The New Fragments from Hipparchus' Star Catalogue

Centre Léon Robin de recherches sur la pensée antique, UMR 8061

Victor Gysembergh (CNRS / Sorbonne Université)

victor.gysembergh@cnrs.fr

Pliny the Elder, *Natural History*, II, 26

Hipparchus, who has never been sufficiently praised as the man who, more than anyone else, proved the affinity of the stars with mankind and that our souls are part of the heavens, **discovered a new and different star** that came into being in his own age, and by its motion, where it glittered, he was led to doubt whether this might happen more and **whether those stars, which we regard as fixed, might not be in motion**. Therefore, he tried to do a thing that would be excessive even for a god, namely **to number the stars for posterity and enumerate the constellations by name**, with the help of instruments devised for that purpose, by means of which **he designated the position and magnitude of each single star**, so that it could easily be seen from his work, not only whether stars perish and come into being, but whether some actually change their positions and are in motion. Thus he left the heavens as an inheritance to all men, if anyone could be found to take over that inheritance.

Hipparchus' *Commentary on the Phenomena of Eudoxus and Aratus* (ed. Manitius, 1894)

ʽΙΠΠΑΡΧΟΥ

ΤΩΝ

ΑΡΑΤΟΥ ΚΑΙ ΕΥΔΟΞΟΥ ΦΑΙΝΟΜΕΝΩΝ

ΕΞΗΓΗΣΕΩΣ

ΒΙΒΛΙΑ ΤΡΙΑ.

HIPPARCHI

IN

ARATI ET EUDOXI PHAENOMENA

COMMENTARIORUM

LIBRI TRES

AD CODICUM FIDEM RECENSUIT
GERMANICA INTERPRETATIONE ET COMMENTARIIS INSTRUXIT

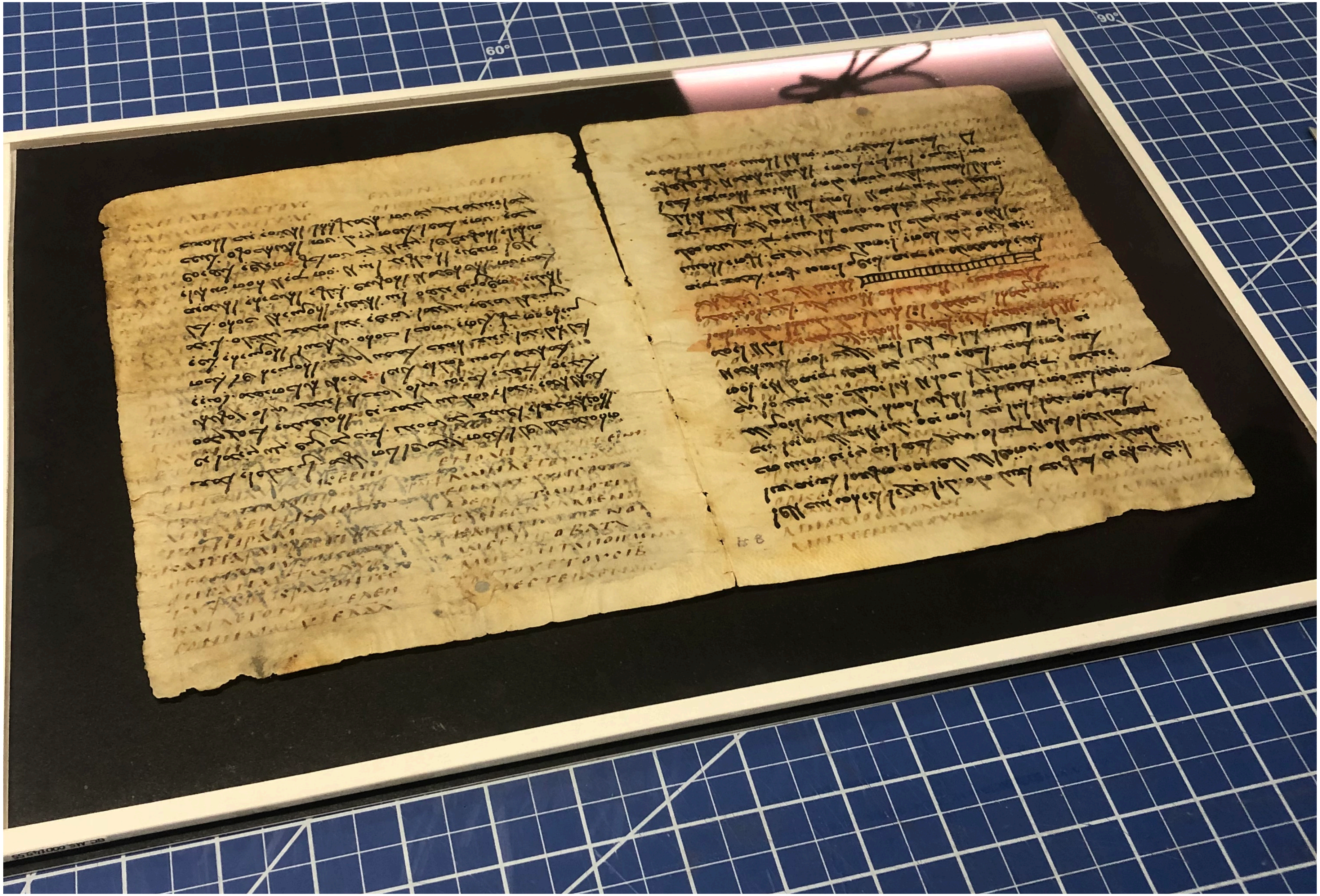
CAROLUS MANITIUS.

LIPSIAE
IN AEDIBUS B. G. TEUBNERI.
MDCCCXCIV.

Coin Issued under the joint Reign of Valerian and Gallienus ca. 253-260 CE. Reverse: Hipparchus with Globe. © American Numismatic Society.

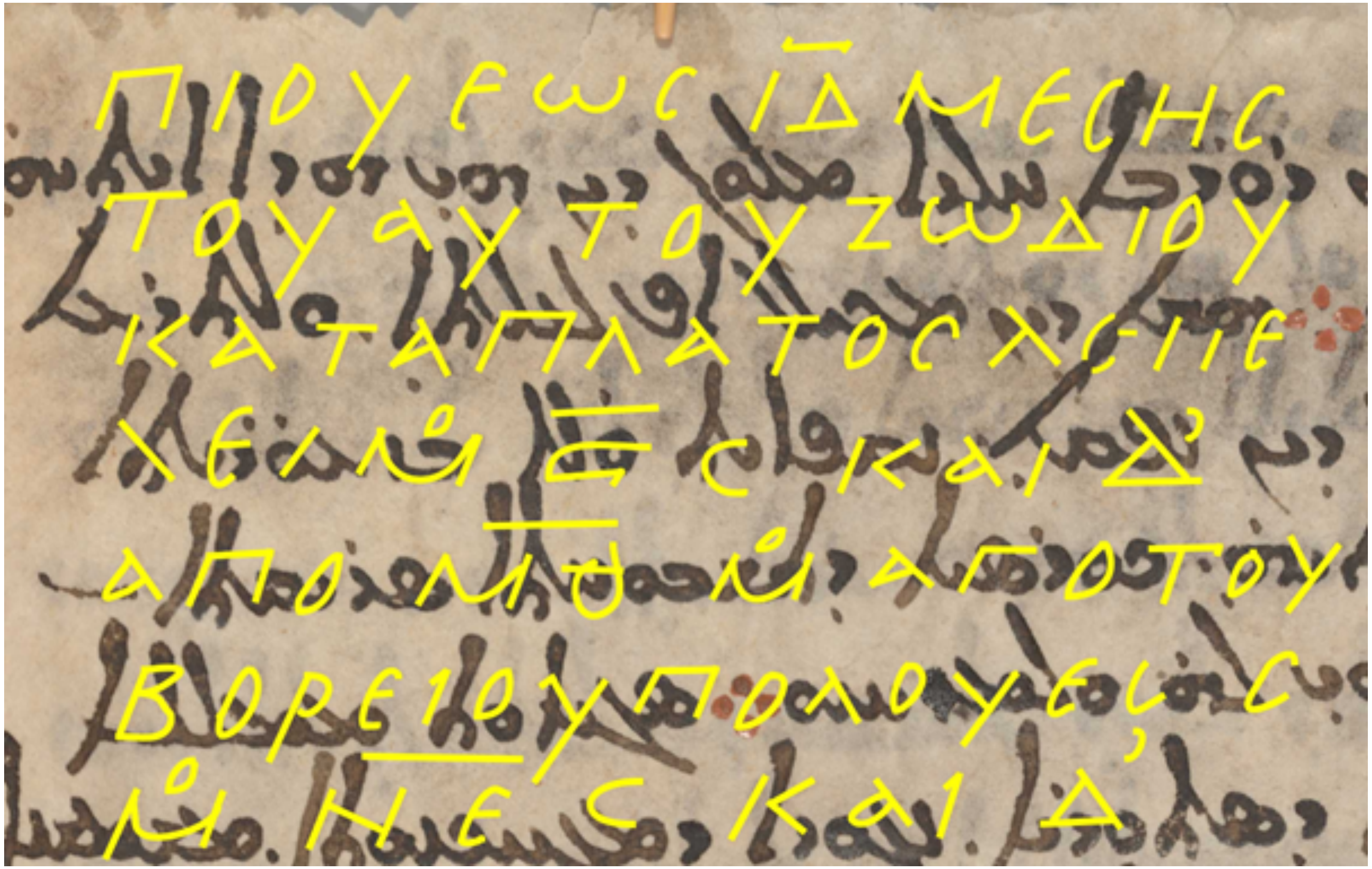
Hipparchus in his observatory in Alexandria (modern reconstruction)

