Rebooting Physics: Smolin on Strings, Relativity, and the Dark Underbelly of the Academy

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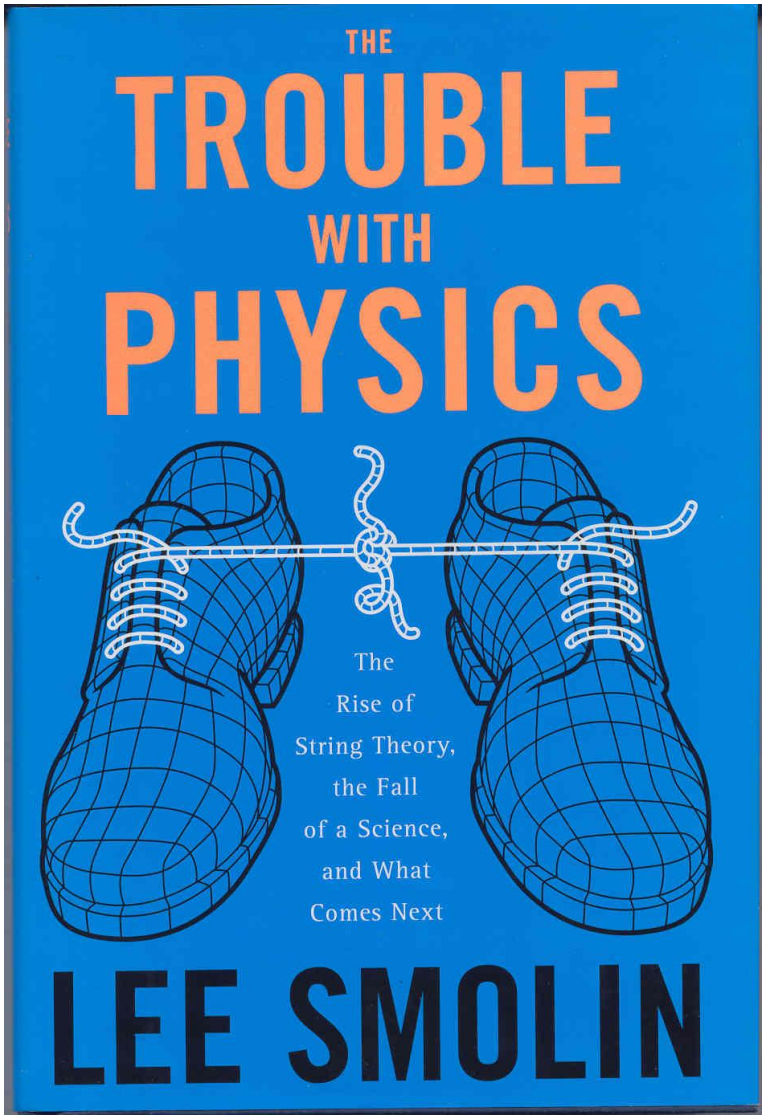
Who is Lee Smolin?

- PhD (Harvard).
- Many publications on GR, cosmology, theoretical biology, quantum gravity, and particle theory (including 18 papers on string theory)
- Currently at Perimeter Institute, Waterloo.
- Books include the following:
  - *The Trouble With Physics*, 2006.
  - *Three Roads to Quantum Gravity*, 2001.
  - *The Life of the Cosmos*, 1997.



- Smolin's question: "Why, despite so much effort by thousands of the most talented and well-trained scientists, has fundamental physics made so little definitive progress in the last twenty-five years?"

It's Not Just the Fault of String Theory!

- There are serious theoretical problems with string theory; however, the real problems lie with the way science is done these days:
  - "Group think"
  - Excessive risk-aversion
  - Short-term perspective ("how do we get the next grant?")
  - Unwillingness to think philosophically.

What Is String Theory?

- Hypothesis that elementary particles are quantized excitations of tiny 1-d elastic lines of force (strings).
  - It seems that all elementary particles could be understood as functions of natural eigenfunctions (β-functions) of such strings.
  - Veneziano (1968); Nambu, Nielsen, Susskind (1970), Green and Schwarz (1984).
- For details, see Smolin 2006, or Brian Greene, *The Elegant Universe* (1999).

