Lunar Lunacy and the Chicago Criminal Element

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Abstract— **The lunar effect on humans is a constant fascination. The general public believes that people behave strangely when the moon is full. Even if the moon itself doesn't cause mischievous activity, the belief that the full moon invokes lunacy could drive poor behavior. Predicting these periodic increases in crime is an important factor in ensuring a safe and stable society.**

There exists conflicting studies on the possible connection between the full moon and criminal activity. Using the last 18 years of crime in the city of Chicago we investigated the effect of crime during the full moon vs a normal day. We examined the 95% confidence interval of each crime over each weekday controlling for indoor and outdoor locations.

Ultimately, we were unable to find any meaningful change in criminal activity based on the phase of the moon. Future research could examine the implications of a belief in the lunar lunacy among the general public in the face of mounting evidence that no relationship exists between crime and our celestial neighbor.

Keywords—— **Full Moon, Crime Rate, Lunar Lunacy, Chicago**

I. INTRODUCTION

One of the ultimate goals of a prosperous society is to ensure safety and fairness by working to remove crime from the daily lives of its people. Analyzing crime statistics to identify trends in criminal behavior is an important factor in the attempt to reduce the rate of crime. Identifying relationships between criminal activity and societal or environmental factors can be key in helping reduce the rate of crime. One such environmental factor that is embedded in a multitude of cultures is the fascination with inflated aggressive activity on the night of a full moon. This lunar fascination is anecdotally present in doctoral residents even today reporting that in medical training there is consistent speculation between crime and suicide rates being higher than average on a full moon [1]. The concept of this lunar effect isn't without merit as all animals have an internal circadian clock that can affect their behavior and actively change the environment in which we inhabit. The study of these activities in relationship to a full moon range from the mating habits of coral to the more aggressive, such as a crab that feasts from the high tide that is spun from the moon's gravitational pull [2]. The most obvious effect that the presence of a full moon has is the increase in natural light availability, which in a pre-industrialized world could lead to a speculation between a link that more daylight allowed for longer stretches of time with available light and thus providing more time to be active. This lunar effect on humans is of constant fascination, but unfortunately there exists very little, and conflicting at best, studies on the validity of the connection. One such study of patients in psychiatric wards across New Zealand during lunar cycles concluded that there is little substantive evidence to draw a link between the full moon and aggressive behavior over 105 weeks [3], while a more recent study of homicides in Finland was able to conclude that there was a relationship between the lunar cycles and homicide [4]. The availability of huge datasets of criminal activity allows an opportunity to take another approach to investigating whether or not there is a significant relationship between a variety of criminal behavior and full moons. By analyzing nearly 20 years worth of data logged for the modern city of Chicago and linking it to the lunar cycle, one can investigate for more long-term and wide-stretching parallels between the full moon and increased criminal behavior. The gathered crime data will be used to establish a baseline for over all criminal activity and the individual crime types so that we can compare against periods that

are above and below the baseline. These baselines will be separated by days of the week with the assumption that Friday nights have different baseline of crime compared to Wednesdays. To avoid false positives, it is important to compare indoor and outdoor criminal activity. This will determine if there is a correlation between a specific crime and the moon phase versus the overall criminal activity for a given day, e.g., a given day may have the baseline criminal activity but a huge spike in Narcotics related crimes.

II. PROBLEM CHARACTERIZATION

It's been shown in multiple studies, that the number of police officers patrolling a city directly affects the crime rate.[5] The effect of manpower on existing and future crime makes it vitally important for crime trends to be predicted. An expected rise in crime should be met with a rise in police presence. In a small survey [6], 49.4% of undergraduates at Florida International University believed that people behave strangely when the moon is full. Even if the moon itself doesn't cause mischievous activity, the belief that the full moon causes lunacy might drive people to behave poorly.[7] If the moon drives criminal behavior then this would be an easy predictive measure to scale the police force on a month to month basis.

Determining that the moon causes the crime rate to rise is difficult to tease out. If the belief in the full moon is causing crime to rise, then highly publicized moons like the Super Blood Wolf Moon should cause an especially high spike. Conversely, other large media events like the Ferguson, Missouri riots would cause non-moon related spikes.

Another potential cause is the luminosity of the moon. The fact that it's easier to see and move around in a full moon might encourage more activity during the night. However, a cloudy night or a daytime moon would mask the light and the criminal trend.

Due to societal pressures or norms, not all crimes are reported by the victims or bystanders of a crime. For instance, during the period from 2006 to 2010, 52% of all violent victimizations, or an annual average of 3,382,200 violent victimizations, were not reported to the police [8]. In the case of victims of violence, the sample size of the crimes that are reported may not be large enough in order to be able declare whether or not a correlation exists. Additionally, showing a significant link between the full moon and an increase in the overall rate of crime or even a subset of committed crimes could have a major impact on future regulatory decisions. For example, we could see mandated curfews put in place on days that a full moon occurs in order to reduce the opportunity for criminal behavior to occur.

To avoid false positives we chose to investigate criminal activity on a indoor and outdoor basis. The 'Crimes - 2001 to present' dataset does not categorize crimes at this level, but provides a location description. It was up to us, the data scientists, to categorize whether or not a crime location should be considered to have occurred indoors or outdoors. Some instances of the location description appeared to be straightforward to categorize in either the indoor or outdoor bucket. The location descriptions of 'wooded area', 'sidewalk', and 'street' are examples where categorizing them in the outdoor bucket is uncomplicated. Other locations were much more ambiguous, for example, 'vehicle - delivery truck' could imply an indoor location if the vehicle was located indoors or outdoor if the vehicle was located outside. For the purposes of this paper, we chose to categorize this particular location description as outdoors, but could have chosen to categorize it differently.

III. DOMINANT APPROACHES TO THE PROBLEM

Owen et al [3] studied 5 mental health facilities over the course of 2 years. They had mental health professionals record acts of violence on Morrison's eight level hierarchy of violence in the relatively controlled environment of a medical building. A 95% confidence interval of a Poisson Regression was used to evaluate those acts of violence during the 4 phases of the moon. Across the board they found a value of 1, meaning a static or no change in expected level based on the phase of the moon.

This was a good baseline approach to find variance in behavior around the full moon. The controlled environment and professional monitoring lent itself to good clean data. The largest problem with this data set is that all the incidents occurred indoors. There was no analysis made to determine if the light of the moon increased night time activities. The type of crime was also limited to violence towards other people. No consideration for strong night time behaviors such as theft or vandalism.

A much broader population was studied by Simo Nayha [4]. He collected 50 years of homicide data from Finland, and controlled for a wide variety of confounding influence such as sex, age, seasons, weekdays, major holidays and temperature. A 95% confidence interval of a Poisson Risk Regression was used to measure homicides against the luminosity of the moon's 'disk'. A 15% decline in homicides was measured on the full moon in comparison to the new moon.

An excellent look at a very broad population set over a very long period allowed for a reverse trend to be observed in lunar homicides. The new moon, not the full moon seems correlated to murder. Violent deaths of this nature tend to be indoor crimes, so it's interesting that both papers focused on indoor problems, yet came to different results.

