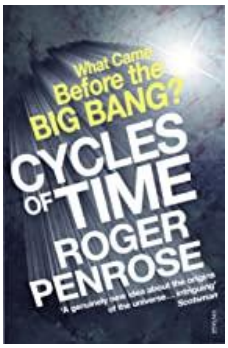

Cycles of Time:
An Extraordinary New View of the Universe

English edition
by Roger Penrose
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In deinem Nichts hoff' ich, das All zu finden.
In your Nothingness, I hope, the All I will recover.
Part 2, Act 1 Faust to Mephistopeles (J. W. Goethe)

The subtitle of the book promises an extraordinary new view of the universe. The author sheds an astonishing new light on the often-asked question, what came before the Big Bang and where is our Universe heading to?

Penrose starts with an in-depth explanation of the second law of thermodynamics and the complex meaning of ever increasing entropy (S) for closed systems, concluding the Big Bang started from a special low entropy in a very tiny space. Entropy is depending on mass - and according to Einstein ($E= m c^2$) and Planck ($E= h v$), mass is equivalent to time.

In the book – which is a combination of lectures in mathematics and physics – an exhaustive overview of cosmological developments and the Big Bang since Einstein is presented.

The robustness of the second law of thermodynamics and its underlying mysteries is emphasized by Penrose stating: "The mere existence of life provides in itself no argument whatever for the full violation of the second law…and there is no indication that entropy comes down in the future except an exotic possibility which can't be ruled out".

In chapter 2 the original steady state model, abandoned after the observed expansion of our Universe by Hubble in 1929, Einstein's modification of the mathematical representation of the general relativity theory by removing and later re-introduction of the "cosmic constant", Penrose explains the Cosmic Microwave Background (CMB) and delves into discussion of space-time, null cones, phase-spaces, metrics and conformal geometry leading to black holes and the oddities of the Big Bang.
As a non-physicist you tend to get lost in the mathematically founded physical explanations and accompanying illustrated diagrams reaching deep into the mathematical and experimental physicist's toolbox.
Chapter 2 concludes with a schematic conformal diagram of Paul Tod's (University Oxford) proposal for a form of 'Weyl curvature hypothesis', "asserting that the Big Bang provides a smooth boundary to the space-time $\mathscr{M}$ ($\mathscr{M}$ Minkowski space)."
Penrose: "To make this condition mathematically clearer, it is convenient to assert it in the form that the space-time can be continued smoothly, as a conformal manifold, a little way **prior** to the hypersurface $\mathcal{B}$-. To before the Big Bang? Surely not: the Big Bang is supposed to represent the beginning of all things, so there can be no '**before**'. Never fear— this is just a mathematical trick. The extension is not supposed to have any physical meaning! Or might it . . .?"

In chapter 3 Roger Penrose elaborates his proposed "Conformal Cyclic Cosmology" (CCC) model with rigorous mathematical logic and his deep knowledge as physicist.
Penrose: "However, I am suggesting 'the next best thing', which is to propose that there is a physically real region of space-time prior to $\mathcal{B}$- which is the remote future of some previous universe phase, and that there is also a physically real universe phase that extends beyond our $\mathcal{J}+$ to become a big bang for a new universe phase. In accordance with this proposal, I shall refer to the phase beginning with our

$\mathcal{B}$- and extending to our $\mathcal{J}$+ as the present **aeon**, and I am suggesting that the universe as a whole is to be seen as an extended conformal manifold consisting of a (possibly infinite) succession of aeons, each appearing to be an entire expanding universe history (see Fig. 3.3).
The '$\mathcal{J}$+' of each is to be identified with the $\mathcal{B}$- of the next, where the continuation of each aeon to the next is achieved so that, as a conformal space-time structure, the join is perfectly smooth." [Cycles of Time, page 147]

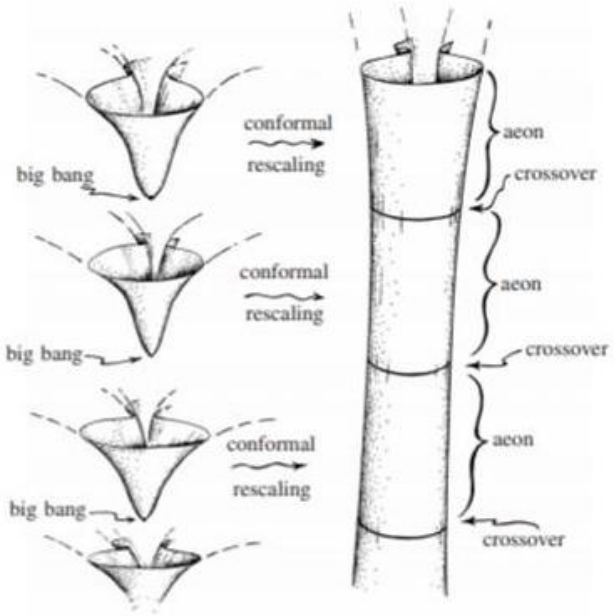

Fig. 3.3 Conformal cyclic cosmology. (As with my drawing in Fig 2.5, I am trying not to prejudice the issue of whether the universe is spatially open or closed.)

