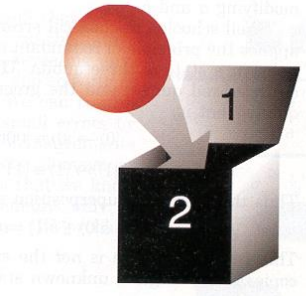
Irreversibility:

from

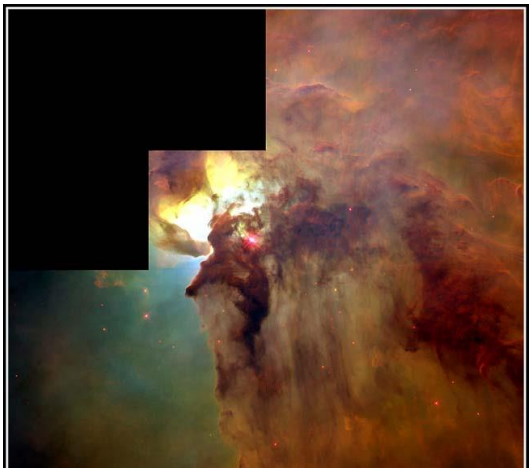
Bit



(Preskill)

to

Bang



Andreas Albrecht

Isaac Newton Institute workshop on

Complexity, Computation and the Physics of Information

July 1999

A perspective from a cosmologist/particle physicist

My Baggage:

- At a fundamental level the entire Universe is a perfectly reversible "machine" (a perfectly coherent quantum computer)
- There is no "external environment"
- Concepts such as the arrow of time remain essential, even in situations where eqm is not achieved and entropy can not be define.
- Current?

Key Points

1) Thermodynamics and entropy are not required to understand erasure and the arrow of time

(relates to the Thermodynamic cost of computation, Maxwell's Demon)

Generalizations of these concepts are required.

Key Points (continued)

2) The notion of a complete thermodynamic cycle can be irrelevant (or even distracting)

"Low entropy" initial conditions of the Universe:

- Create the arrow of time.
- Give us a "huge supply of free blank tape" to use as we wish.

Key Points (last one)

3) The “low entropy” starting point of the Universe can only be appreciated from a very particular: {perspective/coarse graining/algorithm generating machine/etc}.

The {coarse graining/machine} dependent aspects are crucial, and *must* not be ignored.

→ The Plan

•Discuss:

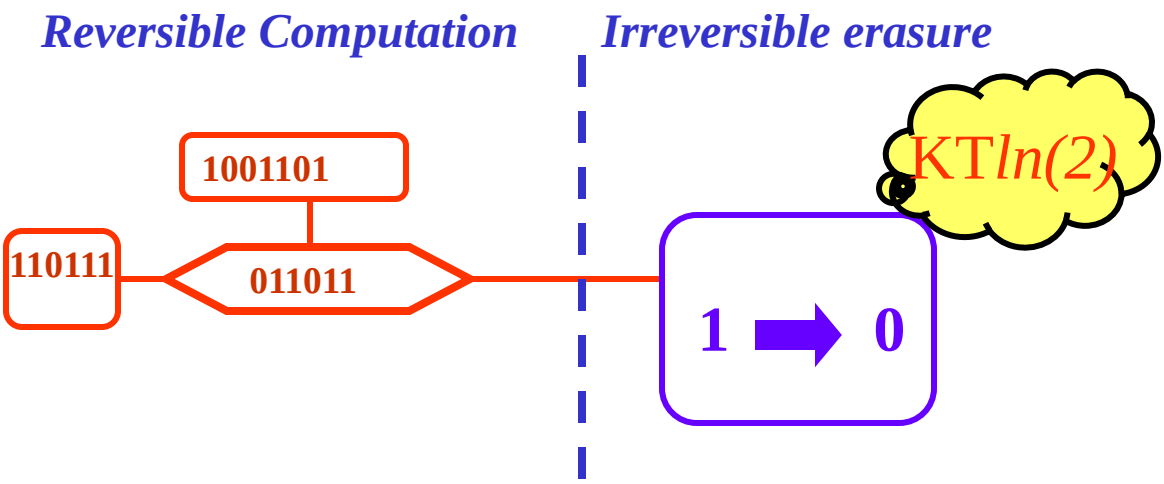
Erasure and bit stability with and without thermodynamics

