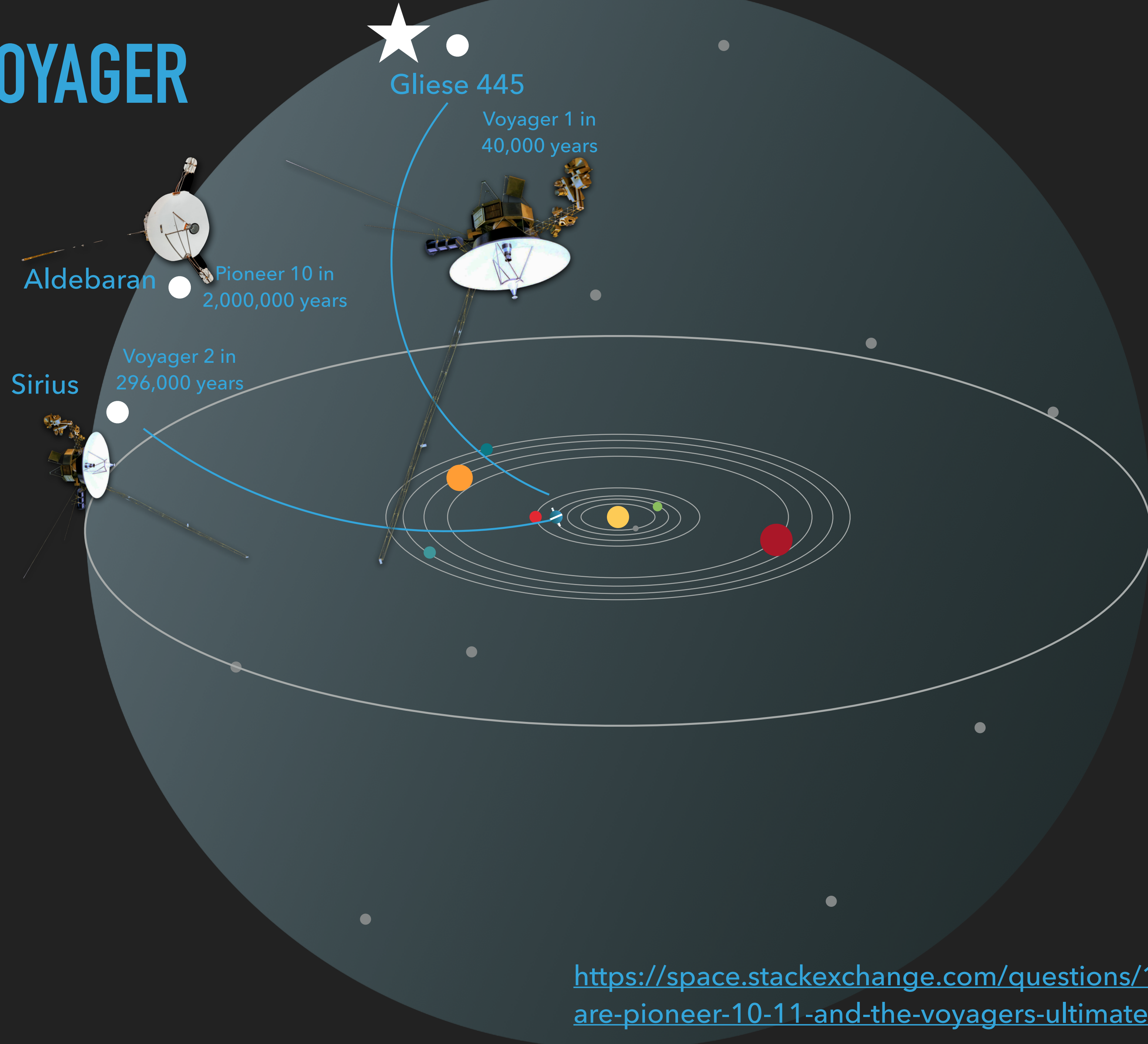


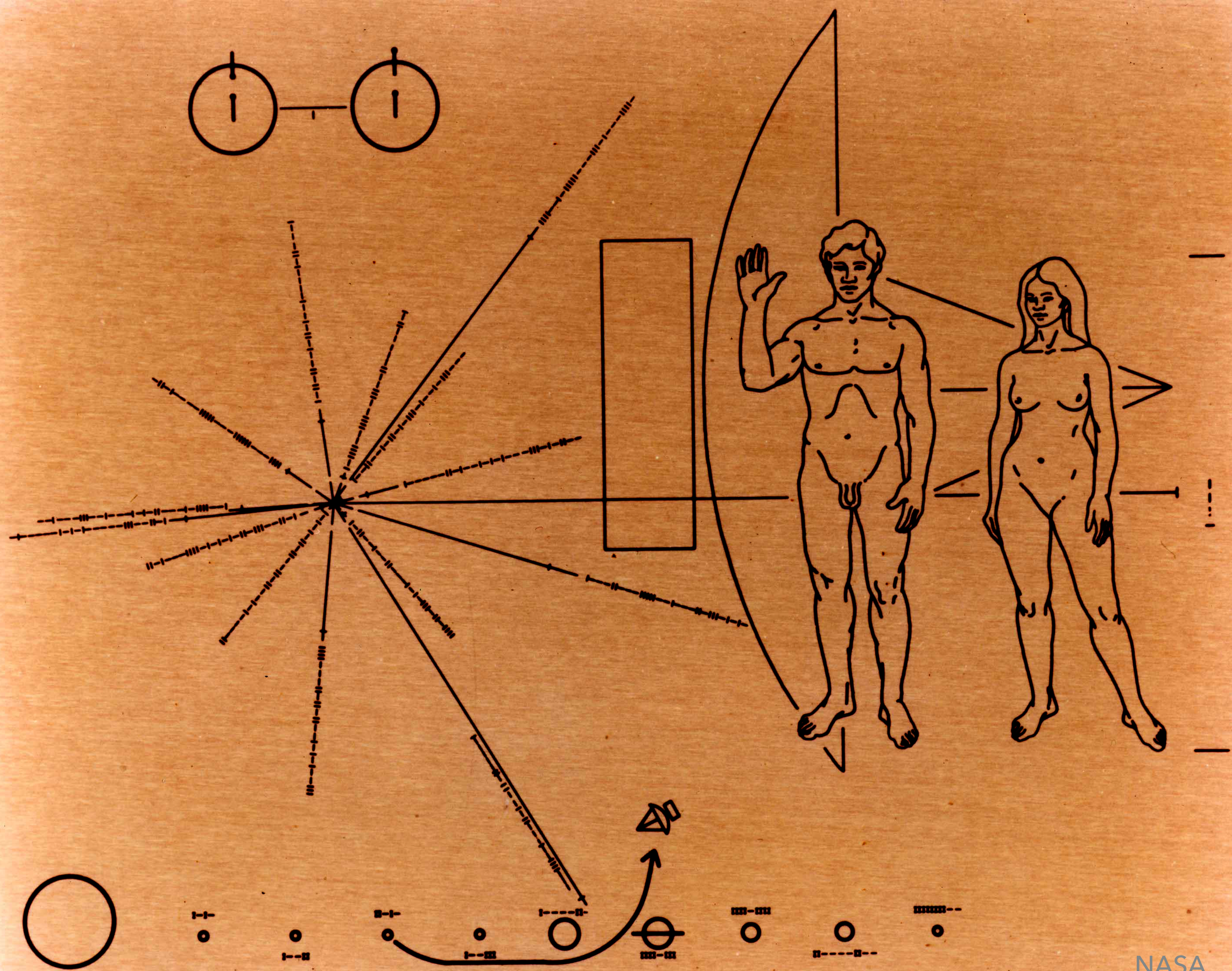
TIME IN PIONEER AND VOYAGER

VOYAGER

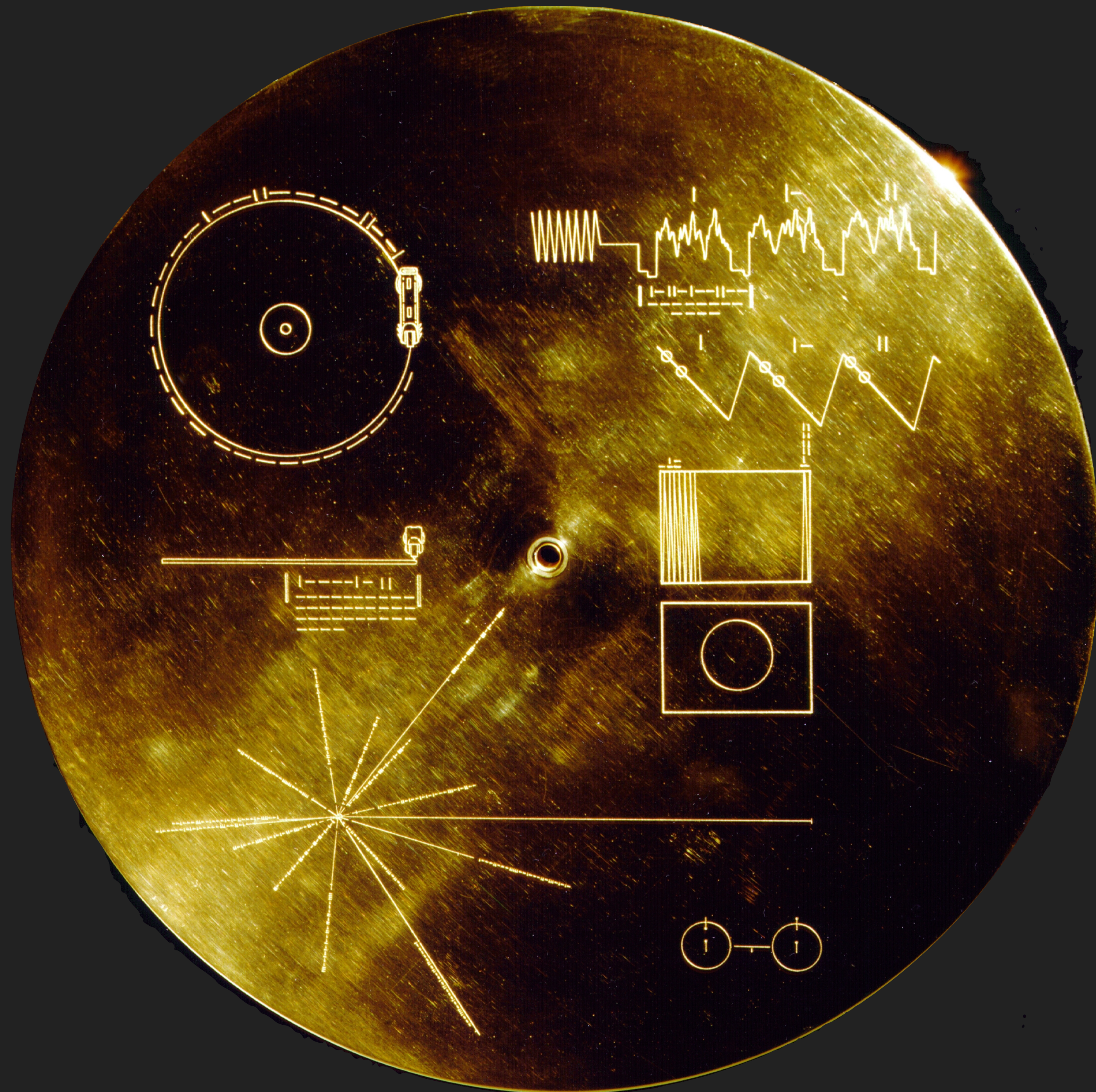


<https://space.stackexchange.com/questions/1621/where-are-pioneer-10-11-and-the-voyagers-ultimately-headed>

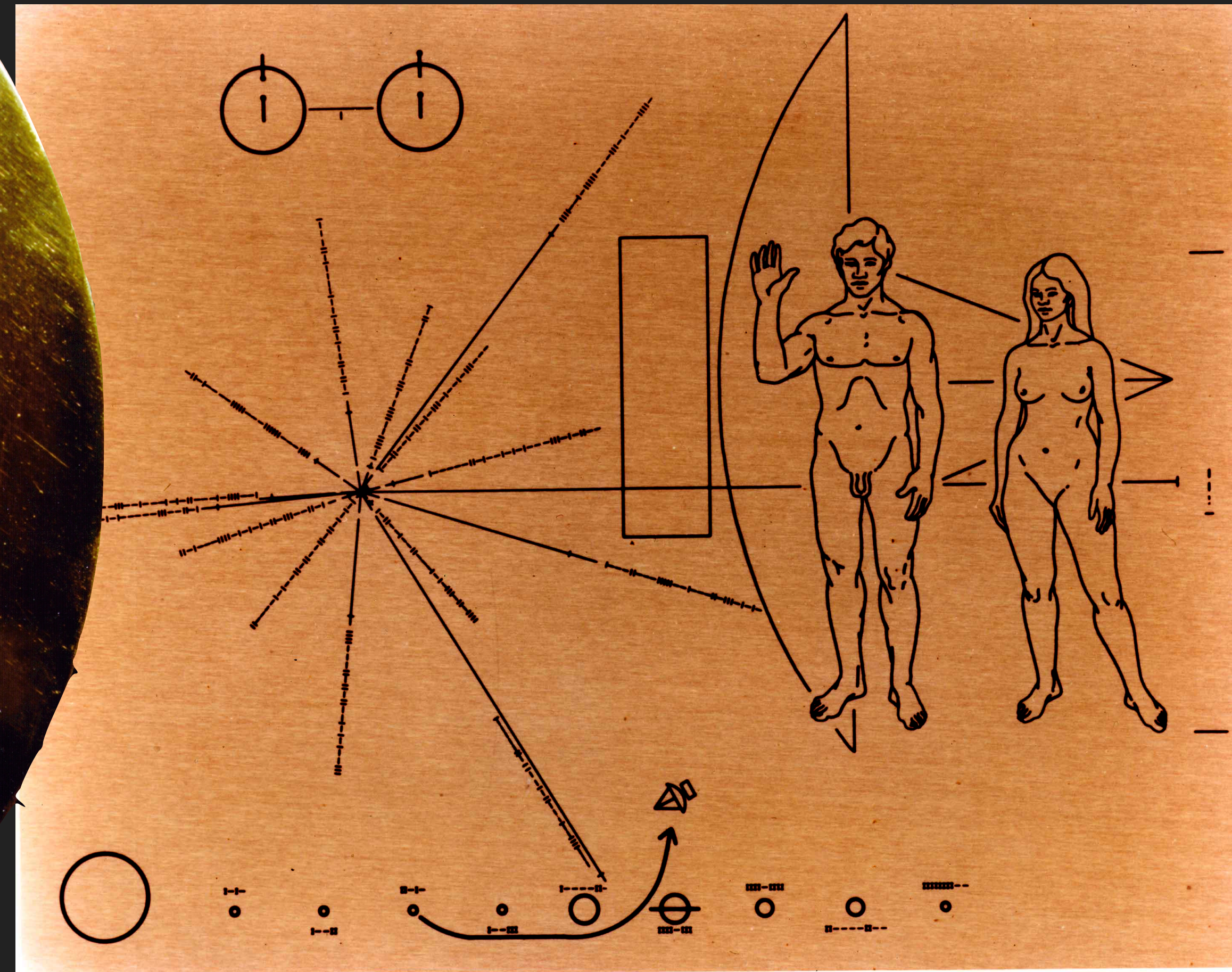
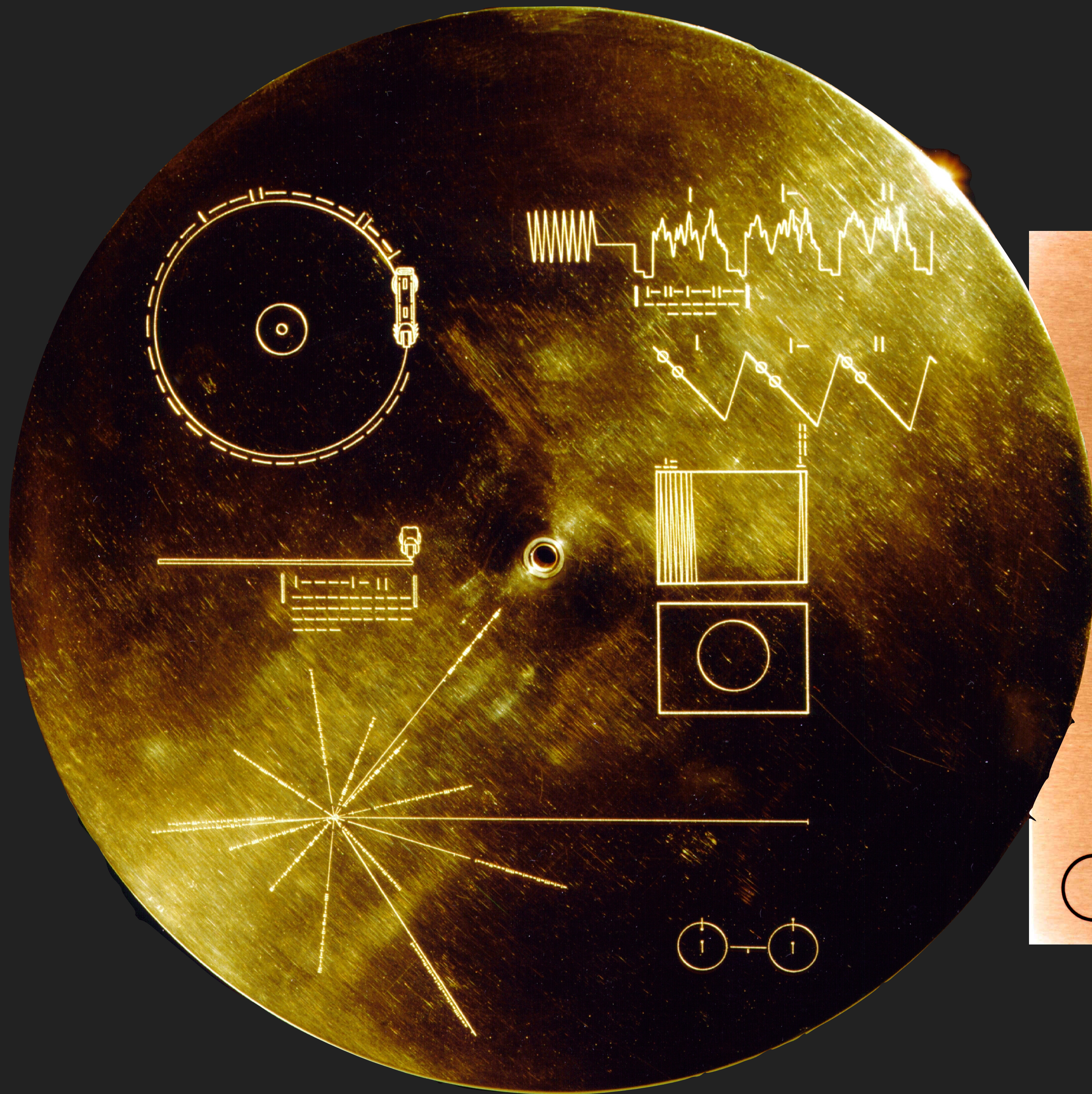
PIONEER