Open and Closed Strings in Space

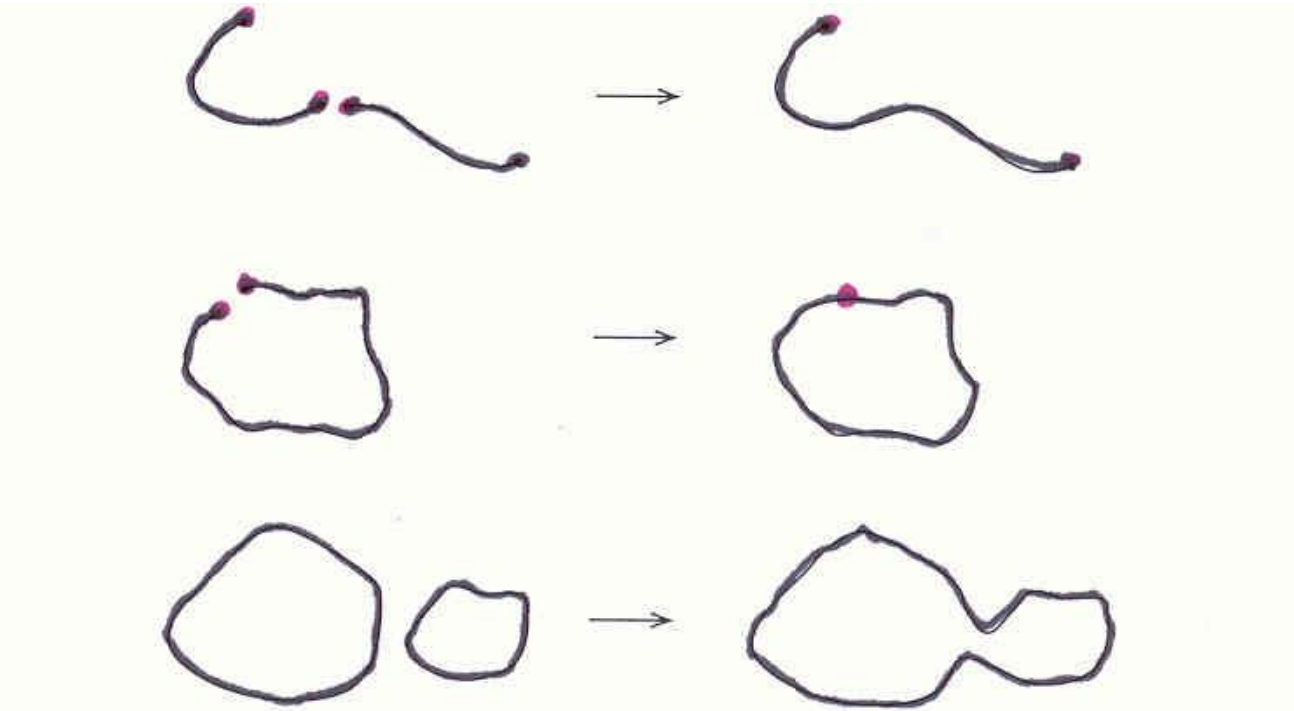


Fig 5. Top: Two open strings join at their ends. Middle: The two ends of an open string join to make a closed string. Bottom: Two closed strings join to make a single closed string.

