

ABSTRACT:

The interplanetary medium is capable of confining the electric fields of charged celestial bodies within space-charge sheaths of limited dimensions. This phenomenon explains the success of gravitational theory in describing and predicting orbital motions in the present, relatively stable Solar System. Disruption of space-charge sheaths during close encounters between electrified planetary bodies may account for the catastrophic electromagnetic effects observed and reported by the survivors of near-collisions in ancient times. The known characteristics of the interplanetary medium suggest not only that the sun and the planets are electrically charged, but that the sun itself is the focus of a cosmic electric discharge--the probable source of all its radiant energy.

Reconciling Celestial Mechanics and Velikovskian Catastrophism

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I

Physical scientists were outraged in 1950 when Immanuel Velikovsky (1) published historical evidence from around the world suggesting that the order and even the number of planets in the solar system had changed within the memory of man. Ideas in nearly every field of scholarship were challenged, but most seriously challenged of all were certain dogmas in the field of astronomy which had only in recent centuries succeeded in convincing mankind that Spaceship Earth was a haven of safety.

The emotional outburst from the community of astronomers that so blackened the name Velikovsky and so successfully if only temporarily--discredited *Worlds in Collision* has been laid to many causes, from the psychological and the political to simple resentment against invasion of the field by an outsider. Whatever the nature of such intensifying factors, however, I believe it is only fair to acknowledge an underlying and totally sincere scientific disbelief in the historical record.

Perfectly valid dynamical theories valid in the sense of having met and passed every conceivable kind of test--simply could not be reconciled with the story told by Velikovsky. In short, conventional celestial mechanics, which had proved time and again its ability to describe and predict planetary motions in today's solar system, could in no way accommodate a disordering and rearrangement of the planets as recently as 3,000 or 4,000 years ago.

In terms of celestial mechanics, a system of bodies whose motions are governed entirely by gravitational forces and the inertia of masses could not conceivably restabilize itself within mere millennia--let alone within the few decades or centuries allowed by the historical record--following disruptions of the kind described in *Worlds in Collision*.

Even were each near-collision in such a series so providentially contrived as to leave one or the other participant moving along a near-circular orbit close to the ecliptic plane, the final encounter must necessarily leave at least one participant traveling on a highly eccentric orbit--one that must return the body again and again to at least one point of possible collision with its late antagonist. Yet today's solar system--with one possible exception involving Neptune and Pluto--seems ordered in such a way that further planetary collisions are out of the question.

Velikovsky was quite aware of the discord between his findings and current ideas as to what constitutes propriety in celestial mechanics. He insisted, however, that the fault must lie in dynamical theory, not in the evidence of history. He suggested that the sun and the planets must be electrically charged, and that electromagnetic and electrostatic forces--which could quite easily be capable of cushioning collisions, altering rotational motions, tilting axes, and perhaps even damping orbital eccentricities over relatively short spans of time--must play unrecognized roles in celestial affairs.

As we shall note presently, there is compelling evidence to indicate that the sun, the earth, and the moon, to name only a few major bodies in the solar system, are electrically charged. Yet the very precision with which gravitational theory accounts for the planetary motions seems to belie this evidence. Perturbations due to repulsive electrical forces, for example, are nowhere in evidence today --not even, I hasten to suggest, in the strange behavior of comet tails, about which I shall have more to say later.

This impasse between celestial mechanics and the notion of cosmic electrical interactions was recognized long ago. A reconciliation seemed so unlikely that physical scientists of half a dozen successive generations felt compelled to devise all sorts of exotic theories to explain away the most obvious evidence for electric charge on the earth.

An important clue to the vanity of all such *ad hoc* theorizing was radioed back to earth in 1962 by Mariner 2.

Man's first successful Venus probe established once and for all that the interplanetary medium is not a near-vacuum, as most astronomers had always supposed, but is actually a plasma--a gas of dissociated positive ions and electrons. This disclosure instantly invalidated the argument that the planets, if electrically charged, would perturb one another in most obvious ways.

According to the physics of electricity, a charged body isolated in a vacuum, which is a dielectric medium, surrounds itself with an electric field that reaches to infinity, with strength diminishing as the square of the distance. Thus, in a vacuous interplanetary medium, or even in a medium of neutral atomic or molecular gases, planetary charges must give rise to electric fields detectable by their influences upon planetary motions.

