Ice Age people find their ways by the stars: A rock picture in the Cueva di El Castillo (Spain) may represent the circumpolar constellation of the Northern Crown (CrB)

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Summary

A rock picture found in the Cueva de El Castillo (Spain) shows a particular pattern of points. Examined from an astronomical viewpoint, it may be a pictorial representation of the lower culmination of the constellation of the Northern Crown (CrB) at about 12000-11,000 BC. The research works starts with a precise description of the pattern and picture. Then this is designated hypothetically as a constellation, by reason of its appearance. Finally a comprehensive astronomical computation is made to determine its shape, position and time of visibility during the millennia at the geographical latitude of the cave. The analysis considers the precession of the equinox, the proper motions of the stars, the refraction and the extinction of starlight, the visual horizon and the star phases. Two myths, handed over by the Greeks and the celts, are told, helping to understand the function of the constellation for the ancient Ice Age cultures. At last the function of the Northern Crown for orientating and navigating at land and sea is discussed in connection with a similar example from the Lascaux grotto (France) and new discoverys about seafaring at the end of the last Ice Age.

The mountain of Pico del Castillo rises to a height of 355 m near Puente-Viesgo in the province of Santander (Spain). In the steep sides of the mountains, caves have been found which contain engravings and paintings: El Castillo, Las Chimenes, Flecha, Pasiega and Las Monedas (fig. 1). In one of the caves on the eastern side of the mountain, the Cueva de El Castillo, there is a remarkable rock painting, showing a particular pattern of points, which could depict a constellation of stars, the Northern Crown (Corona Borealis; CrB), in its circumpolar position in the sky 12000-11,000 BC. At that epoch this constellation like the that of Cassiopeia (Cas) today could serve as an excellent

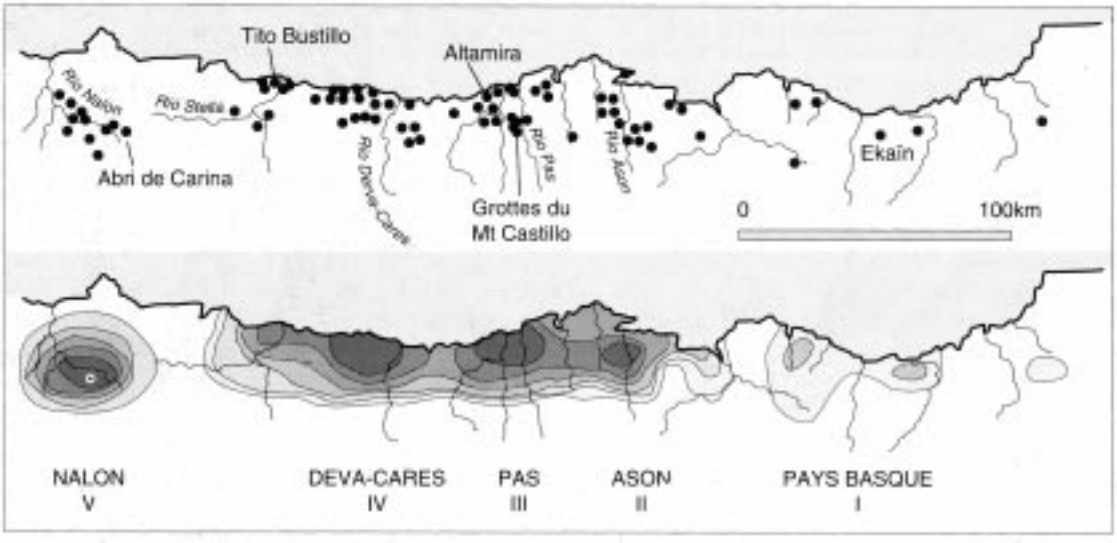

Fig. 1 A map of the Cantabrian coast showing the mean places of the Paleolithic caves, equipped with rock pictures. The Cueva di Castillo is located in the center of the map. After Lorblanchet, 1997: 36.

heavenly marker of the direction to the polar point.

The opening of the cave lies about 80 m high above the valley floor of Río Pas, being only about 175 m away from the Cueva de Las Chimenes which is particularly renowned for its many rock paintings.[1]

For the picture in the Cueva di El Castillo several archaeological dates are available, mostly based on radiocarbon-dating, but also on other techniques. The resulting ages of the rock picture, as computed by astronomical method, are compared with the archaeological determined ones. Considering the examples in the cave of El Castillo the dates established by archaeological and astronomical methodology fit together.

