ESSAYS ON SCIENCE
*by Isaac Asimov*

ONLY A TRILLION

FACT AND FANCY

VIEW FROM A HEIGHT

ADDING A DIMENSION

OF TIME AND SPACE AND OTHER THINGS

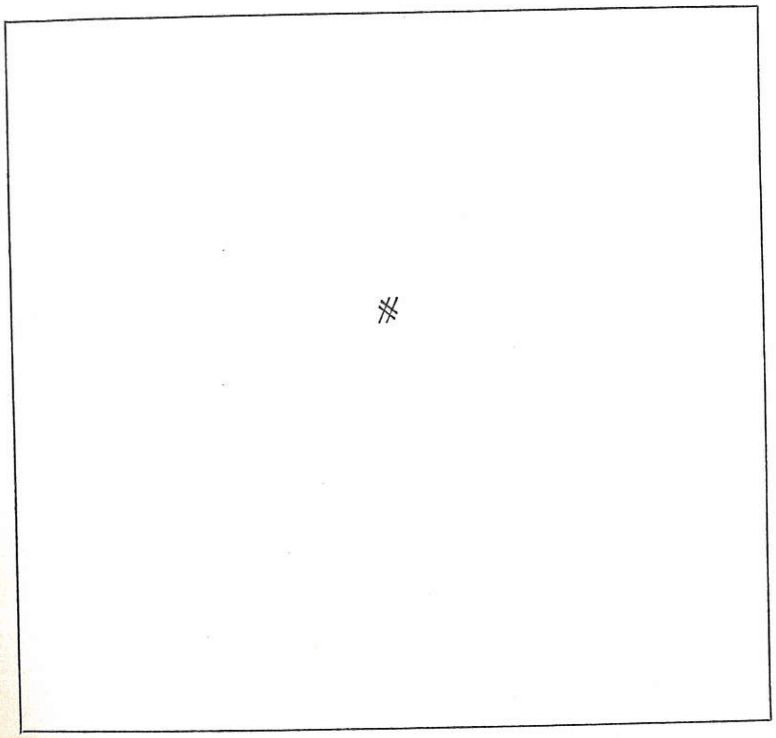
FROM EARTH TO HEAVEN

IS ANYONE THERE?

SCIENCE, NUMBERS, AND I

# SCIENCE, NUMBERS, AND I

## BY ISAAC ASIMOV



*Doubleday & Company, Inc., 1968, Garden City, New York*

# 15. NON-TIME TRAVEL

My father was brought up in the sternest of traditions, and is to this day able to quote Biblical passages of incredible length, word for word, together with several reams of Talmudic commentary on each verse. Since all this is in Hebrew, of which I understand only an occasional word, it does me no good, except for what spiritual edification osmoses inward as a result of hearing the sound of the sonorous syllables of the Language of the Prophets and Patriarchs.

However, all those Biblical and Talmudic passages have served to inculcate in my father a lofty code of virtue which he has tried for many years (with mixed results) to pass on to me. One of the fruits of that code, for instance, is my father's complete inability to make use of strong language. In fact, all I have ever heard him say, under even the most extreme provocation, is a phrase which, being translated, means, literally, "Eighteen black years!"

I believe that this represents a wish that the person or object at whom this phrase is aimed suffer eighteen consecutive years of misfortune, but my father refuses to confirm this, considering it an unfit subject for discussion. And when I ask him the significance of "eighteen" and suggest that "seventeen" might be sufficient, he turns away in sorrow, convinced that I am hopelessly sunk in frivolity.

The saddest part of the matter, alas, is that this inconvenient



habit of his of speaking without colorful phrases, is something he has indeed managed to pass on to me. I consider even "eighteen black years" to be a rather harsh and unwarranted remark, and, when strongly moved, I usually give vent to an "Oh, dear me!" or an "Oh, goodness gracious!" I may even, in transports of fury, go so far as a "Good Heavens!"

