

# How topology can help medicine?

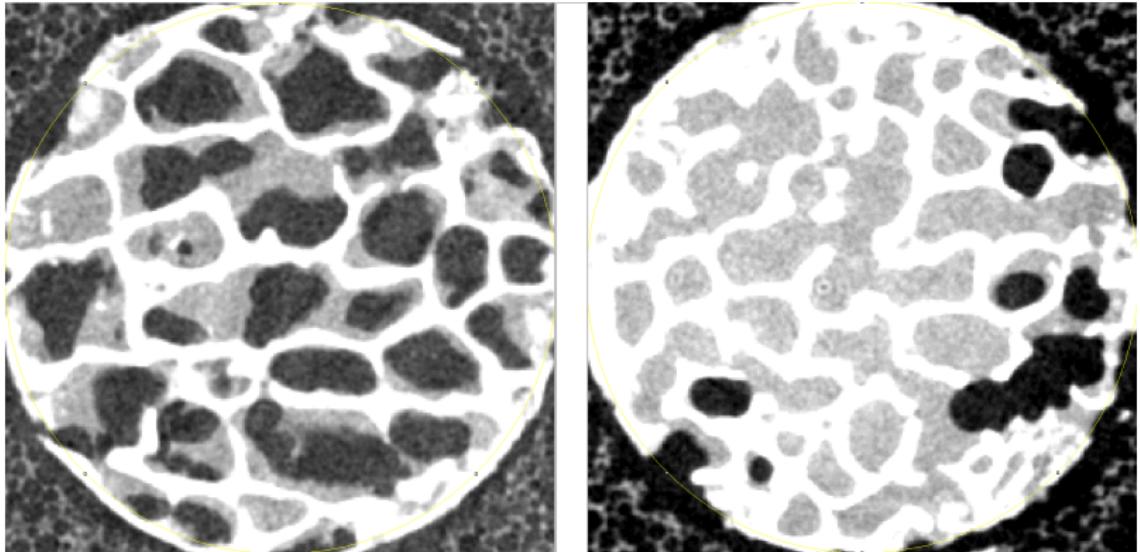
Paweł Dłotko,  
Dioscuri Centre in TDA, IMPAN,  
Warsaw, Poland.

## How topology may help?

- ▶ Image summaries for (2/3/4 dimensional) medical image analysis,
- ▶ Mapper, Gene microarray analysis, patients data, hospital management
- ▶ Periodicity detection: are we walking straight?

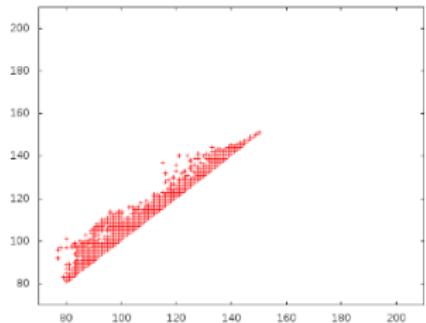
# Bones

With Richard Abel, Jan Senge

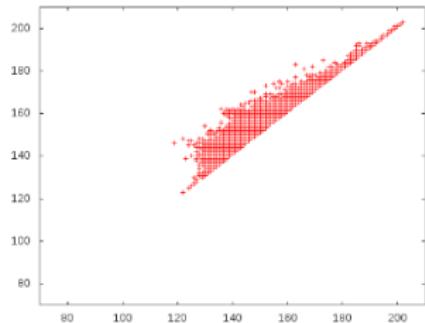


Example of bad and good bone, 3d Cubical complexes.  
Number of hight persistence cycles plus the thickness of trabecula  
makes the difference!

