

Total Eclipse

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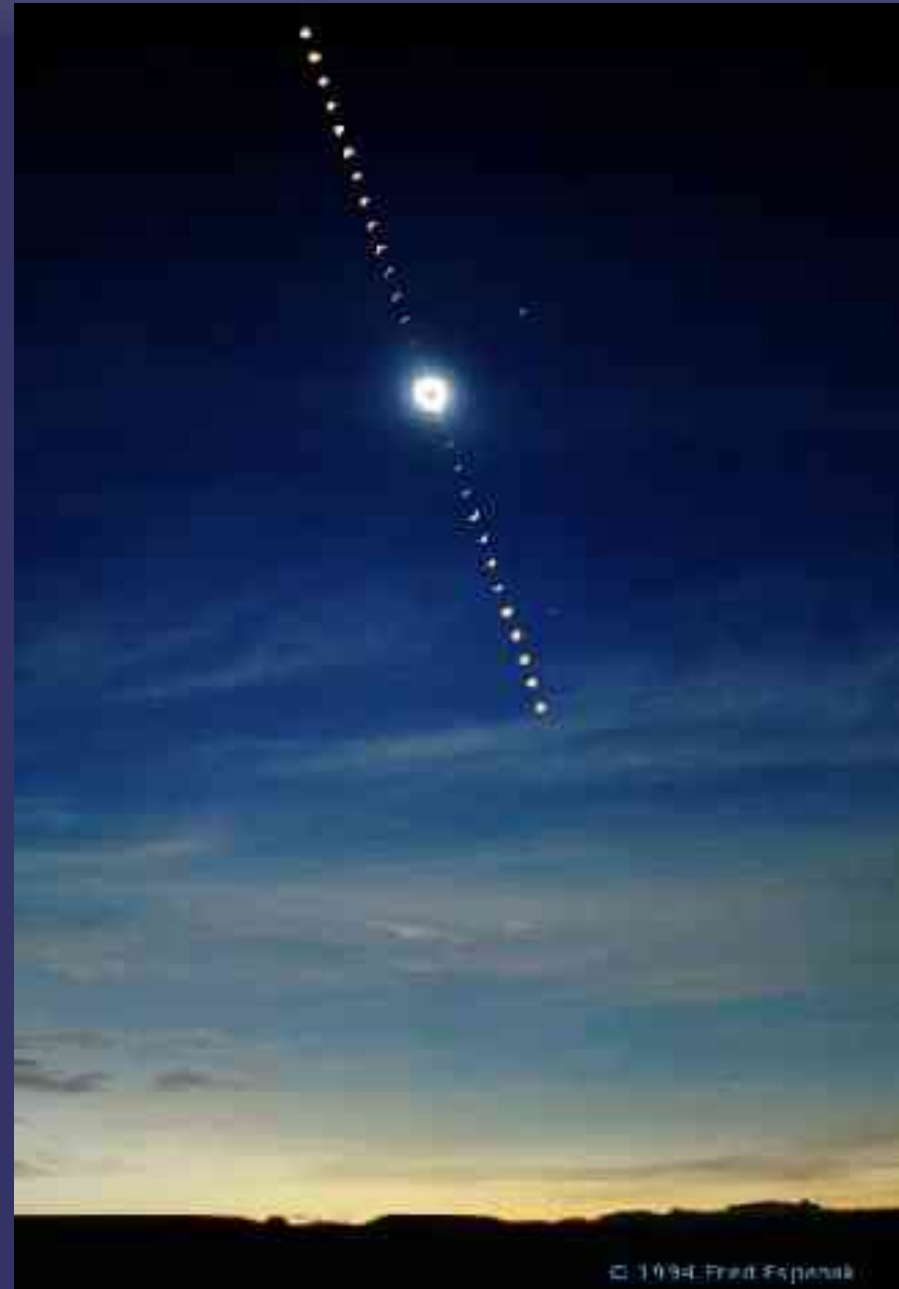
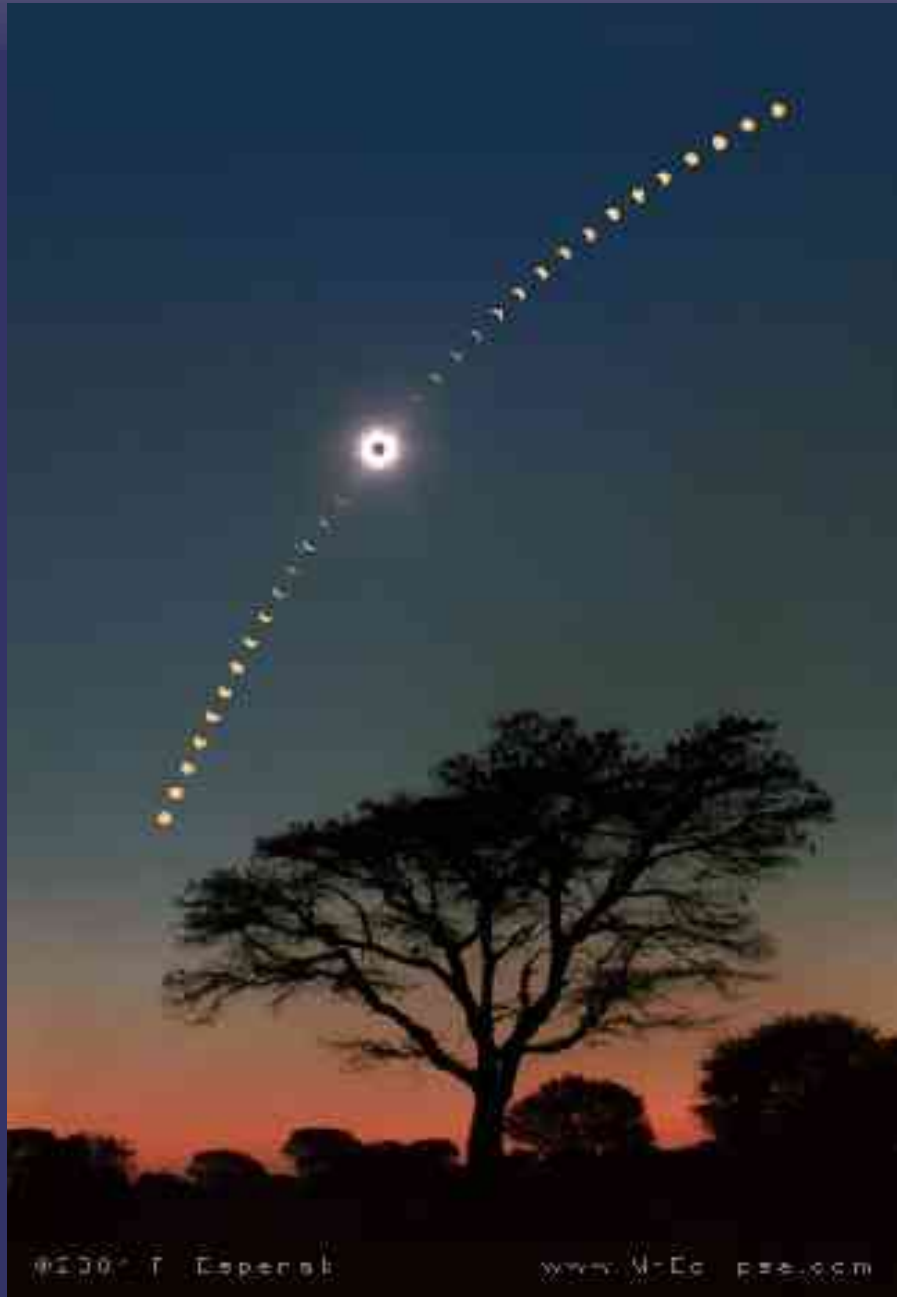
Fact: the moon is just big enough and close enough to cover up the sun's surface **completely**.

