Whirligig World[1]

Writing a science fiction story is fun, not work. If it were work I wouldn't be writing this article, which would then constitute a chapter for a textbook. I don't plan to write such a text, since if the subject is teachable I'd be creating competition and if it isn't I'd be wasting time.

The fun, and the material for this article, lies in treating the whole thing as a game. I've been playing the game since I was a child, so the rules must be quite simple. They are; for the reader of a science fiction story, they consist of finding as many as possible of the author's statements or implications which conflict with the facts as science currently understands them. For the author, the rule is to make as few such slips as he possibly can.

Certain exceptions are made by both sides, of course. For example, it is commonly considered fair to ignore certain of Dr. Einstein's theories, if the story background requires interstellar travel. Sometimes a passing reference is made to travel through a "hyperspace" in which light can travel faster or distance are shorter, but in essence we ignore the speed-of-light rule since we can—so far—see no way around it. The author assumes that problem, or perhaps others equally beyond our present ability to solve, to be answered, and goes ahead from there. In such a case, of course, fair play demands that all such matters be mentioned as early as possible in the story, so that the reader has a chance to let his imagination grow into the new background.

I always feel cheated when the problem which has been developed in a story is solved by the discovery in the last chapter of antigravity, time travel, or a method of reviving the dead; such things *must* be at least near full development and known to the reader long enough in advance to give him a chance to foresee the ending. I have always assumed, perhaps wrongly, that others felt as I do; I try to write accordingly.

[1] This article originally appeared in *Astounding Science Fiction*, June 1953.
Converted from the book "Heavy Planet" to digital media by Gregory Brannon, as accurately as possible except with additions in the footnotes, on Halloween Eve 2019. Images may not be reproduced completely accurately as they were simple edited photographs taken with my smart-phone. *Imagine saying that to someone in 1953.*

In *Mission of Gravity* I've been playing this game as fairly as I could.

The author has one disadvantage, of course; all his moves must be completed first. Once the story is in print, the other side can take all the time in the world to search out the mistakes; they can check with reference libraries or write letters to universities, if they play the game that seriously. Sooner or later the mistakes will come out, there is no further chance to correct them. If *Mission of Gravity* contains such errors, they're out of my hands now. I did my best to avoid them, but you still have a good chance to win. As I said, my moves were fun, not work.

