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ON THE SOLAR CORONA PETROGLYPH IN THE CHACO CANYON

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ABSTRACT

Piedra del Sol is a free-standing rock in Chaco Canyon that marks June solstice sunrise. The petroglyph on the south face of Piedra del Sol in Chaco Canyon may depict the solar corona observed during the total solar eclipse of July 11, 1097 CE The southwest area of the rock contains features consisted with a sun watching station and faces December solstics sunset. During the 19th century, coronal mass ejection appears to have been observed during two total solar eclipses. The petroglyph on the south face appears to show a configuration of the solar corona that is consistent with a coronal mass ejection (CME). The hypothesis that a CME is depicted at Piedra del Sol is testable and can be disproven if the maximum of solar activity did not occur near 1097 CE. Recent studies indicate that 1097 CE was inded close to solar maximum. Miyahara et al. (2010) locate the maximum in 1098 CE based upon cosmogenic-isotopes. Vaquero and Trigo (2012) also found that 1098 CE was a maximum of solar cycle using a combination of documentary sources. The eclipse of 1097 CE occurred during a period of high solar activity, consistent with the interpretation of the petroglyph as a representation of solar corona during the solar eclipse of that year.

KEYWORDS: Chaco Canyon, petroglyph, solar eclipse, coronal mass ejection

1. INTRODUCTION

One of the more interesting petroglyphs with possible astronomical meaning in the southwest of USA is located in the southern face of the Piedra de Sol in Chaco Canyon. This petroglyph can be described as an unusual circle with curved rays, which resemble the curved coronal structures of the eclipsed sun during a coronal mass ejection or, even, exaggerations of curved polar streamers of the corona. Malville (2008) has noted that the totality path of the eclipse of July 11, 1097, crossed the Chaco Canyon. In fact, it was the only visible total eclipse during the period of maximum great house construction (1020-1130 CE) in Chaco Canyon. The representation of a Coronal Mass Ejection (CME) in this petroglyph is a hypothesis that is impossible to prove, but it can be tested and falsified.

2.1 Coronal Mass Ejections

During peak of solar activity, which occurs approximately every 11 years, the sun produces about three coronal mass ejections (CME) every day, while at minimum solar activity the frequency drops to one every five days. CMEs consist of a collection of electrons and protons entangled in a magnetic field. Their speeds range from 20 km/sec to 3200 km/sec. Typically they start with a slowly rising bubble near the sun's surface, followed by rapid acceleration. Most CMEs miss the earth, but when one reaches the earth it causes a disruption of the magnetosphere, which results in strong auroral displays around the earth's magnetic poles. It also may disrupt radio transmission, endanger electrical circuits, and damage satellites.

During the twentieth century CMEs were reported during two total eclipses. At the Spanish eclipse of July 18 the astronomer Gugleimo Temple, stationed in Torreblanca, recorded in a drawing an anomalous feature of the corona, which appears to have been a CME (Figure 1). Of the 46 firsthand accounts of that eclipse that were made across Spain, about half reported observing this feature (Eddy 1974).

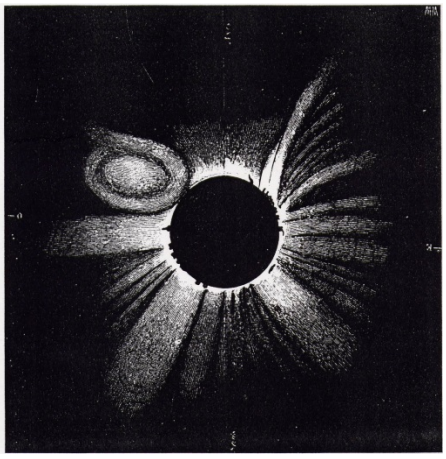

Figure 1 Drawing of the eclipse of July 18, 1860 by Tempel

The second CME was photographed in Chile using the Schaeberle 40 foot camera of Lick Observatory on April 16, 1893. Schaeberle made a remarkable tracing of prominences and structures of the corona using eight 18x22 inch glass plates (Figure 2; Pearson 2010). Cliver (1989) has suggested the feature in the lower right that is labeled "comet" was another CME.