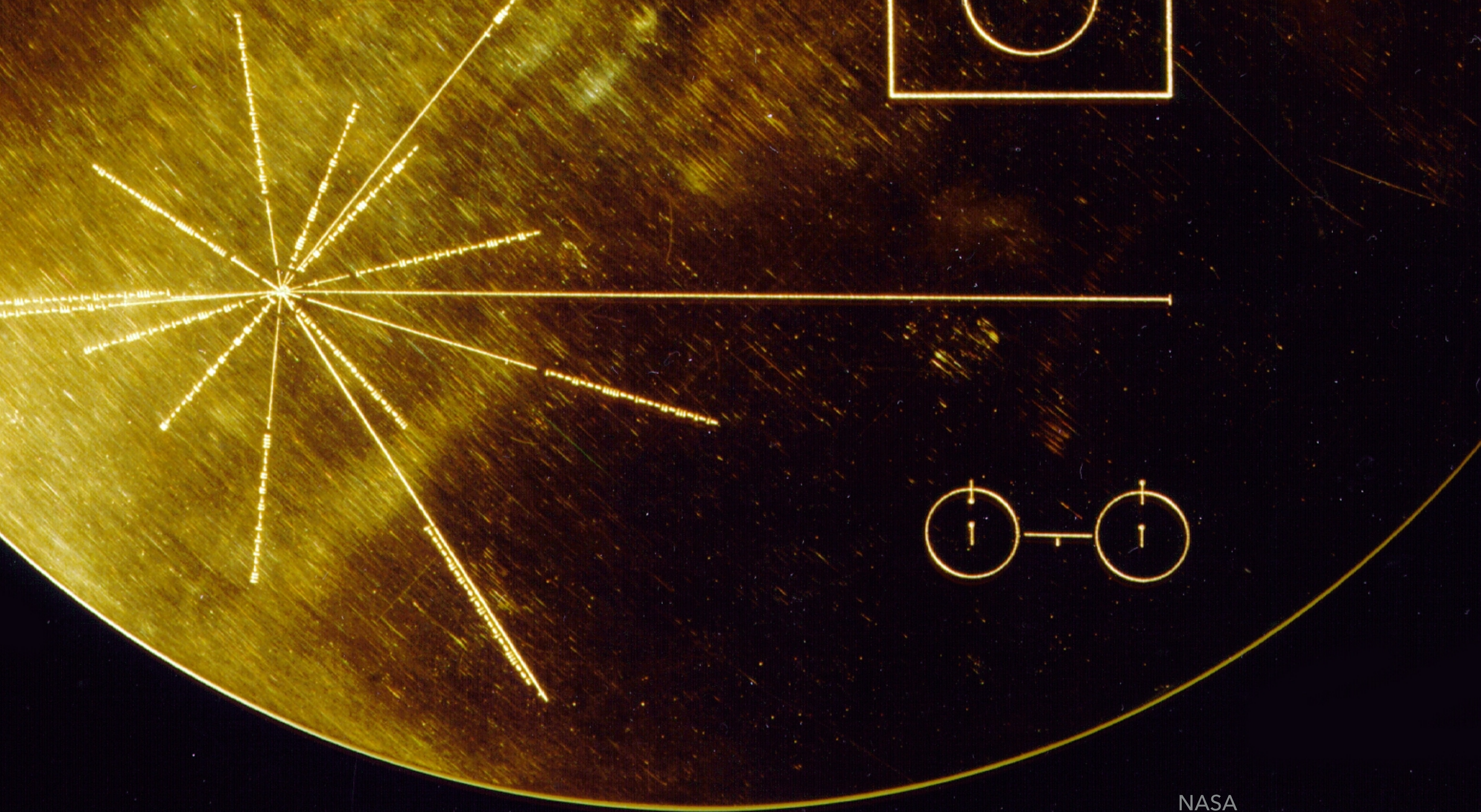


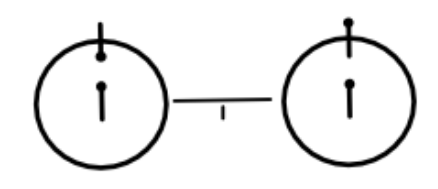
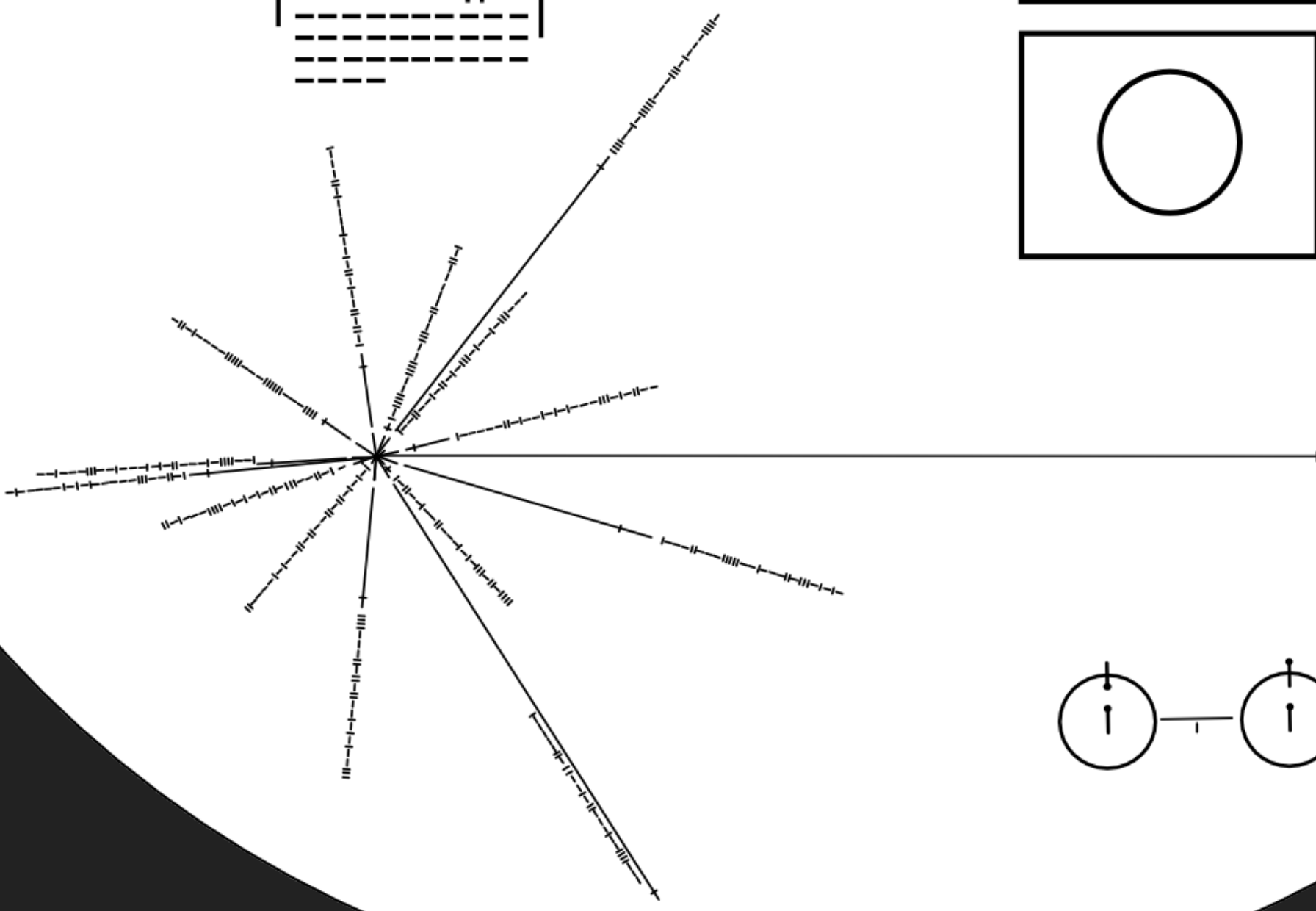
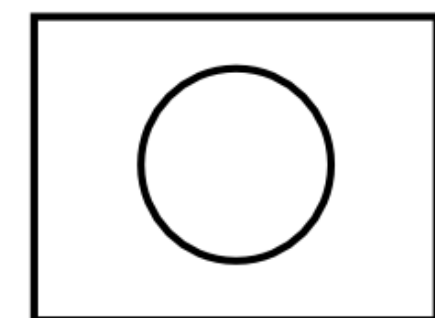
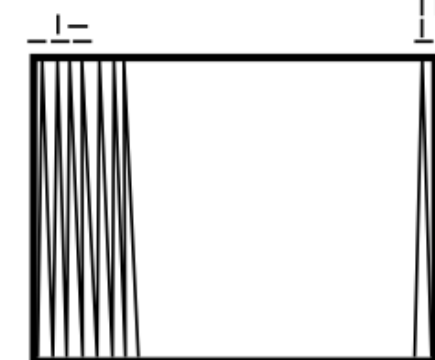
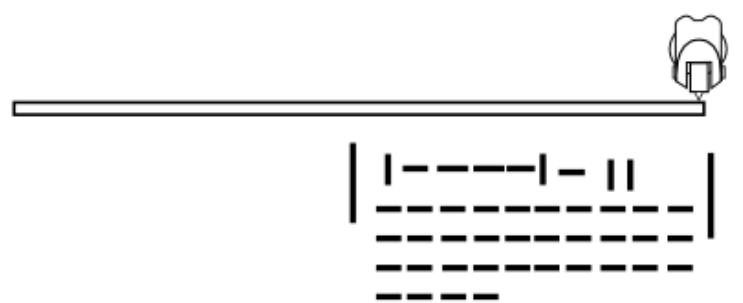
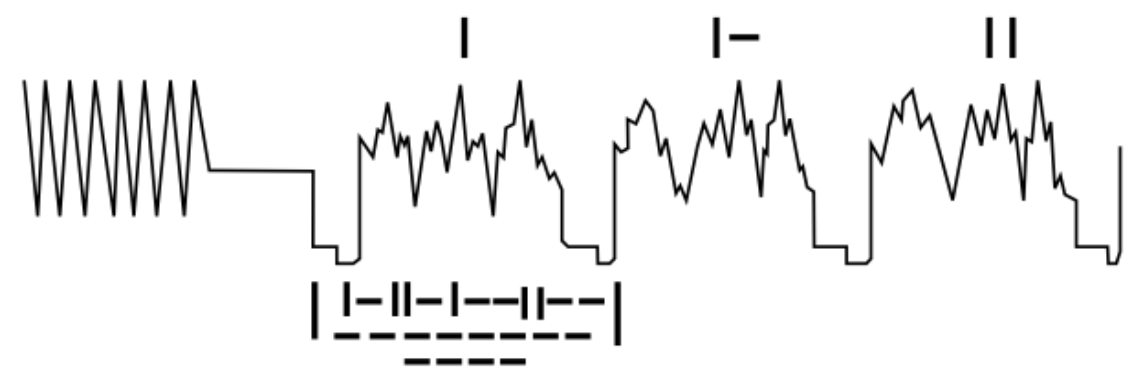
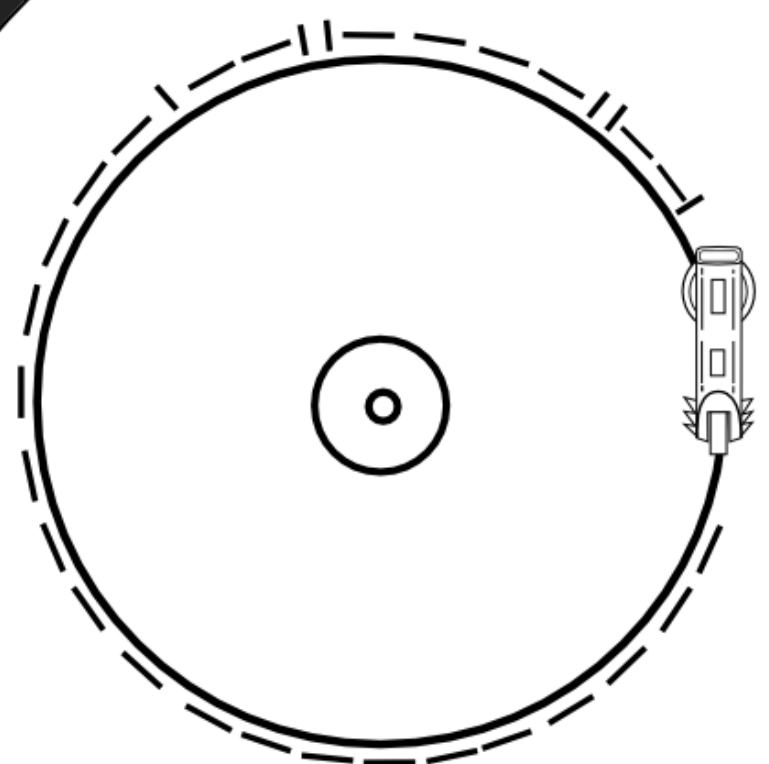
VOYAGER

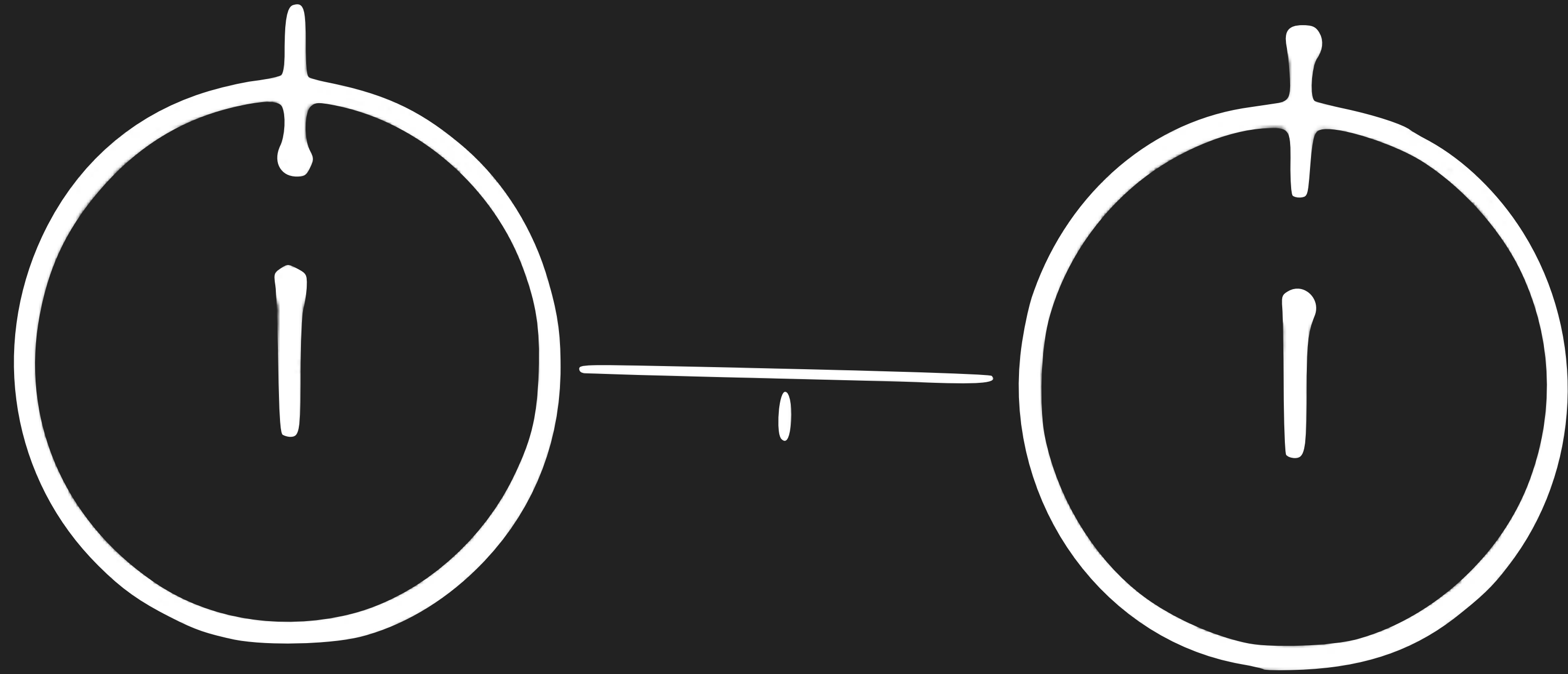


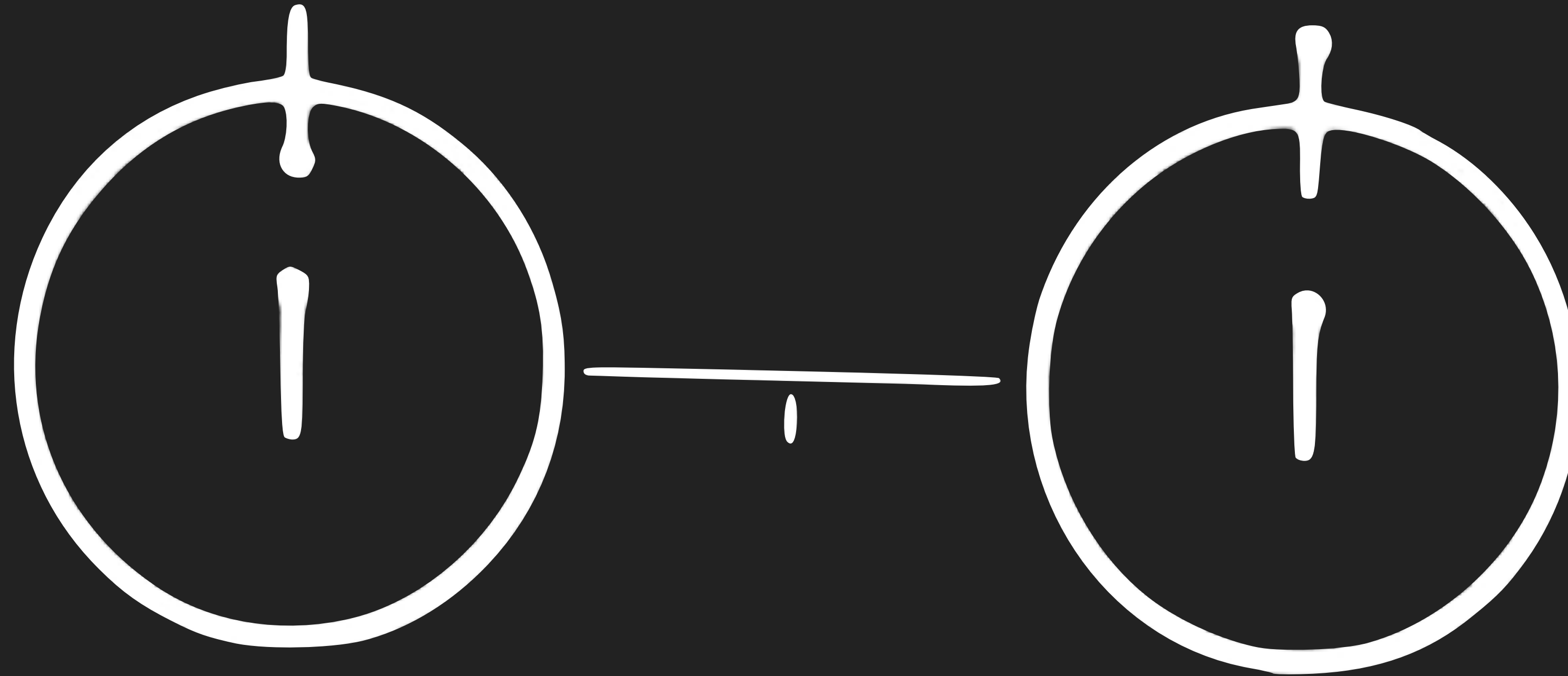
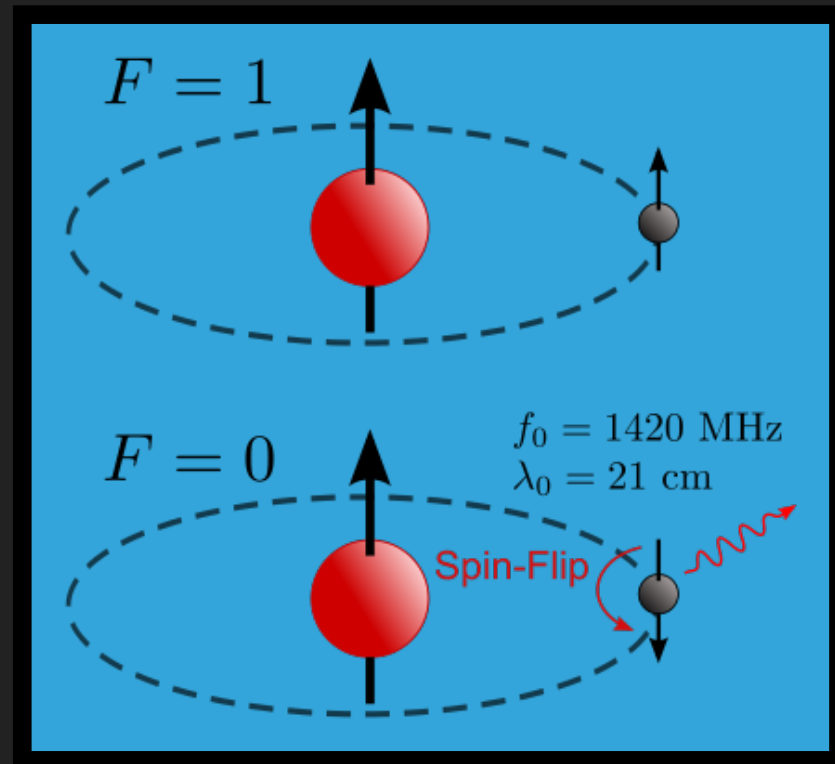
NASA



