Child's Book of Light
ADDENDUM II
March 23, 2017

BODANIS, DAVID, *EINSTEIN'S GREATEST MISTAKE,* Boston and New York:Houghton Mifflin Harcourt, 2016. [*Parenthetical potential alternate terms* are supplied. *Further, single quotation marks often are used, if not in all cases, around terms involving ambiguity related to new concepts approached in "Child's Book of Light."*]

"Two great concepts dominated European science in 1879…recognition that the forces that made the world's great industrial civilization…were all but different manifestations of one fundamental entity, called energy." Page 3.

"[R]ealization that energy cannot be created or destroyed, only transformed…contained extraordinary implications. …[That] all types of energy are connected; all types…neatly balanced…became known as the law of conservation of energy….[which combined with] the second great idea..: 'matter' never entirely disappears… " Page 4.

Einstein's 1905 series of papers culminated after his (September) special relativity theory established that energy and matter were interchangeable--"…$E=mc^2$ …insist[ing]—quite accurately—that energy was just a very diffuse form of mass, and mass was simply exceptionally dense energy. … [but] "why did there still remain a seemingly separate domain of empty space? … What if space wasn't quite as empty…as it seemed? … If Einstein's suspicions were right [that] space is somehow 'curved'.., what, possibly, is it 'curving' around?" Pages 32, 35, 38, 39.

"If energy and mass were interrelated, why wouldn't things and space be as well?" Einstein's new project would yield "a new theory…called general relativity." Page 50.

"…[W] think that an invisible force of gravity is stretching up from the center of our planet and pulling us downward. But what if what's really going on is that when we fall we're gliding along some curved pathway in space…impossible…to sense directly, but that mathematical analysis might be able to reveal? … In Einstein's radical reconception of space, there's no need to imagine an additional force of gravity; rather, gravity simply is the result of the 'warping' of space." Pages 52, 75.

Bodanis' symbolistic description: "…[A]ny arrangement of things (T) produces [*is caused by?*] a [*the?*]distinctive…geometry (G) around it. … How to tell how things are going to move? Simply look at the distorted geometry of space [*the area?*] around them." Briefly, "The geometry of space…guides how things move [*and are aggregated/contained?*]; Geometry guides Things; G guides T; G = T." Page 77.

"…[A]ccording to his [Einstein's] theory, it wasn't just the planets that would be pulled along by space's curvature…. Light, too, would be 'bent' *(redirected?)* by gravity." Page 85.

1919, after tedious eclipse expeditions, the "most trustworthy results came out at 1.60 inch, with a margin of error of 0.15 inch. "…After a careful study of the plates [it was announced] there [could] be no doubt that they confirmed Einstein's prediction" of the curving *(redirection?)* of light as it got close to the sun. "Einstein's new, geometric picture of sufficiently massive things curving space enough for us to detect had been shown to be true." Pages 104-105.

However, even early on in 1917, "Einstein had discovered what seemed to be a catastrophic flaw in his great G = T equation. …[S]cientists of his era believed that the universe was static, fixed, unchanging…. Yet [per] G = T—[i]f the 'things' floating in space already were separated enough from one another, his equation allowed their random motion to start sending them even farther away from one another. …[W]orse…if…close enough so that they did start clustering…the curvature of space *(the regional energetic balance)* which that created might make even more objects sliding toward them, producing a runaway collapse. [Taken to the extreme] a sky-spanning *(conceived)* 'valley' taking shape,…making everything tumble into it. … …Einstein now saw that *[as it stood)* if his simple G = T equation of 1915 was true…everything would constantly move." Pages 115-116.

"…[H]e had to fix the equation …small-scale effects ["sun making space sag enough to deflect starlight passing nearby"] would still be allowed to hold…larger-scale effects…would have to be corrected." And Einstein said, at the February 1917 Prussian Academy in Berlin, that "…the equations of gravitation hitherto presented by me need to be modified…. ... He would have to insert an extra term in his original equation, [which] new term would take away some of the power on the left-hand side…the one concerned with geometry of space. It would come to be known as the **cosmological constant**…represented…by the Greek letter lambda (A" which yielded the "hobbled G-A = T." Page 117 (emphasis added).

