Welcome to The Natural World N190: Stars and Galaxies

Dale E. Mais

Pharmacologist by trade-Biotechnology

-Women's health care

-Astronomy is my hobby

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Welcome to Astronomy AST203: Stars and Galaxies

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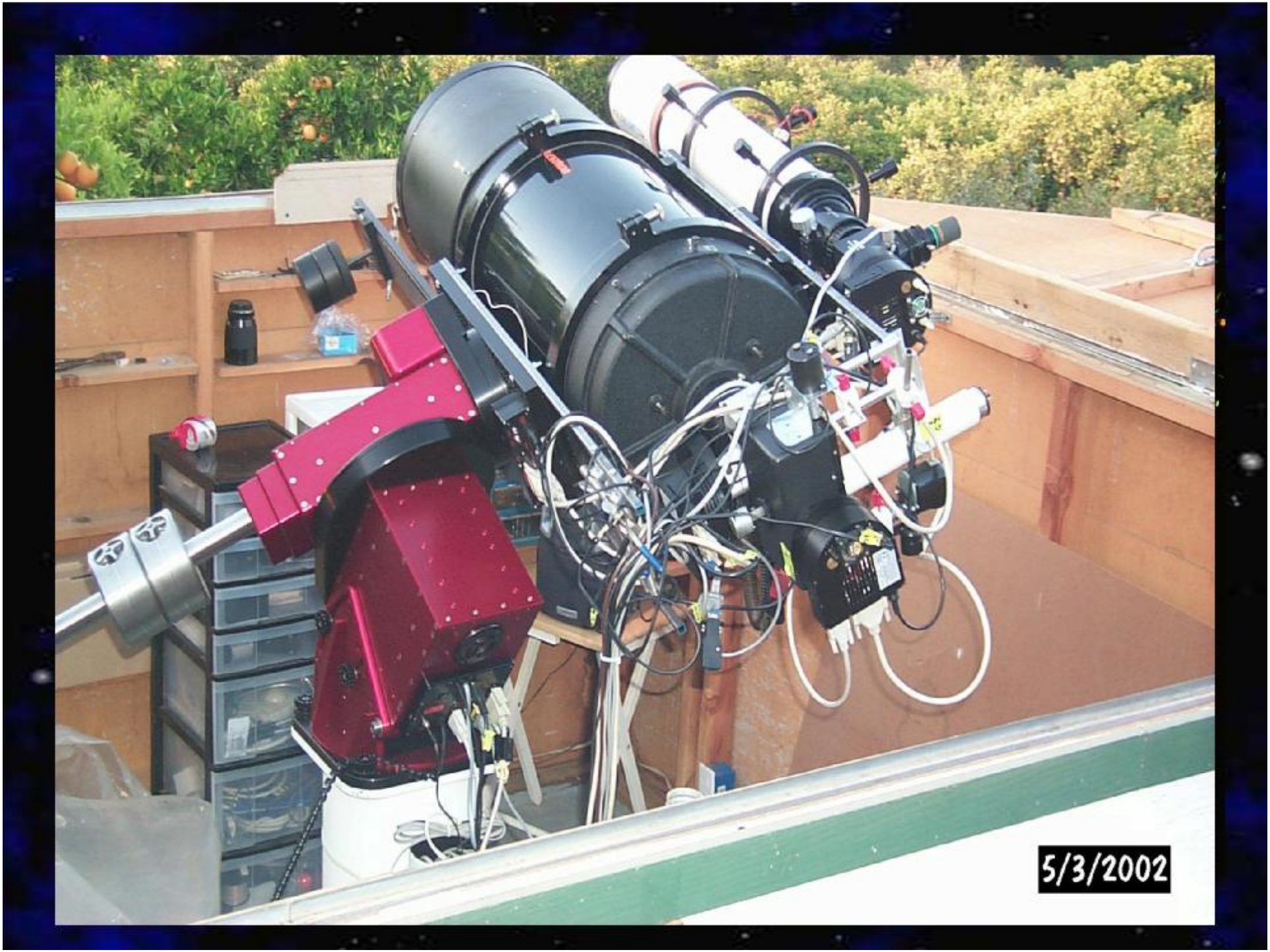
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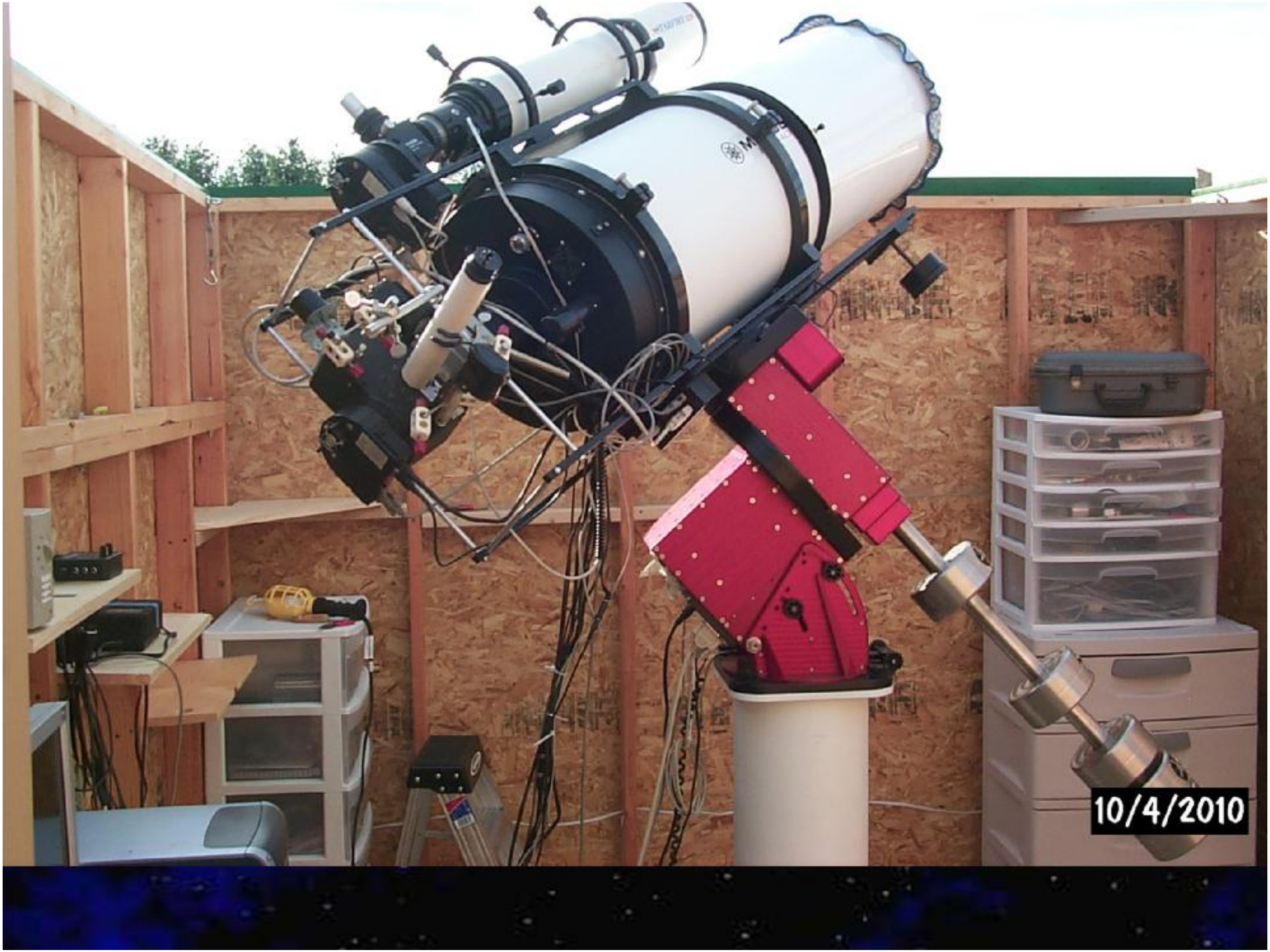
10/4/2010

The Natural World N190 COURSE OUTLINE
Spring 2012

1. Organization of the Sky

The Sky at Night	
Seasons / Lunar Phases / Eclipses	
Geocentric/Heliocentric Cosmology	

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2. Geocentric to Heliocentric transition
The rise of the Scientific Process

Copernicus – Brahe	
Kepler's Laws	
Galileo	
Newton's Laws	

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3. How we gather information: The tools of the trade

The Nature of Light – Radiation	
The Nature of Light – Spectroscopy	
The Tools of Astronomy	

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4. The building blocks of galaxies: Stars, how they live and die

The Nature of Stars	
The Interstellar Medium	
Stellar Formation	
Stellar Evolution	
Stellar Death	
Neutron Stars/Black Holes	

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5. The building blocks of Universe: Galaxies

The Milky Way Galaxy	
Normal Galaxies	
Types of galaxies, A universe of galaxies	

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All Powerpoint lecture slides are posted at my website as pdf files

Download and print if you wish
Take notes on
Can use on exams / quizes

Mais-ccd-spectroscopy.com

Go to links for Palomar College

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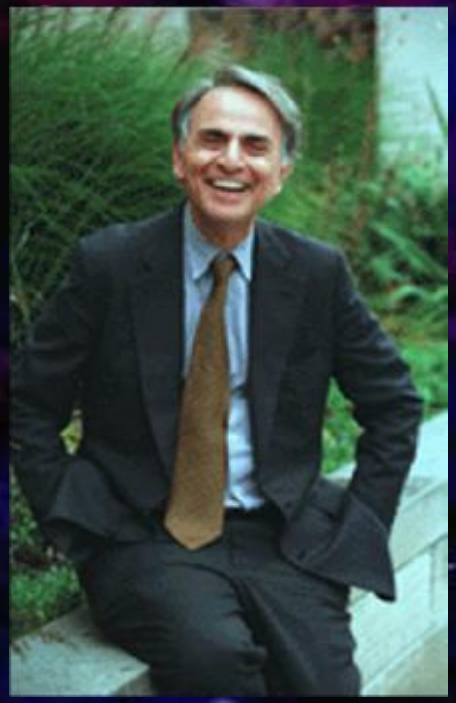
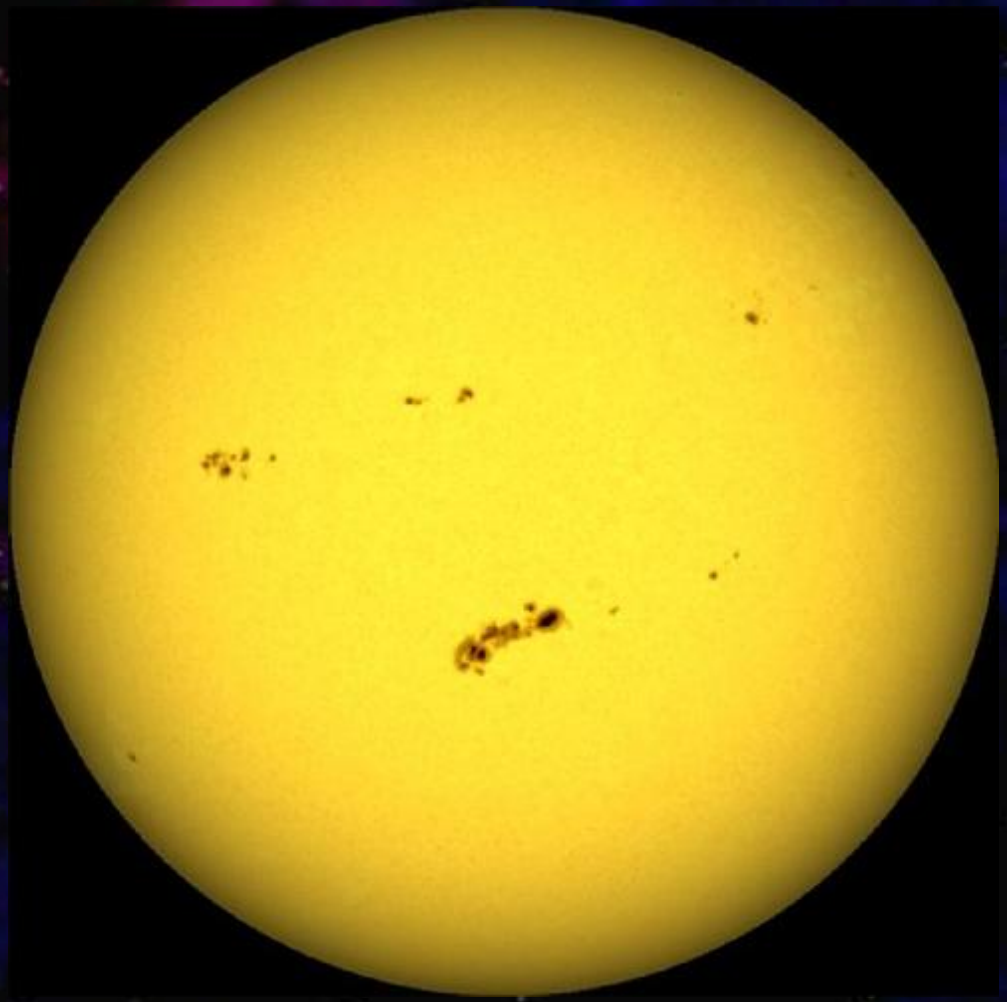
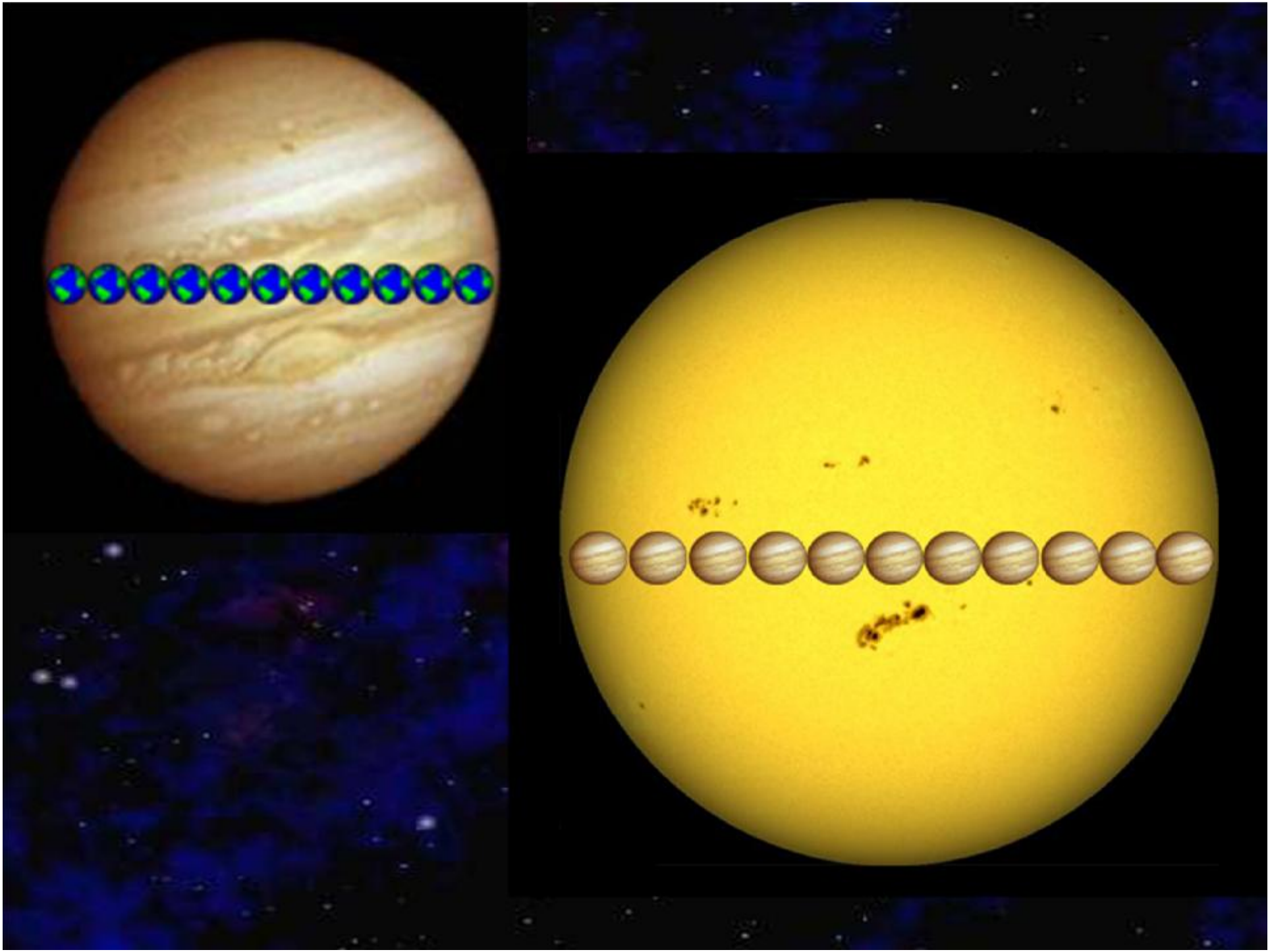
“The COSMOS is all that is…
or ever was… or ever will be”



- Carl Sagan
COSMOS

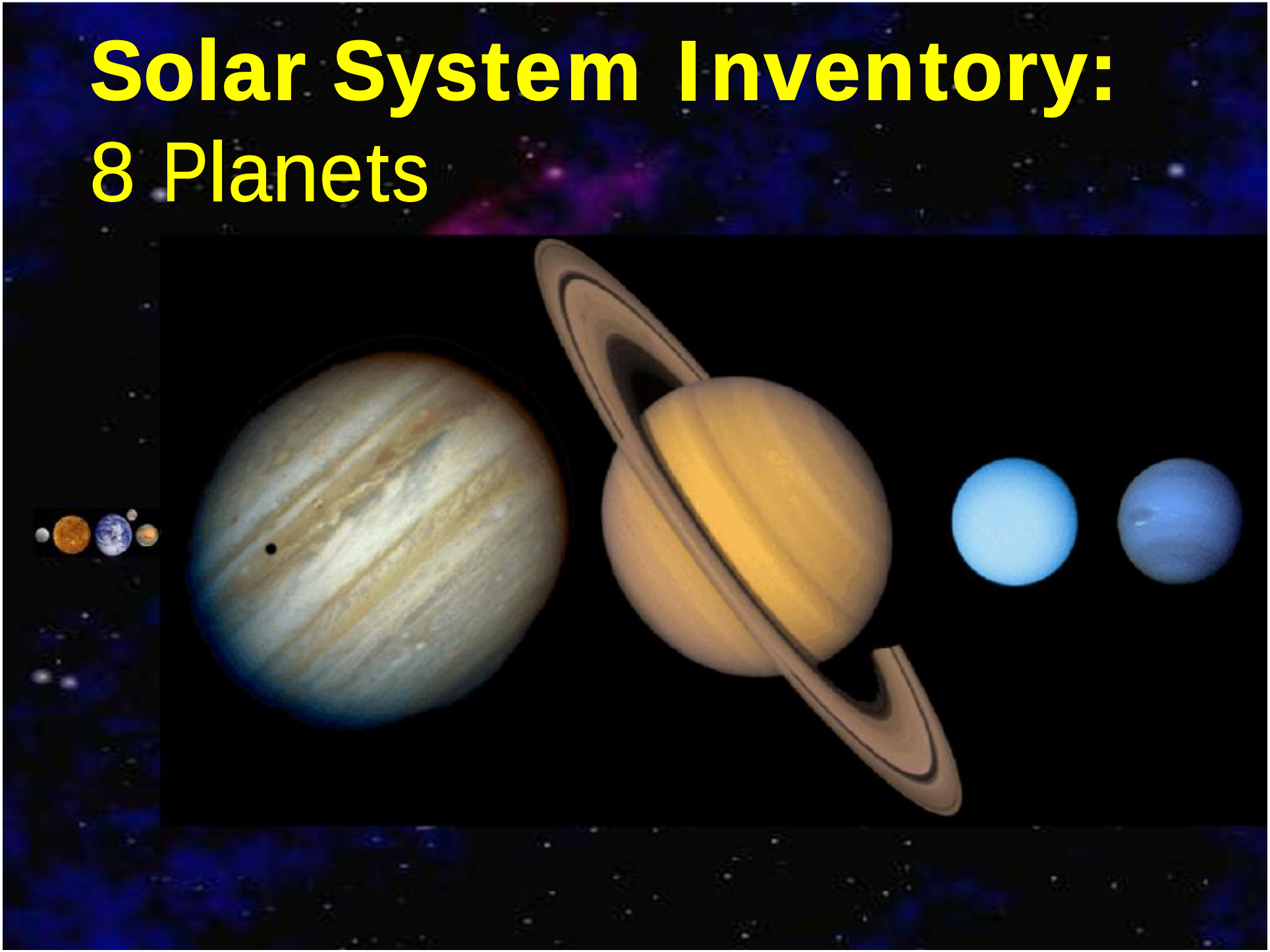
Solar System Inventory: 1 Star



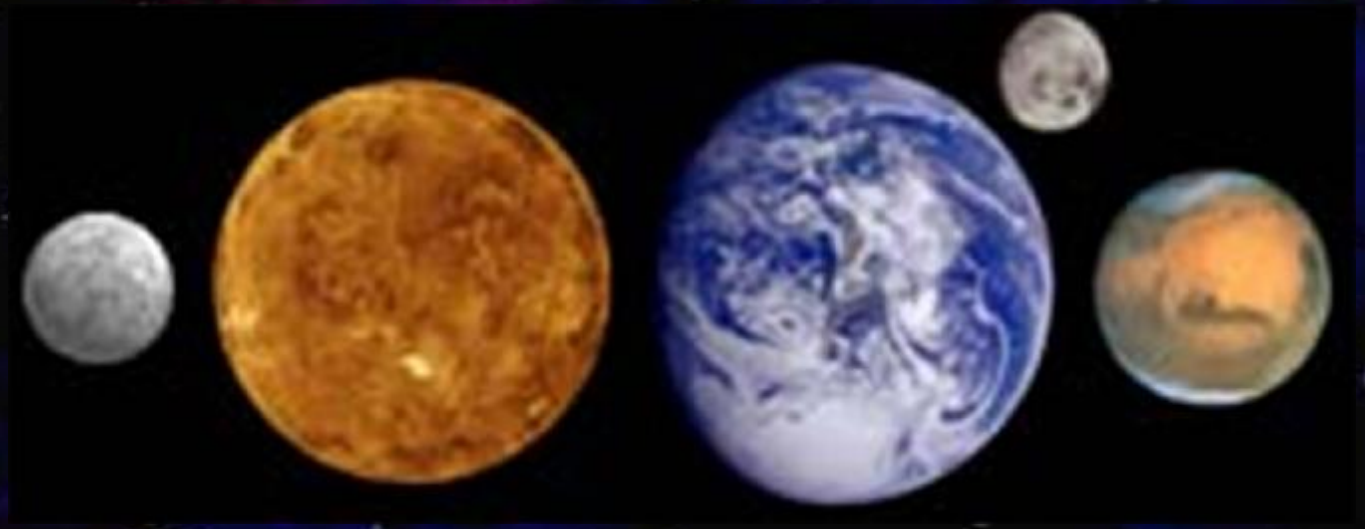


Solar System Inventory:

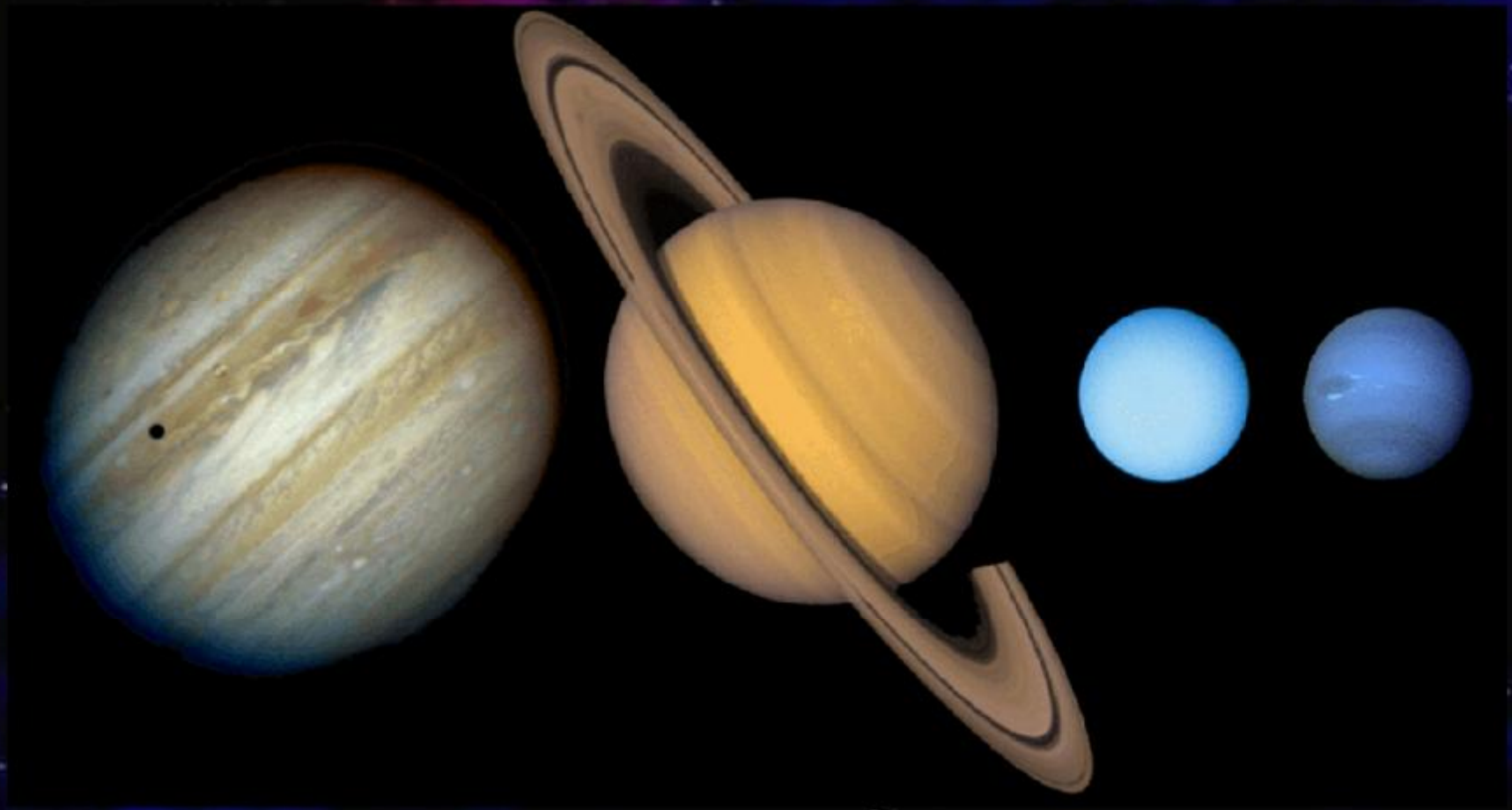
8 Planets



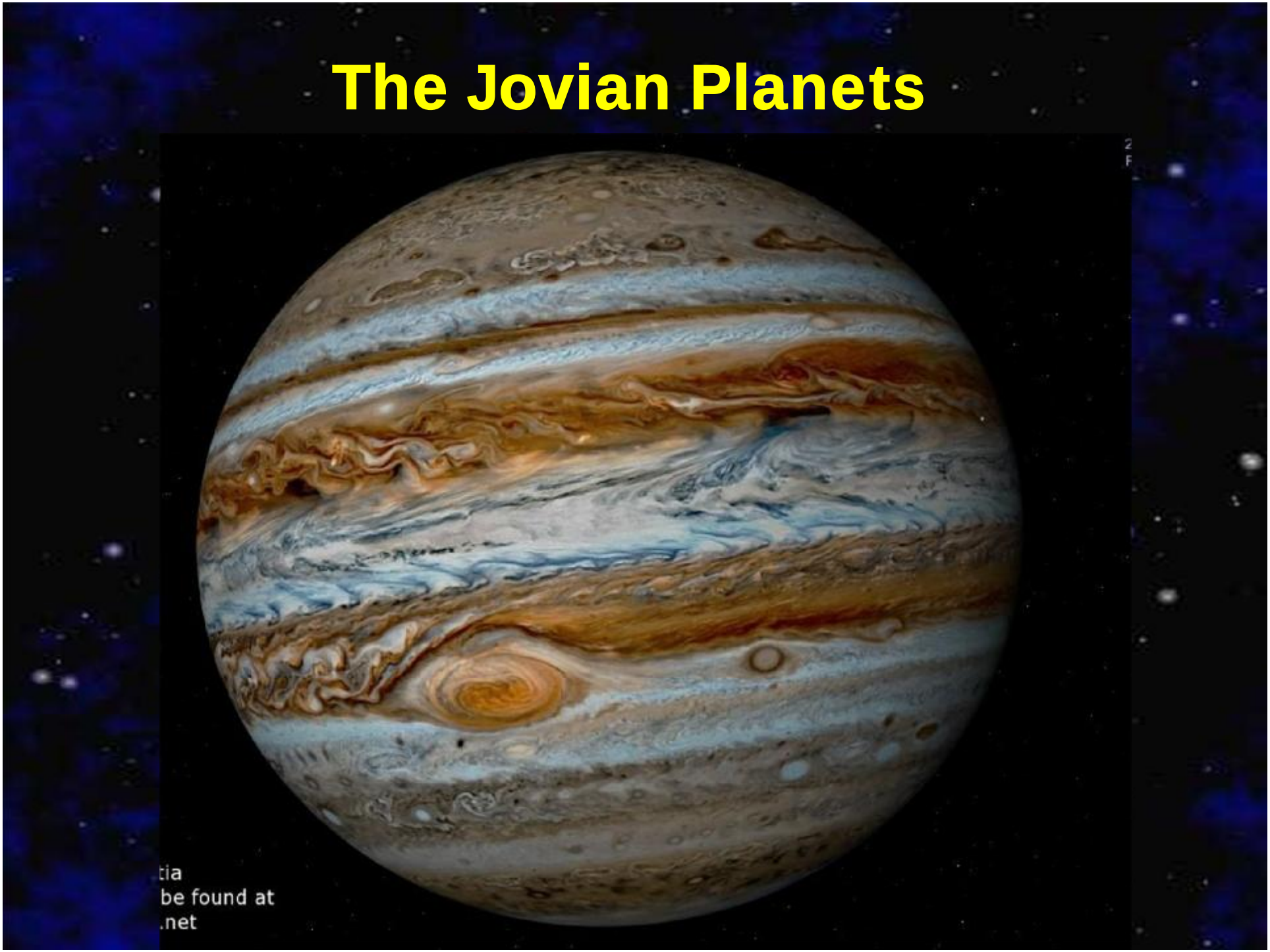
The Terrestrial Planets



The Jovian Planets



The Jovian Planets



The Jovian Planets

Mimas, from Cassini fly by, 2010

Solar System Inventory:

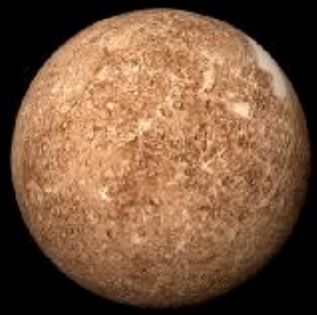
91 + moons

Ganymede

5262 km

Titan

5150 km

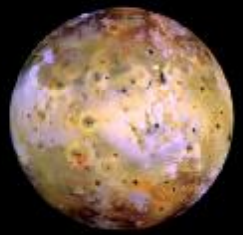


Mercury

4880 km

Callisto

4806 km



Io

3642 km

Moon

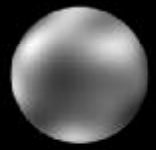
3476 km

Europa

3138 km

Triton

2706 km



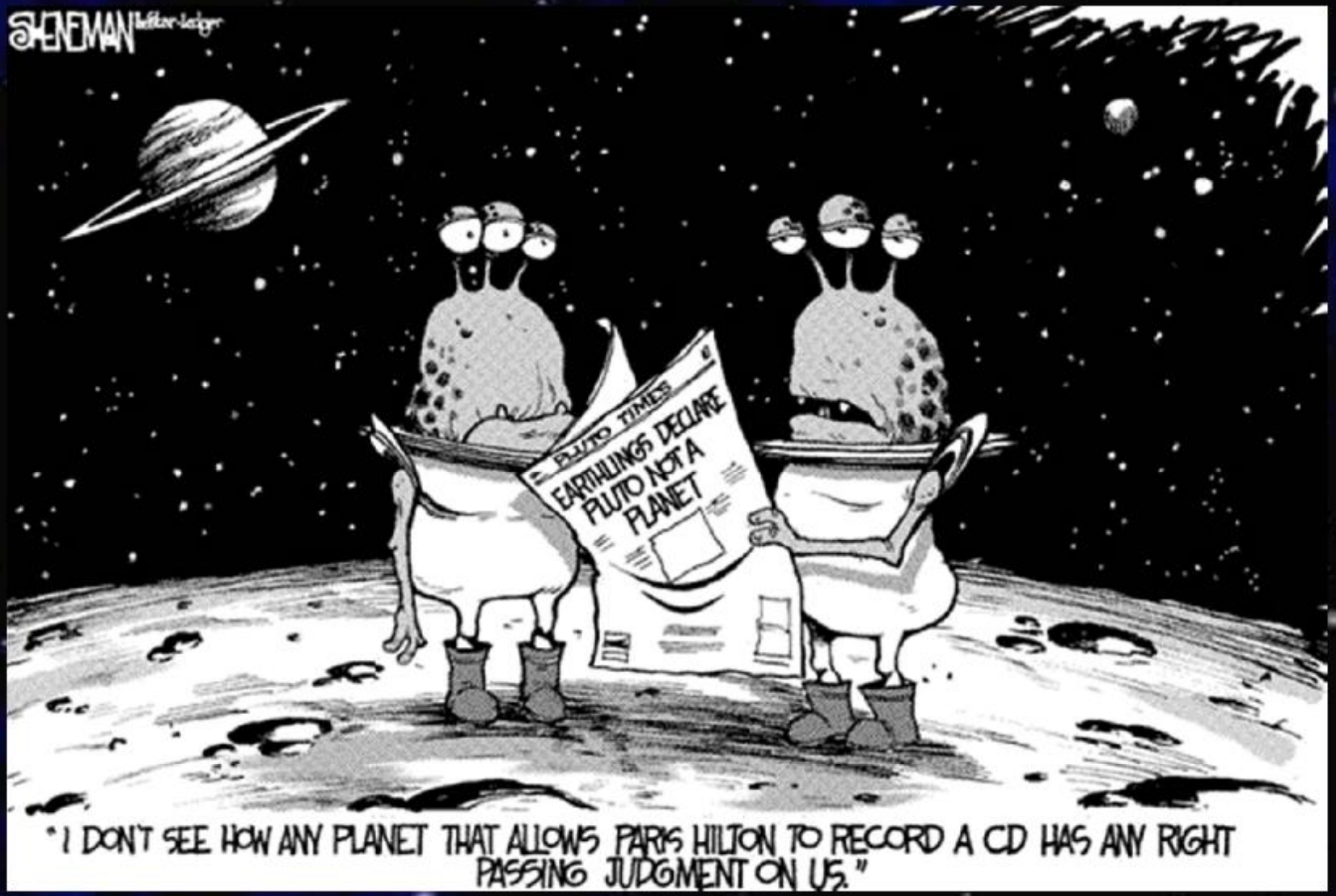
Pluto

2300 km

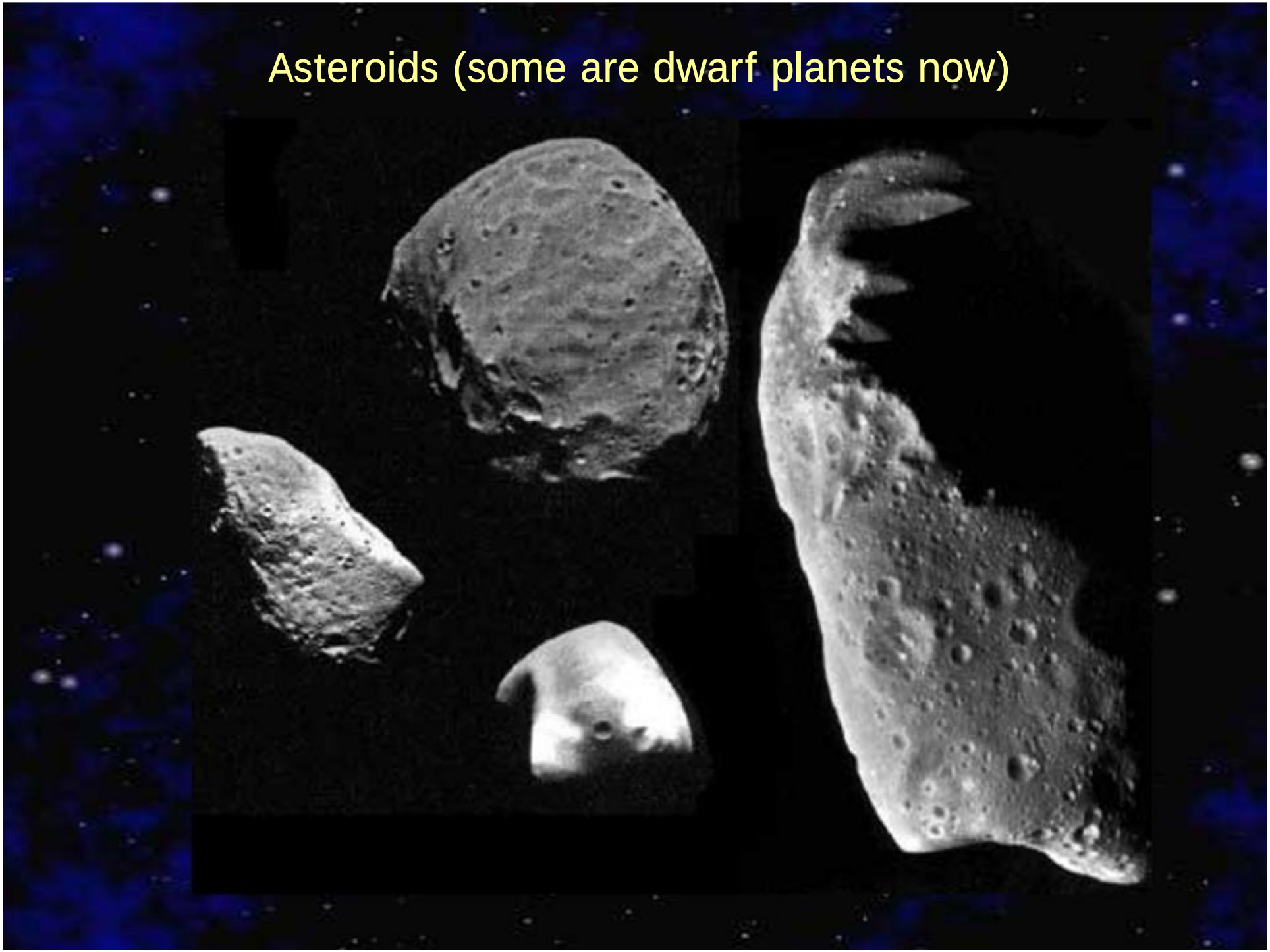
Titania

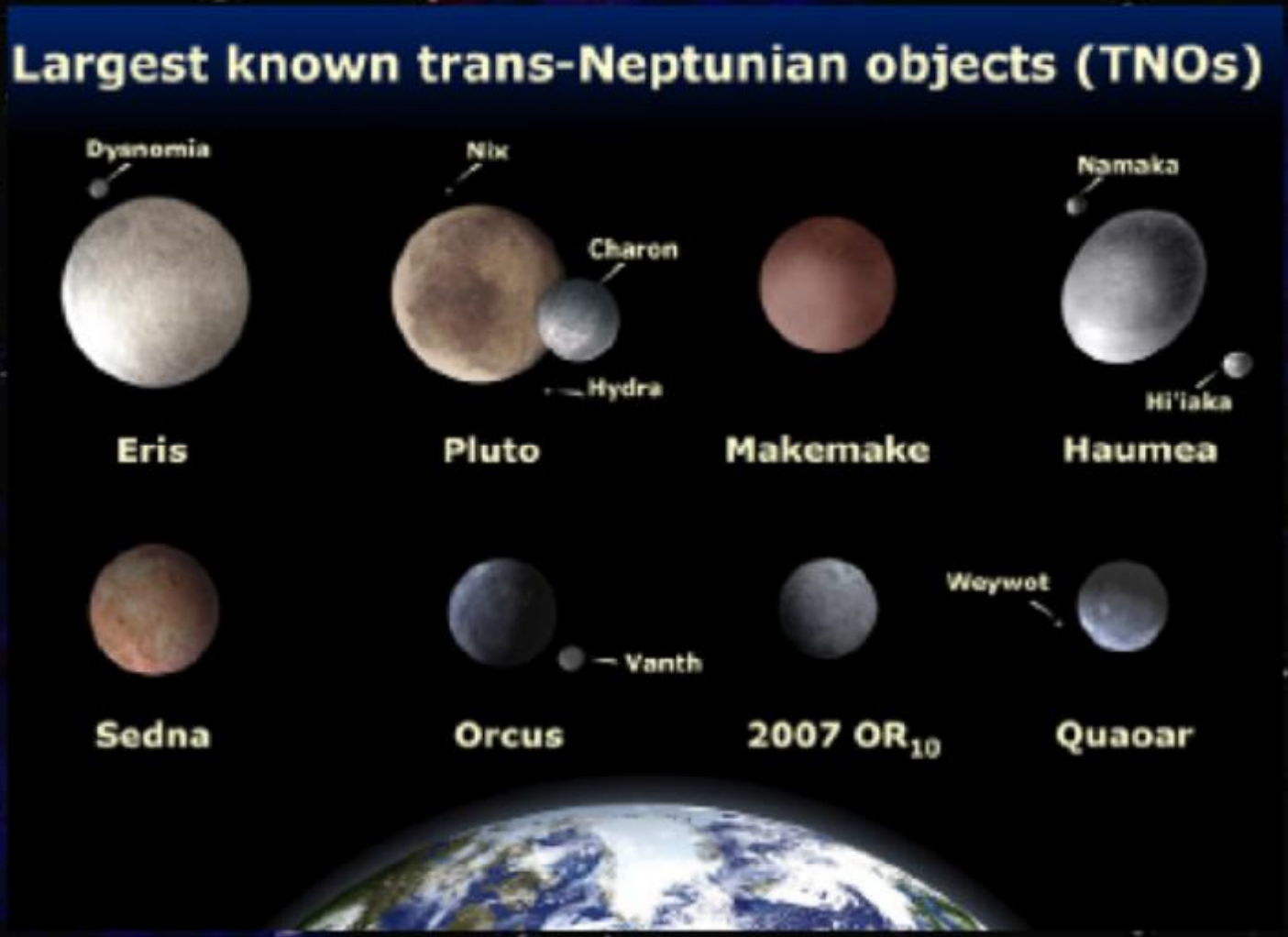
1580 km

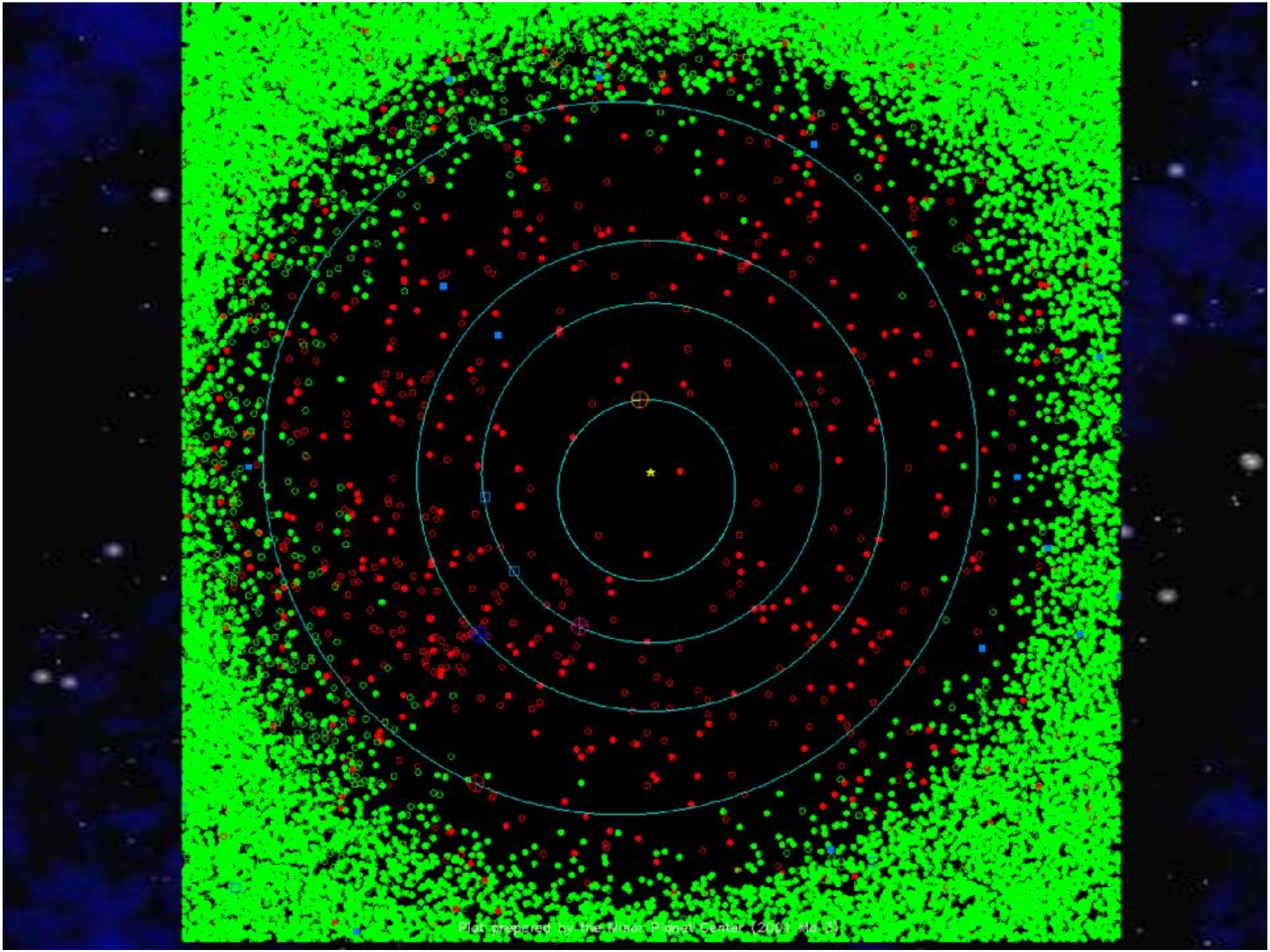
Solar System Inventory:
Countless numbers of Asteroids, Comets, Meteors, Dust


SHENEMAN Inquirer-Ledger
PLUTO TIMES
EARTHLINGS DECLARE PLUTO NOT A PLANET
"I DON'T SEE HOW ANY PLANET THAT ALLOWS PARIS HILTON TO RECORD A CD HAS ANY RIGHT PASSING JUDGMENT ON US."

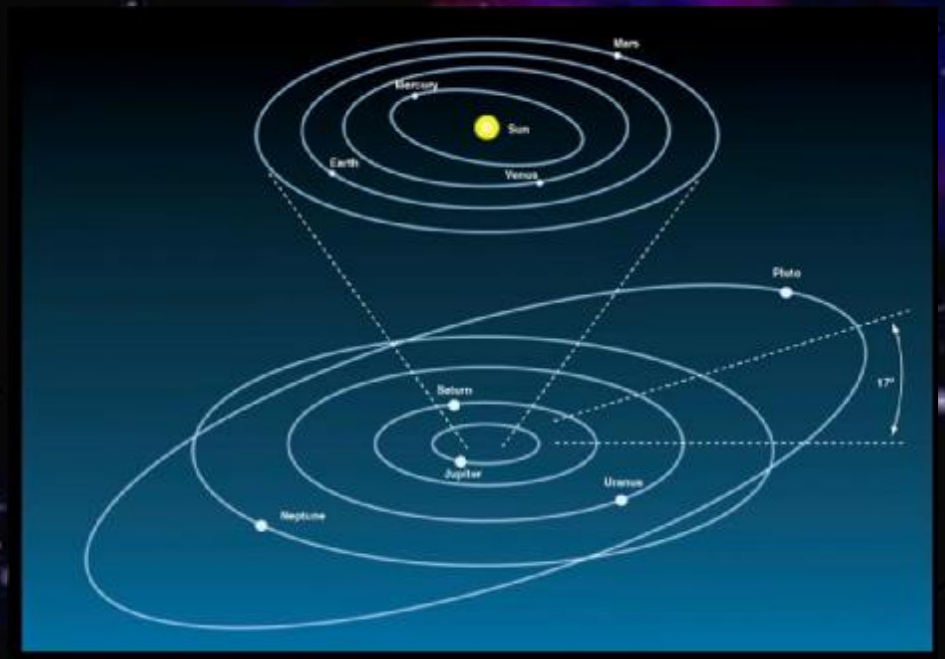
Asteroids (some are dwarf planets now)

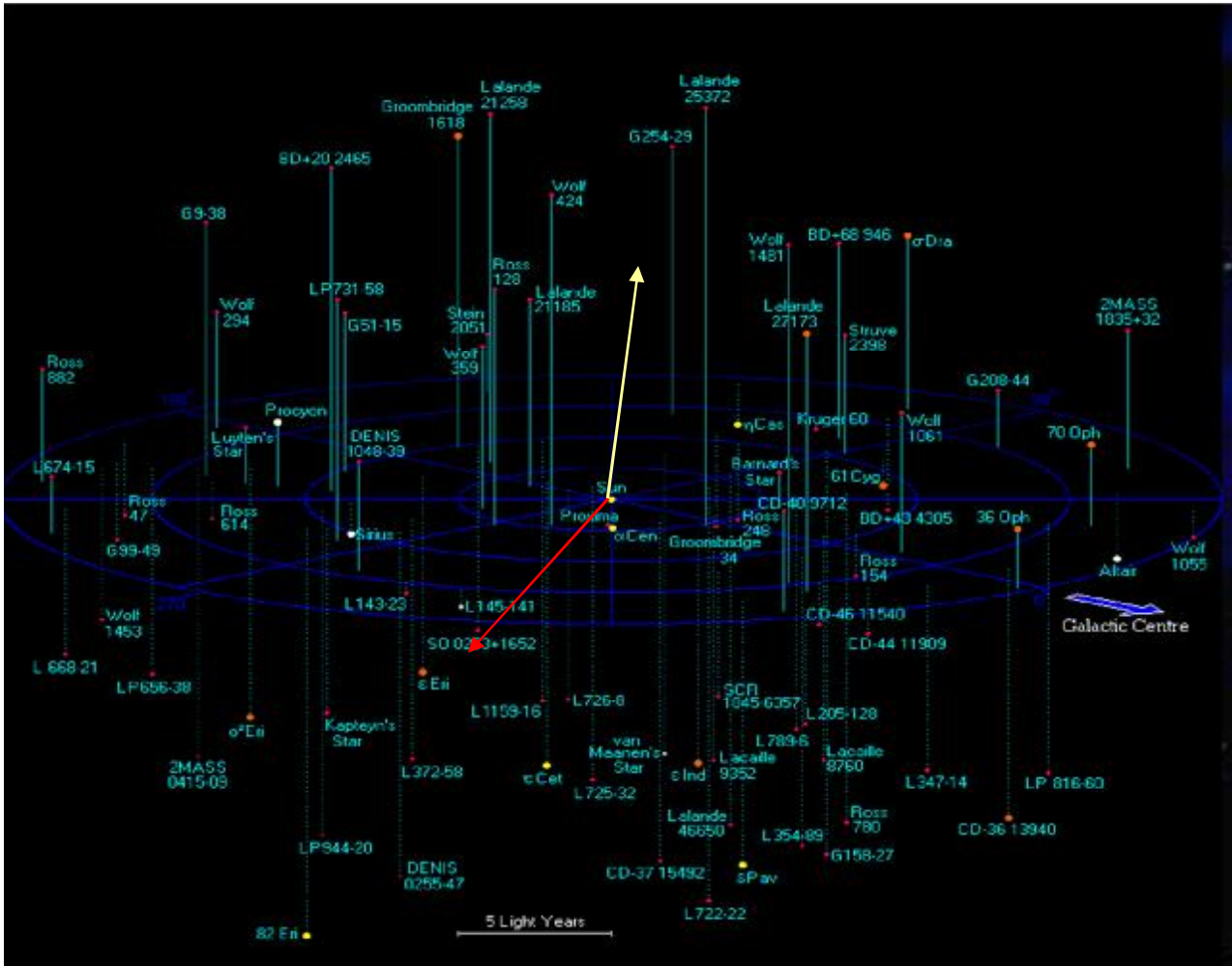


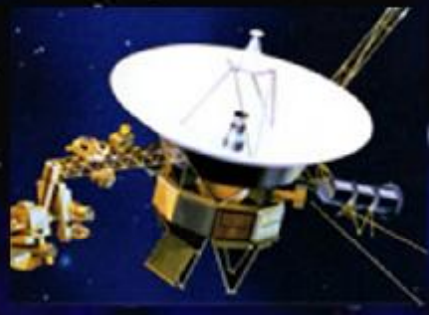

Largest known trans-Neptunian objects (TNOs)
Dysnomia
Eris
Nix
Charon
Hydra
Pluto
Makemake
Namaka
Hi'iaka
Haumea
Sedna
Vanth
Orcus
2007 OR10
Weywot
Quaoar


Plot prepared by the Minor Planet Center (2001 Mar 3)

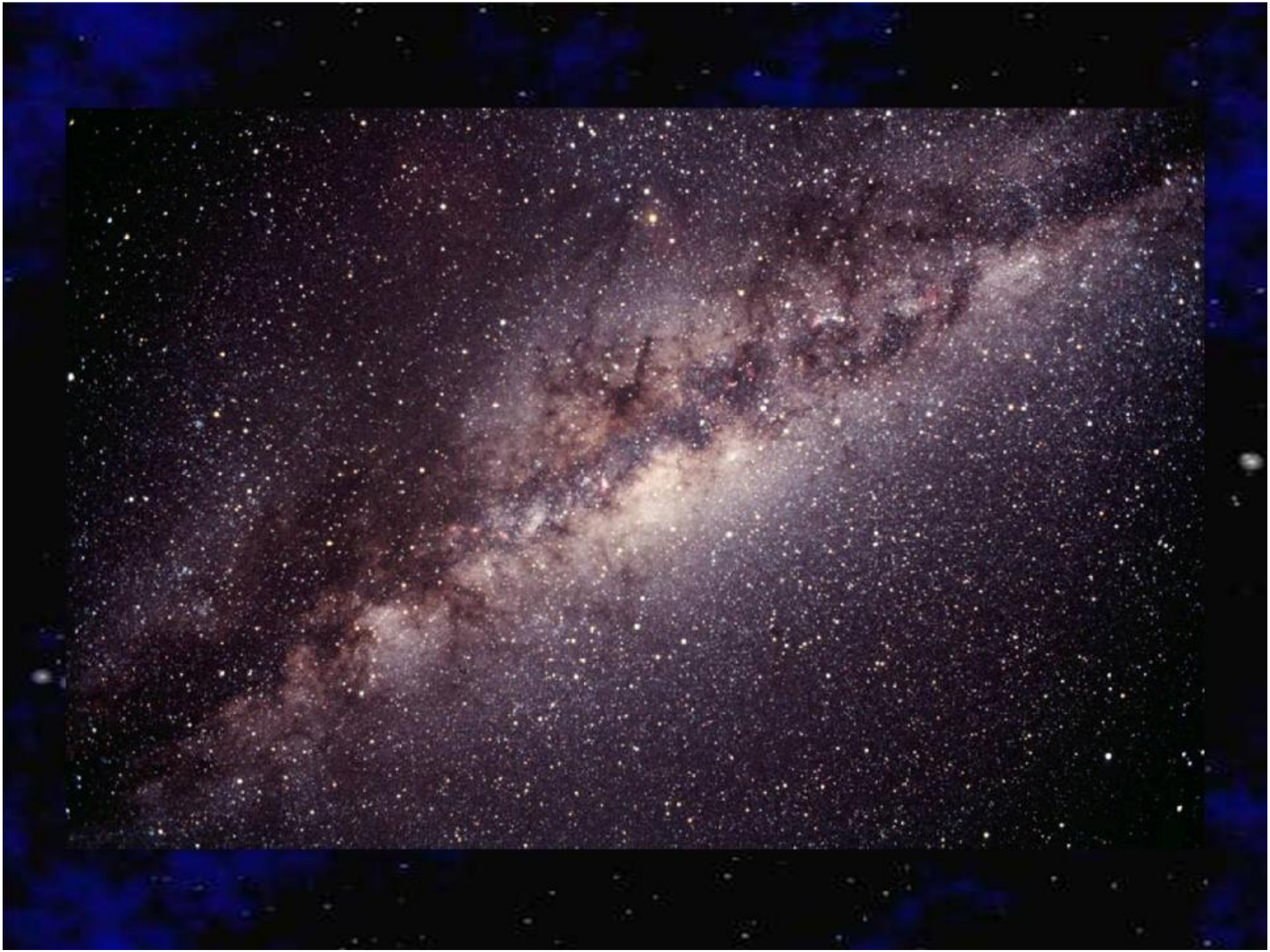
What is our *PLACE* in the COSMOS?

