Cosmology, Entropy and the Philosophy of Inventions. Date: December 28th 2004.

This is a dinner lecture which I gave during the first Indo-US Workshop on Inventions, Innovations and Radical Innovations. The talk was presented to a semi-technical general audience. Many slides have photographs of some of the greatest inventors/physicists/scholars placed along the right hand border. During the talk I often took detours to highlight their extraordinary contributions.

ABSTRACT

I have attempted to correlate our inventiveness with the cosmic destiny of our universe. The talk begins with a quick review of the origin of the universe and the predictions one would make of our future if we follow Einstein's cosmological thinking. However, it appears to me that quantum mechanics, now supported by string theory allows us the possibility that intelligence may overcome the very definite transformation and demise which is predicted by the second law. All this has profound implications on what and how we will invent in the future. I also find that science and theology are not necessarily at odds with each other and may only be expressing the same thought perhaps in different languages.

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Different estimates put the **Big Bang** some 13 to 17 thousand million (more recent analysis is 13.7 **billion**) years ago. Since then the Universe has expanded, cooled down and has become much less dense.

J. A. Sekhar: Inventions, Miracles and Entropy.
The Universe expands by Billions & Billions

Now $10^{10}$ years  $10^{10}$ K

Nucleo synthesis

10 years  $10^3$ K

Galaxies and Solar system

10$^4$ K

10$^4$ years

$10^8$ K

10$^{-36}$ s Grand unification

$10^3$ K

10$^{32}$ K

$10^{-43}$ s Plank time

Temperature-Time

Big Bang and Cosmic Inflation.

4.5 billion years ago, the Earth was born. Nearly 4 thousand million years passed after the Earth's inception before the first animals left their traces.

Planck's Constant $h = 6.63 \times 10^{-34}$ J·s

The product $hv$, where $v$ is the frequency of vibration of a radiation, is actually the smallest amount of heat.

Max Karl Ernst Ludwig Planck (1858-1947) Germany

Brian Green: The Elegant Universe.

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Quarks led to Protons and Neutrons and then assembled with electrons giving atoms which formed into molecules which then assembled into life as we know it.

The universe also contains many more fundamental particles. All fundamental particles are composed of vibrating strings which also describe gravitons, weak force, strong force (gluons) and the electromagnetic force and more... At one point these were unified in grand unification and then weak unification.

Evolution drives life toward increasingly varied and complex forms
Some oddities

- The universe did not just expand to complete random disorder.
- Symmetry was lost with space-time but some local order was created.
- The four forces (at least two of them) began clustering behavior and even though on a cosmological scale there is great uniformity, on a smaller scale there is some ordering. We will come back to this aspect when we talk about the Higgs field (named after the Scottish physicist James Higgs), and the words of Frank Ramsey.
Evolution

A process in which diverse entities compete for limited resources in an environment. The more successful organisms are able to survive and reproduce (to a greater extent) into subsequent generations. Over many such generations, the organisms could become better adapted at survival.

It took billions of years until the chaotic swirl of mass and energy created the information-processing, structural backbone of DNA, and then used that DNA to create the next stage. Which created you and me.
With DNA, evolution had an information-processing machine to record its experiments and conduct experiments in a more orderly way.

So the next stage, such as the Cambrian explosion, went a lot faster, taking only a few tens of millions of years.

The Cambrian explosion then established body plans that became a mature technology, meaning that we didn't need to evolve body plans any more.

Once the designs worked well, evolution could then concentrate on higher cortical function, establishing another level of mechanism in the organisms that could do information processing.

Then animals developed brains and nervous systems that could process information, and then that evolved and continued to accelerate.
Molecular self assemblies like DNA’s produced life which created order . . . Dealing with complexity. The evolution of management…..

Produced humans who acquired more knowledge and built more humans and who finally built machines “the advent of what we call inventions” which lead to innovations and more inventions and great creature comforts which lead to increased productivity and the ability to restrain the spread of knowledge and profit.

Ego!