•Comment on

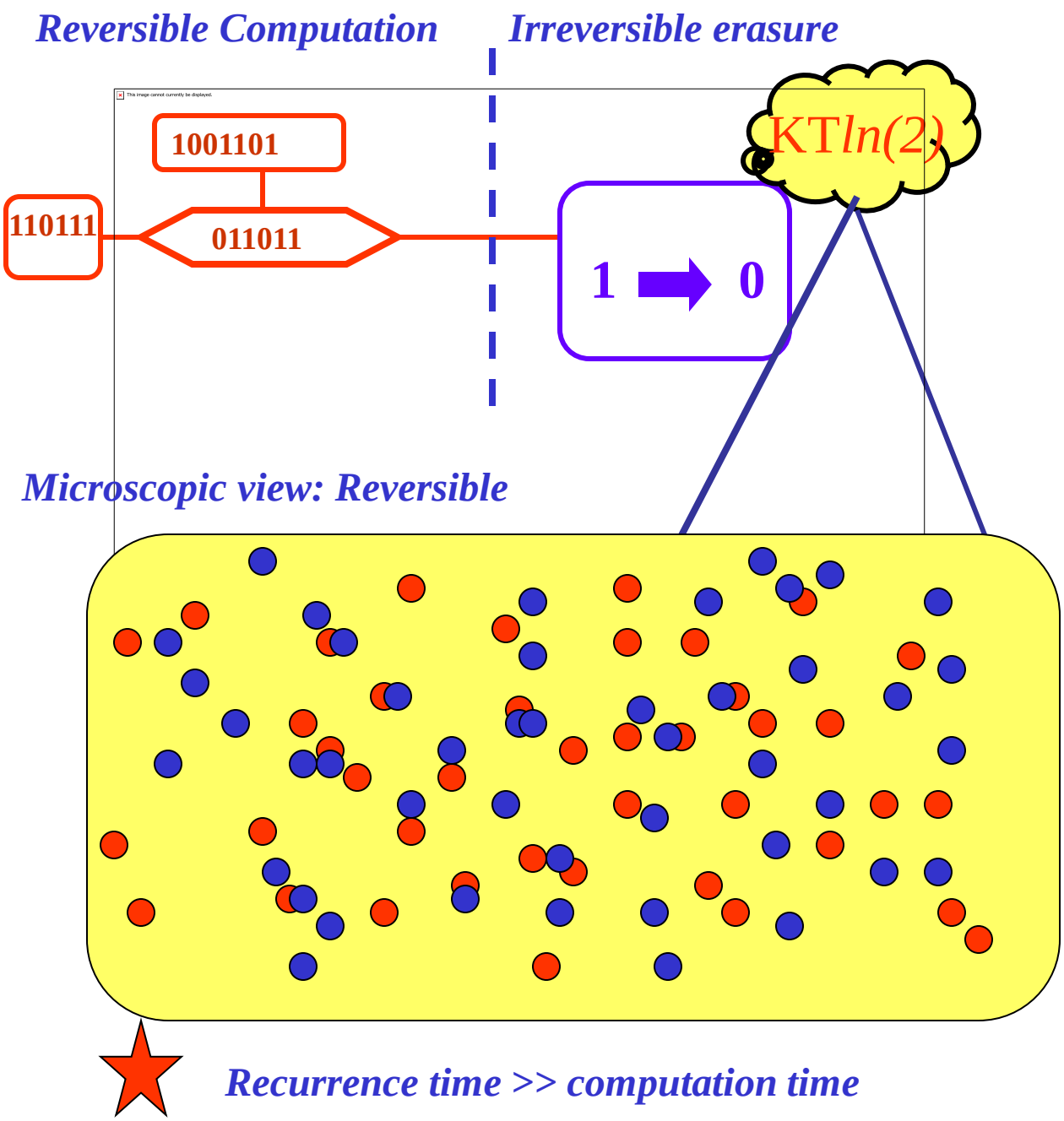
Special initial conditions & Cosmology

Algorithmic issues

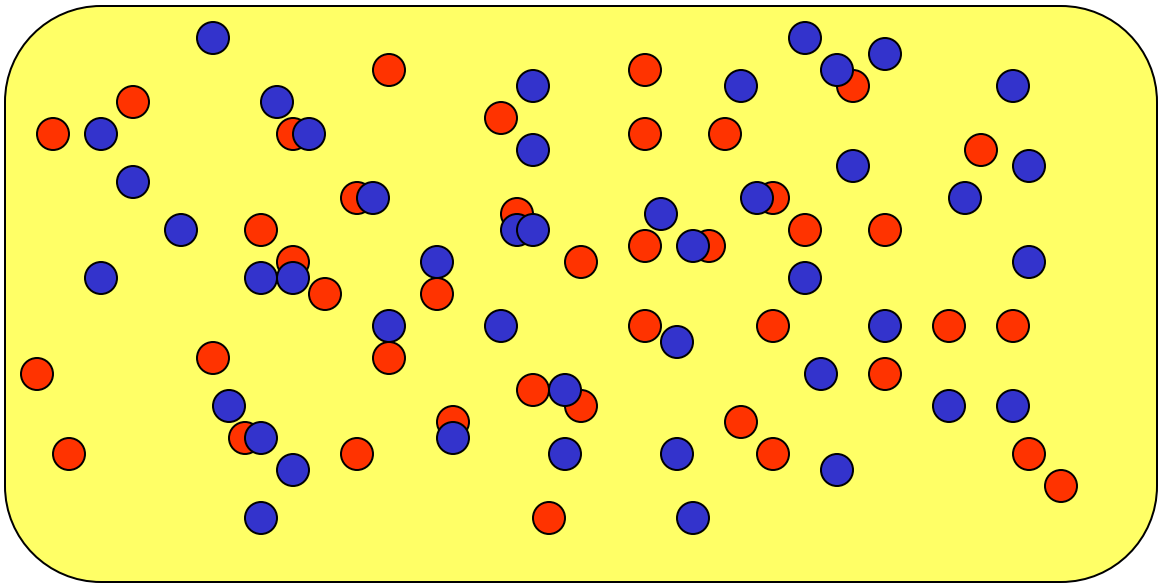
Erasure... a standard picture:



Another perspective:

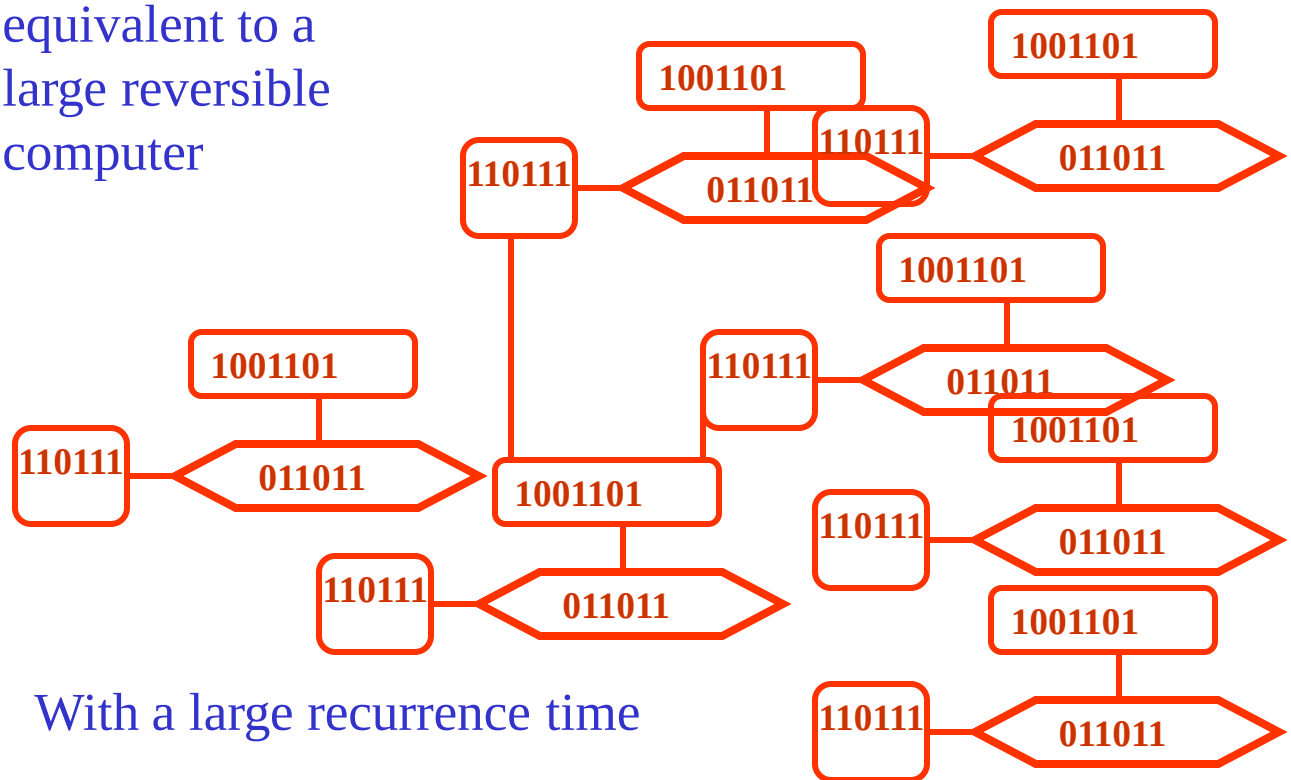


And



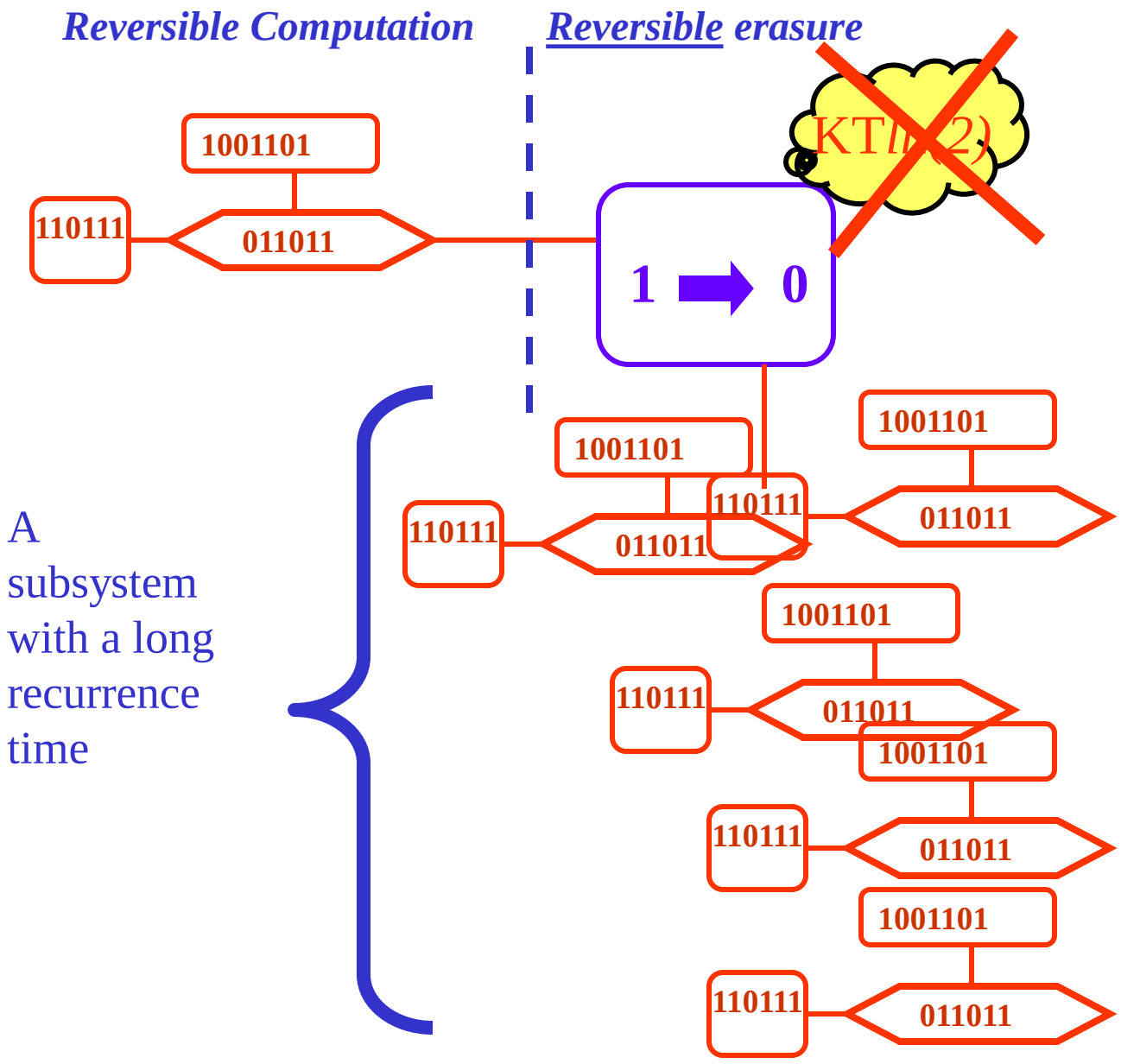
The physical system is equivalent to a large reversible computer