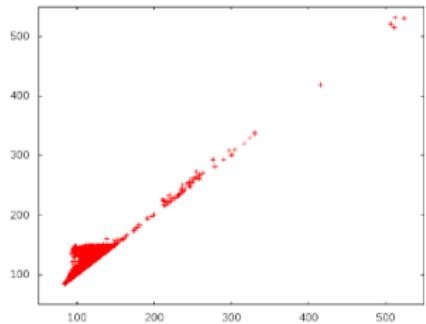
# Healthy vs. osteoporotic persistence



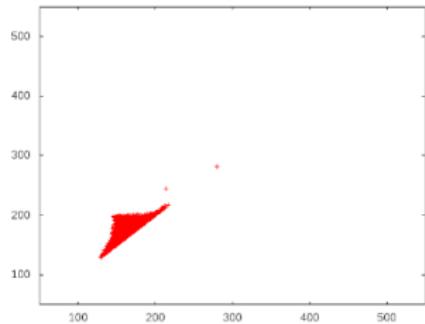
Dimension 0 osteoporotic



Dimension 0 healthy

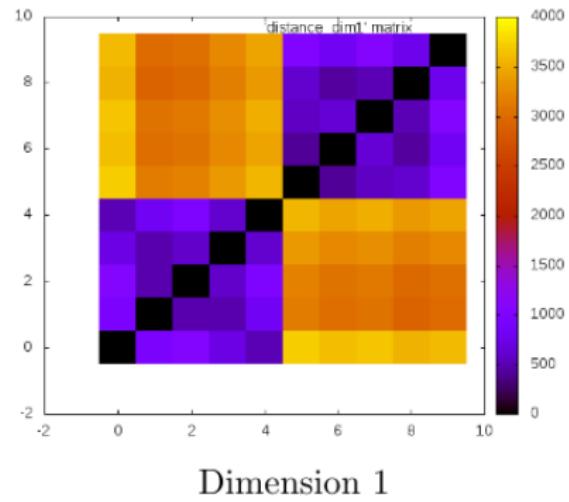
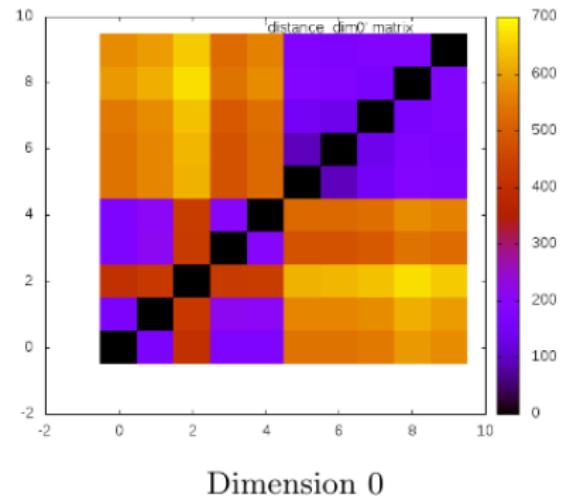


Dimension 1 osteoporotic

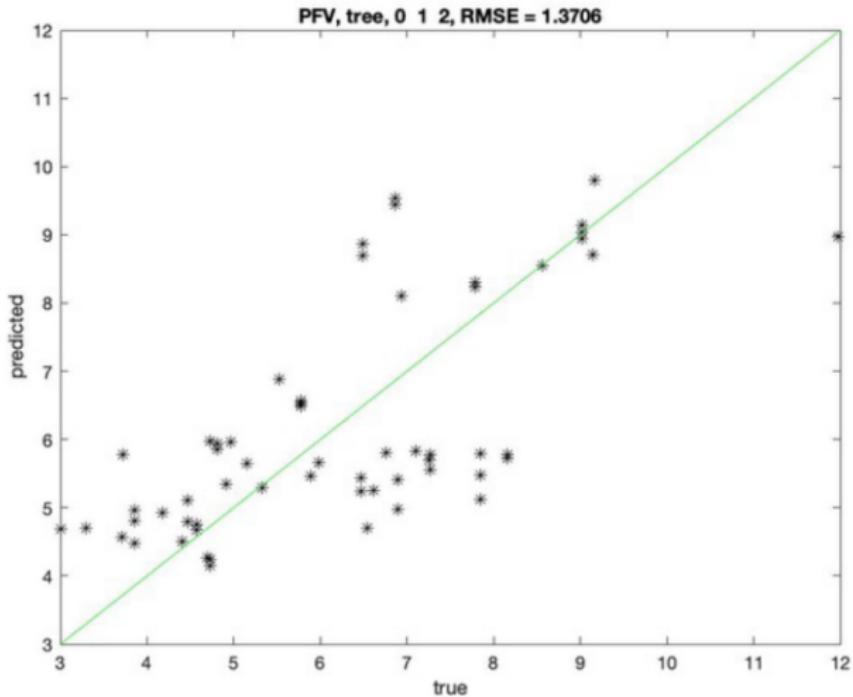


Dimension 1 healthy

# Distance between healthy and osteoporotic



# Predicted vs. true resistivity



## Grayscale vs mechanical robustness

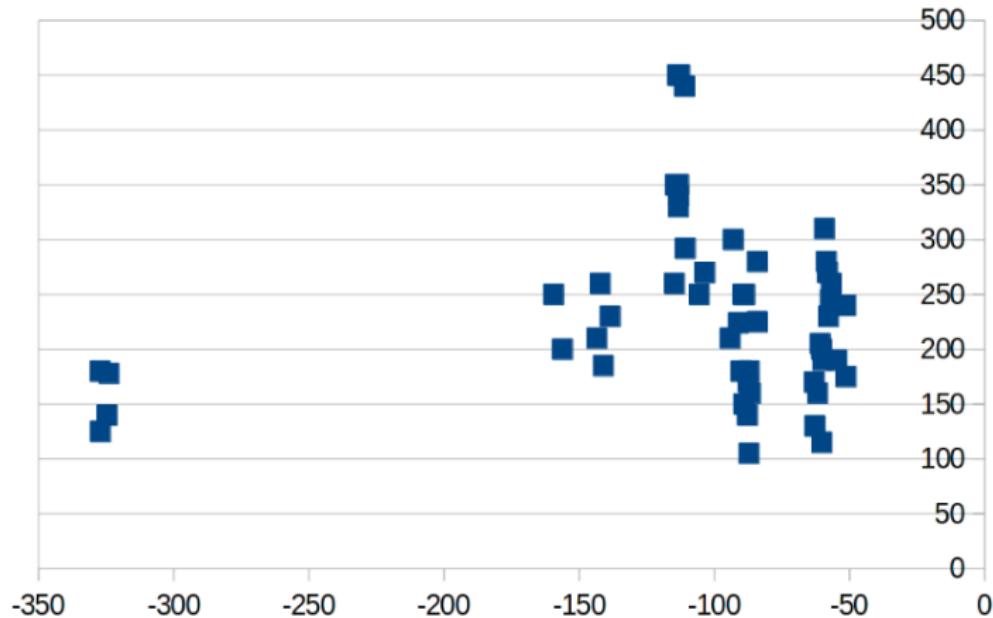
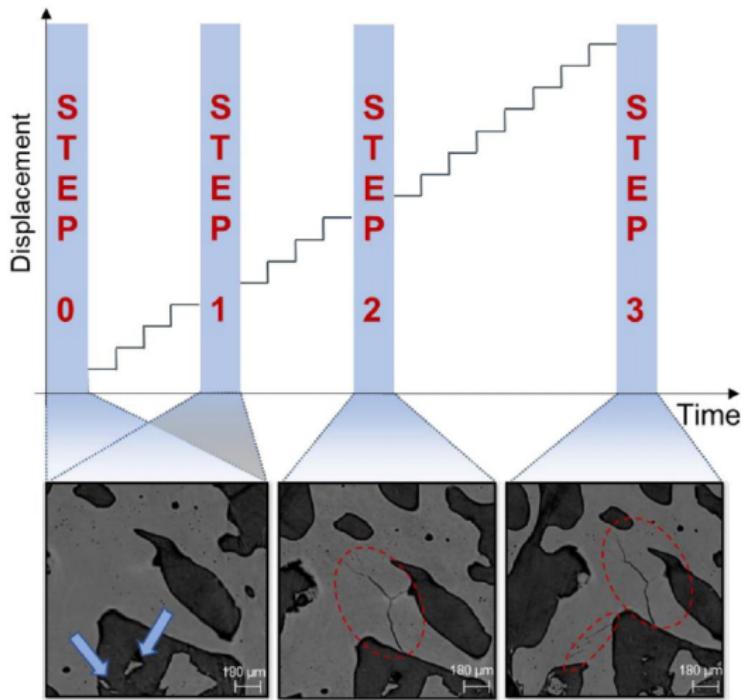


