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GEOPHYSICAL PARAMETERS AND UFO SIGHTING FREQUENCIES

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ABSTRACT Reports of UFO sightings have been assembled into a detailed database spanning many decades of this century (*U* UFO data base) These data which represent a time series of observations within the earth s environment, have been subjected to a comparative study with geophysical parameters The parameters encompass the high-energy components of the radiation reaching the earth such as galactic cosmic rays (GCRs) capable of producing radiation damage within any matter when subjected to the extremely high energies carried by this type of particle This preliminary study is based on the assumption that UFOs spend substantial periods of time at altitudes where the radiation shielding of the atmosphere is diminished However, when solar-modulated GCRs have access to the heliosphere and near-earth environment UFOs may choose to operate deeper within the atmosphere and sighting frequencies are increased Comparing these two time series results in a modest but significant correlation coefficient, suggesting that further statistical investigations are warranted

One of the most striking characteristics of UFO reports is the large variation in their number over time The level of sighting reports has varied greatly from year to year, for example, there have been many reports in some years, such as 1947, 1952, and 1973 in the United States, 1954 in France, or 1978 in Italy, and in other years there have been relatively few reports, as was true during much of the 1980s worldwide These wide swings in the number of reports per unit of time were recognized early in the modern era of UFO investigations, and many hypotheses have been advanced as explanations (Bullard, 1988) Societal stress, extraterrestrial interest in the space program and atomic weaponry, and media-stimulated interest in UFOs, among others, have been suggested as possible causes for this variation No explanation has received much empirical support, and few have had in-depth investigation This is unfortunate, since it is most likely that this variation is a clue to the ultimate sources of UFO reports

Data on the physical nature of UFOs are largely either unknown or unavailable and probably represent a continuum of properties that vary with individual cases Nevertheless, there seems to be a solid component to the phenomenon of UFO observations, which is clearly apparent from extensive ground or landing-trace studies

(Philips, 1973, Zeller, 1976). Therefore, it is appropriate to examine the record of sightings to determine whether it may contain statistical evidence of direct physical effects. Since matter is susceptible to radiation effects, and assuming that a significant number of UFOs are solid objects composed of normal matter, high-energy radiation is clearly one of the forces that they may encounter in the near-earth environment. The damaging effects of energetic particles on spacecraft, for example, have been recognized since the early 1970s. Cosmic rays (high-energy protons or heavier nuclei) originating in the sun or in unknown sources outside the galaxy can cause electronic circuits to fail by producing radiation damage in solid state components (Ziegler & Landford, 1979).

We may hypothesize that UFOs undergo a similar type of radiation damage and that they most frequently seek shielding within the earth's atmosphere from the high-energy galactic cosmic rays and also from the more infrequent solar cosmic rays, thereby becoming subject to observation.

Given these ideas, and the large variation in UFO reports over time, it becomes reasonable to ask whether various physical parameters correlate with the level of UFO reports. This question is of interest no matter what the ultimate cause of UFO reports. UFO research today is in a preparadigmatic state (see Kuhn, 1970), and one characteristic of such a science is that relationships among important variables are yet to be established—and often what variables are critical is yet to be determined. Therefore, the discovery of interesting relationships between UFO reports and physical parameters remains a meaningful activity for investigators. One such parameter is the radiation environment of the earth.

For this reason, the specific objective of this preliminary study has been to examine the UFO sighting record through time and determine the extent to which it may correlate with trends in geophysical parameters related to solar activity, as represented by sunspots, and galactic cosmic ray flux as measured by neutron monitors. These type of data are, by their nature, totally reliable and objective, whereas inherently any data series of UFO reports is incomplete. Such reports are based on chance observations, and not all observations are being reported. Furthermore, a number of phenomena might contribute to the generation of UFO reports, including misidentifications of planets. Nevertheless, the number of reports are so numerous and global in nature that a statistical evaluation becomes possible. However, any discussion and interpretation of the influence of radiation on UFOs must remain speculative.

