Topic 2: Introduction to Shear-wave Splitting with *Pytheas*

The properties of shear-wave splitting (the polarization direction of the fast shear-wave – φ – and the time-delay – t_d) can be acquired by analysing waveforms of local earthquakes. The density of the seismological network in the Western Gulf of Corinth provides a vast wealth of available data. In the current exercise, we will use the *Pytheas* software to determine the splitting in the upper crust of the Gulf of Corinth.

Quick Installation

To install the software:

1. Follow the link here and download the compressed file that includes the latest release of the software.
2. Extract the files to any directory (e.g. for Windows users, C:\Users\<username>\Documents, where <username> is your computer's username).
3. Download the latest Python 3.7 release. It is highly recommended to install the 64-bit (amd64) version.
   - Windows: Download the binary installation file (*Windows x86-64 executable installer*) from here (select the latest 3.7 version)
   - MacOS: Download the binary installation file (*macOS 64-bit installer* for OS X 10.9+ or *macOS 64-bit/32-bit installer* for OS X 10.6+) from here (select the latest 3.7 version)
   - Linux: Most modern Linux distributions (e.g. Ubuntu & OpenSUSE) already include Python 3. However, it is recommended to check your native package manager for the latest 3.7 release. Please make sure that *pip* is installed for your distro.

> **IMPORTANT (Windows users):** Make sure you have selected "Associate files with Python (requires the py launcher)" and "Add Python to environment variables" in the Advanced Options page, during installation. If you haven't, you will need to add the Python path to the system path manually.

4. Install the dependencies required by *Pytheas*. For Windows users, double-click on the *install_reqs_windows.bat* file located in the main *Pytheas* folder. MacOS/Linux users will have to run the *install_reqs_linux.sh* through a terminal:

   ```
   sh install_reqs_linx.sh
   ```

   In any case, the user's guide included in the *docs* folder contains details about installing the dependencies manually, through a terminal, with the *pip* package manager.

5. Pytheas should be ready to launch! For Windows users, it is recommended to create a desktop shortcut to the *LaunchPytheas.exe* file and use it to run the program. MacOS/Linux users will have to use the *LaunchPytheas.pyw* file.

Exercise 2: Shear-wave Splitting

The goal of this exercise is to measure splitting from local waveforms recorded by stations of the Corinth Rift Laboratory Network in the Western Gulf of Corinth. The software requires the following files:

> ➢ A directory with seismic waveform recordings
> ➢ A seismic catalogue that (preferably) contains arrival information about the shear-waves
> ➢ A station information file
> ➢ A local velocity model (optional)

All these files are already included in the *example* folder.

1. Launch *Pytheas* and open the given dataset. It contains waveform and event data for four earthquakes.

HINT: To start working, go to *File->Open Catalogue*. A new window will pop up, where the data directory (up), seismic catalogue (middle) and database (bottom) need to be specified. The first two should be properly set-up. To select a target database, use the *Browse* button of the respective field and specify a new file (or, alternatively, copy & paste the catalogue path from above, and change `xml` to `db3`.

2. Select an event-station pair to start working on. Preferably, use the station located closest to the earthquake, in which the seismic ray should be the most sharply incident.

HINT: Open up the *Event Selection* window with the Shift+E shortcut. After selecting an event, the closest station (sharpest angle of incidence) will be loaded automatically. However, if you wish to analyze a different event-station pair, you can select a new station in the *Station Selection* window (press Shift+S). The pairs are sorted in ascending order per the angle of incidence.

3. Measure the polarization direction of the fast shear-wave (φ) in the polarigram (visual inspection method). What is the value of φ for the selected event-station pair and how does it relate to the local stress field?

HINT: Inspect the recordings in the two horizontal components of the seismometer (N-S and E-W), i.e. the middle and bottom seismograms in the window. To remove unwanted noise, filter the seismograms in the 1-20 Hz band (Ctrl+F). Then, identify the first arrival of the shear-wave in either components and select ("pick") the respective vector in the polarigram with Ctrl+Left Mouse. You can see the measurement at the bottom left of the information panel.

4. Measure the time-delay between the arrivals of the two split shear-waves. What is the value of the time-delay in your example? Can you infer any information about the stress state from it?

> **HINT:** To have a clear view of the splitting in the two components, rotate them to the axial system defined by the measured φ and its perpendicular vector (Ctrl+2). You can now use the Left and Right Arrow Keys to temporally shift the "Slow" component (bottom seismogram). The goal is to match the arrivals of the shear-waves in both horizontal components.

5. Validate your results. Did you effectively remove the splitting effect from the recordings? If not, what factors can affect the measurements? What is the polarization angle of the shear-wave, assuming that the propagation medium is isotropic?

> **HINT:** To validate your result and estimate the quality of the measurement, rotate the horizontal waveforms back to the initial axial system (Ctrl+3). If splitting is adequately removed, you will see that shear-waves arrive at the same time in both horizontal recordings. The polarization angle in this case (i.e. with the splitting effect removed) can be seen in the `pol` field of the information panel. Do not forget to assign a qualitative grade to your measurement (Ctrl+X) from `D` (worst) to `A` (best).

You can now generate a figure that showcases a summary of your measurement. To do this, use the *Database->Export Figure* tool.