



Philosophy of cosmology workshop

Granada, 2011

The philosophy of cosmology

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The core issue for the philosophy of cosmology is,
What constitutes an explanation in the context of
cosmology?

This has two specific aspects:

What kinds of things are we trying to explain?,
and
How do we test if the kinds of explanation we are offering
are valid?

The questions that result are,
What kinds of questions do we want our models to solve?
Do our models take reality seriously?

USE OF MODELS IN DESCRIPTION

How accurate are they?

What degree of detail will they encompass?

the testability of proposed models?

What kinds of things will they describe?

Don't confuse models with reality!

Each model has a domain of validity
in terms of what it includes and what
it excludes e.g scales of description

- which should be stated clearly and not exceeded

USE OF MODELS IN EXPLANATION

What are the limits of our models?

Specific issues relate to the nature of causation in cosmology,
the testability of multiverse and cyclic theories,
and the problematic nature of claimed physically realized
infinities in cosmology.

Don't confuse models with reality!

Each model has a domain of validity
e.g kinds of causation envisaged
- which should be stated clearly and not exceeded

THE UNIQUENESS OF THE UNIVERSE

Only one object to look at

No similar objects to compare it with

No chance to rerun in an experiment

**Not clear how to separate “Laws” (generic)
from initial conditions (contingent)**

**Hence not clear how to relate to usual explanation:
Laws and initial conditions**

THE PHILOSOPHY OF THE HISTORICAL SCIENCES

general laws and specific applications

justifying historical theories vs experimental theories

the influence of universal aspects (necessity)

versus contingent events (chance)

the role of initial conditions versus general laws

Is chance a genuine causal category?

Or just means we don't have the data?