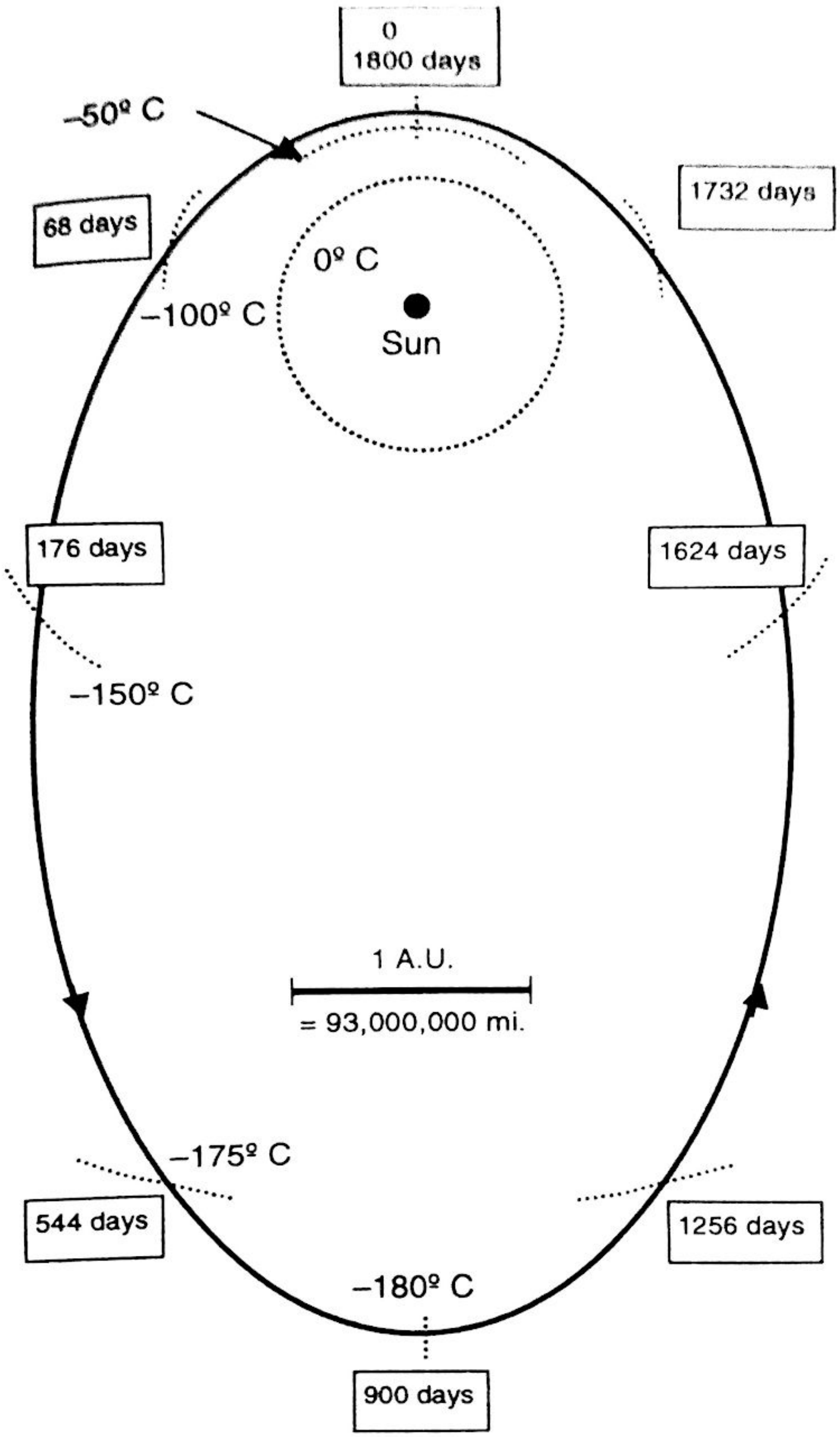
The basic idea for the story came nearly ten years ago. In 1943 Dr. K. Aa. Strand published the results of some incredibly—to anyone but an astronomer—painstaking work on the orbit of the binary star 61 Cygni, a star otherwise moderately famous for being the first to have its parallax, and hence its distance, measured. In solving such a problem, the data normally consist of long series of measurements of the apparent direction and distance of one star from the other; if the stars are actually moving around each other, and the observations cover a sufficient fraction of a revolution, it is ordinarily possible if not easy to compute the actual relative orbit of the system—that is, the path of one assuming the other is stationary. Dr. Strand's work differed from the more usual exercises of this type in that his measures were made from photographs. This eliminated some of the difficulties usually encountered in visual observation, and supplied a number of others; but there was a net gain in overall accuracy, to the extent that he was not only able to publish a more accurate set of orbital elements than had previously been available, but to show that the orbital motion was not regular.

The fainter star, it seemed, did *not* move around the brighter in a smooth ellipse at a rate predictable by the straightforward application of Kepler's laws. It did, however, move in a Keplerian path about an invisible point which was in turn traveling in normal fashion about the other sun.

There was nothing intrinsically surprising about this discovery; the implication was plain. One of the two stars—it was not possible to tell which, since measures had been made *assuming* the brighter to be stationary—was actually accompanied by another, invisible object; the invisible point which obeys the normal planetary and stellar laws was the center of gravity of the star-unknown object system. Such cases are by no means unusual.

To learn which of the two suns is actually attended by this dark body, we would have to have more observations of the system, made in relation to one or more stars not actually part thereof. Some stars exist near enough to the line of sight for such observations to be made, but if they have been reduced and published the fact has not come to my attention. I chose to assume that the object actually circles the brighter star. That may cost me a point in the game when the facts come out, but I won't be too disheartened if it does.