Deep in the cave the so-called "Great Chamber" is situated (fig. 2). There the rock surfaces facing north are covered with a striking 5 m long painting: the "Frieze of Hands" (fig. 3, area IV).[2]

The panel shows thirty red hands,

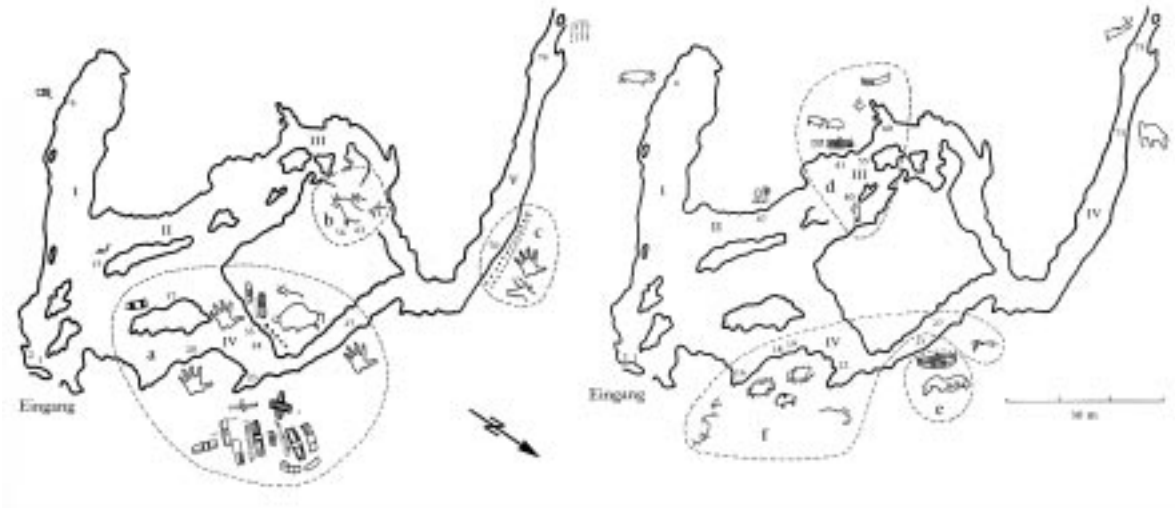

Fig. 2 A map of the El Castillo grotto, showing the "Great Chamber" with the area IV. There the "Frieze of Hands" is to be found. The arrow indicates the cardinal direction north. After Leroi-Gourhan, 1982: 377, 138.

Fig. 3 The "Frieze of Hands". At the right side there is an extremely unusual and prominent pattern which consist of seven discs arranged in an arc-like shape. After Breuil, 1935: Fig. 75.

painted as negative images, dot-like symbols (red discs, pairs, in single and multiple rows) as well as strokes, angles, compound symbols (straight or curving rectangles, brackets). The red discs can be divided into three sections: first, four discs in pairs to the left; a clearly structured pattern of 17 discs covering a larger area in the middle and finally on the right, an extremely unusual and prominent pattern which consists of seven discs arranged in an arc-like shape.

On the limits of the eastern part of the "Frieze of Hands" there is a small and unusual shape: seven dots form a semicircle which is open at the top (fig. 3). No one has as yet paid much attention to the painting or tried to interpret it. An astronomer however recognises something very familiar in this rock painting a small, but prominent constellation of stars (fig. 4, 5): the Northern Crown (CrB) in its position 11,000 BC as seen from the location of the cave. Is this astronomers guess correct?

To come close to the proper answer, the picture has to be described as exactly as possible. What can we see? Seven ochre coloured dots with an average diameter of 2 cm form a regular curve whose deepest part is directed downwards to the floor of the cave. In order to better describe the coloured dots and their form and sequence, in this study the dots starting from the right and ending on the left will be given the letters A to G. The dots have different diameters. The C dot is the moist immediately striking: its area is distinctly larger than that of the neighbouring dots. The fact that all the dots can be connected through the middle of their surface to a semicircle (K) which is open at the top, shows just how regular the curve is. The centre (M) is then located exactly on the line AG (ca 36 cm), the diameter (d) of the pattern. Furthermore the pattern is tipped ca 18 cm to the left of its horizontal plane, as measured from

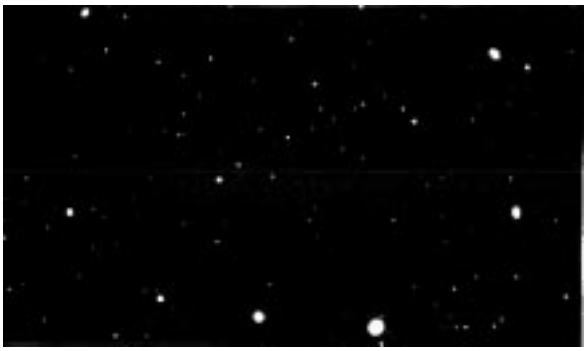

Fig. 4 The constellation of the Northern Crown (Corona Borealis; CrB) in the sky today and …

Fig. 5 … the semi-circle of seven dots at the rock panel. Photograph by Michael A. Rappenglück/ drawing after Anati, 1991: 197.

