Chapter 2
When Will Mankind Achieve "*First Contact*" with Extraterrestrial Life Forms

It now appears very unlikely that our astronauts will encounter any kinds of life in our solar system that are of the intelligent persuasion anywhere close to our Earth-bound multicellular animal or even human types. However, as I indicated in Chap. 1, many of our space scientists now think it is possible, and a few believe even likely, that early stage primitive forms of life may have been able to evolve in the earlier histories of some of our inner planets (e.g., Venus and Mars) or on some of the moons of the outer planets, and some of these creatures may still be alive today. Although single-cell or microbial forms of life might still be present today in some locations, no multicellular forms are likely, assuming, of course, that life elsewhere is based on something equivalent to our "cells". If man wants to search for life forms that are anywhere close to being like us in terms of being intelligent and even capable of communicating with us in some manner, we will need to extend our search for ET to other worlds outside our own solar system. At least for the near future, rocket science will not help us very much with this task. Mankind will need to become incredibly patient and somehow learn to cope with the real possibility that it may be our great-great-great. . .grandchildren and not us that will first view the exciting pictures and other data/information that our incredibly fast unmanned inter-stellar rocket ships will beam back to us sometime in the far distant future. This would, of course, assume that the speed of light is our ultimate speed barrier, or that nothing like "worm holes" or other fancy future technologies could be developed that might make it possible to somehow cancel or alter what appears to be a insurmountable and universal time/space restraint.

There appears to be another "universal" truism or law of nature that would also preclude us from searching for intelligent forms of life in our own solar system and that is that the evolution of intelligent life, in addition to probably being a very rare event in the universe, is also incredibly slow. If it turns out that humans are the only

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advanced intelligent life forms that exist in our solar system, we must look beyond our own "backyard" to even have a chance at finding other life forms that have had enough time, as well as luck (in terms of avoiding destruction) to be able to slowly evolve into creatures more similar to us. Fortunately, the recent amazing discoveries that homes for extraterrestrial life may be common elsewhere in the universe and that life may be both diverse and quite resilient, is triggering many of us (scientists as well as non-scientists) to pose the profound question of how soon it will be before we make the giant leap from speculating about extraterrestrials to being able to actually observe them close up and perhaps develop some form of social relationships. Therefore, it now appears that, if we want to hunt for more intelligent forms of life, we must focus our searches on those incredibly vast and hostile regions of space that lie beyond our own little corner of the universe. Thus far, even the closest exoplanets that are believed to be possible candidates for harboring life are located so far away (the closest one found to date is 20 light years away) that even our best and most optimistic rocket scientists doubt we will be able to visit them anytime soon.[1] And our astronomers tell us that the largest and most powerful land-based telescopes we currently have, as well as the even larger systems including space telescopes that are planned for the near future, will probably be inadequate (for many years to come) to allow our astronomers to visually examine an exoplanet's surface for any physical signs (e.g., cities, large engineering projects) of the presence of advanced technological civilizations. What makes the direct viewing of exoplanets so difficult is that they are all located extremely close to their incredibly bright home stars. Many stars are at least 1,000,000,000 (one billion) times more bright than even their larger exoplanets, and 1,000,000 times brighter if just the infrared portion of the light spectrum is measured. The task of viewing exoplanets, therefore, is comparable to trying to use a telescope to look at a small insect (housefly or bee) flying a few feet away from a powerful search light that is located many miles away. Nevertheless, our computer scientists, astronomers, and rocket scientists now believe this task is not impossible but may actually be accomplished, if not by the end of the present century, then perhaps sometime in the next century or two. The sad reality is that our scientists may presently be very close to possessing the necessary technology to accomplish this exciting feat if only the monies to pay for it could be found. It would likely cost no more than a small fraction of the world's combined military (defense) budgets for a single year. Having expressed this somewhat depressing thought, I will now

[1] In early October, 2012, a team of astronomers led by Stephane Udre and Xavier Dumusque used the 3.5 m telescope at the European Southern Observatory to verify that the closest star to our sun, Proxima Centauri, which is located only 4.35 light years from the Earth, hosts an exoplanet. This planet is similar in size to Earth, orbits its home star every 3.3 days and, therefore, has a mean surface temperature of 2,240 °F which would definitely not be friendly to carbon-based life forms like us. However, astronomers are now intently studying the Alpha Centauri triple star system for possible evidence of other exoplanets that might be orbiting in cooler life friendly habitable zones.

proceed to describing how our diehard scientists plan to accomplish this exciting and important task if the cost issue can be resolved.

What Kind of Telescope Could View Small Dim Exoplanets Located Close to Extremely Bright Stars

If we want to conduct searches for real living creatures on other worlds, we have to do much more than just look for dips in the brightness levels of distant stars that transiting exoplanets produce, or minute changes in color (light Doppler shifts) associated with stars being made to wobble by their larger exoplanets. We must look through the clouds and hazy atmospheres of the exoplanets themselves and look for visual or spectrographic evidence of the presence of living creatures that are busy polluting or otherwise altering their planets' surfaces in such a way that can only be explained by the presence of industrious life forms. Since our turbulent and increasingly polluted atmosphere is the astronomer's single greatest impediment in using telescopes to observe distant exoplanets, one solution to this problem would be to place telescopes containing extremely large optical systems (e.g., mirrors for collecting light from distant stellar systems) into space or to build them on the surface of the moon. However, the problem is that telescopes big enough to allow us to see distant planets in sufficient detail to determine whether life might be present, would be truly ENORMOUS! Telescopes of the necessary size to accomplish this feat would be, for the foreseeable future, far too expensive to construct.

Another less expensive solution would be to launch telescopes into space that contain special ***star shades*** that could block out most of the home star's light and allow the telescope to focus specifically on the light being emitted by the exoplanet itself. NASA has already designed such sun-block systems that could, if funded, be built and placed into space to view exoplanets. Figure 2.1 shows an artist's drawing of what one version of this type of telescope might look like. This telescope utilizes an internal light blocking technique or device known as a *coronograph* that was originally invented by astronomers to block out the glare of the sun's surface and allow them to view solar eruptions or prominences being ejected up into space from the sun's surface. This internal coronograph procedure method has been successfully used with both space and land-based telescopes (e.g., the Hubble space telescope and the Canadian Gemini land-based observatory) to separate the light emitted from orbiting exoplanets from that of their home stars (Fig. 2.2a, b). Since the Hubble space telescope is close to its well-deserved retirement age, NASA scientists have been busy developing the next generation of space telescopes which will commence with the launching of the powerful new James Webb Space telescope sometime between 2014 and 2020 (Fig. 2.3a, b). Some scientists have just recently proposed that an external type of star shade method (Fig. 2.4) may be used in conjunction with the James Webb space telescope (JWST). A separate

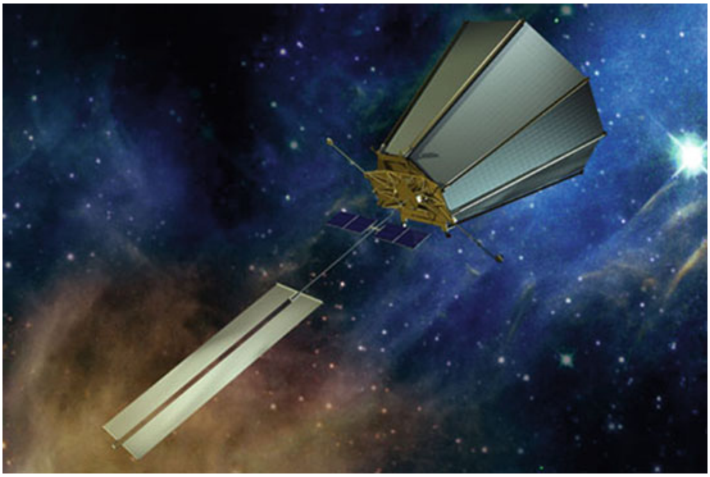

Fig. 2.1 Artist's drawing of a special type of planet hunting space telescope that contains an internal device (coronograph) to block the home star's light and allow astronomers to view the light reflected by the exoplanets (image credit: NASA)

maneuverable spacecraft could be launched along with the JWST which could be moved to a location about 100,000 miles in front of the Webb telescope which could then deploy a large sun screen to block the light from stars suspected of hosting planetary systems The JWST could then focus on the light from any nearby exoplanets with minimal interference from the host stars own light.

Fortunately, the advent of powerful high speed digital computers during the second half of the twentieth century has allowed our scientists to come up with another amazing solution to this problem which might eventually work even better than the sun shade idea. What astronomers can now do is to use several spatially separated telescopes such as the Keck Observatory "twin" telescopes in Hawaii (Fig. 2.5) or the newly constructed even larger European Southern Observatory's *Very Large Telescope* (*VLT*) array in southern Chile (Fig. 2.6), which has four large telescopes linked together, to simultaneously gather light from distant celestial objects. The images from each of the separate telescopes would then be sent to a special computer that can digitally "add and subtract" the different individual components (i.e., light waves) from the distant objects' light spectrums to produce a composite image that has much higher optical resolution and clarity than is possible with each individual telescope alone. This new computer assisted multiple telescope technique is referred to by scientists as ***interferometry***. In order to eliminate atmospheric effects and obtain much better images than is possible even with the best land-based interferometry systems, our astronomers are now planning on placing ***flying formations*** of several smaller spatially separated telescopes into space high above the Earth. The separate smaller space telescopes, like their land-based cohorts, will be electronically connected so that the light collected

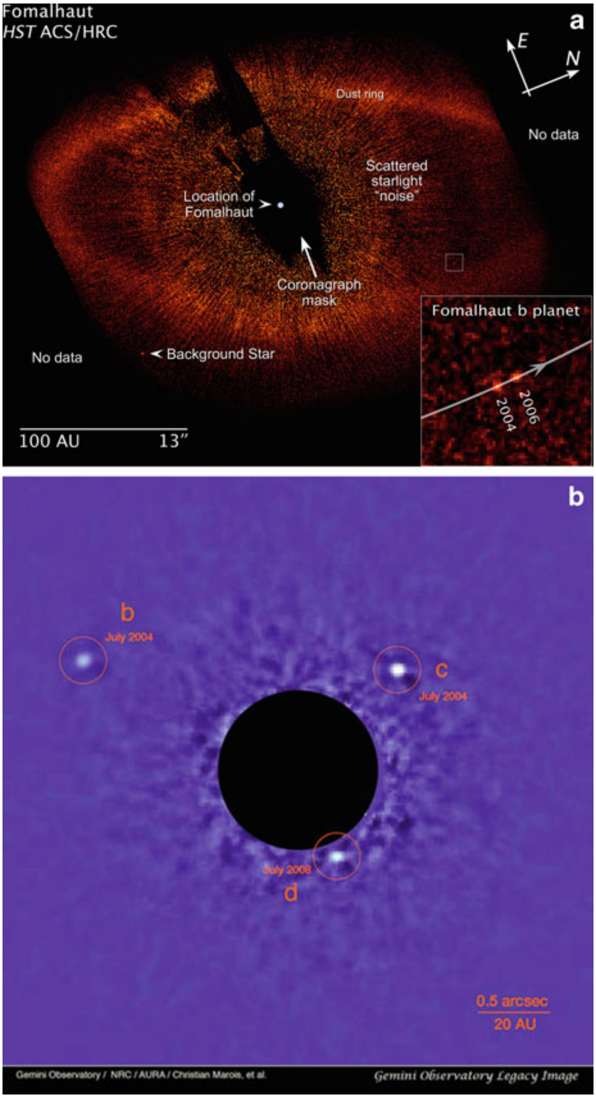

Fig. 2.2 Photographs showing how coronographs installed inside space telescopes or even land-based telescopes can block a star's light and allow us to directly view the reflected light from orbiting exoplanets. (**a**) Shows a photograph taken by the Hubble space telescope of the actual movement of an exoplanet as it orbits its home star (image credit: NASA Hubble space telescope team), while (**b**) shows a photograph taken by the land-based Gemini Observatory of three exoplanets orbiting their blocked out star (image credit: Christian Marcos et al., Gemini Observatory)

by each of them can be fed into a special computer which will then digitally process and combine the individual images.