IV. Methodology

The first step we performed in gathering relevant data was to extract specific metrics from the total number of crimes committed in the Chicago area. This included 35 unique crime types that the dataset included, the 4 different moon phases, and location of the crimes broken down into Indoor and Outdoor areas, as detailed:

- Moon Types: Days were broken down by their 4 moon phases: New Moon, First Quarter, Full Moon and Last Quarter.
- Day of Week: The 7 days of the week, linked between the two datasets.
- Locations: There were 177 unique locations that were divided between being an Indoor Location (100) (e.g., Church, Garage, House,. etc.,) and an Outdoor Location (77

total) (e.g., Cemetery, Lake, Parking Lot., etc.,).

These metrics were separated into different outputs that included the final total count for individual crimes and their distinct type tallied in reference to the following circumstances:

- Day Of Week Crime Statistics: Total number of Crimes partitioned by type and counted for a given day of the week regardless of Moon Type.
- Day Of Week Crime Statistics With Full Moon: Total number of Crimes partitioned by type and counted for a given day of the week only occurring on a Full Moon.
- Day Of Week Crime Statistics With Non-Full Moon: Total number of Crimes partitioned by type and counted for a given day of the week only occurring on a Non-Full Moons.
- Full Moon Crime Statistics: Total Number of All Crimes partitioned by type and counted for entire dataset that only occur on a Full Moon.
- Non-Full Moon Crime Statistics: Total Number of Crimes partitioned by type and counted for entire dataset that only occur on Non-Full Moons.
- Indoor Full Moon Crime Statistics: Total Number of Crimes partitioned by type and counted for entire dataset that only occur on Full Moons and that occurred by our definition of Indoors.
- Indoor Non-Full Moon Crime Statistics: Total Number of Crimes partitioned by type and counted for entire dataset that only occur on Non-Full Moons and that occurred by our definition of Indoors.
- Outdoor Full Moon Crime Statistics: Total Number of Crimes partitioned by type and counted for entire dataset that only occur on Full Moons and that occurred by our definition of Outdoors.
- Outdoor Non-Full Moon Crime Statistics: Total Number of Crimes partitioned by type

and counted for entire dataset that only occur on Non-Full Moons and that occurred by our definition of Outdoors.

With this immediate output, we were able to establish a baseline for all criminal activity and the individual criminal activity type so that we can compare against periods that are above and below an established baseline. The relevant metrics for the crime types separated by the specified scenarios listed above included their percentage of the total number of crimes, standard deviation, and their resulting confidence interval. The baselines were separated by days of the week so that there will be a mean crime rate with a 95% Confidence Interval for Mondays, Tuesdays, etc. What our Confidence Interval offers is a means to compare against the calculated Crime Level averages that are outside of the Confidence Interval and note when these results are abnormal.

Once this data had been gathered we created charts to investigate if there were any results that stood out on specific days with full moons compared to non-full moons. Any crime type that appeared to stand out with some imbalance between full moon and non-full moons would lead us to see if any trends were consistent throughout each day of the week. These crimes were then compared taking into account their confidence intervals if any strong conclusions about the correlation between crimes and a day of the week with its respective moon type.

Our dataset provided a broader crime types and variation from previous research. The dataset source for Criminal Activity was much more broad in crime type, but specific to only one city. Previous research had been able to draw a correlation between full moons to a specific crime type of Homicide [4], while another study concluded little correlation between moon type and increased aggressive behavior [3]. Our analysis challenges previous studies by approaching the problem from three unique standpoints: first, a longer time frame by analyzing Criminal activity data from over 18 years. Second, a larger sample size of Criminal Activity type to study if there is a correlation between unique criminal activities in relationship to a full moon. This considers actions that fall outside of the normal assumption that the full moon may only be limited to inflicted harmful activity. Lastly, our analysis takes into account indoor versus outdoor crimes in order to see if society's interaction with the moon itself appears to influence criminal activity.

No analysis is perfect and we realize that further analysis can be done using our setup to both eliminate still-present bias and potentially produce more accurate results. These could be to compare each Moon Type against one another (e.g., Full Moon versus New Moon) instead of Full Moon versus the entire category of Non-Full Moon. However, after analyzing our results we feel that we mitigated much of this bias by comparing the total Crime Count for Full Moon versus Non-Full Moon categories by comparing against their total percentage that the crime type accumulates for that category instead of comparing strictly the counts against one another (e.g., Arson accounts for 2% of all Crime on a Full Moon over 18 years versus 2.5% of all Crime on a Non-Full Moon).

Another consideration that could be made is taking specific days as part of the analysis that could potentially influence results, namely holidays. When holidays occur on specific days of the week repeatedly over years these days could potentially be consistent in having the same moon type and thus skew the results. However, given the span of years that we analyzed we believe that some conclusions can be made about the results as our longer duration of study gives a higher likelihood of a variety of these holidays having unique moon types to make up for the bias.
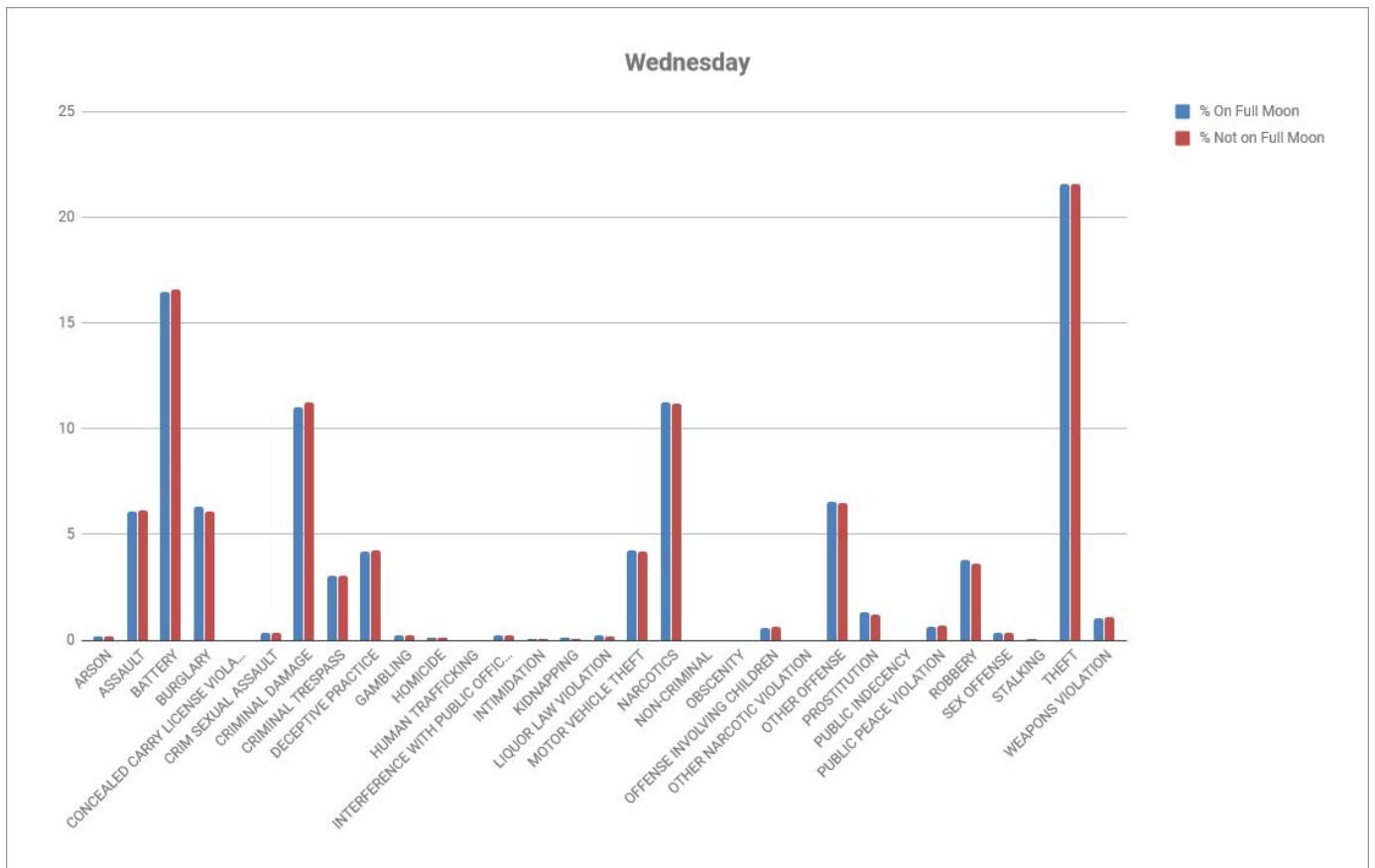
V. EXPERIMENTAL BENCHMARKS