There was still the question of just what this object was.



ORBIT of MESKLIN
The positions of the isotherms and time of isotherm crossing are approximate and assume that the sun is 61 Cygni A

In other such cases where an invisible object betrayed its presence by gravity or eclipse, as in the system of Algol, we had little difficulty in showing that the companion was a star of some more or less normal type—in the case of Algol, for example, the “dark” body causing the principal eclipse is a sun larger, hotter, and brighter than our own; we can tell its size, mass, luminosity, and temperature with very considerable precision and reliability.

In the case of the 61 Cygni system, the normal methods were put to work; and they came up immediately with a disconcerting fact. The period and size of the orbit, coupled with the fairly well-known mass of the visible stars, indicated that the dark body has a mass only about sixteen thousandths that of the sun—many times smaller than any star previously known. It was still about sixteen times the mass of Jupiter, the largest planet we knew. Which was it—star or planet? Before deciding on the classification of an object plainly very close to the borderline, we must obviously decide just where the borderline lies.

For general purposes, our old grade-school distinction will serve: a star shines by its own light, while a planet is not hot enough for that and can be seen only by reflected light from some other source. If we restrict the word “light” to mean radiation we can see, there should be little argument, at least about definitions. (If anyone brings up nontypical stars of the VV_2 Cephei or $Epsilon_2$ Aurigae class I shall be annoyed.) The trouble still remaining is that we may have some trouble deciding whether this Cygnus object shines by intrinsic or reflected light, when we can’t see it shine at all. Some educated guessing seems in order.

There is an empirical relation between the mass of a star, at least a main-sequence star, and its actual brightness. Whether we could be justified in extending this relation to cover an object like 61 Cygni C—that is, third brightest body in the 61 Cygni system—is more than doubtful, but may be at least suggestive. If we do, we find that its magnitude as a star should be about twenty or a little brighter. That is within the range of modern equipment, *provided* that the object is not too close to the glare of another, brighter star and *provided* it is sought photographically with a long enough exposure. Unfortunately, 61 C will never be more than about one and a half seconds of arc away from its primary, and an exposure sufficient to reveal the twentieth magnitude would burn the image of 61 A or B over considerably more than one and a half seconds’ worth of photographic plate. A rotating sector or similar device to cut down selectively on the light of the brighter star might do the trick, but a job of extraordinary delicacy would be demanded. If anyone has attempted such a task, I have not seen his published results.

If we assume the thing to be a planet, we find that a disk of the same reflecting power as Jupiter and three times his diameter would have an apparent magnitude of twenty-five or twenty-six in 61 C’s location; there would be no point looking for it with present equipment. It seems, then, that there is no way to be sure whether it is a star or a planet; and I can call it whichever I like without too much fear of losing points in the game.

I am supposing it to be a planet, not only for story convenience but because I seriously doubt that an object so small could maintain at its center the temperatures and pressures necessary for sustained nuclear reactions; and without such reactions no object could maintain a significant radiation rate for more than a few million years. Even as a planet, though, our object has characteristics which will call for thought on any author's part.

Although sixteen times as massive as Jupiter, it is *not* sixteen times as bulky. We know enough about the structure of matter now to be sure that Jupiter has the largest volume of any possible "cold" body. When mass increases beyond this point, the central pressure becomes great enough to force some of the core matter into the extremely dense state which we first knew in white dwarf stars, where the outer electronic shells of the atoms can no longer hold up and the nuclei crowd together far more closely than is possible under ordinary—to us, that is—conditions. From the Jupiter point on up, as mass increases the radius of a body decreases—and mean density rises enormously. Without this effect—that is, if it maintained Jupiter's density with its own mass—61 C would have a diameter of about two hundred fifteen thousand miles. Its surface gravity would be about seven times that of Earth. However the actual state of affairs seems to involve a diameter about equal to that of Uranus or Neptune, and a surface gravity over three hundred times what we're used to.