What you see here is the corona, 1 million times dimmer than the sun, about as bright as the full moon

outline

- ⇒ Observing eclipses
- ⇒ Famous eclipses in history
- ⇒ What you can do with eclipse observations
- ⇒ Solar eclipses without the moon
- ⇒ Along the way we'll talk a little about differences between:
 - astrology
 - astronomy
 - astrophysics

A picture every 5 minutes..



total eclipse

1999 August 11

Total Solar Eclipse of 1999 August 11



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The corona is only seen during “totality”.

Who thinks the “corona” belongs to: the Earth, the Moon, the Sun, something else?

different ways of watching an eclipse (1999 August 11)

Automatic
camera all
by itself ->

Which method do
you prefer?



Viewing the 2003 annular eclipse- Iceland!



Cloudy, but who cares?...

History-- early

"Here lie the bodies of Ho and Hi,
Whose fate, though sad, is risible;
Being slain because they could not spy
Th' eclipse which was invisible."

- Author unknown. Said to refer to the Chinese eclipse of 2136 BC or 2159 BC. Royal astronomers Ho and Hi were drunk and failed to predict the eclipse, so that the people did not prepare to drive away the dragon which caused the eclipse... They lost their heads.

"On the day of the new moon, in the month of Hiyar, the Sun was put to shame, and went down in the daytime, with Mars in attendance." -- One of the earliest written records of an eclipse of the Sun, on 3 May 1375 BC, found in the city of Ugarit in Mesopotamia.

Classical period..

". . . and the Sun has perished out of heaven, and an evil mist hovers over all." -- Said to refer to a total solar eclipse of 16 April 1178 BC.
From: Homer (Greek), The Odyssey (8th century BC).

"Zeus, the father of the Olympic Gods, turned mid-day into night, hiding the light of the dazzling Sun; and sore fear came upon men." -- Archilochus (c680-c640 BC), Greek poet. Refers to the total solar eclipse of 6 April 648 BC.

"The original discovery (of the cause of eclipses) was made in Greece by Thales of Miletus, who in the fourth year of the 48th Olympiad (585/4 BC) foretold the eclipse of the Sun that occurred in the reign of Alyattes, in the 170th year after the foundation of Rome (584/3 BC)". -- Probably refers to the total solar eclipse of 28 May 585 BC.
From: Pliny, Naturalis Historia, II, 53.