Comparing individual crimes on Full Moon days vs all other days as a percentage of total crimes showed no significant difference in the types of crime committed. Fighting, vandalism, drugs, and theft were the dominant crimes in Chicago over
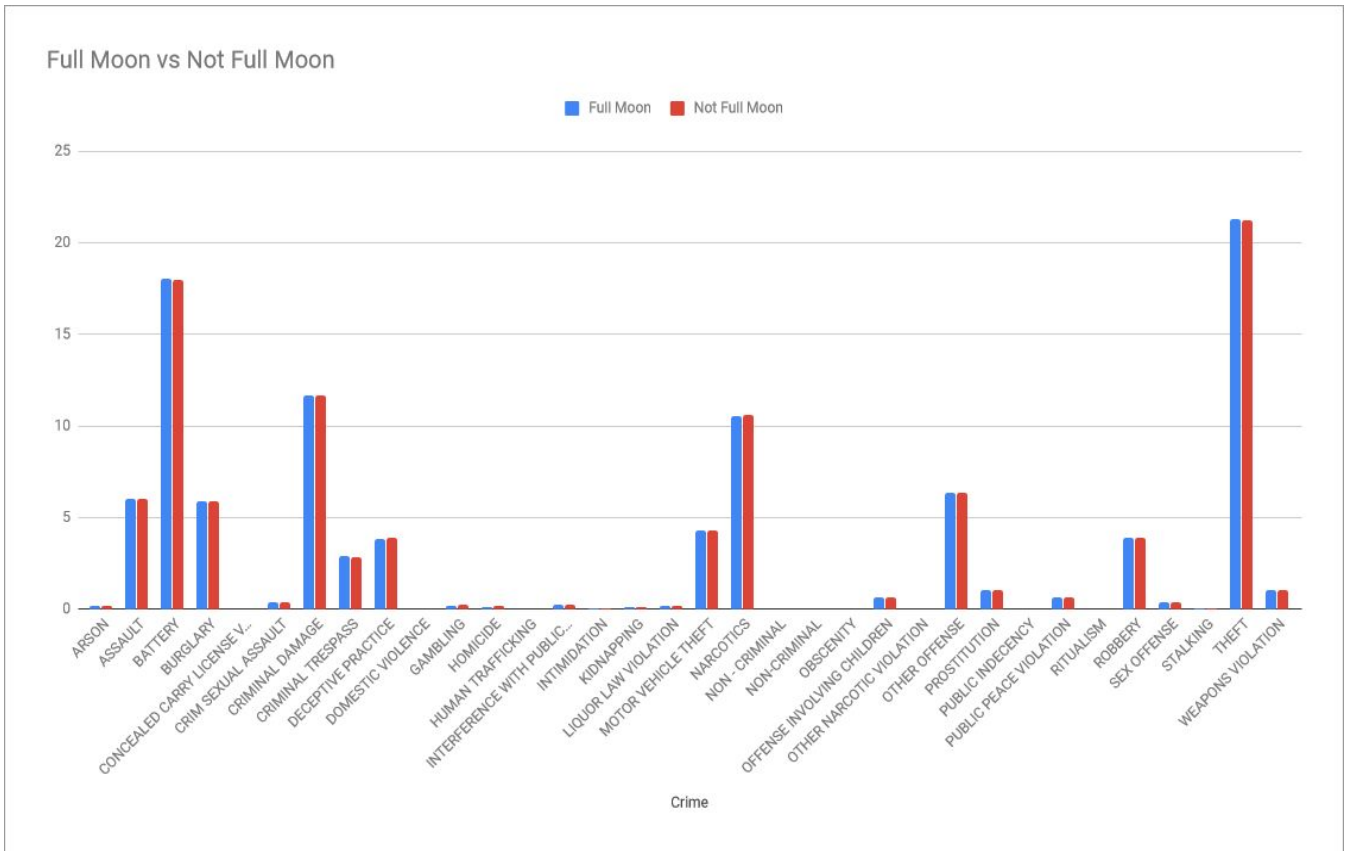
[Fig1: Full Moon vs Not Full Moon]
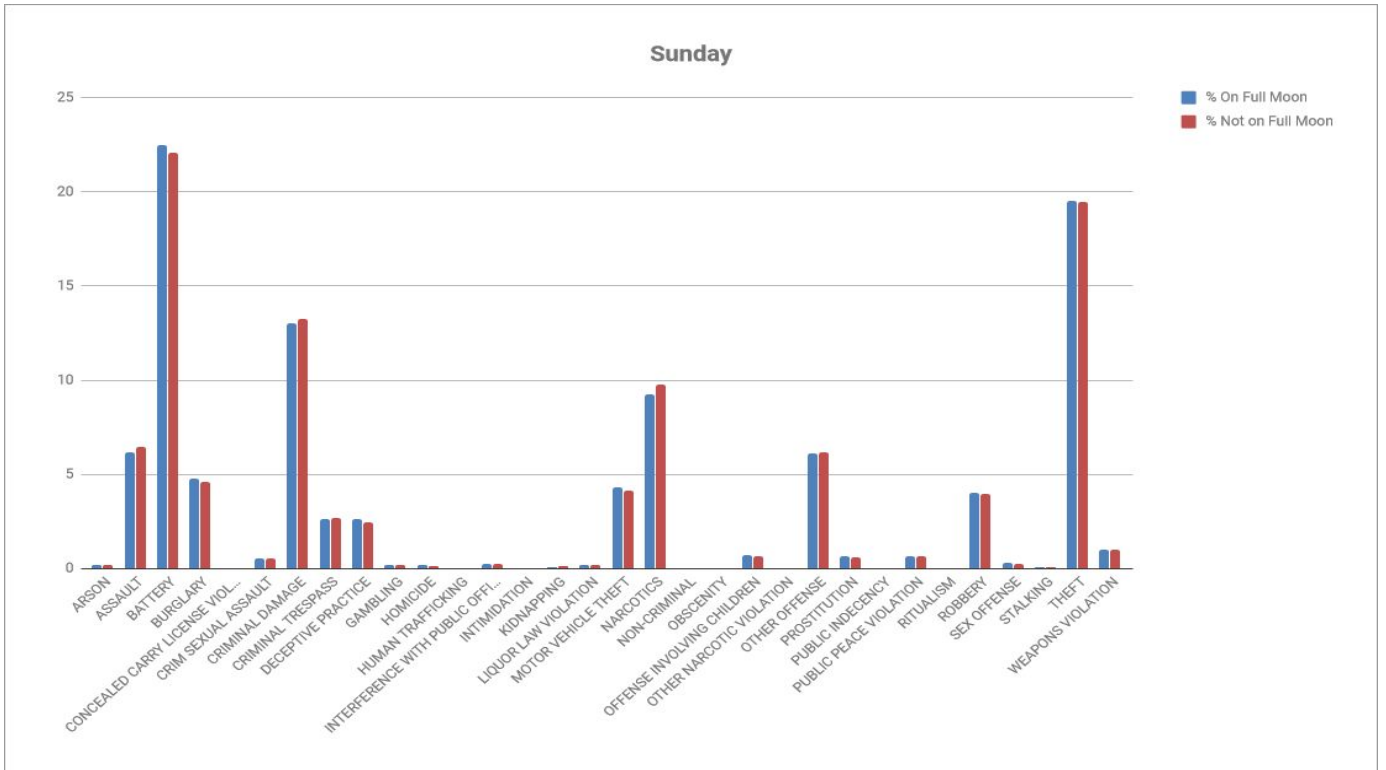
[Fig 2: Day of Week: Sunday]