Any science fiction author can get around that, of course. Simply invent a gravity screen. No one will mind little details like violation of the law of conservation of energy, or the difference of potential across the screen which will prevent the exchange of anything more concrete than visual signals; no one at all. No one but *Astounding* readers, that is; and there is my own conscience too. I might use gravity screens if a good story demanded them and I could see no legitimate way out; but in the present case there is a perfectly sound and correct means of reducing the effective gravity, at least for a part of a planet's surface. As Einstein says, gravitational effects cannot be distinguished from inertial ones. The so-called centrifugal force is an inertial effect, and for a rotating planet happens to be directed outward—in effect—in the equatorial plane. I can, therefore, set my planet spinning rapidly enough to make the characters feel as light as I please, at least at the equator.

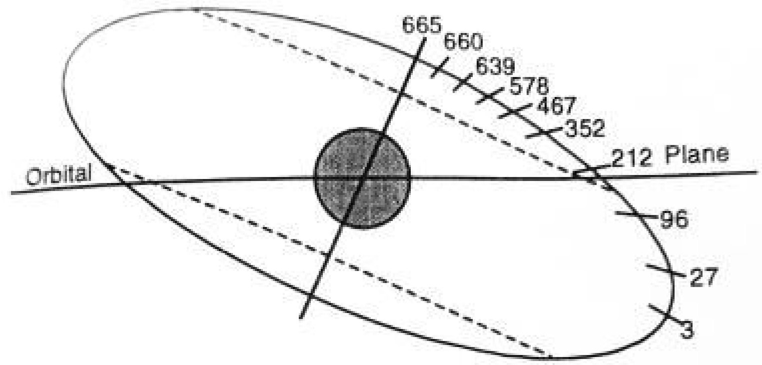
If that is done, of course, my nice new world will flatten in a way that would put Saturn to shame; and there will undoubtedly be at least one astronomer reading the story who will give me the raised eyebrow if I have it squashed too little or too much. Surely there is some relation between mass, and rate of spin, and polar flattening—

I was hung up on that problem for quite a while. Since I had other things to do, I didn't really concentrate on it; but whenever a friend whose math had not collapsed with the years crossed my path, I put it up to him. My own calculus dissolved in a cloud of rust long, long ago. I finally found the answer—or *an* answer—in my old freshman astronomy text, which is still in my posession. I was forcibly reminded that I must also take into account the internal distribution of the planet's mass; that is, whether it was of homogeneous density or, say, almost all packed into a central core. I chose the latter alternative, in view of the enormous density almost certainly possessed by the core of this world and the fact that the outer layers where the pressure is less are presumably of normal matter.

I decided to leave an effective gravity of three times our own at the equator, which fixed one value in the formula. I had the fairly well known value for the mass, and a rough estimate of the volume. That was enough. A little slide-rule work gave me a set of characteristics which will furnish story material for years to come. I probably won't use it again myself—though that's no promise[2]—and I hereby give official permission to anyone who so desires to lay scenes there. I ask only that he maintain reasonable scientific standards, and that's certainly an elastic requirement in the field of science fiction.

The world itself is rather surprising in several ways. Its equatorial diameter is forty-eight thousand miles. From pole to pole along the axis it measures nineteen thousand seven hundred and forty, carried to more significant figures than I have any right to. It rotates on its axis a trifle better than twenty degrees a minute, making the day some seventeen and three quarter minutes long. At the equator I would weigh about four hundred eighty pounds, since I hand-picked the net gravity there; at the poles, I'd be carrying something like sixty tons. To be perfectly frank, I don't know the exact value of the polar gravity; the planet is so oblate that the usual rule for spheres, to the effect that one may consider all the mass concentrated at the center for the purposes of computing surface gravity, would not even be a good approximation if this world were of uniform density. Having it so greatly concentrated helps a great deal, and I don't think the rough figure of a little under seven hundred Earth gravities that I used in the story is too far out; but anyone who objects is welcome if he can back it up. (Some formulae brought to my attention rather too late to be useful suggest that I'm too high by a factor of two; but whose formulae are the rougher approximations I couldn't guess—as I have said, my math has long