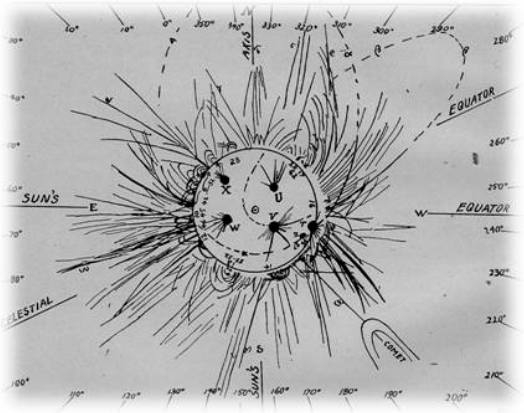

Figure 2. Drawing of coronal structures by Schaeberle for the total eclipse 16 April 1893. A coronal mass ejection appears in the lower right-hand side of the figure labeled as a comet.

2.2 Piedra del Sol

In the summer of 1992, the University of Colorado and Ft. Lewis College organized a field school in archaeoastronomy, lead by jointly by W. James Judge and J. McKim Malville. During that field school, one of the staff, Rick Watson, discovered a large spiral petroglyph on a free standing rock near the visitors' center in Chaco Canyon

(Figures 3-6). It appeared possible that a pyramidal rock on the northeastern horizon would cast a shadow on the spiral close to June solstice. The following summer, that possibility was confirmed by GB Cornucopia (Watson et al. 1996). The south face of the rock contains a number of petroglyphs, including two of Kokopeli and an unusual one that appeared to depict the total solar eclipse of July 11, 1097 (Figures 7-10). In addition, the southwest side of the rock contains a pecked basin and a grinding area (Figures 11 & 12), which are often found associated with astronomical observing stations in Mesa Verde (Malville and Munson 1998). Later that year, Cornucopia confirmed that the southwest side of the rock faced December solstice sunset near a prominent horizon feature. Because of the multiplicity of solar events that appears to be associated with the rock, we proposed that it be named "Piedra del Sol."

Figure 3. Piedra del Sol Piedra del Sol, viewed from the east. The side of the rock to the left, slightly in shadow, contains the possible coronal petroglyph.

Figure 4. Spiral petroglyph on the northeast side of Piedra del Sol.

Figure 5. June 5 Sunrise viewed from the center of the spiral.

Figure 6 June summer solstce viewed from the center of the spiral.

Figure 7 Possible solar eclipse petroglyph

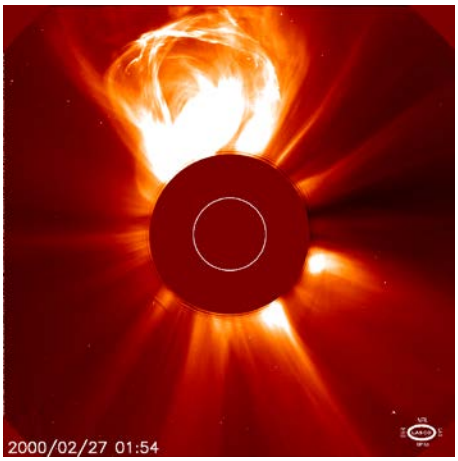

Figure 8 Coronal mass ejection, March 9, 2000 (SOHO spacecraft, NASA)

Figure 9 South Face of Piedra del Sol showing the possible eclipse petroglyph and two Kokopeli petroglyphs

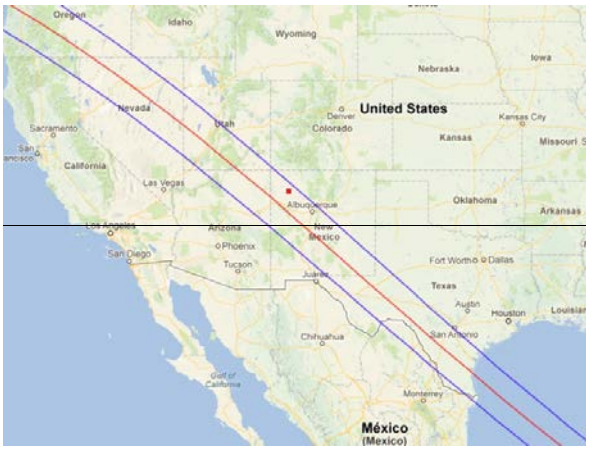

Figure 10 The path of the solar eclipse of 11 July 1097. Red square represents the Chaco Canyon (eclipse predictions by Fred Espenak, NASA's GSFC).

