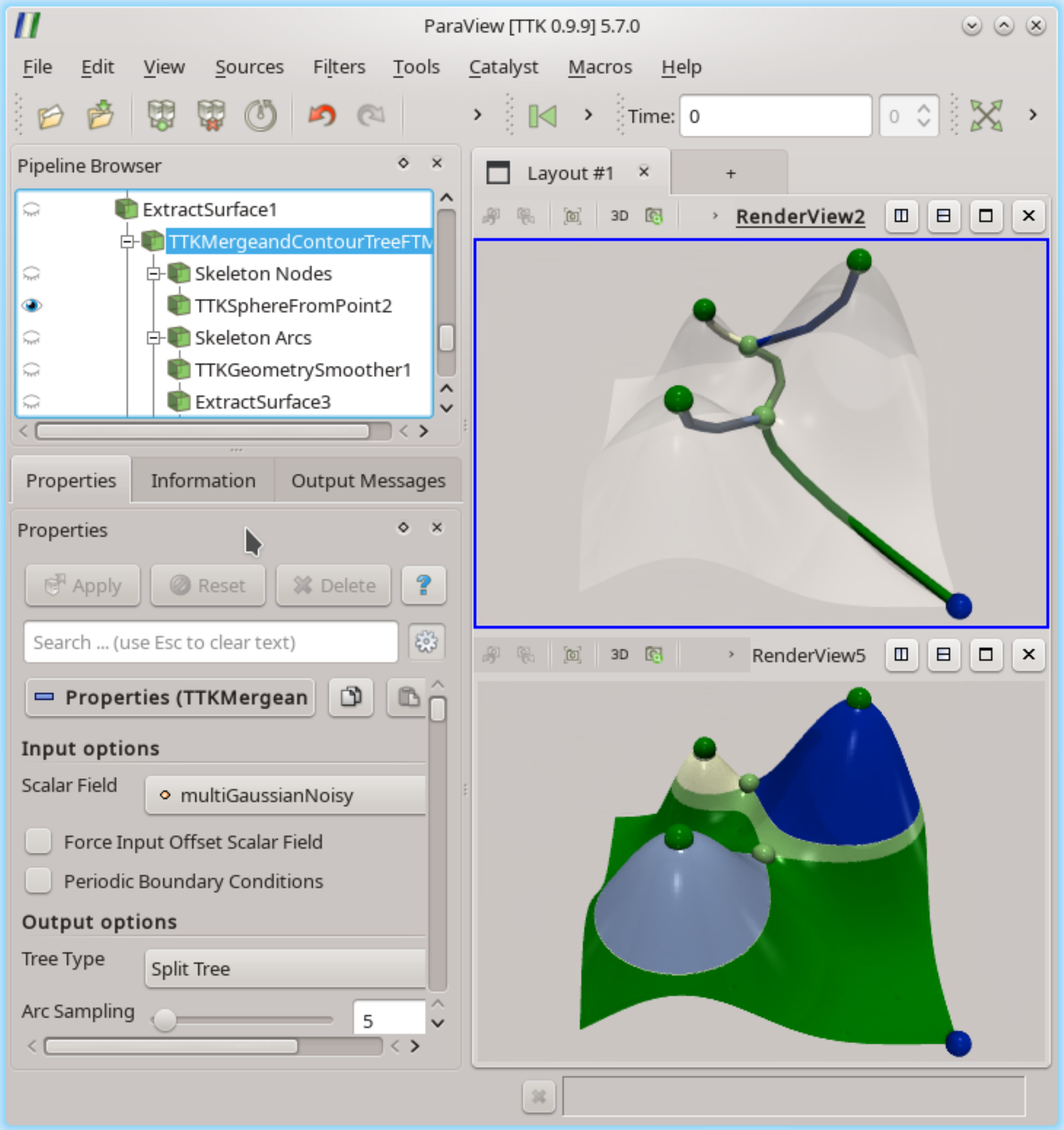

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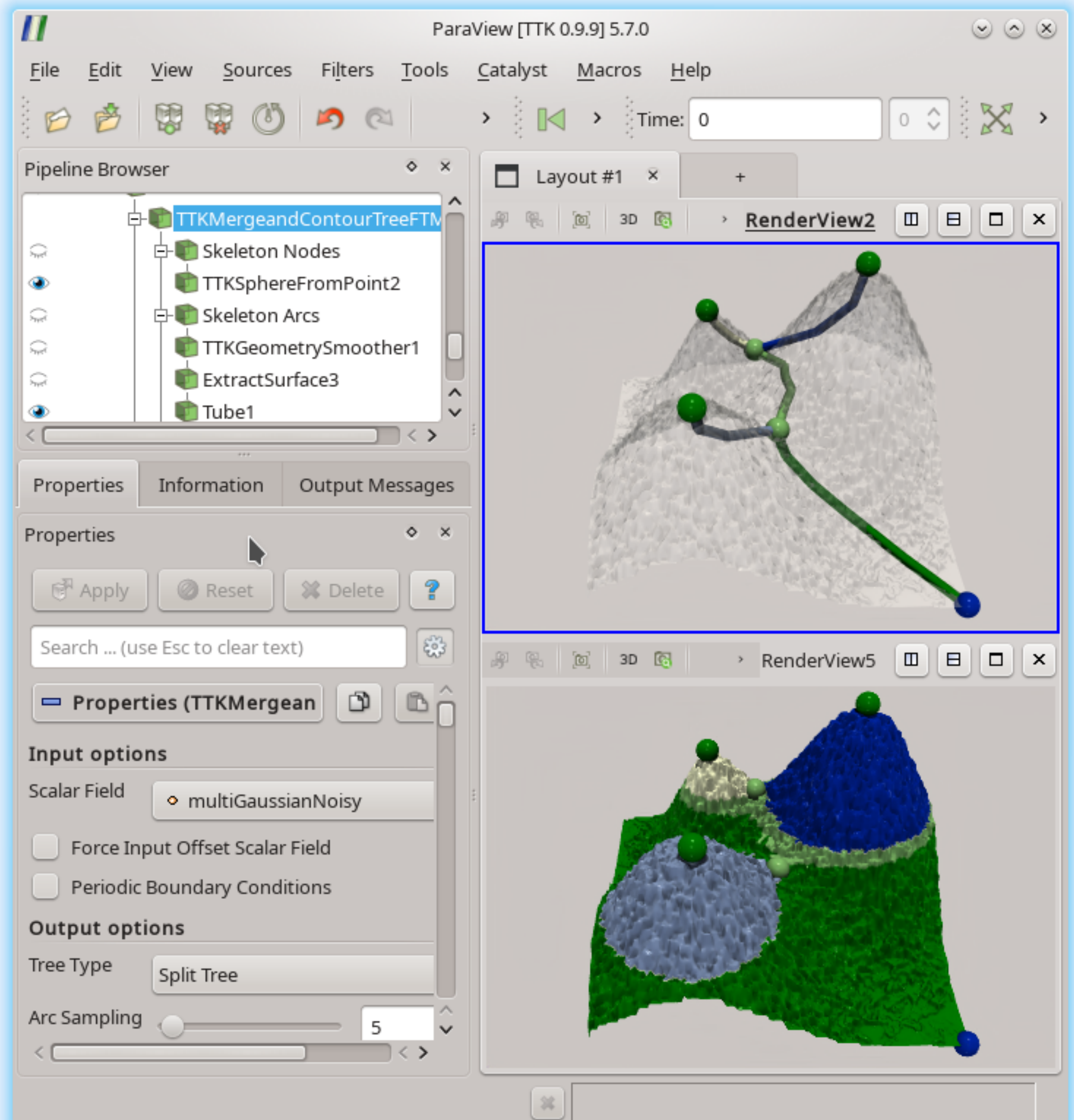
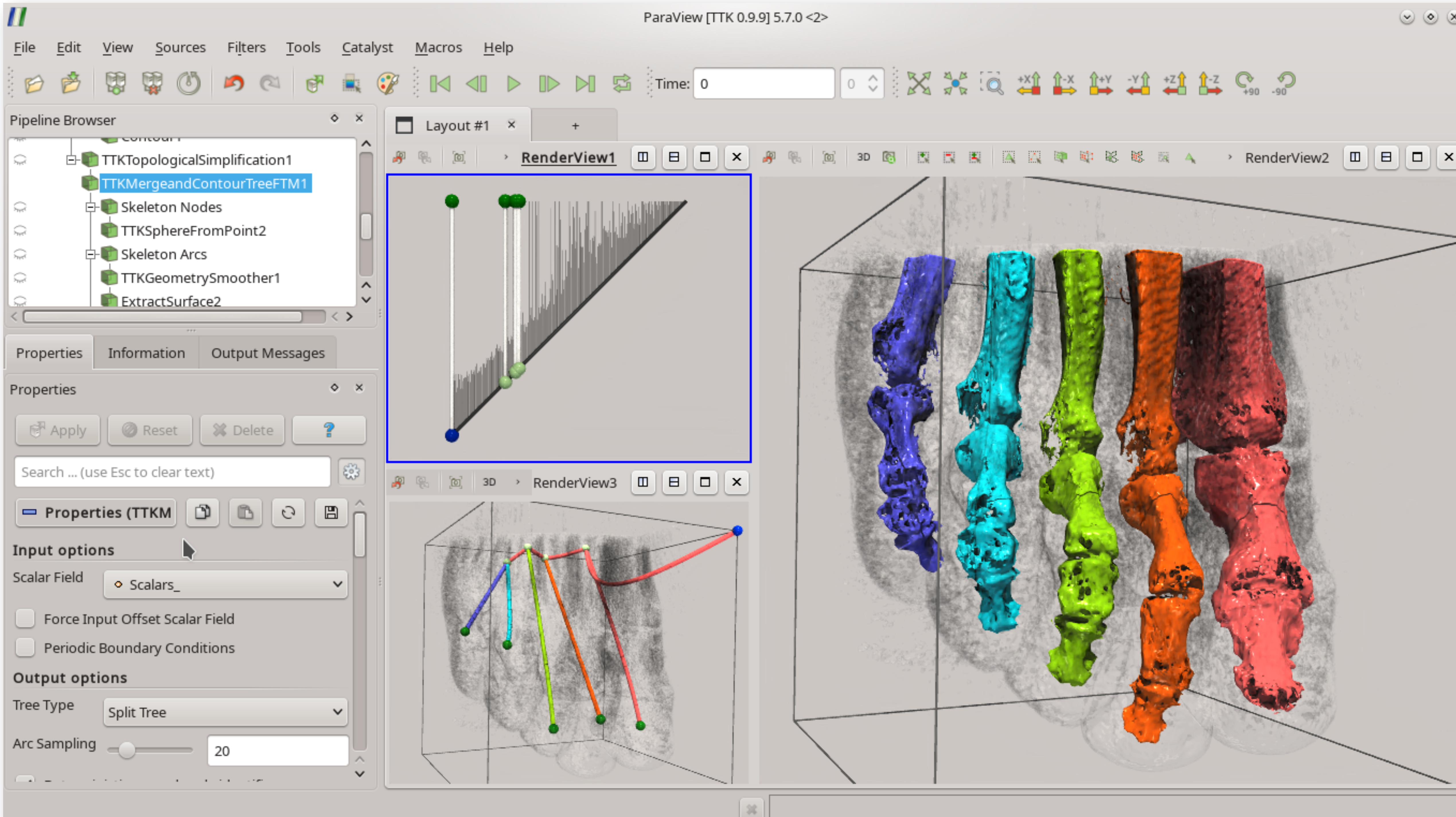


