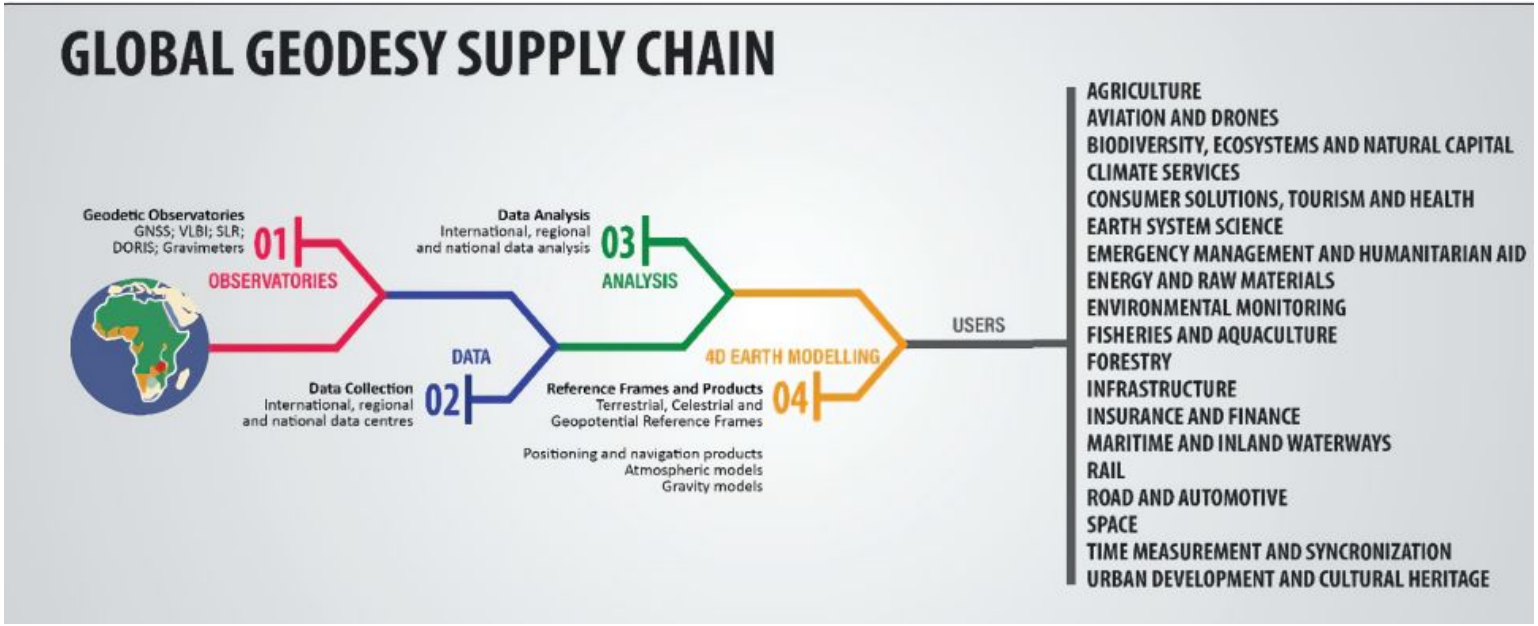
Space Geodesy

The history of and interactive sciences of Astronomy and Geodesy

Message from last time



Provides the TIME and POSITION products that nearly all aspects of modern society requires

The UN established the Global Geodetic Centre of Excellence in order to support the supply chain.

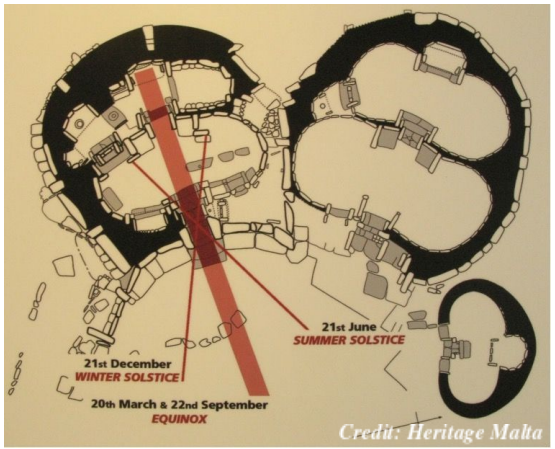
More information at: https://geodesy.science/

