



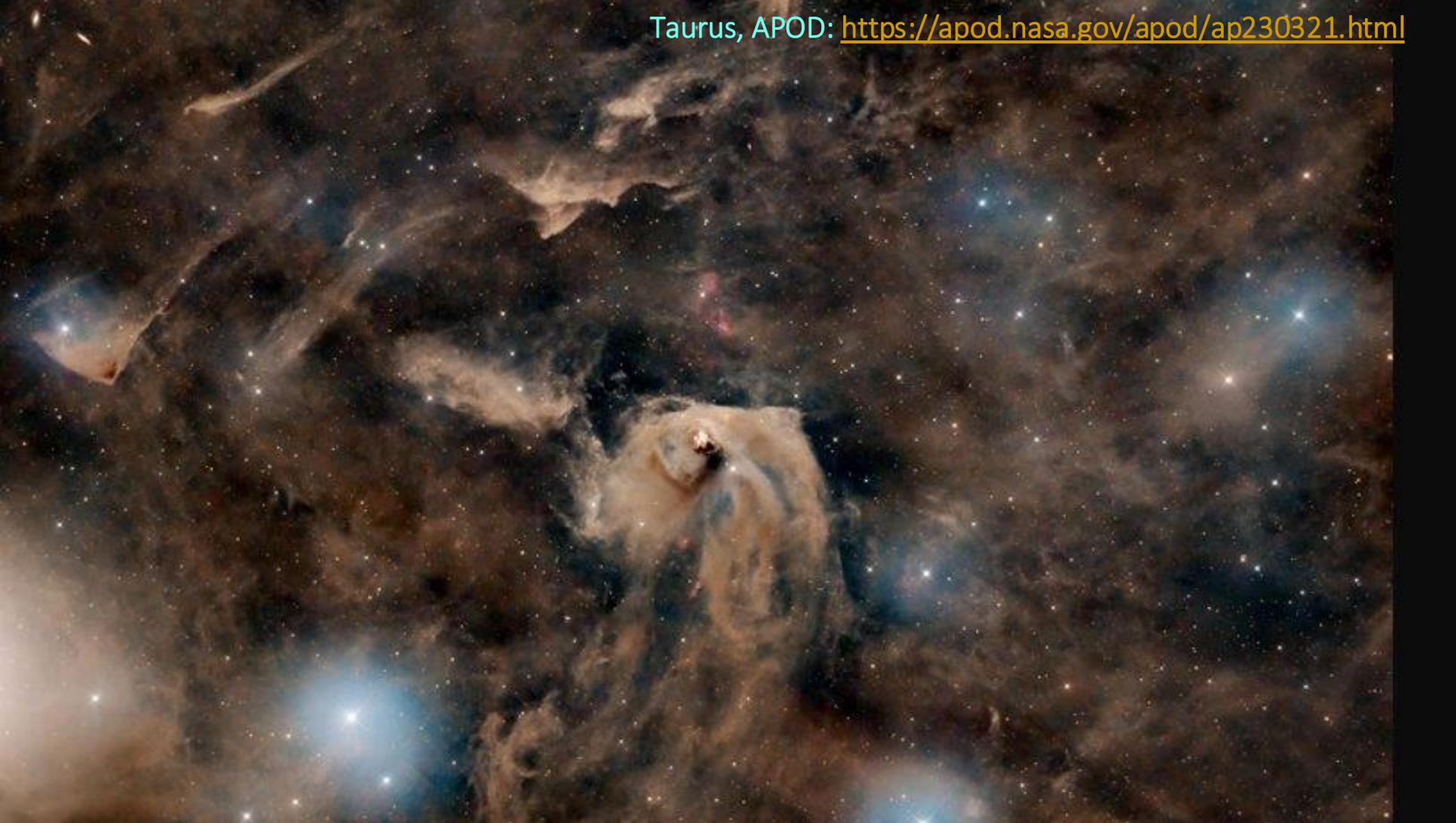
UNIVERSIDAD
DE VALLADOLID

Proyecto PID2023-146635NA-I00 financiado por:



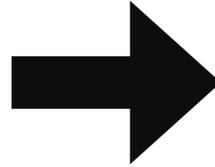
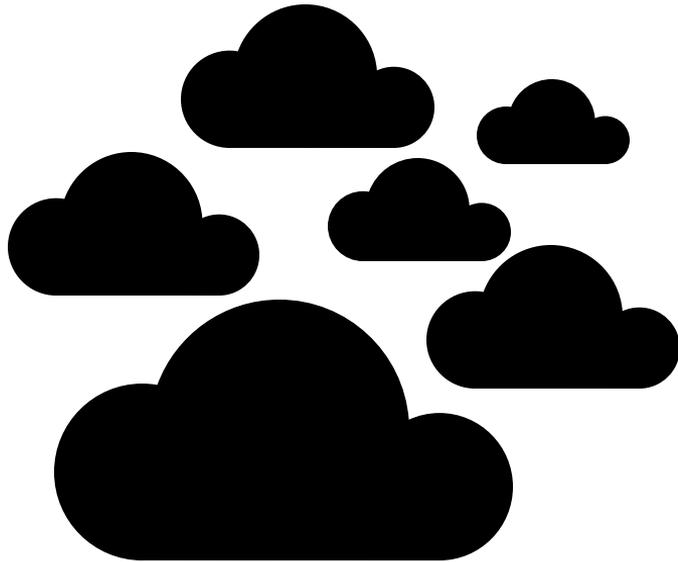
Topological Data Analysis applied to star formation

MARTA GONZÁLEZ GARCÍA



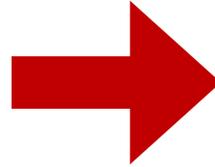
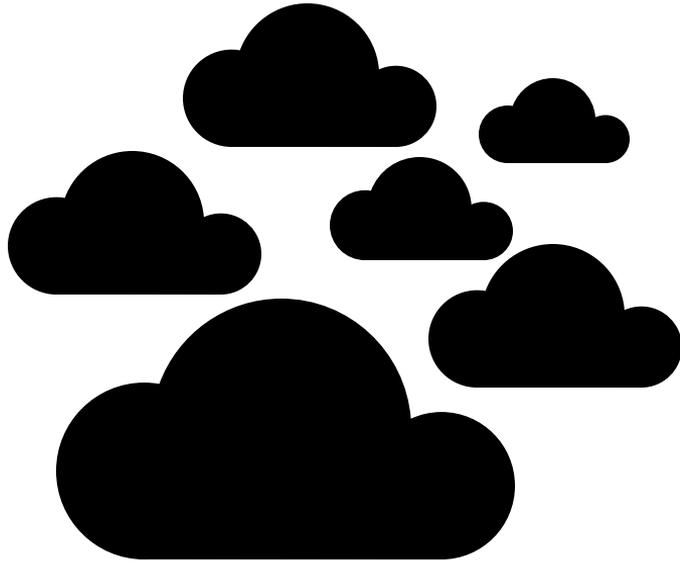
Star Formation

