Funded by the European Union
NextGenerationEU

SUMMIT
SOFIA UNIVERSITY MARKING MOMENTUM FOR INNOVATION AND TECHNOLOGICAL TRANSFER

SOFIA UNIVERSITY -
MARKING MOMENTUM
FOR INNOVATION AND TECHNOLOGICAL TRANSFER

National Recovery and Resilience Plan
OF THE REPUBLIC OF BULGARIA

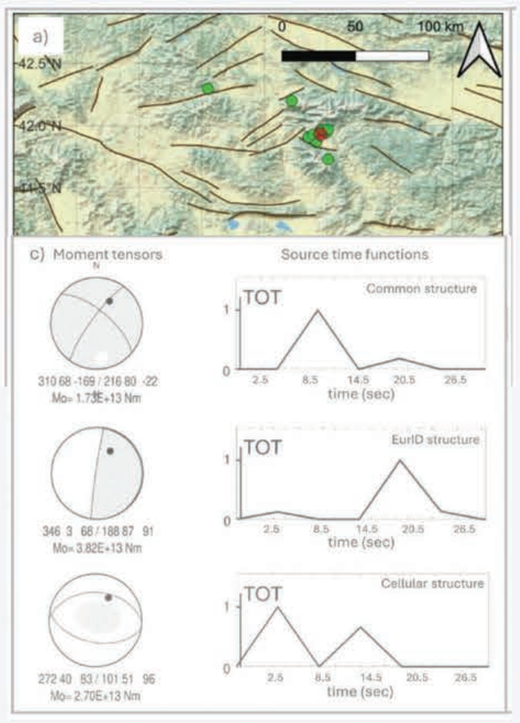
research group 3.4 project 70-123-265
research area: Earth physics

Head of the research group
Assoc. Prof. Reneta Raykova
Members of the group
PhD Lyuba Dimova
Elitza Pandourska

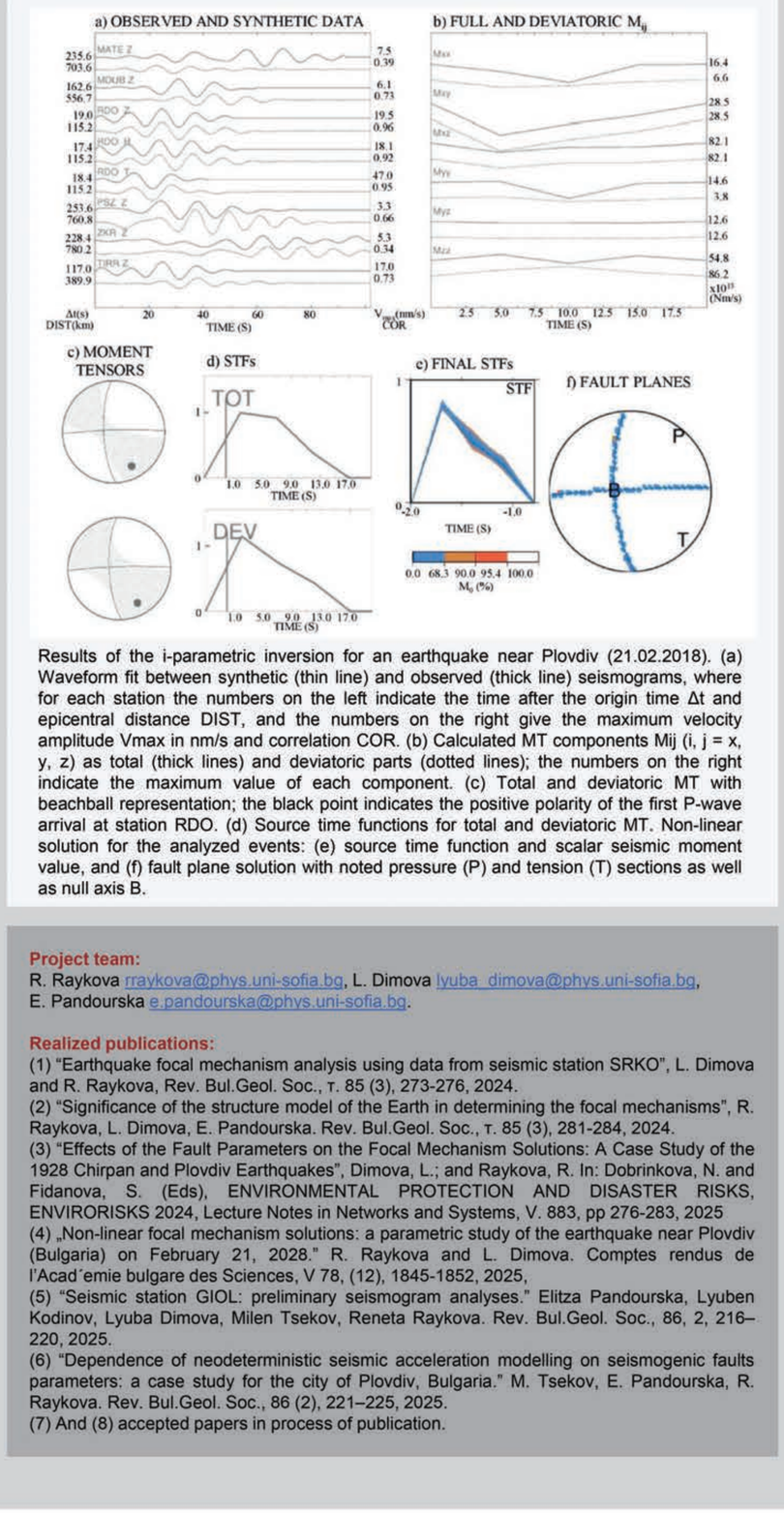
Investigation of the focal mechanisms of earthquakes with magnitude M≥4 on the territory of Bulgaria and its surroundings