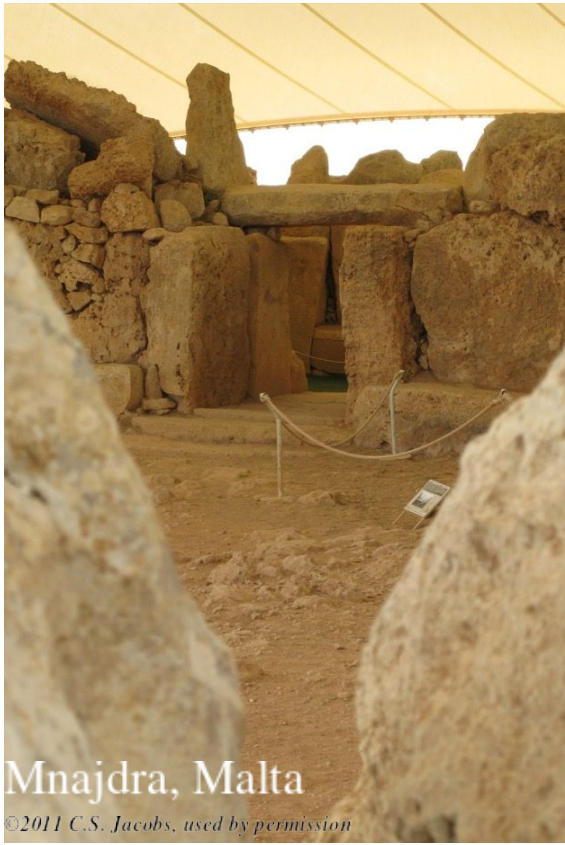
Astronomy goes back over 5000 years!

Island of Malta's monolithic temples

Some of the oldest known human structures aligned with celestial events.

At Equinoxes, the sunlight passes through the central doorway to light up a central stone - a clear sign of intentional astronomical alignment
→ Time of year / season





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Ancient Astronomers

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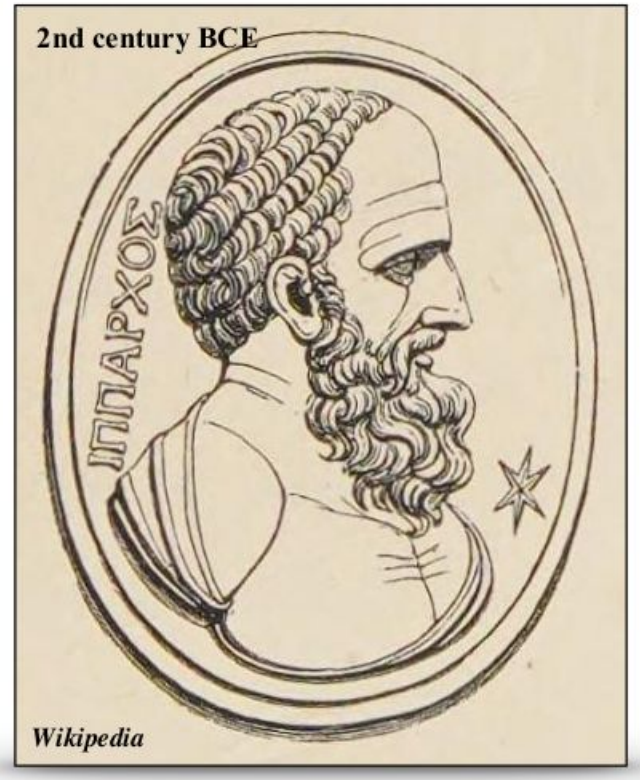


—Hipparchus—

Father of Scientific Astronomy

Created the first star catalog, discovered precession, invented idea of geographical coordinates, developed methods to convert between geographical and celestial coordinates

—Ptolemy—

Architect of Classical Astronomy

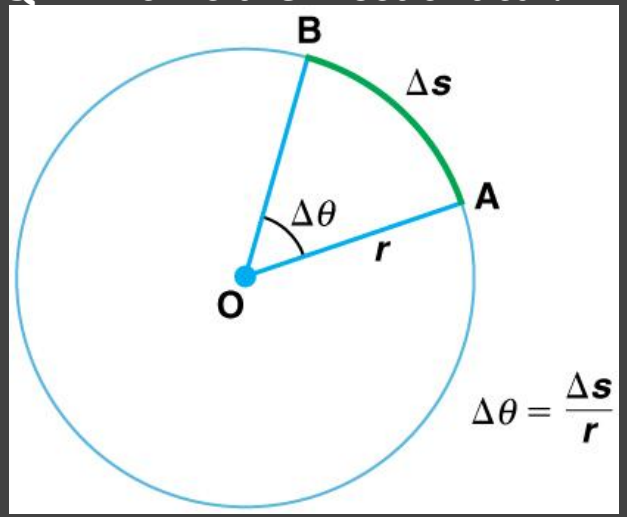
Geocentric model of the Universe, star catalog of positions and magnitudes of almost 1000 stars, applied and expanded the geographical coordinate system