The Radiation Environment of the Earth

The space environment around the earth is filled with plasma or ionized particles with energies that range from a few electron-volts to above many billion electron-volts. We know that high-energy particles can come to the earth from two major sources. One of these is external to the solar system and is the source of highly energetic cosmic rays, mainly protons, that frequently carry energies greater than one billion electron-volts and are called galactic cosmic rays (GCRs). They have been accelerated by unknown processes in other parts of our galaxy, perhaps by supernovae (Joselyn & Whipple, 1990).

The other primary source of high-energy particle radiation is our sun itself. During sporadic solar surface eruptions, large numbers of charged particles may be ejected and some of them accelerate to energy levels as high as one billion electron-volts. These particles, frequently called solar cosmic rays (SCRs), travel outward and may be deflected by the earth's magnetic field or they may be intercepted by impacting the upper atmosphere of the earth. Although on average, SCRs are less energetic than those of galactic origin, they may be many times more abundant during peak flux periods. Specifically, at times when intense brightening of local areas on the solar surface produce so-called solar flares, charged particles from this source may escape from the solar surface and exceed the flux of galactic cosmic rays by many orders of magnitude. For this reason, any spacecraft operating outside the earth's atmospheric shield could be subjected to sharply elevated radiation levels for periods of a few hours to a few weeks.

The sun produces, in addition to these sporadic bursts of highly energetic particles, a relatively low-energy plasma called the solar wind. The solar wind can warp the terrestrial magnetic field, producing the magnetosphere. Beyond the magnetosphere, interplanetary space is filled with solar wind particles expanding out past the planets until they come into pressure equilibrium with the interstellar medium, forming the space called the heliosphere. It is conditions in the heliosphere that determine the access of GCRs to the solar system and ultimately to the earth's environment.

Furthermore, the combination of particle radiation and electromagnetic radiation can produce dramatic effects in the earth's upper and middle atmosphere. Above 100 km, molecules dissociate as a result of ultraviolet absorption and can be ionized through the action of charged particles as well. The resulting plasma of positive ions and electrons make up the ionosphere, which extends roughly from 70 km to 3000 km, with the largest concentrations of electrons at an altitude near 300 km (Schunk & Sojka, 1988). The ionospheric layers are responsible for the reflection of radio waves, and the critical frequency for penetration of the ionosphere increases sharply during years of sunspot maximum (Smith, 1967). However, GCRs are the primary source of ionization in the stratosphere down to about 20 km altitude, and may also serve as a major source in the lower mesosphere at night or during solar eclipses (Heaps, 1978). Their range of energy allows them, on a global scale, to penetrate into the atmosphere and produce secondary radiation, i.e., muons and neutrons, which reaches to the surface of the earth. However, the lower energy component of the GCRs have more ready access to the atmosphere at higher latitudes. Since the earth's magnetic field regulates the incoming cosmic rays, in the polar regions the vertical or "open" field lines permit penetration to lower altitudes and thus ionization to take place by particles of less than about 100 MeV.

On a larger scale, perturbations in intensity of GCRs in the earth's environment are directly related to the radiation from the sun and its associated magnetic field. As Ustinova (1995) states, "the dynamics of processes in the solar system are determined by the solar corpuscular radiation The solar cosmic rays and, especially, the plasma of the solar wind and solar flares, moving from the sun together with the 'frozen' magnetic fields, create a rigid barrier for the penetration of galactic cosmic rays into the heliosphere, so that the galactic cosmic ray intensity in the solar system anticorrelates with the solar activity"

DATA

Due to the modulation processes originating with the solar wind permeating the heliosphere, the GCR intensity changes with the 11-year solar cycle, and short-term variations are related to solar flare outbursts The intensity variations of the GCRs capable of reaching the earth can be measured using neutron monitor count rates of the secondary neutrons produced by the primary cosmic rays entering the atmosphere Neutron monitor stations are scattered at a number of localities ranging from the tropics to both polar regions Examination of these records shows that although the absolute counting rates vary because of station altitude and location, the form of the time series curves is generally very similar over the whole earth These data are published in *Solar Geophysical Data Prompt Reports* from the National Oceanic and Atmospheric Administration at the National Geophysical Data Center in Boulder, Colorado

