MODERN TIME

William D. Phillips – At first it seems quite crazy: the idea that you can make something cold by shining light on it… When you shine light on something it should get hotter! But think about what temperature means: think about a gas of atoms… The hotter the gas, the faster the atoms are moving, in fact the kinetic energy of the atoms is a measure of the temperature. If we can push on the atoms to make them slow down, it means we're cooling the gas! And we can push on the atoms with light from a laser. Why do we care? We care because atomic clocks, the most accurate time-keepers in existence, will work better, a lot better, if the atoms are slower… We started out by trying to cool a gas of sodium atoms. The prediction was that laser cooling could get to a temperature as low as 240 millionths of a degree above absolute zero! It took several years but we and others finally cooled a gas of sodium atoms to 240 millionths of a degree…

But then, something remarkable happened: we measured temperatures even colder; not just a little colder, but in the first experiments we measured the temperature to be six times colder than the coldest temperature the theory said was possible! Soon our friends in Paris had figured out what was happening! Nature was more subtle and more beautiful than we had imagined. The new theory showed how to get to even lower temperatures and within a few years we had cooled a gas of cesium atoms to less than a micro degree… Cesium atoms are the ones used in primary atomic clocks, because cesium is the thing we use to define what we mean by time! And clocks with laser-cooled cesium are now the best clocks anywhere, better than a second in a hundred million years! And these clocks are keeping time for countries like the United States and France and England and China. But other clocks using other atoms have gotten to better than a second in three billion years! But think about this: when I first came to this laboratory, in 1978, the best clocks in the world had an accuracy of a part in ten to the thirteen… Those clocks were in Boulder, Colorado, in the mountains, about fifteen hundred meters above sea-level. Now Einstein's theory of general relativity predicted a gravitational red shift that would make the clocks in Boulder run about a part in tent to the thirteen faster than clocks at sea-level. To-day, clocks are so good that they would be able to detect a change in altitude of just ten centimeter!...

But making these clocks allowed us to explore those new insights to see that indeed Einstein was telling us what's right and it might be that using these clocks we can find ways in which Einstein wasn't right. Now that would be really exciting! All the tests we've made about Time have shown that Einstein was right! But somehow we feel that's there's got to be something, someplace where what Einstein told us about is going to break down! And it may be that these incredibly good clocks will be the way in which we first discover experimentally where that should be! As you know, Einstein was not right about everything, he wasn't right about quantum mechanics… And it's such an amazing experience to be able to work in a field where we see every day that Einstein was so right about so many things and so wrong about… other things.

And you know, it gives me a great feeling of satisfaction, that here is a person who is probably one of the greatest minds of all times… And he was so right and so wrong…

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