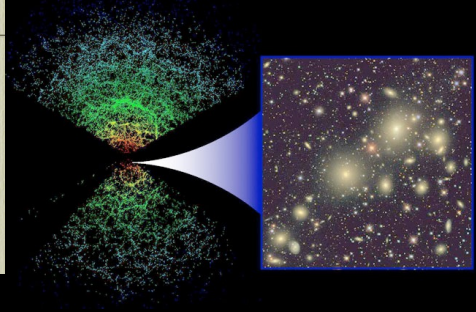




# Babylon to the Big Bang

Peter Watson



## What do we see when we look at the sky?

Credit: ESO, Stefan Gillessen (MPI), F. Eisenhauer, S. Trippe, T. Alexander, R. Genzel, F. Martins, T. Ott



If the stars should appear but one night every thousand years how man would marvel and stare. Ralph Waldo Emerson

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Sky view : Stars seem to rotate in circles, centred on the North Celestial Pole



Lets turn off the sun, and track the planets now

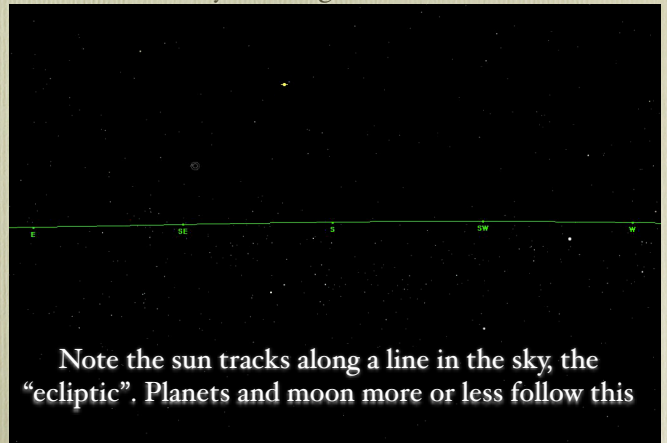


Stars near the equator set 4 minutes earlier each night.



Isn't it complicated!

We can make things a bit easier by freezing the stars and always looking South



Note the sun tracks along a line in the sky, the "ecliptic". Planets and moon more or less follow this

12h 01m 16.46s Dec: -45° 22' -1.3" LHT 09:18:00 P11 Wnd 1kg 4, 2011 Ottawa: 75° 42' 00.0" W 45° 24' 00.0" N

## The first observatory (or the earliest we know about)



- Midsummer day: sunrise aligns with "heel stone"
- Measured at Stonehenge: defines seasons and hence time to plant crops



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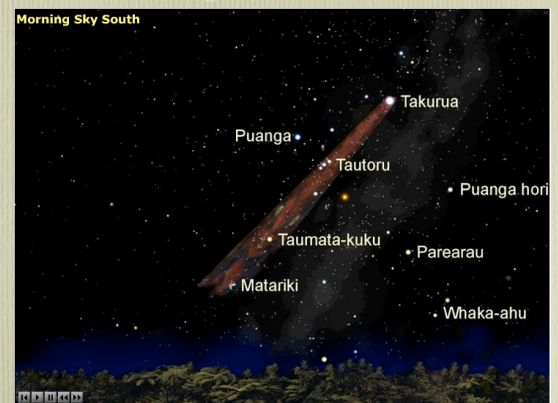
## Taatai Arorangi (Maori Astronomy)

- Stars are guarded by Star fairies
- One polished his star so much that the others became jealous, chased him and threw a stone which broke it in seven pieces
- Hence the Matariki (the Pleiades)



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## e.g. Orion



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- Appearance of Matariki (the Pleiades) marks the beginning of the New Year.
- Note complex mythology hides a **HUGE** practical application to navigation
- "If you sail for Kahiki (Tahiti) you will discover new constellations and strange stars over the deep ocean. When you arrive at the Piko o Wakea you will lose sight of Hokupaa (North Star), and the Neve (Southern Cross) will be the southern guiding-star, and the constellation of Humu will stand as a guide above you." Percy Smith

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## They also used

- Wind
- Waves (reflected from islands)
- Clouds (Land of the Long White Cloud)
- Birds

No compasses  
No Iron!

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## When we are in Hilo

- Take the tour to 'Imiloa Astronomy Centre



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## So did anyone use the stars earlier?

- Dung-beetles?



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- How do dung beetles find their way?
- By the sun during the day, but by the Milky Way on moonless nights



## Moral:

If you think you are buried in it,  
remember to keep your eyes on the  
stars!