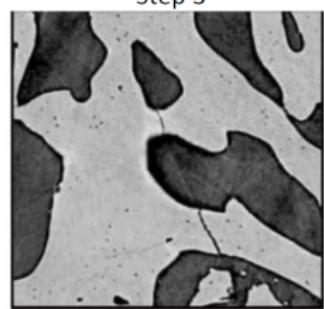
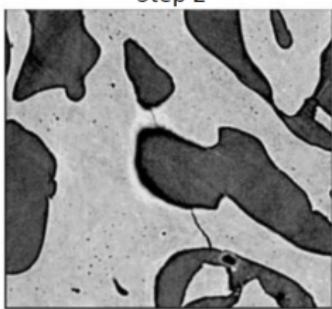
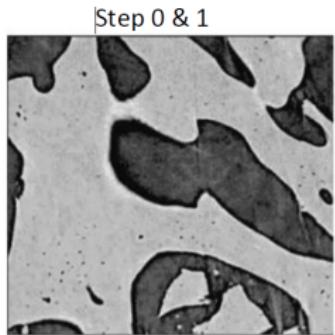
Figure 4: Location of minus an averaged gray-scale value against the mechanical robustness of a bone.

# Bone in much greater detail



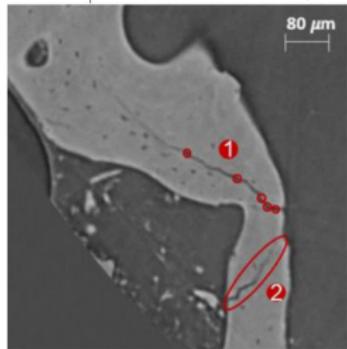
Bone under compression, synchrotron image.

# Cracks in bones

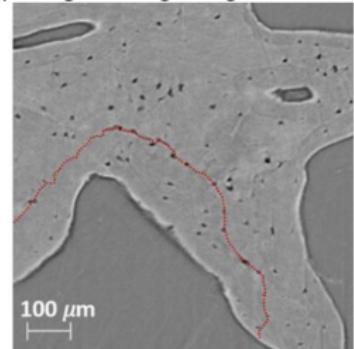
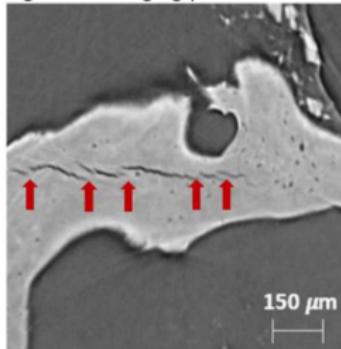


# Crack formation

Lacunae act as crack deviators;