What we know



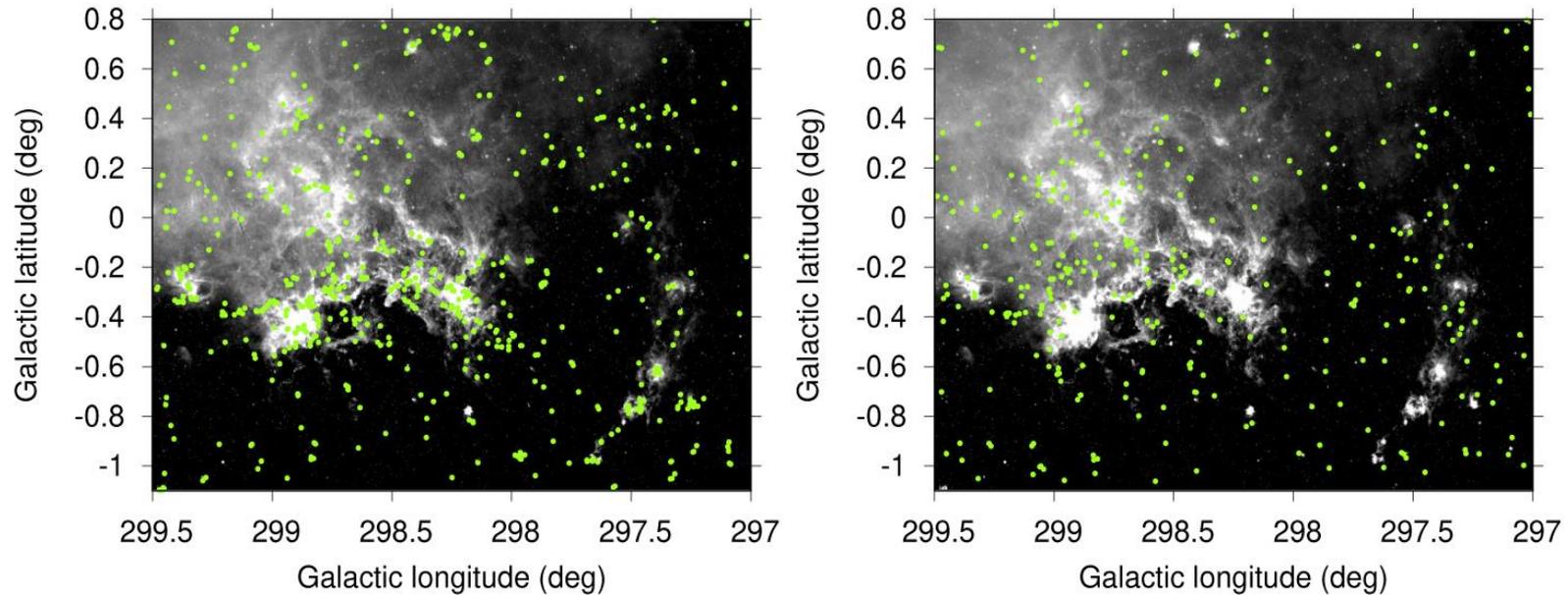
Star Formation

What we **don't** know



- Collapse
- Fragmentación
- Massive star formation
- Feedback
- ...

Dragonfish

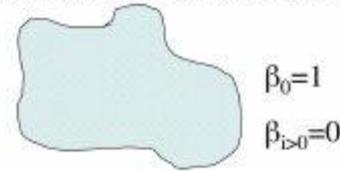


Sanchez, N., Nespoli, E., Gonzalez, M., and Climent, J. B., "Cloud structure and young star distribution in the Dragonfish complex", *Astronomy and Astrophysics*, vol. 688, Art. no. A224, 2024. doi:10.1051/0004-6361/202450830.

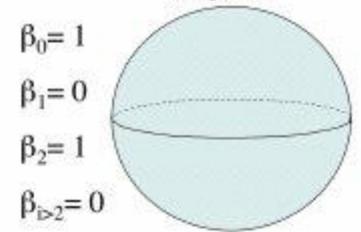
Topological intuitions

- Topology: Branch of math associated with the study of spaces, both globally and locally.
- Topological features can be intuitively understood as qualitative 'shape' notions, and are resistant to deformations: "**rubber-sheet geometry**"
- Betti number β_D counts the number of "D-dimensional holes" within a shape:
 - 0D – Connected components
 - 1D – loops
 - 2D voids...

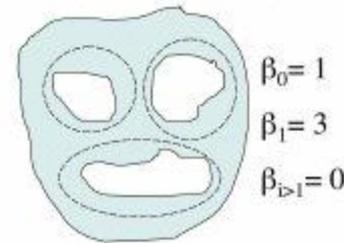
A solid 2-dimensional blob



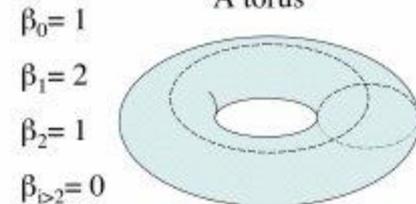
A sphere



A 2D blob with three holes

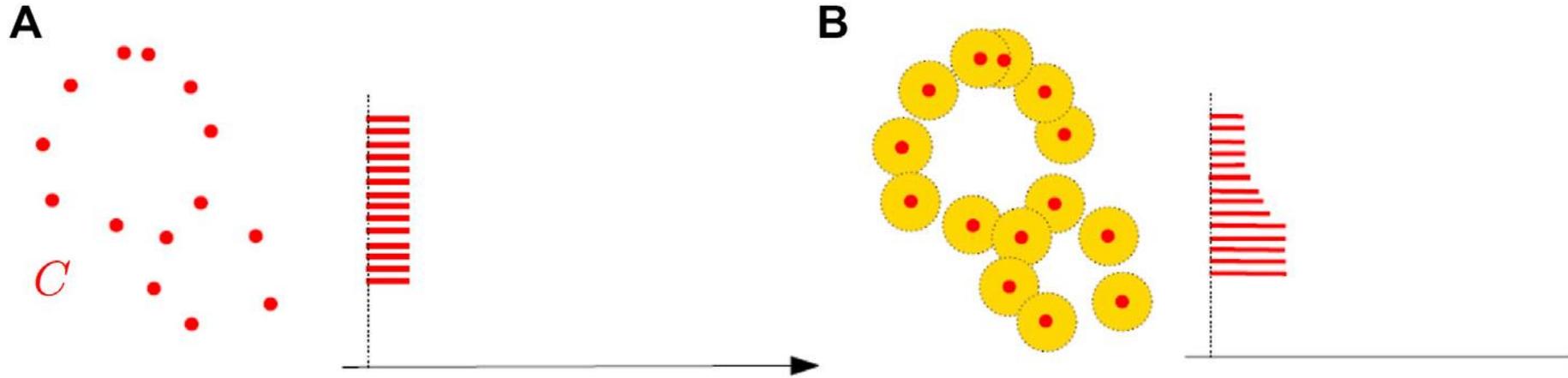


A torus



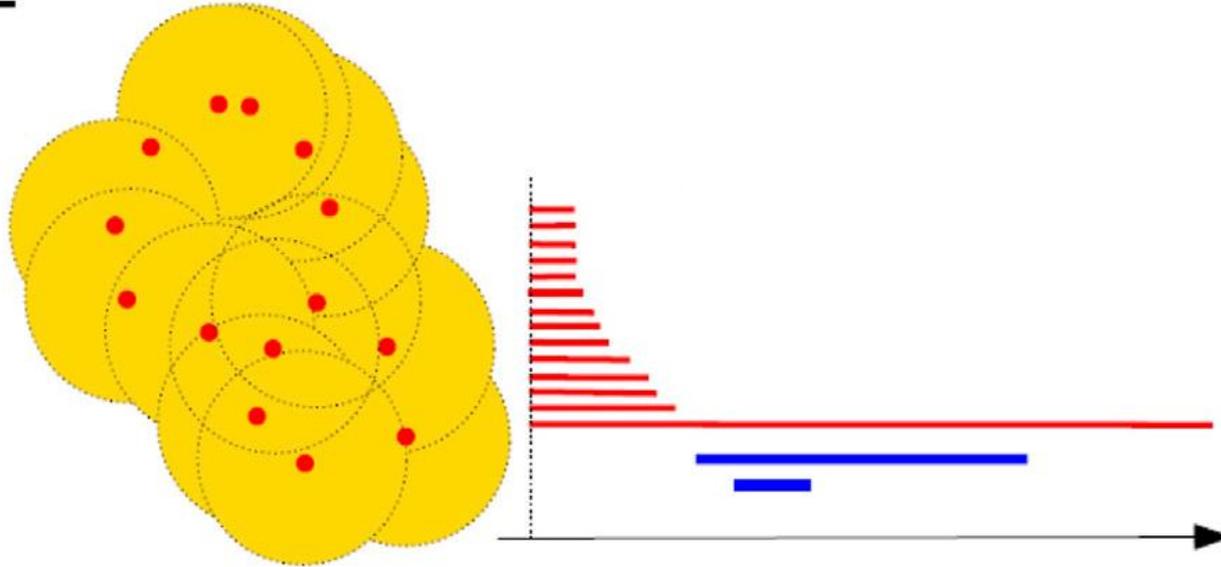
Brenton Walker. 2008. *Using persistent homology to recover spatial information from encounter traces*. In Proceedings of the 9th ACM international symposium on Mobile ad hoc networking and computing (MobiHoc '08). Association for Computing Machinery, New York, NY, USA, 371–380. <https://doi.org/10.1145/1374618.1374668>

