Quadranscentennial KIAS Lecture (Zoom)

Professor Roger Penrose (Oxford)
2021 October 14 (Thu) 5-6 pm (Korean Time)
Zoom Link: **https://us02web.zoom.us/j/82481634235**
Poster: http://newton.kias.re.kr/~choe/Penrose_poster.pdf

Title: Black Holes, Singularities, and Cyclic Cosmology

Abstract: A 1939 paper by Oppenheimer and Snyder (O-S) showed that, according to an extreme situation of Einstein's general relativity theory (GR), a spherically symmetrical body of material without pressure ("dust") could collapse under gravity to a singularity where the density and the space-time curvatures diverge to infinity. However, the artificiality of the lack of pressure in the O-S model and, more importantly, the assumption of exact spherical symmetry, led most astrophysicists to disregard the appearance of the singularity, even in the unlikely event of such an extreme situation of gravitational collapse actually arising in nature.

Nevertheless, from around 1960, the discovery of quasars—celestial bodies that can emit radio signals of an intensity that can exceed that of a thousand galaxies, yet having a diameter less than that of our solar system—showed that the scales of collapse envisaged in the O-S model would actually be relevant. Yet the presence of the central singularity was not considered to be relevant by most astrophysicists, because of the artificiality of the assumption of spherical symmetry (and of dust) that are made in the O-S model.

However, in 1964, I was able to prove a "singularity theorem" which demonstrated, in effect, that in a collapse situation as extreme as that of the O-S model, singularities are inevitable, irrespective of these O-S symmetry and "dust" assumptions, so long as the local energy flux never becomes negative. This led to the apparent inevitability of a black hole, where the actual space-time singularity remains unseen, hidden by the black hole's visual horizon.

The mathematical techniques that I had developed, were then extended by Stephen Hawking, so as to apply to the singularity that describes the Big Bang, showing that this, also, cannot be evaded by the introduction of irregularities that spoil the symmetry. There is a

time-symmetry in all these mathematical procedures, showing that the classical theory of GR cannot evade these singular blemishes, either in the past or the future. But what about the actual physics of the situation? It is the common view that we must bring in quantum theory (QT), and turn to a quantized version of GR—i.e. quantum gravity—which should tell us how the physical world must actually operate under these very extreme circumstances.

Yet, there is something very odd about the expected nature of these two types of singularity: future and past, this being profoundly related to the origin of the 2 nd Law of thermodynamics (which asserts, in effect, that the randomness in the universe is relentlessly increasing with time). We seem to need a profound time-asymmetry in the combining of QT with GR if this is to explain the time-asymmetry of the singularities, where the Big-Bang singularity is enormously constrained. It can be argued that any standard quantization of GR cannot resolve this issue without, perhaps, an accompanying "gravitization of QT" in which the fundamental "measurement problem" of QT is also resolved. Such a theory is currently fundamentally lacking, however.

Nevertheless, a deeper understanding of the special nature of the Big Bang can be illuminated by examining it from the perspective of conformal geometry, according to which the Big-Bang singularity becomes non-singular, this being quite different from the situation arising from the singularities in black holes. In conformal geometry, big and small become equivalent, which can only hold for a singularity of the type we seem to find at the Big Bang. This situation is also relevant in relating the extremely hot and dense Big Bang to the extremely cold and rarefied remote future of a previous "cosmic aeon", leading to the picture of conformal cyclic cosmology (CCC) according to which our Big Bang is viewed as the conformally continued remote future of a previous cosmic aeon. It turns out that there are now certain strong observational signals, providing some remarkable support for this highly non-intuitive but mathematically consistent CCC picture.