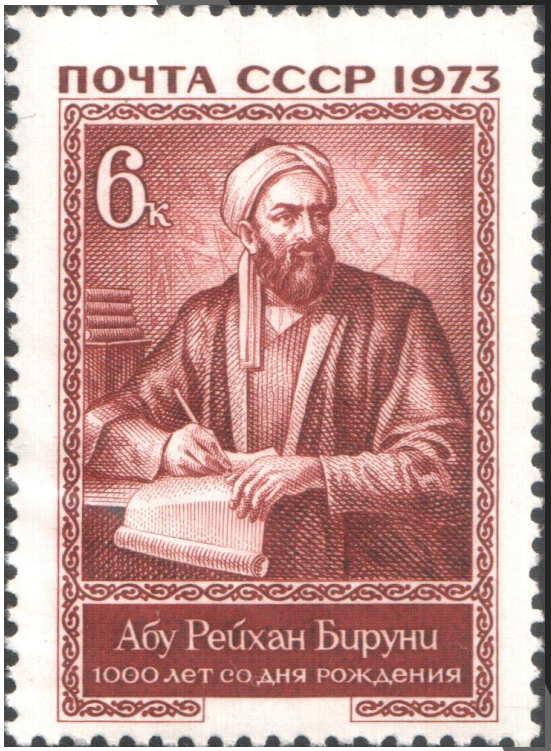
Astronomers need to know…

- the position from which they observe
- the local time,

to be able to find celestial objects…

Q: Which is the most critical?



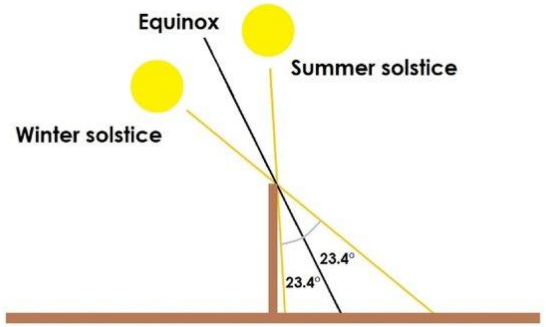


Latitude and Longitude

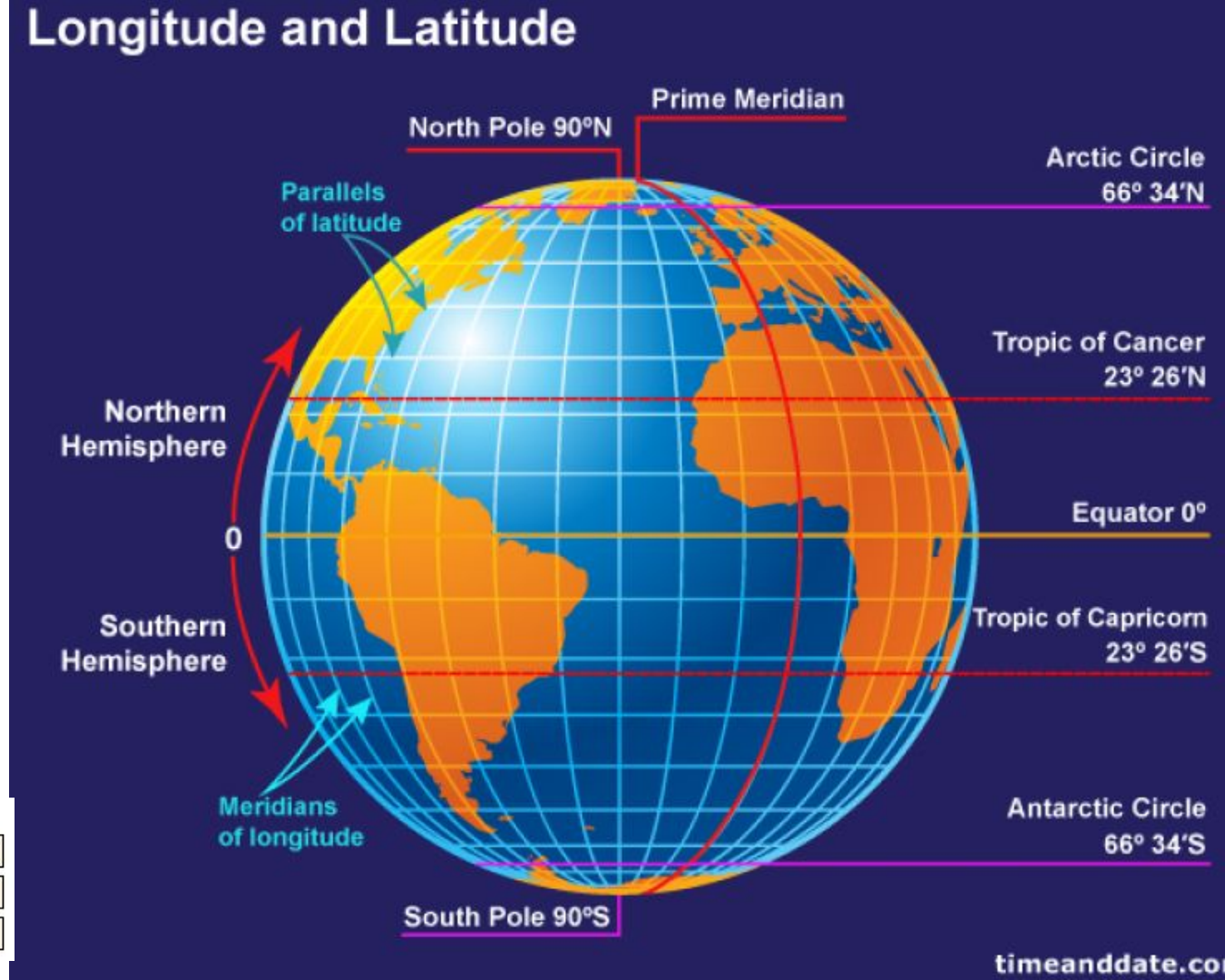
- 5th century BC: Ancient Greek philosophy conceptualises the round Earth
- 3rd century BC: Eratosthenus proposed a system of latitude and longitude
- 2nd century BC: Hipparcus the first to use such a system to uniquely specify places on Earth – he also proposed longitude determination by comparing local time of a place with absolute time
- 11th century AD: **Al-Biruni** believed the Earth rotated on it's axis and this forms our modern notion of how time and longitude are related