Now, how do the computers work their magic to produce this amazing trick? Since the early 1800s scientists have known that light propagates (i.e., moves through space) as waves, like waves on the surface of water. When two light waves meet, they interact with each other. Scientists refer to this interaction as "interference" (Fig. 2.7). If the crests (or troughs) of two waves are coincident (perfectly aligned), they will combine (add) together to produce an amplified wave in what is called constructive interference. However, if the crests of one wave are

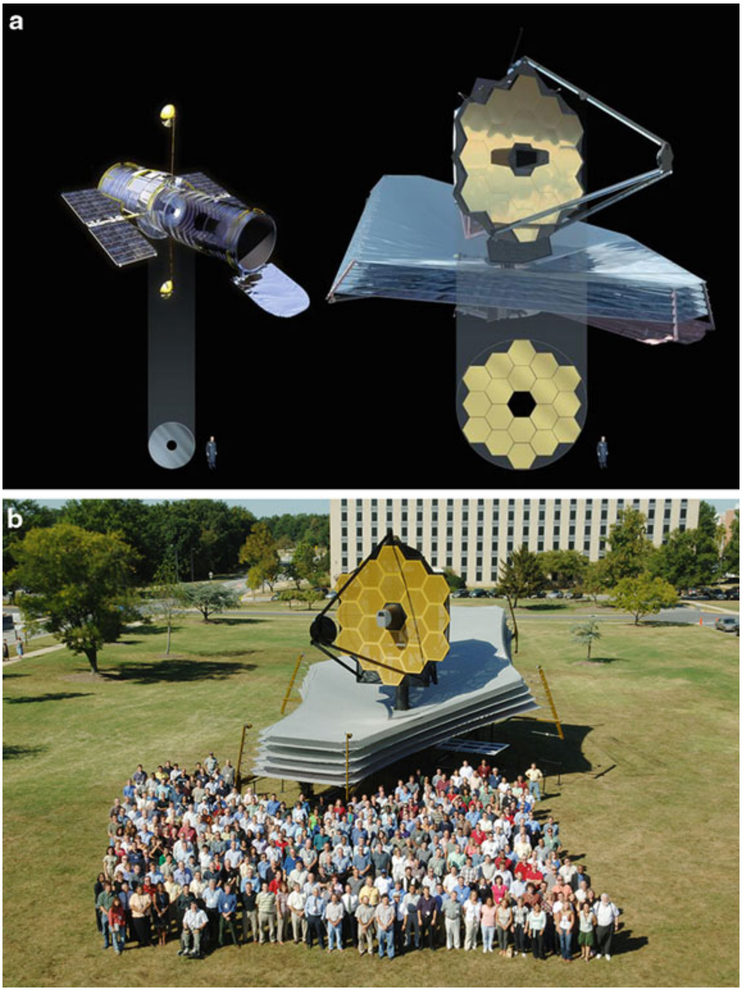

Fig. 2.3 Aging causes both humans and space telescopes to eventually retire. After 24+ years of tireless service, having been launched into space in1990, the Hubble telescope is expected to be retired sometime between 2014 and 2020. (**a**) Shows a NASA artist's drawing that compares the aging Hubble space telescope (*left image*) with the new James Webb space telescope which will be launched sometime before 2020 to replace the Hubble telescope. (Note that the telescope mirror of the more powerful Webb telescope is twice the size of the Hubble telescope's mirror.) (**b**) Shows a family portrait of the team of scientists, technicians, and support people proudly standing in front of a life-sized model of their Webb apace telescope science project (image credits: NASA).

completely aligned with the troughs of the other wave, they will totally cancel each other out and the light will disappear. This effect is called destructive interference. Between these two extremes (which scientists refer to as being totally "in-phase" or "180° out-of-phase"), the two waves may be only partially "phase-locked" (aligned) which will permit large variations in the brightness or dimness level of

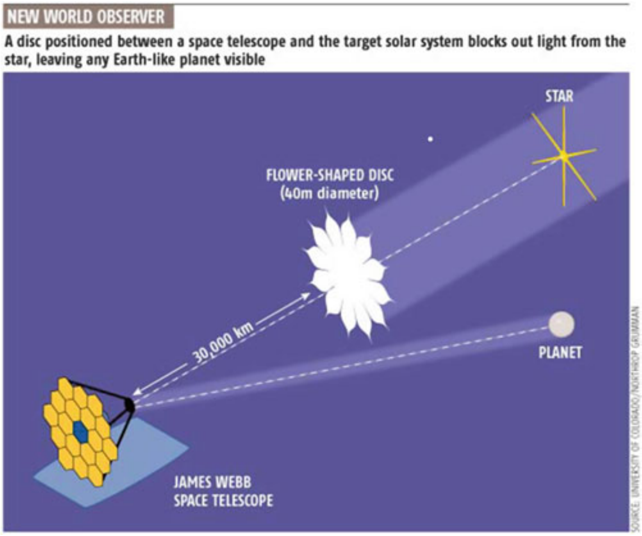

Fig. 2.4 Some scientists have suggested that an external star shade could be launched along with the James Webb Space Telescope and placed approximately 100,000 miles in front of the telescope where it could block out the light from the home stars of any suspected exoplanets and allow the JWST to directly view the planets (image credit: Northrop-Grumman/University of Colorado, Boulder)

Fig. 2.5 Photograph of the Keck twin interferometry telescopes in Hawaii. Two telescopes really can see better than one! (image credit: NASA/Wikipedia Commons)

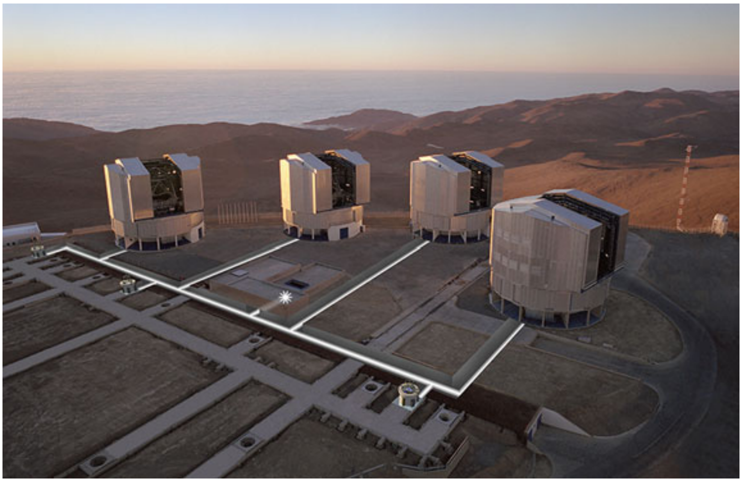

Fig. 2.6 Shows a photograph taken from a helicopter of the European Southern Observatory's Very Large Telescope Array in southern Chile which consists of four large telescopes that are linked together electronically (image credit: European Southern Observatory/Wikipedia)

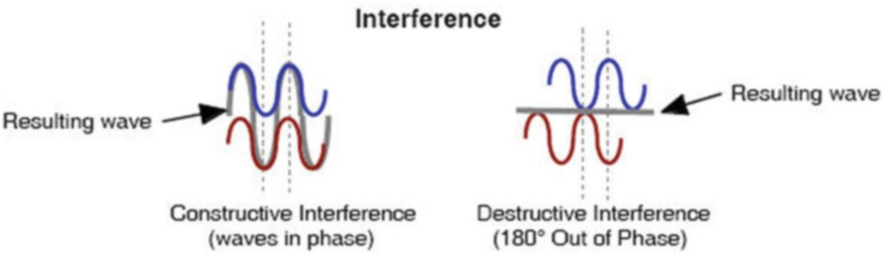

Fig. 2.7 Depicts the two types of interference that occurs when light waves encounter each other in space. When two light waves are in-phase, the light gets brighter (*left drawing*). When the light waves are out-of-phase, they cancel each other and the light disappears (*right drawing*) (image credit: Ricky Leon Murphy, http://astronomyonline.org)

the combined light. Basically, interferometry permits astronomers to ***take advantage of the physical phenomena of constructive and destructive interference to digitally separate the extremely dim light being reflected by an exoplanet from the horrendously bright light being emitted by its home star***. Since the home star and the exoplanet are located in slightly different locations in space, and the individual telescopes of the flying formation are also located in different locations, the pathways the different light waves take in traveling from the exoplanet/star pair to the different telescopes will exhibit extremely small differences in both length as well as travel time. Today's computers are able to take advantage of the constructive and destructive interference that results from this situation to mimic the optical resolution capabilities of single much larger telescopes, as depicted in Fig. 2.8. For several years, NASA scientists and engineers have been busily working on

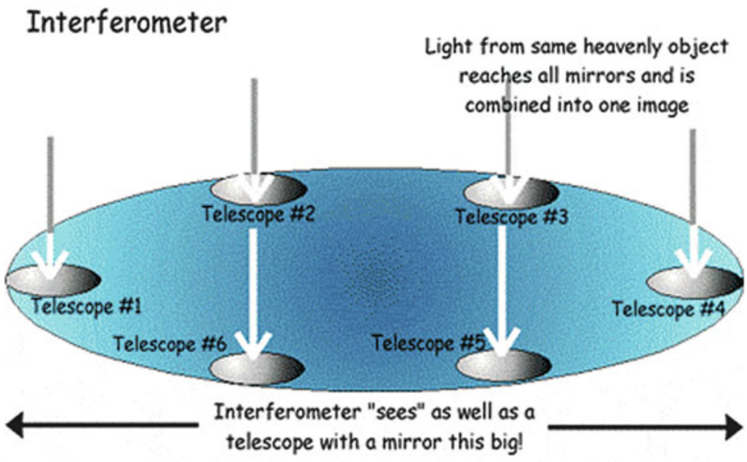

Fig. 2.8 Shows how interferometry telescopes work (image credit: NASA/JPL)

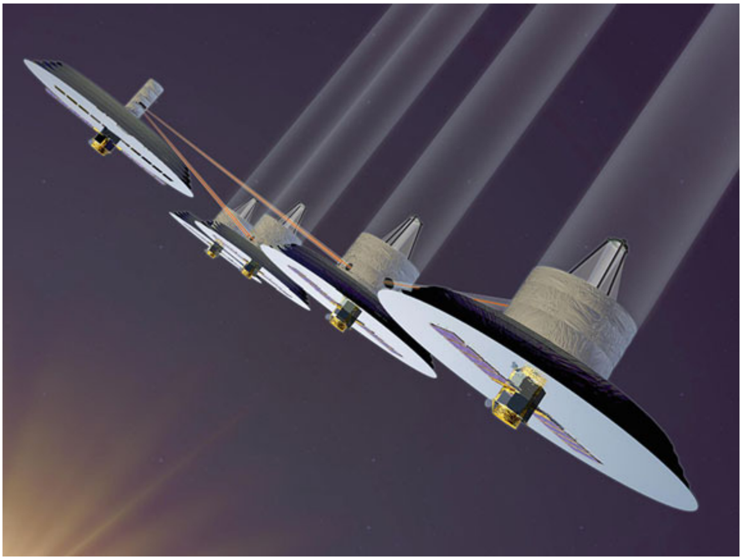

Fig. 2.9 An artist's drawing of what the world's first space telescope system that incorporates the powerful new interferometry technique may look like (image credit: NASA/JPL)

developing flying formations of such individual smaller telescopes which are called ***Terrestrial Planet Finder*** (***TPF***) systems (Fig. 2.9) that could be placed into space above the Earth (i.e., in heliocentric solar orbits that parallel the Earth's orbit) to assist in detecting and viewing exoplanets.

Although Many ETs May Be "Alien" with Different Chemistries, Science Must Initially Search for Life Forms That Are Dependent on Carbon and Water

Although the newer interferometry telescope systems (both land-based and those placed in space) will greatly increase our ability to detect even the smaller and the more distant exoplanets in our own galaxy, It will likely be many years before we can place telescopes in space or on the moon that will allow us to view distant exoplanets in sufficient detail to see and photograph physical objects or structures on the planets' surfaces that would indicate the presence of advanced technological civilizations. Even the largest engineering structures that ET might place on their planet's surface might be too small to be easily seen with any of our current land-based or space telescopes. Nevertheless, most of our scientists are quite confident that future breakthroughs in telescope technology will eventually solve this seemingly impossible situation. In the meantime, our rocket scientists might be able to develop and construct special robotic space probes carrying sophisticated camera systems or remote sensing technology that could travel at speeds close to that of light (186,000 miles/s). Given the time required for such spacecraft to get up to full speed, it might take 40 or more years for the craft to reach a star system that is located 20 light years away. However, once the photographic session is completed, all the collected data (spectrograms, pictures, etc.) would only require 20 years to be beamed back to Earth. In the next few years, it is quite likely that our astrobiologists will begin to identify some distant twin-Earth type rocky worlds orbiting in their home stars life friendly habitable zones that appear to be warm and wet enough to have a good possibility of supporting carbon-based life similar to ours. Once such planets are identified, our radio astronomers (e.g. SETI) will immediately point their telescopes in the direction of these systems and begin listening for any signs of "deliberate" communication attempts from extraterrestrials such as radio or television transmissions (Ballesteros 2010; Kaufman 2011; Ross 2009; Tarter and Impey 2012; Zuckerman and Hart 1996), or other types of electronic signal "leakage", that might be produced by intelligent inhabitants (Shuch 2011). The SETI scientists will also look for indications of possible visible light transmissions involving pulsing laser beam signals (or signs of nighttime city lights, or even heat related infrared radiation escaping from large ET cities) (Ekers et al. 2003; Valoch 2011; McConnell 2001; Michaud 2007; Mason 2008).

Looking for "Chemical" Rather than "Visual" Signs of Alien Life

However, our scientists will not have to wait until extremely powerful telescopes or extremely fast photographic robotic missions become available in order to begin searching for signs of life on other exoplanets. Since the middle of the nineteenth century, our scientists have had another "trick up their sleeves" that can provide powerful but indirect evidence of the presence of extraterrestrial life. Once we begin launching terrestrial planet finder systems into space that can successfully separate the light from exoplanets from that of their host stars, we can study the reflected light from the exoplanets to determine what kinds of chemical elements may be emitting it. This technique is called ***spectroscopy***. Spectroscopy is the use of light to study what physical objects are made up of in terms of their construction, i.e. what kinds of atomic elements they are made of. A device called a spectrometer (or spectroscope) is used to record or measure the spectrum of a specific object or material, i.e., to determine what kind of light it either emits or absorbs. Astronomers can take the light emitted by a star or light from a planet's surface and separate it into its different individual spectral components. Light which is visible to the naked eye is made up of a multitude of different colors. If you pass light through a glass or crystal prism, you will see the light spread out in a series of different colors (Fig. 2.10a). A similar effect occurs when, following a rain shower, sunlight passes through water droplets in the sky to produce a rainbow. However, not all light is visible to the human eye. The human eye is only sensitive to a very narrow portion of what scientists call the total ***electromagnetic spectrum*** (Fig. 2.10b). All light (i.e., electromagnetic radiation), whether visible to the eye or not, consists of a mixture of different frequencies (colors) that have different wavelengths (some shorter and some longer).