### 2013 Ig Nobel prizes

JOINT PRIZE IN BIOLOGY AND ASTRONOMY: Marie Dacke [SWEDEN, AUSTRALIA], Emily Baird [SWEDEN, AUSTRALIA, GERMANY], Marcus Byrne [SOUTH AFRICA, UK], Clarke Scholtz [SOUTH AFRICA], and Eric J. Warrant [SWEDEN, AUSTRALIA, GERMANY], for discovering that when dung beetles get lost, they can navigate their way home by looking at the Milky Way.

REFERENCE: "Dung Beetles Use the Milky Way for Orientation," Marie Dacke, Emily Baird, Marcus Byrne, Clarke H. Scholtz, Eric J. Warrant, Current Biology, epub January 24, 2013. The authors, at Lund University, Sweden, the University of Witwatersrand, South Africa, and the University of Pretoria

- The questions:
- (Easy) Why do you believe the earth is not flat?
- (Hard) Why do you believe the earth rotates?
- (Very hard) Why do you believe the earth orbits the sun?

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# Why Babylon?

- Most detailed ancient observations.
- Star Catalogs 1600 BC.
- Eclipse Observed 1500 BC.
- Continuous Records 900 BC.
- Records on stone/clay tablets.

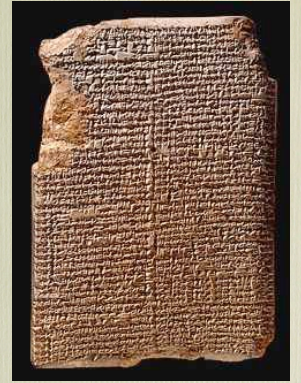


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## Babylon: Mul Apin tablet

[http://www.mesopotamia.co.uk/astronomer/explore/exp\\_set.html](http://www.mesopotamia.co.uk/astronomer/explore/exp_set.html)

On the 1st of Nisannu the Hired Man becomes visible.  
On the 20th of Nisannu the Crook becomes visible.  
On the 1st of Ayyaru the Stars become visible.  
On the 20th of Ayyaru the Jaw of the Bull becomes visible.  
On the 10th of Simanu the True Shepherd of Anu and the Great Twins become visible.  
On the 5th of Du'uzu the Little Twins and the Crab become visible.  
On the 15th of Du'uzu the Arrow, the Snake, and the Lion become visible; 4 minas is a daytime watch, 2 minas is a nighttime watch.  
On the 5th of Abu the Bow and the King become visible.



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## Enuma Elish tablets : the first (written) Creation Myth From The First Tablet

When in the height heaven was not named,  
And the earth beneath did not yet bear a name,  
And the primeval Apsu, who begat them,  
And chaos, Tiamut, the mother of them both  
Their waters were mingled together,  
And no field was formed, no marsh was to be seen;  
When of the gods none had been called into being,  
And none bore a name, and no destinies were ordained;  
Then were created the gods in the midst of heaven,  
Lahmu and Lahamu were called into being...  
Ages increased,...



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## Need some definitions (roughly as the Babylonians might have used them)

- Year: interval between midsummer days  
~365 1/4 days
- (lunar) Month: interval between full moons ~  
29 1/2 days
- Solar day: interval between times when the sun is due south = 24 hours



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## But note

- Year is not a whole # of days
- Year is not a whole # of lunar months
- However 19 years = 235 lunar months (+ 2 hours)
- Most societies fudge 12 months = 1 year by adding in extra days.



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## Eclipses

Tablet with a list of eclipses between 518 BC and 465 BC, mentioning the death of king Xerxes.  
[British Museum, London](#)



Why do these matter?



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**GLOUCESTER** These late eclipses in the sun and moon portend no good to us:.....

**EDMUND** I am thinking, brother, of a prediction I read this other day, what should follow these eclipses.... I promise you, the effects he writes of succeed unhappily; as of unnaturalness between the child and the parent; death, dearth, dissolutions of ancient amities; divisions in state, menaces and maledictions against king and nobles; needless diffidences, banishment of friends, dissipation of cohorts, nuptial breaches, and I know not what.

**EDGAR** How long have you been a sectary astronomical?

Chinese astronomers Hi and Ho executed for failing to predict eclipse.

