Experimental

# LUNAR CORRELATES OF NORMAL, ABNORMAL AND ANOMALOUS HUMAN BEHAVIOR

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## ABSTRACT

From ancient times, people have believed that the moon affects human behavior. To test this belief, total lunar cycle (29.5 day synodic period) was correlated against 35 variables recorded during the calendar year 1993. The variables included global geophysical factors, local weather in Las Vegas, NV, indices of abnormal and criminal activities in Clark County, NV, fluctuations in mutual fund prices, and lottery payout percentages for six US state lotteries. All data were averaged to smooth out daily fluctuations, data related to criminal and abnormal human behavior were adjusted for day-of-week periodicities, and the financial data was de-trended.

Three types of relationships were explored: Correlation with total lunar cycle; mean differences between the waning and waxing lunar cycles; and sudden changes on the day of the full moon.

Besides obtaining expected correlations with some geophysical variables, statistically significant relationships were also observed with some behavioral variables, mutual fund price residuals and state lottery payout percentages. Bivariate spectral analyses confirmed the presence of 29.5 day cycles in the crisis calls, abnormal, financial and lottery payout behavior. Variables showing sudden changes on the day of the full moon included crisis calls, suicide, and psychiatric admission rates. Variables showing significant differences between the waning and waxing moon included homicide and crisis calls.

We conclude that this dataset supports popular beliefs about interrelationships of lunar phase and human behavior.

KEYWORDS: Lunar, lottery, human behavior, abnormal behavior

# INTRODUCTION

## HISTORY

*It is the very error of the moon; She comes more near the earth than she was wont, And makes men mad.*

— William Shakespeare (1564-1616), Othello, Act V, Scene ii.

For millennia, primitive peoples associated the bright, forthright sun with masculine, and the veiled, mysterious moon with feminine. The female monthly cycle was undoubtedly one reason why most of the ancient moon deities were feminine, *e.g.*, Ishtar of the Babylonians, Ix Chel of the Mayans, Hanwi of the Oglala Souix, Artemis of the Greeks, and Zirna of the Etruscans.[1] In fact, it is often noted that the term menses means month. Religious ceremonies and magical rituals were often timed to match precise phases of the lunar month,[2] and calendar years were based on moon cycles, including the Islamic, Hebrew, Chinese, and Mayan calendars. To this day, popular holidays like Easter and Passover are still timed according to the lunar cycle.[3]

The moon also figured prominently in medieval talismans, good luck charms, and magic. The "witching hour" was midnight under a full moon, because that is when magical forces were considered to be most powerful.[1] Based on secrets from the Cabala, lunar charms were often used to enhance fertility, start new ventures, and enhance psychic powers.[4, p.37]

Along with religious and ceremonial practices, it was common knowledge that human and animal behavior were affected by the moon. Pliny the Elder, a Roman naturalist from the first-century, wrote that

> We may certainly conjecture that the moon is not unjustly regarded as the star of our life . . . The blood of man is increased or diminished in proportion to the quantity of her light".[1, p.110]

Nearly two thousand years later, modern medical researchers have reported that post-operative bleeding peaks around the time of the full moon.[1]

From medieval times, it was considered dangerous to sleep in the moonlight or to gaze at the moon. The 18th century French psychiatrist, Daquin,[5] wrote in his book on mental disorders: "It is a well established fact that insanity is a disease of the mind upon which the moon exercises an unquestionable influence." Sir William Hale, chief justice of England, wrote in the 1600s that "the moon hath a great influence in all diseases of the brain . . . especially dementia."[1, p. 142] Two hundred years later, in writing England's "Lunacy Act of 1882," Sir William Blackstone, the great English lawyer, defined "A lunatic, or *non compos mentis*, is one who hath . . . lost the use of his reason and who hath lucid intervals, sometimes enjoying his senses and sometimes not, and that frequently depending upon the changes of the moon."[5]

Dipsomania, or periodical alcoholism, was mentioned in the early psychiatric literature, and was often associated with lunar cycles.[5] In light of legal treatments of lunacy, it is interesting to note that the nefarious "Son of Sam," a serial killer in New York City in the 1970s, killed five of his eight victims on nights when the moon was either full or new.[1, p. 148]

Public fascination with "creatures of the night," including vampires and werewolves, continues to the present day, ensuring that this age-old folklore will remain in the forefront of our imagination for generations to come.[6] Contemporary surveys confirm that many people still believe that strange behavior peaks around the time of the full moon.[7-9]

## RESEARCH

*This is the excellent foppery of the world, that, when we are sick in fortune—often the surfeit of our own behavior - we make guilty of our disasters the sun, the moon, and the stars.*

—William Shakespeare (1564-1616), King Lear, Act I, Scene ii.

Researchers investigating relationships between lunar phase and human behavior usually search for lunar correlations with indices of abnormal behavior, including homicide, suicide, criminal activity, disturbances in psychiatric settings, admissions to mental institutions, and telephone calls to crisis centers. Less frequently, relationships with traffic accidents, fire alarms, ambulance runs, Dow-Jones averages, voting patterns, children's unruly behavior, and drug intoxication are studied.[10,11]

Some of these studies found significant relationships,[12-17] while others reported only small, inconsistent correlations.[18,19] For example, Frey, Rotton and Barry[20] studied fourteen types of calls to police and fire departments over two years. They found that 6 out of 56 tests had significant "but very small" lunar effects, and concluded that those few effects were instances of Type I errors.[21]

Reviews of the literature have been generally negative. A meta-analysis published in 1985 concluded that lunar phase influences were "much ado about nothing," and the authors hoped that their report would be "much adieu about the full moon."[10, p. 302] In a later report, they stated that after dividing the lunar cycle into four equal sections, activities usually termed lunacy accounted for 25.7% instead of the chance expected 25%. They concluded that "we are not impressed by a difference that would require 74,477 cases to attain significance in a conventional (*i.e.,* chi-square) analysis."[11, p.131,22] A few years later, Martin, Kelly & Saklofske[23] reviewed suicide and lunar cycles and concluded that:

> A consideration of the 20 studies examined here indicates that a knowledge of lunar phase does not offer the clinician any increase in ability to predict suicide and does not contribute to the theoretical understanding of suicide.[23, p. 794]

In sum, in spite of the fact that lunar myths and lore have endured for millennia, modern science remains skeptical and uncertain what to believe. Contemporary popular articles range from the uncritically dismissive[24] to the uncritically credulous.[25]

## The Moon

There are five lunar cycles. The lunar cycle considered in this analysis, the *synodic,* is the most commonly known full—new—full moon cycle of 29.53 days. Other cycles are called the *anomalistic* (from apogee to apogee, lasting 27.55 days), the *sidereal* (time for one lunar orbit of the Earth with respect to a fixed-star background as seen from the Earth, 27.32 days), the *tropical* (time between lunar passages across a given celestial longitude, also 27.32 days), and the *draconic* cycle (time between passages of the moon through the point where the lunar orbital plane crosses that of the Earth/sun orbit, 27.21 days).

# METHOD

## VARIABLES

Table I lists the 37 variables used in this analysis. All variables were collected to cover the calendar year 1993. Some data items were not available every day, for example the financial and some lottery data were typically available only for week days because the stock market and some state lotteries do not operate on weekends and holidays.

The financial data was formed by calculating a linear regression of the average of 250 Mutual Fund daily prices, and using the residuals as the raw data.[26] That is, the financial data was the daily difference from the de-trended mean. The crime, abnormal and financial variables were normalized to account for day-of-week periodicities, and all data were smoothed by taking a moving mean with a lag of plus and minus three, *i.e.*, each datapoint was the mean of the original data item plus the adjacent three items.

The lottery variable was the daily "Pick 3" game, popular in many U.S. states. In this game, you guess three digits, and if your guess matches the winning number selected randomly the next day, typically using a machine that relies on random movements of ping-pong balls, then you win. We did not average "Pick 3" lottery data for potential day-of-week biases because lottery payout percentages are based only upon the number of winning lottery tickets per day, and the number of winners (according to conventional assumptions) is a pure chance event. Thus, although there are typically more lottery players on Friday and Saturday, the number of winners, and therefore the final payout percentage, is not affected by the day of the week.

