Acoustic tomography for standing trees

Robert Mařík
Valentino Cristini
Vojtěch Semík
Jan Zlámal

Mendel University in Brno

Content

Acoustic tomography
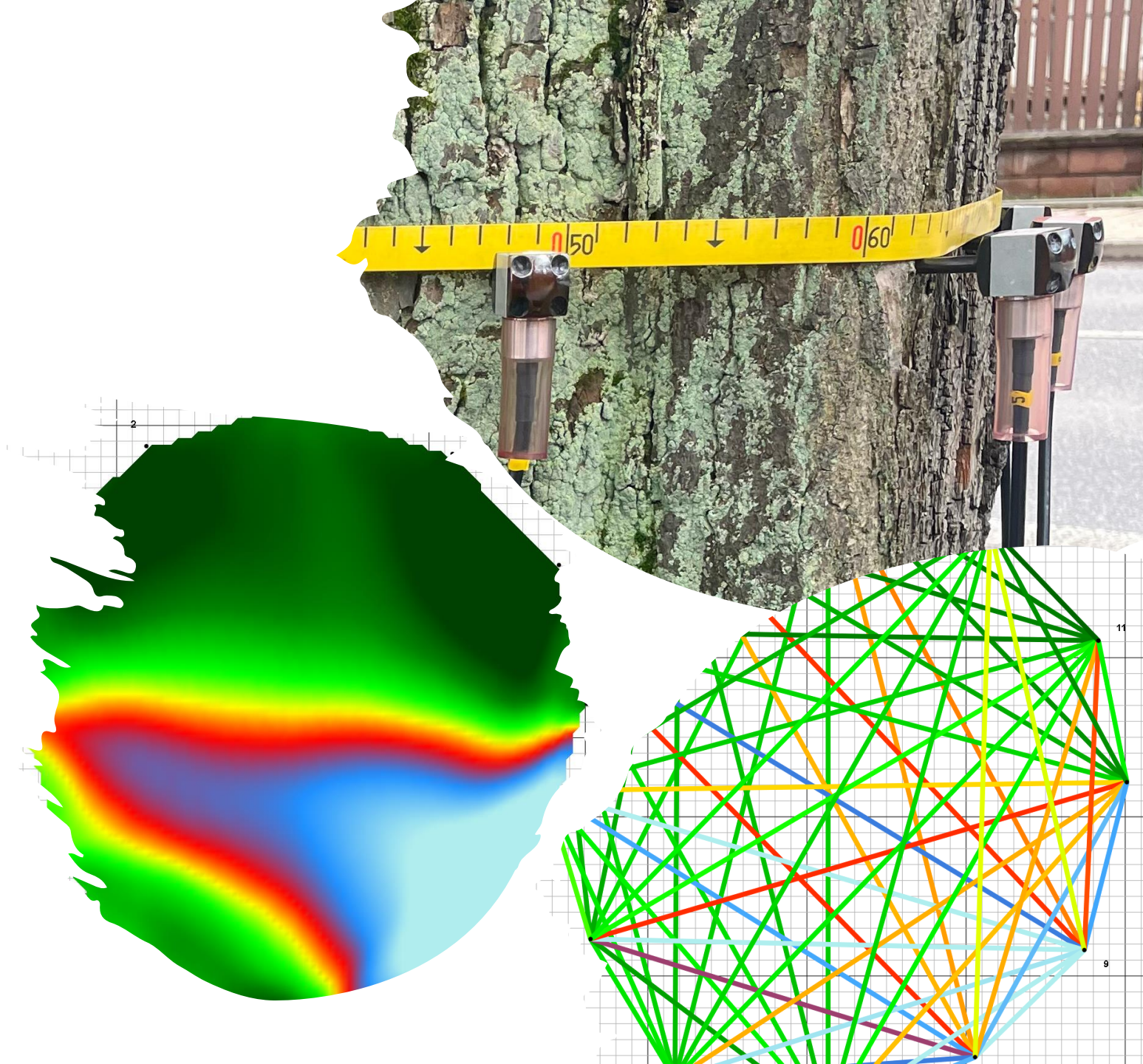
Image reconstruction in CT

TomoTree library

Sample outputs

Acoustic tomography

- Noninvasive (almost) method to assess condition of trees

- Sensors around the trunk allow to measure speed of sound wave

- Slower sound wave propagation is an indicator of possible decay

- Dense information (tomogram) is obtained from sparse information (speeds between sensors)

Principles of CT

- Projection of an object along lines (Radon transform).
  - Input: function of two variables and beam of parallel rays
  - Output: projection along rays (line integral)

- The results are recorded in a sinogram. (Trace of isolated object is a graph of sine function.)

- Object is scanned from many angles.
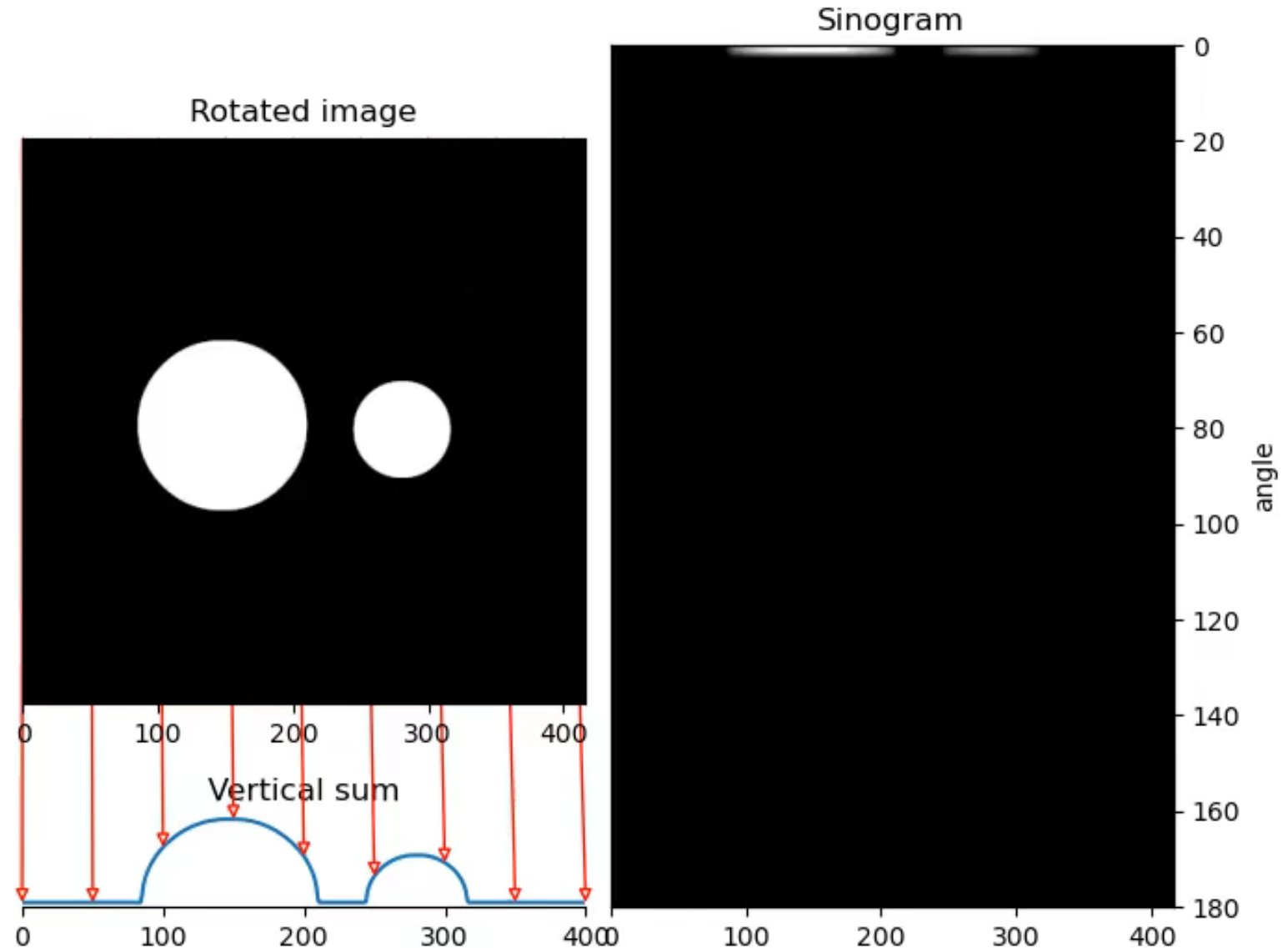
Principles of CT

- Projection of an object along lines (Radon transform).
  - Input: function of two variables and beam of parallel rays
  - Output: projection along rays (line integral)

- The results are recorded in a sinogram. (Trace of isolated object is a graph of sine function.)

