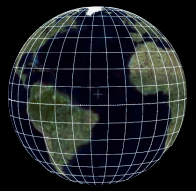
Winnetu
41° N, 70° W

Lost without Longitude

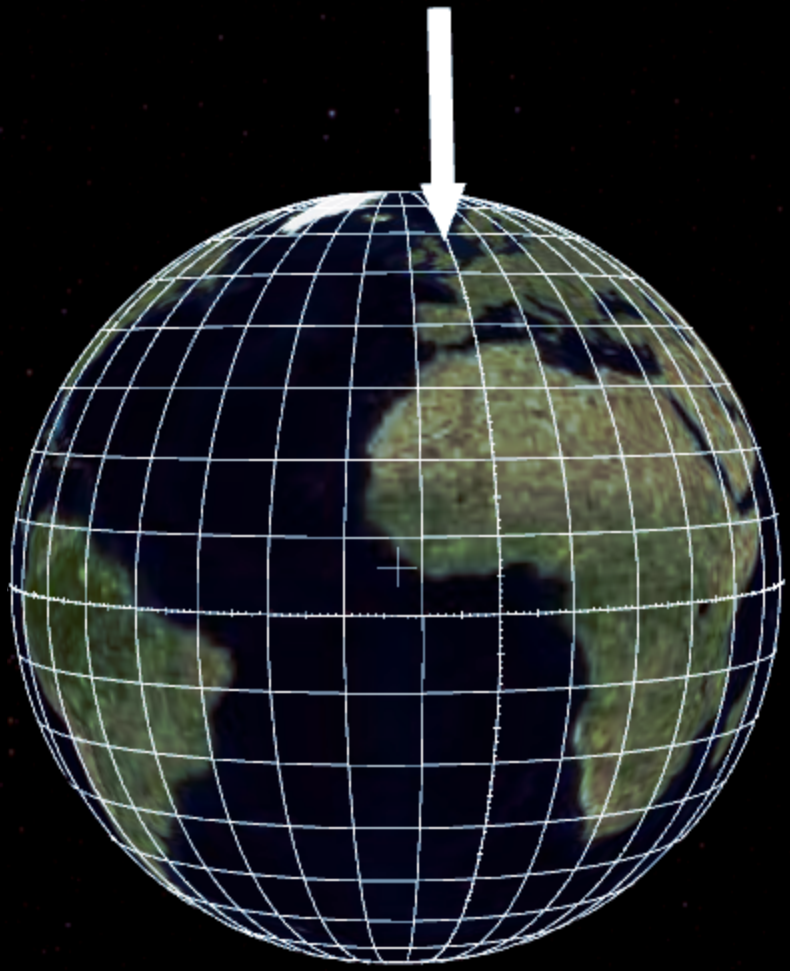
Alyssa Goodman
Harvard-Smithsonian Center for Astrophysics
@aagie, #PredictionX



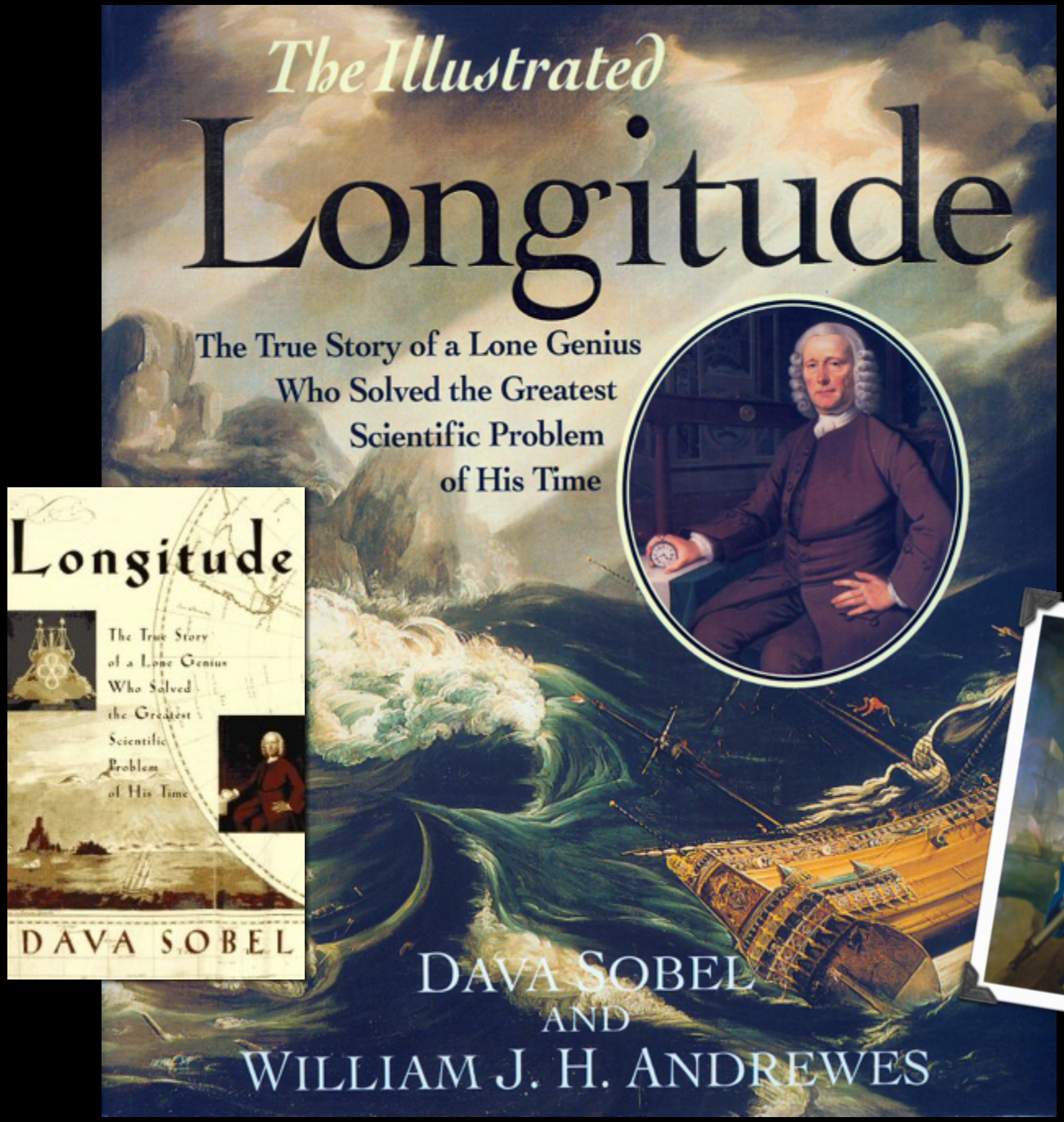
Latitude, Longitude,
and

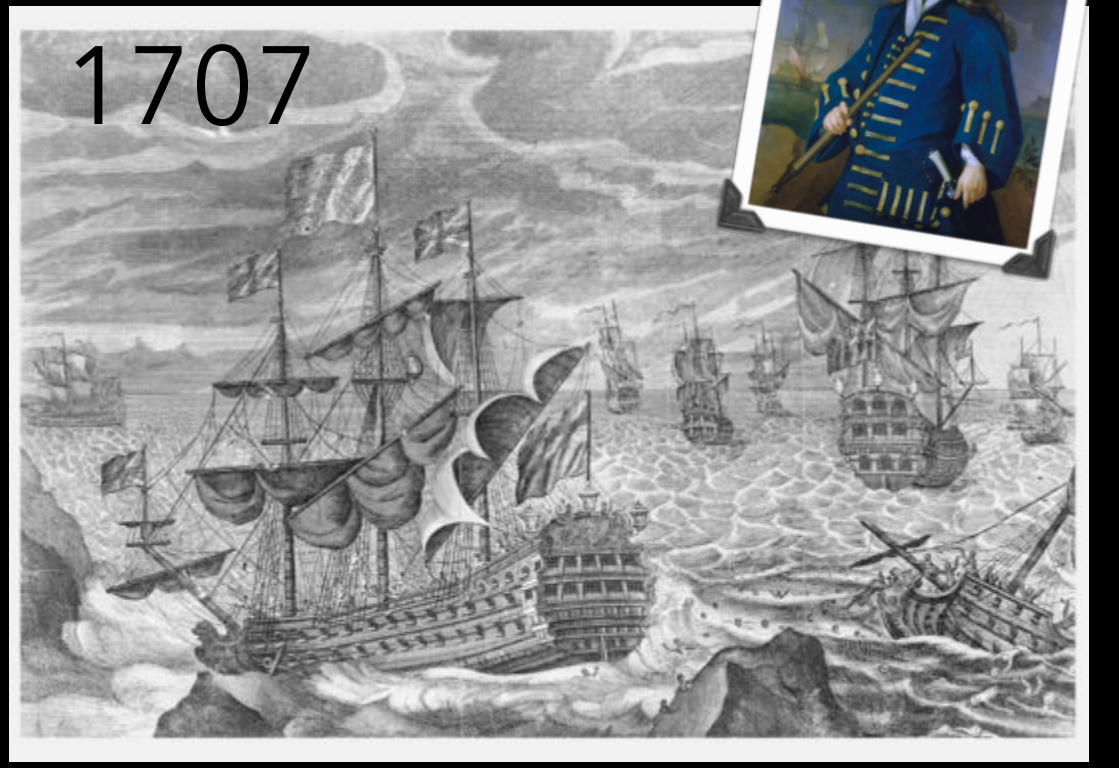
WorldWide Telescope

But Longitude has no natural "zero."
Today, we use Greenwich, England.