Spatial and Spacetime Views of Strings

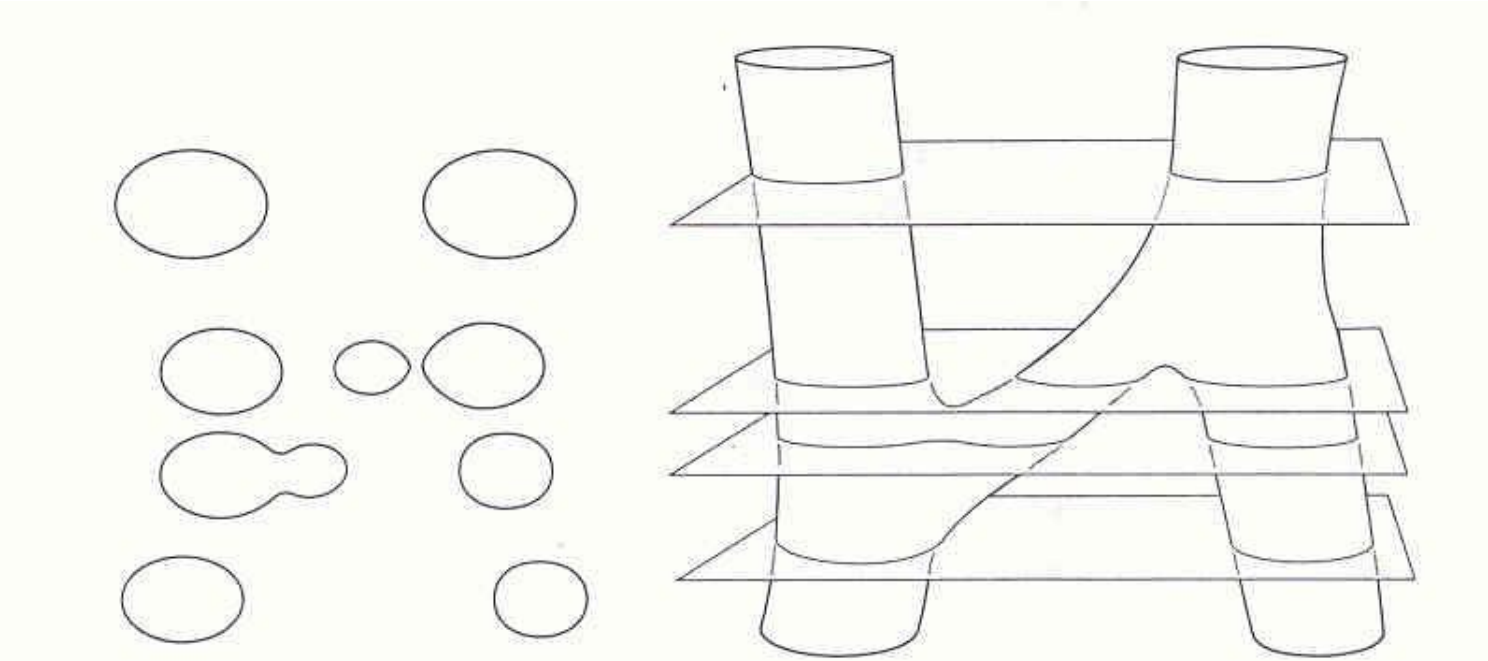


Fig. 6. The propagation and interaction of strings are determined by the same law, which is to minimize the area of the surface in spacetime.

Encouraging Facts about Strings

- In its early days, it seemed to offer a natural unification of the forces, and automatically predicted the existence of the graviton (massless spin 2 quantum of gravity).
- String theory has many cool features, such as multiple spatial dimensions and “branes” which are fun to think about and mathematically interesting.

Problems With Strings

- Predictions too hard to calculate, or untestable at available energies.
  - String theory is “finding approximate solutions to approximate equations.” (Greene, 1999, 140)
  - Georgi: theoreticians jump into higher and higher excited states until there is an observation; then they all fall back into their ground states…!
  - Bring back the SSC!!

Wrong on Cosmological Scale!