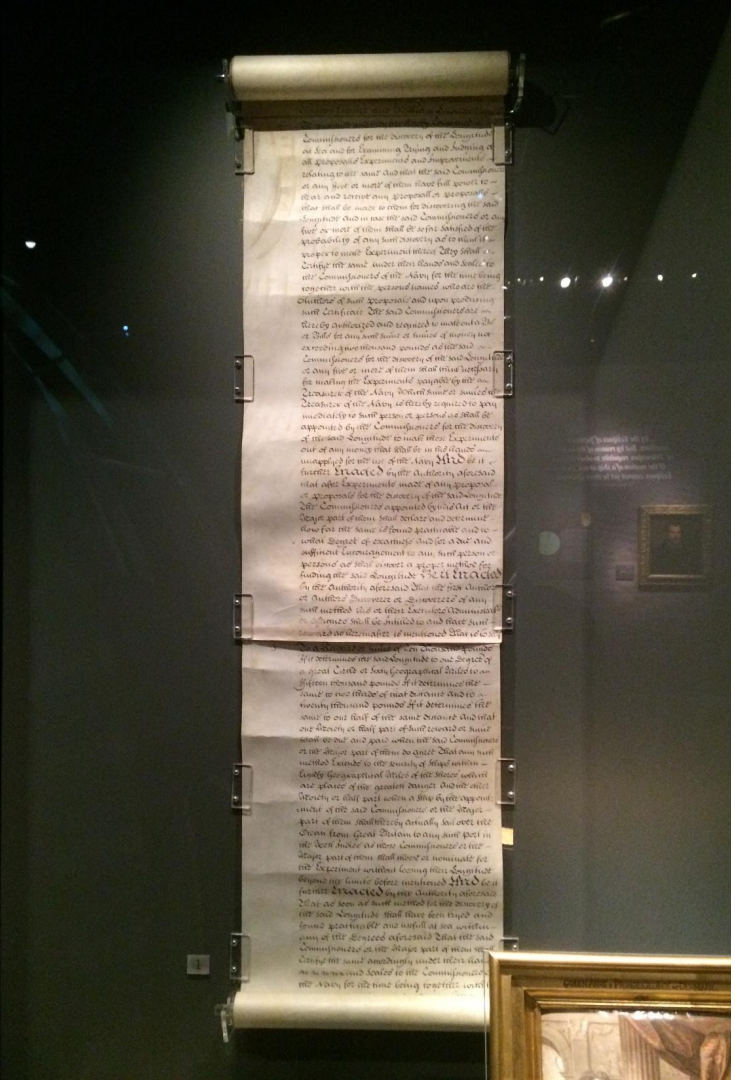
Latitude and Longitude

Equinox (equal night): March and September, when the Sun is exactly above the Equator – signifies the start of the next season