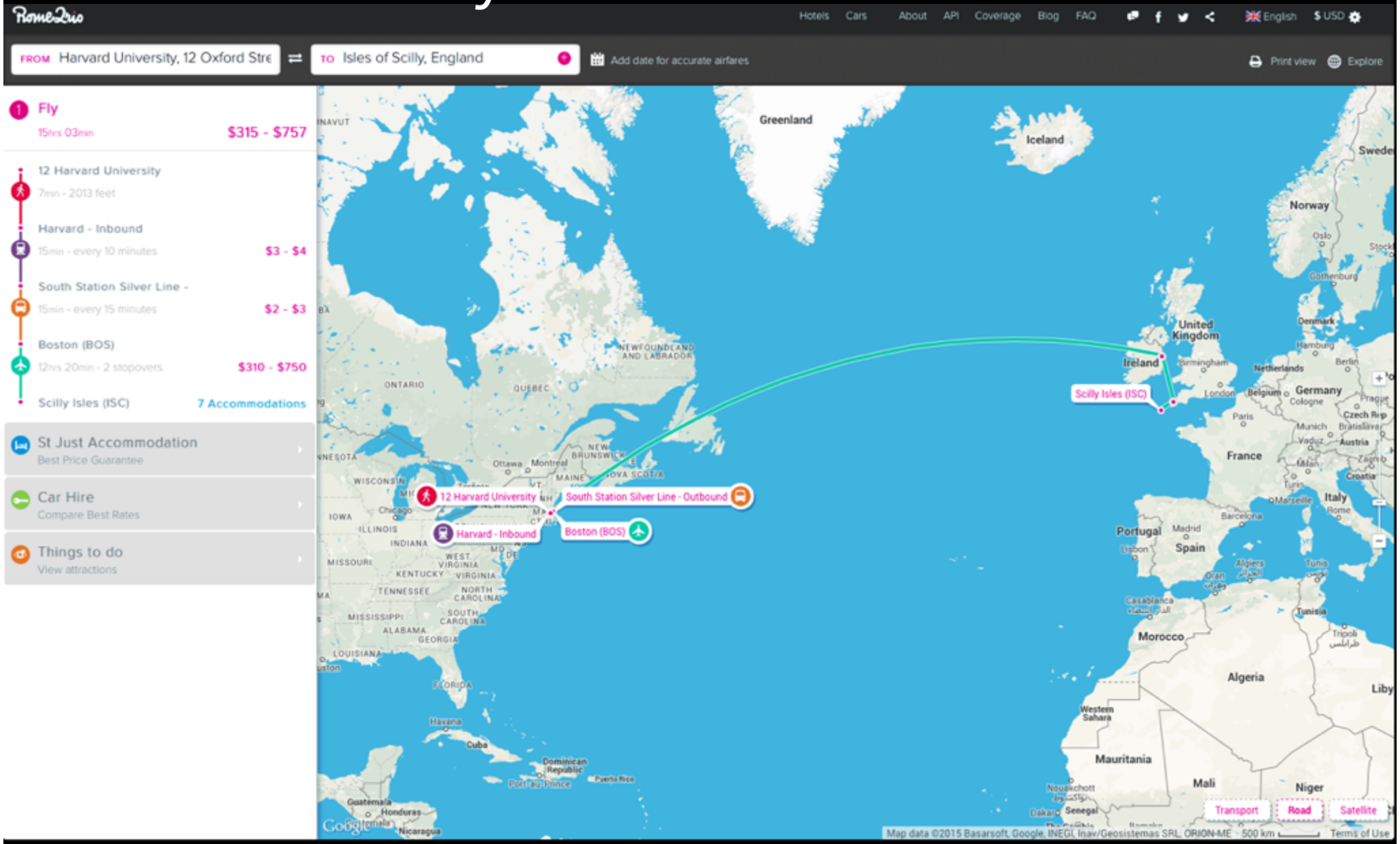
Lat_Long_HMNH3.wtt


The Illustrated
Longitude
The True Story of a Lone Genius Who Solved the Greatest Scientific Problem of His Time
DAVA SOBEL
AND
WILLIAM J. H. ANDREWES
Longitude
The True Story of a Lone Genius Who Solved the Greatest Scientific Problem of His Time
DAVA SOBEL

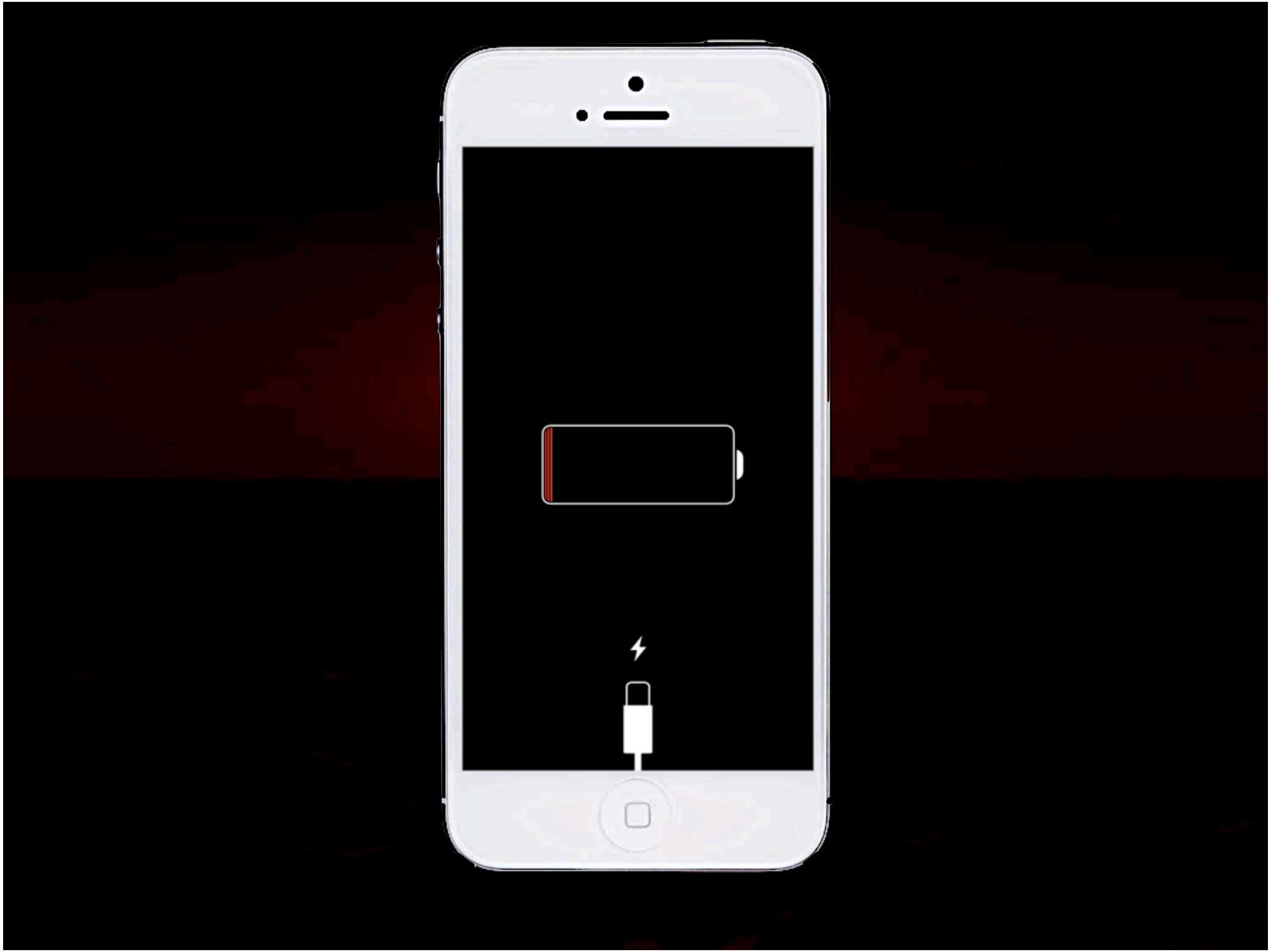

1707

T-Mobile 4G 10:07 AM 38%
Personal Hotspot: 1 Connection
Isles of Scilly
Bryher
Tresco
Tresco
2007
St. Mary's
Isles of Scilly Heritage Coast
Hugh Town
Google
Isles of Scilly
Isles of Scilly, United Kingdom
Route

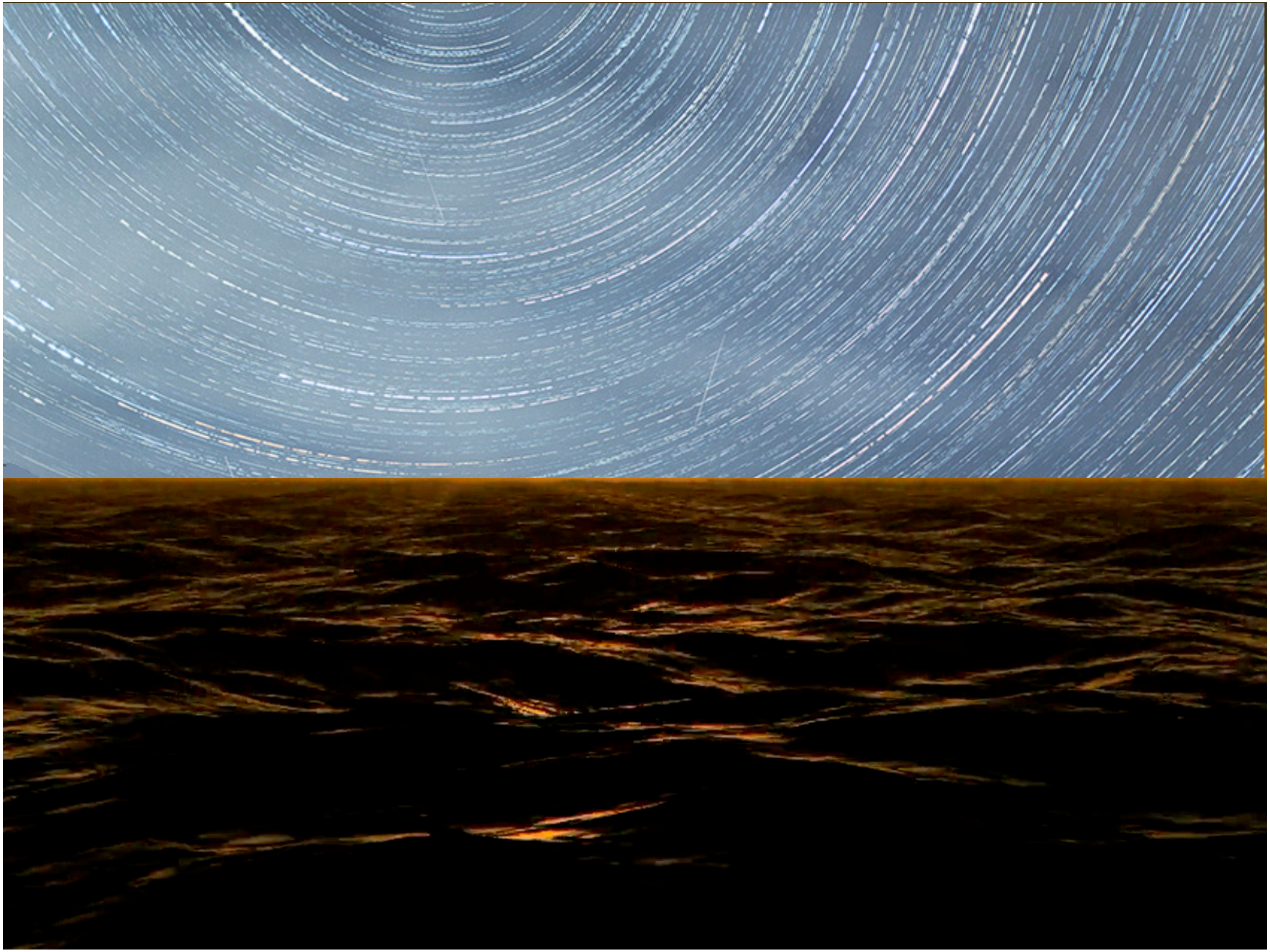
Isles of Scilly



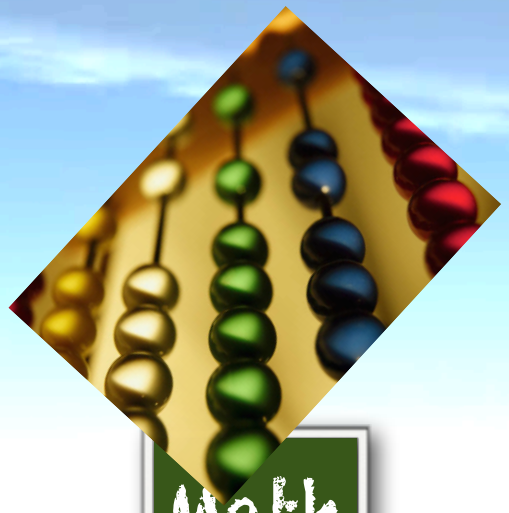
http://www.rome2rio.com/s/Harvard-University-12-Oxford-Street-Cambridge-MA-02138-USA/Isles-of-Scilly



