ELECTRYONE
ΗΛΕΚΤΡΥΩΝΗ
ISSN 2241-4061
9 772241 406118

ARE THE NEWGRANGE ENGRAVINGS EVIDENCE OF SOLAR OBSERVATION?

Raul Perez-Enriquez, Emiliano Salinas
Departamento de Física
Universidad de Sonora
raul.perez@unison.mx
esalinas@correo.fisica.uson.mx

ABSTRACT: A discussion about a possible origin of the engravings at Newgrange Mound is given. The engravings are one of the most famous megalithic tombs in Ireland that could be evidence of 'pinhole optics' used for solar observations. Also, they could represent an early manifestation of the construction of a specially oriented astronomical instrument in ancient times. Newgrange's inside chamber dimensions (orientation, depth and height) are analysed to give support to the hypothesis that the figures in the east recess at the 'roof stone' were made following the images produced by an array of pinholes. The instrument, we suggest, was located at several positions along the passage before it was covered by the mound; the images inspiring the engravings were observed on the day of the winter solstice at sunrise around 5000 years ago. The evidence reported here could help to relate other engravings and figures to the use of 'pinhole optics' by other cultures.

KEY-WORDS: Megalithic tombs, Ireland, Engravings, Optics, Solar Observation

One of the most astonishing engravings found in Ireland is the Newgrange's 'roof stone' which is located in the east recess of the cruciform chamber. The

aforementioned engraving is formed by several motifs: circles, undulations and a lozenge symbol at its center (see Fig. 1b)[1]. Several analyses have been done on this petroglyph. As it is shown in the figure, this complex motif forms part of a more wide 'art work' containing different types of curves, zigzags, and ovals. However, there were made with stone tools as mentioned by Krupp[2].

Newgrange engravings have been analyzed from several points of view: artistic[3], geometric[4], and symbolic[8], which are some of the approaches toward the understanding of this ancient cultural artwork. We suggest that these engravings represent an expression of the artistic ability of the inhabitants of around 5ooo years ago and their knowledge about the Sun, the behaviour of light and the myths and beliefs at that time. We state this because as we show in this paper, several features of the engravings involve those ideas. Also, because passage tombs must have been built after the performance of rituals in which light and darkness played the main role[5] which can be implied by the fact that the engravings on the 'roof stone' must have been done well before it was placed in the position it occupies today. There is some archaeological evidence pointing towards a first stage of the construction of the mound in which only an uncovered passage existed.

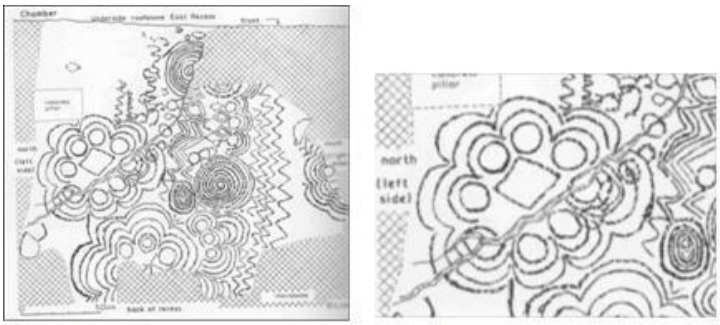

Fig. 1. Engravings on the 'roof stone' located in The chamber of Newgrange Mound: a) Global look; b) selected engraving representing eight circles with a "lozenge" symbol inside and surrounded by curves that delineate concentric circles(O'Kelly drawing)[6].

[1] Jones, *Temples of Stone*,
[2] Krupp, E.G., *Echoes of the ancient skies*. Dover (1994), 122
[3] O´Kelly, *Newgrange*, 181.
[4] Frank Prendergast, *Shadow Casting Phenomena at Newgrange*, Survey Ireland, (1991) 13.
[8] Krupp, *Echoes of the ancient skies*, 123.
[5] Richard Bradley, *Darkness and light in the design of megalithic tombs*. Oxford Journal of Archaeology 8(3), 253.
[6] Jones, *Temples of Stone*, 204.

