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COSMIC CACTUS

*Article No. 10 in the
Study of the Solar System*

by JOHN W. CAMPBELL, Jr.

IT SEEMS TO ME that in all human history no man was so fortunate as Galileo, the first astronomer to look through a telescope. The Greeks had specified six magnitudes of stars, the first being the brightest stars in the heavens: Sirius, Betelgeuse and such great suns; the sixth magnitude, the faintest *there were*. Not, remember, the faintest the human eye could see; they did not believe that. They thought those the faintest that existed.

Galileo discovered a new universe. He found that there were far, far more stars—stars never before seen because of their dimness. He had to invent new terms, such things as “seventh magnitude.” There were no such terms; they were strange to his tongue, sounded queer in his ears, no doubt. They sounded strange to all astronomers. The Greeks had said there were six magnitudes; then who was this upstart Italian who said there was a seventh magnitude? Stars Aristotle and Ptolemy had not mentioned?

And these moons that he reported, the things he had thought at first simply more of the infinite number of new, strange stars that made all existing catalogues meaningless? He had caught sight of them on January 7, 1610. “In the first hour of the following night, when I was viewing the constellations of the heavens through a telescope, the planet Jupiter presented itself to my view.

“As I had prepared for myself an excellent telescope, I noticed a circumstance which I had never been able to notice before, owing to want of power in my other telescope, namely, that three little stars, small but very bright, were near the planet. Though I then believed them to belong to the number of fixed stars, yet they made me somewhat wonder, because they seemed to be arranged exactly in a straight line parallel to the ecliptic, and to be brighter than the rest of the stars equal to them in magnitude. The position of them with reference to one another and to Jupiter was as follows:

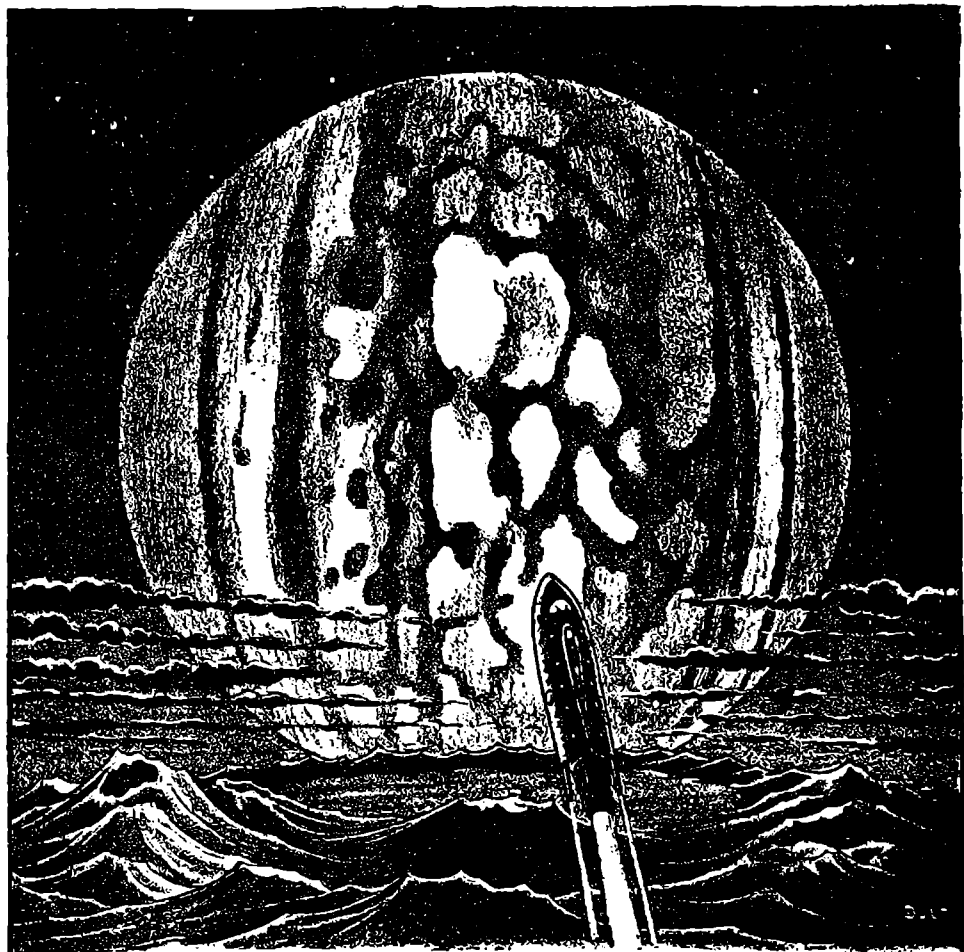
East * * 0 * West

On the east side there were two stars, and a single one toward the west. The star which was farthest toward the east, and the western star appeared rather larger than the third.”*

