Evidence for a new interpretation of the Berlin Celestial Globe fragment SK1050A

Ulrich Kuehne (Berlin)
ULRICH.KUEHNE.1987@BALLIOL.ORG
Version: 1.0

ABSTRACT
Since Thiele (1898) the fragment SK1050A in the Neue Museum *in Berlin has been interpreted as being part of an ancient vessel garnished with arbitrary astronomical ornaments. In this paper evidence is collected that the fragment was in fact part of a sophisticated astronomical instrument:*

(1) Structures of the fragment indicate that the celestial globe was fitted with a water-clock similar to the design by Ctesibius and that this water-clock propelled an astronomical model of the universe.

(2) Iconographic parallels between SK1050A and the Atlas Farnese suggest that the latter was intended to be a replica of the Berlin celestial globe.

(3) The arrangement of the 'star-markings' on SK1050A might be explained as geometrical constructions to establish spherical coordinate transformations.

In consequence, SK1050A appears to be the product of a profound astronomer while some evidence beyond that prompts the hypothesis that the fragment is from the celestial globe of Archimedes.

CONTENTS
I. The traditional interpretation of SK1050A by Georg Thiele (1898)
II. Towards an new interpretation of SK1050A
a. SK1050A as part of a water-clock
b. A comparison of SK1050A and the Atlas Farnese
c. The astronomical engravings on SK1050A
(i) The placement of the constellation figures
(ii) The placement of the 16 'star-markings'
III. Open questions
Appendix: Figures

I. The traditional interpretation of SK1050A by Georg Thiele (1898)

The Berlin Celestial Globe (BCG) fragment was bought 1889 by the *Antikensammlung Berlin* from unknown provenance and is listed with inventory number SK1050A. It is publicly displayed in the basement floor of the *Neue Museum* on the Museumsinsel in Berlin. **Figure 1** shows some current photographs. The caption in the museum dates it to the Roman imperial period, first century CE.[1]

In his seminal book *Antike Himmelsbilder* Georg Thiele in 1898 wrote a lengthy paragraph stating the facts and interpretations about the fragment which have been basically undisputed until now. As to the facts, Thiele writes:

> Streifenartiges Stück eines Gefässes aus blauem Marmor (Bigio); Länge 0,33m, Breite 0,112 m. Darin figürliche Vertiefungen, in die vier Sternbilder aus anderem Material eingelegt waren, die sämtlich herausgebrochen sind. Die Vertiefungen lassen erkennen Kassiopeia, Schwan, ein Stück der Milchstrasse, Lyra, die Hälfte vom Engonasin. Um die Figuren herum sind 16 Stifte aus Giallo eingelassen, um Sterne anzudeuten. Der kürzere obere Längsrand des zonenförmigen Streifens ist glatt, der lange untere gebrochen. An den Seitenrändern ist kein Bruch, sondern je eine vertiefte Linie sichtbar, die wie ein Ansatz für ein weiteres Stück aussieht. Vergleicht man das Fragment mit der betreffenden Zone des Atlas Farnese, so sieht man deutlich, dass es von einem Globus stammt und etwa 1/3 der zwischen nördlichem Polarkreis und nördlichem Wendekreis gelegenen Zone gebildet hat.[2]

Thiele continues with his interpretation:

---

1 www.neues-museum.de. A high-resolution image file of SK1050A has the registration number 00042839 in the database of www.bpk-images.de.

2 Georg Thiele: *Antike Himmelsbilder*, Berlin 1898, p. 42. English translation: "A stripelike piece of a vessel made of blue marble (Bigio); length 33 mm, width 11.2 mm. In it figurine-shaped depressions in which four star constellations had been inlaid which were all removed. The depressions point towards Cassiopeia, Cygnus, part of the Milky Way, Lyra, half of Engonasin. The figurines are surrounded by 16 Giallo brads indicating stars. The shorter upper horizontal edge of the zone-shaped strip is smooth, the long lower one is broken. The side edges show no breakage, instead two grooves are discernible, one on each side, that look like the base of a further piece. A comparison of the fragment with the corresponding zone of the Atlas Farnese clearly shows that it comes from a globe representing approximately on third of the zone between the Arctic Circle and Tropic."

> Da der kurze Rand glatt ist, so war hier ohne Zweifel die obere, vom nördlichen Polarkreis begrenzte Calotte als Gefässdeckel aufgesetzt. Dergleichen Spielereien produziert die moderne Industrie übrigens auch; es wäre aber das Stück, das sich durch Hinzufügung der Milchstrasse vor dem Farnesischen Globus auszeichnet, von grossem Werte, wenn das ganze Gefäss die getreue Nachbildung eines astronomischen Globus gewesen wäre. Diese Erwartung bestätigt sich jedoch nicht, denn die um die Figuren herum markierten Sterne sind ganz willkürlich gesetzt und finden sich weder bei Ptolemaios noch auf modernen Sternkarten in dieser Lage. Auch die Lage der Sternbilder-Figuren stimmt zu wenig mit Hipparchos, d. h. mit der Wirklichkeit überein, denn der Schwan und die Kassiopeia kommen viel zu nahe an den nördlichen Wendekreis heran; Kopf, unterer Teil des Halses und linker Flügel des ersteren liegen sogar auf dem Wendekreis, was Hipparchos als falsche Angabe von Eudoxos kritisiert (I, 10, 14 p. 104 M.). Andererseits ist auch die Astrothesie des Aratos und Eudoxos auf dem Fragment ausgeschlossen, da keiner von beiden die Kassiopeia sich bis an den nördlichen Wendekreis erstrecken liess. Dem Künstler des betreffenden Marmorgefässes hat eben nichts an einer genauen Kopie gelegen, da der Globus nur einem dekorativen Zwecke diente.[3]

In summary, Thiele interprets the fragment as having been part of a purely decorative object with no astronomical value whatsoever. His main reasons for this are:

(1) Thiele takes it for granted that the BCG was a vessel which originally had a lid fitting to the smooth northern edge. Thus it was made rather to store some precious objects in it than to use it as a representation of celestial objects.

