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Presentation of changes in the legend of celestial globes using virtual 3D models - technical report

Summary: Researching star charts and celestial globes is not a simple project: only few of the published maps and globes subsist, and they are scattered throughout the world. For this reason, their comparative analysis is almost unimaginable without the reproduction digital technology.

The representation of the star maps and celestial globes has a complex and dual nature. On the one hand, we can speak about depicting the stars and then the deep-sky objects, while on the other hand, the representation of the constellation they have formed, or rather the constellation that includes them.

In this article, we provide a research report about the process of working on digital globes of international collections to try to draw conclusions about changes in the legend of celestial globes. We are looking for answers to the questions of whether an exact time of switching between the eccentric and geocentric representation modes can be determined. We will try to figure out how the representation of constellations evolved, and try to find contexts about how each style of representation refers to the particular creators.

Research has not been completed, given that many questions cannot be answered satisfactorily and professionally. With this article, we would like to draw the attention of curators of collections that the digitization and service of globes – albeit not an easy task – are a necessary and a single opportunity to explore and search celestial globes around the world.

Questions

We investigated two questions during this study. In the first step we examined the geocentric-eccentric representation of the globes and the change of formal representation. We processed a total of 226 globes which are available in European public collections (see Table 1) with accurate bibliographic descriptions and illustrated with images. During the examination, each globe of each globe maker published in different years and with different diameter was considered as an independent item, only the unequivocally similar editions were merged. The time interval was not determined in advance, because we wanted to process the whole material currently available. As a result, the processed material includes the celestial globes published between 1600 and 1999. We specifically examined printed pieces belonging to the European culture.

Content changes of figurative motifs

As the second step for content changes of the figurative representation we examined the figurative representation of the three constellations of each celestial globe from which a digitized copy was available. These globes came from three collections: the Gallica collection of the National Library

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of France[1] (18 copies), the Czech Virtual Map Collection[2] (18 copies) and the Hungarian Virtual Globes Museum[3] (7 copies). Altogether, we were able to examine 43 celestial globes.
The distribution of the examined globes according to their date of issue:

17th century	12 pcs
18th century	22 pcs
19th century	7 pcs
20th century	2 pcs

Method

During the data collection, we paid particular attention to the credibility and accuracy of bibliographic or catalogue description. In each case we have verified the data shown on the pictorial representation of the given globe. During the processing we recorded parameters of individual globes, such as the author's name, year of publication, diameter (cm), collection (name and ID number), related literature and source.

Geocentric-Eccentric

The peculiarity of celestial globes is that they represent celestial objects on a surface that are at given distances from the centre of the Earth. The representation of sky can be made from a geocentric viewpoint, in which case the observer looks at the sky from the Earth, that is from inside. In this case, the stars displayed on the globe are exactly in the same position as we see them in the sky. Another possibility is that the celestial objects are depicted from the outside, from the direction of the universe. In this case, the stars appear vertically reflected in relation to their actual position in the sky. This is called eccentric viewpoint. At the beginning of this research we assumed that there is a reason and / or a period that resulted in this change of viewpoint.