HE DIDN'T KNOW then the importance of that discovery, but they intrigued him. The next night he observed again, but found their positions shifted. Still further interested, he eagerly awaited the next evening.

The next night he saw the moons, and identified them definitely as moons, because they were still near Jupiter, though Jupiter had moved on its orbit. He found a fourth presently, and the roster of the four giant satellites of the

* From “The Sidereal Messenger,” by Galileo Galilei, 1610; translated by E. S. Carlos, 1880.



Hour after hour, day after day, fuel would have to roar into the driving rockets ceaselessly striving to break the grip of the planet.

giant planet—Io, Europa, Callisto and Ganymede—was complete. No other satellite was found during the course of two and three quarters centuries; not until 1892 did E. E. Barnard find a fifth, tiny moon very close to the planet.

Then, in December 1904 and January 1905, C. D. Perrine photographically detected two more very small moons. In 1908 photographs were a bit more sensitive perhaps, and the eighth known satellite was discovered; the ninth, but quite probably not the last, was discovered in 1914. However,

the following table gives some idea of why the two and three quarters centuries elapsed before further discoveries were made:

JUPITER'S SATELLITE SYSTEM				
Satellite	Distance From Jupiter's Center (miles)	Period Of Revolution (days, hrs., mins.)	Diameter (miles)	Date Of Discovery
V	112,600	0 11 57	100?	1892
Io	261,800	1 18 27	2320	1610
Europa	416,600	3 13 13	1960	1610
Ganymede	664,200	7 3 43	3200	1610
Callisto	1,168,700	16 16 32	3220	1610
VI	7,114,000	250 16 0	80?	1904
VII	7,292,000	260 1 0	25?	1905
VIII	14,600,000	738 21 0	16?	1908
IX	15,000,000	745 0 0	15?	1914

The numbering of the satellites is somewhat irregular, because they were originally numbered in their order out from the planet, those now named being I, II, III, and IV. But when Satellite V was discovered in 1892, and remained unnamed, it was numbered in the wrong order. Then the remaining four were numbered as discovered, and we can only be thankful the order isn't more confused than it is.

Incidentally, Satellites VIII and IX are a particular annoyance to astronomers, because, though they are very small and very unimportant, they do nasty things to theories of the origin of the system, how the planets were torn from the Sun.

All the planets revolve about the Sun in the same direction; they all turn on their axes in the same direction. The Moon, Diemos, Phobos, all the other satellites of Jupiter, nearly everything else in the system—except comets and meteors, and Heaven alone knows what one of those will do. But those two little, fifteen-mile hunks of rock go the wrong way. Two boys on roller skates going the wrong way in traffic. But when the astronomer devises his theory that accounts for tearing the inconceivable masses of Jupiter, Saturn and the other planets from the Sun, of the creating of worlds and the moving of them—the roller-skate brigade must be accounted for, too. They haven't done it yet, which is particularly annoying, considering their size, and general unimportance in the scheme of things.

But they are interesting in another way: they show vividly the titanic power of Jupiter. Fifteen thousand thousand miles from his center, those little worlds bow to his sway, turning in regular orbits, bound inexorably by his gravity. Fifteen millions of miles, nearly half the distance from the Sun to Mercury. Their periods of more than seven hundred days are twice the length of Earth's year; yet, despite the savage

pulls and cross pulls of Saturn, the Sun and all the other planets, those satellites stay put.

And in a different way, that one hundred-mile world, Satellite V, tells the same story of immense power. At just about half the distance of the Moon from Earth, it circles Jupiter; but it makes its trip, not in twenty-eight days, but in eleven hours. Io, a world as large as the Moon, is whipped around in an orbit larger than Luna's, but in the fierce grip of Jupiter, the Moon, as large as a minor planet, makes the circuit in a day and two thirds!