Of course, on days when the winning lottery number matched typical response biases, such as when the winning number was 711, or 123, then the payoff

**Table I**
Variables used in the investigation.

| Daily Variable | Description |
|---|---|
| | **Weather** in Las Vegas, Nevada, USA |
| Sunlight | percentage of possible sunlight |
| MinTemp | minimum outdoor temperature |
| MaxTemp | maximum outdoor temperature |
| Precip | precipitation, in inches |
| WindSpeed | wind speed |
| Humid | outdoor humidity |
| Baro | barometric pressure |
| TempDiff | difference in maximum and minimum temperatures |
| | **Geophysics** |
| Ap, Cp, C9 | daily planetary geomagnetic indices |
| SSN | sunspot number as reported by NOAA |
| radio flux | 10.7 cm solar radio flux |
| | **Abnormal Behavior** in Clark County, Nevada |
| Crisis calls | 911 crisis calls |
| Strange | admissions to Clark County Mental Hlth Dept. for observarion |
| Psycho | admissions to Menral Hlth Dept. for long-term treatment |
| Suicide | suicide |
| SuicideM | suicide, male |
| SuicideF | suicide, female |
| | **Crime** in Clark County, Nevada |
| Homicide | homicide |
| HomicideM | homicide, male |
| HomicideF | homicide, female, Clark County, Nevada |
| | **Death Rates** in Clark County, Nevada |
| Death Toral | total deaths |
| Death M | total deaths, male |
| DeathF | total deaths, female |
| DeathMV | death, motor vehicles |
| DeathMVM | deaths, motor vehicle, male |
| Death MVF | deaths, motor vehicle, female |
| DeathAcc | death by accident, not including motor vehicles |
| | **Financial Behavior** |
| Stocks | average of residuals of 250 de-trended mutual funds |
| | **Lottery** |
| MI% | Michigan state lottery payout% for "Pick 3" game |
| VA% | same for Virginia state lottery |
| KY% | same for Kentucky state lottery |
| MO% | same for Missouri state lottery |
| IL% | same for Illinois state lottery |
| CA% | same for California state lottery |
| Lottery% | average state lottery payout percentage for above six states |

percentages tended to be quite large. Chance payoff percentages are normally adjusted in most states to pay out an average of 50% of the day's take, but because of response biases, the actual payoffs on a day-to-day basis ranged from lows of about 15% to highs of about 300%. Daily variations in payout were not completely due to response biases. On some days there were payouts of 80% or 90% when the winning number did not match any stereotypical response bias. We included the lottery percentage as a variable in this study to explore whether some of the variations in daily payout percentages might correlate with lunar phase.

## Analyses

The first analysis was a linear correlation for each variable vs. the synodic lunar phase. To do this, we defined the full moon as "1" and the new moon as "-1," then calculated a sine wave from -1 to 1, then 1 to -1 in 29 steps, one step per day. Thus, day 15 was the full moon, day 1 was the preceding new moon, and day 29 was the following new moon.

Next, for each variable we took the average of all data items falling on the day of the full moon, the day after the full moon, the day before, and so on, until averages from all 29 days were determined. A correlation then was performed on the 29-step sine curve representing the lunar phase versus the 29-element average variable array.

The second analysis was to examine each variable for where the maximum and minimum values occurred in relationship to the full moon, and where the maximum deviations occurred in relationship to the full moon. In these analyses, "0" referred to the day of the full moon, and minus and plus numbers referred to the days before and after the full moon, respectively.

The third analysis examined the mean value of data items 14 days before the full moon (the waxing moon) vs. the mean for items 14 days after the moon (the waning moon). A paired *t*-test compared the two means.

# RESULTS

In this section we report the results of the analyses described above, without much comment. We discuss these results in more detail in the Discussion section.

## TABULAR RESULTS

Table II shows the results of the total phase correlations, along with $t$-scores testing $r = 0$, and the associated $p$-values (two-tailed). Note that this table lists $t$-scores and probabilities as "adjusted." The adjustment is necessary because the data used in these correlations are smoothed twice: once due to the moving average transformation applied to the raw daily data, and then again when averaged by the day of the lunar cycle. This double-smoothing decreases the variation of the individual datapoints, and thereby decreases the standard deviation of each data series assumed by the correlation. This in turn inflates the $t$ score, and the probabilities. Through Monte-Carlo simulations, we determined that to provide a more accurate estimate of the probability of the correlation given the smoothing transforms, the adjusted standard deviation should be approximately doubled. Thus, the $t$ scores and probabilities reflect this adjustment of the standard deviation.

The table indicates some expected significant correlations with geophysical variables.[27,8] Other variables traditionally associated with lunacy, such as crisis calls, homicide and strange behavior (as described in Table I), were not significantly correlated with total lunar phase, but psychotic behavior was significant ($p < .04$, one-tailed).

Of interest is that the correlation for death rate by motor vehicle accidents was significant for men, but not for women, that financial data resulted in a strong positive correlation, and that lottery payout percentage resulted in a strong negative correlation. Five of the six state lotteries resulted in a negative correlations, with Michigan showing independent significance.

Table III shows the result of the maximum/minimum deviation analysis. Of primary interest here are effects observed in cases where the total phase correlations are not significant. For example, sunlight, and minimum and maximum temperatures are not significant in Table II, and yet in Table III we see that

**Table II**

Results of total lunar phase correlation, where N = 29. Variables highlighted in bold are significant at $p < .05$, two-tailed.

| Name | $r$ | $t$(adjusted) | $p$(adjusted) two-tailed |
|---|---|---|---|
| **Lottery** | | | |
| MI% | -0.640 | -2.167 | 0.0393 |
| IL% | -0.239 | -0.639 | 0.5285 |
| CA% | 0.028 | 0.073 | 0.9421 |
| VA% | -0.343 | -0.949 | 0.3509 |
| MO% | -0.278 | -0.751 | 0.4594 |
| KY% | -0.280 | -0.757 | 0.4556 |
| Lottery% | -0.743 | -2.884 | 0.0076 |
| **Weather** | | | |
| max temperature | 0.288 | 0.782 | 0.4410 |
| min temperature | -0.060 | -0.156 | 0.8774 |
| temperature difference | 0.682 | 2.423 | 0.0224 |
| precipitation | 0.449 | 1.304 | 0.2033 |
| barometric pressure | 0.497 | 1.487 | 0.1486 |
| windspeed | -0.484 | -1.437 | 0.1622 |
| percentage of sunlight | 0.139 | 0.365 | 0.7178 |
| humidity | -0.386 | -1.086 | 0.2873 |
| **Geophysics** | | | |
| **ln(Ap)** | 0.696 | 2.519 | 0.0180 |
| **SSN** | 0.976 | 11.608 | 0.0000 |
| **solar radio flux** | 0.984 | 14.563 | 0.0000 |
| **Abnormal Behavior** | | | **(one-tailed)** |
| crisis calls | -0.167 | -0.440 | 0.6683 |
| strange behavior | 0.058 | 0.151 | 0.4404 |
| **psychotic behavior** | 0.597 | 1.932 | 0.0319 |
| suicide | 0.401 | 1.138 | 0.1325 |
| homicide | 0.180 | 0.475 | 0.3243 |
| homicide M | 0.264 | 0.712 | 0.4828 |
| homicide F | -0.115 | -0.301 | 0.6170 |
| suicide M | 0.311 | 0.850 | 0.2013 |
| suicide F | 0.338 | 0.934 | 0.1792 |
| **Death** | | | |
| **total death** | 0.668 | 2.329 | 0.0276 |
| death M | 0.415 | 1.185 | 0.2464 |
| death F | 0.390 | 1.101 | 0.2806 |
| accidents | 0.297 | 0.809 | 0.4253 |
| MV death | 0.572 | 1.810 | 0.0814 |
| **MV death M** | 0.804 | 3.510 | 0.0016 |
| MV death F | 0.031 | 0.080 | 0.9372 |
| **Financial** | | | |
| stocks | 0.721 | 2.703 | 0.0117 |