Newgrange Mound in Ireland is located around 50,6 km north of Dublin (53.694° N Latitude, 6.475° W Longitude)[7]. It was erected about 3300 B.C. and, one of its firsts stages was the erection of orthostatic stones for a passage of around 19,6 meters long, which was covered later by a mound. At the end of the passage a 4,4 meters width cruciform area (converted into a chamber later) received the Sun's rays at dawn on some days around the winter solstice. In such a place, we suggest a stone would play the role of a screen to receive the images of the Sun produced by an 'array of pinholes'. The array, located at several positions along the passage, would project figures as those shown in Figure 2 and would have inspired the engravings that appear in Figure 3.

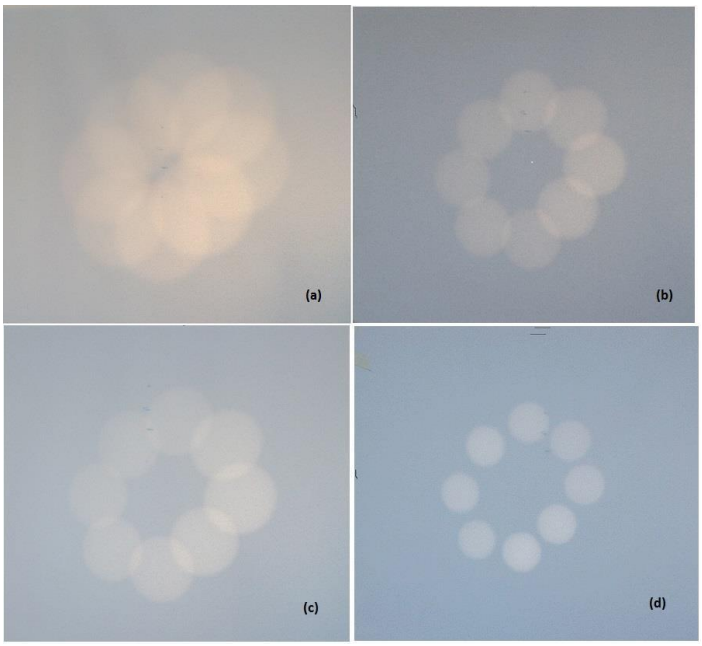

Fig. 2 Photographs of images produced by the "array of pinholes" at four different distances from the screen taken at sunset in Hermosillo (see text). (Perez-Enriquez photos)

Seven years ago, one of the authors (RPE), while studying the Stonehenge Monument at Salisbury Plain, UK, suggested the possibility that 'pinhole effects' could have been used to define the length units of the inch and the foot[8], implying knowledge of some principles of optics. This idea lead us to consider the main engraving shown in Figure 1b as an image inspired by the observation of the Sun

[7] John Walker, *Solar System Live*. (Internet. 2012).
[8] Raul Perez-Enriquez, Posible Origen Astronómico De Las Unidades De Longitud Del Sistema Inglés, *EPISTEMUS* No. 9 (2010), 83.

with the aid of the already mentioned 'array of pinholes'. The images of the Sun could have been projected on the 'roof stone' and carved there before it was placed in its today's position.

The pictures in Figure 2 were taken last March in a parking lot at Hermosillo, Sonora, Mexico, (29.08° N Latitude, 110.96° W Longitude) when an array of 0,005 m holes received the sunrays at sunset. Such an observation could be similar to the one done 5300 years ago at Newgrange. The picture of Figure 3 is the section of the 'roof stone' we are discussing taken recently; it is located in the East Recess of the chamber.

Fig. 3 Photo of the engravings we suggest were inspired by the projection of Sun's images on the 'roof stone' using an 'array of pinholes'.

