

On Sale Third Wednesday of Each Month

VOLUME XVIII  
Number 2

# ASTOUNDING STORIES

OCTOBER  
1936

A STREET & SMITH PUBLICATION

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Cover Painting by *Howard V. Brown*

Story illustrations by *Wesso, Dold, Marchioni, Thomson, Flatos*

Single Copy, 20 Cents



Yearly Subscription, \$2.00

Monthly publication issued by Street & Smith Publications, Inc., 79-89 Seventh Avenue, New York, N. Y. George C. Smith, Jr., President; Ormond V. Gould, Vice President and Treasurer; Artemas Holmes, Vice President and Secretary; Clarence C. Vernam, Vice President. Copyright, 1936, by Street & Smith Publications, Inc., New York. Copyright, 1936, by Street & Smith Publications, Inc., Great Britain. Entered as Second-class Matter, September 13, 1933, at the Post Office at New York, N. Y., under Act of Congress of March 3, 1879. Subscriptions to Cuba, Dom. Republic, Haiti, Spain, Central and South American Countries except The Guianas and British Honduras, \$2.25 per year. To all other Foreign Countries, including The Guianas and British Honduras, \$2.75 per year.

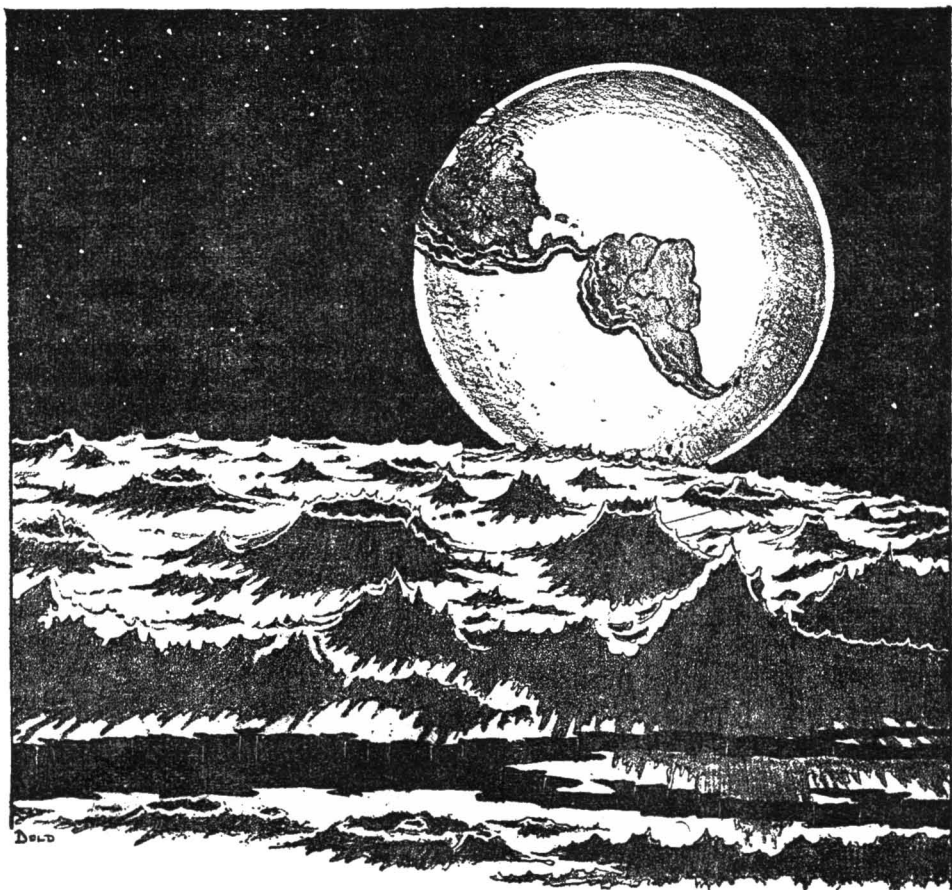
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## *A Study of the Solar System*

*Article No. 5*      by John W. Campbell, Jr.



# The Double World

**I**T IS HARD to write a short article about the third planet. Every one knows the simple things about Earth, the fact that it has atmosphere, that it is about 93 million miles from the sun, that it is 8,000 miles in diameter, with a temperature range in the lower half of water's liquid range. These simple things we all know.