Credit: NEW YORK PUBLIC LIBRARY / SCIENCE



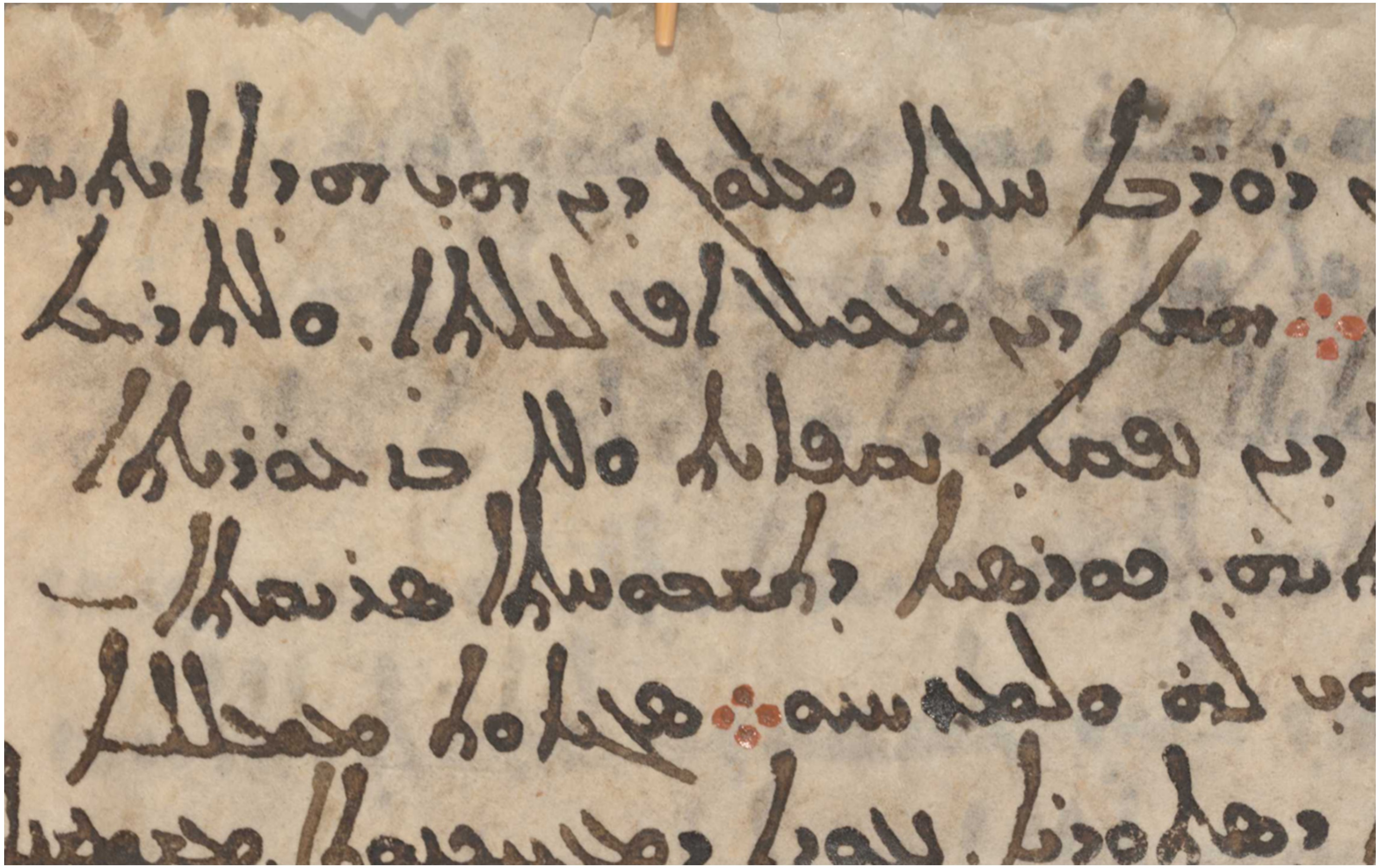
A leaf from Codex Climaci rescriptus. © Peter Malik