THEY ARE barren, airless, frozen rocks, these small satellites, but when men develop space ships, they will approach them with deep respect. No man is going to venture quickly and thoughtlessly near to Satellite V. There is the difference between a major planet and a minor. The surface gravity of Jupiter is only 2.5 times that of Earth, not a vast difference. But when a space ship once goes from our Earth to the Moon, it will be a simple task to reach Mars.

Luna is three fourths of the way to Mars, in one sense. The hardest part of the trip, fighting free of Earth's gravity, will have been accomplished. Actually, it would be, right to-day and with present knowledge, a not impossible task to go from Mars to Luna, but we can't make the trip from Earth to Luna!

In space, distance is not so important; you can coast forever. But what will drink the power of space ships is the force of gravity, reaching out dragging fingers between the worlds. The force falls off as the square of the distance increases, and with small worlds, that is a very swift decrease in force. Thus, when you have fought your way from Earth up through a quarter of a million miles to the Moon, the force of gravity has declined from the normal-surface

gravity of Earth to one thirty-six hundredths as much.

Thus: Earth's surface is four thousand miles from the center of the planet, and gravity there is one unit. The moon is sixty times as distant, therefore the

1

force will be $\frac{1}{60 \times 60}$, or 1 thirty-six

hundredth. Luna's surface gravity falls even more swiftly.

But Jupiter will be mighty hard to leave, even after its crushing pressure has been conquered. Before Jupiter's pull is reduced to one thirty-six hundredths of Earth's gravity, the ship will have to pull to a distance of four million

to roar into the driving rockets, ceaselessly striving to break the grip of the planet.

When space-ship pilots are the tough he-men of the solar system, the men that run the ships from Earth to Luna will be mere ferryboat pilots, to be scorned by those who cross the gulfs to Mars and on to Pluto. But not so the men who run the ships from Io and Europa and Callisto. That is no ferryboat run. It will require the finest, toughest, most powerful ships in space.

It will be a savage run, accounting first for the mighty drag of Jupiter, then allowing for the swiftly changing, shuttling pulls of the four giant moons,



one hundred thousand miles, out beyond Callisto, and more than halfway to Satellite VI. And every foot of all those four millions of miles, the ship will be battling the savage grip of the giant planet. Even there, of course, the ship will still have the rest of the field to shake off—even at that distance, a three thousand six hundred-ton ship will still have to use a steady drive of one ton to hold its own. Hour after hour, day after day, fuel would have

weaving and interweaving their by no means insignificant fields of force.

But is there anything on those moons of Jupiter worth going to all that immense labor to procure? Are they worlds, or are they some genus of cosmic cactus plant, bleak, barren rocks without value and particularly hard to approach?

IN THE FIRST PLACE, the smaller satellites can be discarded as

being of no direct value. They are inevitably bleak, utterly barren masses of dead rock. One possible application of practical use they may have however: Satellite VI, the eighty miles of rock that revolves seven million miles out from Jupiter, might some day be of immense value as one rung of a vast ladder reaching from the inner satellites of Jupiter out into space; it might serve as a refueling station for interplanetary ships. There they could break the long, long climb from Jupiter's grip.

But the four major satellites are the ones of real interest. Io and Europa are each nearly two thousand miles in diameter; Ganymede and Callisto each approximately three thousand. The latter two are slightly larger than Mercury, somewhat smaller than Mars. Is there anything we can deduce from these facts that may apply to four worlds, near planets in their own right, at a distance from us so great that no accurate observation is practicable at present?

First, from the Earth-Moon system we might guess that they all face Jupiter eternally. They revolve once on their axes, while making one sweep around the planet. This is confirmed by photometric work, in the case of three, and in the case of the fourth, spots can be seen on its surface to substantiate the photometric work. Then Io has a solar day of one and two third Earthly days; Europa's equals three and a half of ours; Ganymede's day is about equal to our week. But Callisto turns with respect to the Sun only about once a fortnight; a day something like Luna's. That is too slow for a world of that size

The long, long night at that vast distance from the Sun, brings cooling too severe for the day's heat to entirely overcome. The density of Callisto is only one and three tenths times that of water. Jeffrey has suggested that it is water—ice.