Skymarks
Landmarks



Elements of Navigation …at Sea



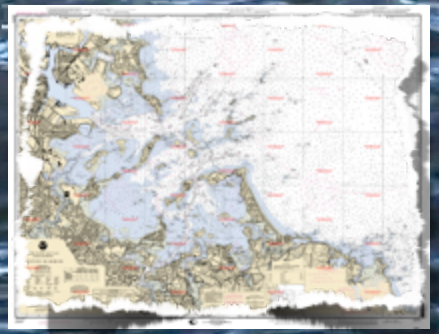
Math

SPEED

Astronomy

Timekeeping

Direction



Maps

Uncertainty

Accuracy of Maps

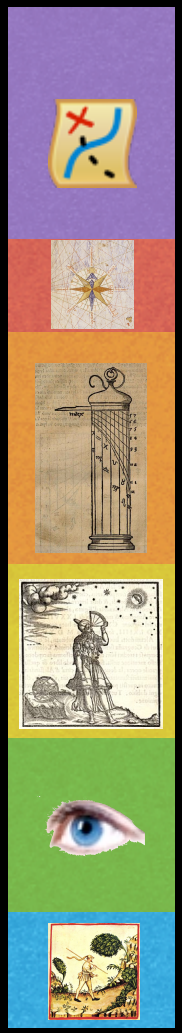
Direction Measurement

Time Measurement

Angular Measurement

Astronomical Measurement

Measuring Speed



1200

1675

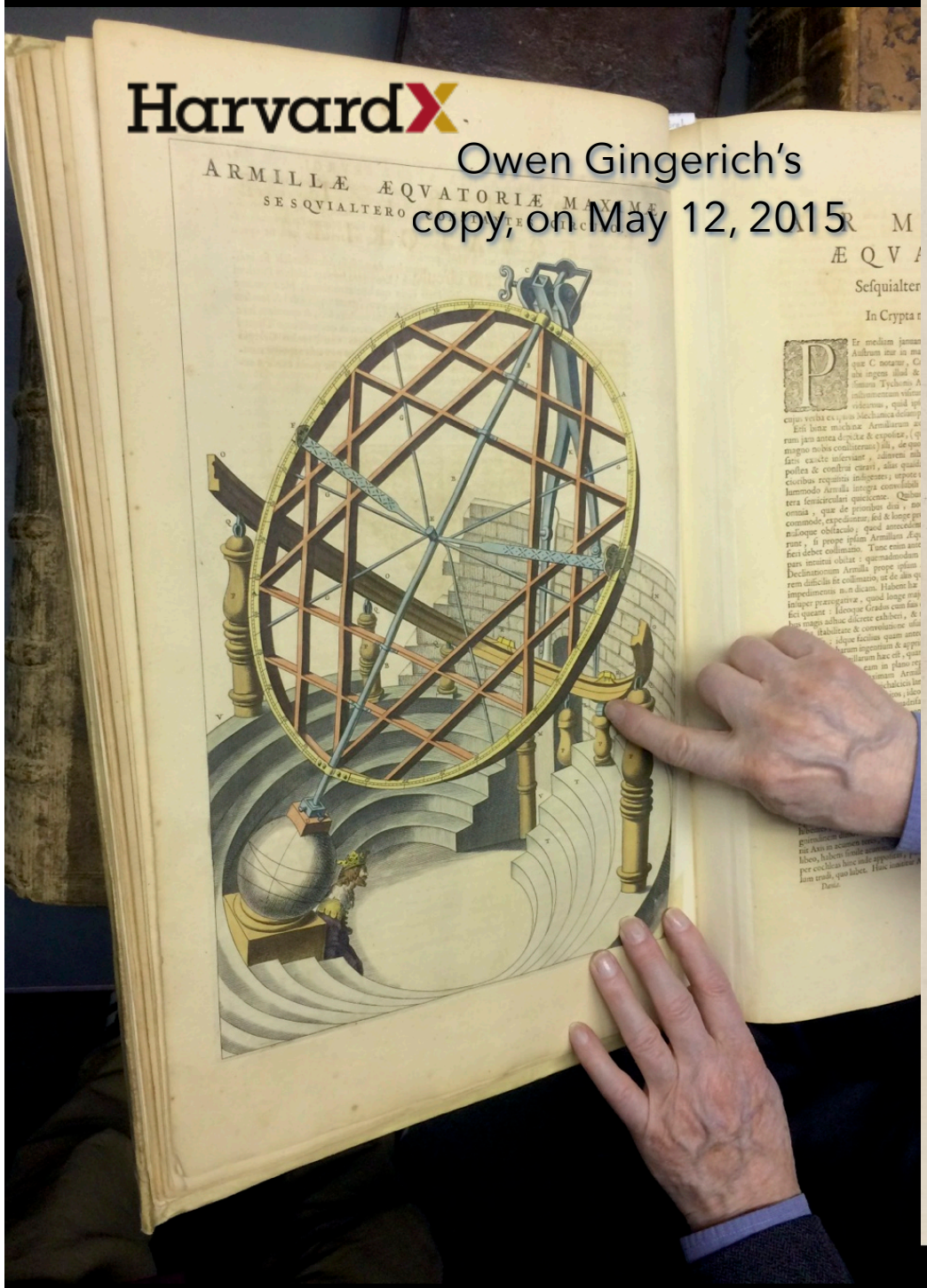
1750

2000

now

HarvardX

Owen Gingerich's copy, on May 12, 2015



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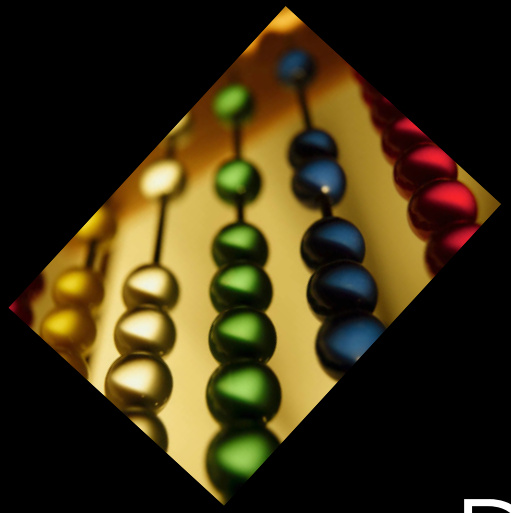
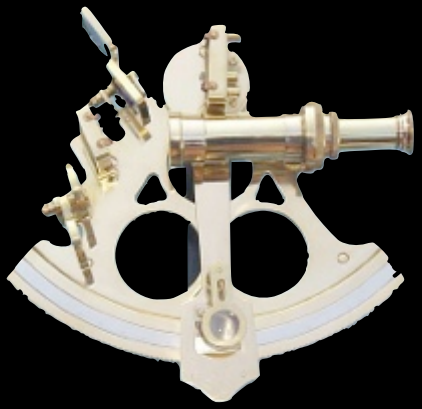
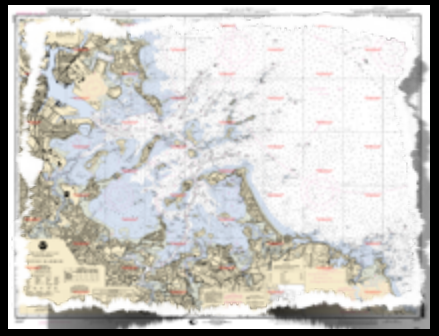
www.geheugenvannederland.nl/?/en/items/NESA01xxCOLONxxL01-0370





Dead Reckoning



“Once they were out of sight of land…”

from: The Clock That Changed the World (BBC History of the World)

presenter: Adam Hart-Davis; https://www.youtube.com/watch?v=T-g27KS0yiY

Latitude is “Easy”...

Earth, Sun and Stars

The Earth **spins** on its axis, once per ~24 hours.

Earth's **spin** causes distant stars to appear to go in **circular paths** (as if painted on to a very distant sphere).

Earth's spin axis is **tilted** by 23 degrees from the plane of its orbit.

Because of the tilt, the rise, **transit**, and set times for a star whose path dips below the horizon **depends** on where the Earth is in its orbit (**on date**).

The value of the maximum **altitude** (at transit) any star reaches on a particular day **depends on latitude**. (+Altitude of North Star=Latitude.)

A star will reach **its maximum altitude ("transit")**, at the *same* (local) time on any given day, as viewed from any place with equal latitude.

Earth, Sun and Stars

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best_clock.wtt

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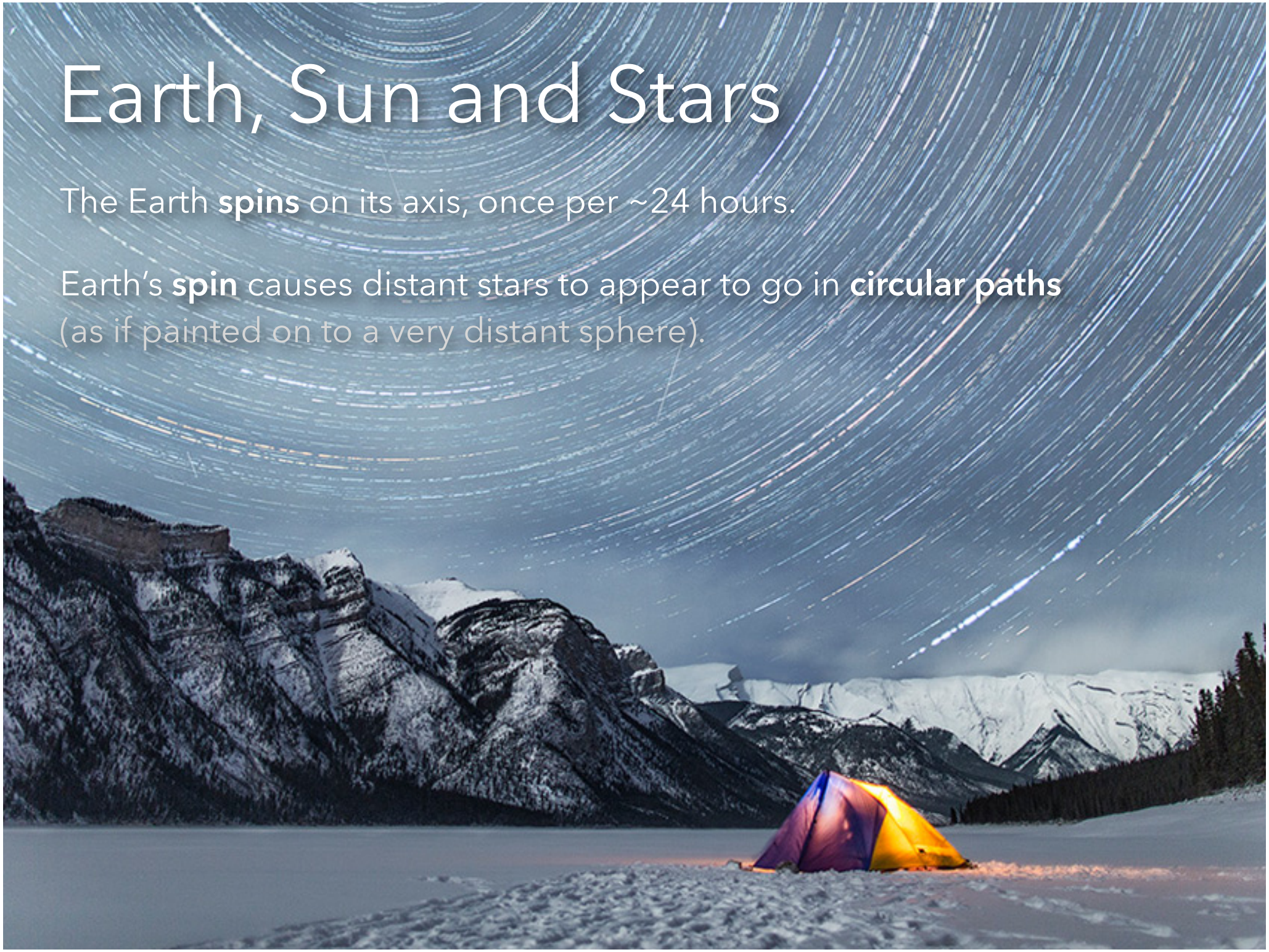

