

Appendix F

Generally Covariant Thermodynamics and Statistical Mechanics

F.1 Gravitational Statistical Mechanics

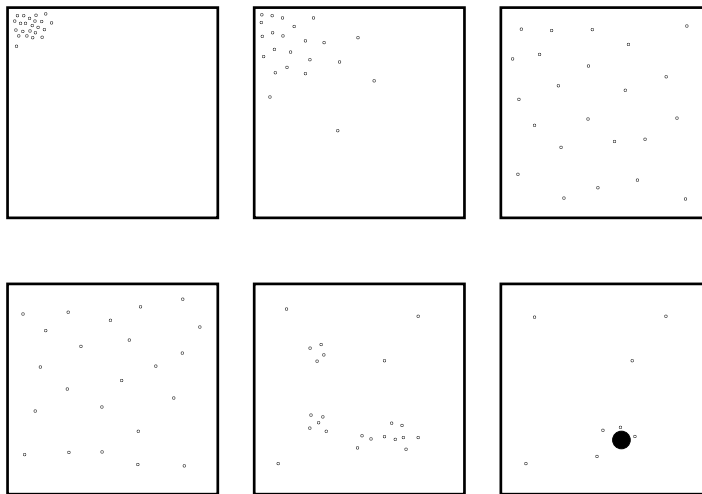


Figure F.1: For a gas, increasing entropy tends to make the distribution more uniform. For a system of gravitating bodies the reverse is true. High entropy is achieved by gravitational clumping and highest of all, by collapse to a black hole.

It would seem at first that the primordial gas was in a high entropy, that is, a disordered state. But this turns out not to be true. This completely ignores gravity.

Entropy overall increases even though certain constituents have become more ordered.

No object in the universe contains more entropy than a black hole.

for some reason the early universe was filled with a hot, uniform gaseous mixture of hydrogen and helium.

How is it that the universe began in such a highly ordered configuration? Such an extremely low state of entropy?

Consider a “high temperature” early-universe regime. This is usually described in terms of fluctuations around a background metric; is there a genuinely general covariant description of this physics? And what is temperature in this context, if we do not fix a background metric?