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# World Building For Fun And Profit, Part 1

by
Michael McCollum

Over the last two months, we discussed alien life, their biochemistry, and what they may (or may not) look like. In fact, what we have been reviewing is formally called Exobiology, which so far is a science in search of a subject. With the possible exception of the "Martian meteorite" in which fossilized microbes may have been discovered in 1997, we have not yet had a single sample of alien life to put under our microscopes. (In case you haven't been following the controversy, a number of scientists now claim that the fossilized microbes are actually of Earthly origin and that the sample was contaminated sometime during those 14,000 years that the meteor lay on the Antarctic icecap. Stay tuned for future developments.)

You would think any science that lacked even a single sample to study would be moribund. If so, you would think wrong. Exobiologists have amassed a mountain of theoretical data concerning their particular specialty. It's sometimes amazing how much you can learn merely by thinking about a problem. However, a word of caution is in order. The exobiologists aren't the first scientist/philosophers to view the universe as a purely theoretical puzzle. The great Greek thinker Aristotle maintained that all anyone needed to do in order to understand the world around them was to contemplate their surroundings. As a result, humanity was stuck in a scientific dead end for nearly two thousand years, believing that all things were made up of Aristotle's four elements: earth, air, water, and fire. It wasn't until the late middle ages and the invention of the scientific method that we loosed that particular set of blinders from our eyes.

Intellect is a necessary prerequisite for scientific problem solving, but it doesn't substitute for actually having some facts on which to base one's opinions. This, then, is the reason why the search for alien life in the universe is so important. As any scientist or engineer will tell you, it is difficult to extrapolate a curve when you have only a single point on your graph. The next extraterrestrial life form we encounter will be the first, and on that day we will have at least doubled our knowledge of what life is and how it operates in this universe. May that day be soon in coming.

The good news is that science fiction writers don't labor under the same constraints that scientists do. In fact, we aren't constrained by the need for facts at all -- or at least, we don't think we are. If we need facts in our writing, we make them up as we go along. If we need an intelligent race of spacefaring aliens to be the villains of our piece, then all we need do is imagine them. Be they Kzinti, Merseians, Klingons, Ryall, Romulans, or Narns, we can create them from out of the whole cloth of our imaginations. We can imagine them in any number of sizes and guises. They can look like angels or devils, horses or hamsters, people or great gelatinous globs. We can give them two hands, four hands, a dozen hands, or no hands at all. We can make them beautiful or ugly, malevolent or beneficent, smart, dumb, or so alien that human beings can never know whether they are thinking at all. However, when it comes right down to it, even we science fiction writers have our limits. If we are to stay in the world of SF and out of that of Fantasy, we must cling to a few basic principles.

One of these is that we can't violate known physical law, at least not without being able to explain ourselves to the readers. For instance, we cannot imagine a race of flying aliens who look like Pegasus, not unless we radically redesign them to make them aerodynamically plausible. Pegasus has too big a body and too small a wingspan to ever get off the ground on any planet with an Earthlike atmosphere and gravity, unless, of course, one of the being's internal organs is an antigravity generator.

There are other constraints on our imagined aliens, some of which aren't immediately obvious. For instance, an article I read suggested that civilization would be impossible for any race of aliens smaller than a rabbit. Why? Because small animals are too small to gather firewood efficiently. Think it through and you will see the problem. While the tiny hunters are out gathering twigs for their fire, combustion burns up all the twigs they managed to heap together to start the fire in the first place. You have to have a certain minimum size and strength in order to drag in logs and branches big enough to keep ahead of the fire.

The foregoing examples are intended to point out that postulating a logical alien isn't as easy as it might first appear. In fact, it can be a fairly prodigious task if you care to make it so. For when you imagine your alien characters, you cannot stop with just that character alone. You have to imagine his world as well. Remember, in the real universe, life doesn't happen overnight. To create life on Planet Earth required billions of nights to assemble random atoms into long chain organic molecules. The primordial soup cooked for several epochs before anything living appeared in its murky depths and that was merely the beginning. The process then slowly worked its way up through amoebae, trilobites, fish, lizards, and small furry mammals before bringing forth a race of relatively hairless apes with delusions of grandeur.