Application: Time and Arrow of time

Special initial conditions at the start of the universe

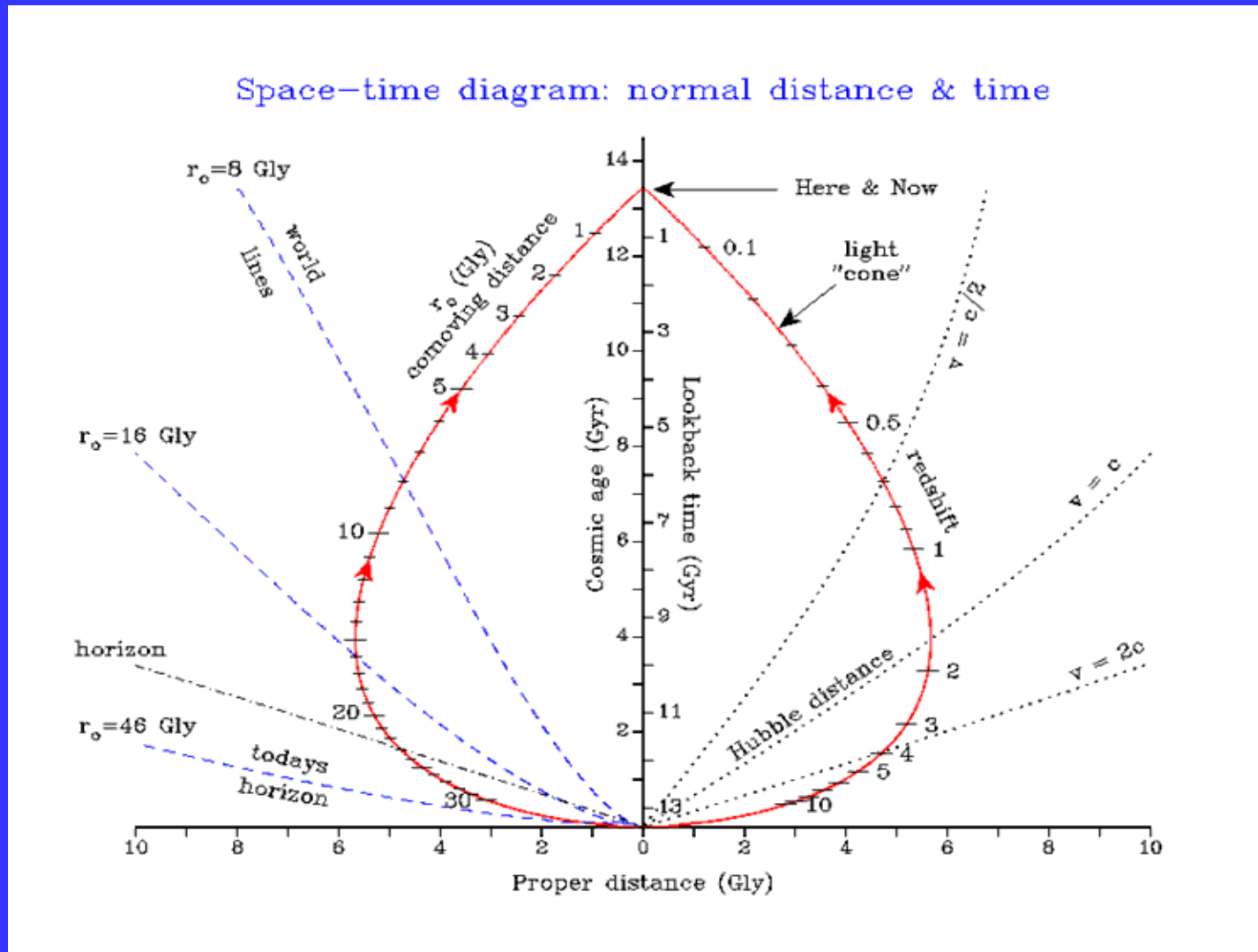
EPISTEMOLOGY AND ONTOLOGY

Relating knowledge to reality

Observational access strictly limited

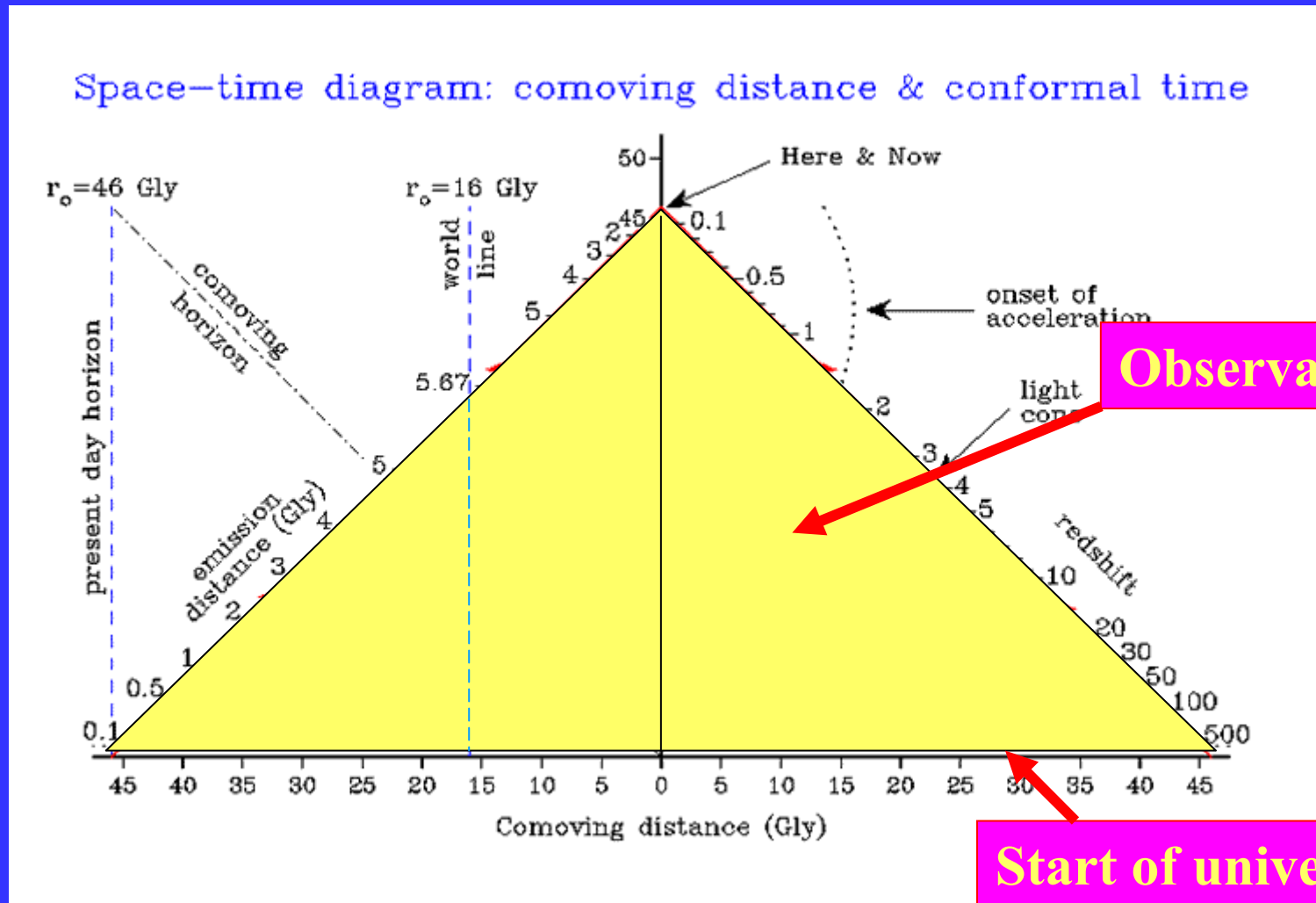
- **Particle horizon, visual horizon**
 - can only see out to 42 billion light years
- **Physics horizon**
 - can only test physics back to somewhere like start of inflation

The key observational point is that the domains considered in multiverse explanations are beyond the particle horizon and are therefore unobservable.

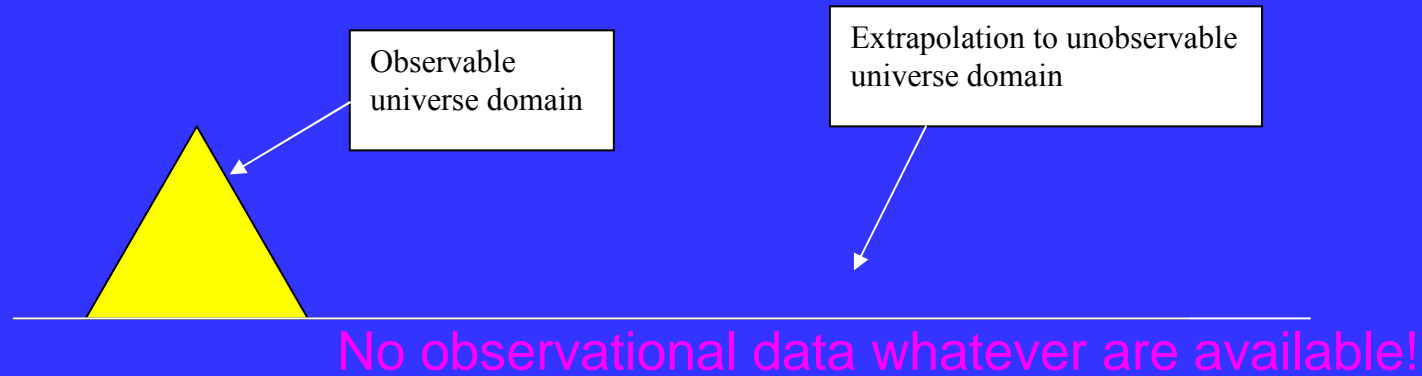


Diagrams of our past light cone by Mark Whittle (Virginia)

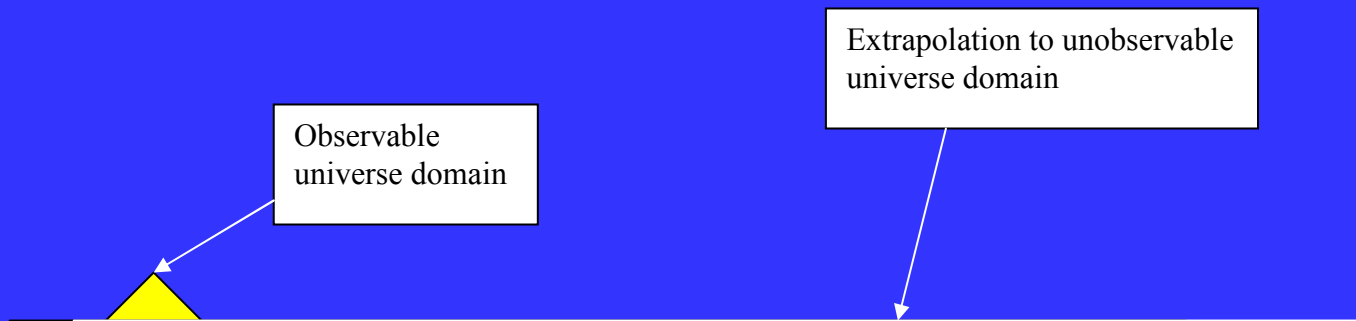
Expand the spatial distances to see the causal structure (light cones at $\pm 45^\circ$)



Now it is clear what the observational and causal limits are:



Better scale:



The assumption is we that can extrapolate to 100 Hubble radii, 10^{1000} Hubble radii, or much much more ('infinity')
– go to Cape Town and we haven't even started!

The motivation for multiverses

1. - claimed as the inevitable outcome of the physical originating process that generated our own universe [e.g. An outcome of the chaotic inflationary scenario]
2. - seen as the result of a philosophical stance underlying physics: “everything that can happen happens” [The logical conclusion of the Feynman path integral approach to quantum theory]
3. - proposed as an explanation for why our universe appears to be fine-tuned for life and consciousness

Giving probabilistic explanation for why we can exist

Fine tuning: The Anthropic Issue

- “The universe is fine-tuned for life” [J Barrow and F Tipler, *The Anthropic Cosmological Principle*]
 - as regards the laws of physics [Max Tegmark “Parallel Universes” astro-ph/0302131]
 - as regards the boundary conditions of the universe [Martin Rees: *Just Six Numbers, Our Cosmic Habitat*]
- A multiverse with varied local physical properties is one possible scientific explanation:
 - an infinite set of universe domains allows all possibilities to occur, so somewhere things work out OK
- NB: it must be an **actually existing** multiverse - this is essential for any such anthropic argument

Fine tuning: *Just Six Numbers* [Martin Rees]

1. $N = \text{electrical force/gravitational force} = 10^{36}$
2. $E = \text{strength of nuclear binding} = 0.007$
3. $\Omega = \text{normalized amount of matter in universe} = 0.3$
4. $\Lambda = \text{normalised cosmological constant} = 0.7$
5. $Q = \text{seeds for cosmic structures} = 1/100,000$
6. $D = \text{number of spatial dimensions} = 3$

Application: *explaining Cosmological constant*

Particularly: explaining **the small value of the cosmological constant** [Steven Weinberg: astro-ph/0005265; Susskind, *The Cosmic Landscape*] by anthropic argument

- too large a value for Λ results in no structure and hence no life
- then anthropic considerations mean that the value of Λ we observe will be small [in fundamental units]:
- thus justifying an actual value extremely different from the 'natural' one predicted by physics: 120 orders of magnitude

* ***making the extremely improbable appear probable***

- ***the true multiverse project***

JUSTIFYING UNSEEN ENTITIES

When can unseen entities be justified?

