PARTICLES RAINING ON US

Kumiko Kotera – I have started working on cosmic rays utterly by chance, actually... I was interested in galaxies, large scales, and I went to the office of my director, who was proposing a Ph.D. subject, and he said: “Well, cosmic rays are great, you will have to solve fundamental enigmas --like, what is the origin of cosmic rays.” I said okay, why not, I will still deal with large scales, they are tiny particles, it looks fun, and here I am...

So a hundred years ago, a great physicist, Victor Hess, went on a balloon with an electroscope, and he did the very first Physics experiment in space. He saw that the higher we climbed in the air, the more bombarded we were by strange particles. And he ended up concluding that these particles were coming from space, and he had actually discovered cosmic rays, this way. So a cosmic ray is a charged particle, like a proton or a heavier nucleus, like iron. They fall on us constantly and some of them reach us with a speed - an incredible speed, of many hundreds of joules. That's the energy of a gun bullet, but confined in a subatomic particle… It's quite colossal, and then the problem is that we don't know where they are coming from. It's not like for photons, that come to us in straight lines. They are going to be deflected by all the magnetic fields in the Universe, and in the Universe, there are lots of magnetic fields, it's full of magnets! Usually, when we look in the direction of a source, we see a light bulb, the sun, the moon, stars. When we look in the direction of a cosmic ray, well, we don't see anything! Because that's not at all where it's coming from! Because it was deflected, completely, by these magnetic fields. Well then, one needs, in order to find the sources of cosmic rays, to use some tricks, for example, try to find models of magnetic fields in which we will try to see how cosmic rays can propagate. That's the kind of things theorists like me do. So we have some leads, we think that anomalously violent explosions of stars, that we call gamma-ray bursts, or super powerful galaxies with large jets, that we call active galactic nuclei, are possible sources maybe. So my favorite model is a pulsar model! Pulsars, which are the tiniest stars, and that rotate very rapidly, are actually very good candidates. Because they rotate very fast and are very magnetized, they are going to do some induction mechanism, and will generate very strong electric fields in which one can accelerate charged particles.

It is difficult to test cosmic ray models because, at the highest energies, the number of cosmic rays that we receive is very small. It's of order one particle per km2 per century, and we thus have to build gigantic observatories, such as the Pierre Auger Observatory, that covers 3000 km2 in the pampa, in Argentina. There are water tanks of diameter 1.5-2 meters, spaced by 1.5 kilometers… With cows grazing in the middle, the Andes far in the distance, and, when a cosmic ray enters the atmosphere, it's going to produce what we call an air-shower, it's going to interact with the molecules of the atmosphere, and create a sort of shower of particles that we can get on the ground, with these water tanks… And so with these observatories, all we can do is wait, meaning, wait for cosmic rays to fall on us. And we get about two, at the energies we are interested in, only two per month... If we find the origin of

ultrahigh energy cosmic rays, it would open a phenomenal window on astrophysics, because 99,999 % of the information we have on the Universe comes from light. And cosmic rays are matter! They are protons, nuclei, and thus another source of information, that comes from the Universe. And to be able to do astronomy with cosmic rays, to point objects with particles, it would be… something quite fantastic…

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