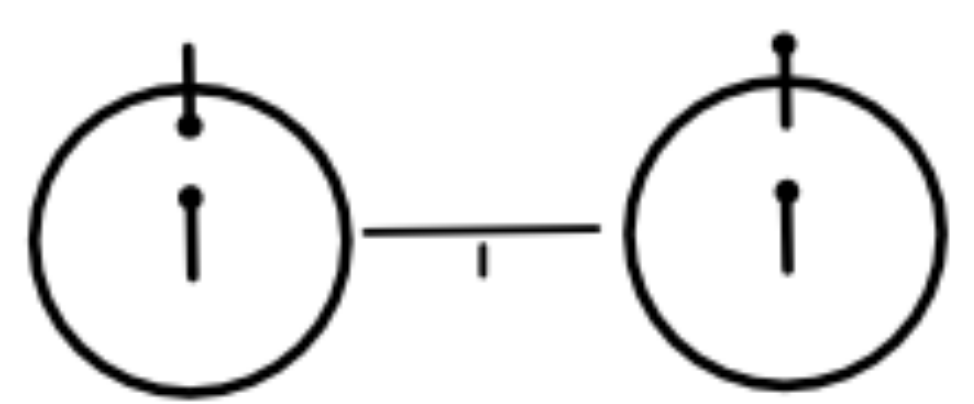
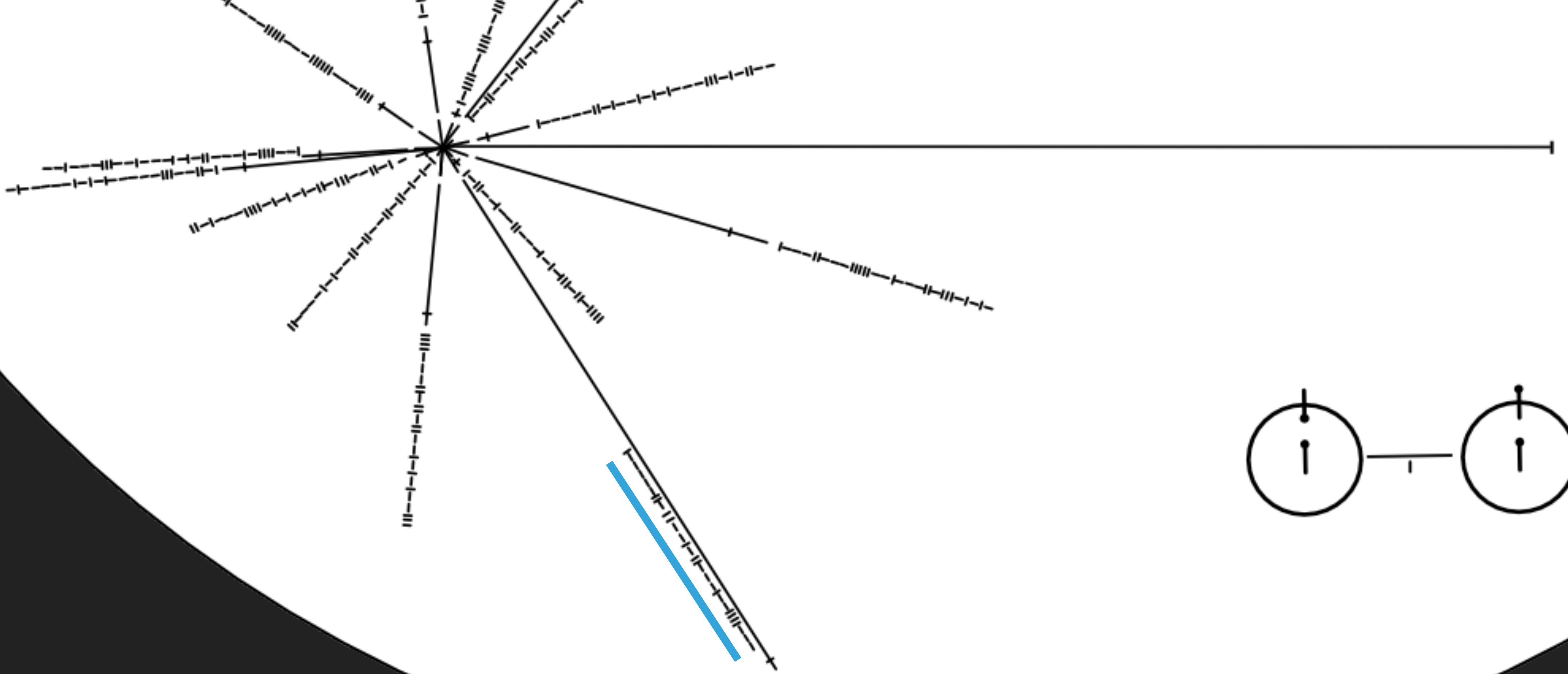


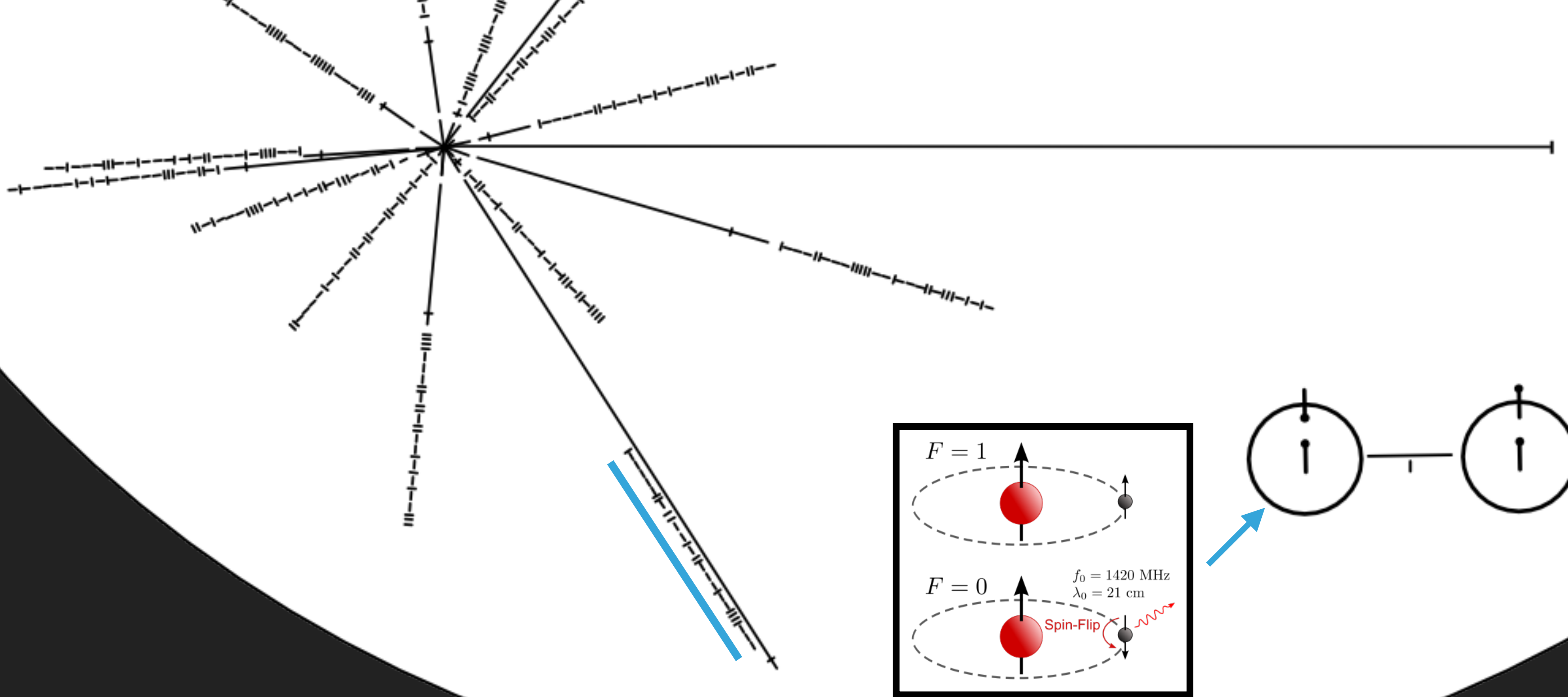






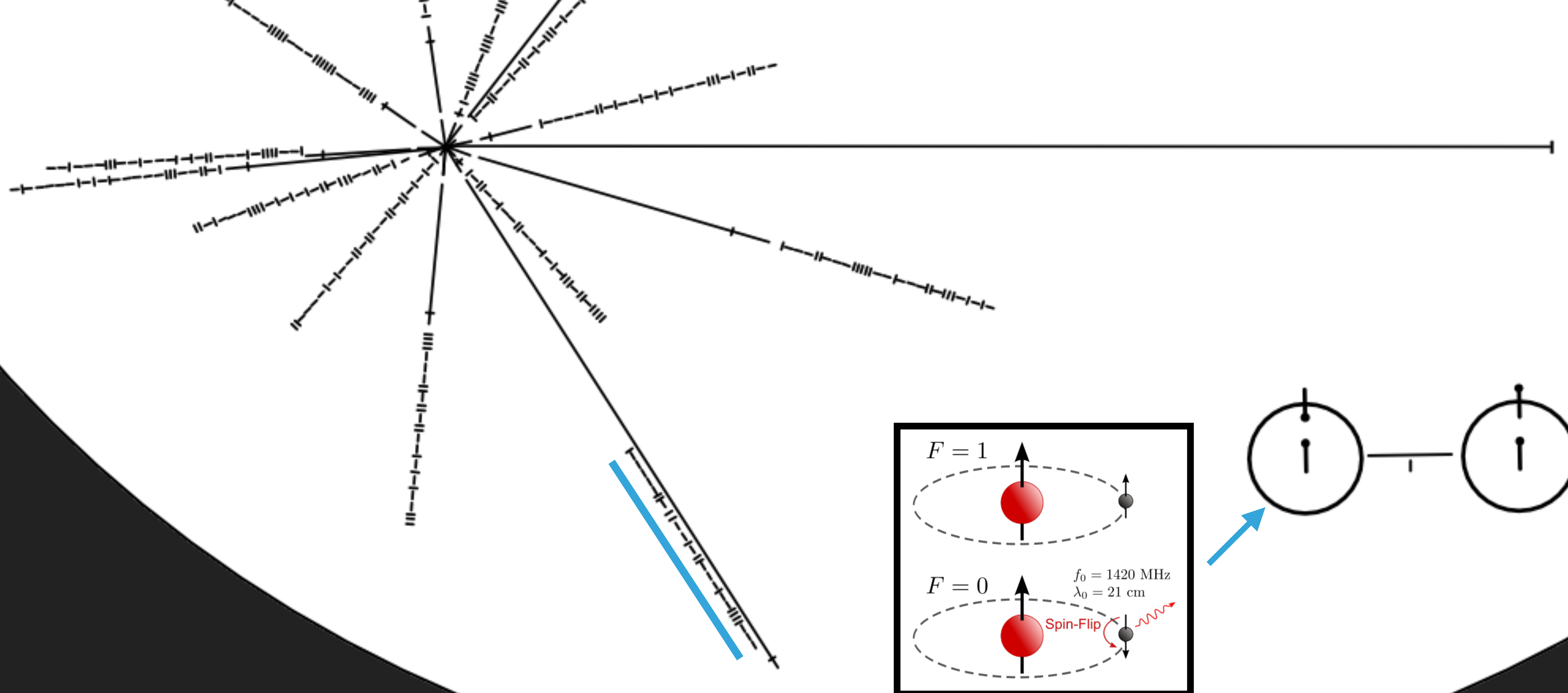
“During the 1930s, it was noticed that there was a radio 'hiss' that varied on a daily cycle and appeared to be extraterrestrial in origin. After initial suggestions that this was due to the Sun, it was observed that the radio waves seemed to propagate from the centre of the Galaxy”





