THE GRAVITATIONAL EFFECTS ON THE VOLCANISM OF IO. K. M. Naegeli [1], H. L. Lehto [1], K. W. Carrell [1], Angelo State University [1], 2601 W Ave. N, San Angelo, TX 76909 (knaegeli@angelo.edu).

Introduction: Jupiter's closest moon, Io, is one of the most volcanically active bodies in our solar system. Since the first satellite flyby, we have seen volcanic eruptions occurring continuously on the surface and have calculated around 30.3% of the total surface of the moon to be lava flows or patera floors (Williams, D. et al. 2011). There are hundreds of active volcanoes or patera, (irregular crater-like shapes that are not formed by meteor impacts, but can include volcanic activity) which litter the surface of Io (Radebaugh, J., et. al., 2001). Most of the volcanoes are relatively small, ranging from just several kilometers to tens of kilometers across (Williams, D. et al. 2011). Most of the volcanoes have been observed to be located towards the poles of Io and their eruptions can last from a few hours or up to a day in eruption length.

To understand why there is such a high amount of volcanism on Io, we must take a look at its surroundings and the environment that may cause the moon's volcanism. As seen with our own moon, tidal forces are present on Earth in the form of ocean tides which are produced by the pull of the Moon's gravity. Io has an eccentric (or oval shaped) orbit, with an eccentricity (e), of about e=0.0041(Brahe, T, n.d.). Along with having an eccentric orbit, Io is also tidally locked, so that only one side faces Jupiter at all times. As seen with our own moon, tidal forces are present on Earth in the form of ocean tides which are produced by the pull of our Moon's gravity. For Io, it is believed that tidal movement can be seen in the formation of magma and the buckling of the crust, allowing the gravitational force to be expelled on its surface either through eruptions of volcanoes or crustal bulging. It has been proposed that the tidal forces are the cause of the major volcanism seen on Io. Because of the large size difference, the gravitational pull of Jupiter causes Io to heat up due to the tidal forces in the form of friction and crustal budging. The stretching and squeezing produces heat which is then released from Io in the form of volcanoes and lava flows, similar to the way the ocean water on Earth is shifted and moved by our Moon to create tides (De Pater, I., A, 2014).

To test the hypothesis that volcanism on Io is produced by the gravitational forces imposed by Jupiter, this study analyzes the instances of volcanic eruptions observed by others and published in existing literature to look for periodic trends, which are then compared to Io's orbital period of 1.77 days or 42.48 hours.

Experimental Methods: In order to identify any periodicity in the eruptions caused by gravitational forces, we must find the location in Io's orbit around Jupiter where the eruptions occur the most.

Dates of eruptions observed on Io were collected from many different sources of data previously published. All of the dates of the eruptions were converted into Julian dates. The lowest Julian date in the data set for this study was subtracted from all of the other Julian dates to provide the beginning of the orbit (being 0.0). Then was divided by the period that it takes Io to orbit Jupiter (1.77 days or 42.48 hours), which produced the number of orbits that Io has experienced since the first eruption was recorded in this study's data set. Focusing only on the remainder in the number of orbits Io had completed, we are able to identify in decimal how much of the next orbit Io was in when the eruption was recorded. The fractional part of the orbit was then recorded in the form of histograms (Figures 1-3) to show the relationship between location in Io's orbit and the amount of eruptions that were recorded that have the same decimal value. Figure 1 shows every eruption collected in this study, figure 2 shows the eruptions from the volcano, Pele, and figure 3 shows the eruptions from Pilian patera. Pele and Pilian are the two most notable volcano and patera, allowing them to have more data on their eruptions.

Results and Interpretations: In analyzing Figure 1, there is an increase of volcanic eruptions at three parts of the orbit. The first cluster begins at 0.0 and lasts until 0.1 peaking at 12 eruptions that produced the same fractional location into the next orbit. The other two clusters occur towards the end of one full orbit, located at 0.7- 0.8 with a peak of 19 eruptions and a total of 66 eruptions in the span, and 0.85-0.95 with a peak of 25 and a total of 63 eruptions within the range. These three areas could be signs of gravitational impact on the volcanism.

In Figure 2, the histogram represents eruptions just from Pele. There is periodicity throughout the data collected, almost every other bar, representing 0.03 of the orbit in width, starting at 0.02 of the orbit. There is some

variance in the periodicity though, ranging from 0.03-0.06 between peaks of volcanism. Between 0.7-0.8 of the orbit there is a large amount of eruptions, which could be due to gravitational forces since it affected the full data histogram as well (figure 1).

