Cosmological Laws without Real Time

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Questions in Cosmology

- What kind of science is cosmology? (Historical? Law-seeking?)
- What are the appropriate explanatory aims of cosmology?

Smolin and Mangabeira Unger

- These questions intricately connected to the status of time
- Agenda for cosmology based on "Real Time" and Leibnizian approach

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Outline

1. Manifest and Scientific Image of Time
2. Nature and Aims of Cosmology
3. Evolving Laws

Manifest Image of Time

1. Duration, Intervals
   - Parts of "all Time"
   - Points in time
2. Temporal Order (absolute)
3. Past / Present / Future
4. Flow or Passage (universal)

Scientific Image of Time

What properties of time are presupposed by successful scientific theories?

Many aspects of manifest image (apparently) *not needed* for physics

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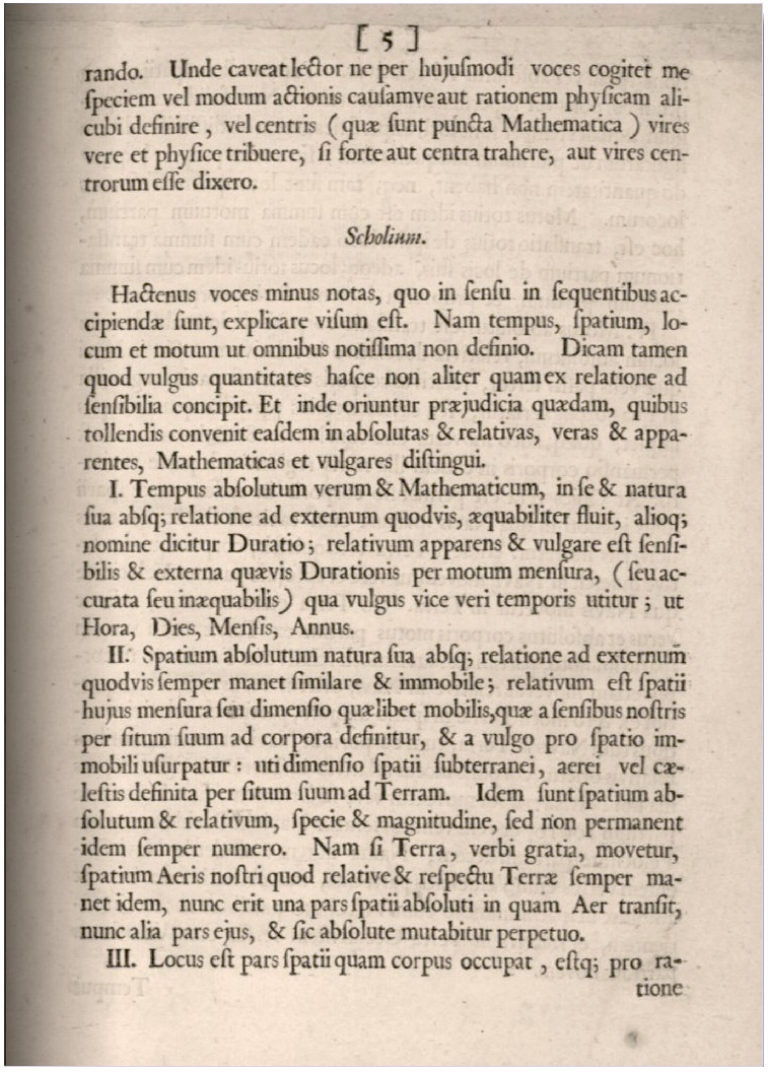
Newtonian Time



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rando. Unde caveat lector ne per hujuſmodi voces cogitet me ſpeciem vel modum actionis cauſamve aut rationem phyſicam alicubi definire, vel centris (quæ ſunt puncta Mathematica) vires vere et phyſice tribuere, ſi forte aut centra trahere, aut vires centrorum eſſe dixero.

