WHAT NOISE CAN DO

George Papanicolaou – I thought that I would speak about imaging as an interdisciplinary science, and the subject that I started about fifteen years ago, imaging was very successful in various disciplines in seismic, in geophysics, seismic imaging, in radar, in optical sciences, but as a mathematical discipline, it was ignored, it was not considered as mathematics. I didn't understand why and that was really one of the reasons also that I came to Stanford, it was because I really wanted to expand into the science of imaging.

And the first thing that I did was to go deeply into the geosciences, seismic imaging, with a group of about 25-30 devoted younger colleagues mathematicians, and we were also very fortunate to come in contact with Mathias Fink, in Paris, so the role of time reversal came in, and time reversal is a very simple and effective way to visualize imaging because, since imaging very often involves wave propagation, seismic waves propagate into the Earth, the information comes back to the surface, and then from the recordings we can reconstruct the structure of the Earth underground.

And the most recent thing that I have been doing with Josselin Garnier, primarily, is passive imaging. Passive imaging means that we do not send any signals out, we just have passive sensors that record. Seismic imaging, which up until about ten years ago was completely driven by earthquakes, the way we are understanding the interior of the Earth was from earthquakes, we waited for earthquakes to happen to illuminate what's underground. So for the geophysicists, the earthquake is the best thing that can happen. The disadvantage of that is that we can only see where the illumination is, namely we can only see near faults, where the earthquakes occur. But we cannot see wherever we want, if we want to look somewhere underneath the Earth, we can't, because there may not be earthquakes there. Now here comes this idea that you can passively image the Earth, you can put recording devices geophones anywhere, on the Earth, and let them record. So here was a dramatic change in our understanding of what noise can do. And then the real question is: where does the energy that creates the noise, where is it coming from? It is from the agitation of the oceans. So it's the energy that is illuminating the solid Earth comes from the constant agitation from the waves in the Ocean. And it turns out that imaging with seismic noise that is generated by ocean waves is extremely accurate. So accurate, for example, this was a work that Michel Campillo did in Grenoble some years ago, that by recording noise signals in the Alps, one can detect a typhoon in South-East Asia. And so by taking the noise signal from one geophone here, and another geophone some distance away, and cross-correlating them, you could actually create images of the underground.

I would like to finish with a comment about the history of these passive methods. There was a history of this, and here is a case where technology killed a subject, in the 1960ies when weather satellites went up! Everybody lost interest in cross-correlations and they were rediscovered in 2005. So, technology has a dual role to play: sometimes it can kill an idea, because a new technology comes in with the satellites and then we forget about something that is extremely useful and then we rediscover it a few years later, I'll stop with that.

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