There is an enormous mass of intensely interesting material to draw on: the slow, majestic wobble of Earth's axis; the strange, short-term wavering of that same axis; the magnetic poles caused by a flow of electric current of some 10 million amperes flowing ceaselessly about the Earth; the causes and histories of the great land masses.

But these are things no short article could readily handle; their bare statement would lose, by its mere factual presentation, all the interest of the deep thought that went to make them known: the solidity of the Earth is determined by measuring tides in little glass tubes, tides two thousandths of an inch high; the north pole, in midsummer, receives half again as much heat from the Sun as the equator, more heat than any other point of the Earth; the tides are draining the stored energy of Earth's rotation at the stupendous rate of 1,877,000,000 horse power, and slowing it, in consequence, one second in 150,000 years.

The simple things we know. The mass of more important data is too great to hope to use and explain here. Yet remember, an exact knowledge of Earth is an absolute necessity for the astronomer. Earth is, to the astronomer, not only the Earth on which he lives, and must mount his instruments, but also Earth, Planet Three, an example of a stellar satellite at close range.

Saturn, another stellar satellite, has a density bewilderingly low. How can that be? What are the density distribution curves? Perhaps the motions of the satellites can tell us? Well, we can measure the density distribution of Earth fairly well, by earthquake shock and gravity pendulum experiments; we can chart the motions of our satellite, really our planetary twin, Luna, and see if the results check. But first we must know Earth's density distribution. Is it denser deep within? Much denser?

Again, is Pluto's slow orbital movement irregular, or is the polar axis of Earth rocking slowly and slightly? We have to find out—and incidentally damn the Moon. That twin of ours throws old Earth back and forth in a crazy sort of way, like an unbalanced flywheel on a one-lunger gas engine. The motion is not a simple oscillation either. The Moon is no mere satellite. Why, if Jupiter had one as large in propor-

tion it would be a major planet 22 thousand miles in diameter.

The Moon is one fourth as large as the Earth; naturally Earth heaves around a good bit to that huge thing. But, because Earth's pull is weakening very rapidly by the time you get 238,000 miles out, the moon isn't gripped rigidly and immovably. Of course the pull is fairly considerable. If you had a steel cable replacing it, the cable might snap, and on the broken surface leave room for Massachusetts, Connecticut and New Jersey; though 250 miles in diameter, a steel cable would snap like a pack thread under the titan pull of the Moon's centrifugal force.

BUT that is not a very solid binding in the solar system. A good binding is one that will swing a satellite in a day or two, not in four weeks. Earth swings the Moon once in 28 days, at 238,000 miles. Jupiter has a satellite at 261,000 that it snaps around in a day and three quarters! Things move under Jupiter's lash, and it takes a mighty pull to disturb their motion. But ours yields and wavers "in her circled orb" to every passing influence. It stretches out to the Sun; it wobbles aside to Mars, and ogles a bit when Venus passes near. Jupiter half a billion miles away lays violent hands on the orbit and twists it a bit. The Moon's orbit is not exactly a precise and steady thing. And since it is not an ordinary satellite, but, a planet in its own right, only by accident a twin to Earth, Earth rocks and shakes in its orbit every time the Moon moves and stirs a bit.

To express the Moon's motions, an equation covering some eight or nine pages of mathematical symbols is required; thousands and thousands of terms; the first describing the basic motions of the Earth-Moon system as though it were isolated in space, then a correction for the influence of the Sun, and a consequent correction for the

reaction of the Earth-Moon to that attraction; next, an expression of Mars' influence, and Venus', with resultant cross corrections on Earth's part.

And remember that since Mars' influence of the Moon depends on Mars' orbit about the Sun, then that expression of Mars' influence on the Moon must, of necessity, include the complete data for Mars' own orbit. The influence of Venus equally requires the complete and complex data of Venus' orbit. So in the end, to express to a fair approximation the movements of the Moon, the equation must include the movements of half the solar system.