Scholium.

Hactenus voces minus notas, quo in ſenſu in ſequentibus accipiendæ ſunt, explicare viſum eſt. Nam tempus, ſpatium, locum et motum ut omnibus notiſſima non definio. Dicam tamen quod vulgus quantitates haſce non aliter quam ex relatione ad ſenſibilia concipit. Et inde oriuntur præjudicia quædam, quibus tollendis convenit eaſdem in abſolutas & relativas, veras & apparentes, Mathematicas et vulgares diſtingui.

I. Tempus abſolutum verum & Mathematicum, in ſe & natura ſua abſq; relatione ad externum quodvis, æquabiliter fluit, alioq; nomine dicitur Duratio; relativum apparens & vulgare eſt ſenſibilis & externa quævis Durationis per motum menſura, (ſeu accurata ſeu inæquabilis) qua vulgus vice veri temporis utitur; ut Hora, Dies, Menſis, Annus.

II. Spatium abſolutum natura ſua abſq; relatione ad externum quodvis ſemper manet ſimilare & immobile; relativum eſt ſpatii hujus menſura ſeu dimenſio quælibet mobilis, quæ a ſenſibus noſtris per ſitum ſuum ad corpora definitur, & a vulgo pro ſpatio immobili uſurpatur: uti dimenſio ſpatii ſubterranei, aerei vel cæleſtis definita per ſitum ſuum ad Terram. Idem ſunt ſpatium abſolutum & relativum, ſpecie & magnitudine, ſed non permanent idem ſemper numero. Nam ſi Terra, verbi gratia, movetur, ſpatium Aeris noſtri quod relative & reſpectu Terræ ſemper manet idem, nunc erit una pars ſpatii abſoluti in quam Aer tranſit, nunc alia pars ejus, & ſic abſolute mutabitur perpetuo.

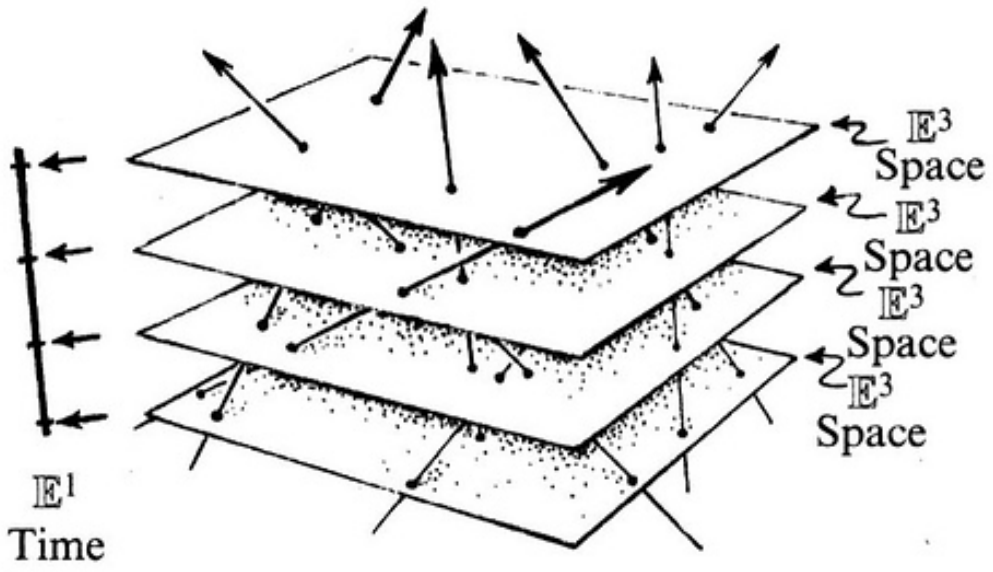
III. Locus eſt pars ſpatii quam corpus occupat, eſtq; pro ratione