Application to biomedical imaging



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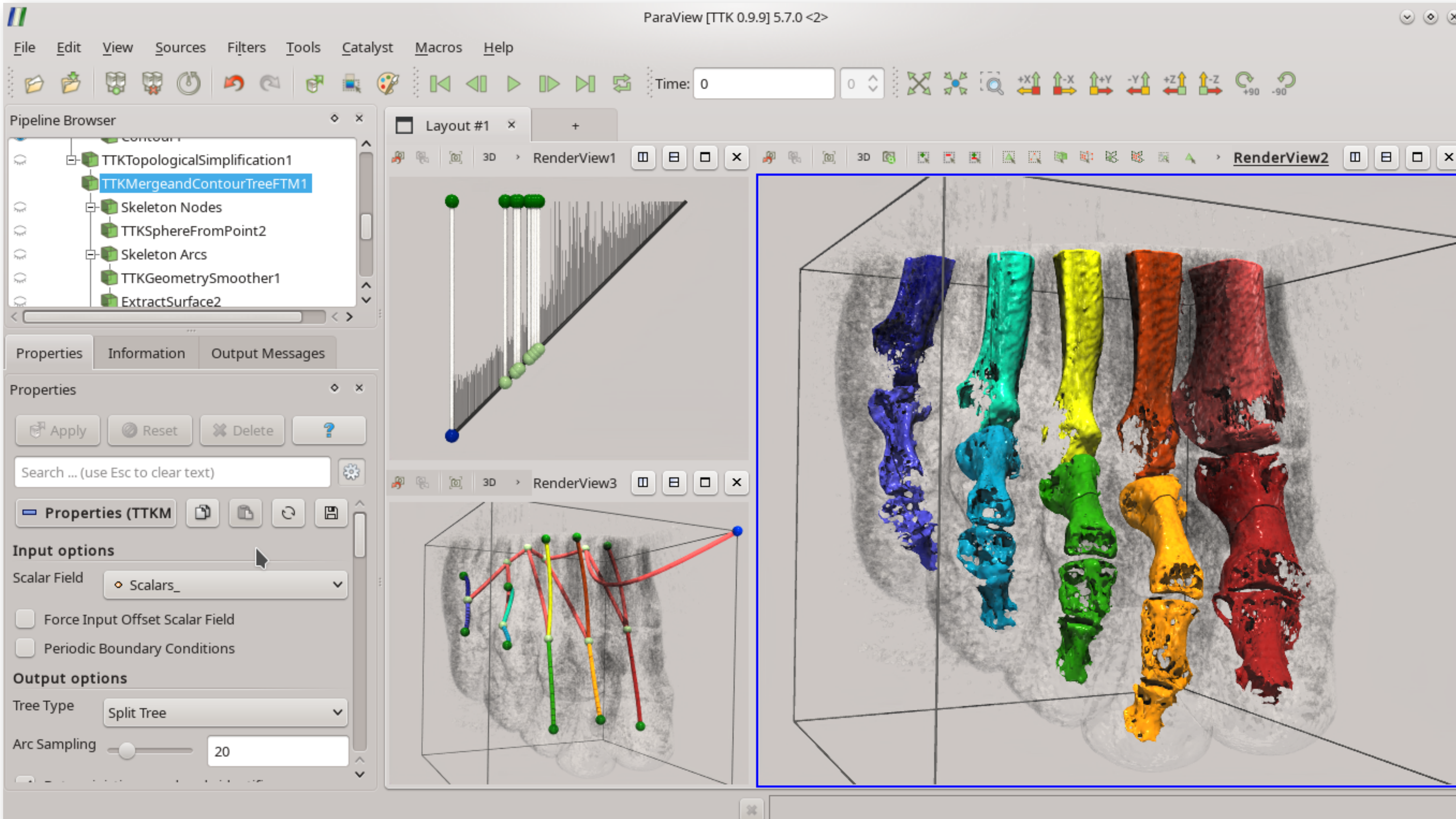
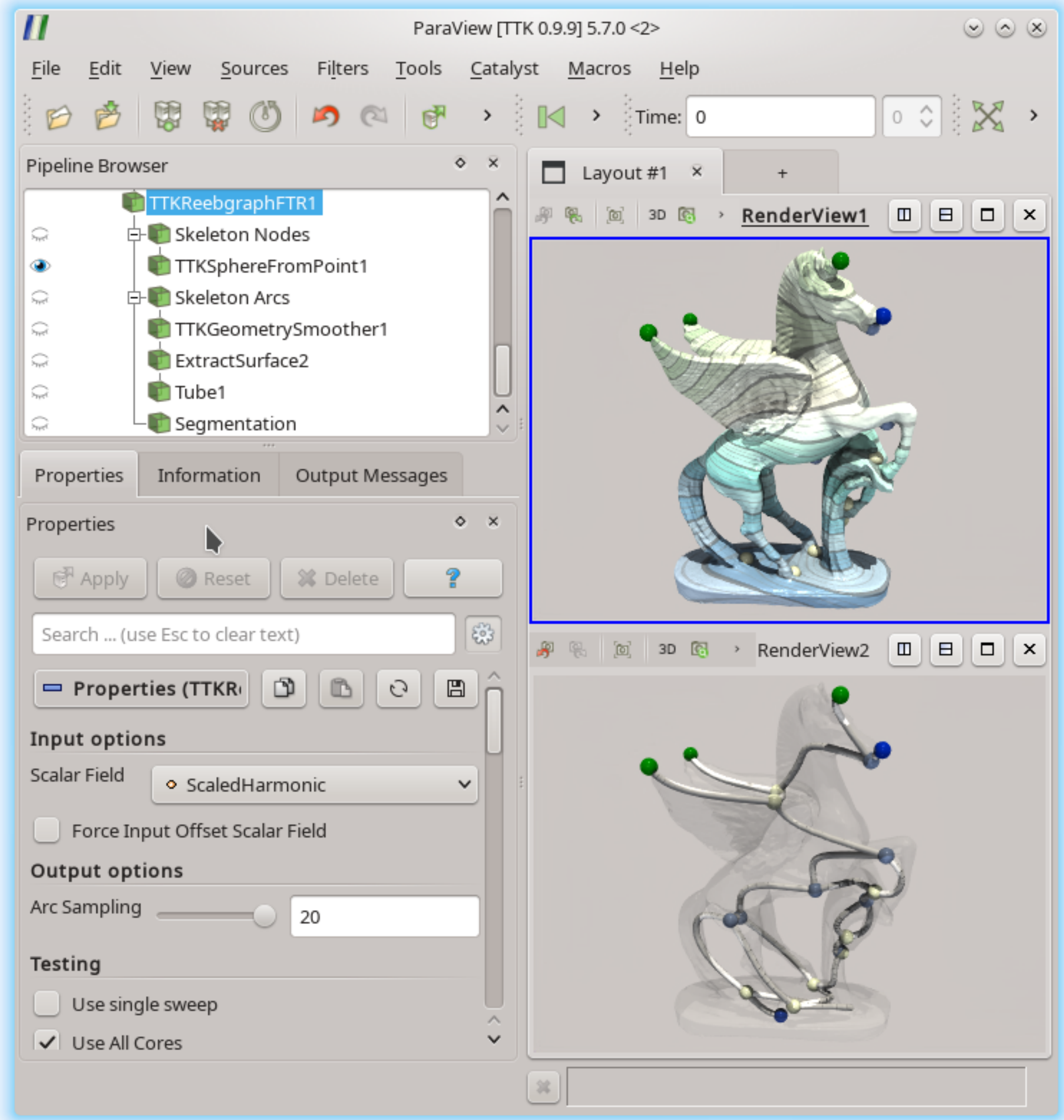


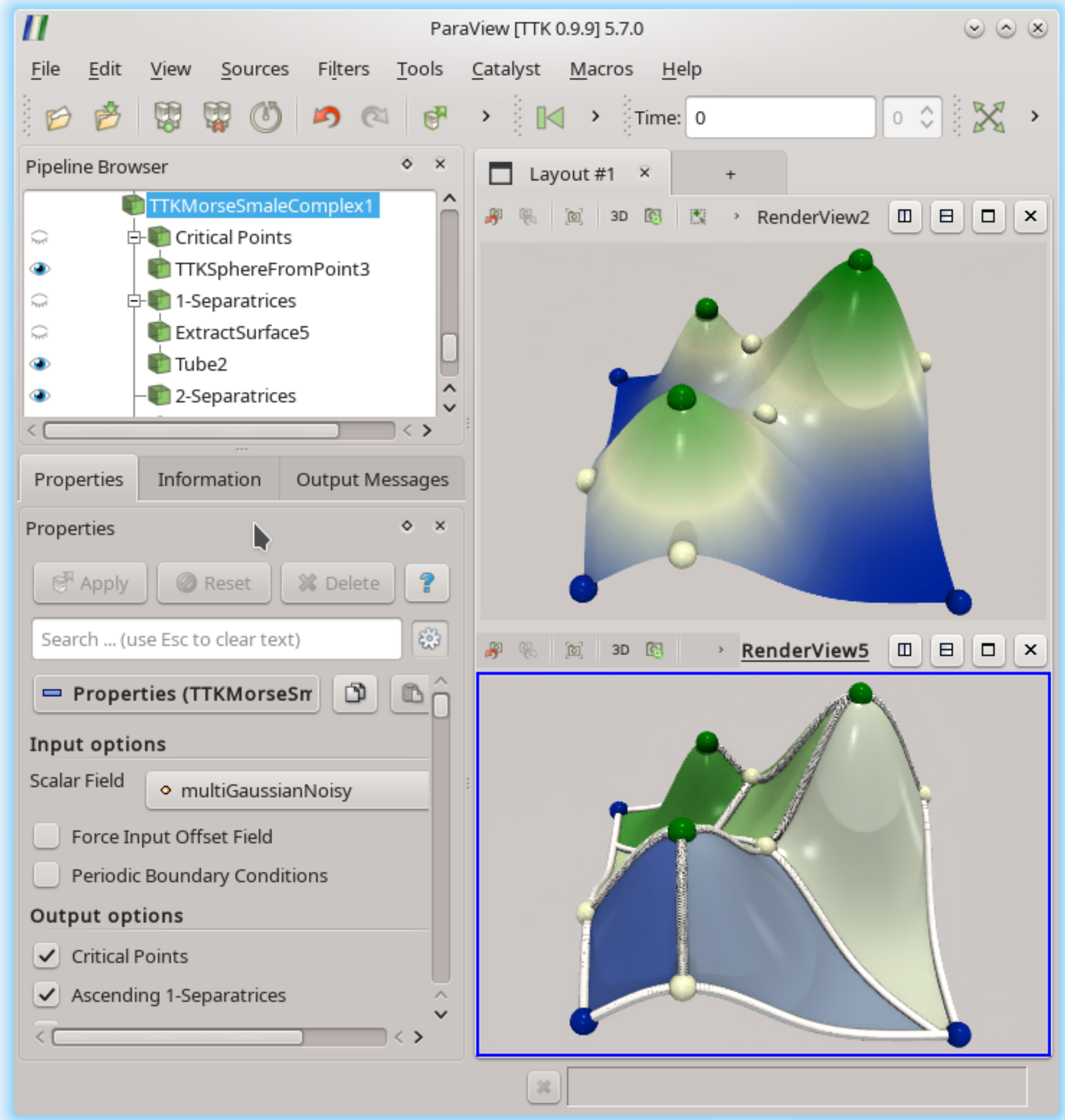