≈



With a large recurrence time

Thus erasure (and in fact all of computation) can have zero thermodynamic cost:



Comments:

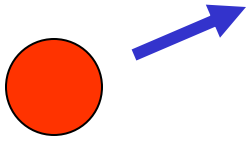
• All about the choice of coarse-graining (I have moved the “long recurrence time” system out of the coarse-grained domain). Tracing out over the erasure subsystem would produce an increasing “entropy”. (The recurrence time could be much shorter than for a “real thermodynamic system”.)

•The essential point is achieving a long recurrence time, one way or another.

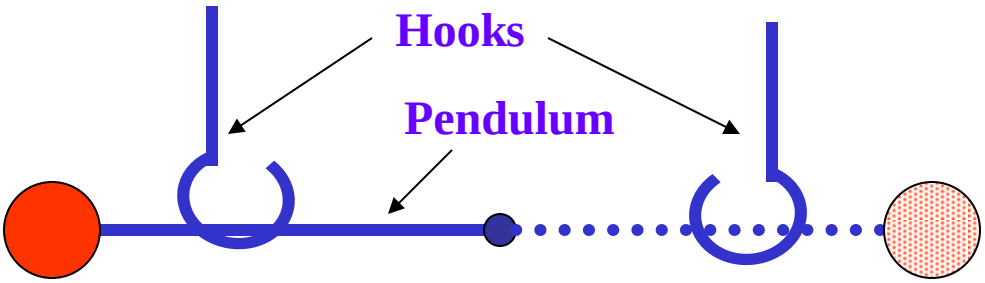
•The arrow of time comes from special initial conditions for the long-recurrence time system (compare with flow of heat into rather than out of a thermal bath) Moral equivalent of “thermodynamic cost” but looks quite different.

Another system with a long recurrence time:

A particle moving in empty space.

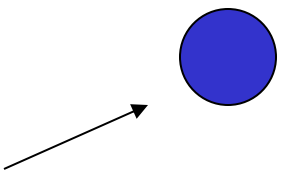


A “Space-Based” erasure device:



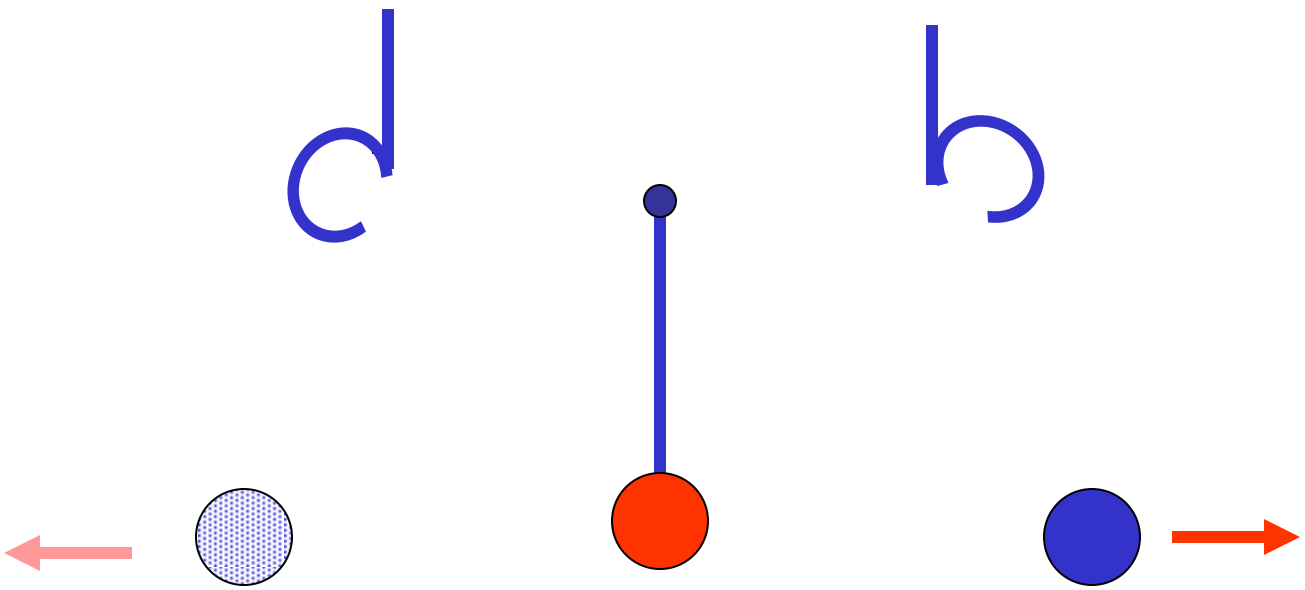
State 0

State 1



Mass of Ball = Mass of Bob

Erasure:



(Elastic collision)

•Blue ball does not come bouncing back = long recurrence time

•The fact that space is not full of blue balls flying in from all directions = arrow of time

→ Comments

1) This process can be used by a computer, Maxwell Demon, etc (MP1)

2) Should I be charged $\{KT\ln(2)\}$ to fetch the ball?

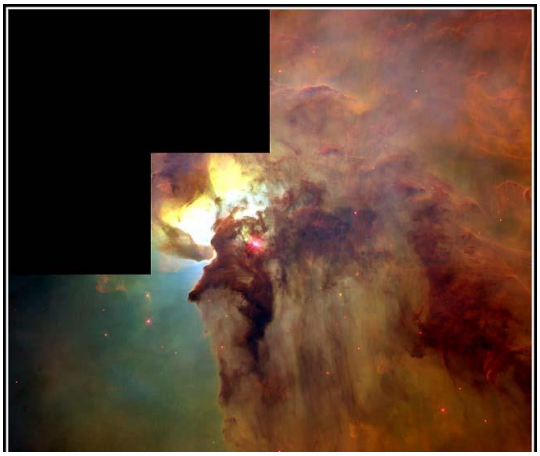
i) Don't need **T**

ii) Can just use another ball. Harness the actual arrow of time in the Universe (MP2)

iii) Situation Dependent: Does the power company charge you, or can you tap into "free" time's arrow of the Universe?

→ Arrow of time of the Universe:

•Gravity clumping up an initially homogeneous state (long range forces…)



•Arrow of time defined by actual physical dynamics, not by abstract notion of complexity. (Without gravity, the initial state would have *maximum* **S)**

•But, more abstract discussion useful because out of eqm.

•Arrow of time: -It's free. -Enjoy it.
-That's what life's all about!