Saint Catherine's Monastery, Sinai, Egypt

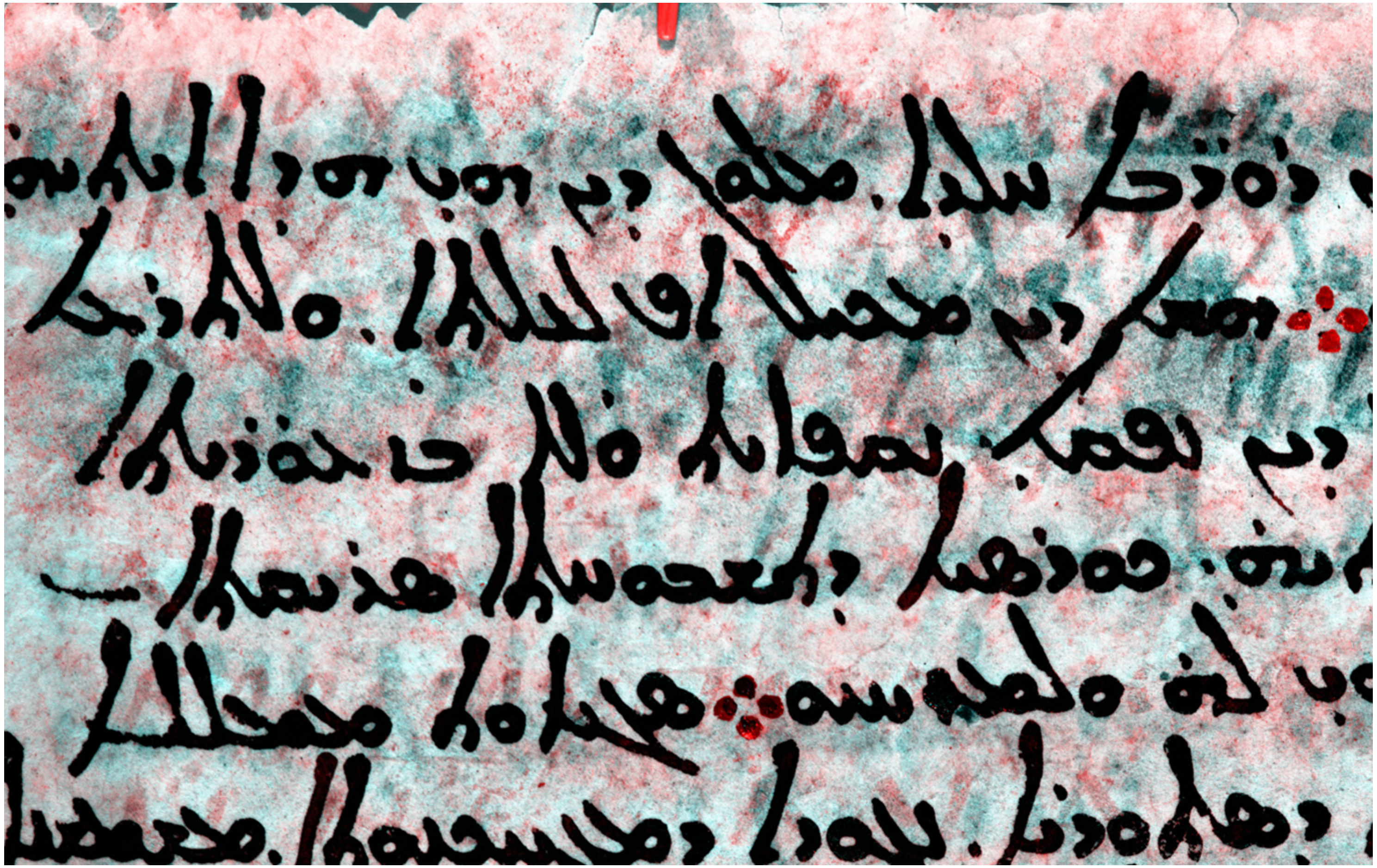


Codex Climaci rescriptus, f° 53v, beginning of first column of erased text. In yellow, tracing of the erased text by Emanuel Zingg (Sorbonne Université).

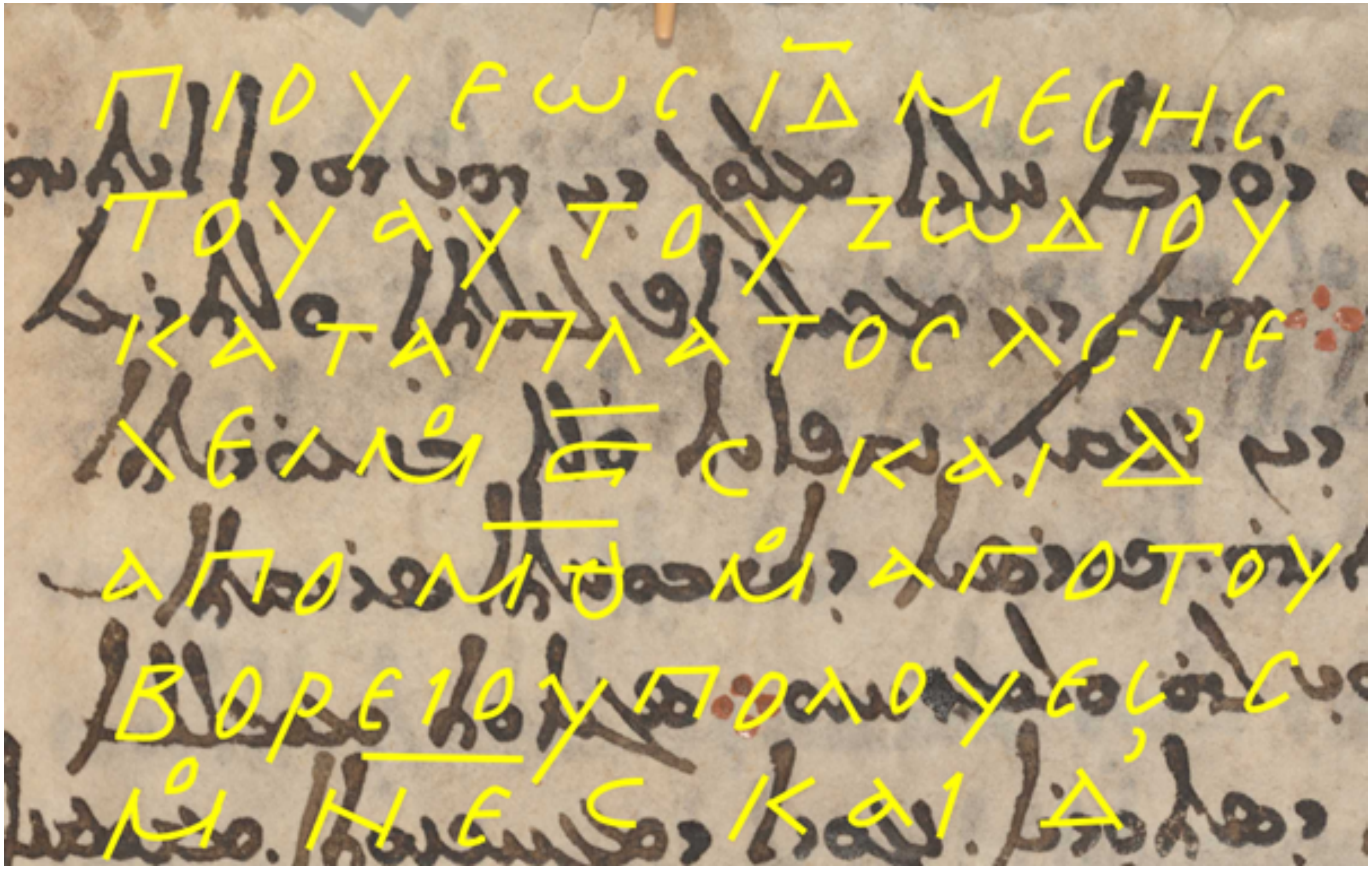
Publication: Gysembergh, Williams et Zingg, *Journal for the History of Astronomy* 2022, 383-393.



Codex Climaci rescriptus, f° 53v, beginning of the first column of erased text. Color image by Early Manuscripts Electronic Library, Lazarus Project of the University of Rochester and Rochester Institute of Technology.



Codex Climaci rescriptus, f° 53v, beginning of the first column of erased text. Multispectral image by Early Manuscripts Electronic Library, Lazarus Project of the University of Rochester and Rochester Institute of Technology, processing by Keith Knox.



Codex Climaci rescriptus, f° 53v, beginning of first column of erased text. In yellow, tracing of the erased text by Emanuel Zingg (Sorbonne Université).

Publication: Gysembergh, Williams et Zingg, *Journal for the History of Astronomy* 2022, 383-393.

Corona Borealis, lying in the northern hemisphere, in length spans 9°1⁄4 from the first degree of Scorpius to 10°1⁄4 in the same zodiacal sign (i.e. in Scorpius). In breadth it spans 6°3⁄4 from 49° from the North Pole to 55°3⁄4. Within it, the star (β CrB) to the West next to the bright one (α CrB) leads (i.e. is the first to rise), being at Scorpius 0.5°. The fourth star (ι CrB) to the East of the bright one (α CrB) is the last (i.e. to rise, π CrB) [. . .] 49° from the North Pole. Southernmost (δ CrB) is the third counting from the bright one (α CrB) towards the East, which is 55°3⁄4 from the North Pole.

Ὁ στέφανος ἐν τῷ βορείῳ ἡμισφαιρίῳ κείμενος κατὰ μῆκος μὲν ἐπέχει μ̊ θ̅ καὶ δ̅′ ἀπὸ τῆς α̅ μ̊ τοῦ σκορπίου ἕως ι̅ <καὶ> δ̅′ μ̊ τοῦ αὐτοῦ ζῳδίου. Κατὰ πλάτος δ᾽ ἐπέχει μ̊ ς̅ C καὶ δ̅′ ἀπὸ μ̅θ̅ μ̊ ἀπὸ τοῦ βορείου πόλου ἕως μ̊ ν̅ε̅ C καὶ δ̅′. Προηγεῖται μὲν γὰρ ἐν αὐτῷ ὁ ἐχόμενος τοῦ λαμπροῦ ὡς πρὸς δύσιν ἐπέχων τοῦ σκορπίου τῆς α̅ μ̊ τὸ ἥμισυ.