Example: the metric tensor

Example: the electric field

What is the process of justification?

- An essential link in a chain of argument with well supported foundations and outcome?

Maybe – if there is no other possible explanation

Application: the multiverse

The non-uniqueness of Occam's razor

Multiverse *Implied by known physics* that leads to chaotic inflation?

The key physics (e.g. Coleman-de Luccia tunneling, the string theory landscape) is extrapolated from known and tested physics to new contexts; the extrapolation is unverified and indeed is unverifiable; it may or may not be true.

The parameter values that lead to eternal chaotic inflation may or may not be the real ones.

The physics is hypothetical rather than tested!

Known Physics → **Multiverse ??**

NO!

Known Physics → **Hypothetical Physics** → **Multiverse**
Major Extrapolation

It is a great extrapolation from known physics.

This extrapolation is untestable: it may or may not be correct.

CAVEAT 1: DISPROOF possibility?

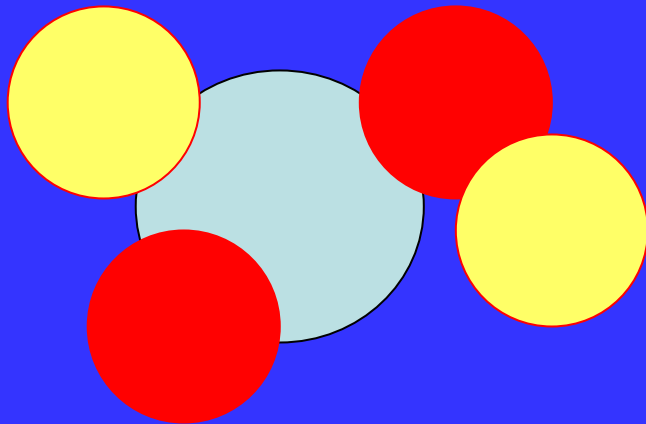
Chaotic inflation version can be *disproved* if we observe a small universe: have already seen round the universe. Therefore spatially closed:

- **Can search for identical circles in the CBR sky, also CMB low anisotropy power at large angular scales (which is what is observed).**
- **A very important test as it would indeed disprove the chaotic inflation variety of multiverse.**
- **But not seeing them would not prove a multiverse exists. Their non-existence is a necessary but not sufficient condition .**

CAVEAT 2: PROOF possibility?

Proof of existence: Multiverse collisions?

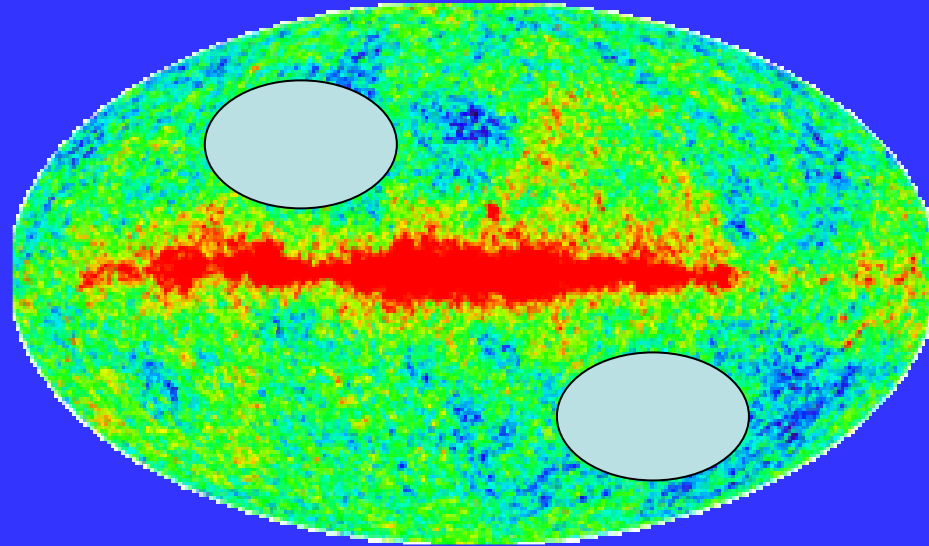
- Bubbles in chaotic inflation might collide if rate of nucleation is large relative to rate of expansion



Observable in principle by circles in CMB sky with different fundamental constants

Not seeing them does not disprove

Implied by anomalous filled circles in CBR anisotropy observations ??



- Suggested it might have already been seen
- *But very disputed*

And then you are in danger of causing chaotic inflation to come to an end (when all the compact comoving inflationary expansion space is used up)

Criteria for a scientific theory

- 1. Satisfactory structure:** (a) internal consistency, (b) simplicity (Ockham's razor), (c) beauty' or `elegance'.
- 2. Intrinsic explanatory power:** (a) logical tightness, (b) scope of the theory --- unifying otherwise separate phenomena,;
- 3. Extrinsic explanatory power:** (a) connectedness to the rest of science, (b) extendability - a basis for further development;
- 4. Observational and experimental support:** (a) the ability to make quantitative predictions that can be tested; (b) confirmation: the extent to which the theory is supported by such tests .

These will conflict with each other. You have to choose!
It is particularly the last that characterizes a scientific theory, in contrast to other types of theories

THE ISSUE IS WHAT YOU WANT YOUR MODEL TO DO

To describe how things came into existence
and then developed

To relate to why they came into existence

These are interrelated
but the first cannot imply the second

Scientific models per se cannot answer why questions

But some cosmologists are claiming they can
Hawking and Modlilow, Susskind

Extending laws *within* the universe to laws *for* the
universe – definitely untestable.

NATURE OF CAUSATION:

Four types of causation

1. **Purposeless algorithms grinding away [necessity]**
2. **Random events meaninglessly making things happen [chance]**
3. **Selection processes creating order where there was none**
4. **Purposeful action related to meaning, ethics, aesthetics**

They all occur in the real universe

Which is fundamental and which derivative?

Which applies at what scales?

Which applies to the universe itself?

NATURES OF EXISTENCE

Physical and abstract realities

Nature of physical laws:

pre-existing the universe?

Nature of mathematics:

Platonic space?

Application:

laws of physics and creation of the universe

Physical Laws at the fundamental level: What is the nature of their existence:

-is it prescriptive? Are the laws of physics somehow written in a Platonic space from which they control the nature of existence? If so where and how?

-This would in some sense be a mathematical description

- It would precede the existence of the universe, somehow governing its coming into being

is it descriptive? This is just the way matter behaves, the laws we love are phenomenological: they just describe what is

- But then why is the behaviour of matter the same everywhere?

A key issue is, what does it mean if we discover that the universe must have had a beginning?

How do we handle the idea of creation of the universe and

what kind of pre-existing entities might have been responsible
or do we give up the idea of causation?

Are there laws for the universe per se?

What is the nature of physical laws and what is the nature of their existence?