FOCAL MECHANISMS FOR THE MODERATE EARTHQUAKES (4≤M≤5) IN BULGARIA AND SURROUNDINGS

Moment tensor mechanisms from moderate earthquakes were studied in the region of Bulgaria. Some comprehensive studies were done in order to evaluate the significance of the different parameters in the modelling of the rupture process. We evaluated the FM for 20 earthquakes in the period between 2012 and 2022 and after August 2024. The nature of the rupture is complex and depends on many physical properties.



Focal mechanism determination for an earthquake in Bulgaria using three different sets of Earth models: (*1*) a common structure, (*2*) a specific structure defined for each epicenter-to-station path derived from Du et al. (1998), and (*3*) a specific structure defined for each epicenter-to-station path based on cellular models from Raykova et al. (2018). (*a*) Location of the event on 29.12.2019 (ISC solution, red point) and all locations reported by different seismological data centres (green points); known active faults are shown as brown lines (Basili et al., 2013). (*c*) Obtained focal mechanisms represented by the total moment tensor with corresponding source time functions. The black dot indicates the positive polarity of the first arrival at station PLVB.



Results of the i-parametric inversion for an earthquake near Plovdiv (21.02.2018). (a) Waveform fit between synthetic (thin line) and observed (thick line) seismograms, where for each station the numbers on the left indicate the time after the origin time Δt and epicentral distance DIST, and the numbers on the right give the maximum velocity amplitude Vmax in nm/s and correlation COR. (b) Calculated MT components Mij (i, j = x, y, z) as total (thick lines) and deviatoric parts (dotted lines); the numbers on the right indicate the maximum value of each component. (c) Total and deviatoric MT with beachball representation; the black point indicates the positive polarity of the first P-wave arrival at station RDO. (d) Source time functions for total and deviatoric MT. Non-linear solution for the analyzed events: (e) source time function and scalar seismic moment value, and (f) fault plane solution with noted pressure (P) and tension (T) sections as well as null axis B.

Project team:
R. Raykova rraykova@phys.uni-sofia.bg, L. Dimova lyuba_dimova@phys.uni-sofia.bg,
E. Pandourska e.pandourska@phys.uni-sofia.bg.