The sun undergoes a complex 11-year cycle of various forms of activity, which is generally expressed in the variation of the number of sunspots visible on the solar disc, the most obvious manifestations of solar variability (sunspot data are available from the World Data Center at Boulder, Colorado) The quantities plotted in Figure 1a are the mean monthly sunspot number and neutron monitor data from the monitoring station at Climax, Colorado Taken together, these two data series provide a rough measure of the total radiation flux and energy spectrum in the near-Earth environment In general, the radiation effects represented by these time series are global and apply fairly equally to all areas on the Earth Accordingly, the data series can be compared to UFO sightings occurring anywhere on Earth Figure 1a illustrates the variation in cosmic-ray intensity over the past several sunspot cycles, i e , approximately 44 years of data, and shows a clear inverse relationship with solar activity over the same period

No comprehensive catalog of UFO reports exists One of the best records is the *U* UFO Data Base, developed by Hatch, which consists of more than 12,000 reports of high quality from all areas of the world (www jps net/larryhat/index html) It includes information on each sighting, such as type, location, duration, and so on, and it contains reports through 1995 The record of the frequency of UFO sightings is shown in Figure 1b

The UFO database is less reliable than the data series for sunspots and neutrons (GCRs) The *U* database is based, for the most part, on English-language publications Because of this, it contains a greater proportion of reports from North America and Great Britain than occur in the general population of UFO sightings In addition,