Energy did not have to be funneled through the biological system to do work.
Energy and Entropy

Energy as we understand means capability. Energy is conserved. We know this but what does it mean. The universe started with a fixed $4 \times 10^{69}$ Joules ($2.5 \times 10^{79}$ GeV). {According to the latest estimates, dark energy (which pushes the universe apart) makes up 75 percent of the universe and dark matter (which cause galaxies to form by a strong pull) accounts for another 23 percent, leaving ordinary matter and energy with a distinctly minority role of only 2 percent}. We know that as we use energy it degrades. By combining the concept of the forward arrow of time and the reduction in the capability of the energy to be useful we arrive at the concept of Entropy.

The main source of useable energy in the universe is from the conversion of the matter of the stars into energy through thermonuclear reactions.
Entropy

Ludwig Boltzmann before he died in 1906 (suicide - defending atoms) came up with the notion of a measure of equilibrium and entropy (the second law is statistical). The equilibrium state is when entropy of the universe is highest (often called the state of highest disorder). Forces like gravity and forces from dark matter, try to create order, but order is unsustainable, entropy must be created. Otherwise there is no concept of time.

- Entropy is a measure of the probability of a particular result.
- Entropy is a measure of the disorder (distribution) of a system.
- Entropy measures the heat divided by the absolute temperature of a body.
The Cosmic Microwave Background is blackbody radiation at a temperature of 2.725 Kelvin.

Critical density \( \Omega < 1 \) Expanding universe

However, if omega equals one, the universe is at the "critical density." The critical density is found to be

\[
3H_2/8\pi G = 5 \times 10^{-30} \text{ grams cm}^{-3}
\]

(3 hydrogen atoms per cubic meter)

Figure. Dilution of the cosmos by the expansion of space affects different forms of energy in different ways. Ordinary matter (orange) thins out in direct proportion to volume, whereas the cosmic background radiation (purple) weakens even faster as it is stretched from light into microwaves and beyond. The energy density represented by a cosmological constant (blue) does not change, at least according to present theories.
The Fate of the Universe

If the repulsion from dark energy is or becomes stronger than Einstein's prediction, the universe may be torn apart by a future "big rip," during which the universe expands so violently that first the galaxies, then the stars, then planets and finally atoms come unglued in a catastrophic end of time. Currently this idea is very speculative, but being pursued by theorists. The other extreme, a variable dark energy might fade away and then flip in force such that it pulls the universe together rather than pushing it apart. This would lead to a "big crunch" in which the universe ultimately implodes. "This looks like the least likely scenario at present. Understanding dark energy and determining the universe's ultimate fate will require further observations. Hubble and future space telescopes capable of looking more than halfway across the universe will be needed to achieve the necessary precision. The determination of the properties of dark energy has become the key goal of astronomy and physics today.

For now lets assume that the Universe is Expanding perhaps even accelerating its expansion.

The night sky is dark: This tells us that the universe is not both infinitely large and infinitely old. Galaxies have a radial speed proportional to their distance: This tells us that the universe is expanding uniformly. The universe is filled with a Cosmic Microwave Background: This tells us that the universe was once hot and dense enough to be opaque; since then, it has expanded by a factor of more than a thousand. Free electrons have disappeared making the universe transparent.
Billions of years ago the universe was too hot for life as we know it--to exist (but the entropy of the universe was very low). Countless eons hence, it will become so cold and empty that life, no matter how ingenious, will perish and the entropy will be very high.

Even the entropy of black holes increases (Bekenstein-Hawking)
Information and Entropy

The difference between entropy states is information. Information is related to entropy loss.

Knowledge Decreases with Time

Eventually all objects not decoupled from the background expansion, i.e. those objects not bound to the local supercluster, will disappear in this fashion. The time-scale for this disappearance is surprisingly short cosmologically speaking ~ 150 Billion years.

~ Wolfgang Amadeus Mozart

Neither a lofty degree of intelligence nor imagination nor both together go to the making of genius. Love, love, love, that is the soul of genius.
To sleep or to die. An ultimate question? What is the meaning of life?

According to common wisdom from the law of entropy increase, intelligence is irrelevant to cosmological thinking. It is just a bit of froth dancing in and out of the crevices of the universe, and has no effect on our ultimate cosmological destiny.