Evolution on an alien planet ought to be at least as complicated as it was on our own small ball of rock in the cosmos. The ancestral tree of any intelligent being we are likely to meet will be at least as complex and bifurcated as is our own. How is it that the alien villain of your magnum opus ended up looking like a man-size Tyrannosaurus rex with a bulging cranium? And how could such a being possibly have developed the craving for raw *Homo-sapiens*-on-a-stick that your plot requires?

You don't know? Why not? Remember that we writers are the demigods on our fictional worlds. You can't be much of a god if you are ignorant of the history of your domain. So sit back, relax, and learn what it means to build a whole world from out of the whole cloth of your imagination.

## Aliens and Their Planets

The acknowledged master for alien design and scientific world building is Poul Anderson. For the past 40 years he has filled the sky with planets and odd-looking beings to inhabit them. Many of his stories of the Polesotechnic League hinge on either the uniqueness of the aliens or of their planets, and you could do worse than study these stories to get some idea of how it is done.

Another first class world builder for purposes of fiction is Larry Niven, whose *Tales of Known Space* feature some of the most unique worlds in literature. This is less a result of careful calculation (like Poul Anderson performs) than a unique premise that permeates Niven's early writing. The postulate is this: That humanity initially colonized the stars with slower-than-light ramscoop starships. To find habitable planets, human beings sent out robot probes as pathfinders. The probes then radioed their findings back to the Earth and a colony ship was dispatched to the world in question. Unfortunately, the builders of the robot spacecraft made a fatal error in their design. Instead of sending them out to look for habitable worlds, they sent them to look for habitable *points*. Once the colony ships were sent out, there was no turning back, even though the colonists found conditions at their destinations considerably different than they expected.

There is the world of Plateau, where the whole planet is submerged in an atmosphere too thick and hot to support human life, except for one really tall mountain that sticks up above the noxious clouds. The colonists dubbed their aerie "Mt. Lookatthat," and they are forever peering over the edge and down into the Venus-like clouds that shroud the rest of their world. There is Canyon, a world where a deadly disintegrator beam during the Man-Kzin war left a deep gash in which people now live. There is Jinx, where the gravity is more than twice that of Earth and where the people tend to be built squat and strong. In addition to their strength, Jinxians are not known for their patience.

There is We Made It, a perfectly fine world except for the fact that it orbits on its side, and each pole faces directly into the sun at some time during the year. "What problem could that possibly cause?" you ask. How about the 500 kph (300 mph) winds that blow continuously from hot side to cold during the summer and winter months. Only during the spring and fall when the poles are pointed away from the sun do the killer winds calm down. (Guess in which season the robot from Earth arrived and decided that the planet was a paradise?)

"But wait a minute," you respond. "A world lying on its side such that its poles face the sun isn't possible, is it?"

Actually, it is very possible, and we have Neptune in our own Solar system to prove it.

The assumptions you make for your planets can have a major effect on your story. For decades, *Analog Science Fiction Magazine*, the acknowledged center of the hi-tech SF universe, has been filled with stories in which the odd conditions on alien worlds are the major linchpin around which the plots revolve. To better illustrate my point, I would like to introduce you to one of the most famous worlds in all of science fiction; a rapidly spinning giant of a planet named Mesklin...

## Mission of Gravity

In the early 1950s, Hal Clement wrote what has become the prototypical "world as character" novel, his SF masterpiece, *Mission of Gravity*. The world of Mesklin is both large and dense, resulting in a gravitational pull that will squash a human being flat. The world is also rotating rapidly. These two characteristics result in very odd conditions on the surface of the planet. For the rapid spin causes increased "centrifugal force" as you move away from the poles and toward the equator, which in turn reduces the effective gravity of the planet. In other words, you get lighter as you approach the equator and heavier as you approach the pole.