Receiver	Position
PolaRx5-3052128 (hrtb)	Lat: S25°53'24.3004" 0.903m
IP Address (Eth): 10.254.1.5	Lon: E27°41'13.0649" 0.725m
Uptime: 17d 10:01:09	Hgt: 1432.669m 1.910m



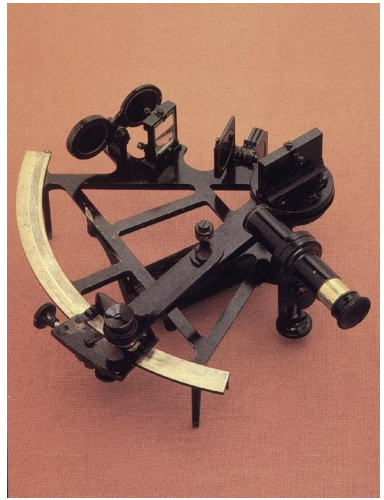


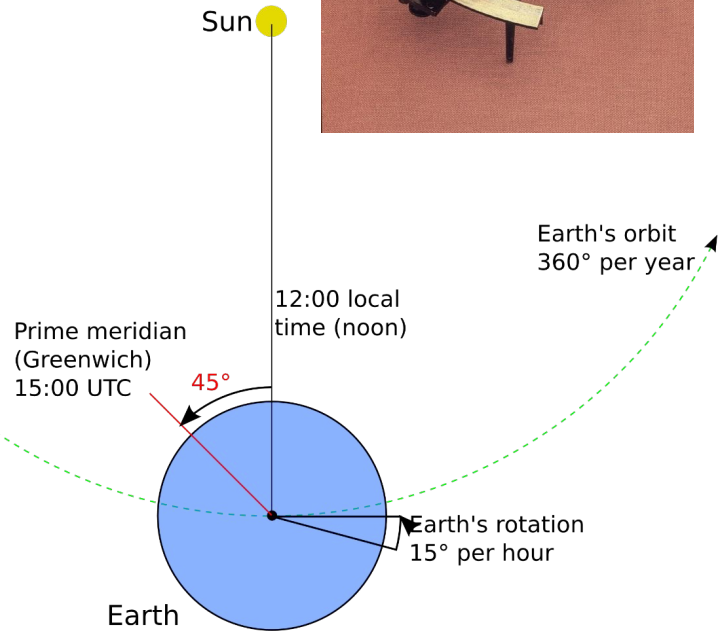
Latitude and Longitude

- **Latitude** can easily be determined from:
  - the altitude of the Sun at noon,
  - or from stars at night.
- **Longitude** was determined by dead reckoning (calculate current position by using the previous value and advancing it for an estimated speed over a certain time) – cumulative errors!
  - Much harder while at sea than on land
  - Sailors would sail to latitude of destination, and then follow that latitude E or W *(running down a westing or easting*)
  - Errors in longitude led to many disasters
  - 1714: British government establishes the Board of Longitude. Prizes were offered for the discovery and demonstration of a practical method to determine longitude while at sea.

Time equals longitude…

- Local solar time varies by one hour for every 15 degrees change of longitude
- If the navigator knew the time at a fixed reference point, the difference between the reference time and the apparent local time would give the position relative to the fixed reference point
- Finding apparent local time is relatively easy (the Sun, the Moon and stars)
- The problem, ultimately, was to determine the time at the reference point…



