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King David's Altar in Jerusalem Dated by the Bright Appearance of Comet Encke in 964 BC

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ABSTRACT

At the time corresponding to our end of May and beginning of June in 964 BC a bright comet with a very long tail dominated the night sky of the northern hemisphere. It was Comet Encke that was very bright during the Bronze Age, but today it is scarcely visible to the naked eye. It first appeared as a small comet close to the zenith, but for every night it became greater and brighter and moved slowly to the north with its tail pointing southwards. In the first week of June the tail was stretched out across the whole sky and at midnight it was visible close to the meridian. In this paper the author wishes to test the hypothesis that this appearance of Comet Encke corresponds to the motion in the sky above Jerusalem of "the sword of the Angel of the Lord", mentioned in 1 Chronicles, in the Old Testament. Encke was first circumpolar and finally set at the northern horizon on 8 June in 964 BC at 22. This happened according to the historical chronology between 965 and 960 BC. The calculations of the orbit of Comet Encke have been performed by a computer program developed by the author. It has been calibrated from depictions on Swedish rock-carvings, Chinese texts and Sumerian cylinder seals and gives useful results at least back to 2654 BC.

Keywords: *Comet Encke, orbit integration, non-gravitational forces, David's Altar, sword of the Angel of the Lord, Swedish rock-carvings, Chinese texts, Old Testament.*

INTRODUCTION

The absolute chronologies for the early Near Eastern cultures have been dependent on identifiable solar eclipses that have taken place during a known year of rule of a certain king. If there exist a series of years of rule for kings in a country it is enough to get a single absolute year to convert the relative years to absolute years. Furthermore, if a specific common year is known in relation to a king in another country, an absolute chronology can also be achieved for that country. With this technique a common absolute chronology for the Eastern Mediterranean countries have been established during the last 200 years by a cooperation between historians and astronomers. I have also contributed to this during the last 20 years (Henriksson 1999, 2005, 2006, 2007, 2008).

Unfortunately, for the early history there exist periods without solar eclipses preserved in the written sources and with no reliable links between time of rule even for important kings.

In these cases one can try to use other important astronomical phenomena such as the appearance of a bright supernova or a bright comet that are mentioned with enough characteristic details to be uniquely identified as a known astronomical object.

In an earlier paper, (Henriksson 2013), I have used both a solar eclipse and a bright appearance of Comet Encke to date the Assyrian King Sennaherib's attack in the land of Juda and his attempt to conquer Jerusalem in 702-700 BC.

In another well-known situation, during the end of rule of King David, a frightening celestial phenomena appeared above Jerusalem described as "the sword of the Angel of the Lord". It has been interpreted as the appearance of a bright comet. Some authors have tried to identify this as Halley's comet as this was the only bright periodic comet known.

THE SEARCH FOR AN EARLY BRIGHT COMET

D. Justin Schove and Alan Fletcher (1987) write: "The early dates of Halley's comet have been estimated by various methods with inconsistent results. Schove 1955, 288 noted that there were 8 appearances in a millennium, so that extrapolating backwards from AD

2066±, 1066 and 66 he reached –934 or 935±5 BC and queried whether 965 BC would be a suitable date for the comet of David that pointed to Ornan's threshing-floor and led to the building of the Temple at Jerusalem."

With these speculative calculations an astronomer should have a very low profile in relation to the historical chronologies based on comparisons with the known history of neighboring countries even if the exact year is not known. A great effort to solve the problem with the many early indications of passages of a bright comet was made by Donald K. Yeomans and Tao King (1981) when they performed an ambitious integration of the orbit of Halley's comet back to 1404 BC. They had to stop that year because of a very close encounter with the earth that made further calculations useless. They assumed that the comet's non-gravitational forces remained constant from one appearance to the next. Nowadays, after a detailed study of the Chinese and other sources, the earliest known observation of Comet Halley was made in 240 BC. This seems to be the first appearance of Comet Halley in the inner solar system.