Why are physical laws so well describable by mathematics? (Wigner)

As mathematics describes ordered patterns of relationships, it is perhaps not surprising that these relationships and processes can be described mathematically.

The very nature of mathematics is indeed to describe patterns: in space and time, and indeed in patterns (leading to recursion and higher order relations)

What is surprising is that fundamental physical relationships can often be described so accurately by very simple laws, such as an inverse square law.

My suggestion is that this is because the underlying nature of these fundamental laws is geometrical, which results in them being accurately represented by simple analytic relations.

- Geometric conservation of particles or fields gives an inverse square law
- Parallel transport along curves underlies Yang Mills, Aharonov-Bohm, and Feynman path integrals, leading to holonomy as a fundamental entity
- Geodesic paths (extremal distance) underlie variational principles as a mathematical description

RELATION TO MATHEMATICS

Beware mathematics: Eddington
Abstraction and simplicity: the core processes

Abstraction and over simplicity
depth and scope of models

Beware reductionism and fundamentalism

Applicability of models: domain of application
Beware models beyond their domain of application

Application: The wave function of the universe
and the existence of time [Carroll]:
*Extrapolate from atomic to Hubble scales without
comment!*

NB: The often claimed existence of *physically existing infinities* (of universes, and of spatial sections in each universe) in the multiverse context (e.g. Vilenkin: *Many Worlds in One: The Search for Other Universes*) is **dubious**

- **infinity is an unattainable state rather than a number**

(David Hilbert: “the infinite is nowhere to be found in reality, no matter what experiences, observations, and knowledge are appealed to.”)

- **completely untestable**: if we could see them, which we can't, we could not count them in a finite time.

INFINITIES

Remember the true nature of infinity:

-an entity that can never be attained

Hilbert's Golden Rule: if infinities occur as a core part of your model it's not physics

it's definitely not provable: not science

Example: Boltzmann brain arguments

Application: David Deutsch *The beginning of Infinity: Explanations that transform the world*

Ratio of infinite number of instances of particles in output channels gives the Born rule

An important point is that the philosophy of cosmology must adequately take reality into account.

Remember the limitation of equations as representations of reality
consider the types of data that will be taken into account.

Don't use equations and theories based on limited data to try to talk about the metaphysical meaning of the whole,

don't stretch equations beyond the limits of their validity.

If you want your model to relate to the existence and meaning of life then you must take biological processes and complexity seriously

You can't just use highly simplistic physics models and talk about the origin of biology

Certainly not about meaning

If you want to enter these terrains you must take philosophy seriously

Not decry it as meaningless

How does complexity arise?

At the astronomical scale:

Gravity causes structures to come into being spontaneously

- Locally apparently against the second law
- attractors in phase space so there must be a definition of gravitational entropy that makes it OK
- still not understood but probably related to Weyl tensor
- (Penrose Weyl Curvature Conjecture)

How does complexity arise?

At the everyday life scale:

To some degree it comes by self-organisation:
But that is very limited.

The key process is adaptive selection

- Which requires randomness to create an ensemble from which a preferred set of states is chosen, the others discarded

NB: this can be a once-off process

In biology it gains its power by repetition

-But that is not necessary to the concept

An example of top down causation: depends on the environment that is the context for selection

CONTEXT AND TOP DOWN CAUSATION

The most interesting issue in the future development of cosmology may well lie in the interaction between bottom-up and top-down effects in the physical universe

Context as a determinant of outcomes

Bottom up causation and reductionism

Top down causation in cosmology

Mach and inertia

Olbers and life

The arrow of time

The Hierarchy of Structure:

Cosmology

Astronomy

Space science

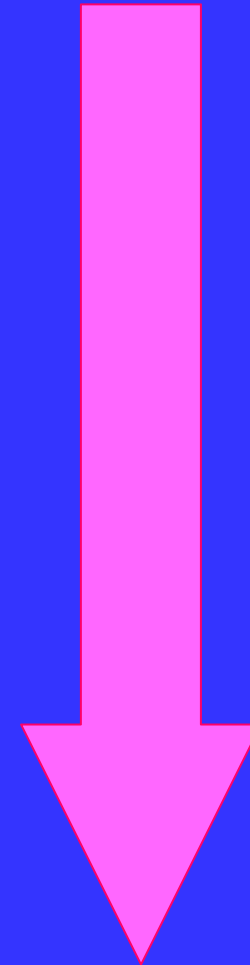
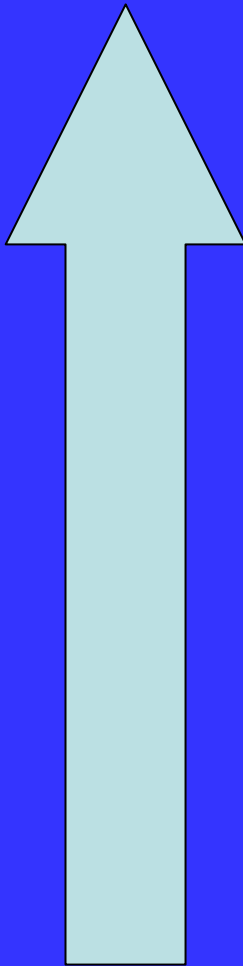
Geology

Materials science

Chemistry

Atomic Physics

Particle physics



The Hierarchy of Structure:

Sociology/Economics/Politics

Psychology

Botany/Zoology/Physiology

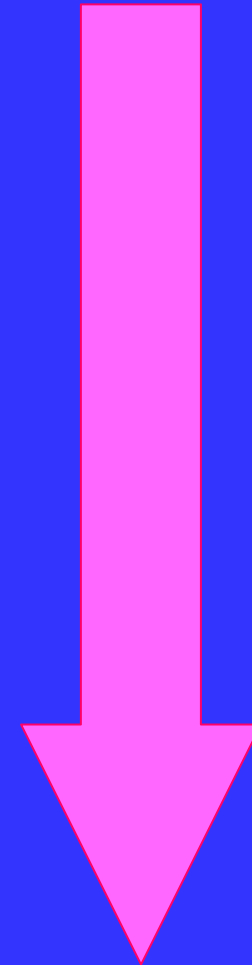
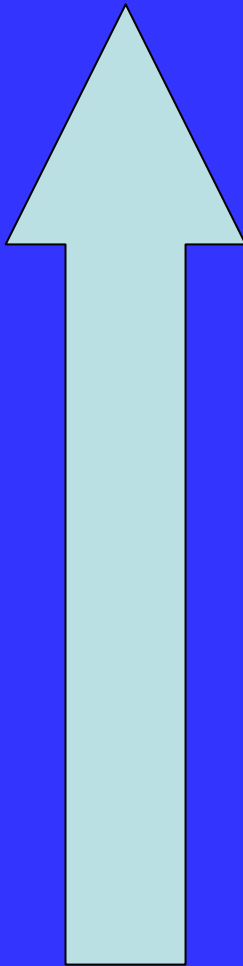
Cell biology