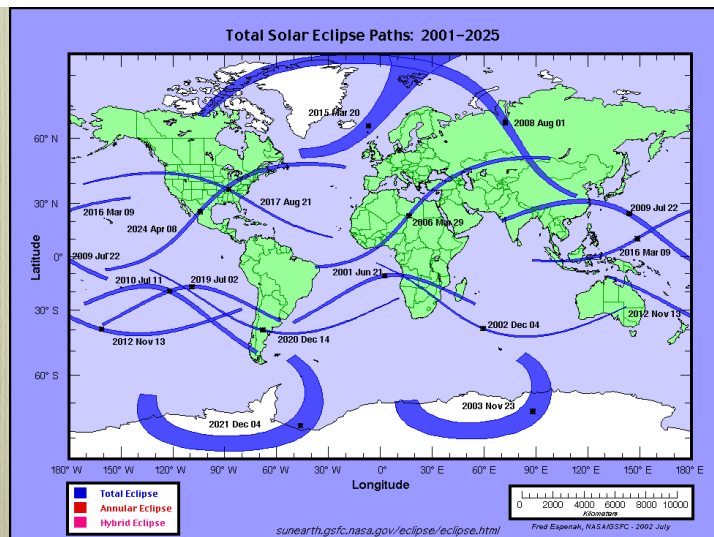
And they even mattered to artists



St Benedict, by Cosmas Damian Asam 1735

Wikipedia

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## Saros cycle

- Eclipses repeat after 18 years and 11.3 days.
- The .3 days shifts the eclipse about 110° degrees west, so can only see cycle after many years.
- Why is it so complicated? Need to combine
  1. Earth's rotation
  2. Moon's orbit (not quite circular)
  3. Earth's orbit (ditto)
  4. and the plane of the moon's orbit precesses

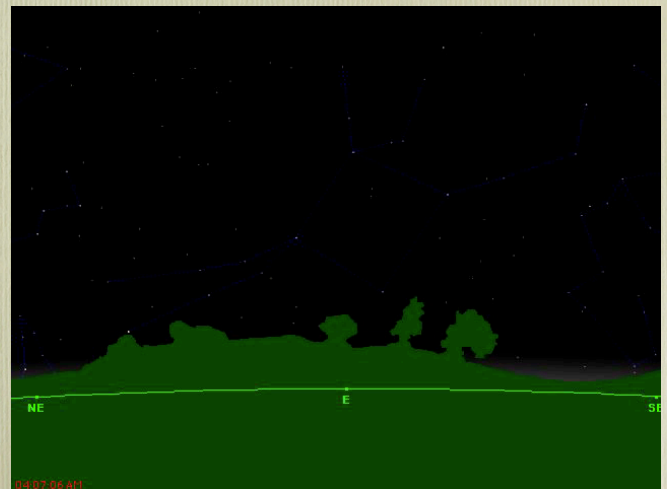
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## Eclipse of 1999 seen from Mir



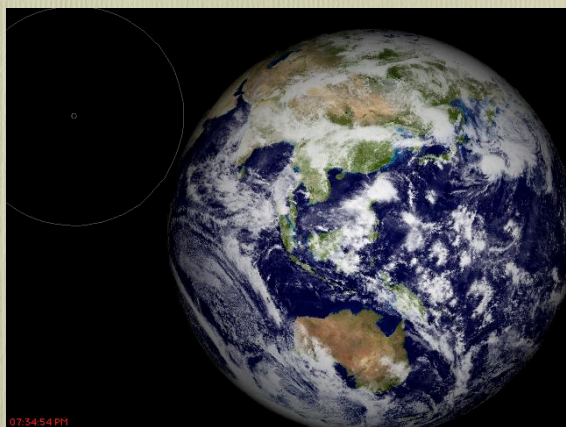
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Babylonians observed total eclipse 15 April 136 BC.



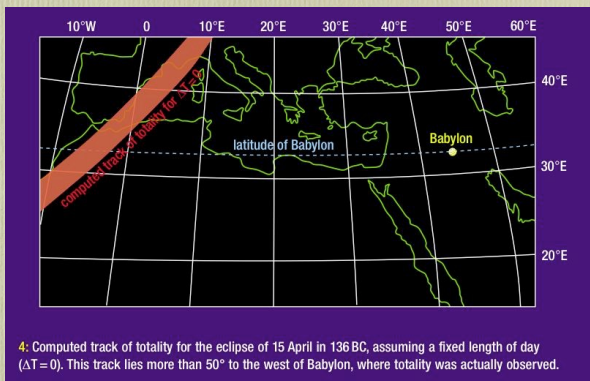
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and they would even have seen it from the moon !



07:34:54 PM

But they shouldn't have!

