Graduation Ceremony

- After the class in Patty's Pub

A. **Patty's Pub**
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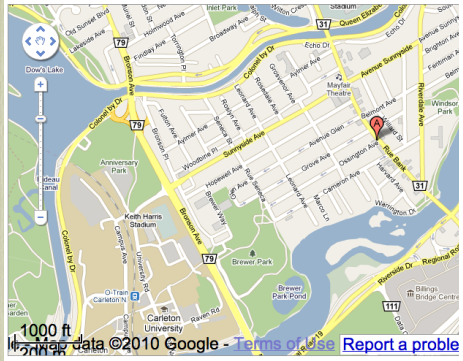
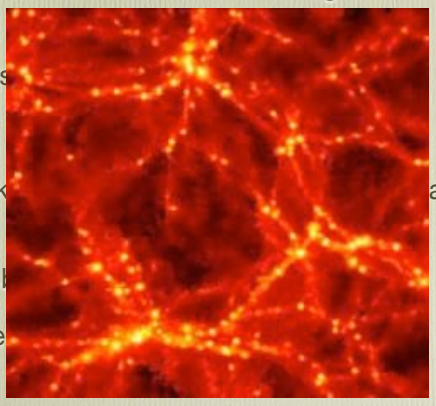


Peter Watson

A walk on the Wild Side

The story so far

- Hubble expansion tells us the universe began ~15 billion years ago
- Future of univers
- Ω_{matter} ~.01, but
- Microwave back at 400,000 yrs
- Dark Matter pro
- Dark Matter nee



Peter Watson

"Would you tell me, please, which way I ought to go from here?" Alice speaks to Cheshire Cat

"That depends a good deal on where you want to get to," said the Cat.

"I don't much care where--" said Alice.

"Then it doesn't matter which way you go," said the Cat.

"--so long as I get somewhere," Alice added as an explanation.

"Oh, you're sure to do that," said the Cat, "if you only walk long enough."

Alice felt that this could not be denied, so she tried another question. "What sort of people live about here?"

"In that direction," the Cat said, waving its right paw round, "lives a Hatter: and in that direction," waving the other paw, "lives a March Hare. Visit either you like: they're both mad."

Peter Watson

And just when you thought it was safe to go out at night....

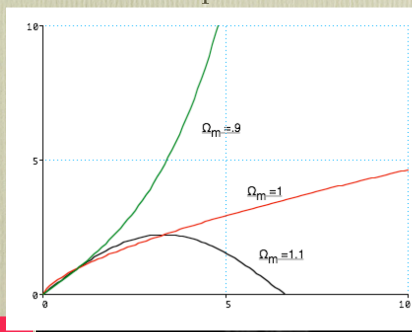
- Dark Matter is bad enough, but now dark energy ...

Pe

- Obviously the expansion of the universe is slowing down (decelerating).
- Need to look a long way out: Perlmutter & Saul measured distances via Type 1a supernovae
- Now use Canada-France Hawaii Telescope

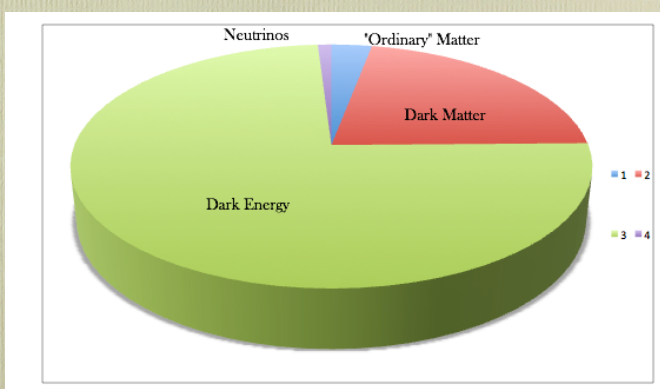
Peter Watson

- Obviously the expansion of the universe is slowing down (decelerating).
- Unfortunately it isn't..... it's accelerating
- Collect the 2011 Nobel prize