In this paper I have identified David's comet as Comet Encke which is expected to have been extremely bright during the Bronze Age. The problem was that it has not earlier been possible to calculate a useful orbit before 1786 when it was discovered with a telescope by Pierre Méchain. Johann Franz Encke realized that the same comet had been observed in 1795, 1805 and 1818 and he computed its first orbit in 1819. This was a very difficult and laborious task and therefore the comet was named "Encke" to honour him. The period of Encke is 3.3 years and it moves always in the inner part of the solar system and its orbit is perturbed by many planets. It has weakened since the Bronze Age and there seems to have been no observation between 1600 and 1786. It has been very difficult to determine the evolution of the non-gravitational forces that perturbs its orbit. This makes the calculations very uncertain.

These non-gravitational accelerations are due to the rocket effect of outgassing volatiles from the icy-conglomerate nucleus proposed by Fred Whipple (1950). The title of his paper is: "A comet model I. The acceleration of comet Encke". When this model was further developed, Whipple and Hamid (1972) tried to use it to find Comet Encke among the more than 300 early Chinese records of comets. They write in the abstract: "Using the Gauss-Hill method it was possible to establish roughly the plane of the orbit and direction of perihelion for P/Encke over this interval of time. All but about 40 of the objects could be eliminated by comparing the observed locations with possible locations of P/Encke. ….. Large uncertainties in the non-Newtonian motion as yet prevent our certain identification of P/Encke among the remaining possibilities." After the failure of this very competent and ambitious attempt to identify Encke among the detailed Chinese observation records this problem has been considered to be impossible to solve.

In 1994, after identification of many total solar eclipses on the Swedish rock-carving from the Bronze Age (1800-500BC), I started an investigation of the great number of depictions of possible bright comets. The result was that all the investigated depictions of comets can be identified as Comet Encke. Fortunately, at that time I did not know about the problems with the calculation of the early orbit of Encke and that it was considered as "impossible" to solve.

The identification of Encke's comet on the Swedish rock-carvings is of course interesting for the dating of them, but it is of more general importance for the study of the evolution of Encke's orbit and the possibility to establish absolute chronologies for ancient cultures. A short description of my method to calculate the orbit of Comet Encke and some details about the identified passages around 1000 BC, including a mentioning of Comet Encke in the oldest Chinese cometary text, are discussed at the end of this paper.

Comet Encke As The Sword Of The Angel Of The Lord

I want to test the hypothesis that the motion in the sky above Jerusalem of "the sword of the Angel of the Lord", mentioned in 1 Chronicles, in the *Old Testament*, was a description of Comet Encke's appearance at the end of May and beginning of June 964 BC when it first was circumpolar and finally sets at the northern horizon of Jerusalem. This date is in good agreement with known facts.

It is written in 1 Chronicles 21:15-16, "And God sent an angel to Jerusalem to destroy it, but as he prepared to destroy it, the LORD looked and relented from the calamity. And He said to the angel bringing the destruction, 'It is enough. Remove your hand.' The angel of the LORD was then standing by the threshing floor of Ornan the Jebusite. 21:16: Then David lifted up

his eyes and saw the angel of the LORD standing between earth and heaven with his sword drawn in his hand stretched out over Jerusalem. So David and the elders, covered in sackcloth, fell on their faces".

King David decided to buy the threshing floor of Ornan and to build an altar there. This became the Altar for the Great Temple that later was built by his son Solomon. The year 964 BC for this bright passage of Comet Encke falls perfectly within the historical estimates 965-960 BC for the foundation of the Altar in Solomon's Temple in Jerusalem.