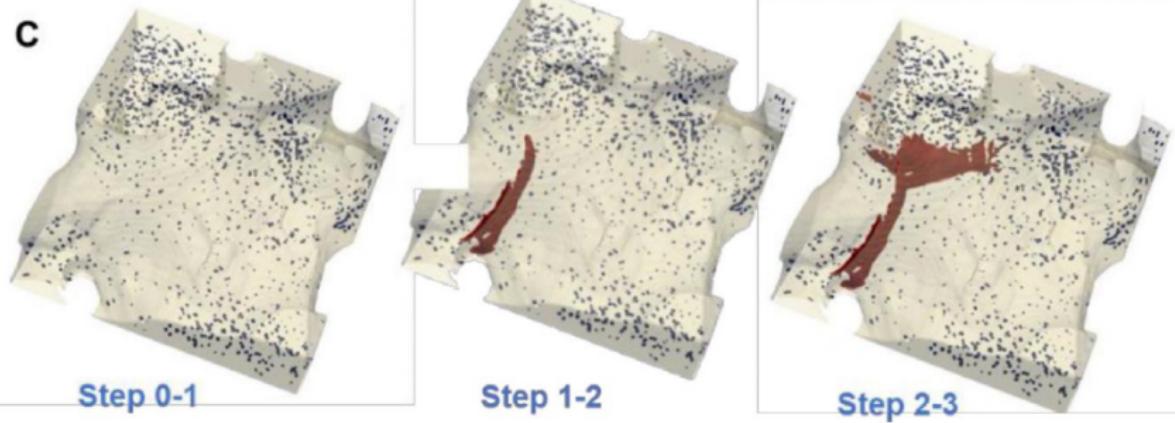


Ligament bridging phenomenon appearing as a toughening mechanism



## Crack formation, 3d

C



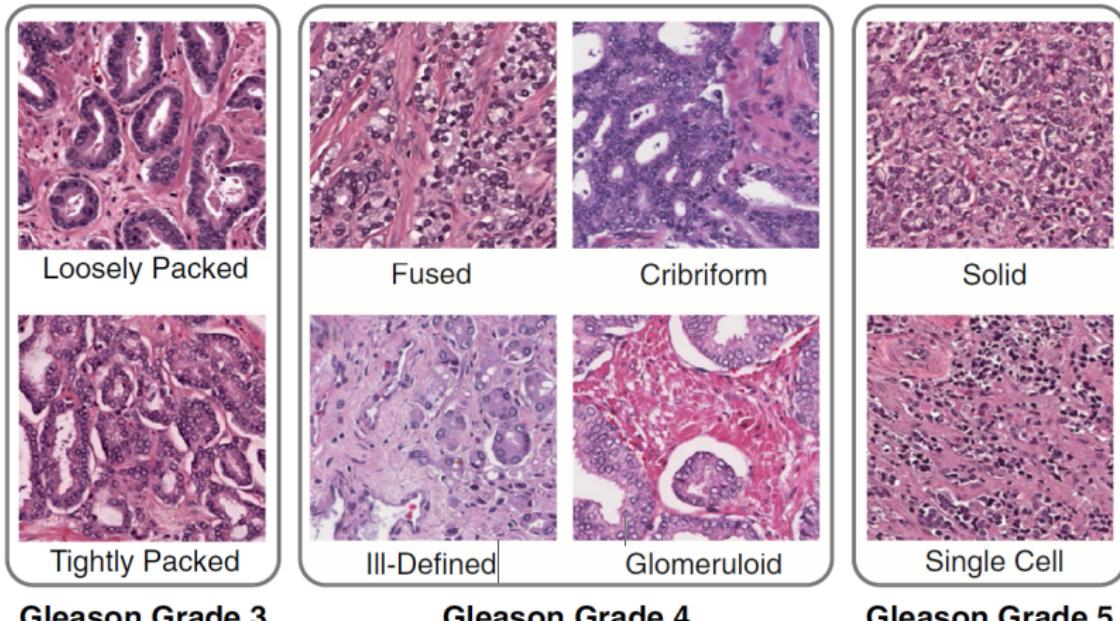
# Cracks in bones

1. Crack in a bone is a local lost of connectivity
2. We detect them with topological methods
3. Fundamental understanding of micro-cracks in bones
4. Relation to lacunae
5. Microarchitecture
6. Topology on a large data (0.5 TB per  $1mm^3$  of a bone),

# Histology

With Davide Gurnari

# Prostate cancer histology



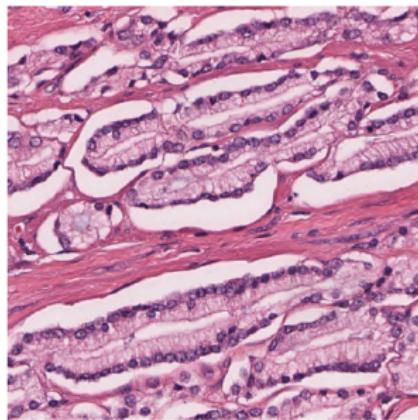
Gleason Grade 3

Gleason Grade 4

Gleason Grade 5

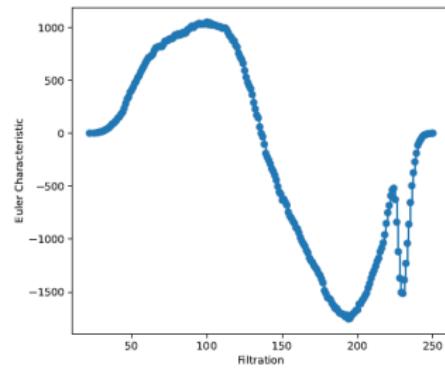
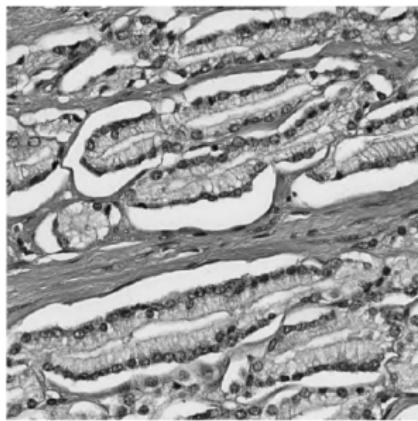
Supervised task to decide a grade.  
Experiment inspired by work of Oliver Vipond (Oxford)