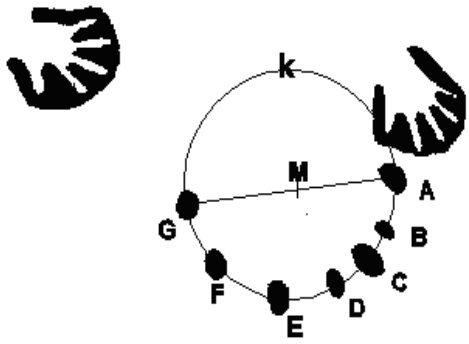

Fig. 6 The pattern of the dots follow a well-shaped semicircle. Drawing by Michael A. Rappenglück.

AG and in relation to the caves floor.

The dots of the semicircle and the stars of the Northern Crown can clearly be related to each other (fig. 6): A is 4 • θ CrB (4.16 mag), B/3 • CrB (Nusakan; 3.66 mag), C/5 • CrB (Alphekka, Gémma; 2.22v mag), D/8 • CrB (3.82 mag), E/10 • CrB (4.60 mag), F/13 •

CrB (4.14 mag) and G/14 • CrB (4.99 mag). The larger dot C corresponds to the brightest star in the constellation of Gémma (5 • CrB; 2.22 mag.). At first glance the semicircle of the rock painting and of the stars seem to fit well. Certain nuances could be considered the result of the “artistic freedom” of the creator. If it were not for an important fact: the proper motion of the stars change the shape of constellations slowly but definitely, over the course of thousands and tens of thousands of years. The appearance of the constellation of the Northern Crown as seen in the sky today

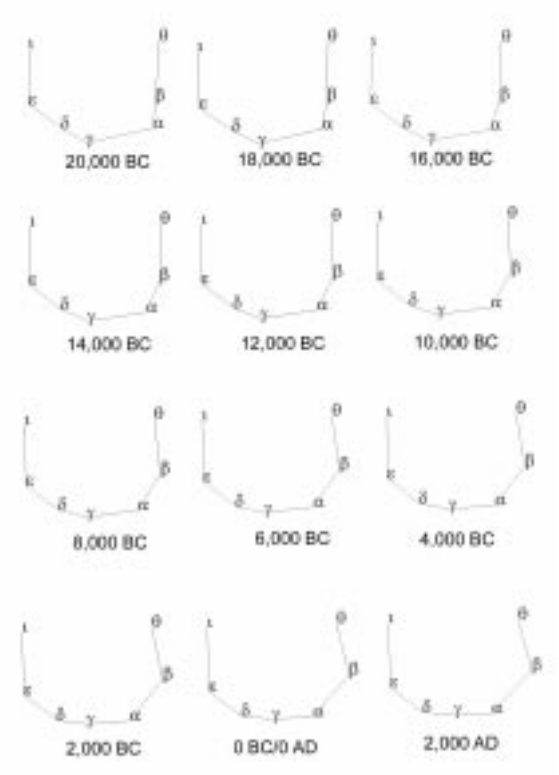

Fig. 7 The proper motions of the stars changes the form of the constellation. Between 10,000 BC and 6,000 BC the seven stars formed a perfect semicircle. If the pattern of dots really shows the Northern Crown, then the rock picture is clearly not coming from the Aurignacian or Gravettian epoch, but from Magdalenian or Azilean time. Drawing by Michael A. Rappenglück using the Software Guide 7.0.

reminds one strikingly reminiscent of the rock painting from the distant past in the Cueva de Castillo. But how did the constellation look at that time, when the proper motion of the stars is considered? Did the old star gazers see a slightly different constellation in the heavens a millennium ago than we do? And did they record what they saw in the image, as concerned about accuracy in the depiction as we are?

The minor but still noticeable difference in the shape of the rock painting and the constellation could therefore be the result not of artistic freedom but of the way the constellation has changed its shape because of the proper motion of the stars. By making calculations based on special designed astronomical software[3] and representing the results graphically, the change in the shape of the constellation through the epochs can be seen and if it ever corresponded exactly with the dots on the rock painting.

It is necessary not only to track the motions of the stars in the constellation but also that of those stars which today belong to other constellations, but which at that time might have been present in the locality of the Northern Crown. No other stars up to an apparent magnitude as large as 5.5 mag. apart from the seven stars of the Northern Crown were present in this narrow segment of the sky, until 18,000 BC.[4]

The rock painting depicts the seven coloured dots arranged in a semicircle. The constellation today has a similar shape but one not nearly so perfect. If the rock painting accurately depicts the shape of the constellation as it was thousands of years ago, then it must be possible to pin point the exact epoch, by searching the form of the constellation which corresponds best of all to the semicircle. When was this the case?