Reeb graphs

- Module
    - **`FTMGraph`**
    - Skeleton extraction
    - Level-set based segmentation
    - For non simply-connected domains
- Algorithm
    - Gueunet et al. EGPGV 2019
    - Linearithmic time
        - Fast Parallelization of Parsa SoCG 2012
- Output
    - Nodes of the trees, Arcs, Data segmentation



Morse-Smale complexes

- Module
  - `MorseSmaleComplex`
  - Extremal curves, separating surfaces
- Algorithms
  - Discrete Morse Theory, Forman SLC 2002
  - Complex extraction via v-path collection (BFS)
    - Quadratic time (worst case)
  - Discrete gradient
    - Tierny et al. IEEE TVCG 2017
- Output
  - Critical points, separatrices, segmentation



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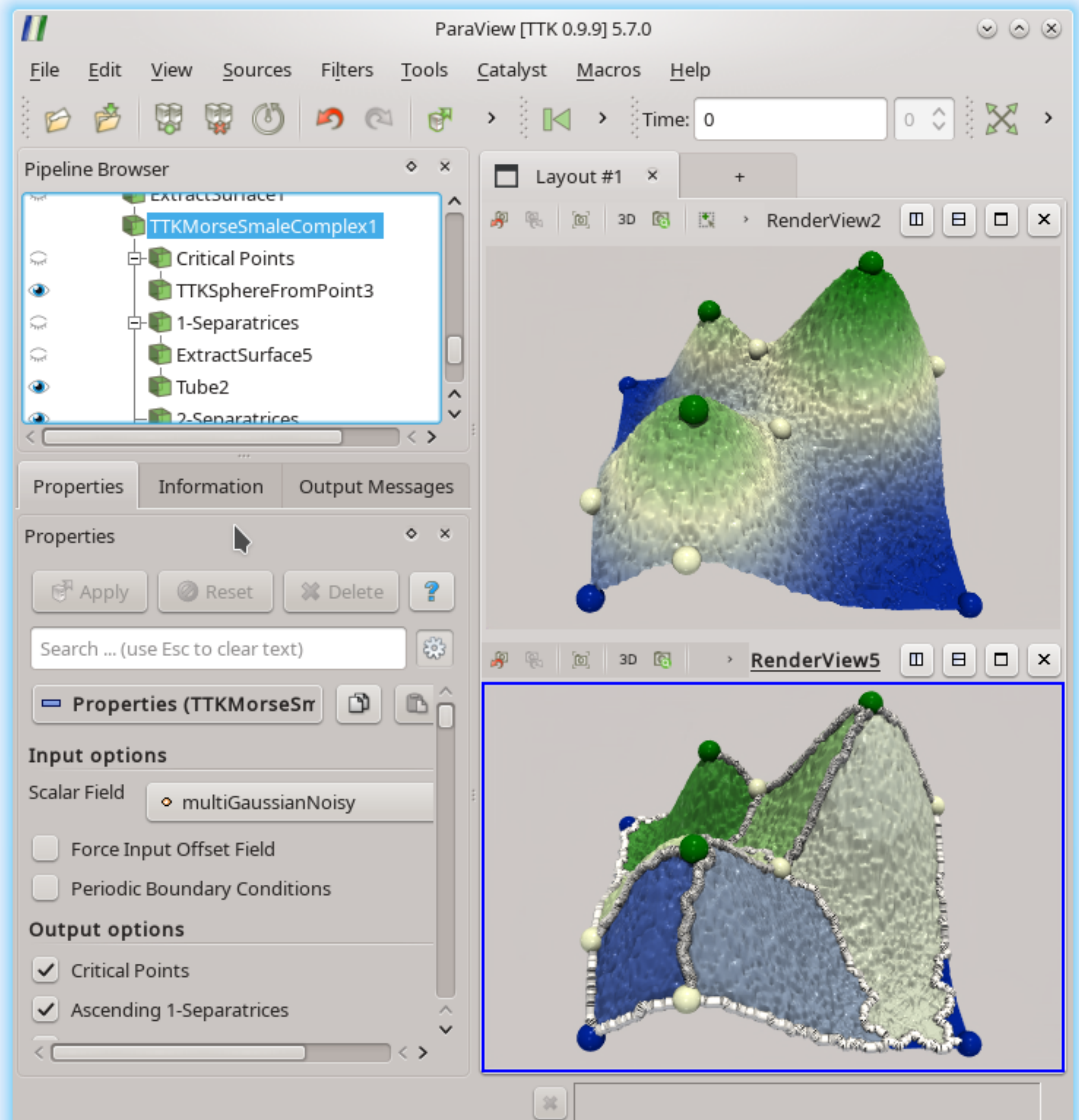