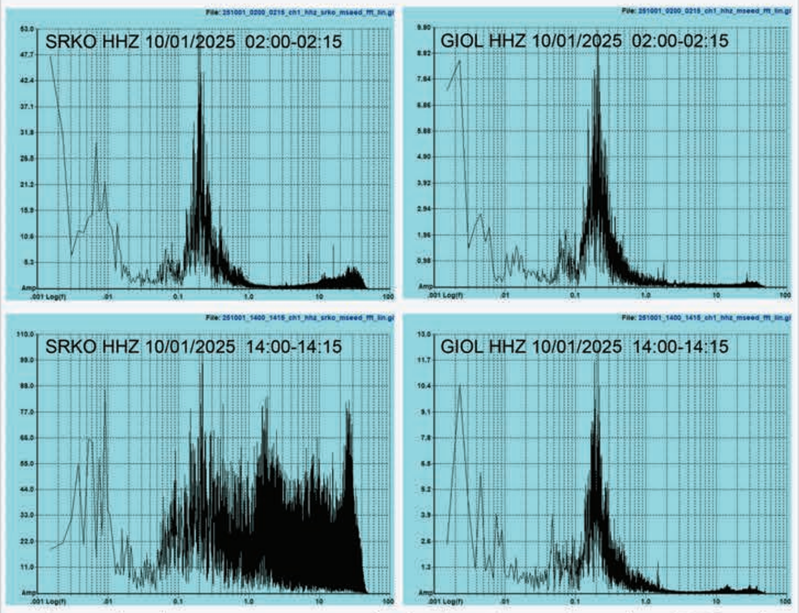
Realized publications:

(1) "Earthquake focal mechanism analysis using data from seismic station SRKO", L. Dimova and R. Raykova, Rev. Bul.Geol. Soc., т. 85 (3), 273-276, 2024.
(2) "Significance of the structure model of the Earth in determining the focal mechanisms", R. Raykova, L. Dimova, E. Pandourska. Rev. Bul.Geol. Soc., т. 85 (3), 281-284, 2024.
(3) "Effects of the Fault Parameters on the Focal Mechanism Solutions: A Case Study of the 1928 Chirpan and Plovdiv Earthquakes", Dimova, L.; and Raykova, R. In: Dobrinkova, N. and Fidanova, S. (Eds), ENVIRONMENTAL PROTECTION AND DISASTER RISKS, ENVIRORISKS 2024, Lecture Notes in Networks and Systems, V. 883, pp 276-283, 2025
(4) „Non-linear focal mechanism solutions: a parametric study of the earthquake near Plovdiv (Bulgaria) on February 21, 2028." R. Raykova and L. Dimova. Comptes rendus de l'Acad´emie bulgare des Sciences, V 78, (12), 1845-1852, 2025,
(5) "Seismic station GIOL: preliminary seismogram analyses." Elitza Pandourska, Lyuben Kodinov, Lyuba Dimova, Milen Tsekov, Reneta Raykova. Rev. Bul.Geol. Soc., 86, 2, 216–220, 2025.
(6) "Dependence of neodeterministic seismic acceleration modelling on seismogenic faults parameters: a case study for the city of Plovdiv, Bulgaria." M. Tsekov, E. Pandourska, R. Raykova. Rev. Bul.Geol. Soc., 86 (2), 221–225, 2025.
(7) And (8) accepted papers in process of publication.

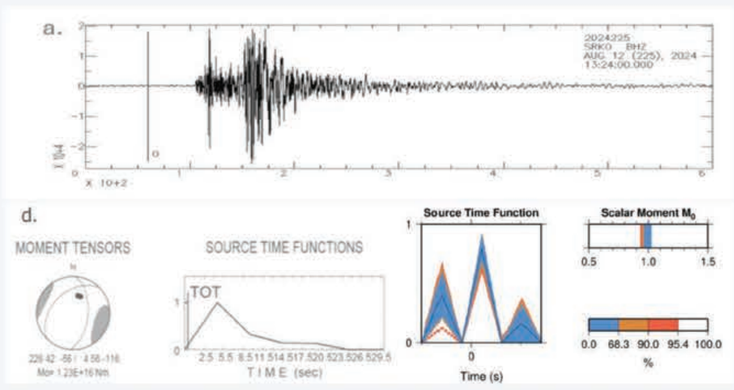
TWO BROAD-BAND SEISMIC STATIONS

Equipment for two broad-band seismic stations was purchased (in the frame of this project) and installed in Sredni Kolibi (near Veliko Tarnovo) and in Giolecitza base of SU (near Samokov). Period range of the seismometers allowed the study of earthquakes from local to global scale. In the frame of the present project the seismic records were used to obtain the focal mechanisms of earthquakes with magnitude between 4 and 5 on the territory of Bulgaria and its surroundings as well as dispersion curves from teleseismic waves.

