Overview

Astronomy is a subject that heightens our imagination, piques our curiosity, and invokes our pondering of our place in the Cosmos. There are several astronomical issues brought up by Christopher Boone (i.e., author Mark Haddon) in *the curious incident*. Because the book only mentions these topics in passing (primarily), I have chosen seven here to elaborate on slightly, with some references to the text in the book. Furthermore, where available, I provide some references to websites that develop these topics at great lengths.

Topics Discussed

i. Olbers’s paradox: why is the sky so dark? (p. 10)

ii. The expanding universe and the future of the cosmos (p. 10)
   (!!!) http://www.aip.org/history/cosmology/

iii. Stellar evolution and supernovae (p. 51)
    http://casswww.ucsd.edu/public/tutorial/StevI.html

iv. Black holes and singularities (p. 32)
    (!!!) http://cosmology.berkeley.edu/Education/BHfaq.html#top
    http://www.fourmilab.ch/gravitation/orbits/
    http://en.wikipedia.org/wiki/Wormhole

v. Constellations and their origins (p. 126)
   (!) http://www.fillingthesky.com/constellationhistory.html
   http://www.astro.wisc.edu/~dolan/constellations/

vi. Qualifications for astronauts (p. 50)
   (!!) http://www.nasa.gov/audience/forstudents/postsecondary/features/F_Astronaut_Requirements.html
   http://www.nasa.gov/astronauts/index.html

vii. Astrobiology and life on other planets (p. 164)
    http://www.gps.caltech.edu/~mbrown/

(!!!) Must see website, (!!) Informative, (!) Good
i. Olbers’s paradox: why is the sky so dark?

“And then I thought about how for a long time scientists were puzzled by the fact that the sky is dark at night, even though there are billions of stars in the universe and there must be stars in every direction you look, so that the sky should be full of starlight because there is very little in the way to stop the light from reaching earth.”

(p. 10)

The question of ‘Why is the sky dark?’ is one that astronomers (philosophers and even poets, like Edgar Allan Poe) have pondered for centuries. “Olbers’s paradox” (although Willhelm Olbers was not the originator of the quandary, and in reality, it is not a paradox but rather a riddle or puzzle) states that if the universe is infinite and filled uniformly with stars, then the brightness of the night sky should be equivalent to the day. As an analogy think about the old adage that the forest cannot be seen for the trees. When I am deep in a forest, in every direction my vision only detects a tree trunk rather than an opening out of the forest. In the same way, an assumption that the infinite universe is filled with stars should also cause the effect of seeing a star in every direction. Stars are hot; our own Sun’s corona is in excess of one million degrees. If stars were located in every direction, a significant increase in the mean temperature of outer space (currently about 3K, –270 degrees Celsius). Therefore, another equally valid “paradox” is, ‘Why is the universe so cold?’.

There are at least two pieces of information that lead us to correctly solving the riddle. First and most importantly, the idea that the universe is infinite and filled uniformly with stars is only an assumption. In fact, the big bang theory claims just the opposite, namely that the universe is finite in age. No matter how strong our telescopes, astronomers do not see the darkness of the night sky ‘filled’ by a greater number of stars (and the galaxies that house them). Therefore, by taking the well-founded viewpoint that the universe (and therefore the number of its stars) is finite (in age) provides a sufficient (and correct) path out of the conundrum. This is the view of folks like Johannes Kepler, William Herschel, and even Edgar Allen Poe. The second piece of information is to understand the nature of dust. For many years, several astronomers thought that the answer to the dark night sky lay within the dust located between stars. They propose this dust absorbed much of the light from the distant stars, and therefore presented a darkened sky to the earth-bound observer. If there were an infinite number of stars shining on the dust of the universe for an eternal age, the dust would have sufficient time to heat up and radiate in near manner to the stars themselves. As was previously mentioned, the cold background of outer space proves that extinction of starlight by dust is not a valid explanation of the riddle.