(2) Thiele states that the 16 ‘star-markings’ and the constellation figures are

[3] Thiele (1898) 42. English translation: “Since the short edge is smooth it was undoubtedly here that the upper calotte, adjacent to the Arctic Circle, was placed as the lid of the vessel. Such gadgets, by the way, are also produced by modern industry. However, the piece that differs from the Farnese globe by adding the Milky Way would be of great value if the whole vessel were a faithful copy of an astronomical globe. This expectation cannot be validated, however, because the stars marked around the figurines are placed utterly at random and cannot be found in these places in either Ptolemy or modern celestial charts. Furthermore, the position of the constellation figurines correspond too little to Hipparchos as well as to reality, since Cygnus and Cassiopeia are positioned much too closely to the Topic of Cancer; the head , the lower part of the neck and the left wing of Cygnus appear even *on* the Tropic – which was criticized as erroneous in Eudoxos by Hipparchos (I, 10, 14 p. 104 M.). On the other hand, the astrothesis of Aratos and Eudoxos cannot be applied to the fragment either, since neither one had Cassiopeia stretch to the Tropic of Cancer. The artist who made this marble vessel was simply not interested in creating a precise copy, since the globe served but decorative purposes.”

misplaced to such a degree that they neither represent real celestial objects nor can they be interpreted to be derived from any astronomical source from antiquity we know of. Thus he concludes that SK1050A is the work of an artist who placed the astronomical ornaments “utterly at random”.

By looking at the fragment in real in the *Neue Museum* and examining detailed pictures of it I came to different conclusions.

For reference, **figure 2** labels all relevant parts of the fragment according to the following listing. The third column lists Thiele’s interpretation which will in parts be disputed later on.

Label	Description	Interpretation **according to Thiele 1898**
E1	lower edge, smoothly cut	Arctic Circle
E2	upper breaking edge, front part with cut notch	Tropic of Cancer
E3	left breaking edge partially with cut notch	cut hem to piece adjacent slabs of the globe together
E4	right breaking edge, front part with cut notch	cut hem to piece adjacent slabs of the globe together
S1	circular hole with yellow inlay	markings of stars, however, all arbitrarily placed for purely decorative purposes (not representing real stars)
S2	circular hole with yellow inlay	
S3	circular hole with yellow inlay slightly damaged	
S4	circular hole with yellow inlay	
S5	circular hole with yellow inlay, marked with engraved quarter circle	
S6	semicircular hole cut by M1, no inlay	
S7	circular hole with yellow inlay slightly damaged	
S8	semicircular hole cut by E2, no inlay	
S9	circular hole with yellow inlay	
S10	circular hole with yellow inlay	

S11	circular hole, no inlay	
S12	circular hole with yellow inlay	
S13	circular hole with yellow inlay	
S14	circular hole with yellow inlay	
S15	circular hole with yellow inlay slightly damaged	
S16	circular hole with yellow inlay	
M1	smoothly cut notch of semicircular cross section	Milky Way
C1A	engraved figure, cut by E4	left hand and forearm of constellation figure Hercules (Engonasin)
C1B	engraved figure, cut by E4, lower part broken off	foot and lower leg of Hercules
C2A	engraved figure	upper part of Lyra
C2B	engraved figure	lower part of Lyra
C3A	engraved figure, top part cut by E2	head and neck of Cygnus (swan)
C3B	engraved figure, top part cut by E2	left wing of Cygnus
C3C	engraved figure	body of Cygnus
C3D	engraved figure, cut by M1, stone damaged	right wing of Cygnus
C3E	engraved figure, lower part cut by M1	left leg and claws of Cygnus
C3F	engraved figure, middle part cut by C3D and M1	right leg and claws of Cygnus
C4	engraved figure (hoof of horse?)	(not mentioned by Thiele)
C5A	engraved figure	head of constellation figure Cassiopeia
C5B	engraved figure, cut by E3	left upper arm of Cassiopeia
C5C	engraved figure	upper part of the body of Cassiopeia
C5D	engraved figure	(cloak?)
C5E	engraved figure	right arm and hand of Cassiopeia
C5F	engraved figure	(throne of Cassiopeia?)
C5G	engraved figure	(base of the throne of Cassiopeia?)

II. Towards a new interpretation of SK1050A

There are many starting points to argue for the initial suspicion that Thiele's interpretation cannot be the final truth about SK1050A. For instance,

(T1) The 'head of Cassiopeia' C5A seems to be fitted with a beard.

In C5A I see a male head in half-view looking left seen from the back and wearing a hat and a beard. This would be odd for Cassiopeia and for Andromeda but fits with the iconography of Cepheus.

(T2) Constellation figure C5 is Cepheus.

However, normally (as in the *Phenomena* of Aratus) Cepheus is standing upright, thus:

(T3) C5F and C5G do not represent parts of a throne or a seat.

Equally, Thiele's idea of the BCG as being assembled from separate marble slabs seems odd since E2, E3, and E4 are clearly breaking edges caused by a destructive force. But all three edges have carefully cut notches, all perhaps half of a centimeter deep from the front.[4]

(T4) The BCG was cut out of a monolithic stone. It was not assembled from separate slabs.

(T5) The artificer of the BCG cut the notches on the edges E2, E3, and E4 for functional reasons. Only later, when the BCG was destroyed by brute force these notches accidentally served as breaking points and produced the present shape of the fragment.

[4] I apologize for the vagueness of this description. As of present I have no access to accurate measurement data on SK1050A. However, the press release idw-online.de/pages/de/news406669 announces a publication by Gerd Graßhoff with such data which will obviously be essential for testing the hypotheses in this paper.

II.a SK1050A as part of a water-clock

The assigned task is to find the functional reasons for the notches in E2, E3, and E4, and to provide a sound interpretation for C5F and C5G. A rough sketch of my interpretation is depicted in **figure 3**.

It is remarkable that the notch in E3 is not cut through right to edge E1 but ends halfway in C5G.

(T6) The notch at E3 was bearing a rotatable axle which was mounted at an inlay base at C5G. I.e., C5G is the base shape of an axle bearing.

(T7) The notch of the Milky Way (M1) was bearing a water pipe.

(T8) Mounted on the axle in E3 was a wing blade which had an edge shape matching C5F.

That is: A surge of water passing through the pipe in M1 hit at the blade at C5F and consequently turned the axle in E3. If this construction is to be functional we should additionally assume the following:

(T9) The lower edge E1 has always been at the bottom of the BCG, E2 facing up. (In consequence all constellation figures on the fragment are placed upright.)

(T10) The end of the pipe in M1 had to be bent upwards in such a way that the water is diverted radially away from the globe thus maximizing the transfer of momentum from the water to the blade. To this end, there was presumably a little cone at the corner of C5F touching M1.

(T11) Because of the C5F-shaped blade mounted to the axle in E3 the axle could at most perform half-turns forwards and backwards. But we should assume that after every surge of water the blade was again pressed to the globe by a counter weight attached to the axle at right angle to the blade. If so, the axle performed quarter-turns forwards and backwards with every surge of water.