Spectroscopy, therefore, allows light to be collected from a celestial object and then dissected into a multi-colored pattern that shows its spectral content. Since each of the 92+ individual atomic elements that all physical objects in our universe are known to be constructed from have their own unique "signatures" in terms of what color of light they either emit or absorb, astronomers can carefully examine the spectral pattern of the light collected by their telescopes to determine what kinds of specific atoms the celestial objects are made up of. The spectral pattern from a specific source of light will look very similar to that of the bar code that you see in a grocery store on produce labels, except that instead of alternating thin and wide bars that may be light or dark, you will see a series of different colored bands intermixed with a series of black bands. *The different colored bands will indicate which frequencies were emitted, while a black band (no color) will indicate a specific frequency that was absorbed by a celestial object*. For many years, and in many laboratories, scientists have performed extensive studies to determine exactly what spectral patterns are produced by specific kinds of atomic elements (atoms) or molecules (collections of atoms bound together). When astronomers see a particular pattern of spectral lines collected from some celestial body, they can compare this pattern with those collected in our Earth-bound science laboratories to confirm what kinds of atoms or molecules the celestial object is composed of. Figure 2.11a–c shows how different kinds of light spectrums are collected from different celestial objects by astronomers.

Since TPF space telescopes that can totally separate the light emitted by stars from that emitted from the surfaces of at least their larger exoplanets is not yet a reality, our astrobiologists have just recently started using another special form of

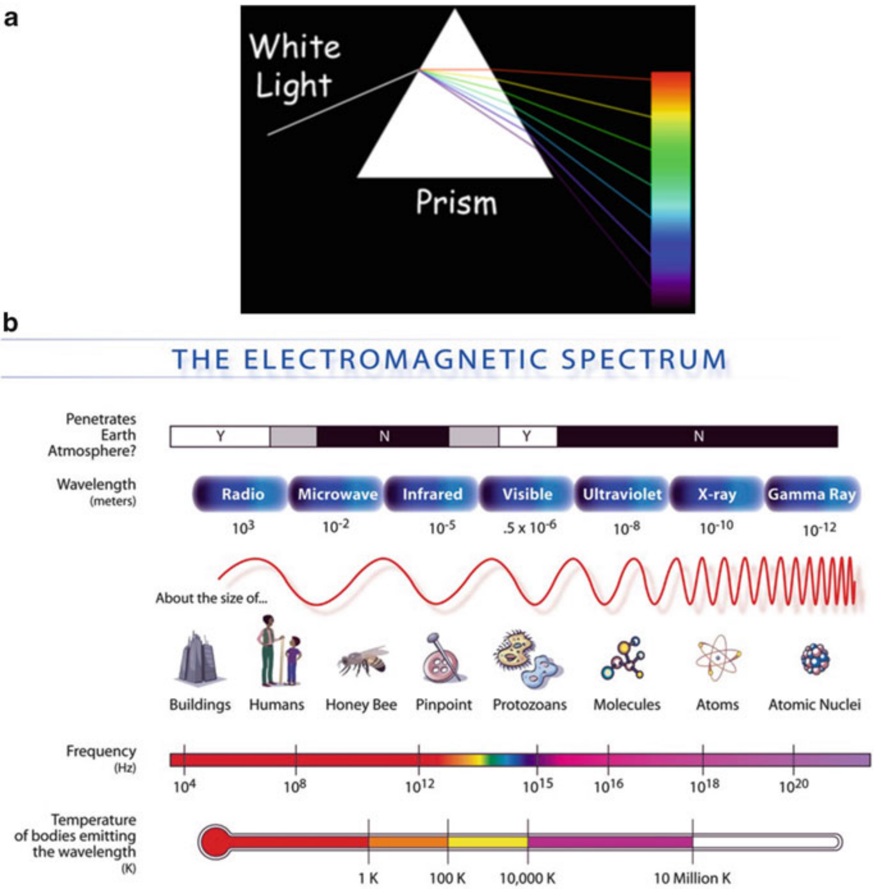

Fig. 2.10 (**a**) When light that is visible to our eyes (i.e., so-called "white" light) is sent through a crystal prism (or droplets of rain in clouds), it becomes separated into a collection of different colors ranging from *red* to *blue* (image credit: NASA). (**b**) Shows that the total range of light energies (i.e., the ***Electromagnetic Spectrum***) is far wider than our eyes can see. The eye evolved while our early ancestors still lived in the oceans. Since much of the total electromagnetic spectrum is blocked by the oceans, eyes evolved specifically to see in the available narrow visible light range. When our ancestors later emerged onto land they still did not need to see beyond the visible range since much of the shorter and longer light wavelengths are also blocked by the atmosphere. Astronomers, however, have found that in order to obtain a more accurate and detailed view of the different celestial objects in space they need to "see" at these normally invisible parts of the total light spectrum (image credit: NASA)

spectroscopic measuring procedure to attempt to determine whether any gases may be present in the atmospheres of distant exoplanets that might indicate the presence of some kind of carbon-based life. This technique is a modified version of the transit method (see Fig. 1.8a) used to detect exoplanets and is called the ***Secondary Transit Method***. This method (Fig. 2.12a) relies on the fact that a transiting exoplanet and its home star sometimes "overlap their images" (when the exoplanet

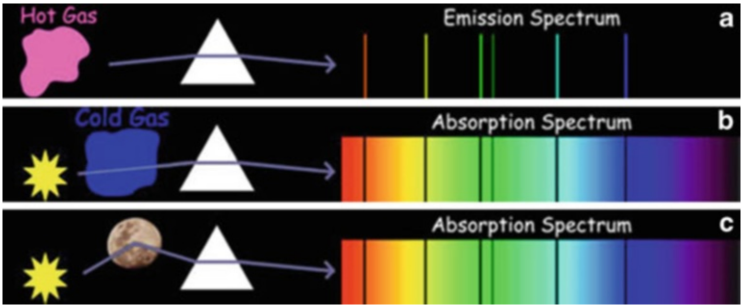

Fig. 2.11 In order to determine what kinds of atomic elements a specific celestial object in space is made of, astronomers typically measure three kinds of spectra. (**a**) Shows the first kind of spectrum. Light from hot objects, such as hot interstellar dust/gas clouds, will display an ***emission spectrum***. These spectrums contain a large number of different kinds of narrow colored bands. The pattern of these bands will tell the scientist what specific chemical ingredients (atomic elements) are present in the cloud that is emitting light energy. (**b**) Shows what is called an ***absorption spectrum***. This kind of spectrum occurs when light from a distant hot object (e.g., a star) passes through a cool or cold interstellar gas or dust cloud. In this case a pattern of black bands will be mixed among the colored bands. The location of the black bands will tell the astronomer what parts of the distant star's light energy is absorbed (i.e., removed) by the chemical elements in the gas or dust cloud and thus reveal the chemical composition of the cloud itself. *Finally, for astronomers specifically interested in determining whether life friendly gases may be present in the atmosphere of an exoplanet*, scientists record a special third kind of spectrum. (**c**) Shows this **"special" absorption spectrum** which involves recording the spectrum of the light that is emitted from the surface and/or atmosphere of the exoplanet itself (image credits: NASA)

is in front of its home star) and, at other times, the exoplanet is behind its home star and not visible. Astronomers can take the "blended" light from the overlapping star and planet and use special computers to subtract this light from that of the star when the planet is behind the star. The resulting "difference" light can then be subjected to spectrographic analysis to determine what kinds of unique chemicals might be present in the planet's atmosphere that are not present in the star's atmosphere. Figure 2.12b shows one of the first successful uses of this Secondary Transit Method. In 2007, Mark Swain and his colleagues from the Jet Propulsion Laboratory in California used the NASA Infrared Telescope in Mauna Kea, Hawaii, to image a Jupiter-size exoplanet that circles a star that is about 63 light years away from the Earth. The scientists used the secondary transit procedure to identify the presence of water vapor, carbon dioxide, and methane in the exoplanet's atmosphere. While these chemicals might suggest the presence of some form of carbon-based life, it is unlikely that this planet is life friendly since it is far too hot (it orbits its home star in a little over 2 days) and is too large to probably support life, at least *as we know it*.

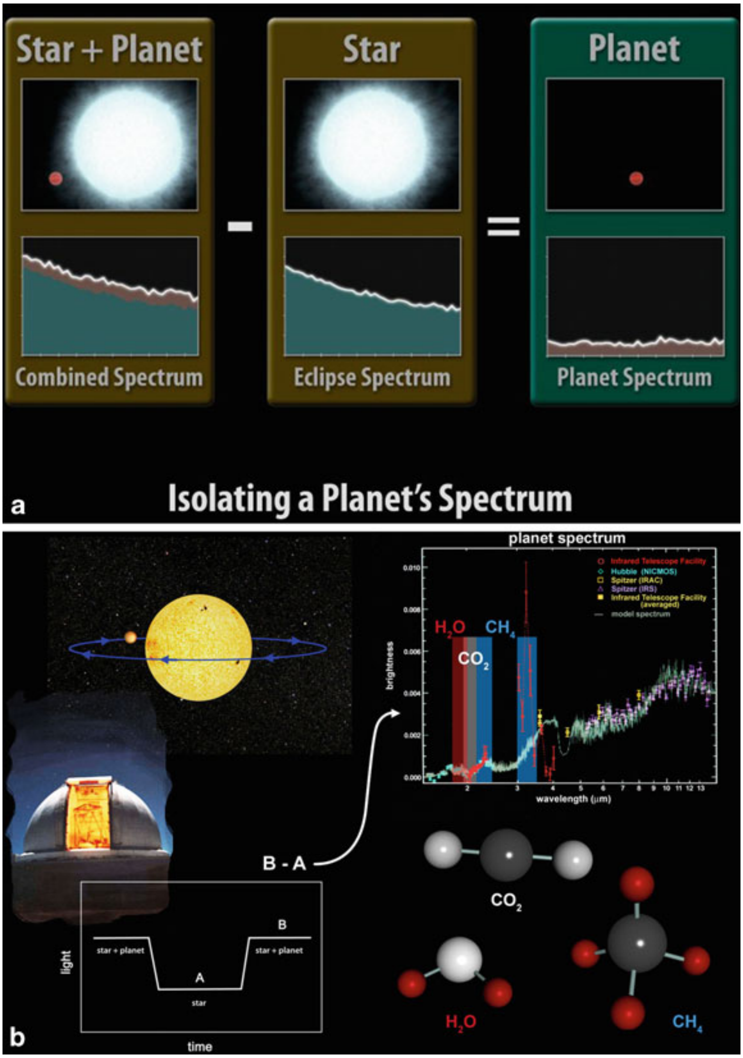

Fig. 2.12 Sometimes an orbiting exoplanet goes behind its home star and at other times it is in front of the star. (**a**) Illustrates the procedure that scientists use to separate the spectrum of exoplanets from the combined spectra of overlapping home stars and exoplanets. (**b**) Summarizes the findings of a group of astronomers that successfully used the Secondary Transit Method technique to isolate the spectra of a distant Jupiter sized exoplanet (image credits: NASA)

Strategies Astrobiologists Will Use to Search for Life on Other Worlds

Therefore, because of economic necessity and scientific conservatism, the search for ET will not initially be focused on finding possible exotic forms of life but on searching for carbon-based life analogous to that found on Earth. Since we currently know nothing about what exotic alien life might look or act like, or be made up of (chemically), our scientists would be totally clueless as to how to even begin such searches (de Vera and Sackbach 2013; Schulze-Makuch 2013; Ward and Bennett 2008). Our best chance for succeeding will be to look specifically for forms of life that we already know exists in the universe. Although our universe is known to be built from at least 92 different kinds of atoms which range from the lightest *hydrogen* atom (which is made up of a single positively-charged proton in the nucleus and one negatively-charged electron that circles the nucleus) to the heaviest *uranium* atom (with 92 protons and 92 electrons), all living things (plants, animals) that we know about on our planet are made up of so-called life friendly organic molecules that are built from a much smaller pool of only six different kinds of atoms (i.e., hydrogen, carbon, oxygen, nitrogen, sulfur, and phosphorus) that were selected from this larger construction pool. Thus, since life is so remarkably rampant and diverse on our own home planet, it would seem entirely reasonable to assume that life based on similar life friendly molecules may have popped up more than once in our vast universe. This means we will need to focus on searching extraterrestrial bodies (planets or moons) where lots of life-sustaining liquid water is thought to exist, and where the different chemical by-products of carbon-based life processes can be easily detected with our current technologies. For example, specific chemicals or gases which, on Earth, are detectable in either the atmosphere or on the surface and are known to be produced by or associated with our form of life will be the top targets on the scientists' search lists. Some examples of such atmospheric gases are oxygen and ozone (which are associated with plant photosynthesis), carbon dioxide (especially when it occurs along with oxygen, could be a metabolic waste product of animals), and methane gas (which on Earth is commonly found in the excrement or poop of barnyard animals and emitted as a metabolic waste product by certain kinds of bacteria). Even more complex chemical substances on a planet‘s surface itself, such as the chlorophyll content of plant life can be detected from space with light spectroscopy techniques.