Between 6,000 BC and 12,000 BC the seven stars formed a perfect semicircle. Before and after this time the bow is more angular (fig. 7). The changed position of the star 5 • CrB (Alphekka, Gémma) in particular disturbs the form.

The astronomical arguments suggest that the rock picture should not be classified to the Aurignacian (31,000-26,000 BC), Gravettian (26,000-20,000 BC) or the Solutrean (20,000-17,000 BC) period, as some researchers have claimed.[5] So, seen from an astronomical viewpoint, the picture must be at least 8,000 and at most 14,000 years old. But it must to be taken into account, that the naked eye, in the best conditions of visibility, only can separate two light points (stars) in the sky, which are about 1´ away. This value is equivalent to an error in dating of about 1,000 years plus/minus. Therefore the astronomical dating has to be adjusted and then the constellation had its most perfect shape between ca 7,000 BC and ca 13,000 BC. The probability that it was painted in the thousands of years before is minute. The direct and indirect method of C-14 dating both support this astronomical estimate of the age of the best possible constellations shape: 13,060 ± 200 BP (GifA 91004; cal. 14,400-12,500 CalBC) and 12,910 ± 180 BP (GifA 91172; 14,200-12,400 CalBC), 12,390 ± 130 (OxA 972, CS. 11; 13,600-12,100 CalBC) and 10,310 ± 120 BP (OxA 970, CS. 6; 10,900 – 9,600 CalBC). The best date fitting to the astronomical analysis is 10,310 ± 120 BP (OxA 970, CS. 6; 10,900 – 9,600 CalBC).[6] Another date 16,850 ± 220 BP (OxA 971, CS. 7; 19,000-17,300 CalBC) clearly falls outside the limits of the astronomical estimates of age.[7]

The rock painting thus can be classified without hesitation as belonging either to the late phase of the Magdalenian or even the early Azilean phase. The possibility of it belonging to older epochs can be discounted.

People of that epoch should be delighted in seeing the perfect form of the constellation of the Northern Crown. The semicircle of bright stars could also have possessed from the earliest times a special significance on account of the symbolism connected with the number seven.[8]

Now another question arises: Was the constellation visible above the natural horizon at the grotto and at that epoch during any of the seasons of the year? This is not so clear, as it might be supposed.

As a result of precession[9] the stars appear to change their positions against the background of the celestial sphere in the course of hundreds and thousands of years. Some constellations are not visible at certain epochs or else they can be seen only at certain times during the year above the horizon from a given observational point of the earth. Other constellations are permanently above the horizon at certain epochs, i.e. some or all of their stars never rise or set, because of their proximity to the north (or south) celestial pole. Such stars are circumpolar. It is necessary to check how precession changed the position of the constellation of the Northern Crown above the horizon when seen from the Cueva de Castillo at different epochs.

The result showed that for the geographical latitude of the Cueva de Castillo all the stars of the Northern Crown were visible (during all the epochs) for a certain period of the year above the horizon. One question which is particularly interesting is: was there in the past any one position which might have especially stimulated the observers to try and capture the image by painting it on a rock wall? In some millennium the constellation does however have a very striking position above the Cueva de Castillo. It is both circumpolar and near the horizon. When was this the case?

To determine the time it is necessary to calculate the apparent positions and visibility of the stars of the Northern Crown, when they become circumpolar. These depend not only on geometry of the sky-sphere but also on some physical aspects of the atmosphere, known as refraction, absorption, scattering and the landscape forming the visual horizon. Empirically based

average values help to compute the real visibility of the constellation at a given epoch an time of the year.[10] At the location of the Cueva de Castillo the star 5 • CrB (Gémma; 2.2 mag) must not fall below the 2° altitude mark above the apparent horizon, to be just visible for the naked eye. The dates ascertained in this way would still lie within the margins of error of C-14 method. Refraction and the visual horizon can therefore be ignored. That means that at and after 12,000 BC the conditions existed to observe the brightest star in the Northern Crown. The star 4 • θ CrB (4.1 mag) must be at least 5° - 6° above the apparent horizon (fig. 8). 14 • CrB (4.99 mag) is problematic: Under good conditions it must be at 15° above the apparent horizon to become visible. This situation arises around 11,000 BC. The earliest date at which the whole constellation of the Northern Crown could be seen without any difficulty by naked eye closest to the horizon was 11,000 BC (fig. 9).