- Object is scanned from many angles.
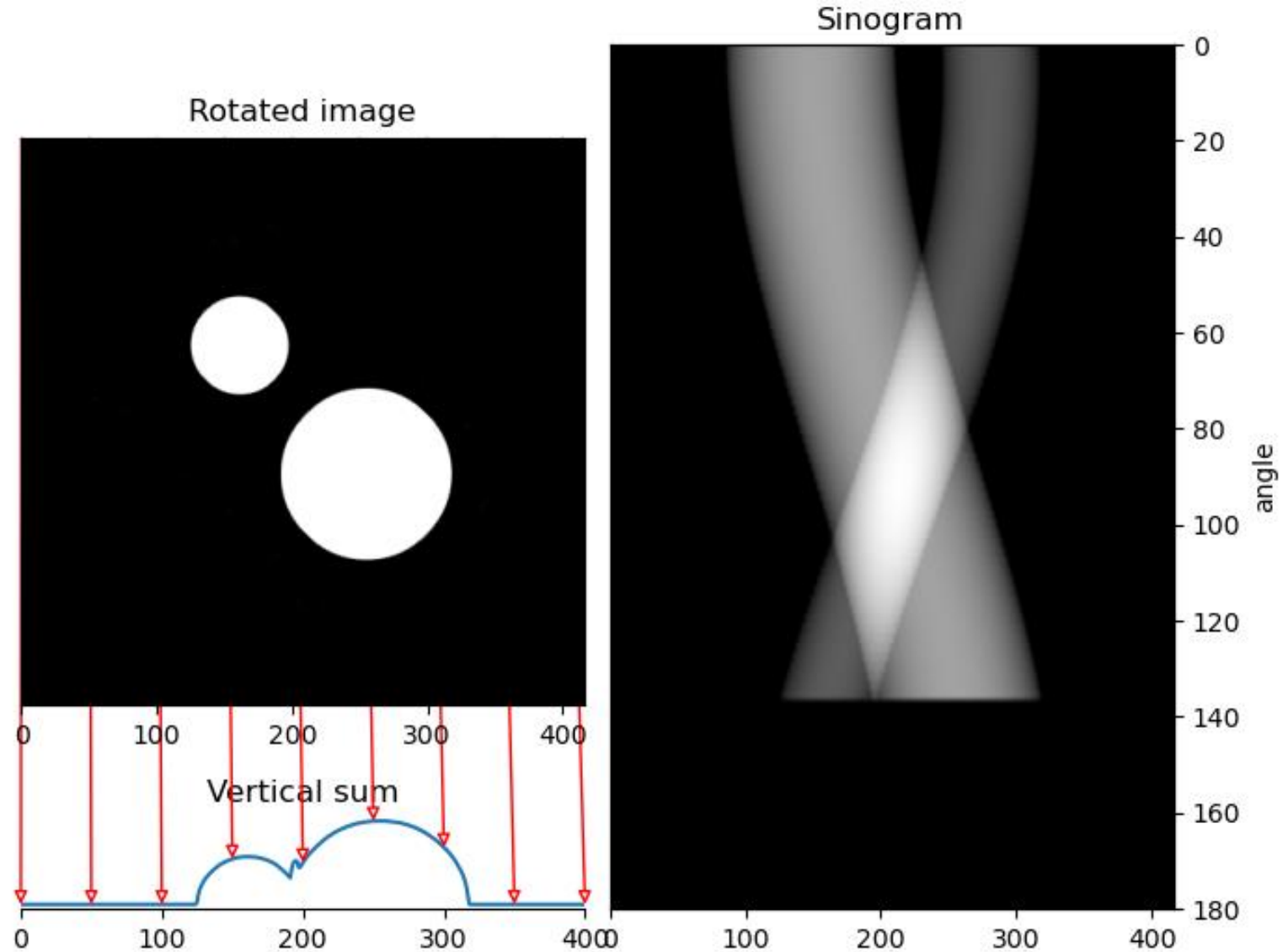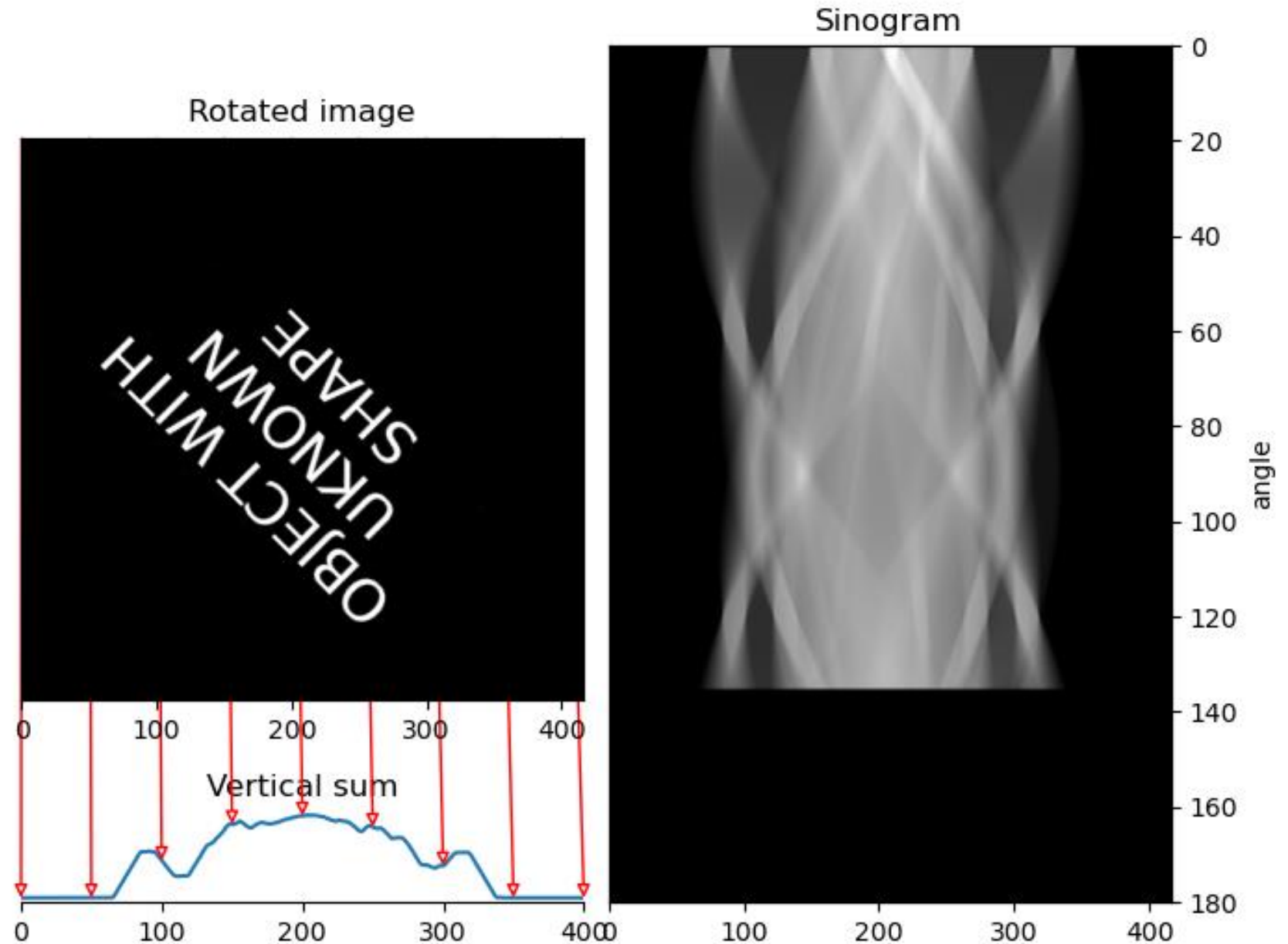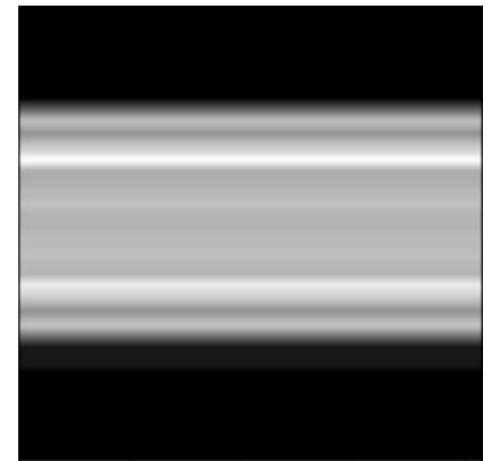
Image reconstruction