In an interplanetary medium consisting of ionized gas, however, things are radically different.

One of the primary characteristics of a plasma has up to now received little or no attention from astronomers. This is its ability to shield itself from the electric field of any body in contact with it, or contained within it, and charged to an electric potential different from that of the plasma itself. The mechanism by which such shielding is accomplished was named the space-charge sheath by those who first studied the phenomenon.

In a space-charge sheath, positive and negative charges collect and arrange themselves in such a way that the electric field of a body with alien potential is contained within a limited region surrounding the body. This does not mean that the total electric charge of the isolated body must be compensated by equal and opposite charge in the sheath; rather, it means only that enough charge must be assembled in the sheath to increase or decrease the potential of the outer sheath boundary to match the potential of the surrounding plasma.

As a laboratory phenomenon, the space-charge sheath was described, studied, and given a measure of quantitative theoretical explanation half a century ago. The most lucid

accounts of this work are probably those to be found in the papers of Irving Langmuir (2), the physicist who coined the term "plasma" in reference to fully ionized gases.

Up to this point I have neglected to mention two most important facts about space-charge sheaths and plasmas:

1. An isolated body whose alien potential is not continually renewed by means of electric currents will quickly acquire the potential of the surrounding plasma, and its sheath will disappear; and

2. A plasma does not necessarily possess an intrinsic electric potential. Where plasmas form in electrical discharges, however--and this is the connection in which Langmuir studied them--they do acquire non-zero potentials.

These are clearly matters of immense importance. I will return to them later.

For now, we can say that in a solar system pervaded by plasma, each charged planet with a potential unlike that of the local plasma must have its electric field bound up in a space-charge sheath of limited volume. When no orbital conflict exists, the system operates serenely under the direction of forces accounted for in conventional celestial mechanics.

But let us imagine what might occur should two electrically charged major bodies in this system find themselves on intersecting orbits. Inevitably, as the two bodies pursued their separate paths on separate time tables, the stage would be set eventually for a rendezvous at one or another point of orbital contact. Since the spacecharge sheaths of the bodies would occupy greater volumes than the bodies themselves, a collision between sheaths would actually be more likely to take place than a direct, bodily collision, and in any case it would occur first.

When the moment arrived for the inevitable encounter, sheaths would make contact. Unleashed electric fields would clash. Almost instantly, forces immeasurably greater than gravitation would be brought to bear on the charged bodies. Cosmic thunderbolts would flash between the bodies in an effort to equalize their electric potentials.

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The list of unthinkable disastrous effects that would result could go on and on. The point to be made, however, is that *Worlds in Collision*--at least in my opinion--documents historical evidence to indicate that phenomena associated with spacecharge-sheath destruction were actually suffered and survived by peoples of antiquity.

II

Let us now consider the problem posed by the seeming fact that the sun and the planets, all immersed in the interplanetary plasma, ought to acquire the electric potential--zero, one would guess --of that plasma.

Some might claim that the problem itself is spurious, and that dispensing with it is as

simple as chucking *Worlds in Collision* into the trash heap. I contend, nevertheless, that the problem is real, and that observational evidence from many parts of the solar system can be marshalled to resolve it.

This problem is real because we have ample evidence that the sun, the earth, and the moon are electrically charged bodies. Only one of the three--the moon--seems to have an electric potential equal to that of its environment, but from this we can only conclude that the environment itself has a potential as high as that of the moon.

A quick review of just a few points of evidence will serve here to establish the reality of our problem.

The sun is known to have a magnetic field of great complexity. Observations of coronal streamers at the poles of the sun during total eclipse suggest that at least a portion of this field has a dipole configuration, similar to that of the earth's field. Other observations suggest that in the sun's lower atmosphere the field is in a state of continual torment. The existence of the field, however, and even the existence of the complexities of that field in the lower atmosphere, can only be laid to electric currents. No matter how much theorists might like to minimize or even deny it, the fact remains that only electric currents give rise to magnetic fields.