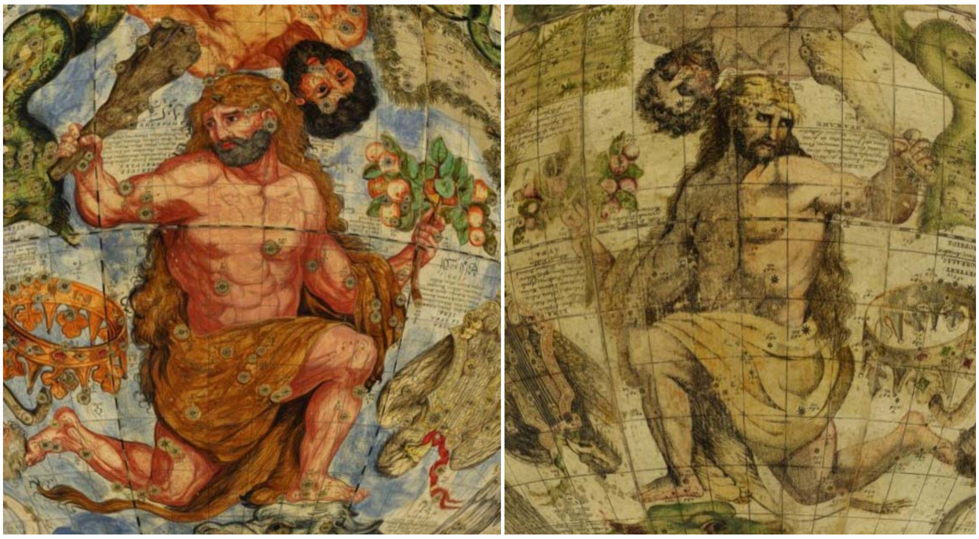

Figure 1: Hercules on Coronelli's celestial globes (1688 and 1690) in geocentric viewpoint (left) and eccentric viewpoint (right).

[1] http://gallica.bnf.fr
[2] http://chartae-antiquae.cz
[3] http://terkeptar.elte.hu/vgm/

Based on available descriptions and 3D models, each globe is recorded how they represent the sky: from the direction of the universe (eccentric) or the Earth (geocentric).

Depicting of constellations

For grouping the depictions of constellations, the following categories have been defined:

1. figural representation
   The representation is a figure that impersonates the constellation of stars.
2. figural representation only of the zodiac, others with curved boundaries
   Only zodiac signs are displayed with figurative representation, stars of the other constellations are separated by curved boundaries.
3. figural representation with curved boundaries
   Each constellation is represented by figurative portrayal and curvilinear boundaries indicate the frontiers of each constellation.
4. figural representation with straight boundaries
   Each constellation is represented by figurative portrayal and straight boundaries indicate the frontiers of each constellation.
5. figural representation with curved boundaries, and connecting lines
   Each constellation is depicted by a figurative representation, curved line representing the boundaries of each constellation, and the major, brighter stars of each constellation are colligated by straight lines.
6. straight boundary lines and connecting lines
   Constellations are only represented by their stars, straight lines representing the boundaries of each constellation, and the major, brighter stars of each constellation are joined by straight lines.
7. curved boundary lines and connecting lines
   Constellations are only represented by their stars, curved lines representing the boundaries of each constellation, and the major, brighter stars of each constellation are colligated by straight lines.
8. only curved boundary lines
   Constellations are only represented by their stars, including curvilinear boundaries for each constellation frontiers.
9. only connecting lines
   The constellations are only represented by their stars; the major, brighter stars of each constellation are joined by straight lines.
10. no constellation representation
    Only the stars are displayed.
11. no data is available

All globes which we have available are listed in one of these categories.

Content changes of figurative motifs

We selected three constellations from figurative representations, which are already included in the ancient constellations and are part of today's official regulations; that is, they are present in every age and on the work of every globe maker. These are Bootes, Hercules, and Orion. Bootes is a simple shepherd figure, Hercules is the famous mythological hero, and Orion is a hunter from the

Greek-Roman cycle. In their representation, we were looking at what influenced the unique features of the shaping (clothing, accessories), and how they changed in time and geography.

(Partial) Results

Geocentric-Eccentric

During the processing, the following distribution was observed for the 226 celestial globes:

eccentric	189 pcs
geocentric	17 pcs
no data is available	20 pcs

In the case of globes whose bibliographic description did not include the viewpoint, and this could not be ascertained on the visual material, we did not give any data if it could be inferred from the creator.

a. Geocentric globes

Globe maker	Year of publication	Diameter (cm)
Coronelli	1688	109
Homann	1715	7
Cushee	1731	7
Hill	1754	7
Lane	1776	7
Lane	1779	7
Palmer&Newton	1783	7
Miller	1793	7.6
Lane	1810	7.5
West	1815	7
Minshull	1816	7
Lane	1818	7
Johnston	1850	7.6
de Lopez	1860	12
Räth	1950	33
Räth	1957	33
Räth	1975	33

It is clearly visible that there is a certain scattering in time and place, as well as in dimensions. Based on the above, it can be stated that the geocentric representation cannot be related to a specific period, although -we think- there may be some scientific explanation for such a continuity of its appearance.