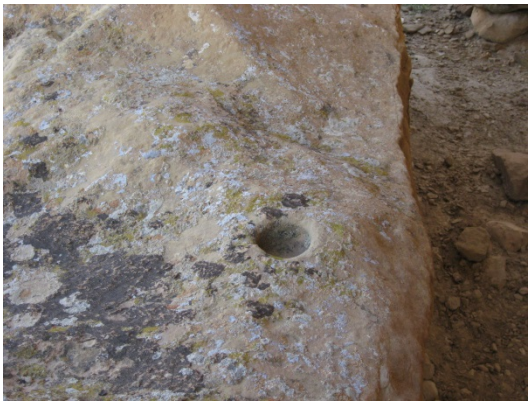

Figure 11 Pecked basin on west side of Piedra del Sol

Figure 12 Grinding area on west side of Piedra del Sol

2.3 Solar Activity during 1097

We use the high dependence of the observed solar corona during total eclipses upon the solar cycle to check the consistency of the hypothesis of the solar corona represented in the petroglyph of the "Piedra del Sol". If AD1097 was a year of low solar activity, the solar corona would be very different from the one represented in the petroglyph in which case the hypothesis of the solar corona represented in the Chaco Canyon should be abandoned. However, if AD1097 was a year of high solar activity, the hypothesis would be strengthened.

Fortunately, some recent studies can help us to check the status of solar activity around 1097. Therefore, the aim of this paper is to show that this hypothesis is compatible with the state of solar activity in this date.

We have some sources to study the past solar activity. First, we have some documentary sources describing auroral observations (Eather 1980) or records of sunspots with the naked eye (Whittmann and Xu 1987) . These records are not very homogeneous but have a high temporal resolution. Moreover, we also have indirect evidence of past solar activity based on cosmogenic radionuclides (e.g., ^{10}Be and ^{14}C), which are produced by cosmic rays in the Earth's atmosphere. These records are more homogeneous but have a lower temporal resolution than historical documents. Obviously, both sources have their advantages and disadvantages.

We have compiled the available information on solar activity around AD1097 in Figure 3. The red line represents the smoothed sunspot number reconstructed by Solanki et al. (2004) based on dendrochronologically dated radiocarbon concentrations. Note that the resolution of these data is not enough to detect the 11-year solar cycle. However, 1097 is located very close to a local maximum, the first one after the Oort Minimum (1010–1070) and the first one belonging to a period of relatively high solar activity called Medieval Solar Maximum (1100–1250) (Jirikowic and Damon 1994).

In Figure 13, the annual number of naked-eye observations of sunspots (Vaquero et al. 2002) is represented by the blue line and the annual number of auroral nights (from the catalogue compiled by Křivský and Pejml (1998) is represented by the orange line. Arrows of these colors correspond to estimated maxima of solar cycle using naked-eye observations (blue) and auroral nights (orange) respectively (Vaquero and Trigo 2012). Finally, green arrows correspond to the estimated maxima of solar cycle using a high resolution ^{14}C record from tree rings (Miyahara (2010). Therefore, different records are available to assess the phase of the solar cycle around 1097 using documental records and cosmogenic proxies. Both kinds of information suggest that the date of maximum of the solar cycle is close to 1098. This fact is, therefore, a support for the hypothesis of the solar corona represented in the petroglyph of the "Piedra del Sol".