Homological persistence: Barcodes



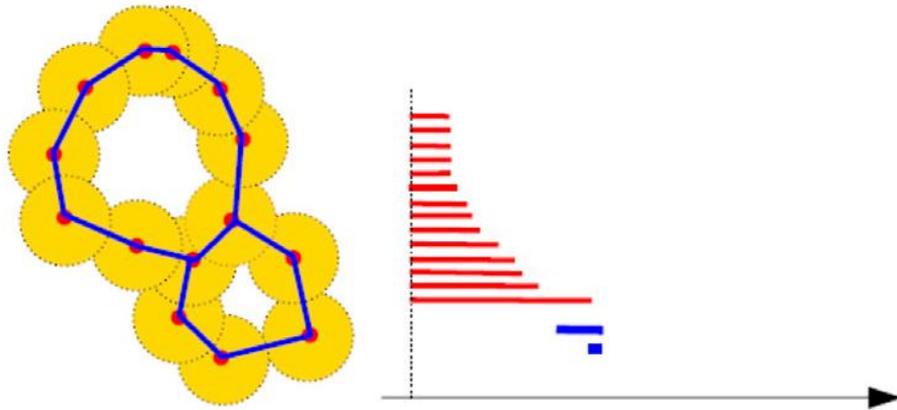
Homological persistence: Barcodes

E

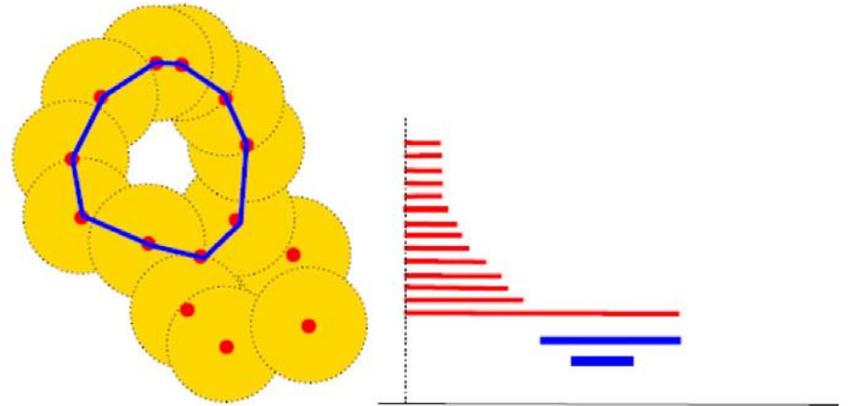


Homological persistence: Barcodes

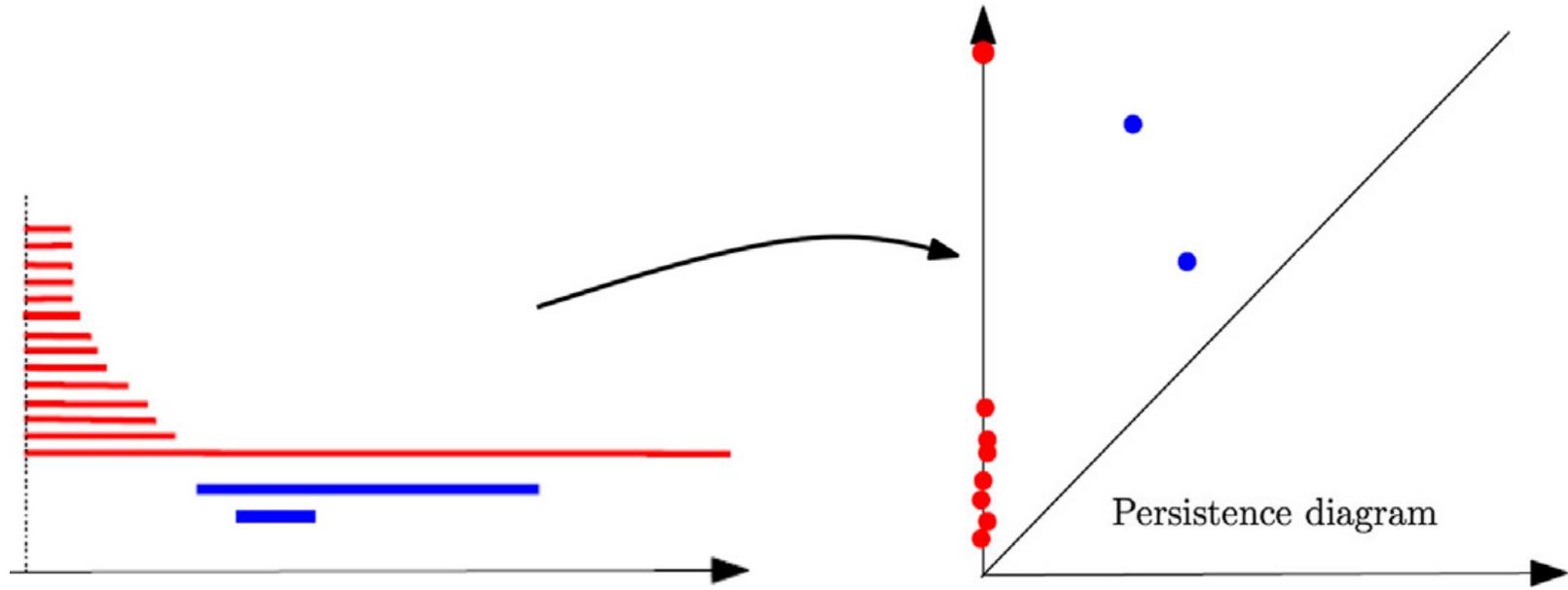
C



D



Persistence diagrams



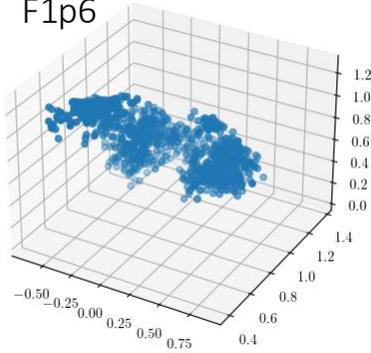
Calibration



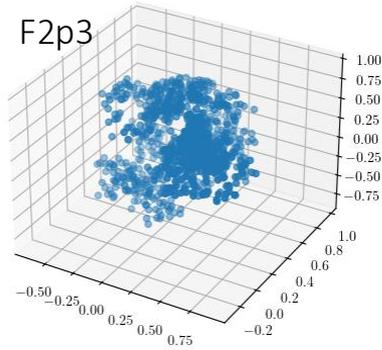
EXTREMELY PRELIMINARY

Sample distributions (n=1000)