The far east..

"On the day chi-ch'ou, the Sun was eclipsed, and it became dark in the daytime. The Empress Dowager was upset by it and her heart was ill at ease. Turning to those around her she said, 'This is on my account.'" -- Szu-ma Ch'ien Shih-chi. Refers to a total solar eclipse of 4 March 181 BC. The Empress died on 18 August 180 BC.

"36th year of Empress Suiko, spring, 2nd month, 27th day. The Empress took to her sick bed. 3rd month, 2nd day. There was a total eclipse of the Sun. 6th day. The Empress' illness became very grave and (death) was unmistakably near . . . 7th day. The Empress died at the age of seventy-five." -- Refers to a total solar eclipse April AD 628, in the Yamato region of Japan.



A dreadful Chinese space monster, preparing to eat our Sun.

The “crucifixion eclipse”

"And I will show portents in the sky above, and signs on the earth below - blood and fire and drifting smoke. The Sun shall be turned to darkness, and the moon to blood, before that great, resplendent day, the day of the Lord, shall come." -- Peter in Acts of the Apostles.



The crucifixion occurred at passover (i.e. full moon), on a Friday. The dark, blood-red evening moon strongly suggests a total lunar eclipse. These conditions set the date of the crucifixion to 3 April AD 33. Other references to a darkened daytime sky suggest that a dust storm raised by the **khamisin**, a hot, springtime wind, produced unusual darkness. Contrary to popular belief the sun was NOT eclipsed during the crucifixion (Q: how do we know this, if indeed a lunar eclipse occurred?).

Bishops, birds, animals

"In this year Aethelbald captured Somerton; and the Sun was eclipsed, and all the sun's disc was like a black shield; and **Acca was driven from his bishopric.**" -- The Anglo Saxon Chronicle. Refers to the annular solar eclipse of 14 August AD 733.

"In the year of salvation 1485, in the month of January, according to the ancient custom, the consuls of Augsburg . . . were elected. On the 16th day of March, at the 3rd hour, during meal-time, the Sun was totally eclipsed. This produced such horrid darkness on our horizon for the space of half an hour that stars appeared in the sky. **Crazed birds fell from the sky and bleating flocks and fearful herds of oxen unexpectedly began to return from their pastures to their stables.**" -- Refers to a total solar eclipse in Augsburg, Germany, of 16 March 1485.

Jamaican eclipse: Columbus takes advantage?



Columbus was smart, but do you think was he fair?

There are many other examples where eclipses changed the outcome of important battles, the deaths of monarchs, and history itself.

- ➔ Trouble on Columbus' 4th voyage (1504): low supplies, natives tired of feeding his crew
- ➔ Columbus had an **almanac**, computed by Regiomontanus, telling that there would be a lunar eclipse
- ➔ He told the natives that unless they fed him his God would make the moon disappear that night... they laughed
- ➔ The eclipse happened. He knew totality would last 1³/₄ hours, so he said he would consult his God to see what to do. Just before the moon re-appeared, he emerged and said God had agreed to restore the moon provided the natives agreed to feed them!

Eclipses are bad? Did we do something wrong to cause them?

In ancient (and fairly recent) times, solar eclipses were often seen as bad omens or were just plain frightening, because the life-giving sun was being extinguished for unknown reasons.

Gloucester: "These late eclipses in the sun and moon portend no good to us..."

Edmund: "This is the excellent foppery of the world, that, when we are sick in fortune, - often the surfeit of our own behaviour, - we make guilty of our disasters the sun, the moon, and the stars: as if we were villains by necessity; fools by heavenly compulsion; knaves, thieves," -- **William Shakespeare -- King Lear (1605)**