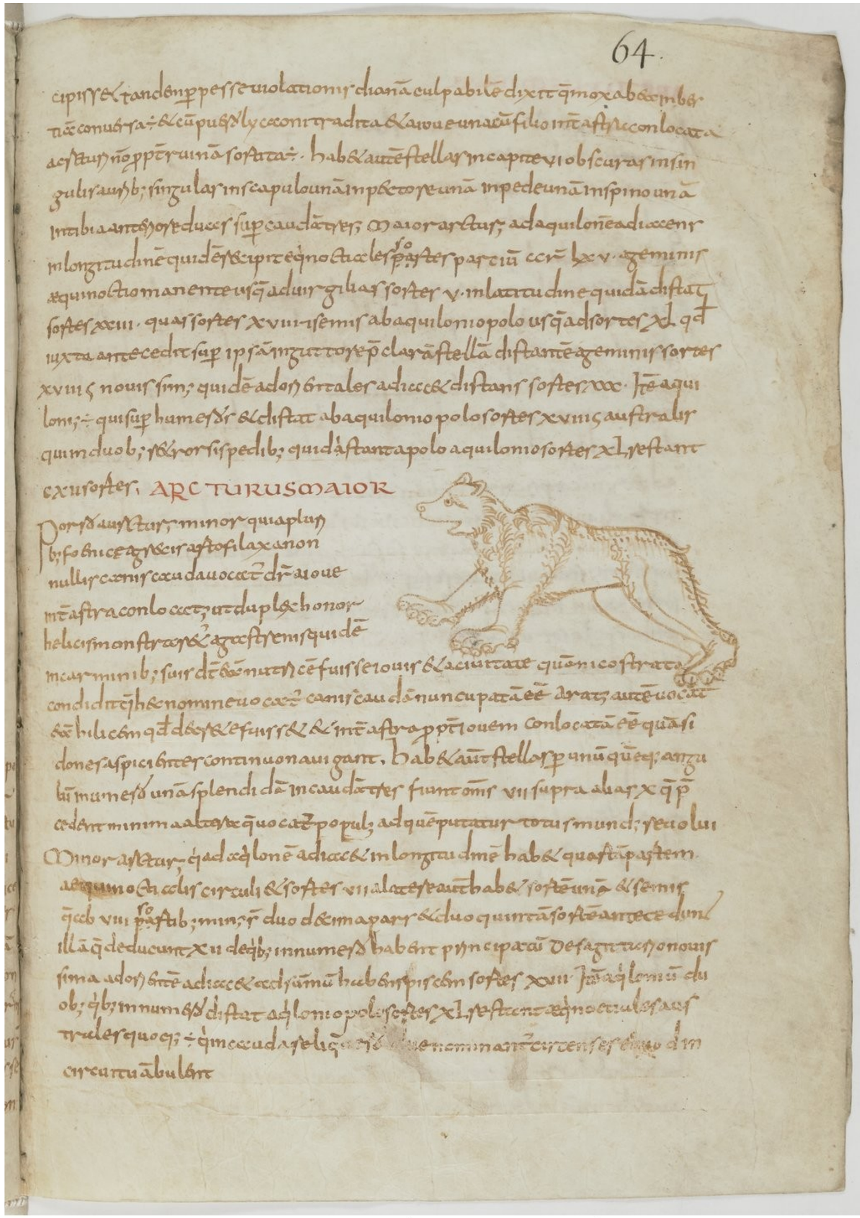
Ἔσχατος δὲ πρὸς ἀνατολὰς κεῖται ὁ δ′ ἐχόμενος ἐπ᾽ ἀνατολὰς τοῦ λαμπροῦ ἀστέρος [. . .] τοῦ βορείου πόλου μ̊ μ̅θ̅· νοτιώτατος δὲ ὁ γ′ ἀπὸ τοῦ λαμπροῦ πρὸς ἀνατολὰς ἀριθμούμενος ὃς ἀπέχει τοῦ πόλου μ̊ ν̅ε̅ C καὶ δ̅′.

Table 1. Boundaries of Corona Borealis according to CCR.

	α (right ascension)	Δ (codeclination)
β CrB	210°30′	
π CrB		49°
δ CrB		55°45′
ι CrB	220°15′	

Corona Borealis, lying in the northern hemisphere, in length spans 9°1⁄4 from the first degree of Scorpius to 10°1⁄4 in the same zodiacal sign (i.e. in Scorpius). In breadth it spans 6°3⁄4 from 49° from the North Pole to 55°3⁄4. Within it, the star (β CrB) to the West next to the bright one (α CrB) leads (i.e. is the first to rise), being at Scorpius 0.5°. The fourth star (ι CrB) to the East of the bright one (α CrB) is the last (i.e. to rise, π CrB) [. . .] 49° from the North Pole. Southernmost (δ CrB) is the third counting from the bright one (α CrB) towards the East, which is 55°3⁄4 from the North Pole.

Bibliothèque Nationale de France, Latin 12957, f° 64r (Aratus Latinus)



From left to right:

1) Museum of the Bible, Washington, DC
2) Main Library, University of Birmingham
3) Saint Peter's Abbey, Corbie, France
4) Rhodes, Greece
5) Iznik, Turkey
6) Saint Catherine's Monastery of Mount Sinai, Egypt

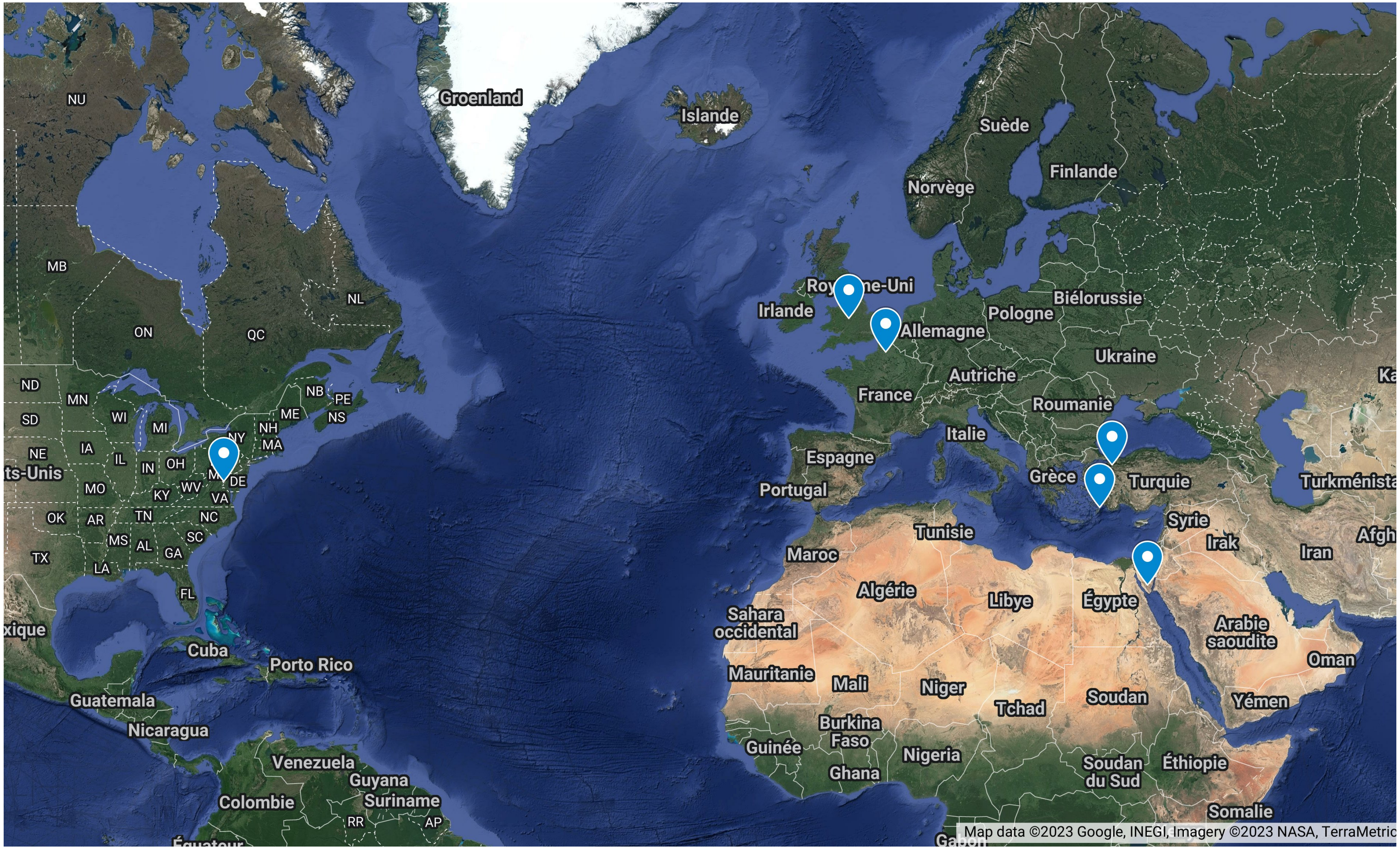


Table 6. Comparison of star coordinates from Hipparchus' Star Catalogue and Ptolemy's.