At the OXFORD IX Conference held in Lima, Peru, in 2011, Morgan Saletta presented a hypothesis about a possible source of inspiration for those images: the Airy disk produced by diffraction from a pinhole of circular section[9]. In Figure 4a, we reproduce the figure from his paper and compare it with a separated pinhole image (Fig. 2b). Saletta's argument is the following:

> I would also like to briefly present the highly suggestive fact that the characteristic diffraction rings (Airy's disk) produced by a point source of light through a small aperture bear a close resemblance to the concentric circles and rings carved on the roof stone at Newgrange (Fig. 6). Of course, this

[9] Morgan Saletta, *The archaeoastronomy of the megalithic monuments of Arles–Fontvieille: the equinox, the Pleiades and Orion*. Proceedings IAU Symposium No. 278 (2011), pag. 371.
[14] Saletta, *The archaeoastronomy of the megalithic monuments*, 371.

> resemblance may be purely coincidental but it is striking—and it is possible that the exploitation of one or multiple apertures to create visual plays of light within the monuments might be one explanation for the artwork at Newgrange as well as at sites with similar motifs such as at Gavrinis.[14]

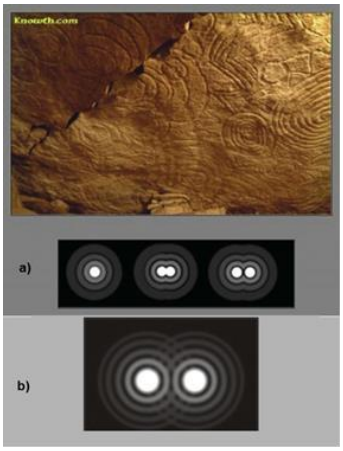

Fig. 4 a) Figure from Saetta's paper with a diffraction section from one and two pinholes; b) image of diffraction from two separated pinholes (added from Culp, 2012)[10].

When one walks below the branches of a tree in a sunny day, it is possible to observe on the ground small circles of light; the rays passing through make the effect of a pinhole and what we see are images of the Sun jumping from one place to another. This same observation could have been made in the past, many years ago. The lack of any physical evidence or written reports does not allow us to give a date for the first acknowledgement of the effect.

However, there are several written testimonies on the deliberate use of a pinhole, one that appeared in AD 1021 is attributed to Alhazen. The Persian scientist related it to the 'camera oscura' effect. Moreover, Aristotle 1500 years earlier, asked himself about the reasons

> Why, when sunlight passes through quadrilaterals, for instance through wickerwork, does it not produce shapes that are rectangular, but circular ones? Is it because the emission of visual rays is a cones, and the base of a cone is a circle, so that whatever object the rays of the Sun fall upon, they appear circular? For the shape produced by the Sun is necessarily contained by straight lines, since the rays are straight....[11]

[10] R. Culp, *Telescope Equations* Web-page. (2012), 1.
[11] Aristotle, *Aristotle Problems 1 - 19,* LOEB Classical Library (2011), 463.

The image of partial solar eclipses were seen and identified by these means. In China, also, back in 5th century B.C., Mozi made a brief description of an inverted image of a pagoda observed through a pinhole. Then the idea that pinhole optics could have been known in by Newgrange's builders, seems to be plausible.[12]

The 'array of pinholes' we have used to produce the images of Figure 2, was primarily obtained through an analysis of the original engraving, identifying the centres of the image circles and then by direct measurement of the length of the axes of opposite centres; we have found that all the four axes have a common central point, as shown in Table 1. This centre point is located almost equidistantly from the circles. The angles were measured from axis A (1 – 5) which was considered as the main axis of the array. Figure 5 shows the image of the array and one image obtained from it.

Table 1 Description of the 'array of pinholes'
from the Newgrange engravings on the 'roof stone'

Axis[1]	Length[2]	Centre[3]	Angle[4]
A (1 – 5)	0,40	0,20	0,0
B (2 – 6)	0,42	0,20	42,5
C (3 – 7)	0,38	0,19	85,4
D (4 – 8)	0,32	0,16	134,0

[1] Pinholes making the axes.
[2] Separation between pinholes (m).
[3] Distance from centre to first pinhole (m).
[4] Angle to the A axis (°).

[12] Perez-Enriquez, *Posible Origen*, 88.