*A lot lighter and a lot heavier!*

Obviously, since it spins so rapidly, Mesklin isn't a sphere like the Earth. (Actually, the Earth isn't a sphere either. It's an oblate spheroid, which means it is a little bit squashed through the poles.) Mesklin is massively squashed through the poles, so much so that the rapidly whirling planet looks like a beach ball out of which the air is slowly leaking. And, of course, the day is only a few minutes long.

So what sort of creatures inhabit such a planet? Small, strong ones. The average Mesklinite looks like a centipede, built low to the ground and with lots of strong, stubby legs to support it against the titanic pull of gravity. The hero of the book is Barlennan, a sea captain whose vessel was built by one of the polar civilizations, and who is leading an expedition to the equator. Barlennan is concerned about his ship and crew. Having reached the equator, everything is substantially lighter than they are used to at home, and the crew is picking up bad habits. For instance, he sees one of his crewmates with several segments of his body lifted off the deck so that he can repair one of the ship's masts without taking it down. If that same crewmember tries to lift himself off the ground at home, he will likely break a leg. And on Mesklin, a broken leg is invariably fatal.

The ship, like everything else built by the polar Mesklinites, is a high gravity design. It is a series of low rafts hinged together so they can flex, with a stubby mast and sails that catch the dense wind on each segment. The crew lives outside on the deck, since no high gravity Mesklinite would ever allow anything like a roof to hang over his head. It might break and fall down, squashing him flat. Things fall so quickly at Mesklin's poles that even a Mesklinite cannot see them in motion as they fall. Needless to say, Barlennan's ancestors were not cave dwellers!

The Mesklinite equatorial expedition has discovered something unexpected: human beings! Despite the killing gravity of the planet at the equator, a properly equipped human can withstand the pull for awhile. Not so at the poles, where gravity is hundreds of times that of Earth. Humans have been using instrumented spacecraft to probe the polar regions of Mesklin, but have recently lost contact with one of their very expensive probes. The humans hire Barlennan and his crew to retrieve the data from their downed robot.

It is during the expedition to the far pole (the opposite pole from Barlennan's home) that we learn about Mesklin and its strange inhabitants. They are strange only in form, however. Their motivations are all too human, the better for us mere mortals to experience their environment. En route to the pole, Barlennan and his crew have to fight off equatorial savages -- Mesklinites who live near the equator. These beings are twice as large as the pole-dwelling Mesklinites and due to their lower gravity field, have developed projectile weapons and even aircraft.

We experience the swift days of Mesklin, lasting only a few minutes each. We watch Barlennan navigate his ship using a bowl-shaped atlas and a weight tied to the end of a wooden spring to indicate latitude. (The closer one gets to the pole, the more gravity bends the stick.) We watch as Barlennan's wariness about low gravity wanes and he adopts new and more efficient methods of working. And we identify with him as well as with any character in fiction, even if he is small, black, and has a hundred or more legs. In fact, we get to like Barlennan quite a lot.

As with the work of Poul Anderson, if you wish to be a hi-tech science fiction writer, you could do a lot worse than reading *Mission of Gravity*. Another book in the same vein (undoubtedly inspired by Hal Clement) is Robert L. Forward's *Dragon's Egg*, about the lives and tribulations of a small race of creatures who inhabit a rapidly rotating neutron star. In *Dragon's Egg*, Forward does something that I would have thought impossible. He writes a sex scene involving these tiny neutron star dwelling creatures and actually manages to arouse a hint of prurient interest.

**World Building 101**

By this time you are probably saying, "I can't possibly design a world like Mesklin!" In this you are probably correct. Hal Clement is the pen name for Harry Clement Stubbs, a college professor at the time he wrote *Mission Of Gravity*. Such an extreme case of visualizing what an alien world ought to look like is beyond most of us. However, it is the very fact that Mesklin is such a radical a departure from what we consider "normal" that makes *Mission of Gravity* such a valuable lesson in the technique of world building.

What then is the technique? How do you go about building a world of your very own? Simply stated, you begin at the center, which for any inhabited world, must be its parent star. After that, you imagine your way outward, building first the aliens' world and then their entire star system.