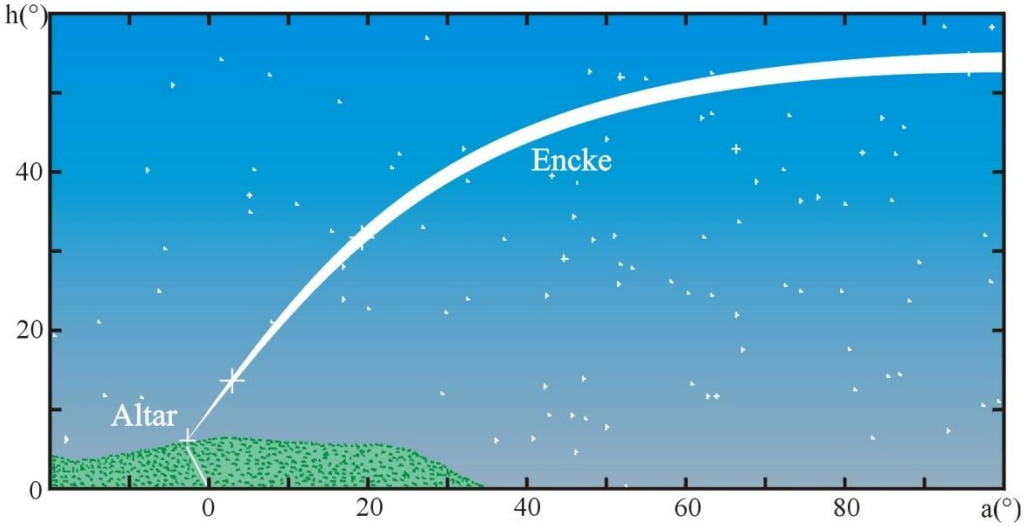

Figure1.*The setting of Comet Encke on 8 June in 964 BC, at 21.59 local mean solar time in Jerusalem. The comet had earlier been circumpolar and visible all the night, but for every night it came closer to the horizon in the north. The point at the horizon where Encke was setting corresponded to the threshing floor of Ornan. King David decided to build an altar at that place. This became later the Altar of the Temple in Jerusalem.*

The length of Encke's tail in the picture is 0.5 AU. If the total length had been 1.0 AU = 149.6 million kilometers it had reached the horizon in the south. (Mean anomaly of Encke = 350.4°, distance to the sun = 0.838 AU, distance to the earth = 0.275 AU, magnitude = -6.1, Δt = -8.03 days, phase of the moon = 13.1° and stellar magnitudes <4.5.).

The people of Jerusalem saw the tail of Comet Encke as a straight line above their heads. In Figure 1 the tail is bent because of projection effects.

If King David, in the evening of 8 June 964 BC, had been watching the sky in the North, from the roof terrace of his palace, close to the main gate in the upper part of "David's City", the oldest part of Jerusalem, he had seen Comet Encke setting at Ornan's threshing floor at 21.59 local mean solar time in Jerusalem, Figure 1. The roof terrace is assumed to have been about 5 m above the ground level.

The Same Passage of Comet Encke From Different Sources

At the SEAC conference 2004 in Kecskemet the author presented a paper with an interpretation of Aaron's and Moses' rod that was stretched out over the land of Egypt as the unusually bright appearance of Comet Encke in December 1259 BC and January 1258 BC. Its appearance in May-June 1252 BC corresponded to the pillar of cloud and pillar of fire during Exodus (Henriksson 2007). The first time Encke corresponded to the "sword of the Angel of the Lord" was in 1212 BC and it is written in Numbers 22:31, "Then the LORD opened the eyes of Balaam, and he saw the Angel of the LORD standing in the way, with his sword drawn in his hand. And he bowed down his head, and fell flat on his face".

After the end of Encke's career as the rod stretched out over the land of Egypt, in January 1258 BC, it moved northwards and was depicted on a Swedish rock-carving, at Himmelstalund in Norrköping, below the full moon on 2 February 1258 BC. The comet was depicted as a straight sword and the full moon was depicted in the normal way as a pair of feet. The situation with a comet close to the full moon is unusual because this means that the comet appeared bright beyond the earth's orbit and opposite to the sun where it normally is brightest. I have also found a similar depiction from the same night on a rock-carving at Solberg in Østfold in southern Norway.