This has had a serious effect on me, aside from the fact that I am occasionally the recipient of a dubious glance or two. When someone makes a remark that shows him to be particularly ignorant of some very simple aspect of science,* a person other than myself could respond with a vile word or two and, unburdening his soul in this manner, pass on to other things. I cannot. Helpless to relieve my feelings with an expletive, I am forced to say, "Well, no, that's not quite right. Here, let me try to explain . . ."

And thus my way of life has been forced upon me.

I'll give you an example. Occasionally I have been on the scene when an individual has discovered that in crossing the Pacific Ocean from Tokyo to San Francisco, there comes a place where you "go backwards in time one day." A look of heavy concentration may come over this person and then the grinding gears produce an awe-inspiring thought:

"Listen," he says, "if you keep on going around the Earth west to east time after time after time, you go backward one day each time and if you go fast enough you can keep from growing older and live forever."

I then search for the proper remark and failing to find it, I am forced to say, "Well, no, that's not quite right. Here, let me try to explain . . ."

We can begin by making things very simple. Let us suppose we have frozen an instant of time. The Earth has stopped in mid-spin at just the moment when the Sun is crossing the meridian over your head so that it is exactly noon at the point

* A "simple aspect of science" may be defined as one which, through good fortune, I happen to understand.

at which you are standing. Furthermore, the day of the week is (pardon me, while I toss my seven-sided coin) Tuesday.

Very well, then, it's noon on Tuesday where you're standing and for our purposes here, it doesn't matter where that point is. Call it Home.

Since we've frozen an instant of time and the Earth is standing still, it is going to be noon on Tuesday indefinitely at Home. You can wander away wherever you want and when you come back the Sun will still be crossing the meridian and it will still be noon on Tuesday. This will give us a chance to experiment at leisure.

Suppose you travel due east from Home. As you travel east along Earth's curved surface, the Sun will seem to move to the west because of the very existence of that curvature. The farther you move east, the further the Sun seems to sink in the west, till finally, if you move far enough eastward, the Sun touches the western horizon.

We associate this apparent westward journey of the Sun from meridian to western horizon with that of a forward-moving time from noon to evening, so we would naturally assume that as we travel east it is getting later in the day.

But we have frozen time. The Sun is in actuality (according to the mythical situation we have arranged) motionless over the meridian of Home. Therefore, the change in time as we travel eastward is an illusion born of our convention that the apparent westward motion of the Sun *must* mean that time is moving forward.

How did that convention arise? Well, let's consider.

The basic and original concept of time is physiological; it is our own sense of duration; our own sense that something is happening and *then* something else is happening and *then* something else is happening and so on.

Of course, our sense of duration is strongly influenced by environment. A period of time at a dull lecture seems to stretch



out tremendously. The same period of time (as judged by someone else) spent with a charming girl is alarmingly brief.

You might, of course, take your own sense of duration as an absolute standard of time measurement. If you feel that the lecture endured long and the girl's stay did not, why accept someone else's opinion that the two intervals were about equal in duration?

Alas, you must, if you are outvoted. If there is to be cooperation in the world, and if people are to do anything at all together, they had better drown their own particular senses of duration and choose some average that will suit them all as well as possible. The trick is to choose some change which seems constant in rate over long periods and to use that as a commonly agreed upon measure of time.

The first such steady change available to primitive man, when he began to feel the need of an objective measure of time, was the steady and constant progression, day after day, of the Sun from eastern horizon to western horizon.

Of course, the Sun's apparent motion is not really a fundamental phenomenon. It depends on the accidental fact that the Earth is rotating on its axis at a rate that does not match its revolution about the Sun. Furthermore, this motion is a useful measure of time, only because the Earth's rate of rotation happens to be virtually constant.

Yet it must be pointed out that the apparent progression of the Sun from east to west takes place at a constant rate *only when the observer does not change his position, east and west, on the Earth's surface.* (He can move north and south all he wants provided he ignores the changes introduced by the tilting of the Earth's axis—like a six-month day or night at the poles.)