Scholium to the Definitions, from *Principia Mathematica*

Formulating Dynamics

- *Inertial* vs. *accelerated* motion
- Quantities appearing in force laws (e.g., spatial distance at an instant)

Newtonian Time



From Roger Penrose, *The Road to Reality*

Formulating Dynamics

- Time as one-dimensional space $\mathbb{T}$
- Global: well-defined time interval between *any* two events
- Absolute: interval independent of state of motion

Manifest Image of Time

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- $\mathbb{T}$ includes (1) and (2)
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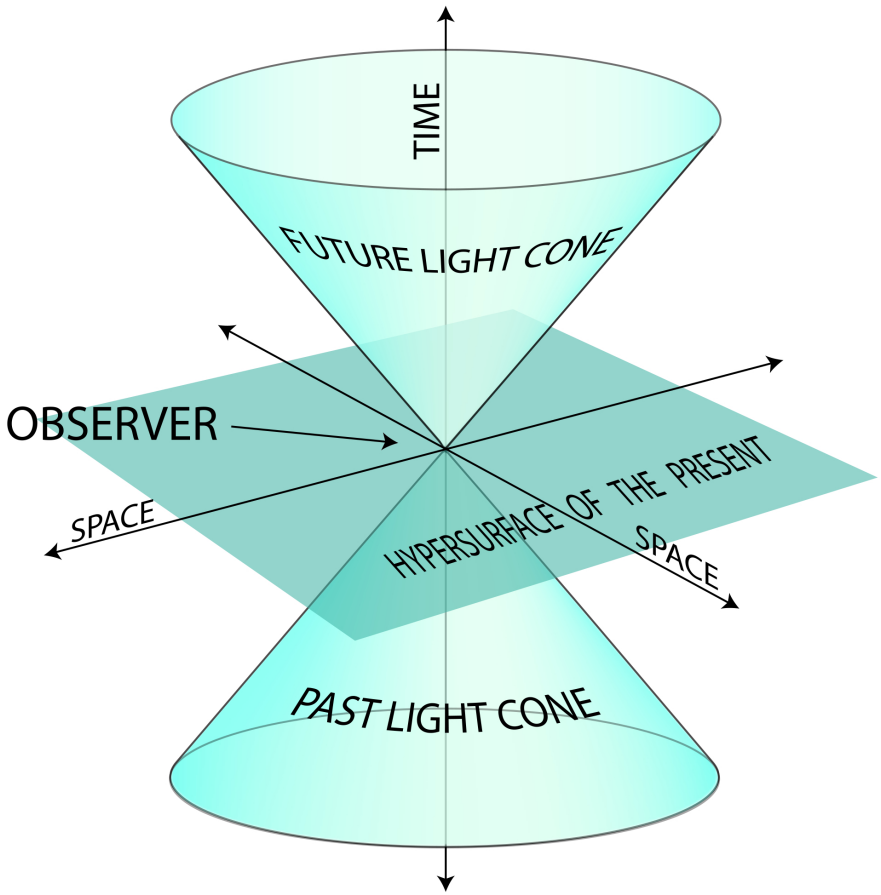
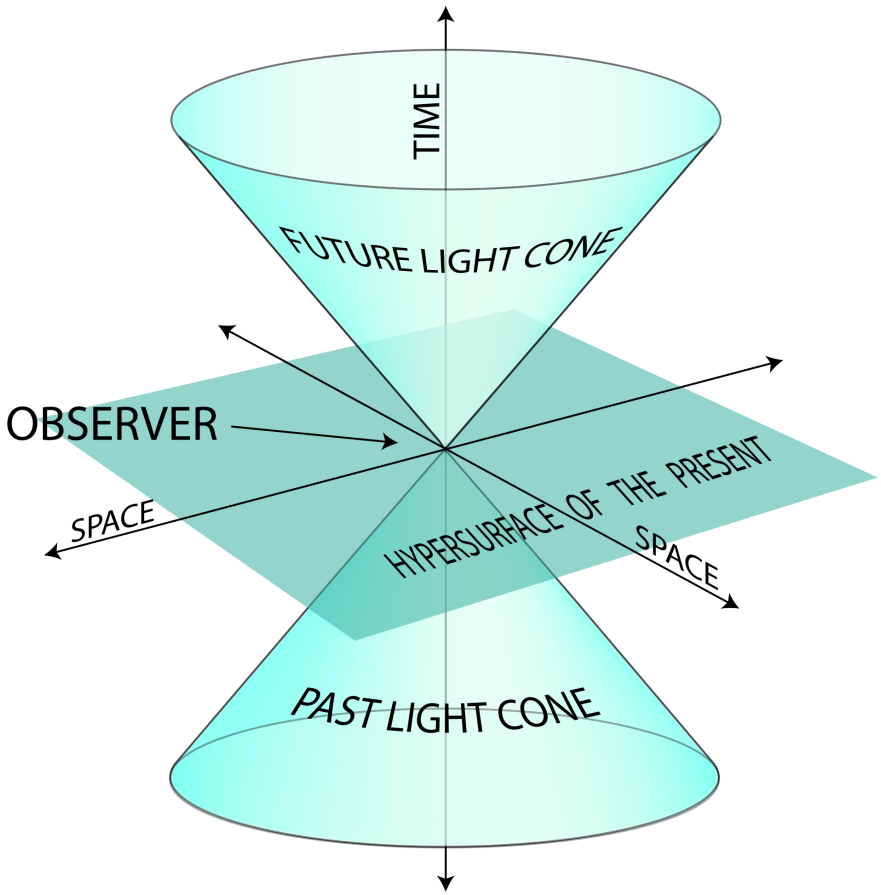
Reconcile Manifest and Scientific Images?

