



UNIVERSIDAD  
DE VALLADOLID

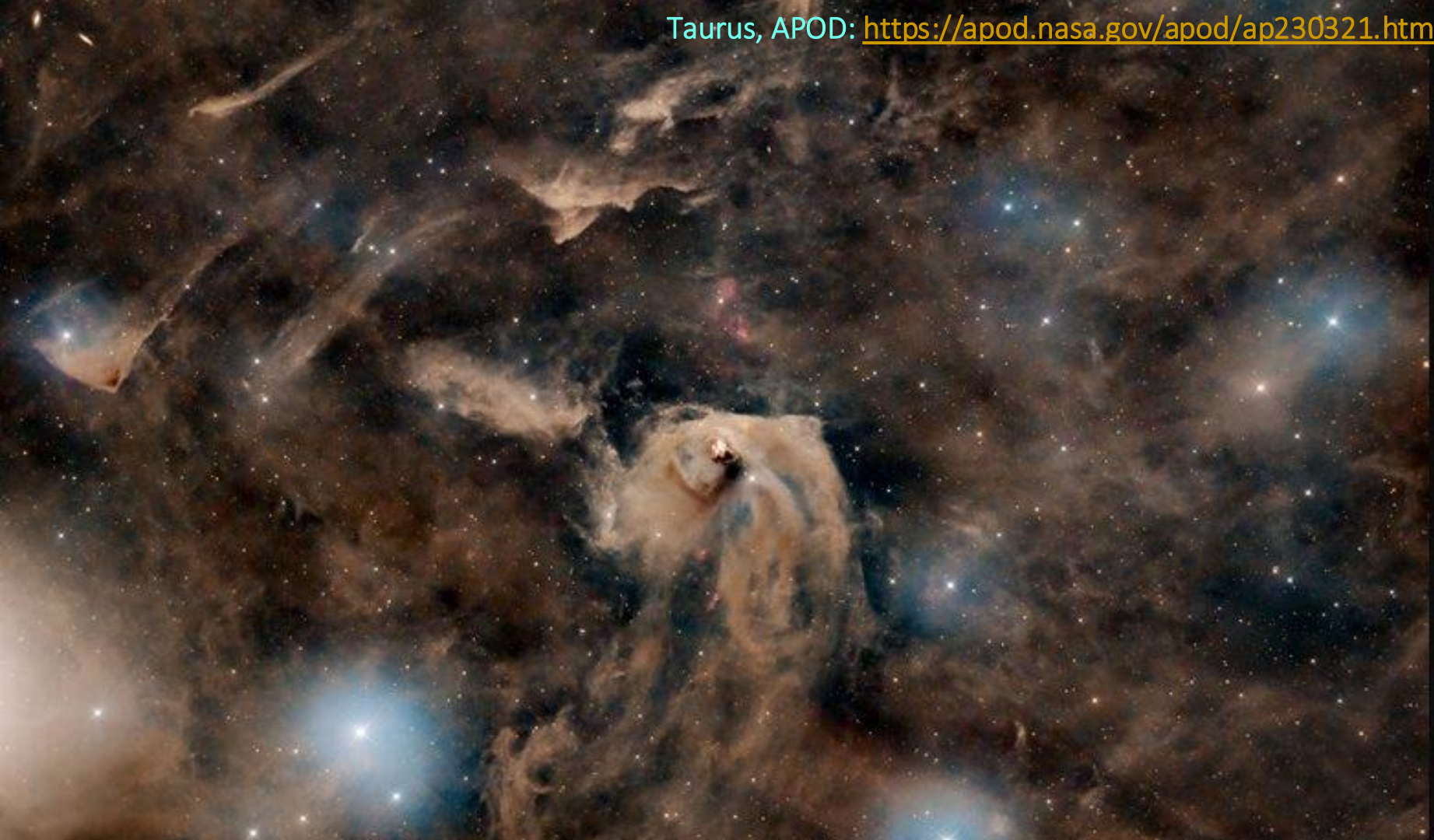
Proyecto PID2023-146635NA-I00 financiado por:



# Topological Data Analysis applied to star formation

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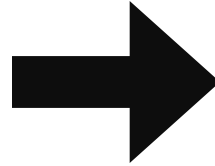
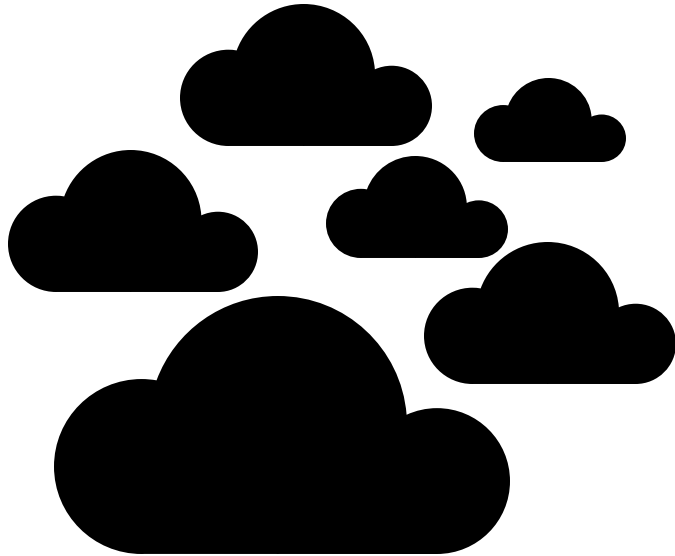
MARTA GONZÁLEZ GARCÍA



# Star Formation

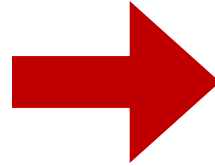
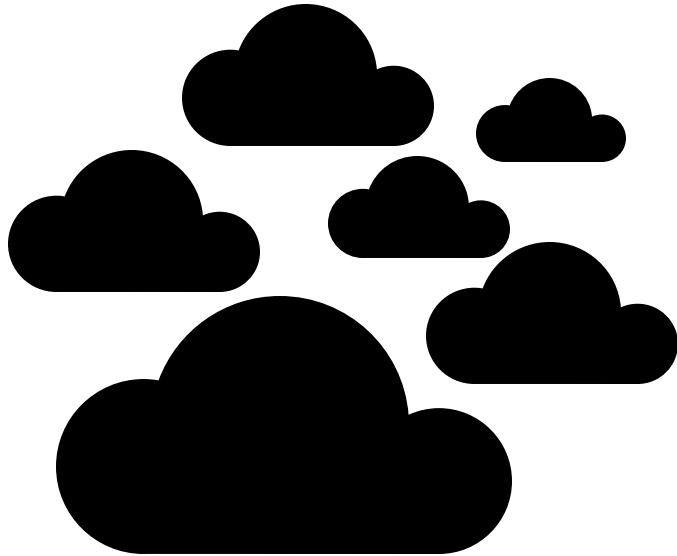
What we know