Life Giving Stars

We studied stars earlier in this series (*The Art of Science Fiction, Volume 1*, "Astronomy For Science Fiction Writers: Stars,") so we won't go over that ground again. However, as was noted during our survey of astronomy, there are some stars that are better suited for sustaining living things than others. It is not enough to pick a fancy name out of an astronomy text book and decide that will be the home star of a violent and bloodthirsty beings known as the *Xaradjin*, who just happen to be the villains in your latest space epic. If the Xaradjin home star is of the Wolf-Rayet class, or one of the big blue bruisers of the O, B, or A classes, a few knowledgeable readers may laugh at you. Worse yet, they may tell their friends who don't know enough astronomy to realize what a boneheaded choice you have made. Pretty soon, the word will get around, however, and even the non-astronomers in your readership will be chuckling.

When it comes to picking homelike stars, you can't do better than choose one like our own sun. Sol is a yellow dwarf star of spectral class G2 and G-class stars are to be preferred in the universe (it's an innate bias evolution has built into the human outlook). Unfortunately, there aren't that many G-Class stars in our local neighborhood. So you might have to settle for a star in another spectral class, say one of the F or K stars. Our own star is near the hot end of the G-class, which makes it just beyond the low end of the F-class. That is, F stars are hotter than the sun and tend to shine with a yellow-white light. On the other side of us are the F stars, which are somewhat cooler than the G stars, and shine with an orange light.

Any star hotter than F class is probably too energetic to support the development of life. The blue white giants of the O, B, and A classes all pump out dangerous levels of ultraviolet light. Besides, these big stars are like drunken sailors when it comes to expending energy. They last only a few millions years and have too short a life span to allow sufficient time for evolution to take place.

Then there are the variable stars like Mira. These stars are unstable, and over periods varying from a few days to a few years, they brighten and dim in a predictable pattern. Most variable stars change their power output so drastically that any planets in orbit about them would be subjected to violent swings of solar radiance. It is difficult to see how intelligent life might evolve where the heat of the noonday sun can vary by a factor of 100 or more. Talk about global warming!

We humans have other biases concerning stars. We are used to having only one close-by star in our sky. However, single star systems are a minority in the universe. Approximately 75% of all star systems have more than one star in them. Some have as many as six! While pretty to look at, multiple stars can make it difficult for life to take hold for the same reason that variable stars present a challenge. Depending on how close the multiple stars orbit one another, conditions on the planets in the system may be wildly variable.

This isn't to say that no multiple star systems should be considered for planting either human colonies or alien civilizations. In multiple star systems like Procyon, a large central star is orbited by much smaller star (a white dwarf). Our nearest neighbor is, in fact, a triple star system. Alpha Centauri consists of two stars, a G2-class star that is very nearly Sol's twin, and a smaller K0 star, both of which are orbited at a considerable distance by a very small Class M dwarf star, Proxima Centauri. It is, in fact, Proxima Centauri that is the closest star to the sun. Proxima Centauri is 4.22 light years from Sol, while Alpha Centauri A and B are 4.35 light years distant.

Whatever star you choose to shine on your alien civilization, you should know its spectral class, luminosity, whether its power output is stable, and whether or not it travels alone in the firmament. And having chosen a candidate, whether it be real or fictional, you are ready to populate your new stellar system with planets.

## At What Distance Does Your New Planet Circle Its Star?

Just exactly where do you plan to plant your new planet, anyway? As a recent American comedy program stated, Earth is the "third rock from the sun." Only Mercury and Venus orbit closer to our star than we do, which is why both of them can only be seen in the early evening or just before dawn. They are never very high in the night sky because they are "inferior planets." This isn't a value judgment, but rather a technical term used in astronomy. It means that they orbit closer to the sun than we do. All the other planets occupy "superior" positions, meaning that they are farther out in space than Earth.