Fig. 5 Experiment held in Hermosillo, Sonora, showing the array of pinholes and the corresponding images of the Sun on a screen located at 12,0 m apart: a) The 'array of pinholes';
b) The array of Sun disks reproducing the Newgrange engraving (Perez-Enriquez photos).

In the Winter solstice of 3014 BC the Sun was at a distance of 0,994 au (astronomical unit = 1,496X10^{11} m)[13]. Considering the Sun's diameter of 1,92X10^{9}m, we have an image of 0,105m, as those shown in the engravings under analysis, at half way between the ´roof box' and the chamber. It can be said that the place where the "array of pinholes" was located to produce the Sun's images observed is about 11,22 m from the 'chamber' as it is sketched in Figure 6.

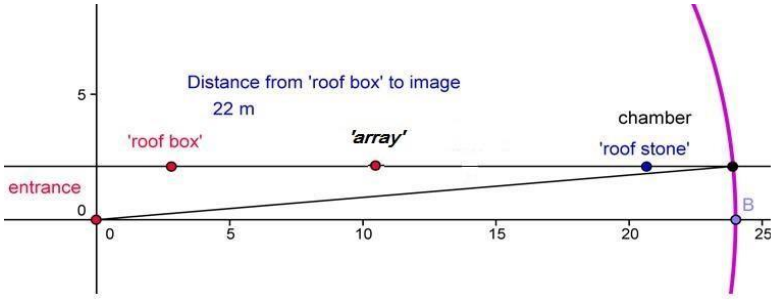

Fig. 6 Diagram showing the Sun's image formation at the chamber on the 'roof stone' allowing to see the circles with the 'array of pinholes' about midway between the 'roof box' and the chamber (Perez-Enriquez drawing).

There we can see the 'roof box' and the 'image' places in the same level as the incoming light ray coming from the sunrise.

We consider that our hypothesis suggesting that the array of concentric circles represents the observation of the images of the Sun as produced by an array of pinholes (estenotopos in Spanish) is better that of Saletta suggesting that it was

[13] Clark, *Solar System Live*.

inspired by the image produced by an array of micrometric pinholes (Airy disks obtained in the diffraction mode). The feasibility of our approach can be supported by the evidence of stone beads similar as those shown in Figure 7.

Finally, we shall summarize briefly the main differences between the Airy disks of diffraction effect and the images of the Sun produced in the camera oscura effect:

i) Pinhole Diameter. In Figure 8a, it can be seen how the radius of the image changes as the pinhole diameter grows. In the region of the intersection of both curves, the smaller the diameter, the better diffraction and Airy´s disk produced; however, the border definition of the circle diminishes. A very large diameter produces a blurry border and no concentric circles.

On the other hand, as it can be seen in Figure 8b, the size of the Airy disk in the diffraction mode cannot grow easily; while in the 'camera oscura' mode, the focal length, and as a consequence, the size of the images depend on the size of the pinhole. This allows for the projection of the images of the Sun (circles) with sizes as large as the ones of the engravings.

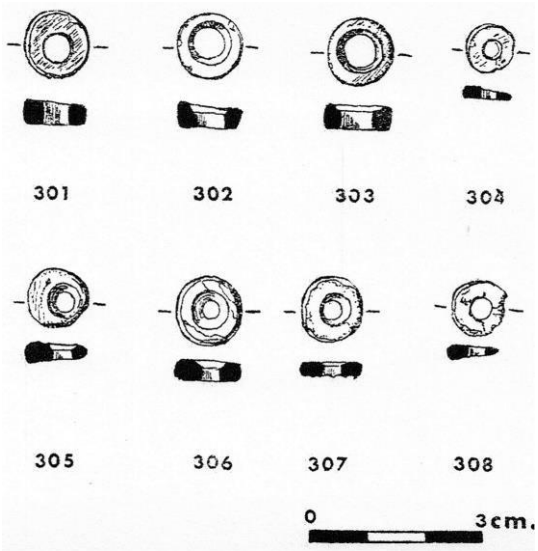

Fig. 7 Megalithic beads found in Coli, County Meath, Ireland. Jones affirms that similar beads have been found at the majority of passage tombs in Ireland (Hunt drawing)[14].

