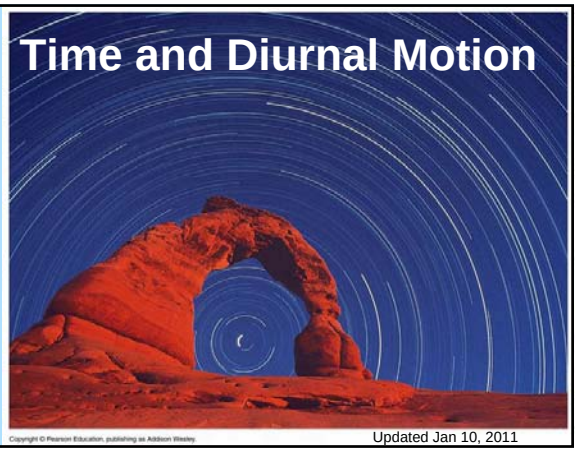
Time and Diurnal Motion



Updated Jan 10, 2011

Time and Diurnal Motion

A. Geography: mapping the earth

B. Equatorial Coordinates

C. Local Horizon System

A. Geography: mapping the earth

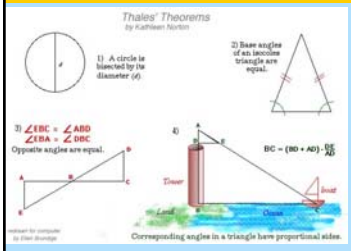
Geometry: measure the earth!

1) The earth is a ball

2) Geographic Coordinates

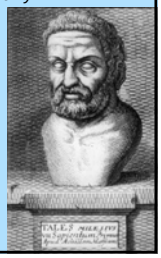
3) Definition of Time

1a. The Earth Is Flat



Thales of Miletos
(624-545BC)

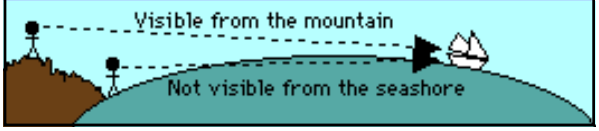
"the father of Greek science and astronomy"



the earth is a disk floating on the world ocean, surrounded by the rotating celestial sphere carrying the stars and other heavenly objects.

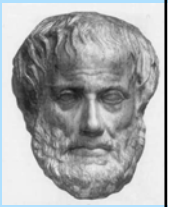
1b. The Earth Is Round

- **Pythagoras of Samos (569-475 BC)**
- *"the first pure mathematician"*
- **lunar eclipses imply shadow of earth is round**
- **Bottoms of ships vanish first as ship goes to sea**



1c. Aristotle (384-322 BC)

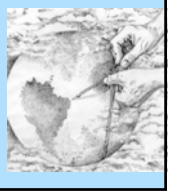
- **notes change in altitude of north star as travel south**
- **Estimates circumference of earth is 74,000 km**
  (true value is 40,000 km)



1d. Erastotenes (275-194 BC)

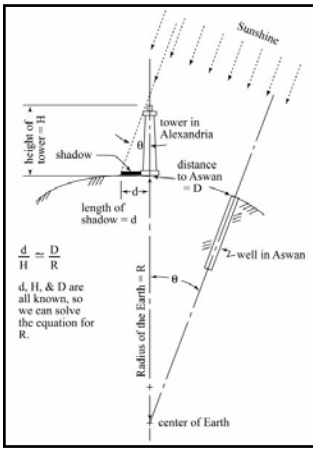
7

- **236 BC Director Library of Alexandria**
- **240 BC Was told that on midsummer day (June 21) in the town of Syene in southern Egypt (today Aswan, near a huge dam on the river Nile) the noontime Sun was reflected in a deep well, meaning that it was right overhead, at zenith.**
- **But at Alexandria, on same day it was NOT overhead!**



Erastotenes

8



In Alexandria sunlight was at angle of 7.2 degrees.