More recent history

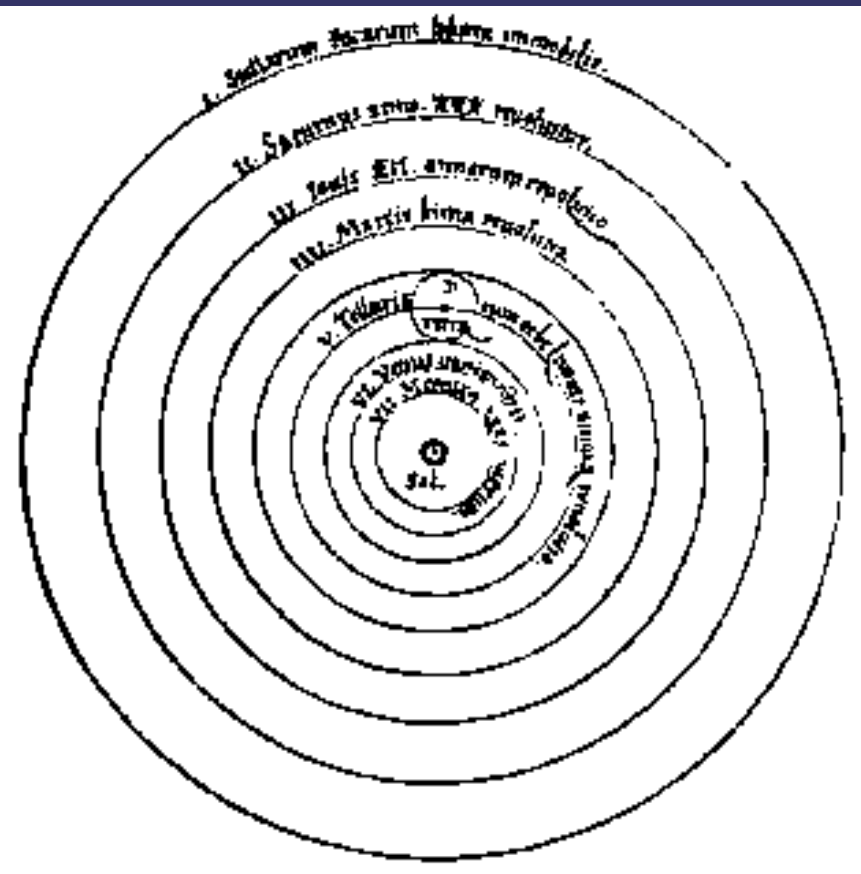


Pink Floyd, "The Dark Side of the Moon"

1973

final track- "Eclipse"