Uncomfortable with it from the beginning, Einstein declared, "'That term is necessary only for the purpose of making possible a near-static distribution of matter, as required by the fact of the small velocities of stars.' … The new, ungainly A…was just an arbitrary component, added to the left-hand side to make the 'pull' *(push?)* of gravity weaker. But the word of the world's astronomers was unequivocal. … Since his 1915 equation predicted the opposite of what the facts seemed to show, then that equation had to be wrong. This was his first *(then-believed)* great mistake. … …[E]ither he hadn't yet reached the deepest level of truth, or the universe lacked the simplicity he so wanted to believe was there." Pages 117-120

In 1922 Russian mathematician Alexander Friedmann, exploring the G = T equation with nothing added "came up with a startling array of possibilities for how space and 'things' in it might change over time [*e.g.*]…a universe would steadily grow…." He believed that--with a paper that was published in a prestigious physics journal--that Einstein would love it and be able to get rid of the new term; but Einstein in a letter published claimed the solution it gave didn't satisfy his equations. Friedmann corresponded with Einstein wishing to present his calculations, but due to the developing anti-Jewish politics developing in Germany Einstein embarked on a long steamship tour and was not moved to review Friedmann's work until May of 1923 and acknowledged to the journal in question that his earlier criticism "was based on an error in my calculations." Although Friedmann determined to see Einstein personally in the latter part of 1923, it was not to be. Besides, Einstein "still had too much invested in the 'fix' he'd made in 1917. For, if Friedmann was right and Einstein's original equation did show that the universe was expanding, eventually there just would be a vast aloneness of burnt-out stars and lifeless planets steadily moving farther and further apart…too awful to imagine…. On the other hand, if Friedmann's other scenarios held and Einstein's original equation showed our universe was collapsing, then sometime in the future…all the stars above came tumbling toward us…also too unpleasant to believe." Pages 126 ff.

[Next chapter, 12, deals with Harvard U's observatory's computerized tabulations, particularly computerizer Henrietta Swan Leavitt's incredible work (*e.g.* 1906, "1,777 Variables in the Magellanic Clouds"). Leavitt longed to go to the Andes observatory from where photographic plates she tabulated came; however, Edward Pickering, the observatory's director, removed her to other work; but she managed a 1912 paper with "even more details about how to use her Cepheid variables to measure true distances in the outer universe." Pages 135-142.]

Chapter 13 begins with Einstein managing to push aside the "haze of confusion after the fall of 1923"--being "thrown by Friedmann's unexpected paper suggesting that the original ideas in the raw G = T equation were right, and the curvature of the entire universe could be changing." Reported in sequence are 1927 involvement with Father Georges Lemaitre's paper in which he tried a range of values for lambda. The "most interesting results arose when lambda was set to zero, so that the equation went back to its original pure form of G = T": again, "another scientifically trained man telling Einstein that there was valid evidence that the universe was expanding. Einstein didn't bite, but Friedmann's and Lemaitre's "ideas preyed on him…he could sense the underlying truth: something was wrong…." Pages 143-147.

Chapter 13 continues into the work of California's Mount Wilson Observatory's Edwin Powell Hubble, prefacing it with following: Leavitt's stunning work using Cepheid variables to measure distance was subsumed by Harlow Shapley (who then had taken over the Harvard U observatory directorship); but his claim to having done the main work did cause Leavitt's work to receive a wider audience. Enter Edwin Hubble and the powerful Mount Wilson scope. He and astronomer Milton Humason, comparing photographs of a particular nebula in the constellation Andromeda, noted a Cepheid variable Leavitt had analyzed: light received which should have been bright was dim, leading to conclusion it must have been diminished over its distance to earth. Hubble's calculations put the Cepheid a million light years from earth. "Hubble's finding could mean only one thing: our galaxy was not alone." Page 152.