- *Indifference*: Aspect of manifest image *not* presupposed by or relevant to particular inquiry; no *obstacle* to reconciliation
- *Elimination*: Aspect of manifest image decisively undermined or rendered otiose; *explained away* rather than reconciled



Minkowskian Image of SpaceTime

- Invariant *spacetime* interval
- Field equations: local interactions



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Henceforth space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality.

(Minkowski 1908)

Eliminativist Argument

Spatial and temporal distance, separately, no longer invariant.

"Explain away" these features of manifest image; distance traveled by light in one second $>>$ length scale of ordinary objects.

Eliminativist Argument II: Relativity of Simultaneity

Introduce R ="Real with respect to," or "definite" (transitive, reflexive relation R over events)?

- Putnam et al.: there is no such relation, relativity implies "block universe"
- Stein (1968, 1991): define R' = "already definite," "having become" as past light cone of a given point.
- *Can have a sense of passage*, albeit with counterintuitive features. (Observer dependent.)

I remarked that all that occurs objectively can be described in science; on the one hand the temporal sequence of events is described in physics; and, on the other hand, the peculiarities of man's experiences with respect to time, including his different attitude towards past, present, and future, can be described and (in principle) explained in psychology.

(Carnap 1963, reporting discussion with Einstein)

Arguments for Timelessness

- Aspects of manifest image *not needed* in physics...

  ... *yet*. Could be introduced in new physics or in other domains.

- *Reform* conception of time, without eliminating it entirely as an illusion

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Timelessness and the Newtonian Paradigm

- Smolin's assessment of Eliminativist Arguments
  - Establish "timeless" view, block universe
  - 9 arguments, from different theories; one common ingredient
- Newtonian Paradigm
  - Dynamical theories applicable to subsystems of the universe
  - Operationalized contrast between laws and initial conditions
  - Time treated as "external parameter"

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Aims for 21st Century Cosmology

1. Conservative: preserve existing successes
2. Scientific: "imply specific testable predictions"
3. Why these laws?
4. Why these initial conditions?