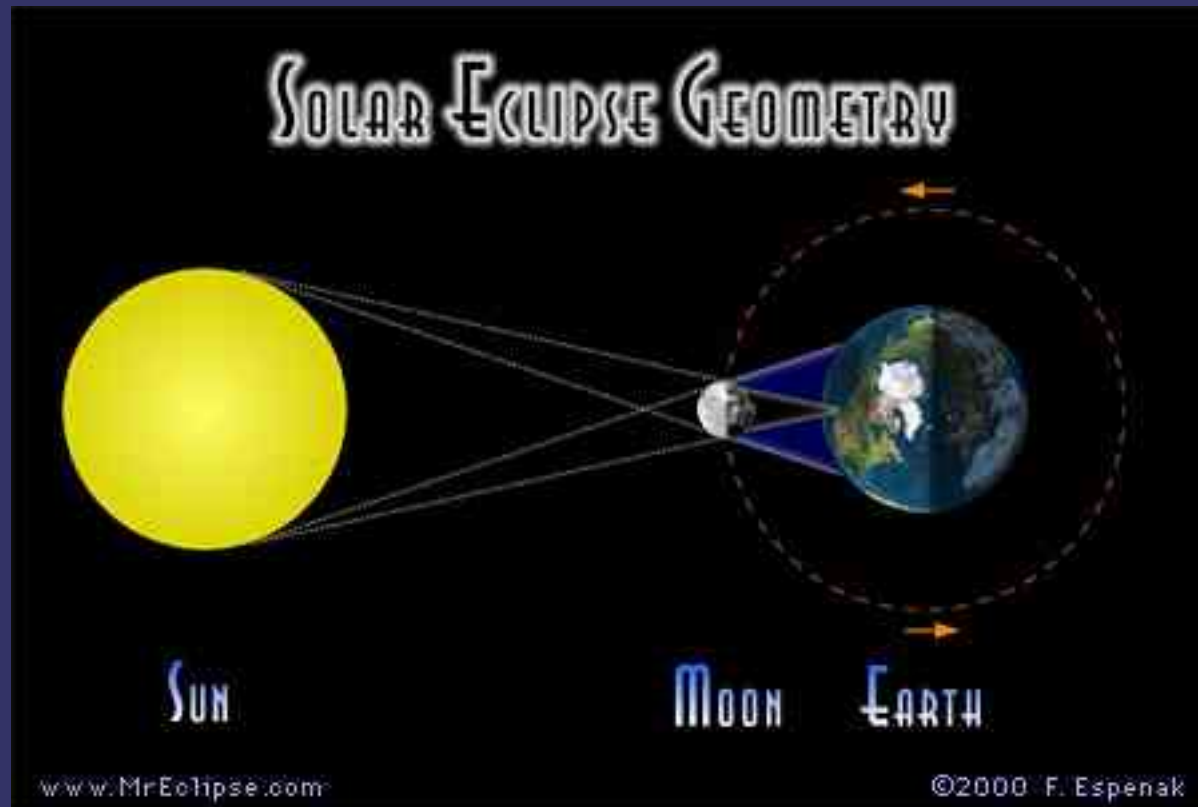
Solar system geometry



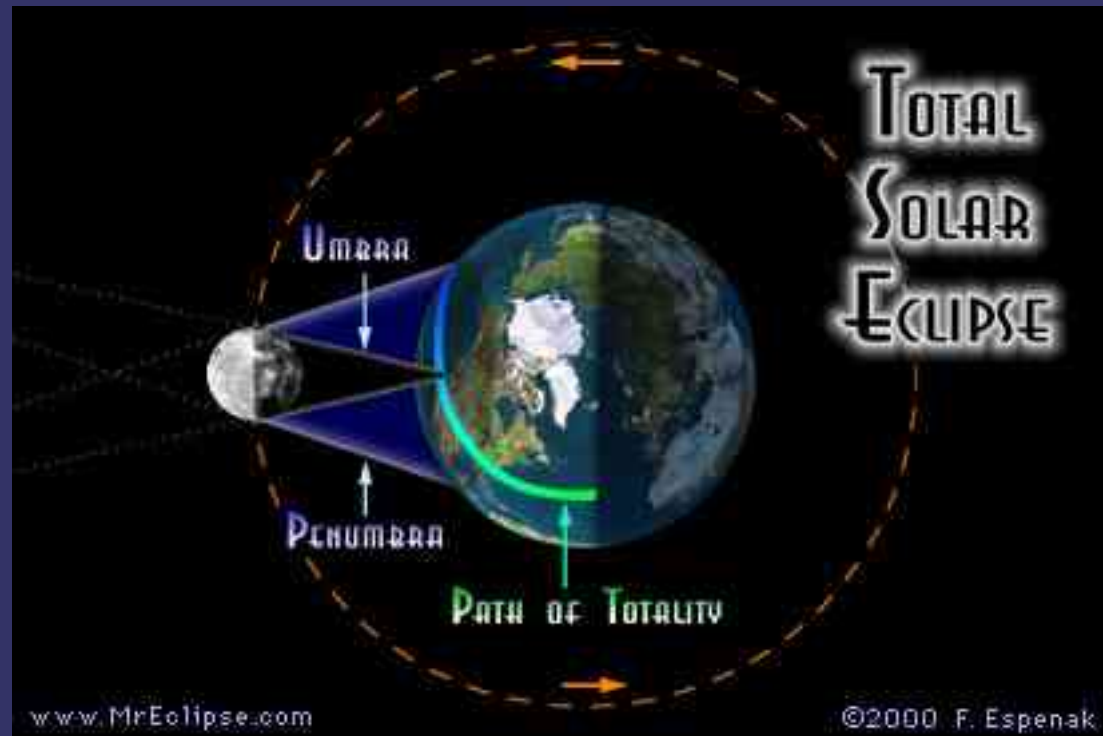
- ⇒ Hipparchus (270 BC): **heliocentric**
- ⇒ Ptolemy (b. ~100 AD): **geocentric**
- ⇒ Copernicus (b. 1473): **heliocentric**
- ⇒ Kepler (b. 1571) **elliptical orbits**
- ⇒ Newton (b. 1643) **equations of motion**

Copernicus' heliocentric solar system

Total and partial solar eclipses

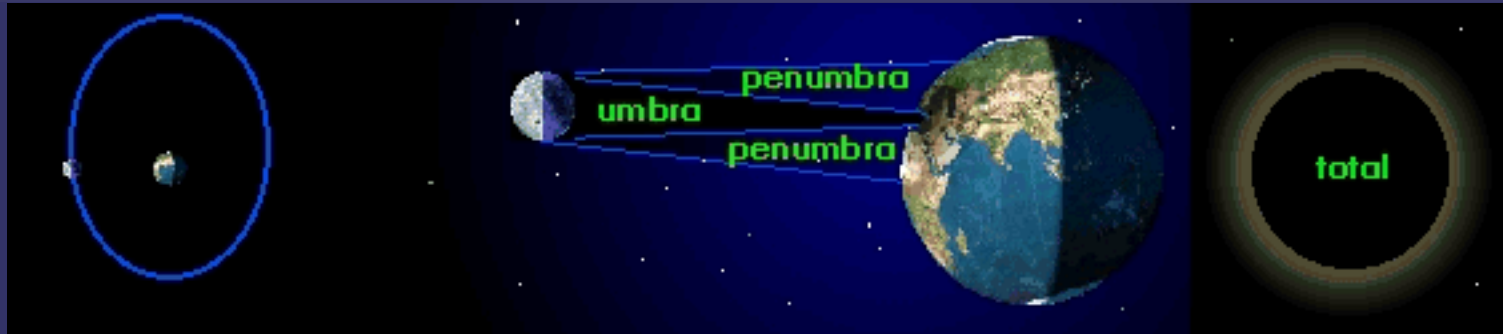


***Total eclipses are hard to find
partial ones are MUCH easier..***



People travel to the “path of totality”, and watch from cruise ships, planes, beaches,...