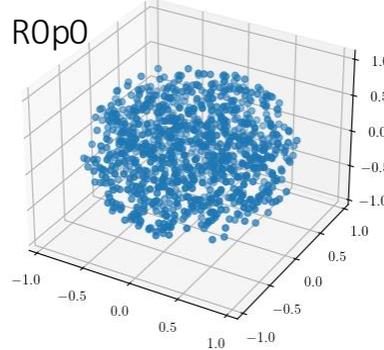
F1p6



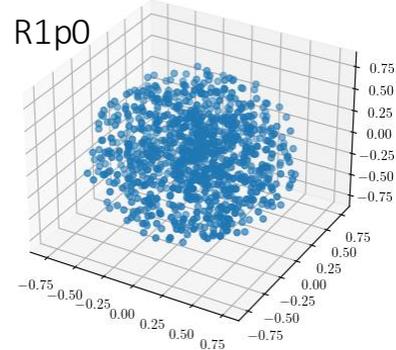
F2p3



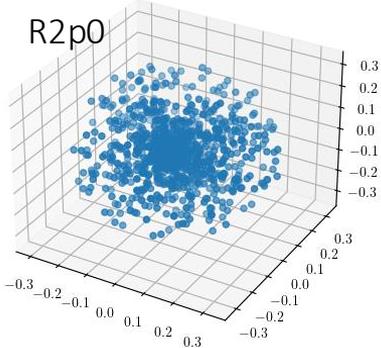
R0p0



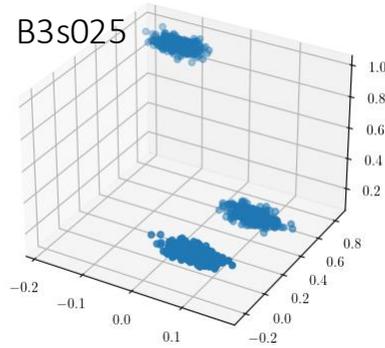
R1p0



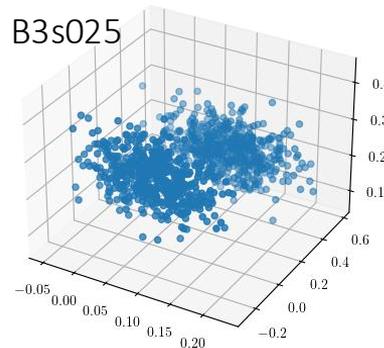
R2p0



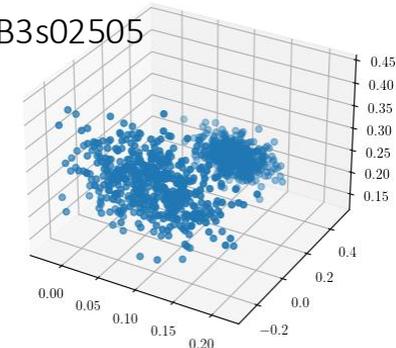
B3s025



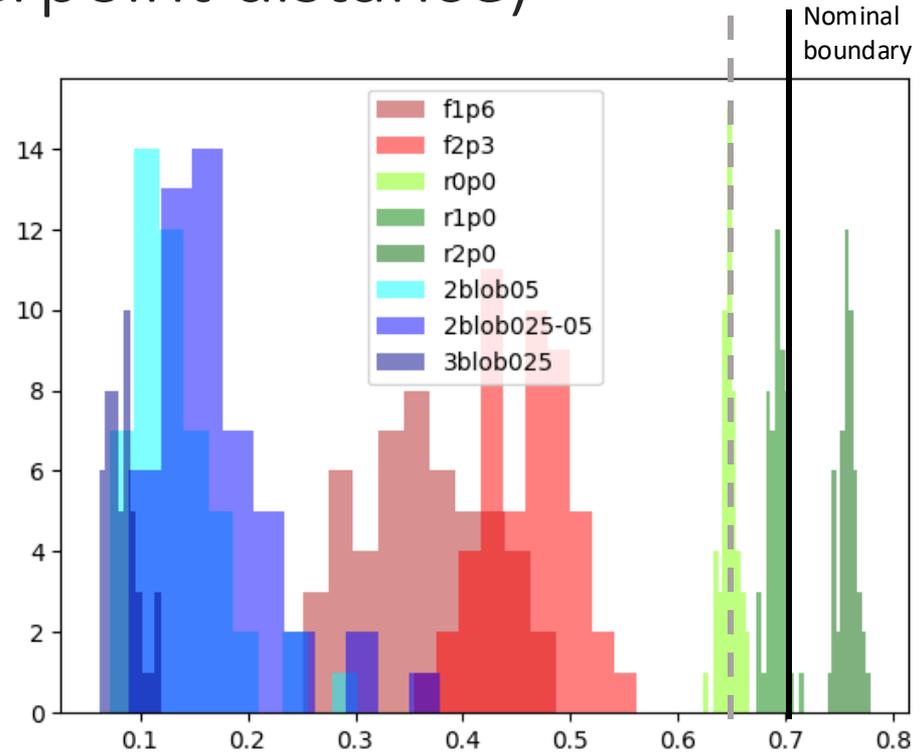
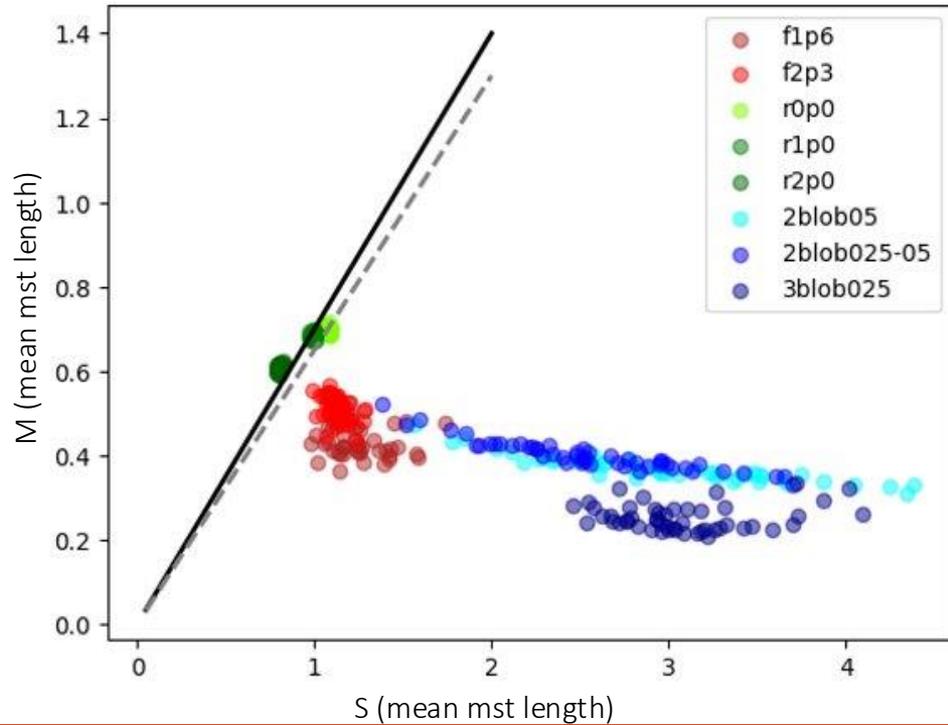
B3s025



B3s02505

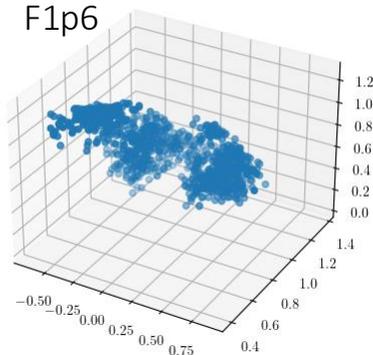


Classical analysis Q parameter (quotient of normalized mst length/interpoint distance)