Charles Fort, in "Lo," mentioned the inaccuracy that astronomy revealed at the time of the solar eclipse, some seconds off the time given, some hundreds of feet wrong in space. The astronomers expect that; it's a real triumph to be as incredibly accurate as they are. It becomes understandable when we appreciate the superhuman complexity of the motions which are involved.

Earth wobbles like a run-down top; she heaves and pants like a worn-out horse. Every time she wiggles a little, the telescopes mounted on her surface writhe, too. The astronomer can't hope to make his telescopes less agile than the Earth, but he can hope to describe Earth's every inaccuracy of motion so accurately he can correct for it. That is one reason why he watches eclipses with such intense interest. If the Moon is out of its calculated position by one inch at the time of eclipse, that means a displacement of the shadow on Earth's surface, of 25 feet. One inch, mind you, does that. And the Moon is, 2,000 miles in diameter.

SINCE our every prediction of motion of other planets is based on observation made on Earth, since our every estimate of distances is based on Earth-founded observation, the immense importance of knowing Earth's position ac-

curately becomes understandable. We speak of the motions of the Moon, though accurately it is the motion of the Earth-Moon system. These motions have been described mathematically with greater accuracy, greater labor, and more infinite care than the motions of any other thing known to man.

The problem resolves itself always to that of making mathematical theory about 50 per cent more accurate than the finest telescope existent. It is useless waste of effort to get any closer theory than the telescopes allow in practice—like getting pi to 700 decimal places. Useless, because nothing in the universe is as accurate as pi to 700 places, except the imaginary circle you describe with it. I've forgotten the exact statistics, but it runs something like: "If you describe a circle, using Pluto's distance from the Sun as radius, the true circle and the inaccurate circle due to using only 700 decimal places would leave room for a filterable virus to pass, but not a microbe of ordinary size.

That is one phase of the importance of knowing thyself. Next comes the important fact that aside from Earth being our observatory, it is important as the only available planet on which we can make experiments. If you wanted to determine the properties of a make of car your neighbor had, an excellent way to do it would be to get one like it yourself and experiment. Unfortunately, our nearest neighbor, Venus, has a similar, but slightly different make, Mars has another, and Jupiter still another, and all the manufacturing companies seem to have gone out of business. But all the cars have certain, basic similarities; so have the planets.

We can't test Jupiter exactly by tests on our little planet, but we can get certain basic rules. Earthquakes show us something of the density and physical properties of the deep interior of this

planet, and hence of planets in general. Dynamical studies of Earth indicate certain things about the dynamical properties of planets. Studies of Earth's age and development make a fair data for the other planets.

One thing we want to know first is whether the deep material of planets yield to tidal stresses as a thick tar, or as a piece of fine steel, a spring. If it yields like soft tar, the tides are doing an immense amount of work distorting it, then pulling it back into a new shape; if it yields as a spring, the work done in distorting it is immediately restored by the return under its own power.

To determine this is obviously difficult because of the fact that we are raised and lowered with the tides; all our cities and mountains rise and fall with the deep tides of the very stuff of the Earth. That is why they measure tides in glass tubes. Ocean tides are perfectly fluid, since water is neither highly like tar, nor rigid and elastic like steel. Unfortunately, ocean tides near coast lines are influenced by everything from last week's garbage disposal to the shape of the coast line, and whether the mountains came down to the sea.

The Himalaya Mountains exert so powerful a gravitational attraction that the Indian Ocean is not at sea level. Remember that there is enough mass in those mountains to make up a fair-sized planetoid. The sea, like Mohammed, goes to the mountains, since the mountains don't come to it.

TO AVOID these influences—quite incalculable influences—the experimenters made glass tubes to house tides of their own, mounted them in a laboratory, and watched results under ideal conditions. The tides weren't very high—.002 of an inch—but quite enough to observe. They could calculate the difference to be expected between a viscous mass like warm tar, the elastic yielding of steel,

and the fluid nonviscous, nonelastic water, and so determined quickly enough that the Earth is almost purely elastic in its yield; it bounces rather than squashes under tidal forces.

But—if tides continued in one direction long enough, instead of moving about the Earth as the planet spun on its axis, the tidal yielding would cease to be elastic, and become a permanent flow. Cold tar will bounce, if dropped. But if you leave it there long enough, it will “cold-flow” and acquire a new shape, which it will now hold under a momentary force.