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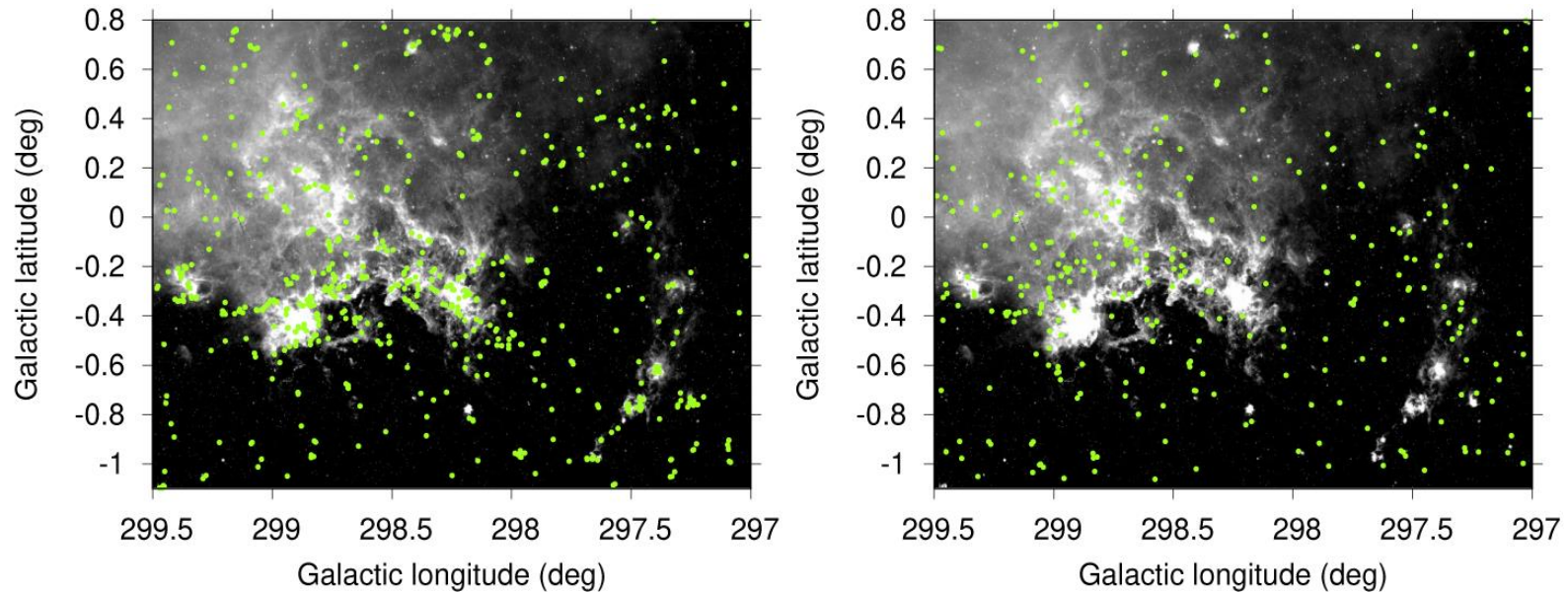
# Star Formation

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.

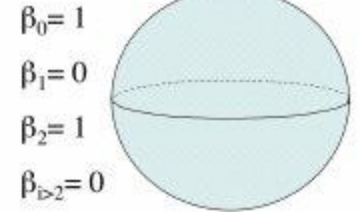
# Topological intuitions

- 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  $\beta_D$  counts the number of "D-dimensional holes" within a shape:
  - 0D – Connected components
  - 1D – loops
  - 2D voids...

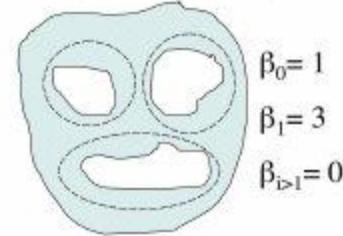
A solid 2-dimensional blob



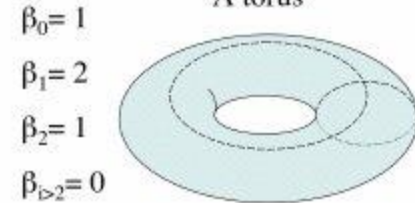
A sphere



A 2D blob with three holes

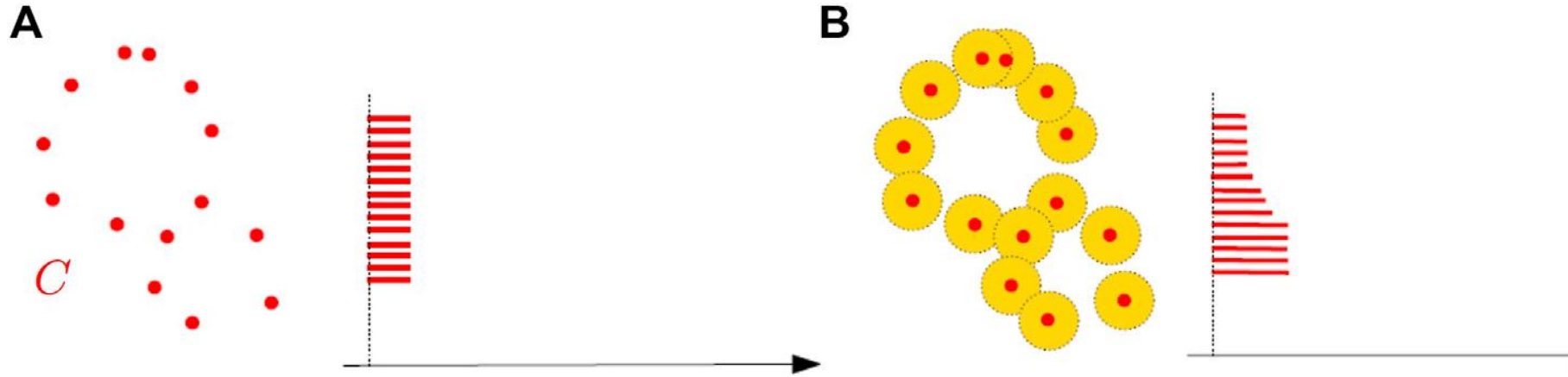


A torus



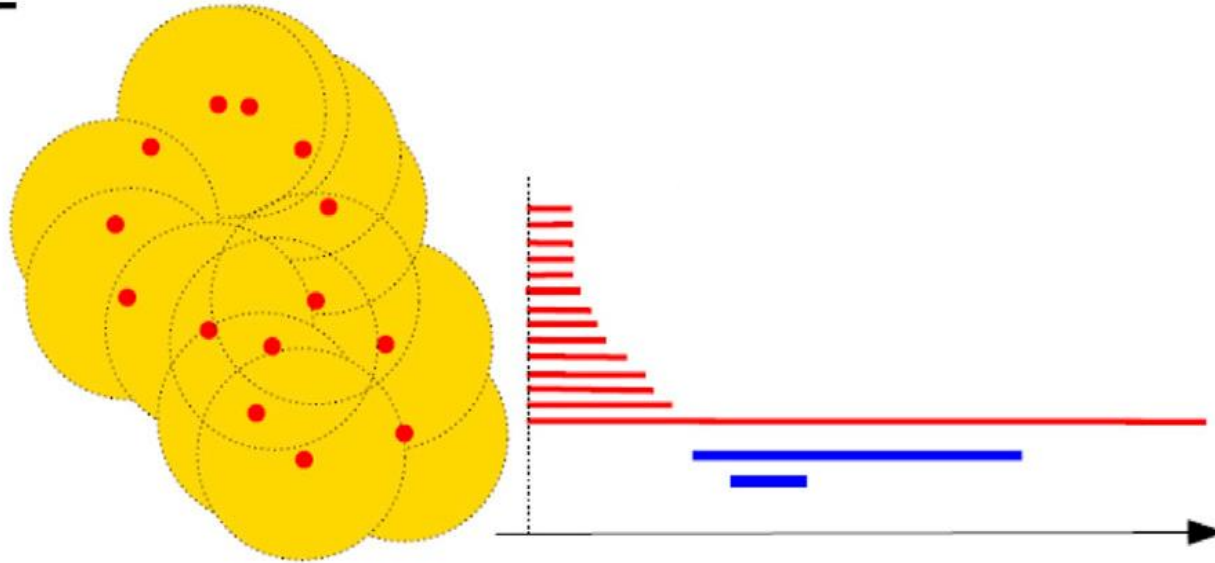
Brenton Walker. 2008. *Using persistent homology to recover spatial information from encounter traces*. In Proceedings of the 9th ACM international symposium on Mobile ad hoc networking and computing (MobiHoc '08). Association for Computing Machinery, New York, NY, USA, 371–380. <https://doi.org/10.1145/1374618.1374668>