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Lat_Long_HMNH3.wtt

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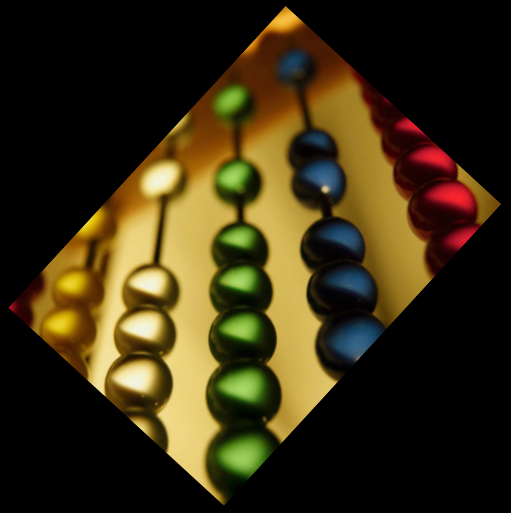
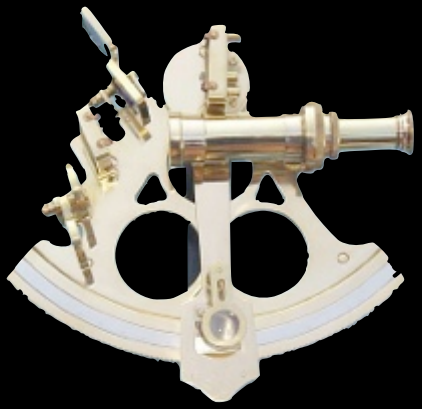
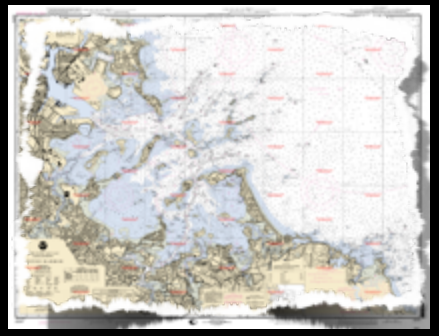
[demo]





"Sail the Parallel"



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Earth, Sun and Stars

The value of the maximum **altitude** (at transit) any star reaches on a particular day **depends on latitude**. (+Altitude of North Star=Latitude.)

Great! We can easily use the stars to find latitude.

A star will reach **its maximum altitude ("transit")**, at the *same* (local) time on any given day, as viewed from any place with equal latitude.

Drat! We can only use the stars to find longitude if we know the time, very well.

Uncertainty→Tragedy

Accuracy of Maps

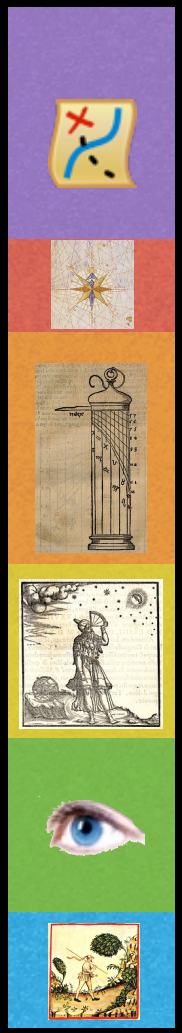
Direction Measurement

Time Measurement

Angular Measurement

Astronomical Measurement

Measuring Speed



1200

1675

1750

2000

now

The Longitude Act

from: The Clock That Changed the World (BBC History of the World)

presenter: Adam Hart-Davis; https://www.youtube.com/watch?v=T-g27KS0yiY

Measuring Astronomical Objects' Positions

Cross Staff 1432

Quadrant 240 BC

Astrolabe 1500

Backstaff 1594

Videos Copyright 1992, The Mariners' Museum. Featuring Captain Eric A. Speth, maritime program manager, of the Jamestown-Yorktown Foundation.

Finding Longitude

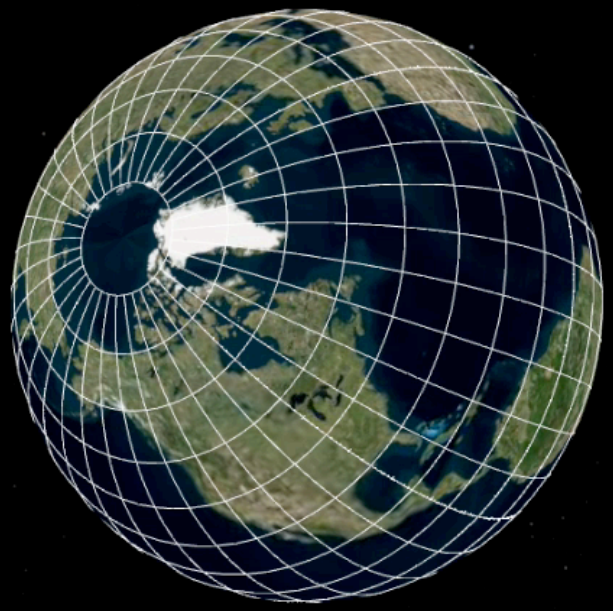
...use the stars to find longitude if we know the time, very well...

Hard

Crazy

Simple

Time-based navigation relies on known speed...
of Earth's rotation.



scene from “The Longitude”, reproduced from YouTube, without permission
https://www.youtube.com/watch?v=XUhhdwvLuyk

scene from “The Longitude”, reproduced from YouTube, without permission
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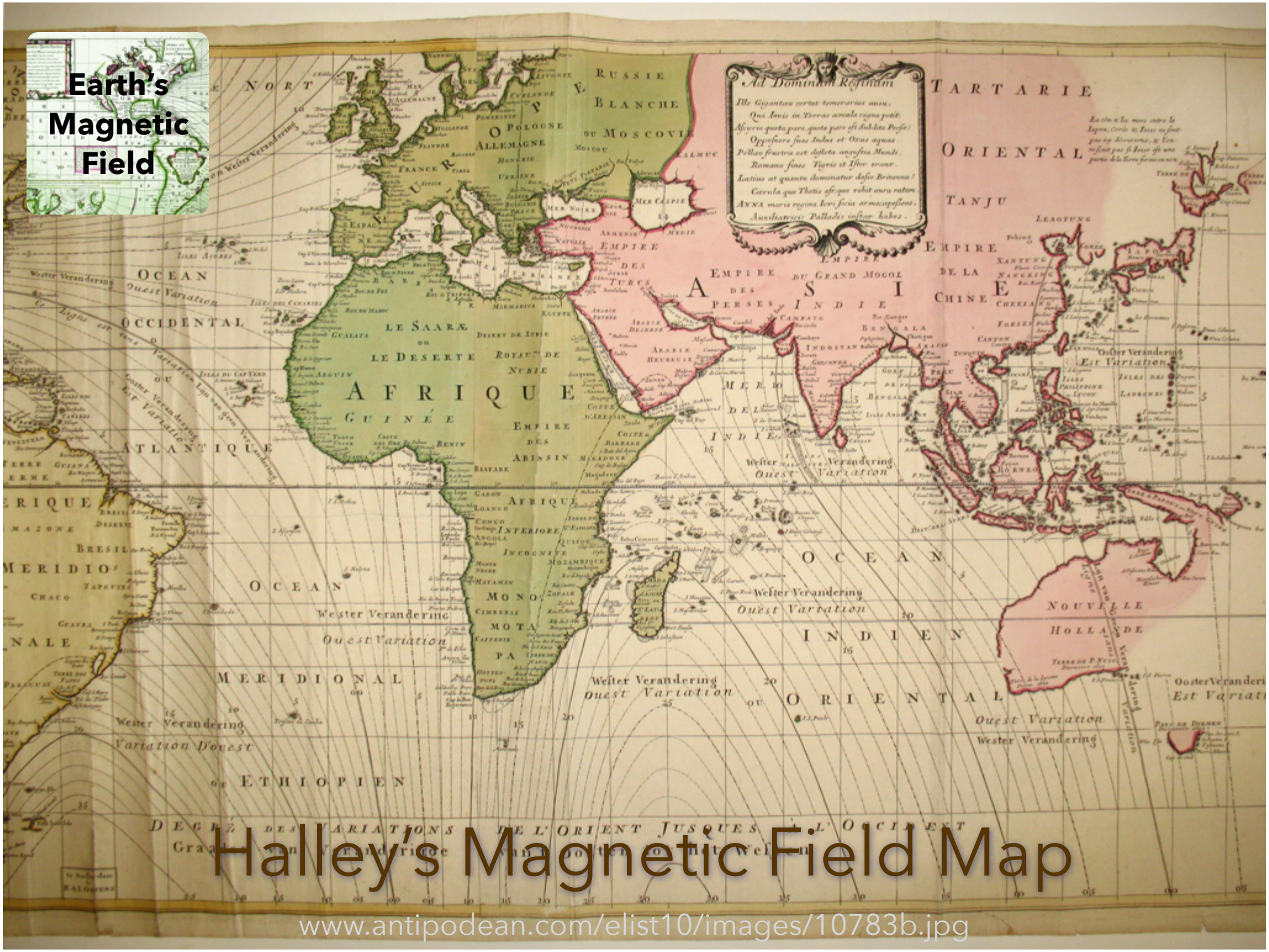
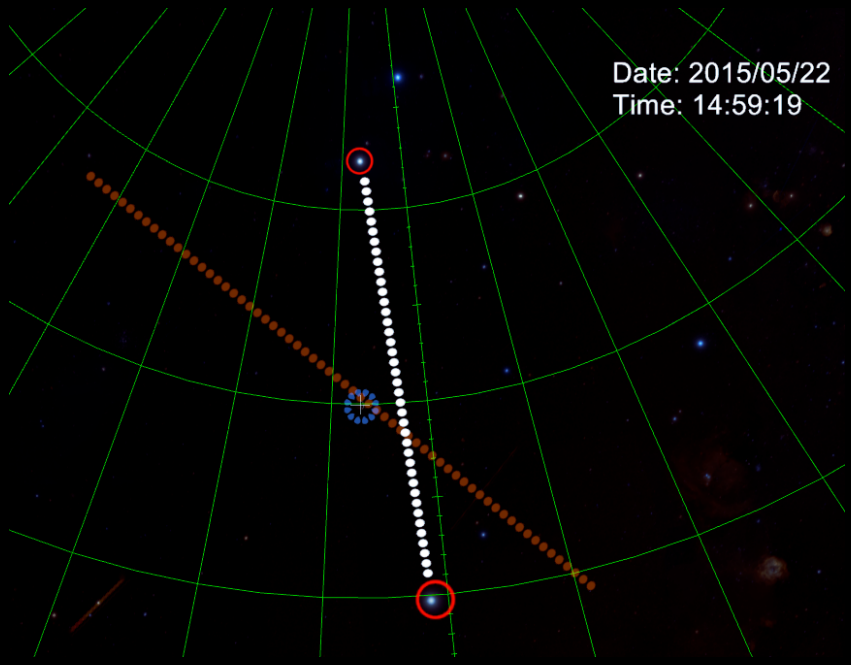

Earth's Magnetic Field
Halley's Magnetic Field Map
www.antipodean.com/elist10/images/10783b.jpg

The "Lunar Distance Method"

To find time: Calculate the exact path of the moon, as a function of time, read off position, calculate time.