# Option 1: Euler Characteristics Curves



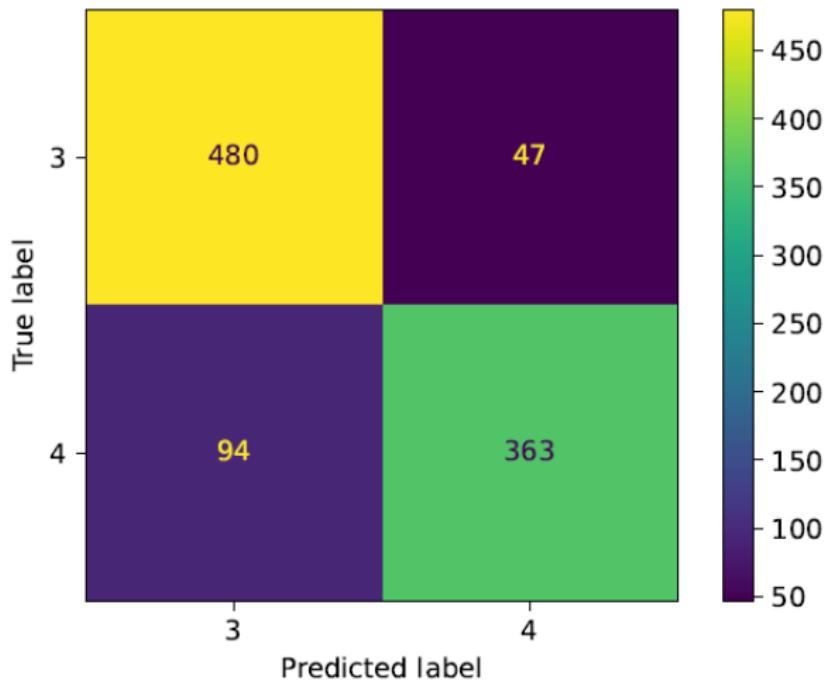
An image

# Option 1: Euler Characteristics Curves

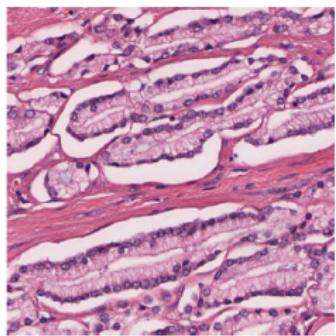


Thresholding + ECC

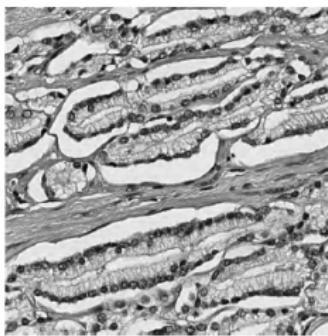
# Option 1: Euler Characteristics Curves



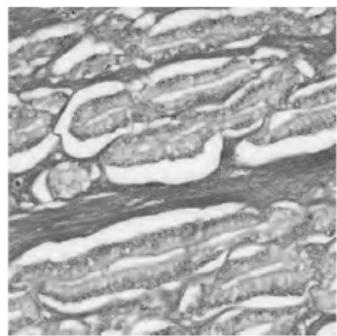
## Option 2: Euler Characteristics Profiles



Full image

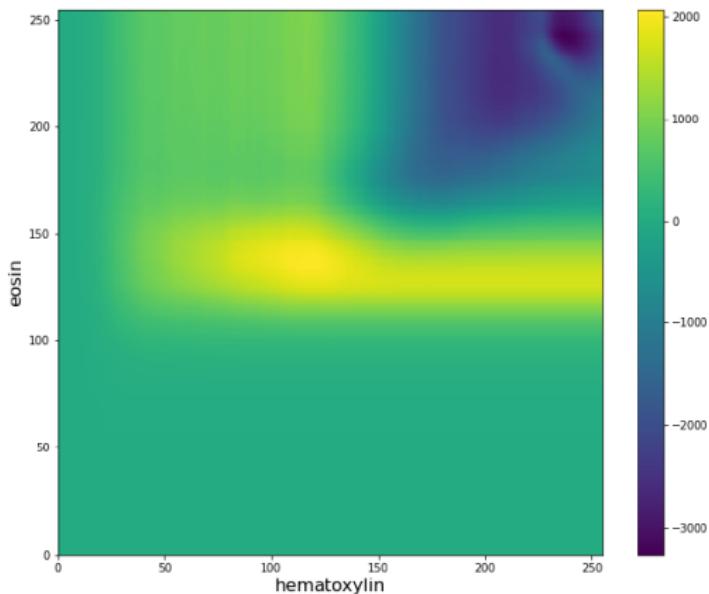


Hematoxylin



Eosin

## Option 2: Euler Characteristics Profiles

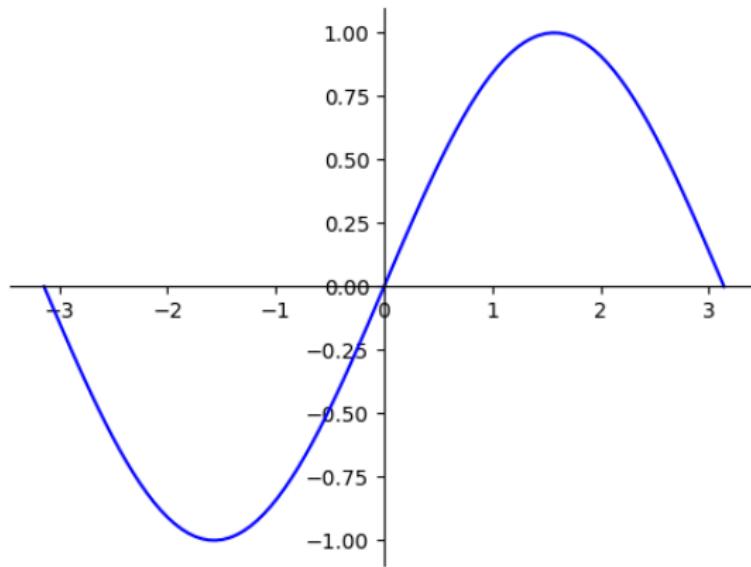


Similar classification results,  
Suitable for big data,  
ML-friendly.