[2] Indeed, he used it three more times—*Star Light* written at the request of John W. Campbell, "Lecture Demonstration" written at the request of Harry Harrison for *Astounding: The John W. Campbell Memorial Anthology*, and "Under" written at the request of NESFA Press for [Heavy Planet] but first published in *Analog*, Janurary 200 as the cover story of its 70th Anniversary issue.—Editors

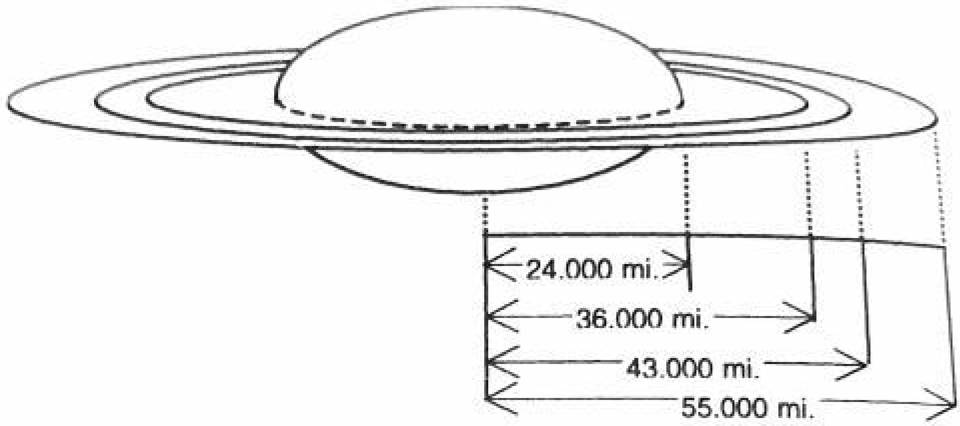


CROSS SECTION of MESKLIN
Shaded portion represents Earth on the same scale. Dotted lines are arctic and antarctic circles. Listed values of gravity (effective), represented by numbers at appropriate latitudes, are very approximate.

since gone to a place where I can't use it for such things. In any case, I'd still stagger a bit under a mere thirty tons.)

I can even justify such a planet, after a fashion, by the current(?) theories of planetary system formation. Using these, I assume that the nucleus forming the original protoplanet had an orbit of cometary eccentricity, which was not completely rounded out by the collisions during the process of sweeping up nearly all the raw material in the vicinity of its sun. During the stage when its "atmosphere" extended across perhaps several million miles of space, the capture of material from orbits which were in general more circular than its own would tend to give a spin to the forming world, since objects from outside its position at any instant would have a lower velocity than those from farther in. The rotation thus produced, and increased by conservation of angular momentum as the mass shrank, would be in the opposite direction to the world's orbital motion. That does not bother me, though; I didn't even mention it in the story, as nearly as I can now recall.

The rate of spin might be expected to increase to the point where matter was actually shed from the equator, so I gave the planet a set of rings and a couple of fairly massive moons. I checked the sizes of the rings against the satellite orbits, and found that the inner moon I had invented would produce two gaps in the ring similar to those in Saturn's decoration. The point never became important in the story, but it was valuable to me as atmosphere; I had to have the picture clearly in mind to make all possible events and conversations consistent. The inner moon was ninety thousand miles from the planet's center,



SCALE DRAWING of MESKLIN and RING SYSTEM

Inner ring reaches to less than 1,000 miles of planet's surface; gaps are of corresponding width.

giving it a period of two hours and a trifle under eight minutes. The quarter-period and third-period ring gaps come about twelve and nineteen miles respectively from the world's surface. The half-period gap would fall about thirty-three thousand miles out, which is roughly where Roché's Limit would put the edge of the ring anyway (I say roughly, because that limit depends on the density distribution too.)