The reason why distance is important when designing your planet is amply demonstrated by the case of Earth's near-twin, Venus. Earth is a beautiful, blue-white world covered largely by oceans. Venus is a hellhole hot enough to melt lead without a drop of water on it anywhere. The reason for this is that Venus is too close to our sun. At 0.72 astronomical units, Venus receives 93% more sunlight than does Earth. This heightened solar flux, when coupled with the thick carbon dioxide atmosphere, causes a regenerative "greenhouse" effect that long ago boiled off all the water on the planet. In fact, it was the discovery of just what conditions were like on Venus that raised public concerns about the possibility that our own planet might be heating up.

What saved Earth from Venus's fate is that our planet orbits inside Sol's "temperate zone." The temperate zone is that shell that surrounds every star where a planet receives enough energy to maintain its bulk temperature in the range where water is liquid. This is important if you are going to have oceans on your fictional world. Planets that lie closer to their stars than the temperate zone will boil off their oceans, while those too far out will be forever ice bound. It is conceivable that life might arise on either world (especially the cold one), but one thing of which we can be certain: that life won't be like us.

It was once thought that Venus orbited at the inner boundary of Sol's temperate zone and Mars orbited at the outer boundary. We now know that the edge of the zone is not very far inside the Earth's orbit, which is why Venus is a super hot desert world. The changing Martian polar ice caps indicate that the Red Planet is on the outer fringe of the zone, although the atmospheric pressure there is too low for liquid water to exist.

For a star the size of Sol, Earth's distance of 150 million kilometers (93 million miles) places it comfortably in the temperate zone, but for another star with a different luminosity, this might be far from true. So, when designing a star system for your writing, after selecting your star, make sure that the inhabited worlds orbit at the requisite distance to place them within the temperate zone.

If this sounds difficult, it isn't. Actually, it's a much easier calculation to make than you might think.

## The Inverse Square Law For Electromagnetic Radiation

Sunlight is a form of electromagnetic radiation and it obeys what is known as the inverse square law. That is, as the sun radiates its light out in all directions, the energy density of sunlight drops off with the square of the distance. For each doubling of distance, the solar flux drops off by a factor of four. Earth, at one astronomical unit (AU) from the sun, receives approximately one kilowatt per square meter of solar energy. Mars, at a mean distance of 1.52 AU, receives only 43% of the sunlight that Earth does. Jupiter is 5.2 times as far from the sun as Earth, and receives only 3.6% of our solar flux. (One logical assumption is that someone on the moons of Jupiter would have to use a flashlight to get around, even at high noon. Luckily for our fictional astronauts, the human eye is highly adaptable in terms of its light gathering power, and we can see quite well at 3.6% of our normal light level. Think of how bright Jupiter is in the night sky, and that is merely the reflected portion of that 3.6% solar flux!)

The luminosity of a star is determined by its size and enthusiasm for spraying photons in every direction. Luckily for science fiction writers, the star catalogs all give luminosity in relation to our own sun. This allows us to apply the inverse square law in order to calculate how far a planet must be from any particular star in order to have an Earthlike environment. See Equation 6 at the end of this article.

If your system primary is a big star, say a giant G-class like Capella, then you will need to pull your planets back from the central furnace to keep from overcooking them.

Capella has an intrinsic luminosity 160 times that of the sun. If a planet were only one AU from Capella (the same distance that Earth is from Sol), it would be far hotter than Mercury. In fact, its crust would be molten, or nearly so. To be in Capella's temperate zone, a planet would have to orbit nearly 13 astronomical units out from the star. This would place it farther from its primary than Saturn is from the sun.

Thirteen astronomical units is 1.95 billion kilometers (1.17 billion miles). Obviously, a planet that far out from it star will take a lot longer than Earth does to make one complete orbit. In other words, it will have a much longer year than we do. Unfortunately, it isn't enough to merely look up the length of Saturn's orbital period (29.5 years) and add a bit to get the length of your Capellan planet's year. The problem is complicated because the star's mass, as well as the distance at which the planet orbits (Equation 4) determines orbital periods.