Table III

Results of maximum/minimum analysis. The values refer to the number of days from the full moon, thus 0 is on day of the full moon, and 7 indicates one week after the full moon

| Variable | Maximum Value | Minimum Value | Maximum Positive Change | Maximum Negative Change |
|---|---|---|---|---|
| **Lottery** | | | | |
| MI% | 12 | -4 | -3 | 13 |
| VA% | 14 | -10 | 2 | -10 |
| KY% | 4 | -4 | 4 | 11 |
| MO% | -10 | 6 | 13 | 6 |
| IL% | 10 | 3 | -10 | -3 |
| CA% | -8 | 14 | -12 | -7 |
| Lottery% | -6 | 1 | 10 | -4 |
| **Weather** | | | | |
| sunlight | 6 | 0 | 4 | 11 |
| minTemp | 9 | -4 | 0 | -4 |
| maxTemp | 8 | -11 | 0 | -4 |
| windspeed | 14 | 7 | 0 | -13 |
| precip | 5 | -5 | -1 | 6 |
| humid | -9 | -5 | -4 | -5 |
| baro | -6 | 11 | -7 | 0 |
| tempdiff | -5 | -14 | -7 | -4 |
| **Geophysics** | | | | |
| In(Ap) | 4 | -11 | 0 | 7 |
| SSN | 1 | 13 | -2 | 6 |
| solar flux | 2 | 13 | -4 | 8 |
| **Abnormal** | | | | |
| crisis calls | 11 | -6 | 0 | 14 |
| srrange | 4 | 11 | 12 | 9 |
| psycho | 5 | 14 | 0 | 9 |
| suicide | -3 | -10 | -3 | 0 |
| suicide M | -2 | -10 | -3 | -10 |
| suicide F | -3 | -12 | -9 | -2 |
| homicide | 5 | -2 | -9 | 11 |
| homicide M | 5 | -13 | -9 | -2 |
| homicide F | -10 | 12 | 4 | -7 |
| **Death** | | | | |
| Total death | 2 | -6 | -4 | -7 |
| death M | 2 | -6 | -4 | -6 |
| death F | -2 | 6 | 7 | 14 |
| MV death | 0 | -11 | -5 | 2 |
| MV death M | 0 | 13 | -12 | 10 |
| MV death F | 13 | -11 | -5 | 14 |
| accidents | 11 | -10 | -8 | -12 |
| **Financial** | | | | |
| stocks | 0 | -7 | -5 | 7 |

**Table IV**

Results of mean difference for waning vs. waxing moon,
*t*-test performed with 14 pairs.
Variables highlighted in bold are significant at $p < .05$, two-tailed.

| Name | MeanWax | sd | MeanWane | sd | *t* | *p* (2-*t*) |
|---|---|---|---|---|---|---|
| **MI%** | 52.337 | 1.664 | 55.671 | 3.524 | 2.378 | 0.032 |
| VA% | 45.435 | 7.270 | 49.153 | 3.784 | 2.061 | 0.058 |
| KY% | 61.941 | 0.657 | 62.153 | 1.153 | 0.538 | 0.599 |
| **MO%** | 50.567 | 0.868 | 45.751 | 1.533 | -6.929 | $<10^{-5}$ |
| IL% | 49.185 | 0.766 | 49.085 | 4.402 | -1.632 | 0.125 |
| **CA%** | 51.289 | 0.987 | 49.684 | 2.318 | -3.298 | 0.005 |
| Lottery% | 52.302 | 1.393 | 51.874 | 1.298 | -0.894 | 0.386 |
| Sunlight | 87.734 | 0.902 | 87.897 | 2.165 | 0.294 | 0.773 |
| **MinTemp** | 54.996 | 0.661 | 57.134 | 0.324 | >8 | $<10^{-9}$ |
| **MaxTemp** | 78.568 | 0.297 | 80.851 | 0.486 | 8.345 | $<10^{-9}$ |
| WindSpeed | 22.640 | 2.280 | 23.005 | 1.379 | 0.834 | 0.418 |
| **precip** | 0.010 | 0.010 | 0.017 | 0.008 | 3.042 | 0.009 |
| Humid | 20.517 | 0.052 | 20.717 | 0.432 | 0.713 | 0.487 |
| **Baro** | 27.695 | 0.035 | 27.658 | 0.012 | -3.523 | 0.003 |
| TempDiff | 23.572 | 0.958 | 23.718 | 0.330 | 0.479 | 0.639 |
| **C9** | 2.663 | 0.698 | 3.460 | 0.657 | 3.133 | 0.007 |
| **CP** | 0.598 | 0.158 | 0.755 | 0.133 | 2.974 | 0.010 |
| **AP** | 2.272 | 0.142 | 2.524 | 0.166 | 3.505 | 0.003 |
| SSN | 53.163 | 15.405 | 54.118 | 9.776 | 0.215 | 0.833 |
| Xray | 108.713 | 12.494 | 109.090 | 7.854 | 0.103 | 0.919 |
| **Crisis calls** | 1966.964 | 18.340 | 2004.276 | 4.639 | >8 | $<10^{-9}$ |
| **Strange** | 5.151 | 0.287 | 5.065 | 0.334 | -2.439 | 0.029 |
| Psycho | 1.015 | 0.039 | 1.052 | 0.177 | 0.857 | 0.406 |
| Suicide | 0.666 | 0.049 | 0.706 | 0.032 | 1.462 | 0.166 |
| Suicide M | 0.549 | 0.023 | 0.588 | 0.026 | 1.799 | 0.094 |
| Suicide F | 0.110 | 0.018 | 0.120 | 0.018 | 0.837 | 0.416 |
| **Homicide** | 0.293 | 0.008 | 0.329 | 0.053 | 3.383 | 0.004 |
| **HomicideM** | 0.208 | 0.021 | 0.261 | 0.030 | 5.718 | 0.000 |
| **HomicideF** | 0.079 | 0.012 | 0.062 | 0.023 | -2.896 | 0.012 |
| Death Total | 20.867 | 0.553 | 20.944 | 0.271 | 0.558 | 0.586 |
| **Death M** | 11.916 | 0.204 | 12.160 | 0.263 | 3.141 | 0.007 |
| **Death F** | 8.951 | 0.349 | 8.784 | 0.160 | -2.193 | 0.046 |
| MV Death | 0.433 | 0.088 | 0.478 | 0.039 | 2.032 | 0.062 |
| **MV-F** | 0.135 | 0.032 | 0.192 | 0.047 | 7.004 | $<10^{-5}$ |
| MV-M | 0.292 | 0.056 | 0.286 | 0.049 | -0.340 | 0.739 |
| Death-Acc | 0.354 | 0.060 | 0.377 | 0.047 | 1.404 | 0.182 |
| **StockRes** | -0.038 | 0.067 | 0.017 | 0.032 | 2.682 | 0.018 |

the minimum sunlight value was on the day of the full moon, and the maximum positive change of minimum and maximum temperatures were also on the day of the full moon. In addition, crisis calls in Table II are not significantly correlated with lunar phase, but in Table III we see that the maximum positive change for crisis calls occurred on the day of the full moon.

Table IV shows the results of the mean difference analysis for waxing vs. waning moon. The results indicate that homicide, which is not remarkable in either Tables II or III, significantly rises from the waxing to waning moon. A possible gender effect is revealed in death by homicide for men, which significantly *rises* on the day of the full moon, while death by homicide for women significantly *drops*. In addition, crisis calls rise, strange behavior drops, and motor vehicle deaths of women rise.

## Graphical Results

Graphs can better illustrate the nature of some of the significant effects observed in Tables II, III and IV. For example, Figure 1 shows the relationship between solar radio flux and lunar cycle. By inspection, solar radio flux closely follows lunar phase, lagging by about two days.

