

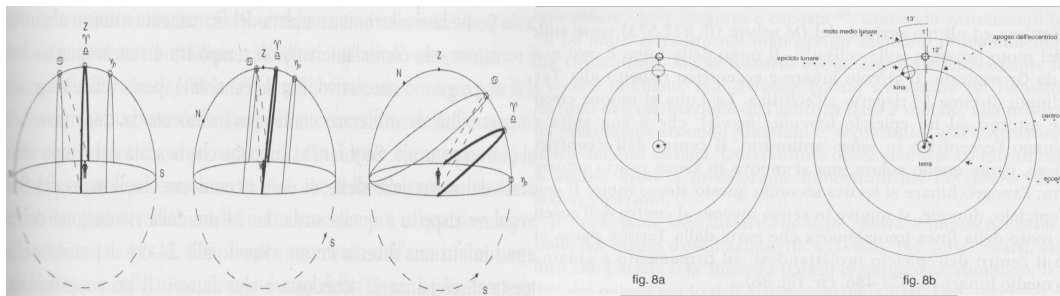
# Visualising the Universe: Modern Representations of a Medieval Cosmology

Jack Smith

October 14, 2016

## 1 Introduction

Robert Grosseteste was a 13th century medieval scholar often thought of as “the real founder of the tradition of scientific thought in medieval Oxford, and in some ways, of the modern English intellectual tradition” [3]. He wrote multiple treatises on light, the universe and the tides. I spent 8 weeks this summer working as part of the cross-disciplinary ‘Ordered Universe Project’, analysing Grosseteste’s texts to challenge contemporary views of the so-called ‘dark ages’. Specifically, I looked at his *De sphaera* [4] :a treatise on motions within the universe. Whilst the text contains a complete and detailed model, there are no diagrams and the descriptions are complex. Panti [5] has produced a detailed commentary on the text , which includes 2D diagrams (see figures a,b). This description provided an invaluable introduction to the text and was the starting point for my work. Modern 3D visualisation technology, however, can further enhance the description by providing animations and interactivity. Furthermore, advances in web browser technology can now put 3D graphics on a website, bringing it to a wider audience and providing better integration with explanatory text.



(a) Solstice positions at different latitudes.

(b) Relative motions of the Sun and Moon.

## 2 Implementation

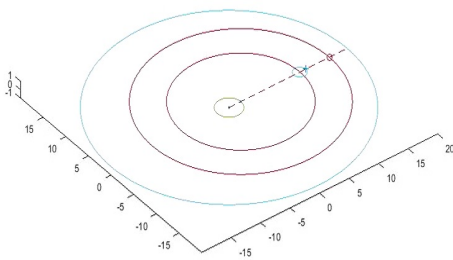
This project gave me a lot of freedom in how I went about visualising the text. I started by making relatively simple diagrams of the main ideas in Matlab, to aid my understanding of concepts [see section 4]. I then considered the best way to present the ideas to a wider audience. I chose WEBGL (specifically the THREEjs library) [see section 5], as this allowed the 3D visualisations to be interactive and viewable in most browsers. Another advantage was that it does not require any additional downloads that deter users. In order to implement this, I learnt HTML and CSS for page design and menus [see section 6], then JavaScript for the interactivity. This format is used in the construction of most web pages and will prove a useful skill.

### 3 The Treatise

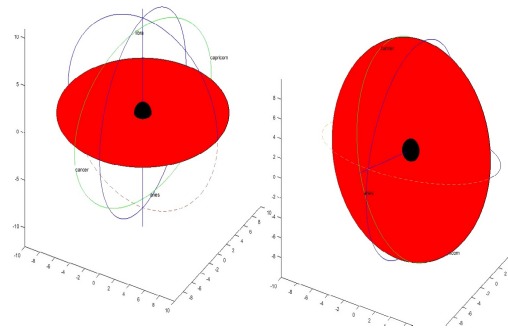
Understanding the text often proved quite conceptually difficult, often vague or unintuitive to the modern scientist. However, by cross-referencing the original text, the commentary on it by Panti[5] and the ideas in other related texts[2][6][7], the nature of the ideas became clear. This was aided by the opportunity for considerable cross discipline interaction with latinists, historians and visualisation experts. Key points for visualisation are his base construction of a geocentric universe with an outer sphere onto which the stars are placed and his complex descriptions of the movements of the Zodiac signs. In fact, it was only upon creating the visualisations that earlier errors in my understanding became clear. Other important ideas are the timings of eclipses, the orbit of the Moon and the motion of the Sun through the seasons. Most of these are reasonably accurate descriptions, however Grosseteste’s reasoning is often unenlightened. For example, it was thought that the sun was further from the Earth in the Northern hemisphere’s summer and closer in winter, so as to make it habitable, with the southern hemisphere being too cold and hot respectively. Conversely, given only rough data, his approximation of the elliptical orbit of the Moon to multiple superimposed circles gives a reasonably accurate model.

### 4 Matlab

As I already knew some Matlab from my course, it proved an easy way to get to grips with the diagrams. I decided to use polar coordinates for most of them, since it is a geocentric model, so most diagrams involve Earth centred circles. To achieve this, I produced a series of functions to describe the geometric constructions and their evolution with time, then coding them in Matlab to produce animations. These included the motion of the moon around the Earth (figure a), the position of the solstices and zodiac signs at different lattitudes (figure b), and the rotation of the Zodiac around the Earth. I built upon the diagrams in Panti’s commentary[5], converting them into 3D and programming each diagram iteratively, tweaking the code from the previous diagram and re-using its functions. The short duration of the project encouraged me to properly organise my programs and I also learnt much about streamlining and rationalising code, as the animations were processor intensive.