How will we as a species of humans react to this inevitable march to annihilation.

Will inventions be directed toward prolonging life or enjoying life or destroying life? How?
Continued Evolution……leads to the following types of inventions…machines……no more miracles

“Right now we have $10^{26}$ calculations per second in human civilization in our biological brains. Non-biological computation is growing at a double exponential rate, and right now is millions of times less than the biological computation in human beings. Biological intelligence is fixed, because it's an old, mature paradigm, but the new paradigm of non-biological computation and intelligence is growing exponentially. The crossover will be in the 2020s and after that, at least from a hardware perspective, non-biological computation will dominate at least quantitatively”. Ray Kurzweil

“Machines (not necessarily inorganic - can share their knowledge. Machines can do things quickly. Machines have a type of memory that's more accurate than our frail human memories. Nobody at this workshop can remember billions of things perfectly accurately and look them up quickly. The combination of the software of biological human intelligence with the benefits of non-biological intelligence will be very formidable. Ultimately, this growing non-biological intelligence will have the benefits of human levels of intelligence in terms of its software and our exponentially growing knowledge base.”

human like qualities! A more evolved human! Part machine part organic
The merger of evolution and intelligence will displace biological intelligence.

"What are nanobots"?

As the level of complexity that we can manage increases, we will be able to reverse-engineer the human brain. We've shown that we can model neurons, and even whole brain regions. We are well down that path. Some estimates are that within 25 years we'll have all of the necessary scanning information and neuron models and will be able to put together a model of the principles of operation of how the human brain works. Ray Kurzweil.

So the first thing I expect we will do is to follow Mark Twain and simply tweak our imagination much like the Ostrich.

Biological complexity to cortical complexity unveiled.
so far………gloomy

- The universe is mercilessly propelling us to our doom as the universe expands and entropy increases. Our evolutionary behavior is certainly helping this along as we speed things up. Resource utilization is important. Energy efficiency becomes important. Inventions that are useful will use smaller and smaller amounts of energy to do the same type of tasks…. Efficient. However accessible energy will decrease leading to decreasing information.

- Nano and Pico bots will emerge and enter our minds to create sensations

- Clustering also occurs e.g. self assembly in biological structures leads to local decrease in entropy

- The theme for inventions is clear. Or is it?
As order exponentially increases, time exponentially speeds up (i.e., the time interval between salient events (radical innovation) grows shorter as time passes). For example, life on earth was relatively static until cellular life developed, and biological evolution, like technological evolution in the twentieth century, exploded over shorter intervals of time between milestones in complexity of organisms. Moore's Law can be seen as a subset of this law.

At today's rate of progress, we'll make the same amount of progress as what occurred in the 20th century in 14 years, and then again in 7 years. The 21st century will see, because of the explosive power of exponential growth, something like 20,000 years of progress at today's rate of progress—a thousand times greater than the 20th century, which was no slouch for radical change. Ray Kurzweil.

Will the rate of entropy production be important? Are fuel cells important? Does it matter cosmologically speaking?
Did Evolution create something special? Choice

Evolution. It starts out very slow, but then something with some power to sustain itself and to overcome other forces is created and has the power to self-replicate and preserve that structure. Evolution creates a capability and then uses that capability to create the next. But… Is there a special capability that humans have - called choice?

Oh, you're sure to do that," said the Cat, "if you only walk long enough."
The goal here is to keep you from walking so far before you get SOMEWHERE. :)

Is there choice.
Really.........
Law of acceleration of knowledge

Create more and more order—not less order. And creating it faster and faster….creating information –

One exponential **pattern** ----- Moore's Law---- **paradigm** of shrinking **transistors** on **integrated circuits**. At some point, **integrated circuits** will run out of steam. Molecular size 3-D computing will take over just like transistors took over from vacuum tubes..
Frank Ramsey (philosopher and mathematician)

A belief is knowledge if it is obtained by a reliable process and if it always leads to success. Case in point: entropy increases and increases...

Also postulated:

Complete disorder is an impossibility. Any structure will always contain an orderly substructure.
ANTHROPIC UNIVERSE. We were created to observe the Universe. Brandon Carter

While other universes either expand too quickly and flatten (first below) or close before life can evolve (last three), our universe (second from left) seems perfectly poised to support life.