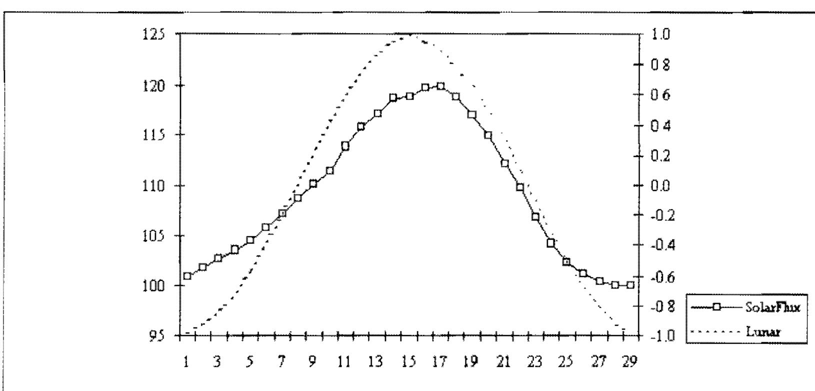


***Figure 1.*** *Graph of solar radio flux vs. lunar cycle. Each point in this and succeeding graphs are averages over 12 months. The left ordinate shows the variable of interest and the right ordinate shows the new moon (-1) to the full moon (1). The abscissa shows the 29 day lunar cycle, with day 15 being the full moon.*

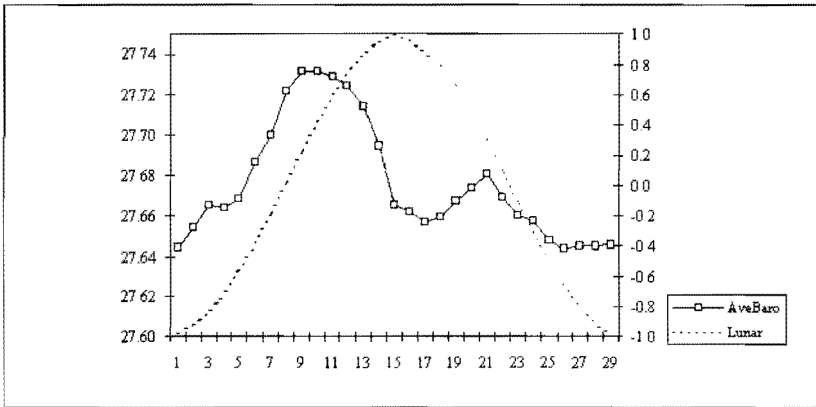


***Figure 2.*** *Graph of barometric pressure vs. lunar cycle.*

Figure 2 shows the relationship between barometric pressure and lunar cycle.[28] This curve shows that barometric pressure leads lunar phase by about five days, then rapidly drops at the time of the full moon. Rapid drops in barometric pressure are often associated with disturbed weather, which is possibly related to increased levels of violence and disturbed behavior.

Figure 3 shows the relationship between admissions to the psychiatric ward of the Clark County Mental Health Department versus lunar phase. The graph indicates a sudden rise of psychotic behavior on the day of the full moon.

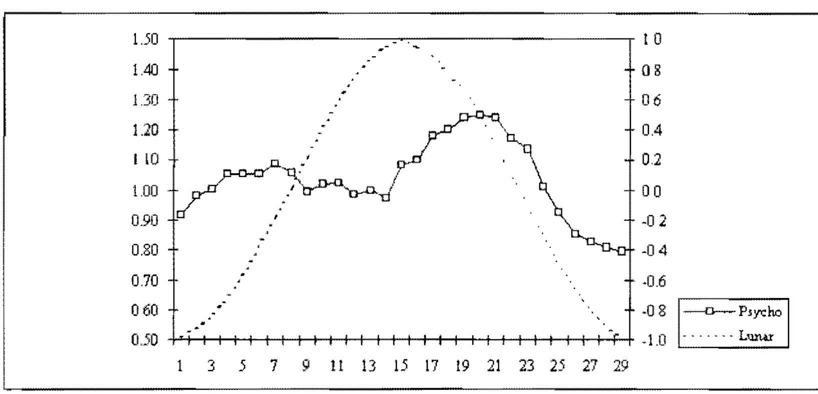


***Figure 3.*** *Graph of psychotic behavior vs. lunar cycle.*

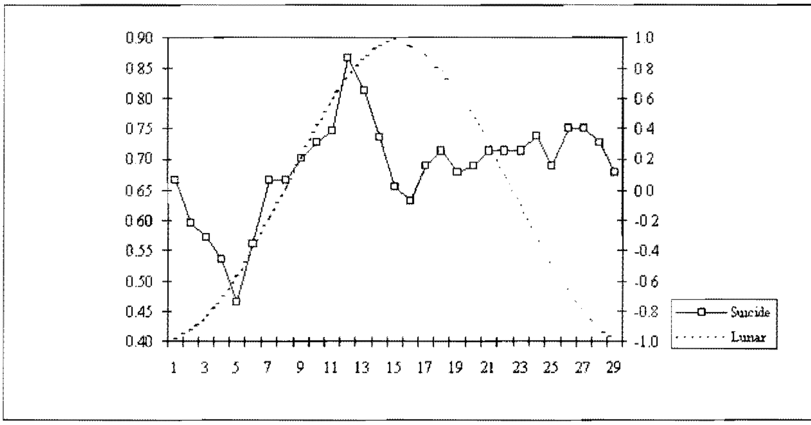


*Figure 4. Graph of death by suicide vs. lunar cycle.*

Figure 4 shows the relationship between death by suicide and lunar phase. This graph indicates that suicide rates increase almost linearly during the waxing moon, then rapidly decline three days before the full moon.

Figure 5 shows the relationship between total death rates and lunar phase. Death rates drop about six days before and after the full moon, and peak about two days after the full moon.

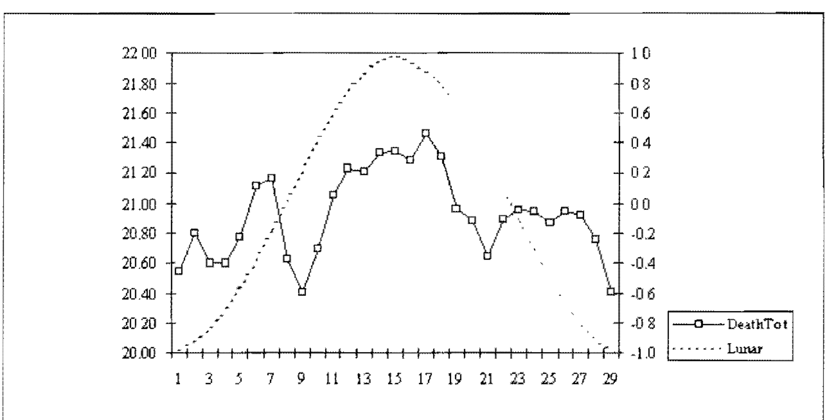


*Figure 5. Graph of total deaths vs. lunar cycle.*

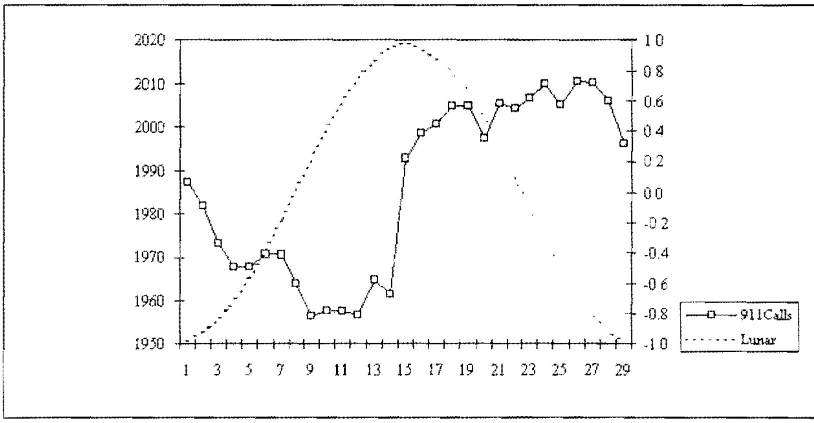


*Figure 6. Graph of crisis calls vs. lunar cycle.*

Figure 6 shows the relationship between 911 crisis calls and lunar cycle. This curve suggests that people may attribute increased levels of crisis on the day of the full moon because of the abrupt change on this day compared to other days.

Figure 7 shows the relationship between mutual fund residuals and lunar cycle. This curve suggests that mutual funds should be purchased about a week before the full moon, and sold on the full moon. It also suggests that the mutual fund market may lag lunar cycle by 5 days.