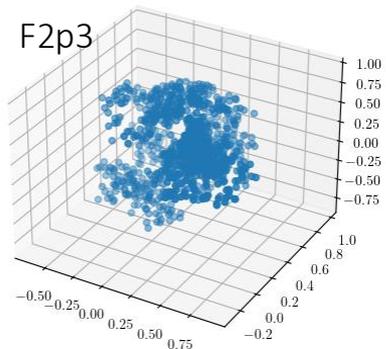


Persistence diagrams

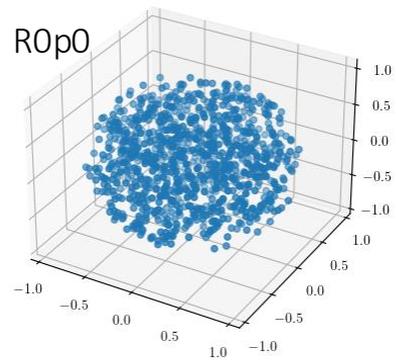
F1p6



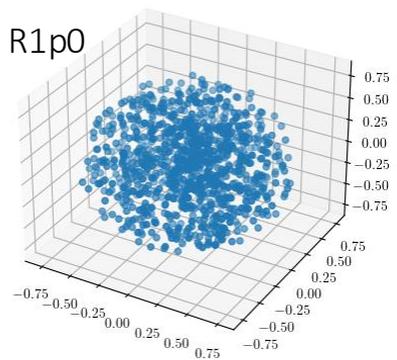
F2p3



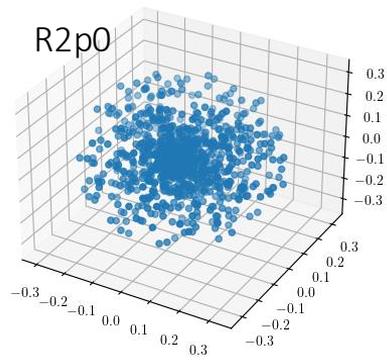
R0p0



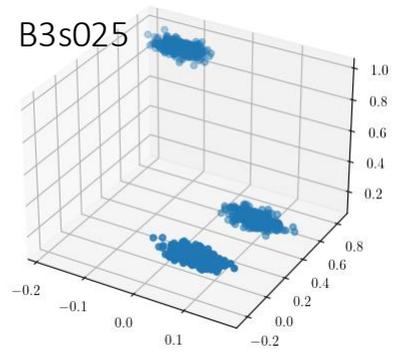
R1p0



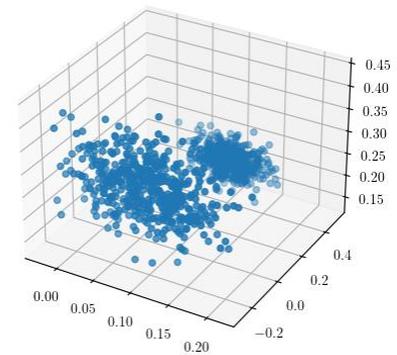
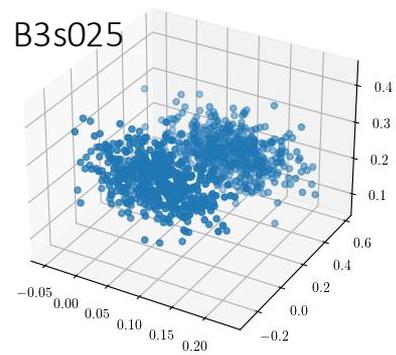
R2p0



B3s025



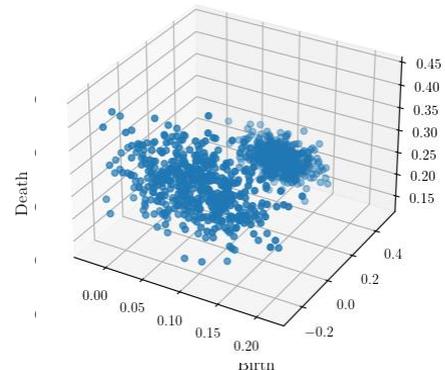
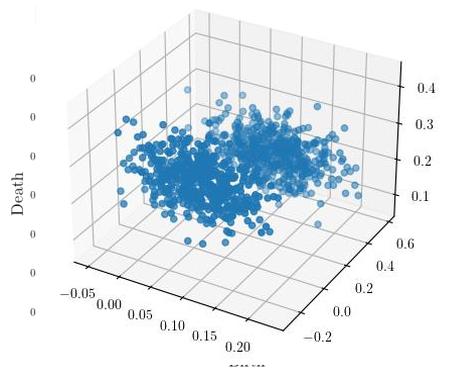
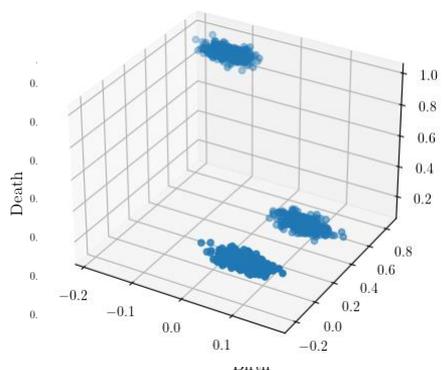
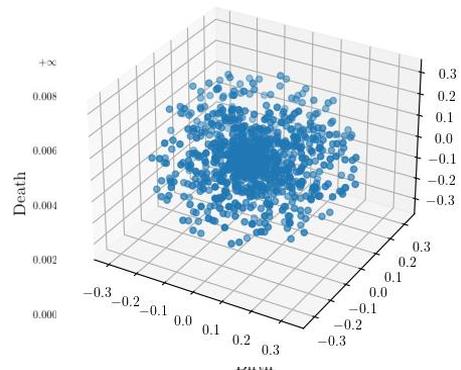
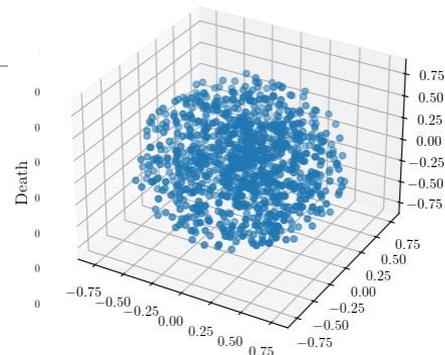
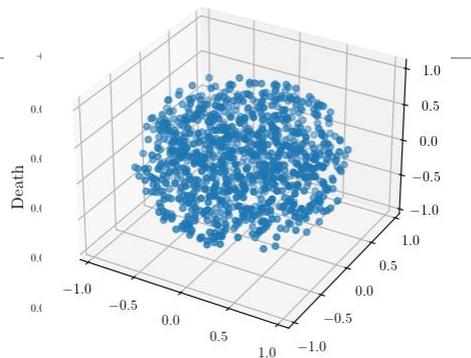
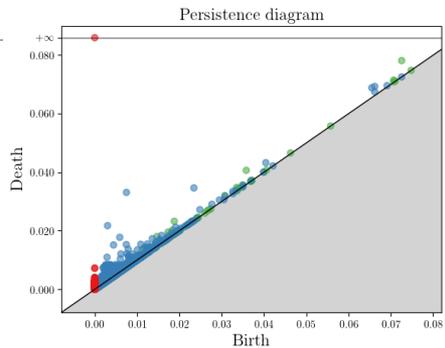
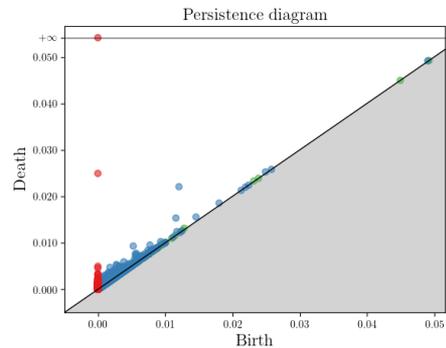
B3s025



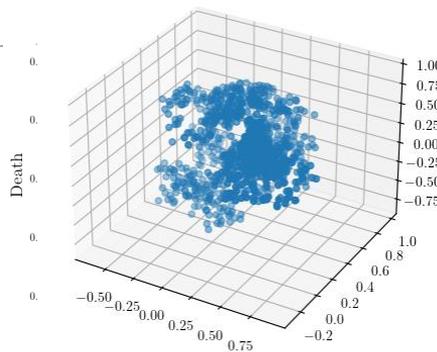
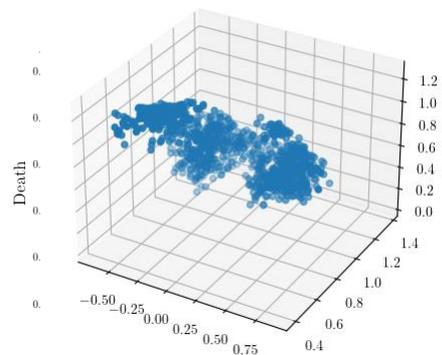
Persistence diagrams