# Homological persistence: Barcodes



# Homological persistence: Barcodes

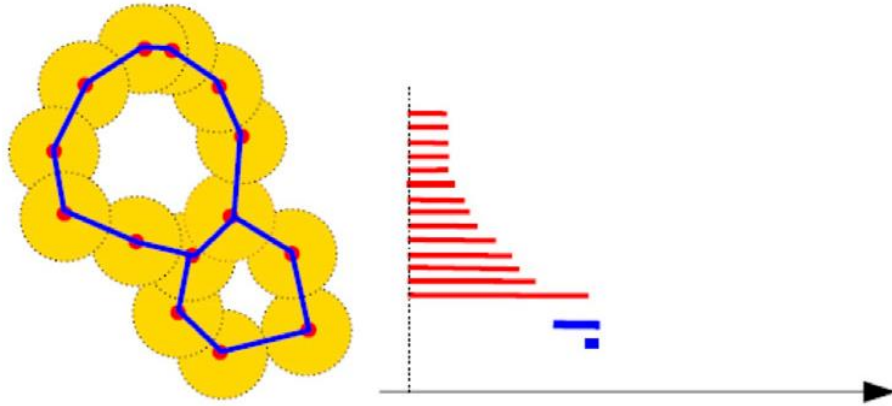
E



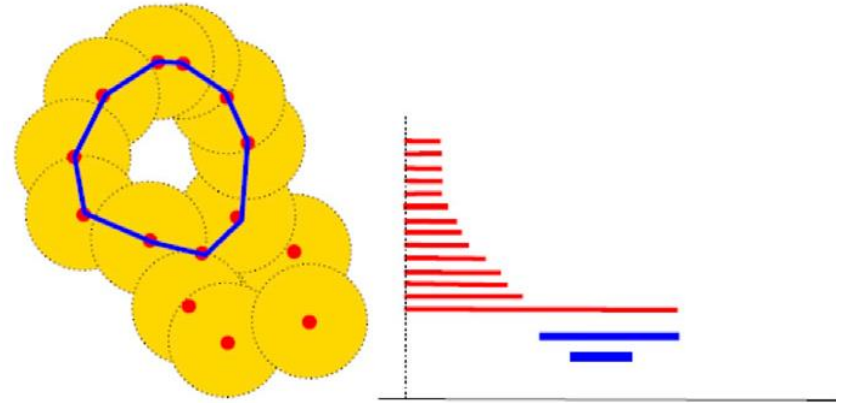


# Homological persistence: Barcodes

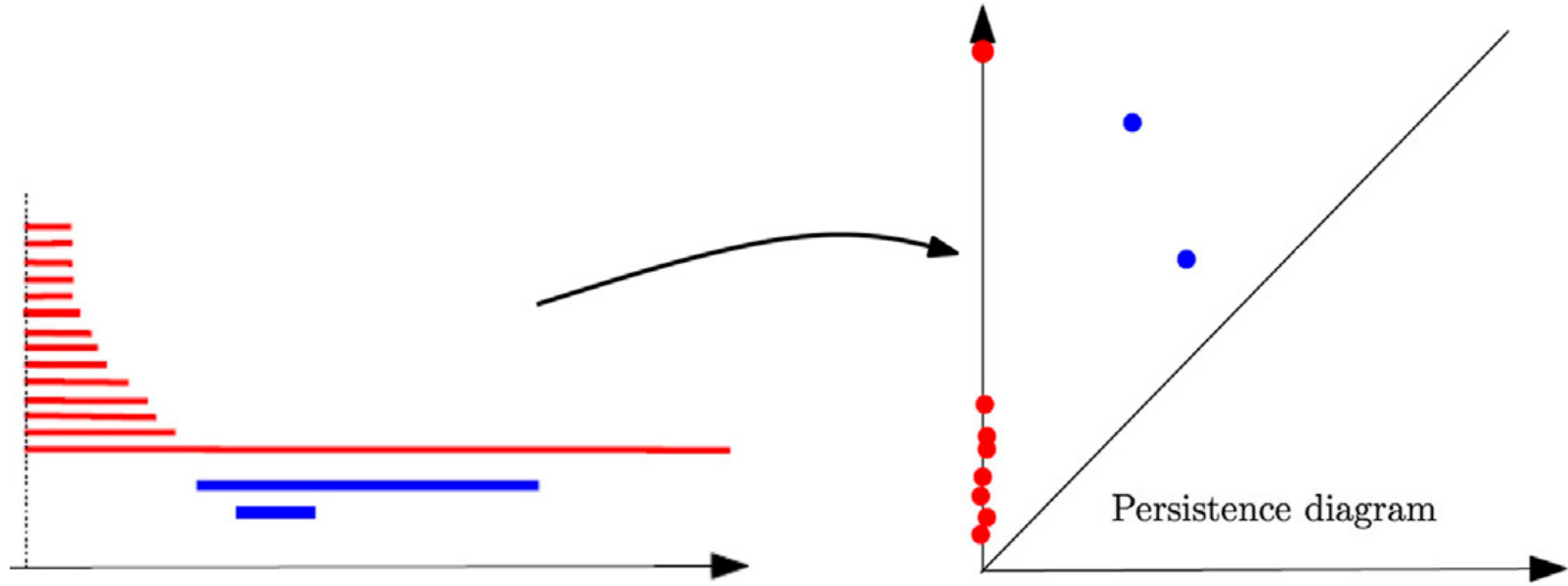
C



D



# Persistence diagrams



# Calibration

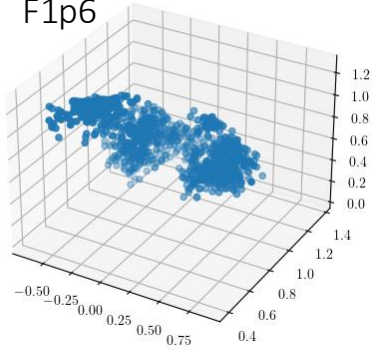


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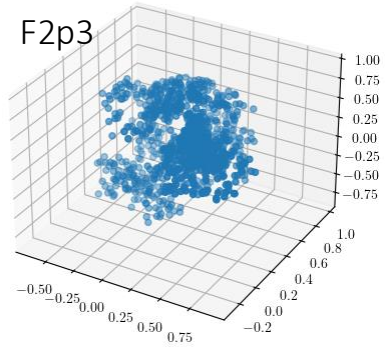
EXTREMELY PRELIMINARY