From Gysembergh et al., JHA 2022

	α	Δ	α_{Alm}	Δ_{Alm}	$\lvert\alpha-\alpha_{Alm}\rvert$	$\lvert\Delta-\Delta_{Alm}\rvert$
α UMi	347°	12°24′	345°41′	13°02′	1°19′	38′
β UMi		*8°*		*8°25′*		25′
γ UMi	240°		238°36′		1°24′	
o UMa	78°30′		77°22′		1°8′	
α UMa		*18°30′*		18°49′		19′
μ UMa		40°		40°09′		9′
η UMa	180° or 185°		184°8′		(4°)52′	
γ Dra		37°		36°49′		11′
ε Dra	298°		296°50′		1°10′	
κ Dra		10°		8°46′		1°14′
λ Dra	121°? 124°?		121°47′		47′ or 2°13′	
β CrB	210°30′		209°58′		32′	
π CrB		49°		48°58′		2′
δ CrB		55°45′		55°43′		2′
ι CrB	220°15′		219°6′		9′	

From Gysembergh et al., JHA 2022

Table 5. Star coordinates given in both Hipparchus' *Commentary* and CCR or *Aratus Latinus*.

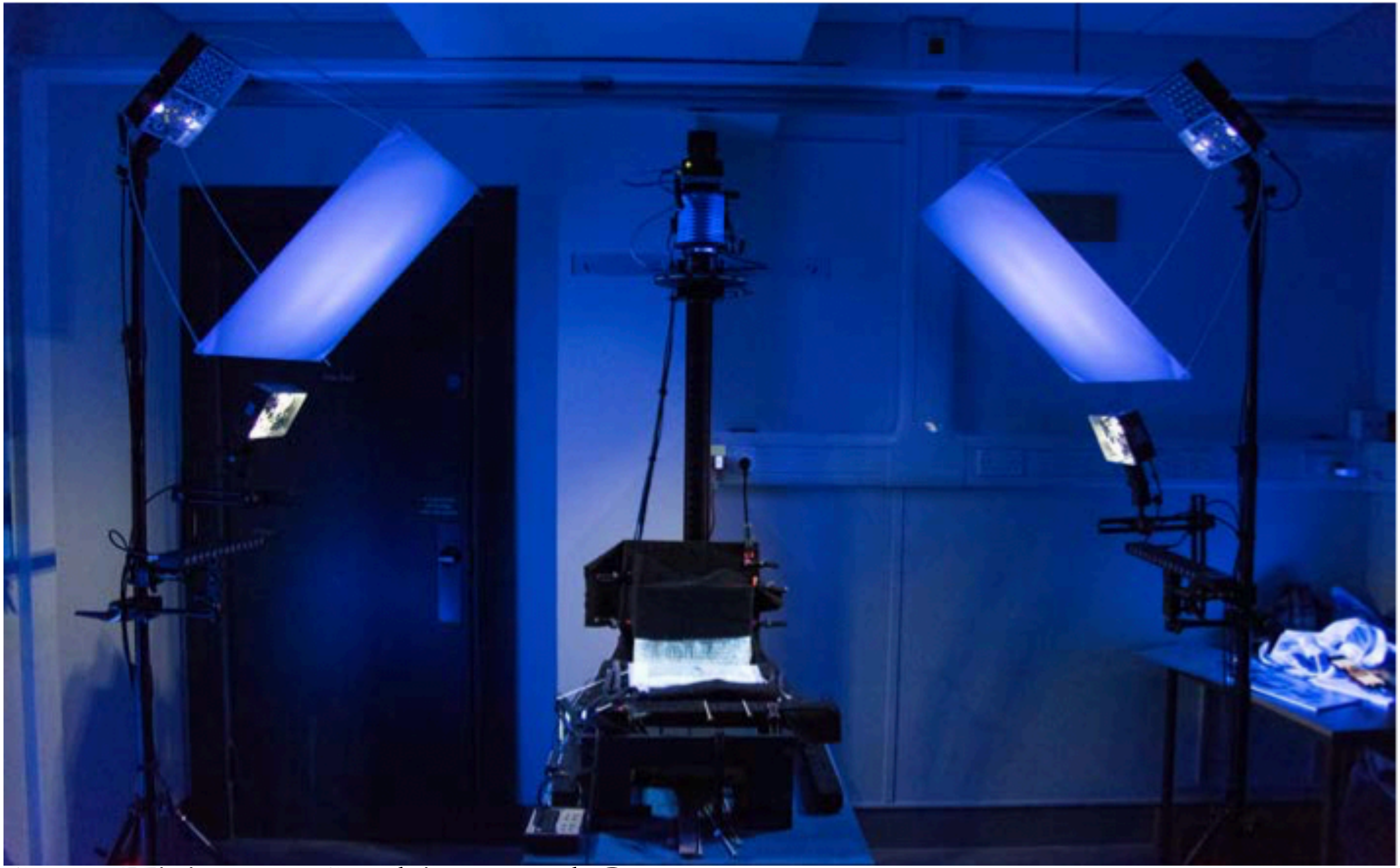
	α*Comm*	Δ*Comm*	α	Δ
α UMi	**348°**	**12°24′**	**347°**	**12°24′**
β UMi	240°	–	–	8°
γ UMi	**240°**	–	**240°**	–
α UMa	122°	–	–	18°30′
η UMa	**184°**	–	180° or **185°**	–
γ Dra	–	**37°**	–	**37°**
λ Dra	**123°**	–	121°? **124°?**	–
β CrB	**210°30′**		**210°30′**	

Biographical data about Hipparchus:

- Date of birth and death unknown
- Born in Nicaea (today Iznik, Turkey)
- Earliest dated observation 26 June 158 BCE (known since 2014!, cf. Fournet-Tihon 2014)
- Latest dated observation 7 July 127 BCE
- All known observations made in Bithynia (probably Nicaea) and in Rhodes
- …?

Hipparchus' main achievements:

- Table of chords (trigonometry)
- Schröder numbers (combinatorics – known since 2003!, cf. Acerbi 2003)
- Theory of the Sun and Moon's motions (with underlying Babylonian parameters)
- Sizes, Distances and Parallax of the Sun and Moon
- Eclipse table (descriptive? predictive?)
- *Commentary on the Phenomena of Eudoxus and Aratus*
- Catalogue of fixed stars (≥ 692 entries, cf. Gysembergh 2019)
- Determination of precession of equinoxes (> 1/100° per year)
- Observation of a nova (presumably Nova Scorpii, 134 BCE)
- Mathematization of geography
- Meteorology
- Optics
- Astrology
- Theory of Gravitation?



MegaVision E7 Multispectral Camera

Photo © Damianos Kasotakis, Early Manuscripts Electronic Library

Article

Statistical Processing of Spectral Imagery to Recover Writings from Erased or Damaged Manuscripts

Roger L. Easton and David Kelbe | Rochester

Abstract

Imaging techniques for recovering historical writings that have been deliberately erased to make palimpsests or otherwise damaged have a long history. These writings often may be recovered from images collected under different illuminations over a range of wavelength bands. These spectral images are combined in subsequent image processing to enhance the visibility of the desired text. This paper considers the application of several processing algorithms based on the spectral statistics of the image data. These methods may be tailored to the specific condition of the manuscript and may enhance erased or damaged writings better than other techniques.

1. Introduction

Many historical manuscripts have been damaged by a variety of mechanisms: the ravages of natural processes over time, inappropriate storage, and deliberate action. Inks fade, manuscripts may have been scorched or charred by fire or damaged by animal excretions, parchments were often deliberately erased and reused to make palimpsests, etc. These faded, erased, or otherwise damaged manuscripts may be impossible to read without artificial aids to human vision. Moreover, simple devices (such as optical magnifiers to enlarge the text) and more complicated tools (e.g. ultraviolet lights to enhance the contrast of erased text relative to the background parchment) only improve the appearance to the human eye. The ultimate limit to the success of these visual aids is the human vision system itself, which is limited by the capability of the eye lens, the photochemical mechanism for sensing light, and the perception of images by the brain. One example of the constraint of the visual system is its narrow range of spectral sensitivity, which is limited to wavelengths between approximately 400 nm (blue) and 700 nm (red). Significant information is often present at wavelengths outside this range.