During the search for conjunctions between Encke and the full moon, an even more unusual

conjunction was found that, in fact, was an occultation of Encke's nucleus by the moon! This extremely unusual situation happened on 23 December 1249 BC, just after moonrise. This rare event could only be observed within the rock-carving area around Norrköping. After the corrections from the other observations had been included, in the model for the time shifts, only a small shift of –0.2 days was needed for the moment of occultation to be visible at the rock-carvings around Norrköping.

Encke's Comet on Swedish Rock-Carvings

During the 1990s the author studied the Swedish rock-carvings from the Bronze Age (1800-500 BC) and found that the most dominating motives could be depictions of total solar eclipses and other impressive celestial phenomena such as a bright supernova and the appearance of bright comets (Henriksson 2005). By comparing the position of the symbol for the eclipsed sun in relation to ships it was possible to establish a series of six different types of ships along the ecliptic, each corresponding to a double month. The solar months were reckoned from the summer solstice and the corresponding ship was very elegant with a head of a horse as the bowsprit decoration. Sometimes the closest constellation visible during the total eclipse was depicted in correct position to the sun together with the visible planets. In some cases there was a sword or an object with rays pointing to the sun. It was quite obvious that the latter type of objects were depictions of comets. It is known from the antique sources, for instance Plinius the elder (23-79), who in his *Naturalis Historia* XII described comets as sword-like (Heath 1932). Josephus (37-ca100) wrote in his *History of the Jews* that a sword hanged over Jerusalem (Whiston 1737). This has been interpreted as the bright appearance of Comet Halley in 66 AD.

From the angle between the swords or the rays in relation to the rail of the ships it became clear that they mostly differed by about 10° and therefore the most likely candidate among the known comets was Comet Encke with a mean inclination of about 11° to the plane of the ecliptic, the path of the sun in the sky.

In 1994 the author asked Dr Mats Lindgren, one of the experts from the Comet Group at the Astronomical Observatory in Uppsala, to calculate the orbit for Comet Encke back to 2000 BC, from all available observations back to 1786, but without non-gravitational forces. It was known that the non-gravitational forces was weak for this comet and the author assumed that the orbital elements was not significantly perturbed by other forces than the gravitational forces from the 8 planets, the moon and the sun. The only effect of the non-gravitational forces was assumed to be a shift of the position along the orbit. Because the inclination is so low the components of the forces in latitude is negligible and therefore it is motivated from celestial mechanical arguments that a model with one component in longitude is enough. The result of the non-gravitational forces will only correspond to a time shift along the orbit.

The time shift was first approximated as a parabola through the modern observation after 1786 and the positions in 858 BC and 1596 BC when the comet was visible during total solar eclipses. From this parabola it became possible to identify some of the Chinese observations and to get more points on the curve. The next approximation was a fourth degree polynomial, and finally a sixth degree polynomial was implemented in the computer program.

With this polynomial approximation of the time shifts it was possible to calculate all comet observations known to me, from texts or rock-carvings that could be expected to be Comet Encke, back to 2000 BC with individual time shifts of less than 10 days. It has also been possible to identify 16 Chinese records of Encke between 1060 BC and 1600 AD. Aristotle observed a comet split up in two comets. That comet was Encke on 1 January 371 BC.

Another member of the Uppsala Comet Group, Dr Mats Dahlgren, wanted to test my hypothesis that the secular perturbations of Encke's orbital elements were small and that the orbit was stable. He spent a whole night on the Observatory's computer to integrate orbits back to 2000 BC for 30 equally distant starting positions along Encke's orbit. He concluded the next morning that all the orbital elements varied very little around a mean value and there was no risk that Jupiter could capture it as some of my critics had claimed. I have had many useful discussions with the founder of the Uppsala Comet Group, Professor Hans Rickman. He has been General Secretary of the International Astronomical Union.