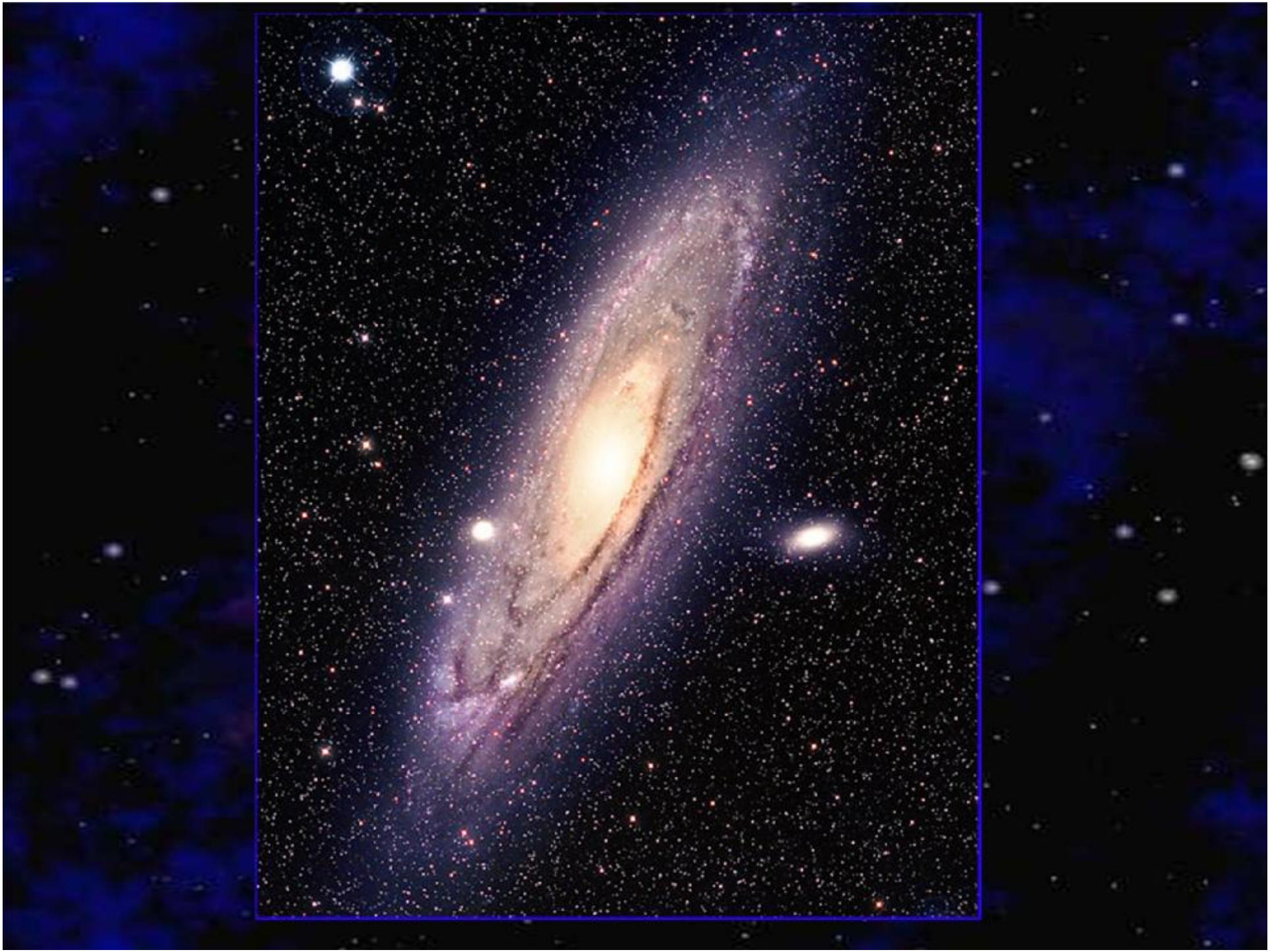


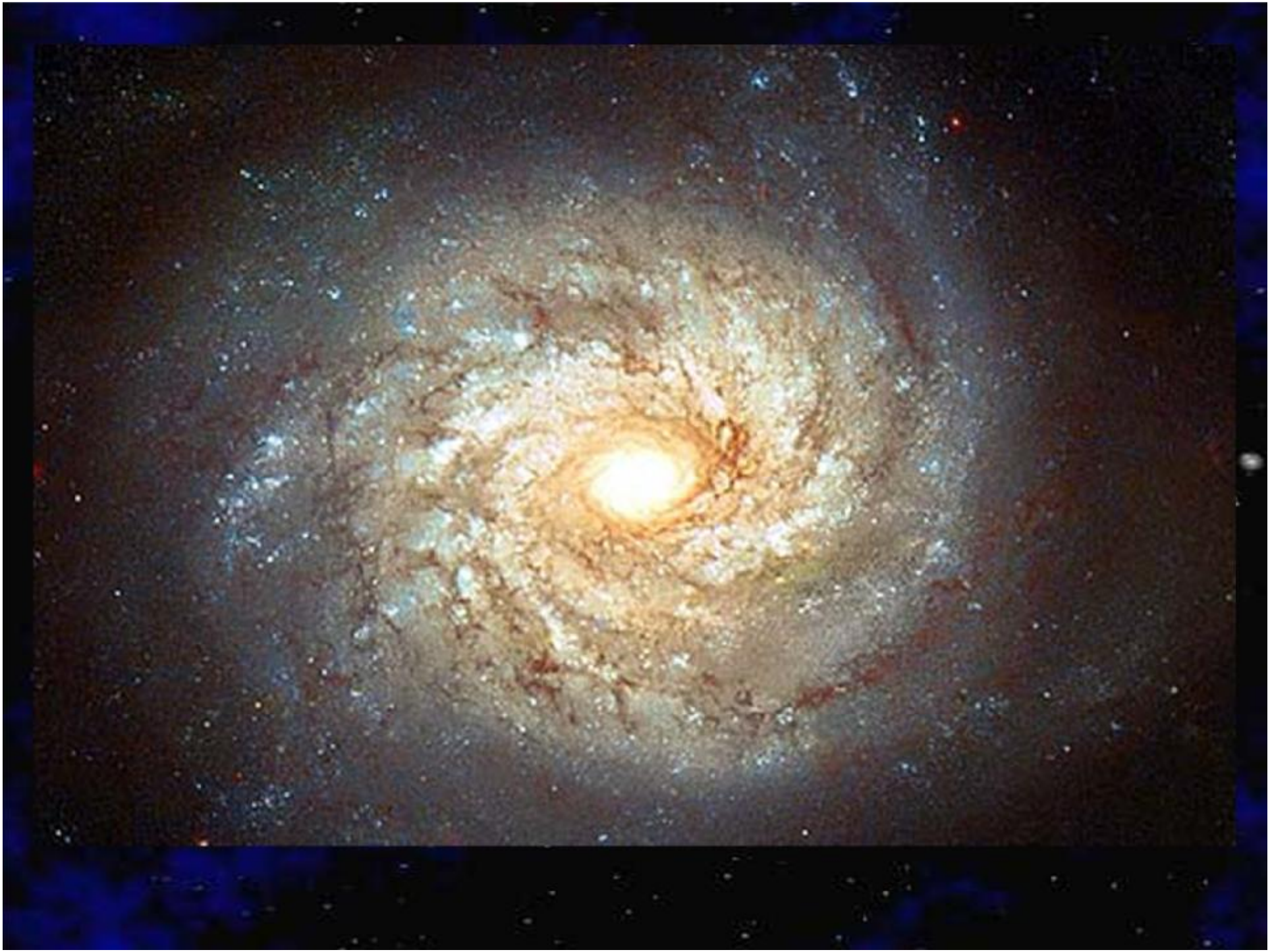


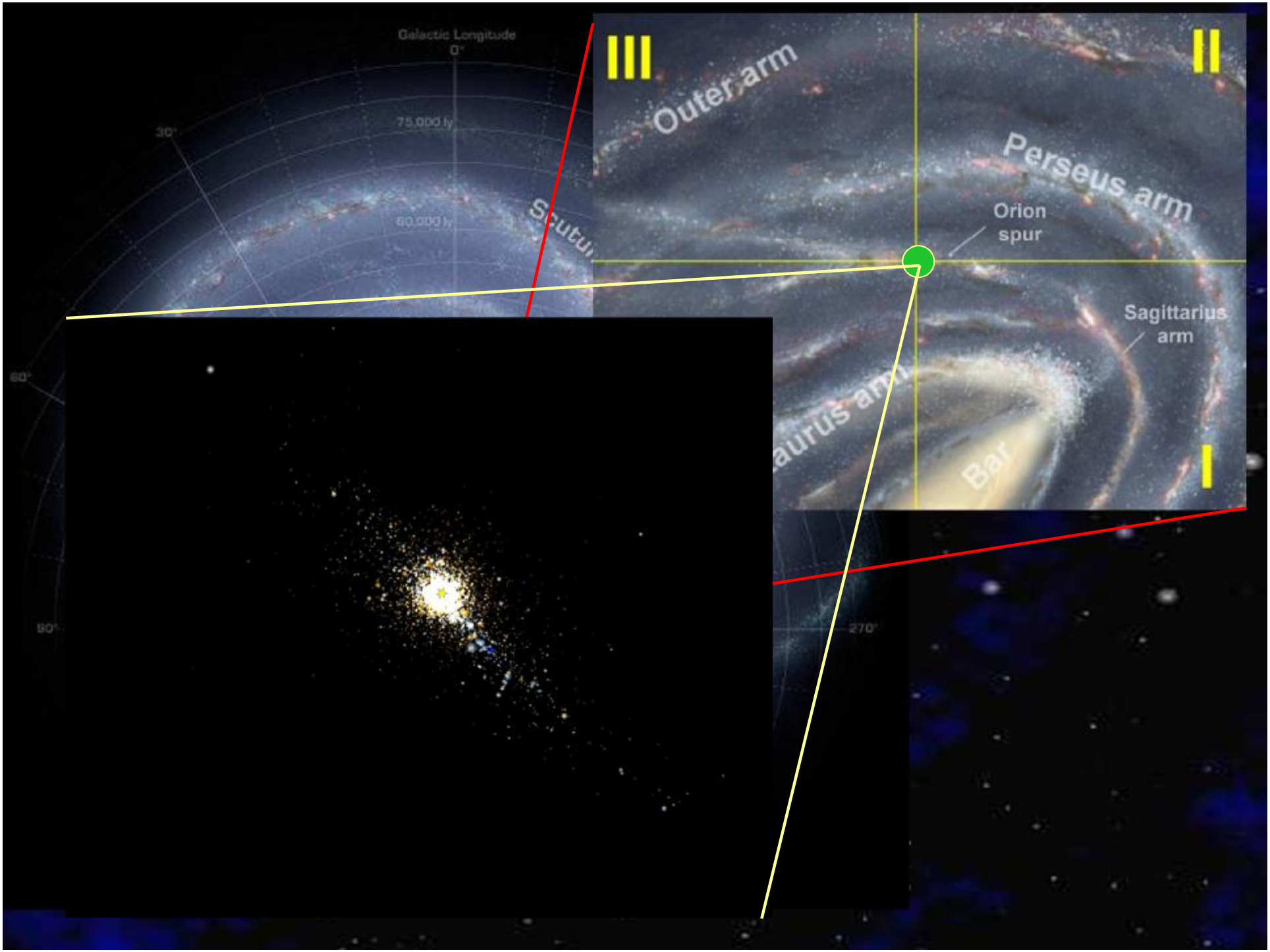


	Sun	α¹ Cen	α² Cen	Barnard's	BD +36° 2147	Lalande 21185	Sirius	ε Eri	CoD -36° 15693	61 Cyg A	Procyon	61 Cyg B	ε Ind	τ Cet
s.d:	1.0	1.20	0.90	0.06	0.14	0.15	1.43	0.77	0.20	0.52	1.77	0.36	0.69	0.85
Ly.:	0.0	4.39	4.39	5.94	8.20	8.31	8.60	10.49	10.73	11.35	11.40	11.42	11.82	11.89








Galactic Longitude
0°
30°
75,000 ly
60,000 ly
60°
90°
270°
III
II
I
Outer arm
Perseus arm
Orion
spur
Sagittarius
arm
Bar

A New Scale of Things

Sun....the size of a volley ball

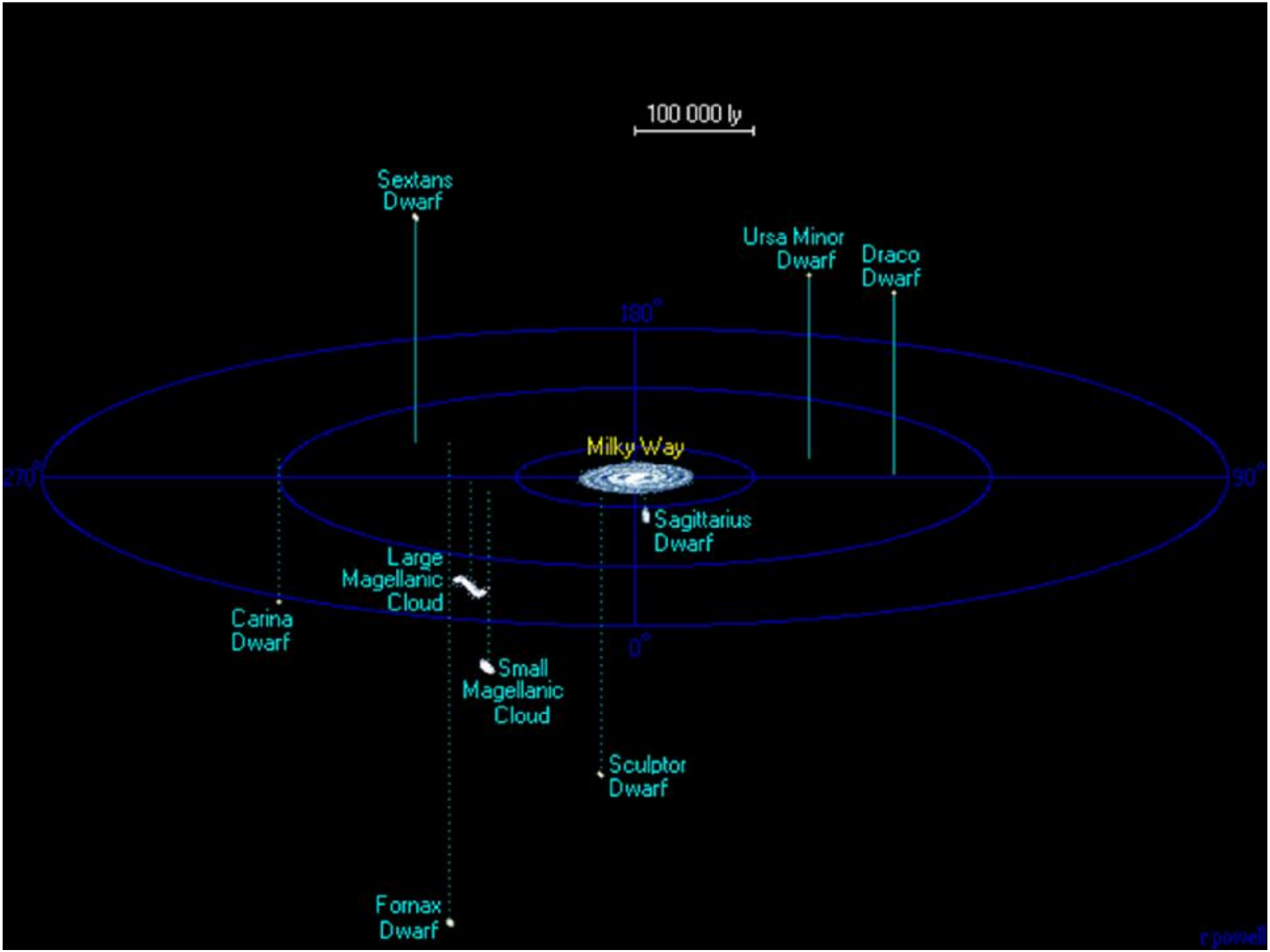
Earth....half the size of a BB, 100 yards away

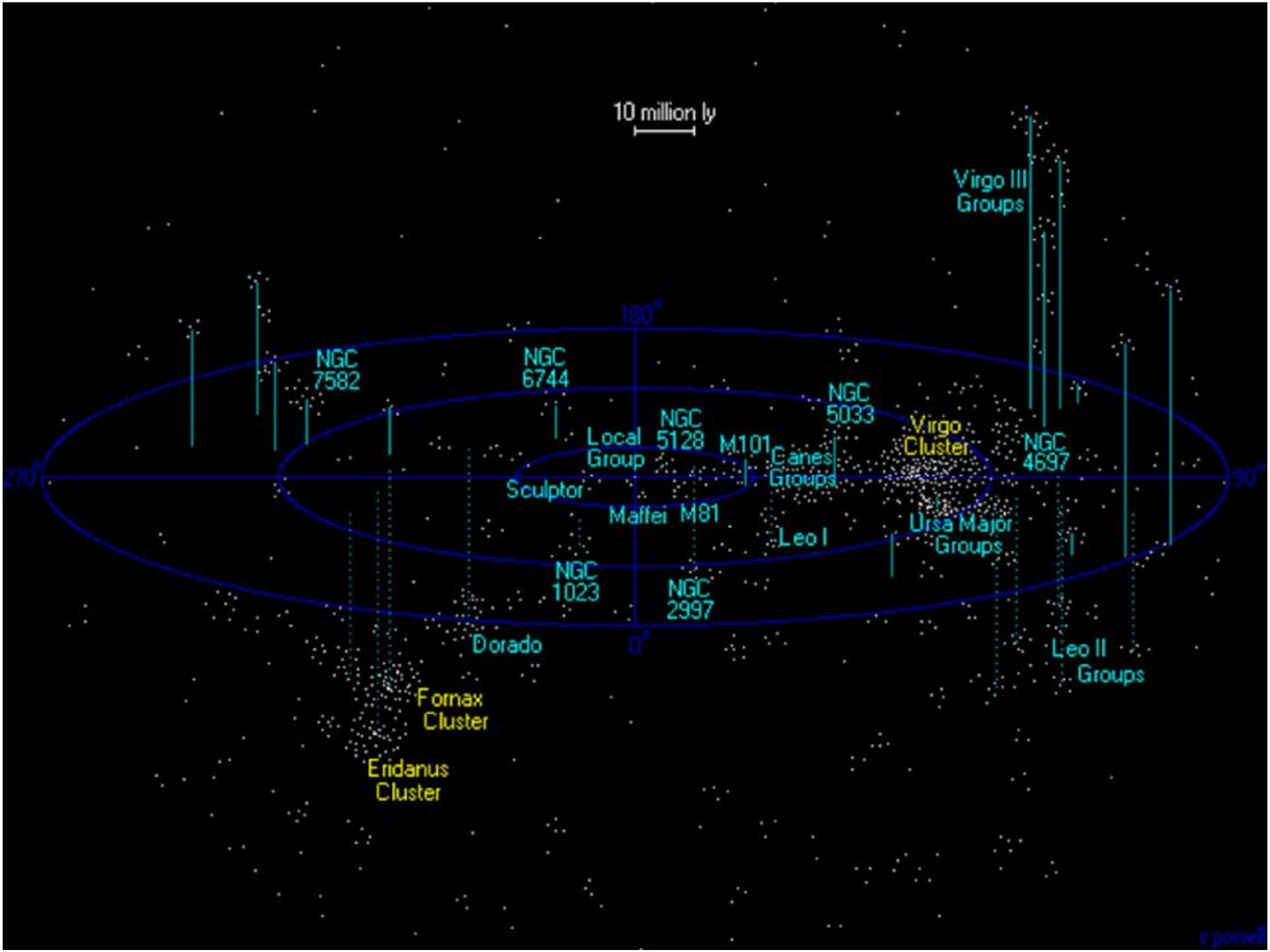
Solar System....ends at Notre Dame campus

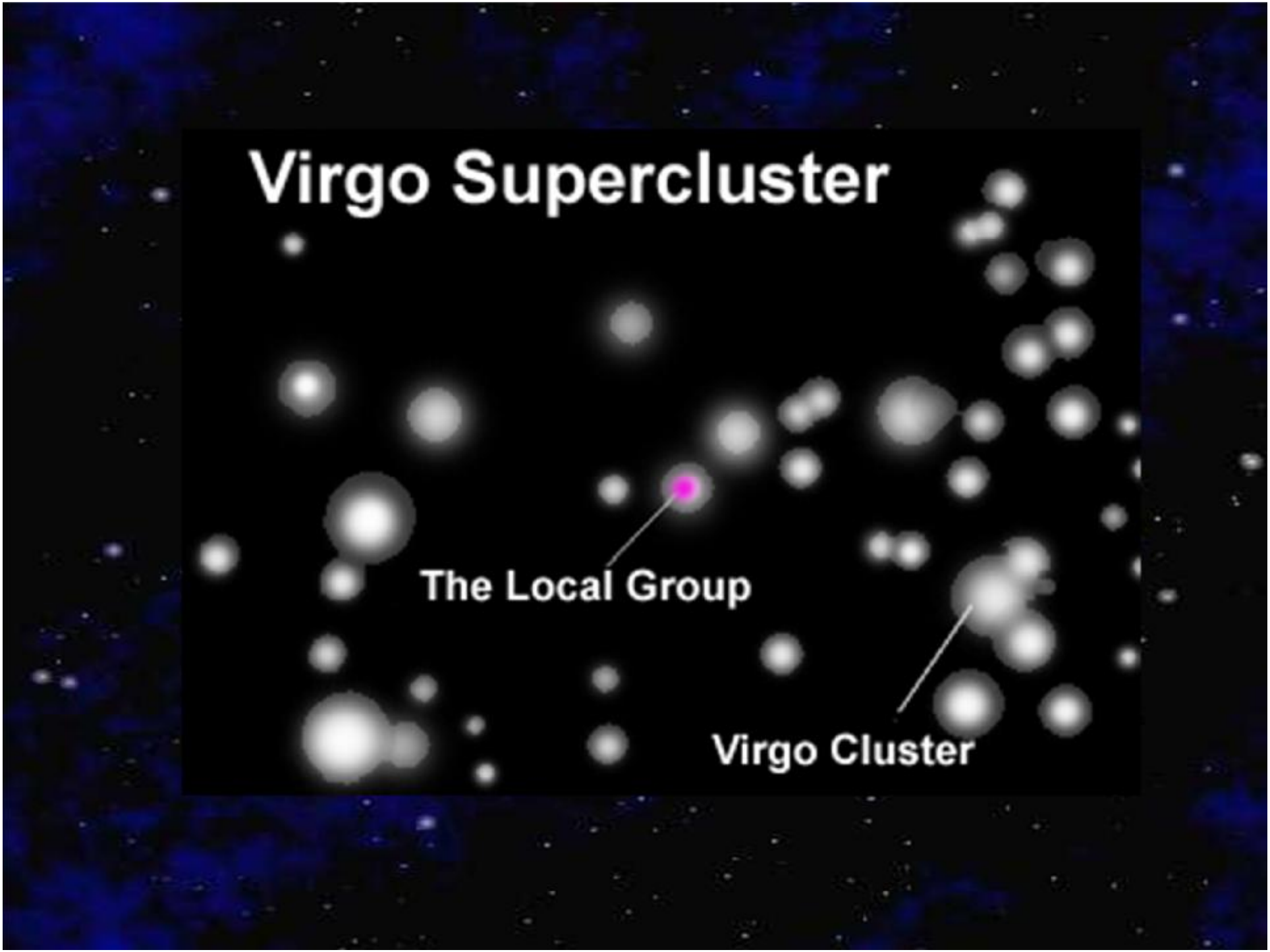
Pioneer Space Craft....approaching Niles