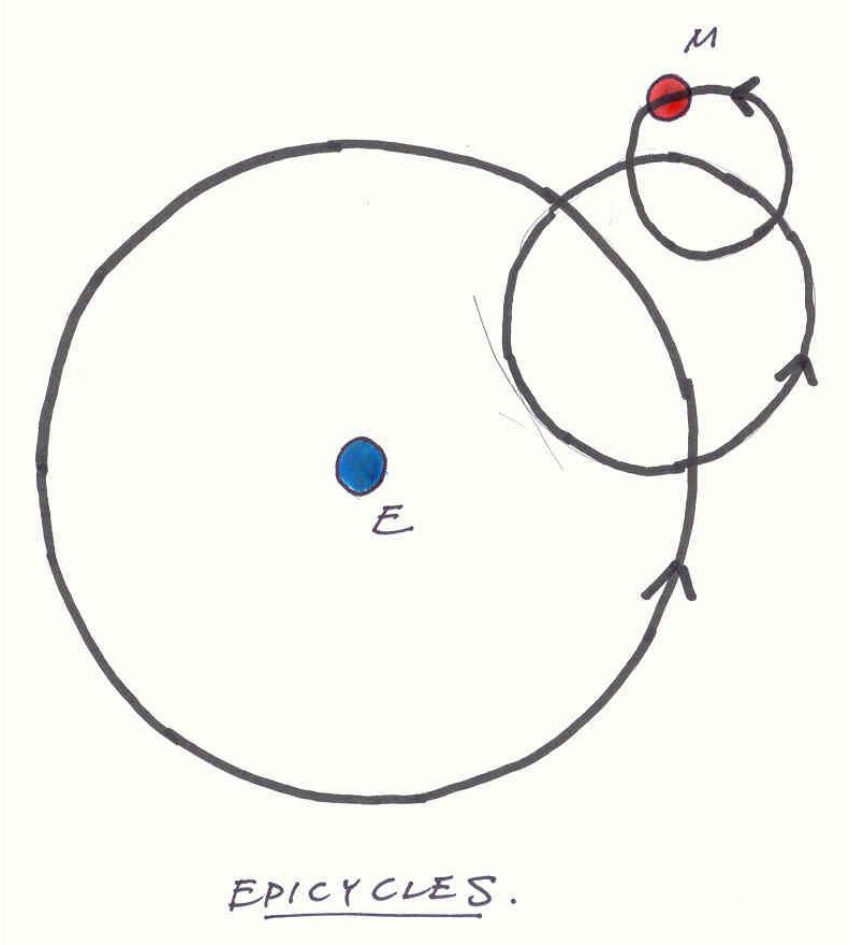
- Predicts wrong sign for cosmological constant.
  - Acceleration of expansion (discovered in 1998) shows that Λ has to be positive.
  - Attempts to get around this lead to 10^{500} or more possible string theories (the "landscape"!)

More Problems…

- There really is no such thing as string theory, just a family of theories held together by conjecture.
  - "M" theory (where "M" stands for "maybe"…)
  - Parameters can be adjusted at will, like Ptolemaic epicycles; you could always add more epicycles.
  - The ability to make testable predictions seems to be one of the most basic criteria for a theory to be considered scientific at all!

The Beauty of Epicycles

- If the theory clashes with observation, just add more epicycles!
- Hence the theory is unfalsifiable.
- Poor Martians!



And the biggest theoretical gap…

- String-theory (like quantum field theory) is background-dependent:
  - This means that it describes what it describes (wiggling quantized strings) against a fixed Minkowski spacetime backdrop.
  - Such theories can be very useful, but such an approach could not possibly be a fundamental theory, because it is not generally covariant; i.e., it violates general relativity.

Toward Quantum Gravity…

- Message of GR is that space itself is a dynamical object.
  - Particles and fields interact in nonlinear way with “background” geometry (“gravitation gravitates”), so there really is no such thing as background geometry; there are no privileged coordinates.

A New Copernican Revolution

- Carlo Rovelli: "GR is the discovery that there is no spacetime at all … quanta … cannot 'live' in spacetime: they must build 'spacetime' themselves … the Universe is not made up of fields on spacetime; it is made up of fields on fields." (2004, 9)
- Move to general covariance is like the Copernican demotion of the Earth from the fixed centre of the universe to merely one of the planets.

Other Cogent Approaches

- Don’t ask me to explain all of these!
- Loop quantum gravity (quantized spacetime, finite, generally covariant)
- Non-commutative geometries (Connes…)
- Twistor theory (Penrose…)
- Connections with quantum statistical mechanics (is quantum gravity the statistical mechanics of space?).
- Spacetime as “emergent” structure.

The Scary Part…

- Most new approaches require major revisions to special relativity:
  - Vacuum becomes dispersive at very high energies.
  - New invariance principle (based on Planck length, Planck time, or Planck velocity? As in DSR).
  - Variable speed of light (helps to explain inflation).
  - Faster than light? (Even Smolin doesn't want to "go there", but we may have to.)
  - Current observations of gamma ray bursts may reveal dispersion.

Where are the predictions?