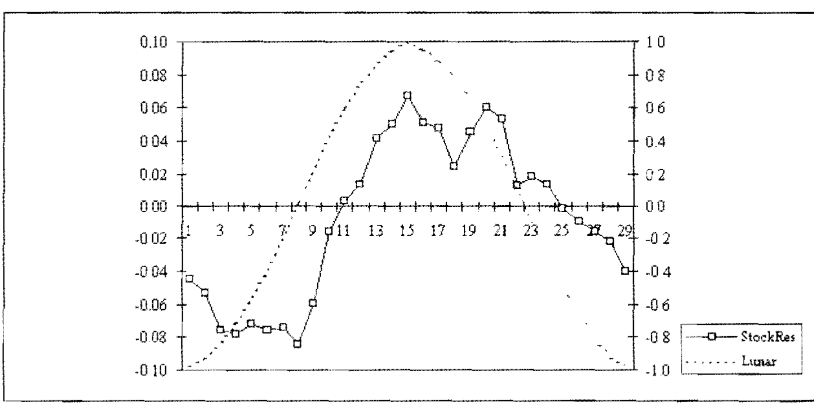


*Figure 7. Graph of mutual fund residuals vs. lunar cycle.*

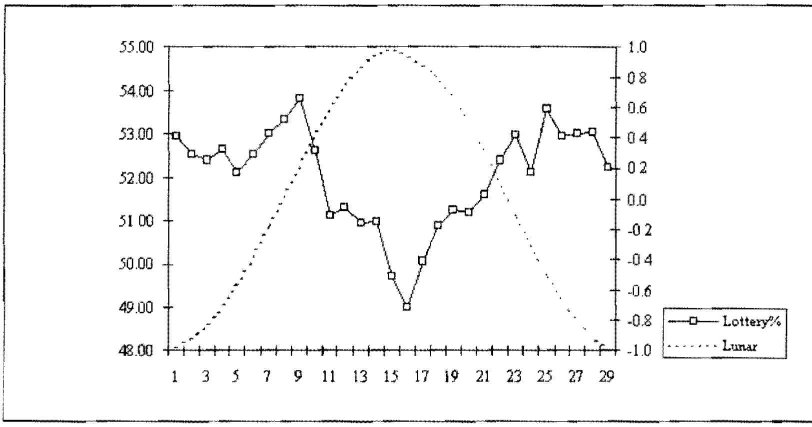


*Figure 8. Graph of lottery percentage vs. lunar cycle.*

Figure 8 shows the relationship between average lottery percentage payout and lunar cycle. This curve shows that lottery payouts are poorest on the day of the full moon. Because the lottery payouts reflect, on average, how "lucky" people are in guessing the lottery numbers, these fluctuations are suggestive of a precognitive capacity. We discuss this in more detail later.

## Cross-Spectrum Analysis

If the results observed in the previous two sections reflect genuine correlates with lunar phase, and there actually are repeating periods 29.53 days in length in geophysical, weather, and human behavior, then a cross-spectrum analysis should reveal these cycles.[29] However, rather than examining lunar phase directly against say, lottery payout percentage, a more powerful argument would be made if a *correlate* of lunar phase, say, ln(Ap), revealed a cross-spectrum relationship with lottery percentage. This is because a spectrum analysis of lunar phase would result in a single frequency spike at a period of 29.53 days (because that period is defined as the synodic cycle), and it can be difficult to interpret a cross-spectrum analysis if one of the time series involved (*i.e.,* the synodic cycle) is perfectly regular. If, however, log(Ap) and lottery payout percentage *both* exhibit 29.53 day cycles, then we would have greater confidence that these two variables have the lunar cycle in common.

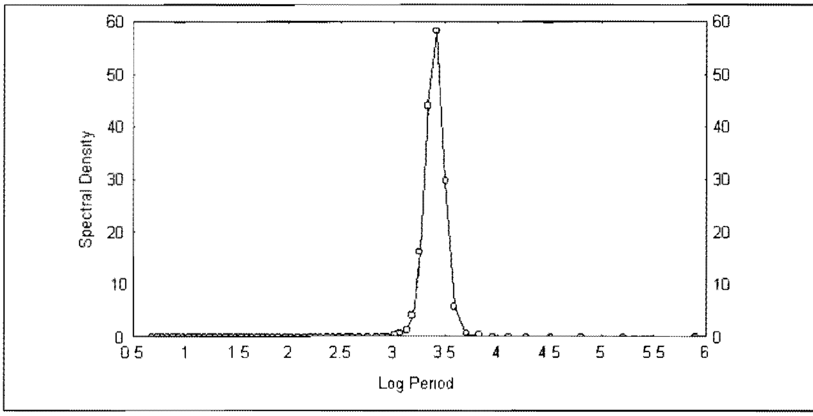


*Figure 9. Illustration of spectral analysis for synodic lunar phase.*

As often recommended in spectral analyses to avoid frequency "leakage," before we subjected the data to cospectral analysis the raw data mean was subtracted, the series was de-trended, and then trimmed 15% using split-cosine-bell tapering.[30] In some cases, to improve the resolution of the results, the data was padded with zeros to equal a power of 2 (in this case, padding increased the raw data arrays from 364 to 512 items; this is a common procedure used in Fast Fourier Analysis to force the length of the data array to be a power of two).

For illustration purposes, Figure 9 shows the results of a single spectrum analysis of the synodic lunar cycle. For ease in viewing the results, log (period) is plotted rather than period. Thus a synodic period of 29.53 days should result in log period of about 3.4, and this is the peak shown in Figure 9. Figure 10 shows a similar analysis conducted on log(Ap). This curve shows a peak at about 2.2 (9 days), a second peak at 2.6 (13 days), and a third peak at 3.4, the synodic lunar cycle. Figure 11 shows the spectral density for xray flux. He we see a more striking correlation with synodic phase, with a clear peak at log period = 3.4 (the 29.5 day cycle).

## A Technical Digression

At this point, for readers unfamiliar with cross-spectrum analysis, we must digress a bit to explain what "cross-amplitude" means, as we will be using it

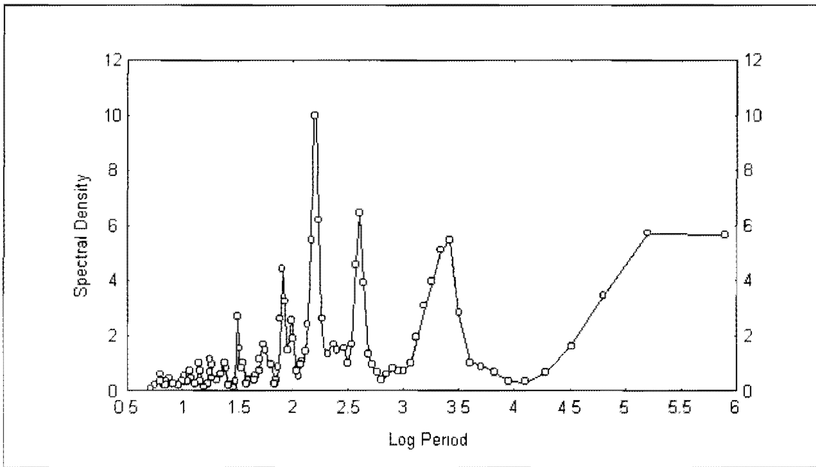


***Figure 10.*** *Spectral analysis of ln(Ap).*

in the remaining graphs.[31] When a time series is decomposed by a Fourier transform into sets of frequencies, two sets of coefficients are produced: sine and cosine. The sine and cosine coefficients can be interpreted as regression coefficients in that they tell us the degree to which the sine and cosine functions