[14] Jones, *Temples of Stone*, 176.

ii) Concentric Circles. Their observation comes directly from the Fraunhofer effect, but as it can be seen in Table 2, the intensity decreases drastically between first order and second order diffraction. Also, when the main pinholes of the Airy disks do not overlap as it is shown in Figure 3b, the concentric circles appear complete. This fact is in contradiction with the profile shown on the engravings at Newgrange (see Figure 1a). On the other hand, these images of overlapping circles could be produced by changing the distance between pinholes and the screen were they are being observed.

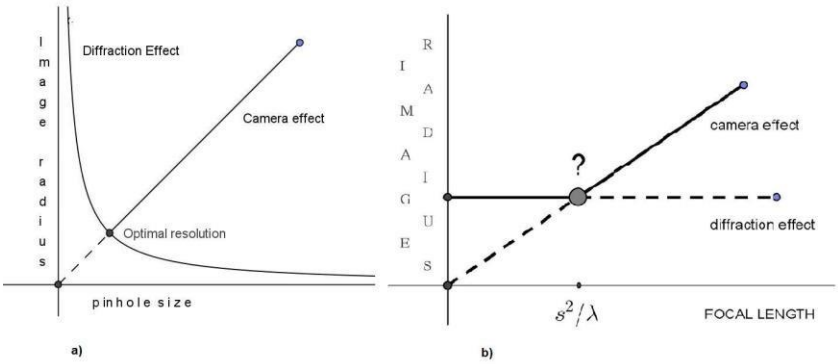

Fig. 8 Pinhole optics: a) Behaviour of the image radius vs pinhole size. Where the far field diffraction effect and the 'camera oscura' effect are compared (adapted from Young, 1989)[15]: b) Image Radius vs Focal Length, showing both effects: diffraction and camera oscura (adapted from Young, 1989)[16][17].

Table 2 Successive Diffraction Maxima for a Circular Aperture[17]

Order	Relative Radius	Relative Intensity
0th	0	1.00
0th	1.22	0
1th	1.64	0.0174
1th	2.22	0
2th	2.69	0.0041

[15] Matt Young, Pinhole Camera: Imaging. *The Physics Teacher 1989*, 648.
[16] Young, *Pinhole Camera*, 649
[17] John Strong, *Concepts of Classical Optics*, (Dover Pub., Inc 2004), 205

2th	3.24	0
3th	3.72	0.0016
3th	4.24	0

iii) Lozenge. Along the same line of thought, we can mention that the lozenge that appears in the centre of the engraving under analysis is a representation of the dark region inside the region of concentric circles. See Figure 2 and Figure 9 where a simulation of successive images of pinhole projections is shown.

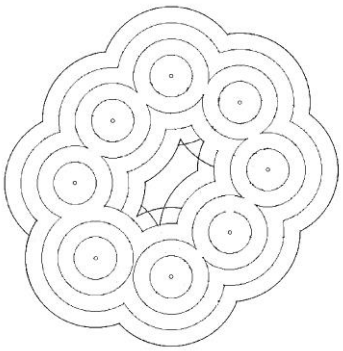

Fig. 9 Simulation of the image produced by the array of pinholes described in Table 1, when the screen position changes (Perez-Enriquez drawing).

We close this essay with a conclusion suggesting that the analyzed engraving found on the 'roof stone' could represent an astronomical observation of the Sun when the passage was still uncovered; it could represent a sequence of images obtained with the aid of an array of pinholes. These would imply the knowledge of the use of pinhole optics in the 'camera oscura' mode and the deliberate construction of an instrument for that purpose by the builders of Newgrange back in 3300 BC.

We gratefully acknowledge the University of Sonora for its support (Project CEN13-PI08). Also, we want to thank Dr. Carlos Lizarraga for his comments and discussions while preparing this paper. Perez-Enriquez give thanks to

Instituto de Investigaciones Estéticas, UNAM, for the support received during his Sabbatical stay and, in particular, to Dr Jesus Galindo Trejo.

R. P.-E. & E. S.

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