$$f = 1420 \text{ MHz}$$

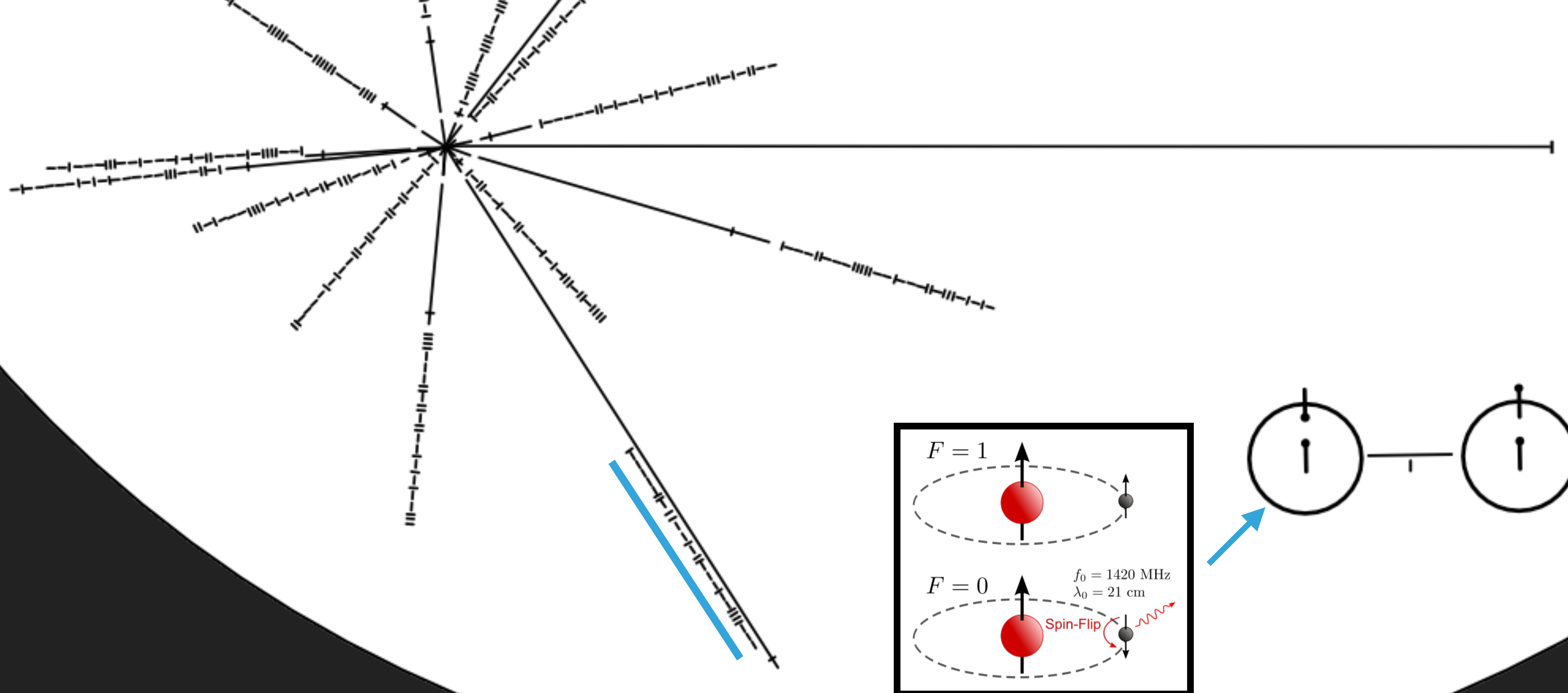
$$d = 1/f$$



100000110110010110001001111000

$$f = 1420\text{Mhz}$$

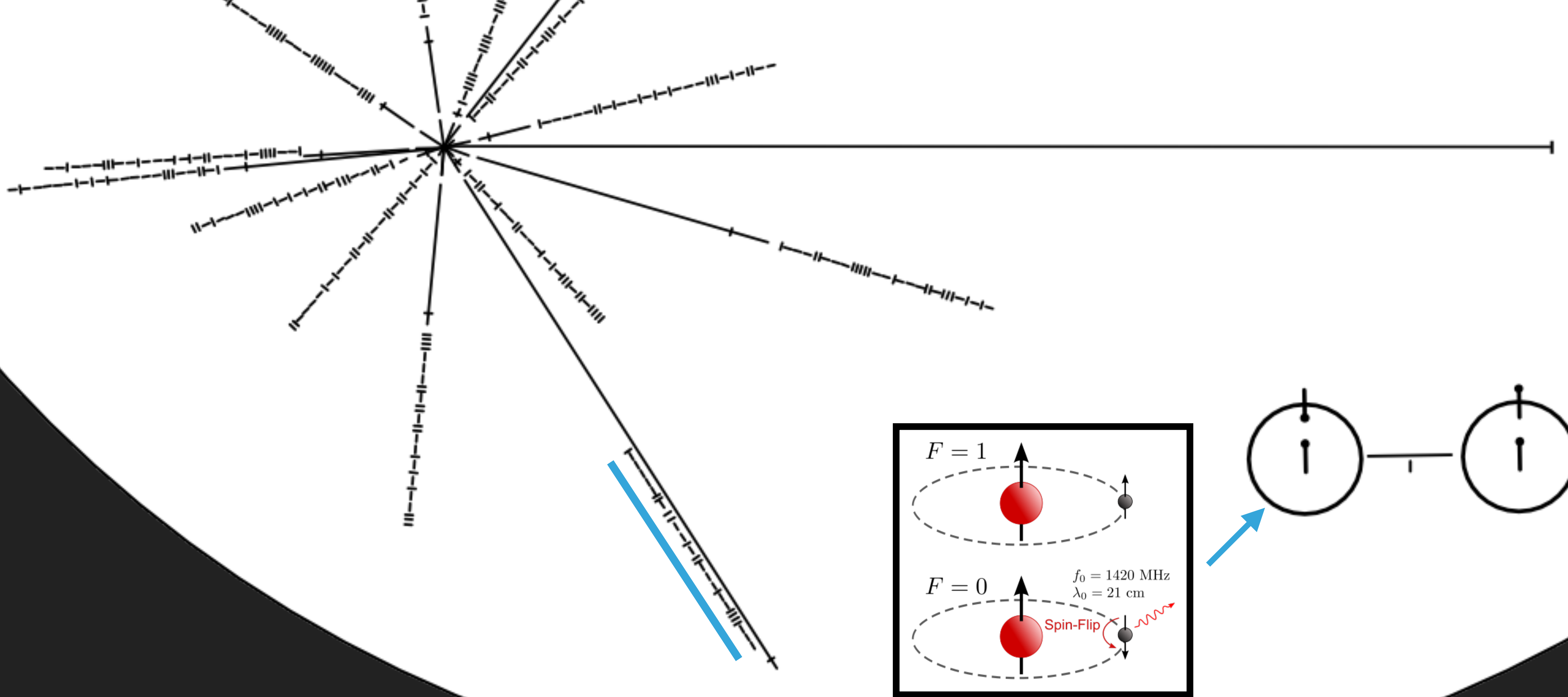
$$d = 1/f$$



100000110110010110001001111000
 = 551117432

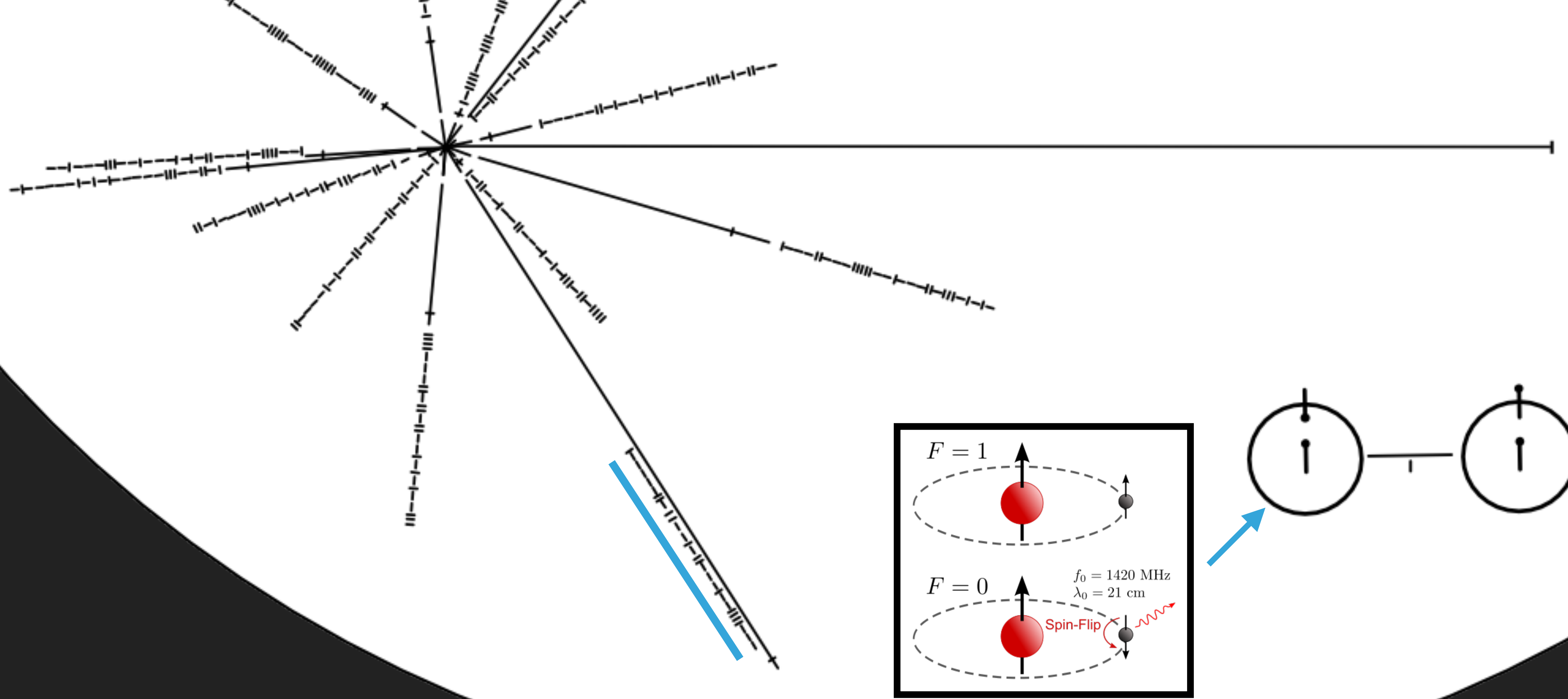
$$f = 1420\text{Mhz}$$

$$d = 1/f$$



100000110110010110001001111000
 = 551117432 * 1/f = .388s

$f = 1420\text{Mhz}$
 $d = 1/f$

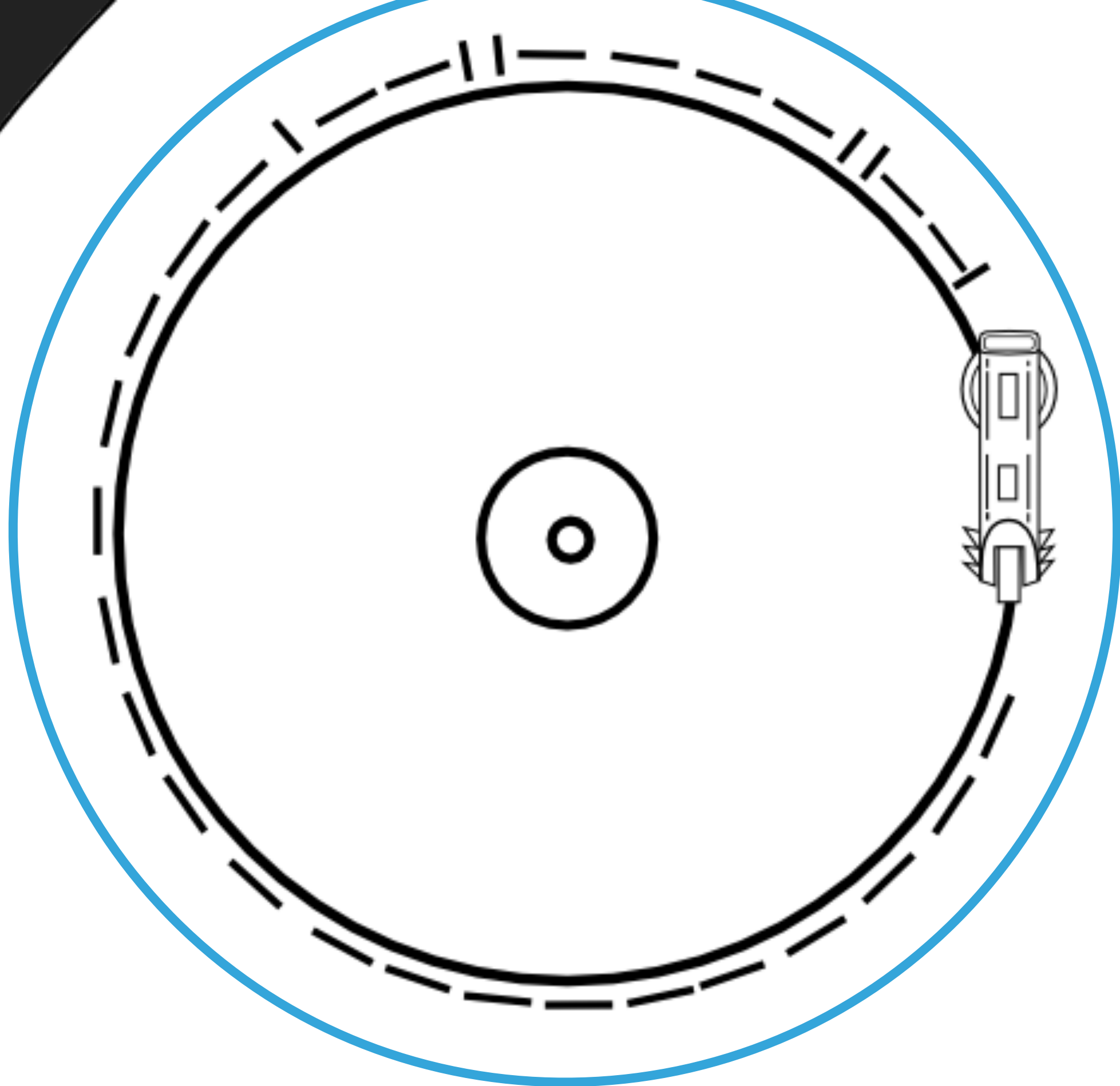


.388s = frequency of pulsar
 "1240" (aka J1243-6423)

-wikipedia

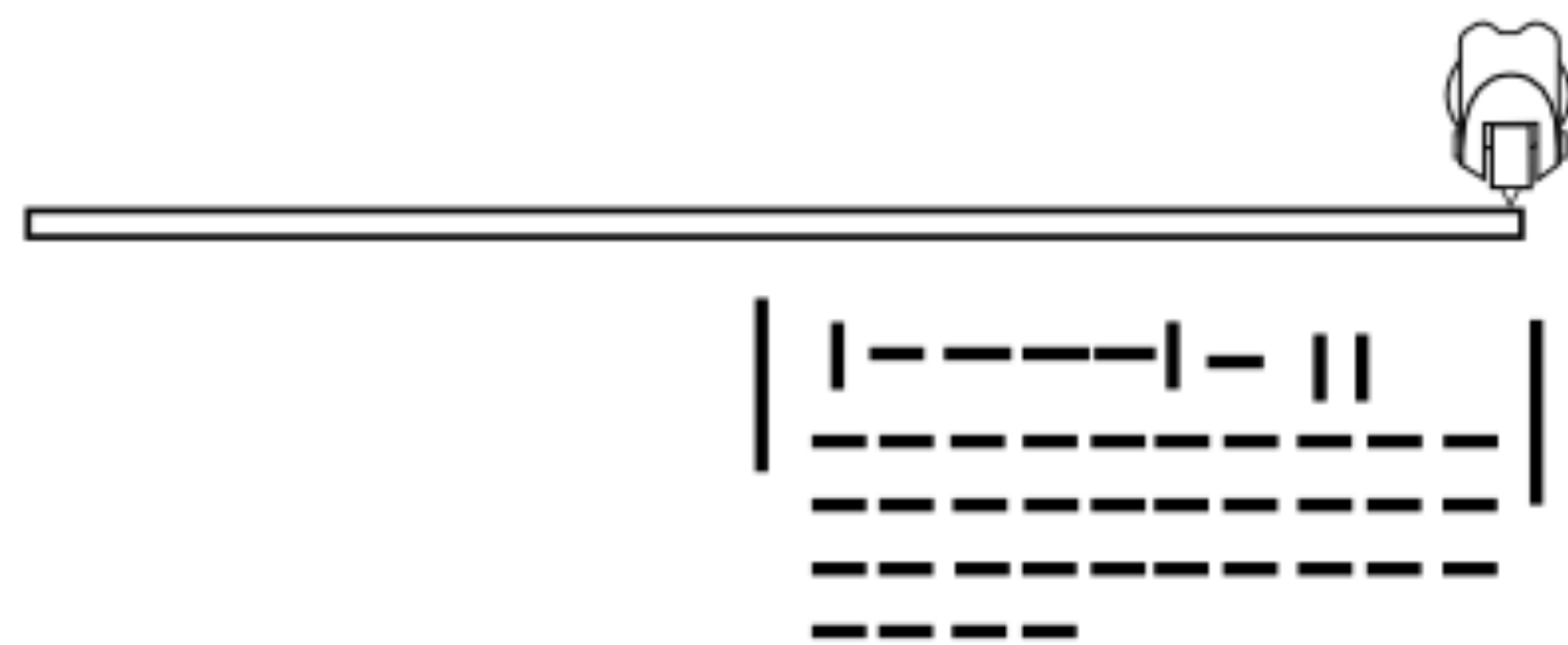
$$f = 1420\text{Mhz}$$

$$d = 1/f$$



100110000110010000000000000000000000000000000000000
 = $5113380864 * 1/1420405751.7667$
 = 3.6 seconds / revolution
 = ~16RPM

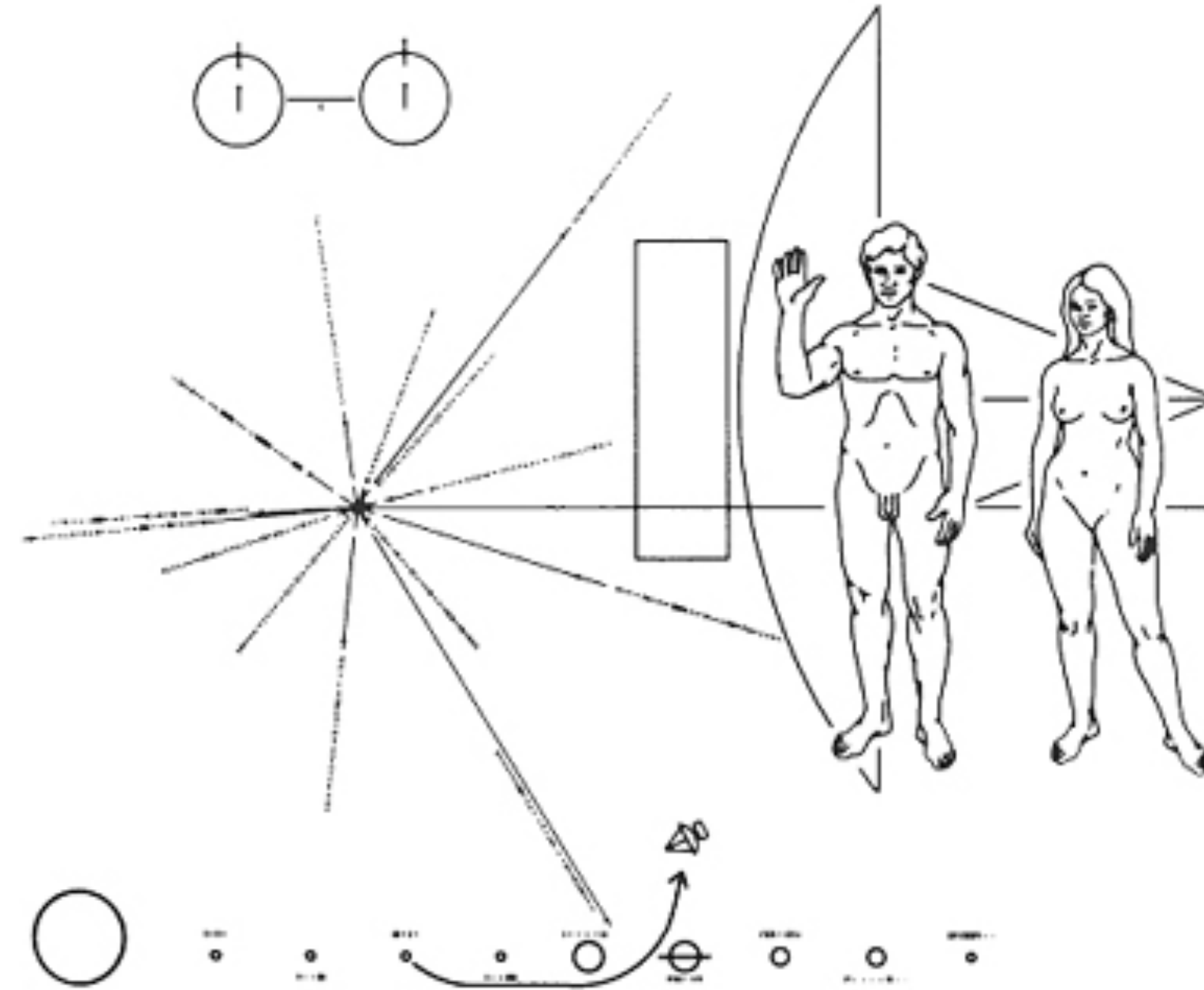
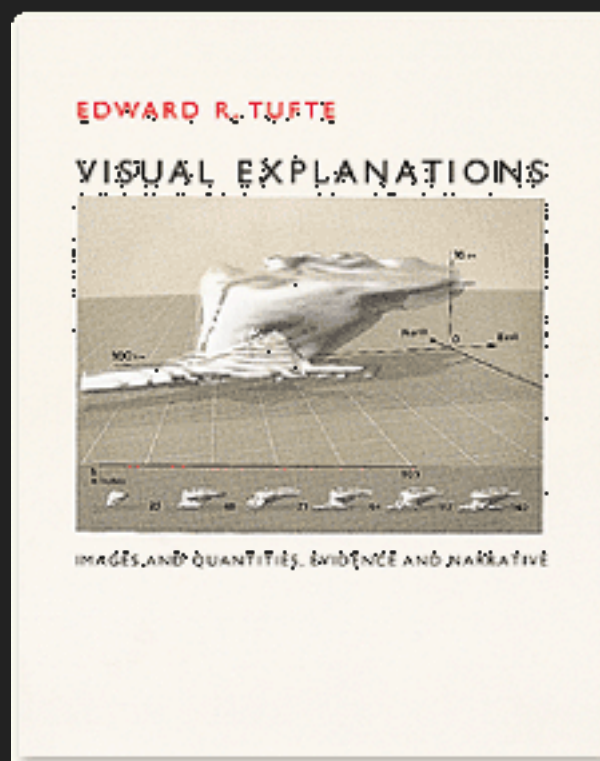
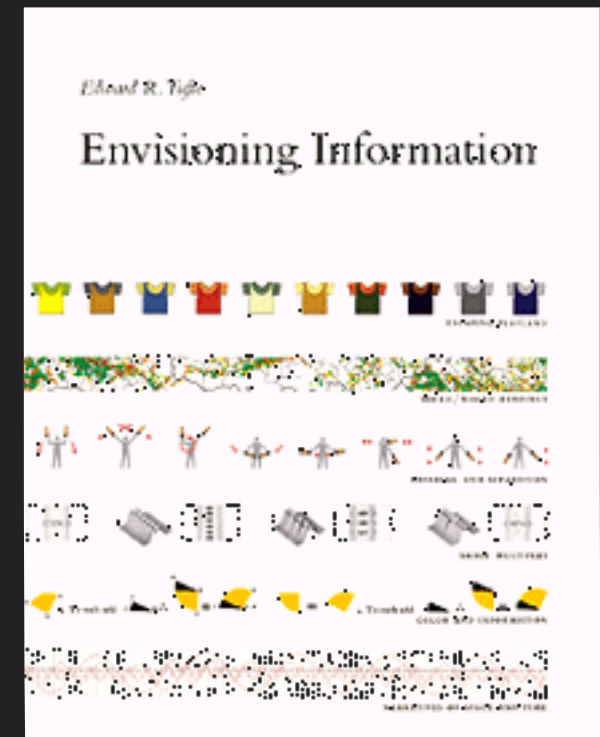
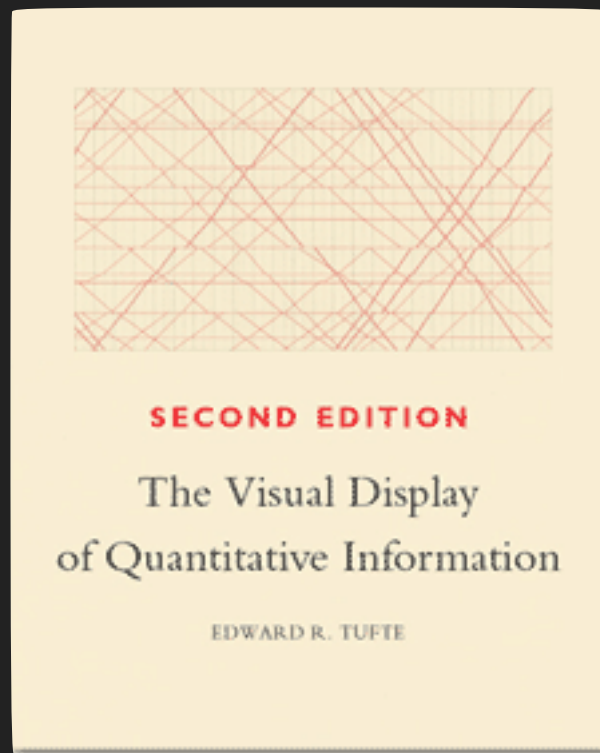
100001011 0000000000 0000000000 0000000000 0000



$= 4587025072128 * 1/1420405751.7667$
 = 3229.3 seconds
 = ~54 minutes

PIONEER SPACE PLAQUE REDESIGN

EDWARD TUFTE



Magic, the production of entertaining illusions, has an appeal quite independent of the local specifics of language or culture. In vanishing objects or levitating assistants, conjurers amaze, delight, and even shock their audiences by the apparent violation of the universal laws of nature and our daily experience of those laws. Since the principles of physics hold everywhere, magic is conceivably a cosmological entertainment, with the wonder induced by theatrical illusions appreciated by all, regardless of planetary system. Accordingly the plaque aboard the Pioneer spacecraft for extraterrestrial scrutiny billions of years from now might have escaped from its conspicuously anthropocentric gestures by showing instead the universally familiar Amazing Levitation Trick.