- Inverse Radon transform.
- In applications the sinogram is known.
- The image (function of two variables) has to be reconstructed from the sinogram.
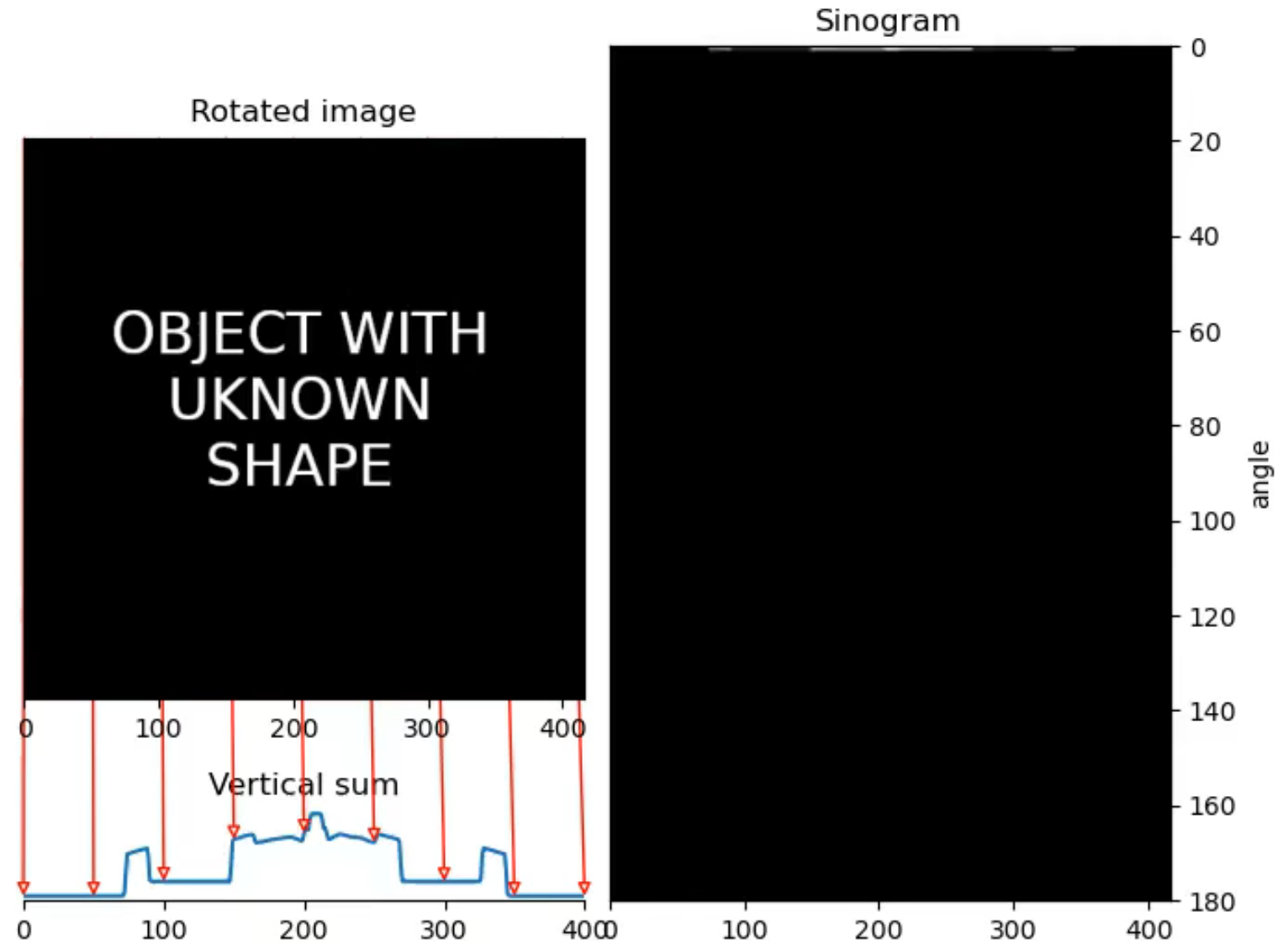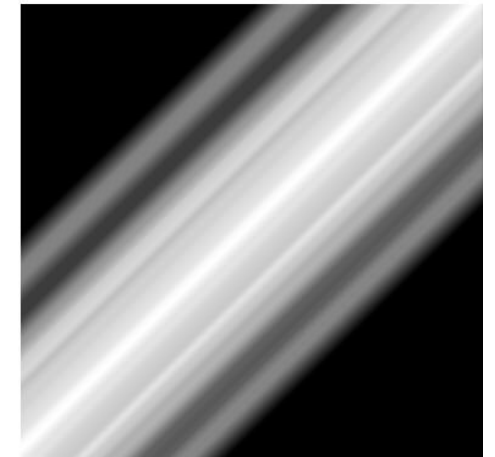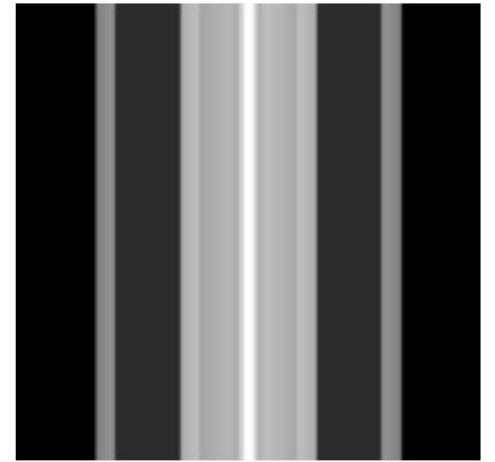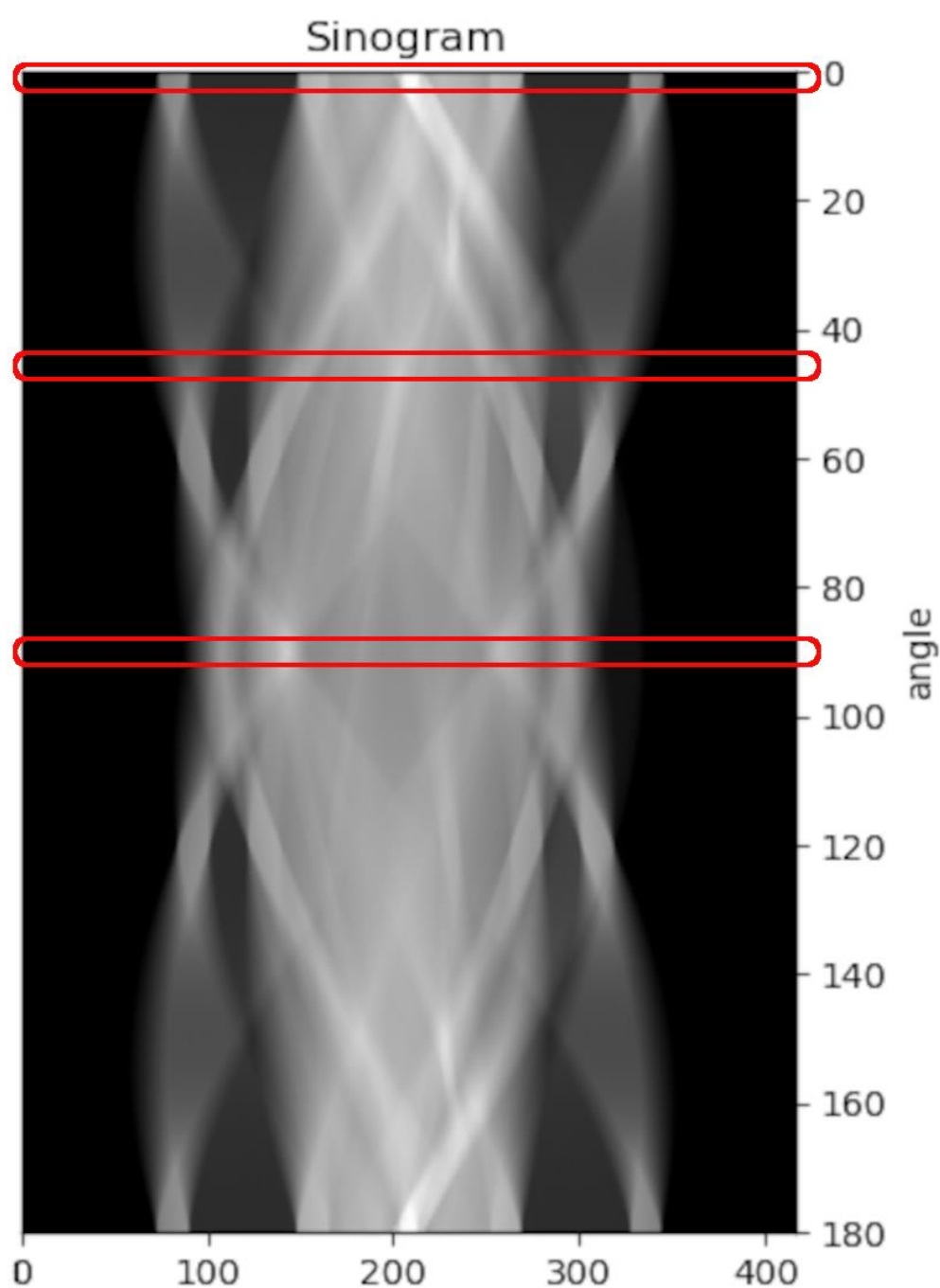
Image reconstruction

- Inverse Radon transform.
- In applications the sinogram is known.
- The image (function of two variables) has to be reconstructed from the sinogram.

Algorithm for image reconstruction

- Use the sinogram rows.
- Project the rows back to the image.
- Sum up.
- Filtering should be used to improve the reconstructed image.

Algorithm for image reconstruction
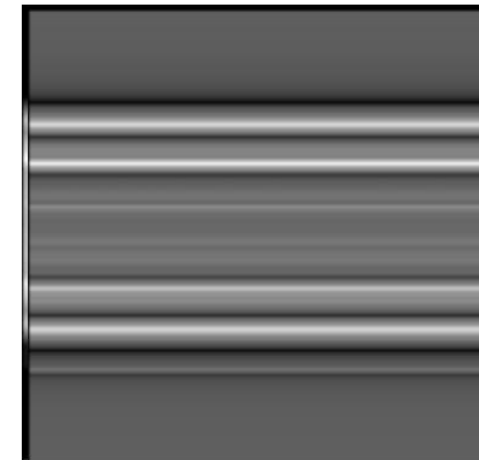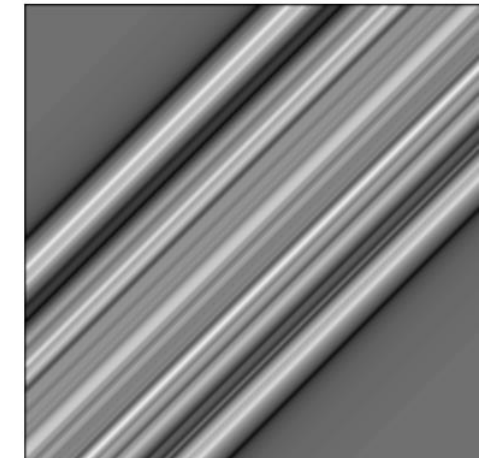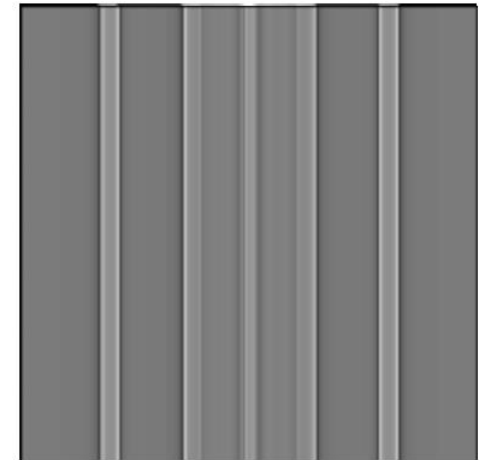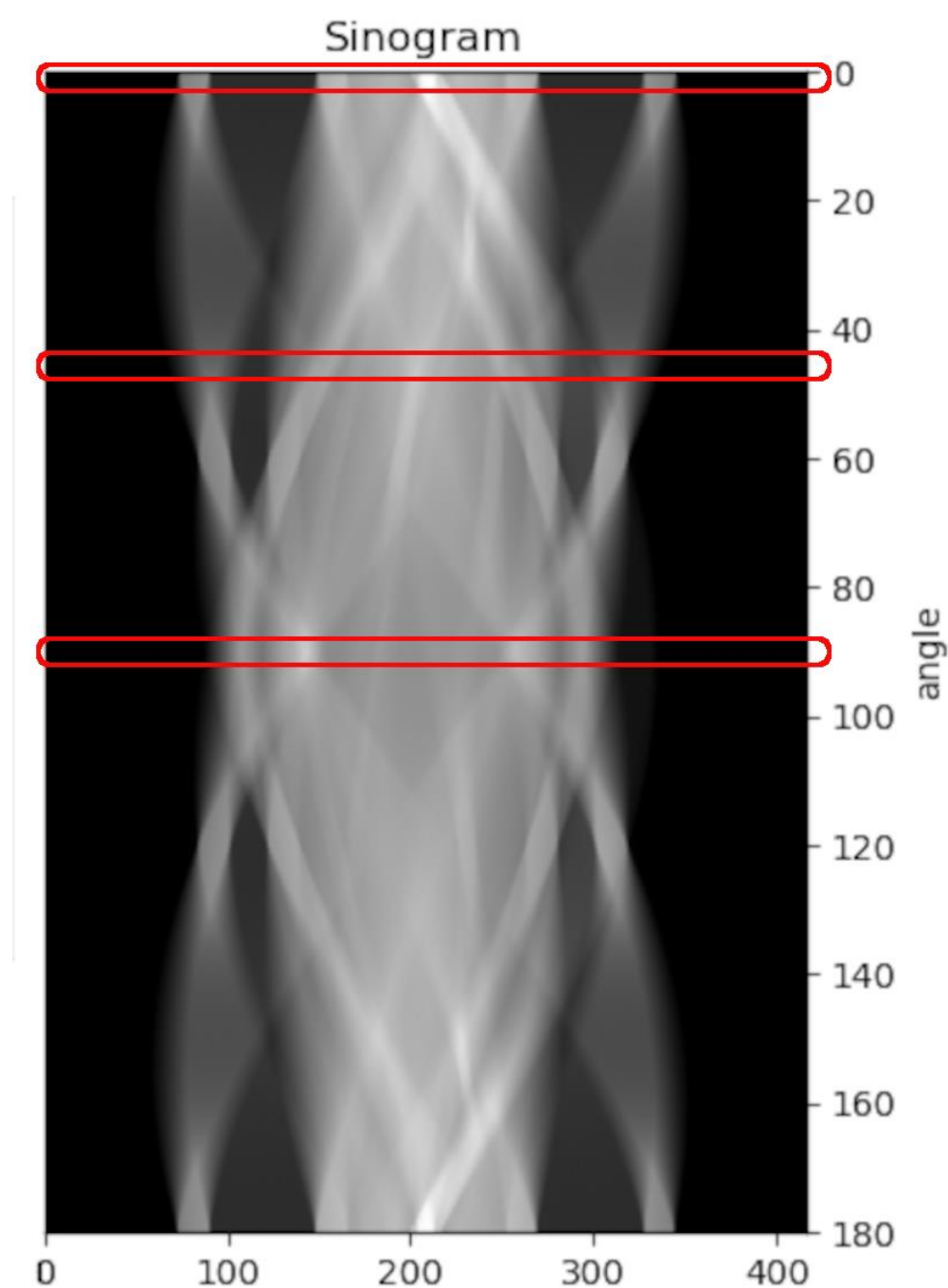
- Use the sinogram rows.
- Project the rows back to the image.
- Sum up.
- Filtering should be used to improve the reconstructed image.