Basically, to obtain a planet's orbital period, you take the distance at which it orbits (in AU), cube it, divide by the star's mass (measured in solar masses), and then take the square root of the resulting number. The problem with using this technique is that most astronomy books don't list the mass of stars. Luckily, this too, is a relatively easy number to obtain.

One of the things that star tables do list is luminosity, which is basically the amount of energy a star puts out compared to our own sun (Sol has a luminosity of 1). A fair rule for determining stellar masses is that you take the $4.5^{th}$ root of the luminosity number for stars dimmer than Sol ($L<1$) and the $3.5^{th}$ root of luminosity for stars brighter than Sol ($L>1$) to obtain their mass. (Equations 5a and 5b.) Thus, with a luminosity of 160, Capella masses approximately 4.24 times more than our own sun. With this, we can calculate the year of our fictional planet orbiting at a distance of 13 AU. It will take this world 22.7 terrestrial years to circle Capella one time.

Note: Despite being a G-class giant star, Capella might not be a good site for an inhabited world. It has a companion red dwarf (M-class) star that orbits so close that it has an orbital period of only 104 days. We can't see it with our telescopes, but it shows up in our spectrograms. It likely would make life interesting for any native Capellans.

## Conclusion

So, you know what your planet's star looks like and you know how far out from its primary the planet orbits. It's time to begin designing your new world.

What sort of a world will it be? How large is it? How strong is the pull of gravity at its surface? What sort of atmosphere does it have? How much of it is covered with oceans? How big are its mountains and polar ice caps? Does it have one or more moons, and how large are they? What's the axial tilt and how does that affect the weather? The answer to these questions will give you many of the details you need to plot your story.

### EQUATIONS FOR WORLD BUILDING

1. Planetary Orbital Velocity (absolute): $$V_{circ} = \sqrt{\frac{GM}{R}}$$

   Where: G = Universal Gravitational Constant, ($6.672 \times 10^{-11}\ Nm^2/Kg^2$)

M = Mass Of Star. (Sol = 1.98 X $10^{30}$ Kg)
R = Distance Of Planet From Star (Earth = 150 X $10^{6}$ Km)
$V_{circ}$ = Orbital Velocity In meters/second

2. Planetary Orbital Velocity (relative to Earth's): $$V_{circ-rel} = \sqrt{\frac{M_r}{R_r}}$$

Where: Mr = Mass Of Star. (In Solar Masses, $M_{sol}$)
$R_r$ = Distance Of Planet From Star (In Astronomical Units, AU)
$V_{circ-rel}$ = Orbital Velocity As A Multiple Of Earth's Orbital Velocity (29.7 km/sec)

3. Stellar Escape Velocity: $$V_{esc} = \sqrt{\frac{2GM}{R}}$$

Where: G = Universal Gravitational Constant, (6.672 X $10^{-11}$ $Nm^2/Kg^2$)
M = Mass Of Star. (Sol = 1.98 X $10^{30}$ Kg)
R = Distance From Star (Earth = 150 X $10^{6}$ Km)
$V_{esc}$ = The velocity required to escape a star's gravitational pull in km/sec, when at distance R from the star.

4. Orbital Period, Relative To Earth: $$P_{rel} = \sqrt{\frac{D_r^{\,3}}{M_r}}$$

Where: $M_r$ = Mass Of Star. (In Solar Masses, $M_{sol}$)
$D_r$ = Distance Of Planet From Star (In Astronomical Units, AU)
$P_{rel}$ = Planetary Orbital Period, (in years)

5. Star Mass, Relative To Sol

a) For Stars Dimmer Than Sol: $$M_r = \sqrt[4.5]{L}$$

b) For Stars Brighter Than Sol: $$M_r = \sqrt[3.5]{L}$$

Where: Mr = Mass Of Star. (In Solar Masses, $M_{sol}$)
L = Luminosity compared to Sol. Can be found in most star tables.

6. Light Intensity (Solar Flux Density): $$I_2 = I_1\left(\frac{D_1}{D_2}\right)^2$$

Where: $D_1$ and $D_2$ are distances from the star.
$I_1$ and $I_2$ are the light intensity (solar flux density) at $D_1$ and $D_2$, respectively.