It is misleading to state simply that "moving charges" generate magnetic fields. Any body of ionized gas, for example, might be described as a collection of moving charges, since its charged particles are indeed in motion. For that matter, each charged particle moving about in such a gas can be said to constitute an elementary electric current. But so long as there is no net differential motion between positive and negative charges, the net electric current will be zero, and the body of gas will generate no magnetic field regardless of how violently it may be agitated. (However, if charges of one sign predominate over charges of the opposite sign, so that the body of gas indeed has a net electric charge, the effect of bulk gas motion will be quite different.)

The fact that magnetic fields and effects attend motions in the sun's ionized gases--prime examples being the strong fields evident in connection with rotary motions in sunspots--is explainable most simply and satisfactorily by the conclusion that the solar gases are electrically charged--they contain an excess of particles of one kind--either positive or negative, but almost surely negative.

The dipole component of the solar magnetic field can only be attributed to the rotation of the charged sun as a whole, as Dr. Velikovsky pointed out more than two decades ago (3).

The earth's magnetic field was tentatively ascribed to electric charge on the earth nearly 100 years ago. In 1878, H. A. Rowland attempted to calculate the electric potential the earth would have to sustain to produce its observed magnetic field. His result--more than 4×10^{16} volts, negative--seemed to him so ridiculous that he rejected it immediately. An electric charge of the necessary magnitude to give the earth such a potential, wrote Rowland, "would undoubtedly tear the earth to pieces and distribute its fragments to the uttermost parts of the universe (4)."

Such arguments have convinced geophysicists ever since Rowland's time that an electric charge on the earth cannot be held responsible for terrestrial magnetism.

Most recently, it has been fashionable to rest content with the so-called dynamo theory as an explanation for the earth's magnetic field. It is supposed that the field is

generated by motions in the molten core of the earth. No one, however, has yet been able to show how electric currents might be produced by such motions.

Professor James Warwick, of the University of Colorado, recently pointed out that the "dynamo theory has not yet successfully predicted any cosmical [magnetic] fields. Its use today rests on the *assumption* that no alternative theory corresponds more closely to observations (5)." [Warwick's italics]

Even stronger objection to the dynamo theory is implied in this remark by Palmer Dyal and Curtis W. Parkin of NASA's Ames Research Center: "No rigorous theory has evolved that satisfactorily explains the earth's permanent magnetic field (6)."

"Satisfactorily," of course, means without acknowledging the electric charge of the earth.

Before proceeding, let us consider Rowland's notion that an enormous electric charge must blow the earth to smithereens. This is the same idea advanced by Donald Menzel in 1952 to add zest to his "quantitative refutation of Velikovsky's wild hypothesis" that the sun is electrically charged (7).

In the first place, as Professor Fernando Sanford pointed out 40 years ago, "[Such] conclusions are all based upon the assumption that electric charges are held to conductors by [gravity] ... If this assumption were correct, it would be impossible to give a negative charge to any small conductor while in the gravitation field of the earth (8)."

Sanford also pointed out that "a soap bubble and a platinum sphere of the same diameter, if joined by a connecting wire and charged from the same source, will take equal charges. This shows conclusively that whatever the force may be which holds electrons to a charged conductor it is not a force which acts between the electrons and the atoms of the conductor. This being the case, the outward pressure of the charge upon a conductor will have no tendency to pull the conductor apart."

The earth's atmospheric electric field has been the subject of controversy ever since it was discovered, about 200 years ago. At issue is the question of where resides the electric charge responsible for it--negative charge on the earth itself, or positive charge high in the atmosphere?

In 1803 Professor Erman, of Berlin, demonstrated the negative charge of the earth by a simple experiment. He found that a gold-leaf electroscope fitted with a short, pointed collecting rod showed positive electrification when he first grounded it and then raised it a few feet in the air. When he discharged it to the ground while holding it in the upper position and then lowered it, it showed negative electrification. After he placed a ball over the collecting rod--even after he placed the entire apparatus inside a sealed glass tube--and found the same results, he concluded, correctly, that the effects observed were due to electrical induction from a negatively charged earth (9).

Erman's findings were derided, then promptly forgotten, even though only one year later two balloonists were mystified, when their collector and electroscope gathered only negative charge from high-level air, instead of the positive charge they expected (10).