Algorithm for image reconstruction

- Use the sinogram rows.
- Project the rows back to the image.
- Sum up.
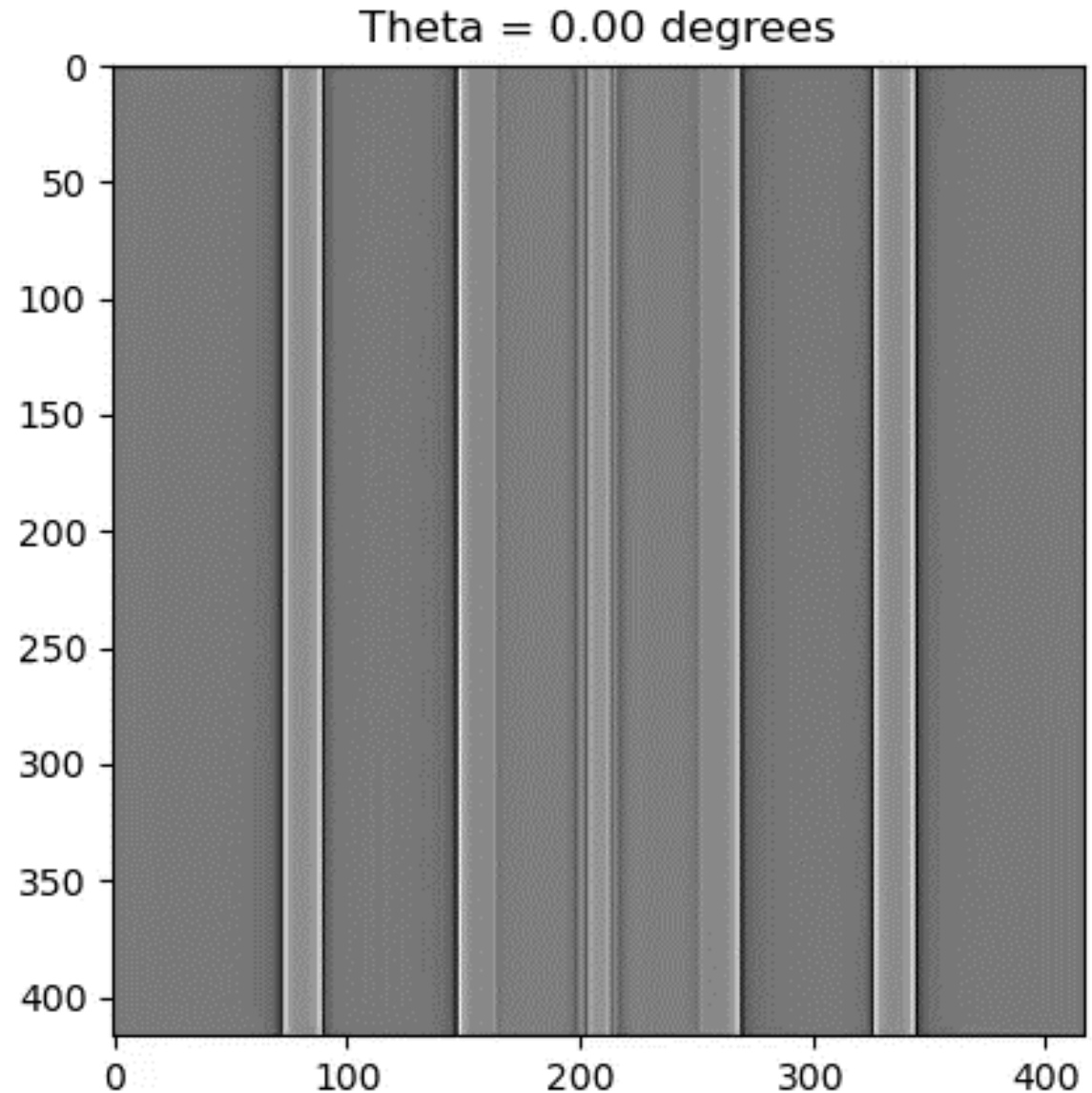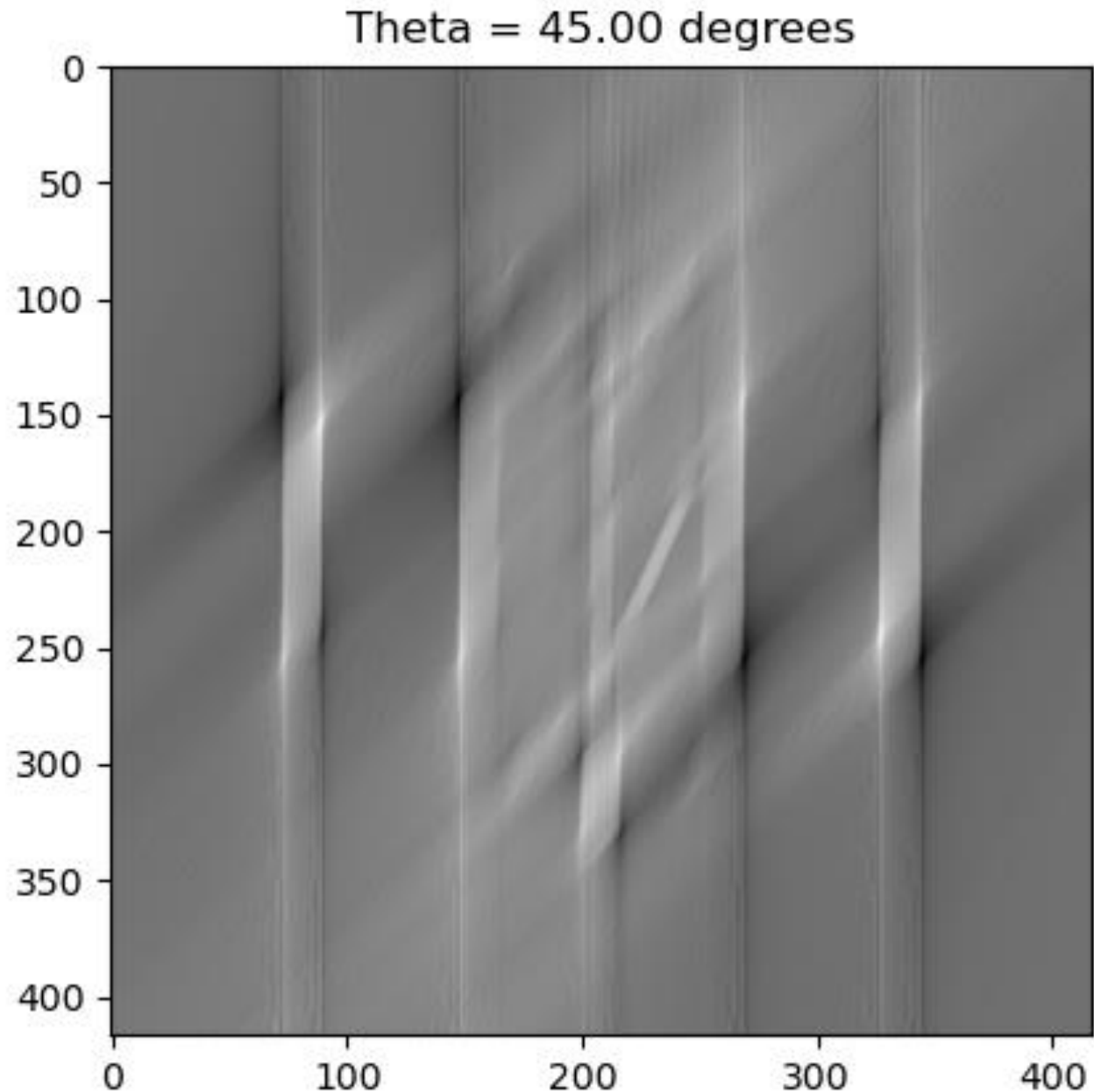- Filtering should be used to reduce high intensity in the center and blur.

Theta = 0.00 degrees

Algorithm for image reconstruction

- Use the sinogram rows.
- Project the rows back to the image.
- Sum up.
- Filtering should be used to reduce high intensity in the center and blur.

