A Formal literary text

The close symbiotic relationship between observational astronomy and astrophysics is inspiring new ideas and models, and these, in turn, suggest more penetrating observations. In this final chapter, let us consider how observations have shaped our knowledge of the structure of the Universe as a whole. This knowledge is embodied in the so-called **standard model of cosmology**, the **Lambda–Cold–Dark–Matter model** (see below).

Its theoretical structure is underpinned by the huge intellectual achievement of **Einstein's General Theory of Relativity**, worthy of a law of the Universe in its own right.

The two key observational discoveries supporting the model are:

- the expansion of the Universe, and
- the cosmic microwave background (CMB) radiation.

Newton's theory of gravitation successfully accounts for the detailed motions of all the planets in the solar system—except one. In 1855, the French astronomer **Urbain Le Verrier** pointed out that **Mercury**, the planet nearest to the Sun, showed an anomalous orbital precession which could not be explained by Newtonian theory.

The **perihelion** of an orbit is its closest point to the Sun, and when an orbit precesses, the perihelion rotates around the star. Einstein's first test of general relativity used these observations to account successfully for Mercury's motion.motion in this region of more curved spacetime causes the perihelion to advance exactly as predicted by Einstein's theory.

Bolstered by this success, in **1917** Einstein applied his equations to model the **Universe as a whole**.

In this, he assumed the **cosmological principle**, namely that the Universe has no preferred centre and, on large enough scales, looks the same in any direction.

The model predicts **three possible geometries of the Universe**, depending on how much matter is present.

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1. Closed (spherical) Universe

If the matter density is large, space curves to form a **closed or spherical Universe**.

In this geometry, the angles of a triangle in space add up to **more than 180°**, and the expansion of the Universe will eventually slow down and be followed by contraction towards a **big crunch**.

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2. Open Universe

If the matter density is small, space curves into a **saddle shape**, forming an **open Universe**.

In this case, the angles of a triangle add up to **less than 180°**, and the Universe will continue to expand forever, ending ultimately in what has been called the **big freeze**.

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3. Flat (Euclidean) Universe

Between those two cases is the finely balanced geometry of a **flat (Euclidean) Universe**.

Here, the angles of a triangle add up to **exactly 180°**, and the Universe contains just enough matter to **slow the expansion down**

(*an excerpt from Geoff's Cottrell's Observational astronomy)*

A Literary technical text

Relativity permitted continuous deformation, but no cutting and pasting. Why not? Because it had to allow for cause and effect. Influences had to be localized, traveling from point to point at a finite velocity; chop up space-time and rearrange it, and the causal structure would fall apart. What if you were an observer, though, who had no causal structure? A self-aware pattern appearing by chance in the random twitches of a noise machine, your time coordinate dancing back and forth through causally respectable "real time"? Why should you be declared a second-class being, with no right to see the universe your way? Ultimately, what difference was there between so-called cause and effect, and any other internally consistent pattern?

Why shouldn't the pattern we think of as "the universe" assemble itself, find itself, in exactly the same way?"I can piece together my own coherent space and time from data scattered so widely that it might as well be part of some giant cloud of random numbers … then what makes you think that you're not doing the very same thing?"

The djinn's expression hovered between alarm and irritation.

Squeak.

"Paul… what's the point of all this? 'Space-time is a construct; the universe is really nothing but a sea of disconnected events…' Assertions like that are meaningless. You can believe it if you want to… but what difference would it make?"

"What difference? We perceive—we inhabit—one arrangement of the set of events. But why should that arrangement be unique? There's no reason to believe that the pattern—"

Squeak.

“Trial number four. Model partitioned into fifty sections and twenty time sets; sections and states randomly allocated to one thousand clusters.”

“One. Two. Three.”

Paul stopped counting, stretched his arms wide, stood up slowly. He wheeled around once, to examine the room, checking that it was still intact, still complete.

Then he whispered:

“This is dust. All dust. This room, this moment, is scattered across the planet, scattered across five hundred seconds or more—but it still holds itself together. Don’t you see what that means?”

The djinn reappeared, but Paul didn’t give him a chance to speak. The words flowed out of him, unstoppable. He understood.

“Imagine… a universe entirely without structure, without shape, without connections. A cloud of microscopic events, like fragments of space-time… except that there is no space or time.

What characterizes one point in space, for one instant? Just the values of the fundamental particle fields, just a handful of numbers. Now take away all notions of position, arrangement, order—and what’s left?A cloud of random numbers.”

“That’s it. That’s all there is. The cosmos has no shape at all—no such thing as time or distance, no physical laws, no cause and effect.

What we’ve found is the only coherent way of ordering the dust.

There must be billions of other universes coexisting with us, made of the very same stuff—just differently arranged.

If I can perceive events thousands of kilometers and hundreds of seconds apart to be side by side and simultaneous, there could be worlds, and creatures, built up from what we’d think of as points in space-time scattered all over the galaxy, all over the universe.

We’re one possible solution to a giant cosmic anagram… but it would be ludicrous to believe that we’re the only one.”

Squeak.

Durham snorted.

“A cosmic anagram? So where are all the leftover letters? If any of this were true—and the primordial alphabet soup really *is* random—don’t you think it’s highly unlikely that we could structure the whole thing?”

Paul thought about it.

“We haven’t structured the whole thing. The universe is random, at the quantum level. Macroscopically, the pattern seems to be perfect; microscopically, it decays into uncertainty.

We’ve swept the residue of randomness down to the lowest level.