Biochemistry

Chemistry

Atomic Physics

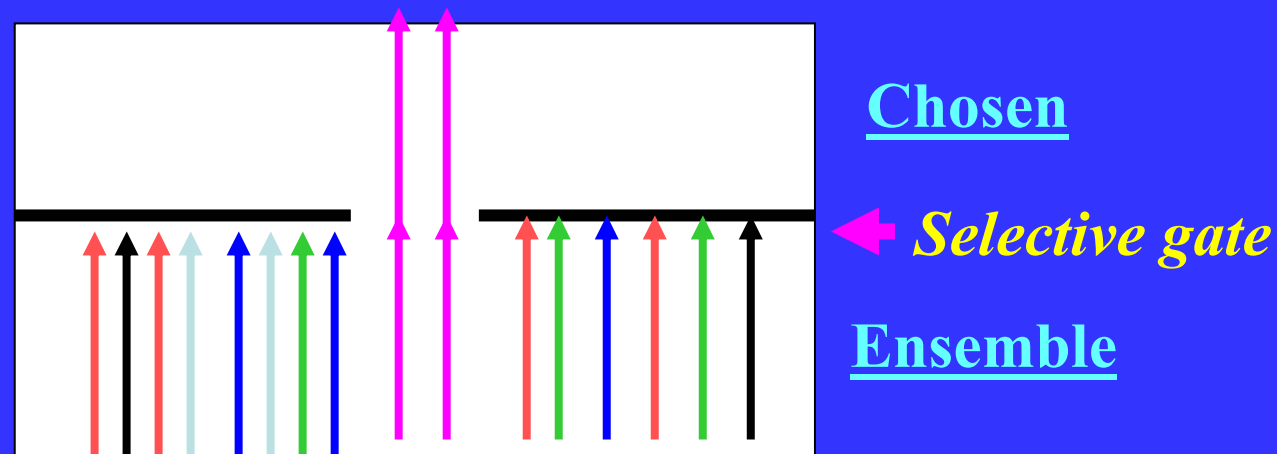
Particle physics



Selection is the way meaningful information is created for a jumble of disordered objects

-Everything you need to know is there but it's hidden in the ensemble: you have to select what is relevant

Notional picture:



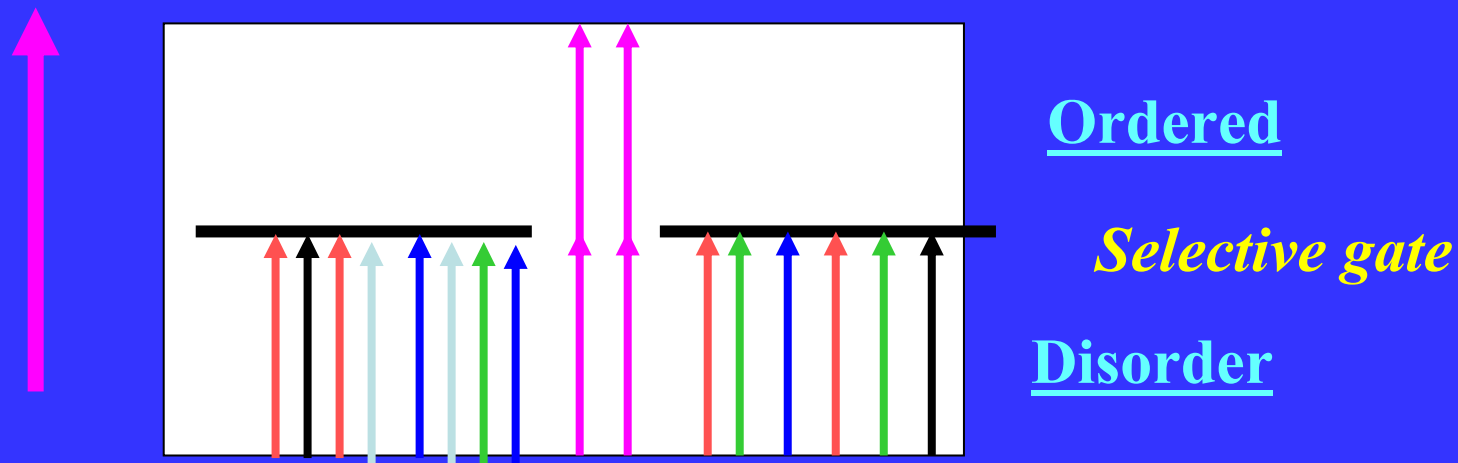
Adaptive selection allows local gains against the overall flow of entropy

Entropy is decreasing as order increases

Example: Maxwell's Demon

Selection principle: speed of molecule

- Meaningful information is gained by discarding all the
- information received that is not meaningful



Implies irreversibility

- can't determine the initial state from the final state
- decrease in entropy (by selection process)

MAY BE FAR MORE COMMON IN PHYSICS THAN REALISED SO FAR

[G Ellis: [arXiv:1108.5261](https://arxiv.org/abs/1108.5261)]

Physical determinism and life today:
is what is happening today an inevitable outcome of
what happened at the start of the universe?

Quantum uncertainty and the nature of existence:

we can't predict the existence of the galaxy nor the
earth on the basis of data at the start of inflation

we can't predict the existence of the giraffes or
humans on the basis of data about the Earth 2
billion years ago

* Take spacetime domains and epochs seriously

NATURE OF CAUSATION:

Four types of causation

1. Purposeless algorithms grinding away **[necessity]**
2. Random events meaninglessly making things happen **[chance]**
3. Selection processes creating order where there was none **[adaptation]**
4. Purposeful action related to meaning, ethics, aesthetics **[purpose]**

They all occur in the real universe

Which is fundamental and which derivative?

ULTIMATE CAUSATION

If everything has a cause, what causes the universe?

Relation to life and the anthropic issue

**Relation to purpose and human qualities
Special or general nature**

**Emergence of totally new kinds of existence
Or are they preordained: If so how and why**

**Application: can meaning really emerge
out of non-meaning?**

It has at least to be foreshadowed in the possibility space

**And the data relates to the whole of life
- Not just physics and astronomy**

WHAT KINDS OF QUESTION DO YOU WISH TO ANSWER?

Why does the Alhambra exist?

Cosmology or cosmology?

Purpose and meaning?

Or just physical causation?

Use models and data of adequate scope for your purpose

Multiverses: The big issue

The very nature of the scientific enterprise is at stake in the multiverse debate: the multiverse proponents are proposing weakening the nature of scientific proof in order to claim that multiverses provide a scientific explanation. This is a dangerous tactic. **And it does not solve ultimate issues!**

Note: we are concerned with ***really existing*** multiverses, not potential or hypothetical.

Ironic when Dawkins on the one hand insists that the virtue of science is testability and on the other strongly supports a multiverse to explain fine tuning

Science aims at constructing a world which shall be symbolic of the world of commonplace experience. The external world of physics has thus become a world of shadows. In removing our illusions we have removed the substance, for indeed we have seen that substance is one of the greatest of our illusions. Later perhaps we may inquire whether in our zeal to cut out all that is unreal we may not have used the knife too ruthlessly. Perhaps, indeed, reality is a child which cannot survive without its nurse illusion. But if so, that is of little concern to the scientist, who has good and sufficient reasons for pursuing his investigations in the world of shadows and is content to leave to the philosopher the determination of its exact status in regard to reality

(Eddington: The Nature of the Physical World)



NATURE OF CAUSATION:

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Which is fundamental and which derivative?

Given suitable lowest level laws, with restricted structure and coupling constants (Paul Davies), a hierarchy with effective higher level laws can emerge.

But what essentially underlies the lowest level laws on which the rest is based? Why do they exist, with the form they have?