On the whole, I have a rather weird-looking object. The model I have of it is six inches in diameter and not quite two and a half thick; if I added the ring, it would consist of a paper disk about fourteen inches in diameter cut to fit rather closely around the plastic wood spheroid. (The model was made to furnish something to draw a map on; I like to be consistent. The map was drawn at random before the story was written; then I bound myself to stick to the geographic limitations it showed.) I was tempted, after looking at it for a while, to call the book *Pancake in the Sky*, but Isaac Asimov threatened violence.[3] Anyway, it looks rather more like a fried egg.

There are a lot of characteristics other than size, though, which must be settled before a story can be written. Since I want a native life form, I must figure out just what conditions that form must be able to stand. Some of these conditions, like the temperature and gravity, are forced on me; others, perhaps, I can juggle to suit myself. Let's see.

Temperature depends, almost entirely, on how much heat a planet receives and retains from its sun. 61 Cygni is a binary system, but the two stars are so

[3] This refers to Isaac Asimov's novel *Pebble in the Sky.* —Editors

far apart that I needn't consider the other one as an influence on this planet's temperature; and the one which it actually circles is quite easy to allow for. Several years ago I computed, partly for fun and partly for cases like this, a table containing some interesting information for all the stars within five parsecs for which I could secure data. The information consists of items such as the distance at which an Earth-type planet would have to revolve from the star in question to have the present temperatures of Earth, Venus, and Mars, and how long it would take for a planet to circle the sun in question in each such orbit. For 61 Cygni A, the three distances are about twenty-eight, thirty-nine, and sixty-nine million miles, respectively. As we have seen, 61 C's orbit is reasonably well known; and it is well outside any of those three distances. At its closest—and assuming the primary star is 61 A—it gets almost near enough to be warmed to about fifty below zero, Centigrade.[4] At the other end of its rather eccentric orbit, Earth at least would cool to about minus one hundred eighty, and it's rather unlikely that this world we are discussing gets too much more out of the incoming radiation. That is a rather wide temperature fluctuation.

The eccentricity of the orbit is slightly helpful, though. As Kepler's laws demand, the world spends relatively little time close to its sun; about four fifths of its year it is outside the minus one hundred fifty degree isotherm, and it is close enough to be heated above minus one hundred for only about one hundred thirty days of its eighteen-hundred-day year—Earth days, of course. Its year uses up around one hundred forty-five thousand of its own days, the way we've set it spinning. For practical purposes, then, the temperature will be around minus one hundred seventy Centigrade most of the time. We'll dispose of the rest of the year a little later.

Presumably any lifeform at all analogous to our own will have to consist largely of some substance which will remain liquid in its home planet's temperature range. In all probability, the substance in question would be common enough on the planet to form its major liquid phase. If that is granted, what substance will meet our requirements?

Isaac Asimov and I spent a pleasant evening trying to find something that would qualify. We wanted it not only liquid within our temperature limits, but a good solvent and reasonably capable of causing ionic dissociation of polar molecules dissolved in it. Water, of course, was out; on this world it is strictly a mineral. Ammonia is almost as bad, melting only on the very hottest days. We played with ammonia's analogues from further along the periodic table—phosphine, arsine, and stibine—with carbon disulphide and phosgene, with carbon suboxide and hydrogen fluoride, with saturated and unsaturated hydrocarbons

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[4] Hello 1953, from 2000—we now know that the superjovian planet in the 61 Cygni system is in orbit around 61 Cygni B.—Editors.

HELLO 2000, from 2019! We know now that the planet was completely spurious, and it never existed at all!—Greg

both straight and with varying degrees of chlorine and fluorine substitution, and even with a silicone or two. A few of these met the requirements as to melting and boiling points; some may even have caused dissociation of their solutes, though we had no data on that point for most. However, we finally fell back on a very simple compound.

