CHAOS IN THE WAVES

Nalini Anantharaman – If I had to summarize my research, I would say that I try to find a link between the theory of chaos, and wave mechanics. At the origins of the theory of chaos, there's the work of Henri Poincaré at the end of the 19th century on the solar system. He was trying to prove mathematically that the motion of planets is stable, but he actually showed, unexpectedly, that the motion of planets may in the long run have a disordered behaviour, unpredictable, instead of the regular, periodic motion that is observed on small time scales. The theory of chaos was born from this discovery. The idea is to describe the disorder that can arise in the evolution of certain systems in physics. Then one tries to find abstract mathematical concepts to describe this disorder, the unpredictability of certain phenomena! Said like that, it sounds like a negative notion not being able to predict anything but in the end, turning it into a mathematical notion makes it something positive, that allows to understand better these phenomena. Chaos is the impossibility to predict what will happen, even if we know where we start from. Even if we know the laws of physics governing these systems, it's impossible to make the slightest prediction! It describes the evolution over time of the systems. This is not a static notion that can be shown on a picture, it's really about evolution over time.

Then, wave mechanics: it's more or less synonymous to quantum mechanics. This is the name of the new laws of mechanics that were born in the 30s, when it was realized that Newtonian mechanics can't describe the atomic scale. In this new description, objects, for instance electrons, are waves instead of particles… Waves do not propagate like particles at all, there are interferences, diffraction. In mathematical terms, the motion of waves is described by what is called a partial differential equation, whereas the notion of a particle is described by ordinary differential equations. The mathematical theory of chaos has been tailored to be applied to ordinary differential equations, and thus it does not apply to waves. We do not have any mathematical concepts to describe the fact that a wave can have a disordered behaviour! I am precisely trying to develop such concepts…

So, we discover new mathematical truths, we invent new objects, and we try to support our discoveries by mathematical proofs. My friends find it funny, they ask: there's an Anantharaman theorem, like there's a Pythagoras theorem? Well, actually yes, you could say there's such a one, but nobody calls it like that, because it's not as universal as the Pythagoras theorem! The laws of physics, of the inanimate world, are expressed by mathematical equations, the most abstract possible, and it's quite miraculous to see that it works! This is what the physicist Eugene Wigner called "the unreasonable effectiveness of mathematics in the natural sciences".

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