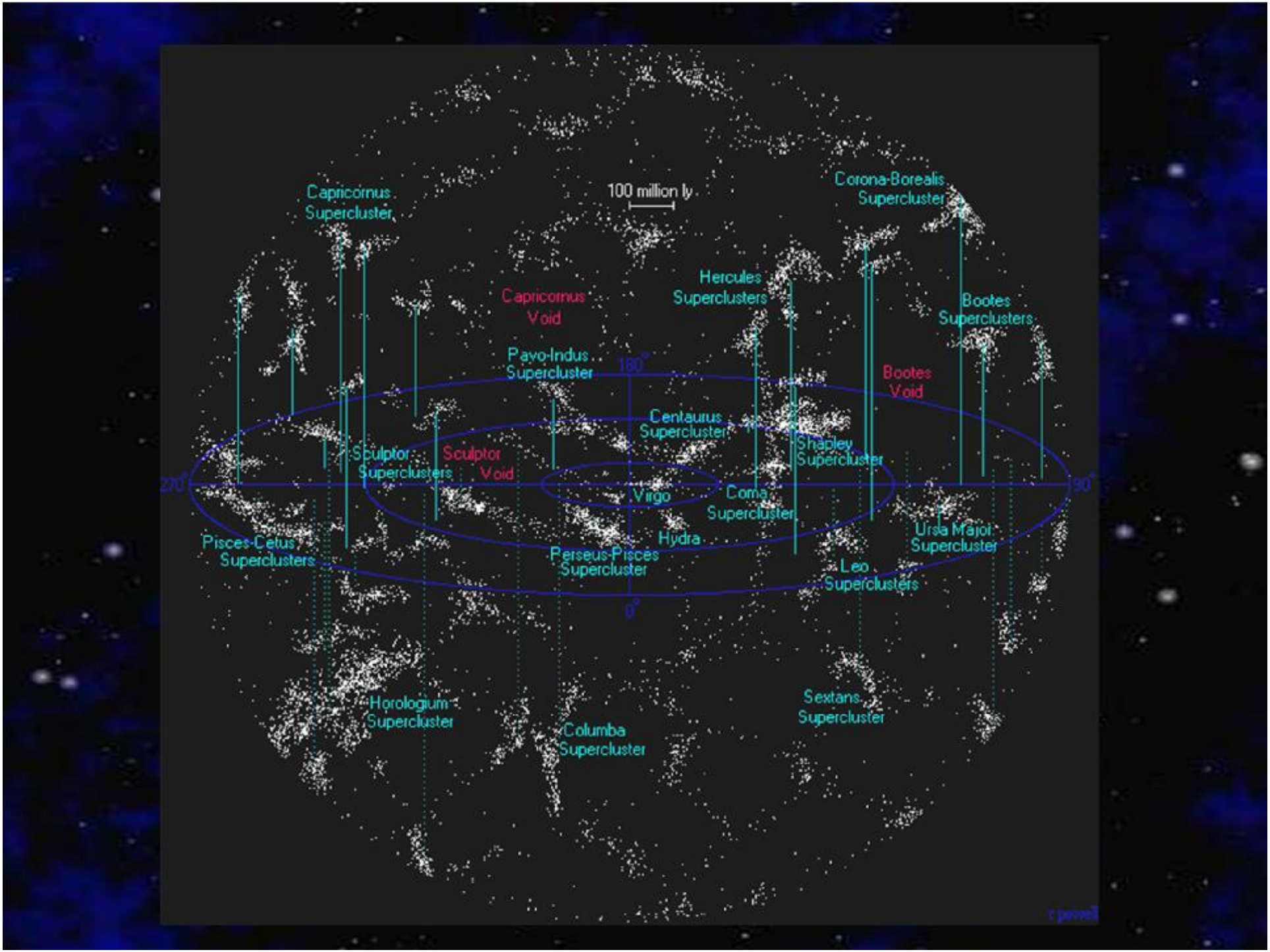
Nearest star....State of New Mexico

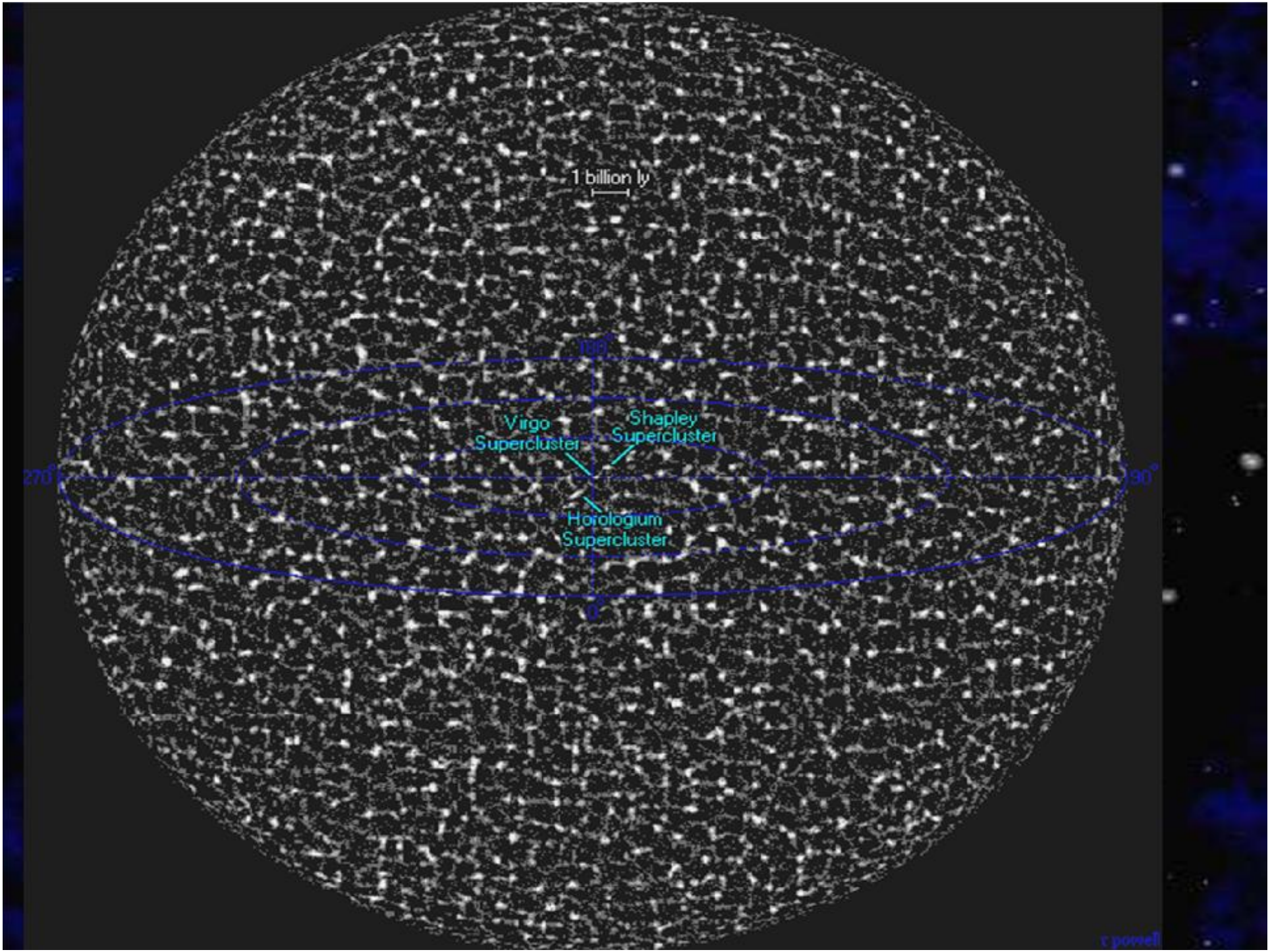
Center of Milky Way Galaxy....40x farther then Earth-Moon

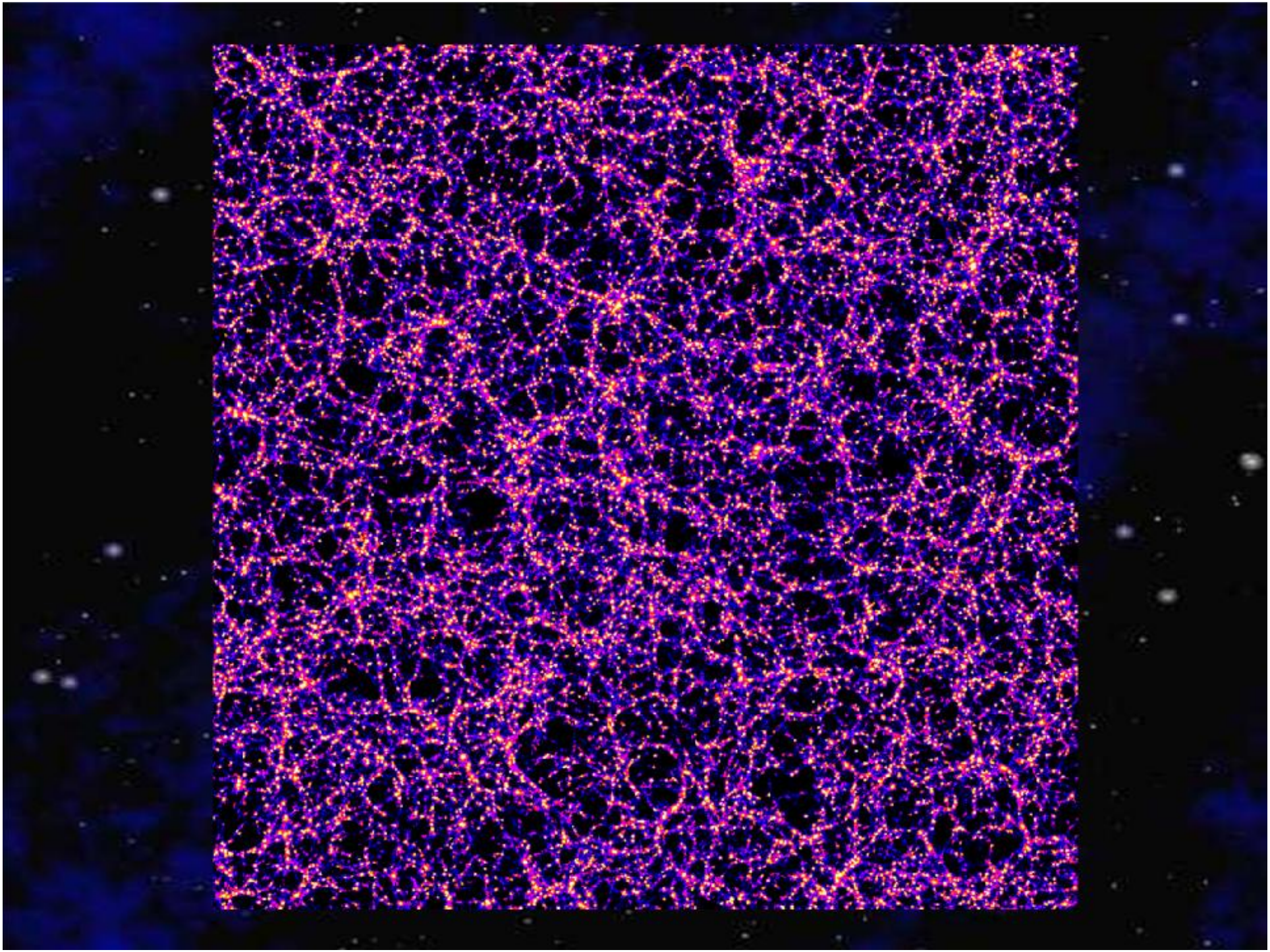

100 000 ly
Sextans Dwarf
Ursa Minor Dwarf
Draco Dwarf
180°
Milky Way
270°
90°
Sagittarius Dwarf
Large Magellanic Cloud
Carina Dwarf
0°
Small Magellanic Cloud
Sculptor Dwarf
Fornax Dwarf
r powell

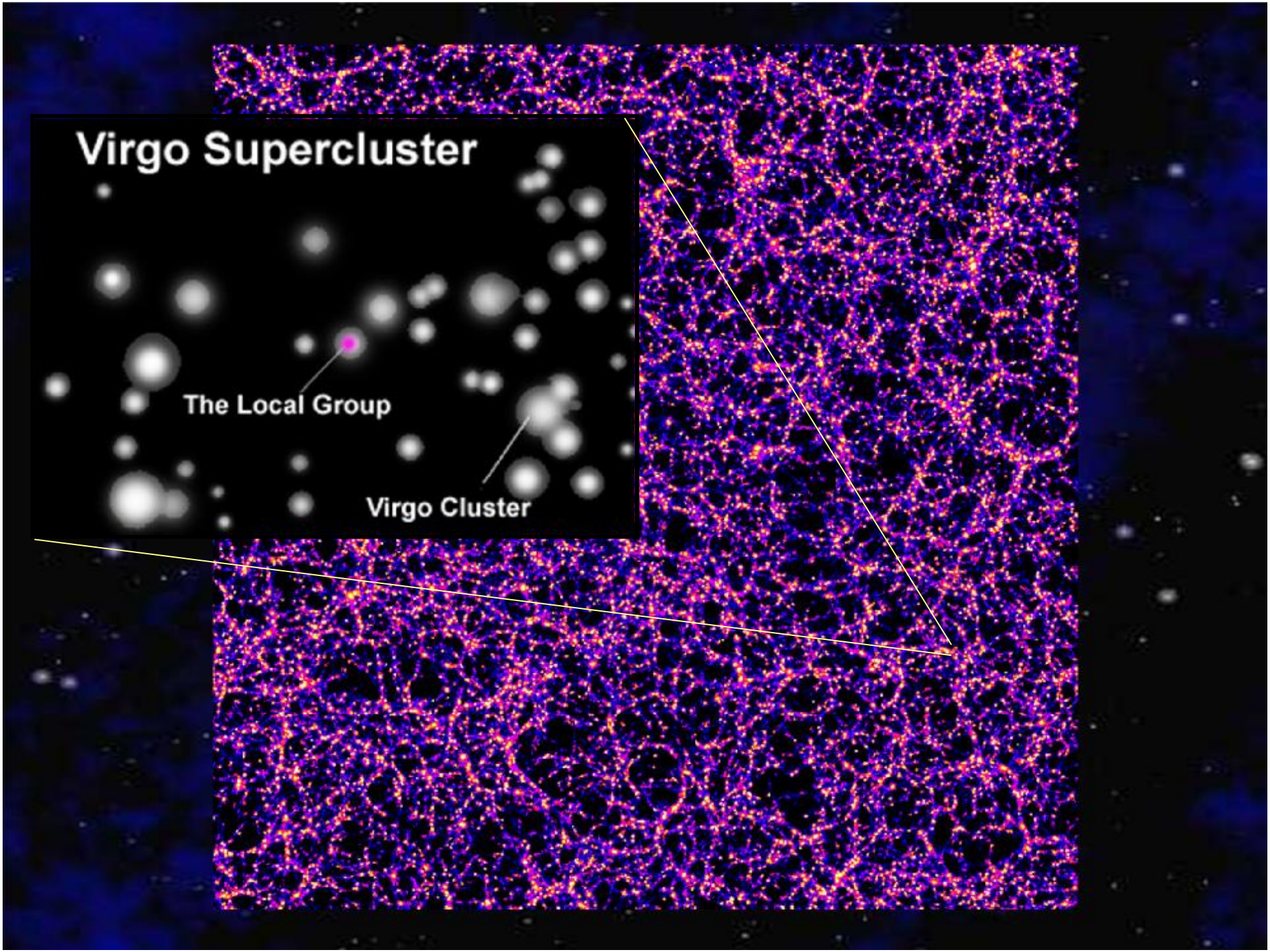

10 million ly
Virgo III
Groups
180°
NGC
7582
NGC
6744
NGC
5033
NGC
5128
Local
Group
M101
Canes
Groups
Virgo
Cluster
NGC
4697
270°
90°
Sculptor
Maffei
M81
Leo I
Ursa Major
Groups
NGC
1023
NGC
2997
0°
Dorado
Leo II
Groups
Fornax
Cluster
Eridanus
Cluster
rpowell


Virgo Supercluster
The Local Group
Virgo Cluster


Capricornus
Supercluster
100 million ly
Corona-Borealis
Supercluster
Hercules
Superclusters
Capricornus
Void
Bootes
Superclusters
Pavo-Indus
Supercluster
180°
Bootes
Void
Centaurus
Supercluster
Shapley
Supercluster
Sculptor
Superclusters
Sculptor
Void
270°
90°
Virgo
Coma
Supercluster
Hydra
Ursa Major
Supercluster
Pisces-Cetus
Superclusters
Perseus-Pisces
Supercluster
Leo
Superclusters
0°
Horologium
Supercluster
Columba
Supercluster
Sextans
Supercluster


1 billion ly
180°
Virgo
Supercluster
Shapley
Supercluster
270°
90°
Horologium
Supercluster
0°




Virgo Supercluster
The Local Group
Virgo Cluster


Deepest Image EVER

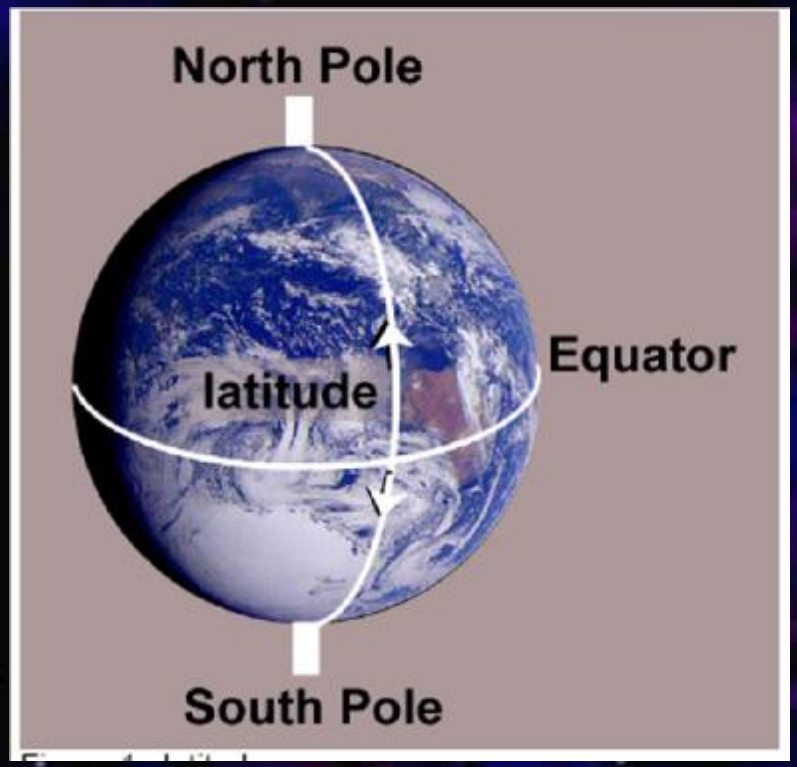

Organization of
the Sky

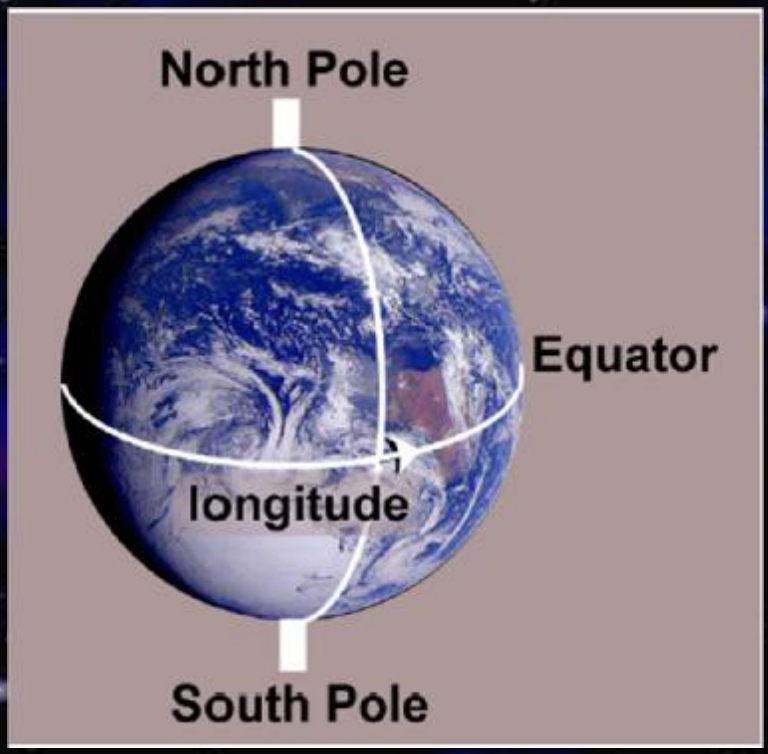
Three Main Ideas:

- What do we see in the sky?
- Is there ORDER or CHAOS?
- How are the motions related?