Complications: Relies on VERY accurate records, predictions, measurements and calculations.



moon_star_motions.wtt

lunars_hard.wtt

Galileo & Jupiter's Moons

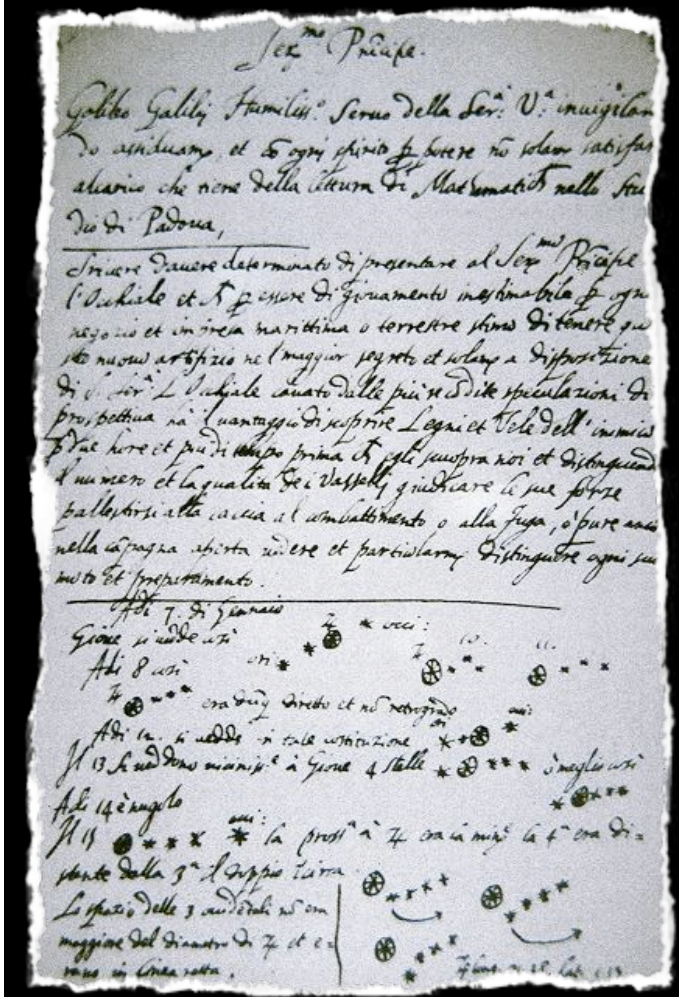
To find time: Calculate the positions of Jupiter's moons as a function of time. Observe moons, know time.

Complications: Relies on high-resolution observations, requiring a very stable observing platform (not a ship!!)

Galilleo.wtt

Galileo Galilei

(1564-1642)

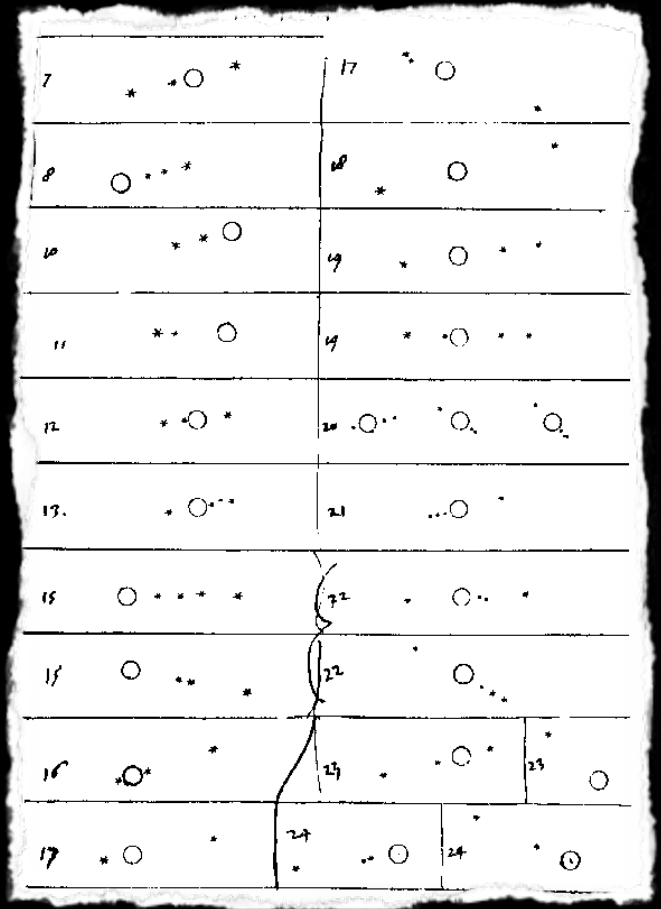


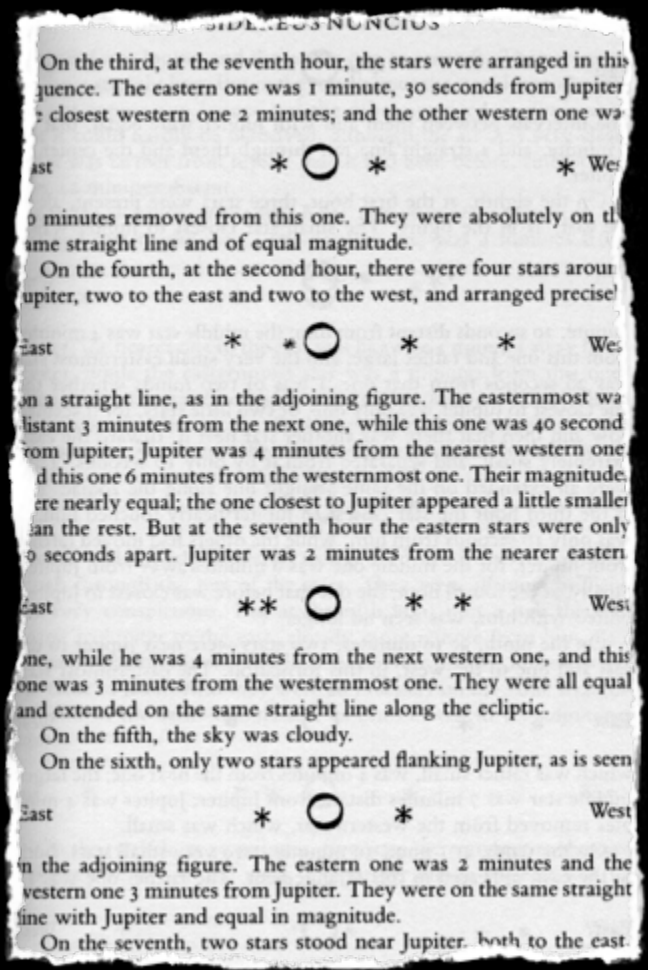
Sec^mo Prencipe.

Galileo Galilej Humilis^o Servo della Ser^a V. A. inviglian
do assiduamente, et da ogni spirito procurare non solam satisfa
altrui che viene della Lettura di Mathematica nello stu
dio di Padova,

Stimerei d'havere determinato di presentare al Sec^mo Prencipe
l'Archimede et A^o essere di giovamento inestimabile a ogni
negotio et impresa marittima o terrestre stimo di tenere qu
sto mio novo artificio nel maggior segreto et solum a dispositione
di V. A. S^r. L'Archimede cavato dalle più astruse et alte speculazioni di
prospettiva hà guadagnato di scrivere Leggi et Regole dell'inventio
d'hore et più di tempo prima di quello sempre noi et distinguendo
il numero et la qualità de i Vasselli giudicare le sue forze
ballestrarsi alla caccia al combattimento o alla fuga, o pure esa
nella campagna aperta vedere et particolarm^te distinguere ogni sen
sato et proportionatamente.

Adi 7. di Genaro
Giove si vedde così
Adi 8 così
era due verso Ponente et assai vicini fra di loro
Adi 10. si vedde in tale costituzione
Il 13 fu cattivo tempo
Adi 14 è seguito
la prossima à 24 ore in circa più la 4^a ora di-
stante della 3^a il doppio meno
Le stelle delle 3 ultime notte non
maggiore del diametro di 24 et e-
rano in linea retta.





SIDEREUS NUNCIUS

On the third, at the seventh hour, the stars were arranged in this
quence. The eastern one was 1 minute, 30 seconds from Jupiter
closest western one 2 minutes; and the other western one wa

East * ○ * * West

0 minutes removed from this one. They were absolutely on th
ame straight line and of equal magnitude.

On the fourth, at the second hour, there were four stars arou
upiter, two to the east and two to the west, and arranged precisel

East * * ○ * * West

on a straight line, as in the adjoining figure. The easternmost wa
listant 3 minutes from the next one, while this one was 40 second
rom Jupiter; Jupiter was 4 minutes from the nearest western one
d this one 6 minutes from the westernmost one. Their magnitude
ere nearly equal; the one closest to Jupiter appeared a little smaller
an the rest. But at the seventh hour the eastern stars were only
0 seconds apart. Jupiter was 2 minutes from the nearer eastern

East ** ○ * * West

ne, while he was 4 minutes from the next western one, and this
one was 3 minutes from the westernmost one. They were all equal
and extended on the same straight line along the ecliptic.

On the fifth, the sky was cloudy.

On the sixth, only two stars appeared flanking Jupiter, as is seen

East * ○ * West

n the adjoining figure. The eastern one was 2 minutes and the
western one 3 minutes from Jupiter. They were on the same straight
line with Jupiter and equal in magnitude.

On the seventh, two stars stood near Jupiter, both to the east

Notes for & re-productions of Siderius Nuncius

Galileo & Jupiter's Moons

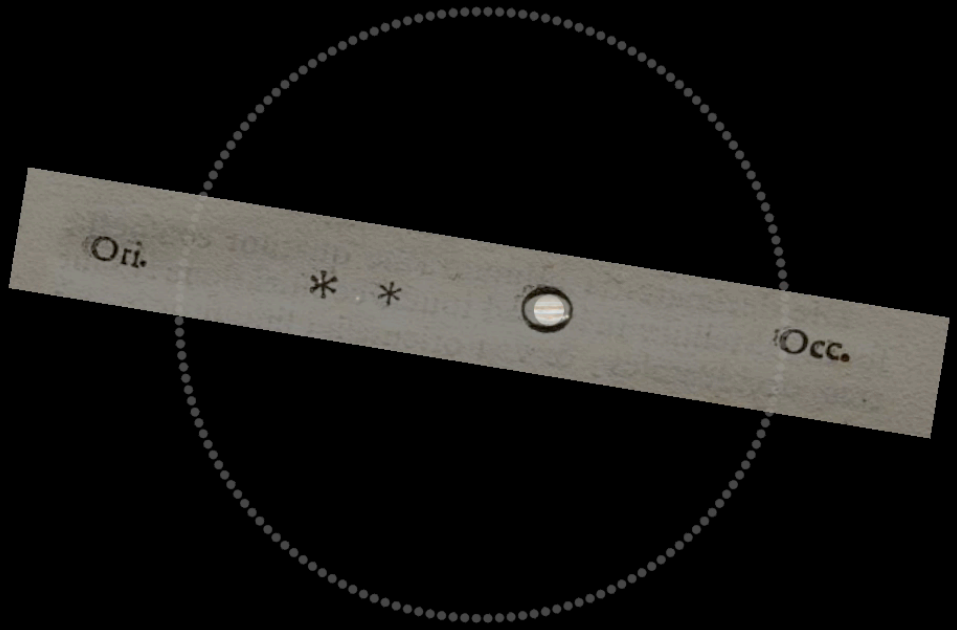
GALILEO'S "NEW ORDER"

Created by Alyssa Goodman, Curtis Wong and Pat Udomprasert,
with advice from Owen Gingerich and David Malin

Galileo's New Order, A WorldWide Telescope Tour by Goodman, Wong & Udomprasert 2010
Microsoft Research WWT Software (~now "OpenWWT"): Wong (inventor), Fay (architect), et al.