# Mapper

## What is mapper?

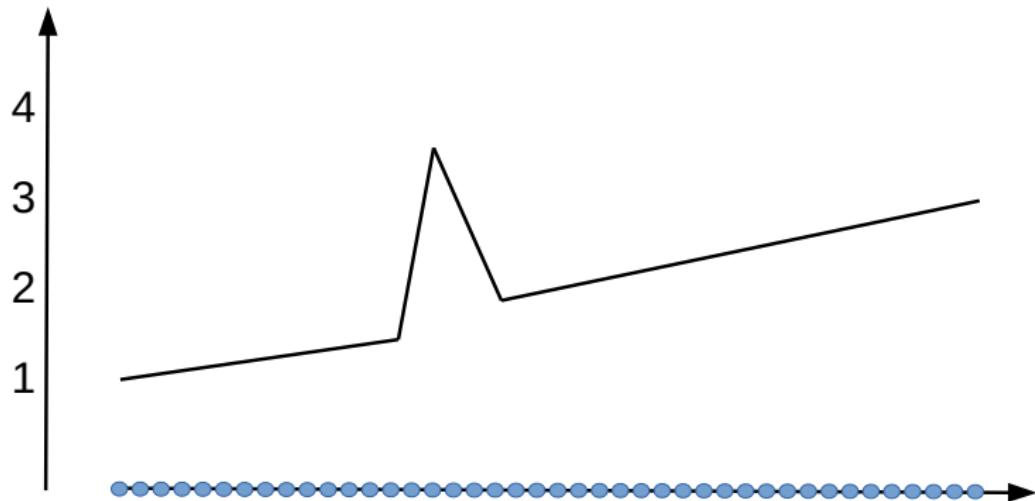
1. Mapper is a way to plot functions,
2. the domain of which is a high dimensional point cloud.



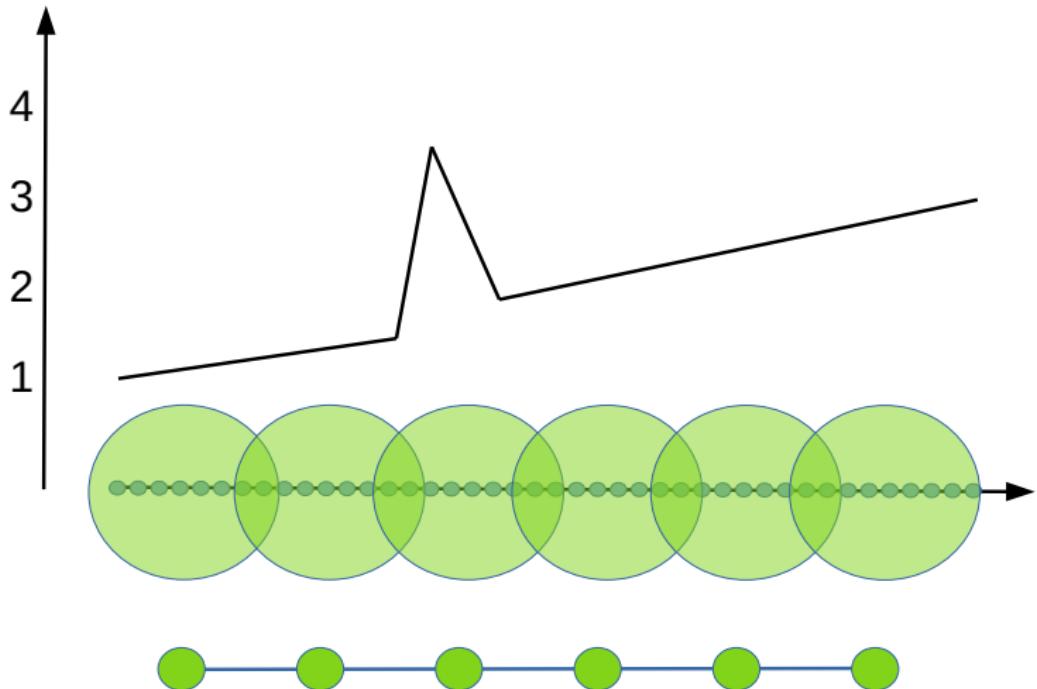
The space (normally high dimensional)