Mt. Wilson's scope allowed them to identify pulsating Cepheids in galaxies before too distant to discover and, additionally, the "way to measure how quickly [they] were moving…could be done using a variation of the well-known Doppler effect." ***(But see below, <u>Doppler Effects/Question.)</u>***

"Humason and Hubble were simply working out Lemaitre's discoveries," for which he had not had such accurate information to work. "By 1929 Hubble and Humason were done. …[T]he main thrust was clear. Galaxies were speeding away from us, and the more distant they were, the faster they sped. … …[R]eaching Einstein in Berlin…he couldn't hold out against the evidence any longer…[and] let it be known that lambda was now dead...." As Einstein said *(although still somewhat tentatively)* in a celebrated visit to the Mt. Wilson observatory, "New observations by Hubble and Humason…concerning the redshift of light in distant nebulae make the presumptions *near* that the general structure of the universe is not static. Theoretical investigations made by Lemaitre…show a view that fits well into the general theory of relativity." In his formal paper announcing the changed view he wrote: "It is remarkable that Hubble's new facts allow general relativity theory to seem less contrived (namely, without the lambda-term)." Pages 153, 154.

[Bodanis gives an example of putting dots on a balloon, then blowing it up and watching the dots separate on the surface: "dots…near one another will be separating slowly. Dots that are far away will be separating faster. … …[I]magine this happening on earth. … …[H]ow can both London and New York [each] feel as if they're the static epicenter of some giant planetary lava flow? This only can happen if the entire volume of our planet is expanding. … And the fact that not only are [distant galaxies [like the dots] moving apart; but that, regardless of which dot you are standing on, the nearby ones are moving slowly, and the farther ones are moving more quickly… … By analogy, our three-dimensional universe, with all our galaxies and planets, must be expanding into four-dimensional space—a logical consequence that our limited minds can't possibly visualize." Pages 160-161.

"Einstein had *(did he have?)* what he had hoped for. … The prediction contained within his original equation…was right. Our universe is just the surface of something like a giant sphere. Galaxies are scattered all over its surface, and at the moment they're flying apart …as the 'underlying' sphere is expanding." Pages 161-162.

[*Doppler Effects/Question*: Should it be revealed that the universe is not 'static' but energetically indivisible, *i.e.* a self-contained medium, would then a change be required in calculations related to the actuality of expansion?:

> The total Doppler Effect may result from motions/velocities of (a) the transmitting/conveying medium, (b) the source, (c) the observer. For sound waves, taken as propagated in a medium, each (b) and (c) relative to (a), analyzed separately, are taken into account. <u>For waves which it is assumed do not require a 'medium', such as light or gravity in general relativity, only the relative difference between (b) and (c) are considered.]</u>

Chapter 15 proceeds into Einstein's "greatest mistake," *vis-à-vis* quantum mechanics advances that already had been underway: evidences suggesting it was not as prior thinkers assumed possible, to find precise laws that explained how objects both large and small moved. Ernest Rutherford's subatomic particles experiments, followed by Niels Bohr's proposition that electrons really couldn't operate like Rutherford's imagined miniature atomic "solar system;" instead "were restricted to making tiny hops from one particular orbit to another…quantum jumps…in discrete fixed amounts" --a "revolution [that] would threaten everything Einstein held to be true, and his response would lead to the scientific isolation that he [subsequently] endured at Princeton." Pages. 172-174.

Einstein had won a Nobel Prize for 1905 work "explaining how light could be *(behave as)* a particle and a wave at the same time," including findings about photon ("Light Amplification through the Stimulated Emission of Radiation," which laid out basic LASER dynamics and fiber-optics, etc. at heart of the Internet). He had detailed "how electrons that weren't otherwise liable to plummet down from 'higher' orbits around their atoms could, sometimes, be excited if we pumped in extra light to strike them. … [S]ince he couldn't know when the jumps were made, he had introduced the probability of their occurring with no cause." But "Einstein disliked [that]…he couldn't tell exactly which electrons were going to be knocked out of their orbits first," stating: "The weakness of the theory lies…in the fact…that it leaves the duration and direction of the elementary processes to 'chance'. … Einstein's belief that randomness would eventually be dispelled from his theory explains why he put the word 'chance' in quotation marks…to show his belief that if we took time to look at the details, we'd no doubt see that each transition had simple, precise causes. … [A]t heart he remained a classical physicist." Pages 175-177.