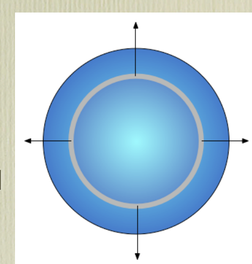
- Likeliest explanation is that the vacuum itself has an energy (!), so the universe can just create more(!!)
- The Good News:
- we have a theory with a strange vacuum which has an energy: The Higgs field behaves very like a vacuum, so maybe it **is** the vacuum
- The Bad news
- The calculated energy is 1 million-million-million-million-million-million-million-million-million-million-million-million-million-million-million-million-million-million-million-million times too big
- The worst prediction in physics (so far)

- What can dark energy be?
- List of all well-motivated models for dark energy:



Are there alternatives?

- We've assumed we live in a homogeneous universe: i.e everyone see the same universe
- might be wrong.
- Suppose we are at the centre of a large (really!) void: then we'd see shells of material being accelerated outwards



- Gives local acceleration (and hence mimics dark energy) but suggests we are in special place in the universe

- So we should be able to remove energy from empty space

United States Patent
Haisch et al.

(10) **Patent No.:** **US 7,379,286 B2**
(45) **Date of Patent:** **May 27, 2008**

QUANTUM VACUUM ENERGY EXTRACTION

Cole, D. C. and Zou, Yi 2003, Quantum Mechanical Ground State of Hydrogen Obtained from Classical Electrodynamics, Physics Letters A, vol. 317, No. 1-2, pp. 14-20 (Oct. 13, 2003), quant-ph/0307154.

(Continued)

Primary Examiner—Nikita Wells
(74) *Attorney, Agent, or Firm*—Pritzkau Patent Group, LLC

(57) **ABSTRACT**

A system is disclosed for converting energy from the electromagnetic quantum vacuum available at any point in the universe to usable energy in the form of heat, electricity, mechanical energy or other forms of power. By suppressing electromagnetic quantum vacuum energy at appropriate frequencies a change may be effected in the electron energy levels which will result in the emission or release of energy. Mode suppression of electromagnetic quantum vacuum radiation is known to take place in Casimir cavities. A

Unfortunately

- We can figure out the total quantum energy contained in (e.g) this room
- roughly 1 nJ (billion of a Joule).

"What do you mean, 'a quantum fluctuation?' Didn't we discuss cause and effect?"

Note

- There have been 3 scientific revolutions, all devastating for man's dignity.
- Copernicus: We are not the centre of the universe
- Darwin We are no different from the

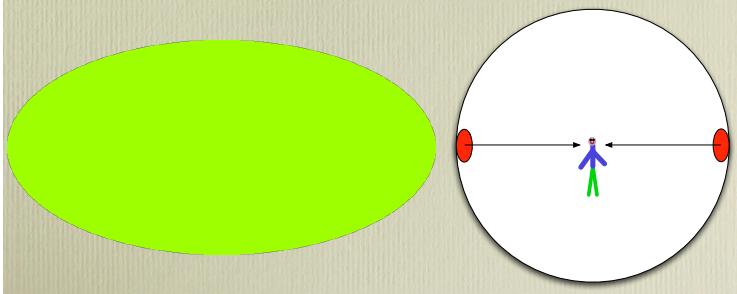
Some more questions

- Why is the universe large and flat?
- It is naturally much smaller, and there is no reason to have $\Omega = 1$ (this is the "Why the hell" question!)
- Why is the universe all the same temperature?
- Parts of it have never been in contact.
- Why is the universe matter?
- If it starts as energy, would expect equal amounts of matter and anti-matter

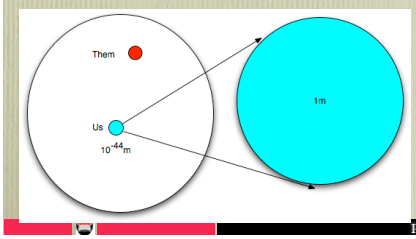
- Suppose $\Omega = 0.999999999999999999999999999999999999999999999999$ one billionth of a second after the Big Bang
- It would now be zero: the universe would be empty
- Suppose $\Omega = 1.00000000000000000000000000000000000000000000000000$ one billionth of a second after the Big Bang
- The universe would now be over!
- so $\Omega = 1.00000000000000000000000000000000000000000000000000000000000000000000$

Like pencil balanced on end!