But there are other conclusions we can consider; from any theory we may choose to accept, we can feel sure that at some time in the early history of our solar system every body was heated to an enormous temperature, thousands and tens of thousands of degrees. Mars, slightly larger than Ganymede, cooled from that furious heat, losing most of its atmosphere as it cooled. But, being a small mass, it cooled swiftly, swiftly enough to retain some air still. Ganymede, a similar small body—could not cool! Those moons found themselves permanently parked in the near neighborhood of what was at that time a full-fledged sun. Jupiter was hot, and it stayed hot. It was three thousand times as massive as Mars, with three thousand times as much matter to cool off. But when both planets were gaseous, Jupiter was denser than Mars, for its greater gravitation compressed things thoroughly. That meant that far more mass, far more condensed, had much less cooling surface in proportion.

By the time Jupiter, at last, decided to cool down, the satellites had long since cooled to equilibrium with their surroundings, but the surroundings (Jupiter) hadn't helped any. They stayed hot much longer than a body that size had any right to. And their atmospheres must have floated away into space. Airless—bleak—

BUT—how about the vast quantities of flaming hydrogen and oxygen that Jupiter, still white-hot, was throwing out into space? It couldn't entirely escape its gravitational field—the field was too vast. But it may have made a fine flying start, and fallen part way back, back only as far as those much cooler satellite worlds.

Bleak, airless rocks, exposed only to the Sun and vacant space, are black, or brown. The Moon's airless rocks are grayish, pumicelike stuff. Such material has a low reflecting power. But

measurements show that Io is as reflective as Jupiter's surface, the shining, cloud-wrapped surface of a deep-atmosphere planet! Europa is even brighter, while Ganymede is four fifths as brilliant. Only Callisto is dim, about one third as reflective as Jupiter. Io, Europa and Ganymede all have fairly high densities, two and two tenths to three and five tenths times that of water, resembling that of Luna, or ordinary Terrestrial rock. Callisto, as has been mentioned, might be a vast sphere of ice, with its density one and three tenths, covered by a thin layer of dust and rocky dirt to make the reflective power low. But, at any rate, the three high-density planets—which would suggest rock—have high reflective powers suggesting atmospheric elements. The one dark moon has so low a density it *must* have the atmospheric elements hydrogen and oxygen.

Let us guess now; we haven't enough observational data to do much more. Ganymede is as large as Mercury, a bit larger. It is at a low temperature, so far from the Sun, and would be quite able to retain the slow-moving, chilled atoms of atmosphere. The atmosphere would probably consist of heavy gases such as carbon dioxide, oxygen, perhaps a trace of water vapor. It would be a cold, cold world, nearly one hundred degrees below centigrade zero. No fit habitation for life to develop in; it was not warm long enough to give stubborn life a chance to develop, evolve an adaptable form that could withstand the cold.

Jupiter no longer does any good; it is cold, terrifically cold on the water standard. Its vast disk reflects some slight amount of heat from the Sun, but

not enough to do much practical good. Ganymede is, perhaps, very like the antarctic in the middle of August—its coldest month. But while the antarctic thaws out each summer, Ganymede has no summer; the cold is eternal. Men might live there, find minerals worth braving that unending, horrible cold to reach. With insulated domes, heated by atomic power, perhaps, gaining breathable air by electrolyzing water frozen in great motionless glaciers (even glaciers would be frozen motionless there) they could survive.

Io and Europa must be much the same. It snows there frequently probably, thin-voiced blizzards that howl around mountains of ice, driving flakes of frozen carbon dioxide. It is too cold to permit water to melt, and volatilize; only carbon dioxide steams into the atmosphere to fall in blizzards.

There might be something worth seeking—weird, accidental deposits of rare elements not found on Earth. There is no predicting the vagaries of nature. One of the rarest of the rare Earth elements is ytterbium, a queer element, useless to-day. It is an element present only in vast dilution in Earth's crust. Yet, by some queer trickery of nature, there is a mineral in which this element is found as an almost pure compound, ytterbium phosphate.

Some such vagary might have occurred, making Callisto or Ganymede, Europa or Io important in the trade of worlds to come. But—people seldom study carefully the cacti of the world. They repel attention. It would probably go unnoticed; the great moons would be left to their bleak, cold blizzards of carbon dioxide, in the mighty grip of Jupiter.

Next Month:

BEYOND THE LIFE LINE

Article No. 11 in the Study of the Solar System

by John W. Campbell, Jr.