[Fig 3: Day of Week: Wednesday]

the last 18 years. They occurred in the same ratio regardless of the phase of the moon.[Fig 1]

Drilling down a bit, we split the data by day of the week. As you can see, [Fig 2] the types of crime vary a bit depending on the day. Consider Sunday, where fights [Battery] average 22% of all crime on the day. This is a large uptick from Wednesday [Fig 3] where fighting only accounts for 16.5% of total activity.
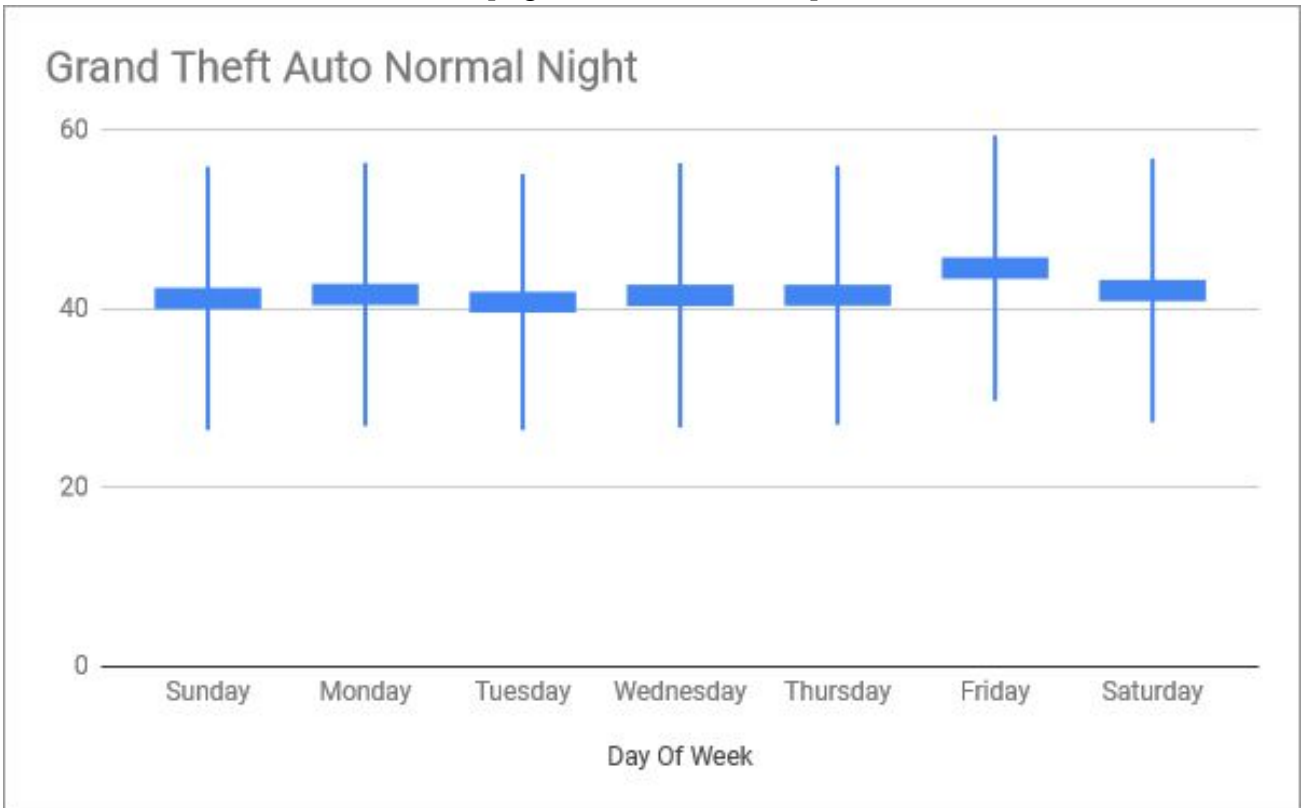
Ultimately, while there was a variation in the types of crime, there were only very small variations when comparing a full moon vs no full moon. For example, if we look at Motor Vehicle Theft, popularly referred to as Grand Theft Auto [Fig 4], you can see the ratio on the different days. The changes are slight, but no real trend is apparent. GTA crimes on a given day did not significantly change based on the moon.