- Suppose we look at two points on opposite sides of the sky as far out as we can see
- The radiation from each has only just had time to get to us
- So how do they know to be at exactly the same temp, if they have never been in contact?



- Can fix this by "inflation"
- Universe could have been very lumpy
- Period immediately after the Big Bang when it suddenly expanded
- All "wrinkles" smoothed away



- Sakharov (1965) suggested that to make matter as opposed to anti-matter need to have a particle that decayed with a slight bias
- X->proton + electron > X->anti-proton +positron
- At one millionth of a second for every billion positrons we had one billion + 1 electrons (roughly!)
- at one second almost all have annihilated (like in a PET scanner!)
- small # of extra electrons is why we have matter

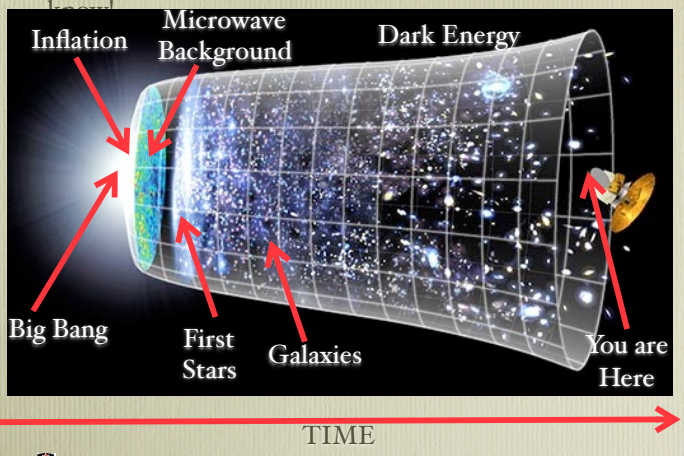
"I can't believe THAT!" said Alice.

"Can't you?" the Queen said in a pitying tone. "Try again: draw a long breath, and shut your eyes."

Alice laughed. "There's not use trying," she said: "one CAN'T believe impossible things."

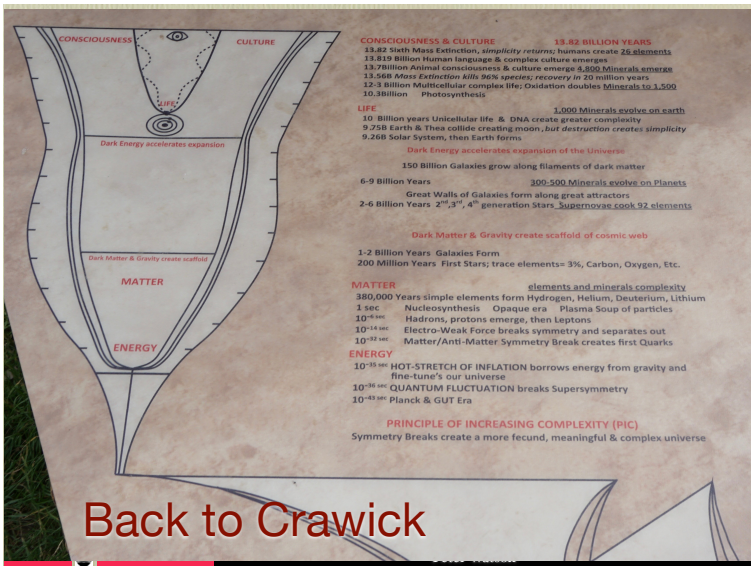
"I daresay you haven't had much practice," said the Queen. "When I was your age, I always did it for half-an-hour a day. Why, sometimes I've believed as many as six impossible things before breakfast."