Picture credit Hawkings

Web site

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Evolutionary history apparently conflicts with the Second Law in a number of ways. The number of species, structural complexity, diversity of species, and acceleration of energy flow have all increased with time. The increase in complexity is measured in informational, structural, energetic, and flow component terms. What about consciousness?
Intelligence-Wisdom-Consciousness:

Reject the hypothesis that according to common wisdom, intelligence is irrelevant to cosmological thinking. It is NOT just a bit of froth dancing in and out of the crevices of the universe, and has no effect on our ultimate cosmological destiny.

Many believe that the universe has been set up exquisitely enough to have intelligence. There are intelligent entities like ourselves that can contemplate the universe and develop models about it. Intelligence is, in fact, a powerful force and we can see that its power is going to grow not linearly but exponentially, and will ultimately be powerful enough to change the destiny of the universe.
It’s a bird no it’s a man no its Superman. Instead of despair………

INTELLIGENCE CAN REVIVE HOPE BUT CAN SCIENCE SUPPORT THIS TYPE OF FUZZY THINKING?
Quantum Physics allows odd scenarios for causality (small stuff)

Commanding our local area of the sky is, of course, very small on a cosmological scale, but intelligence can overrule these physical forces, not by literally repealing the natural laws, but by manipulating them in such a supremely sublime and subtle way that it effectively overrules these laws.

The dream of deterministic predictability was shattered by the emergence of the new science of Chaos that showed that apparently random patterns in nature, such as the turbulent flow of a liquid or the weather, could be elegantly modeled mathematically, but not predicted. In these models, scientists also observed that very small perturbances of the system led to large unpredictable changes in the behavior; furthermore, these systems never reached a steady state of equilibrium. The famous description that the flap of a butterfly wing in China causing the monsoons in India has been commonly used to illustrate the cascade of effects that small, seemingly isolated, events play in shaping whole chaotic systems. Causality is still hotly debated among physicists, but in the quantum world, there appears to be a break in the direct link between cause and effect.
Professor Feynman liked to speak of "the laws," meaning the laws of nature, in a particularly clean and classical sense. "If the only laws that you find are those which you have just finished observing, then you can never make any predictions," he said. Remember that cat in *Alice and Wonderland* we just saw…….

"Of course, this means that science is uncertain - the moment that you make a proposition about a region of experience that you have not directly seen, then you must be uncertain," he continued. "But we always must make statements about the regions that we have not seen, or the whole business is no use."

The problem is all this applies only on very small scales whereas cosmology is large scale stuff.
Conflict with Einstein

How does all this affect our predicted Cosmological demise. Space time was so elegantly modeled by relativistic Physics. Can the small stuff theory (quantum physics) really change the large stuff prediction

Advent of string theory. Physics again turned upside down.
String Theory - Vibrating strings (infinitely thin) describe everything from quantum mechanics to gravity.

At the early stages of the universe when the density was very high and the size extremely small cosmology and quantum physics require unification. This is provided by string theory.

11 dimensional string theory

All dimensions initially curled up and very equivalent and then 3 of these expand. Why three? Anti-string annihilations. Space time rips can be repaired.
Before the beginning

The whole notion of singularity can be avoided by string theory. NO MIRACLES? HAPPY PHYSICISTS.

Gasperini and Veneziano (Torino)- The Universe did not begin as a plank size nugget. Time zero is not when the big bang occurred but much earlier. The real universe started cold and vast. Then a fluctuation occurred which gave us the nugget for our universe.

Other universes also exist - some with different laws of physics. Black holes are seeds for other universes which are hidden from each other because of the black holes. Can black holes collapse?
What about inventions i.e. if we believe that humans and intelligence are special to the universe……..unending life thought…..

- Quantum Transitions. Worm holes.
- Find Black Holes (great energy scavengers).
- Explore the Universe
- Transition to Other Universes
- Other similar ideas
1. The statement; "For every action there is an equal and opposite reaction", does not necessarily apply. Rejection of Newton. Go beyond Einstein.