Hired soldier to march out distance between cities: 5040 Stadia

Calculates circumference is 250,000 stades

[within 1% true value]

2. Cartography

9

in Greek chartis = map and graphein = write

a) Anaximander (611-547 BC)

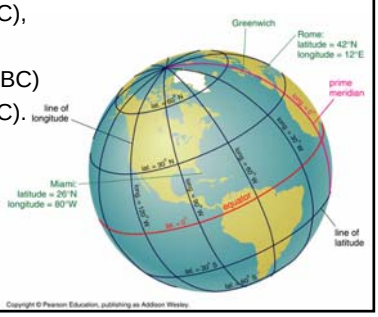
- **Pupil of Thales**
- **First map maker**
- **Invented Longitude & Latitude**
- **Earth is a stone cylindrical column, we live on the top of it**

2b. Geographic Coordinates

10

Spherical coordinates probably first done by

- Pythagoras (470 BC),
- Aristotle (330 BC),
- Eratosthenes (240 BC)
- Hipparchus (120 BC).



2c. Latitude

11

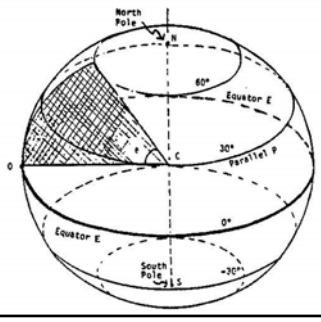
is measured up from equator

Hayward is 37°N40'08"

Equator is 0°

N pole is 90°

What is latitude Of South Pole?



2d. Longitude

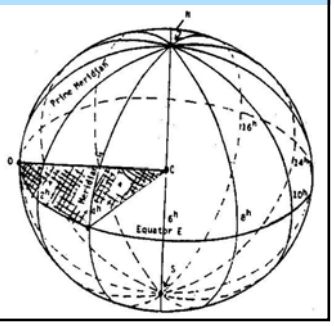
12

is measured westward from Greenwich, England

Hayward is 122°W04'51"

Greenwich is 0°

What is the longitude of the north pole?

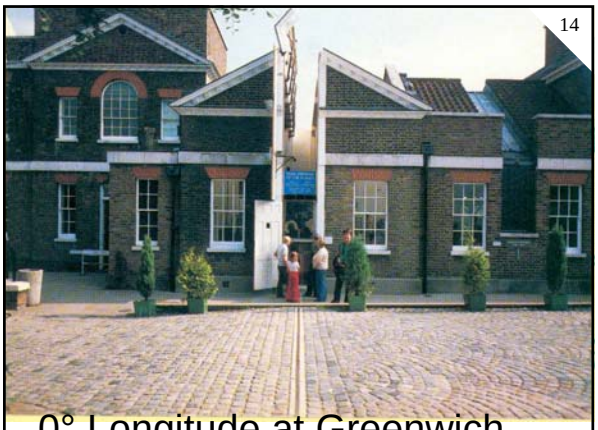


13

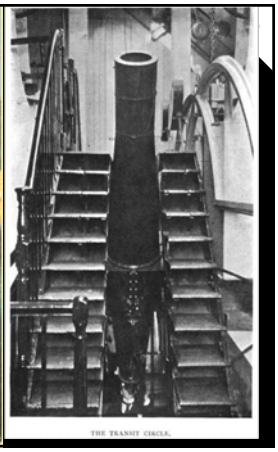
Greenwich Observatory England

(established 1675)

14

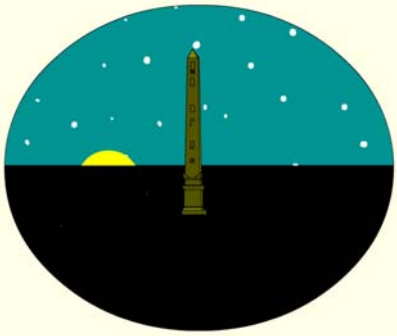


0° Longitude at Greenwich



3. Solar Time

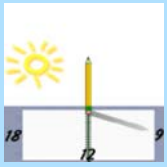
16



3. Sundial measures "Solar Time"

17

- Gnomon invented by Anaximander (611 – 547 BC). Shadow tells time of sun (first sundial)



3a) Sundials

18

- 340 BC Berosus Sundial Shaped like a bowel. The "longitude" line on the bowel tells how many hours before or after noon the sun is.

- The transit of the sun (when sun crosses local prime merdian) happens at NOON (12 hours) local time.