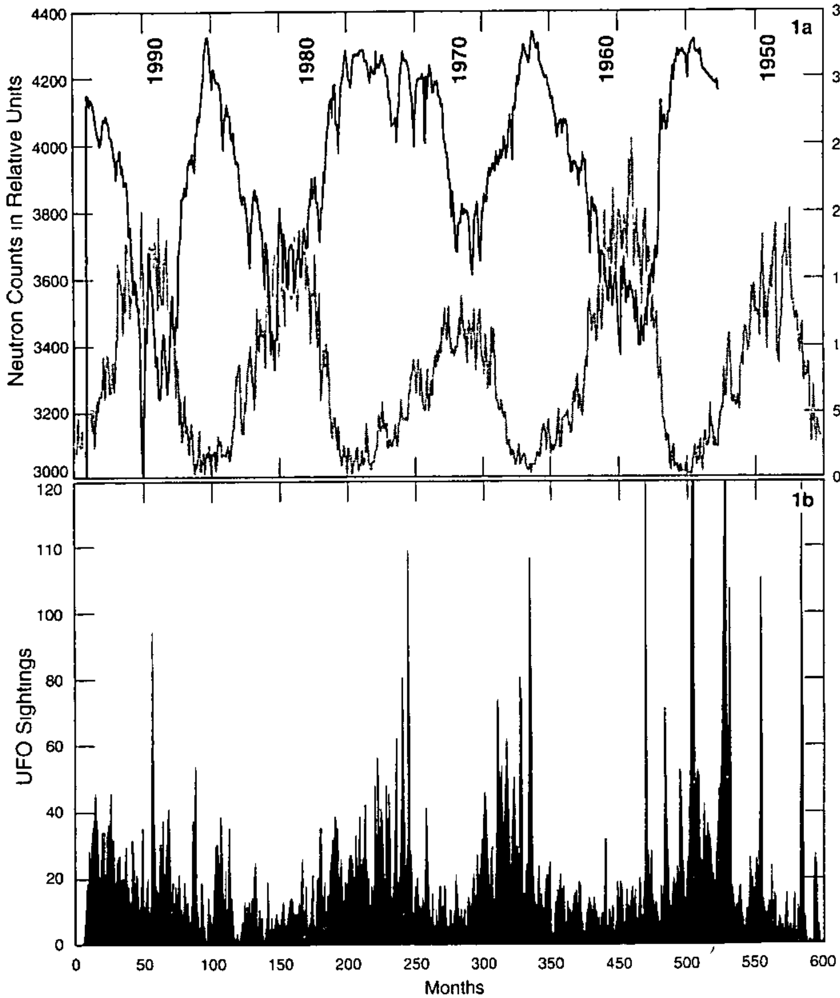

Fig 1 Plotted are the monthly mean sunspot numbers (gray) and the neutron monitor count rate (black) in 1a, compared to UFO sighting frequencies in 1b

other chance factors have influenced which UFO reports are included For example, the French UFO wave of 1954 was reported by several authors in English or in English translations, and so these cases are included in the database Conversely, other reports from France in later years have received less English-language coverage and are less likely to be included

The version of the *U* database we used contains a total of 10,373 reported sightings between 1952 and 1995, inclusive Since so few UFO reports occur on any one day, the sighting frequencies have been aggregated to the monthly level for comparison to the two geophysical data series. It is important to note that the great majority of reports in the database are likely to be true UFOs, i.e., not explainable as inaccurate observations of conventional objects and astronomical phenomena. Hatch carefully selected reports that appeared in the published literature, which means that some screening and investigation had occurred in most instances. Thus, although the database undoubtedly contains some sightings of conventional objects, their number is unlikely to bias any statistical analysis. Nevertheless, since some cases that could be explained must be in the UFO database, the correlations between it and the geophysical data series will be attenuated below their theoretical maximum.

Results and Discussion

The relationship between monthly UFO sighting frequency, GCR flux, and sunspot numbers is shown in Figure 1a and 1b. Inspection of these graphs makes evident the positive correlation between GCRs and UFO reports, whereas sunspot numbers and UFOs are clearly anticorrelated. One of the simplest and most reliable approaches to determine the linear, quantitative relationship between two time series is to calculate the nonparametric Spearman rank correlation coefficient (Porkness, 1991, Harnett, 1975). Table 1 contains Spearman coefficients between all three time series.

The strongest, although negative, correlation coefficient of $r = -0.59$ clearly conveys the close interrelationship between the two time series of monthly sunspot numbers and neutron monitor count rates (galactic cosmic rays). In general, the same variability seems to be displayed by the UFO sighting frequencies, but in phase with GCRs arriving at the earth. This relationship shows a relatively modest, but statistically very significant, correlation coefficient of $r = 0.37$. The much lower correlation between UFO activity and sunspot numbers may result in part because sunspots are only a rough measure of solar energetic particles reaching the earth. The negative correlation with solar activity suggests that times of high solar activity are associated with periods of reduced UFO sighting frequency. This result corresponds to the suggestion, by examining Figure 1 and the correlation coefficient $r = 0.37$, that UFO sightings occur more often at times when cosmic ray flux is highest. A notable ex-

Table 1. Correlation coefficient r between Mean Sunspot Numbers, Neutron Flux (GCRs), and UFO Reports

Data Series	r	Sample Size
UFOs and Neutrons (GCRs)	0.374[a]	510
UFOs and Sunspots	−0.175	576
Sunspots and Neutrons (GCRs)	−0.594	510

[a] All correlations significant at the .0001 level

ception is seen, however, in 1958 at the maximum of sunspot cycle 19, which is known to have been a time of extremely high solar activity, hence SCR flux

The less than perfect reliability of the UFO database means that the correlations with neutron flux and UFO sightings are lowered by some unknown factor Thus, this modest correlation should not be necessarily viewed as an indication of a low relationship between the level of UFO activity and high-energy radiation

Given these correlations, the question is what physical interpretation can be placed on the findings Within the framework of the radiation environment near the earth we can make the following observations