2. The shortest distance between any two points is neither a curve nor a line, but rather, a point.

3. Anything which can be imagined can be achieved. Any place which can be imagined can be reached. Wormholes.

4. Time is an illusion. As perceived by humans, it does not exist. Rather, all events exist in simultaneity. Space and time are related + quantum physics applies.

5. The chief characteristic of a higher dimension is to complicate (complexify) the aspects of the immediately preceding lower dimension. That is, each aspect so complexified in a higher dimension possesses a greater number of qualities than it does in a lower dimension.
DO BLACK HOLES REALLY EXIST? How can we use them for mankind?

A supermassive black hole with 2 billion times the mass of the Sun apparently lurks in the nearby giant galaxy M87. Even more convincing evidence has come from the centers of several large galaxies, where stars move about so quickly that they must be caught in the grips of a massive object. By calculating the size and mass of these objects, the only conclusion seems to be that the center of these galaxies harbor supermassive black holes.
Multiverse transitions

Quantum Transportation.

Was the big bang really a singularity or was it ..... 

What about Gasperini and Veneziano?
What about that pesky entropy?

One thought - The universe is a self-renewing system in dynamic equilibrium. The increase of the entropy of matter is only temporary and does not affect the total entropy of the universe that is zero. I can’t buy into this says Jai Sekhar.

Another crazy thought - The evolution of life is a continuation of the evolution of the universe. It is a negentropic process that is continuously developing towards a zero entropy of the universe. All over the universe life is developing towards conscious species. … (this is wrong as second law cannot be violated). Therefore I can’t buy into this either. Note that this (– big crunch-) is more pessimistic than expanding entropy theories

Intelligence and consciousness overcome the entropic demise. Can the US Patent Office be wrong (the same patent office which denied women from holding Patents) - can the second law actually be violated. Remote possibility but maybe.

Do we transition to the multiverse. New Physics. New laws in a different universe?.

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Metastability

**Higgs Field.**
How does this reasoning apply to the early universe? Strange as this may sound, the universe also went through phase transitions. Immediately metastability becomes available as a route to extend life.

**Concept of Supercooling**

**Confined by metastable equilibrium**
If you explore too greatly you’ll perish. Sneak in energy and create knowledge. Quantum Transportation to and from multiverses.
The struggle of entropy and human civilization is symbolized in many religions

- Does religion teach the following of the second law?
- An overriding feature of many creation stories is that chaos is overcome by God(s), which heralds the beginning of the universe. **In other words, the Gods' actions formed the universe, by decreasing its entropy enough to free up energy.**
- Greek legends speak of Cronos (the father of the gods) overcoming chaos to found the universe. Some cultures limit their gods to creating the universe in a low entropy state. Madagascan legend tells us that Zanahary made earth but left it empty (Ratovoantany created everything on it), and Zulu myths say that Unkulunkulu evolved alone in emptiness before creating men from grass.
- The Egyptian God Re brought forth the first pair of gods as he emerged from the waters. In Babylon, pairs of gods rose to the surface as the waters of Abzu and Tiamat met.
- Most, but not all religions, conserve entropy in that they allow only one universe, which degenerates from a perfect beginning. This is not true of Hinduism or Buddhism, in which creation ebbs and flows on a vast scale. In Hinduism, this is symbolized by the several Yugas.
- The question most creation stories leave unanswered is the question of what will happen at the end of the universe, preferring to let it continue infinitely or indefinitely. Even when a definite end is mentioned, there appears no definite date for the end - perhaps this is God's way of telling us that we have nothing to fear in the future.
So far...

- The second law of entropy is correct in our universe but exotic possibilities of multiverse transitions exist.
- We may be in a meta-stable equilibrium. What are the implications of a giant disturbance?
- Inventions (discovery) will be exponential. Is the speed of light a limitation for information?
- Inventions will be determined by our cosmological destiny which certainly is not that clear regardless of the second law.
- Consciousness/Intelligence .....is to be alive......to reason, to find meaning in things.....to discover....to invent......is the only possible salvation to overcome the second law predictions of doom.
Credits and Acknowledgements

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