In 1836 Peltier, on the basis of experiments similar to but rather more elegant than Erman's, came to the same conclusion: the earth is negatively charged, and this charge gives rise to the atmospheric electric field (11).

Through all the years since, no one has come up with a more plausible theory of atmospheric electricity than that of Erman and Peltier. Time after time, scientists have tried

by one means or another to detect an excess of positive charge high in the atmosphere, but always in vain. (In *Scientific American* for March 1972, Professor A. D. Moore, writing on the subject of "Electrostatics," states: "The atmosphere Of the earth is somehow supplied with a positive charge that sets up a downward electric field amounting to between 100 and 500 volts per meter on a clear day." One might question the efficacy of "somehow" as an explanation; but perhaps it suffices for a phenomenon whose existence no one has been able to demonstrate.)

In the closing years of the nineteenth century the electrical genius Nikola Tesla built and operated an electrical observatory in the Colorado mountains. Very early in his researches he proved that the earth harbors enormous numbers of free electrons. One of his obsessions at the time was to transmit electric waves through the ground. He reasoned that if the earth were not negatively charged, it would act as a vast sink into which enormous amounts of electricity would have to be injected to bring it to a state where it would vibrate electrically. He discovered that the necessary electrification was already present in great abundance (12).

Tesla's finding was recently--and quite inadvertently--repeated for the moon. In *Nature* for November 12, 1971, Winfield Salisbury and Darrell Fernald, of the Smithsonian Astrophysical Observatory, reported that they had received signals from the command module of the Apollo 15 flight at a time when it was behind the moon. The signals had been carried around the curvature of the supposedly radio-opaque moon by electric waves in the moon's surface layers (13).

If then the sun, the moon, and the earth are electrified bodies, how may we square this fact with the ubiquitous presence of plasma in the solar system?

One is nagged by the suspicion that F. A. Lindemann was not entirely mistaken concerning free (excess) charges on the sun when he wrote as follows in 1919: "It is easy to show that appreciable electrostatic forces cannot exist on the sun. The outer layers ... must certainly be highly ionized ... so that any charges on the sun as a whole would rapidly be neutralized by the emission of ions (14)." In other words, the mutual electrical repulsions among excess like charges must drive them outward and away from the sun.

Lindemann went on to assume that the electric forces must be balanced by gravitational forces --the concept later shown to be invalid by Sanford. But if we neglect gravity, the argument seems to lead to the conclusion that the sun's potential can only be zero, instead of the few thousand volts calculated by Lindemann.

Furthermore, Lindemann's case seems to gain from our present knowledge of the inter-planetary medium. Surely a conducting plasma pervading space can only facilitate the dissipation of excess charge by the sun.

But Lindemann's argument is sound only if two unstated assumptions are valid:

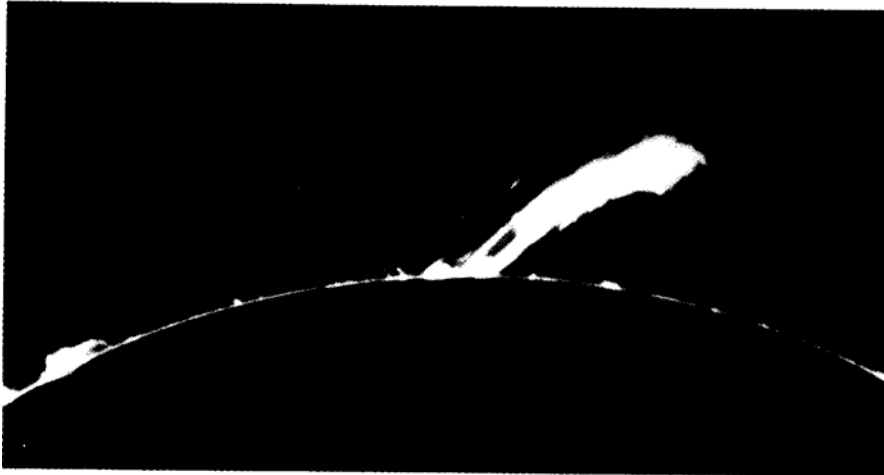
1. The interplanetary medium is devoid of electrical strain the plasma harbors no electric potential of its own - and can therefore serve as a sink for excess solar charges; and

2. The sun's electric charge is not continually renewed via electric currents.

I propose to challenge both these assumptions. However, as the reader may already surmise, this can be done only at the cost of challenging astrophysical dogmas more precious than that which denies the sun and the planets electrostatic charge.