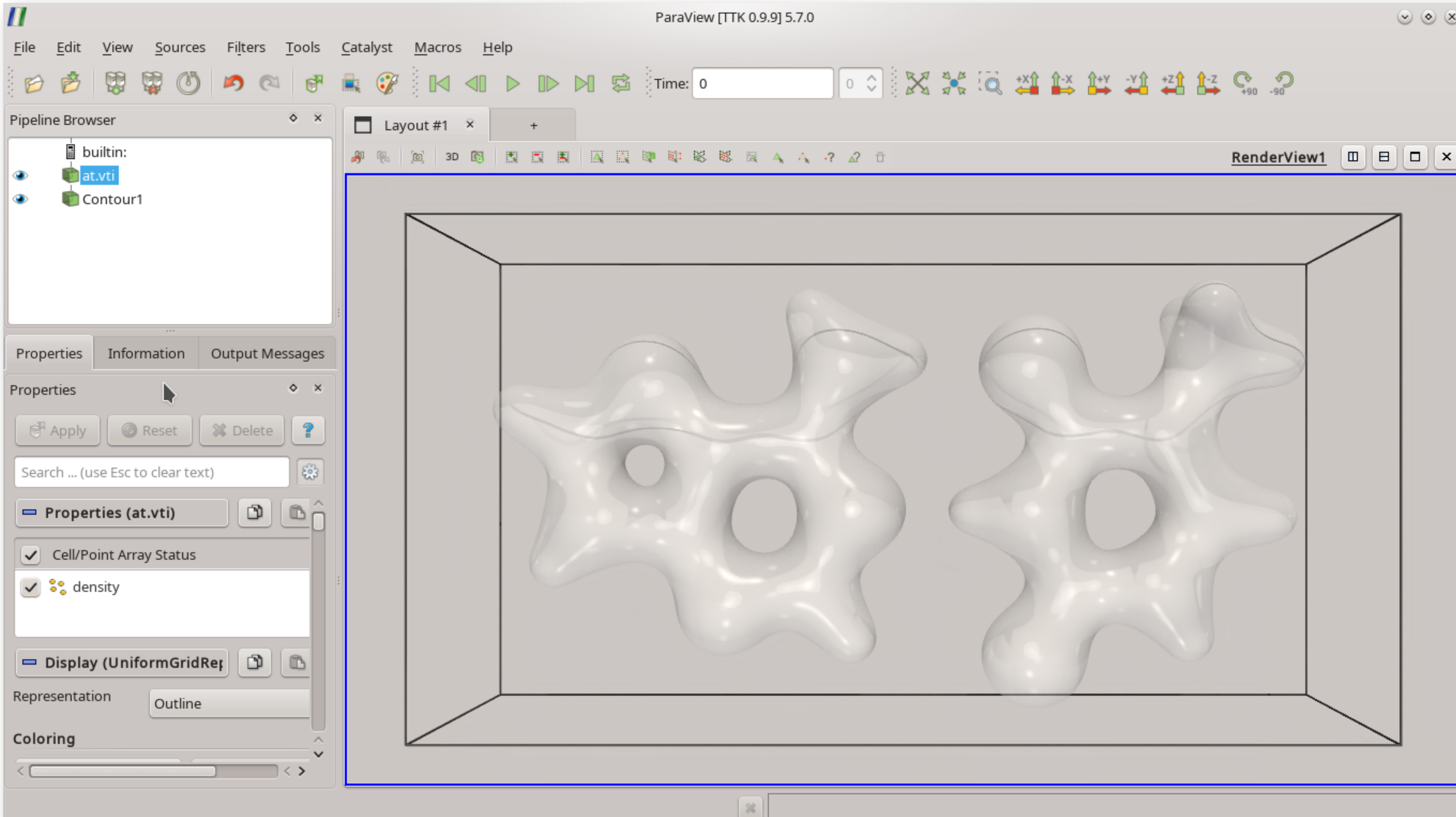


Application to quantum chemistry



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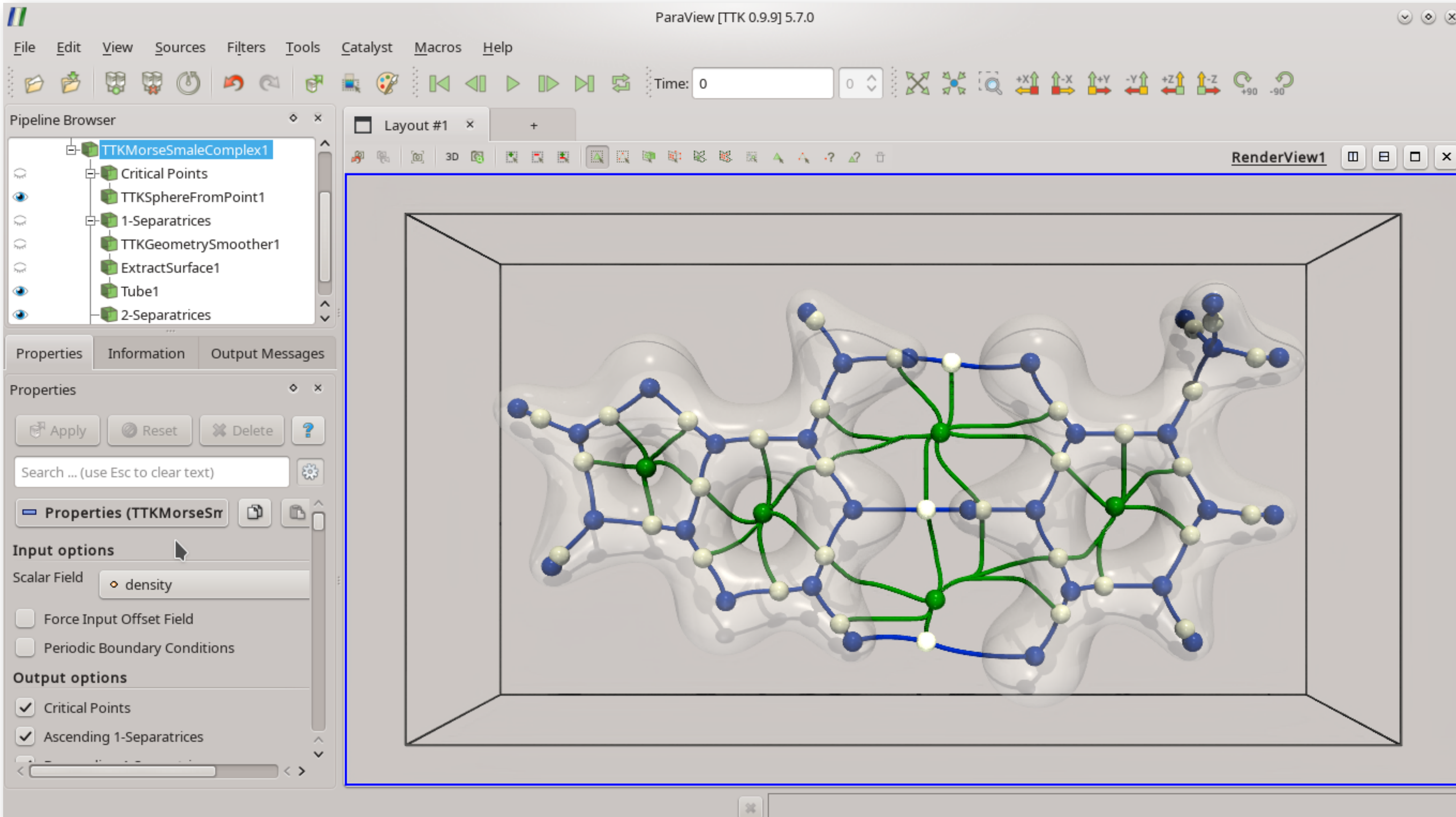

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