Observations Used for Calibration of Comet Encke's Orbit Around 1000 BC

The two fundamental calibration observations for the non-gravitational forces along the orbit

of Comet Encke was its appearance during the two total solar eclipses in 858 and 1596 BC, depicted on two Swedish rock-carvings. The first one, in 858 BC, was a depiction on a standing stone on a grave field from the late Bronze Age, which means that its age was approximately known. It was easy to identify this total solar eclipse because of the unique position of the symbol for the planet Venus above and somewhat to the right of the symbol for the totally eclipsed sun as is shown in Figure 2.

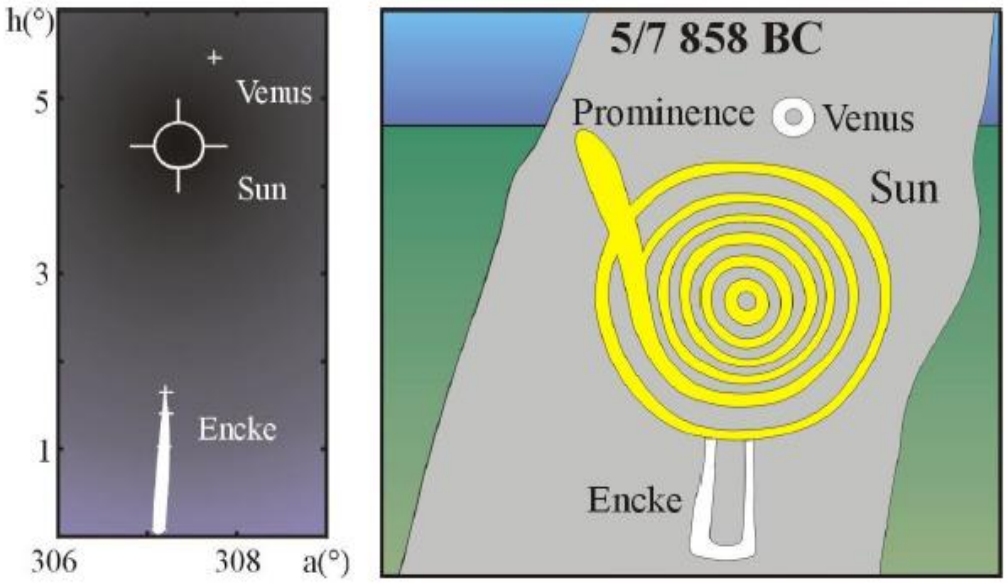

Figure2.*Left image: The total solar eclipse on 5 June, in 858 BC, at 20.01 local mean solar time in Asige. (Δt = +1.3 day.)*

Right image: Rock-carving on a standing stone at "Hagbard's gallows" in the parish of Asige in the province of Halland. The solar eclipse took place 4.5° above the horizon, to the left of the standing stone. (After a photo by Henriksson 1991.)

The appearance of prominences cannot be predicted, but can only be seen during a total solar eclipse. The "handle" below the eclipsed sun fits very well with the position of Comet Encke visible below the eclipsed sun.

When the preliminary correction was approximated by different polynomials, it became possible to make a search for other possible bright passages of Encke. One of the early identifications was a passage of Comet Encke below the calendar ship Gemini-Taurus on a rock-carving at Herrebro, in the parish of Borg in Norrköping. The identification of the year was made from Encke's unique position below this ship and its relation to the right foot pointing downwards, the symbol for the third quarter moon.

The tail of Comet Encke was depicted as a so-called frame figure just below the keel of the Gemini-Taurus ship and with the bright nucleus of the comet as a big cup-mark to the left of the comet's tail. The other four cup-marks represented the four visible planets. This situation can be dated by the right foot representing the third quarter half-moon, in a position to the right of the bow of the Gemini-Taurus ship that only occurs every 19th year and always on 8-10 July during this period of the Bronze Age, Figure 3b.