In 1990, our scientists actually used this spectrographic technique to confirm that there is indeed evidence that our own home planet hosts some kind of carbon-based life. In that year, NASA launched a special unmanned spacecraft (Galileo mission) to Jupiter that was designed to perform spectroscopic studies of Jupiter's atmosphere to determine what kinds of gases it contained. In order to get the spacecraft to Jupiter, the NASA scientists first had to make it circle the sun, then re-approach the Earth where the Earth's gravity would then act like a sling-shot to "toss" it in the direction of Jupiter. Carl Sagan talked NASA into having Galileo, prior to its being slung in the direction of Jupiter, to perform a spectroscopic study of Earth to see if it could detect any special chemicals that might suggest Earth harbored life. Galileo detected high levels of oxygen and methane in Earth's atmosphere plus signs of chlorophyll on the surface. All three of these chemical ingredients are known to be associated with carbon-based microbes as well as plants and animals. So, first things first—scientists at NASA and ESA have unanimously chosen to give top priority to "following the water" at least for the near future, in hopes of having the best chances of finding life out there. **For at least the immediate future, the absolute *Holy* Grail of all searches for ET will be, therefore, to focus on finding Earth-size rocky planets that are warm and wet enough to host carbon-based life forms that might be reasonably familiar to our scientists**.

What the first Terrestrial Planet Finder systems will do is to use spectroscopy to look for any signs of the presence of chemicals in the atmospheres or on the surfaces of exoplanets that are ***out of equilibrium*** (i.e., different) from what would be expected to be present based on known physical and chemical laws of nature as well as the specific type and location (size, chemical composition, distance from parent star) of the exoplanet. If an alien civilization in the Alpha Centauri star system (which is a little over 4 light years away from us) were to build something equivalent to our TPF systems and launch them into space above their home planet, they would probably be able to detect the presence of water vapor, carbon dioxide, methane, nitrogen, and free oxygen in the Earth's atmosphere. All of these gases, in combination, would be a strong clue (but not definitive proof) to the presence of extensive carbon-based life forms on our planet. The presence of free oxygen gas in the atmosphere of a world that does not harbor life would be unexpected since oxygen is notorious for electrically bonding (forming molecules) with other atomic elements and making itself invisible to spectrometry. The reason we have so much free oxygen in our atmosphere is simply because we have extensive plant life that is constantly replacing it. For the first two-thirds or more of the history of Earth, any intelligent ETs living in the Alpha Centauri star system would not have been able to detect our oxygen. It was only following the arrival of cyanobacteria and other forms of plant life which proceeded to rapidly build and inject huge quantities of oxygen gases into our atmosphere that oxygen would have been detectable. Carbon dioxide, while not itself a strong indicator of carbon-based life could, in combination with oxygen suggest the presence of animal life (if not volcanoes or forest fires) that ejected this gas as a metabolic waste product. Large detectable quantities of methane in a planet's atmosphere is also suggestive of life (e.g., especially the larger smelly varieties such as cows, pigs, etc.). Like oxygen, methane cannot survive "out of equilibrium" in an atmosphere without some means of continuously replacing it, most typically via life processes. Small quantities of methane can be, however, sometimes formed via volcanic activity. The recent detection of larger than expected quantities of methane gas in the Martian atmosphere has stirred a debate among scientists as to whether some of the Martian volcanoes might still be active enough to do this, or whether colonies of subsurface methane-producing bacteria (e.g., anaerobic *methanogens*) might be churning it out as a metabolic waste by-product (Fig. 2.13).

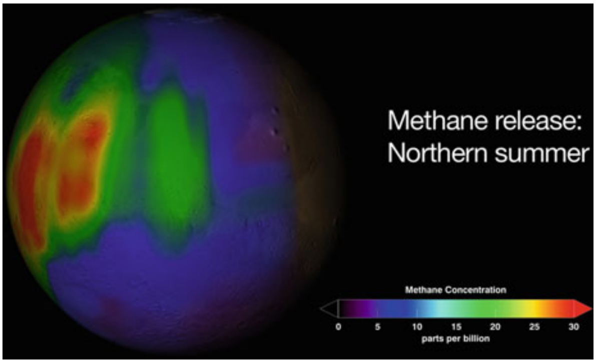

Fig. 2.13 While the surface of Mars is thought to be far too dry today to allow the existence of living organisms, the planet 3 or 4 billion years ago had a thicker atmosphere and a warmer climate which permitted seas, oceans, and running water sources (rivers) to cover large portions of the surface. If any primitive Martian organisms exist today, they would need to have taken up residence in warmer and wetter subsurface regions of the planet. NASA scientists have now found evidence that single-cell lifeforms, similar to those on Earth that exhale methane (CH_4) rather than carbon dioxide (CO_2) as a metabolic waste product may be very plentiful on today's red planet (image credit: NASA)

Scientists Find Evidence that the Chemical "Stuff of Life" May Be More Common in Universe than Previously Believed Possible

In the 1950s many scientists thought that other planetary systems in the universe were extremely rare. Today we know they are quite common. Also, in the 1950s, we thought life was complex and extremely fragile and required just the right kinds of environments in order to develop. The discovery of extremophiles thriving in Earth's most unfriendly environments now suggests life may be tougher than we previously believed possible and might be able to easily pop up elsewhere in the universe.

Life friendly organic molecules found inside meteorites and comets In the latter part of the 20^{th} century, our scientists suddenly started finding evidence of different complex molecules imbedded deep inside meteorites that had fallen to Earth from space.[2] These molecules included amino acids (i.e., the building blocks of life's proteins), sugars, and many other varieties of large molecules (i.e., "macromolecules") that contain what our life scientists now call the ***Big Six*** life friendly elements, i.e., carbon, hydrogen, oxygen, nitrogen, phosphorus, and sulfur which

[2] Meteorites are small rocky or metal objects that are the leftover remnants of the early stages of stellar system formation. These objects (which include the "shooting stars" we see in the nighttime sky) can range in size from grains of sand to several feet or more in diameter. The smaller ones are capable of breaking through the roofs of homes and severely bruising the hips of ladies sleeping on couches, while the larger ones can destroy entire cities.

are required to build our carbon-based form of life. Scientists who specialize in studying the chemical bases for life (i.e., biochemists) refer to any molecule that contains carbon as an **organic molecule**. It is important to note that organic molecules are, by themselves, not "alive" but are the raw ingredients that, when bonded with any of the other members of the "big six" group of atoms in a particular format, and in a particular supportive environmental setting, can become incorporated (at least on Earth) into real "living things"! These large organic molecules are usually composed of carbon atoms bonded to other members of the big six life friendly group in the form of rings or long chains. In the 1950s, almost all scientists believed that outer space was far too hostile (extreme heat and cold, plenty of intense and deadly radiation from stars) to allow complex organic molecules containing large numbers of atoms to be constructed. Therefore, the discovery of such organic molecules imbedded deep inside meteorites was believed to be the result of the meteorites being contaminated (polluted) by the Earth's environment either after landing on Earth or by the scientists themselves who later handled them in the laboratories. However, in a very short time the scientists were able to determine that the organic molecules they were finding inside the meteorites were not the result of contamination but had probably been inside the meteors for billions of years having been placed there when these objects were originally formed from interstellar gas and dust clouds.

And even more exciting is the recent discovery that some extraterrestrial meteorites may, in addition to the basic building blocks for proteins (i.e. amino acids), also contain the building blocks for DNA (Deoxyribonucleic Acids), i.e., those huge molecules that carry the genetic instructions (blue print) for all life on Earth. Dr. Michael Callahan and team members Drs. Jennifer Stern, Daniel Glavin, and James Dworkin from NASA's Goddard's Astrobiology Analytical Laboratory ground up samples of 12 carbon-rich meteorites found in Antarctica and other locations on Earth and used complex chemical and spectrographic techniques to determine that the meteorites contained *adenine* and *guanine* which are two of the four components called *nucleobases* that together form the genetic code that controls how every living organism (microbes, elephants, man, apple trees, tulips, etc.) on our planet is constructed and functions (Fig. 2.14).

At the beginning of the new twenty-first century, thanks to the development of powerful high speed computers, large radio telescopes, space telescopes, and more sensitive tools (spectroscopy) for determining the chemical composition or makeup of distant celestial objects (stars and planets), we also developed the technology to study the chemical makeup of far distant interstellar gas and dust clouds from which new stars and planets are formed. This allowed our scientists to suddenly begin discovering that outer space may be incredibly more life friendly than we dared imagine just a few short years ago. We now have evidence that the atomic elements that are critical for life may actually be chained (bonded) together in outer space to form special kinds of molecules that our life scientists refer to as "prebiotic" (i.e., molecules that are the precursors to actual living or "biotic" groups of macromolecules). Scientists now believe there are special regions or active "factories"

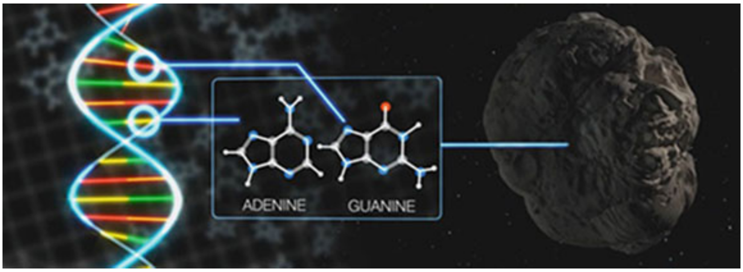

Fig. 2.14 In addition to amino acids, the building blocks for life's proteins, scientists have recently discovered that the chemical building blocks for our DNA genetic materials may also be constructed in interstellar space and then later delivered to new forming planets inside meteors (image credit: NASA's Goddard Space Flight Center/Chris Smith)

located throughout the universe (inside interstellar gas and dust clouds, and especially protoplanetary accretion disks that later produce exoplanets) that are pre-fabricating many of these prebiotic molecules that are then delivered to the surfaces of exoplanets (or the moons of some exoplanets) via meteorites or comets where the final stages of creating actual "biotic" life is then performed (Thomas et al. 2006; Kwok 2012, 2013).

How complex organic molecules are constructed in interstellar dust and gas clouds Before I begin actually describing how and where those complex organic macromolecules that are so critical for life (or at least the kind of life we know about) are constructed, the *diehard educator* in me insists I must make sure my readers understand where our scientists believe such large molecules come from in the first place. If the reader is already familiar with what makes stars shine (i.e., that phenomenon that scientists call "nuclear fusion"), you are free to skip the next few paragraphs of this chapter in which the author will briefly describe how the heavier atomic elements (e.g., carbon, oxygen, and other members of the "big six" life friendly elements plus even heavier elements) are created and made available for the construction of planets and life (Lequeux 2013; Spangenburg and Moser 2003).

As mentioned earlier in the present book, many scientists now believe that, prior to the Big Bang event approximately 13.7 billion years ago, nothing existed in the universe but an unbelievably dense plus extremely hot piece of pure energy that was much smaller than an atom. The first true physical matter created following the Big Bang, however, was not even atoms, but those strange and extremely small "sub-atomic particles" that scientists tell us are themselves the building blocks of atoms Although we now believe there are 36 confirmed kinds of sub-atomic particles, atomic scientists are still searching and will probably discover even more in future years. However, within the first 3 min following the start of the Big Bang expansion (Delsemme 1998), these sub-atomic particles were beginning to link up with each other to form the first hydrogen atoms plus a very small trace of slightly heavier helium and lithium atoms. From that time forward, all the components of our known universe (i.e., matter, energy, space, and even time) were created, and by

380,000 years following the Big Bang all of the hydrogen atoms that we presently have in the universe were created. At first the only physical matter that was created was a huge (a definite understatement) cloud of hydrogen atoms mixed with extremely small traces of slightly heavier helium and lithium atoms. Thus, for all intents and purposes, our young universe shortly after its birth consisted of nothing but a rapidly expanding cloud of incredibly hot hydrogen gas.

Before stars and planets could begin to be formed, however, this huge initial cloud of hot hydrogen gas had to begin breaking up into different regions that contained different amounts of hydrogen gas. Thus, our original gigantic cloud of hydrogen gas that filled the entire universe began to spontaneously break up into a huge number of smaller hydrogen clouds that were surrounded by other adjacent regions that contained far fewer hydrogen atoms. Some of these separate smaller clouds of hydrogen gas then started collapsing (because of their weight, i.e., gravity) and transforming into a much smaller round shape. Starting about 100 million years after the Big Bang, the first stars began to be formed. Many of these stars, which astronomers refer to as our universe's "first generation" stars, were extremely large and massive in comparison to later generations of stars, including today's stars.

As these first giant stars continued to shrink in size, they became increasingly dense and much hotter. Finally, the shrinking ball of hydrogen got so dense and so hot that the nuclei of the hydrogen began to collide with other hydrogen nuclei to produce heavier helium (containing two protons) nuclei. This collision between the nuclei of lighter elements to produce new heavier elements is called "nuclear fusion" by atomic scientists. When two smaller atomic nuclei (e.g. hydrogen) fuse together to produce a heavier nucleus (e.g., helium) a very small amount of the matter is converted to a very large amount of energy (it is this energy from untold numbers of these fusing atoms which is the source of the incredible amounts of heat and light that stars generate). With the onset of nuclear fusion, shining stars are born. Therefore, the first stars created after the Big Bang event contained only hydrogen gas, but when they became dense enough to begin triggering nuclear fusion, new heavier atomic elements began to be formed that contained larger and larger numbers of protons. Eventually, these first generation stars that had gone through the process of creating new heavier elements from fusing hydrogen nuclei together would "die" in a sudden explosion (known as a supernova) and all of their contents (hydrogen plus the newly formed heavier elements) would be scattered into the surrounding space to form what would now be called "gas *and* dust clouds".