Theta = 45.00 degrees

Algorithm for image reconstruction

- Use the sinogram rows.
- Project the rows back to the image.
- Sum up.
- Filtering should be used to reduce high intensity in the center and blur.
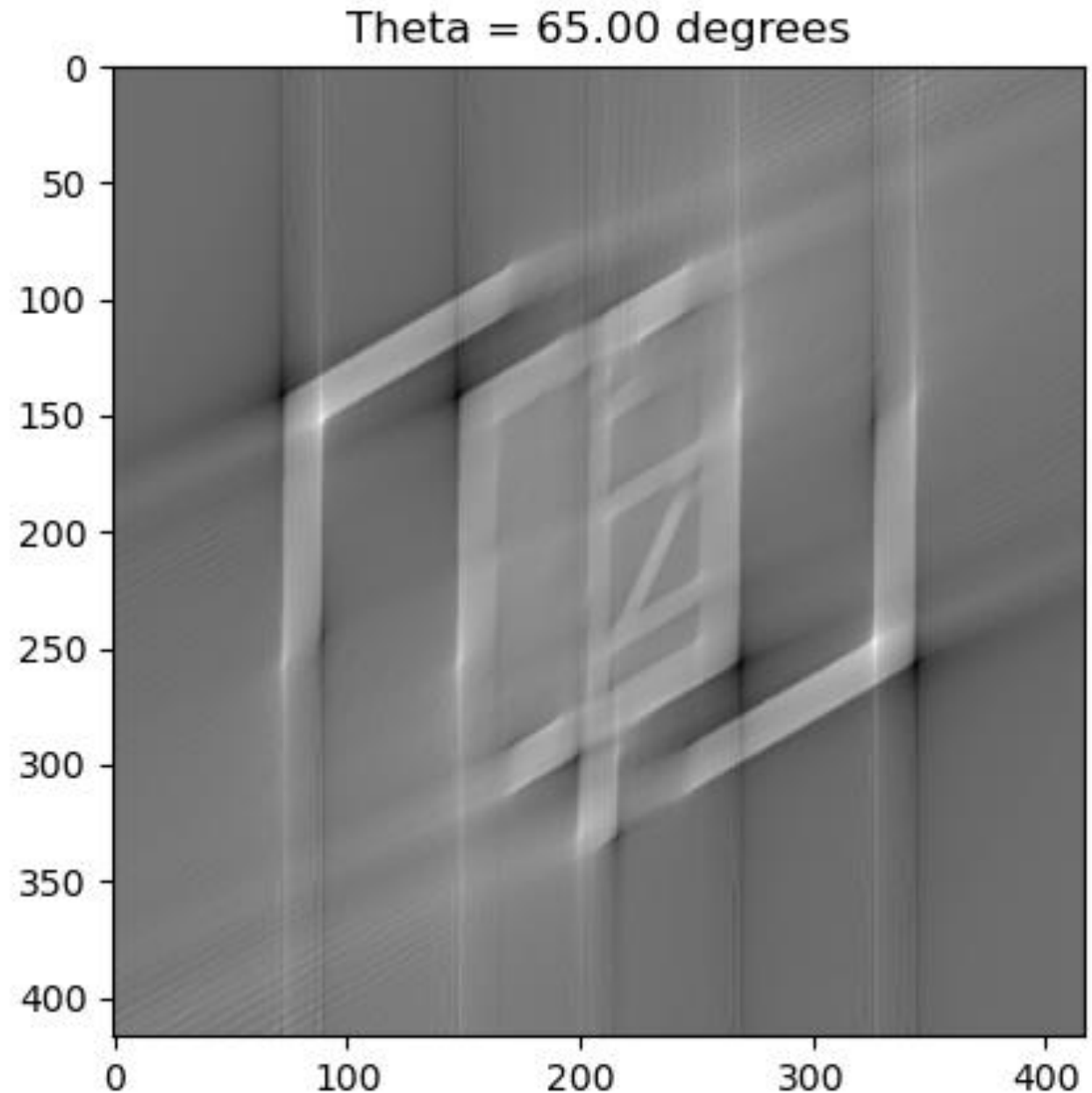

Theta = 65.00 degrees

Algorithm for image reconstruction
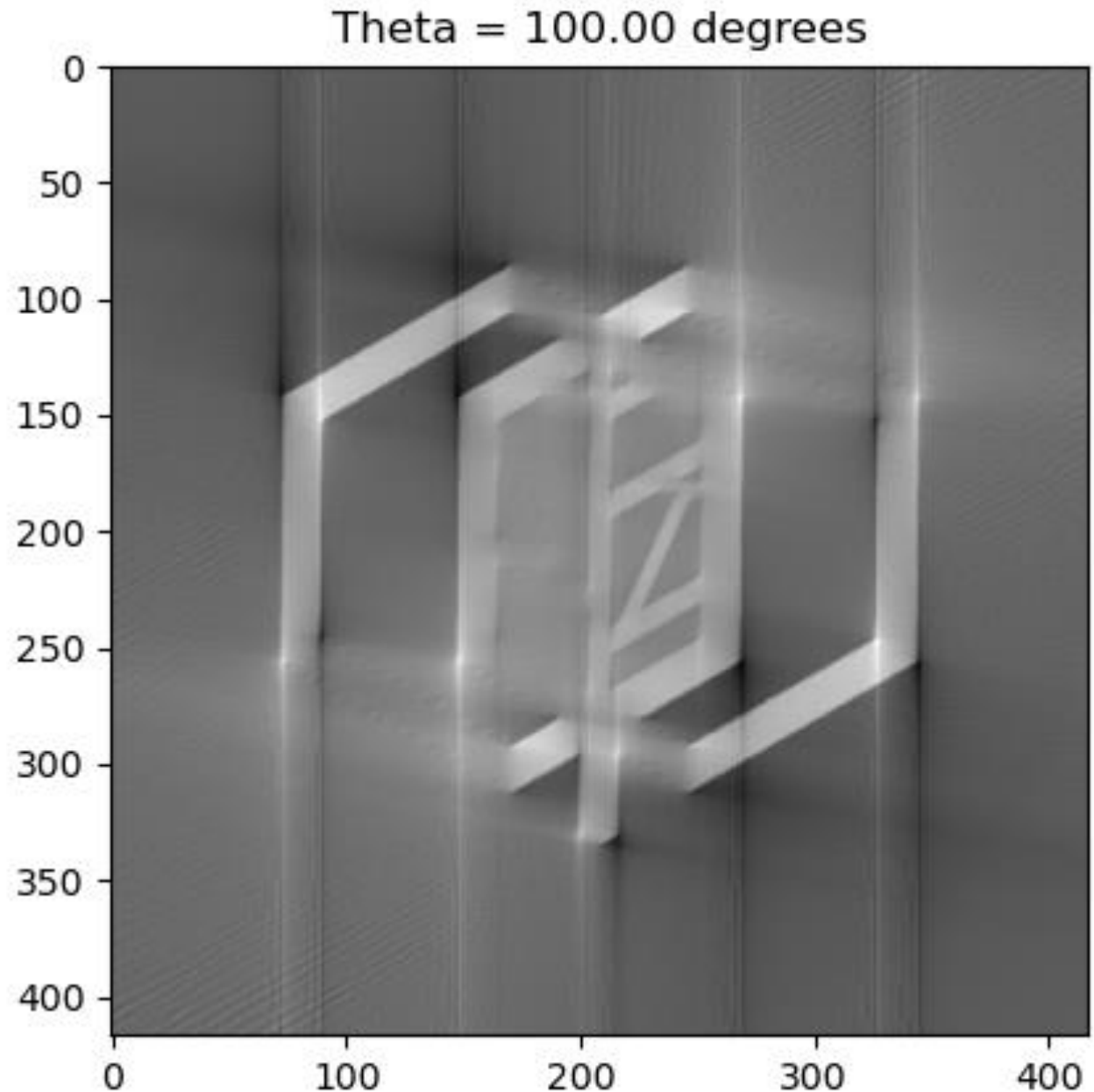
- Use the sinogram rows.
- Project the rows back to the image.
- Sum up.
- Filtering should be used to reduce high intensity in the center and blur.

Theta = 100.00 degrees

Image reconstruction steps

- "Sum up" (in some sense) the data from projections.

- Tweak the quality of the result using some magic, such as filtering (FFT).

- Using a lot of rays improves the image.

- Using a lot of angles improves the image.

Backprojection without filter


Filtered backprojection
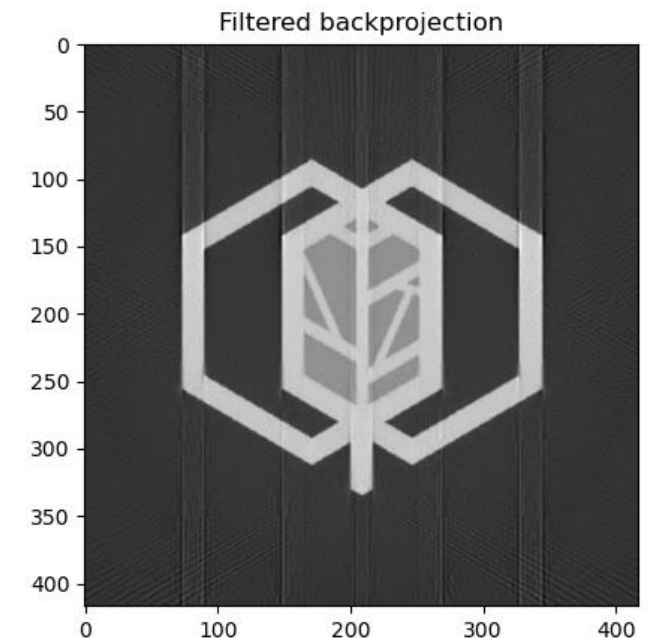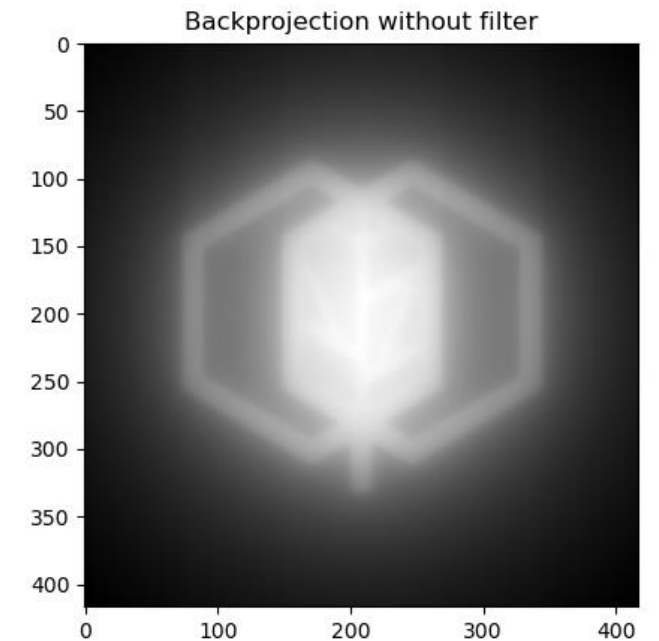
Principles of our tomogram reconstruction

- **Anisotropy** compensated.
- **Straight rays** composed from **segments**.
- Each ray and segment have defined their **region of interest** (ROI).
- The speed of each segment is defined as *average* of the speeds of rays intersecting the ROI of this segment.
- The segments define the segmentation of the ROI of the ray.
- The speed in certain part of the cross section is an *average* of speeds across all ROI which contain this point.
- The difference between computed and measured TOF is minimised using a transformation.
- **Average ≈ rescaled sum ≈ back projection**