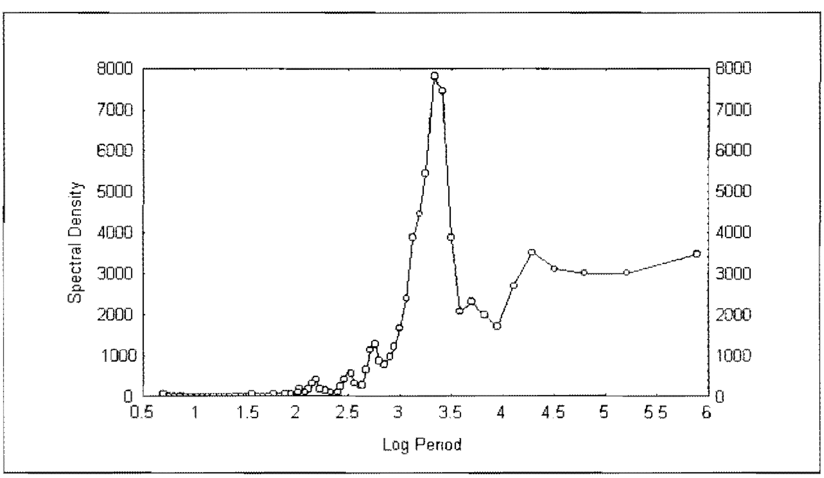


***Figure 11.*** *Spectral analysis of solar radio flux.*

are correlated with the data at the respective frequencies. From the sine and cosine coefficients, a periodogram is computed, which is the sum of the squared sine and cosine coefficients at each frequency (times N/2, where N is the length of the data series). The *periodogram* values can be interpreted in terms of variance of the data at the respective frequency or period. From a periodogram plot, *spectral density* estimates are computed by smoothing the periodogram values, using one of several types of smoothing functions. By smoothing a periodogram we can identify the general frequency regions or spectral densities that contribute significantly to the cyclic behavior of the series.

A *cross-periodogram* is analogous to a single series periodogram, however a cross-spectrum consists of complex numbers that can be divided into a real and an imaginary part. The *cospectral density* is computed by smoothing the real part of the cross-periodogram values, and the *quadrature spectrum* is computed by smoothing the imaginary part of the cross-periodogram values. Finally, the cross-amplitude plot is computed as the square root of the sum of the squared cross-density and quad-density values. The *cross-amplitude* can be interpreted as a measure of covariance between the respective frequency components in the two series, combining both the real and imaginary frequencies of the decomposed time series. We use cross-amplitude in the following graphs as a convenient way of illustrating both the real and imaginary cross-spectrum frequencies in a single graph.

## CROSS-AMPLITUDE GRAPHS

Figure 12 shows a cross-amplitude density plot of log(Ap) versus crisis calls and Figure 13 shows the same plot for psychiatric admission rates. Both plots reveal that log(Ap), crisis calls, and psychiatric admission rates consists of several frequency peaks. Of interest here is the common peak at log period = 3.4, the lunar synodic period.

Figure 14 shows a cross-amplitude density plot of log(Ap) versus mutual fund residuals, and Figure 15 shows the same plot for lottery payout percentage. Again, both plots show common peaks at the synodic period.

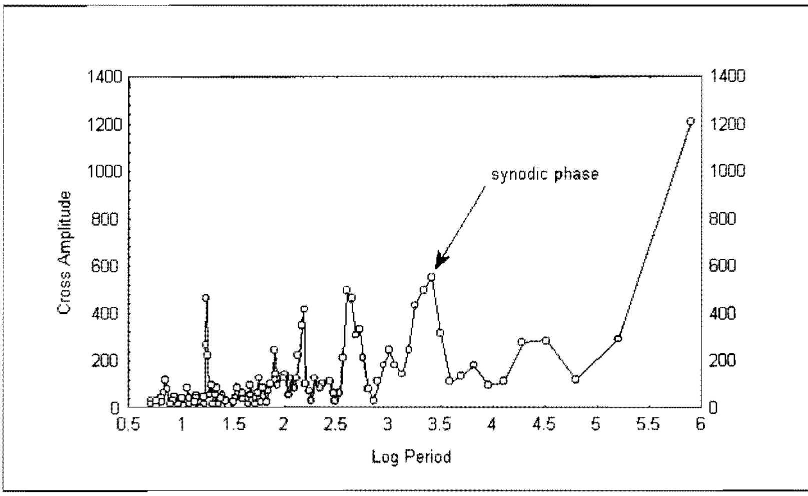


*Figure 12.* *Cross amplitude analysis of log(Ap) versus crisis calls. The X and Y referred to in the graph title, and in subsequent graphs, indicate the two series subjected to cospectral analysis, and not to the X and Y axes in the graph.*

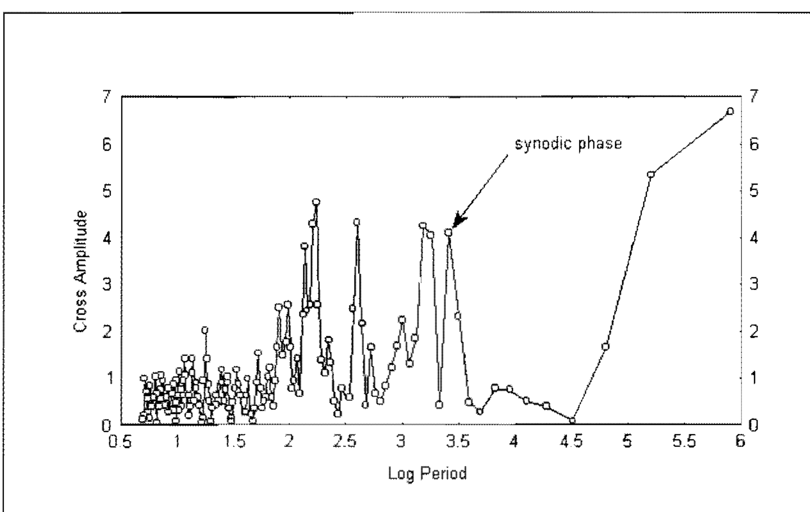


*Figure 13.* *Cross amplitude plot of log(Ap) versus psychiatric admissions rate.*