(T12) Since the axle location in E3 clearly directs towards the equator of the BCG we may assume that the movements of the axle propelled, similar to the balance wheel in a mechanical clockwork, some mechanism situated around the equator of the BCG. Possibly, there was a crown-wheel at the top of the axle in E3 which transformed the periodic quarter-turns back and fourth of the axle E3 into a uniform forward rotation of a large gear tire which was hung freely rotating around the equator. This gear tire would then drive many other tires which represented the planets, the sun, and the moon around the ecliptic.

But how did the artificer accomplish that periodic surges of water run through the pipe in M1? A siphon as used by the Greek inventor Ctesibios (fl. 285-222 BCE) for his water-clocks stands to reason, see **figure 4a**: A continuous flow of water fills a cylindrical vessel. A discharge pipe at the bottom bends up to nearly the top edge of this vessel and down again ending just beneath the bottom of the vessel. When the water level inside the vessel reaches the top extension of the discharge pipe the vessel completely empties in a single surge through the discharge pipe. The sequence is repeated as soon as the continuous inflow of water has again filled the cylindrical vessel up to the level of the top extension of the discharge pipe.

(T13) Inside the BCG and aligned with the polar axis was a cylindrical water tank. The edge E1 defines the size of the surface of the cylinder. At the top of the BCG was a hole of the same size as defined by E1 for the bottom of the BCG. An exterior intake pipe filled the cylinder from the top.

This shows that Thiele was wrong in supposing that the BCG originally had a lid fitting to E1. The polar regions north and south were both missing by design.

(T14) If the point of contact of M1 and C5F was the end of the discharge pipe along the Milky Way M1 we may assume that the beginning of the discharge pipe was also on the milky way to the left of SK1050 and slightly upward (to the south). Thus, if C5 is Cepheus (T2) the location of a small hole in the BCG connecting the water tank inside with the water pipe along the Milky Way would be near the constellation of Cassiopeia.

The notch in E4 is similar in shape to the notch in E3. So we may assume that E4 was bearing a rotatable axle, too. However, different from the notch in E3 the notch in E4 does not end in an axle bearing but extends from E2 to E1. Noteworthy is the fact that at the corner of E4 and E1 (underneath the foot of Hercules) a significant piece of marble is broken.

What could the function of the axle in E4 be? Assuming that the blade-bearing axle in E3 is the only motor of all mechanical movements around the ecliptic, an axle in E4 can only have the function to transmit a rotational movement from the ecliptic down to E1. Following (T13), E1 was also the bottom edge of the BCG. Thus a rotational movement at E1 would imply a rotational movement of the BCG as a whole.

(T15) The notch at E4 was bearing a rotatable axle. At E1 this axle ended in a gear wheel fitting in diameter to the gap broken out of the marble at the corner of E1 and E4.

(T16) The gear wheel of (T15) rotated the BCG as a whole (with the water-cylinder and all mechanical parts of the orrey attached) around a fixed base. The fixed base was probably a cylinder of the same diameter as the water vessel inside the BCG (T13) and was inserted into the BCG through the omitted polar region of the north pole. In the center of the circle on top of the cylindrical base was an axis tip touching the center of the bottom circle of the water-cylinder. The entire weight of the BCG rested on this axis tip. The gear wheel of (T15) rotated the BCG by driving the lower edge of the BCG (E1) against the top edge of the cylinder base.

Looking at the notch in E2, it seems impossible that there were movable parts close to the surface of the globe because E2 is intersected by the pipe in M1 and the axles in E3 and in E4. But from all said so far it seems clear that the mechanism around the ecliptic must have had a considerable size. Since the globe was rotatable as a whole no part of the mechanism could be supported from the base. The entire mechanism had to be fixed to the globe. A statically reasonable solution to this would use metal rings tightened to the globe and radial rods for bracing.

(T17) In the notch at E2 was a tension ring which was needed to fix the mechanism for the celestial movements of the sun, the moon, and the planets to the ecliptic plane of the BCG.

My assessment of the external dimensions of SK1050A results in an angular distance of c. 90 degrees of longitude between E3 and E4 and of c. 20 degrees of latitude between E1 and E2.[5] For a first rough estimate of the reach of SK1050A on the sky I additionally assume that:

(i) SK1050A is oriented towards either the celestial or the ecliptic pole,
(ii) the constellation figures on SK1050A are from left to right Cepheus (T2), Cygnus, Lyra, and Hercules,
(iii) M1 is placed on SK1050A closely to the modern definition of the galactic equator, and that
(iv) for hydrodynamic reasons the point of contact between M1 and C5F roughly defines the point of the closest approximation of the galactic equator to the pole.

(aT18) If SK1050A is aligned on the celestial pole and additionally assuming epoch c. 250 BCE, SK1050A covers roughly the area of the firmament marked in green on the map of **figure 5a**.

If equatorial, SK1050A would extend roughly from the 30th to the 50th degrees of latitude. The astronomical meaning of the axle in E4 would be to model the diurnal motion of the sky, i.e. the BCG rotated once every day.

(bT18) If aligned on the ecliptic SK1050A covers roughly the area of the firmament marked in blue on the map of **figure 5b**.

If aligned on the ecliptic, SK1050A would roughly extend from the polar circle of the ecliptic (i.e. latitude c. 66.5° north of the ecliptic) to the bisector of the ecliptic north pole and the ecliptic (i.e. latitude 45° north of the ecliptic). The only reasonable

[5] Thiele estimated (see quote above) “one third of the zone between the Arctic Circle and Tropic”, i.e. 120 degrees of longitude and 43 degrees of latitude. This seems implausible to me.

astronomical meaning of the axle in E4 would then be to model the precession of the equinoxes. This, however, would be an astonishing result since it implies a mechanism that has been created to carry out one rotation of the BCG in c. 26,000 years.

The consequence of the rough estimates of (aT18) and (bT18) is negative:

(T19) It is plainly obvious that in both maps of **figure 5a** and **5b** there is no close mapping of objects in the sky to the location of astronomical engravings on SK1050A.

The initial reason why we should nonetheless not follow Thiele in assuming that the astronomical engravings are the arbitrary work of an artist but follow a rational plan comes from a comparison of SK1050A with the celestial globe of the Atlas Farnese.

II.b A comparison of SK1050A and the Atlas Farnese

The Farnese Celestial Globe (FCG) is the most prominent of the very few celestial globes which have come down to us from antiquity and has been subject to many controversial interpretations.[6] However, without going into details it seems sound to assume the following:

(F1) The artificer of the FCG was an artist rather than an astronomer. From an astronomical point of view and according to all different interpretations, the artificer made quite a lot of mistakes.