Rather than looking at crime in relationship to each other as a percentage of total crime, we decided to examine the mean occurrence of a crime on a given day. For example, there are 41.2 vehicle thefts on Sunday when the moon is not full. When the moon is full, there is an average of 37.3 vehicle thefts. An exciting difference until you take the 95% confidence interval.
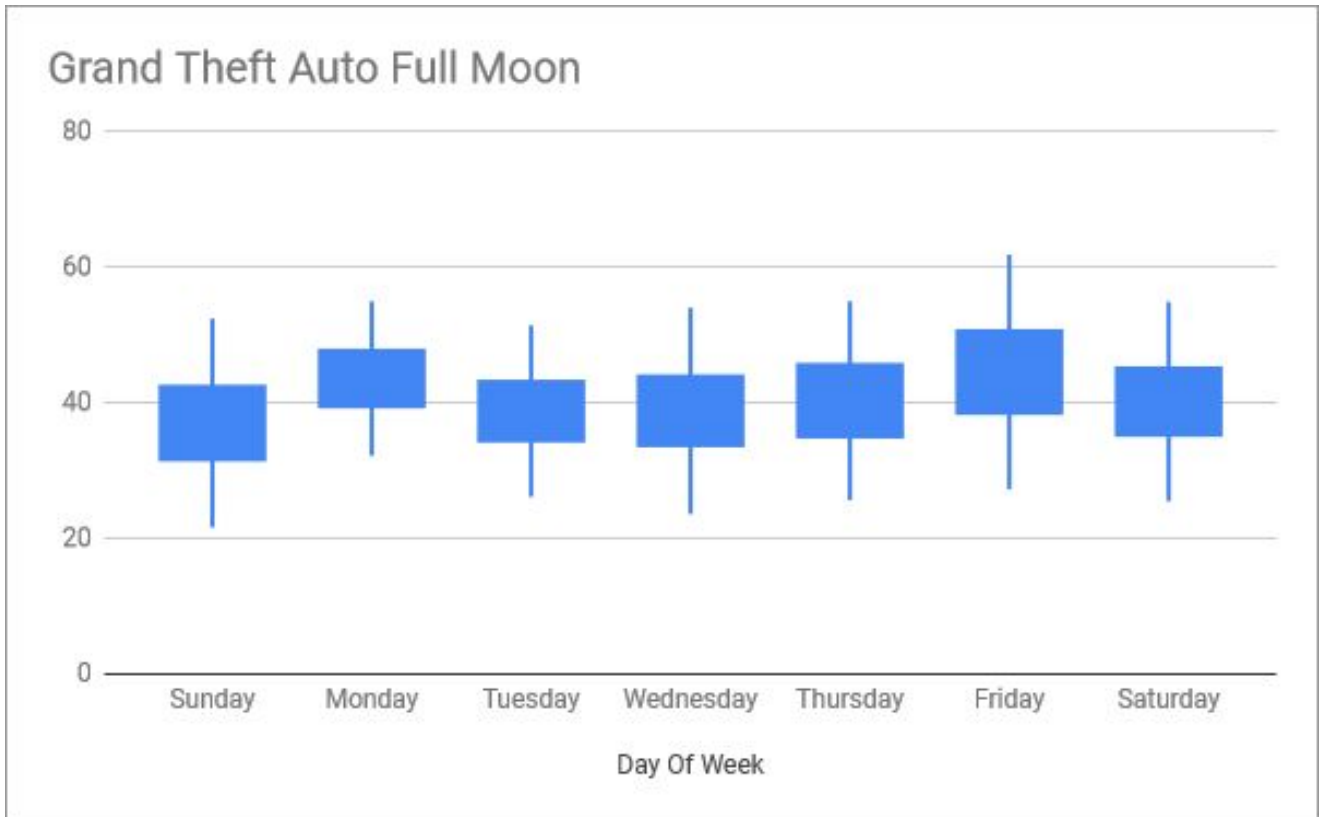
In the below graph, the high and the low are represented by the standard