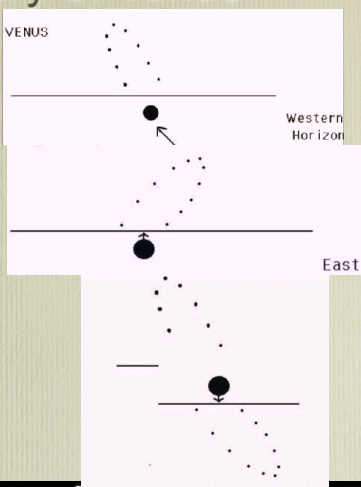


4. Computed track of totality for the eclipse of 15 April in 136 BC, assuming a fixed length of day ( $\Delta T = 0$ ). This track lies more than  $50^\circ$  to the west of Babylon, where totality was actually observed.

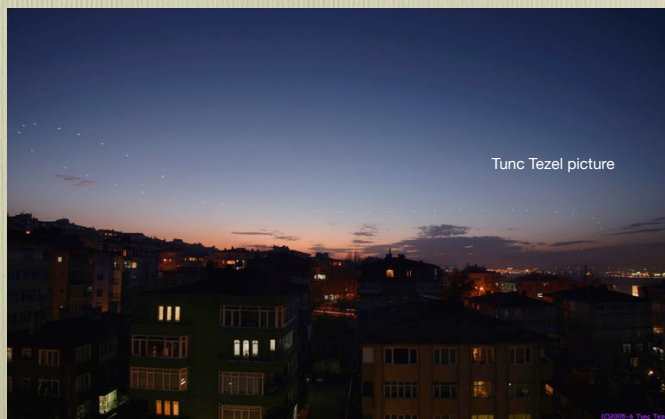
- Earth's rotation has slowed down, by  $\sim 0.01$  sec/century, because of tidal effects! i.e. earth isn't a very good time-keeper

## Discovery of Venus

- Hesperus is a bright evening star for about 8 months.
- Phosphorus follows as morning star for 8 months in the Eastern sky
- become Venus, -497 BC.

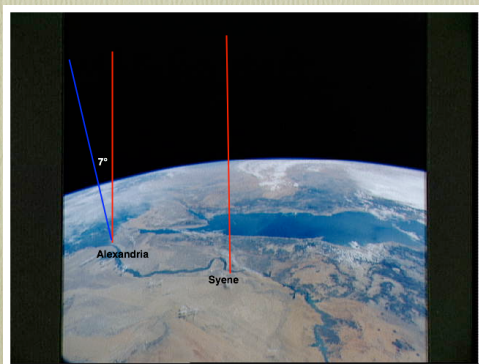


- Note that this is much more difficult to study than it sounds, because the orbit is tilted to the horizon, and the orbit is distorted.



## Eratosthenes: 276-195 BC

- How big is the earth?



- Sun is vertically above Syene (Aswan) when it is  $7^\circ$  off the vertical at Alexandria,
- Distance is 720 km gives  $\sim 5900$  km (actually 6400)
- First step into finding how big the universe is!

## How far is the Moon?

- Moon is about  $1/2^\circ$  in the sky: use it as a "screen" for the shadow of the earth.
- The shadow of the Earth  $\sim 2^\circ$  wide.



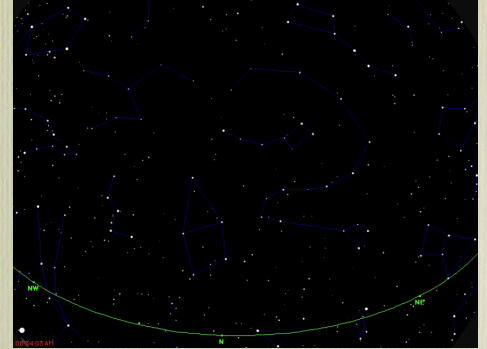
Photo by Anthony Ayiomitas

Gives  $d \sim 375,000$  km (384,400 km)

## One more discovery by the Babylonians/Greeks

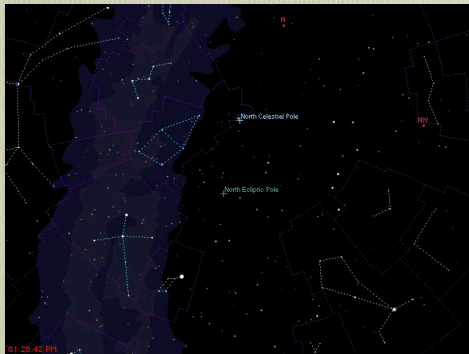
What is the North star

The point the stars appear to rotate round



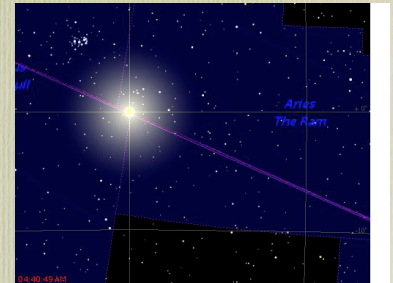
## Hipparchus: 160-127 BC. Precession of the Equinoxes

Earth's axis is tilted, but doesn't always point to the same place (i.e. the North Star isn't always!)