3b) UT: Universal Time

19

GMT: Greenwich mean time, the solar time at Greenwich Observatory

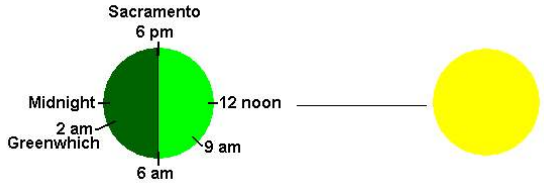
[nearly the same as UT: "Universal Time" and ET: "Ephemeris Time"]

3b) Time is Relative

20

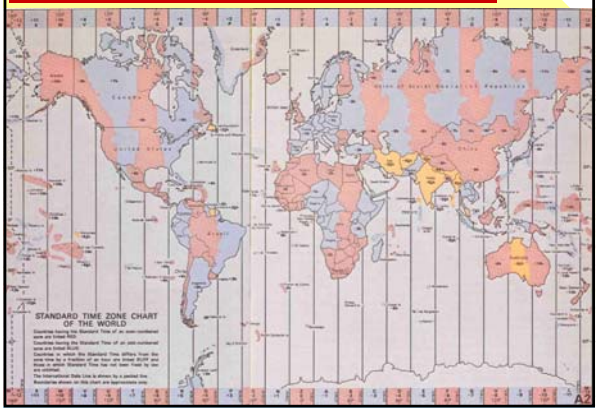
When its 6 pm here

- *What time is it in Boston?* **9 pm**
- *What time is it in Greenwich?* **2 am**
- *Definition of time depends upon your longitude*



3b) Time Zones are 15° (1 hr) wide

21



California is in Pacific Zone

22

- **Pacific Standard time: PST**
- **PST = GMT – 8 hours**
- **Pacific Daylight Time: PDT = PST+1**

Zone #	Name	Central Longitude	Symbol
5	Eastern	75	EST
6	Central	90	CST
7	Mountain	105	MST
8	Pacific	120	PST

3c. Local Mean Time

23

- **At Lake Tahoe (120 degrees longitude) sun transits on average at 12:00 noon PST.**
- **At Hayward, sun transits on average 12:08 PST. This is because we are 2 degrees longitude west of Lake Tahoe. It takes 8 minutes for the sun to travel from Lake Tahoe to here.**
- **Local Mean Time: LMT = PST – 8 minutes**
- **Sun Transits (on average) at 12:00 LMT**

3c. Longitude

24

Measure longitude in terms of time

- If 360° is equal to 24 hour
  - **15° is equal to 1 hour**
  - **1° is equal to 4 minutes**
  - **1' is equal to 4 seconds**
- Hayward's Longitude is hence
  - **8 hours, 8 minutes, 19.4 seconds**
  - **West of Greenwich, England**

3c) Relate Time & Longitude

25

- **LMT**: Local mean time or sundial time the time at our location
- **LMT=GMT - Longitude**
  - Hayward's Longitude is 8^h8^m
  - LMT =GMT – 8^h8^m
  - LMT = PST – 8^m

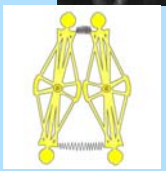
3d) Navigation

26

- To accurately determine longitude
- Measure Local Time (from stars)
- Compare with Greenwich time
- Need a good clock!
- Prize of 20,000 pounds!

John Harrison (1693-1776)

27



1730-1735 Maritime Clock

1737-1740 Maritime Clock #H2

28

In 1740 Harrison realized its design was wrong. The bar balances did not always counter the motion of a ship

1740-1759 Maritime Clock #H3

29

New design got rid of pendulums in favor torsion pendulum.

1. a bimetallic strip, to compensate the balance spring for the effects of changes in temperature
2. a caged roller bearing, the ultimate version of his anti-friction devices.

(1755-1759) Maritime Clock #H4

30

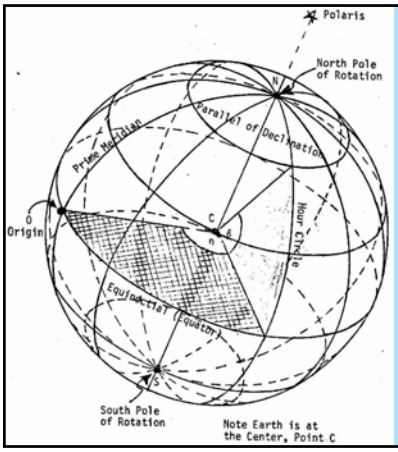
watch's error was computed to be 39.2 seconds over a voyage of 47 days, three times better than required to win the £20,000 longitude prize