<https://www.edwardtufte.com>

**HOW BIG IS THE
UNIVERSE?**

COMIC DISTANCE LADDER

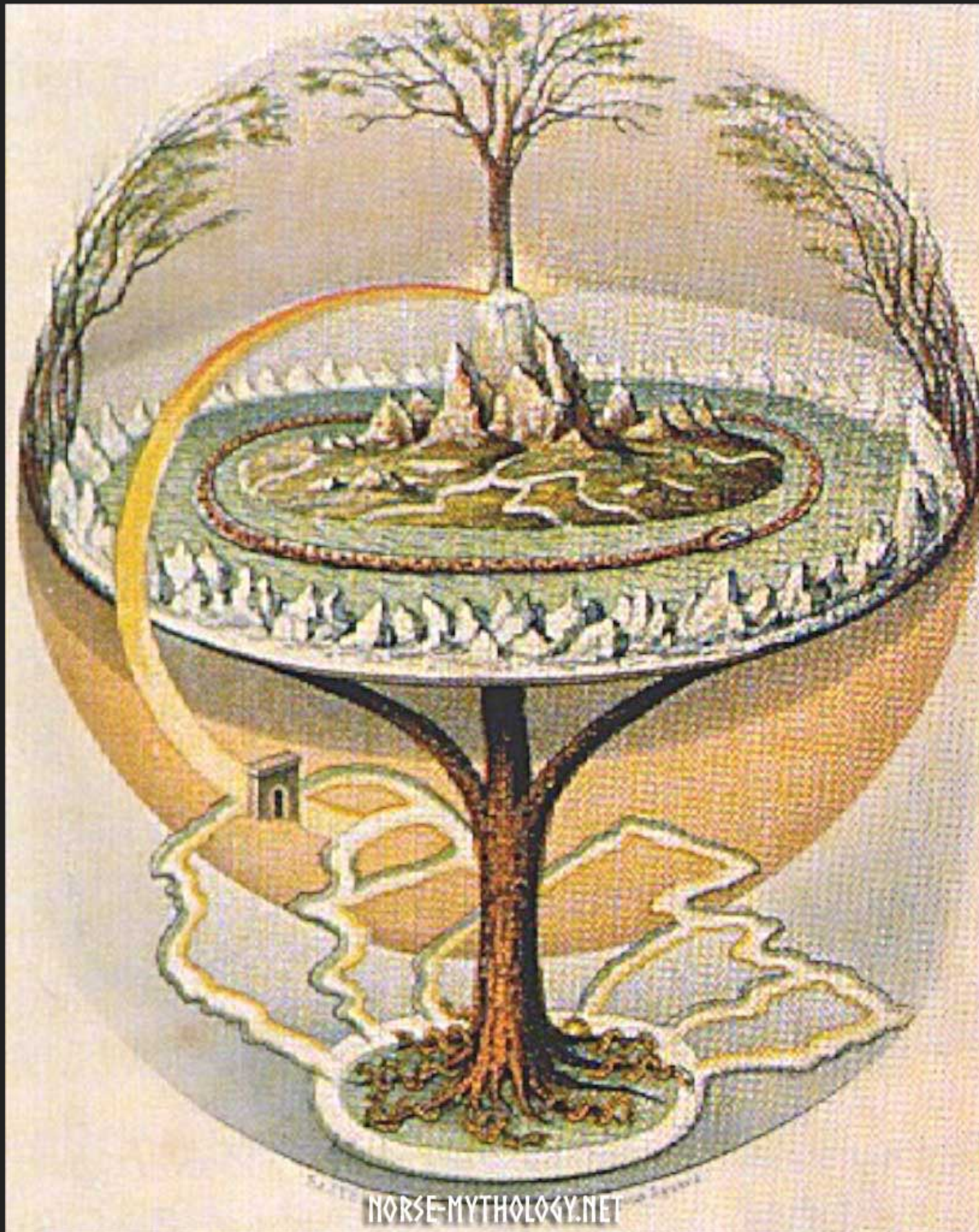
See: Mentalfloss, [The Expanding Universe: How the Universe Got Bigger As We Measured It](#)
and Terrance Tao (UCLA), [Cosmic Distance Ladder](#)

GEO METRY

EARTH

MEASURE

YGGDRASIL THE WORLD TREE NORSE



PTOLEMAIC MODEL GEOCENTRIC



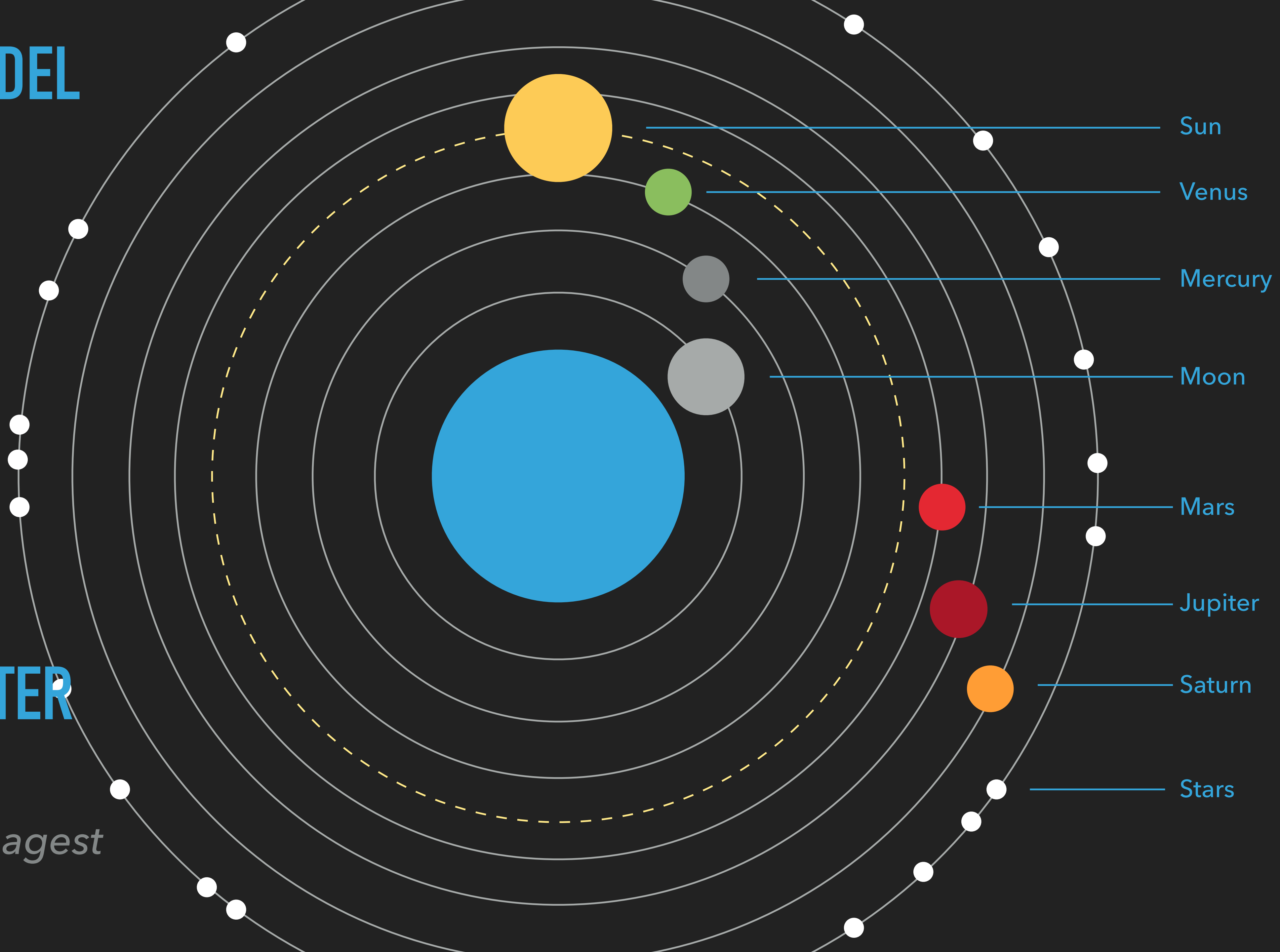
WE'RE THE CENTER
OF EVERYTHING

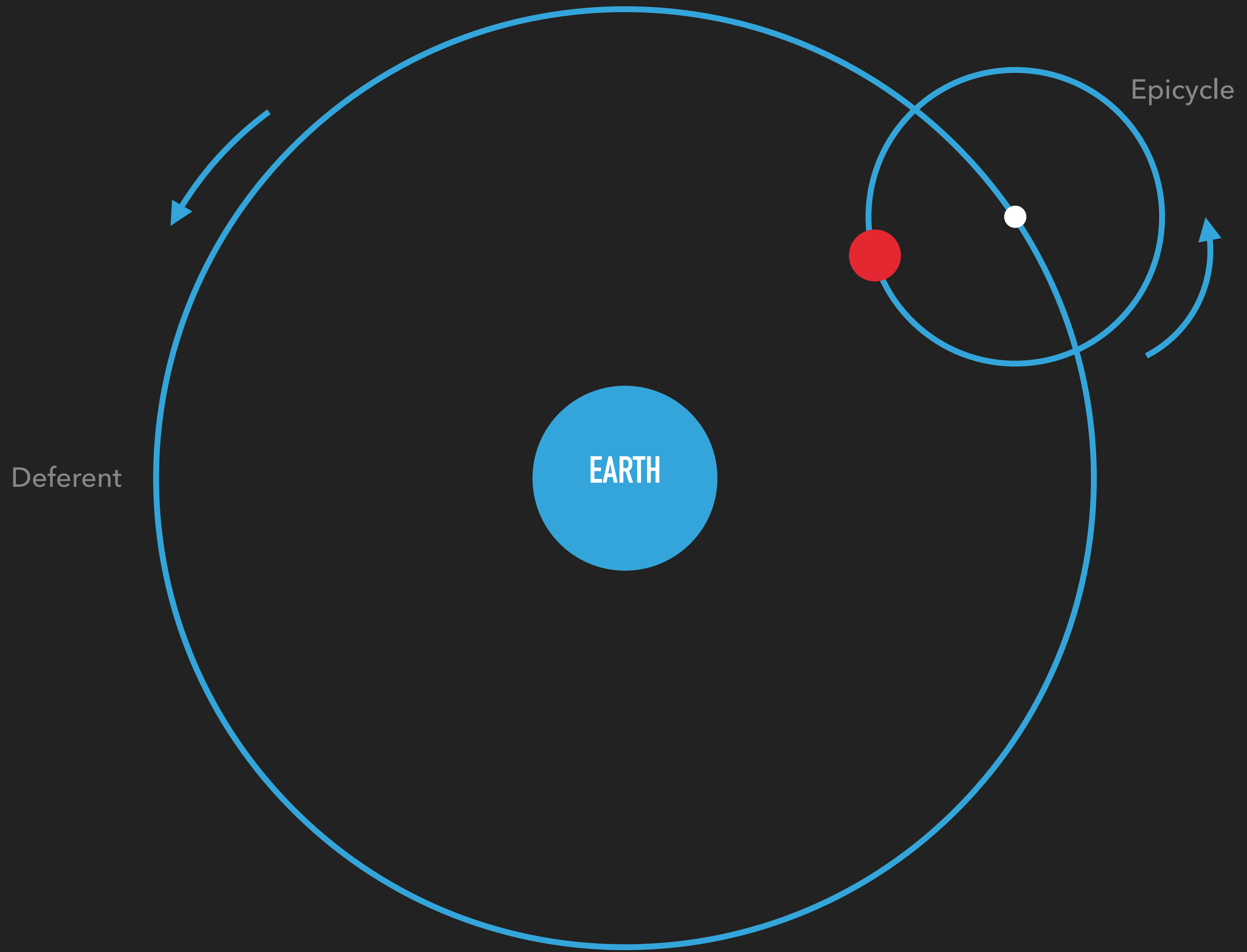
Detailed in the Almagest
~150BC

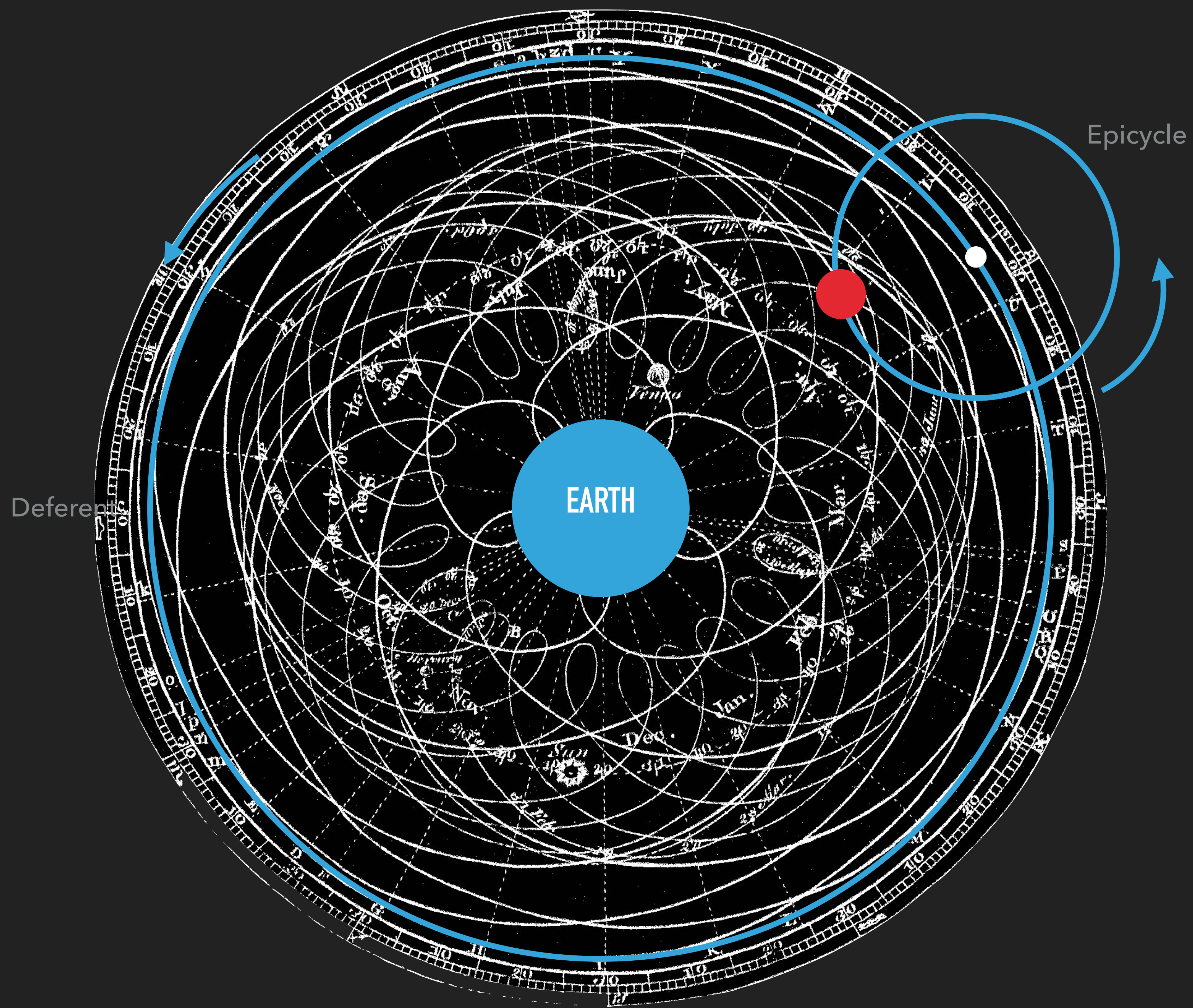
PTOLEMAIC MODEL GEOCENTRIC

**WE'RE THE CENTER
OF EVERYTHING**

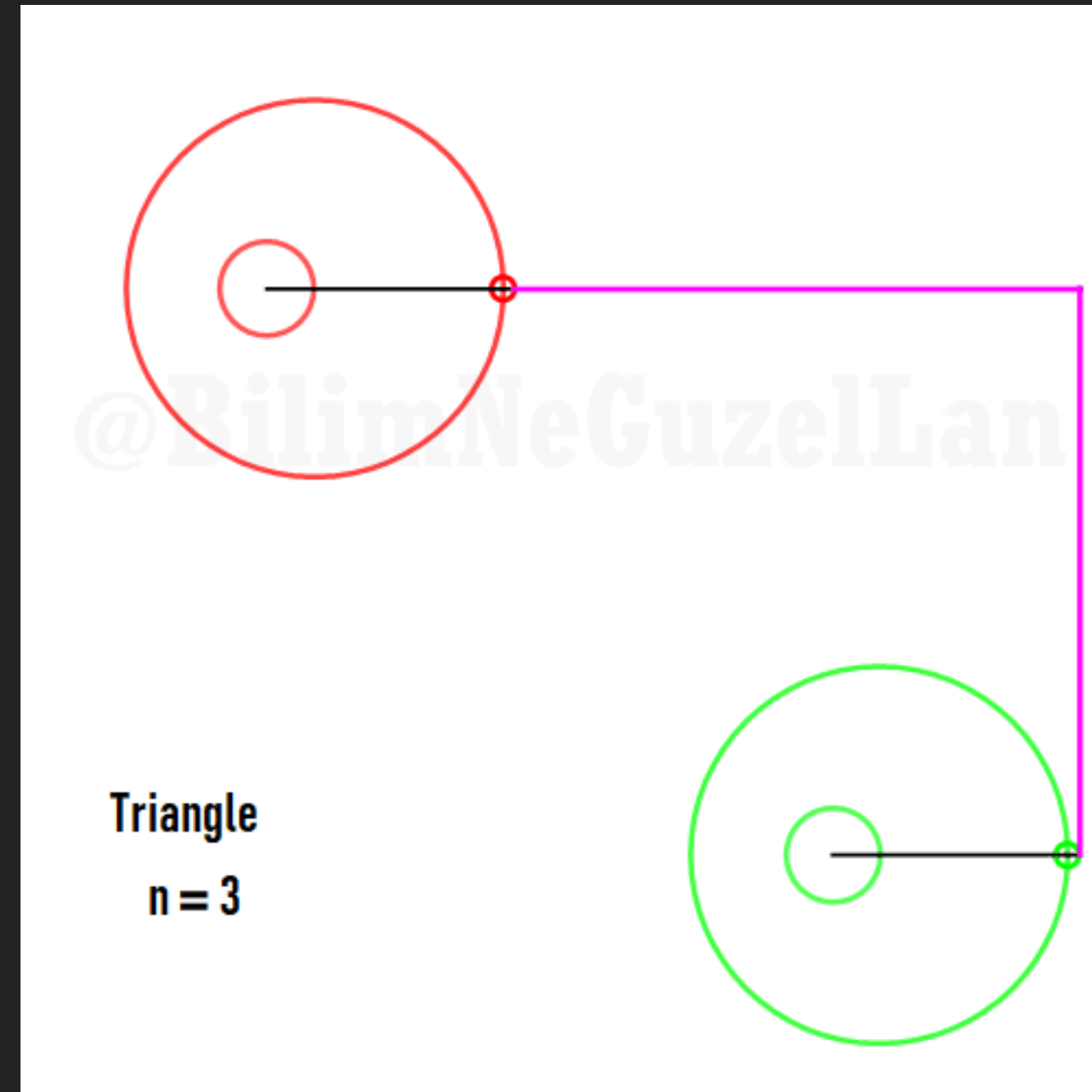
*Detailed in the Almagest
~150BC*







(ASIDE)



“PTOLEMY'S UNIVERSE WOULD FIT WITHIN THE ORBIT OF EARTH”

-Calli Arcale, for MentalFloss



ARISTARCHUS OF SAMOS

Heliocentric model, **300BC**

HIPPARCHUS OF NICAEA

Precession of the equinoxes, **150BC**



YU XI (虞喜)

"In **336 AD** Yu Xi wrote the *An Tian Lun* (安天論; *Discussion of Whether the Heavens Are At Rest or Disquisition on the Conformation of the Heavens*). He observed that the position of the sun during the winter solstice had drifted roughly one degree over the course of fifty years relative to the position of the stars."