In reality, we know the mean distance between adjacent stars in our own Galaxy (and even the mean distance between adjacent galaxies). When considering a sphere with radius $10^{10}$ light-years (the maximum distance that we can observe due to the finite speed of light and the finite age of galaxies), there are simply not enough stars (and galaxies) to cover that sphere (by a long shot). Consider this, it would take an extra $10^{40}$ (that’s alot of zeroes) stars to cover the sphere of our maximal seeing (with radius equal to $10^{10}$ light-years). Therefore, Christopher need not invoke the idea of an expanding universe to explain the darkness of the night sky. It comes quite readily when we consider the temporal nature of the stars & galaxies, the speed of light, and the universe itself.
ii. The expanding universe and the future of the cosmos

“And when the universe has finished exploding, all the stars will slow down, like a ball that has been thrown into the air, and they will come to a halt and they will all begin to fall toward the center of the universe again.” (p. 10)

In the 1930s, Edwin Hubble observed that galaxies at further distances appeared to recede from us at faster speeds, which was almost immediately interpreted as a uniform expansion (i.e., constant speed of increase) of the Universe. Since then, we have come to understand that it is, in fact, the space(-time) between galaxies that expands uniformly (rather than the galaxies themselves that are moving away from us). While a uniform expansion aptly describes the galaxy distribution in the past, several questions are often posed about the future of our expanding Universe.³

In the book, Christopher mentions (p.10) the scenario that our Universe will one day collapse after it has reached its maximum expansion radius. In fact, there are three basic scenarios for the future of the Universe: (i) collapsing, as Christopher suggests is like a ball tossed up with moderate speed and then returns (often called “the Big Crunch”); (ii) uniformly expanding forever similar to an astronaut floating away in space (the “Flat” scenario); and (iii) the accelerating universe, i.e., expanding at an ever-increasing rate like a ball dropped from a tall building (the so-called “Big Rip”).

For most of the 1980s and ‘90s, the debate was open about the future and several indirect measurements led many astronomers to think that the Universe was Flat (which gives the same rate of expansion forever and ever). While somewhat boring, this model of the Universe fit with many other cosmological measurements that were more accurately determined. All of this changed rather suddenly in 1999 (and following) when two groups (or “collaborations”) of astronomers and astrophysicists discovered new observations of supernovae. Interpretation of the distances to these exploding stars revealed that our Universe was, in fact, accelerating so that galaxies were expanding away from one another at an ever-increasing rate. Since those initial observations around the turn of the century, there is a continued debate about the accuracy of supernovae as a measure of distance.⁴ Part of the great excitement of science is seeing how such controversies are resolved.

In summary, there are three traditional views of the future of our expanding Universe: collapse, flatness, and acceleration. While the competition among these models was fierce in the mid to late 20th century, several measurements around the turn of the century have led most astronomers to realistically consider the accelerating cosmologies as plausible descriptions of our (not too imminent) future. Therefore, Christopher is a bit amiss by stating matter of factly that the collapse of the universe is uncontested.
iii. Stellar evolution and supernovae

“And all I could see would be stars. And stars are the places where the molecules that life is made of were constructed billions of years ago. For example, all the iron in your blood which stops you from being anemic was made in a star.” (p. 51)

One of the most basic questions astronomers ask is ‘How do stars begin to shine and what causes the vast array of colors, sizes, and types of stars that are observed?’ Although basic, this is a question still not completely understood by astronomers. When enough cold, hydrogen gas has collapsed (for that is the basic model of a star’s birth), the gas heats and the temperatures are raised to the point of causing fusion (i.e., nuclear explosion, see p.126) in the core of the star. There are two primary reasons to believe that nuclear fusion is the basic process of energy generation within every star (including our own sun). First, the energy output for most “normal” stars is enormous AND constant. When astronomers observe stars (some now for over one hundred years), they do not change significantly. Nuclear energy is the only viable process known to humans that can provide a constant stream of energy with such extreme brightness over billions of years.