1. The Sky at Night
2. Seasons, Lunar phases, Eclipses
3. Geocentric ⟶ Heliocentric Cosmology

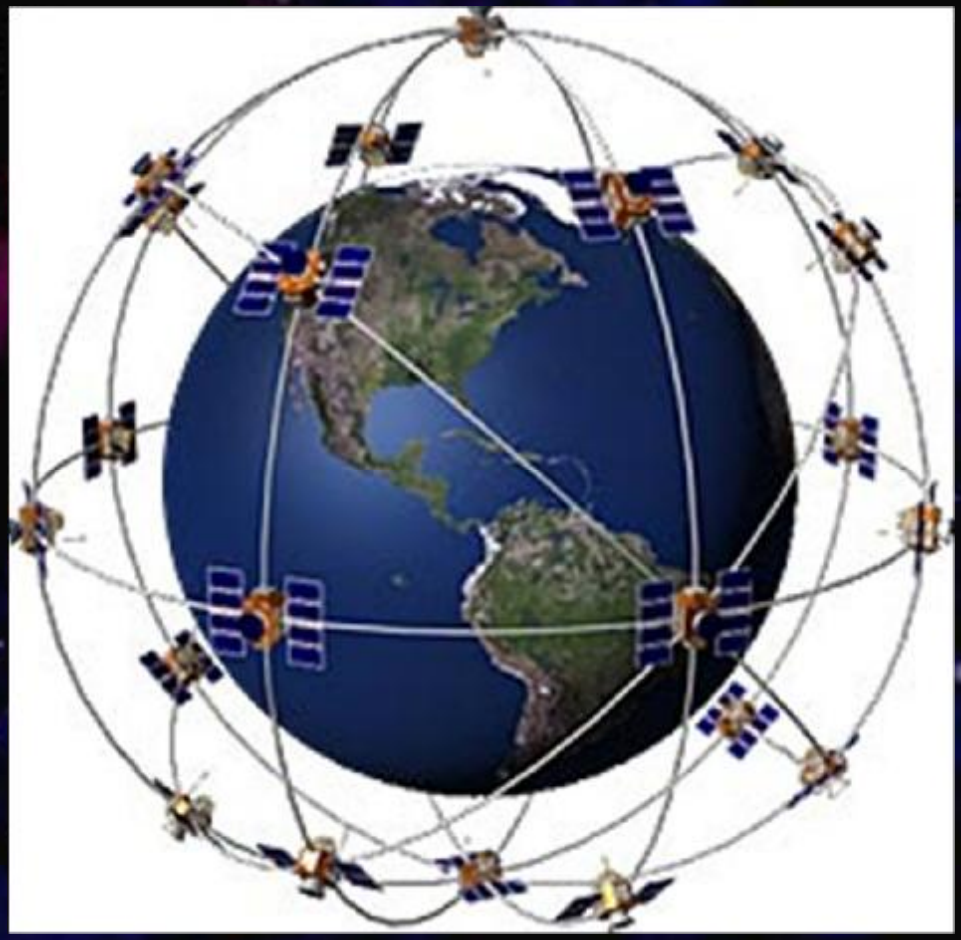
Navigating the Night Sky -The Earth



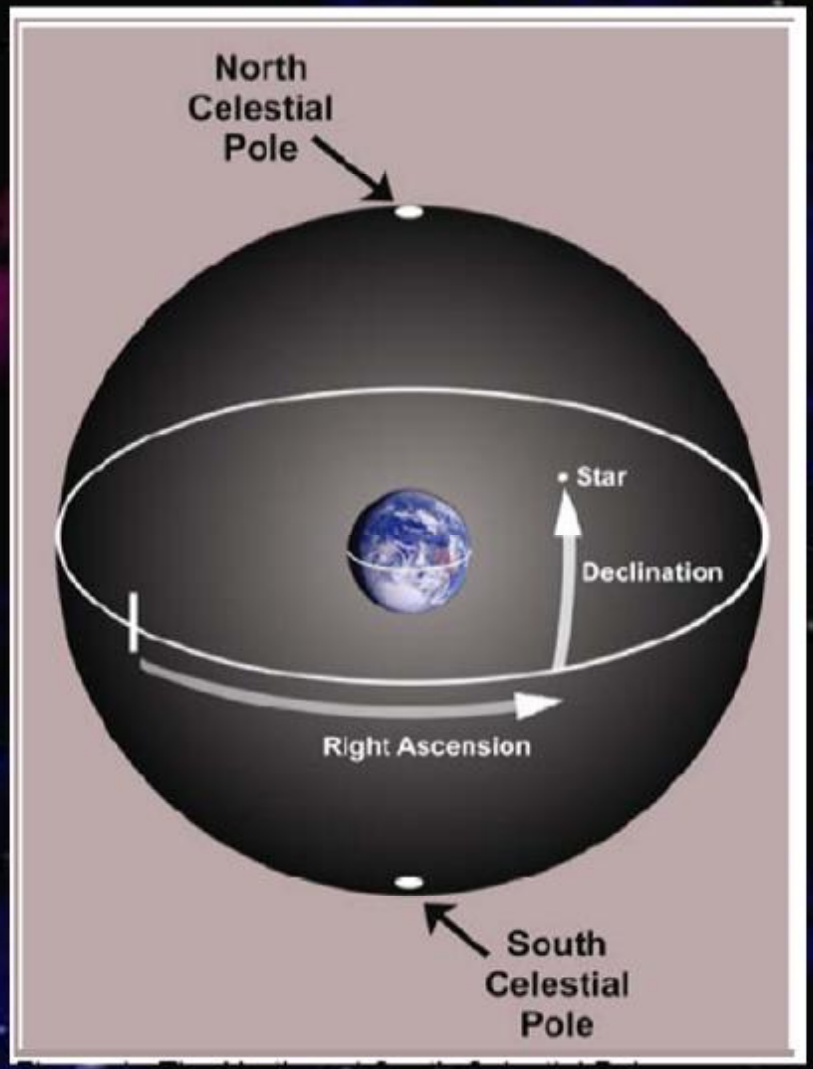


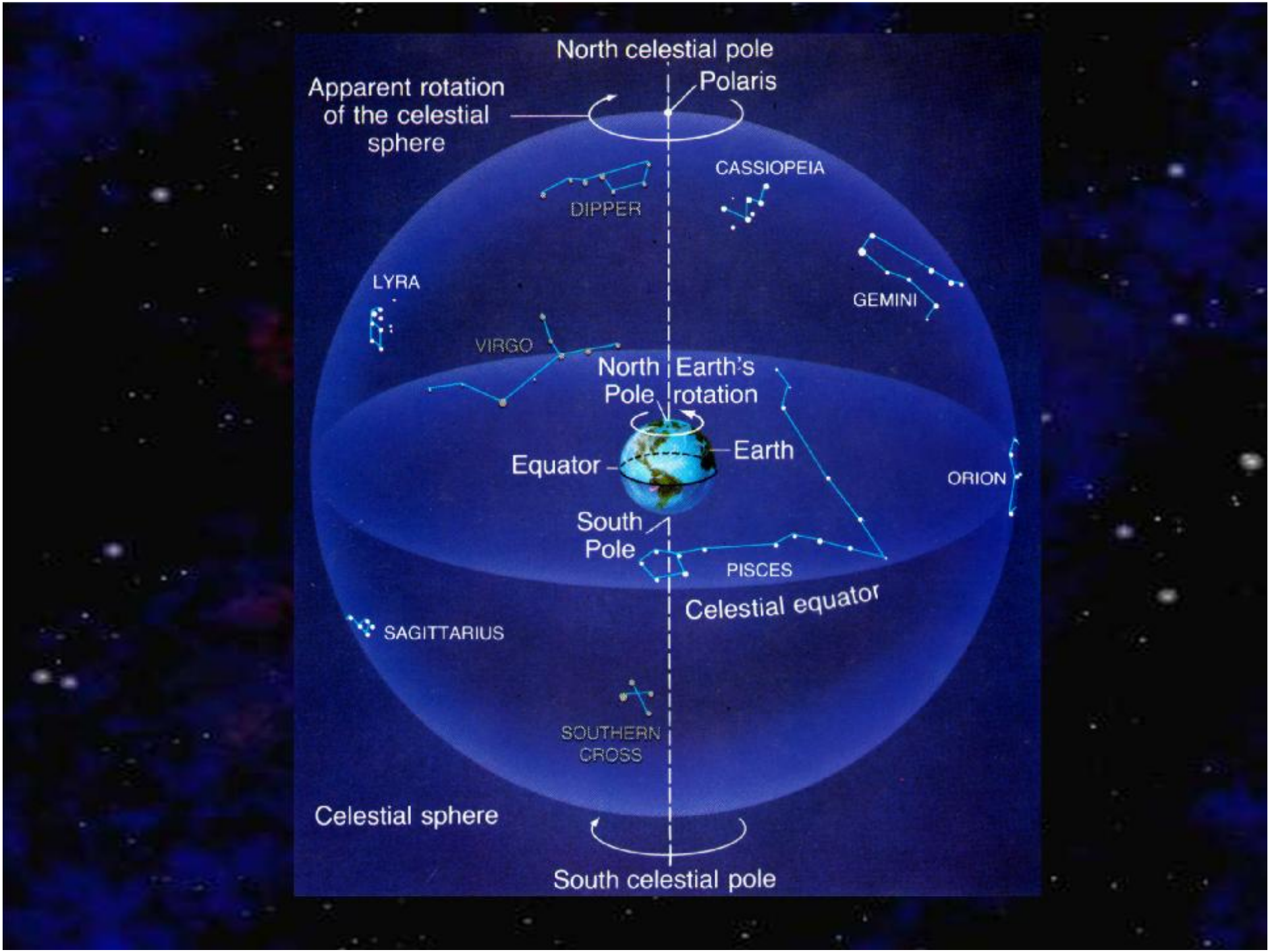
Latitude and Longitude

Navigating the Night Sky - The Earth



Navigating the Night Sky - The Sky




North celestial pole
Polaris
Apparent rotation of the celestial sphere
CASSIOPEIA
DIPPER
LYRA
GEMINI
VIRGO
North Pole
Earth's rotation
Earth
Equator
ORION
South Pole
PISCES
Celestial equator
SAGITTARIUS
SOUTHERN CROSS
Celestial sphere
South celestial pole

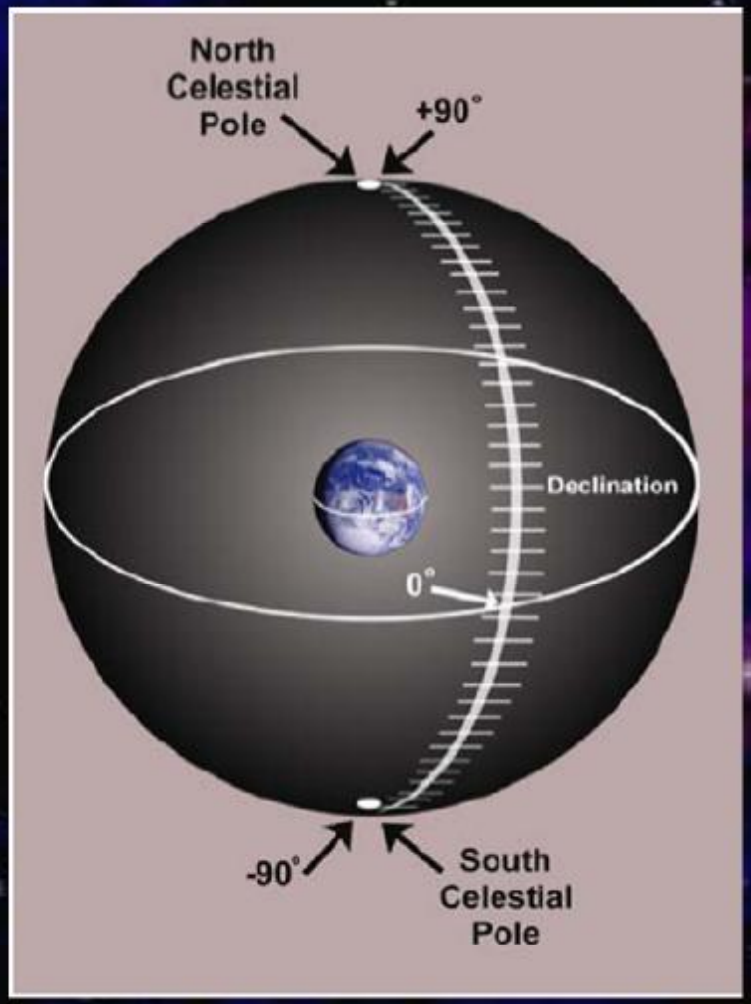
Star Trails:

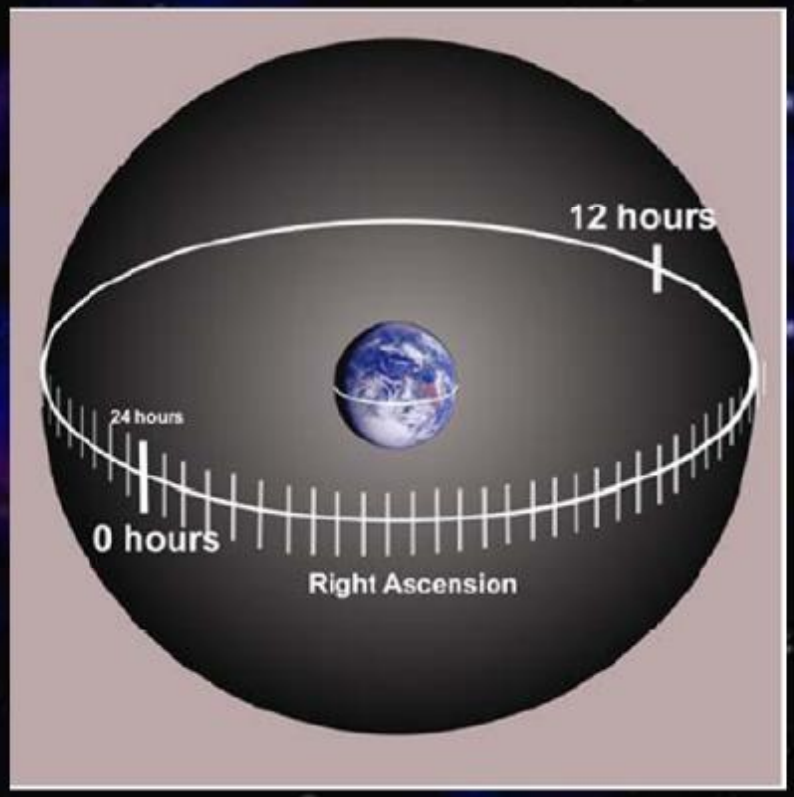
Star Trails:

Star Trails:

Star Trails:

Navigating the Night Sky - The Sky





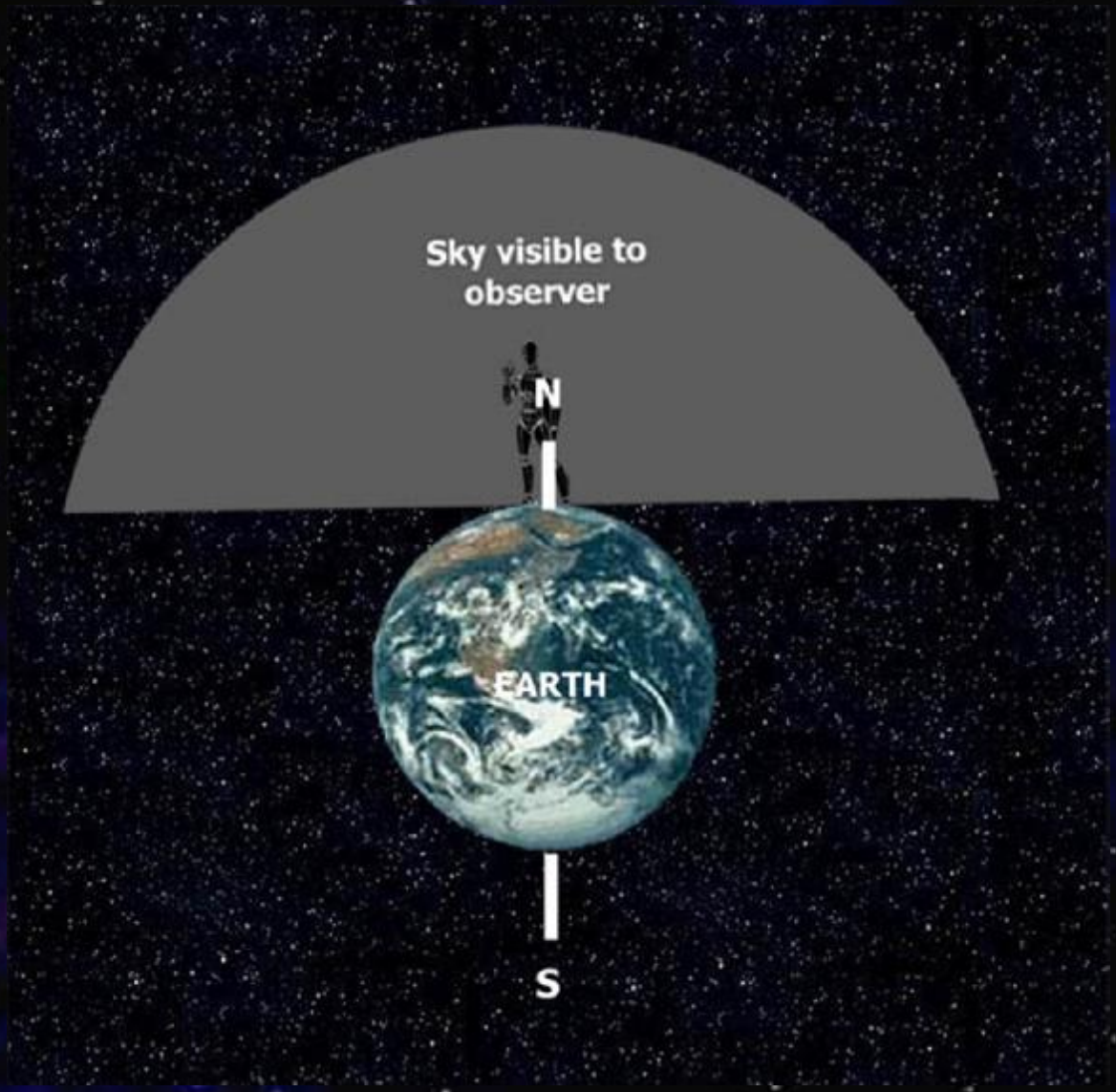
Declination and Right Ascension

Latitude and Longitude = Declination and Right Ascension

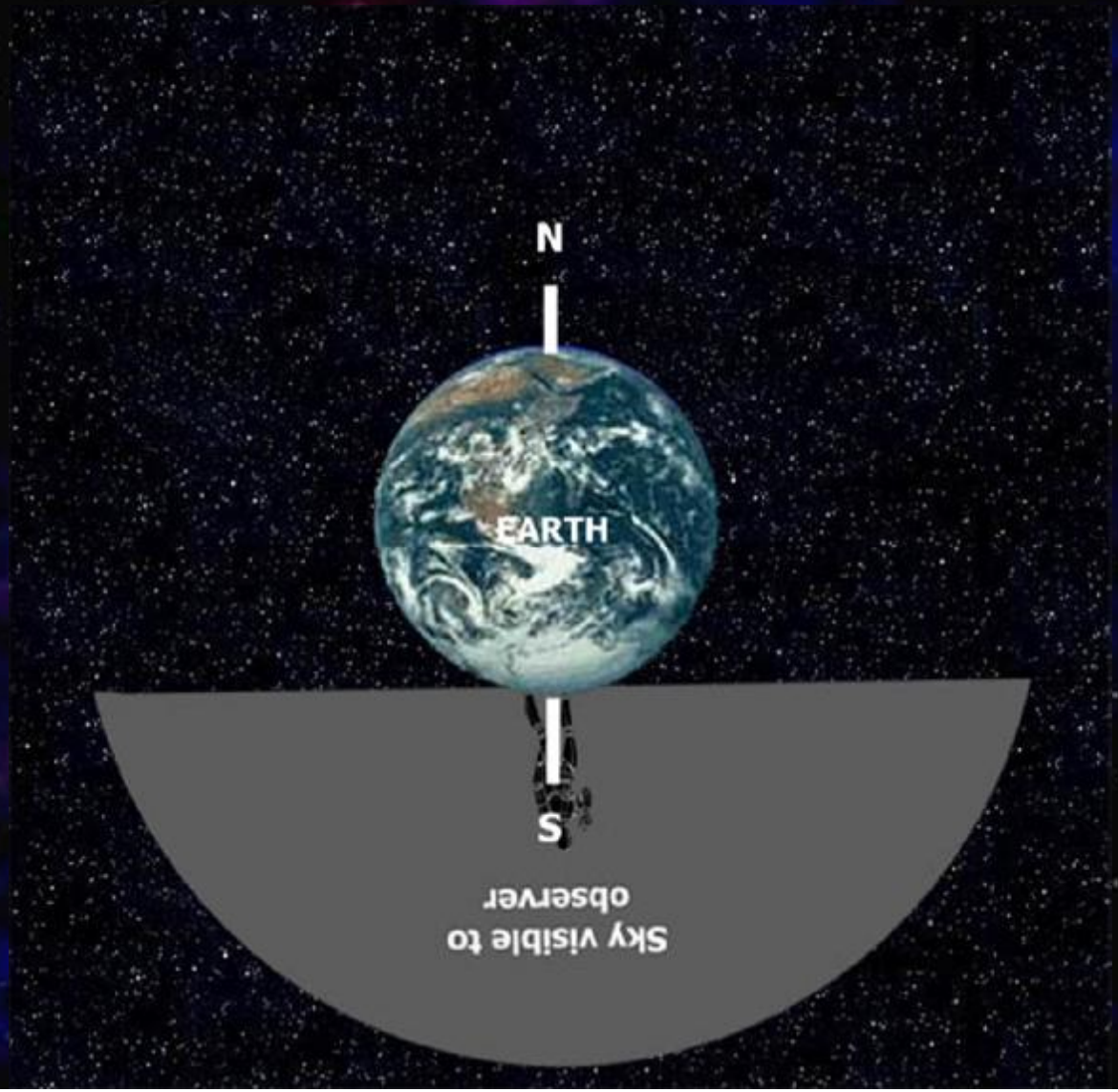
CELESTIAL SPHERE

It is often convenient to imagine the Earth is at the center of a great “sphere of the sky”