-Wikipedia

MARAGHA ASTRONOMERS

"The Maragha school of astronomy in Ilkhanid-era Persia further developed 'non-Ptolemaic' planetary models involving Earth's rotation. Notable astronomers of this school are Al-Urdi (d. **1266**) Al-Katibi (d. 1277), and Al-Tusi (d. 1274)."

-Wikipedia

COPERNICAN MODEL

THE SUN IS THE CENTER, BUT
WE'RE STILL PRETTY SPECIAL

Detailed in *On the Revolutions of the Celestial Spheres*
1543CE



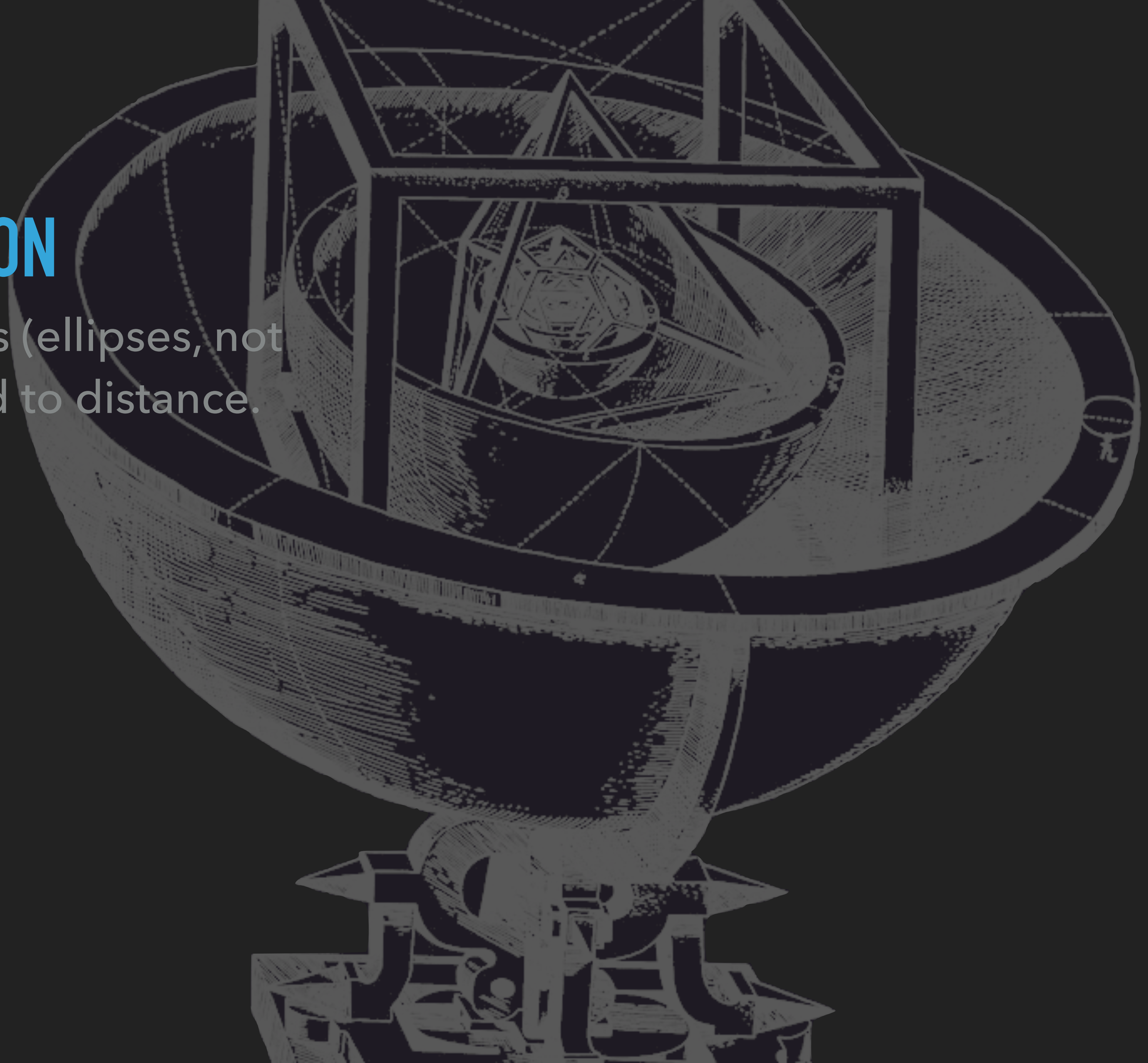
KEPLER

1609

LAWS OF PLANETARY MOTION

These set the true shape of orbits (ellipses, not circles) and related orbital period to distance.

Detailed in Astronomia nova
1609CE



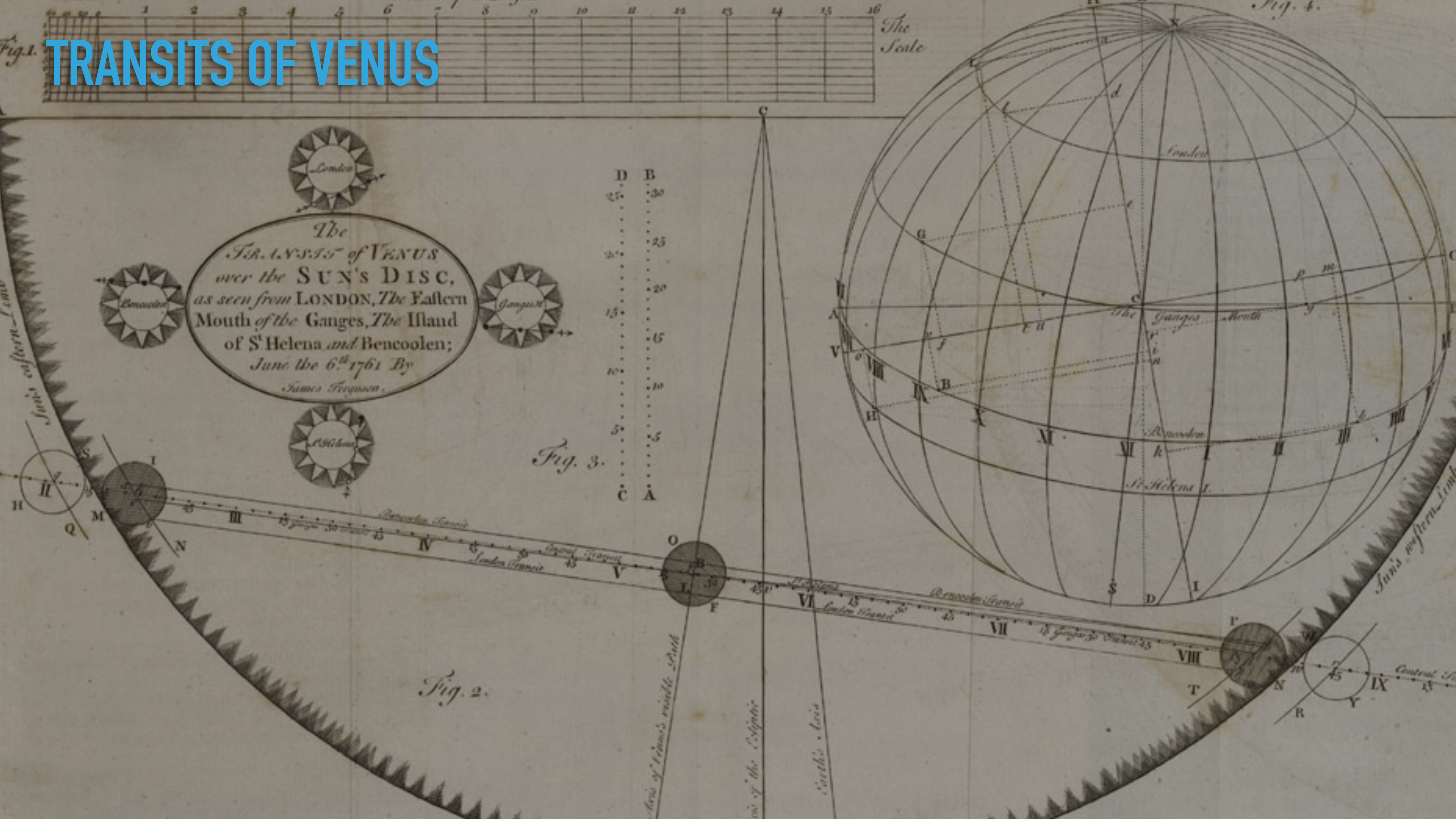
GALILEO 1610-1615 GANYMEDE, CALLISTO, IO, EUROPA SUNSPOTS

THE SUN IS THE CENTER, AND WE'RE LESS SPECIAL

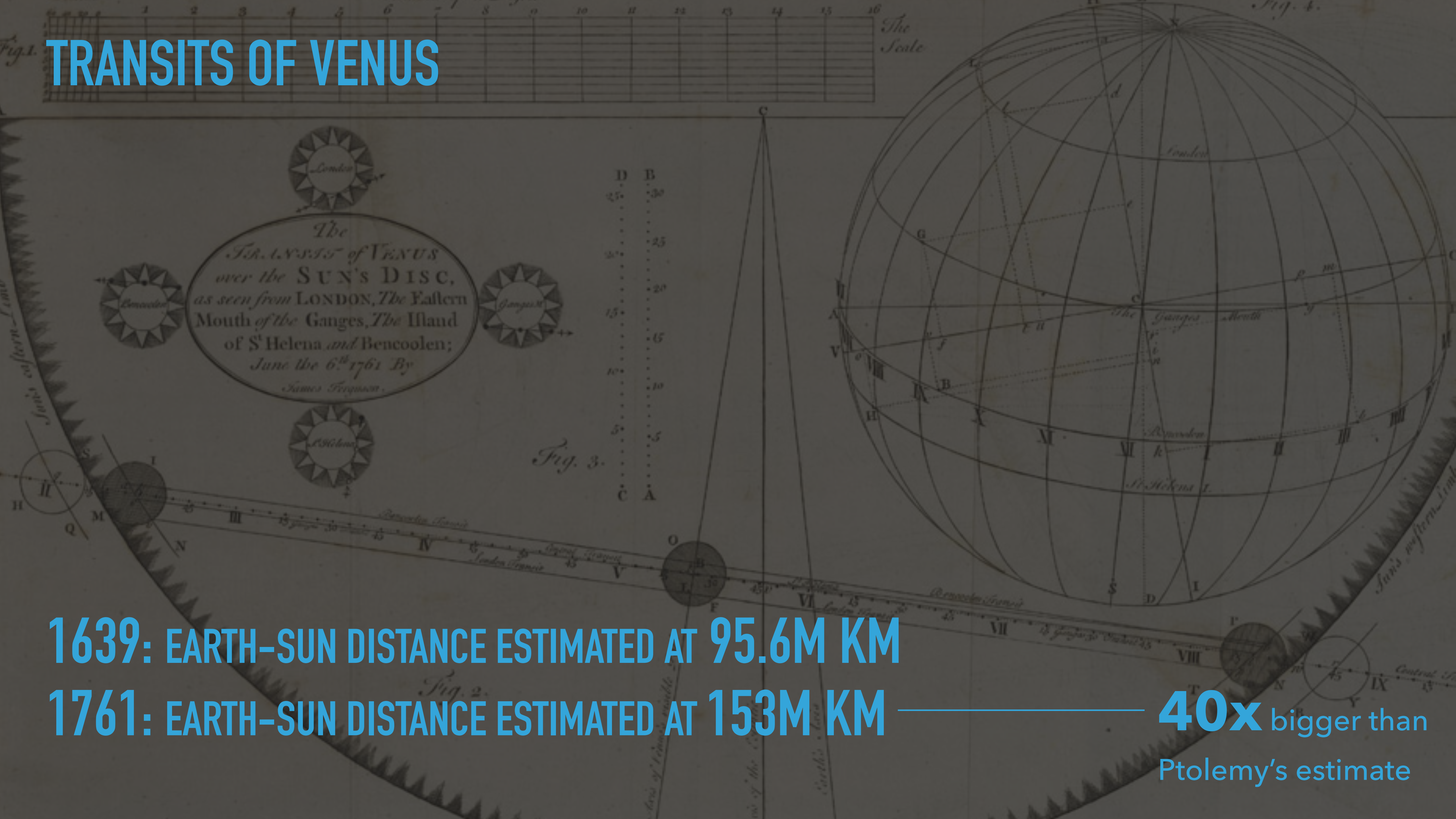
Other planets have moons, and
the sun itself rotates



TRANSITS OF VENUS



TRANSITS OF VENUS



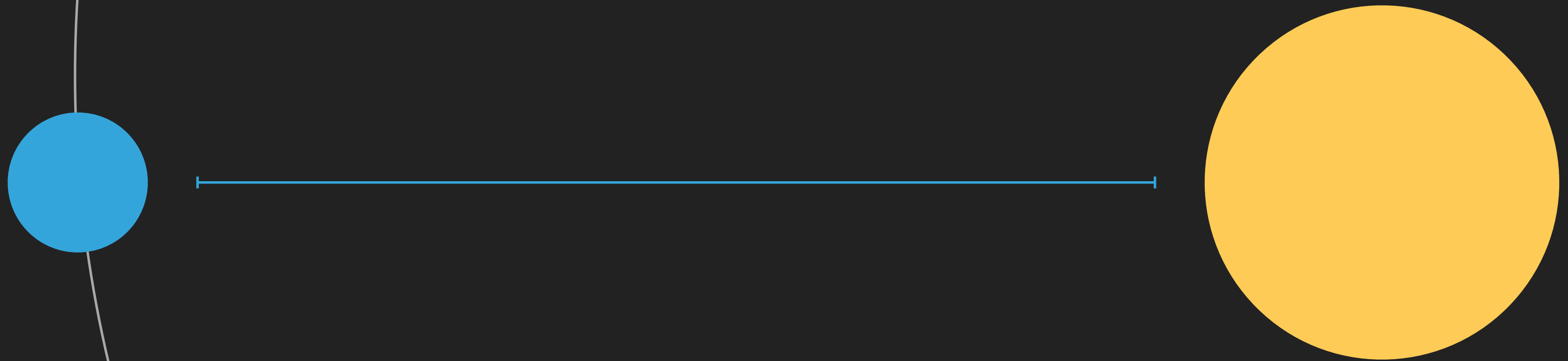
1639: EARTH-SUN DISTANCE ESTIMATED AT 95.6M KM

1761: EARTH-SUN DISTANCE ESTIMATED AT 153M KM

40x bigger than Ptolemy's estimate

149,597,900 KM

**ASTRONOMICAL UNIT (AU)
MODERN VALUE**



1600s – TITAN AND OTHER MOONS OF SATURN

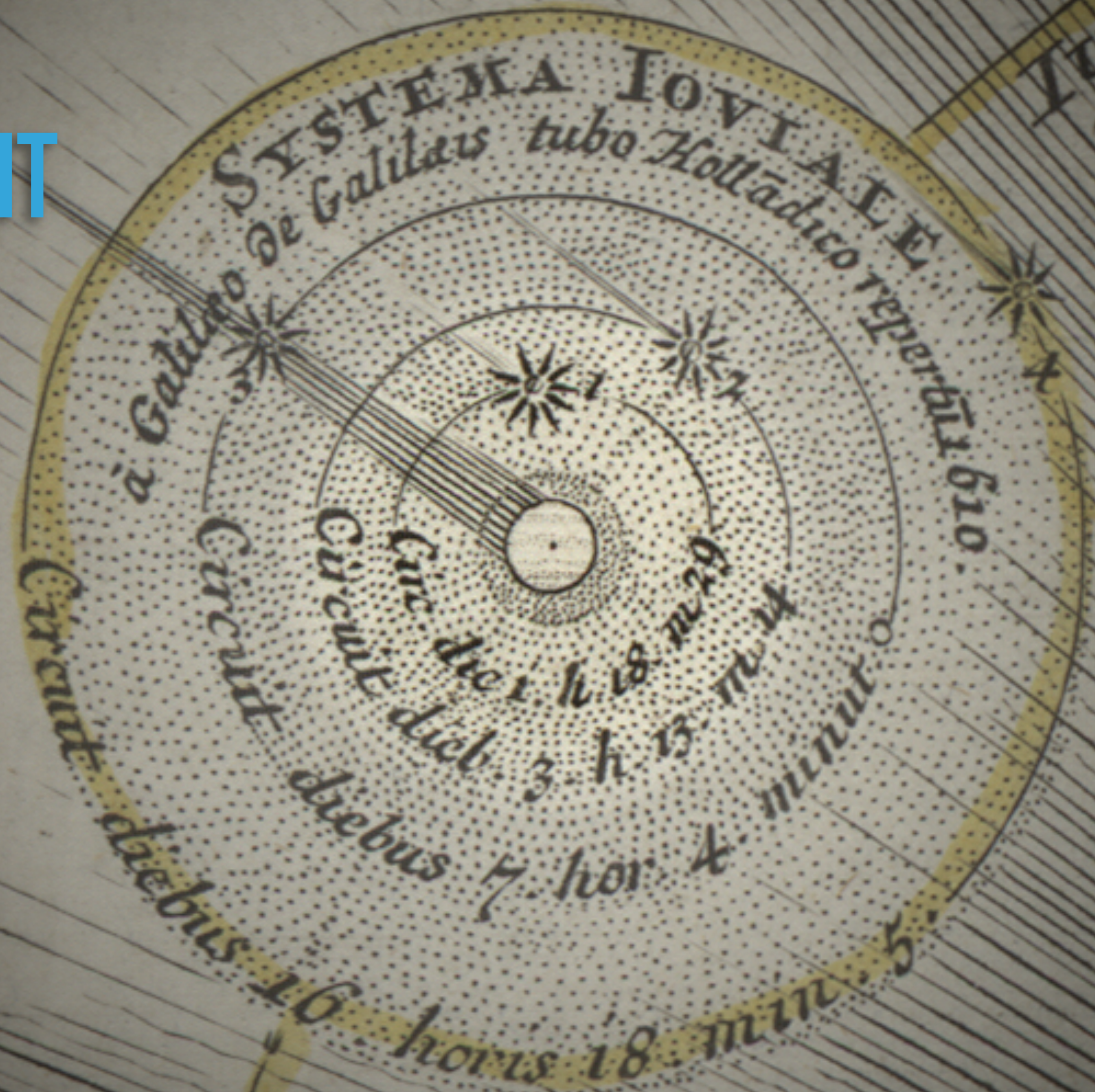
1700s – MORE PLANETS (URANUS) MORE MOONS (OR URANUS, SATURN)