- Smolin argues that even these other promising approaches are very short on testable predictions.
- “there is something basic we are all missing, some wrong assumption we are all making. … we need to isolate the wrong assumption and replace it with a new idea.”

“[A]toms do fall, so the relationship between gravity and the quantum is not a problem for nature. If it is a problem for us, it must be because somewhere in our thinking there is at least one, and possibly several, wrong assumptions.” (Smolin 2001, 6)

It's About Time…

- Smolin's suggestion: a lot of our theoretical hang-ups have to do with a lack of understanding of the nature of time.
- "We have to find a way to *unfreeze time* — to represent time without turning it into space." (257)
- Similar views have been expressed by William Unruh, Carlo Rovelli.

The Dark Underbelly…

- How did string theory turn from a legitimate line of inquiry into an ideology?
- Partially due to the culture of particle theory from the 1950s onward:
  - Aggressive, competitive atmosphere, with each researcher trying to be cleverer than the last.
  - Hostility to foundational questions: “just calculate, dammit!”
  - This may have made some sense when the object was to consolidate the gains that had been made by QFT and apply them as widely as possible.

Smolin:

”My hypothesis is that what’s wrong with string theory is the fact that it was developed using elementary-particle physics style of research, which is ill suited to the discovery of new theoretical frameworks. … This competitive, fashion-driven style worked when it was fueled by experimental discoveries but failed when there was nothing driving fashion but the views of a few prominent individuals.” (263)

- Not a knock against string theory *as such*!!
  - "…what has failed is not so much a particular theory as a particular style of research." (262)
  - "The standard model of particle physics was the triumph of a particular way of doing science that came to dominate physics in the 1940s … pragmatic and hard-nosed and favors virtuosity in calculating over reflection on hard conceptual problems."

In other words…

- String theory took off so rapidly after Green and Schwarz 1984 because it was by far the most promising unification proposal that did *not* require us to ask foundational questions (about the nature of space, time, relativity, the quantum…).
- It's basically fancy local QFT.

No Room for Heresy

- "…young string theorists have told me that they feel constrained to work on string theory whether or not they believe in it, because it is perceived as a ticket to a professorship…" (xxii)
- "In the U.S., theorists who pursue approaches to fundamental physics other than string theory have almost no career opportunities…"

Endemic Problems in the Sociology of Science These Days…

- "Groupthink":
  - similar to that which led to Bay of Pigs and Iraq disasters.
  - Smolin found that when he went to the literature to check views that "everyone knows are true," he found that such views often had not, in fact, been proven.
- Cult of personality:
  - "What does Ed think?"

Problems (con't…)

- Short-term thinking:
  - Risk-taking, visionary approaches are strongly discouraged; you have to get a "result" within conventional paradigm to get a job, funding.
- Could similar criticisms be made of other fields of fundamental science (e.g., medical research?)

Seers and Craftspersons

- No room for what Smolin calls the “seers,” the potential Einsteins, de Broglies, and Schrödinger’s we so desperately need.
  - Field is dominated by “master craftsmen” who excel at “normal science.”
- No doubt we need master craftsmen (and women) but something else is needed, too…!

It Gets Worse…

- Increasingly large proportion of grant money goes to older scientists working within accepted paradigms.
- Racism and sexism still persist:
  - Theoretical physics dominated by white male “silverbacks” who are not comfortable with diversity.

Where do we go from here?

- Promote “ethics of science”:
  - Science as “ethical and imaginative community”;
  - by joining, we give up the “childish” need to feel we are in possession of absolute truth
  - “In exchange, [we] receive membership in an ongoing enterprise that over time will achieve what no individual could ever achieve alone.” (302-303)

Hire more crazy people…

- even if their ideas seem too risky.
  - "Deep, persistent problems are never solved by accident; they are solved only by people who are obsessed with them and set out to solve them directly." (314)
- Support other approaches to fundamental physics besides string theory!
- Support foundational work as well as technical work!

Last words from Feynman and Polanyi:

- “Science is the organized skepticism in the reliability of expert opinion.”
  - (R. P. Feynman, Quoted in Smolin, 2006, 307)
- “Authority in science exists to be questioned, since heresy is the spring from which new ideas flow.”
  - (John C. Polanyi, *Globe and Mail*, 2005.)