Now, that is the result of calculations made on Earth. Are there any other bodies like that? Would the other planets yield elastically to momentary—a month or so—tides, and set finally if the tide acted over centuries and millenniums? How can we tell?

No other planet has such tidal pulls as Earth. No other planet is part of a double planet, with a near-by twin of almost the same size—except, of course, the Moon.

The Moon is a twin, not a child, of Earth. There were originally two theories of the Moon's origin: one, that it was torn out of the Earth in a long-gone day, when the Earth rotated on its axis far faster than now, spinning once in 4 hours instead of in 24; the other, that they were children of the same birth, not child and parent. The final decision in favor of one or the other depended on dynamical theory, on the dynamics of the problem, and nobody had developed it; they didn't know how.

Modern dynamics show that a combined Moon and Earth would not break up. Rotating once in 4 hours, a small mass like the Earth-Moon body would be no less stable than Jupiter now, rotating in nine hours. It would be more flattened, yes, but not unstable. Emphatically, the answer is no; the Moon was not born of Earth.

But both theories, and the modern theory, now agree that at one time the Moon whirled round the Earth at a distance less than 9,000 miles, a monstrous, mad Moon, filling the sky. But even then our twin world was dying, the slighter, slighted twin, cheated at birth, being robbed by the greater world, clutched in the mighty, deadly grip of the greater world's gravity.

It was still struggling, rotating on its own axis swiftly then, but the immense grip of Earth's gravity was setting up enormous tides. These tides acted as a giant brake, slowing the axial span of the Moon, and by the reaction of the braking, driving it farther from the Earth. It went swiftly at first, for the tides were immense, both on Earth which the Moon slowed, and on the Moon slowed by Earth.

As the tides drove the Moon out, they hastened the natural tendency of so small a body to loose gas, atmosphere. So small a world could not hold atmosphere, even in its deepest canyons and buried caverns, for rocks are porous. But Earth was whipping and lashing the primeval atmosphere that remained, snatching it up in irresistible tides till it flew free. But free of the Moon was not free of Earth; Earth's far greater, far more far-reaching gravity gathered much of it in, to add to Earth's own atmosphere.

EVENTUALLY Luna was a dead world, airless, waterless, moveless, 90,000 miles from Earth, throttled by her stronger sister till she no longer rotated on her axis with respect to the larger planet.

Now the tides act constantly in one direction, century after century, millenium after millenium. Tides do not stop when rotation ceases; the distorting influence of gravity goes on forever. But the tidal wave that had moved about the Moon, ever slower, had come to rest

at last. Matter, stressed for countless ages in one direction, crept, and settled. The tidal wave remained forever a fossil tide, inelastic and unmoving. A tidal wave a mile high froze forever, facing Earth.

Earth still turned, despite the age-long braking of the Moon, continued to drive Luna farther out, past the 100,000-mile mark, past 200,000, out to 238,000 miles now. Five feet each century, Earth is still driving her. But that fossil tide remained.

At 90,000 miles Luna's orbit, being shorter and nearer Earth, required much less time for a circuit; the month was far shorter than it is to-day. Month and Lunar day were equal then. Had the Lunar day remained unchanged as the Moon was driven out, and the month increased in length, the Moon would have taken on an apparent reverse rotation. But the lengthening month was exactly balanced by the lengthening day, for Earth's gravity had crushed the imprint of its fingers into the Moon. Luna was no longer a sphere, but a neatly ridged body that gave gravity a perfect handle; the fossil tide that could no longer move.

Every attempt Luna made to turn again was hopeless, for Earth's gravity had the handle, and dragged it back. Calculations show that if the center of Luna's disk is so much as one fifteenth of an inch to one side of exactly facing Earth, gravity will drag it back. A two-thousand-mile sphere of rock and matter—quintillions of tons of matter—bound to less than a fifteenth of an inch motion!

At 90,000 miles Earth's work was done. Her smaller sister has been killed and bound, a lifeless, sun-baked, space-frozen world, airless, waterless, hopeless. Tamed to follow, a blind corpse forced to stare forever with dead eyes at her greater sister's finery—finery of air and water stolen from Luna as she was subdued.