1800s – CERES, NEPTUNE, THE MOONS OF MARS (PHOBOS AND DEIMOS)

RØMER

1676

FINITE SPEED OF LIGHT



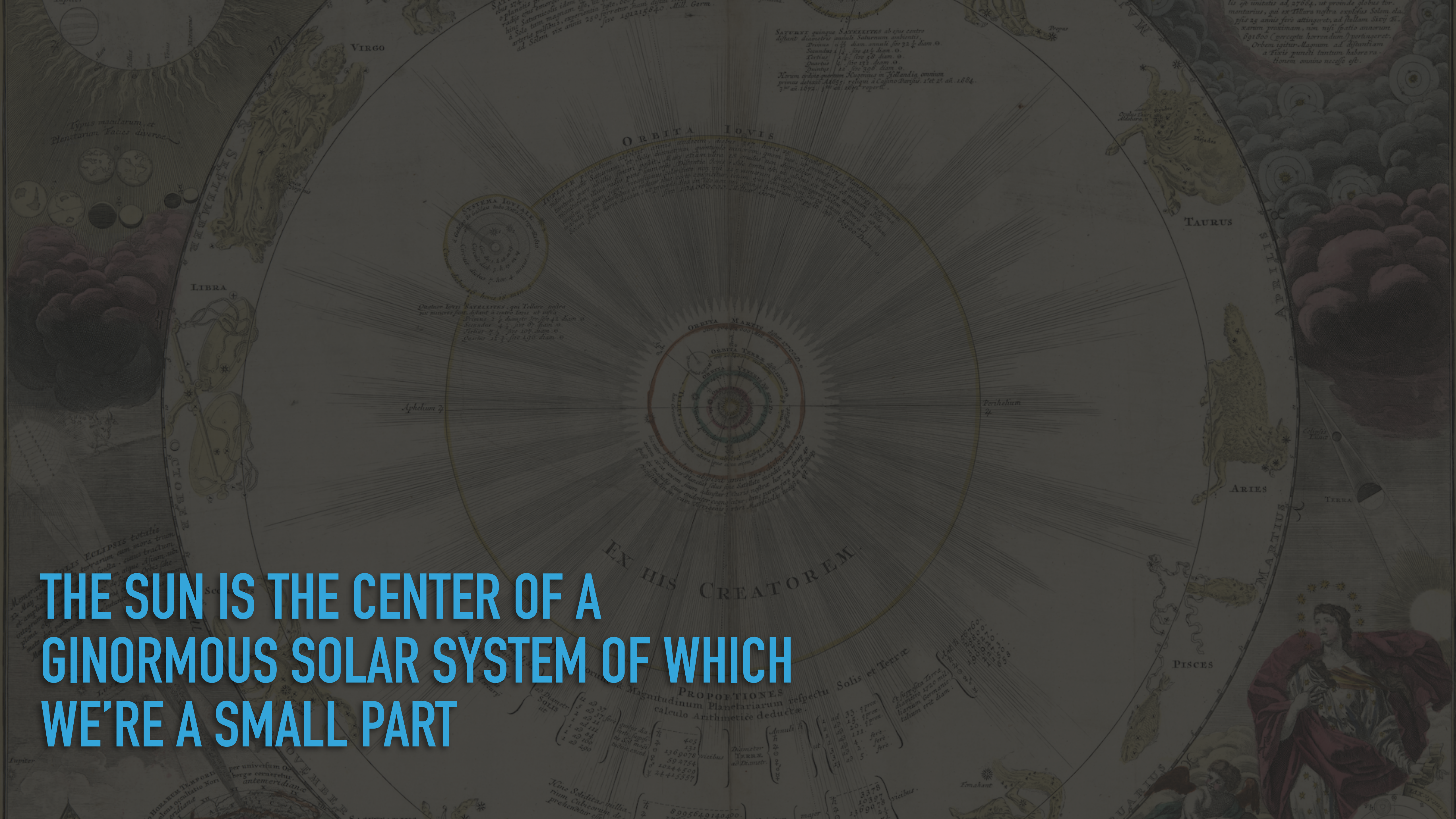
IUPITER
videre queunt
tantum pars ab illis
proximitatem illius radiis
emissus ea, quam supra
maculis Iovis abeuntibus
Solem fieri horis

Quatuor IOVIS SATELLITES, qui Tellure nostra
vix minores sunt, distant à centro Iovis ut infra

Primus $2 \frac{5}{6}$ diametr. Iov. sive 42 diam. ☉

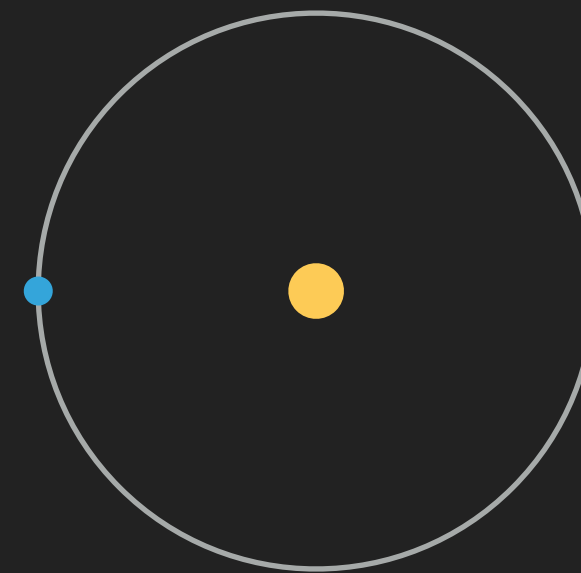
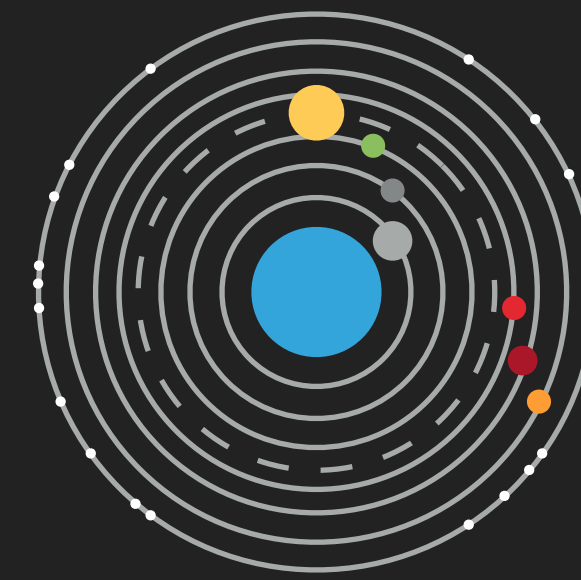
Secundus $1 \frac{1}{2}$ sive 67 diam. ☉

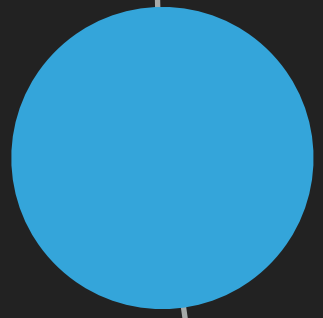
THE SUN IS THE CENTER OF A
GINORMOUS SOLAR SYSTEM OF WHICH
WE'RE A SMALL PART

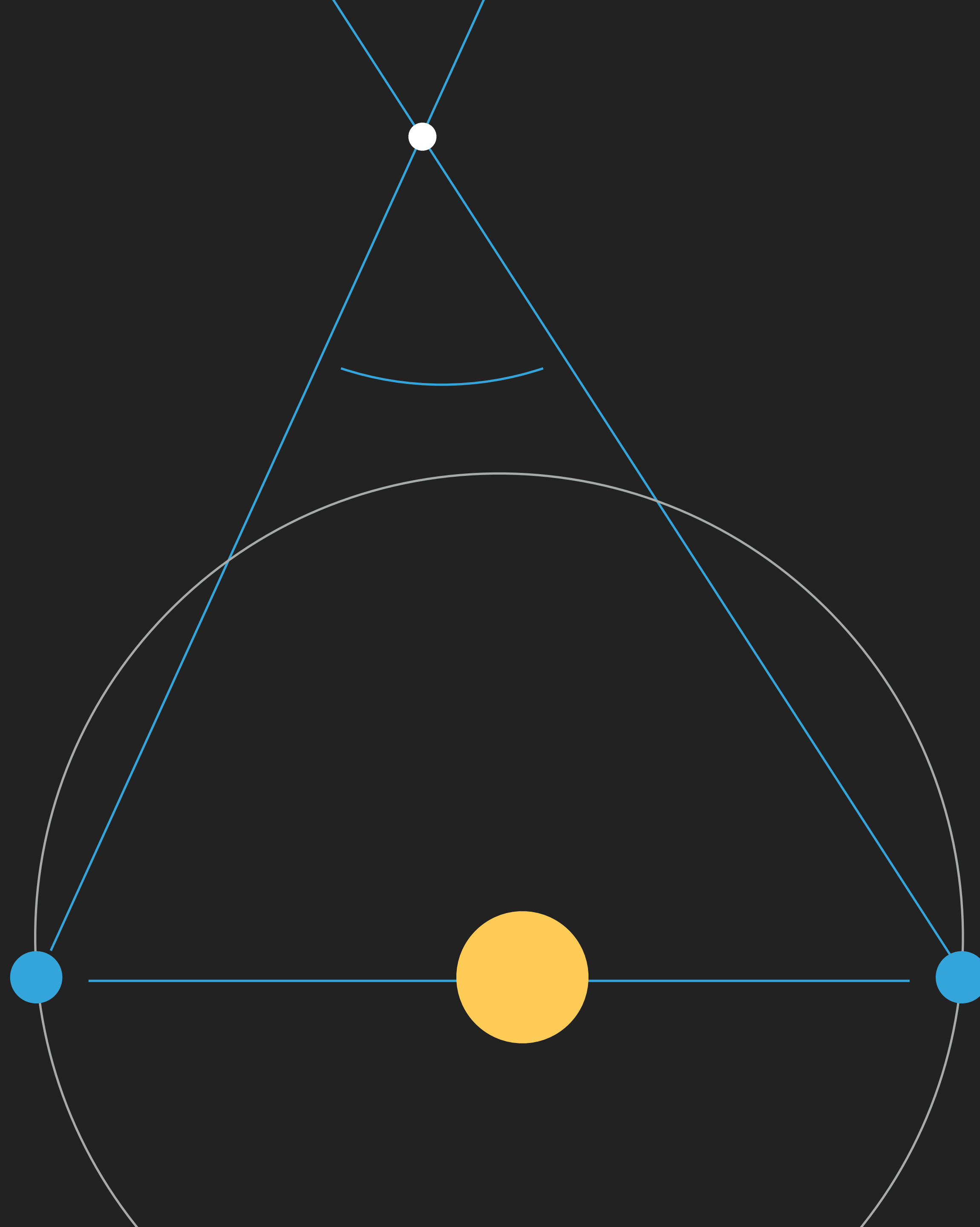


“PTOLEMY'S UNIVERSE WOULD FIT WITHIN THE ORBIT OF EARTH”

-Calli Arcale, for MentalFloss





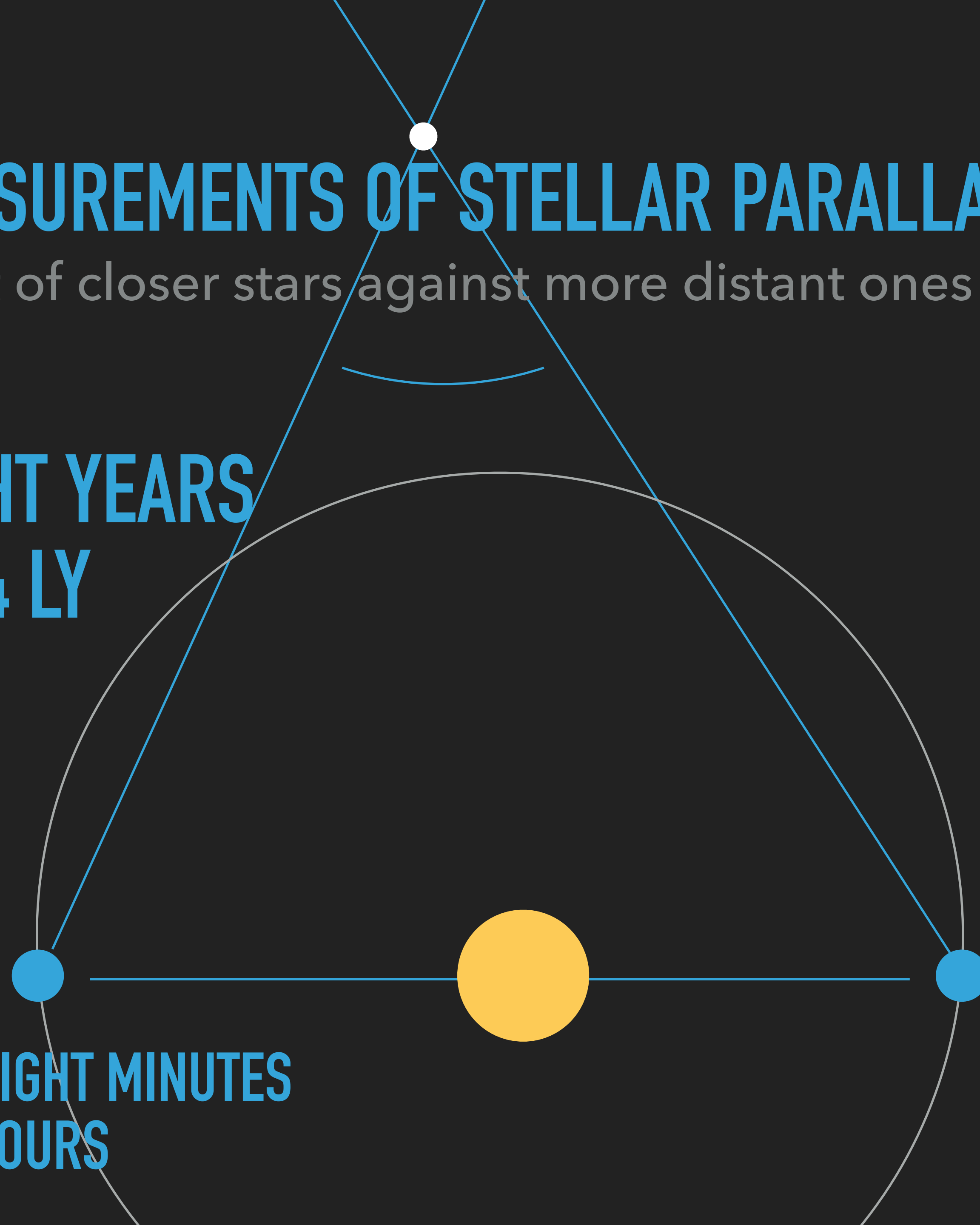


1830s – FIRST MEASUREMENTS OF STELLAR PARALLAX

Apparent seasonal shift of closer stars against more distant ones

CYGNUS : 11.4 LIGHT YEARS
ALPHA CENTAURI: 4 LY

EARTH-SUN DISTANCE: 8 LIGHT MINUTES
SOLAR SYSTEM: 8 LIGHT HOURS



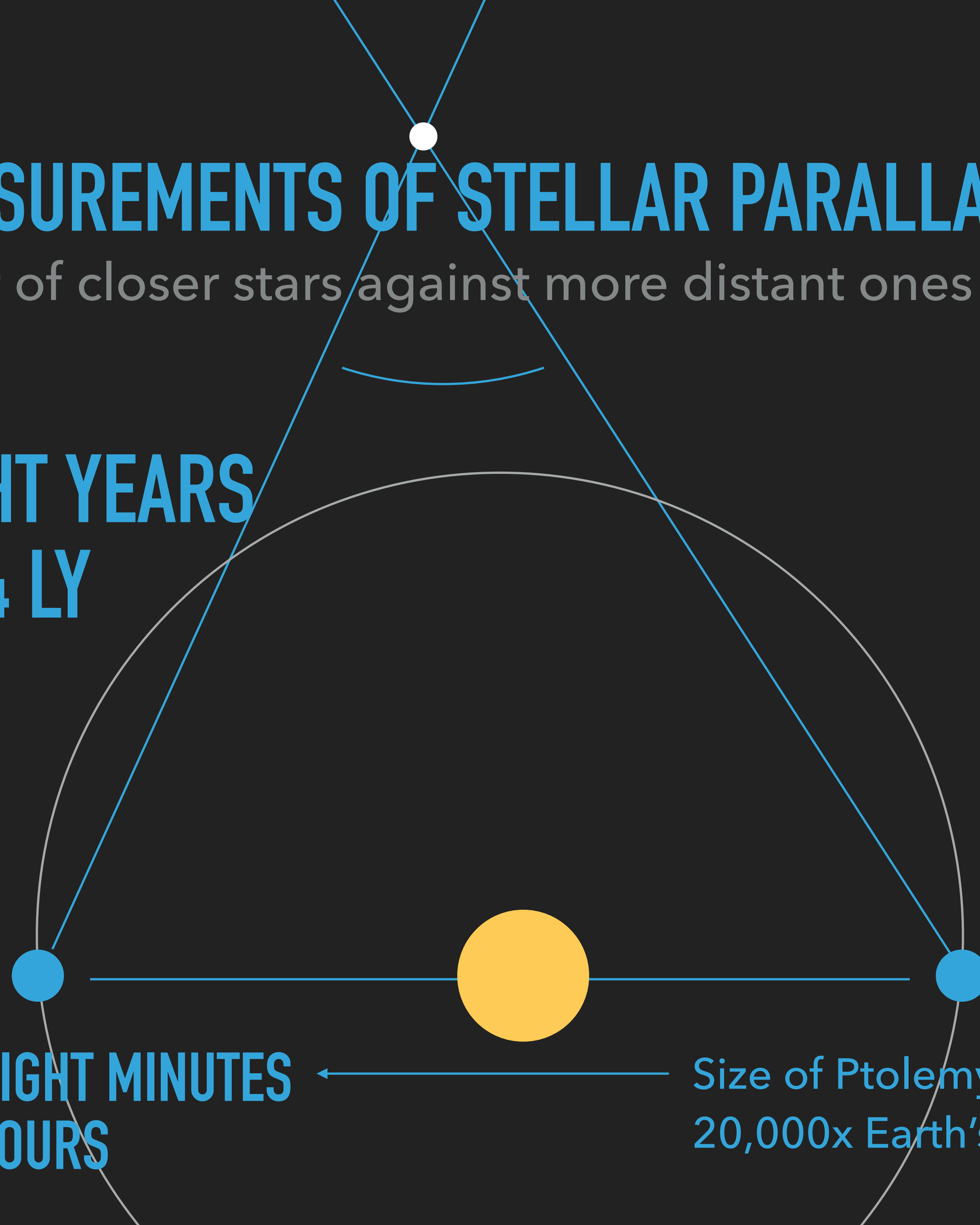
1830s – FIRST MEASUREMENTS OF STELLAR PARALLAX

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CYGNUS : 11.4 LIGHT YEARS
ALPHA CENTAURI: 4 LY

EARTH-SUN DISTANCE: 8 LIGHT MINUTES
SOLAR SYSTEM: 8 LIGHT HOURS

Size of Ptolemy's Entire Celestial Sphere:
20,000x Earth's radius \approx 7 light minutes



EARLY 1900S

Parallax method maps thousands of the nearest stars (within **100ly**). Correlations between brightness, spectrum, and distance allow us to infer position of more distant stars within this galaxy, up to about **300ly**.