Zheng (2013), Du (2015, 2018), …
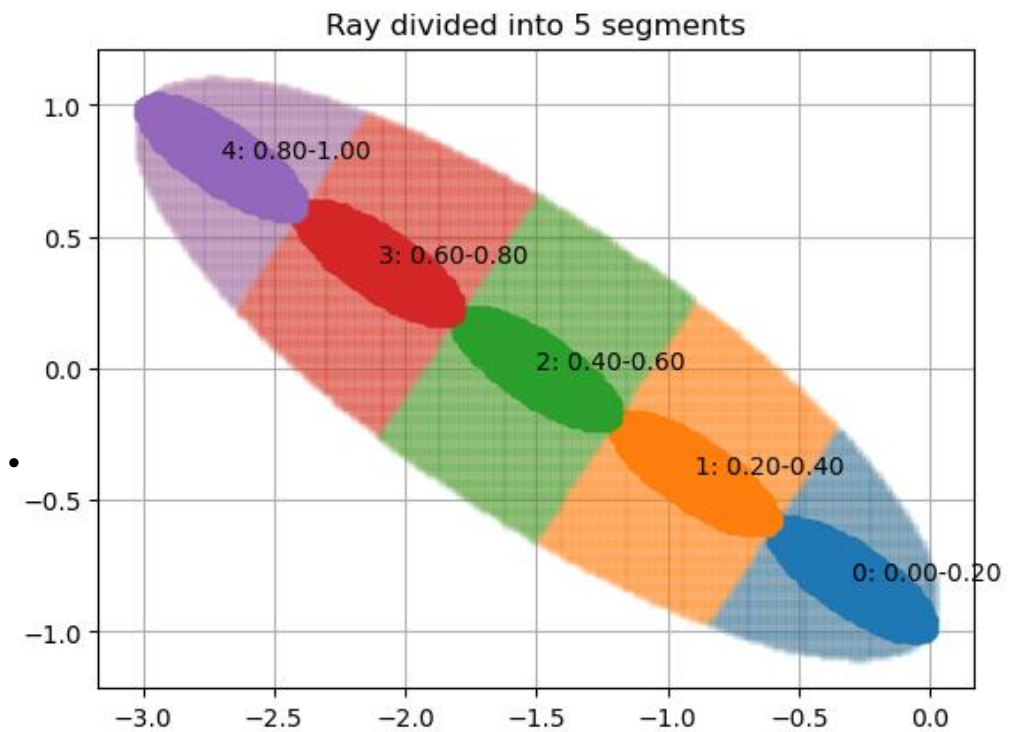
Technology

- Code written as a Python library TomoTree

- NumPy library for data processing

- Code on Github will be available when the code reaches beta stage.

- Streamlit www interface with alpha version already available. `tomotree.streamlit.app`

TomoTree Web Interface

A python package for acoustic tomography of trees by Robert Mařík and Valentino Cristini

Plot type
- ⊙ rays only ● cells only
- ⊙ both

Fix anisotropy using $\frac{v}{1-0.2\theta^2}$
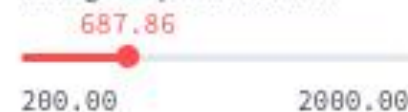- ● True ⊙ False

Plot with contourf
- ⊙ True ● False

Shading
- ● flat ⊙ gouraud
- ⊙ nearest
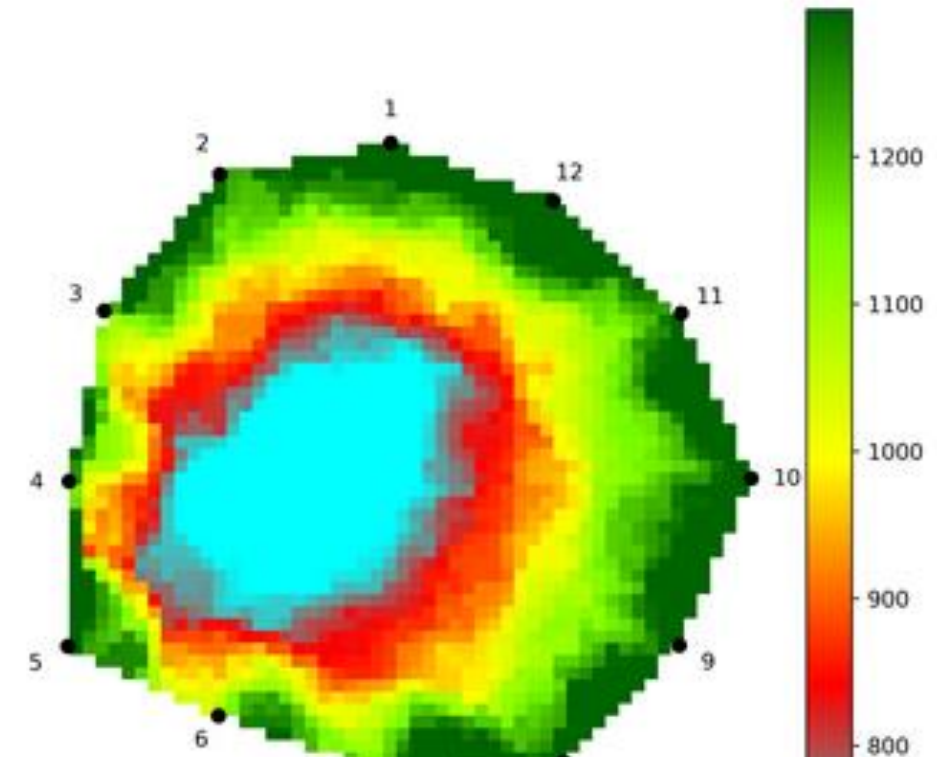
Basic EBSI ERSM Angle plots Info

Number of cells on one side of square for ERSM method
55

10   120

Tomogram speed min. ERSM
687.86

200.00   2000.00

Tomogram speed max. ERSM
1299.94

200.00   2000.00

Test data

- Real trees have been used rather than wooden discs.
- Trees from Jičín, the longest in Europe linden alley (2.2 km).

Image: Wikipedia, Valdštejnova alej
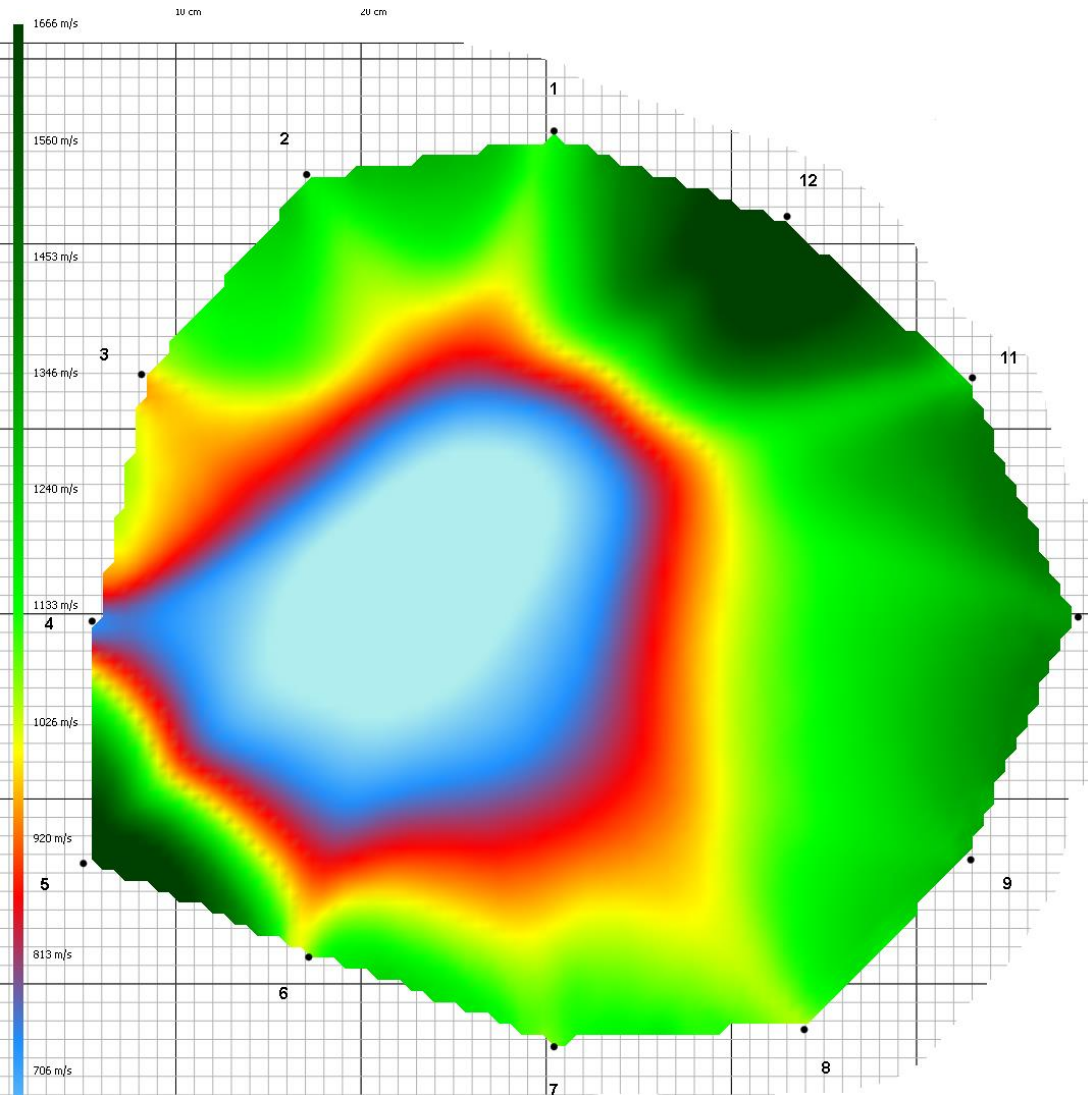
Cross section cuts