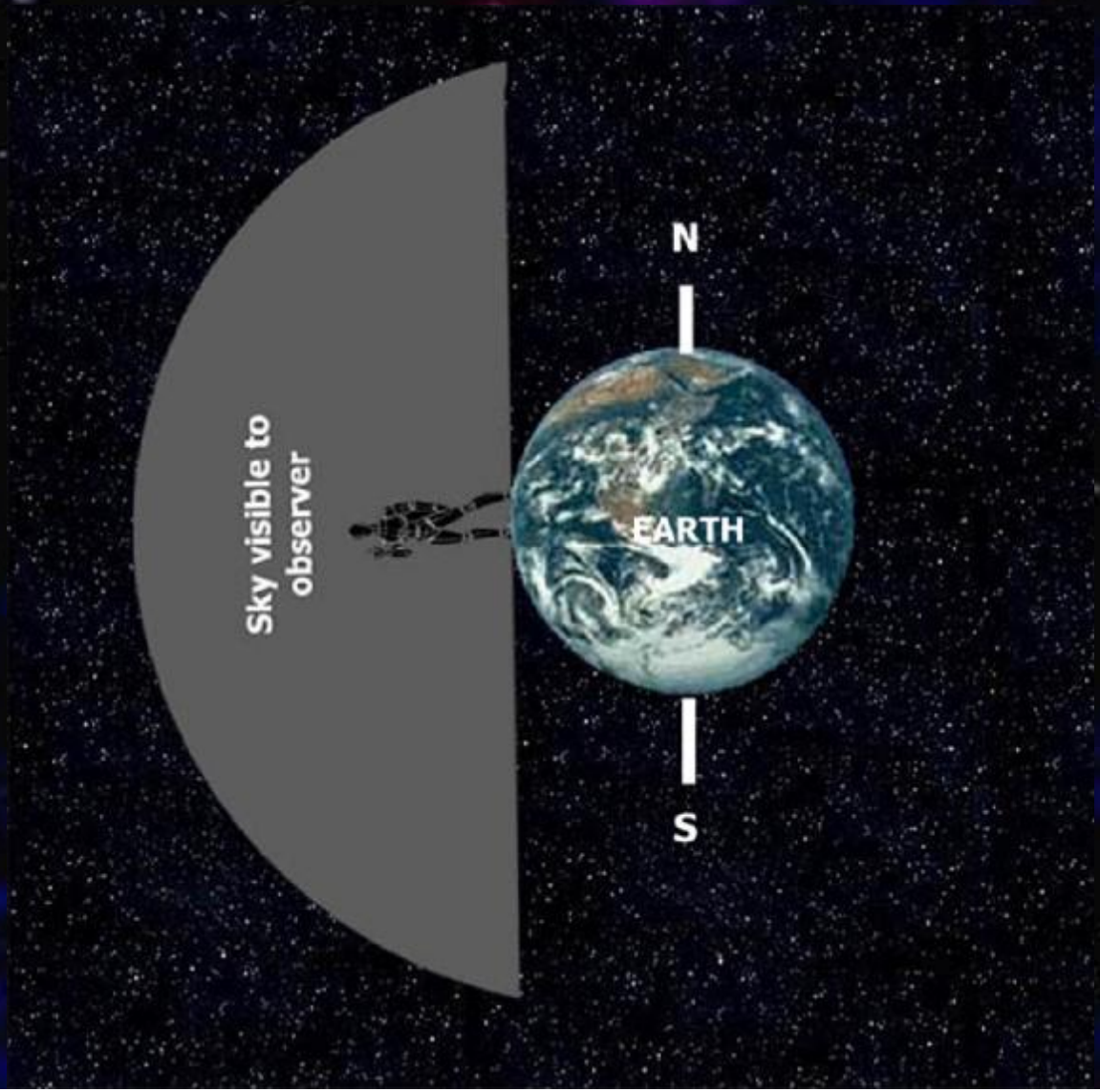
Observer at North Pole



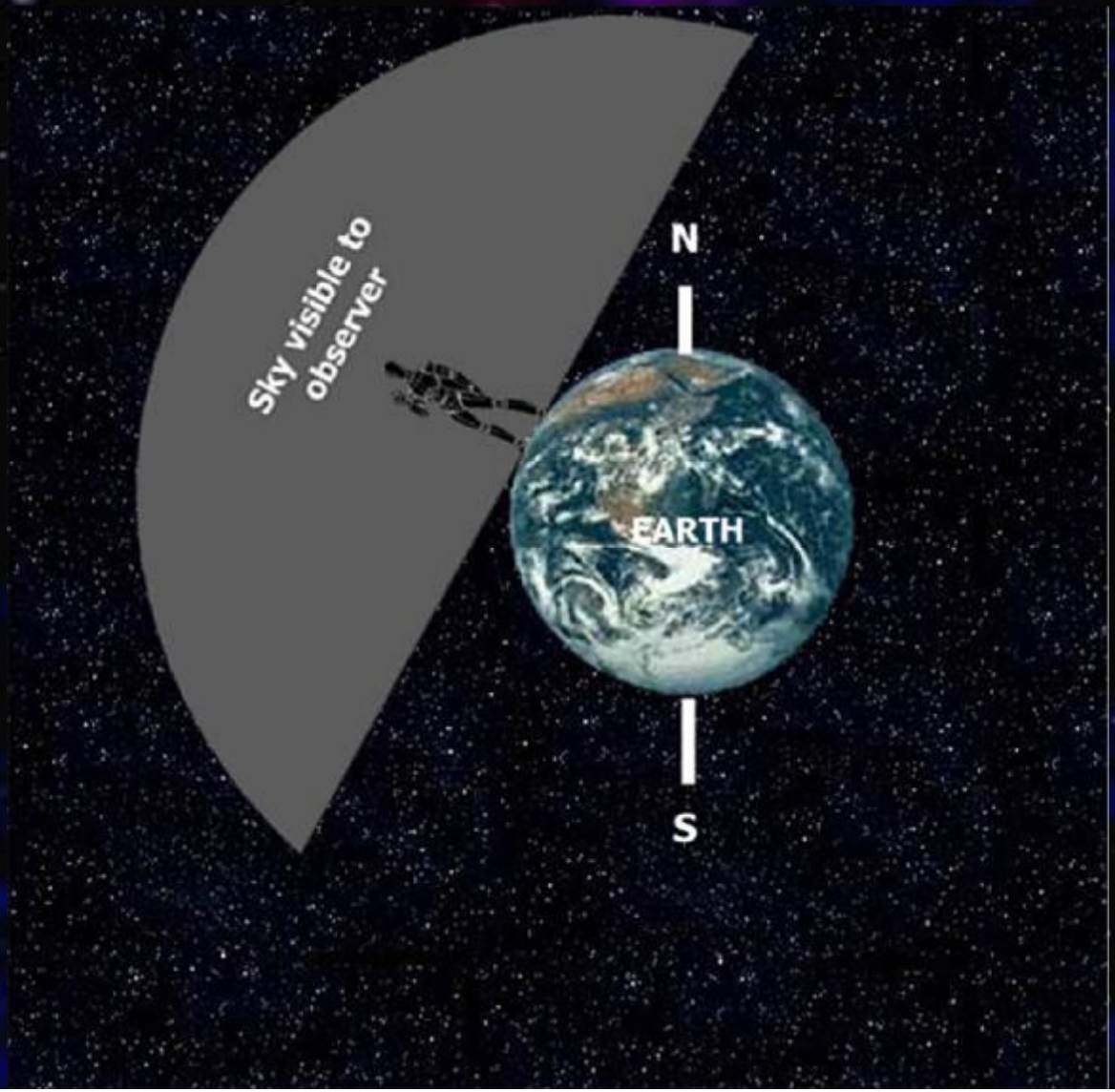
Observer at South Pole



Observer at Equator



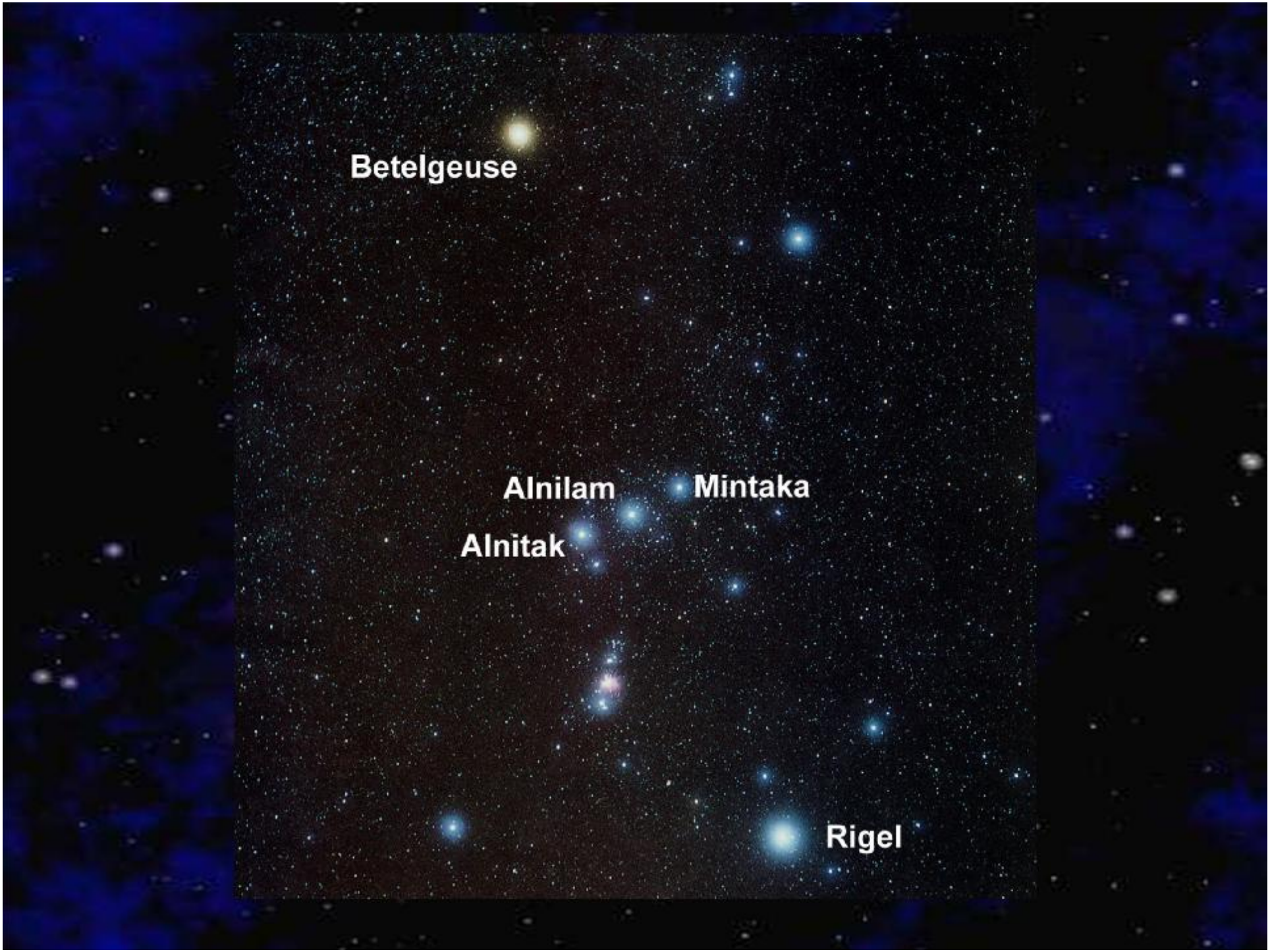
Observer at San Diego



CONSTELLATIONS

A pattern of stars named after mythological animals, “characters” or objects.

A constellation name or pattern usually has no physical significance!


Betelgeuse
Alnilam
Mintaka
Alnitak
Rigel

Bayer System (Johann Bayer 1603)

Developed the modern system of star designations

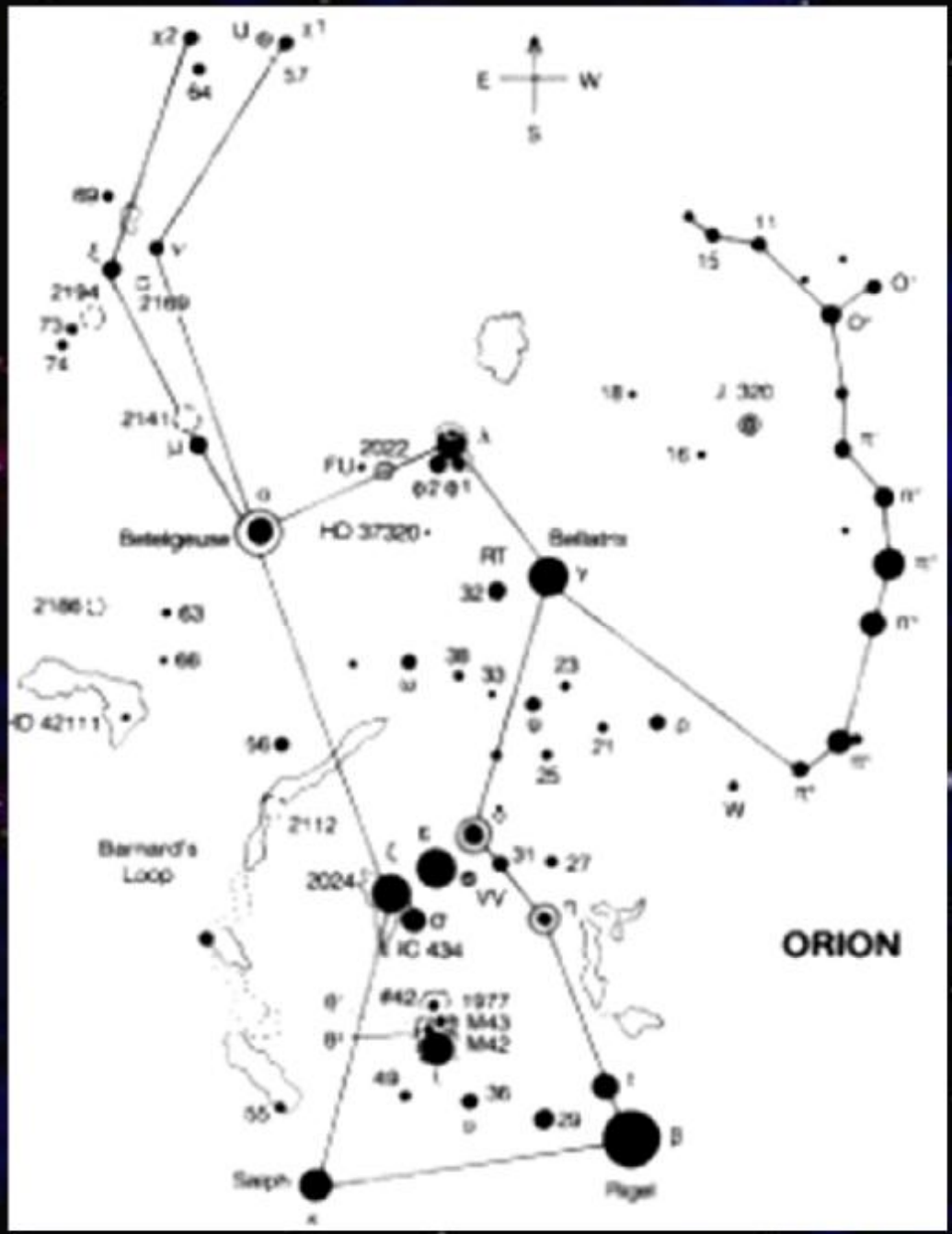
Greek Alphabet + Possessive ending:

α – brightest β – 2nd brightest γ – 3rd brightest

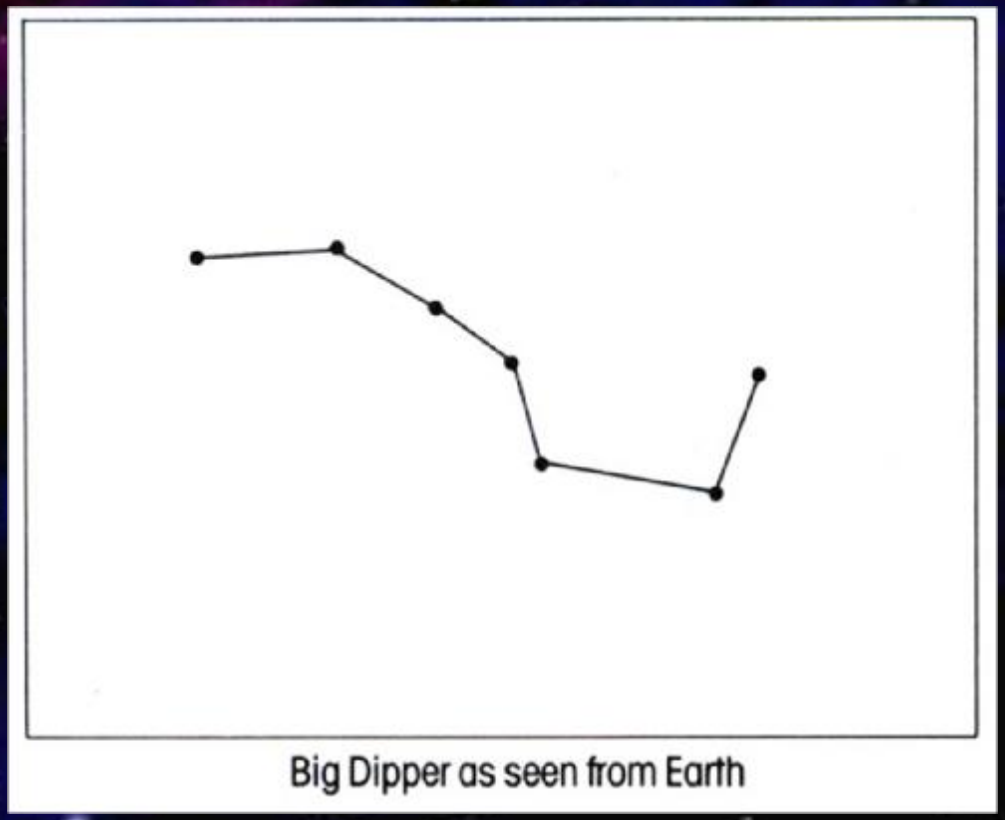
α Centauri

β Cygni

δ Cephei

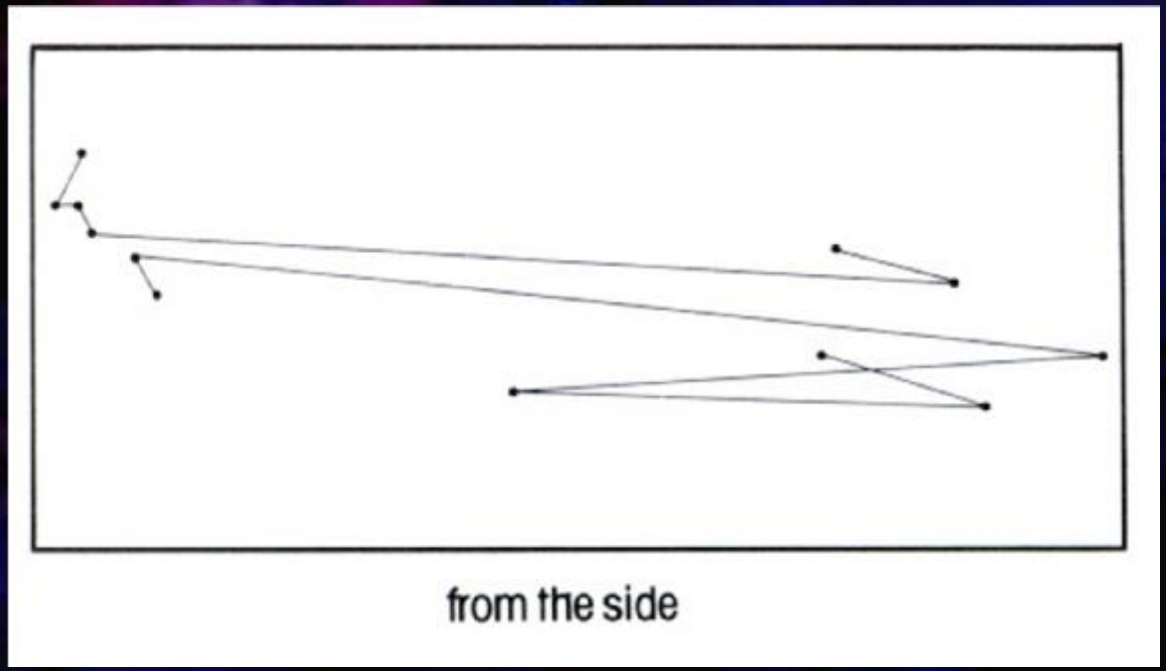

N
E
W
S
Betelgeuse
Bellatrix
HD 37320
RT
FU
2022
2141
2194
2189
2186
2112
2024
IC 434
M43
M42
1977
HD 42111
Barnard's Loop
Saiph
Rigel
ORION