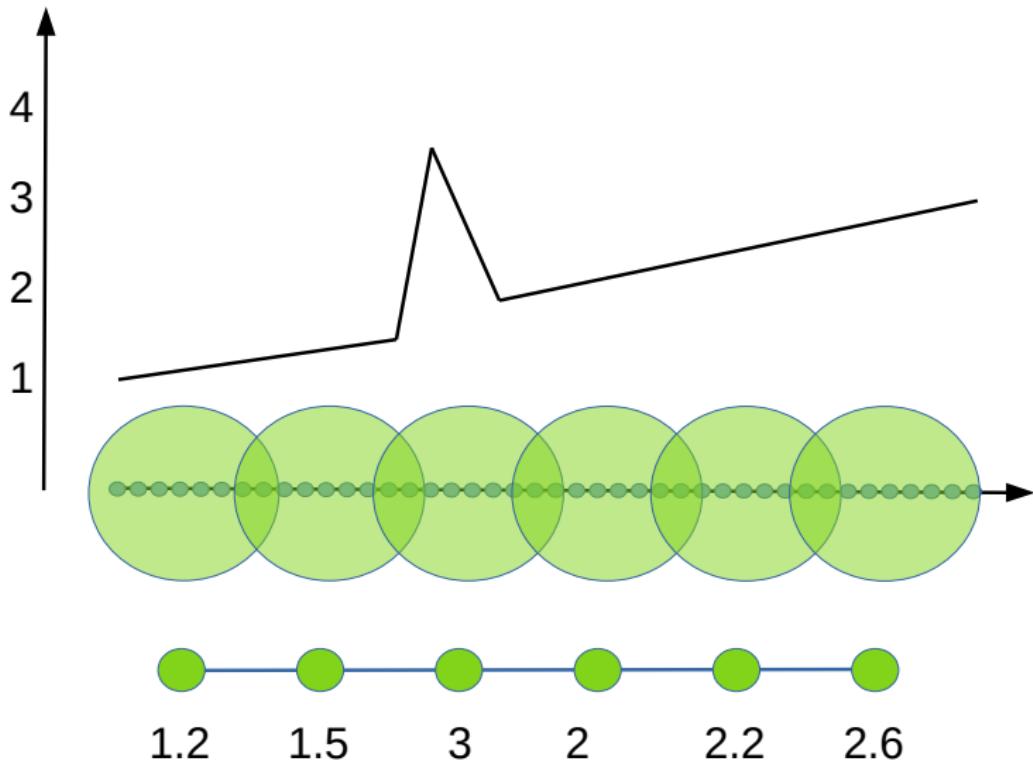
## Function on the space



## Model of the space

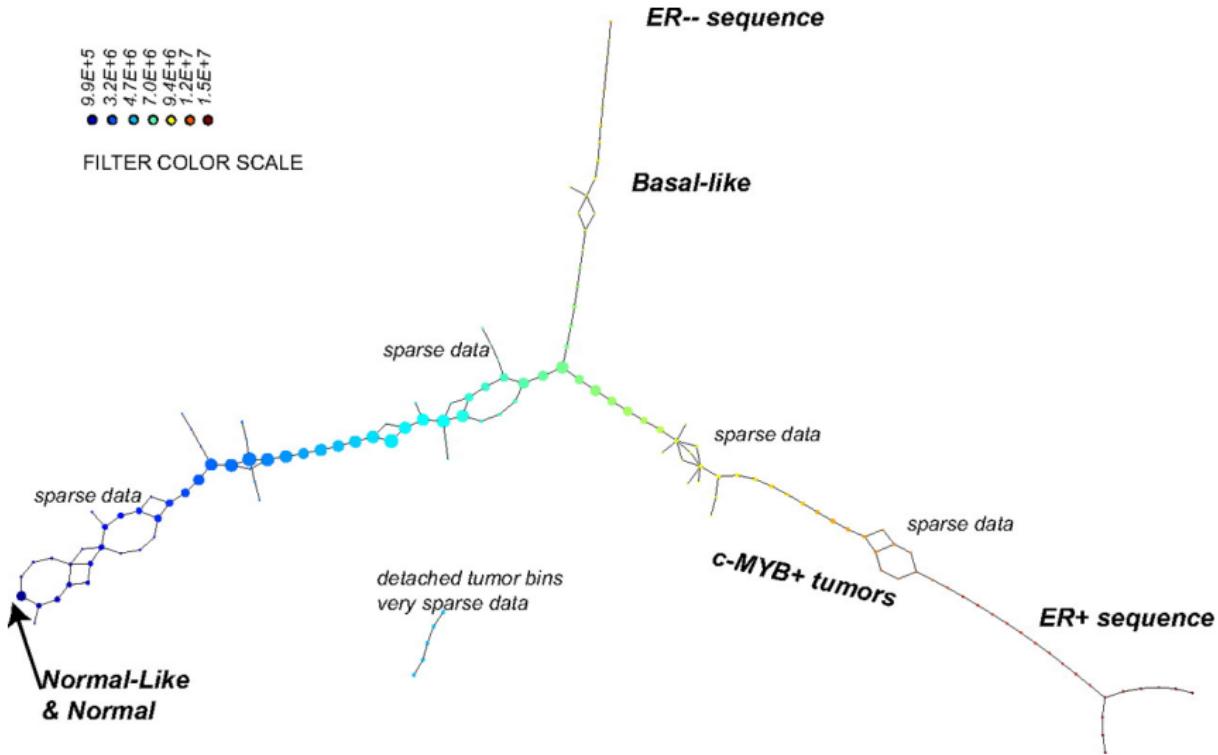


## Function values on the model of the space



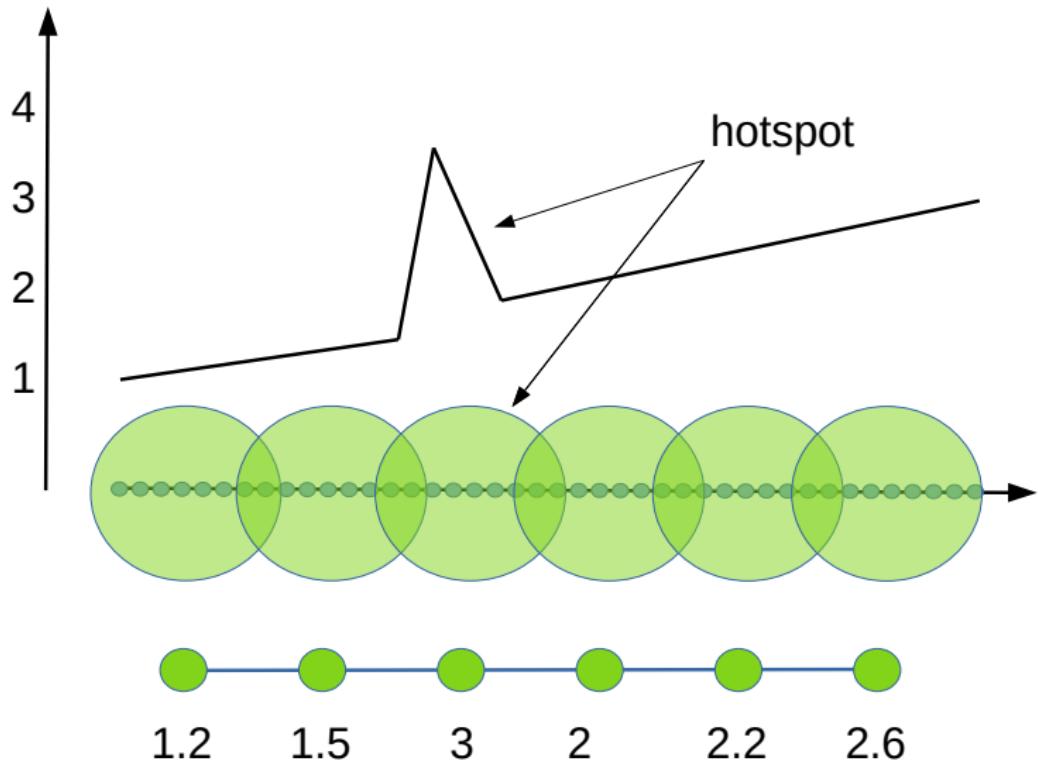
# Episode 5, Mapper and cancer data

With Ciara Loughrey, Sarah Maguire, Nick Orr and Anna Jurek-Loughrey



Nicolau, Levine, Carlsson, PNAS

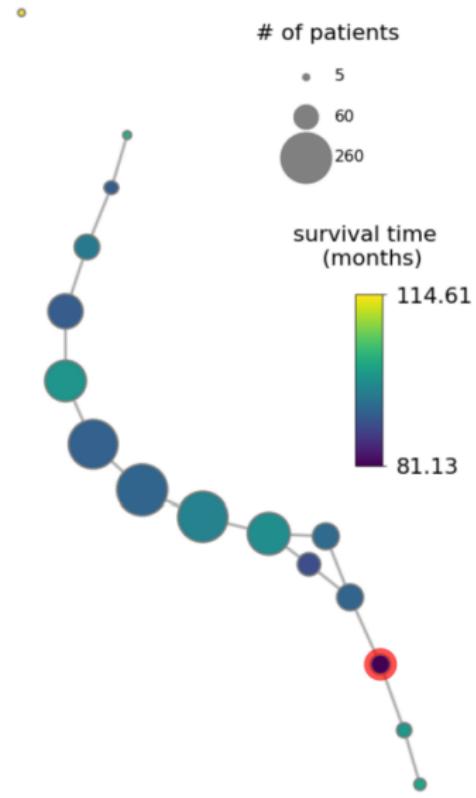
## Hotspots in mapper



## Our work

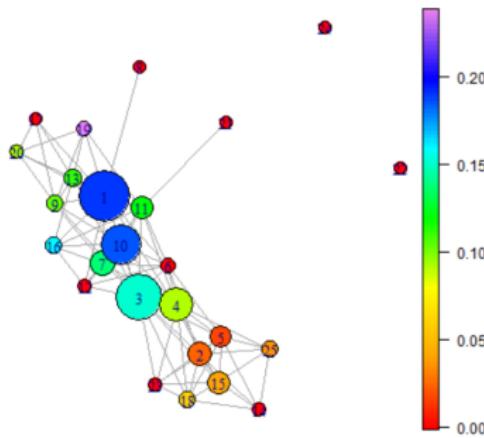
1. We took various datasets of ER+ breast cancer patients,
2. Use one of them to locate hotspot of lower survival,
3. Verify that the hotspot exist on the other,
4. Recognize which genes are responsible for the hotspot.

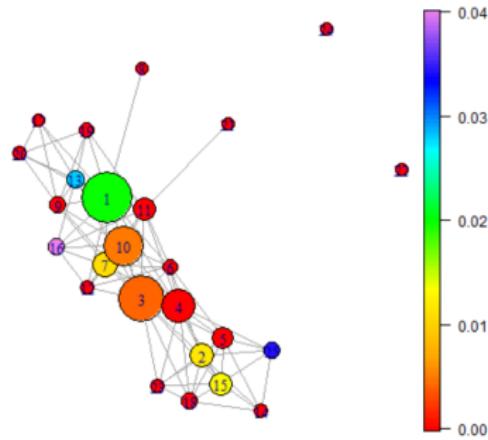
# The hotspot



# Mapper and covid

1. Our work from early days of Sars-Cov-2 pandemic.
2. Take blood results of patients (circa 600) form a hospital
3. 100 of them had covid. Where are they?





Similar risk patterns for patients from general admission?  
Data? Anyone?

# Mapper and economical management

# Ayasdi work

1. <https://medcitynews.com/2014/08/ayasdibigdata/>
2. <https://medcitynews.com/2018/07/hospital-ayasdis-ai/>

## Data mining questions that can be asked

1. Hospital entry questionaries – how combinations of answers may allow us to find patients requiring special attention?
2. Medical records together - do they together give us more information about patient's prognosis than individually?
3. Optimal economical management.

# Generalized periodicity

## Recordings of patients movements

1. Division to left / right side.
2. Check if they are mirror images (strong assumption),
3. Check if they are dynamically equivalent with half phase shift?
4. Assumption free methods to check generalized periodicity may be helpful.
5. I can go to details in blackboard.

# All thanks to my my Dioscuri team



If you have a problem,  
If no one else can help  
And if you can find them  
Maybe you can hire the TDA-Team.

Thank you for your time.

Dioscuri Centre in Topological Data Analysis  
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