As soon as an observer moves east or west, he adds to the apparent east-to-west motion of the Sun that results from the Earth's west-to-east rotation, an additional change that is the reflection of his own motion. And since the observer's own motion is bound to be erratic, the progression of the Sun is

no longer constant to the moving man and that progression may therefore no longer be a useful measure of time.

To be sure, it is not quite as bad as all that. Ordinary motion, such as walking to the post office, or driving to work, is over distances so short and at a rate so slow compared to the planet's rotational speed, that the irregularity introduced into the Sun's apparent motion is small enough to be ignored. Until a quarter century ago, in fact, motion-induced irregularities were of importance only under highly specialized and exceptional conditions.

Since World War II, however, jet-plane travel has become commonplace. Travel over long distances at great speeds is indulged in. The result is that the apparent motion of the Sun across the sky for such travelers has no reasonable relation whatever to one's sense of duration or to the time measurements conducted by a stay-at-home individual.

Since the traveler tries to adjust his activities to the Sun's position at all times, partly out of habit and partly out of a desire or need to synchronize his activity with those of the natives of the place he has reached, he tries to accept the fact that it is dinner time just because the Sun is on the western horizon. Since his own internal clock knows it *isn't* dinner time there is a conflict that causes the traveler to feel rotten. And so our age gets a new disease, the Jet-set Jitters.

The progression of the Sun is not, of course, the only method we have of telling time. In fact, when it comes to telling time to better than the nearest hour, we've *got* to use something other than the Sun. We use the constant periodic motion of a hairspring in a wristwatch, for instance.

Not only does the wristwatch tell us the time to the second (if it is working well) but it is not significantly affected by our motion, or change in position, even as a result of jet travel. Our wristwatch will measure a time lapse roughly equivalent to our sense of duration whether that time lapse has taken place while we were in our bed at Home, or while we traveled half around the Earth in a jet plane.



And yet do we go by our wristwatch? No, we do not. Synchronization with the activities of the natives which, in turn, are matched to the progression of the Sun, is a matter of overriding concern. If we jet from New York to London, we ignore our correct wristwatch; we change its setting to match the position of the Sun, and it's hello, Jitters, hello.

Indeed, think of how convenient things might be if we lived underground and never saw the Sun. It would be simplicity itself (in principle) to set up a single light-dark alternation for the entire planet, so that it could then be noon everywhere at the same time. We could then travel quickly or slowly through such an underground world, and over distances that were large or small, yet never experience any of the time problems we experience on the Earth's surface.

In other words, then, our time problems on Earth arise entirely out of the fact that we are living on a spinning sphere and have gotten into the habit of matching our behavior to the relative position of ourselves and the Sun. Our problems are a matter of convention only and have nothing to do with time itself as a physical phenomenon.

Nothing we can do on the surface of the Earth does more than play games with convention; nothing we can do affects the steady flow of physical time.

Forget, then, about time travel. That is not involved in the slightest. Forget about time as a physical phenomenon. Think only of the convention of the Sun's apparent movement and let's see how we can handle that convention in such a way as to keep us from becoming involved in contractions and paradoxes.

Let's start again at Home at a frozen instant of time at noon, Tuesday, and travel eastward. Every fifteen degrees we travel will make Sun-based time one hour later (see Chapter 14). It is therefore 1 P.M. Tuesday at 15° eastward, 2 P.M. Tuesday at 30° eastward, and so on, until we reach 12 P.M.—that is,

midnight—when we have traveled 180° eastward and have completed a journey that is exactly halfway around the world on the particular parallel of latitude we are following. (The same holds true for any parallel of latitude, of course. Movement north and south from one parallel of latitude to another, does not affect Sun-based time.)

Back we go Home, where time's freeze means it is still noon on Tuesday. Now we travel due westward. As we travel westward, the Sun seems to move eastward in the sky and if we go far enough westward it will be seen at the eastern horizon. In short, Sun-based time will be earlier and earlier as we go westward.

Again, each 15° stretch that we travel westward makes the Sun-based time one hour earlier. It is 11 A.M. Tuesday at 15° westward; 10 A.M. Tuesday at 30° westward, and so on, until we reach a time of midnight when we travel 180° westward and have completed a journey that is again exactly halfway around the world on the particular parallel of latitude we are following.