I offer what follows merely as a very brief summary of my own notions as to how and

why the solar system is electrified in spite of all arguments that it can't be.



"It seems astonishing that in the course of half a century of studies of the sun in context with the thermonuclear theory, very few professional astrophysicists have ever expressed the slightest discomfort over discrepancies between observation and theory, or even over the fact that an *ad hoc* extra

theory has had to be devised to explain practically every individual feature of the solar atmosphere. "

III

I can find no way to state this diplomatically, so let me be blunt: *The modern astrophysical concept that ascribes the sun's energy to thermonuclear reactions deep in the solar interior is contradicted by nearly every observable aspect of the sun.*

It seems astonishing that in the course of half a century of studies of the sun in context with thermonuclear theory, very few professional astrophysicists have ever expressed the slightest discomfort over discrepancies between observation and theory, or even over the fact that an *ad hoc* extra theory has had to be devised to explain practically every individual feature of the solar atmosphere.

Apparently with a steady hand, Fred Hoyle wrote some years ago: "We should expect on the basis of a straightforward calculation that the Sun would 'end' itself in a simple and rather prosaic way; that with increasing height above the photosphere the density of the solar material would decrease quite rapidly, until it became pretty well negligible only two or three kilometres up ... Instead, the atmosphere is a huge bloated envelope (15)." And today we know that this "bloated envelope" extends out among the planets.

Even the photosphere, where theory would suggest the sun ought to "end," fails miserably to conform with expectations. Its opacity almost conspires to prevent the sun from radiating away its internal energy, if that is indeed where the energy comes from. The granular structure of the photosphere is still attributed to "non-stationary convection," even though Minnaert pointed out decades ago that the Reynolds number of the photospheric gas exceeds the critical value by eight powers of ten--which is to say, by a factor of 100 million--and therefore convection currents in the photosphere should be completely turbulent (16).

(The convection currents themselves are postulated to explain how all that internal radiant energy is brought to the surface in spite of photospheric opacity.)

In the solar atmosphere at intermediate altitudes, astronomers observe an amazing variety of phenomena, none of which can be shown to have any business there if the sun's prime purpose is to shed energy liberated deep in its interior, as the thermonuclear theory would have it.

Essential to the received theory is the conviction that inside the sun is a steep temperature gradient, falling toward the photosphere, along which the internal energy flows outward. If we stack this internal temperature gradient against the observed temperature gradient in the solar atmosphere, which falls steeply *inward*, toward the photosphere, we find we have diagrammed a physical absurdity: The two gradients produce a trough at the photosphere, which implies that thermal energy should collect and become stuck there until it raises the temperature and eliminates the trough. That this does not occur seems to bother no one.

But suppose we remove the hypothetical internal temperature gradient. What then? Why then we see that the sun's bloated atmosphere and the "wrong-way" temperature gradient in that atmosphere point strongly to an external source of solar energy.

Professor Melvin Cook dared to call attention to this matter in the 1950's (17). However, since he was not a professional astrophysicist, his comment was as unnoted as it was unsolicited.

The phenomena of the photosphere, the phenomena of the chromosphere, the phenomena of the corona, and the known characteristics of the interplanetary medium all fit so nicely into a unifying hypothesis based on energy supplied to the sun from the outside that I cannot resist mentioning it here: I believe that the sun behaves as an anode collecting electric current from its environment, and that the energy it radiates is delivered entirely by way of this postulated electrical discharge.

C.E.R. Bruce identified an impressive number of solar atmospheric phenomena as electrical-discharge effects as long ago as 1944 (18), and since then he has compiled an impressive record of prediction in the field of astrophysics with a comprehensive theory of cosmic electrical discharges (19). Apparently, however--and puzzlingly, too, in view of some of his conclusions concerning the nature of our galaxy--he does not question the idea that the sun and the stars are thermonuclear engines that live and die totally oblivious of their surroundings.