deviation, and the open and close (the candle part) is the confidence interval. With non full moon days, the 95% confidence interval is very tight. [Fig 5] However, the full moon data has a much wider interval because we have fewer data points. [Fig 6] Unfortunately, the two overlap, so we can't rule out the null hypothesis, that the full moon has no effect.
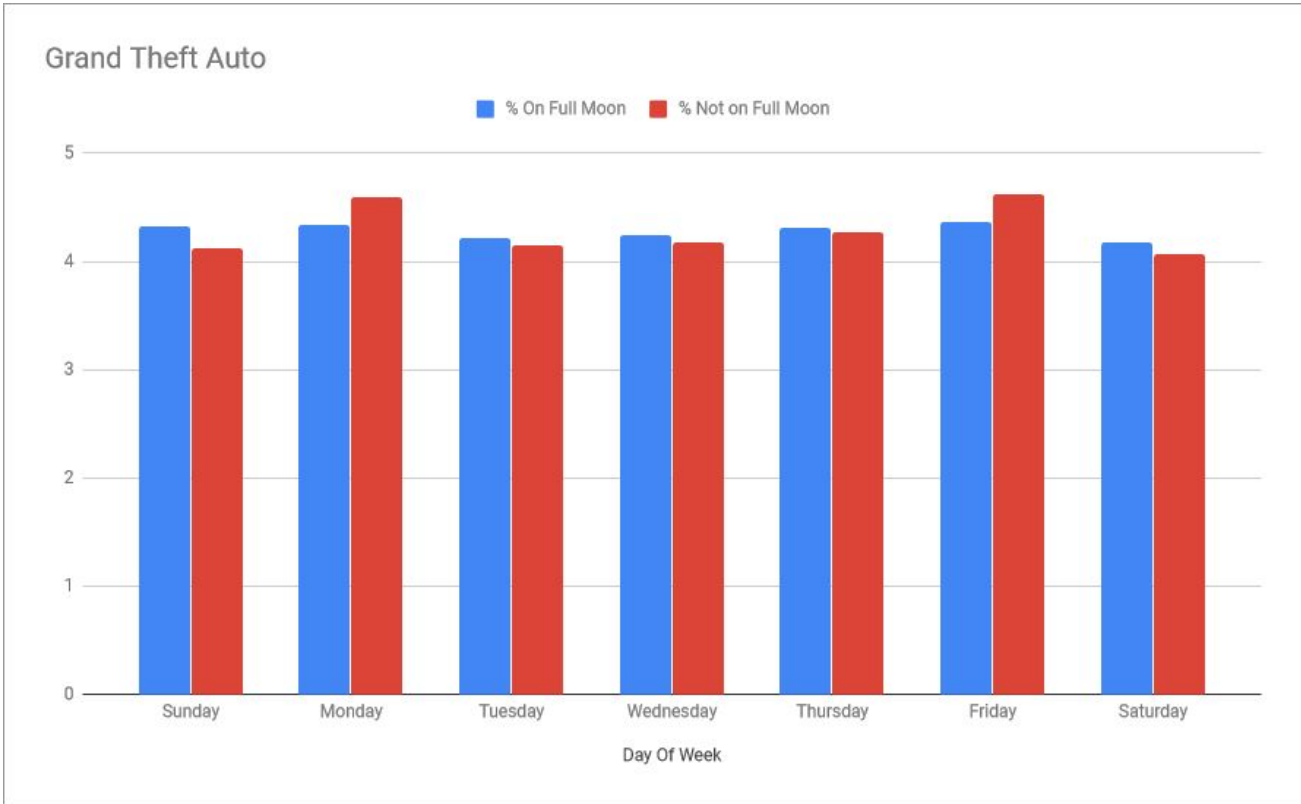
[Fig 4: Grand Theft Auto]
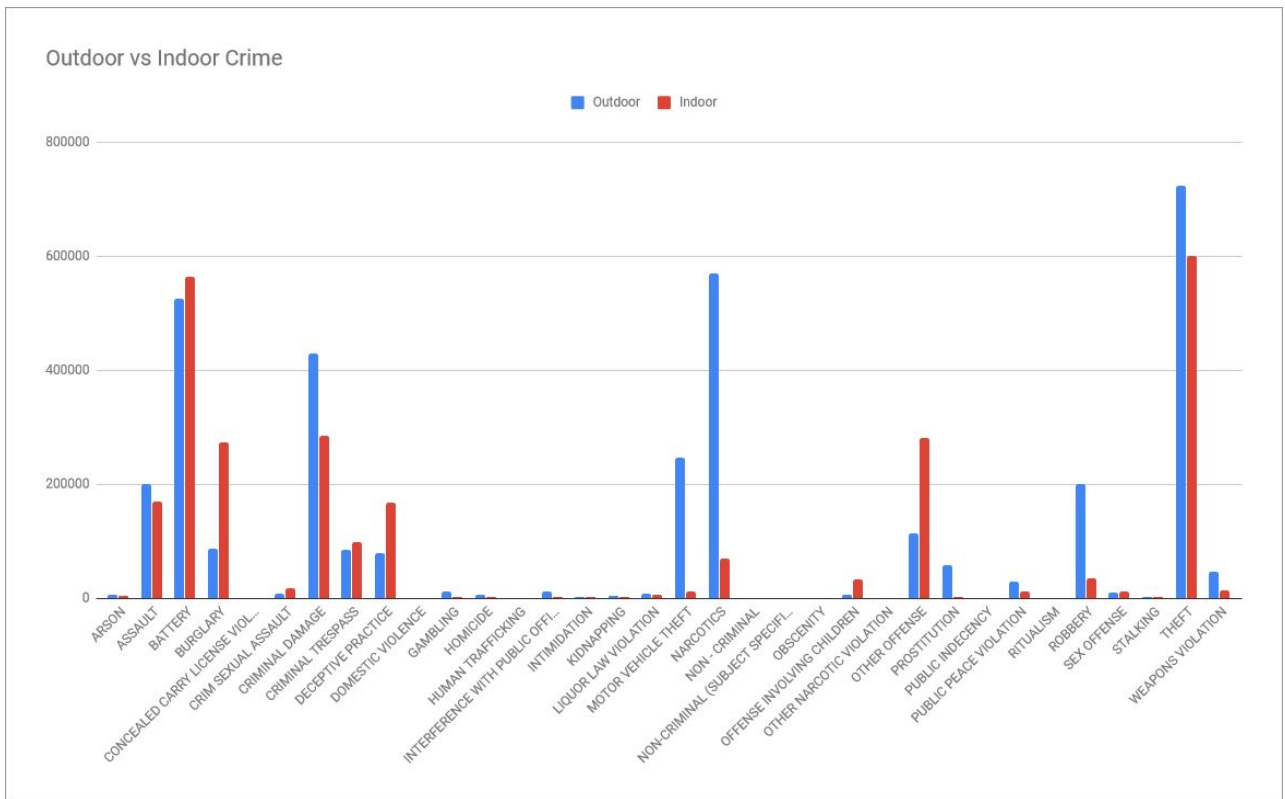
Grand Theft Auto Full Moon