Vincenzo CORONELLI (1650-1718), a theologian and cosmographer of Venetian origin, travelled to Paris at the invitation of Cardinal D'ESTRÉES around 1680, and he made a pair of globes with 3.9 m diameter for Louis XIV. The specialty of these globes is that, according to Coronelli's description, 30 people could enter into them through a door[4] and that the stars and planets were in the position of the king's birthday.[5] According to some sources, Venetian and Parisian celestial

[4] MURIS□SAARMANN (1961) p. 170
[5] Die Welt in Händen (1989) p. 89

globes from 1688, with 109 cm diameter, are the smaller versions of this globe.[6] The same source mentions that globes consisted of pieces of canvas stretched out on a wooden structure, with only the outer surface painted. It is assumed that if it was possible to go into the globe, it is most likely that it had something of interest also on its inner surface, which – to be in harmony with the external, eccentric image – had to be geocentric.

b. The pocket globes team

In terms of their dimension, 12 pieces of geocentric globes are in the range of 7 to 7.6 cm diameter. They all belong to the group of pocket globes. It is worth noticing the author's home:

Johann Baptist Homann	Nuremberg	1715
Richard Cushee	London	1731
Nathaniel Hill	London	1754
Nicolas Lane	London	1776, 1779, 1810, 1818
William Palmer	London	1783
John Newton	London	1783
John Miller	London, Edinburgh	1793
West	London	1815
W. & A. K. Johnston	Edinburgh, London	1850

As seen, all pocket globe manufacturers, except Johann Baptist HOMANN, were in London. Their relationships can be explained in the way below:
Richard CUSHEE (worked 1758-1761) and Nathaniel HILL (1708-1768) were brother-in-laws, as both married the daughters of the WYETH family: Richard married Elizabeth in 1728 and Nathaniel married Anne in 1742. William PALMER (1739-1812) was a disciple of Thomas BATEMAN (1754-1781), who was trained by HILL, the HILL who also had a student, John NEWTON (1759-1844).[7] Hereafter, HILL's pocket globe was released again by PALMER and NEWTON.
Nicolas LANE cannot be included in this "family"-system. According to sources, he used CUSHEE's plates to publish a globe as his own. We do not know much about WEST, just that he released LANE's globe again. The pocket globe makers in London were in very close relationship, and their professionalism -and thus the geocentric viewpoint- has been repeatedly handed over through such interlacements.
With regard to the structure of pocket globes we would assume that the use of the geocentric viewpoint resulted from the concave physical design. By examining the relationship between viewpoints of pocket globes and their physical design, the following ratios were obtained:

	convex	concave	gores
geocentric	1	11	-
eccentric	9	19	4

Based on the above data, it is likely that the geocentric viewpoint may have tied to concave shaped globes, but this statement cannot be fully supported.

[6] KLINGHAMMER (1998) p. 51
[7] CROUCH (2017) p. 13.

c. Räth Verlag

Modern-edition geocentric Räth Verlag's celestial globes are designed for school use. In fact, they are versions of one celestial globe released in different years. It is clear that presenting the stars as if the schoolchildren were staring at the starry sky is the best teaching aid. Although there is no proof of this, the conclusion is plain and logical, even though modern astronomical spheres are being created in an eccentric view even nowadays.

Depicting of constellations

Evolution of the representation of constellations from the formations of the early period has evolved through modern straight lines, drawn to the lines connecting the major stars of each constellation. We could think that progress was going straight and consistently, but it did not happen so. Constellation representations of the observed 226 globes were as follows:

figural representation	171 pcs
figural representation only of the zodiac, others with curved boundaries	2 pcs
figural representation with curved boundaries	11 pcs
figural representation with straight boundaries	3 pcs
figural representation with curved boundaries, and connecting lines	1 pc
straight boundary lines and connecting lines	10 pcs
curved boundary lines and connecting lines	9 pcs
only curved boundary lines	11 pcs
only connecting lines	4 pcs
no constellation representation	1 pc
no data is available	3 pcs

We found 55 celestial globes, which are different from the representation of the early celestial globes (only figurative representation).