- This explains the WMAP picture: it is our "concordance model" and agrees with everything we

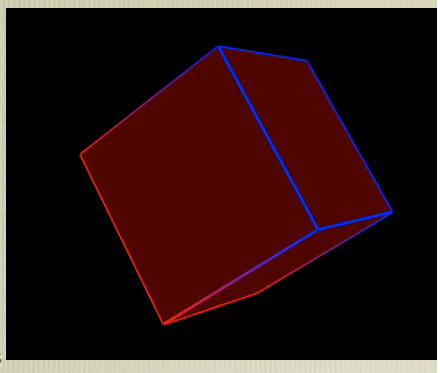


Back to Crawick

- The multiverse



- After 500,000 years universe was cool and dark and uniform
- What happened next?
- First stars created "holes"
- Galaxies took ~ billion years to form
- Next generation of telescopes (James Webb?) will look at this



- We have now understood (?) most of the basic ideas:
- however there are a number of very speculative ideas which may be confirmed over the next few years.....
- This is a sampling....
- Warning: for the rest of this course, you are on the hairy edge of science!

Do we understand Gravity?

Nature and Nature's Laws lay hid in Night

God said "Let Newton be" and All was Light

Alexander Pope

- Gravity gives us
- Motion of planets
- Motion of Galaxies
- Mass of Stars
- Cosmology .....

Do we understand Gravity?

Nature and Nature's Laws lay hid in Night

God said "Let Newton be" and All was Light

It did not last: the Devil howling "Ho

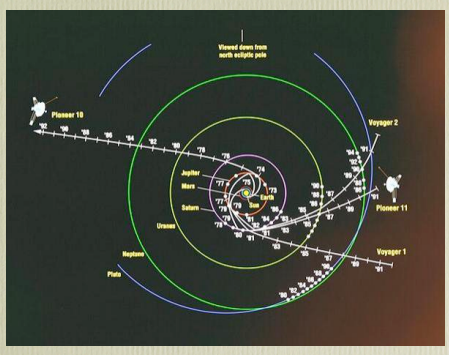
Let Einstein be!" restored the status quo.

J. C. Squire

- No known conflict between theory and experiment so maybe we should quit while we are ahead ....

A curiosity?

- Pioneer 10 and 11 launched 1972/73: last signal received from Pioneer 10, on 27 April 2002, distance = 80 AU.



- But its acceleration is not exactly the rate predicted by gravity: about 0.99999999.
- Most likely it is leaking radiation
- (But NASA has lost the blueprints!)

- We don't understand gravity
- e.g take two electrons

WHY?

However the electric force is

40000000000000000000000000000000000000000

larger

Actually 4.2×10^{42} times larger: Hitchhiker's Guide fans note!

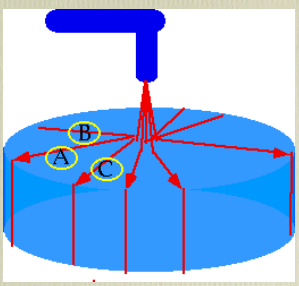
- Maybe because gravity works in a higher dimensional space:
- It is really strong at short distances, but "leaks away" into extra dimensions
- Maybe

But .....

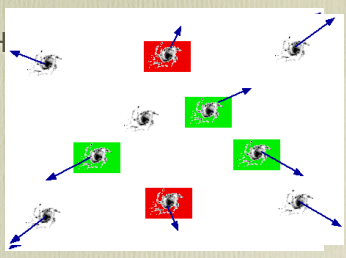
- There are other theories which have been tried
- E.g. Dark energy might rip the universe apart
- or

Steady state theory of Bondi, Hoyle, Gold

- Basic assumption is that universe is not only isotropic in space, but also in time: i.e. No beginning , so it always looked much the same.
- How can this be squared with expansion?
- Imagine a stream of water falling into full bucket:
- (A) will see (B) and (C) receding even though the situation does not really change.