This appears delightfully consistent. Whether we travel 180° due east or 180° due west we end up at exactly the same place, the point exactly opposite Home on its parallel of latitude. (If Home is Boston, for instance—42.3° North Latitude, 71.1° West Longitude—then 180° either due east or due west is near the town of Pai-yun-o-po in Inner Mongolia.) And whether we go due east or due west, it turns out to be midnight at that 180° opposite point.

But wait, heave no sigh of relief, for we are in trouble!

Look more closely at the eastern progression from Home. As we travel over 15° intervals, we move to 1 P.M. Tuesday, 2 P.M. Tuesday, 3 P.M. Tuesday until we finally reach, at 180° eastward, the midnight that follows one minute after 11:59 P.M. Tuesday. It is the midnight that forms the boundary between Tuesday and Wednesday. Let's call it: 12 P.M. Tuesday/Wednesday.

If we move westward from Home, however, the progression



is 11 A.M. Tuesday, 10 A.M. Tuesday, 9 A.M. Tuesday, until we finally reach, at 180° westward, the midnight that just precedes by one minute the time of 12:01 A.M. Tuesday. That is the midnight that separates Monday from Tuesday and we can call it: 12 P.M. Monday/Tuesday.

In short, in traveling either east or west we find that it is indeed midnight at the 180° line in either case, but it is a *different midnight* in each case. The westward travel takes us to the 180° line at a time which, apparently, is 24 hours *earlier* than that same 180° line is when reached by eastward travel.

This is a paradox that is caused, let me repeat, not by the nature of time itself, but by the conventions of Sun-based time only. It is a man-made paradox!

The paradox gets worse if we continue our travel past the 180° line. Suppose we have reached the 180° line traveling eastward and find it is 12 P.M. Tuesday/Wednesday and continue traveling eastward another 15°. Judging by the Sun (which is on the other side of the Earth and is not visible, but whose position can be calculated), another hour has been gained and it is now 1 A.M. Wednesday. Another 15° eastward brings us to 2 A.M. Wednesday and so on.

Finally, when we have gone 180° past the 180° line, and have traveled 360° eastward altogether, we find we have made a complete circle and have returned Home. By that time, we calculate the time to be noon on Wednesday. In other words, in traveling 360° eastward (and returning Home), we have passed over twenty-four 15° intervals and considered ourselves to have moved forward in time one hour for each of those intervals, and twenty-four hours (or one full day) forward for the complete circuit. Hence, while we considered it to be noon on Tuesday when we left Home, we considered it noon on Wednesday when we returned Home.

Yet we have been assuming frozen time. The Earth has not moved; the Sun is still where it was.

Next, suppose you had traveled westward instead of eastward.

Now you would have counted one hour earlier at each 15° interval, reaching 12 P.M. Monday/Tuesday at the 180° line and 11 P.M. Monday when you had reached 15° west of it, then 10 P.M. Monday, 9 P.M. Monday until when you reached Home again, you could consider it noon on Monday.

Imagine, then, three men at Home. One stays Home, one travels eastward at a constant speed, and one travels westward at a constant speed. The two travelers return Home at the same moment. The one who has not left Home says: "It is still noon on Tuesday." The one who traveled eastward says, "It is noon on Wednesday." The one who traveled westward says, "It is noon on Monday."*

Furthermore, if our travelers keep on traveling at constant speed in the same direction, they will continue periodically to meet at Home. Each time they meet, the eastward traveler will add a day, the westward traveler will subtract a day, and the stay-at-home will insist on an unchanged day.

The situation would not be altered, in essence, if the travelers went at unequal speeds, or each at varying speeds, just as long as one moved generally eastward and the other generally westward.

You might wonder if there would be a difference if we allowed for the fact that the Earth is rotating, and that time is not actually frozen. No! The rotating Earth would advance time for all three individuals, the stay-at-home and the two travelers, but superimposed on that advancing time which all three would experience equally, there would be a day added for each circle of the earth by the eastward traveler and a day subtracted for each circle of the earth by the westward traveler.