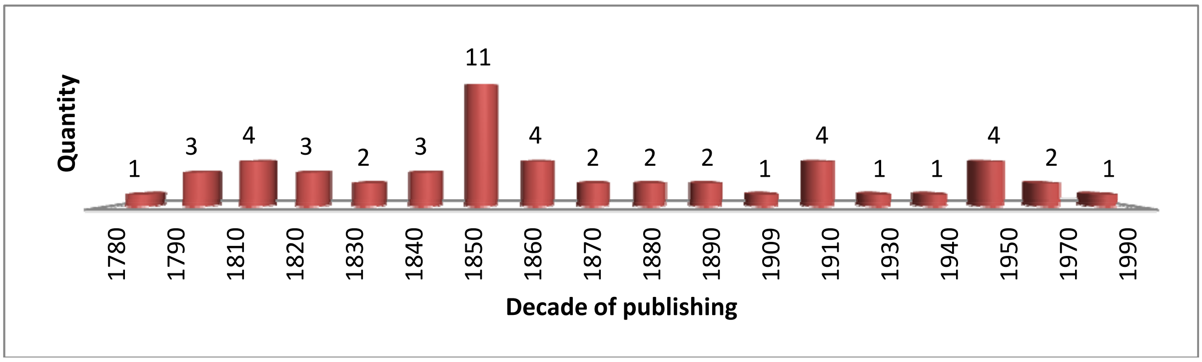

Figure 2: The number of non-figurative depicted globes as per publishing.

Sorted by their publication, the globes whose depiction is different from figurative representations were made between 1782 (Dunn, 13 cm) and 1999 (Karl-F. Harig, 30 cm). The maximum of issues was in the middle of the 19th century, when the school globes boomed and, in the case of celestial globes, the Felkl Company in Prague flooded the market with its non-figurative depicted globes.

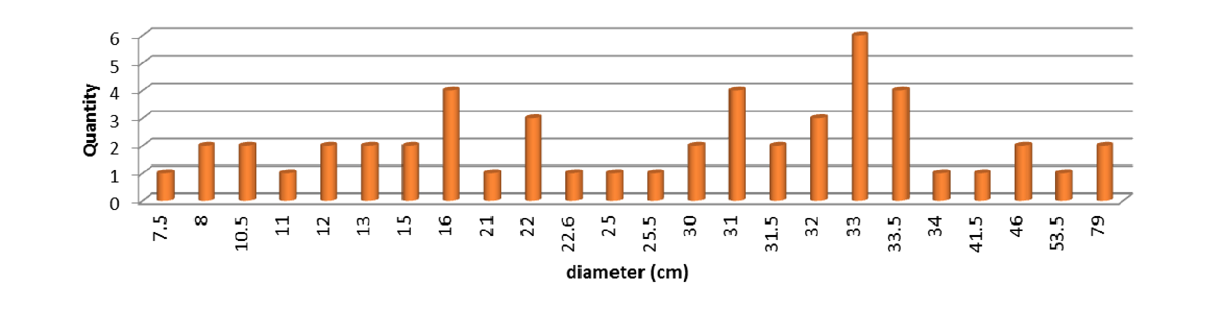

Figure 3: The number of globes with non-figurative constellations according to diameter.

Considering their diameter, the smallest is 7.5 cm (Kenn, 1790), the largest is 79 cm (Reimer, 1854 and 1910). In the range of 30 to 34 centimetres can we find the maximum number of examined pieces (six with 33 cm), that is 25% of the globes, which can be explained by the school use of modern globes.

There is more regularity in the groups of globes issued after 1928. The General Assembly of the International Astronomical Union in 1928 accepted the proposal to organize constellations. Eugène Joseph Delporte (1882–1955) was tasked with developing an unified nomenclature and setting the map of stars and precise boundaries of constellations. Delporte developed the way of joining the bright stars which are clearly visible to the naked eye, causing unsophisticated shapes to facilitate free perception and identification. It can be observed after the regulatory period that all publishers followed the official regulations, and if they did not use the traditional figurative representation, they portrayed each constellation with straight boundaries and connecting lines.