For reasons I can only touch upon here, I would urge Bruce to modify his grand scheme to embrace the idea that stellar energy is electrical in origin. This, to my way of thinking, would finally justify his vision that "it is the breakdown of electric fields ... which has shaped and lit the universe from the beginning (20)."

The kind of electric discharge I conceive to be responsible for solar radiation must necessarily be driven by an electric potential in interstellar space--a condition to be expected in a galaxy electrified by the separation of charges on a truly magnificent scale. Just such a situation is postulated by Bruce, who explains the spiral arms of our galaxy as electrical discharges initiated by the breakdown of a radial electric field extending through the entirety of galactic space. And just such a situation could provide the enormously high space potential (negative) that the discharge hypothesis requires.

As I see it, then, the sun, already negatively charged to an extremely high electric

potential, behaves as an anode and collects more negative charge because its interstellar environment has a potential that is even higher, in the negative sense. It is a matter of relative potentials.

By analogy with electrical discharges studied in the laboratory, we can predict certain conditions that should prevail in interplanetary space if the sun is indeed fueled electrically. For now, I would mention only this: The interplanetary medium near the earth seems to be characterized by approximately equal numbers of protons and electrons, which fact identifies it as a true plasma. Farther out--say, near the orbit of Jupiter--the protons should be traveling away from the sun with considerably increased velocities, and the electrons should be present in lesser numbers than the protons.

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Hopefully, the Grand Tour space probe of the outer planets, which is projected by NASA for the late 1970's, will be instrumented to sample the interplanetary medium, and thus will be able to furnish evidence in support or in refutation of the discharge hypothesis. The presence of thermal electrons from the solar corona as far out as Jupiter would put the idea on very shaky ground, it seems to me. But if protons alone are still being accelerated away from the sun at that distance, no other conclusion could be drawn but that an electric current flows through interplanetary space.

Even in the earth's neighborhood, by the way, solar-wind theorists have been experiencing great difficulty in reconciling observations of particle densities and temperatures with Eugene Parker's hypothesis (21) that the solar wind represents material unavoidably boiled off by the sun's hot corona (whose millions-of-degrees temperature, so predictable on the basis of a discharge hypothesis, is unexplained in terms of the conventional theory of stellar energy). Positive ions in the solar wind cross the orbit of the earth with velocities and in numbers close to those predicted by Parker. Solar-wind electrons, on the other hand, seem unacquainted with the rules of the game. In numbers they match the protons pretty well, but they travel rather too slowly and tend to become sidetracked along magnetic field lines (22).

Interestingly enough, a solar-wind model that claims better than average success in squaring predictions with observations is that of two Belgian scientists, J. Lemaire and M. Scherer (23). An unusual feature of this model is that it calls for an electric field high in the solar corona to slow electrons and accelerate protons to observed speeds.

Even more interesting is a recent summary of solar-wind-speed observations covering a nine-year period. Published in 1971 by J. T. Gosling *et al* (24), this study shows that "the yearly distributions of solar wind bulk speeds during the years 1962-1970 ... are found to be remarkably constant from year to year. There is no tendency for the solar wind

speed to increase with increasing solar activity."

This suggests to me that the solar wind is more nearly related to the sun's energy supply, which is also remarkably constant, than to the sunspot cycle. If solar energy actually derived from processes going on inside the sun, one could expect disturbances of the types characteristic of the most active phase of the sunspot cycle to affect the outward flow of the energy; if, however, solar energy did arrive from outside the sun, events upon the solar surface would be much less likely to affect the dissipation of that energy back into space in the form of visible and invisible radiation.

The interplanetary medium, considered as a current-carrying channel in an electrical discharge, offers an explanation of the fact that Jupiter radiates several times as much energy as it receives from the sun (25). If Jupiter and its space-charge sheath (magnetosphere) are intercepting energetic primary electrons headed for the sun, the source of the giant planet's excess energy is no longer a mystery.

In cosmic rays we have a mystery that has never been solved: where and how are these subatomic particles accelerated to the tremendous kinetic energies they exhibit when they reach the earth? But in the fact that they do reach the earth we find one more important bit of evidence that the earth is negatively charged. And the electric-discharge hypothesis suggests a possible answer to the mystery of cosmic-ray energies.