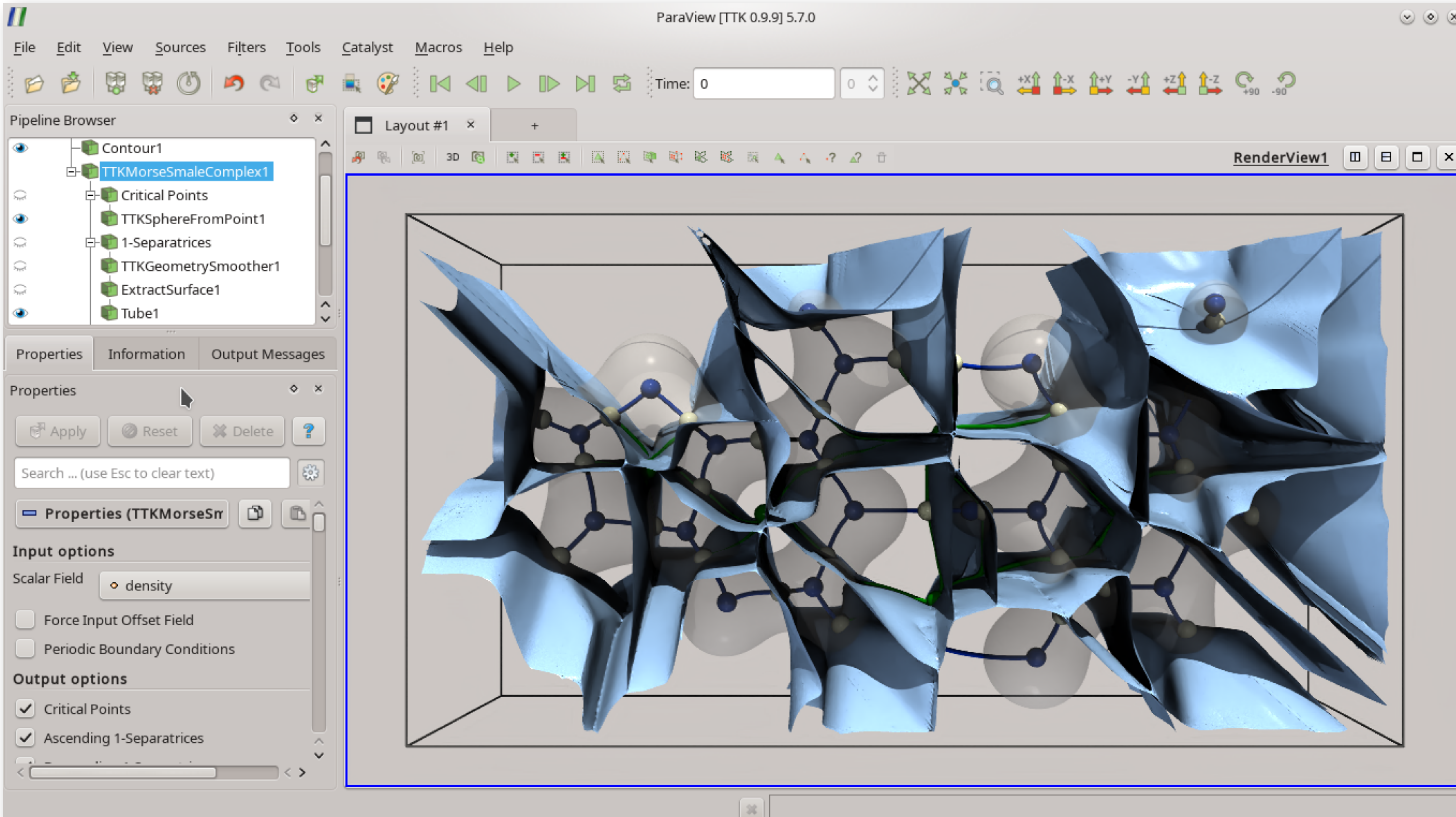

More Demos!

Examples: https://topology-tool-kit.github.io/examples/index.html

Data: https://github.com/topology-tool-kit/ttk-data