This is a very strong set of conditions and Encke's comet has only once, on 9 July in 1060 BC, appeared in this position between 2000 and 500 BC. The visibility of the four planets Mercury, Saturn, Jupiter and Venus, is a further evidence of a correct identification, see Figures 3a and b. (Figure 3b is based on figure 7 B in Burenhult 1973.)

Observation of Comet Encke on 22 June in 1060 BC in a Chinese Text

Ho Peng Yoke (1962) wrote in his *Catalogue of Chinese Guest stars*: "11th century B.C. 'When King Wu-Wang waged a punitive war against King Chou a (hui) comet appeared with its tail pointing towards the people of Yin.' (Huai Nan Tzu 15/6b).

No earlier sources of reference to this observation have been found other than this singular record by Liu An, the Prince of Huai-nan in the 2nd century B.C. Moreover, the year

when the war took place has long been an open question. It has been regarded as 1122 B.C., 1109 B.C. 1055 B.C. and even 1030 B.C. A recent study by CHANG HUNG-CHHIAO (1958) (p. 93 ff) suggests that the year 1055 B.C. was most probable." Yeomans and King (1981) thought that it was Comet Halley in 1059 BC. However, this passage is purely theoretically correct, but can not be supported by any observations before 240 BC, see discussion above.

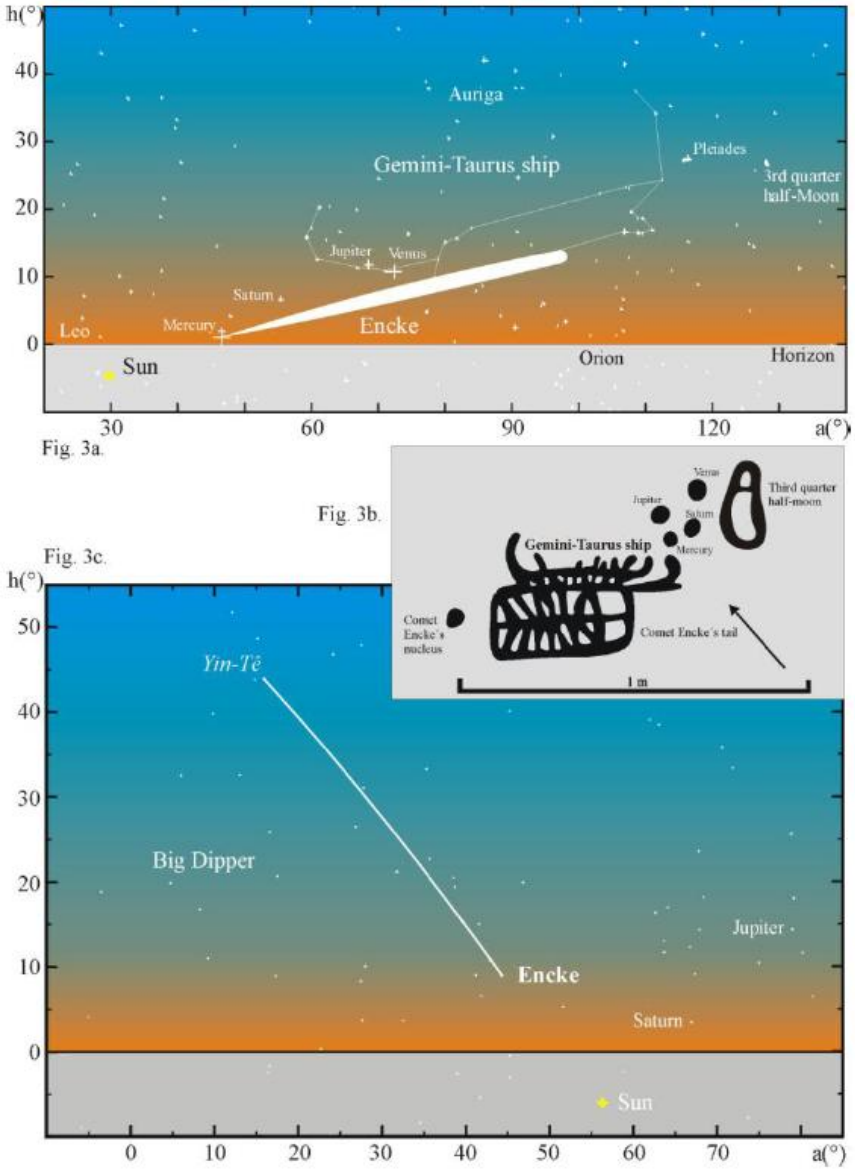