If the astronomical interpretation of the rock painting is correct, then this date forms the lower limit for the age of this section of the whole composition of the

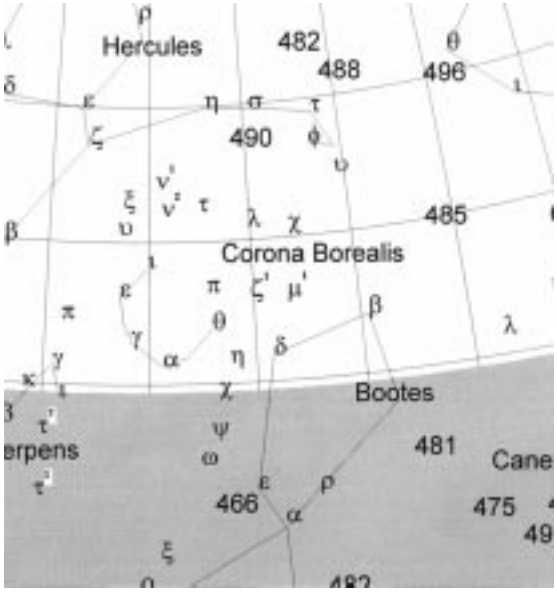

Fig. 8 The Northern Crown 12,000 BC at midnight, 21 March, in its lower culmination above the northern horizon. The precession of the equinoxes and the proper motions of the stars are considered. Drawing by Michael A. Rappenglück using the Software Guide 7.0. At this epoch not all stars are visible at this position of the constellation because of the extinction of the starlight. At 11,000 BC the constellation is beautiful to observe in its lower northern culmination (see fig. 10).

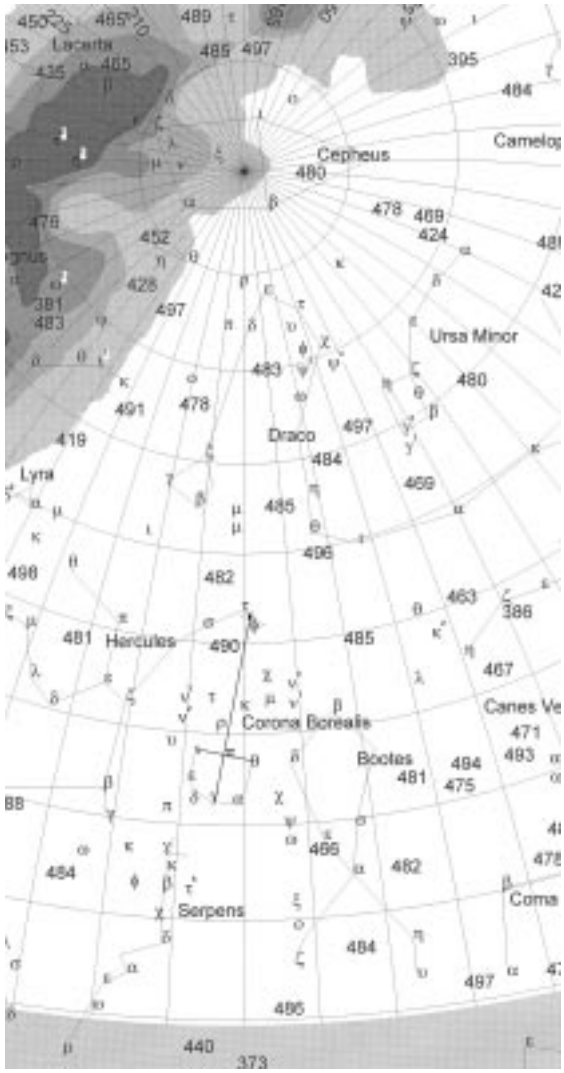

Fig. 9 The stars of the Northern Crown successively reached their position of closest proximity to the north celestial pole, 17° - 21°, between 8,000 BC and 7,500 BC. So the constellation could serve as a excellent pointer to the northern sky pole of the epoch and a polar star, if present. Here at around 7,500 BC midnight, 21 June (summer-solstice) an imaginary line drawn from 8 • γ CrB to the middle of the distance between 14 • CrB to 4 • CrB points directly to the ancient pole star 22 • Her. The precession of equinoxes and the proper motions of the stars are considered. Drawing by Michael A. Rappenglück using the Software Guide 7.0.

"Frieze of Hands". It converges with the one suggested by C-14 or the AMS method: 10,310 ± 120 BP (OxA 970, CS. 6; 10,900 – 9,600 CalBC).[11] When now were the stars of the Northern Crown nearest to the north celestial pole?

The stars of the Northern Crown successively reached their position of closest proximity, between 17° and 21°, to the north celestial pole between 8,000 BC and 7,500 BC. So the constellation could serve as a excellent pointer to the Northern sky pole of the epoch and a polar star, if present.

At around 7,500 BC the star 22 • Her (3.9 mag) was only in 1°41´ distance from the pole, thus making an excellent northern polar star. Sky watchers today as in the past use a constellation which is particularly near to the pole and often in its lower culmination – now it is the Big Dipper (the Great Bear/UMa) or the w-shaped Cassiopeia (Cas) - to help find the northern celestial pole and the northern point on the horizon. At that time the following rule might have existed: look for the constellation of "seven dots in a semicircle". Take the two stars at each end of the arc, divide this distance in half. Then take a perpendicular line and follow it with your eye in the direction of the open arc. The line of vision will show the star closest to the pole 22 • Her. Take a tope with a weight attached and hold it with one end to the "polar star". The plumbline will then indicate the north pole of the natural horizon.