To obtain even better readings from the manuscripts, the limitations of the human visual system in terms of wavelength and sensitivity must be overcome. In other words, it is necessary to render subjectively imperceptible information so that it becomes visible to the eye. The need for better renderings has long been recognized and led to attempts to enhance the legibility of manuscripts by applying the very earliest imaging technologies. Chiara di Sarzana has presented an excellent history of photography applied to manuscripts.[1] In 1840, only one year after the accepted date of the first photograph, Jean Baptiste Biot reported that William Henry Fox Talbot had made images on sensitized paper of a Hebrew psalm, a Persian newspaper, and a 13th-century charter in Latin.[2] Apart from this early work, the use of photography to document historical writings did not become common until the technology of monochrome emulsion imaging matured in the 1880s, when flexible cellulose film substrates became available, thus eliminating the requirement for fragile glass plates. James Rendel Harris was an early imaging experimenter, having photographed manuscripts at St. Catherine's Monastery in Sinai in 1888.[3] Harris also assisted the Scottish twin sisters Agnes Smith Lewis and Margaret Dunlop Smith Gibson when they imaged the *Codex Sinaiticus Syriacus* on a subsequent visit to St. Catherine's in 1892.[4] It is interesting to note that the thousand or so film sheets exposed during that trip to the monastery were not processed until the travelers returned to England several months later, which prevented them from

[1] Di Sarzana 2006.

[2] Biot 1839-1840, *Chronique of Bibliothèque de l'École des Chartes* I, p. 408.

[3] Harris and Harris 1891.

[4] Gibson 1893.

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cis.rit.edu/~ktkpci/Hoku.html

www.cis.rit.edu/~ktkpci/Hoku.html 170 %

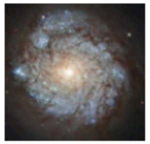
NPauly TLG APh ENT LibGen b-ok ERC SUDOC Loeb Sphère armillaire Hoku DPhA VOD-SU Europresse SD MS Omnia

Hoku

Hoku is a Java-based software package to process multispectral image data sets to recover writings that have been damaged or erased. It is distributed free-of-charge, without warranty. The current version is 1.9.3, released on 6 December 2022.

Installing Hoku

Download the InstallHoku.jar file to your computer's Desktop.
On the Desktop, double-click on the InstallHoku.jar icon to start the process.



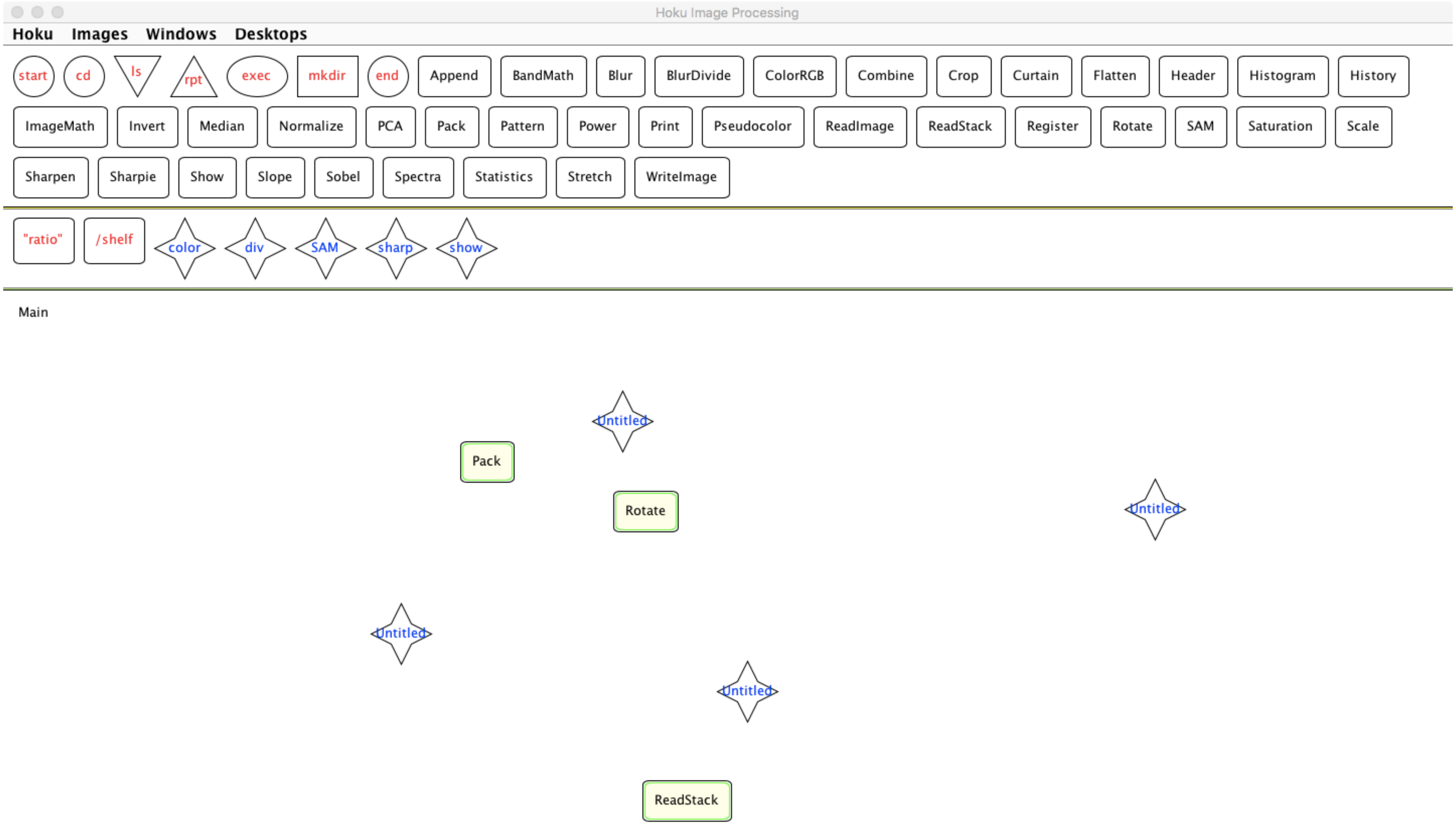
<-- Select to download InstallHoku.jar.

Double-click on the downloaded InstallHoku.jar file. The installation program will determine which type of computer you are using, either Windows or macOS, and install the appropriate routines. Follow the instructions in the program. You may delete the InstallHoku.jar file when it finishes.

On a Mac, if you get an error message that the InstallHoku cannot be opened,

http://www.cis.rit.edu/~ktkpci/Hoku.html

Hoku image processing software, developed by Keith Knox of the Early Manuscripts Electronic Library


Hoku Image Processing
Hoku Images Windows Desktops
start cd ls rpt exec mkdir end Append BandMath Blur BlurDivide ColorRGB Combine Crop Curtain Flatten Header Histogram History
ImageMath Invert Median Normalize PCA Pack Pattern Power Print Pseudocolor ReadImage ReadStack Register Rotate SAM Saturation Scale
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Main
Untitled
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ReadStack