5 inches in diameter

B1. Celestial Coordinates

31

- Anaximander (580 BC) invents idea of celestial sphere. (?)
- Eudoxus (360 BC) makes early map of constellations
- Hipparchus (130 BC) made a star catalog of 850 stars with some sort of coordinates
- Claudius **Ptolemy** (150 A.D.?): The first really accurate map, 48 constellations, 1025 stars with measured ecliptic longitude & latitude



32

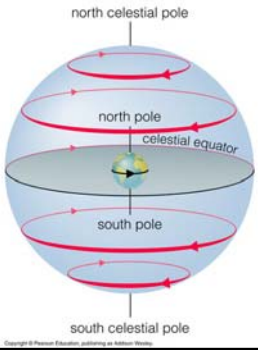
Celestial Latitude is "Declination"

Celestial Longitude is "Right Ascension"

Ascending Solar Node ("First Point of Aries") defines 0 RA

B2) Diurnal Motion

33



Earth Rotates on its axis every day

Celestial Sphere appears to rotate around celestial pole

Sky moves east to west

2) Diurnal Motion

34

You can mimic the moving sky with a starwheel

The rivet is the north pole

B3a). Star Time (sidereal)

35

The RA (right ascension) which is transiting (crossing the prime meridian) is "sidereal time"

Example:
At 6^h Sidereal time, Betelgeuse (Orion) is transiting

B3a). Sidereal vs Solar Time

36

- **Sundial (Solar) Time**
  tells the position of the sun
  (noon or 12:00 = transit)
- **Sidereal (Star) Time:**
  tells which stars are transiting
- Example, January 5th at 3 am, the sidereal time is 10 hours (i.e. the star Regulus with RA=10 hours, is transiting)

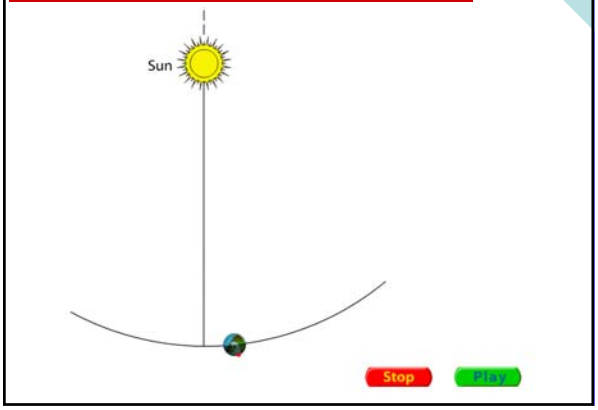
B3b. Sidereal Period

37

- **Solar day: 24 hours**
  time between transits of sun
- **Sidereal day: 23 hours 56 min**
  time between transits of a star
- **This means a star will transit**
  - 4 minutes earlier each day
  - 2 hours earlier each month

B3b. Sidereal Period (animation)

38



B3c). Acceleration of Sidereal Clock

39

Your starwheel converts solar time (plus date) to sidereal time!

LST: Local Sidereal Time

- **LST=LMT at fall equinox**
- **LST= LMT + "acceleration"**
  - Acceleration increases 4 min per day
  - Or 2 hours per month

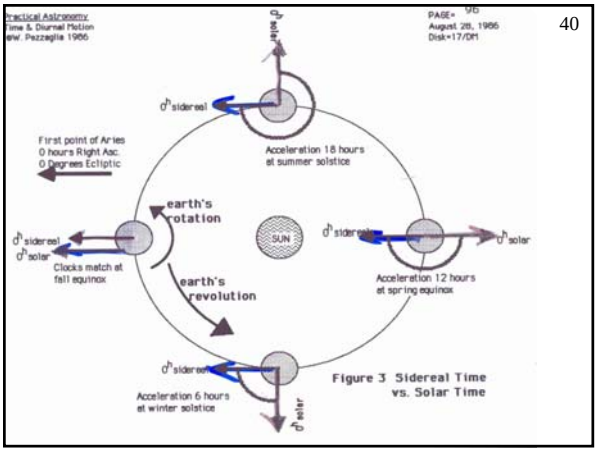


Figure 3 Sidereal Time vs. Solar Time

40

Acceleration of Sidereal Clock

41

- The amount by which the sidereal time is ahead of the solar time
- It's a function of date