Annular (“ring”-shaped) solar eclipses



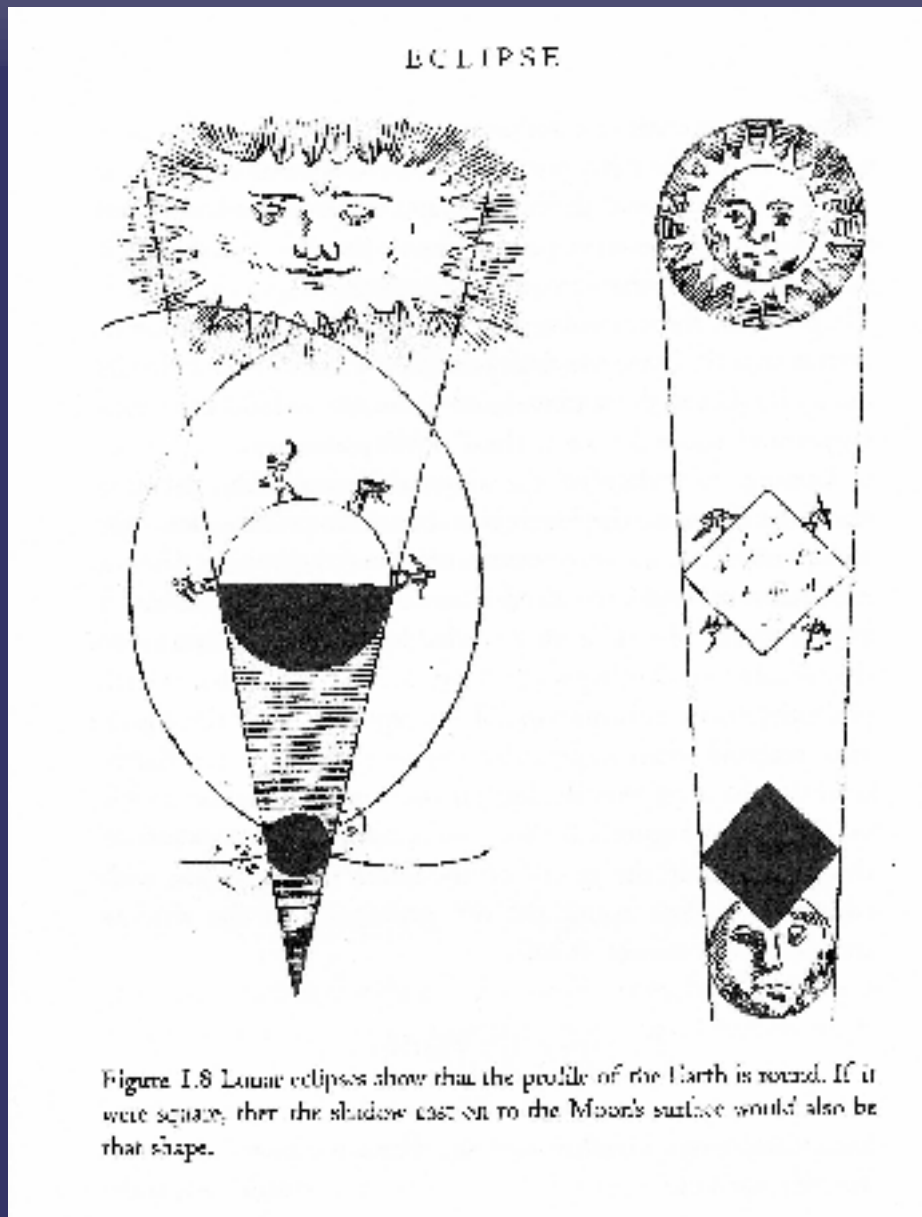
Lunar eclipses

The moon enters earth's shadow.



- ➔ can be seen from half of the earth (with good weather)
- ➔ are much more frequent than solar eclipses
- ➔ total eclipses often are red (for the same reason the sky is blue and the sun is red at sunset)
- ➔ The earth must be **round!**