This creation of heavier atomic elements by the death of the first generation of hydrogen-filled stars would now set the stage for the development of subsequent generations of stars that now contained both lighter hydrogen plus heavier elements that, when they died, would make it possible for planetary systems to develop. All subsequent generations of star formation, including that of our own sun, would now involve these gas and dust clouds beginning to collapse and getting more dense but instead of forming a dense round ball, many of them would now form a flat spinning disk-like structure (similar to the Frisbees that children play with). The center of this disk-like structure now contained a bulge that would give rise to a new star while the flatter surrounding regions of the disk would give rise to planets. **The reader might want to look again at Fig. 1.2 at the beginning of Chap. 1 which**

shows an excellent artist's drawing of how new stars and planetary systems are formed from these rotating disks of dust and gas clouds.

All stars, nevertheless, eventually die. When stars finally start to run out of sufficient amounts of hydrogen to keep on shining, they briefly turn to the use of helium (which they now have a huge supply of thanks to many eons of producing it in the core of the star) as their new fuel source to produce other slightly heavier elements including carbon, sodium, oxygen, etc. The star's core will begin to take on the appearance of a layered onion with the lightest elements (e.g., carbon, sodium, and oxygen) at the periphery and the heavier elements (e.g. silicon and iron) at the center of the core. However, when the star finishes fusing its lighter elements together (e.g., helium, carbon, etc.) and attempts to start using iron as a new fuel source, it runs into a problem. Unfortunately, iron is far too heavy for the star to use it as a fuel source. When the star tries to fuse iron nuclei together to produce heavier elements, it finds that this process requires more energy than the star is now capable of producing. This causes the outer layers of the star to suddenly collapse onto the core to create a catastrophic supernova explosion.[3] The energy created by this explosion is so intense that, for a very brief time, it does allow the fusion and creation of even heavier atomic elements all the way up to and including uranium. It is, therefore, the explosion of giant and supergiant stars that provides all of the raw materials that are needed to construct everything we see in the universe, including other stars, planets, and even living things. Thus, mother nature is definitely into "recycling"!

However, in order to have the universe that we humans are comfortable with today, we need to have much more than large balls of hydrogen gas that are busy fusing hydrogen to helium in order to shine and produce heat. As diehard carbon-chauvinists, we humans need to be surrounded by a universe that, while still filled mostly with hydrogen (approximately 97 % by volume), also contains a small amount (i.e., 2 or 3 %) of atoms that are heavier than hydrogen. Virtually everything we hold dear in our lives, the ground we walk on, the trees that shade us, and our spouses or significant others that tell us to take the garbage out are composed of heavier atomic elements.

Since scientists have known for some time that virtually all of the atomic elements that are heavier than hydrogen are produced by the fusion of lighter elements inside the incredibly dense and hot centers (cores) of stars during their normal life spans or by the extreme traumatic events associated with supernova or

[3] It is important that the reader know that stars that are the size of our own sun or smaller, while making up the majority of all stars in the universe, do not explode when they start running low on their primary supply of fuel, i.e., hydrogen, that is needed to allow them to begin creating their new alternate fuel source of helium and other heavier elements (e.g., carbon, silicon, oxygen). Instead of exploding in a massive supernova event (or an even more intense "hypernova" explosion in the case of much larger supergiant stars), these smaller stars will slowly begin expanding in size to become what astronomer's call "red giant" stars. In the case of our sun, in another 4 or 5 billion years, the sun will expand so much that the outer layer of the new giant star will completely envelop (and burn up) the Earth.

hypernova explosions, we now need to talk about how these different heavier elements are built and put together to form us and the world on which we live. In recent years, our scientists have started discovering that the heavier elements that are ejected into space from dying stars, including helium, carbon, oxygen, nitrogen, phosphorus, and sulfur, plus other heavier elements like iron, gold, and uranium, are mixed together, along with our primordial friend hydrogen, inside huge interstellar gas and dust clouds to form complex collections of grain-like or sometimes fluffy dust particles, many of which are coated with icy materials (Fig. 2.15a, b) These small but complicated structures then become the *interstellar factories* within which complex forms of chemistry can occur (Jastrow and Rampino 2008; Kwok 2013). Various kinds of complex organic (prebiotic) molecules are slowly formed inside these dust grains by a complicated series of different chemical reactions. The

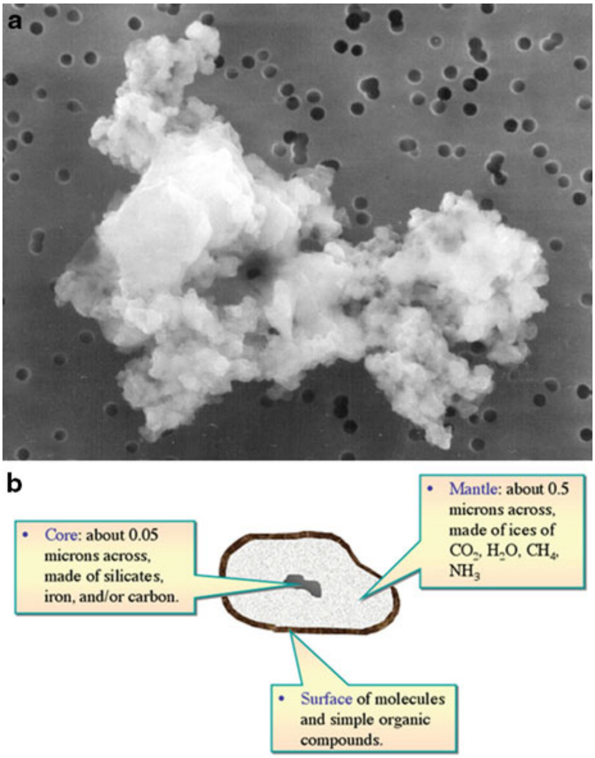

Fig. 2.15 (**a**) Shows a microphotograph of a dust particle that was retrieved by a recent unmanned NASA space mission that gathered and returned dust particles from the tail of a comet. The dust inside the tails of comets (as well as meteors) have been found to contain different kinds of complex organic molecules that originally formed in interstellar gas and dust clouds millions or billions of years earlier (image credit: NASA). (**b**) Shows an artist's drawing of how many interstellar dust particles are constructed. The mantles of many dust grains are composed of carbon dioxide (CO_2), water (H_2O), methane (CH_4), and ammonia (NH_2) (image credit: Centre for Astrophysics & Supercomputing, Swinburne University of Technology)

icy surface of these dust grains both protects the developing molecules from stellar ultraviolet radiation that would normally tear such molecules apart, plus also provides a surface on which atoms and molecules can congregate and chemically interact (bond) with each other to form new and different molecules. Some of the chemical reactions that lead to complex prebiotic molecules only occur in the colder deep interiors of the dust clouds, while others may require the assistance of "just right" (i.e., not too strong nor too weak) doses of heat and radiation from neighboring stars. This "vital dust", as the Nobel prize winning life scientist Christian de Duve calls these organic molecules (de Duve 2002) then finds its way into the interiors of planetary accretion disks where it becomes incorporated into the fabric of growing meteors, asteroids, comets, and other assorted objects that begin raining down on the surfaces of growing planets. As mentioned earlier, analyses of the chemical makeup of meteorites that have landed on Earth have provided evidence that they do contain many varieties of complex organic molecules, including amino acids (building blocks of proteins) and nucleobases (the building blocks of our genes) which carry the detailed instructions for constructing life itself. Dust collected directly from comets by the unmanned NASA spacecraft Stardust probe has also recently been found to contain several varieties of complex organic molecules, including amino acids that are needed to build life (Fig. 2.16).

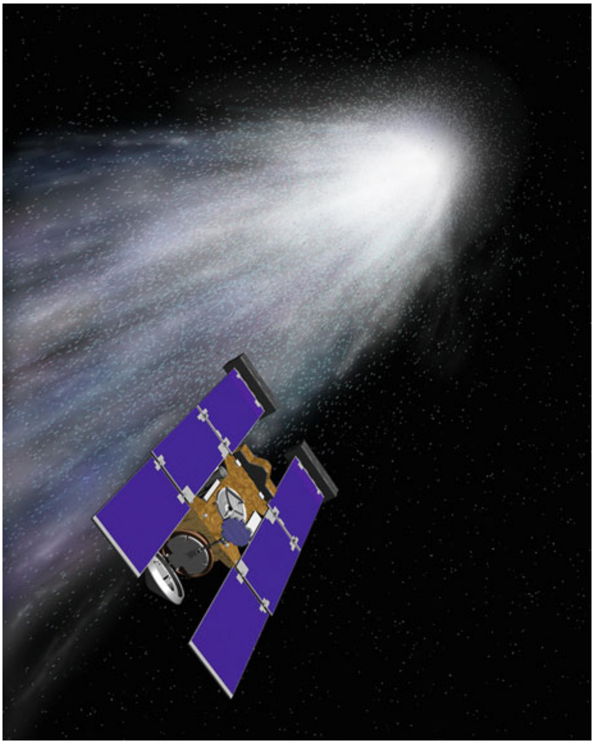

Fig. 2.16 Artists drawing of an unmanned NASA spacecraft that recently flew through the tail of a comet and collected samples of gas and dust particles to be brought back for chemical analysis. The dust particle shown in Fig. 2.15a was one of the particles that were collected in this mission (image credit: NASA)

Not only are complex organic molecules created in space, scientists can now synthesize them in the laboratory In an amazing new series of experiments, scientists at the NASA Ames Astrochemistry Laboratory and NASA Goddard Space Flight Astrobiology Center plus other laboratories around the world (Cranford 2011; Ehrenfreund et al. 2004; Ward 2005) have been actually replicating in the laboratory the environmental conditions that affect the dust particles that are located inside distant interstellar dust and gas clouds (Fig. 2.17a, b). Various kinds of dust particles (containing various kinds of life critical atomic elements, e.g. hydrogen, carbon, nitrogen, etc.) are placed inside small vacuum chambers that mimic the conditions found inside actual interstellar dust and gas clouds and then either cooled to very low icy temperatures or bathed with ultraviolet light similar to what real dust particles in real interstellar dust clouds would receive from real nearby stars. In the last few years, these scientists have begun to find that many of the complex organic molecules that ***occur in living creatures on our planet, or that have been retrieved from comets by NASA spacecraft or found hiding deep inside meteorites that have fallen to Earth***, can now be synthesized in the laboratory!

Therefore, to use a somewhat "far out" analogy, it seems that outer space is not just providing the basic raw ingredients (*building materials*) needed to build life (*e.g. nails, lumber, bricks, mortar, etc.*) but is actually performing some of the critical early construction phases, i.e. pre-fabricating some of the more complex "modular" units (i.e., organic molecules) that, after being delivered to the final building site, i.e. the surface of an exoplanet or its moon, are then put together to form "houses", *or to now drop the analogy*, producing ***LIFE***.

Scientists have developed tools to detect and study the chemistry of complex organic molecules in distant interstellar dust clouds In order to be able to examine the chemical composition of the interstellar gas and dust clouds[4] that are located thousands of light years away from us, astronomers had to develop special tools or instruments that could detect incredibly small concentrations of hydrogen atoms that are mixed with even smaller concentrations (i.e., less than 0.1 %) of other elements such as oxygen, carbon, and nitrogen to build organic molecules. And to make matters even worse, the scientists had to study gas/dust clouds that were extremely reluctant to even let us know they are there! The astronomers quickly discovered that the strength or power of the electromagnetic emissions from even the larger gas/dust clouds were unbelievably weak! ***In fact, astronomers tell us that the act of letting a small postage stamp fall onto a table top creates a much greater "thud" (i.e., amount of energy or power) than the energy that is emitted by atoms and molecules located inside interstellar gas or dust clouds!*** While, with optical telescopes, we can easily detect ("see") the visible light being

[4] It is important to note that the concentration levels of even the more dense of these interstellar gas/dust cloud regions are quite diffuse and may contain considerably fewer than 100 atoms per cubic centimeter. In marked contrast, the Earth's atmosphere at sea level today has an average density of approximately 2,500 air molecules per cubic centimeter.