(F2) But in building the FCG the artificer had proper astronomical prototypes. Analyzing the *astrothesie* and the epoch of the FCG all interpretations agree that at least some of these prototypes were significantly older than the FCG itself.

Let us now, just for sake of a thought experiment, suppose additionally the following three assumptions, and let's see how far we can explain unaccounted features of the

[6] Recently e.g. by Bradly Schaefer, Owen Gingerich, Dennis Duke, and Dennis Rawlins.

FCG with them.

(F3) SK1050A was one of the prototypes used by the artificer of the FCG – i.e. *not* the BCG but the fragment. We shall assume that the BCG was fractured quite early in antiquity, but that SK1050A and possibly some other fragments were preserved and used by different artists trying to make copies of the BCG. The artificer of the FCG had either the original SK1050A or intermediate copies (or both) at hand while making the Atlas Farnese.

(F4) Not knowing about the results of this paper, the artificer of the FCG (or of the parent globes) basically came to the same results as Thiele did: that SK1050A extends from the Tropic of Cancer to the Arctic Circle and roughly from Hercules to Cassiopeia but bears gross mistakes in the localization of astronomical objects.

(F5) However, unlike Thiele the artificer of the FCG was not in the position to discard SK1050A for its alleged mistakes. On the contrary, the artificer treated the fragment with the highest possible respect and tried to 'correct' the alleged mistakes as carefully and charily as possible.

When we now compare the constellation figures on the FCG (see **figure 6**) with those on SK1050A we find some surprising correspondences.

(F6a) Starting our comparison from the upper right corner of SK1050A we note that the lateral extensions of the left arm and left foot of Hercules and of Lyra on the FCG match exactly those on SK1050A if E2 is interpreted as the Tropic of Cancer and E1 as the Arctic Circle. This correspondence is not trivial since in reality the feet of Hercules are significantly south of the Arctic Circle.

(F6b) Regarding the placement of Cygnus on SK1050A Thiele wrote: "The swan […] comes much too close to the Tropic of Cancer." The artificer of the FCG seems to have been worried by the same concern but found a surprising possibility for correcting this mistake: by just swapping the neck of Cygnus (C3A) and the notch of the Milky Way (M1). But since C3A clearly belongs to the bird on

SK1050A, the artificer of the FCG transformed it to some odd rod that protrudes form the left wing of Cygnus and which could either be interpreted as some grossly misshapen left leg or as an arrow that has hit the bird.

(F6c) Moving along E2 to the left, the misunderstanding of E2 as tropic leaves two distinct options of how to interpret the constellation figure C5. C5 could (not noting the beard, T1) represent Andromeda. However, if so, SK1050A would bear the mistake of representing Andromeda too much north since the head C5A on SK1050A is completely north of the tropic. A conservative measure to correct this 'error' would be to leave her legs where they are (at C5F and C5G assuming these were damages of the figure) and extend the upper part of Andromeda to the correct position resulting in the misshapen oversized figure of Andromeda depicted on the FCG.

(F6d) Or one could interpret C5 to represent Cassiopeia (as Thiele did). However, if so, Thiele was right with his objection that Cassiopeia does in fact not reach to the tropic. The conservative measure to correct this 'error' would be to shrink Cassiopeia to the size of the dwarf queen depicted on the FCG.

(F6e) If C5A-C5E are interpreted to represent an oversized Cassiopeia on SK1050A this excludes the possibility of M1 being the Milky Way. This interpretation would, however, suggest that the part of M1 left of Cygnus is part of the Arctic Circle. The notch in E3 would consequently be interpreted as a colure and the finely crafted edge E1 would indicate that the BCG had, in the vicinity of the north pole, a hole intentionally left free.

(F6f) The hole on top of the FCG is a striking correspondence to SK1050A (T13 and T16). Thiele explains the remarkable circular hole on top of the FCG (see **figure 7**) with an accidental damage.

(F6g) Following the misinterpretation of (F6e) the corner E1/E3 of SK1050A corresponds to the place on top of the FCG where the Arctic Circle, a colure, and the edge of the hole meet (see **figure 7**). At exactly this position the FCG bears its greatest mystery: two unaccounted-for 'constellation figures' which

do neither correspond to anything known in reality nor in the astronomical scripture from antiquity. Thiele offers some wild speculations:

Unerklärt blieben am Globus die beiden oben schon erwähnten Reliefbruchstücke, erstens ein etwa 4qcm großer, halbrunder, ganz undeutlicher Ansatz, der zu keinem Sternbilde gehören kann, zweitens der thronartige Gegenstand, der auch schwerlich in seiner ganzen ursprünglichen Form erhalten ist. […] Auch bei dem Throne ist an ein Sternbild nicht zu denken [*Fußnote*: ‚Passeri nennt ihn durchgehends ohne Begründung sella Cassiopeiae.'], da zu keiner Zeit in diese Gegend des Himmels Sternbilder verlegt sind. Es muss also eine Zuthat sein, die sich nicht auf die Sternbilder selbst bezieht, demnach auch nicht auf Hipparchos zurückgehen kann, sondern eher gleichzeitig mit der Kombination von Globus und Atlas ist. Einen Thron im Himmel kann nur ein Gott haben, zu allererst Zeus […] Der römische Copist hätte dann diesen auch auf unserm Globus darstellen wollen, indem der zu den Sternbildern die Figur des thronenden Jupiter fügte, wenn ihm auch der Raummangel nicht gestattete, die Darstellung gehörig hervorzuheben. Diese Erklärung möchte ich, so lange sich kein entsprechendes Sternbild nachweisen lässt, als möglich hinstellen, ist doch die Vorstellung, dass Jupiter im *πόλος* seinen Sitz hat, auch den Dichtern geläufig. Jedoch scheint mir andererseits schliesslich der Umstand massgebend für die Erklärung des Thrones, dass derselbe leer ist. Ein solcher ist nicht sowohl für Jupiter, als für den regierenden Kaiser, der ihn dereinst einnehmen wird, passend. […] Der Globus wäre dann für einen Kaiser bestimmt gewesen.[7]

With our previous results the explanation of these two 'constellation figures' is