DATE	Ecliptic Long. of Sun	Acceleration* of Sidereal Clock	DATE	Ecliptic Long. of Sun	Acceleration* of Sidereal Clock
Sept 21	180°	0h	Mar. 22	0°	12h
Oct. 21	210°	2h	Apr. 19	30°	14h
Nov. 21	240°	4h	May 21	60°	16h
Dec. 21	270°	6h	June 21	90°	18h
Jan. 21	300°	8h	July 21	120°	20h
Feb. 21	330°	10h	Aug. 22	150°	22h

*Equivalently the hour angle of the First Point of Aries at 0 hours local mean time.

C. Horizon Coordinates

42

1. Altitude and Azimuth

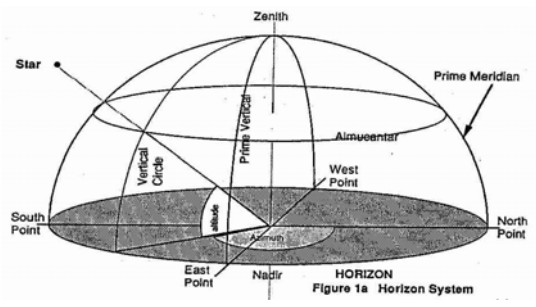


Figure 1a Horizon System

43

Your starwheel is a device for predicting the altitude and azimuth of stars, from the date and time

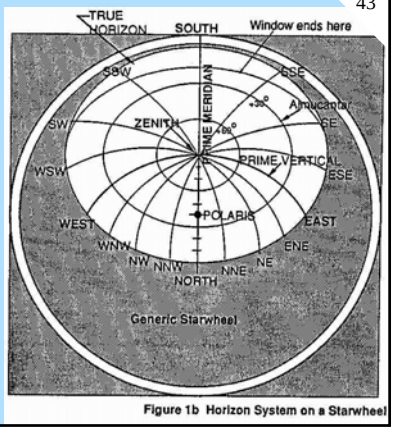


Figure 1b Horizon System on a Starwheel

44

Arabian Astronomers perfected the "Astrolabe", the ancestor of your starwheel (more properly called a "planisphere"

45

2. Relate Horizon to Equatorial

Declination of zenith is your latitude
Declination at North point is 90-Latitude (52°)
Declination at South point is Latitude-90 (-52°)

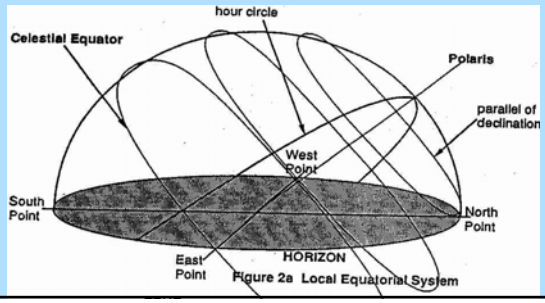
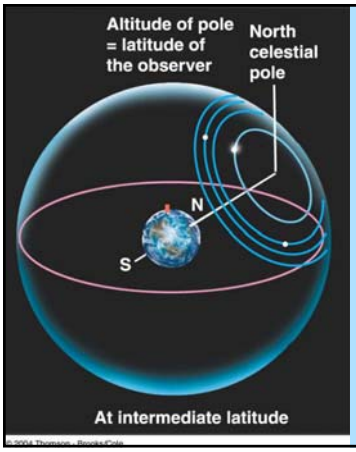


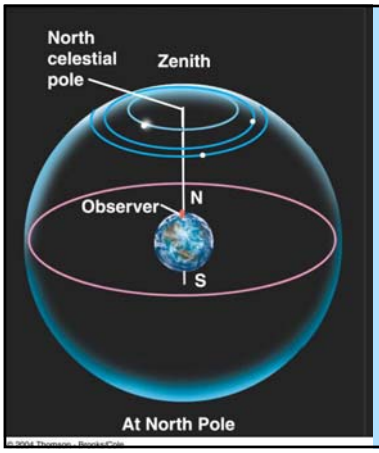
Figure 2a Local Equatorial System

46



Stars inside the "circle of perpetual occultation" are called "circumpolar", and never set!