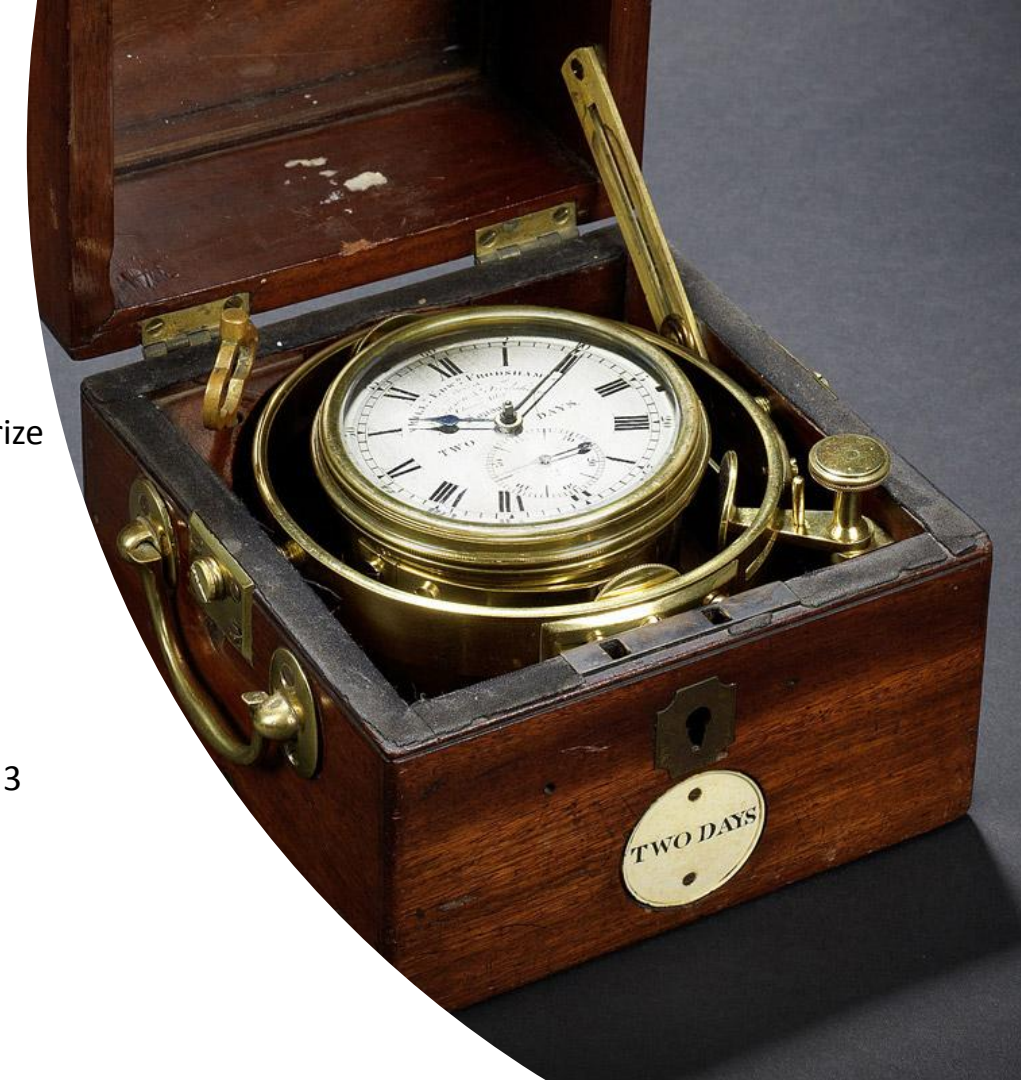


Proposed methods of determining time

- 1514 AD: Johannes Werner proposes using the Moon – tedious calculations
- 1612 AD: Galileo proposes the Jovian (Jupiter's) moons – difficult from the deck of a ship, rather used on land
- 1683 AD: Halley proposed lunar occultations, appulses, magnetic deviation – never used due to inaccuracies
- 1755 AD: Tobias Mayer proposed Lunar distances (based on motion of the Moon) – labour intensive
- 1766 AD: Nevil Maskelyne refined this to a **pre-calculated** *nautical almanac*, published first for data of 1767. Since this was based on the Royal Observatory as the 'reference point', it later led to the *Greenwich Meridian*

The age of the chronometer…

- 1773 AD: John Harrison awarded the the Longitude Prize by the British Parliament for his H-4 chronometer, but very expensive
- 1836 AD: Thomas Earnshaw made a chronometer suitable for general nautical use, still very expensive
- BUT – the Nautical Almanacs were still generally used for several decades and as late as 1906 AD
- By 1850: Chronometers used more widely, but ideally 3 per vessel:
  "Never go to sea with 2 chronometers; take one or three"
- Some vessels like the HMS Beagle carried 22 chronometers