# Sci Fi - Arizona
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The Makers searched for the secret to faster-than-light travel for 100,000 years. Their chosen instruments were the Life Probes, which they launched in every direction to seek out advanced civilizations among the stars. One such machine searching for intelligent life encounters 21st century Earth. It isn't sure that it has found any...

**2. Procyon's Promise - ^US^$5.00**

Three hundred years after humanity made its deal with the Life Probe to search out the secret of faster-than-light travel, the descendants of the original expedition return to Earth in a starship. They find a world that has forgotten the ancient contract. No matter. The colonists have overcome far greater obstacles in their single-minded drive to redeem a promise made before any of them were born...

 

**3. Antares Dawn - US$5.00**

When the super giant star Antares exploded in 2512, the human colony on Alta found their pathway to the stars gone, isolating them from the rest of human space for more than a century. Then one day, a powerful warship materialized in the system without warning. Alarmed by the sudden appearance of such a behemoth, the commanders of the Altan Space Navy dispatched one of their most powerful ships to investigate. What ASNS Discovery finds when they finally catch the intruder is a battered hulk manned by a dead crew.

That is disturbing news for the Altans. For the dead battleship could easily have defeated the whole of the Altan navy. If it could find Alta, then so could whomever it was that beat it. Something must be done…

**4. Antares Passage - US$5.00**

After more than a century of isolation, the paths between stars are again open and the people of Alta in contact with their sister colony on Sandar. The opening of the foldlines has not been the unmixed blessing the Altans had supposed, however.

For the reestablishment of interstellar travel has brought with it news of the Ryall, an alien race whose goal is the extermination of humanity. If they are to avoid defeat at the hands of the aliens, Alta must seek out the military might of Earth. However, to reach Earth requires them to dive into the heart of a supernova.

**5. Antares Victory – First Time in Print – US$7.00**

After a century of warfare, humanity finally discovered the Achilles heel of the Ryall, their xenophobic reptilian foe. Spica – Alpha Virginis – is the key star system in enemy space. It is the hub through which all Ryall starships must pass, and if humanity can only capture and hold it, they will strangle the Ryall war machine and end their threat to humankind forever.

It all seemed so simple in the computer simulations: Advance by stealth, attack without warning, strike swiftly with overwhelming power. Unfortunately, conquering the Ryall proves the easy part. With the key to victory in hand, Richard and Bethany Drake discover that they must also conquer human nature if they are to bring down the alien foe …

**6. Thunderstrike! - US$6.00**

The new comet found near Jupiter was an incredible treasure trove of water ice and rock. Immediately, the water-starved Luna Republic and the Sierra Corporation, a leader in asteroid mining, were squabbling over rights to the new resource. However, all thoughts of profit and fame were abandoned when a scientific expedition discovered that the comet's trajectory placed it on a collision course with Earth!

As scientists struggled to find a way to alter the comet's course, world leaders tried desperately to restrain mass panic, and two lovers quarreled over the direction the comet was to take, all Earth waited to see if humanity had any future at all…

 

**7. The Clouds of Saturn - US$5.00**

When the sun flared out of control and boiled Earth's oceans, humanity took refuge in a place that few would have predicted. In the greatest migration in history, the entire human race took up residence among the towering clouds and deep clear-air canyons of Saturn's upper atmosphere. Having survived the traitor star, they returned to the all-too-human tradition of internecine strife. The new city-states of Saturn began to resemble those of ancient Greece, with one group of cities taking on the role of militaristic Sparta...

**8. The Sails of Tau Ceti – US$5.00**

*Starhopper* was humanity's first interstellar probe. It was designed to search for intelligent life beyond the solar system. Before it could be launched, however, intelligent life found Earth. The discovery of an alien light sail inbound at the edge of the solar system generated considerable excitement in scientific circles. With the interstellar probe nearing completion, it gave scientists the opportunity to launch an expedition to meet the aliens while they were still in space. The second surprise came when *Starhopper's* crew boarded the alien craft. They found beings that, despite their alien physiques, were surprisingly compatible with humans. That two species so similar could have evolved a mere twelve light years from one another seemed too coincidental to be true.