Edward O. Hulburt, writing in *The Scientific Monthly* (Feb., 1954), noted that the primary cosmic rays deliver a very considerable amount of positive electric charge to the earth. By his calculation, an aggregate positive charge of 7×10^6 coulombs, sufficient to prevent the arrival on earth of any more cosmic-ray protons with energies of 10^{10} electronvolts or less, would accumulate in only 16 ½ years. Annually, then, the positive charge collected by the earth from this source amounts to more than 4×10^5 coulombs.

Hulburt brought out these facts before electrons--negative charges--were discovered in the flux of cosmic rays. Electrons are now detected with more sensitive and more sophisticated devices than were available in the early 1950's, but they have proved to be only about one percent as numerous as protons in the total cosmic-ray population. So, for all practical purposes, Hulburt's calculation is still valid.

Cosmic rays, in spite of the fact that they deliver 4×10^5 coulombs of positive charge to the earth each year, continue to arrive in undiminished numbers year after year.

Presumably they have "always" done so. If we assume, then, that "always" is a matter of billions of years, we can only conclude either that the earth started out with a negative charge in excess of, say, 10^{16} coulombs, so that in all those years the cosmic-ray protons haven't yet been able to cancel that negative charge, or the earth picks up at least an equal amount of negative charge each year by some other means. In any case, the earth can be neither electrically neutral nor positively charged; only a negatively charged earth fits the evidence provided by the cosmic rays.

At first glance, the solar-discharge idea might seem confounded by the fact that cosmic-ray protons reach the inner parts of the solar system. After all, the hypothesis requires that protons from the sun be accelerated out of the system, and indeed that these protons carry practically all of the discharge current as far as the local disturbance extends into interstellar space. Should not the cosmic rays--the 99 percent of them that are positively charged particles--be turned around and driven out of the system in the same way?

But suppose that the sun's driving potential--the drop in potential between the sun and the boundary of its discharge is of the order of 10 billion volts. Then solar protons reaching the boundary would be launched into interstellar space with energies of 10 billion electron-volts. They would be cosmic rays in their own right.

Astrophysicists tell us that the sun is a rather mediocre star, as far as radiating energy goes. If it is electrically powered, it would seem reasonable to conclude, at least tentatively, that its mediocrity is attributable in some measure to a relatively unimpressive driving potential. This would mean that hotter, more luminous stars should have driving potentials greater than that of the sun and should consequently expel cosmic rays of greater energies than solar cosmic rays.

A star with a driving potential--cathode drop is a more appropriate term--of only 20 billion volts would expel protons energetic enough to reach the sun, arriving with 10 billion electron-volts of energy to spare. Such would be merely average cosmic rays, as we know them here on earth. Actually, particles with energies up to 100 billion billion electrons volts reach the earth from galactic space; to such cosmic rays, the adverse electric field in the sun's postulated 10-billion-volt cathode drop would be less than negligible.

What all this suggests to me is that cosmic-ray protons and other atomic nuclei reaching the earth are nothing more nor less than the spent current carriers of stars other than the sun. In this connection, it is interesting to note that the calculated energy density of cosmic rays in our galaxy is comparable to the total energy density of electromagnetic radiation, including starlight. This is what one would expect to be the case if electric stars were responsible.

IV

All this has seemingly led us far astray from the subject matter of *Worlds in Collision*. Never-theless, I am convinced that an excursion like this into astrophysical problems in regions of space as far removed as distant stars and the outer reaches of the galaxy is necessary to make some kind of sense out of problems inside the solar system. If the galaxy is electrified, as Bruce supposes, that fact cannot help but have major implications for the solar system. If the galaxy is not electrified, it would seem to me that prospects will ever remain poor for reconciling evidence of electrification within the solar system and celestial motions that seem to deny that evidence.

Back toward the beginning of this paper I promised to return to the subjects of space-charge sheaths and comet tails. Actually, in terms of the postulated electrical discharge centered on the sun, these would appear to be not two subjects, but merely two aspects of a single subject.

