

ATOMS AT NEGATIVE ABSOLUTE TEMPERATURES

Usually we tend to think about temperature as being related to the motion of atoms.

At lower temperatures, atomic motions slow down. Absolute zero, defined as zero Kelvin or -273.15 degrees Celsius, then is the point where all atomic motion stops.

But what comes beyond that, does something like a negative

absolute temperature exist? Indeed, as [Ulrich Schneider](#) and colleagues from

Munich have now demonstrated impressively in this week's issue of *Science*, it

does.

Key here is to understand what temperature actually means. It isn't simply a

uniform speed of atoms in a gas. Atoms at any temperature move randomly and at

various speeds. So temperature is better defined by the energy distribution of atoms

at that particular temperature. In normal systems with positive energies, it is very

unlikely to find atoms at high energies. Indeed, the energy distribution, the

likelihood of finding atoms at increasingly higher energies than the average, is

decreasing exponentially. This is expected because atoms at very high energies

quickly cool down by collisions with others.



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Not so for systems with **negative absolute temperature**. There, looking at the physical formulas negative temperatures mean that the energy distribution of the atoms is reversed. Close to absolute zero the atoms prefer to be at high energy states such that there are more atoms moving at higher speeds than at lower speeds. So negative temperatures work in the opposite way to positive ones – higher energies are preferred to lower ones. In that sense, a system with a negative absolute temperature is ‘hotter’ than systems with positive temperatures. If brought together, energy would flow from the negative to the positive system, as all those many atoms at high energies in the negative system would give their energy to the slow ones in the positive system.

It comes as no surprise that realizing systems with negative absolute temperatures is very challenging, as there the energy distribution is against the long-term tendency found in nature for atoms and other systems to relax to lower energies over time. But it is not impossible.

In the past, negative temperatures have been realized with magnetic spins, which are easier to control by magnetic fields and where such reversed energy distributions can be better achieved.

In the case of atomic movements of gases the situation is more difficult. The system studied now by Schneider and colleagues is an ultracold atomic gas, which is made of atoms at very low temperatures. In these atomic gases not only the interaction between the individual atoms can be tuned experimentally, but also the energetic barrier that separates the atoms from each other is adjustable.

At normal positive temperatures, the atoms repel each other, and this reduces their energy, just as an expanding gas would cool down by itself. To realize negative temperatures, the researchers then swapped the conditions in the atomic gas around by using magnetic fields and adjusting the laser beams that holds the atoms together. Now, the interaction between the atoms was set such that the atoms attract each other. This attractive force between the atoms increases their energy. However, to avoid the atoms smashing against each other, which again would bring their energy distribution down to that for positive temperatures, the energy barrier between the atoms has to be set to keep them separate from each other. In this way the energy distribution between the atoms is stabilized.

More atoms are in a higher energy state than a lower one – negative absolute temperatures are achieved.

Of course, this realisation of negative absolute temperatures doesn't mean that absolute zero can be reached. It is a completely different challenge to slow down atomic motions towards zero than it is to change the overall energy distribution of the ensemble. Still, these are intriguing thermodynamical systems, and there is plenty to study about the implications of such reversed energy distributions.

Source: <http://allthatmatters.heber.org/2013/01/04/atoms-at-negative-absolute-temperatures/>