How's that for a paradox? Well, to repeat once more, it is a man-made paradox based on a man-made convention of Sun-based time. To correct it, one need only adjust the convention properly.

* I believe that Edgar Allan Poe wrote a comic farce based on a situation like the one described here.



How is that done?

Suppose we fix the time on any part of the Earth as it would be calculated traveling east or west from Home *by whichever route is shorter*. Continuing to use frozen time, let's leave Home at noon on Tuesday and travel 90° eastward (crossing six 15° sections). If we cross six 15° sections, we move six hours forward and, on arriving at our destination, we find the time to be 6 P.M. Tuesday.

We might also leave Home at noon on Tuesday and reach the same point by traveling 270° westward (eighteen 15° sections). If we then move eighteen hours backward, we find the time to be 6 P.M. Monday at our destination.

In this case, since the 90° eastward trip was shorter than the 270° westward trip, it is the decision of the former that counts. It is 6 P.M. Tuesday, whether you travel eastward or westward. The same sort of decision can be made for any other combinations of east travel versus west travel.

Consider now, that the eastward trip is the shorter for all points up to 180° eastward of Home; the westward trip is the shorter for all points up to 180° westward of home. It is precisely at the 180° line, which is the same whether you travel east or west, that there is a conflict.

If you travel eastward to a point just short of the 180° line you will find it 11:59 P.M. Tuesday. If you travel westward to a point just short of the 180° mark you will find it 12:01 A.M. Tuesday. If, still moving eastward, the eastward traveler now crosses the 180° line, he must suddenly abandon his own calculations and accept those of the westward traveler. Instead of reaching 12:01 A.M. Wednesday as his own calculations would tell him, he finds himself at 12:01 A.M. Tuesday, as the other's calculations would have it. The eastward traveler moves back in time twenty-four hours—a whole day—by crossing the 180° line.

Similarly the westward traveler who crosses the 180° line, while still moving west, must abandon his own calculations for those of the eastward traveler. Instead of finding himself to be at

11:59 P.M. Monday, as his own calculations would have it, he finds it 11:59 P.M. Tuesday as the eastward traveler would insist. The westward traveler, in moving west across the 180° line, moves forward in time twenty-four hours—a whole day.

It is this moving forward or backward, a whole day at a time that, to the casual observer, seems to introduce the possibility of a paradox. A day has been "gained" or it has been "lost." You have grown "a day younger" or "a day older."

Nonsense! That trick about crossing the 180° line is designed to *prevent* a paradox—the very paradox I mentioned earlier in the article, in which eastward travelers move a day forward each time they circle the Earth, as compared with a motionless observer, and westward travelers move a day backward.

With the modified convention of the 180° line, the situation is as follows: The eastward traveler moves 1 hour forward with each 15° he covers, and has moved 24 hours forward, little by little, by the time he has covered 360° and returned Home. *But* he has moved 24 hours backward, all at once, the instant he crossed the 180° line and that neatly canceled the gradual forward change of the eastward progression. Having moved forward 24 hours little by little and 24 hours backward all at once, he returns Home with no change in time and finds it is still noon on Tuesday as the stay-at-home insists.

Similarly the westward traveler moves 1 hour backward for each 15° he covers, moving 24 hours backward when he has covered 360° and returned Home. *But* he has moved 24 hours forward, all at once, the instant he crossed the 180° line and that change is canceled. He, too, agrees it is noon on Tuesday.

In fact, no matter how many times the travelers circle the Earth, and no matter what their direction of travel, no paradox of time measurement will exist as long as the 24-hour jump exists at the 180° line. Nor is this altered in a steadily rotating Earth where time is not frozen. Without the jump at the 180° line, the paradox *would* exist, and jet-age travel would become a jungle of confusion.



But where should the 180° line be? Home is where your heart is and for every different Home there is a different 180° line and my Home and my 180° line is just as good as yours, aren't they?