The Classical Quarterly (2022) 1–28
doi:10.1017/S0009838822000726

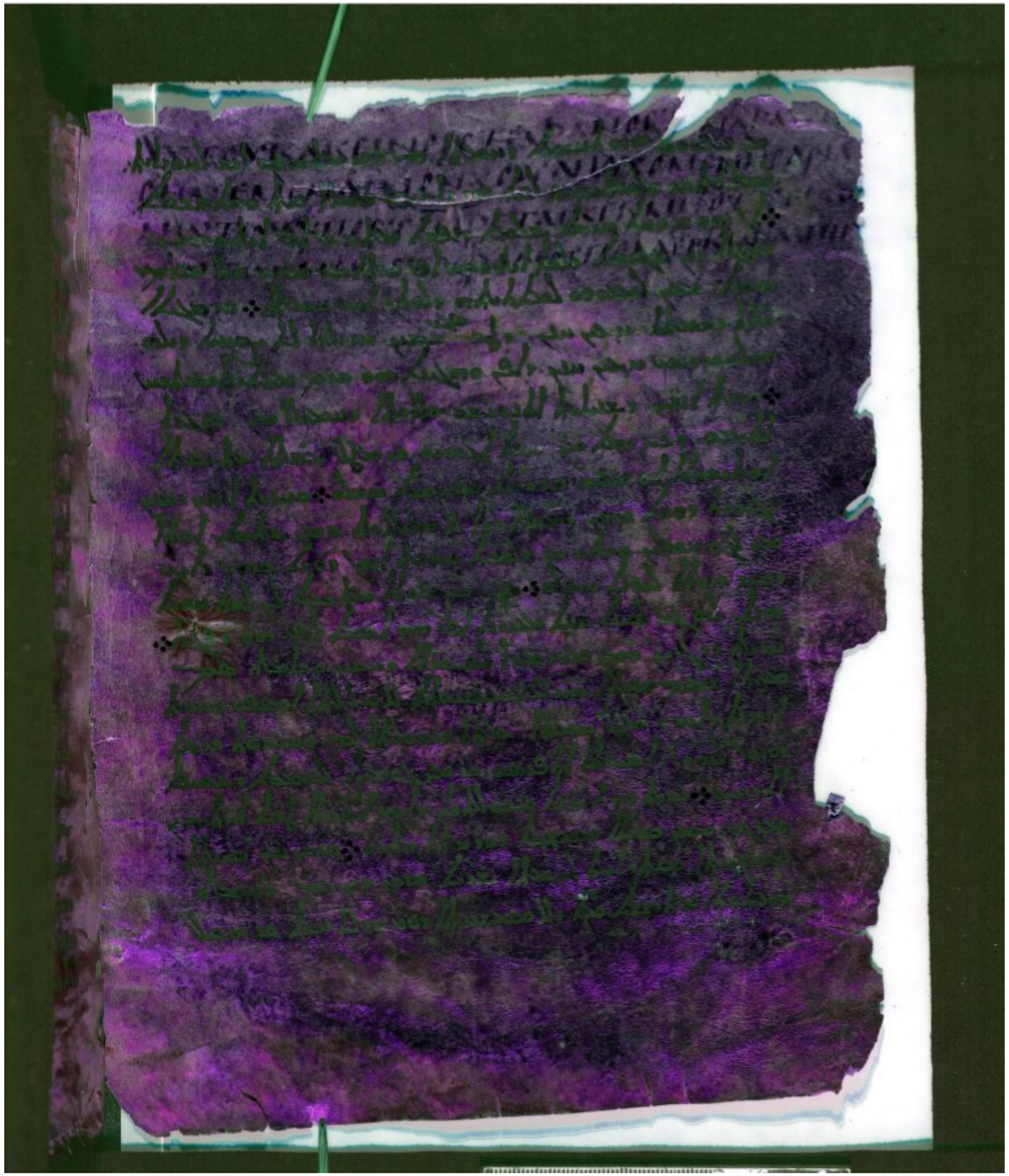
NEWLY DISCOVERED ILLUSTRATED TEXTS OF ARATUS AND ERATOSTHENES WITHIN CODEX CLIMACI RESCRIPTUS*

ABSTRACT

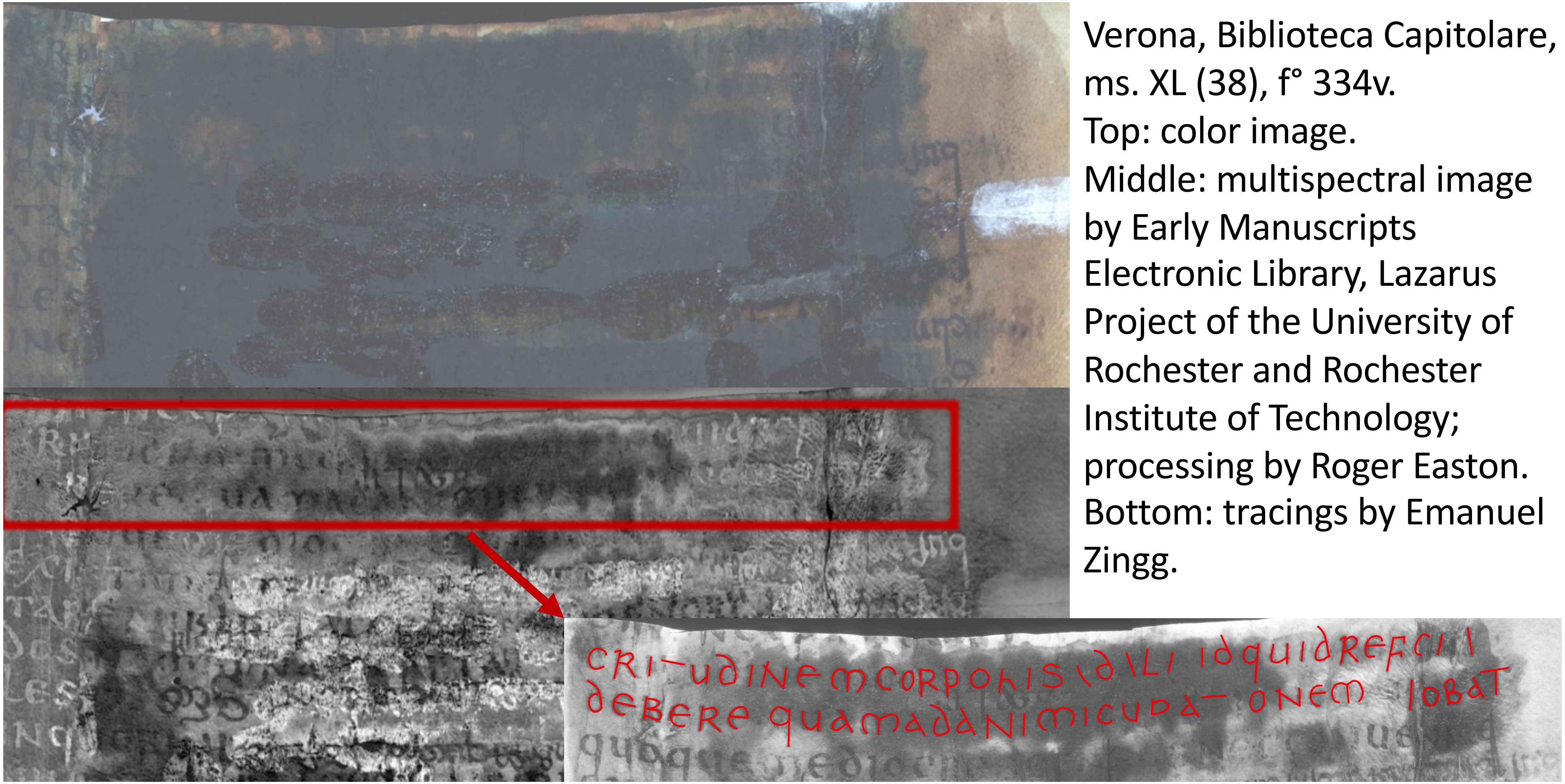
This article presents texts recovered by post-processing of multispectral images from the fifth- or sixth-century underwriting of the palimpsest Codex Climaci Rescriptus. Texts identified include the Anonymous II Proemium to Aratus' Phaenomena*, parts of Eratosthenes'* Catasterisms*, Aratus'* Phaenomena *lines 71–4 and 282–99 and previously unknown text, including some of the earliest astronomical measurements to survive in any Greek manuscript. Codex Climaci Rescriptus also contains at least three astronomical drawings. These appear to form part of an illustrated manuscript, with considerable textual value not merely on the basis of its age but also of its readings. The manuscript undertexts show significant overlap with the Φ Edition, postulated as ancestor of the various Latin* Aratea*.*

Keywords: Aratus; *Catasterisms*; Codex Climaci Rescriptus; Eratosthenes; palimpsest