F1p6

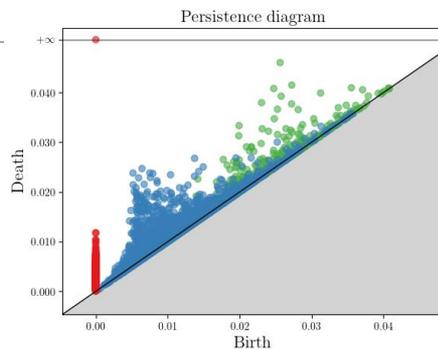
F2p3



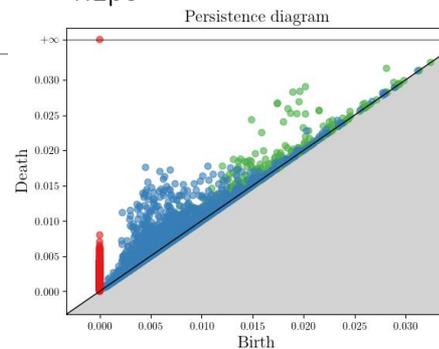
Persistence diagrams



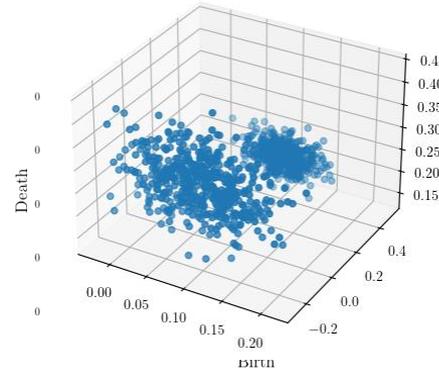
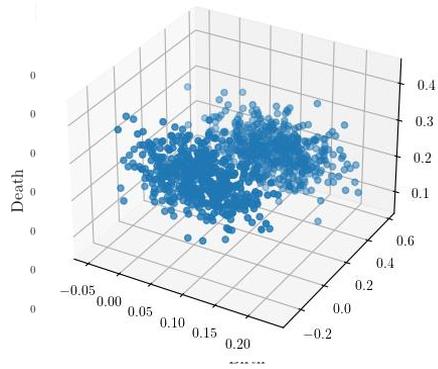
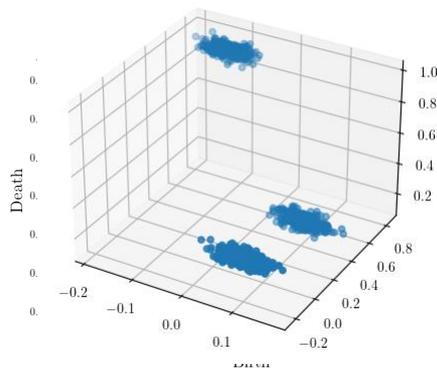
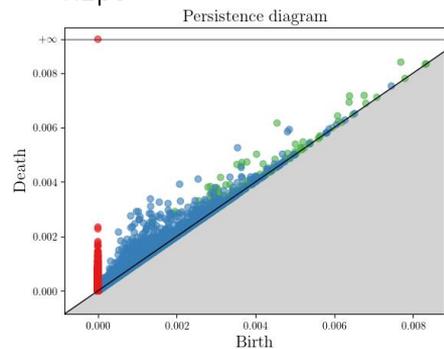
R0p0



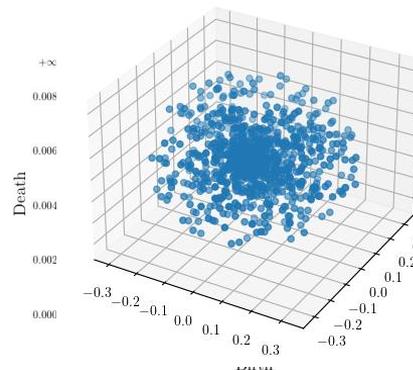
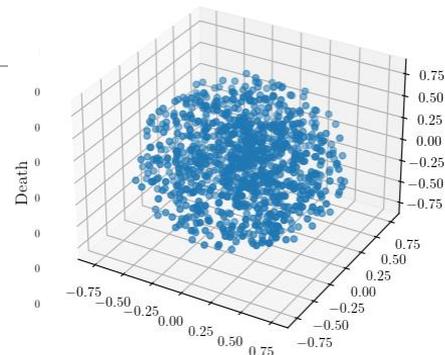
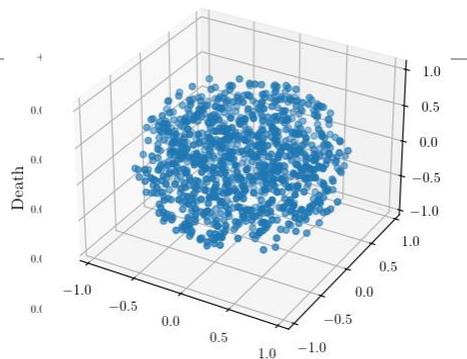
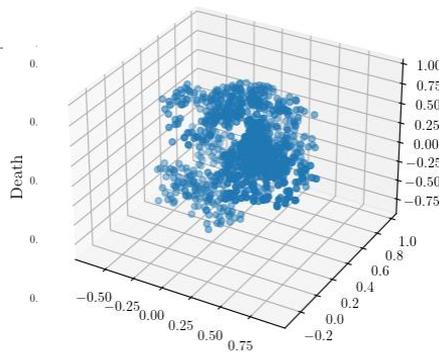
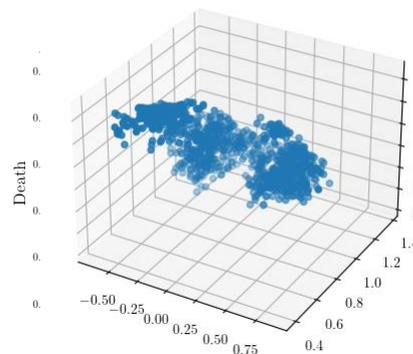
R1p0