1920's progress in subatomic research produced unexpected revelations. 1924 Gottingen professor Max Born remarked that "he was fed up with…half measures and wanted…a theory that could address them." Aware how Newton had worked out mechanics on a large scale, he was insistent "to do the same for the…micro-world where the new, miniscule 'quantum' jumps were taking place." In 1925 "Werner Heisenberg managed to solve Born's problem." Observations of light electrons "produced under different circumstances…changed as the atoms of which [they] were a part were bombarded with light or otherwise stirred about"--to simply "record what went in and record what came out, and work out the mathematical operations to link the two…." Pages 177-179.

Per Heisenberg's 1925 formal calculations, "He could tabulate a range of possible events inside an atom and from that calculate the spectral lines that were seen. As to what 'actually' went on inside the atoms to create the output—whether it inherently was knowable or just too complex to understand yet—was not something that, at that point, he was going to speculate about. … [L]imiting himself to external measurements…he had a different view. Heisenberg's work is considered the birth of the new quantum mechanics." So long as one "didn't worry about tracking the final details inside an atom…remarkably accurate predictions about the light it would spray out could be made. Since…Newton…science had been built on the assumption that, at least in principle, clarity could be found about every process we observe, Heisenberg seemed to be saying that didn't have to be true. Max Born accepted the new approach, pretty much, because Heisenberg's results were so accurate." On Borns's probing, "Einstein explained…more of what he believed: 'Quantum mechanics certainly is imposing. But an inner voice tells me that it is not yet the real thing.' To a close friend, Einstein even was blunter: 'Heisenberg has laid a big quantum egg. In Gottingen they believe in it. I don't." Pages 180-181.

"To Einstein, probabilities were just a sign of gaps in our understanding…temporary fixes that…would be replaced with clearer understanding." Early 1926 he and Heisenberg fell into discussion; as the latter recalled, "to my astonishment, Einstein was not at all satisfied with the argument.." Einstein "still believed that, underneath it all, electrons…moved in some clear ways." Pages 183, 185.

During the same period, Erwin Schrodinger "published a conventional, classical-style equation that to many no longer appeared to require relegating the movements inside an atom to the realms of unseeable mysteries. If his equation was correct, it seemed it would return quantum mechanics to the strictly causal realm of physics that Newton and Einstein inhabited. [If]…so, Schrodinger would be undermining Heisenberg's insistence that only a fundamentally new view--one that didn't even try to describe the inside of the atom in crisp mechanical terms--could be accurate." Heisenberg "turned back to his most central belief…that it was a waste of effort to trace the clear paths that electrons follow within atoms…[and] go further than simply asserting one couldn't measure the behavior of those electrons; he would prove it." Pages 186-187.

“Individual packets of light carry a distinct momentum ‘punch’ as they travel: it’s very small, but enough to ‘push’ a tiny electron. But if you want to be so gentle that you don’t knock it away from where it’s traveling, then you won’t have enough clarity to see exactly where it began. You can choose to measure either where the electron is or how fast and powerfully it’s traveling, but you can’t measure both with full accuracy at once. You’re always going to be a little bit unsure—<u>uncertain—</u>about the complete mix. This is the basis of the famous <u>uncertainty principle</u>, which Heisenberg published in February 1927. [emphases added] It was *(taken as)* irrefutable. It ended centuries of *(arrested for a century?)* belief that the universe followed an inherent perfect order. It *(for some time?)* revolutionized physics. And Einstein would have nothing to do with it.” Pages 189-190.