- Requires creation of new Matter.
- approx. 10^{-35} gm cm^{-3}/sec averaged over space, or 1 H atom/c.c. every 10,000 yr., which is undetectable.
- Does not conserve energy (in usual sense).
- Also predicts expansion should be accelerating.



- Doesn't work in detail.

Anthropic Principle

6) Fortunately there is a special place for us

- And God said " Let us make man in our own image, after Our likeness, and let them have dominion....over all the earth Genesis I.26

Not only is this the **best** of all possible worlds, it is the **only** (observable) of all possible universes.

- Build your-own universe kit depends on very few numbers

G	Grav. const
c	Speed of Light
α	Electric Force
m_e	Electron mass
m_p	Proton mass
m_n	Neutron mass
H_o	Hubble's Constant
T_{CMBR}	Microwave background temp
Ω	Total Density
Ω_B	Matter Density
Ω_Λ	Vacuum Energy

Anthropic Principle:

- We've missed a few constants, but there are enough here so you can design a "Build Your own Universe" kit
- Where do these constants come from?
- Weak Anthropic Principle: We see the universe the way we do because locally it is suitable for our existence
- Strong Anthropic Principle: The laws of the universe are such that it can become self-aware

- Teleological Anthropic Principle (Barrow and Tipler) ..the universe is habitable SO THAT intelligent life can evolve. i.e., habitability is the goal of the universe.
- Extremely Strong Anthropic Principle
- The universe exists to produce
- ...PHYSICISTS!

e.g.How old is the universe?

- Physicists are made of carbon,
- Carbon is not made in the big bang.
- The universe cannot become self-aware until the first stars have completed their life-cycle.
- Age of Universe > 1 Billion years

e.g. Could the forces in nature be any different?

- Nuclei exist because of subtle balances between
- (1) Repulsive Electric Force
- (2) Attractive Nuclear Force
- For heavy nuclei, (1) overwhelms (2), so they are unstable

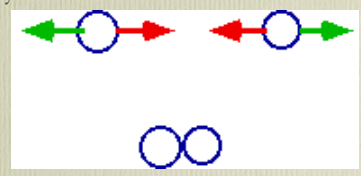
If the electromagnetic force were 10% stronger

Then no nuclei except hydrogen would exist,

- so no chemistry
- so no biology
- so ...NO PHYSICISTS!

e.g. Could the forces in nature be any different?

- If the electromagnetic force were 10% weaker
- Then the "di-proton" would exist
- hydrogen would have been destroyed in the Big Bang
- so no water
- so no biology
- so ...NO PHYSICISTS!



e.g How Dense is the Universe?

- i.e. what is Ω?
- Low Density e.g., Ω<0.999999999999999
- Universe Expands too fast
- no Galaxies
- no stars
- no planets
- ...NO PHYSICISTS!

e.g How Dense is the Universe?

- High Density e.g., Ω>1.0000000000000001
- Universe clumps very early
- but only lasts a few minutes
- ...NO PHYSICISTS!

e.g How Dense is the Universe?

- Goldilocks universe Ω=1.0000000000000000
- Universe just lumpy enough to make galaxies after one million years
- and stars
- and lasts forever
- ...PHYSICISTS!

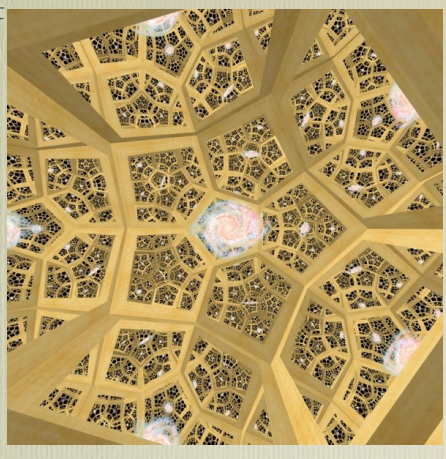
Is this a reasonable scientific theory?