Yes, it is, but if the same 180° line isn't adopted for everybody, then everything tumbles into confusion anyway.

As it happens, the nineteenth century saw an international agreement on the subject of longitude. In 1884 an international conference was held in Washington to decide on a universally-agreed upon Prime Meridian.

Since Great Britain was the dominant maritime power of the time, it seemed logical to set the 0° longitude mark on the meridian passing through the Greenwich Observatory in London. This is the "Greenwich meridian."

This international agreement deals only with the convention for locating objects on the surface of the Earth. It does *not* deal with time measurements and no official international agreement has been reached there.

Nevertheless, it is unofficially accepted that the time based on the Sun's position at Greenwich (or "Greenwich time") is *the* time. Undoubtedly, when we set up our space stations and our colonies under the Moon's surface—all under conditions where the position of the Sun will mean nothing—it will be Greenwich time that will be used.

Why not, therefore, set our standard as noon on Tuesday at Greenwich, and choose as our 180° line the 180° line as calculated from Greenwich? Since Greenwich is at 0° Longitude (neither east nor west) by definition, the 180° line associated with it happens to be the one that is marked 180° Longitude (neither east nor west) on any map or globe of the Earth.

It is at the line of 180° Longitude, then, that one moves a day backward by crossing it traveling eastward, and moves a day forward by crossing it traveling westward.

As it happens, this—through sheer accident—is the most convenient arrangement possible. Greenwich Observatory was chosen as the site for the Prime Meridian for reasons that had nothing

to do with time measurement, yet its 180° line travels north-south right through the middle of the Pacific Ocean, at precisely the point where a day change can be made with the least possible inconvenience.

It would be unthinkable, for instance, to have the 180° line pass through the middle of the United States, or the middle of the Soviet Union and expect people of part of a nation to be operating one day behind or ahead of the people of the other part. As it is the line of 180° Longitude crosses over ocean water through almost its entire length in places that are as far removed from the major land masses as possible. Imagine just that line happening to be opposite London!

To be sure, 180° Longitude does cut across the eastern tip of Siberia and make its way through some island chains. The line along which a sudden twenty-four-hour change takes place is therefore not precisely along the 180° Longitude line throughout its stretch. The accepted line of change bends east and west as much as three to five hundred miles in places in order to place the tip of Siberia with the rest of the Soviet Union on one side of the line and the westmost Aleutian Islands with the rest of the United States on the other side of the line. South of the equator there is an eastern bulge to allow certain islands to be on the same side of the line as Australia and New Zealand.

This somewhat irregular line is the "International Date Line" —which is made use of internationally, even though it has never been the subject of an official international agreement!

And there you are! No amount of crossing the date line can in any possible way involve you in paradoxes, and certainly it can never—by any conceivable stretch of the imagination—involve you in time-travel.

Please say you see it now, for if you don't, I am all out of explanation, and I still don't have any exclamatory remark to fall back upon.

# 16. TWELVE POINT THREE SIX NINE

Once in junior high school, my English teacher gave the class the assignment of reading and pondering Leigh Hunt's poem "Abou ben Adhem." Perhaps you remember it.

Abou ben Adhem awoke one night from a deep dream of peace and found an angel making a list of the names of those who loved God. Ben Adhem naturally wanted to know if he was included and was told he wasn't. Humbly he asked to be included as one who loved his fellow men, at least.

The next night the angel reappeared "And show'd the names whom love of God had bless'd/And lo! Ben Adhem's name led all the rest."

I knew the poem and had a pretty good notion as to the course of the class discussion planned for the next day by the teacher. There would be little homilies about how to love God meant to love mankind and vice versa. I agreed with that, but thought it would be rather dull to spend time on so self-evident a proposition. Could not some alternate meaning be wrenched out of the miserably unsubtle poem? I could find none.

The next day, our English teacher, with a kindly smile, asked, "Now, class, who will volunteer to tell me why Abou ben Adhem's name led all the rest?"

Blinding inspiration struck me. I raised my hand violently and when the teacher nodded at me, I said, with a beatific smile, "Alphabetical order, sir!"