Galileo & Jupiter's Moons

January 11, 1610



Galileo's New Order, A WorldWide Telescope Tour by Goodman, Wong & Udomprasert 2010
Microsoft Research WWT Software (~now "OpenWWT"): Wong (inventor), Fay (architect), et al.

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...use the stars to find longitude if we know the time, very well...

Hard

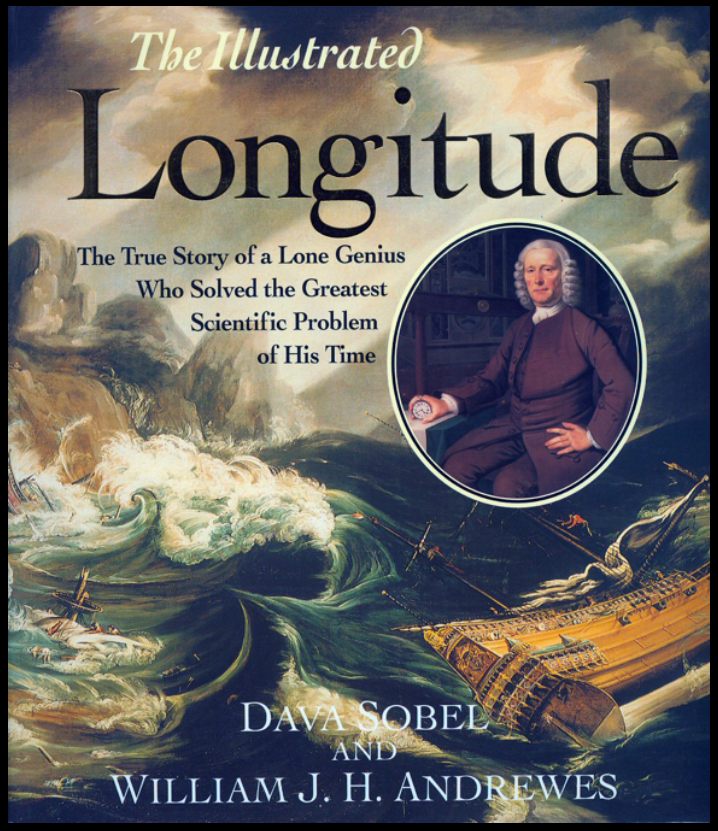
Crazy

Simple

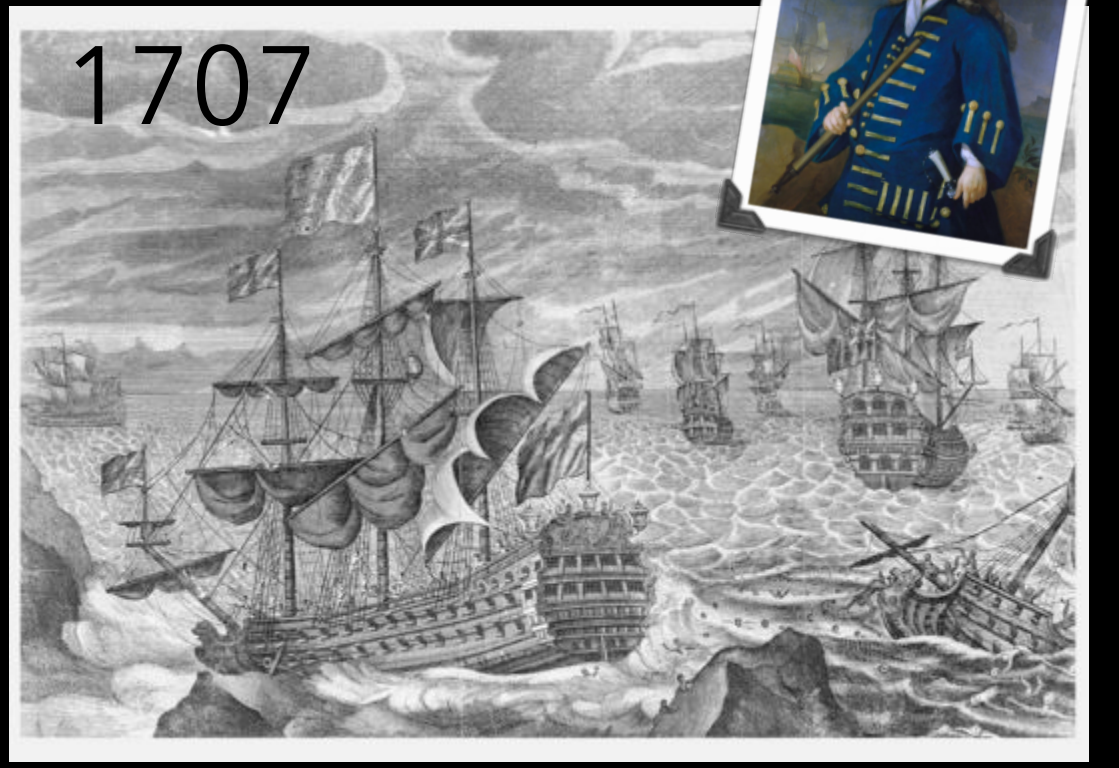
“do it with a clock...”

from: The Clock That Changed the World (BBC History of the World)

presenter: Adam Hart-Davis; https://www.youtube.com/watch?v=T-g27KS0yiY


The Illustrated
Longitude
The True Story of a Lone Genius
Who Solved the Greatest
Scientific Problem
of His Time
DAVA SOBEL
AND
WILLIAM J. H. ANDREWES

"H4"


1707

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Tresco
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Hugh Town
Google
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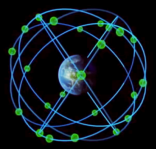
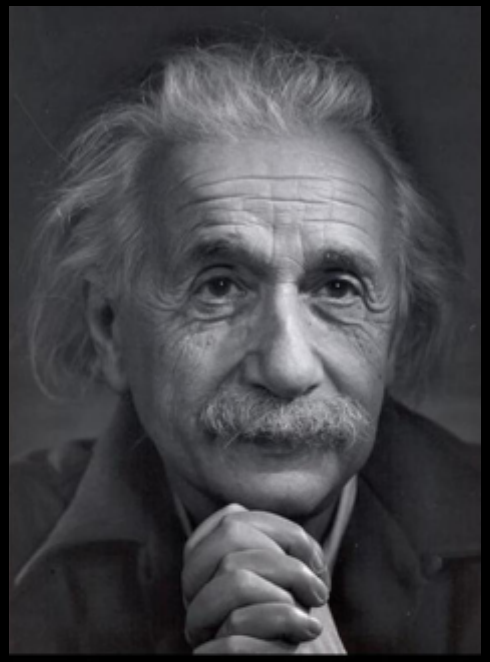
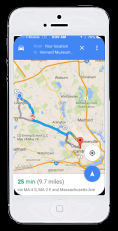
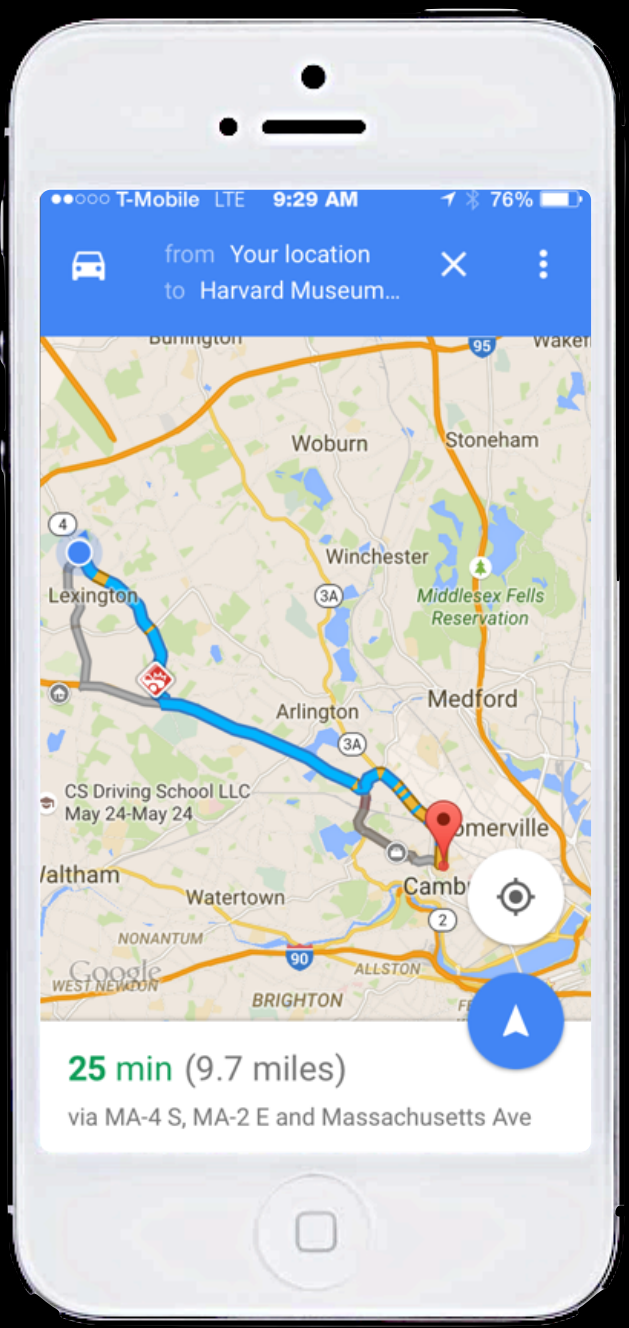
Isles of Scilly, United Kingdom
Route