# Sample distributions (n=1000)

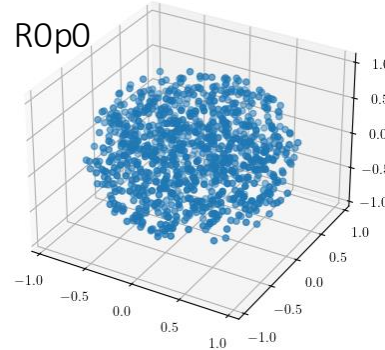
F1p6



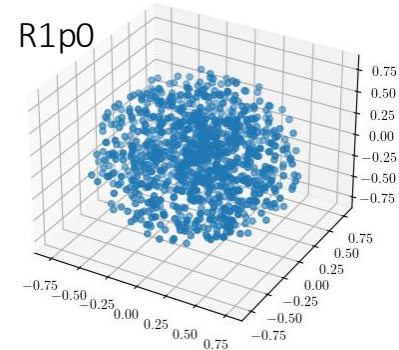
F2p3



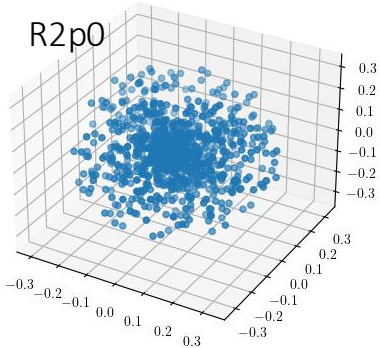
R0p0



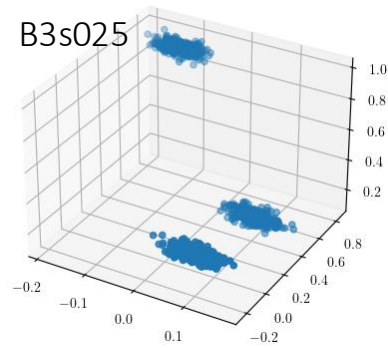
R1p0



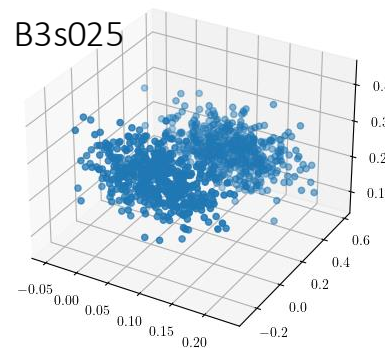
R2p0



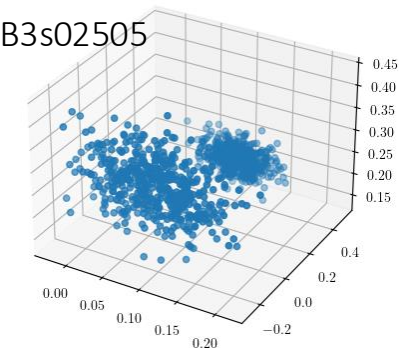
B3s025



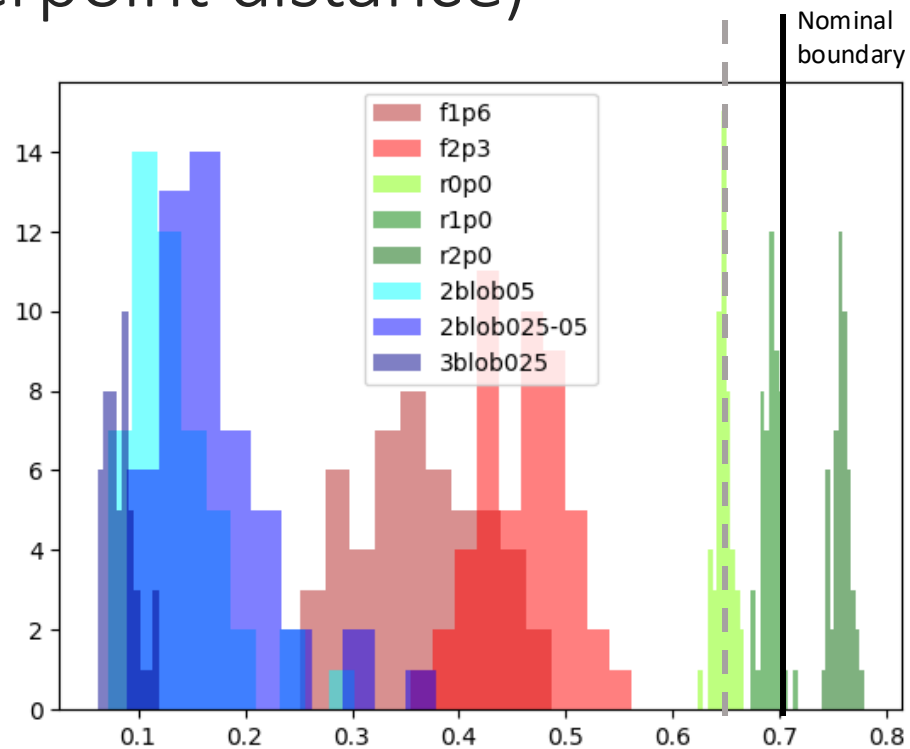
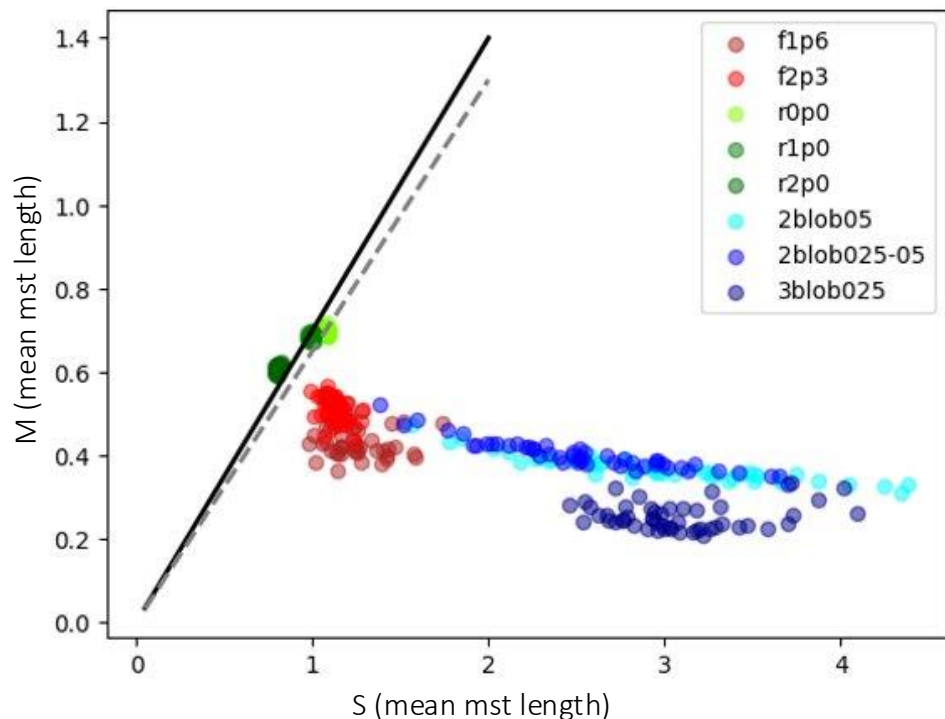
B3s025