Figure 3 represents the eruptions for Pilian. There is no periodicity seen in the histogram for the volcano itself based on the data collected, but there is an increase in eruption from 0.7-0.8, which correlates to both of the other histograms (figure 1 and 2), and 0.0- 0.1 and 0.85-0.95, and is seen in the full eruption histogram (figure 1). These three locations could be regions that tidally influence the eruptions of this patera.

Overall, there is some periodicity in the eruptions on Io between the locations 0.0-0.1, 0.7-0.8, and 0.85-0.95 in Io's orbit. These three locations could be due to the influence of the tidal forces exerted on Io, which would cause more eruptions to take place at these specific locations in Io's orbit. There is also evidence of periodicity in the volcano Pele spanning around 0.03 of the orbit starting at 0.02.

By identifying areas in Io's orbit that have more eruptions, we could begin to understand why those specific areas are affected more than other areas in future studies.

Resources:

Williams, D. A., Keszthelyi, L. P., Crown, D. A., Yff, J. A., Jaeger, W. L., Schenk, P. M., .Becker, T. L. (July 2011). Volcanism on Io; new insights from global geologic mapping. Icarus, 214, 91-112. http://dx.doi.org.easydb.angelo.edu/10.1016/j.icarus.2011.05.007

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Brahe, T, (n.d.), Kepler's Law. Retrieved from http://hyperphysics.phy-astr.gsu.edu/hbase/kepler.html

De Pater, I., A. G. Davies, M. Ádámkovics, and D. R. Ciardi (2014), Two new, rare, high-effusion outburst eruptions at Rarog and Heno Paterae on Io, Icarus, 242, 365–378, doi:10.1016/j.icarus.2014.06.016.

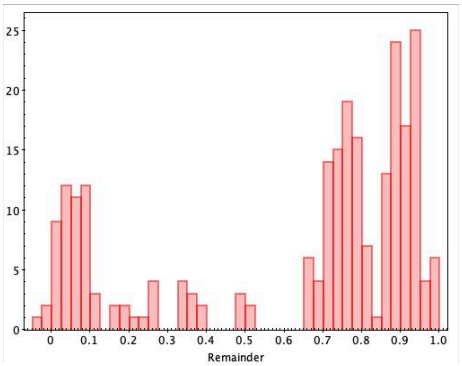

Figure 1. Full eruption data (includes all volcanoes with data on eruptions). The graph shows the number eruptions seen in the location of Io in its orbit around Jupiter. 0.0 represents the location where the orbit begins and 1.0 is one complete orbit.

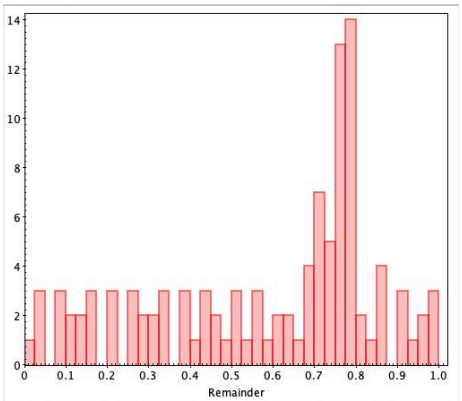

Figure 2. Pele eruption histogram. The graph shows the number eruptions seen in the location of Io in its orbit around Jupiter. 0.0 represents the location where the orbit begins and 1.0 is one complete orbit.

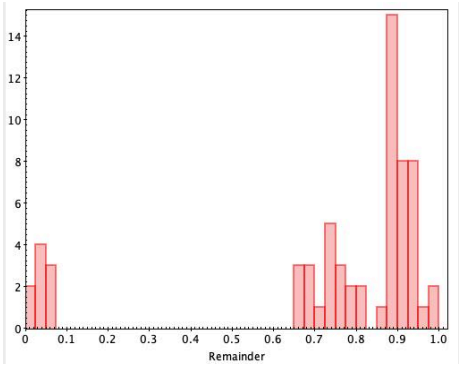

Figure 3. Pilian eruption histogram. The graph shows the number eruptions seen in the location of Io in its orbit around Jupiter. 0.0 represents the location where the orbit begins and 1.0 is one complete orbit.