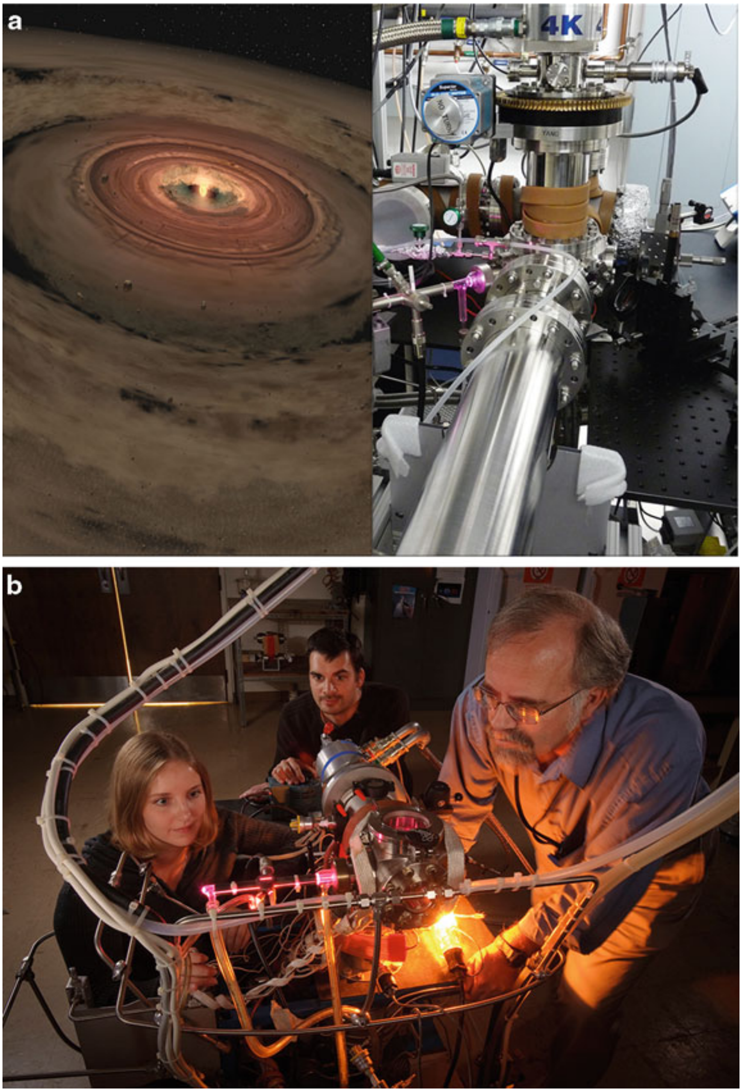

Fig. 2.17 Photographs taken at (**a**) NASA’s Jet Propulsion Laboratory (credit: NASA/JPL-CALTECH) and (**b**) the NASA Ames Research Center in California (credit: NASA Ames Astrochemistry Laboratory) show how Earth-bound scientists are able to mimic and reproduce in the laboratory the environmental conditions that occur inside distant interstellar gas/dust clouds. Experiments conducted at JPL and Ames and other laboratories have been successful in synthesizing many kinds of complex organic molecules that are similar to those that are critical to the formation of life

emitted by a gas or dust cloud (especially if the cloud is hot), more often than not the clouds are dark and cold. Still, in order to be able to effectively determine the chemical makeup of such clouds, astronomers do not need to see them but do need to measure the much longer wavelength (and invisible) infrared, microwave, and radio range of electromagnetic energy (see Fig. 2.10b) that are emitted by specific organic molecules in such clouds. Therefore, since the radio waves and infrared heat emitted by distant dark and cold interstellar dust and gas clouds are so weak, scientists had to develop huge telescopes with amazingly large antennae or receiving dishes to have any chance of being able to detect and record such weak signals.[5] Today's best radio telescopes are, therefore, gigantic and very expensive to construct. Figure 2.18a shows a photograph of one such giant radio telescope that radio astronomers in West Virginia have been successfully using in recent years to study organic molecules in distant interstellar clouds, while Fig. 2.18b shows an artist's sketch (diagram) of a group of eight complex organic molecules that the Green Bank radio astronomers have identified in the gas/dust clouds. About 90 % of these interstellar molecules contain the element carbon which is why biochemists and other life scientists label them as being "organic" molecules. Most organic molecules contain at least 6–15 (or more) other types of atoms including hydrogen, nitrogen, oxygen, phosphorus, or sulfur. A very large percentage of these complex organic molecules are similar or identical to many of the organic molecules that plants and animals on our own planet are constructed from. A team of scientists led by Anthony Remijan at the Green Bank Observatory have been able to successfully record the chemical signatures of molecules in a giant gas cloud located 25,000 light years from the Earth that are believed to be the precursors to a key component of DNA and another that may have a role in the formation of the amino acid alanine. The Green Bank scientists believe that the finding of these complex organic molecules in an interstellar gas and dust cloud means that the important building blocks for both DNA and amino acids may be constructed in such interstellar clouds at the same time that new stars and planetary systems are being born which would then be available to "*seed*" newly-forming planets with the chemical precursors for life.

Several groups of astronomers in the United States and other countries have recently started reporting evidence that organic molecules of unexpected complexity exist throughout our Milky Way galaxy. Professor Sun Kwok and Dr. Yong Zhang at the University of Hong Kong, using NASA's Infrared Space Laboratory

[5] Because the longer wavelength radio, microwave, and infrared waves originating from far distant interstellar gas and dust clouds are so incredibly weak, the radio astronomers at the Green Bank telescope facility in West Virginia had to push the local government of the surrounding community to actually pass a law to forbid the use of cell phones by their citizens in a several mile radius around the telescope facility. The electronic interference from the average cell phone is so intense that it could easily over power the weak radio signals that the astronomers were trying to collect from the distant dust and gas clouds. So, in a very real sense, thousands of private citizens in the Green Bank area are actively participating as "co-investigators" on this exciting search for life in the universe.

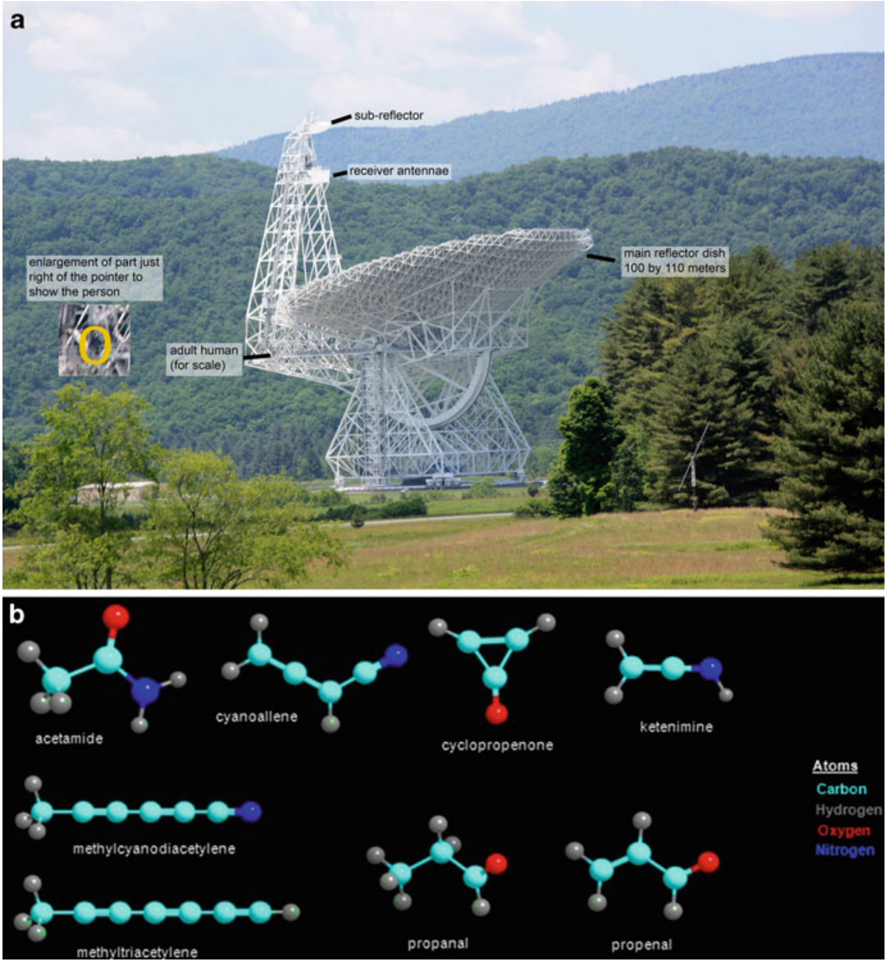

Fig. 2.18 (**a**) Shows a photograph of the National Science Foundation's Robert C. Byrd radio telescope that is located in Green Bank, West Virginia. This incredibly large telescope has so far (as of August, 2006) discovered a total of 141 complex organic molecules located in two typical interstellar dust and gas clouds. (**b**) Shows an artist's schematic model (diagram) of how each of the eight most recently discovered organic molecules are constructed (image credit: Bill Saxton, NRAO)

and the Spitzer Space Telescope have examined the spectra of dust and gas clouds that are located close to distant exploding stars (supernovae) and report that the dust contains a multitude of different kinds of large and complex organic molecules that are very similar to those known to be associated with the development of carbon-based life on Earth (Fig. 2.19). These scientists suggest that such supernova explosions in our galaxy (and other galaxies) eons ago produced shock waves in nearby dust and gas clouds which caused these huge clouds to break apart and

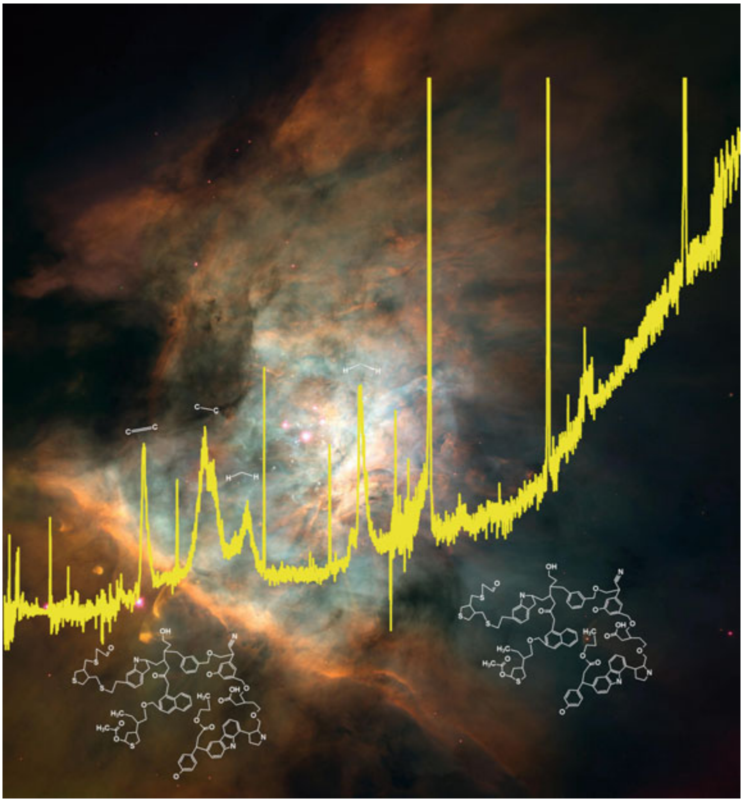

Fig. 2.19 Dust and gas clouds located close to distant exploding supernovas have now been found to contain large complex organic molecules containing carbon and hydrogen that are similar to those needed to build life. The large complex carbon-based molecules which Dr. Sun Kwok found are unusually large and actually resemble coal or petroleum molecules more closely than other simpler forms of carbon molecules (image credit: NASA/C.R. O'Dell and S.K. Wong, Rice University)

collapse into many smaller rotating disks that would eventually give rise to new stars and planetary systems. The dust grains that formed inside these collapsing clouds then began the process of chaining/linking complex organic molecules together and placing them inside meteorites and comets where they would then be delivered via "*local air mail delivery*" to the surfaces of new forming planets to jumpstart life. Many protoplanetary accretion disks throughout our galaxy and even beyond our galaxy may be involved in the manufacturing of complex prebiotic molecules that are needed by any future life friendly planets that may develop in their systems. One of the biggest and most profound questions for our future astrobiologists will be, therefore, determining whether there is a universal formula for developing life (e.g., carbon-based) or whether different kinds of life chemistries (e.g. silicon-based) may develop in different parts of our own Milky Way galaxy or even in far distant galaxies in our vast universe.

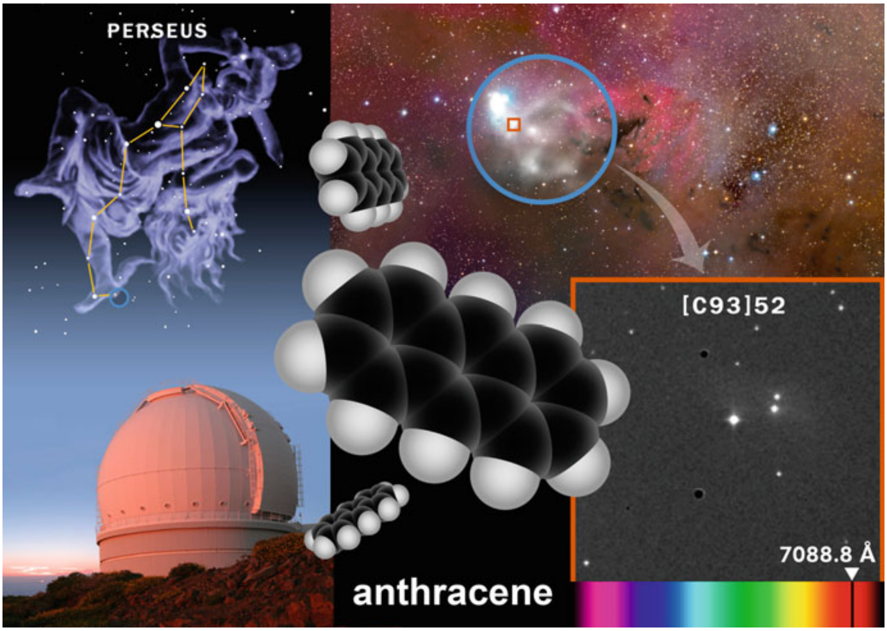

Fig. 2.20 Scientists from the Instituto Astrofisica de Canarias and the University of Texas report finding one of the largest known forms of organic molecules named Anthracene in a distant interstellar dust cloud. This chemical is a common component of coal tar and petroleums (image credit: Gaby Perez and Susana Iglesias-Groth)

Another team of scientists from the Instituto Astrofisica de Canarias and the University of Texas recently found evidence of very large and complex organic molecules in a dense cloud of dust found near a star (Carnis 52, in the constellation Perseus) which is located about 700 light years from the Earth (Fig. 2.20). The molecule is named *anthracene* and is one of the largest known organic molecules in which each molecule contains 10 hydrogen and 14 carbon atoms bonded together. The existence of this large organic molecule in interstellar space definitely refutes science's long held belief that any large organic molecules in space would be immediately torn apart by the intense heat and stellar radiation from close by stars.