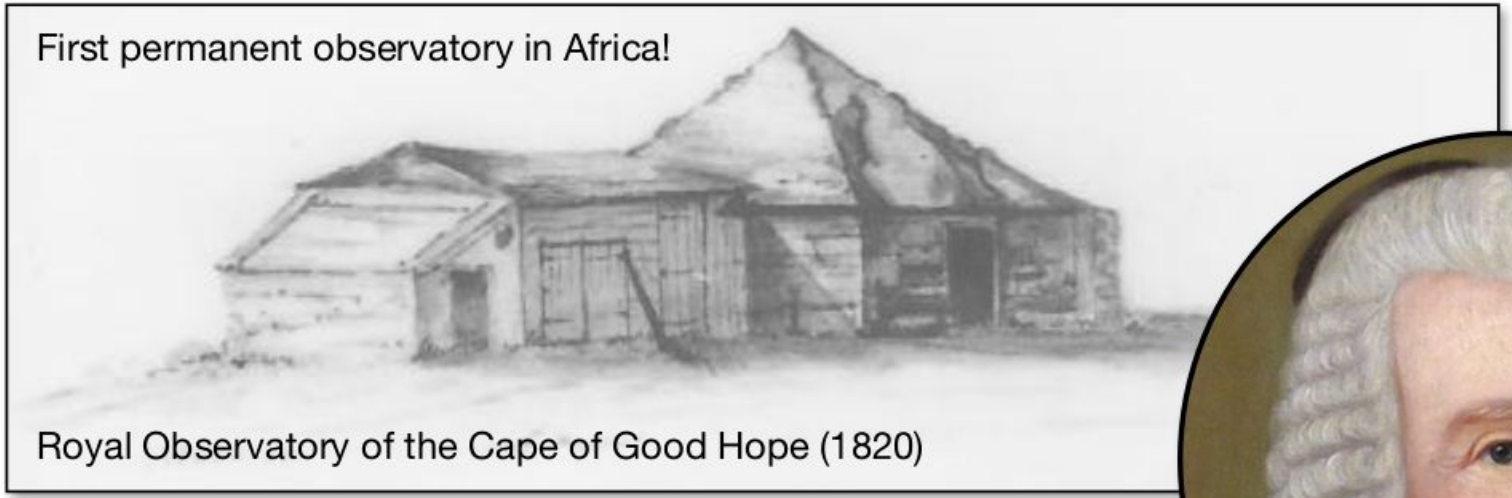


Modern clocks and clock signal distribution

- 1865 AD: Telegraph signals for time coordination between astronomers
- 1904 AD: Wireless telegraphy used for time signals, to correct on-board chronometers
- 1972 AD: Hamilton introduced the first commercial electronic digital wristwatch (driven by a crystal oscillator)
- 1980 AD: GPS-provided time (and position)

In SA in 1820…

First permanent observatory in Africa!



Royal Observatory of the Cape of Good Hope (1820)

Nicholas de la Caille

Nicolas de la Lacaille was sent to the Cape in the mid-1700s, as one of the first visiting astronomers, to map the southern skies. **Why?** Because during the 17th and 18th centuries, European explorers and traders faced serious navigational challenges along the southern African coastline. Lacaille's work created some of the earliest southern star catalogs, and the observatory became a vital center for positional astronomy — laying the foundations for what we now know as SAAO

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In SA - Time from Astronomy…

The Noon Gun on Signal Hill in Cape Town is a pair of historic 18th-century Dutch naval cannons fired precisely at 12:00 PM daily, except on Sundays and public holidays. Operated by the South African Navy at the Lion Battery, it is Cape Town's oldest living tradition and among the oldest working guns in daily use globally.