[7] Thiele (1898) 41f. English translation: "The two relief pieces already mentioned above remain unexplained: firstly, vague semicircular remains of about 4 square centimeters in size that cannot belong to any constellation and, secondly, a throne-like object which has hardly been preserved in its full original form. […] Likewise, this throne cannot be associated with a constellation [*footnote*: 'Passeri refers to it invariably as *sella Cassipieae* without giving reasons.'], since no constellations have ever been placed in this region. So it must be an addition that does not refer to the constellations themselves and thus cannot go back to Hipparchos, but was contemporary to the composition of the globe and Atlas. Only a god can have a throne in the sky, above all Zeus. […] The Roman copyist would then have intended to portray him, too, on our globe by adding the figure of Jupiter on the throne to the constellation, although the lack of space did not permit him to do justice to the subject. I would like to offer this explanation as a possibility as long as no fitting constellation is discovered. After all, the notion of Jupiter having his seat in the *πόλος* is not strange to the poets. On the other hand, the fact that the throne is empty seems decisive to me for the explanation of the throne. Such an empty throne would not fit Jupiter, but rather a reigning emperor who is destined to once occupy it. […] In that case the globe would have been for an emperor."

straightforward: The artificer of the FCG copied parts of the water-clock mistaking them for constellations. The 'semicircular remains' are the artist's impression of the cone at the end of the water pipe in M1 (T10). The 'throne' has exactly the shape of the axle bearing in C5G. Even Passeri quoted in the footnote of Thiele would in a way be right since on SK1050A the 'throne' C5G could be interpreted as the base of the "sella Cassiopeiae".

Of course, most of the interpretations (F6a-F6g) are inconsistent with each other. But we nonetheless find all of them simultaneously realized on the FCG. Even taking into account that some of these speculations about the FCG may have gone too far, the explanatory power of (F3-F5) seems quite remarkable. If we take this as evidence that (F3-F5) are basically right, we have to account for the apparent paradox that the artificer concurrently recognized the gross mistakes in SK1050A and nonetheless accepted it as the prototype for the FCG. Assuming that the artificer of the FCG knew that SK1050A was a surviving fragment of a celestial globe which had been built by an astronomer of the highest esteem would not be enough to resolve the paradox. We need to additionally assume the following:

(F7) The artificer of the FCG was ordered to build a statue in honor of the astronomer who built the BCG. The Atlas Farnese is in fact an allegory exalting the astronomer who built the BCG by comparing him to Atlas – not, as traditionally seen, just a statue of Atlas.

If the Atlas Farnese were just a statue of Atlas this would be a remarkably free interpretation of Greek mythology. Originally Atlas was seen as a young Titan standing upright and shouldering the firmament (not the celestial globe) at the western of the four corners of the (flat) earth. To my understanding, the Atlas Farnese marks exactly the beginning of this new iconography in art history of Atlas as an old man on his knees lifting a globe.[8]

The figure of the 'Atlas' Farnese, which was according to the *Museo Archeologico Nazionale*[9] in Naples originally placed in the library of the Trajan Forum in Rome, bears

[8] For pictures of the Farnese Atlas see, e.g., en.wikipedia.org/wiki/Farnese_Atlas.

[9] museoarcheologiconazionale.campaniabeniculturali.it/thematic-views/image-gallery/RA104?page=106

individual characteristic traits which would rather fit the image of an old man who is known to run at times after a successful struggle with the secrets of nature stark naked through his hometown shouting “Eureka!” than to an archetypical Titan.
Archimedes (c. 287-212 BCE) is the most prominent artificer of a mechanical model of the heavenly objects in antiquity. Even 600 years after his death the Archimedes Celestial Globe (ACG) was so well-known to the public that the poet Claudian (c. 400 CE) could write a little poem “Archimedes’ sphere” which quotes a laughing Zeus:

> “Has the power of mortal effort gone so far? Is my handiwork now mimicked in a fragile globe? An old man of Syracuse has imitated on earth the laws of the heavens, the order of nature, and the ordinances of the gods. Some hidden influence within the sphere directs the various courses of the stars and actuates the lifelike mass with definite motions. A false zodiac runs through a year of its own, and a toy moon waxes and wanes month by month. Now bold invention rejoices to make its own heaven revolve and set the stars in motion by human wit.”[10]

The fullest description of the ACG we owe to Cicero (106-43 BCE):

> He added […] that in this the invention of Archimedes was admirable, because he had calculated how a single revolution should maintain unequal and diversified progressions in dissimilar motions. In fact, when Gallus moved this globe, we observed that the moon succeeded the sun by as many turns of the wheel in the machine as days in the heavens. From whence it resulted that the progress of the sun was marked as in the heavens, and that the moon touched the point where she is obscured by the earth’s shadow at the instant the sun appears opposite.[11]

Since Cicero reports by hearsay about a conversation that took place long before his birth we may assume that in his lifetime the ACG was already fractured. This also explains the slight discrepancies in different accounts of the ACG in antiquity. Cicero tells the story that the conqueror of Syracuse, Marcellus, took the ACG as his only personal war booty in 212 BCE and that Marcellus’ grandson Marcus Marcellus could 50 years later still demonstrate the mechanism of the ACG to his guest Gallus. At this time the

[10] Translation by M. Platnauer in: *Claudian, Volume II*, Cambridge/Mass. 1922.
[11] Translation by C. D. Yonge in: *Tusculan Disputations on the Commonwealth [De re publica]*, New York 1877, p. 371.

mechanics of the ACG were obviously operated by a hand crank, not by a water-clock.

When Claudian wrote his poem the knowledge about the ACG was either folk tradition based on the writings from Cicero and others or there was in fact a conspicuous replica on a public place in Rome: the Atlas Farnese.[12] We may conclude:

(T20) The ACG and the BCG are one and the same. The ACG/BCG was fractured some time during the Roman civil wars after the murder of Tiberius Gracchus 133 BCE and before Cicero's adulthood 90 BCE. The FCG is a defective attempt by a later artist to reconstruct the ACG/BCG.

II.c The astronomical engravings on SK1050A

While all previous submissions might conveniently explain everything else of SK1050A, the most obvious riddle of SK1050A is as yet unaccounted for. If (T19) is the final verdict about the astronomical engravings on SK1050A this would pose a weighty argument against (T20) and against the hypothesis of the BCG having been built not by an ignorant artist but by an astronomer.

As mentioned before, my analysis is limited by the fact that I have no precise geometrical data of SK1050A. Thus my attempt to find the rationale behind the astronomical engravings is largely speculative. The problem of the misplacement of astronomical engravings has two parts: the constellation figures and the 16 'star-markings'.