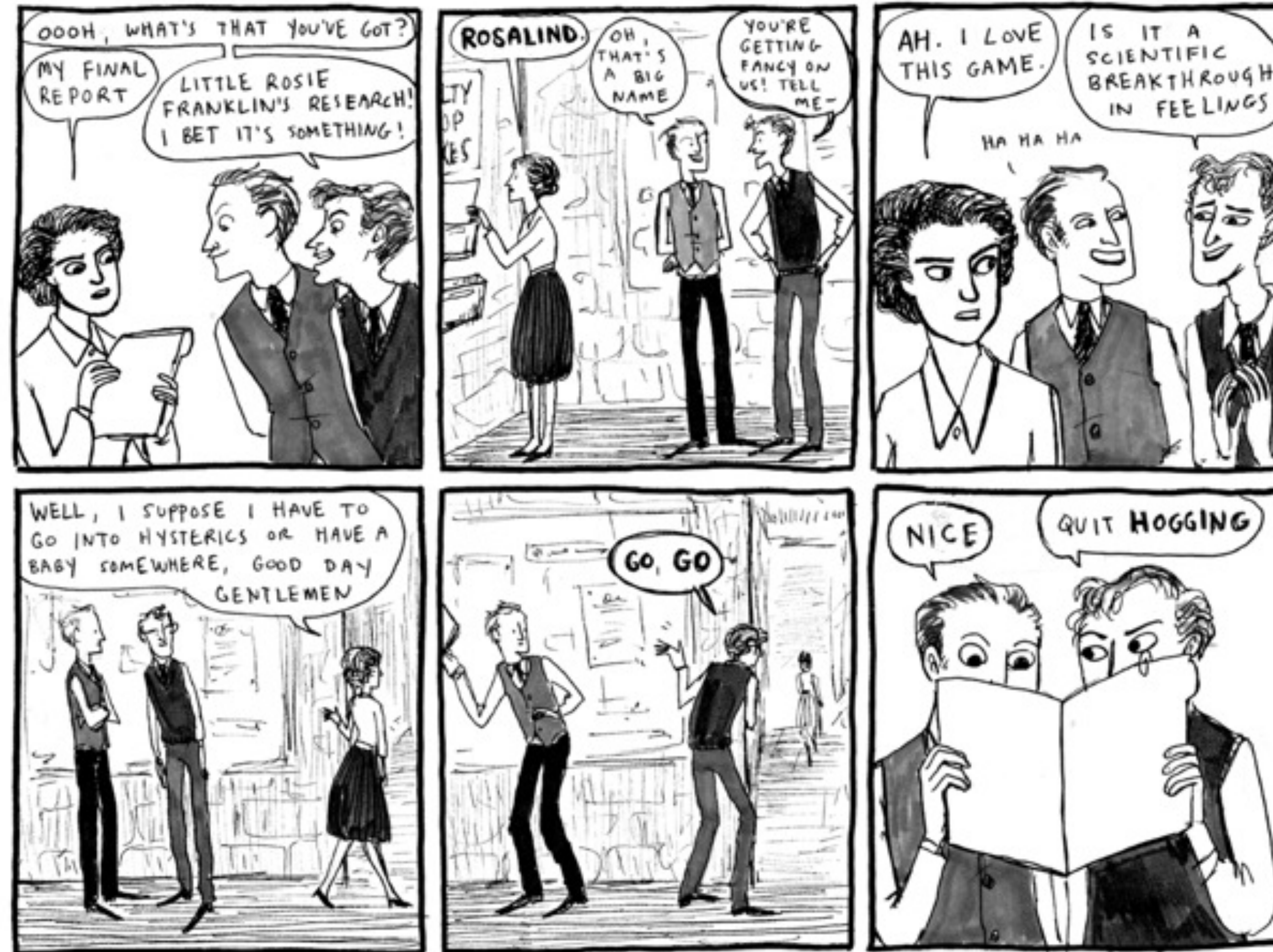
HENRIETTA SWAN LEAVITT

0:31 / 3:56

CC HD

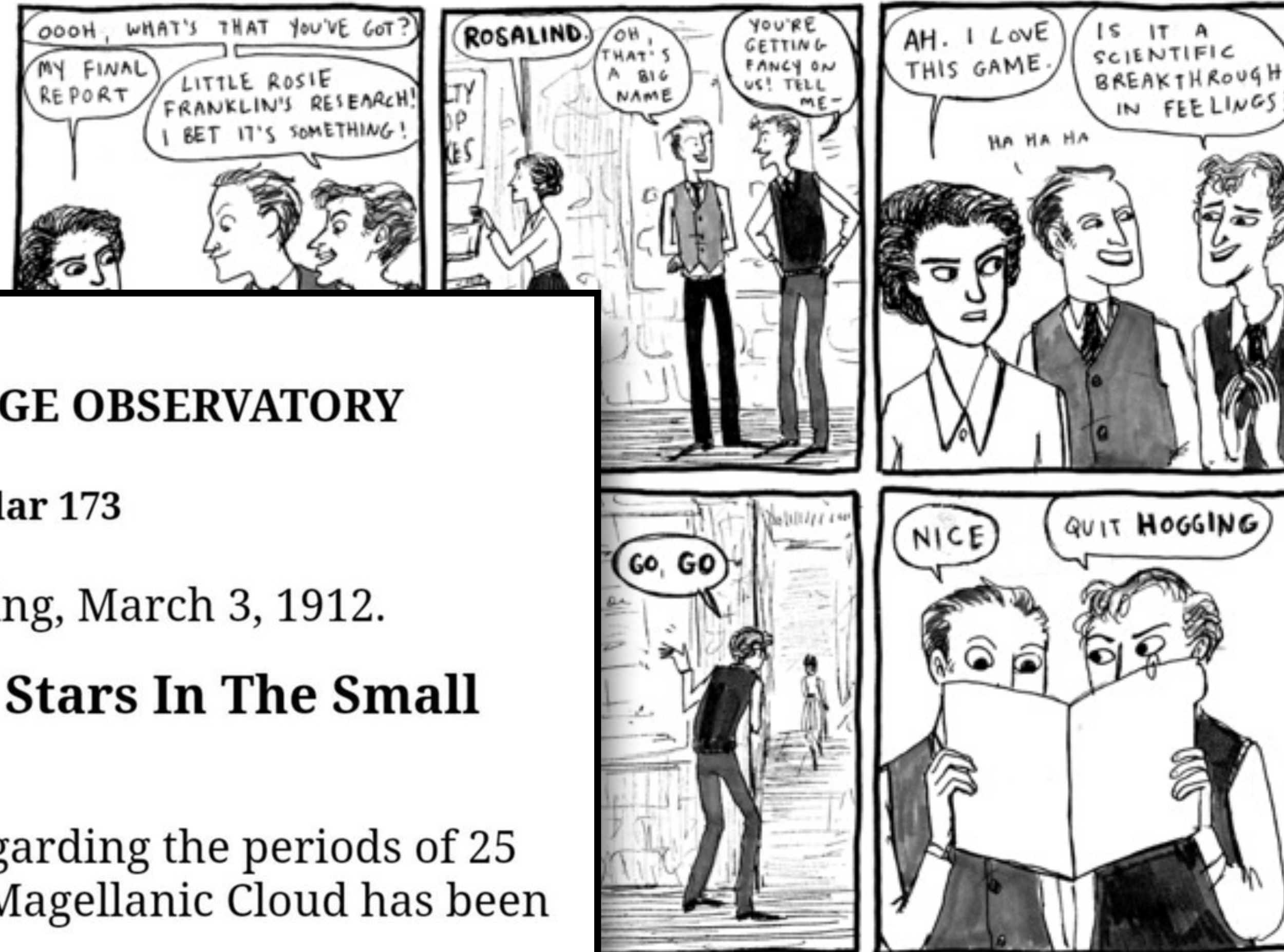
<https://www.youtube.com/watch?v=2FrY6gRPC7k>

EVERY LADY SCIENTIST WHO EVER DID ANYTHING TILL NOW



Rosalind! Don't let 'em get you down. The trouble with reading about any given woman who was born before your mom is that yes, sometimes, they were hilarious, powerful, tough, loud, etcetera, etcetera—all good comic making material! But then sometimes, man, the main thing about them is that they just got screwed, big time. Here's to all the old time ladies of science, and their ideas that were worth stealing.

EVERY LADY SCIENTIST WHO
EVER DID ANYTHING
TILL NOW



HARVARD COLLEGE OBSERVATORY

Circular 173

Edward C. Pickering, March 3, 1912.

Periods Of 25 Variable Stars In The Small Magellanic Cloud.

The following statement regarding the periods of 25 variable stars in the Small Magellanic Cloud has been prepared by Miss Leavitt.

A Catalogue of 1777 variable stars in the two Magellanic Clouds is given in H.A. 60, No. 4. The measurement and discussion of these objects present problems of unusual difficulty on account of the large

ng about any given woman who was born before your mom is that yes, ra, etcetera—all good comic making material! But then sometimes, man, me. Here's to all the old time ladies of science, and their ideas that were

Kate Beaton

<http://www.harkavagrants.com>

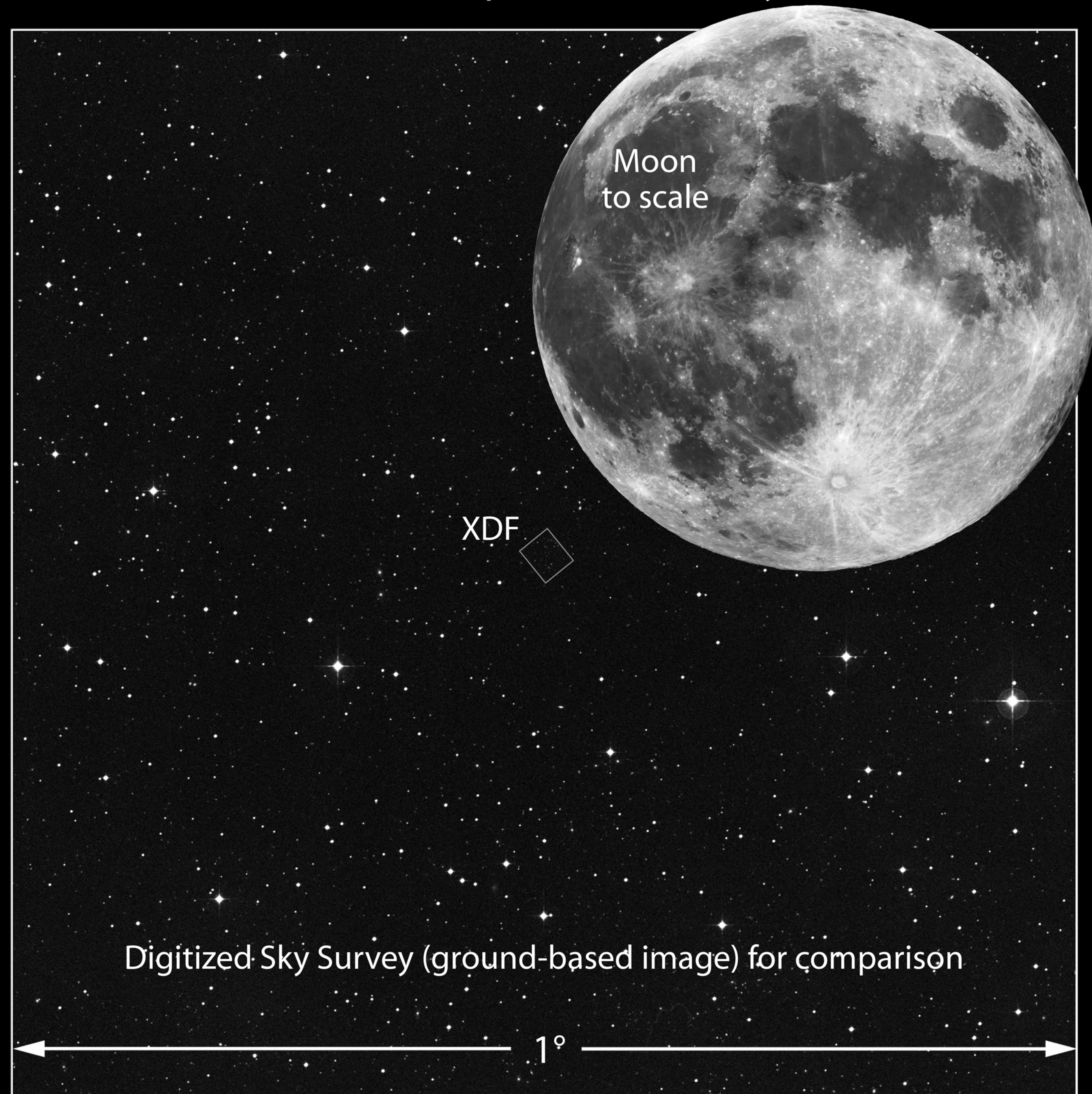
LEAVITT'S LAW (1908)

Leavitt's law allowed determining stellar distance up to **100,000,000ly**.

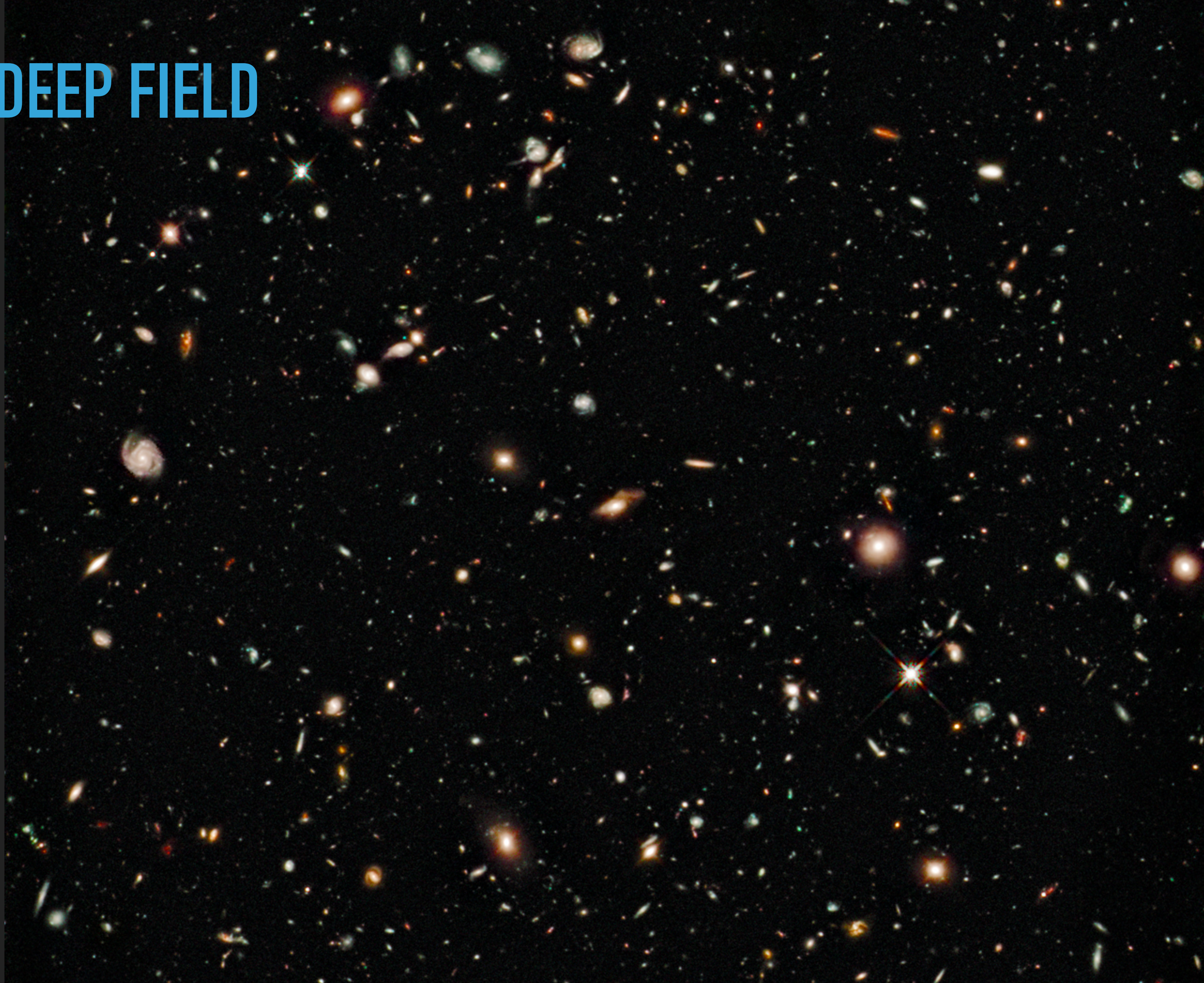
In **1924**, Edwin Hubble used Cepheid variables to determine the distance of the Andromeda Galaxy, providing the first conclusive evidence for galaxies outside the Milky Way.

HUBBLE DEEP FIELD

Size of Hubble eXtreme Deep Field on the Sky



HUBBLE DEEP FIELD



HUBBLE DEEP FIELD



*"The XDF is the deepest image of the sky ever obtained and reveals the faintest and most distant galaxies ever seen. XDF allows us to explore **further back in time than ever before**"*
principal investigator of the Hubble Ultra Deep Field.

1929

Hubble uses Cepheid distances to determine the **Universe is expanding**. This leads to the concept of the Big Bang and an age to the Universe.

1998

Researchers using methods similar to Leavitt's applied to supernovae (finding 'standard candles') determine the **expansion of the Universe is accelerating**.



Image: Carlos Budassi