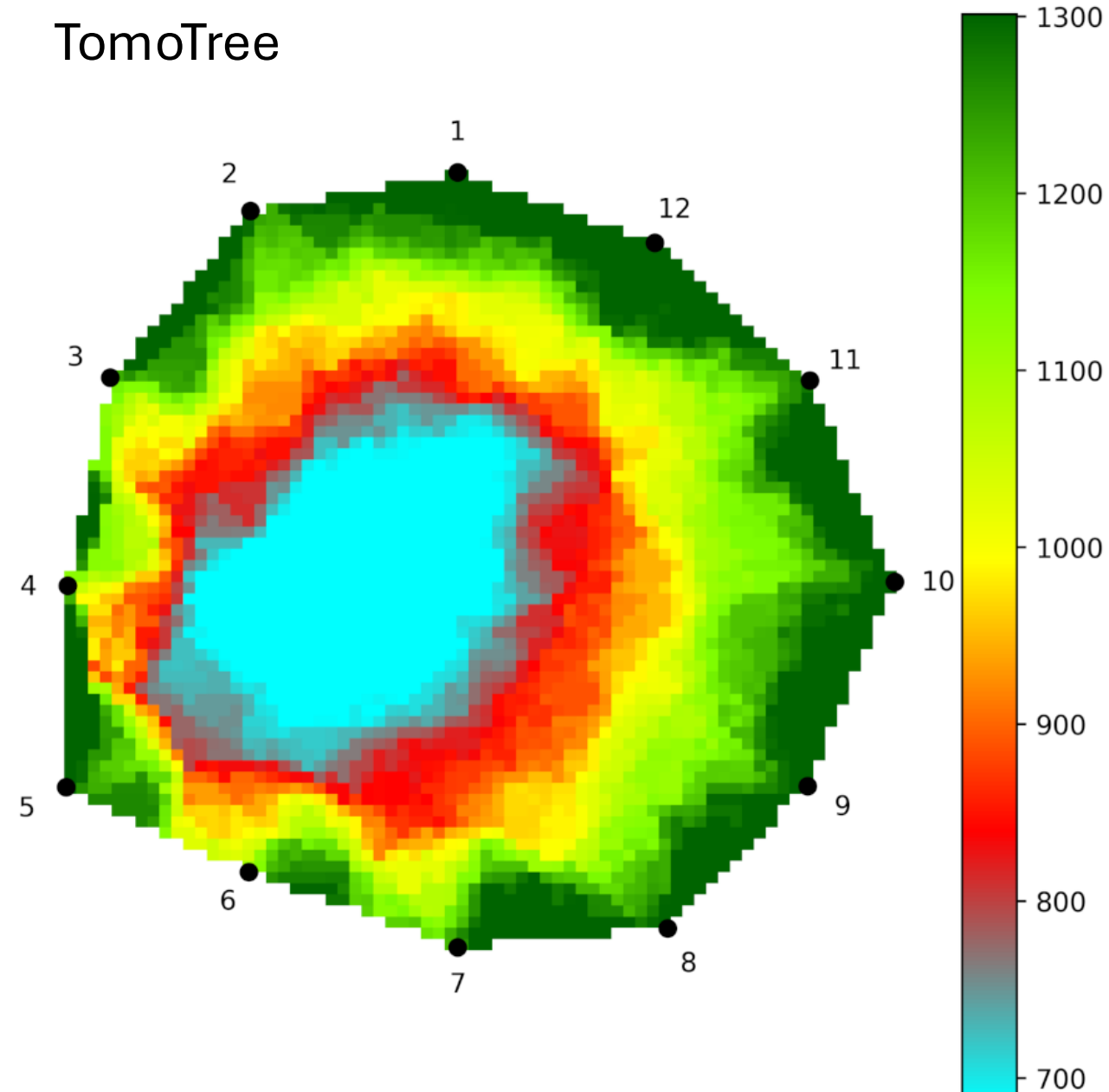Crack (tree 08) and cavities (trees 14 and 15).
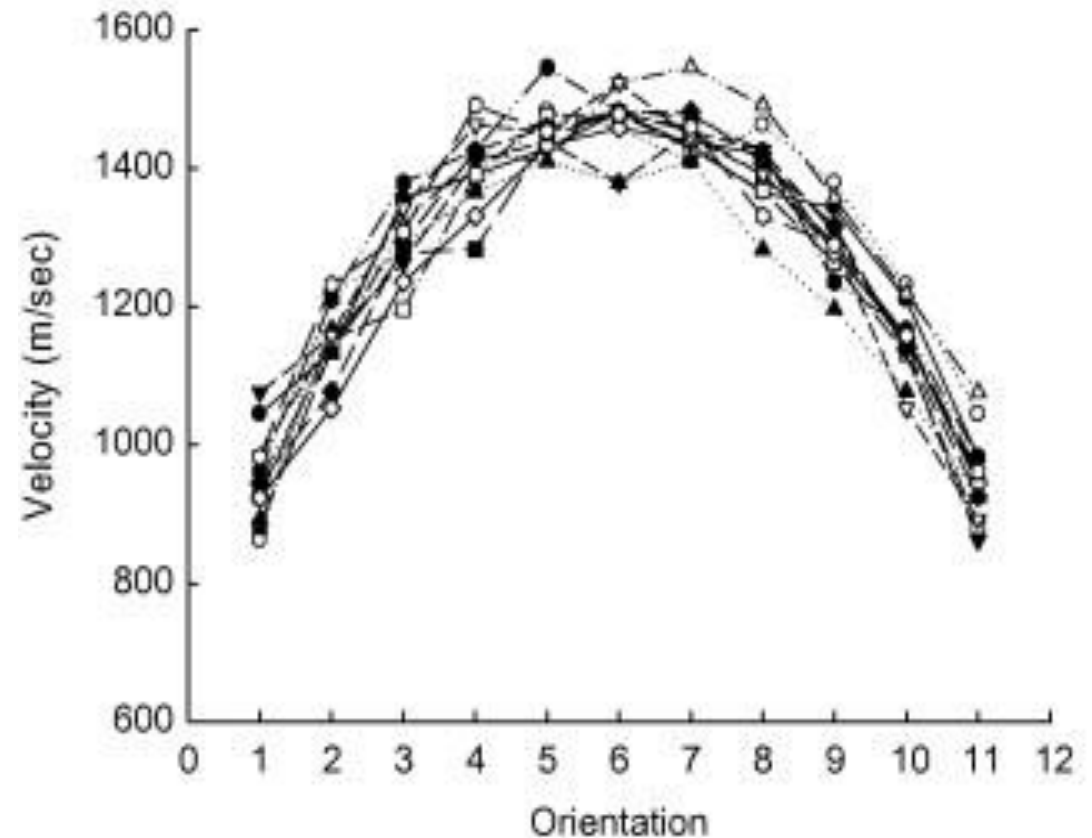
Image reconstruction

ArborSonic 3D

TomoTree

Few words about anisotropy

- Sound speed is higher in radial direction than in tangential.
- The dependence of velocity on the declination from radial direction is approximately quadratic.
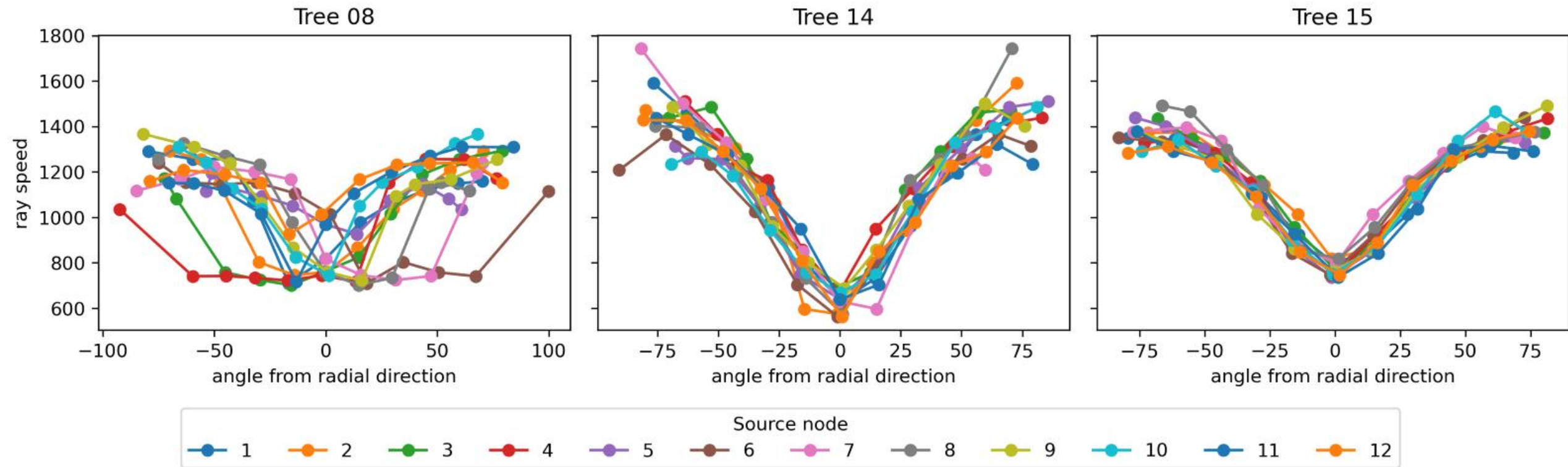- The above-mentioned property can be used to detect decay as well as to compensate the anisotropy.