B3s02505

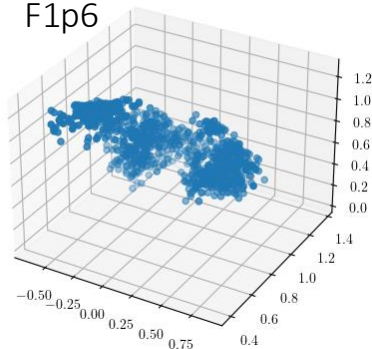


# Classical analysis Q parameter (quotient of normalized mst length/interpoint distance)

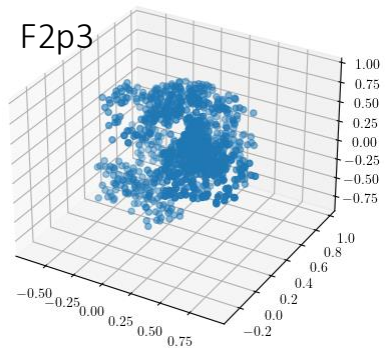


# Persistence diagrams

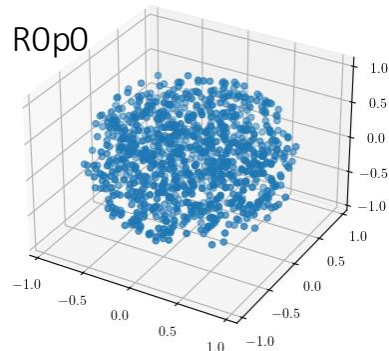
F1p6



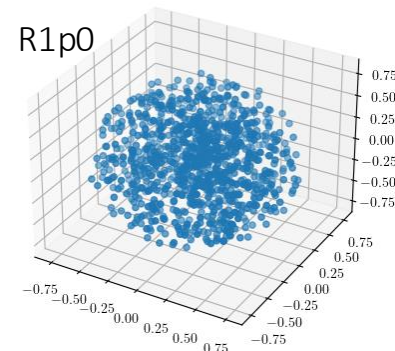
F2p3



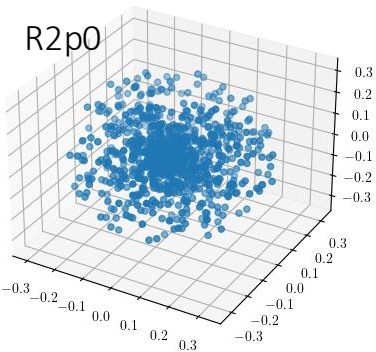
R0p0



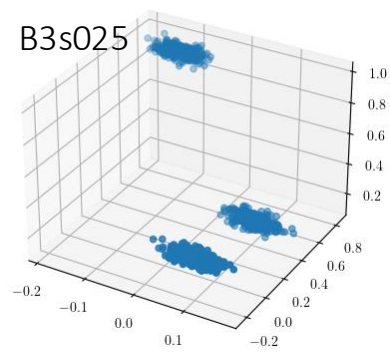
R1p0



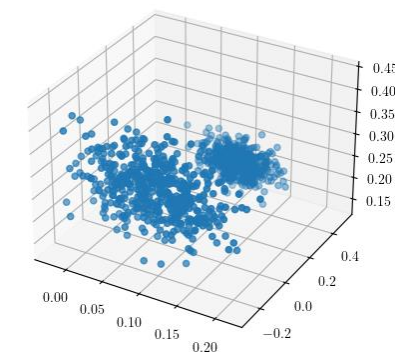
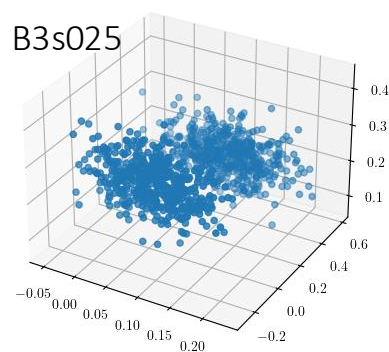
R2p0



B3s025



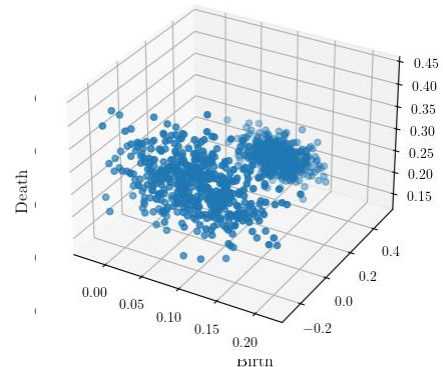
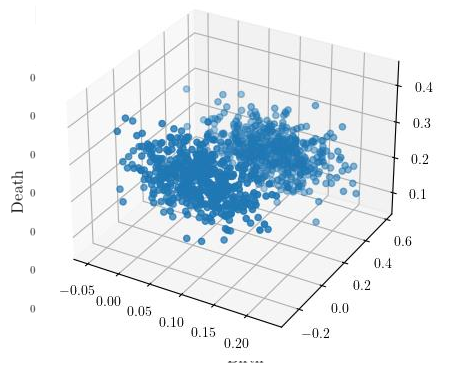
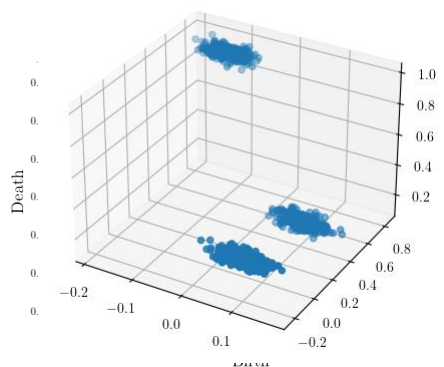
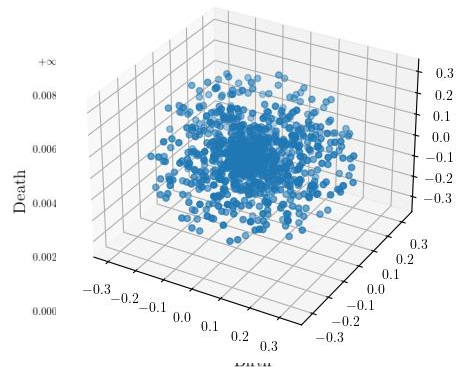
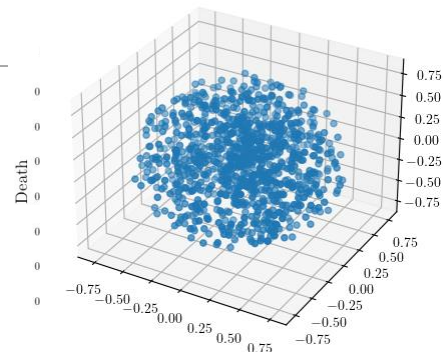
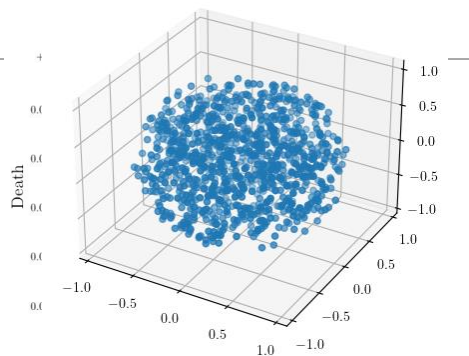
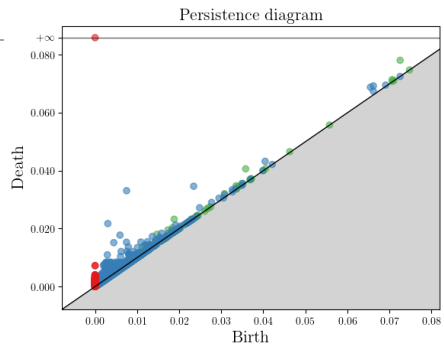
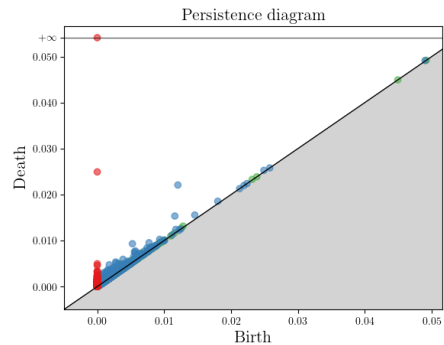
B3s025