Other researchers have also identified the presence of other kinds of complex organic molecules in nearby interstellar dust and gas clouds (e.g., the Orion Nebula) as well as newly forming planetary systems (i.e., protoplanetary accretion disks), including ammonia, methane, silicates, carbon dioxide, acetylene, and hydrogen cyanide (Fig. 2.21a–c). These prebiotic molecules, some of which are the critical gaseous precursors to DNA and proteins, were detected by NASA's Spitzer space telescope inside the protoplanetary dust zone of a young star where rocky planets similar to our Earth are believed to develop. Oxygen molecules, which are critical to some forms of carbon-based life, have also been found in interstellar gas/dust clouds as well as protoplanetary accretion disks (Fig. 2.22).

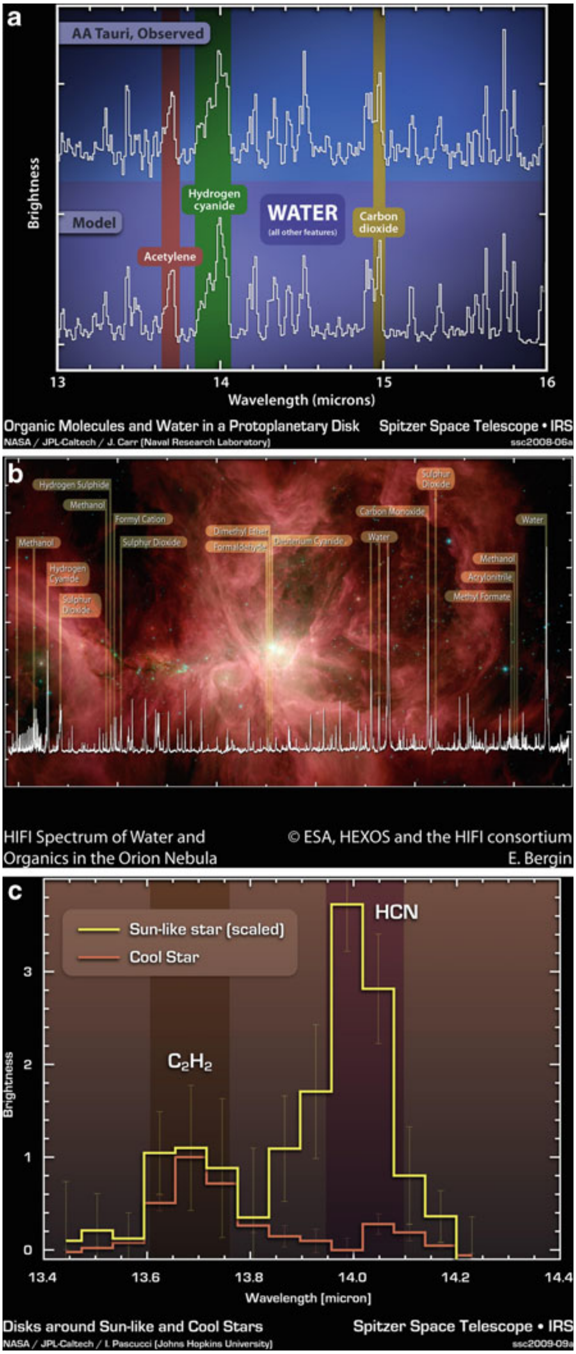

Fig. 2.21 Ices, water, and other forms of complex organic molecules, including hydrocarbons, methanol, and hydrogen cyanide, which have been proposed as precursors to the building blocks of life, including amino acids and nucleic acids, are being found in many locations in space. (**a**) and (**b**) depict the presence of such molecules in distant protoplanetary disks where new planetary systems are being built (image credit: NASA and Caltech), while (**c**) shows evidence that the planet forming accretion disks of distant sun-like stars may also contain more life friendly chemicals than disks around cool stars. While acetylcholine (C_2H_2) is found in both kinds of disks, sun-like stars contain large quantities of prebiotic or potentially life-forming molecules called hydrogen cyanide (HCN) (image credit: NASA's Spitzer Space Telescope)

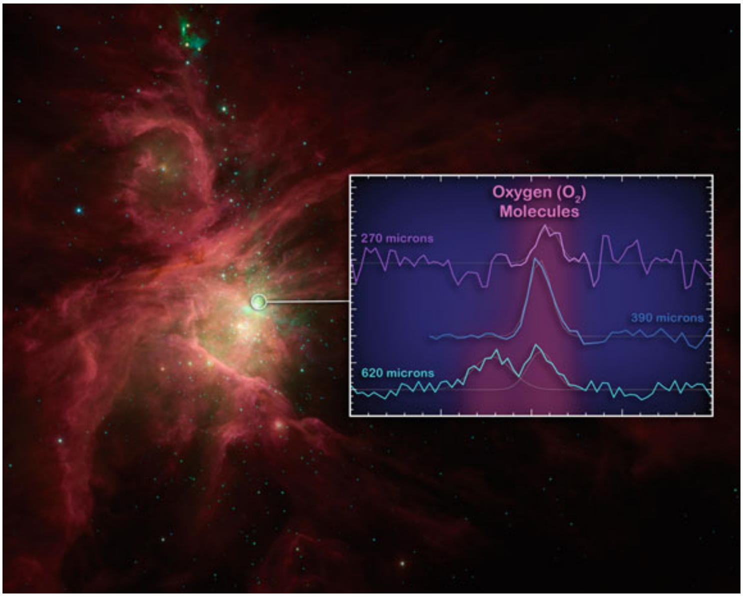

Fig. 2.22 And, of course, some of our scientists have now discovered that the most important chemical molecule, i.e., O_2 oxygen molecules, which are critical for some advanced forms of life comparable to we humans on Earth, are also present in distant interstellar gas and dust clouds (image credit: ESA/NASA/JPL-Caltech)

And, of course, water (H_2O) which most scientists believe is as important for supporting life as is the carbon atom (at least for our form of life), appears to be quite plentiful everywhere in the universe. Our friends at NASA now tell us that water ice is also present everywhere in our own solar system, including even the hottest and coldest environments. Extensive amounts of water ice has been found to be hiding at the bottom of craters on our own moon as well as those located at the north pole of Mercury where they are protected from melting by the shade of surrounding high crater walls.

Scientists have identified life friendly organic molecules in other galaxies in the universe Some scientists are now beginning to expand the search for ET even beyond our own Milky Way galaxy. A team of NASA and European scientists recently used a special form of light spectroscopy to study the light spectra of individual stars in the Andromeda and Triangulum galaxies that are members of the local group of galaxies that includes our own Milky Way galaxy. These two galaxies are located relatively "close" to the Earth at distances of only 2.3 and 3 million light years, respectively (Fig. 2.23a). Another group of astronomers at the University of Massachusetts and Mexico's National Institute of Astrophysics recently used a special type of radio telescope that is setting atop a volcano in a Mexican desert to identify life friendly organic compounds in the Starburst Galaxy (M82) which is located only 12 million light years from the Earth (Fig. 2.23b). The

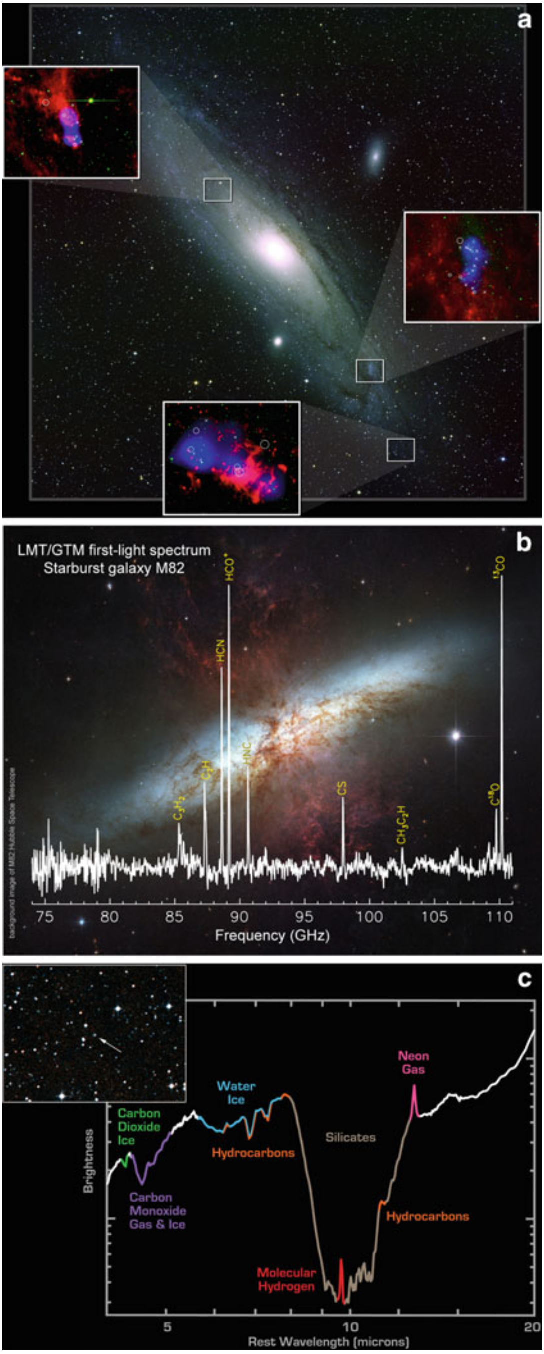

Fig. 2.23 Several types of complex organic molecules that are similar or identical to those needed for life have now been found in other galaxies located beyond our own Milky Way Galaxy. The three *colored insets* in (**a**) are believed to be the spectral light signatures of two types of large

investigators found evidence that certain kinds of large "mystery" organic molecules (that contain at least 20 atoms bonded together) in these stars were absorbing narrow bands of light (which scientists call diffuse interstellar bands or "DIBs" in the visible and near infrared portions of the normal light spectrum. Some of these strange absorption bands are believed to be associated with the presence of large organic molecules.

However, other astronomers (Fig. 2.23c) have found that complex organic molecules are also present in even more distant galaxies. NASA scientists using the Spitzer space telescope, which only sees objects that are emitting infrared light (heat) rather than visible light, have reported the presence of complex organic molecules in another galaxy that is about 1,000 times further away than the Andromeda galaxy at a distance of approximately 3.2 billion light years.

Since the light from all of these distant galaxies took millions and billions of years to reach our telescopes, it would appear that life-friendly organic molecules may have possibly been present in other galaxies in our universe even before life first evolved on our own planet. This remarkable finding suggests that we earthlings may not be the first life forms to develop in the universe. And, as indicated earlier, we now know that our own Milky Way galaxy also hosts many gas and dust clouds that are newborn stellar nurseries where new stars and planetary systems are being formed. The closest such cloud to the Earth and the only one that is visible to the naked eye is the Orion Nebula which is located 1,344 light years away. When our astronomers look through their telescopes at these newly forming planetary systems in the Orion nebula, they are viewing them exactly as they appeared circa 670 A.D. when our human civilization was just entering the early stages of its middle age period and feudal lords lived in castles and our peasant ancestors toiled in the fields to barely eke out a living. ***The reader should now look at the Hubble space telescope photograph shown on the cover of the present book for an image of six such protoplanetary systems that are presently being formed in the Orion Nebula***.

Thus, in addition to not "being the first" life forms to arise in our universe, we may also "not be the last"! Our best scientists currently believe that, although the universe we now live in is at least 13.7 billion years old, it probably has many

Fig. 2.23 (continued) complex carbon-based molecules located in two of our next door galactic neighbors (the Andromeda and Triangulum galaxies) both of which are local members of the 30 or more galaxies that are located closest to the Milky Way that astronomers refer to as the "local group". (**b**) Astronomers at the University of Massachusetts and Mexico's Instituto Nacional de Astrofisca using the Large Millimetre Telescope which sits on top of a 15,000 ft. high volcano in Mexico have identified several varieties of life friendly organic molecules in the Starburst galaxy M82, which is another member of the Milky Way's local group and is located only 12 million light years from the Earth (image credit: National Institute of Astrophysics, Puebla, Mexico). Finally, (**c**) shows another galaxy located approximately 1,000 times further away (approximately 3 billion light years) that also appears to house substantial amounts of complex organic molecules (image credits: NASA Spitzer Telescope team and NASA Goddard Space Flight Center) billions of years left before It will either totally cease to exist via some kind of unknown natural catastrophe, or perhaps transition into a different kind of universe or even expand into multiple or even other parallel universes. And, of course, from mankind's own selfish viewpoint, most of us would obviously like to know how many more times our own descendants or other intelligent life forms somewhere out there will be able to witness the birth, evolution, and eventual demise of other planetary systems in other parts of our incredibly vast universe. The life of our universe is indeed the greatest unsolved mystery of all (Deep) Time!