II.c.i The placement of the constellation figures

A misplacement of the constellation figures does not necessarily imply what Thiele thought: That the placement was made by an ignorant artist. It could, in fact, mean just the opposite: That the placement was made by an astronomer who had higher priorities with the celestial globe than to place ornamental constellation figures on it. If the

[12] From Claudian one could come up with the idea that the hole on top of the FCG was used to hide the drive of a toy-mobile of glass-planets surrounding the FCG.

artificer of the BCG regarded the ornamental constellation figures as a necessary evil to please the crowd or his sponsor he might have moved them towards some place where they did not interfere with the astronomical objectives of the globe.
However, the fact that the water pipe was placed along the Milky Way indicates that the artificer of the BCG had a fine sense for visual metaphors. So, even if the placement of the figures is not determined by a mapping of astronomical objects there might still exist an objective behind it.

The location of C5F and C5G are determined by the hydrodynamic necessities of the water-clock. By placing Cepheus south of C5F and C5G he reaches eye level to Cassiopeia who would be left of E3. Assuming (T14) the water pipe started at the Milky Way near Cassiopeia, encompassed the entire globe, and ended ventrally of Cepheus where the energy of the water flow was transformed to the movement of a scepter-like axle in Cepheus' left hand which subsequently put the entire universe in motion. One can hardly imagine a more powerful allegory on the internal cohesion and the divine power of a royal couple.

If we relate the mythological couple Cepheus and Cassiopeia to the well-documented history of Syracuse in the 3rd century BCE this gives rise to a definite interpretation of the allegory: Cepheus would be Hiero II, the friend and patron of Archimedes, who came from humble beginnings and seized power in Syracuse c. 275 BCE by his talents but also with the help of the noble family of his wife Philistis. The reign of the couple, which lasted until Hiero's death in 215 BCE, is generally regarded as the golden age of Syracuse.

The axle in E4 cuts right through Hercules and ends with a gear at the head of the dragon Draco rotating the globe as a whole. This, too, can be seen as a metaphor. One would not be surprised if the man who is said to have once remarked "Give me a place to stand on, and I will move the Earth." had represented himself on the BCG in the figure of Hercules. But, of course, these iconographic considerations do not have the strength of proofs. The goal was just to have the geographic misplacements of the constellation figures appear less surprising.

II.c.ii The placement of the 16 'star-markings'

Unlike the constellation figures, it is obvious that any interpretation which claims that the star-markings on the fragment are placed with more than one or two degrees deviation to the true location of their corresponding stars excludes the possibility that the BCG was made by a professional astronomer in antiquity.

But indeed, there is evidence that the 16 star-markings are placed with a higher accuracy: The quadrant-shaped marking on the surface of S5 could be interpreted as a shift of the center of S5 by one half of the diameter towards the lower left edge.

(T21) The artificer of the BCG placed the 16 'star-markings' with an accuracy better than half of the diameter of the markings to their intended position. If a misplacement occurred as with S5 the artificer corrected this with a clear mark.

What were the intended positions of the 'star-markings'? Two observations seem essential for finding the answer.

Firstly, one can clearly recognize a sequence in the processing of the BCG. S8 is ruthlessly cut by the notch of E2. S6 was halved by the notch of the Milky Way M1. On the other hand, the figure of Cygnus looks like being pushed into the corner between the notches of E2 and M1. The right claw of the bird (C3F) keeps a distance to M1 suggesting that Cygnus was placed after the notches of E2 and M1 had been cut. Similarly, the upper part of Lyra (C2A) seems to bend near M1 indicating that M1 was there before Lyra was placed on the BCG. However, C4 which could be a hoof of Pegasus is cut by E2. Here the constellation figure seems first and the notch of E2 came afterwards.

(T22) The BCG was built in two distinct processing steps:

(1) At first, the only markings on the BCG were small holes like those of S1-S16 and presumably drawings with paint. At this time the BCG was still a complete sphere (including the polar regions) and an unadorned

measurement instrument.

(2) At a later stage the globe was completely rebuilt. The water-clock and the mechanical model of celestial motions were fitted to the globe and the surface decorated with constellation figures. At this time all or most of the 'star markings' had lost their significance. If they stood in the way of the new engravings they were simply cut away.

The second observation is the unnatural pattern formation of the 16 'star-markings'. There is a significant accumulation of 'star-markings' lined up on geodesics or placed at equal distance. This cannot be explained by the random statistical distribution of the real stars in the sky.

(T23) The 'star-markings' S1-S16 do in most cases not represent stars but mark the intersections of geometrical constructions with threads stretched on the surface of the sphere and with a compass.

What could the significance of these geometrical constructions be? One might guess that these geometrical constructions result from the fact that the artificer of the BCG simply did not have a modern coordinate-system neither a proper star catalog at hand when he started his work with this globe. What we might see here is the invention of both.

(T24) The 'star markings' of the BCG mark in most cases measuring points or define auxiliary lines of coordinate systems. The objective was to record the measurements of celestial objects not only in local horizontal coordinates but also in observer-independent equatorial and ecliptic coordinates.

Some kind of a reverse procedure of what Ptolemy described in chapter five and six of the eighth book of the *Almagest* comes to reason. After a star catalog of sufficient size in objective coordinates was finished the geometric markings and auxiliary lines on the BCG were no longer needed and could thus be removed to make place for new challenges on the frontiers of ancient astronomy.

How could this hypothesis be tested? Even before coming up with a complete reconstruction of the geometrical constructions on the globe there are two kinds of evidence that could corroborate the initial suspicion that this idea points in the right direction.

(1) In some significant cases the great circle of two given 'star-markings' should pass exactly through a bright star. Such bright stars are needed as reference points for any coordinate construction.

(2) If the great circle of more than two pairs of 'star-markings' meet in the same point this would support the hypothesis that they are geometrical constructions, especially if this intersection has an astronomical reference. By appearance, this could be the case with the great circles of GC(S9,S10) × GC(S13,S15) and possibly × GC(S6,S7) × GC(S12,S14). If the BCG is equatorial this intersection could represent the ecliptic pole.

However, going into details with this is beyond the scope of this paper. The intention of this section II.c.ii was just to let it seem plausible that there was an astronomical purpose behind the placement of the 16 'star-markings'.

III. Open questions

These are the main arguments of this paper to consider Archimedes as the artificer of SK1050A:

(A1) The shape of SK1050A indicates that the BCG was fitted with a mechanical model of the universe. We know from Cicero and other sources that the mechanical reproduction of planetary movements was the most striking feature of Archimedes' celestial globe. However, Archimedes was not the only astronomer in the Greco-Roman antiquity who was said to have built a mechanical model of the planets. Posidonius (c. 135- 51 BCE), e.g., could be an alternative hypothesis.