"The reader might well worry about identifying a remote future, where the radiation cools down to zero temperature and expands out to zero density, with a big-bang-type of explosion, where the radiation had started at an infinite temperature and infinite density. But the conformal 'stretching' at the big bang brings this infinite density and temperature down to finite values, and the conformal 'squashing' at infinity brings the zero density and temperature up, to finite values. These are just the kinds of rescalings that make it possible for the two to match, and the stretching and squashing are procedures that the relevant physics on either side is completely insensitive to. It may also be mentioned that the phase space P, describing the totality of possible states of all the physical activity on either side of the crossover (see §1.3), has a volume measure which is conformally invariant, [3.11] basically for the reason that when distance measures are reduced, the corresponding momentum measures are increased (and vice versa) in just such a way that the product of the two is completely unchanged by the rescaling (a fact that will have crucial significance for us in §3.4). I refer to this cosmological scheme as conformal cyclic cosmology, abbreviated CCC." [Cycles of Time, page 147]

Penrose: "The 'kick' that the impulse of energy-momentum that the gravitational wave burst will impart on the (presumed) primordial dark matter will have a component in our direction that could be towards us or it could be away from us, depending on the geometrical relation between u, e, and the crossover surface (see Fig. 3.28). This effect of being towards us or away from us would be the same all around the entire circle C. "
Thus, we expect that for each such black-hole encounter in the previous aeon, for which these two spheres intersect, there would be a circle in the CMB sky that contributes either positively or negatively to the background average CMB temperature over the sky.

Some kind of indirect information transfer from the previous aeon to our aeon is speculated by Penrose to be seen in the CMB using Wilkinson Microwave Anisotropy Probe (WMAP) images. [1]

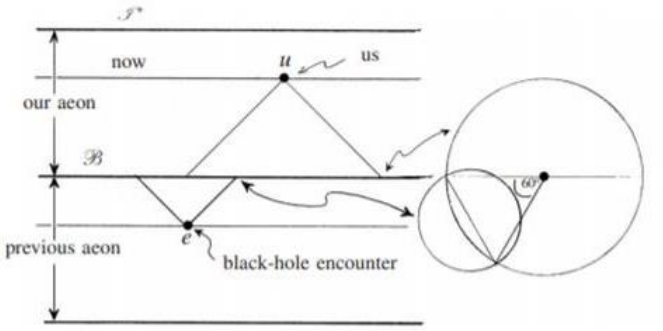

Fig. 3.28 We appear to be about ⅓ of the way up our aeon, in a conformal diagram. If this applies also to the earliest black-hole encounters in the previous aeon, then a cut-off in angular correlations at 60° is to be expected.

After a thorough analysis of the available WMAP images was performed by Penrose and Gurzadyan and further substantiated by Amir Hajian, there appeared to remain various seemingly significant systematic departures from the Gaussian randomness.
Penrose: “A departure, involving an apparent excess of cold circles in a range of angular radii between about 7° and 15°, looked particularly noteworthy and, in my opinion, required explanation…” , however the problem is still worked on, using finer measurements becoming available with new satellite projects. [2]

Penrose critics are still not convinced, because matching up of an infinitely big universe in one aeon with an infinitely small one in the next requires that all particles lose their mass when the universe gets very old. [3]

My summary of the book in layman’s words: Roger Penrose proposes (and substantiates in the book) that the Big Bang started out with very low entropy in a very tiny space. Right after the immediate bang “inflation” the entropy increases and gradually a gravitational “clumping” takes place leading on a large time scale to the emergence of black holes absorbing finally all matter in the universe causing a loss of matter, “information” and time to finally evaporate (Hawking evaporation) with a “plop”, thus setting the stage for a new bang with lowest possible entropy.

The Nobel-Prize – awarded in 2020 for “for the discovery that black hole formation is a robust prediction of the general theory of relativity" [4] will even more enhance Penrose’s CCC theory and as Co-Nobel Prize winner Reinhard Genzel puts it:
“The young generation has to stay on the ball and work hard then science must go on”

Maybe one of the young readers of this book is getting so exiting as to take the next step – for me as interested reader the book opened a whole new (complex) insight into cosmology, mathematics, physics and the impressive research work and knowledge acquired , supported by scientific research satellites – about things unimaginable 50 years ago. It raised new awe about human capabilities to solve scientific riddles about a universe that seems so incredibly complex that even Roger Penrose admitted in an interview:
"I think I would say that the universe has a purpose, it's not somehow just there by chance … some people, I think, take the view that the universe is just there and it runs along—it's a bit like it just sort of computes, and we happen somehow by accident to find ourselves in this thing. But I don't think that's a very fruitful or helpful way of looking at the universe, I think that there is something much deeper about it." [4]

References:

[1] WMAP: https://en.wikipedia.org/wiki/Wilkinson_Microwave_Anisotropy_Probe

[2] CMB analysis: https://arxiv.org/abs/1012.1656

[3] Penrose critics: https://physicsworld.com/a/new-evidence-for-cyclic-universe-claimed-by-roger-penrose-and-colleagues/

[4] Wikipedia: https://en.wikipedia.org/wiki/Roger_Penrose

[5] Very illustrative is also the YouTube iai lecture: https://www.youtube.com/watch?v=ftjwnjR0apY