Is the ultimate reason

- Pure chance?**
- Probability?**
- Necessity?**
- Purpose?**

Consider them in turn

1: *Pure chance* (happenstance, this is just the way it was: there is no suggestion that it was a probable outcome of some underlying dynamics)

- is a logically possible ultimate reason,
- but has no further explanatory power,
- indeed it is denial that at a fundamental level there is any explanation,
- and so is unsatisfactory to almost everyone (whether scientifically or religiously inclined),

primarily because we do know that explanations (both impersonal and personal) do indeed exist in the social and mental world.

-Furthermore it is difficult to resist the argument that the outcome is so unlikely that pure chance simply is not credible as a reason.

-Not merely senses (qualia) and emotions but also complex theories such as Einstein's theory of relativity and quantum field theory have come into existence as extraordinarily complex theoretical constructs.

-To suggest these can all arise without existence of any underlying cause, or can come into existence out of pure chaos or nothingness without any further guiding structure, seem simply absurd;

-but if you have such a cause or guiding structure you don't have pure chaos or nothingness.

2: Probability: For the scientist, probability trumps a lack of any explanation.

-But probability by itself is always an incomplete explanation: for what underlies the laws that govern those probabilities?

-One can do complex calculations to obtain probabilities, but why are the assumed laws underlying these probabilistic calculations valid in the first place?

-And in any case, probability is a good explanation for intermediate levels of explanation but there is no evidence it applies in the context of ultimate causation, indeed the very concept of probability is not applicable if there is only one object (the unique universe) in existence.

-On the other hand, there is no way it can be proved to be true if it does indeed apply via a multiverse context.

-That hypothesis is an attractive explanatory proposal but is not testable physics;

-and if it were to exist, the whole issue of probability arises again as regards the multiverse (why this one rather than another?),

-leading to the spectre of infinite regress: we explain the probability of a specific multiverse by assuming an ensemble of multiverses.

-In brief: the unique universe that actually exists may well not be probable, as was taken for granted in the past, indeed this is probably the case!

3: *Necessity* is highly implausible:

-how could it be that the existence of love and pain and intellect is *necessarily* written into variational principles and symmetries such as SU(10) or E8?

-It seems to fail in any case because fundamental physics is presently going the other way:

-the hoped for uniqueness of fundamental theories has evaporated and been replaced by the multiple billions of possibilities of string vacua.

-In any case the attempt to implement necessity leaves unexplained the choice of those specific realised features that lead to the necessity.

-Why should physics have the specific nature that leads to particular high level features being necessary? (given the nature of the physics).

- What has to be explained includes,

-where do the very causal categories of chance, necessity, and purpose come from?

-How do these concepts arise and have meaning, and what underlying ontological entities or causation do they represent? Why are they themselves necessary?

-How can they even be relevant, as this whole discussion supposes, if there is no ontological referent that makes the dichotomy between them a meaningful issue?

4: Purpose:

Given the totally different quality of existence that emerges in human life from the underlying physics, and the huge fine tuning that is needed for this to occur, an underlying intention or purpose that this should indeed be the case is a possible fundamental option. *It was meant to be that way.*

- It is this higher level set of purposive principles – the underlying telos – that is then the ultimate cause both of existence and its specific nature.

-This then relates to religious or spiritual views of the nature of reality, supported by a variety of evidence relative to those domains

It is unlikely this kind of underlying intention could be effective, with emergence of a physical structure where purpose can be meaningfully deployed so that ethical behaviour is meaningful,

-unless on the one hand the lower level laws had the kind of impersonal regular behaviour that allows reliable higher level behaviour to emerge, and thus allows a mathematical description,

-and on the other something like quantum uncertainty was present so as to free the higher levels from total lower level determinism.

-Thus implementing this proposal necessarily invokes the other two:

-meaningful purpose entails both necessity and chance.

-Each of these kinds of causation (chance in the sense of probability, necessity, and purpose) does indeed occur in the world in various contexts,

-but the only one that seems to entail the possibility of being a deep foundation for the others is purpose.

Thus an underlying intention or purpose that this should indeed be the case is a possible fundamental option, indeed offering the very ground out of which they themselves can come into existence.

The core of being, is then on this view, the underlying ultimate purpose of everything: relating to meaning and morality.

One can argue that this purpose is, as identified by the spiritual tradition all the major world religions, Unselfish Love (“Agape Love”, Sir John Templeton)

-A layered structure emerges: purpose underlies impersonal laws that underlie the emergence of purpose.

-Two kinds of causation: intentional and impersonal, which undoubtedly both exist in the world around us, occur in an intertwined way,

-with chance events intervening and helping to lead to the richness of outcomes we see around us.

- What kind of evidence is relevant?

-data from the whole of life, not just physics or astronomy

- we are part of the universe and live in it;

- dealing with ultimate meaning, therefore what is relevant is whatever seems to give ultimate meaning in human life

- There is indeed purpose in the universe (for example we are here to understand its nature a bit better)

- Either purpose emerges out of nothing, or is there from the start as the foundation, then being reflected in life

- The latter is a possibility for ultimate causation

Finally, it should be emphasized that if one takes this stand, it is not a scientific conclusion,

- nor is the argument presented one that can be sustained on scientific grounds alone;

- it is a philosophically based conclusion.

-The issues considered here (the nature of ultimate causation) are not amenable to scientific resolution,

-precisely because they go beyond the domain where scientific experiments or observations can give a reliable answer.

-The argument is thus a philosophical or metaphysical one, based securely on current science but also taking into account wider philosophical and human issues than can be handled by science *per se*.

- Any attempt to adequately tackle the fundamental issues considered here will necessarily be of this nature.

-If one wishes to deal purely in terms of scientific argumentation, then the above will be beyond what one will consider as legitimate argument.

-But if one takes that stand, allowing scientifically rigorous explanation alone, one should also carefully refrain from making any statements about issues of ultimate causation

-Such statements cannot be made legitimately on a purely scientific basis

“I say to myself as I watch the niece, who is very beautiful: in her this bread is transmuted into melancholy grace. Into modesty, into a gentleness without words ... Sensing my gaze, she raised her eyes towards mine, and seemed to smile .. A mere breath on the delicate face of the waters, but an affecting vision.

I sense the mysterious presence of the soul that is unique to this place. It fills me with peace, and my mind with the words: `This is the peace of silent realms'. I have seen the shining light that is born of the wheat.”

- *Flight to Arras.* Antoine de St. Exupery

So is the ultimate reason

- Pure chance?**
- Probability?**
- Necessity?**
- Purpose?**

They are all logically possible.

Neither science nor philosophy can give a certain answer: metaphysical uncertainty remains.

However if one wants to relate to the deeper meaning of personal life, the last option has the most traction. The others in the end provide a more tentative relation to morality and meaning: but we do have experience these do indeed exist.

Let us then examine the kind of knowledge which is handled by exact science. If we search the examination papers in physics and natural philosophy for the more intelligible questions we may come across one beginning something like this: 'An elephant slides down a grassy hill-side...' The experienced candidate knows that he need not pay much attention to this; it is only put in to give an impression of realism. He reads on: 'The mass of the elephant is two tons.' Now we are getting down to business; the elephant fades out of the problem and a mass of two tons takes its place. What exactly is this two tons, the real subject-matter of the problem? It refers to some property or condition which we vaguely describe as 'ponderosity' occurring in a particular region of the world. But we shall not get much farther that way; the nature of the external world is inscrutable, and we shall only plunge into a quagmire of indescribables. Never mind what two tons refers to; what is it? How has it actually entered in so definite a way into our experience? Two tons is the reading of the pointer when the elephant was placed upon a weighing-machine.