It was also possible to locate the northern celestial pole with the help of the constellation when it was in its circumpolar position near the horizon above the north pole in12,000 BC. The left hand part of the Northern Crowns arc pointed directly at a very bright star 3 • Lyr (Vega; 0.01 mag) which was very close to the northern celestial pole (about 5° away): a magnificent and brilliant polar star. A thousand years later around 11,000 BC (fig. 10), the star 85 • Her (about 4,5° away, 3.81 mag) would have become the northern pole star. The sky watchers of that time must have drawn an imaginary line from

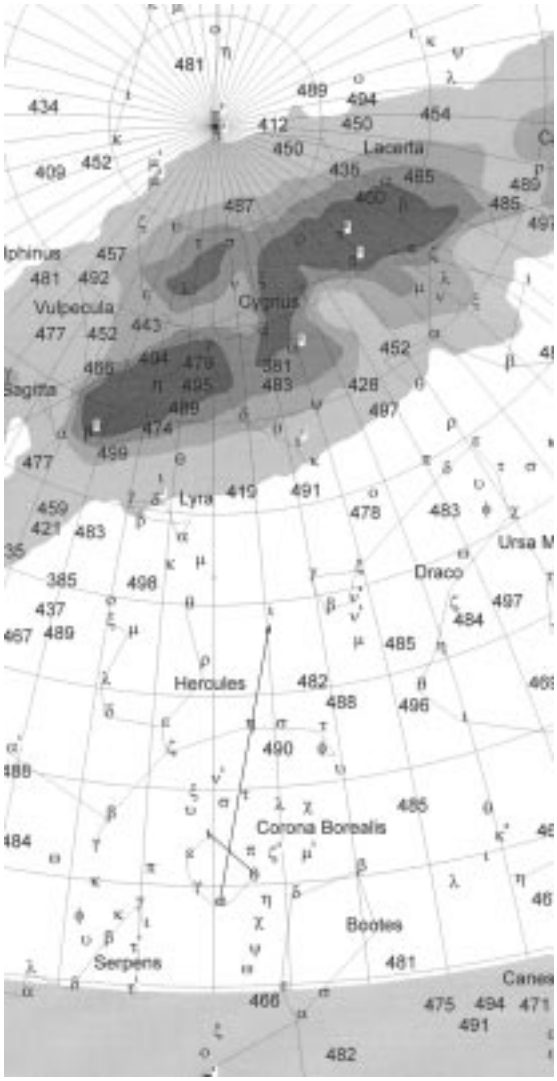

Fig. 10 Here the constellation is shown at 11,000 BC, ca midnight, 21 March (at the vernal equinox) in its deepest lower culmination in the course of the millennia, with respect to the fact that all stars should be easy visible. This was a very significant position for finding the exact northern point at the horizon and the northern pole of the sky. A imaginary line drawn from 5 • CrB Gémma) to the middle of the line of 14 • CrB to 4 • CrB points exactly at 85 • Her the pole star of the northern sky at that epoch. So the Northern Crown (CrB) could be an excellent helper for orientation and navigation at land and at sea. The precession of equinoxes and the proper motions of the stars are considered. Drawing by Michael A. Rappenglück using the Software Guide 7.0.

Gémma to the middle of the line of 14 • CrB to 4 • θ CrB (distance about 7°). The extension of this line through the open semicircle crossed the centre of the constellation of Hercules to point exactly at 85 • Her. This perspective must have been so striking and simple that following our line of reasoning, the date about 11,000 BC must be more probable (fig. 10).

The circumpolar position, near the horizon could be the best observed around 11,000 BC towards midnight local time at the beginning of spring. The same circumpolar position, near the pole could be seen extremely clearly at about the same time of night during summer solstice at about 7,500 / 8,000 BC. At this time the meridian passed through the constellation, which had reached its lower (inferior) culmination: a fact which was again very useful for purposes of orientation. Important to note is that as a result of precession, the constellation of the Northern Crown was so close to the northern celestial pole between 7,500 BC and 12,000 BC, that it became circumpolar. Throughout the year the splendid and striking star must have shone in the northern part of the night sky.

It may be, that the pattern of dots painted in the middle of the “Frieze of Hands” represent other constellations at the epoch 11,000 BC. Ice Age people could have arranged the stars of the today constellations Hercules (Her) and Lyre (Lyr) near the point of the northern pole of the sky in particular constellations of their own. Comparing the skychart of 11,000 BC (fig. 10) with the rock painting, it is remarkable, that the band of hands to the left looks like the Milky Way above the constellation of the Northern Crown (CrB). Here research work must going on.

