On Ludwig Boltzmann

I came across Boltzmann's work when I was about 19, a few years after encountering names such as Newton, Faraday, Maxwell and Rutherford. Boltzmann was a pioneer of his time—perhaps of all times—yet he had enormous difficulties in being accepted. His problems with the two Ernst's, namely Ernst Mach and Ernst Zermelo, were well known. (Show slides.) His detractors often referred to him as the last pillar of atomism that was about to collapse. He was constantly worried that these battles would end his creativity. I was told that Boltzmann killed himself because he was depressed by the rejection of his work.

The reasons for Boltzmann's suicide were more complex. Clearly, however, the depression was brought about in part by the criticism of his work by prominent researchers of his time. He felt overburdened by having to defend his work. You have to imagine the impact of this conclusion on me as a 19-year old youngster: that even great men in science can be hounded by their detractors was a sobering lesson. I vowed to myself that I would never let my detractors diminish my creativity, for what it is worth—no matter what the circumstances. This decision indeed had a subtle but decisive effect on how I dealt with criticisms of my work later (but I am not comparing me with Boltzmann in any way). No other scientist had a comparable impact on me, though perhaps for wrong reasons.

Because of this special affinity with Boltzmann, it pleases me in being able to say a few words here. I am especially pleased to do so in the presence of my friend, Professor Giuseppe Mussardo, whom I like very much, as both a scientist and a colleague. He has now also turned out to be a moviemaker, and you will shortly see his documentary, "Ludwig Boltzmann: the genius of disorder". I thank him and other colleagues who invited me to make these remarks.

Let me recall a few facts. Boltzmann was born in Vienna in 1844, lost his father at 15, earned his Ph.D. when he was 22, and soon became a Professor of Mathematical Physics in Graz. He was a professor of Mathematics in Vienna between 1873 and 1876, then returned to Graz as Professor of Experimental Physics and spent about 14 years there; he then moved to Munich as Professor of Theoretical Physics. Three years later, he was back in Vienna as Professor of Theoretical physics. In 1900, he left Vienna for Leipzig (mostly because he was affected by his the criticisms of Mach in Vienna), but developed animosity with Ostwald in Leipzig (show slide). So he left Leipzig and returned to Vienna, where he was offered his old position on the condition that he would never again leave Vienna. He stayed there for about 4 years before committing suicide in Duino while on a vacation. He was just 62.

What was Boltzmann's main contribution?

Boltzmann is known for many things. In short, along with Gibbs (show slide), he created statistical mechanics. The mechanical theory of heat and matter, in which, continuing

Maxwell's pioneering work (show slide), he gave an expression for the distribution of the energy of atoms; he obtained his celebrated equation for the evolution of the distribution function; the so-called equipartition theorem and the so-called H-theorem, in the context of which he understood the role of statistical fluctuations; he understood the occurrence of macroscopic irreversibility in the presence of microscopic reversibility; he derived the famous equation for the entropy in terms of the logarithm of the number of microstates that are possible for a given macroscopic state (show slide), and so forth. Boltzmann's work deepened our understanding of the classical world.

It should be said that the so-called modern physics, based on radioactivity, relativity and quantum mechanics was gaining ground in the last decade of Boltzmann's life. He was fully aware that he was not a part of it, when he said, "I present myself to you therefore as a reactionary, a man left behind, one who is enthusiastic for the old, the classical, in the face of innovators; but I don't think that I am narrow-minded or blind to the merits of the new." By the way, this does not diminish Boltzmann's contributions even by one iota.

Boltzmann's atomic hypothesis—or the hypothesis that matter is made of little particles that move around in perpetual motion, attracting each other when they are a little distance apart, but repelling upon being squeezed into one another—had several detractors, as I have already said. It can now be said that Boltzmann has won, and nobody now denies the existence of the atoms. The work of people

like Einstein, Smoluchowski and Perrin has really put the notion of molecules and atoms on a firm basis. You will find the following sentence in Feynman's Lectures on Physics: "If, in some cataclysm, all scientific knowledge were to be destroyed, and only one sentence passed on to the next generation of creatures, what statement would contain the most information in the fewest words? I believe it is the atomic hypothesis … that all things are made of atoms… In that one sentence you will see an enormous amount of information about the world, if just a little imagination and thinking are applied."

Boltzmann was an excellent teacher. I cite a statement of one of his younger colleagues of his day: "The way in which Boltzmann got on with his students has remained indelible in their memories. He never played up to his superiority: everyone was at liberty to ask questions and even to criticize him. One could converse with him in an uninhibited way as if between equals, and often one noticed only subsequently how much one had learned from him. He did not measure others with the yardstick of his greatness. He also judged more modest achievements with goodwill, so long as they gave evidence of serious and honest effort."

With all these good things going for him, why did Boltzmann feel vilified in his days, and why was he unable to convince others? Considering that chemists seemed to have accepted the notion of atoms, it is strange that some physicists showed such great skepticism for it. Since his critics were indeed serious people, it is certain that Boltzmann felt under constant pressure to defend himself.

The critics based their reasons on philosophical beliefs and inadequate interpretation of known results, but some of the reaction was no doubt due to the aggressive, anxious and complex character of Boltzmann himself. It emphasizes the fact that science is at the bottom a human enterprise and a scientist's human attributes make great difference to how his work is treated by his peers.

Boltzmann was also somewhat naïve in the way he treated his scientific opponents. In a totally different context, but yet in support of my statement of Boltzmann's naiveté, let me cite an interesting story: After buying a cow for his country house, he is said to have consulted a colleague of his, a professor of Zoology, to find out how to milk the cow!

While Boltzmann's story did affect me adversely as a youngster, it has filled me with hope later. The hope is that truth finally triumphs. The hope is that, in the long run, good ideas do not get forgotten—even if, for whatever reason, they are contested closely in the lifetime of the person who proposes them. I don't know if this hope would console Boltzmann now, but the fact that he has earned his rightful place inspires people like us to do what we do without always worrying about the credit of the moment.

There is a lot about statistical mechanics that Boltzmann missed and there are many of us involved in extending the quests which Boltzmann did not touch. The fact is that we look up to him and follow his thinking. That is the greatest statement on his undiminished value to the community and the world. I don't know if one can ask for more!