It boils, unfortunately, at an inconveniently low temperature, even though we assume a most unlikely atmospheric pressure. It cannot be expected to be fruitful in ions, though as a hydrocarbon it will probably dissolve a good many organic substances. It has one great advantage, though, from my viewpoint; it would almost certainly be present on the planet in vast quantities. The substance is methane—CH_4.

Like Jupiter, this world must have started formation with practically the "cosmic" composition, involving from our viewpoint a vast excess of hydrogen. The oxygen present would have combined with it to form water; the nitrogen, to form ammonia; the carbon to form methane and perhaps higher hydrocarbons. There would be enough hydrogen for all, and plenty to spare—light as it is, even hydrogen would have a hard time escaping from a body having five thousand times the mass of Earth once it had cooled below red heat—at first, that is. Later, when the rotational velocity increased almost to the point of real instability, it would be a different story, but we'll consider that in a moment. However, we have what seems to be a good reason to expect oceans of methane on this world; and with such oceans, it would be reasonable to expect the appearance and evolution of life forms using that liquid in their tissues.

But just a moment. I admitted a little while ago that methane boils at a rather lower temperature than I wanted for this story. Is it *too* low? Can I raise it sufficiently by increasing the atmospheric pressure, perhaps? Let's see. The handbook lists methane's critical temperature as about minus eighty-two degrees Centigrade. Above that temperature it will always be a gas, regardless of pressure; and to bring its boiling point up nearly to that value, a pressure about forty-six times that of our own atmosphere at sea level will be needed. Well, we have a big planet, which should have held on to a lot of its original gases; it ought to have a pressure of hundreds or even thousands of atmospheres—whoops! we forgot something.

At the equator, *effective* gravity—gravity minus centrifugal effect—is three times Earth normal. That, plus our specification of temperature and composition of the atmosphere, lets us compute the rate at which atmospheric density will decrease with altitude. It turns out that with nearly pure hydrogen, three g's, and a temperature of minus one hundred and fifty for convenience, there is still a significant amount of atmosphere at six-hundred-miles altitude if we start at forty-odd bars for surface pressure—*and at six hundred miles above the equator of this planet the centrifugal force due to its rotation balances the gravity!* If there had ever been a significant amount of atmosphere at that height, it would long since have been slung away into space; evidently we cannot possibly have a surface

Pressure anywhere near forty-six atmospheres. Some rough slide-rule work suggests eight atmospheres as an upper limit—I used summer temperatures rather than the annual mean.

At that pressure methane boils at about minus one hundred forty-three degrees, and for some three hundred Earth days, or one-sixth of each year, the planet will be in a position where its sun could reasonably be expected to boil its oceans. What to do?

Well, Earth's mean temperature is above the melting point of water, but considerable areas of our planet are permanently frozen. There is no reason why I can't use the same effects for 61 C; it is an observed fact that the axis of rotation of a planet can be oriented so that the equatorial and orbital planes do not coincide. I chose for story purposes to incline them at an angle of twenty-eight degrees, in such a direction that the northern hemisphere's midsummer occurs when the world is closest to its sun. This means that a large part of the northern hemisphere will receive no sunlight for fully three quarters of the year, and should in consequence develop a very respectable cap of frozen methane at the expense of the oceans in the other hemisphere. As the world approaches its sun the livable southern hemisphere is protected by the bulk of the planet from its deadly heat output; the star's energy is expended in boiling off the north polar "ice" cap. Tremendous storms rage across the equator carrying air and methane vapor at a temperature little if any above the boiling point of the latter; and while the southern regions will warm up during their winter, they should not become unendurable for creatures with liquid methane in their tissues.

Precession should be quite rapid, of course, because of the tremendous equatorial bulge, which will give the sun's gravity a respectable grip even though most of the world's mass is near its center. I have not attempted to compute the precessional period, but if anyone likes to assume that a switch in habitable hemispheres occurring every few thousand years has kept the natives from building a high civilization I won't argue. Of course, I will also refrain from disagreement with anyone who wants to credit the periodic climate change with responsibility for the development of intelligence on the planet, as our own ice ages have sometimes been given credit for the present mental stature of the human race. Take your pick. For story purposes, I'm satisfied with the fact that either possibility can be defended.