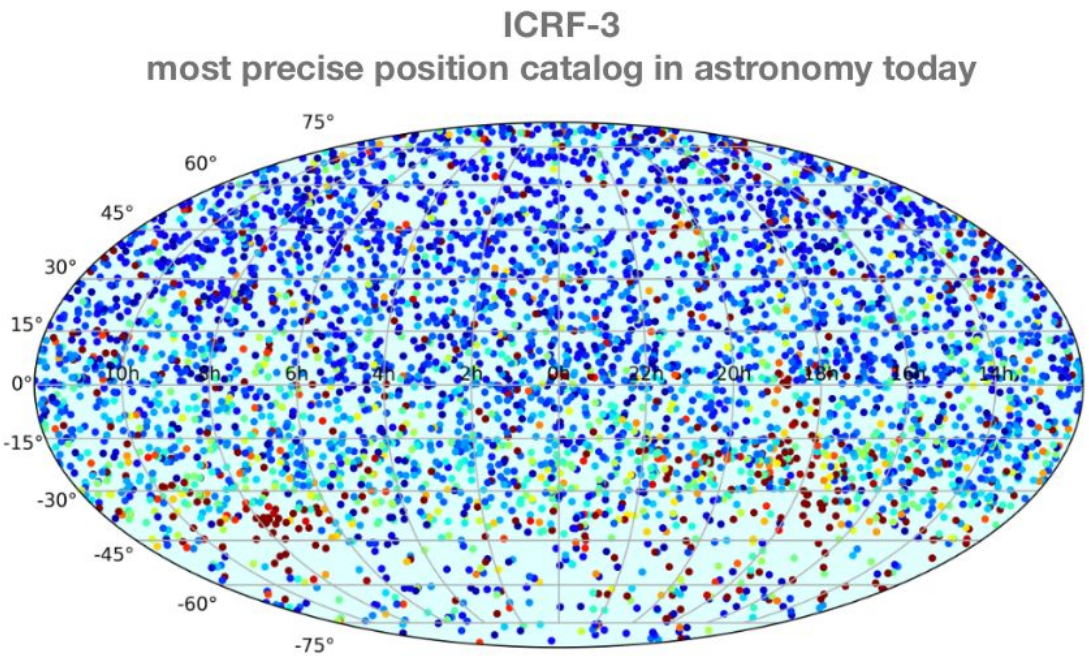
History and Purpose

- Started in 1806 to help ships in Table Bay set their marine chronometers.
- Moved to the Lion Battery on Signal Hill in 1902.
- Triggered electronically via an atomic clock signal sent from the South African Astronomical Observatory


Credit: Graham Richter - Wikipedia

Astrometry: A Subfield of Astronomy, part of Space Geodesy

So, what do we call all of this today? Astrometry!



Everything we've seen so far — from Malta, Hipparchus, Ptolemy, and even early South African astronomy history — was fundamentally about **measuring celestial positions** and **building catalogs!**

In modern science, this work lives on through **absolute astrometry, which** measures the positions of celestial objects in a global, fixed reference frame — without relying on relative positions between nearby stars - **GPS of the sky!**

It is build using **VLBI observations of AGN** — which sits at the intersection between **astronomy** and **geodesy!**

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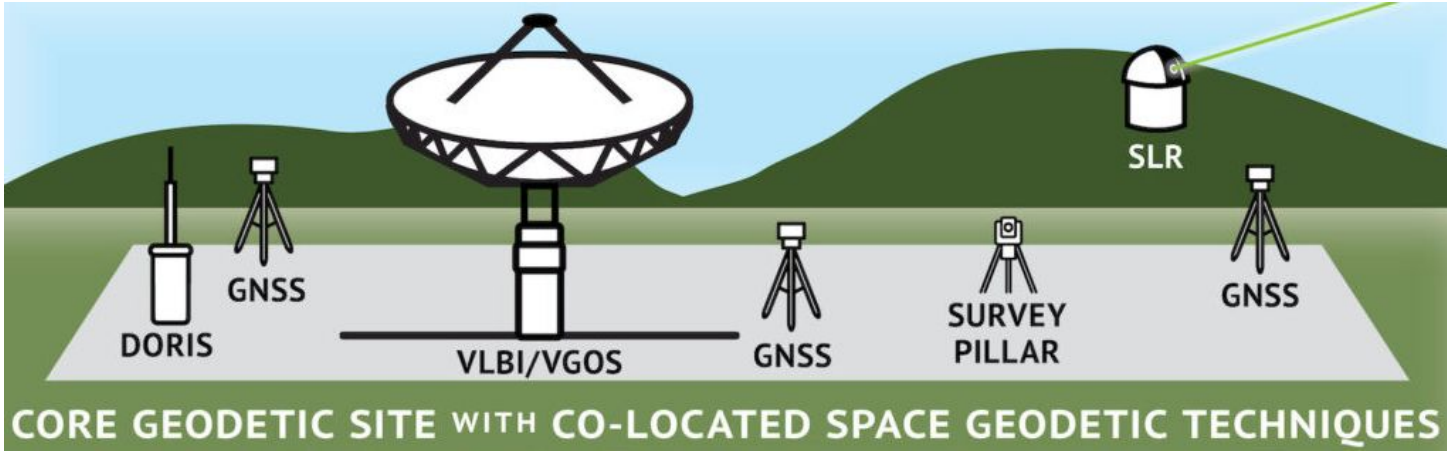
Space Geodetic Fundamental Sites



Geodetic VLBI (international network) - quasars at the edge of the observable universe used as reference positions, to determine inter-telescope baselines (and therefore accurate positions within the Celestial and Terrestrial reference frames

The positions of each of the other instruments on-site can then be determined by terrestrial techniques (eg. Total Station)

The other techniques are then used to determine various position and time values:

- Satellite Laser Ranging: satellite orbit predictions are used as a starting point, to find and track real positions (a small actual orbit segment)
- DORIS transmit reference signals to space, for other satellites to determine their positions from it
- The GNSS reference stations - since the actual position has been determined via VLBI and terrestrial techniques, the offset in the GNSS-derived position is then used to quantify the other influencing factors like atmospheric pressure, ionosphere etc.

Astronomers ***still*** need to know…

- the position from which they observe
- the local time,

to be able to find celestial objects…

So Astronomy needs Geodesy,

Geodesy needs Astronomy.

Geodesy (the international time and position product) is the public benefit of Astronomy…