(a) Matlab diagram of the Earth, Moon and Sun

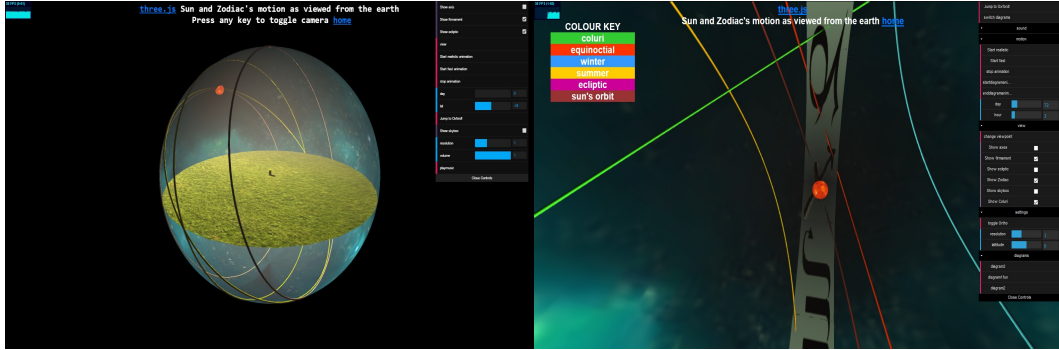


(b) 3D Stills from a Matlab animation

### 5 WebGL Implementation

The Threejs library is the most popular and well documented for WebGL, allowing me to easily create and transform graphics objects, rather than using explicit equations. I recreated all of the Matlab diagrams in Threejs and added interactive adjustable parameters (see figure (a)), along with a satisfying animation to switch diagrams. This has taught me much about 3D graphics and particularly its increasing use in web-based applications. I have also

learnt to efficiently use forums such as Stackoverflow to discuss implementations with other developers. I encountered many problems necessitating innovative coding, such as solving loading time issues by loading a small low resolution texture for the Earth in first, which a more detailed one overwrites later when required.

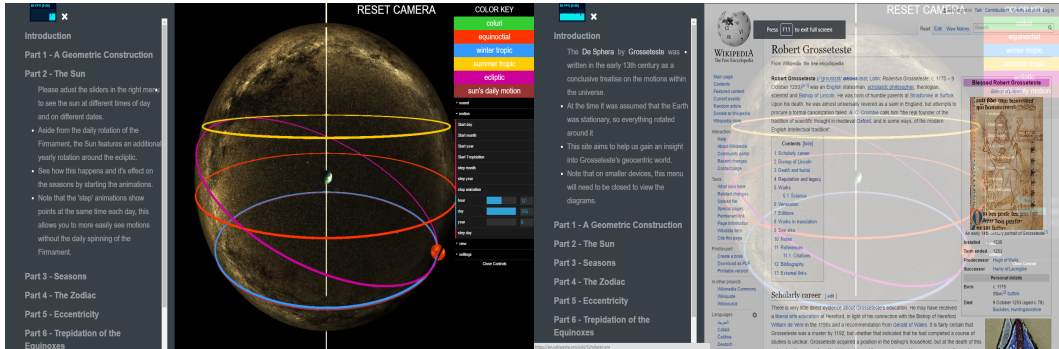


(a) WebGL model with adjustable parameters

(b) WebGL view from Earth with Key

## 6 Website design

Once I had made the 3D diagrams, I constructed an intuitive interface. I decided to use the DAT.gui libraries for changing settings and 2 of the inbuilt control schemes for navigation within the diagrams. Compatibility was quite troublesome and a few workarounds were used, such as only activating the terrestrial controls when the mouse button is pressed. After learning more HTML and jquery, I created a minimalistic collapseable sidebar, for more user friendly explanation and navigation. This proved problematic on phones, but using the CSS '@media screen', I tweaked the interface for different sized devices. I also added further information in a larger iframe, including a help section for common errors and a more in depth explanation of the text.



(a) Final website design

(b) Information overlay

## 7 Summary

To conclude, in 8 weeks I have gone from static 2D diagrams, through 3D animations, to a fully interactive website and learning resource, which was used at an Ordered Universe project Symposium during September. Early feedback seems very positive and after further tuning I intend to present it at a Symposium in Oxford before a general public release of the site[1]. Hopefully it will help inform and interest both historians and enthusiasts on the intricacies of Grosseteste's work.

## References

- [1] The de sphaera project. <http://desphera.comxa.com/>.
- [2] Aristotle. *De caelo*. Manuscript, 350 BC.
- [3] A. C. Crombie. *Robert Grosseteste and the Origins of Experimental Science*. Oxford: Clarendon Press, 1971.
- [4] Robert Grosseteste. *De sphaera*. Manuscript, 2nd half of the 13th century.
- [5] Cecilia Panti and Robert Grosseteste. *Moti, virtu e motori celesti nella cosmologia di Roberto Grossatesta: studio ed edizione dei trattati De sphaera, De cometis, De motu supercelestium*, volume 16. Sismel, 2001.
- [6] Claudius Ptolemy. *Almagest*. Manuscript, 2nd century.
- [7] Johannes Sacrobosco. *De sphaera mundi*. Manuscript, 2nd half of the 13th century.