It should be noted, however, that figurative representations did not cease. Modern celestial globes can also be seen with figurative representations that depict the constellations, not according to the rules of official regulation, but for illustrative purposes, following the traditional figurative representation.

Content changes of figurative motifs

When examining content changes, we have created a simple comparison of image matrices that show changes in the representation of individual shapes over time.

For Bootes, we can distinguish five different presentation modes:

A man in fur coat, boots, in multiple layers of clothing. Empty right hand, left hand holding big cudgel.	Blaeu 1600, Hondius 1600
A shepherd-shape man, in fur lipped **tunic**, with **bare feet**, and right hand with **sickle**, and left hand with **shepherd's crook**.	Habrecht 1621, Blaeu 1630, Coronelli 1688, Coronelli 1690, Delisle 1699, Andreae 1700–1716, Delure 1707, Bion 1712, Pigeon 1714–1739, Depuis 1795
A shepherd-shape man **in tunic**, in sandal or barefoot, **leashes** in his right hand, that has **Canes Venatici at the end**, big cudgel in his left hand.	Valck 1700, Eimmart 1705, Senex 1720, Doppelmayr 1728, Adams 1765, Lalande 1775, Jüttner 1824, Felkl 1850–1900, Adami 1873, McNally 1960
A shepherd-shape man in fur **lipped tunic**, in sandals, **leashes** in his right hand, that has **Canes Venatici at the end**, big cudgel in his left hand.	Vaugondy 1754, Klinger 1790–1800
Custom portrayal	Baradelle 1740, Teubner 1913

Figure 4: Bootes.

For Hercules constellation, we could distinguish seven representation modes:

Naked figure with the skin of Nemean lion on his back, his right hand empty, and in his left hand a cudgel.	Blaeu 1600, Hondius 1600, Delisle 1699
Naked figure with the skin of Nemean lion on his back, in his right hand the apples of the Hesperides, and in his left hand a cudgel.	Habrecht 1621, Coronelli 1688, Coronelli 1690, Andreae 1700–1716, Delure 1707, Bion 1712, Pigeon 1714–39, Baradelle 1740, Depuis 1795
Naked figure, his arm covered with the skin of Nemean lion, in his right hand the apples of the Hesperides, and in his left hand a cudgel.	Blaeu 1630
Naked figure, his arm covered with the skin of Nemean lion, in his right hand Cerberus, and in his left hand a cudgel.	Valck 1700–1750, Eimmart 1705, Senex 1720, Doppelmayr 1728
Naked figure with the skin of Nemean lion on his back, in his right hand Cerberus, and in his left hand a cudgel.	Vaugondy 1754, Klinger 1790–1800, Teubner 1913
Naked figure with the skin of Nemean lion on his back, in his right hand Cerberus and the apples of the Hesperides, and in his left hand a cudgel.	Adams 1765, Lalande 1775, Poirson 1817, Jüttner 1824, Felkl 1850–1900, Adami 1873
Custom portrayal	McNally 1960

Figure 5: Hercules

For Orion constellation, we could distinguish three representation modes:

A soldier in a helmet, with a sword on his side, his shield in his left hand, in his right hand a cudgel. On the basis of military attributes we find Roman and Greek clothing characteristics to be discovered.	Blaeu 1600, Hondius 1600, Habrecht 1621, Coronelli 1688, Coronelli 1690, Valck 1700 (2 pcs), Andreae 1700–1716, Eimmart 1705, Delure 1707, Senex 1720, Doppelmayr 1728, Pigeon 1714–1739, Baradelle 1740, Depuis 1795, Teubner 1913
A soldier in a helmet, with a sword on his side, in his left hand with a flayed skin of lion, in his right hand a cudgel.	Delisle 1699, Vaugondy 1754, Klinger 1790–1800, Poirson 1817
Nomadic military figure with no helmet, with a sword on his side, in his left hand a flayed skin of lion, and in his right hand a cudgel.	Blaeu 1630, Bion 1712, Adams 1765, Lalande 1775, Jüttner 1824, Felkl 1850–1900, Adami 1873, McNally 1960