The earth is round

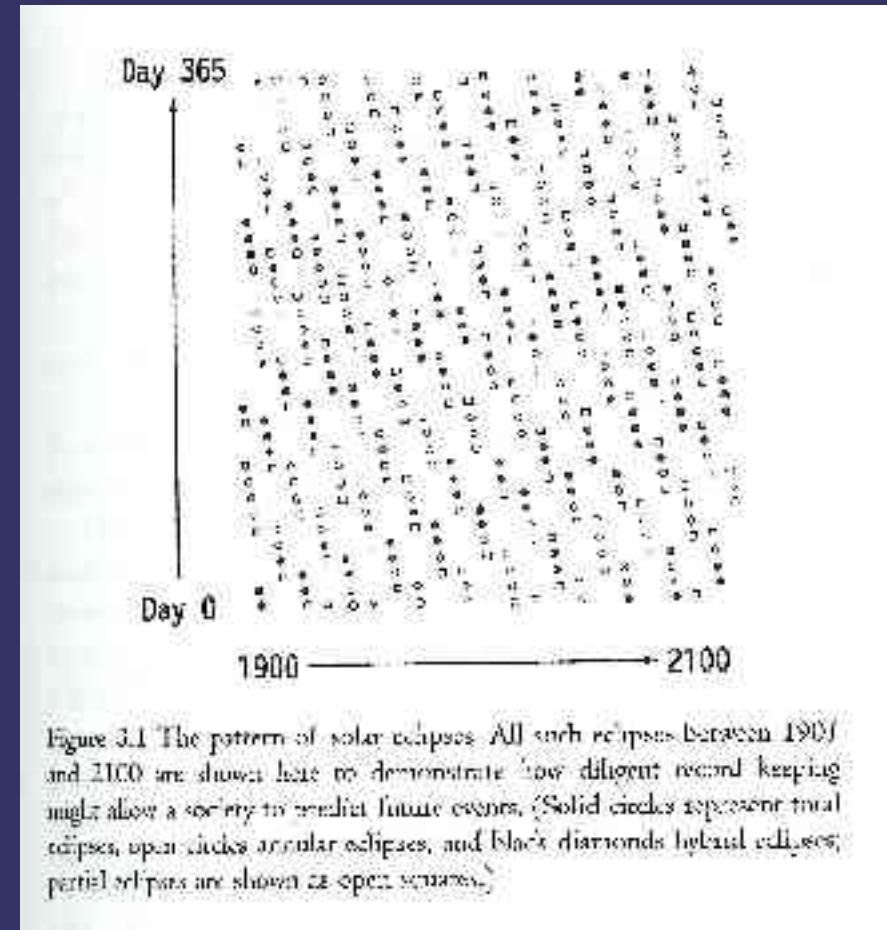


- ⇒ Ancient greek philosophers argued that the earth must be round, in part because of the shape of the earth's shadow on the moon. (Pythagoras, Aristotle)
- ⇒ yet sailors in 15th and later centuries still worried about “falling off”, and
- ⇒ today we still have the “flat earth society”..

More on solar eclipses...

Because of the elliptical orbits, the tilt of 5 degrees of the moon's orbit and the earth's, and the sizes/distances of the sun and moon:

- ➔ Total solar eclipses last between a few seconds and 7 minutes.
- ➔ One happens **somewhere** once every 18 months
- ➔ One happens at the **same place** once every 410 years (on average)
- ➔ They occur in special patterns
- ➔ These patterns helped to determine **calendars**
- ➔ Before our (Julian) calendar based on the sun's position, the seasons did not coincide with the months. An eclipse of 168 BC shows that the Roman calendar of 168 BC was off by 74 days (it was midsummer, in September!)



“Clockwork”, 19 year period, the “Saros”

The moon's shadow



Task: calculate roughly how fast the moon's shadow travels across the earth

Hints: Earth's radius is 4000 miles. The moon-earth distance is 240,000 miles. You'll need to know: how long it takes for the earth to rotate once, for the moon to orbit the earth once, does the earth rotate in the same direction as the moon moves? (Watch the sky!)

Could an airplane travel this fast?

The earth's spin is slowing down

The earth spins on its axis. The axis intersects the earth at the N and S poles. The spin is slowing down. How do we know?

ECLIPSES!

Each year that passes the day gets longer by 0.0017 seconds, hard to measure, but

In 2500 years (written history), this adds up to 4 hours. So, while the Sun and moon keep steadily going, the earth slows down, and a **total eclipse occurs at a quite different place on the earth (longitude)**.

So, historical records tell us about the history of earth's rotation.

The corona- what is it?



- ➔ How can you tell if the corona is attached to the earth, moon or Sun?
- ➔ It was not figured out until photographs were used at the 1860 eclipse
- ➔ photos showed the moon moving across the visible structures. Different places on earth showed the same structures.
- ➔ Also, by 1878 the shape of the corona was known to change with sunspots