Let us pass on. 'The slope of the hill is 60° .' Now the hill-side fades out of the problem and an angle of 60° takes its place. What is 60° ? There is no need to struggle with mystical conceptions of direction; 60° is the reading of a plumb-line against the divisions of a protractor. Similarly for the other data of the problem.

The softly yielding turf on which the elephant slid is replaced by a coefficient of friction, which though perhaps not directly a pointer reading is of kindred nature. No doubt there are more roundabout ways used in practice for determining the weights of elephants and the slopes of hills, but these are justified because it is known that they give the same results as direct pointer readings. And so we see that the poetry fades out of the problem, and by the time the serious application of exact science begins we are left with only pointer readings.

If then only pointer readings or their equivalents are put into the machine of scientific calculation, how can we grind out anything but pointer readings? But that is just what we do grind out. The question presumably was to find the time of descent of the elephant, and the answer is a pointer reading on the seconds' dial of our watch.

The triumph of exact science in the foregoing problem consisted in establishing a numerical connection between the pointer reading of the weighing-machine in one experiment on the elephant and the pointer reading of the watch in another experiment. And when we examine critically other problems of physics we find that this is typical. The whole subject-matter of exact science consists of pointer readings and similar indications

The deep issue in both cosmology and human life is what underlies the existence of the laws of nature, which define the possibility space within which the universe and life comes into being

Why do any such laws exist at all, and why do they have the nature they have, leading to our physical and mental existence?

Is the ultimate reason pure chance, probability, necessity, or purpose?

Furthermore, what is the nature of their existence: is it prescriptive or descriptive?

We want to understand the existence and nature of causal laws that allow true complexity to come into existence:

An evolving universe that leads to existence of galaxies, stars, planets, and life.

True complexity arises in modular hierarchical structures, that allow emergence of complexity

- In evolutionary terms (very long timescales)**
- In developmental terms (long to medium timescales)**
- In functional terms (medium to short timescales)**

This hierarchy is based at the lowest levels in

- specific families of particles, interacting through four fundamental forces (unified at high energies)**
- based in quantum mechanical principles**
- interactions describable by variational principles subject to fundamental symmetries entailing conservation laws**
- with specific masses and interaction strengths**
- subject to special relativity theory**
- with the exact symmetries of the theory broken**
- all taking place in a 4-dimensional Riemannian space-time**

I suggest that, firstly, at each level of the hierarchy of complexity, universal principles apply, best thought of in Platonic terms.

Each level exists in its own right, even though it is based in lower levels, and the laws at that level are effective laws deriving from action at lower level.

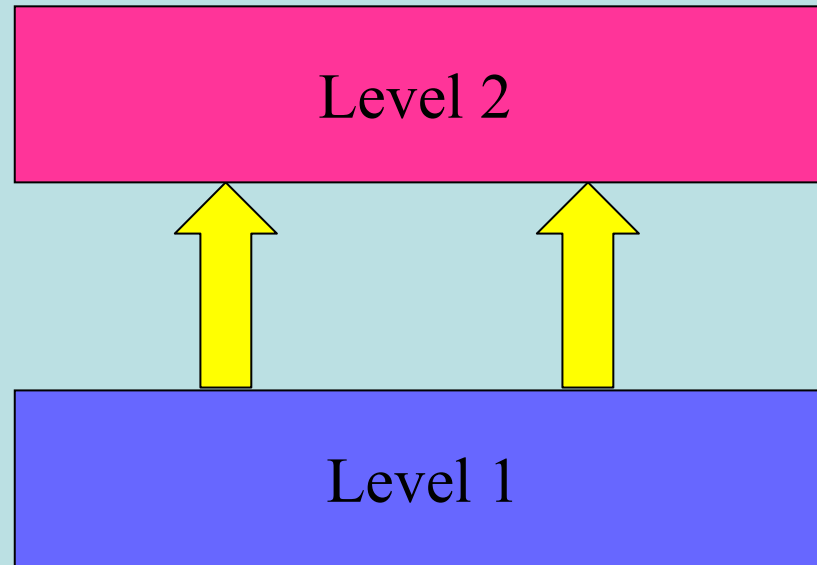
The way these laws work out is shaped by the higher level contexts in which they act, leading to effective laws at each level that may be thought of as having an ontological reality.

They control what happens at each level in a way independent of time and place, and independent of our understandings and descriptions.

2: Bottom-up and Top-down

Bottom-up action is when what happens at the higher levels is controlled by what happens at the lower levels

- *micro-physics underlies macro physics, e.g. kinetic theory of gases, theory of solids (conduction, thermal capacity)*
- *physics underlies chemistry, e.g. nature of chemical bond*
- *protein folding and recognition is based on chemical bonding*
- *cells with their own internal function underlie all life,*
- *physics and chemistry underlie the functioning of the brain*
- *individual human behaviour underlies the functioning of society*



Bottom-up causation alone:

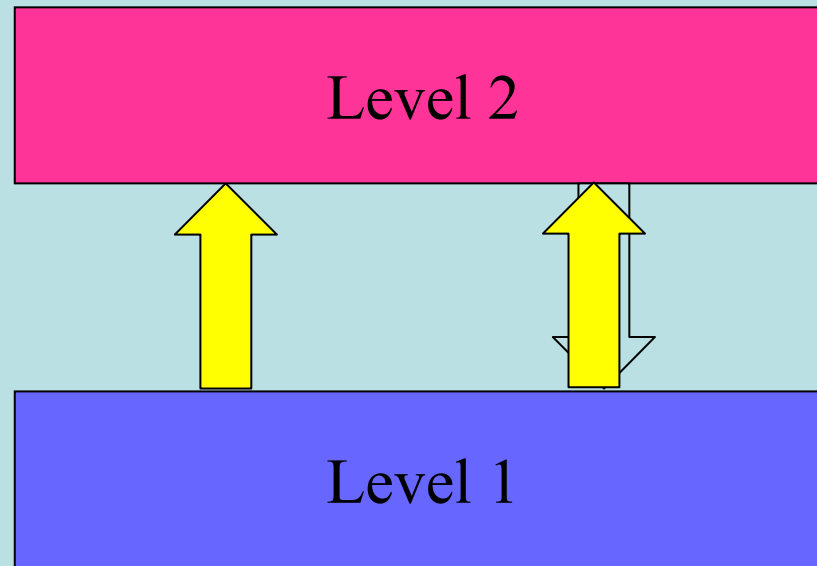
Micro forces determine what happens at the higher levels

They are the foundation of higher level activity

Bottom-up and Top-down action

Top-down action is when the higher levels of the hierarchy causally effect what happens at the lower levels, in a coordinated way.

- *multiple top-down action as well as bottom up action, enables self-organisation of complex systems*
- *enables higher levels to co-ordinate action at lower levels, and so gives them their causal effectiveness, by determining their context*
- is prevalent in the real physical world and in biology, because no real physical or biological system is isolated.
- boundary effects (linking the system to the environment) as well as structural relations in the system itself effect top-down action.



Bottom-up and top-down causation:

*Additionally the higher levels control
causal effects at the lower levels*

1: The synthesis of light elements in the early universe. The amount of helium produced depends on the rate of change of temperature in the expanding universe, which is controlled by the gravitational equations and the average amount of matter in the universe. Thus quantities defined at the cosmological level control the products of detailed nuclear reactions at the micro level.