In the late Magdalenian and early Azilian epoch the constellation of the Northern Crown therefore offered an ideal way of establishing the north celestial pole and through this, the north pole above the natural horizon. This was useful for orientation at land, perhaps navigation at sea and for establishing the calendar. The position of the constellation at the sky throughout the year could serve as a seasonal marker, like a gigantic sky-clock.

There are also stories from the Greek and the Celts, which give some hints on the signification of the Northern Crown for archaic people. According to Greek legend, Ariadne gave Theseus a magical ball of thread.[12] Theseus had to fight with the Minotaur, a monster, half man, half bull in a cave and labyrinth on Crete. By rolling up the brightly shining thread into a ball again, the hero was able to find his way back out of the cave to reach safety. The god Dionysus had given this magical crown of thread to Ariadne as her wedding present. Later the sparkling and fiery crown was set among the stars as the constellation of the Northern Crown.[13] The same semicircle was called Caer Arianrhod, "castle silver wheel"; by the Celts. This name shares similar linguistic and other features with Ariadne[14] Caer Arianrhod is an icy place in the North. This is where the cold winds originate. The constellation of the Northern Crown is the concrete manifestation of the name of the "Crown of the North Wind". This could indicate the circumpolar position of a constellation in the northern skies above the north pole of the horizon. Other features of the Celtic legend confirm this interpretation: Caer Arianrhod, according to the story, rotates without moving between the three elements of water, air and fire.[15] "Without moving" : in fact a pretty accurate description of the closest possible proximity to the northern celestial pole. That Caer Arianrhod is seen as a far away castle following a spiral pattern of rotation, clearly indicates the circumpolar position of the stars.[16] Souls ascend to this place, imagined as a castle in the sky.[17] It is the realm of the death which by the

Celts as with other peoples, is situated in the North.[18] Is the content of these stories familiar from the impressive position of the shining semicircle of stars near the celestial north pole? If the constellation served as a heavenly marker and reference point by which other points in the sky and on earth could be found, then it is perhaps clear why Caer Arianrhod is associated with a magical net or wheel made of string, which forms a reference system.[19]
In the last years I have shown, that Ice Age people observed the sky and arranged the stars in particular constellations.[20] In one case, in the Lascaux grotto, they draw complete cosmographic maps, including a lot of the knowledge of their culture (from mapmaking to shamanism) at the rock walls of the cave.[21] There too a prominent set of circumpolar constellations of the Magdalenian epoch (16,000-10,000 BC) is painted on the rocks. In another study I presented an overview about the abilities of Ice Age seafarers to make considerable sea voyages.[22] Some years ago I drew attention to the fact, that there is a striking similarity between a rock picture in the Grotte de Lascaux[23] (France) and another in the Cueva de Los Maños[24] (Argentina) at the other side of the globe.[25] Both pictures date in the same epoch and are at least 9,000 years old, based on 14C-datings.

Did ancient seafarers travel between the Europe and South America at the end of the last Ice Age?

Now new research work shows, that my hypothesis about Ice Age people finding their ways by the stars at land and at sea could be right: It seems that their had been interactions between Paleolithic cultures in Europe (Cantabrian coast) and in North America, in Solutrean and Magdalenian time (19,000-10,000 BC).[26]

Is it only purely accidental, that the Cueva di El Castillo shows a circumpolar constellation, which is excellent to help navigating and that the cave is situated at an ideal starting point of the suggested connections between North and South America - the Cantabrian coast? No, I believe not.
There are the circumpolar constellations in the deep of the Lascaux[27] grotto, drawn too for purposes of orientation and navigation. They together with the constellation of the Northern Crown in the Cueva di El Castillo proof, that Ice Age people could find their ways by the stars.

Zusammenfassung:

In der Höhle von El Castillo (Spanien) gibt es auf einer Felswand ein merkwürdiges Muster aus sieben Punkten. Aus astronomischer Sicht betrachtet, könnte die Zeichnung das Sternbild der Nördlichen Krone (CrB) in der unteren Kulmination (d.h. über dem Nordpunkt) etwa um 12000/11000 v. Chr. darstellen. Die wissenschaftliche Untersuchung beginnt mit einer präzisen Beschreibung des Felsbildes und insbesondere des Musters der Punkte. Die zunächst hypothetische Zuweisung des Sternbildes zum Felsbild, basierend auf der eindrucksvollen formalen Übereinstimmung beider, wird im Verlauf der Studie mit Hilfe detaillierter astronomischer Berechungen als stimmig erwiesen. Die Analyse bezieht die veränderte Form des Sternbildes, seine Stellung und Sichtbarkeitszeiten im Verlauf der Jahrtausende am geographischen Ort der Höhle im Monte El Castillo ein. Sämtliche astronomische relevante Bestimmungsgrößen wie Präzession der Äquinoktien, Eigenbewegungen der Steren, Refraktion und Extinktion des Sternenlichtes und der scheinbare Horizont werden berücksichtigt. Zwei Mythen,

überliefert von Griechen und Kelten, helfen, die Bedeutung des Sternbildes für die Kulturen der Eiszeit zu verstehen. Zum Schluss wird die Funktion der Nördlichen Krone (CrB) für Orientierung auf Land und Navigation zur See erörtert unter Bezug auf ein ähnliches Beispiel aus der Höhle von Lascaux (Frankreich) und neueren Entdeckungen zur Seefahrt am Ende des letzten Eiszeitalters.