(A2) The surprising parallels between SK1050A and the FCG can be explained if we assume that the artificer of the FCG thought SK1050A was the work of Archimedes. The argument is supported by an analysis of the iconography of the constellation figures on SK1050A. Considering the dry source situation from classical antiquity we should, however, always consider the possibility that there is an alternative interpretation which we don't know of.

(A3) If it is correct that the 16 'star markings' are in most cases not representations of stars but geometrical constructions for spherical coordinate transformations this would indicate that the BCG was created by an astronomer before the establishment of spherical geometry, i.e. before Hipparchos (c. 190-120 BCE).

Essential for the decision on the speculations in this paper will be the analysis of the 16 'star-markings' and of the geometry of the fragment based on precise numerical data.

Additional evidence can possibly be found through a physical-chemical investigation of the fragment. The quarries of the two types of stone used in the fragment might be localized in this way and maybe also the age of the processing.

If the main thesis of this paper that SK1050A was created by an astronomer and not by an artist can be corroborated it might be an inspiring task to try to build a functional replica of the Berlin Celestial Globe. The technical problems that arise in this challenge will certainly lead to a better understanding of the mechanics of the planetary model and of ancient astronomy in general.

Acknowledgments

I am greatly indebted to Prof. Gerd Graßhoff, chair of the *TOPOI Excellence Cluster* in Berlin, for stimulating discussions and for drawing my attention to this fascinating artifact in the first place.[13] Prof. Graßhoff is, however, not responsible for the content of this paper. I sincerely thank Harald Czinczel, Lorenz Lorenz-Meyer, and Peter Richter for proofreading and comments and Jan Hochbruck also for his drawings of figures 4b and 4c. Neither of them can be blamed for any error in this paper.

[13] Cf. the press release idw-online.de/pages/de/news406669.

Appendix: Figures

Figures 1: Photographs of SK1050A as displayed in the permanent exhibition of the *Neue Museum*, Berlin. *(Credits: UK)*

1a: Frontal view, central.

1b: Frontal view, from below.

1c, 1d: View from left (1c) and from right (1d).

Figure 2: Nomenclature used for SK1050A. *(Credits: UK)*

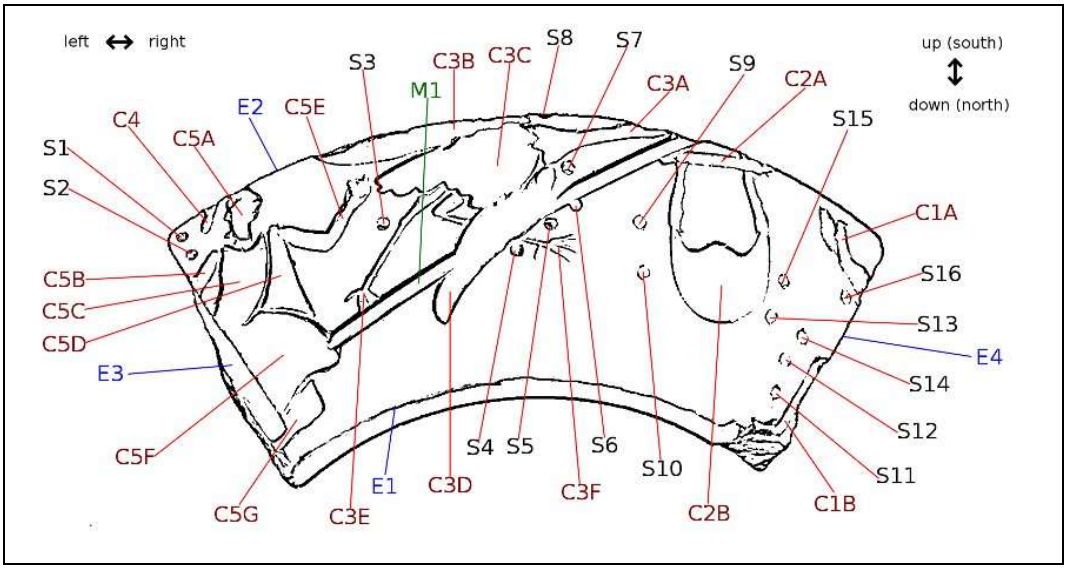
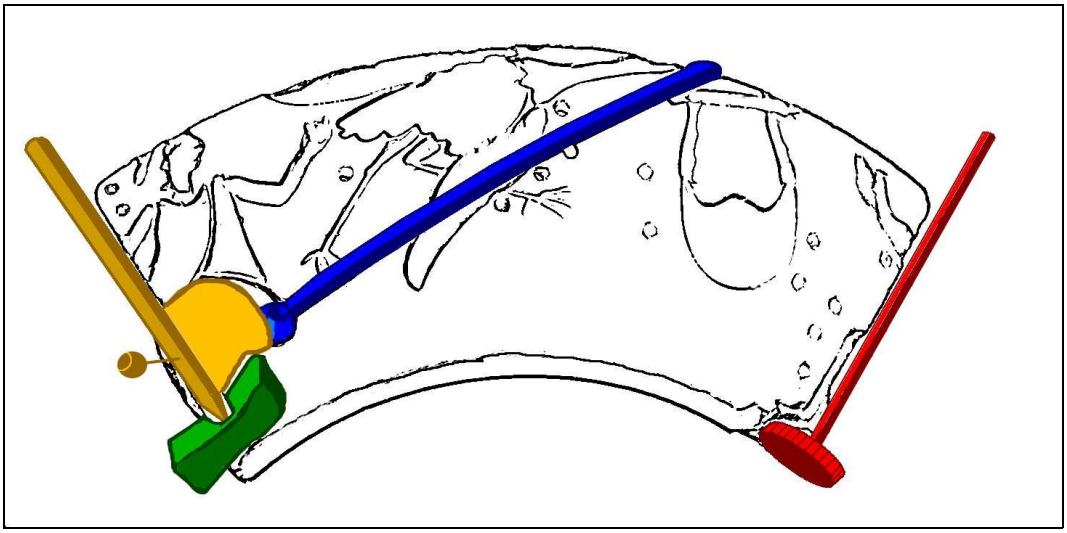


Figure 3: Reconstruction of functional parts of the water-clock. *(Credits: UK)*



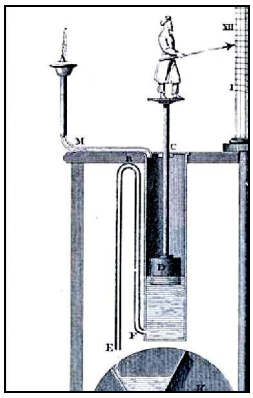


Figure 4a:
Artist's impression of Ctesibius' water-clock (detail) as per description by Vitruvius. *(Credits: A. Rees: "Clocks, Watches, and Chronometers", 1819)*