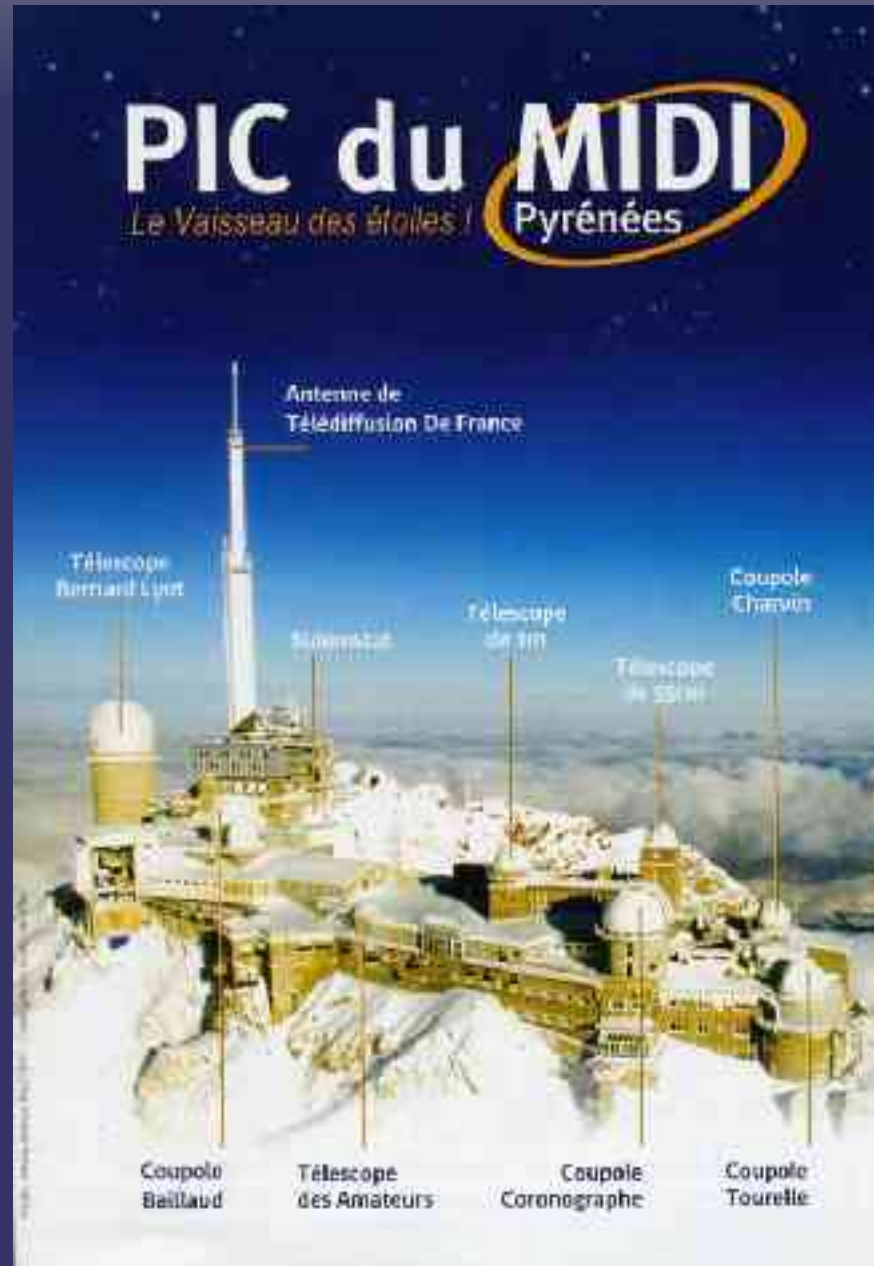
so **the corona belongs to the SUN**

It remains poorly understood even today
Nowadays, you can observe it without an
eclipse

Corona without eclipses



Bernard Lyot

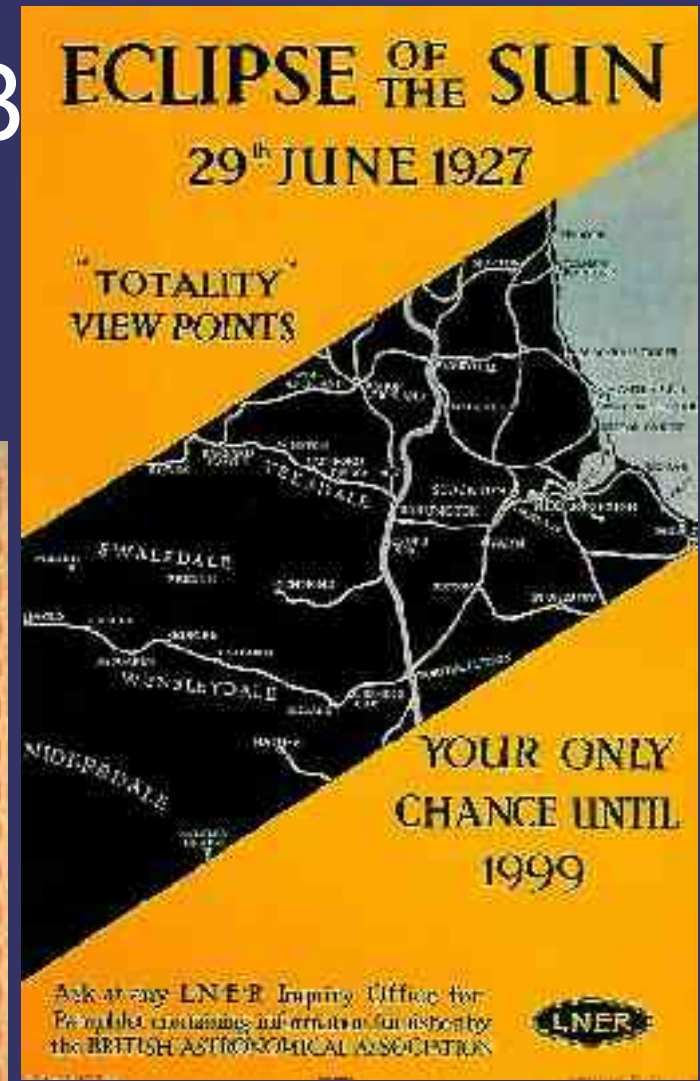


I have a small demonstration of how a Lyot coronagraph works...

Two of these posters contain false statements.. which one is OK?



A



B



C

summary

- ⇒ Eclipses are among the oldest phenomena recorded by humans
- ⇒ They took on important, almost magical meanings to people all over the globe, as omens, and as signs from gods
- ⇒ They were “understood” (as moon and earth shadows) early on, 500 BC or so
- ⇒ Patterns were known to ancient astronomers, maybe 2000 BC or earlier, and predictions could be tried, but
- ⇒ it was not until Newton's time that really accurate predictions could begin
- ⇒ Today we can use eclipses to date historical events, earth's spin, the solar corona
- ⇒ **I did not speak of** eclipses by Venus, Mercury (“transits”), eclipses of other stars, or a famous eclipse in 1919 to verify Einstein's “General Theory of Relativity”, superceding Newton

A 4000 yr old eclipse computer?



The end