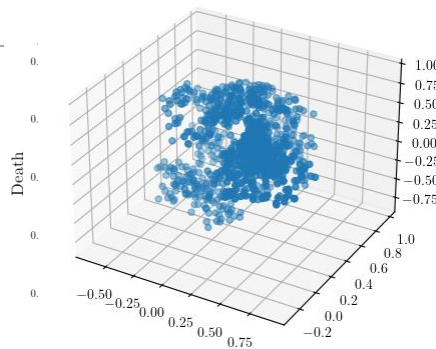
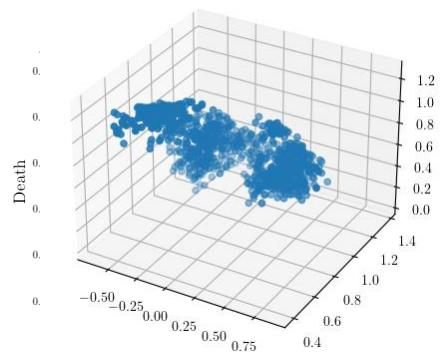
# Persistence diagrams

F1p6

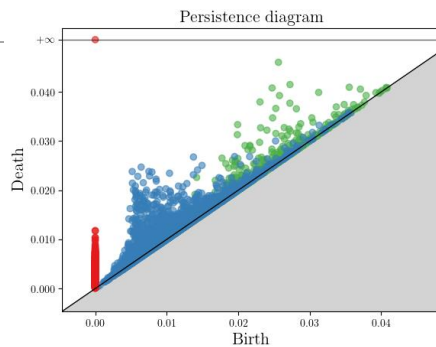
F2p3



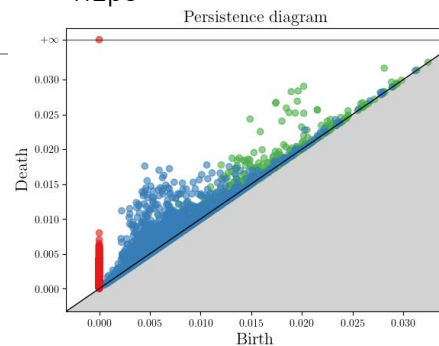
# Persistence diagrams



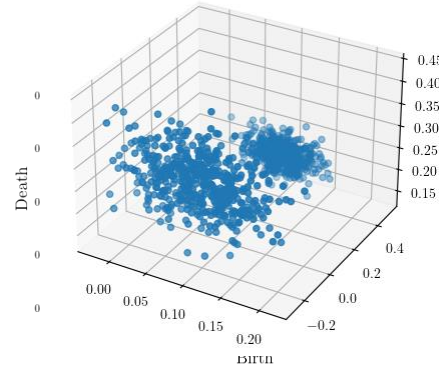
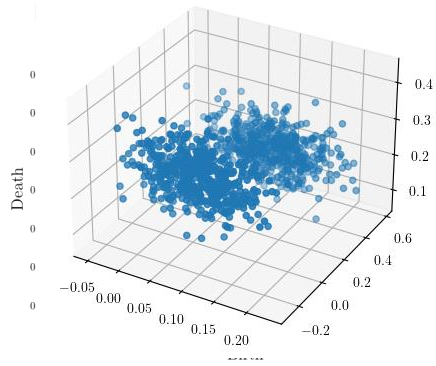
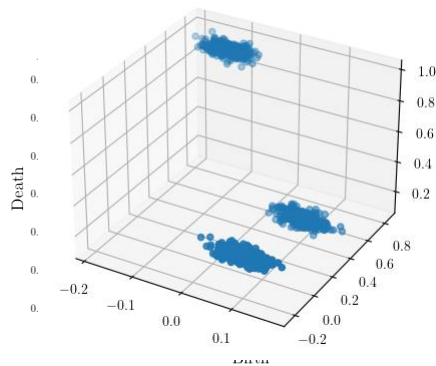
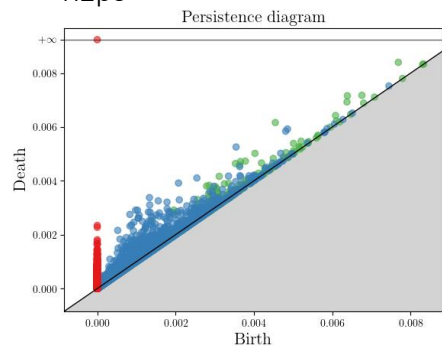
R0p0



R1p0

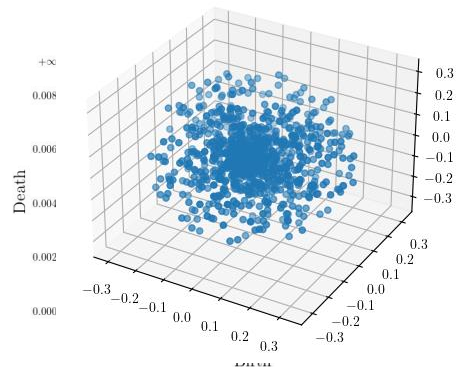
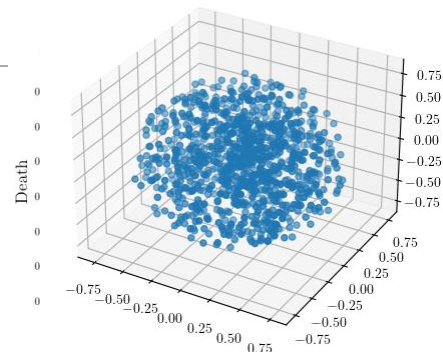
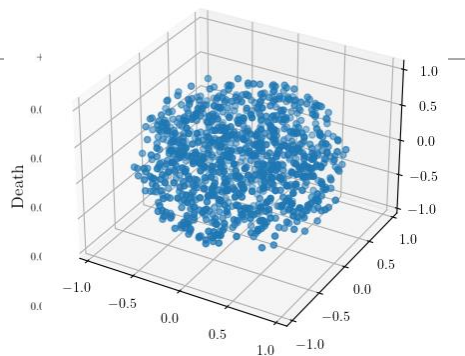
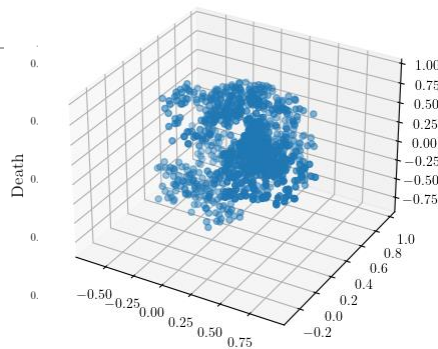
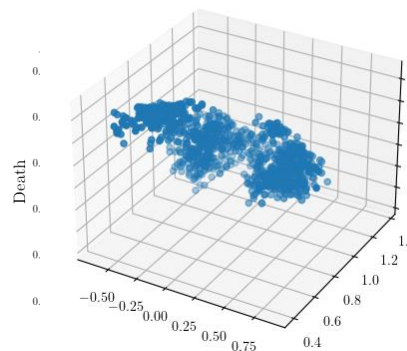