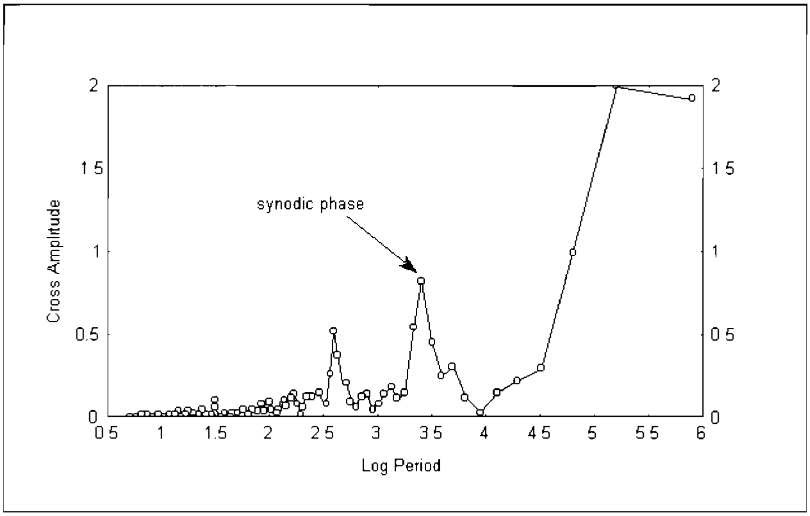


*Figure 14. Cross amplitude plot of log(Ap) versus mutual fund residuals.*

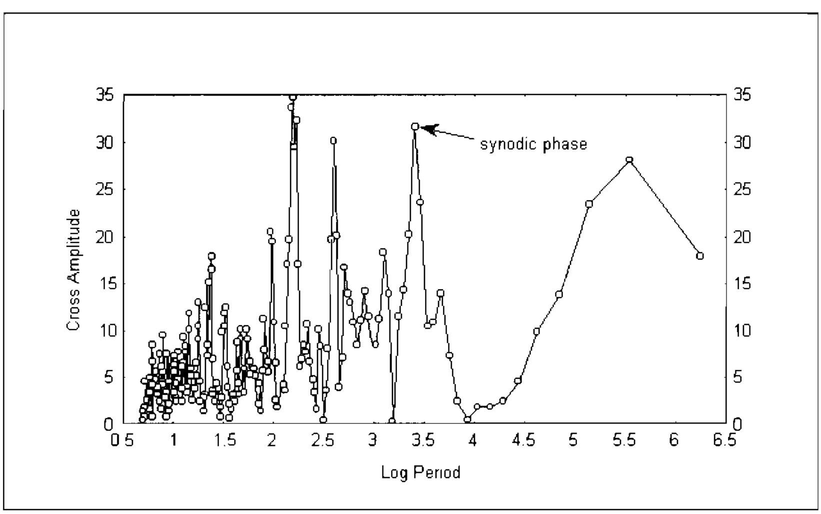


*Figure 15. Cross amplitude plot of log(Ap) versus lottery payout percentages*

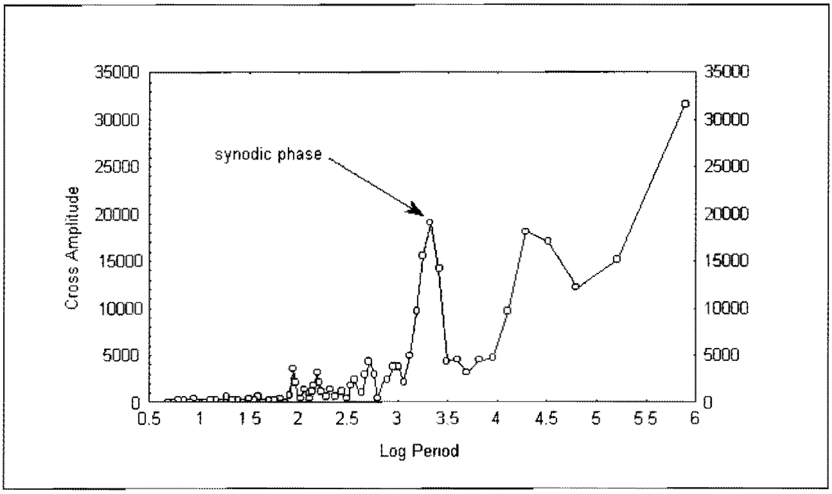


*Figure 16. Cross amplitude plot of solar radio flux versus crisis calls.*

Figures 16 through 19 are analogous to the previous four figures, except that solar radio flux is used rather than ln(Ap).

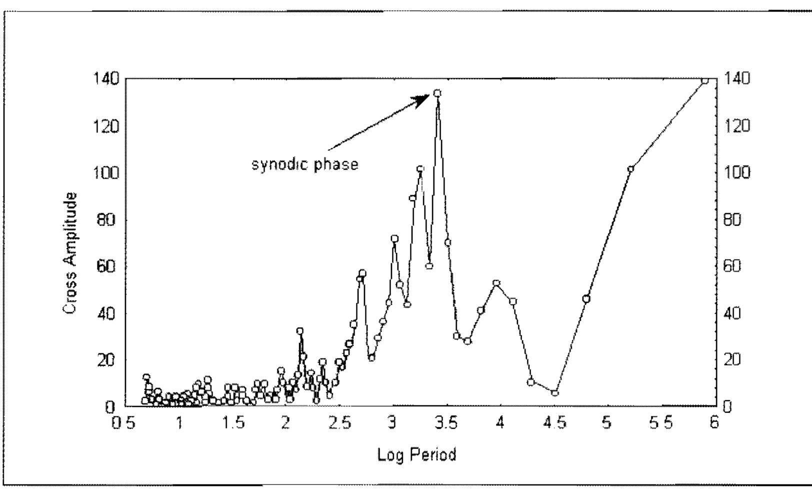


*Figure 17. Cross amplitude plot of solar radio flux versus psychiatric admission* rates.

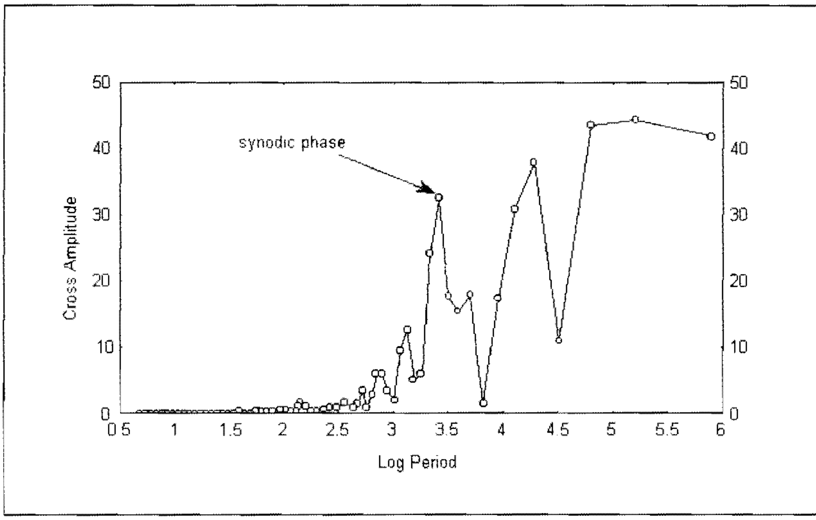


*Figure 18. Cross amplitude plot of solar radio flux versus mutual fund residuals..*

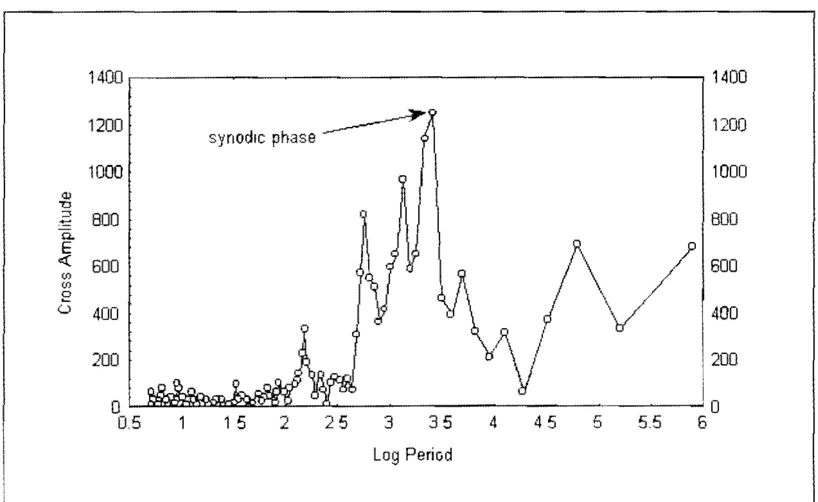


*Figure 19. Cross amplitude plot of solar radio flux versus lottery payout.*

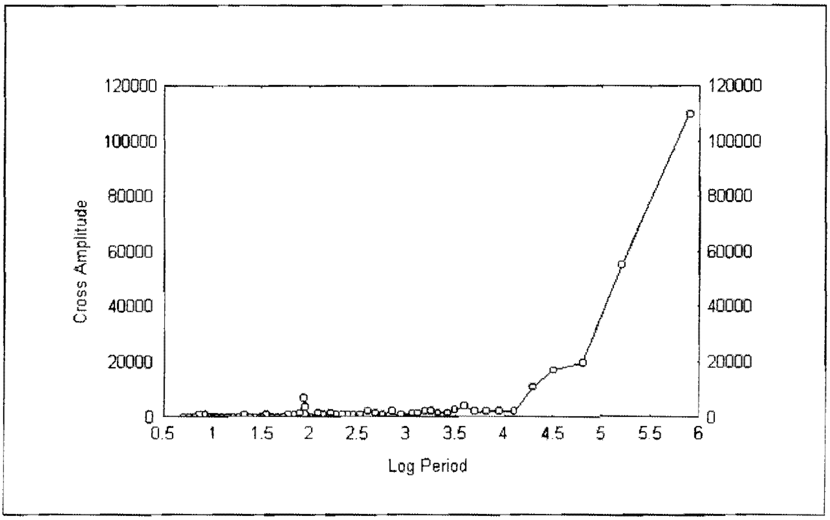


*Figure 20. Cross amplitude plot of maximum temperature versus crisis calls.*

To illustrate that the above synodic peaks are not methodological artifacts, we determined cross-amplitude spectrums of environmental variables and behavioral variables that apparently do not correlate with synodic phase. For example, Figure 20 shows the cross-amplitude plot of maximum temperature versus crisis calls, and Figure 21 shows the same for percentage of sunshine vs. crisis calls. Neither has a notable synodic peak. The peak at log period 5.9 in Figure 20 is a period of about 365 days, a one year cycle. This is expected, as crisis calls correlate positively with temperature, and temperature goes through a yearly cycle of rising in summer and falling in winter. The peaks at log period 1.9 in both Figures are probably due to strong weekly cycles in crisis calls.