- The anthropic principle gives no room for making testable predictions
- Can we construct other universes that "work": i.e. allow for life
- Maybe: Aguirre has constructed a universe with no radio-activity.
- Stars still work, carbon is still created so we can have biology
- Or is it an idea that just depends on lack of imagination?

Thank you, Arnold Campbell

But is it really that simple?

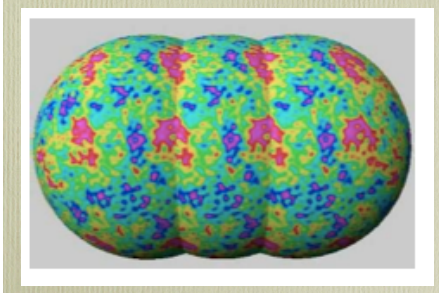
- We've assumed the universe is open, flat or closed, but there are other possibilities.

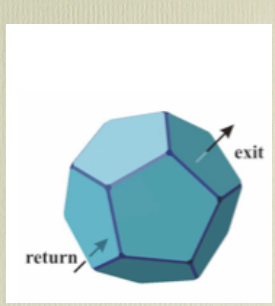


- Our balloon analogy tells us the topology of the universe is "simple"
- What is a topologist?
- Someone who cannot tell the difference between a doughnut and a coffee cup
- We can create finite versions of an unbounded universe:

M.C. Escher
http://www.mcescher.com/

- Could have a universe which folds in on itself
- Might see this as repeated pattern in the sky





7. So what happened before?

Then was not non-existent nor existent
There was no realm of air, no sky beyond,
What covered in and where? and what gave shelter?
Who verily knows and who can here declare it
Whence it was born and whence came this creation
He, the first origin of creation, whether he formed it all or did not form it.
He verily knows it, or perhaps he knows not.

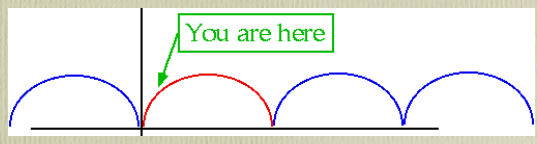
The Rig Veda X.129 (Hindu)

What happened before the Big Bang?

Don't Ask

There is a special hell reserved for people who ask that question.
George Gamow

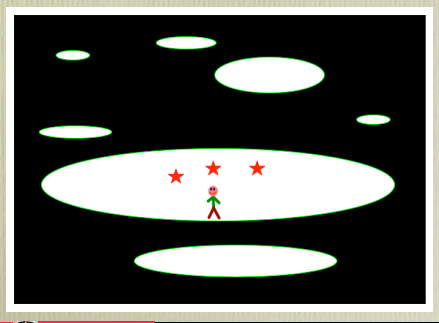
Maybe the Universe Bounces



- We can create models in which the universe bounces
- But they don't work very well

But much more fun: The universe is a quantum fluctuation

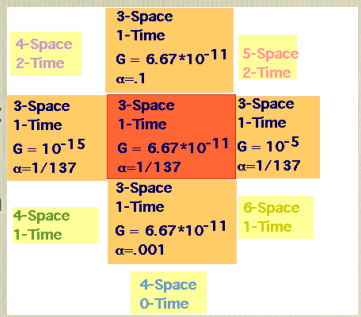
- Implies we can get daughter universes, each with their own big bang



- Implies you can create universe *ex nihilo!*
- Why does the universe get created?
- Universes tend to happen from time to time!
- But are they always the same?