Second, astronomers detect evidence that the byproducts of nuclear reactions (metals like calcium, sodium, and even iron) are present within the outer atmosphere of all normal stars. Nuclear reactions repeated on small scales in laboratories predict these byproducts quite accurately. As the nuclear reactions within the core of a star move from burning hydrogen to helium to carbon (increasingly heavier elements), the byproduct elements given off are also heavier and heavier. In the latest stages of stellar nuclear reactions, iron represents the heaviest and most stable element produced. So the big question remains, “How do these heavy elements, like the iron in our blood, get to the surface of the stars and eventually make up our planet and our bodies?”

The key piece of information in answering this question is to understand a basic relationship between the mass of a star and its transition through the different stages of nuclear core burning. This relationship states that the larger the original mass of hydrogen that forms the star the more quickly the burning transitions to heavier elements in the core. When the original mass of a star is too great, the end result is an explosion that sprays all those heavy elements into space. A star that explodes in this way is called a supernova, of which there are a few types. When the hydrogen gas reforms and new batch of stars is born, there are small amounts of the heavy metals from previous supernovae episodes.

In summary, most astronomers believe the slow and repetitive process of supernovae explosions is responsible for all of the heavy elements (say, carbon and above) in our Universe. Therefore, it is also thought that our planet and its vast array of atoms were originally formed in the cores of massive stars. As for the delicate processes of forming and sustaining molecules, we do not detect their production in the extremely hot cores of stars, although some simple organic molecules do form in space. The most important molecule-forming processes occur on Earth, however, leaving those formed in space to a background role. In closing, it is appropriate that supernovae explosions are the last topic before our discussion of black holes, for it is out of supernovae that such massive bodies are formed.
iv. Black holes and singularities

“Except that there might be [time travel] if you went through a black hole, but a black hole is what is called a singularity, which means it is impossible to find out what is on the other side because the gravity of a black hole is so big that even electromagnetic waves like light can’t get out of it, and electromagnetic waves are how we get information about things which are far away.” (p. 32)

Astronomical compact objects that include black holes, neutron stars, and white dwarfs, are thought to result from the explosive death of normal stars (supernovae). What controls which compact object forms is the original mass of the progenitor star. Black holes originate from the collapse of the most massive stars in the Universe, somewhere between $10^{-70} \times$ the sun’s mass. Because gravity distorts the path of light, the amount of mass contained within the event horizon (i.e., the boundary) of the collapsing object curves light so severely it cannot escape. Due to the massive gravitational field the region of space can not be observed, as Christopher states, and so a black hole is formed by its disconnection from the rest of the universe.7

Because astronomers cannot actually see a black hole, existence of these objects is inferred from the type of radiation emitted (x-ray, radio, optical) or the orbits of bound stars (called companion stars). It is currently thought among most astronomers that a massive black hole inhabits the center of all galaxies. However, not all black holes are “active” (engulfing stars and gas) and therefore are not observable. Though not currently active, the black hole at the center of the Milky Way galaxy was confirmed by mapping out the complete orbits of several stars around the periphery.

Lastly, Christopher mentions the “singularity” of the black hole. The concept of a singularity is actually a mathematical term. It means that there are important quantities found in equations that become infinite in value and, therefore, cannot be calculated or understood from a physical perspective. Although mathematicians and physicists talk about the limit of some quantity going to infinite, we are not really prepared to determine what actually happens if the universe is infinite in dimensions (remember the dark sky riddle?). In the case of the black hole, the curvature and density of matter take infinite values, which in turn gives an infinite value for the gravitational field located within the event horizon. The physical extrapolations of the mathematics of black hole physics is well-developed and includes the notion of wormholes, white holes, and time-travel. The mathematically-allowed (though not physically observed) solutions to the equations of general relativity are most notably developed and discussed in Stephen Hawking’s *A Brief History of Time*. There is an excellent FAQ for black holes and their extrapolations listed on the cover page; I highly recommend it for those with imaginations.
v. Constellations and their origins