The ‘uncertainty principle’ robbed Einstein of many potential allies. “..[M]ost physicists agreed [it] did seem to show that views into the atom were inherently closed off [conceding] Heisenberg… appeared…right—which meant that Einstein…had to be wrong.” The disagreement “first came to a head at the Brussels Conference in October 1927…[where] Niels Bohr emerged as leader of the Pro-Heisenberg faction. … “…[The] new findings seemed to be undermining—in Bohr’s view quite definitively--[that] causality of an absolute, classical sort didn’t exist. … [That…] subatomic goings-on were unknowable…. The micro-world really was different from the ordinary large-scale world…. On the smallest scale, chaos and indeterminacy ruled how the electrons and other particles that make up our bodies and planet operated. Clarity at the micro level did not exist. … Only outside the main sessions…did Einstein begin to argue back. Pages 191-193.

During the conference period Einstein repeatedly proposed thought-experiments to Heisenberg and Bohr , also Pauli (--“like a chess player”--) “coming up with ever new examples”) all ultimately shown to be consistent with the uncertainty principle. “The conference ended in a draw. Einstein had failed to find a counter-example that would refute Bohr, while Bohr remained apprehensive that this new theory on which he’d staked so much still be undercut. Despite DeBroglie being on Einstein’s side, after two years “Einstein began seeing that his side in the quantum debate was losing popularity. [DeBroglie himself caving in, in 1928, with Erwin Schrodinger being one of the few scientists to remain on Einstein’s side.]” pp. 196-197.

By 1929, however, Einstein both had his $E=mc^2$ formula almost universally accepted and Hubble and Humason had published their work showing his G = T originally beautiful equation without the lambda had been right after all. He believed he could hold out on the uncertainty principle…. Pp. 198-199.

At the October 1930 Brussels physics conference all attention was on Einstein and Bohr. Einstein gave Heisenberg a new thought experiment (imagining a box, weighed beforehand, holding a fine cloud of radiation/light particles or photons floating inside, supported on a scale, with a tiny shutter in one wall controlled by a very precise clock. “When the clock strikes a particular time, the shutter opens, one photon is let out, the shutter closes, the box then weighed yields the loss.” The scale tells “how much energy that lost photon carries…(because mass and energy are equivalent) [while] we also know what the time the photon flies out--something that should never happen if Heisenberg’s uncertainty principle were true. …

“Einstein’s thought experiment overwhelmed Bohr. … It was Einstein’s last moment of glory. … Bohr…extremely upset…stayed up almost all night…. [But] in the morning, he had it.

When the shutter opens and the photon flies out, the mass of the box goes down. But the weight of the box is being measured. That means it has to be on a scale. When the photon flies out, the scale rises up—very little, but at least a bit. That means it's ever so slightly higher in the earth's gravitational field. By Einstein's own theory of relativity, time is seen to operate at different rates in a stronger versus a weaker gravitational field. Bohr sketched out the calculations. … Working together Einstein [even] and Bohr concluded that the uncertainty in the weighing, because of that tiny gravitational shift, was just enough to match exactly what's predicted by Heisenberg's uncertainty principle. … Einstein had neglected his own theory of relativity. … Einstein had lost." Pages 199-203.

"Einstein never again attended such a meeting; never again attempted to refute Bohr or Heisenberg in public debate. Nor, however, did he change his beliefs. He still was convinced the world's experimentalists were wrong, their findings incomplete. … In letter after letter now he went over the many ways in which his previous work ostensibly had proved that his beautiful dream was valid. $E=mc^2$ from 1905 showed there was certainty in the universe, since it described in as much detail as one could wish exactly how mass and energy could change into each other. The great G = T of his 1915 equation had been just as clear. Mass made space *(appear to)* curve." Pages 204-205.

[Chapter 18 relates post- WWII movements/lives of the other main physicists. Pages 211-215.]