[Fig 6: Grand Theft Auto: Full Moon Confidence]

The key variable that we wanted to account for was indoor vs outdoor crime. The previous studies tended to focus on indoor crime, but we hypothesized that the amount of luminosity from the moon would increase the likelihood of outdoor criminal activity. The idea being that visibility played an important role in committing a crime. Splitting the day based on location certainly shows a difference in the activity types. [Fig 7]

Unfortunately, this did not seem to affect the crimes on full vs non full days. Motor Vehicle Theft is clearly an outdoor activity, so as an example, here is the breakdown of the 95% confidence interval. [Fig 8] It looks very similar to the previous graph we looked at. A nice tight confidence interval for the larger non full moon data set. When you look at the full moon data, the interval spreads out and encompasses the non full moon average. [Fig 9]
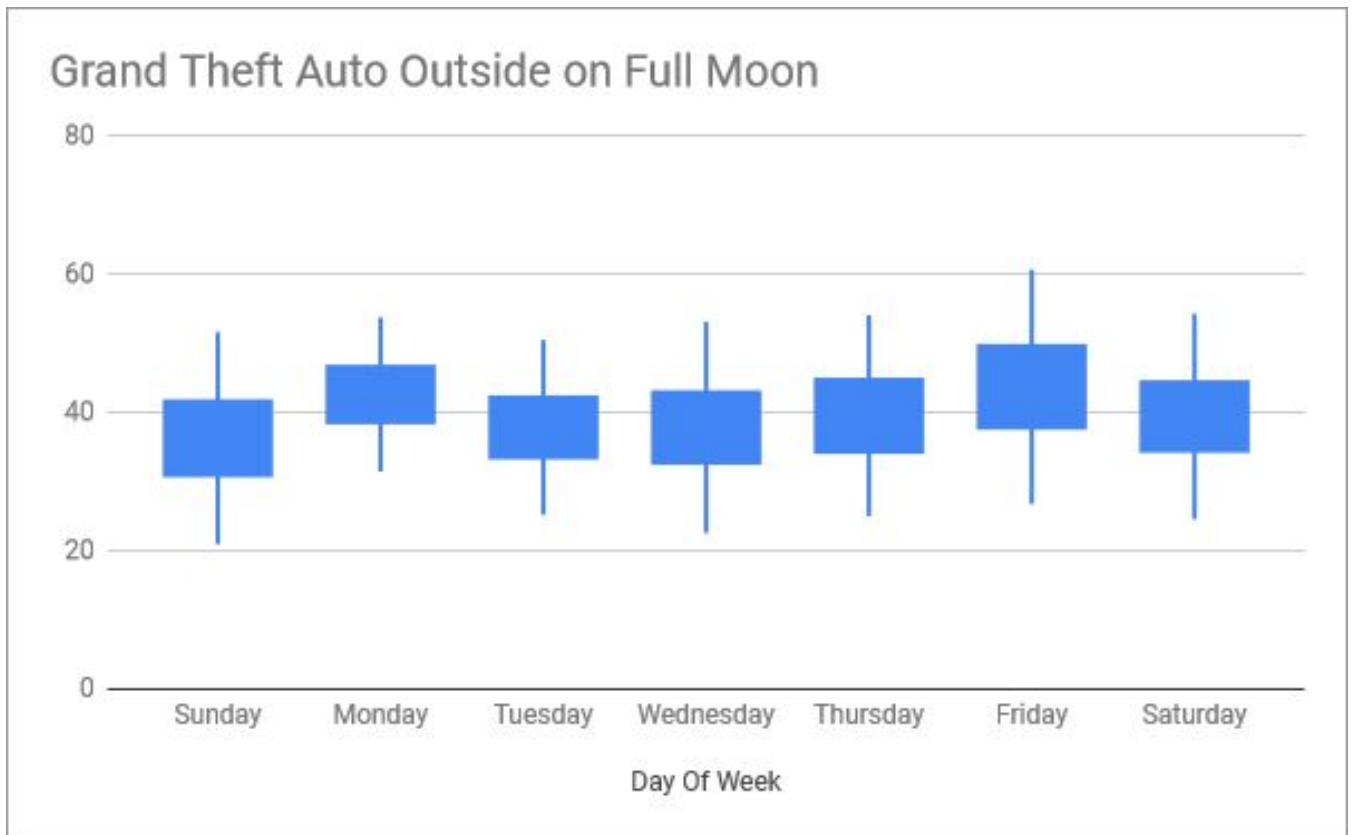
[Fig 7: Indoor vs Outdoor]
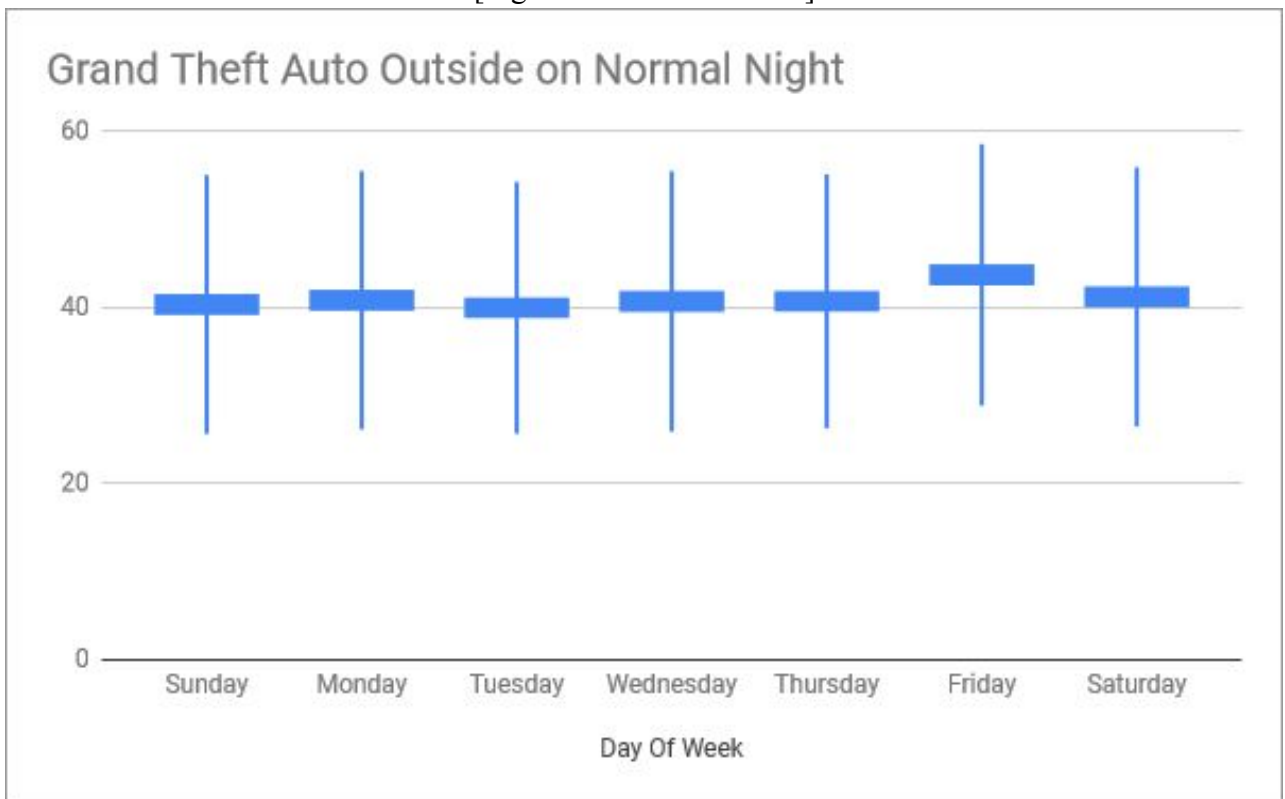
[Fig 8: Grand Theft Auto: Not Full Moon Outside Confidence]

[Fig 9: Grand Theft Auto: Full Moon Outside Confidence]

VI. INSIGHTS GLEANED

Most of the issues our project confronted were only apparent when analysis of our initial extracted metrics began to show flaws in our implementation. Data looked correct, but as we began to analyze it minor mistakes came forward, such as an incorrect comparison between Criminal Activity on Days with Full Moons versus Criminal Activity on all days where the all days category included Full Moons as part of the dataset. This would have lead to incredibly incorrect results without correction but was immediately rectified. We also had a gap in incomplete data, such as not including the total number of crimes for a given day of the week. Including this in our output allowed us to be consistent in our comparisons for Criminal Activity against percentage versus total number of crimes. Implementation of the Confidence Interval proved difficult because it required transforming a multi-column RDD of date, day of week, crime type, and crime location, to a Pair RDD. The Pair RDD required multiple iterations to calculate the mean and then the variance for each crime. We needed those results for the standard deviation and confidence interval.

With more accurate calculations, our initial analysis of our corrected data made us skeptical that we would be able to make any conclusions on our initial premise. Our hypothesis upon studying the results was that at the very least there would be one Criminal Activity that stood out on Full Moon days being dramatically higher or lower than Non-Full Moon days, but no Activity had a strong enough difference to make any substantive conclusions about it.