Figure 6. Orion

From the above groupings it can be seen that, as a result of such comparison, no clear process of changing the characteristics of formal representation can be shown, nor any national or individual characteristics as so often in the case of star charts. We can only observe repetitive clusters. We assume there was a **globe maker**, who was followed by the contemporaries. The followers took over the representation formulas, either bought the earlier plates, or simply the fashionable, popular market products have been copied to make their own product sold.
Such groups may be as follows:

Blaeu 1600, Hondius 1600
Coronelli 1688, Andreae 1700–1716, Delure 1707, Pigeon 1714–1739, Depuis 1795
Valck 1700, Eimmart 1705, Senex 1720, Doppelmayr 1728
Adams 1765, Lalande 1775, Jüttner 1824, Felkl 1850–1900, Adami 1873
Vaugondy 1754, Klinger 1790–1800

Conclusions

Geocentric-Eccentric
During the investigation, it has been shown that the change in geocentricity and eccentricity on the globes cannot be related to a specific time or cause. The first appearance of geocentric viewpoint depicted was Coronelli's celestial globe from 1688, with 109-centimetre diameter, followed by Homann's pocket globe, and then recaptured at the London pocket globe manufacturers. Thereafter, it was only seen on modern globes intended for school use. In addition to the presented contexts, we need to look for specific causes for some authors.

Depicting of constellations
Nor can be a specific date given for when the traditional figurative representation mode disappears and the formal representations begin to change and the modern boundary and

connecting lines appear. We can state with certainty that one of the root causes of non- figurative representations was the spread of school globes in the middle of the nineteenth century, and at the beginning of the 20th century it was the birth of official regulations.

Content changes of figurative motifs

Contrary to star charts, celestial globes do not show specific features of a particular age or creator. Based on the representation attributes, it is possible to detect concentrations that relate to the globe-making work of a certain age or region. However, to detect precise relationships, it is necessary to increase the number of models in order to process multiple copies.

Overall, the changes of legend of the celestial globes are most specific. For the more accurate results of the research presented here, additional collections are required to be included in the study, and it is essential to consider the question after examining the similarities of the star charts.

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Charles University, Prague
Coll. of Daniel Crouch, London
Coll. of Mr. H. van Beek, Arnhem
Csillagásztorony, Eger
Museum of the Reformed College, Debrecen
Drents Museum, Assen
Duna Menti Múzeum, Komárom
Diocesan Library, Szombathely
ELTE Map Department of Cartography and Geoinformatics, Budapest
Cathedral Library, Esztergom
Library, Palace of Keszthely
Jachtslot Sint Hubertus, Hoenderloo
Kastel Eijsden, Eijsden
Klimo Library, Pécs
Koninklijke Nedlloyd Groep, Rotterdam
Královská kanonie premonstrátů na Strahově, Praha
Kunstgewerbemuseum, Berlin
Hungarian Technical and Transport Museum, Budapest
Maritiem Museum, Rotterdam
Martinus Nijhoff, s-Gravenhage
Menkemaborg Gronings Museum, Uithuizen
Middle Temple Library, London
Konkoly Observatory, Budapest
Museum Boerhaave, Leiden
Museum der Stadt, Regensburg
Národní knihovna České republiky, Praha
Národní technické muzeum, Praha
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Nijmeegs Museum, Nijmegen
National Széchényi Library, Budapest
Österreichische Nationalbibliothek, Wien
Benedictine Library, Pannonhalma
Private Collection, Heemstede
Private Collection, Amsterdam
Private Collection, Gelderland
Private Collection, Utrecht
Private Collection, Wassenaar
Private Collection, Wien
Real sociedad económica de amigos del pais de Tenerife, Santa Cruz de Tenerife
Regionální muzeum v Teplicích, teplice
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Rijksprentenkabinet, Amsterdam
Royal Swedish Academy of Sciences, Stockholm
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Science Museum, London
Staatlicher Mathematisch-Physikalischer Salon, Dresden
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Vlastivědné muzeum v Olomouci, Olomouc

Table 1. Location of processed celestial globes