Figure3a. *Encke's comet, on 9 July, 1060 BC, at 02:10 local mean solar time in Herrebro, parish of Borg in Norrköping. The sun was 4.0° below the horizon., but the long tail had been visible earlier in the morning. The phase of the moon was 260.7°. With Δt = -9.0 days: Encke's mean anomaly = 358.6°, distance to the sun = 0.343 AU, distance to the earth = 0.808 AU, magnitude = -5.7 and the length of the tail = 0.7 AU.*

Figure3b.*Rock-carving at Herrebro, in the parish of Borg in Norrköping.*

Figure3c.*Comet Encke's rising on 22 June 1060 BC, at 04.05 local mean solar time in Anyang, the capital of China. The tail was pointing at Yin-Tê in Draco. With Δt = -9.0 days, Encke's mean anomaly = 353.5°, distance to the sun = 0.643 AU, distance to the earth = 0.402 AU, magnitude = -5.8 and the length of the tail = 0.3 AU. Altitude of the sun = -5.8°. This is a camera projection, which means that the axis is not exactly azimuth and height. The stellar magnitudes are <4.5 in Fig. a and c.*

Zhentao Xu, David W. Pankenier and Yaotiao Jiang (2000) wrote in East Asian Archaeoastronomy on page 107: "The 2nd century BC text Huainanzi contains a unique record of a bright comet observed at the end of the Shang Dynasty: 'When King Wu [of Zhou] attacked King Zhou [of Shang], a comet appeared and tendered its handle to Yin'."

This situation can be identified as the appearance of Comet Encke on 22 June in 1060 BC, from the value of Δt = -9.0 days, determined from the rock- carving at Herrebro made 17 days later, on 9 July in 1060, see Fig. 3c.