Late 1932 or early 1933 Einstein and wife Elsa were under armed protection in Belgium before sailing to America. Einstein spent 1933-1955 in Princeton and reportedly grew more close-minded, saying, several years after his arrival, "I still do not believe that the Lord throws dice. Because if he had wanted to do that, he would have done it throughout, and not kept to pattern--gone the whole hog. In [such] case we wouldn't have to look for laws at all." Yet, "Every new discovery was backing the subatomic interpretations of Heisenberg and Born…absolutely no evidence on his side." "Work was taking place In Princeton's main physics department on what would later be called quantum tunneling. … With the insights codified in Heisenberg's uncertainty principle…measuring the electron's velocity requires it to have an indeterminate location, since any measure taken of an electron's speed prevents an accurate reading of its location." [Example given: in classical physics, putting an electron at a wall, it might wobble a bit, otherwise pretty much stay in place. But per quantum mechanics it might stay in front of the wall but, when next looking, appear far on the other side without ever passing through the wall on the way. Pages 216-219 *(harking, there, to "quantum entanglement," below.)*

In his fifties, "Einstein began to concentrate more and more on what he termed his unified field theory." With his $E=mc^2$ he had showed that not just all forms of energy but also all forms of mass were interlinked; with G = T, that the very geometry of space was interlinked as well with the mass and energy held within all 'things'. "But what if he could go further and show that electricity itself was just another aspect of gravity and geometry? … Such…his aim behind unified field theory, it thought here again his stubbornness worked against him…isolating himself from the era's breakthroughs. … For any unified field theory to work, it would have to incorporate those findings…. … He also was isolating himself from fresh analytic tools. … [H]e tried one more paper to show that the predictions of quantum mechanics couldn't be true. <u>In the paper he came up with the concept of what's now called quantum</u>

entanglement…[which] notes that--under the accepted rules of quantum mechanics, if a particle breaks up into, say, two particles that travel very fast and very far—if one ends up at the far side of the solar system or beyond, an experiment on one can cause an immediate change in certain properties that the other possesses. In [his] mind…that distant particles could be instantaneously interconnected demonstrated what was 'wrong' with the field…the [conception of which] others had begun…. When this didn't persuade the new generation…he gave up." Pages 219-222.

"The only thing certain [per this book], at least at the atomic and subatomic levels, is a certain degree of randomness. [However] in time, some of Einstein's efforts to disprove quantum theory would be *(?)* turned against him. Even that paper, coauthored in 1935 showing that quantum mechanics would allow distant particles to be 'miraculously' entangled, only has strengthened the now-accepted view. Those entangled particles actually have been created and are being used in the first generation computers being built today, in the twenty-first century. … Our fundamental understanding of photons, of lasers, of low-temperature physics, and, of course, of relativity stems directly from his papers written in Bern, Zurich, and Berlin. Collectively, these achievements are rivaled only by those of Newton in their impact on our lives and in the way they deepened our understanding of the cosmos.

"The more mass…in those clusters, the more the space around them will bend *(be affected/altered)*, and the more powerful that distant lens will be…helps allow…estimate how much mass [exists]…in such galactic clusters—in informal words, to 'weigh' them." Leading to a startling conclusion that "what we thought filled the universe—stars, planets and the like—is only a small part of the full mass those clusters contain. Most of what exists in the universe is entirely invisible to us, and what it is composed of we do not know. This unseen 'stuff' that Einstein's work allowed us to discover is called dark matter and is a major topic of research.

"As to the lambda…new findings began to suggest that, inadvertently, Einstein might have been right after all…. The universe is not only spreading outward, but something is propelling it apart at an ever faster rate. That enormous force of repulsion has been labeled dark energy and is exactly what a revised lambda term could account for. … Research on a new, revamped cosmological constant is now of great interest, because of its implications for Einstein's work and its connection to burgeoning new subfields of physics. … Everything …makes up perhaps 25 percent of all there is; dark energy perhaps 70 percent. … The dark energy component is what necessitates a lambda term after all…. The dark matter is different, and to a great extent can be seen as just another bit of 'mass' to plug into Einstein's otherwise still valid equations. " Pages 233-235.