Figure from Li et al. (2014). Analysis of wave velocity patterns in black cherry trees and its effect on internal decay detection
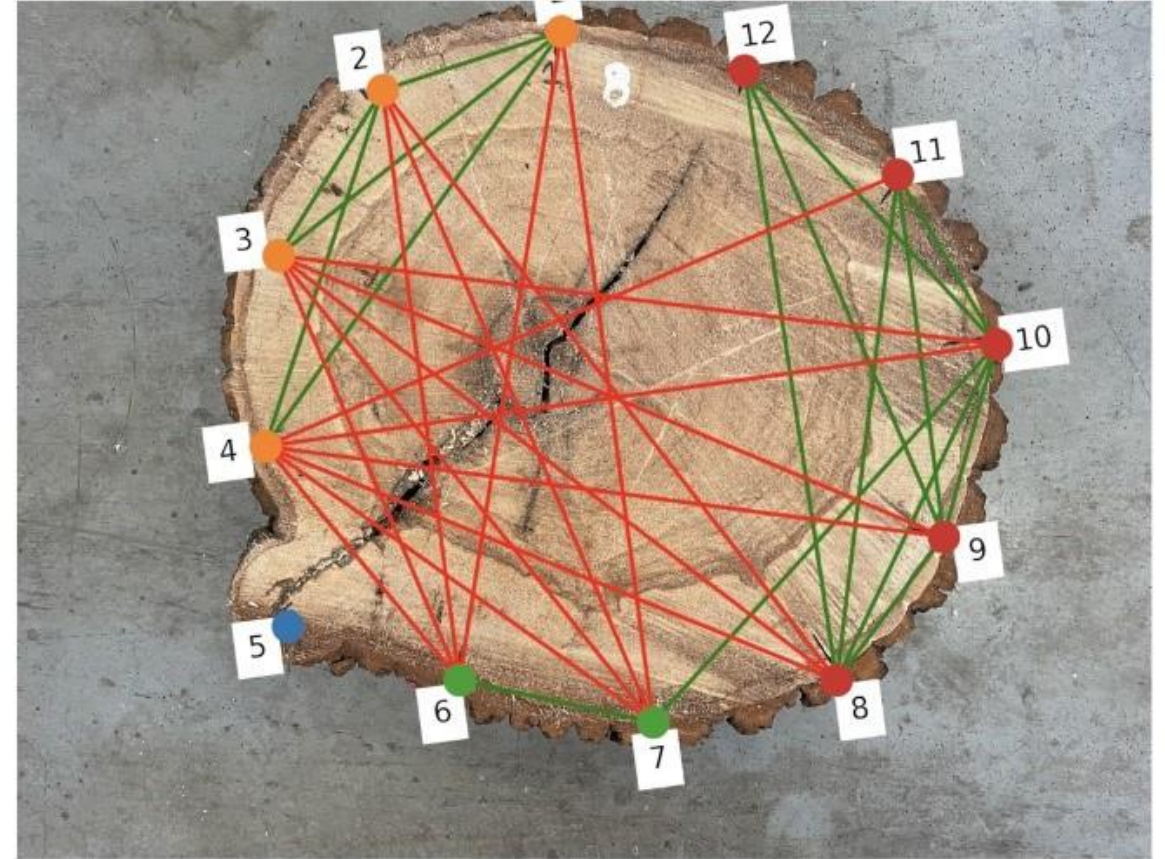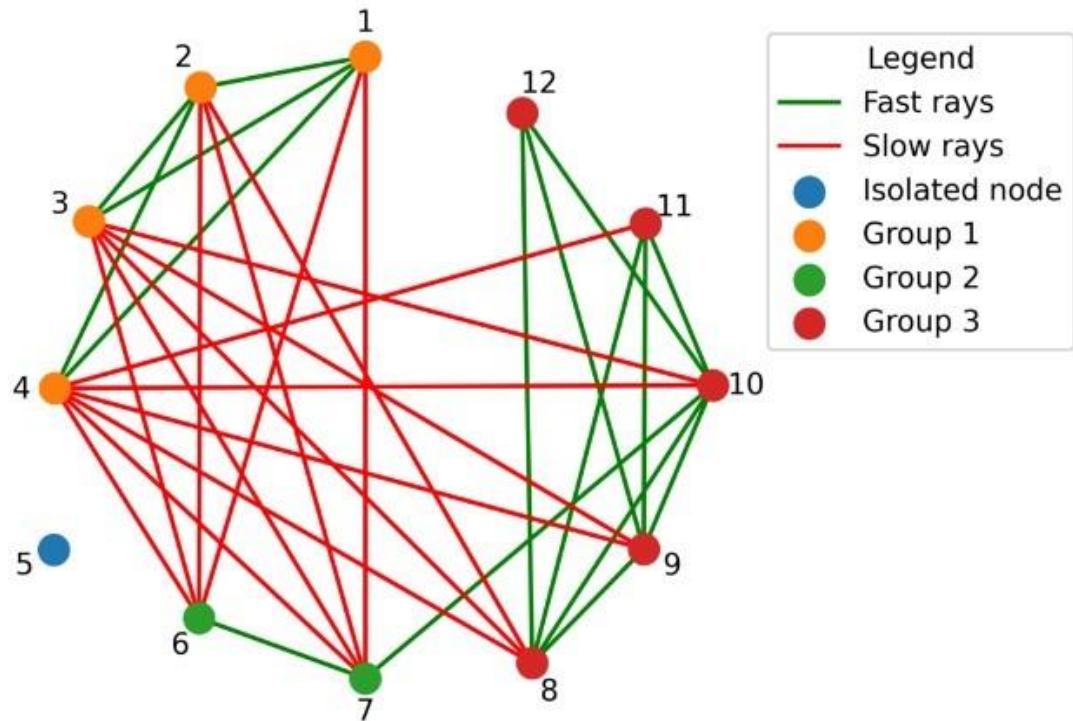
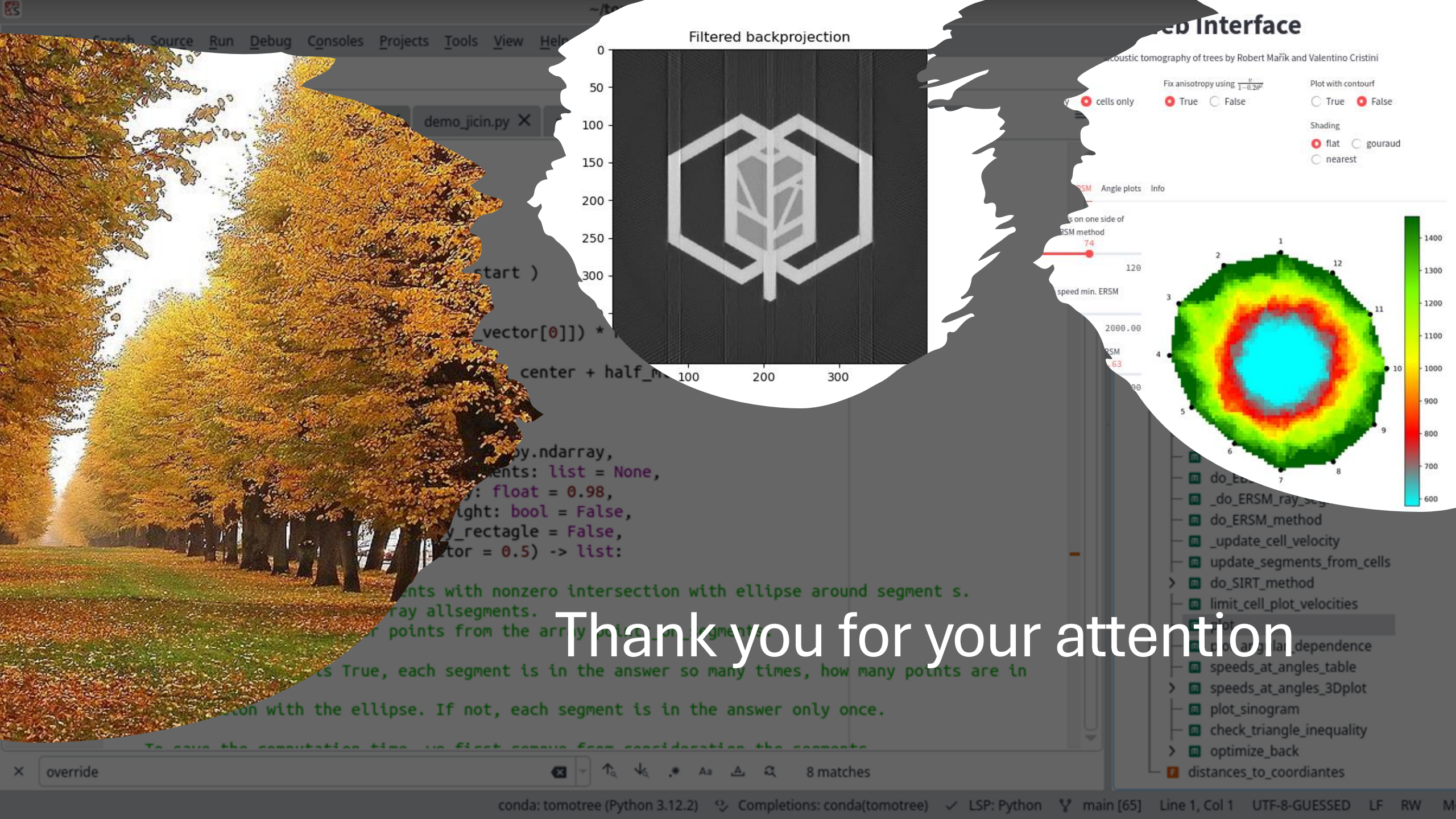Other analyses are also possible

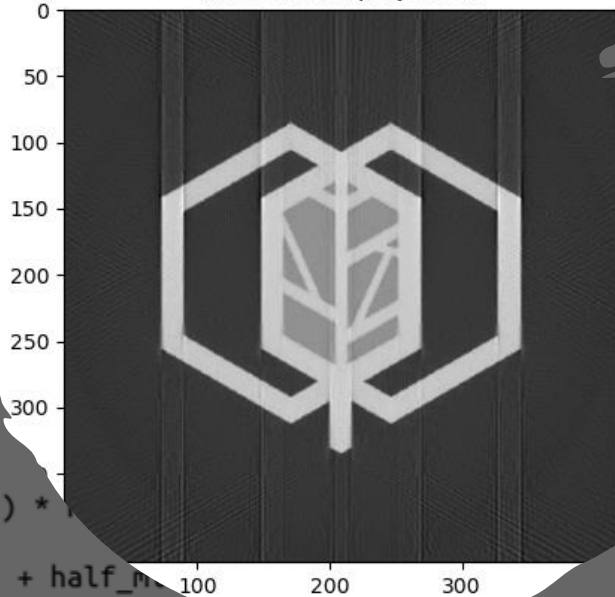Angular dependence of the ray speed

Yet another analysis

Nodes for Tree 08 separated to clusters

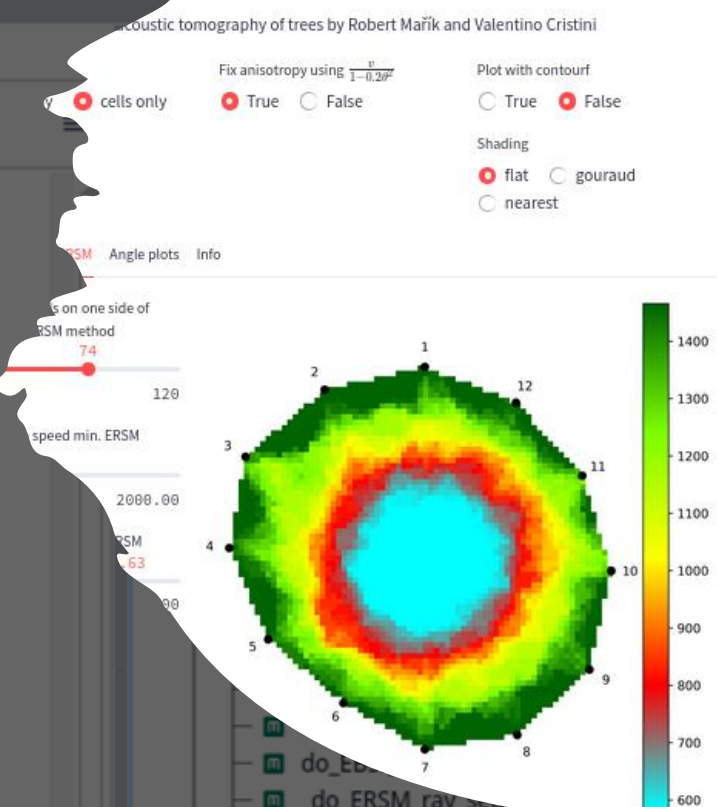Legend
- Fast rays (green)
- Slow rays (red)
- Isolated node (blue)
- Group 1 (orange)
- Group 2 (green)
- Group 3 (red)

Thank you for your attention