R2p0

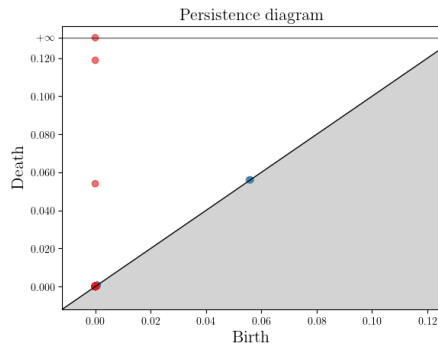




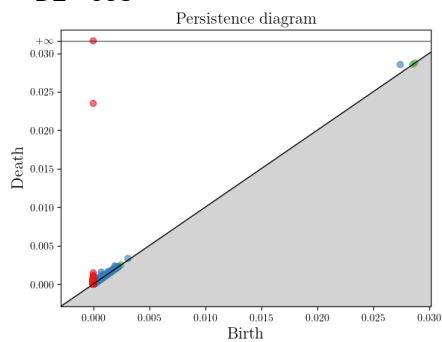
# Persistence diagrams



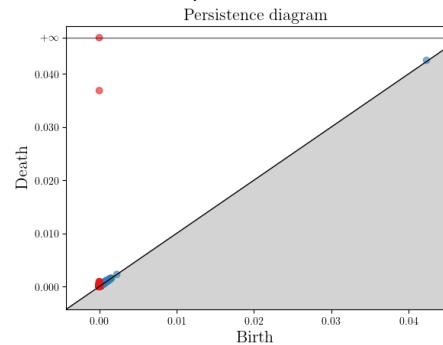
B3 - s025



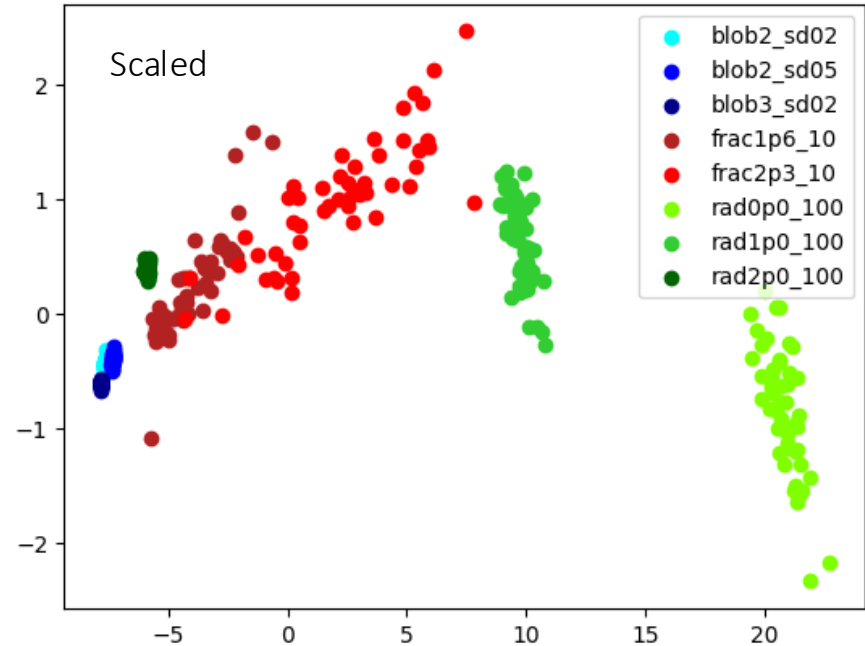
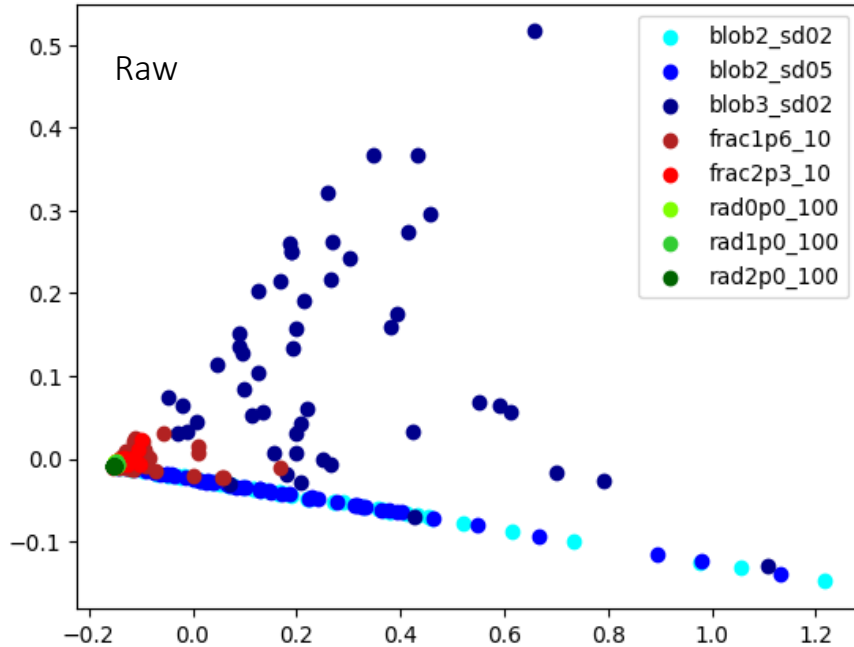
B2 - s05



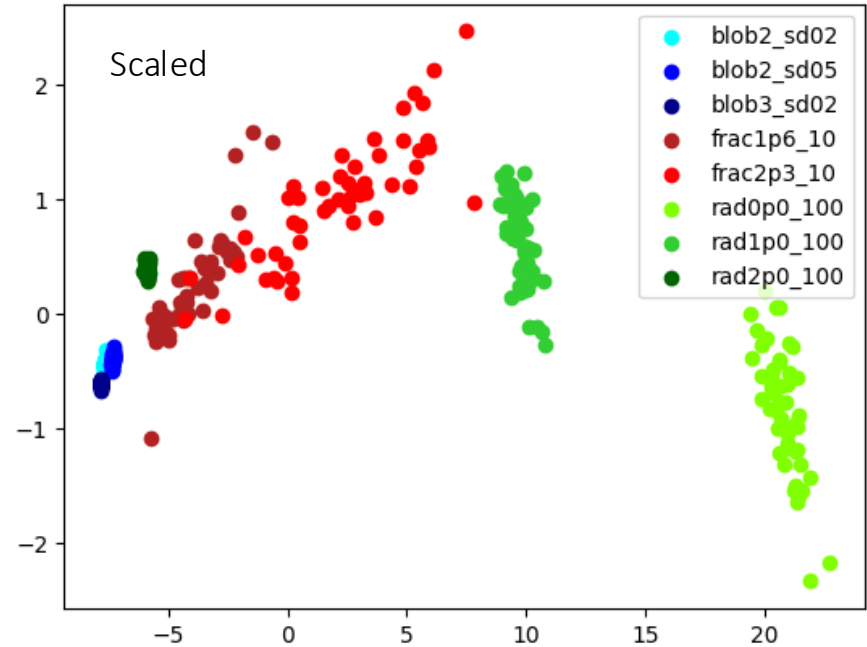
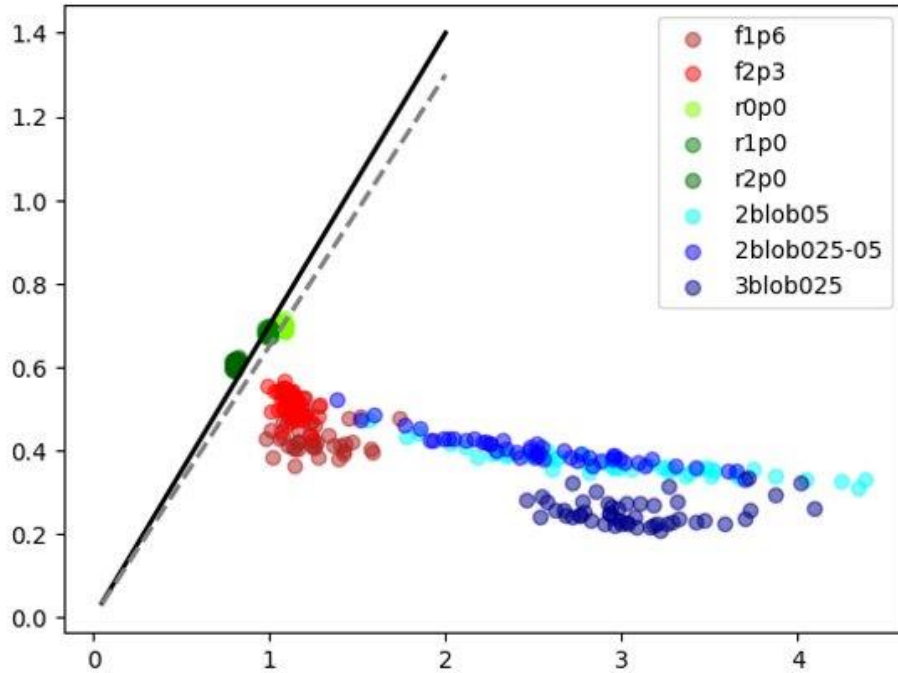
B2 - s025, 05