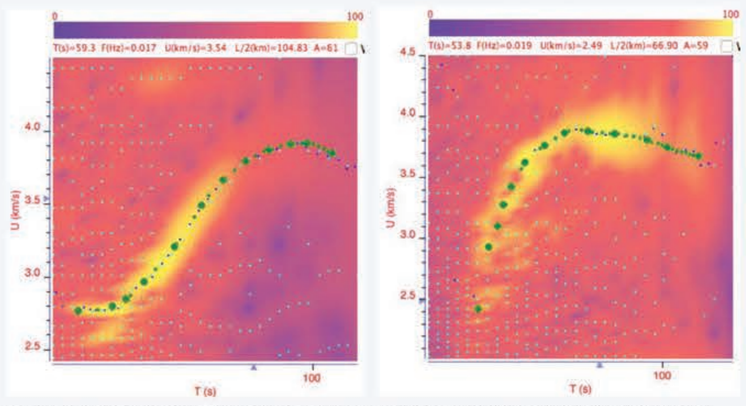
Location of the broad-band seismic stations SRKO (Sredni Kolibi) and GIOL (Giolechitza) and single-station equipment (seismometer and digitizer form SARA Electronic Instruments).



Comparison between spectrum of seismic noise, registered at SRKO and GIOL during night time and day time.



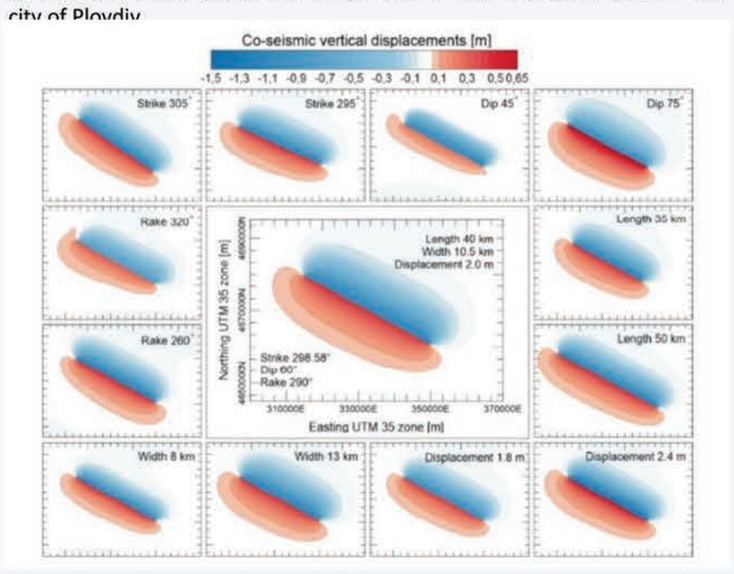
Analyzed earthquake (Mw 4.5) in the Aegean Sea (12.08.2024): Recorded seismic waveform from station SRKO (*a*); focal mechanism solution, source time function and uncertainty, and variation in moment release over time (*d*).



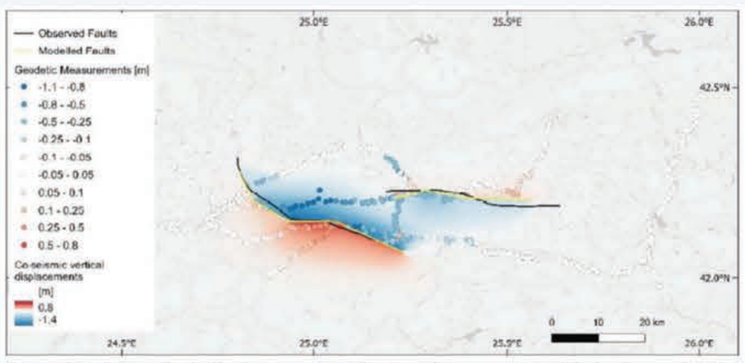
Frequency-time diagram of the Kamchatka earthquake (9.10.2025 13:28:44.2) (left) and the Drake-Passage earthquake (10.10.2025 20:29:22.0) (right) and traced dispersion curves (green circles) from GIOL records.