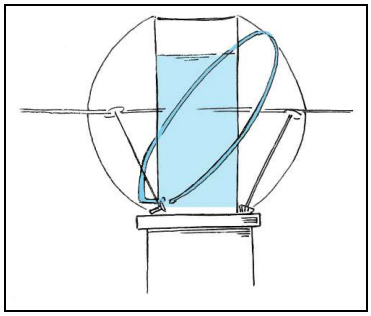


Figure 4b:
Artist's impression of the BCG as per description by this paper, cross section with water-clock. *(Credits: Jan Hochbruck)*

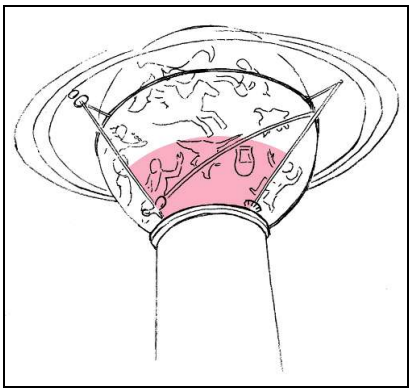
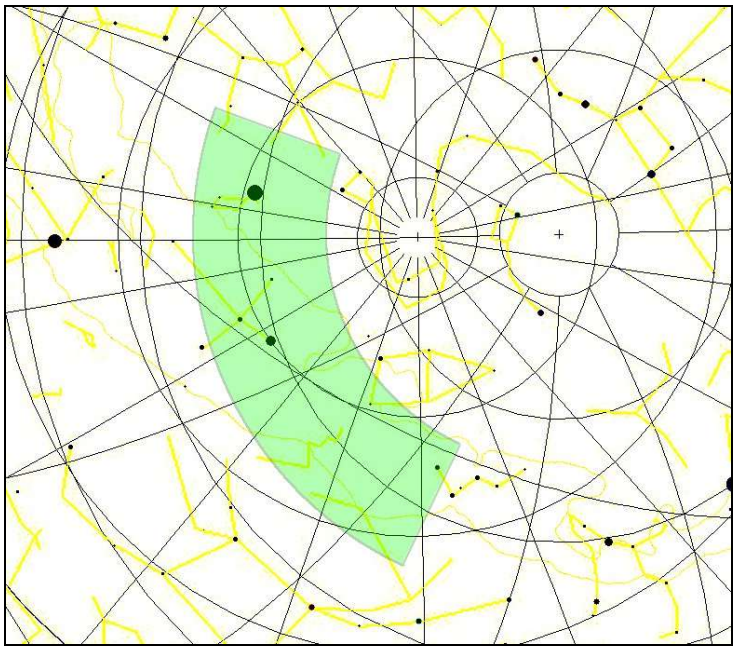


Figure 4c:
Artist's impression of the BCG from below as per description by this paper, reach of SK1050A in red. *(Credits: Jan Hochbruck)*

Figures 5: Mirrored maps of the northern sky. The equatorial north pole was set to epoch 250 BCE and is right of the ecliptic north pole. The intersecting line from top left to bottom right is the galactic equator. *(Credits: Maps generated with Cartes du Ciel Vs. 3.2, UK)*

5a:
Hypothesis A:
Approximate reach of SK1050A if aligned on the equatorial pole.



5b:
Hypothesis B:
Approximate reach of SK1050A if aligned on the ecliptic pole.

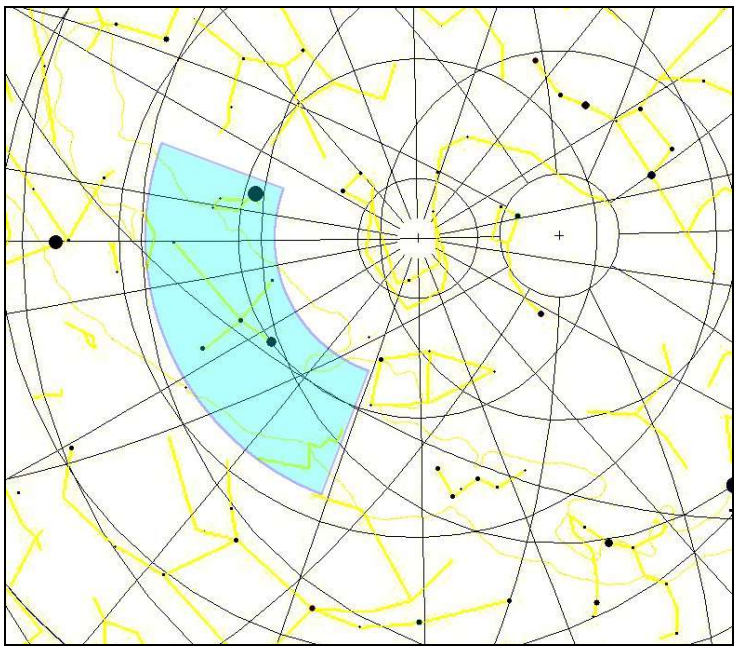
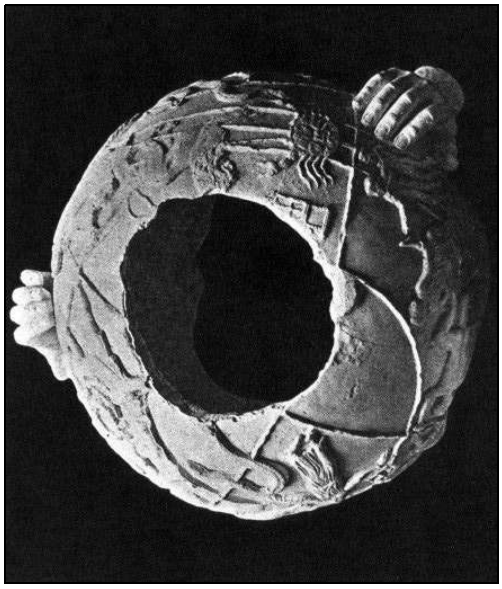


Figure 6: Drawing of the FCG. *(Credits: F. Piranesi, in: E. L. Stevenson: "Terrestrial and Celestial Globes", 1921)*

Figure 7: Photograph of the FCG from above. *(Credits: G. Thiele "Antike Himmelsbilder", 1898)*



*