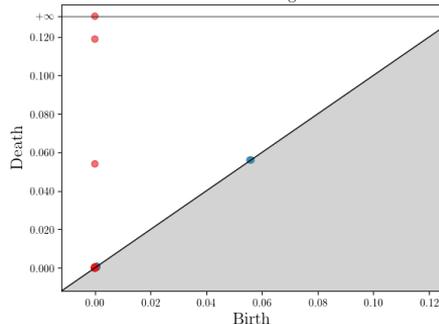
R2p0



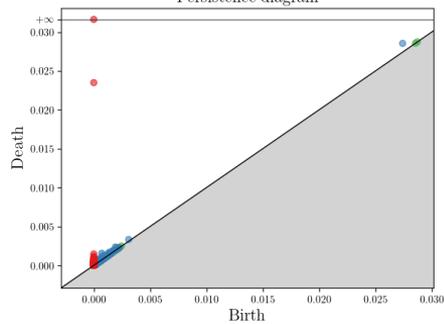
Persistence diagrams



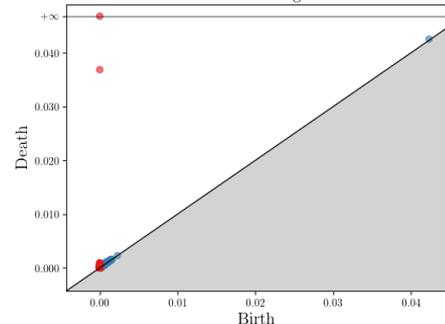
B3 - s025
Persistence diagram



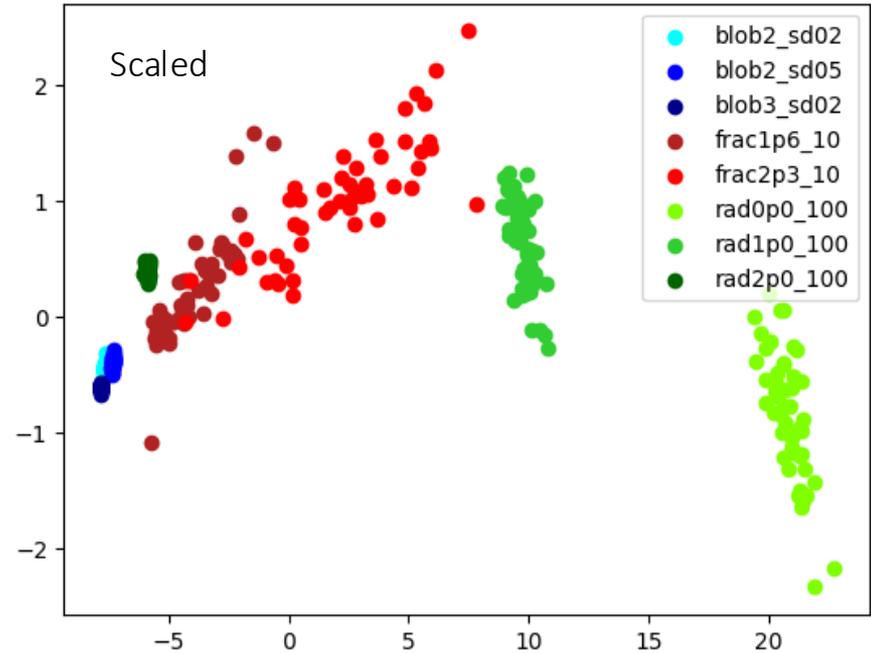
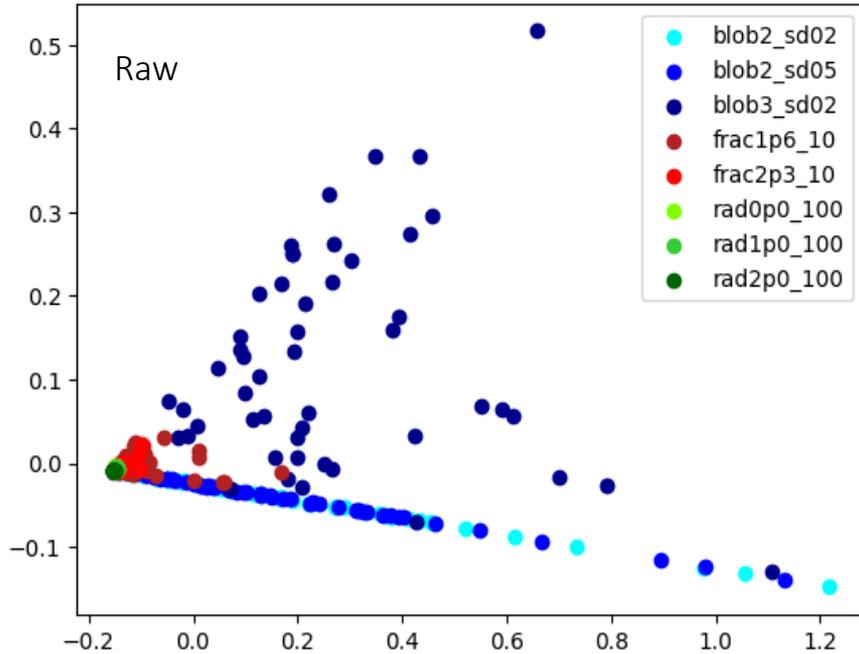
B2 - s05
Persistence diagram



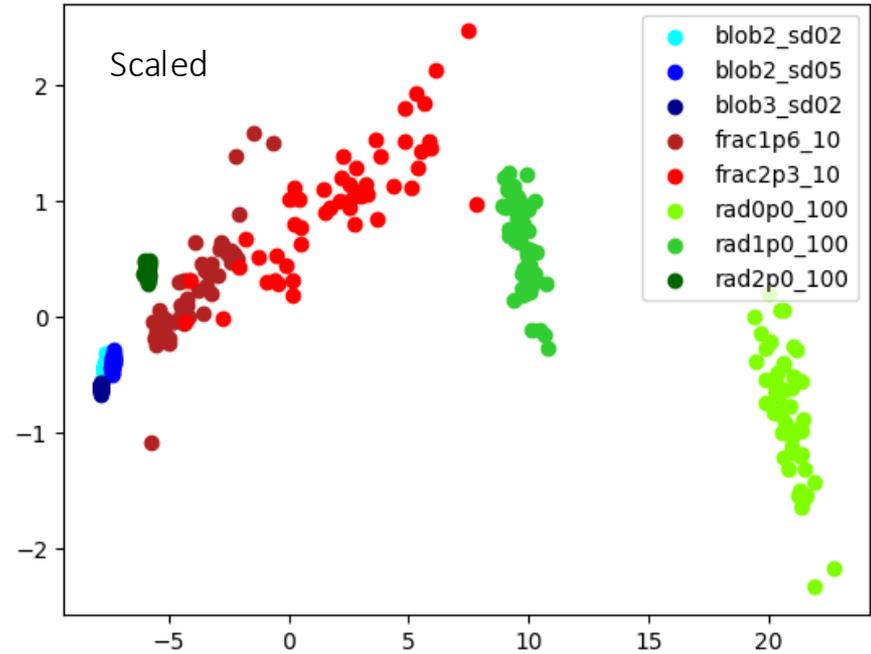
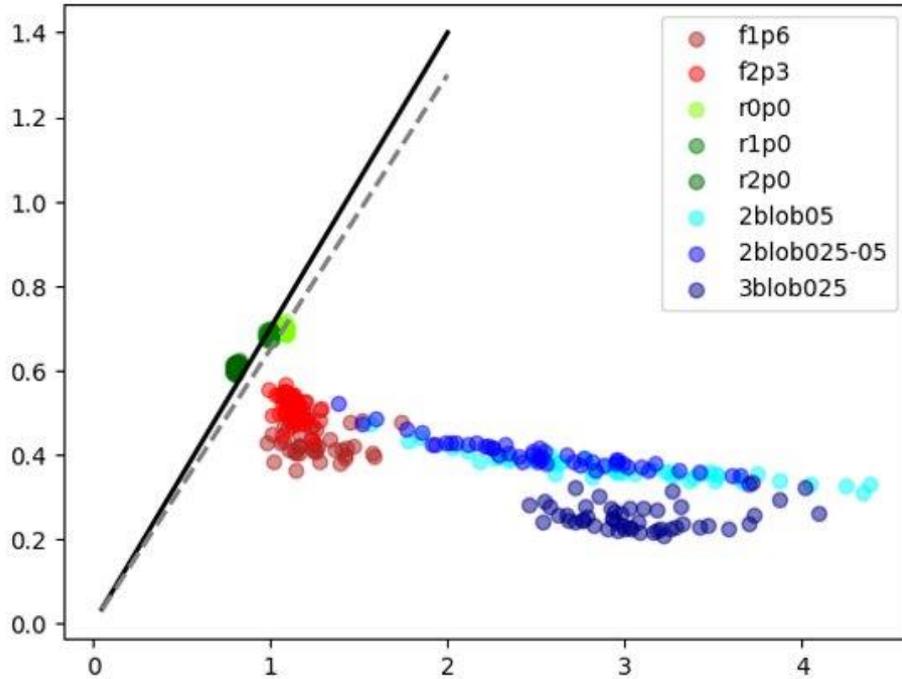
B2 - s025, 05
Persistence diagram