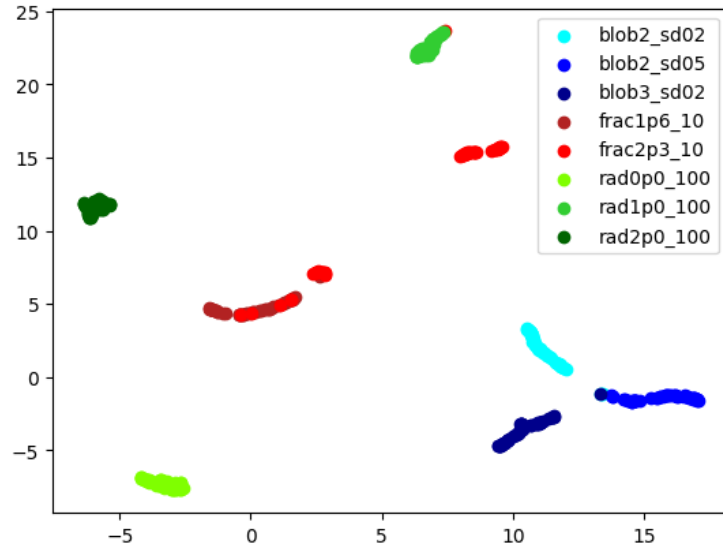
# PCA of D0 persistence diagram



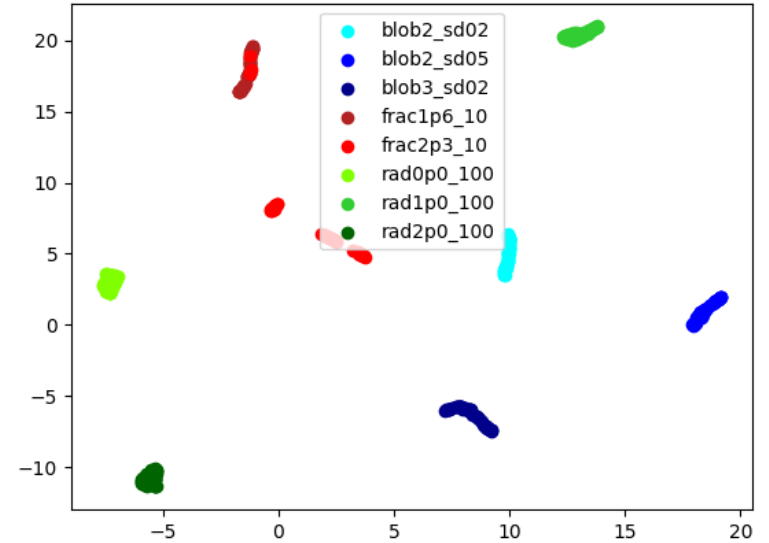
# ...but just comparable to Q



Unsupervised



Supervised



# UMAP (scaled)

# Next steps

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- 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



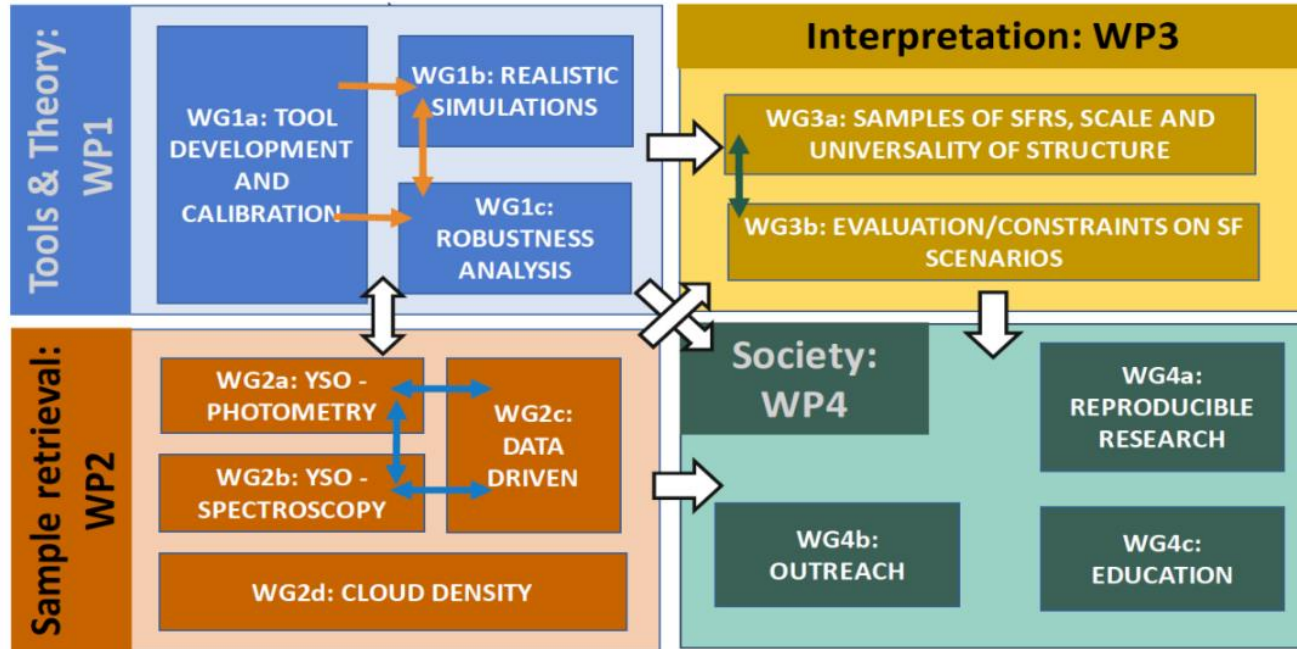
# Thank you!

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QUESTIONS?

# Project TACOS

Topological Analysis of Cloud and Object Structure



# Proof of concept: Dragonfish