However, our own bias of looking at the Crimes that took up the majority of the dataset (such as Battery or Theft) had us overlook some of the smaller metrics we had gathered. When we looked at some of the smaller samples in our results we found metrics that were worth exploring more for correlations. One Criminal Activity trend that stood
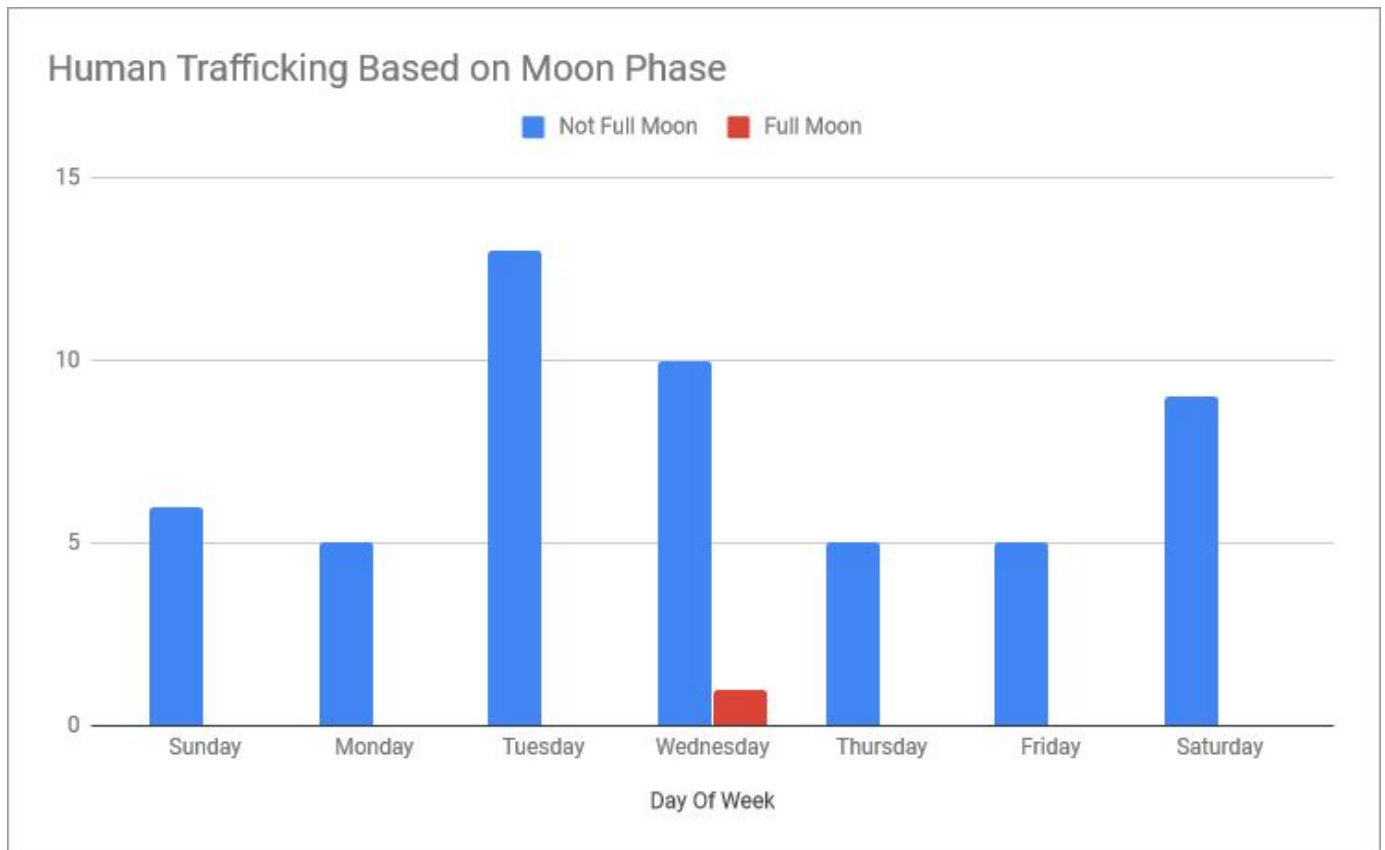
[Fig 10: Human Trafficking Graph]

out to us was criminals avoiding days with full moons entirely. One of these activities was Human Trafficking which almost never happened on a full moon.

When Human Trafficking takes into consideration its Confidence Interval of less than 1% it's clear that the results are fairly accurate. The number of data points for the less frequent crimes are too small to make any strong conclusions about a correlation, but the results do appear to be worth exploring further on other cities' datasets; perhaps where Human Trafficking has a higher percentile of the total number of crimes in the city.

VII.   Looking to the Future

If we look to the future and assume the following statements to be true it could be theorized that the rate of crime across the board will see a decline in activity due to the sheer fact that identifying and prosecuting criminals will be executed at a rate of confidence never seen before.

- The proliferation of surveillance devices continues at the rate we see today with city infrastructure becoming smarter and more connected
- Advancement in facial recognition and growing facial databases
- Improvements to real time AI crime detection techniques
- A higher percentage of crime data is digitally cataloged and publically available
- A greater number of weather history and data is stored digitally
- FPGA hardware acceleration ease of use improvements and greater access to services

With the addition of more accurate weather history, potentially interfering variables related to the weather can be accounted for when analyzing the problem space of this paper. As mentioned earlier in the paper, a cloud covered sky on the night of a full moon may have a direct effect on the full moon's influences and so being able to account for this will improve our analysis.

The advancement in AI crime detection techniques, proliferation in surveillance devices, improved facial recognition algorithms, larger facial

databases as more government departments transition online, and the growth of internet of things will greatly increase the size of the sample set. The increase in intelligent and automated 'Big Brother' like surveillance devices in our smart cities will most certainly help alleviate the problem of unreported crimes slipping through the cracks. Time is also our side allowing for a higher percentage of crime data to be made available digitally. The Chicago crimes dataset used in this paper only spanned the last 19 years.

With a dramatic increase in the number of datasets and the size of these datasets a more efficient method of conducting analyzes in regards to throughput is needed. FPGA as a service (FAAS) will be more widely available and the barrier to entry for data scientists and software developers alike will be dropped significantly. This opens up the Spark framework and its users to the phenomenal throughput advantages FAAS has to offer.

Having a larger and more accurate picture of criminal activity will allow for the confidence interval range of our analysis to be tightened, further enabling a clearer picture of the relationship between the full moon and the rate of crime to be developed.

VIII. CONCLUSIONS

After several iterations and analyzing our data, we believe that for the vast majority of Criminal Activity in the Chicago area that there is no correlation at all with the Full Moon. Any disparities between Full Moon and Non-Full Moon days, even with taking the location of indoor and outdoor into account, ended up showing insignificant differences between any specific criminal activity. This conclusion is supported further with our Confidence Interval taken into account, that even with the widest error percentile between our two moon categories and crime type the total percentage that any crime accounts for still does not show an increase in that crimes' activity. We performed thorough analysis of the data to ensure that any bias was taken into account and eliminated as much as possible. While we found some interesting behavior in some unique criminal

activities that, if anything, proved the opposite. They showed that some criminal activity was avoided under a full moon, but even these results don't yield significant metrics to make a strong conclusion in the opposing side. There is potentially more bias that can be removed from the analysis, such as accounting for holidays where criminal activity could skew the results in either direction depending on the Moon Phase. Furthermore, the criminal activity that did show little activity under a full moon could be compared with other cities to investigate any correlation between those crime types and the moon, potentially with a larger number of those activities to allow for more substantial conclusions to be made on this correlation.

Our project set out to study the environmental phenomena that may potentially cause harm to a society. The full moon and its association with increased aggressive behavior is embedded in many cultures today still. Available studies showed conflicting results of the matter, and there has yet to been an analysis at this scale in terms of both duration and variety of criminal activity to conclude if there is any impact that the natural activity of the moon phase has on public safety. This study shows that there is indeed little to no impact that a moon phase has on criminal activity and can eliminate it as a threat to society. Society can better learn from these results by investing more analysis and resources into evaluating if there are other natural phenomena that may cause a higher impact on the safety of society.

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