“And anyway, Orion is not a hunter or a coffeemaker or a dinosaur. It is just Betelguese and Bellatrix and Alnilam and Rigel and 17 other stars I don’t know the names of.” (p. 126)

The naming and design of constellations in the night sky is over 6000 years old and has its origins in the ancient civilizations of Mesopotamia, Greece, Babylonia, and Egypt. It is thought that primarily farmers in these societies used the night sky to determine the changing of seasons, where climate indicators are not obvious. For example, when a particular constellation was in a certain place in the night sky, farmers knew that it was time to plant. As these imaginative arrangements developed, so did the fabricated history behind them. Indexing historical data as well as his own observations, Ptolemy of Alexandria (c. 150–200 CE) produced *The Almagest* that listed 48 constellations still in use today. For well over a thousand years, Ptolemy’s *Almagest* and its revisions stood as the official authority on the constellations.

Several changes occurred in the 19th century, when explorations (and then astronomical observations) of the Southern hemisphere were conducted. Because the Greeks only observed the Northern skies and a small portion of the Southern skies, a large portion of the night sky had no given constellations. As astronomy became a scientific field of study in the late 1800s, the constellations were again used as markers in the night sky. For example, cataloged objects by Charles Messier were given a reference constellation as well as a number designation (e.g., M31). In the early 1900s, individual and clusters of stellar objects (i.e., stars, nebulae, and galaxies) were named according to the constellation in which they were found (e.g., the great spiral nebula of Andromeda and the Virgo cluster). In 1919, the newly-formed governing body of astronomy, the International Astronomical Union (IAU), officially named 88 constellations with all of Ptolemy “original” 48 surviving the cut. Lastly, constellations are still the single marker for the largest known structures in the Universe, superclusters of galaxies (e.g., Perseus-Pisces, Hercules, Horologium-Reticulum).

A final word about constellations; the member stars are not physically associated with each other. Rather, the shapes of the constellations are abstractions of the human imagination. In this way, Christopher is correct to mention the dinosaur in the night sky. Constellations are, in fact, more difficult to observe in a completely dark sky since a greater number of fainter stars are visible. A distinction must also be made between constellations and their similar cousins, asterisms. An asterism is constructed by using the brighter portions of one or several already established constellations. The most well-known asterism, the Big Dipper, is formed from the brightest stars of the constellation Ursa Major. Asterisms are used primarily by amateur astronomers and orienteers to point toward other fainter objects. For example, a straight line through the bright end stars of the Big Dipper point to the North Star (Polaris). Although the arrangements and their companion stories are fabrications, constellations (and asterisms) serve an important function for all members of the astronomical community.
vi. Qualifications for astronauts

“To be a good astronaut you have to be intelligent ... You also have to understand how machines work ... You also have to be someone who would like being on their own in a tiny spacecraft ...” (p. 50)

Even with the apparent increase in space shuttle missions, becoming a NASA astronaut remains one of the most competitive job opportunities on the planet (and beyond, right?). There is less than a two percent chance (20 out of ∼4000 applicants every two years) that any one person will be chosen to enter the astronaut training program, with an even less chance that you actually ever fly in a mission. Although the NASA qualifications are quite simply stated (see the first link above), make no mistake that the requirements are stringent (see the fuller explanations in the second and third links). There is alot packed into the statement by NASA: “Any adult man or woman in excellent physical condition who meets the basic qualifications can be selected to enter astronaut training.”

There are three basic types of astronauts in the NASA space shuttle program: Pilots, Mission Specialists, and Payload Specialists. Once selected for a two-year astronaut training program, the fun really begins. For example, everyone graduating from the training must swim 75 meters in a flight suit and tennis shoes, and tread water for 10 minutes. As you may have guessed, there are also height, vision, and experience required for Pilot status. Mission specialists must have detailed knowledge of the shuttle (mechanical and electrical) and the payload. All spacewalks are performed by mission specialists. We all may have the best chance of being a payload specialist, since the strenuous physical requirements are relaxed. Of course, extreme specialization in a shuttle-related payload is required (e.g., communications specialist for a deployed satellite), and that may seem an impossible feat for the average person.