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1 : 43°17′ 25″ N | : 03°59′40″ W; H: 197 m above NN; Naber et al., 1976: 225
2 Breuil and Obermaier, 1935: Fig. 75
3 Kammerer, 1990; Guide 7.0 (Project Pluto)
4 Only the stars 9 · Crb (5.57 mag) and 590 Crb (5.90 mag) were in the area too, but so near to the limit of invisibility for the naked eye, that they can be neglected.
5 Naber et al., 1976: 226
6 A stick of bone which has been pierced and engraved 10, 310 ± 120 BP (OxA 970, CS. 6), an harpoon made of bone 12,390 ± 130 BP (OxA 972, CS. 11) and the decorated tip if a spear 16,850 ± 220 BP (OxA 971, CS. 7); Samples of colours were taken from the rock wall near to the entrance ((Zone IV: no 18 and 19) from the picture of the large bison looking to the right: 13,060 ± 200 BP (GifA 91004) and 12,910 ± 180 BP (GifA 91172) (Valladas, 1992: 68, 69, Table 1 / 2). Newer data permit to calibrate 14C years ago to calibrated (“real”) years ago (therefore see Stuiver et. al. , 1998: 1041-1083). The methodology depends strongly on ongoing research work and the timescales may be taken with caution. Data before 12,000 BP are not so sure. But because of the astronomical suggestion of the date lying around 11,000 BC I calibrated the BP years to CalBC years with the help of the program OxCal Version 3.3 written by Ramsey Bronk (1999). BP: before presence.
7 Frolov, 1978/79: 46
8 Short term fluctuations, for example the nutation, also occur, but they will not be taken into account in this study because they are so minute.
9 Petri, 1978: 186-189 und 205-206, Tabelle 7, 9, 10
10 Allen, 1963: 174-178
11 Von Gneisenau, 1979: 544
12 Graves, 1985: 113
13 Graves, 1985: 114, 207
14 Graves, 1985: 122-123
15 Graves, 1985:113
16 Graves, 1985: 112
17 Matthews und Matthews, 1994, 30-31
18 Rappenglück, 1994, 1995, 1997, 1999a, 1999b, 1999c
19 Rappenglück, 1999a
20 Rappenglück, 1999b
21 Com. Montignac, Dép. Dordogne, Rég. Aquitaine, France; : 45°3'12'' N | : 1°10'30'' O, H: 216 m above NN
22 Provincia Santa Cruz, Patagonia, Centro-Meridional, Argentina; : 47°00' S | : 70°35' W, H: 240 m above NN
23 Rappenglück, 1994
24 There is still to discuss the considerable gap between the time of the Solutrean (19,000-17,000 BC)

and Clovis (16,000-10,000 BC) cultures.
25 Rappenglück, 1999

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[1] : 43°17′ 25″ N │ : 03°59′40″ W; H: 197 m above NN; Naber et al., 1976: 225
[2] Breuil and Obermaier, 1935: Fig. 75
[3] Kammerer, 1990; Guide 7.0 (Project Pluto)
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[9] Short term fluctuations, for example the nutation, also occur, but they will not be taken into account in this study because they are so minute.
[10] Petri, 1978: 186-189 und 205-206, Tabelle 7, 9, 10
[11] see footnote 6
[12] Allen, 1963: 174-178
[13] Von Gneisenau, 1979: 544
[14] Graves, 1985: 113
[15] Graves, 1985: 114, 207
[16] Graves, 1985: 122-123
[17] Graves, 1985:113
[18] Graves, 1985: 112
[19] Matthews und Matthews, 1994, 30-31
[20] Rappenglück, 1994, 1995, 1997, 1999a, 1999b, 1999c
[21] Rappenglück, 1999a
[22] Rappenglück, 1999b
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[24] Provincia Santa Cruz, Patagonia, Centro-Meridional, Argentina; : 47°00' S | : 70°35' W, H: 240 m above NN
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[26] There is still to discuss the considerable gap between the time of the Solutrean (19,000-17,000 BC) and Clovis (16,000-10,000 BC) cultures.
[27] Rappenglück, 1999.