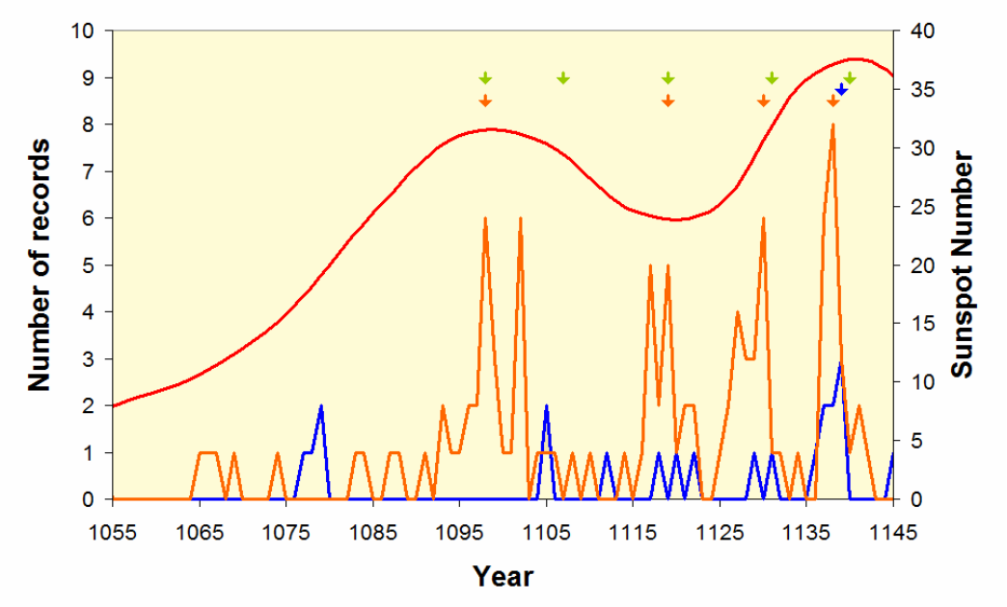

Figure 13 Various solar activity proxies during the period 1055–1145. See text for details.

2.4 The Supernova of 1054CE

This is not the only petroglyph in Chaco Canyon that has been identified with a transient astronomical event. The well-known pictograph, containing a hand, a crescent moon, and a 10-pointed star below the Great House of Peñasco Blanco has been identified (Fisher 2010) with the supernova of AD 1054. That identification has however been questioned on several issues. The anthropologist Florence Halley Ellis pointed out that the rock art symbols of the pictograph are common among rock art of the Pueblos They may have been clan symbols, and she suggests the star more likely was a representation of Venus. Two other sites containing a combination of star and crescent moon that had been identified with the 1054 supernova have also been recently re-evaluated and found wanting. Their identifications with a supernova have also been found to be unlikely (Krupp et al. 2010)

2.4 Eclipse of 1097

In the case of the Piedra del Sol, the putative image of the corona is unique among the rock art symbols of the American Southwest. It certainly does not appear elsewhere in Chaco Canyon. Furthermore, this rock appears to have been a place for monitoring and celebrating the cyclic behavior of the sun. On its east side rock the large spiral petroglyph marks June solstice as well as providing a 15-16 day anticipation of the event. As viewed from the center of the spiral, the sun begins to climb the southern edge of a pyramidal rock on the horizon more than a month before solstice and reaches the top of the rock on June 5. Monitoring the movement of the sun after solstice may well have continued past July 11, and hence people following the behavior of the sun could have been in the neighborhood of Piedra del Sol at the time of the eclipse.

This eclipse had very good viewing conditions in Chaco Canyon: it occurred in mid-after-noon, the sun's altitude was high (58°) and the eclipse had a long duration (4 minutes). One of the often dramatic features of a total eclipse is the sudden appearance of Venus near the sun. At the time of this eclipse Venus had a visual magnitude of -4 and appeared to the east of the sun 10^{o} higher in the sky. The round pecked mark above the petroglyph may represent Venus observed during the eclipse (Figure 9).

The petroglyph panel on the south side of the rock contains two images of Kokopeli, the flute player (Figure 8). The presence of the flute player on a rock so devoted to the sun raises the interesting possiblility of a connection between flute playing and solar ritual. We do know that the sun plays a major role in the Blue and Drab Flute Societies of the Hopi. Sun symbols were used in the regular flute ceremonies. These two societies have one day each in winter and summer for special prayer offerings to the sun called Tawa Baholowu (Voth 1912). The summer ceremony of the Drab Flute Society in June involved quartz crystals for throwing rays of sunlight into a medicine bowl (Voth 1903). Flutes may have played a role in summing or bringing up the sun.