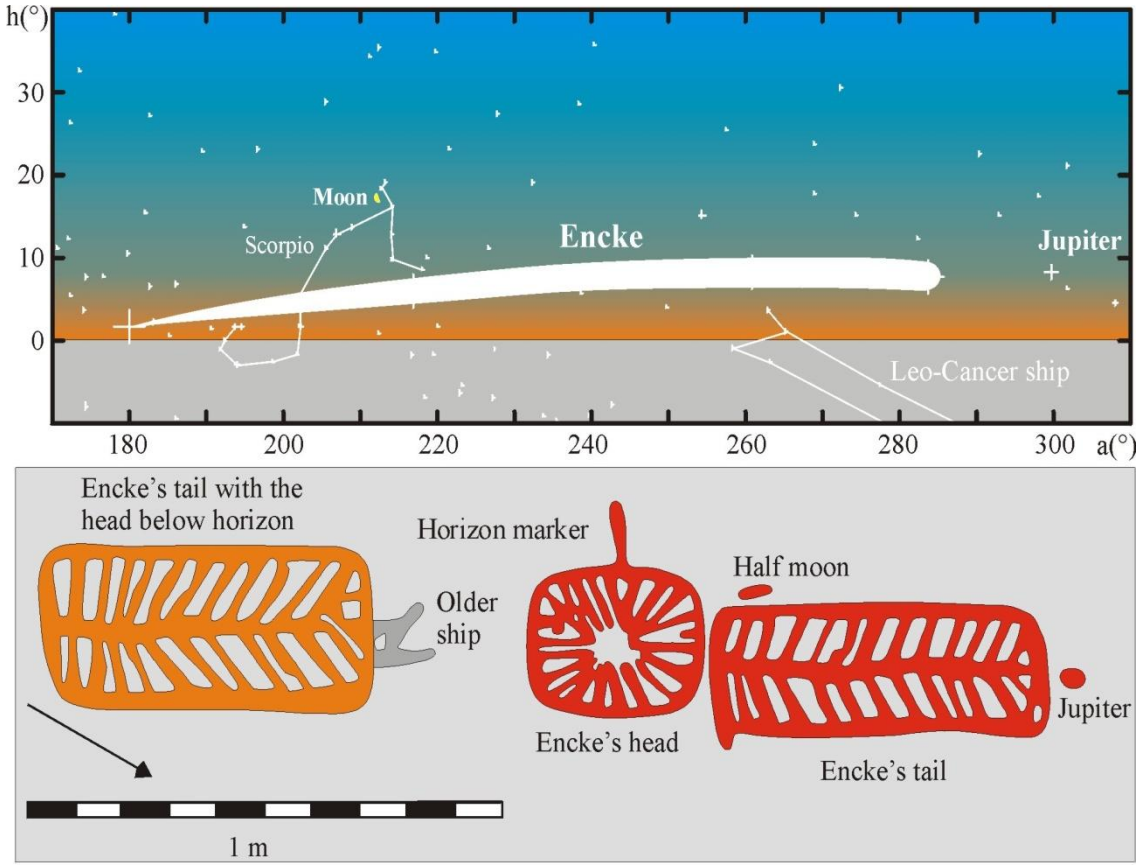

Figure4. *Comet Encke dominated the low south-eastern morning sky on 14 January, 927 BC. The figure corresponds to the situation at 07.55 local mean solar time at Skälv, in the parish of Borg, near Norrköping. This was the first night the extremely bright head of Encke became visible above the horizon very low in the south. At this moment the head reached its highest altitude 1.68°, with magnitude -7.1.*

The only solution was Δt = -6.5 ±0.1 days. Encke's mean-anomaly = 11.01°, the distance to the sun = 0.919 AU, the distance to the earth = 0.160 AU and the magnitude = -7.1. The stellar magnitudes in the figure < 4.0. The altitude of the sun was -5.9°. (Based on the figure Skälv 12A, by Burenhult 1973).

An Unusually Close Passage of Comet Encke in 927 BC

In the middle of January 927 BC there was a very close passage of Comet Encke. It approached the earth below the ecliptic and only the long tail was visible above the horizon during several weeks before the extremely bright nucleus appeared for the first time low in the south. This event was first discovered during a search for close encounters between Encke and the earth with time shifts calculated from the sixth order polynomial with Δt = 0.0 days. With this Δt-value Encke should have been only 0.021 AU, 3.2 million km, from the earth, on 25 January 1060 BC around 14.30, and with apparent magnitude –11.3, almost as bright as the full moon! However, no observation of such an event has been recorded.

The tail was assumed to be 1.0 AU because its end was depicted close to Jupiter, with magnitude -2.2. The calculated position of Encke was strongly dependant on the time shift Δt along its orbit. Many strict criteria must be full filled. On the rock-carving, the third quarter moon was depicted above the tail of Encke, 1/3 of the distance between its head and Jupiter, and the end of the tail pointed at Jupiter. Further, Encke's head must be close to the horizon because it has the special horizon marker, a line at right angle to its head. The moon was at this position on 14 January and the phase was 267.3° which means third quarter. The only solution was Δt = -6.5 ±0.1 days, see Figure 4.

Another well defined situation happened on 17 June in 911 BC, when the third quarter half Moon was depicted within the tail of Encke. The

outer half of the tail was disconnected. The time shift that year was $\Delta t = -5.5$ days.

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