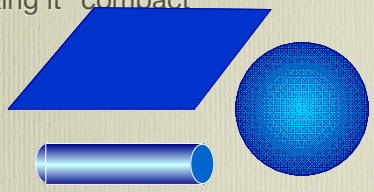
Sakharov (1985)

- suggested that the rules of physics need not be the same in going from one universe to the next:
- i.e. the parameters could be set arbitrarily in the first billion-billion-billionth of a second



Which takes us to... Superstrings and the like:

- Gravity curves space: means going to a larger number of dimensions.
- Kalusza-Klein showed that electricity can be put with gravity by adding a fifth dimension, but making it "compact"



- To include all the other forces in nature (strong and weak) we need to go to a 10-dimensional space.
- You hadn't noticed that the universe is 10-D? tsk-tsk.....
- 6 of the dimensions are compact (R < 1 billionth size of nucleus
- All particles (quarks, photons, electrons.....) are 2-D strings in this 10-D space.

For the first fraction of a second s the universe contained....

Nothing! No forces, no particles! Nada!

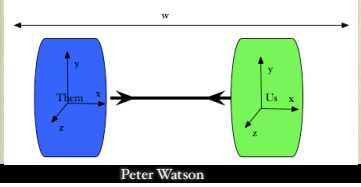
Then the extra dimensions curled up and became compact

=> Forces => Particles => Atoms =>

...PHYSICISTS!

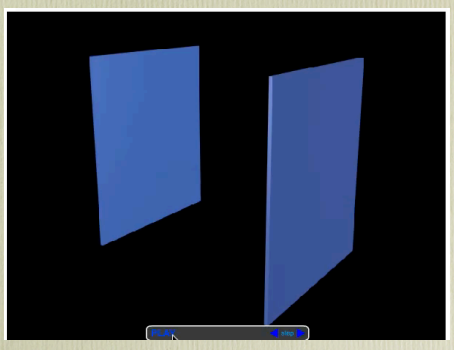
Ekpyrotic Universe

- If we take the idea of extra dimensions seriously .....
- Ordinary particles (forces and matter) live in 3-D mem**brane**
- If we have two branes these would attract gravitationally in 5th dimension.
- Big bang is brane collision: "large" universe is created: allows inflation to be dropped.



Like this

- from Paul Steinhardt



So do we have some sort of executive summary?

Does our Big Bang Model work	Yes
What is Dark Matter?	Probably WIMPs (2015)
What is Dark Energy?	Vacuum?????? (2025)
Do we understand Gravity?	Not in any fundamental way (2020)
Do we understand why the Big Bang model works?	No: same level as Kepler's laws.
Are there alternatives?	Yes: too many!
Is Inflation correct?	Only game in town
Is the multiverse idea correct?	Maybe

And so finally 8) What a beautiful story!

In the beginning, God created the heaven and the earth.

And the earth was without form, and void; and God realised that this was not a very good way to start, so God said, Let there be a reinitialisation, and because God was God, he was able to start over.

In the beginning, God created the heaven and the earth. And the earth was without form, and void; and darkness was upon the face of the deep. And the spirit of God moved upon the face of the waters.

And God said, Let there be light,

But God had forgotten to create electromagnetic interactions, so there was no light, so God said, Let there be a reinitialisation, and because God was God, he was able to start over.

In the beginning, God created the heaven and the earth.

And the earth was without form, and void;

But this time God decided to leave himself plenty of room for manoeuvre, so he created the heaven and the earth to have ten dimensions.

But then God realised that this was a very complicated way to run a universe, so God said, Let there be a reinitialisation, and because God was God, he was able to sta.....

But God had forgotten *shlosha hefsaydim v'ato bachutz,* which being translated means "Three strikes and you are out", so God was stuck with the Universe.

So the Spirit of God moved through the heaven and on the earth and commanded that the extra dimensions should curl up on themselves, and become compact.

And God looked upon it, and saw that while it was not actually good, it was better than it might have been, because at least he had light.

The First book of Moses, called Genesis, (erratum)

- Sources: most pics from
- APOD (Astronomy Picture of the Day)
- NASA
- European Space Observatory
- Notes will be posted at www.physics.carleton.ca/~watson/