Although a bachelor’s degree is the only stated educational specification listed by NASA, a graduate degree was obtained by every astronaut (including payload specialist) that I observed (the bios of all NASA astronauts are available via the first link). For example, several Payload specialists received their Ph.D.s in astronomy related fields, since three shuttle missions were directly related to the Hubble Space Telescope. Also, because each mission is somewhat related to biomedical applications in space, several astronauts have received their M.D. or V.M.D. (veterinary medicine). Regardless of your academic prowess, however, there is an unwritten rule that no one is admitted to the program with any known physical or mental handicaps. I had a friend who completed their graduate work in astronomy and was crushed to find out that she was not eligible for admittance based on a slight birth defect. Whether or not you agree, there is no question that the individuals who inhabit the space shuttle are extremely adept (both physically and mentally).
vii. Astrobiology and life on other planets

“And there are billions of planets where there is no life, but there is no one on those planets with brains to notice ... And there is life on earth because of an accident. But it is a very special kind of accident.” (p. 164)

Astrobiology is a cross-disciplinary field that studies the organization of planets around sun-like stars (including the mere existence of earth-like planets outside our own solar system) as well as the organization of life already present in harsh environments on earth. Therefore, this newly-formed field requires both specialized planetary astronomers and astrophysicists as well as evolutionary biologists and biochemists.

The number of planets discovered by astronomers over the past decade has increased exponentially. As astronomical instrumentation develops at a rapid pace, our understanding of proto-planetary systems and the objects just outside our own solar system (dwarf planets similar to Pluto and planetesimals like comets and asteroids) has expanded. For example, astronomers have developed techniques for determining the atmospheric content of dwarf planets as they transit their host star. This has spawned further theoretical modeling of stellar evolution and the disks that form around these stars. Over the past five years, astrophysicists have developed a working model for the formation of our solar system and our earth-moon system. Although we often take the delicate nature of our planet and the stellar system we inhabit as the natural condition of extrasolar systems, models of other possible habitable worlds do not always fit a sun-like star with earth-like planets. This has created hypotheses and models that produce much larger planets revolving around a hotter star at farther distances than our earth is from our sun.

From the biology end of things, several new findings about the existence of life in harsh environments on our own planet have widened the possibility for life elsewhere, including our own solar system. For example, Christopher mentions “sea creatures who live around sulfur chimneys, which are underwater volcanoes where gases are ejected from the earth’s crust into the water” (p. 80). Another focus of study is the life that thrives in the Antarctic subcontinent. The continual proliferation of life in these harsh climates gives astrobiologists working models for how life thrives in near non-earth environments.

Space travel to neighboring planets or outside our solar system is extremely difficult and dangerous, so we can not personally investigate the existence or non-existence of life there. Consequently, astrobiology remains a field where the larger questions are unanswered. In fact, a major theme of astrobiology deals with the realm of statistics and probability based on the information that we currently know about the Universe. For example, the Drake equation mathematically attempts to establish a probability for finding other civilized universes. Most specialized (and hence narrow) fields of science require a focus on minutia and pedantic detail that often shrouds the bigger picture. Scientists often carry out their research without reference to the larger philosophical questions that motivate our intrigue, such as the philosophical and religious implications of finding life outside Earth. It is false to think that scientists don’t care about the idealistic bigger picture, deeper questions, or grand themes (in fact, most care deeply); it’s just that research forces them into the realistic world of immediate and accessible detail.
Bibliography


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7 Ibid, pp. 335ff.

8 M. A. Seeds, pp. 14–16.

9 http://people.howstuffworks.com/question534.htm

10 http://www.nasa.gov/astronauts/index.html

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