COLLABORATION WITH UNIVERSITY OF TRIESTE

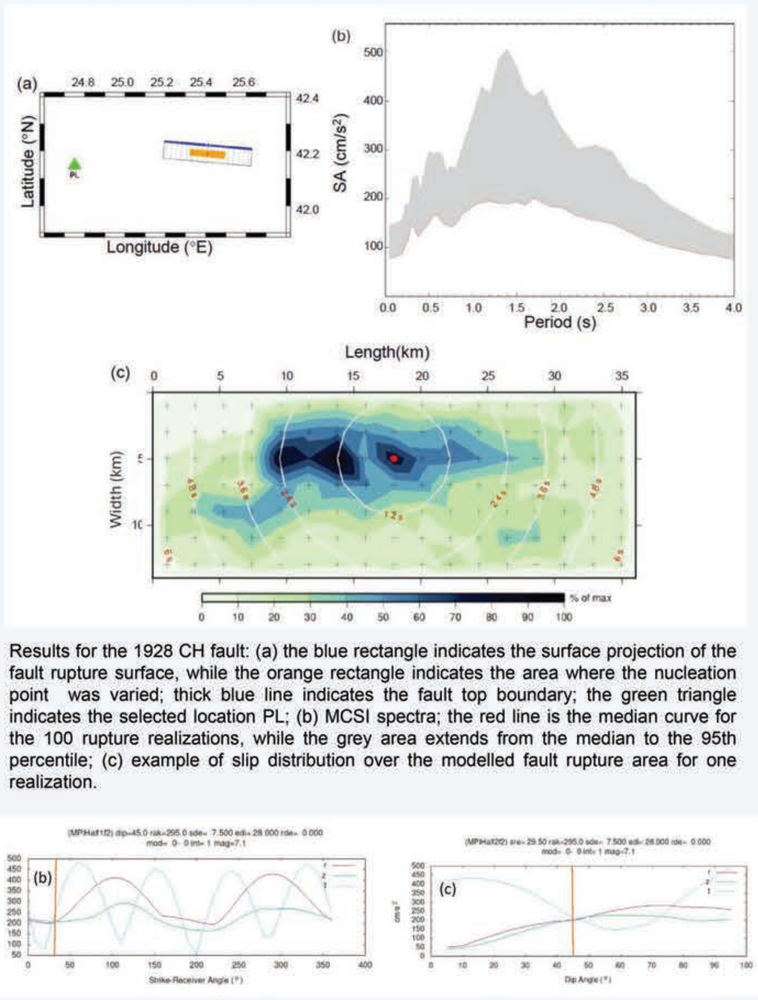
In the project, the INPAR method was used, the software for which was developed at the University of Trieste (Italy). Prof. Fabio Romanelli from the Department of Mathematics and Geosciences visited the Faculty of Physics in May 2024. During discussions, a collaboration in the frame of the evaluation of the seismic hazard was initiated. Using the focal mechanisms along known faults, we studied and evaluated the maximal ground accelerations that can be generated from the faults around the city of Plovdiv.



Modelling of co-seismic vertical displacement along Popovitza fault generated by an earthquake in 1928.



Co-seismic vertical displacement calculated by means of Okada method for the earthquake sequence in 1928. Yellow lines are modelled rupture segments on the surface. Colored dots represent geodetic measurements of the relevant vertical offset. Black lines represent the observed surface rupture after Dimitrov et al., 2020.



Results for the 1928 CH fault: (a) the blue rectangle indicates the surface projection of the fault rupture surface, while the orange rectangle indicates the area where the nucleation point was varied; thick blue line indicates the fault top boundary; the green triangle indicates the selected location PL; (b) MCSI spectra; the red line is the median curve for the 100 rupture realizations, while the grey area extends from the median to the 95th percentile; (c) example of slip distribution over the modelled fault rupture area for one realization.

Seismogenic faults near Plovdiv and the selected location where the ground motion acceleration is to be estimated: dependence of the maximum ground motion acceleration for the selected location on the (*b*) strike-receiver angle; (*c*) dip angle.

Contract BG-RRP-2.004-0008 for the financing of project "Sofia University - Marking Momentum for Innovation and Technological Transfer" under pillar 2 "Establishing a network of research higher education institutions in Bulgaria", component "Innovative Bulgaria" from National Recovery and Resilience Plan part of the program to accelerate economic recovery and transformation through science and innovation