47



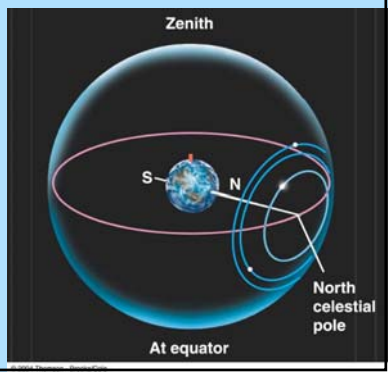
If you lived at the north pole, all stars would be circumpolar!

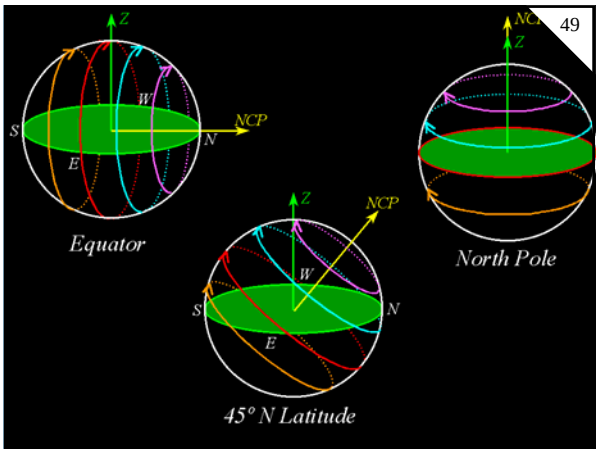
Polaris would be at zenith

48

If you lived at the equator, no stars would be circumpolar!

Polaris would be at horizon





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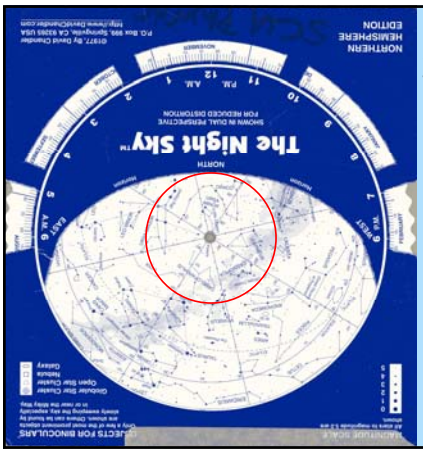


Starwheel shows what is visible

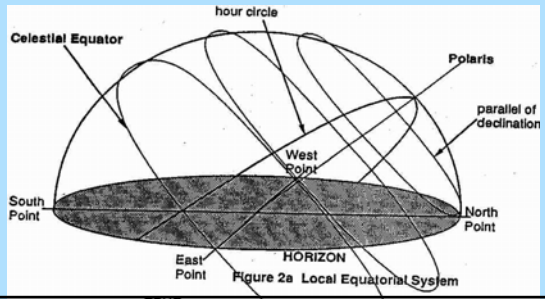
As you turn the wheel, some things never vanish!

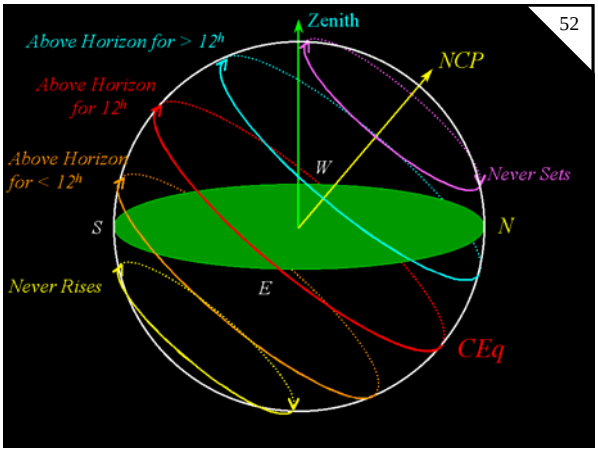
50

3. Path of a star

51

Will follow a parallel of declination
Transit altitude is 90° - | dec – lat |
Rising/setting points will be same each day!





52

References

53

- http://members.optusnet.com.au/~gtosiris/page11-9a.html
- Note: the size of a “stadia” was different for Aristotle than Erastotenes. See
- http://www.eso.org/public/outreach/eduoff/aol/market/collaboration/erathostenes/

Things to Do

54

- Make a movie out of the Wolfram map of sky, and use it in title sequence?