1 The UFOs are sighted most often at quiet periods in terms of solar activity and therefore solar-terrestrial interactions as opposed to extremely rapidly varying conditions during solar maximum periods when, for example, geomagnetic storms and disturbances of the ionosphere are at their highest
2 The in-phase relationship between GCRs and UFO sightings corresponds to the presence of high-energy particles in the near-earth environment, which in turn, is a measure of the solar wind and associated interplanetary magnetic field
3 Highest UFO activity is coincident with maximum global ionization at stratospheric levels due to GCRs having access to the heliosphere and ultimately to the earth (Heaps, 1978) This period is also characterized by the build-up of highest ionospheric potential, which is a measure of the intensity of the fair-weather atmospheric electric field of the earth (Markson & Muir, 1980)

Clearly, the linear relationship between galactic cosmic ray flux and UFO activity is an empirical one established from data that cover almost five complete 11-year cycles The basic assumption is that the UFO–cosmic ray relationship for the last few solar cycles can be extrapolated back in time We cannot know if that is justified or whether the correlation will hold up in the future It is obvious that multiple factors contribute to the phenomenon One example is an approximate 5-year variation in UFO reports, which seems to be fixed to some "extra-solar coordinate system" (Saunders, 1976) However, the data as shown in Figure 1 seem to support the view that the relatively long time series of a large number of UFO sightings is primarily modulated by the presence of GCRs in the near-earth environment

If GCRs are a major contributor to the UFO sighting phenomenon, it is most likely based on radiation damage in solid (inorganic) and organic matter that the high-energy particles can produce in outer space When particles enter the atmosphere of the earth, it serves as a protective shield for objects operating in space and may be the reason for increased reports of UFO sightings This hypothesis may only be a partial explanation for the phenomenon, and it will be necessary in future investigations to look at the UFO signal in greater detail As a matter of fact, the large number of observations or reports contained in the *U* database lends itself to further investigations by filtering out the apparent 11-year periodicity in the UFO data so that all other periodicities can be analyzed which seem to be superimposed on this cycle

One other previous study has attempted to determine if sighting reports might be related to various types of physical parameters, including high-energy radiation in the near-earth environment Accetta (1980) matched specific UFO sightings from UFOCAT, the computer catalog maintained by CUFOS, on a one-to-one basis with specific changes in geophysical measurements, working with the simple hypothesis that UFOs would leave measurable deviations from the normal record For the most part, he used data from stations relatively near the UFO event He obtained some evidence that UFO reports were possibly linked with increases in radiation associated with principal magnetic storms, a worldwide geomagnetic activity index, and the appearance of the sporadic E-layer in the ionosphere No association, however, was found with bi-hourly recorded cosmic ray flux In summary, Accetta stated that there seemed to be sufficient justification for further efforts of this kind Comparing individual UFO observations with short-term geophysical data may not be as meaningful as treating the total UFO sighting record as a time series and comparing the temporal variation of the signal from UFO sightings with the signal from several geophysical time series

Conclusions

This study shows that when the UFO time series is compared with two parallel time series that respond to variations in particle radiation reaching the near-earth environment, statistically significant modulations can be seen The time series comprise more than 40 years and involve more than four solar-activity cycles Particle radiation in the form of galactic cosmic rays seems to be the dominant contributor and only rarely do very large solar proton events influence sighting frequencies In general, solar activity correlates weakly negatively over more than four solar cycles, whereas moderate positive correlations can be found for galactic cosmic rays The extended geophysical and UFO records now available to us permit statistical evaluations at high confidence levels Unfortunately, as seems to be a common characteristic with virtually all aspects of the UFO phenomenon, we are left with a confusing array of possible interpretations The most obvious suggests that UFOs are real, physical objects that are in some sense influenced by radiation effects, but it tells us little about their internal mechanisms and practically nothing about their origins

The present research has been exploratory and should be continued and expanded, with the time resolution increased to intervals of one day (or less) Data are available to serve as a basis for such a study, and more advanced statistical techniques need to be employed to analyze these time series for patterns and all underlying periodicities

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