

Re: Entropy question

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 - *Date:* 20 Aug 2005 04:00:56 -0700
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Hi, Craig,

> Having read all the replies, I see what's going on.

No, you're not quite there yet

- > The gas in space
- > heats up as entropy increase, while the gas in the laboratory cools
- > down as entropy increases. And when the gas gets hot enough, it
- > can access nuclear forces as an energy source.

I did warn you not to believe everything that Penrose writes.

The two most basic theories of modern physics are general relativity and quantum field theory. The fit between GR and QFT is a bit ragged, but for most systems there is no conflict. GR and QFT are theories of mechanics, and the two together allow you in principle to work out how any given system will behave.

I say 'in principle', because in practice systems with very large numbers of particles cannot be analyzed in a reasonable length of time. That's where statistical mechanics comes in, as an approximation method. It's not the only approximation method in physics. GR is often approximated by Newtonian gravitation, and QFT is often approximated by Newtonian mechanics and Maxwellian electrodynamics. Since full-blown GR and QFT require enormous computing power, they are typically only used when only they will give the required accuracy. There are ways of determining when the simpler theories give answers which are good enough.

Modern statistical mechanics is an approximation to QFT. It subsumes all of classical thermodynamics, and explains a lot more besides. Statistical mechanics relies heavily on the idea of thermodynamic equilibrium. It can come up with answers as long as your system is

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closed, and you can break it up into a number of weakly-interacting subsystems, each of which is near equilibrium. The answers it comes up with are good for all practical purposes, but you must remember that the statistical method is not exact. If there is ever a conflict between mechanics and statistical mechanics, the answer from mechanics is the right one. To repeat, statistical mechanics is only an approximate theory. It really only works for systems much smaller than the solar system.

If a theory treats space and time on a different footing, then you know it is not relativistic. In special relativity, the momentum p and the energy together form the energy-momentum 4-vector. The energy is the time component of the energy-momentum 4-vector, and may be symbolized p_t . When observers in different inertial frames measure the energy-momentum 4-vector, they get different answers, say p' and p'' , but p' and p'' are Lorentz transforms of one another. A central concept of statistical mechanics is the partition function Z , which is the sum over all states r of the quantity $\exp(-E_r/kT)$. The Helmholtz free energy F of the system is equal to $kT \ln(Z)$. All other thermodynamic parameters of the system can be derived from F : in particular the entropy S is $(dF/dT)|_V$ (partial derivative wrt temperature, keeping the volume constant). Since statistical mechanics concentrates on p_t and ignores p_x , p_y and p_z , you know immediately that it is not even special relativistic.

In a system at thermodynamic equilibrium, there can be no macroscopic relative motion. In the solar system, relative velocities are of order $1e4$ m/s. A near-earth asteroid has a kinetic energy three orders of magnitude greater than its internal thermal energy. The situation is extremely far from thermodynamic equilibrium, and relativistic effects mean that, strictly speaking, you cannot add the entropies of the different parts to get the overall value. OK, the discrepancy is only of order 0.01%, but the result is not exact, not fundamental, just a rough-and-ready way of calculating.

As I tried to explain in my previous post, in a small container full of gas, the uniform state is stable with respect to small perturbations. However when the volume of gas is of astronomical size, the uniform distribution can become unstable. Local concentrations of gas grow spontaneously, and ultimately form stars. This process is nowhere near equilibrium. The method of analysis I outlined for you involving Fourier decomposition of perturbations is essentially the interplay of Newtonian gravitation and mechanics. Entropy is irrelevant for determining the largest-scale features of the process. Thermodynamics might come in at a lower level, for example in determining the temperature of the local concentration of gas, but there is no way it can be thought of as driving the process. At most, you can bring the entropy in as a way of monitoring what is happening, but it is not guaranteed to be a very good way.

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- > To say the gas in space (1) has lower entropy before it gravitates together
- > just means (2) it has a great deal of potential energy that could be liberated
- > under the right conditions.

Statement (2) is possibly meaningful. Statement (1) is just handwaving.

- > What was conceptually challenging is the fact that, thinking in terms
- > of entropy doing work, the gas needs to get to a higher entropy state
- > (form a star) before it can access the all the potential lower-entropy.

Not to say conceptually challenged. I think that Penrose often puts the cart before the horse. Of course, there's no law against philosophical musings about vast events in the Universe which dwarf our puny selves, and it's morally superior to getting paralytic on a Saturday night and beating up old ladies, but it's more like religion than science.

Cheers,

Zigoteau.

- **Follow-Ups:**

- ◆ **Re: Entropy question**
◇ From: Andy Resnick

- **References:**

- ◆ **Entropy question**
◇ From: Craig Franck
- ◆ **Re: Entropy question**
◇ From: Gregory L. Hansen
- ◆ **Re: Entropy question**
◇ From: Craig Franck

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