- March 21st & Sept 21st are special days: the equinoxes
- Sun is above the equator, but where on the equator?

- Aries 2000 BC
- Pisces 100 BC
- (the early Christians chose the fish as their symbol)



- And now

- **This is the dawning of the age of Aquarius**

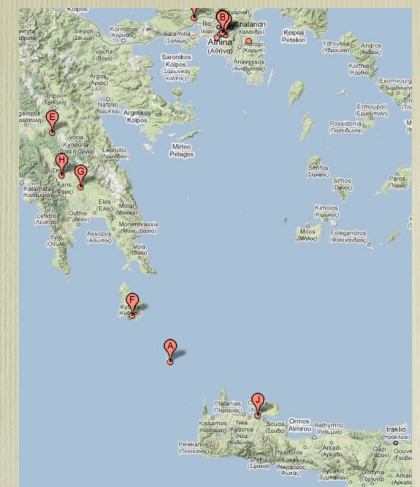
## Why?



## Antikythera



- Wreck full of sculptures



## And amphorae

- Like the one in the dining room!



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## and a piece of rusted junk: Antikythera Mechanism

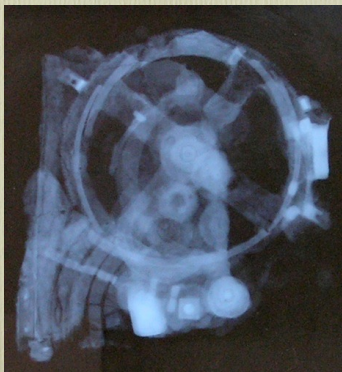
- Found in 1901
- probably late second century BC.
- National Archaeological Museum in Athens
- So what is it?



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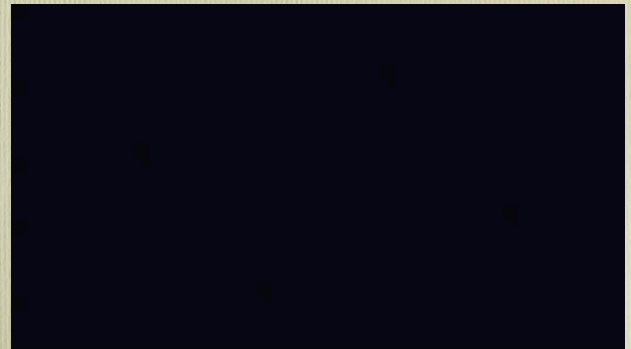
X-rays show very complex structure

Many (at least 30) gears: one has 47 teeth !!!!



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This may be how it works



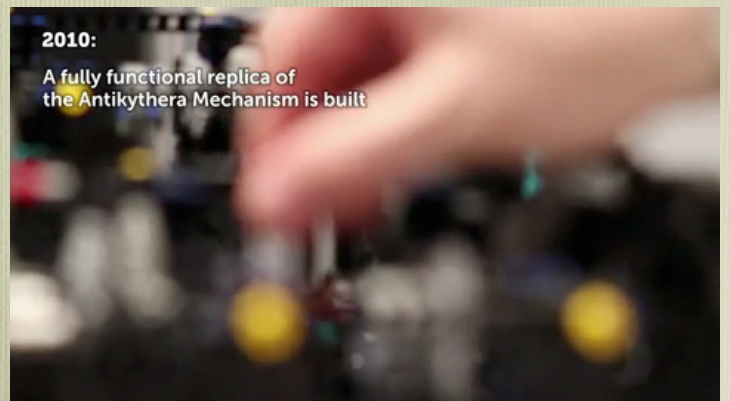
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- Shows Metonic sequence (235 lunar months = 19 solar years + 2 hours)
- $235 = 5 \times 47$ !!!!!!!!!!!!!!!!!!!!
- Shows Saros eclipse cycle (223 lunar months)

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2010:

A fully functional replica of the Antikythera Mechanism is built



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# Acknowledgements

- Astronomy Picture of the Day (APOD)
- Anthony Ayiomitas
- Tunc Tezel
- Simulations: Voyager 4.5 (Carina software)



**Holland America Line**

*A Signature of Excellence*



Peter Watson