The conditions of the planet, basically, are pretty well defined. There is still a lot more detail work. I must design a life form able to stand those conditions—more accurately, to regard them as an ideal—which is not too difficult since I don't have to describe the life processes in rigorous detail. Anyone who wants me to will have to wait until someone can do the same with our own life form. Vegetation using solar energy to build up higher, unsaturated hydrocarbons and animal life getting its energy by reducing those compounds back to the saturated form with atmospheric hydrogen seemed logical enough to me. In the story, I hinted indirectly at the existence of enzymes aiding the reduction, by mentioning that plant tissues would burn in the hydrogen atmosphere if a scrap or two of meat were tossed onto the fuel.

The rest of the detail work consists of all my remaining moves in the game—finding things that are taken for granted on our own world and would not be true on this one. Such things as the impossibility of throwing, jumping, or flying, at least in the higher latitudes; the tremendously rapid decrease of air density with height in the same regions, producing a mirage effect that makes the horizon seem *above* an observer all around; the terrific Coriolis force that splits any developing storm into a series of relatively tiny cells—and would make artillery an interesting science if we could have any artillery; the fact that methane vapor is denser than hydrogen, removing a prime Terrestrial cause of thunderstorm and hurricane formation; the rate of pressure increase below the ocean surface, and what that does to the art of navigation; the fact that icebergs won't float, so that much of the ocean bottoms may be covered with frozen methane; the natural preference of methane for dissolving organic materials such as fats rather than mineral salts, and what that will do to ocean composition—maybe icebergs *would* float after all. You get the idea.

The trouble was, I couldn't possibly think of all these things in advance; time and again a section of the story had to be rewritten because I suddenly realized things couldn't happen that way. I must have missed details, of course; that's where your chance to win the game comes in. I *had* an advantage; the months during which, in my spare hours, my imagination roamed over Mesklin's vast areas in search of inconsistencies. Now the advantage is yours; I can make no more moves in the game, and you have all the time you want to look for the things I've said which reveal slips on the part of my imagination.

Well, good luck—and a good time, whether you beat me or not.

Addendum to "Whirligig World"[5]

When *Mission of Gravity* was finished in late 1952, I had a perfectly honest degree in astronomy. I nevertheless made a few mistakes, including one in basic physics; I said, somewhere in the story, that the *Bree* would sail faster with the wind behind her. Predictably, a sailor caught that one.

More seriously, I erroneously took for granted that the figure of rotation which was Mesklin would be an oblate spheroid, and did all the gravity calculation (on a slide rule) assuming that most of its mass was degenerate matter very close to the center. John Campbell told me when he accepted the story that a mathematician had told him that Euler must be spinning in his grave, but I still don't know what theorem I violated.

More usefully, a few years after the story was published, members of the M.I.T. Science Fiction Society (MITSFS) managed to get enough computer time to figure out more nearly what the planet's shape would be. They were presumably right; all I could console myself with was the realization that I had written the story to give pleasure to people even if that wasn't quite the specific pleasure I'd had in mind.

I eventually did get a computer, wrote a relevant program in BASIC[6], and came up with an object looking more like the discus used in field and track sports—an object fairly sharply curved at the poles, much flatter in the mid latitudes, and coming almost to a real edge at the equator. With arbitrarily chosen three g's at the equator, the polar gravity came out to only about 275, as I recall.

I assume that readers with appropriate background knowledge and computer hardware will want to check this. Maybe someone will want to write a book on the things that minor differences in the basic assumptions will do to Mesklin's shape.

Personally, I wound up doing forty years of high school teaching instead of being an astronomer essentially because of my mathematical weaknesses.

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[5] This addendum, written in March 1999, first appeared in print in *Analog Science Fiction and Fact*, January 2000.

[6] The author can no longer find this program, or we would have included it as an appendix.—Editors