Fitting Earthquake Spectra: Colored Noise and Incomplete Data

by Stefano Maranò, Benjamin Edwards, Graziano Ferrari, and Donat Fäh

Abstract Spectral analysis of earthquake recordings provides fundamental seismological information. It is used for magnitude calculation, estimation of attenuation, and the determination of fault rupture properties including slip area, stress drop, and radiated energy. Further applications are found in site-effect studies and for the calibration of simulation and empirically based ground-motion prediction equations.

We identified two main limitations of the spectral fitting methods currently used in the literature. First, the frequency-dependent noise level is not properly accounted for. Second, there are no mathematically defensible techniques to fit a parametric spectrum to a seismogram with gaps.

When analyzing an earthquake recording, it is well known that the noise level is not the same at different frequencies, that is, the noise spectrum is colored. The different, frequency-dependent, noise levels are mainly due to ambient noise and sensor noise. Methods in the literature do not properly account for the presence of colored noise.

Seismograms with gaps are usually discarded due to the lack of methodologies to use them. Modern digital seismograms are occasionally clipped at the arrival of the strongest ground motion. This is also critical in the study of historical earthquakes in which few seismograms are available and gaps are common, significantly decreasing the number of useful records.

In this work, we propose a method to overcome these two limitations. We show
that the spectral fitting can be greatly improved and earthquakes with extremely low signal-to-noise ratio can be fitted. We show that the impact of gaps on the estimated parameters is minor when a small fraction of the total energy is missing. We also present a strategy to reconstruct the missing portion of the seismogram.


Download code and data used in the manuscript here. Examples for fitting complete and incomplete seismograms are included. See README.txt.