The year 1097 lies within a transitional period of Chacoan culture, when the Classic Bonito Phase of Great House construction was ending and a different style of social organization of the Late Bonito Period was commencing (Van Dyke 2007). A prolonged drought in the Chaco Basin in the decade of 1090 may have weakened the credibility of ceremonies performed Chaco Canyon to maintain sufficient agricultural production. The drought may brought about social tensions that caused migrations out of the Canyon, such as to Salmon Pueblo in the north. The sun must have been an object of great importance, and its eclipse, which would have been observed over a large portion of the Chacoan sphere of influence, could have further diminished the credibility of sun rituals performed in canyon. The eclipse may thus have been more significant than a puzzling event in the sky. Because the eclipse was concomitant with environmental and social changes in the canyon, it may warranted a recording on the rock of Piedra del Sol.

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REFERENCES

Cliver, E. W. (1989) Was the eclipse comet of 1893 a disconnected coronal mass ejection? *Solar Physics,* 122, 319-333.

Eather, R. H. (1980) *Majestic Lights: The Aurora in Science, History, and the Arts.* Washington DC American Geophysical Union.

Eddy, J. A. (1974) A Nineteenth-century Coronal Transient. *Astronomy and Astrophysics,* 34, 235-240.

Fisher, V. B. (2010), Classic Object Lessons in Southwestern Archaeoastronomy, *Archaeoastronomy, The Journal of Astronomy in Culture* xxiii, 27-34.

Krupp, E.C., E. Billo, and R. Mark, (2010) Star Trek: Recovery and Review of the First Alleged Supernova Rock Art, *Archaeoastronomy, The Journal of Astronomy in Culture* xxiii , 35-43.

Křivský, L. and K. Pejml, (1983) *Solar activity, aurorae and climate in central Europe in the last 1000 years,* Publication of the Astronomical Institute of Czechoslovakia No. 75, Prague.

Jirikowic, J. L. and P. E. Damon (1994), "The medieval solar activity maximum" *Climatic Change*xxvi, 309–316.

Malville, J. McKim (2008) A *Guide to Prehistoric Astronomy in the Southwest.* Boulder, Johnson Books.

Malville, J. McKim and Gregory Munson (1998) Pecked Basins of the Mesa Verse. *Southwestern Lore,* 64, 1-35.

Miyahara, H (2010). Variations of Solar Activity and Climate during the Past 1200 Years, *Journal of Geography* cxix, 510–518.

Schove, D. J. (1980) (ed) *Sunspot Cycles.* Stroudsburg, PA, Hutchinson Press.

Solanki, S. K., I.G. Usoskin, B. Kromer, M. Schuessler, and J. Beer, "An unusually active Sun during recent decades compared to the previous 11,000 years",*Nature*, cdxxxi, 1084–1087.

Van Dyke, R. (2008) *The Chaco Experience: Landscape and Ideology at the Center Place.* School of American Research, Santa Fe.

Vaquero, J. M., M. C. Gallego and J. A. García (2002) A 250-year cycle in naked-eye observations of sunspots, *Geophysical Research Letters* xxix.

Vaquero, J. M. and R. M. Trigo (2012) A Note on Solar Cycle Length During the Medieval Climate Anomaly, *Solar Physics* cclxxix 289–294.

Voth, Henry R. (1903) Oraibi Summer Snake Ceremony. *Field Columbian Museum Publication* No 83. Anthropological Series Vol 3 No 4.

Voth, Henry R. (1912) Tawa Baholawu of the Oraibi Flute Societies" Publications of the Field Museum of Natural History. Anthropological Series Vol. 11, No. 2, Brief Miscellaneous Hopi Papers.

Watson, Richard P., J. McKim Malville, and GB Cornucopia (1996) The Petroglyphs of Piedra del Sol in Chaco Canyon. Poster presented at the Oxford V Conference, St. John's College, Santa Fe, August.

Wittmann, A.D. and Z. T. Xu, (1987) A catalogue of sunspot observations from 165 BC to AD 1684, *Astronomy and Astrophysics Supplement Series* lxx , 83–94.

Yau, K. K. C. and F. R. Stephenson, (1988) A revised catalogue of far eastern observations of sunspots (165 BC to AD 1918), *Quarterly Journal Royal Astronomical Society* xxix, 175–197.