This exciting new research that strongly indicates that different kinds of complex organic molecules may be pre-fabricated in interstellar space has suddenly forced many of our scientists into believing that outer space may be far more life friendly than we could ever have imagined. It now seems that, in addition to the creation of the heavier atomic elements (e.g. elements heavier than hydrogen and helium, such as carbon, nitrogen, iron, etc.) by exploding giant or supergiant stars that are needed to build both planets and life, various "sources" (gas/dust clouds, protoplanetary accretion disks) in interstellar space may also be involved in chaining these elements together to form many of the larger organic molecules that are critical for life and then delivering them to the surface of the Earth and other exoplanets (plus some of their moons). Figure 2.24 shows an excellent drawing by artist Bill Paxton that summarizes how this incredible "interstellar life enhancement" process may work. Thus, while some scientists (including the author) believe it is possible that life based on other kinds of chemistries may exist on some of the so-called "hostile" worlds being identified by the new Kepler space telescope, it is possible that our kind of life (i.e., carbon and water based) may itself be more common in the universe than our most optimistic scientists and even diehard science fiction enthusiasts would have dared believe possible just a few short years ago.

Many scientists, however, believe that there may be two different methods by which life friendly organic molecules can be made available for jumpstarting life. In addition to building such molecules in outer space and then delivering them to the surfaces of planets, some of these complex molecules might also be manufactured by heat-related processes inside hot hydrothermal vents deep in our oceans, or inside hot volcanoes, or even as a result of lightening activity that occur inside thunderstorms in our atmosphere. The bottom part of Fig. 2.25 shows how this other important "in-house" means of building some life critical prebiotic molecules may happen.

What if carbon-based life is not the only kind of life that can occur in the universe? Of course, being the conservative hard-nosed creatures we are, many scientists (including the author) have raised a "cautionary flag" by suggesting that the finding of organic molecules everywhere in space may be an artifact related to our own anthropomorphic biases plus highly selective search techniques. **First** of all, some of us "expect" (and others even hope?) that many (but not all) ETs may, like us, rely on carbon and water-based chemistries. And, **secondly**, all of our sophisticated tools for confirming this are based on technologies (radio and space telescopes, spectrographic and biochemical analysis procedures, etc.) that have

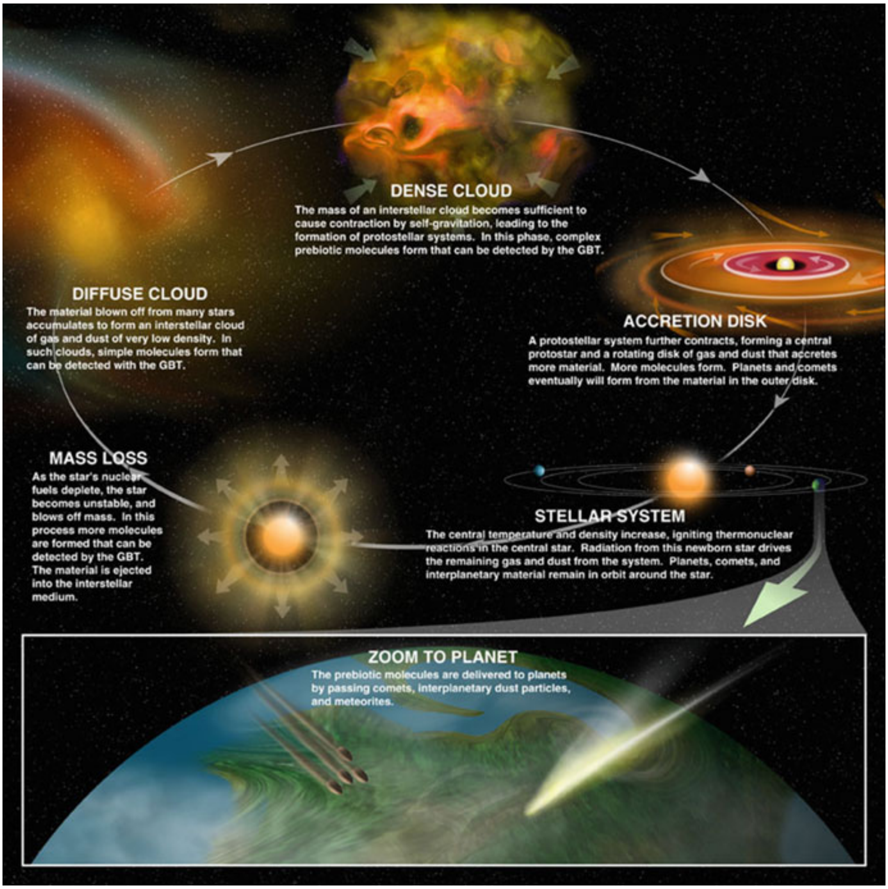

Fig. 2.24 While the transfer (via panspermia) of fully formed living (or dormant) microorganisms from one location to another in the same planetary system might be possible, it is unlikely that this could occur between different planetary systems or other distant locations in the universe. Scientists now believe, however, that it is very possible that many of the complex organic molecules that are needed to build life may be constructed in the protoplanetary disks of new developing planetary systems and then delivered inside comets, meteors, asteroids, or dust grains to the surfaces of their own planets to jumpstart the evolution of life. This excellent artist's drawing depicts the series of events and the actual structures (supernovas, gas and dust clouds, protoplanetary accretion disks, etc.) that are believed to be involved in this complex life building process. Astronomers at the Robert C. Byrd Green Bank Radio Telescope (i.e. the **GBT**) facility in West Virginia (plus similar radio telescope facilities around the world) have been recording the extremely faint radio, microwave, and infrared waves that are emitted by different kinds of complex organic molecules that are constructed when new stars and planetary systems are formed in distant interstellar gas and dust clouds (image credit: Bill Saxton, NSF/AUI/NRAO)

been specifically designed to allow us to detect and identify our own kind of life in our searches. Thus, the finding of carbon-based prebiotic molecules everywhere in space may be largely the result of how and where our scientists are looking and what they are looking for. How many complex molecules based on silicon, or

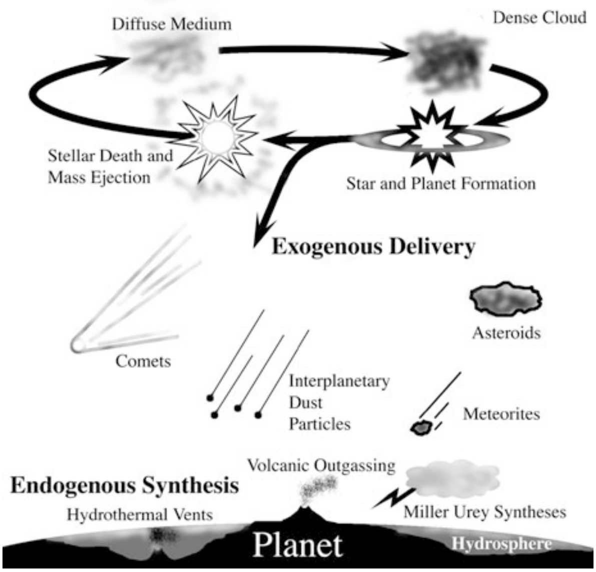

Fig. 2.25 Complex life friendly organic molecules may not always be manufactured "in toto" inside interstellar dust and gas clouds or protoplanetary accretion disks and then later delivered (via **Exogenous Delivery**) to a new planet's surface to jumpstart life. Many scientists believe that some of these organic molecules may be manufactured via **Endogenous Synthesis** in hot hydrothermal vents that are located in the deeper areas of a planet's seas or oceans (if the planet is a water world) or by the mixing of chemicals in the hot interiors of volcanoes, or even as a result of lightening discharges (via Miller-Urey synthesis) in storm clouds which cause simpler molecules in the atmosphere to recombine into more complex organic molecules. This internal or endogenous means of building life friendly molecules is shown in the lower part of this figure. The chemical origins of life on other exoplanets or their moons in the universe may possibly involve one or both of these two complementary but equally important processes. While some amino acids and nucleic acids may be built in distant interstellar dust clouds and then delivered directly to a planet's surface inside comets, asteroids, or meteorites, other types of amino acids or other prebiotic molecules might be built from scratch using special chemicals and the assistance of energetic heat sources inside volcanoes or hydrothermal vents (image credit: NASA Ames Astrobiology Research Institute)

phosphorus, or boron, have we found in interstellar space? And, how hard have we looked? Most scientists believe that complex molecules based on silicon are much less stable than the carbon-based varieties and, therefore, less likely to provide a viable basis for the chemistry of life (ergo, "life as we know it"). Such silicon-based molecules do appear to be less stable (and, therefore, less life friendly) on Earth, but how about other extreme environments in space? Have we performed adequate research to verify this critical difference between carbon and silicon, or have we allowed our personal biases to restrict our investigations and constrain our interpretations of the data? After all, our scientists have been accused by more than a few members of the popular news media of being carbon-chauvinists! Whether ET is boron-, phosphorus-, silicon-, or carbon-based would likely have very little to do with determining whether their outer morphological appearance is in any way similar to that of us long-legged, lanky, and big-headed humans. Some of those giant ugly grasshopper-like creatures that the science fiction people have conjured up as totally alien might not look anything like us but could still be our "first cousins" in terms of their chemistry. On the other hand, some silicon, boron, or phosphorus-based creatures might, if they evolved in virtually identical environments to ours, develop remarkably similar external morphological characteristics to ours since evolution tends to be conservative in using the easiest solutions to allow living creatures to adjust to similar environments. Mammals that chose to return to the oceans (e.g., whales) traded in their legs for fins in order to swim like fish. And, of course, eyes and wings have been reinvented over and over again to allow different animal species to see and fly.

Finally, before ending this chapter, I would like to discuss some very strong personal biases that I, along with probably many other "owner's of human brains" have with regards to what life is and what kinds of life may be out there in our vast universe. Most human brains work virtually the same, having been molded and shaped by a common biological and societal history and a common physical/chemical environment that we all share. In this regard, human brains worldwide are virtual clones of each other. It is no surprise, therefore, that most of us (scientists as well as non-scientists) tend to be close-minded when it comes to considering alternative possibilities to the things we think we know or have learned beginning at a very early age. And, whether they admit it or not, this statement is equally true for the science fiction writers as it is for all the rest of us.

The author freely admits that it is very difficult for him to conceive of alternative types of life forms that could exist elsewhere in the universe that might be markedly different than those that we are familiar with here on Earth. Although living species on our planet come in an amazing variety of different physical sizes, colors, shapes, as well as behavioral characteristics, etc., they are all based on the same chemistries (i.e., the carbon atom and its five "buddies", i.e., hydrogen, oxygen, nitrogen, phosphorus, and sulfur) and all must have easy access to water. Elephants, amoebae, and palm trees may look radically different but they are still our first cousins in terms of their chemical makeup.

At the present time, all of our astrobiologists and other life scientists (plus our science fiction cohorts) would have to admit that, as far as we now know, the only kind of life that exists in the universe is carbon-based and water-dependent, and we are it! The question of whether this is the only kind of life that can possibly exist is, at present, completely unknown. Since we presently do not know whether alternative kinds of life might exist, it makes total sense for our space scientists to focus their initial searches on finding twins of our planet Earth, or reasonable possible alternatives thereof (i.e., not too large or small, too hot or cold, with an oxygen atmosphere, and adequate quantities of easily accessible carbon and water, ***either now or sometime in the past***). In the far distant future, if our space faring descendants do discover that all life everywhere is carbon-based and dependent on water, I personally would be surprised but not too surprised. While it is possible that the inherent chemical and physical features of the carbon atom might make it the leading candidate for supporting life in vast regions of the universe, it is very possible that environmental conditions somewhere out there may have allowed silicon (or boron or phosphorus) to be the primary building block, and water (while it, like carbon, appears to be everywhere) might have lost out somewhere else to liquid methane, or other types of solvents, as the primary liquid facilitator of life. Of course, as is definitely the case on Earth, the carbon/water life combo in other parts of the universe most likely would assume an incredible variety of different physical or morphological formats, some of which (like they do on Earth) would look totally different from what we believe a living creature should look like. And, as for communicating with ET, our scientists may discover that, while many of these strange looking creatures may live in the same universe as we do, they may think, behave, and interact with their environments in a manner that is totally alien to us. When it comes to having a mental or psychological makeup that is similar to ours, we may discover that we have more "in common" with our own family pets (e.g., cats or dogs; or even parakeets) then we do with many ETs. Thus, the question of whether we are alone (if not physically, then possibly psychologically) in the universe may turn out to be more difficult to answer than we now believe.

Finally, it is important to note that all of the current techniques SETI is using to try to identify and locate intelligent life in the universe are based on "*what we think we know*" about what life is and whether or not it might even want to communicate with us (Ballesteros 2010; Tarter 2008; Tarter and Impey 2012). Looking for radio or pulsing laser light signals coming from space is, of course, worthwhile, since some ETs could be similar to our human species and might choose this mode of communication, but many other ETs may rely on techniques that would be totally different from what we might expect or even consider possible.

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