A comet on an extremely eccentric orbit spends by far the greater part of its time in the uttermost parts of the solar system. This is because, according to Kepler's Laws, orbital speeds near aphelion are so much less than near perihelion. Supposing, then, that space potentials in such regions are vastly greater, in the negative sense, than they are close to the sun, as the discharge hypothesis requires, any long-period comet could be expected to acquire local space potential quite readily during its long sojourn far from the sun. Quite possibly, too, its body materials would become electrically polarized in response

to the buildup of charge on its surface.

Consider next what would happen to this charged, electrically polarized body as its orbit brings it with ever increasing speed back toward the sun. By the time it reaches the orbit of Jupiter, solar-wind protons will have stripped away its superficial blanket of negative charge. No longer does its surface potential match that of its surroundings, yet its internal (radial) polarization produces an external electric field, just as polarization in an electret made of wax exhibits an external field here on earth. A space-charge sheath will begin to form to shield the interplanetary plasma from the comet's alien field.

As the comet races toward the sun, its sheath takes the form of a long tail stretching away from the sun. This happens, not because the electrified sun repels the tail material, but because voltage differences between the comet and the interplanetary plasma vary sharply with direction, and because sheath thicknesses are dictated not only by voltage differences, but by gas pressure as well. The potential difference between the head of the comet and the plasma in the direction of the sun might be substantial. But in any case, the potential difference between the comet and plasma farther out from the sun will be greater still. Also, the plasma density is greater nearer the sun than farther from the sun. Hence the sheath remains close to the comet on the sunward side, and it reaches perhaps millions of miles into space on the antisolar side.

This rather sketchy qualitative explanation for comet tails is not advanced here as any sort of final answer to the comet-tail mystery. I include it only as an example of the kind of explanation that can at least be discussed in the light of the discharge hypothesis. Hopefully, too, it offers a measure of solace to those who might feel cheated by the fact that the interplanetary plasma knocks down the idea that comet-tail gases might be repelled by the sun's electric charge.

By the same sort of analysis, I would conclude that the earth has a potential not quite in keeping with its space environment, and that it therefore is surrounded by a space charge sheath. For the same reasons that a comet's sheath is elongated away from the sun, I would suppose that the earth's sheath has a tail; in other words, I would equate the terrestrial sheath with the earth's so-called magnetosphere.

It seems to be pretty well established that the earth's "magnetotail" does not reach as far as Mars, and thus the two planets no longer perturb one another electrically. (The moon, however, sweeping in and out of the earth's sheath every month, does appear to be perturbed by non-gravitational forces--a point emphasized by Dr. Velikovsky on many occasions.) But it seems conceivable that the long reach of the earth's space-charge sheath may have played an important role in settling Mars on an orbit at a safe distance from the earth.

A century ago, James Clerk Maxwell, in his monumental *Treatise on Electricity and Magnetism*, wrote these prophetic words: "The phenomena of electrical discharge are exceedingly important, and when they are better understood they will probably throw great light on the nature of electricity as well as on the nature of gases and of the medium pervading space."

For the next 50 years, studies of the electrical discharge were pursued with considerable vigor, and the world was led into the age of electronics. After that, however, as Professor Hannes Alfvén reminded us when he accepted the 1970 Nobel Prize in Physics

(26), "most theoretical physicists looked down on this field, which was complicated and awkward ... not at all suited for mathematically elegant theories." The theorists, says Alfvén, preferred to approach plasma physics by way of the kinetic theory of gases, which led to "mathematically elegant" theories.

In Alfvén's estimation, "the cosmical plasma physics of today . . . is to some extent the playground of theoreticians who have never seen a plasma in a laboratory. Many of them still believe in formulas which we know from laboratory experiments to be wrong . . . several of the basic concepts on which theories of cosmical plasmas are founded are not applicable to the condition prevailing in the cosmos. They are 'generally accepted' by most theoreticians, they are developed with the most sophisticated mathematical methods; and it is only the plasma itself which does not 'understand' how beautiful the theories are and absolutely refuses to obey them. . ."

The implication of Alfvén's remarks is clear enough: astrophysicists must bone up on the neglected field of electrical discharge phenomena. I, for one, believe that when they do so the new lines of inquiry will rather quickly lead to the rejection of the idea that stars are thermonuclearly powered.

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