Einstein (, Jobs) & GPS

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Stoneham
Winchester
Lexington
Middlesex Fells Reservation
Arlington
Medford
CS Driving School LLC
May 24-May 24
Watertown
NONANTUM
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ALLSTON
Google
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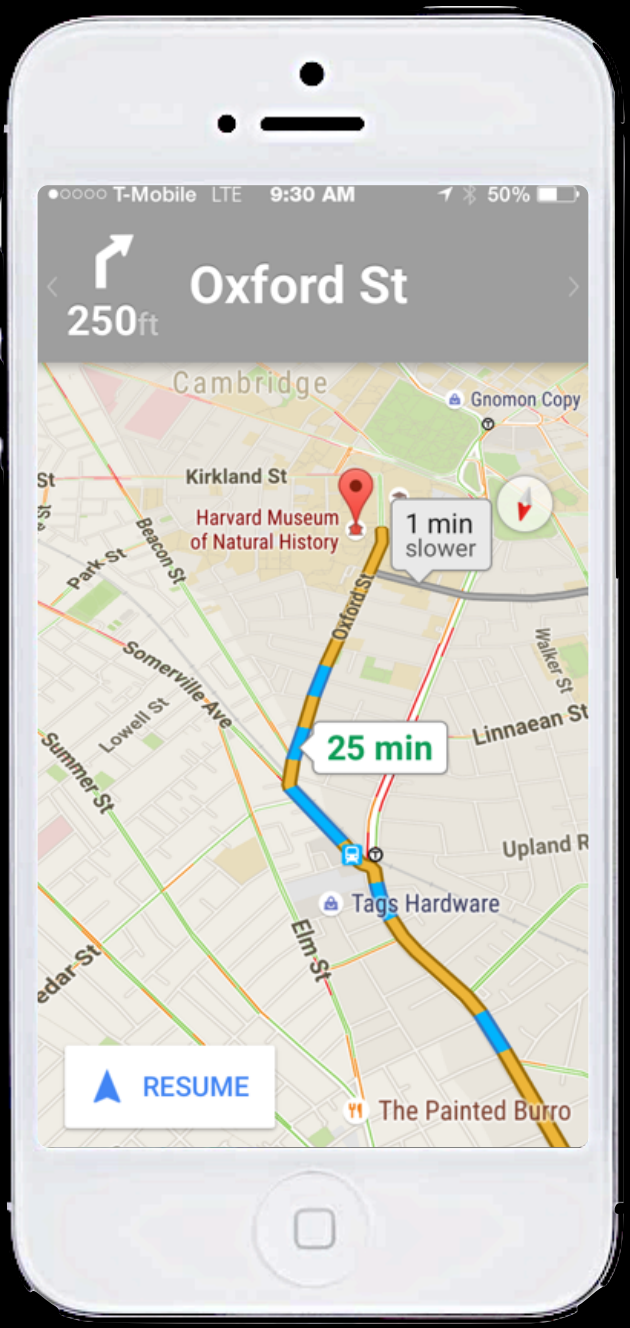
via MA-4 S, MA-2 E and Massachusetts Ave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1 min slower
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Oxford St
Somerville Ave
Lowell St
Summer St
Walker St
Linnaean St
25 min
Upland R
Tags Hardware
Elm St
RESUME
The Painted Burro

https www.google.com/maps/@42.379869,-71.116497,3a,75y,174.8h,74.03t/data=!3m4!1e1!3m2!1sxVlcdAfENlEN12WgXoULZw!2e0!6m1!1e1 — Harvard Museum of Natural History - Google M...
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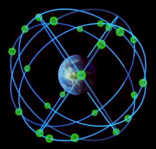
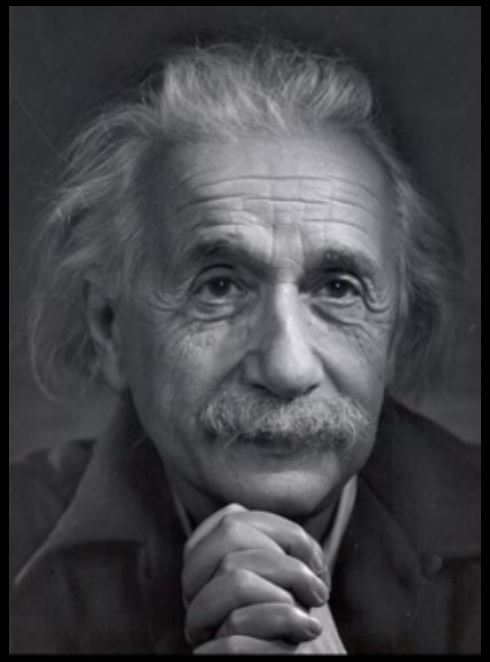
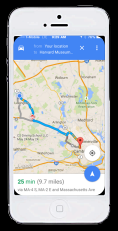
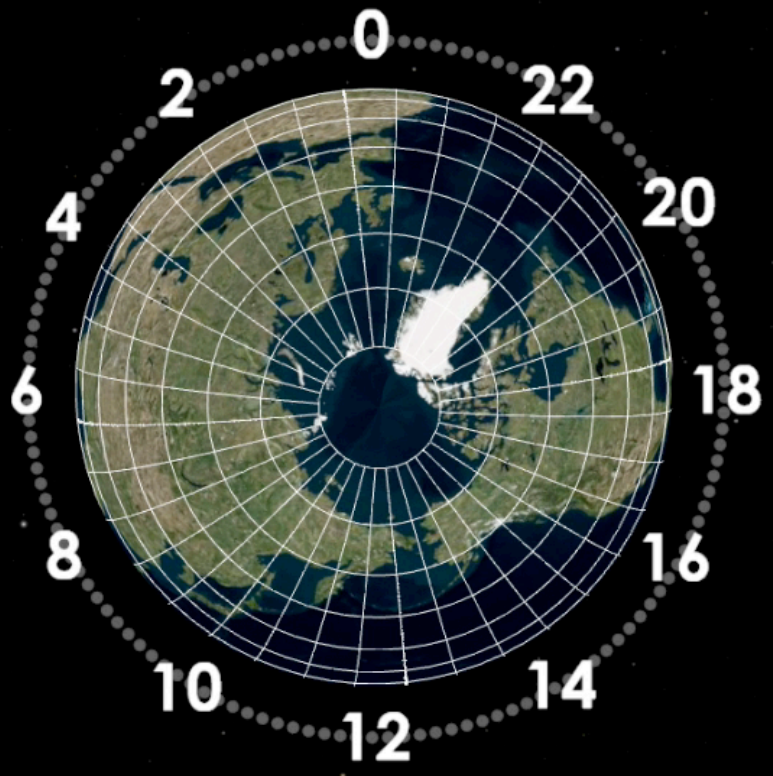




Einstein (, Jobs) & GPS

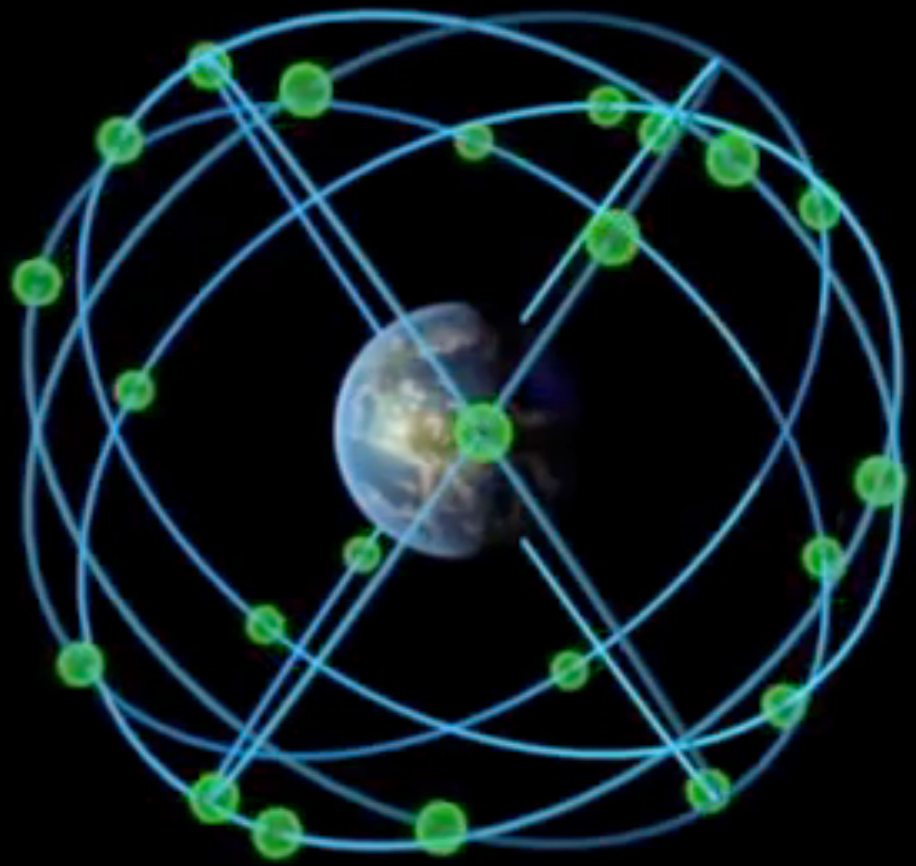


Time-based navigation relies on known speed...
of Earth's rotation.