* The authors are grateful to many people for their assistance in bringing these texts to publication and, in particular, to the sponsors of the research—namely, Museum of the Bible, Washington, DC, and its founders, the Green family of Oklahoma City. Simeon R. Burke, Elspeth R. Darley, Jamie Klair and Jacob L. Madin were undergraduate students when they identified key texts while doing internships at Tyndale House, Cambridge. Together with Anne Burberry, Filip Sylwestrowicz and Douglas Thomas, students who joined the team later, they contributed hundreds of hours to the decipherment of the palimpsest. Christian Askeland, Michael Holmes, Brian D. Hyland, Bethany Jensen, Lauren McAfee, Jerry Pattengale, Daniel Stevens, Amy Van Dyke and Jonathan Wilken have supported the project in many ways. Various stages of imaging have contributed to our understanding of the manuscript: multispectral imaging by Alexander Kovalchuk, Joy Giroux and Lindy Johnson (2010); colour scans by Sarah Zaman (2010); multispectral imaging by Gene Ware (2010); colour photography by Ardon Bar-Hama (2012) and Brittney Brown (2013); Reflectance Transformation Imaging by Bruce Zuckerman, Ken Zuckerman and Marilyn Lundberg of the West Semitic Research Project (2013); multispectral imaging of select folios by Gregory Heyworth and the Lazarus Project (2015); in 2017 the Early Manuscripts Electronic Library and the Lazarus Project captured and provided the most recent processed images which took decipherment to a new level. Their team consisted of Di Bai, Ken Boydston, Helen Davies, Josephine Dru, Roger L. Easton, Christos Georgiades, Gregory Heyworth, Kyle Huskin, Damian Kasotakis, Vasilis Kasotakis, David Kelbe, Keith Knox, Mike Phelps, Nicole Polglaze, Dale Stewart, Sarah Zaman and Alexander Zawacki. At different points in the project Valeria Annunziata, Elly Dekker, Klaus Geus, Kristen Lippincott, Jordi Pàmias, Emma Perkins, Anna Santoni, Liba Taub and Helen Van Noorden have kindly provided academic advice. Victor Gysembergh and Emanuel Zingg provided crucial input on several folios during the final stages of decipherment. Peter M. Head checked some transcriptions and undertook autopsy of the manuscript which contributed to our understanding of its codicology. Williams directed the project and is responsible for the final version of this article, including the final transcriptions. Klair was responsible for the first draft of the article. Malik and James improved transcriptions, and the latter both identified texts and provided some of the textual comment. Zaman has been involved at all stages in the project and helped bring the article to completion.



Codex Climaci rescriptus, f° 48v



Verona, Biblioteca Capitolare, ms. XL (38), f° 334v.
Top: color image.
Middle: multispectral image by Early Manuscripts Electronic Library, Lazarus Project of the University of Rochester and Rochester Institute of Technology; processing by Roger Easton.
Bottom: tracings by Emanuel Zingg.

Archive for History of Exact Sciences
https://doi.org/10.1007/s00407-022-00302-w

Ptolemy's treatise on the meteoroscope recovered

Victor Gysembergh[1] · Alexander Jones[2] · Emanuel Zingg[1] · Pascal Cotte[3] · Salvatore Apicella[3]

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Abstract

The eighth-century Latin manuscript Milan, Veneranda Biblioteca Ambrosiana, L 99 Sup. contains fifteen palimpsest leaves previously used for three Greek scientific texts: a text of unknown authorship on mathematical mechanics and catoptrics, known as the *Fragmentum Mathematicum Bobiense* (three leaves), Ptolemy's *Analemma* (six leaves), and an astronomical text that his hitherto remained unidentified and almost entirely unread (six leaves). We report here on the current state of our research on this last text, based on multispectral images. The text, incompletely preserved, is a treatise on the construction and uses of a nine-ringed armillary instrument, identifiable as the "Meteoroscope" invented by Ptolemy and known to us from passages in Ptolemy's *Geography* and in writings of Pappus and Proclus. We further argue that the author of our text was Ptolemy himself.

Communicated by Jed Buchwald.

✉ Alexander Jones
alexander.jones@nyu.edu

Victor Gysembergh
victor.gysembergh@gmail.com

Emanuel Zingg
emanuelzingg@hotmail.com

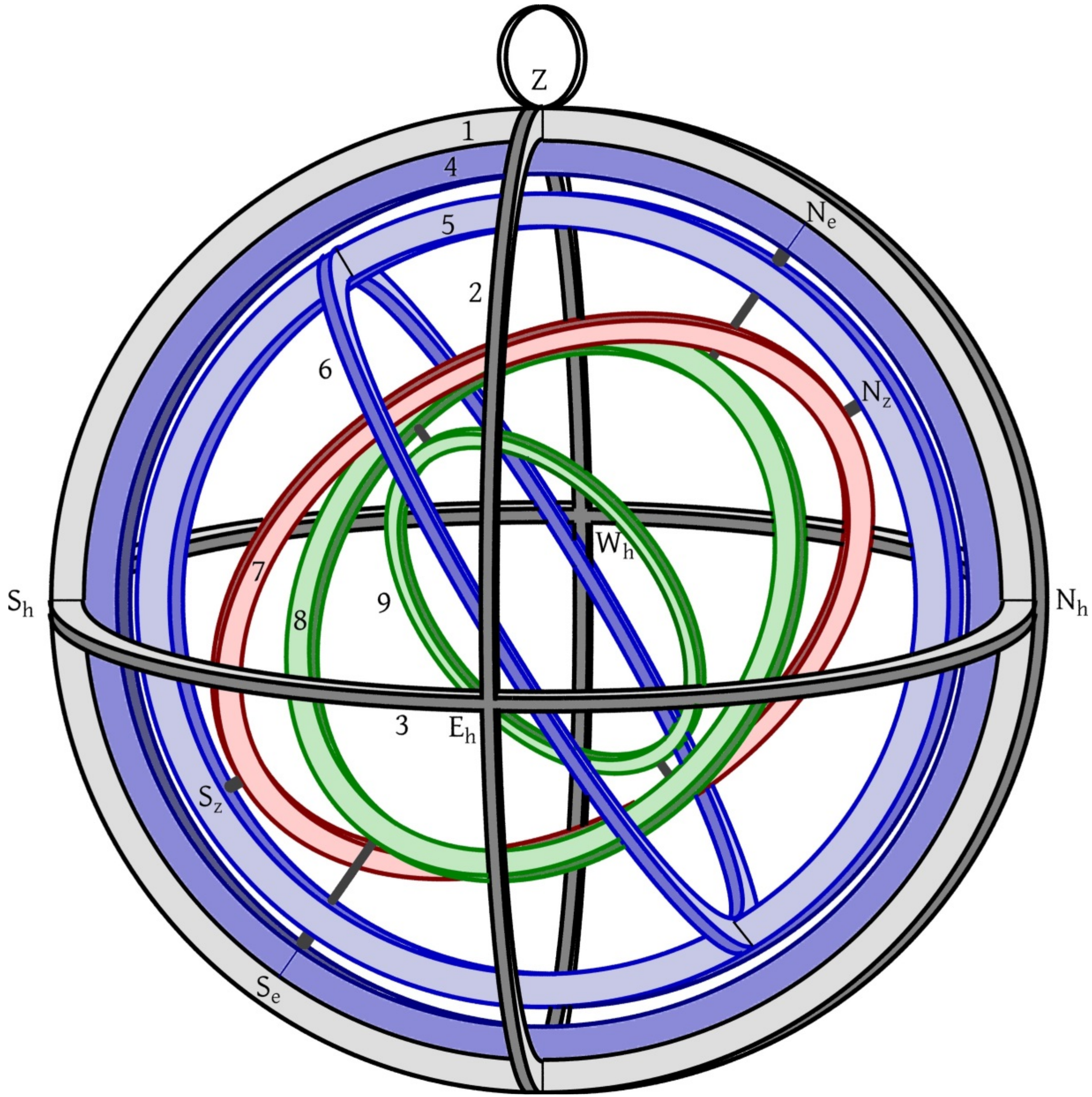
Pascal Cotte
pascal@cotte.com

Salvatore Apicella
salvatore.apicella2@unibo.it

[1] Centre Léon Robin de recherches sur la pensée antique (UMR 8061), Centre national de la recherche scientifique, 1, rue Victor Cousin, 75230 Paris, France

[2] Institute for the Study of the Ancient World, New York University, 15 East 84th Street, New York, NY 10028, USA

[3] Lumière Technology, Ponthierry, France



Ptolemy's "Meteoroscope"
Reconstruction from the Milan palimpsest
Drawing: Alexander Jones (NYU)
Publication: Gysembergh, Jones and Zingg, *Archive for the History of the Exact Sciences* 2023

The New Fragments from Hipparchus' Star Catalogue

Victor Gysembergh (CNRS / Sorbonne Université)

victor.gysembergh@cnrs.fr