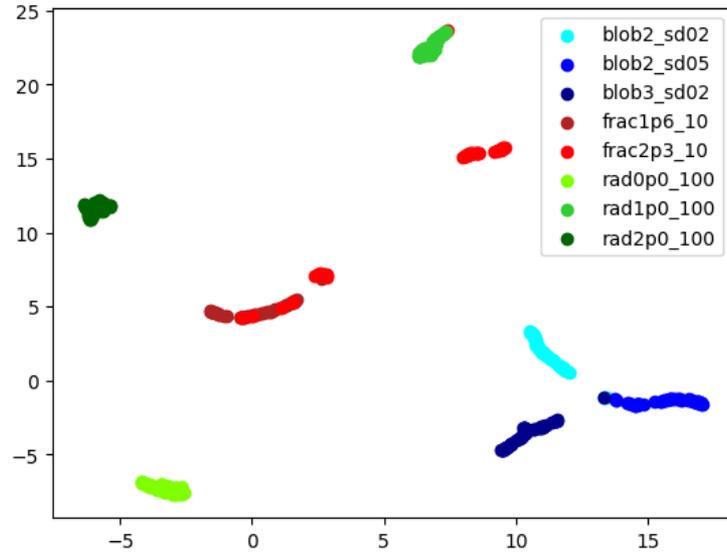
PCA of D0 persistence diagram



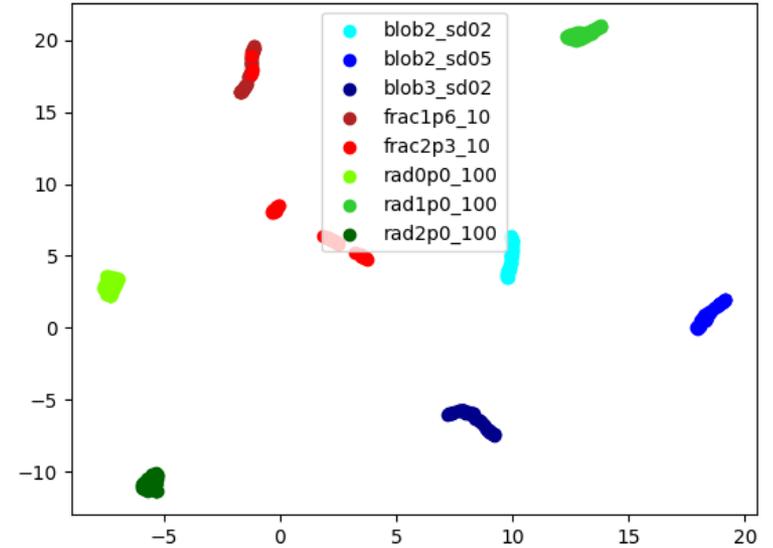
...but just comparable to Q



Unsupervised



Supervised



UMAP (scaled)

Next steps

- Initial tests with **higher order features**
- **Systematically perform a complete study** of the simulations
 - Include relevant simulation families (e.g. More cases, more realistic, with 1/2D topological features...)
 - Test different representations of the persistence diagram
 - Machine learning pipeline

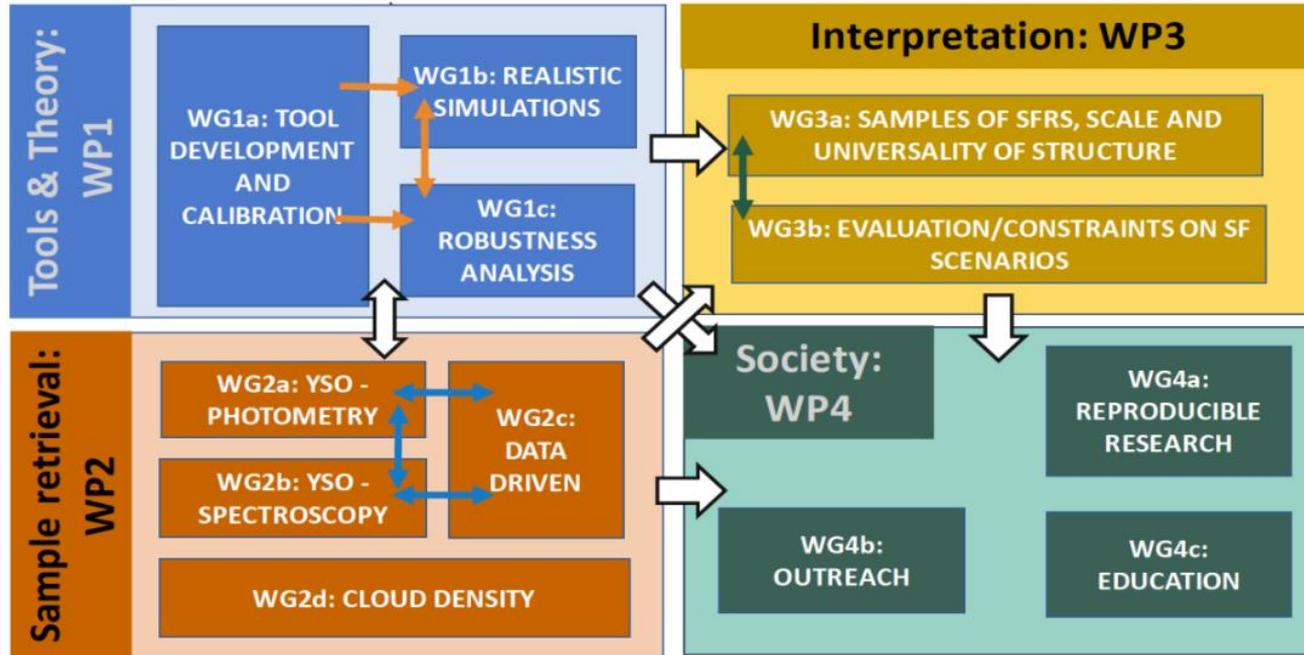


Thank you!

QUESTIONS?

Project TACOS

Topological Analysis of Cloud and Object Structure



Proof of concept: Dragonfish

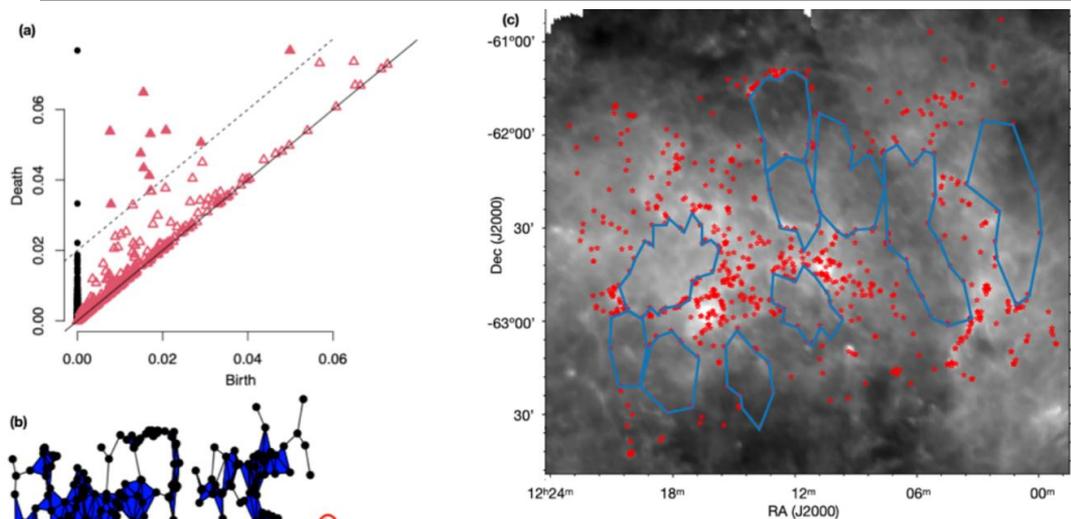


Fig. 2: Results of the proof of concept of the persistence analysis on Dragonfish.
(a) Persistence diagram showing the birth/death scales of 0D (black circles) and 1D features (red triangles). Dotted line marks a persistence threshold for features that last for a scale interval larger than 0.02 deg.
(b) Alpha-complex corresponding to the threshold 0.02 deg to illustrate its three connected components (0D features). Smaller components are highlighted with a red circle.
(c) YSO preliminary sample (red stars) over grayscale intensity of *Herschel* 250 microns. Blue polygons show the representative cycles (1D features) with persistence larger than 0.02.