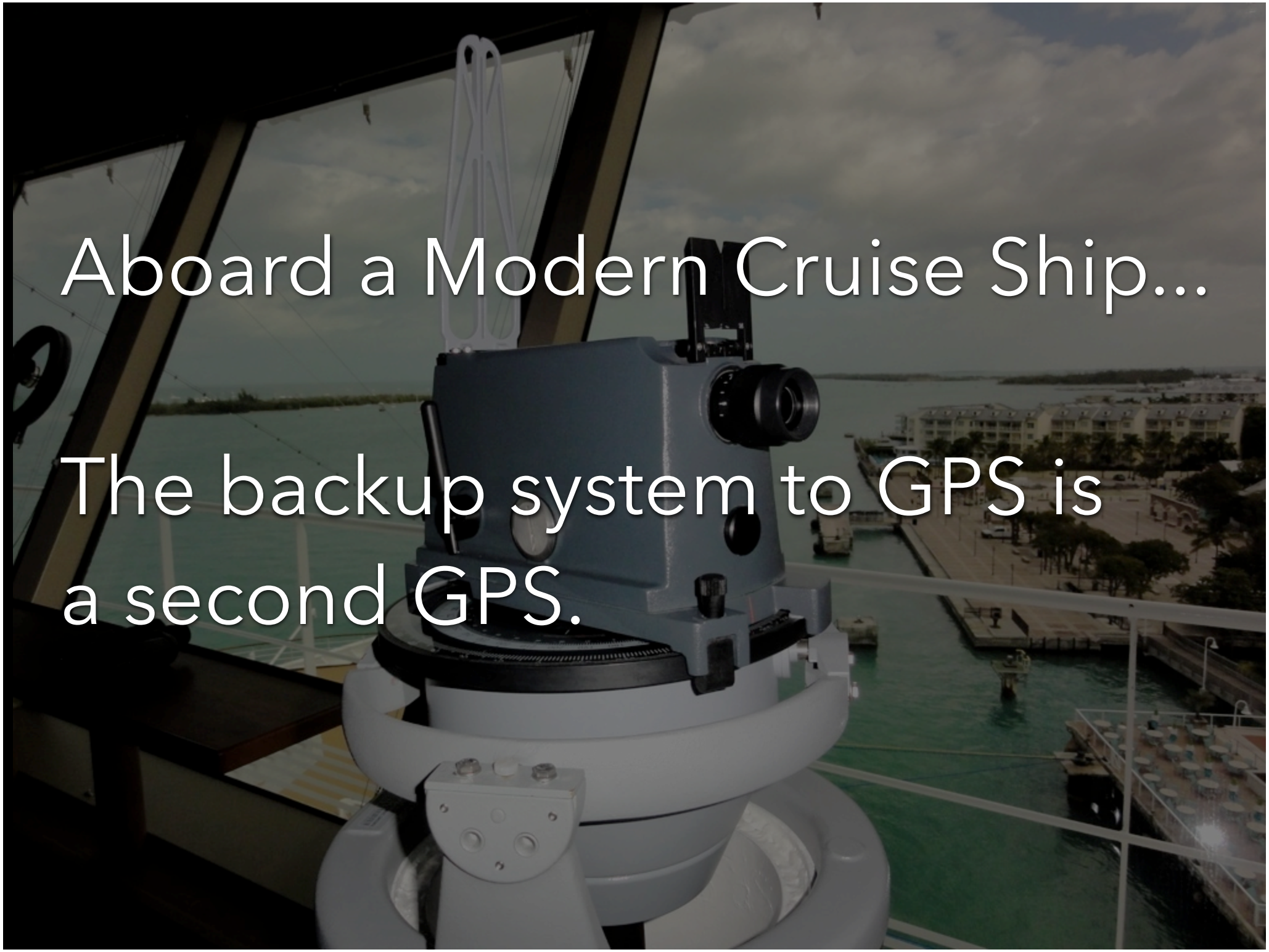


shown at 2 hours per second elapsed on-screen

GPS also relies on known speed...of light

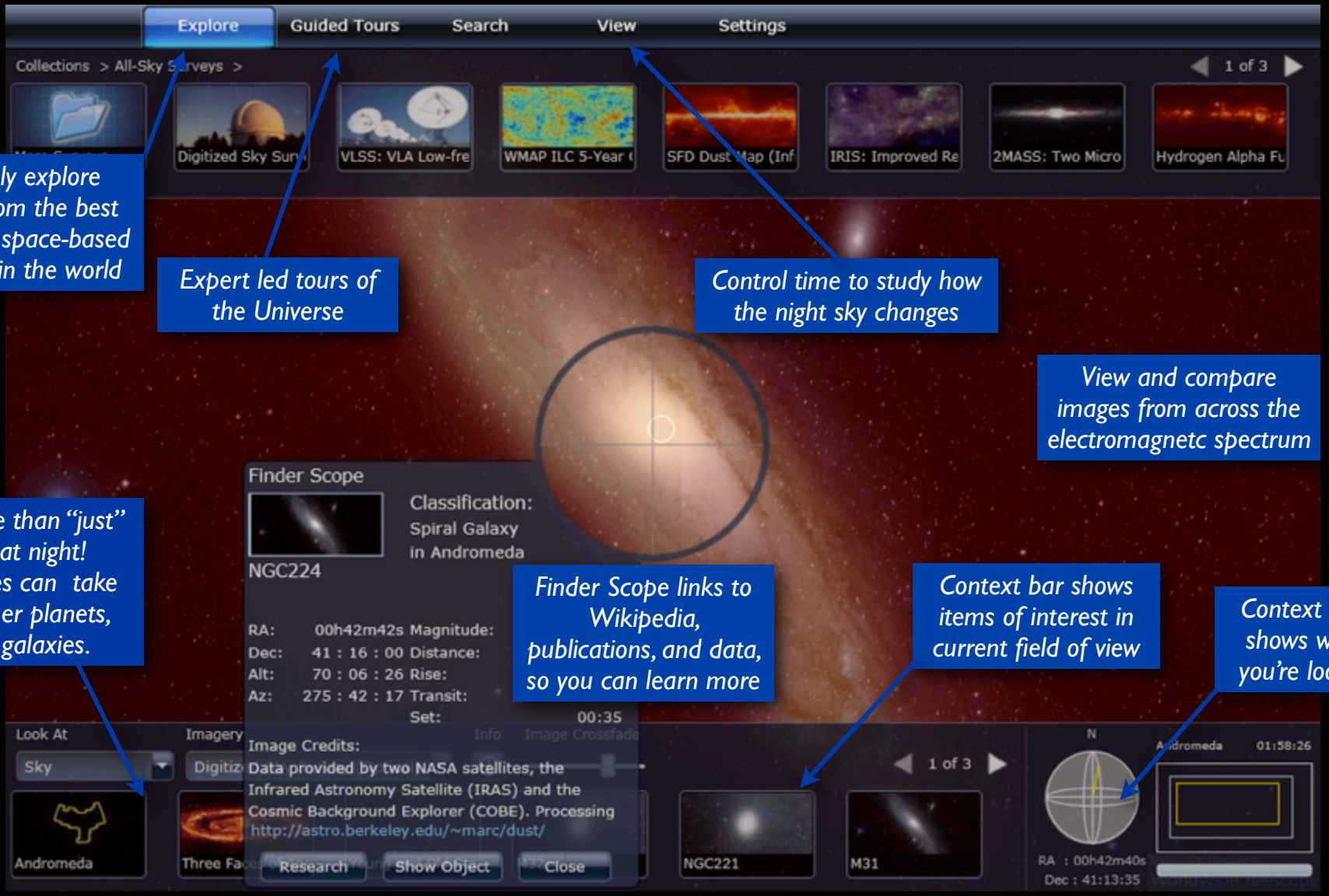


GPS & Relativity, by the Perimeter Insitute: https://www.youtube.com/watch?v=zQdIjwoi-u4


Aboard a Modern Cruise Ship...
The backup system to GPS is a second GPS.

Open WorldWide Telescope

worldwidetelescope.org



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Finder Scope links to Wikipedia, publications, and data, so you can learn more

Context bar shows items of interest in current field of view

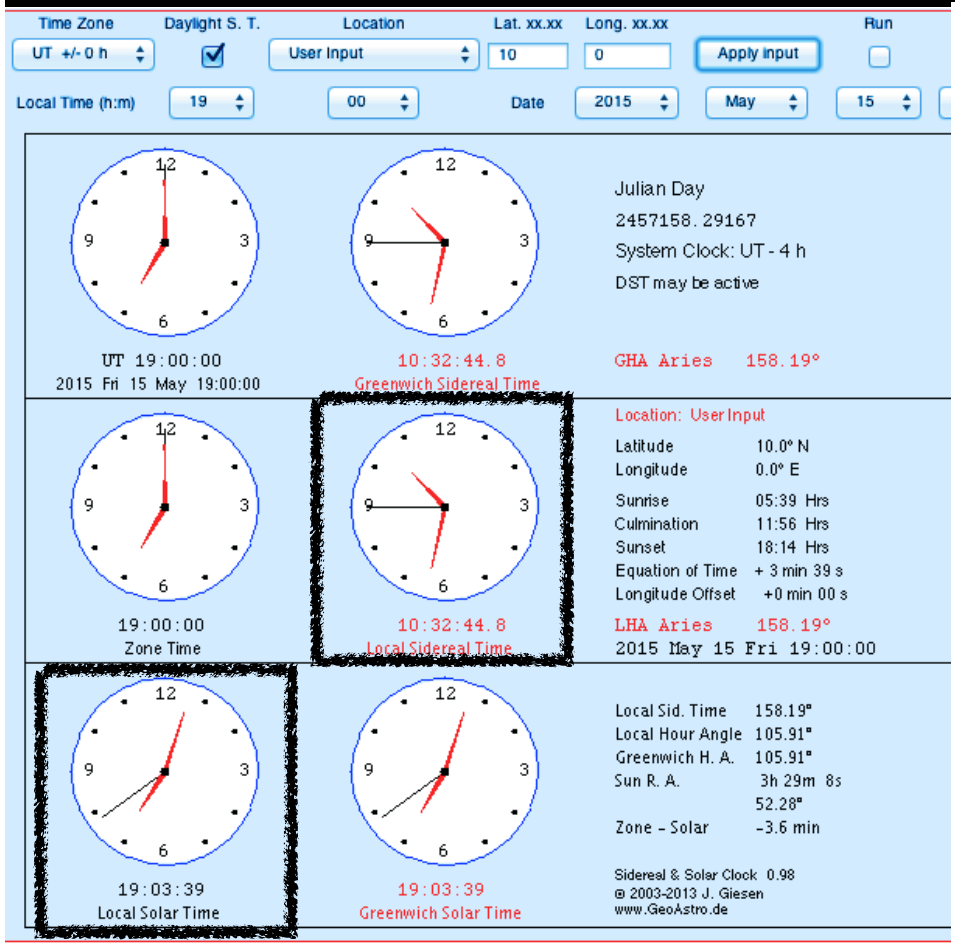
Context globe shows where you're looking.

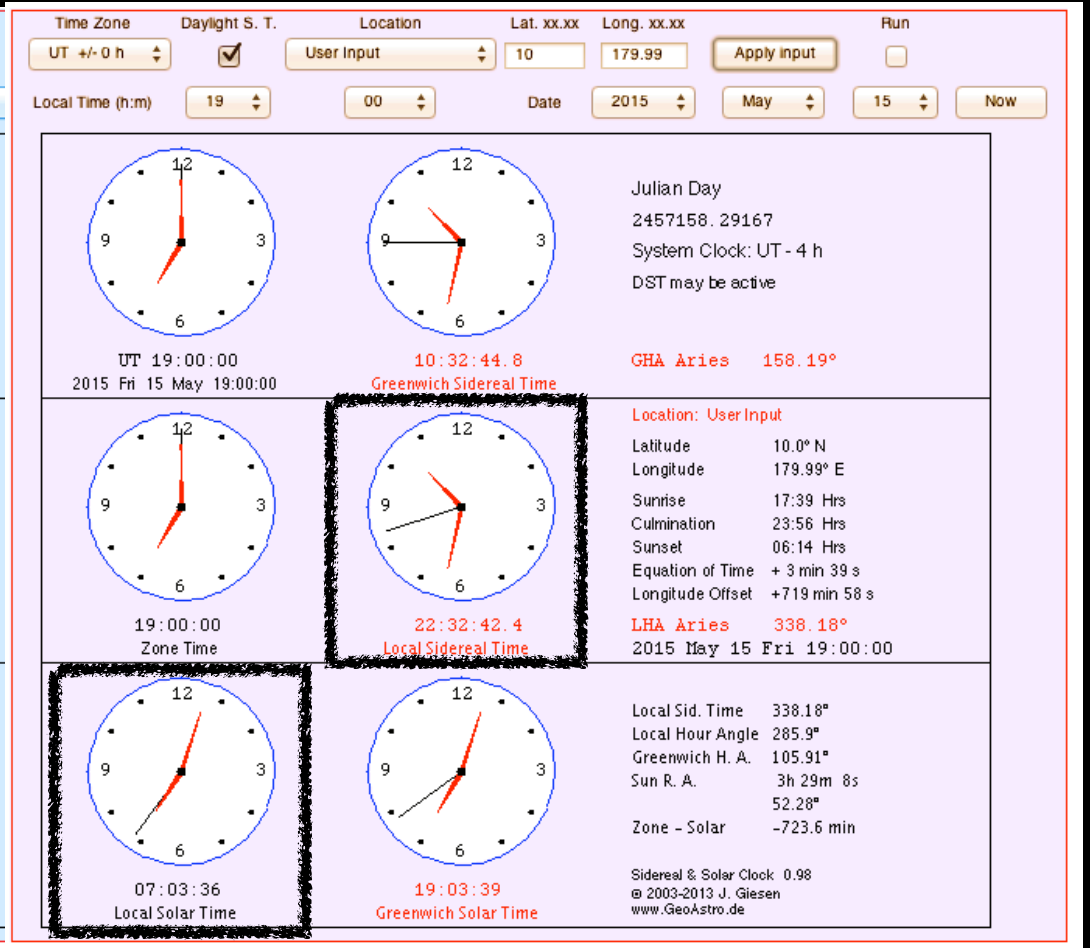
Lost without Longitude

Alyssa Goodman
Harvard-Smithsonian Center for Astrophysics
@aagie, #PredictionX

extra slides

solar-sidereal off by 2 min for 180 deg of longitude difference





Greenwich solar-sidereal= 8h 31m 54.2 s

local solar-sidereal=8 h 29 m 53.6s

Sidereal time is the **right ascension** of stars on your local meridian at any moment.

6
KR.
DANMARK