One human being soon discovered that coincidence had nothing to do with it...

**9. Gibraltar Earth – First Time in Print — $6.00**

It is the 24th Century and humanity is just gaining a toehold out among the stars. Stellar Survey Starship *Magellan* is exploring the New Eden system when they encounter two alien spacecraft. When the encounter is over, the score is one human scout ship and one alien aggressor destroyed. In exploring the wreck of the second alien ship, spacers discover a survivor with a fantastic story.

The alien comes from a million-star Galactic Empire ruled over by a mysterious race known as the Broa. These overlords are the masters of this region of the galaxy and they allow no competitors. This news presents Earth's rulers with a problem. As yet, the Broa are ignorant of humanity's existence. Does the human race retreat to its one small world, quaking in fear that the Broa will eventually discover Earth? Or do they take a more aggressive approach?

Whatever they do, they must do it quickly! Time is running out for the human race…

**10. Gibraltar Sun – First Time in Print — $7.00**

The expedition to the Crab Nebula has returned to Earth and the news is not good. Out among the stars, a million systems have fallen under Broan domination, the fate awaiting Earth should the Broa ever learn of its existence. The problem would seem to allow but three responses: submit meekly to slavery, fight and risk extermination, or hide and pray the Broa remain ignorant of humankind for at least a few more generations. Are the hairless apes of Sol III finally faced with a problem for which there is no acceptable solution?

 

While politicians argue, Mark Rykand and Lisa Arden risk everything to spy on the all-powerful enemy that is beginning to wonder at the appearance of mysterious bipeds in their midst…

**11. Gridlock and Other Stories - US$5.00**

Where would you visit if you invented a time machine, but could not steer it? What if you went out for a six-pack of beer and never came back? If you think nuclear power is dangerous, you should try black holes as an energy source — or even scarier, solar energy! Visit the many worlds of Michael McCollum. I guarantee that you will be surprised!

## Non-Fiction Books

**12. The Art of Writing, Volume I - US$10.00**

Have you missed any of the articles in the Art of Writing Series? No problem. The first sixteen articles (October, 1996-December, 1997) have been collected into a book-length work of more than 72,000 words. Now you can learn about character, conflict, plot, pacing, dialogue, and the business of writing, all in one document.

**13. The Art of Writing, Volume II - US$10.00**

This collection covers the Art of Writing articles published during 1998. The book is 62,000 words in length and builds on the foundation of knowledge provided by Volume I of this popular series.

**14. The Art of Science Fiction, Volume I - US$10.00**

Have you missed any of the articles in the Art of Science Fiction Series? No problem. The first sixteen articles (October, 1996-December, 1997) have been collected into a book-length work of more than 70,000 words. Learn about science fiction techniques and technologies, including starships, time machines, and rocket propulsion. Tour the Solar System and learn astronomy from the science fiction writer's viewpoint. We don't care where the stars appear in the terrestrial sky. We want to know their true positions in space. If you are planning to write an interstellar romance, brushing up on your astronomy may be just what you need.

**15. The Art of Science Fiction, Volume II - US$10.00**

This collection covers the *Art of Science Fiction* articles published during 1998. The book is 67,000 words in length and builds on the foundation of knowledge provided by Volume I of this popular series.

 

**16. The Astrogator's Handbook – Expanded Edition and Deluxe Editions**

The Astrogator's Handbook has been very popular on Sci Fi – Arizona. The handbook has star maps that show science fiction writers where the stars are located in space rather than where they are located in Earth's sky. Because of the popularity, we are expanding the handbook to show nine times as much space and more than ten times as many stars. The expanded handbook includes the positions of 3500 stars as viewed from Polaris on 63 maps. This handbook is a useful resource for every science fiction writer and will appeal to anyone with an interest in astronomy.