In summary, some cross-spectral analyses reveal that time series usually thought of as relatively independent (*e.g.*, mutual fund price fluctuations, crisis calls, psychotic admission rates, and average lottery percentage payouts) in fact have cycles in common matching similar periods in geophysical variables (*e.g.*, solar radio flux, ln(Ap), and these periods are the same as the moon's synodic period of 29.5 days.

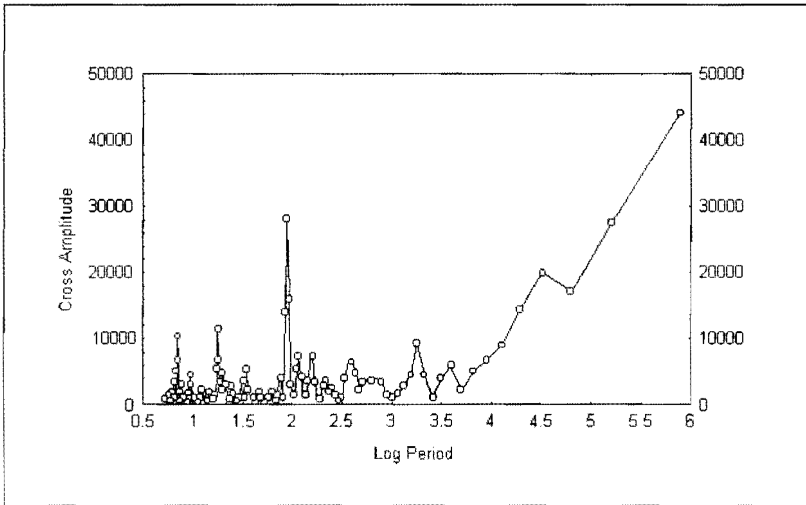


*Figure 21. Cross amplitude plot of percentage of sunshine versus crisis calls.*

# DISCUSSION

## THEORIES

Most researchers reporting behavioral vs. lunar phase correlations speculate on why such correlations might exist. Two main types of theories have been proposed: (a) tidal effects on biological systems, and (b) lunar/ weather/behavioral interactions, including the effects of positive and negative ions in the air.[12,17] Critics of the tidal theories usually point out that the gravitational effect of the moon on individual human beings is far too weak to account for the claimed effects, so while it is accepted that some fish and some small animals have behavior (typically reproductive behavior),[8] linked to tides and the full moon, it is not accepted that tides can account for changes in human behavior.[11]

Criticisms of the lunar/weather/behavioral theories usually point out that correlations do not imply causation, that lunar correlations with weather and geophysical factors are extremely weak, if they exist at all, and therefore the moon is insufficient to cause significant behavioral changes.[10] Critiques of lunar effects in general usually end with declarations like there are no plausible theories to account for the observed data, therefore the results must be due to chance, inappropriate statistics, or psychological biases.[11]

Because we cannot effectively counter the critics' arguments against the proposed theories, we will avoid excessive speculation on why the lunar correlates appeared in this data, and merely point out that this is what the data reveal. We might mention, however, that Table III indicates that on the day of the full moon, windspeed, minimum and maximum temperatures experienced a maximum positive change, barometric pressure experienced a maximum negative change, and percentage of sunlight was at a minimum. Moreover, precipitation went through a maximum positive change the day before the full moon. These effects taken together are consistent with previous observations suggesting that the full moon is related to stormy weather,[1] which is is thought to negatively affect mood.[32] As mood declines, especially if it precipitously declines, we would expect, for example, increases in crisis calls. Thus, we see some support for the lunar/weather/behavioral theory in the present data, at least for crisis calls.

## Magnitude of Effects

We may forestall some consternation about the present results by noting that although some of the correlations in Table II are statistically significant, the magnitude of the lunar effects is generally quite small. For example, the actual increase in psychiatric admissions from the day before, to the day of the full moon, was on average only one tenth of a person. It is not clear that anyone would ever notice such a small increase, even if it is statistically unlikely. Similarly, the actual increase in deaths from one week before, to the day of the full moon, was on average only one person.

Although crisis calls did not directly correlate with lunar cycle, the observed rise in calls on the day of the full moon (about 30 calls) is visually striking (Figure 6). However, because the average number of crisis calls per day was about 1,980, this rise means that the full moon resulted in only about 1.5% more calls than average. Again, it seems unlikely that anyone would notice such a small increase. For mutual fund residuals, the lunar correlation was quite strong, but from one week before, to the day of the full moon, the residuals changed only 0.16 on average (*i.e.*, a price increase of 16 cents over one week).

In sum, while the magnitudes of the effects are for practical purposes negligible, the statistical results of some of the correlations suggests that at least a few lunar cycle relationships are genuine anomalies in search of adequate explanations.

## An Anomalous Correlation

This could be the end of the story, but at risk of arousing the critics' disdain, the present dataset also appears to reveal an anomalous lunar correlation with lottery outcomes. This discovery is sure to be disagreeable because presumably the only way that lottery payoff percentages can be "influenced" is through modulation of guessing behavior. One way to interpret "anomalous guessing behavior" is as precognition, and despite the fact that a meta-analysis of 309 precognition experiments conducted by 62 investigators over four decades establishes that precognition is very likely a genuine phenomenon,[33] this fact is not widely known in the scientific mainstream. Thus, our lunar-lottery claim may be viewed as "mixing anomalies," or as attempting to explain one mystery with another.

To add indirect support to the lunar-lottery results, we can point to previous studies looking at geophysical correlates of anomalous perception. In a growing body of studies, the planetary geomagnetic field has been shown to be quieter on days of improved anomalous perception, including precognition.[34-38] A negative geomagnetic-precognition correlation implies that lottery payoffs should decrease when ln(Ap) rises. Because the present dataset shows that ln(Ap) is positively correlated with the synodic lunar cycle for 1993, we would expect that lottery payout would negatively correlate with lunar cycle, and this is precisely what was observed (see Table II).

Other than a possible geomagnetic link, we can not offer other empirically-based reasons why the moon might be related to changes in precognitive performance. But we could point out that belief in a lunar—psychic connection can be traced to earliest historical times. For example, a key rite in an ancient pagan religion, today called Wiccan, is the ritual of "drawing down the moon." This ceremony, performed on nights of the full moon, is intended to draw the moon's magical powers into the high priestess.[1] By so doing, she becomes an embodiment of the goddess moon, whereupon she experiences visions relevant to her coven. The full moon is said by Wiccans to be "a time of very intense psychic tension."[39, p. 131]

### MUCH ADIEU, OR MUCH TO DO?

Because of the relationships reported here, we must question why previous studies of lunar cycle have not consistently reported similar results. One possibility is that part of our database is markedly unusual, which may be the case because Las Vegas has a very stable environment, with 320 days of sunshine on average per years. This stability may amplify very small lunar effects on local weather and human behavior. Another possibility is that the multiple analyses employed here produced some spuriously significant results. That is likely for some of the correlations with marginal levels of significance, but the co-spectral analyses argue otherwise.

In any case, one wonders if Rotton & Kelly[10] were a bit too hasty in bidding "much adieu about the full moon." Perhaps there is still much to do.

## CONCLUSION

Correlation of total lunar phase with indices of normal (death rates, financial behavior), abnormal (crisis calls, homicide, suicide) and anomalous human behavior (lottery payout percentages) revealed statistically significant relationships with some variables and little or no correlations with other variables. Cross-spectral analyses confirmed the presence of a 29.5-day synodic lunar cycle in some variables. While no adequate theory can be presented to account for these effects, especially an anomalous correlation between lunar phase and average lottery payouts for six US state lotteries, we noted that previous studies reporting a negative correlation between geomagnetic indices and precognition are consistent with the present findings.

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