"Leibnizian" vs. "Newtonian" Cosmology

Newtonian Cosmology

- Local to global extrapolation

  "Cosmological Fallacy": Apply physical laws relevant for subsystems to universe as a whole

Leibnizian Cosmology

- Principle of Sufficient Reason:
  "... there should be an answer to any reasonable question ... about why the universe has some particular feature"
- Principle of Explanatory Closure:
  "No chains of explanation can point outside the universe"
- Principle of Identity of Indiscernibles

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Defense of Newtonian Approach

1. Success of current Standard Model of Cosmology
   - Extrapolation of GR, particle physics far beyond empirically tested domains
   - Require supplementary conditions to derive specific models, but *not* restricted to "subsystems"
   - Cosmological laws: (i) local dynamical laws extrapolated to universe as a whole, (ii) laws formulated in terms of global properties of the universe
2. Implications of Uniqueness of the Universe?
   - Test cosmological laws via successive approximations, more detailed descriptions of unique system
   - Problems with very early universe: due to *inaccessibility* of physics rather than *inappropriate method*

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Smolin's Leibnizian Approach

- Newtonian Cosmology: Explanatorily Insufficient
  - Why these laws?
  - Why these (apparently improbable) initial conditions?
  - These both treated as explanatory stopping points, brute facts
- New Approach
  - Explain laws / initial conditions as products of evolution
  - Real Time: globally well defined "present moment"

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What is an Evolving Law?

Definition

Laws Evolve = not time translation invariant with respect to global time parameter t.

Law L evolves with respect to t if for any model M which entails the law L at some t, there is no M' that: (i) entails the same law L and (ii) is a time translation of M, i.e. $M'|_{t=\epsilon+\delta} \approx M|_{t=\epsilon}$, for all $\epsilon, \delta \in \mathbb{R}, \delta \neq 0$.

Weaker: laws evolve during some period $t_i \leq t \leq t_f$

Historical Aside: Worries about Evolving Laws

But when we wish to consider the behaviour of the entire universe, then the logical basis for a distinction between "inherent" laws and "accidental" conditions disappears. Any observation of the structure of the universe will give as unique a result as, for instance, the determination of the velocity of light or the constant of gravitation. And yet, if we were to contemplate a changing universe we should have to assume some such observations to represent "accidental" conditions and others "inherent" laws.

Such assumptions were in fact implied in all theories of evolution of the universe; they were necessary to specify the problem. Without them, there would be no rules and hence unlimited freedom in any extrapolation into the future or into the past...

(Bondi, Gold, and Hoyle 1948)

Reintroducing Global Time

Shape Dynamics

- Reformulation of GR, introduces global time
- t: parameter along foliation, CMC slicing
- Evolution with respect to global time t

Real Time?

- *No connection* between t and manifest image, "passage" and "global present": globally defined, non-local, compatible with lack of preferred time for subsystems
- Alternative motivation: need global time for formulation of scientific hypothesis (evolving laws)

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Hypotheses without "Real Time"

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Cogency of Evolving Laws

- Meta-Law Dilemma and Explanatory Regress
  - Suppose evolution of law L described as $L(t)$, solution of meta-law $\mathbb{L} \rightarrow$ explanatory regress
  - $\mathbb{L}$ must be of a different character than other physical laws
- Philosophical Accounts of Laws
  - Best Systems Account: evolution ruled out by defining laws as "best system" for instantiations of occurrent properties for *entire universe*.
  - Could define "laws for some spacetime region" instead...
  - Lange (2008): evolution ruled out if laws defined in terms of counterfactual stability

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Time in Cosmology

"Leibnizian" Cosmology

1. Eliminativist Arguments
2. Explanatory Aims
3. Real Time and Evolving Laws

Replies

1. *Reform* rather than *Elimination*
2. Defense of "Newtonian" Approach
3. Evolving Laws
   - *Global* rather than *Real* time
   - Cogency of evolving laws