2: Training of artificial neural nets to perform a specific task (say letter recognition) determines the interaction weights in the network. This is a form of top-down causation from the pattern to be recognized (a high-level concept, as it is defined in terms of the relation between the elements) to the low-level property of network weights. Decision making is a property of the network rather than of any single cell.

3: The power of the human mind in the real world



Boeing 747-400

- Any attempt to adequately tackle the fundamental issues considered here will necessarily be of this nature.

-If one wishes to deal purely in terms of scientific argumentation, then the above will be beyond what one will consider as legitimate argument.

-But if one takes that stand, allowing scientifically rigorous explanation alone, one should also carefully refrain from making any statements about issues of ultimate causation

-Such statements cannot be made legitimately on a purely scientific basis

Varieties of Multiverse

Brian Greene (*The Hidden Reality*) advocates nine different types of multiverse:

1. Invisible parts of our universe
2. Chaotic inflation
3. Brane worlds
4. Cyclic universes
5. Landscape of string theory
6. Branches of the Quantum mechanics wave function
7. Holographic projections
8. Computer simulations
9. All that can exist must exist – “grandest of all multiverses”

They can't all be true! – they conflict with each other.

10. Maybe none of them is true – there is just one universe.

Two central scientific virtues are **testability** and **explanatory power**. In the cosmological context, these are often in conflict with each other.

The extreme case is multiverse proposals, where no direct observational tests of the hypothesis are possible, as the supposed other universes cannot be seen by any observations whatever, and the assumed underlying physics is also untested and indeed probably untestable.

In this context one must re-evaluate what the core of science is: can one maintain one has a genuine scientific theory when direct and indeed indirect tests of the theory are impossible?

If one claims this, one is altering what one means by science. One should be very careful before so doing.

There are many other theories waiting at the door –wanting to be called science (astrology, Intelligent Design, etc)

Given this situation, what are the arguments and evidence for existence of a multiverse?

1: *Slippery slope:*

there are plausibly galaxies beyond the horizon, where we can't see them; so plausibly many different expanding universe domains where we can't see them

Untestable extrapolation; assumes continuity that may or may not be true. Outside where we can see, there might be (a) an FRW model, (b) chaotic inflation, (c) a closed model, (d) an island universe. No test can be done to see which is the case .

If each step in a chain of evidence is well understood and inevitable, then indirect evidence carries nearly as much weight as direct evidence. But not all the steps in this chain are inevitable.

If employed leads to the old idea of **spatial homogeneity**

2 *Implied by known physics* that leads to chaotic inflation

The key physics (e.g. Coleman-de Luccia tunneling, the string theory landscape) is extrapolated from known and tested physics to new contexts; the extrapolation is unverified and indeed is unverifiable; it may or may not be true.

The parameter values that lead to eternal chaotic inflation may or may not be the real ones.

The physics is hypothetical rather than tested!

Known Physics → **Multiverse ??**

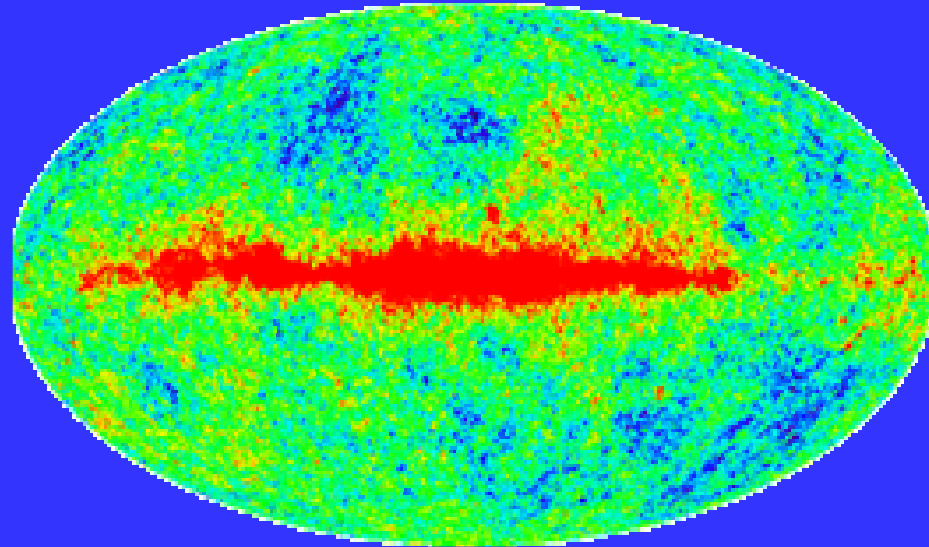
NO!

Known Physics → **Hypothetical Physics** → **Multiverse**
Major Extrapolation

It is a great extrapolation from known physics.

This extrapolation is untestable: it may or may not be correct.

3: Implied by inflation, which is justified by CBR anisotropy observations



- it is implied by some forms of inflation but not others; inflation is not yet a well defined theory (and not a single scalar field has yet been physically detected). **Not all forms of inflation lead to chaotic inflation.**
- *For example inflation in small closed universes*

4: Implied by *probability argument: the universe is no more special than need be to create life.*

Hence the observed value of the Cosmological constant is confirmation [Weinberg].

But **the statistical argument only applies if a multiverse exists**; it is simply inapplicable if there is no multiverse.

In that case we only have one object we can observe; we can do many observations of that one object, but it is still only one object (one universe), and you can't do statistical tests if there is only one existent entity

In fact no value of the cosmological constant can prove a multiverse either exists or does not exist.

This is elementary logic!

1. If $M \Rightarrow L$, it does not follow that $L \Rightarrow M$

2. If $M \Rightarrow L$ only probabilistically, it does not follow that $\{\text{not } L\} \Rightarrow \{\text{not } M\}$

although it may shorten the odds -

IF there is a valid context in which probability applies.

There is no value of Λ that PROVES a multiverse exists

This is in fact a *weak consistency test* on multiverses, that is indicative but not conclusive (a probability argument cannot be falsified).

Consistency tests must be satisfied, but they are not

5: Can be disproved if we determine there are closed spatial sections because curvature is positive: $k = +1$

The claim is that only negatively curved FRW models can emerge in a chaotic inflation multiverse.

5a: because Coleman-de Luccia tunneling only gives $k = -1$;

But that claim is already disputed, there are already papers suggesting $k=+1$ tunneling is possible

- indeed it depends on a very specific speculative mechanism, which has not been verified to actually work, and indeed such verification is impossible.

5b: because the spatial sections are then necessarily closed and are all that is, if they extend far enough

- but we could live in high density lump imbedded in a low density universe: the extrapolation of $k=+1$ may not be valid

6: It is the only *physical explanation for fine tuning of parameters* that lead to our existence,

- in particular the value of the cosmological constant

Valid supportive argument, but not proof

[n.b. theoretical explanation, not observation]

7: It results from the theory that “*everything that can happen, happens*” (Lewis, Sciama, Deutsch) as suggested by Feynman QFT approach

[n.b. theoretical explanation, not observation]

Which is more important in cosmology:

TDC: The key analytic idea

The key conceptual idea is that of **functional equivalence classes**: each equivalence class is a set of lower level states all that correspond to the same higher level state

- When you coarse grain, all of these lower level states correspond to the same higher level state
- Entropy is a measure of how many lower level states correspond to a specific higher level state (Penrose)
- **Whenever you can identify existence of such equivalence classes, that is an indication that top-down causation is taking place**

This is what occurs in gauge theories of physics.

- **Hence existence of gauge theories is an indication of topdown causation taking place in physics.**