The illusion of constellations

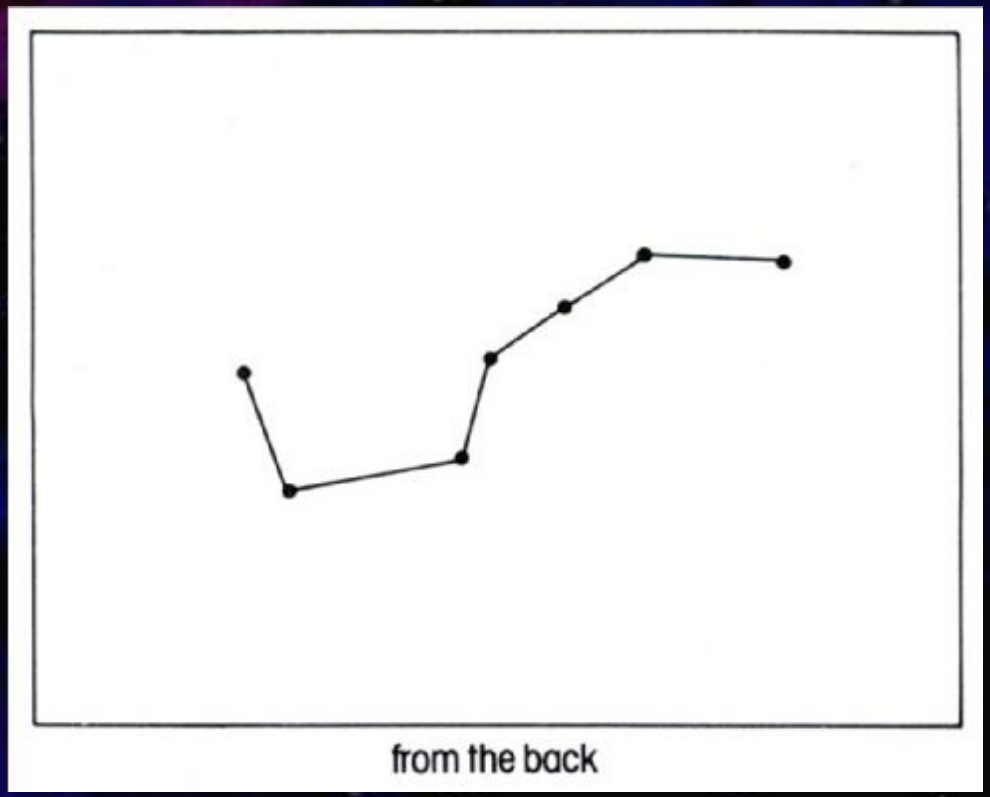


Big Dipper as seen from Earth

The illusion of constellations

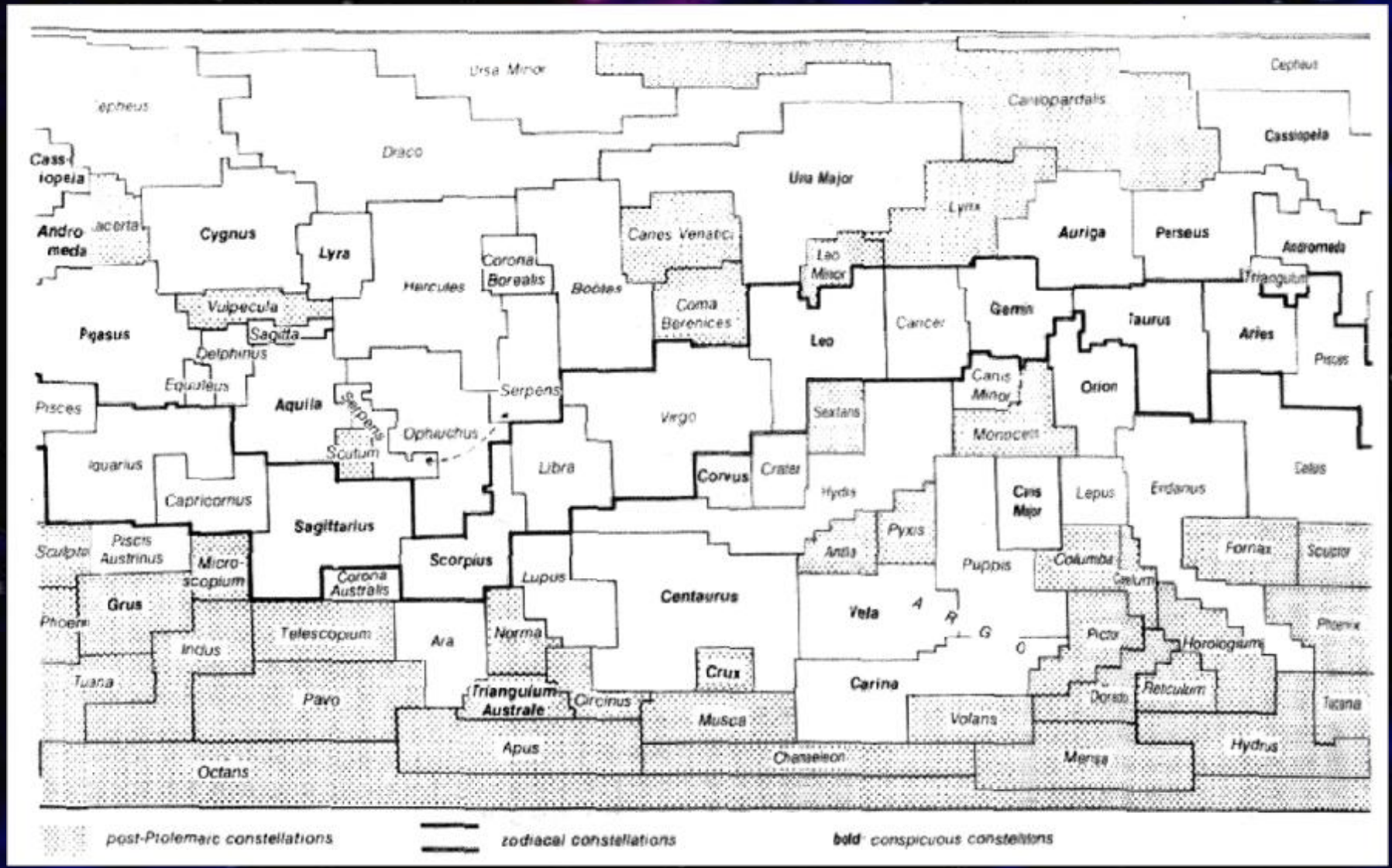


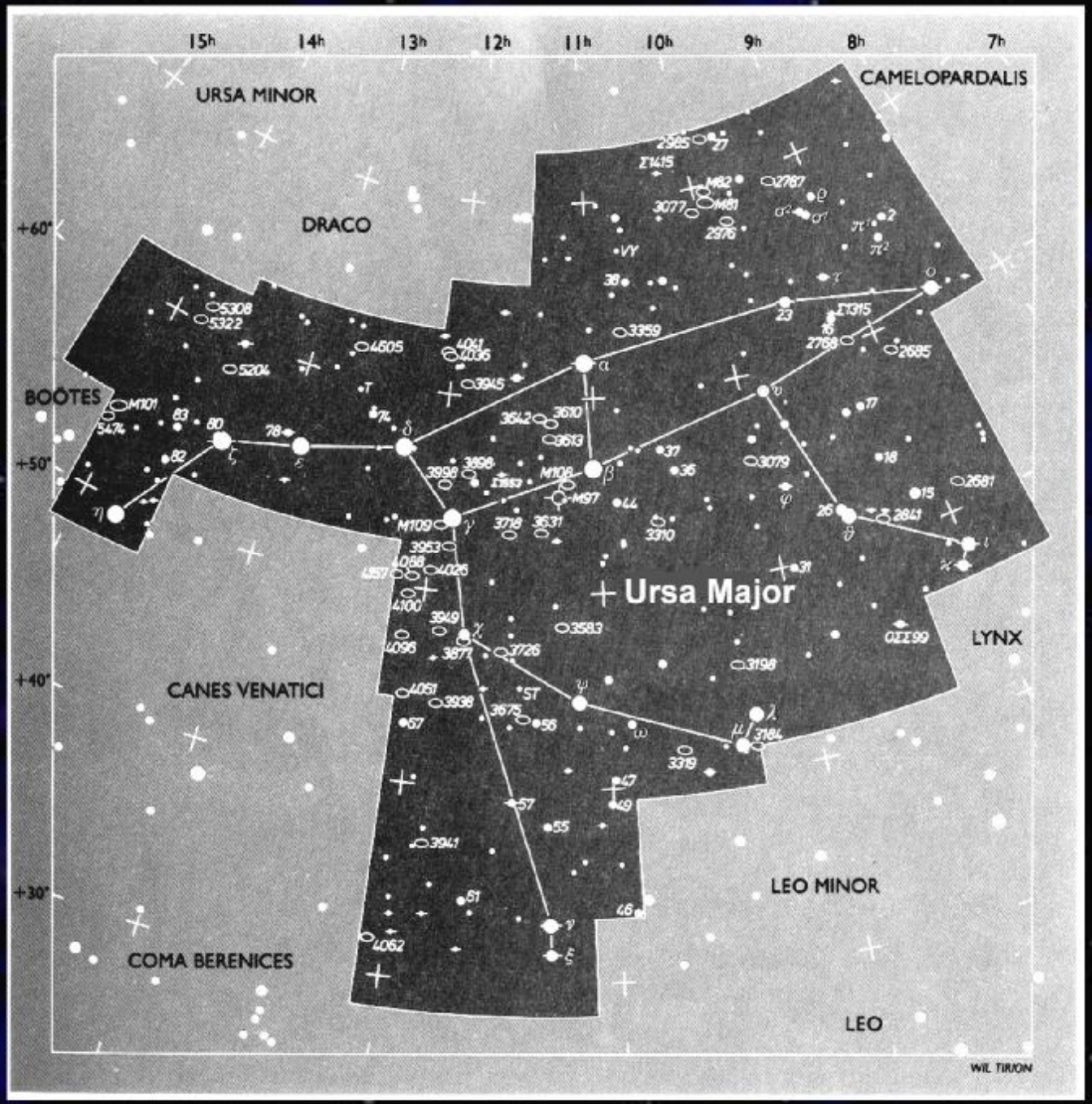
The illusion of constellations



from the back

Constellation Borders




15h
14h
13h
12h
11h
10h
9h
8h
7h
+60°
+50°
+40°
+30°
URSA MINOR
CAMELOPARDALIS
DRACO
BOOTES
CANES VENATICI
COMA BERENICES
LYNX
LEO MINOR
LEO
Ursa Major
WIL TIRION

MECHANICS OF THE SKY:

APPARENT MOTIONS

SOLAR DAY:

The time it takes the Sun to complete two successive crossings of the meridian.

24 hours

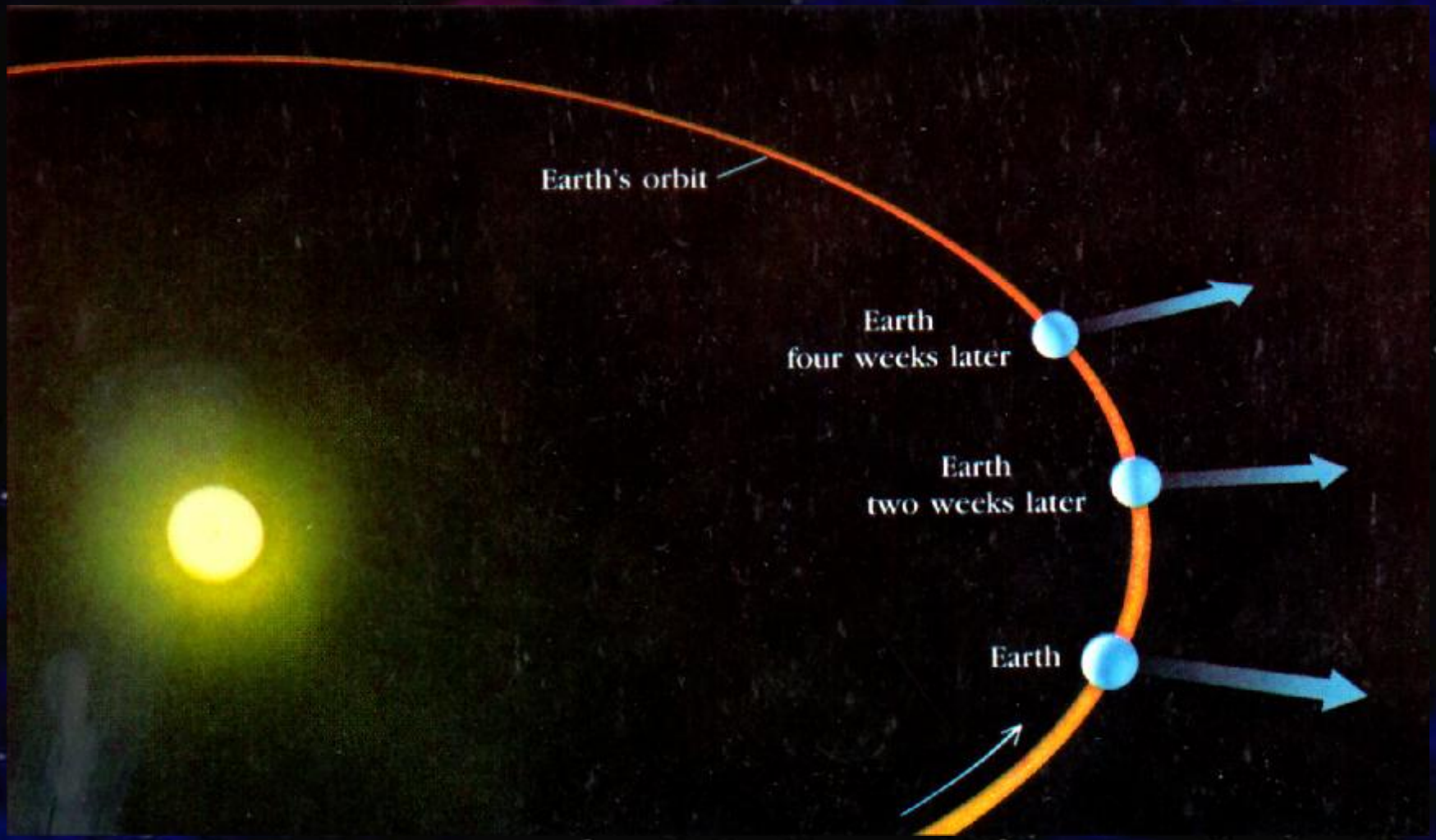
Caused by the ROTATION of the Earth on its axis

SIDEREAL DAY:

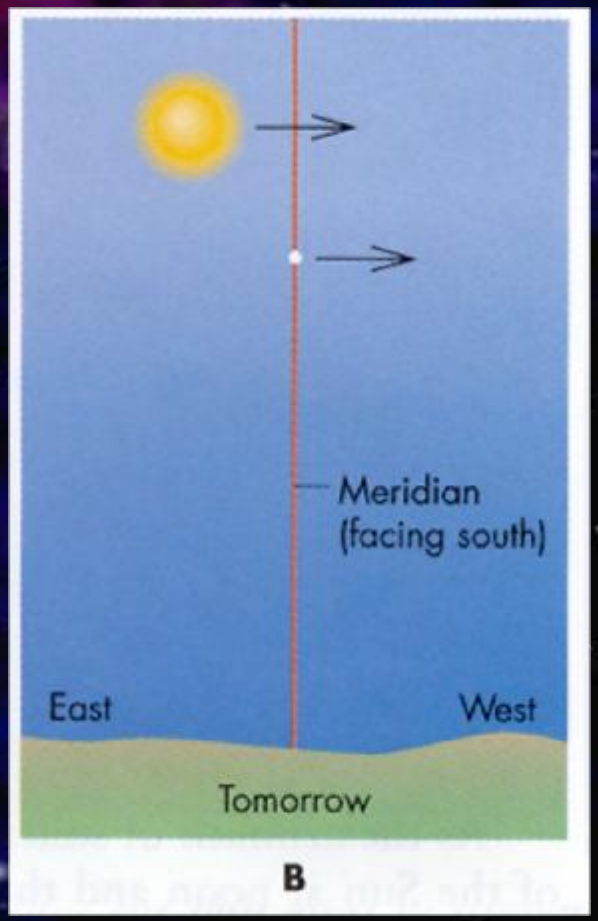
The time it takes for two successive crossings of a celestial object (other than the Sun, Moon or planets) across the meridian.

23 hours 56 minutes 4.091 seconds

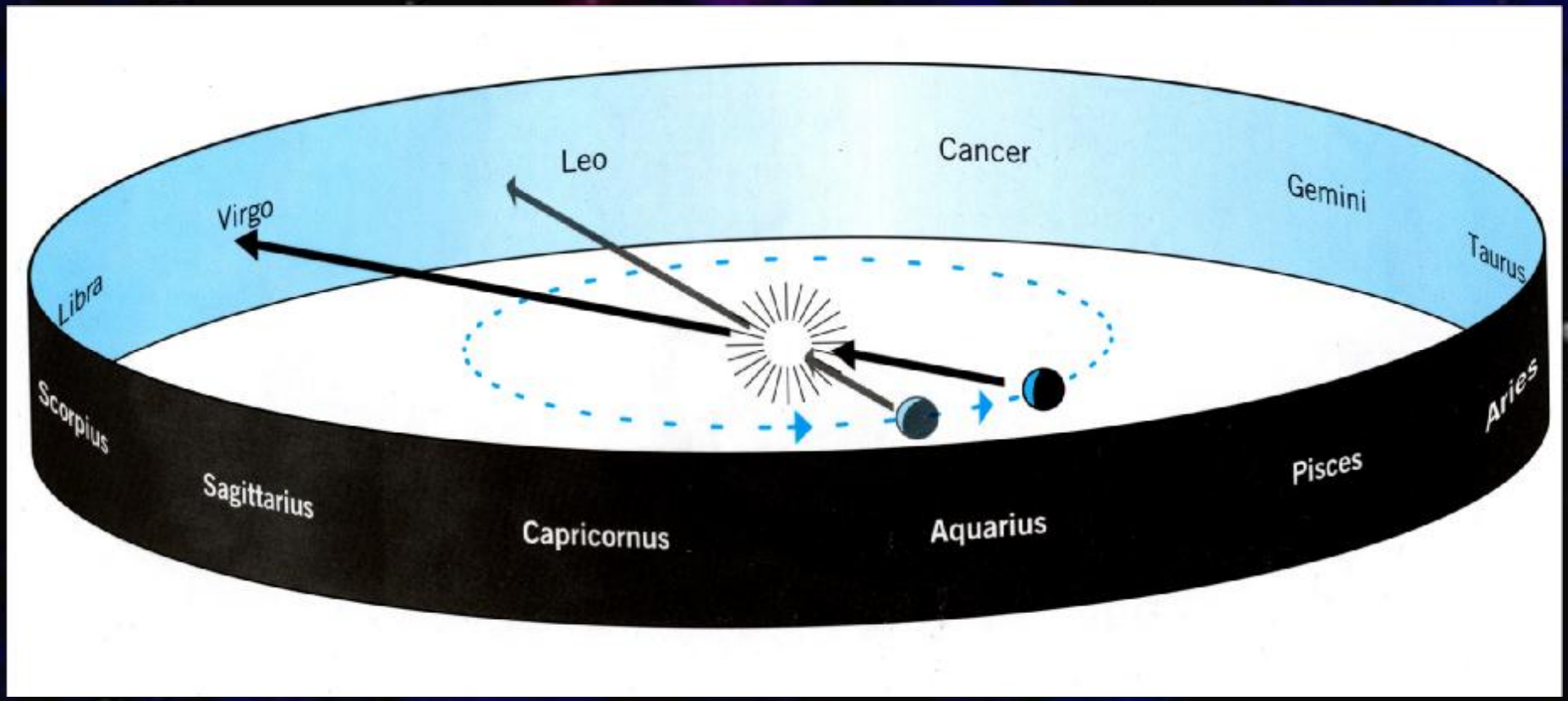
Solar Day vs. Sidereal Day



Solar Day vs. Sidereal Day

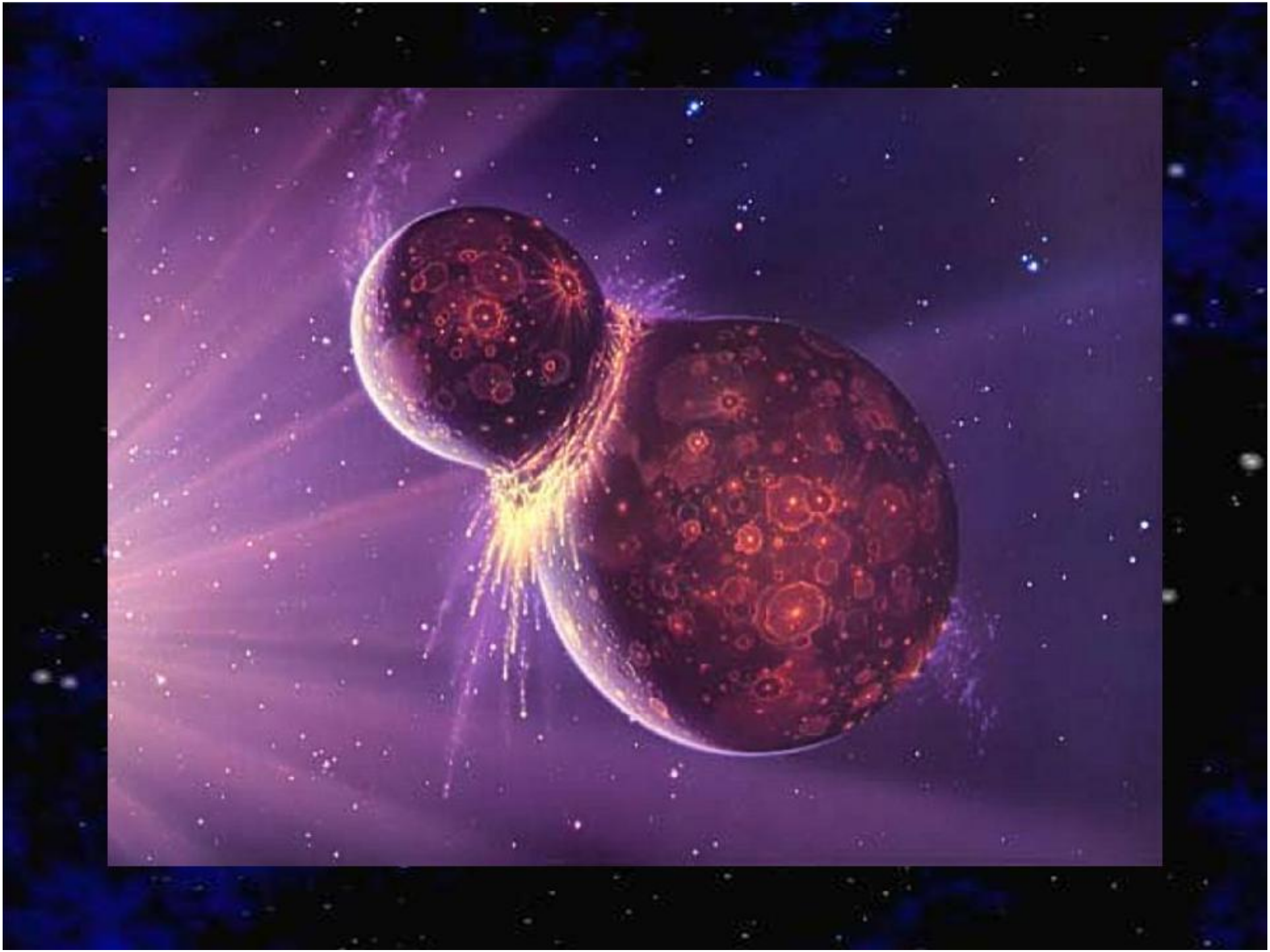


ANNUAL MOTION OF THE SUN



§ ***ECLIPTIC*** – the apparent path the Sun travels across the sky.


NORTH
PACIFIC
OCEAN
MEXICO



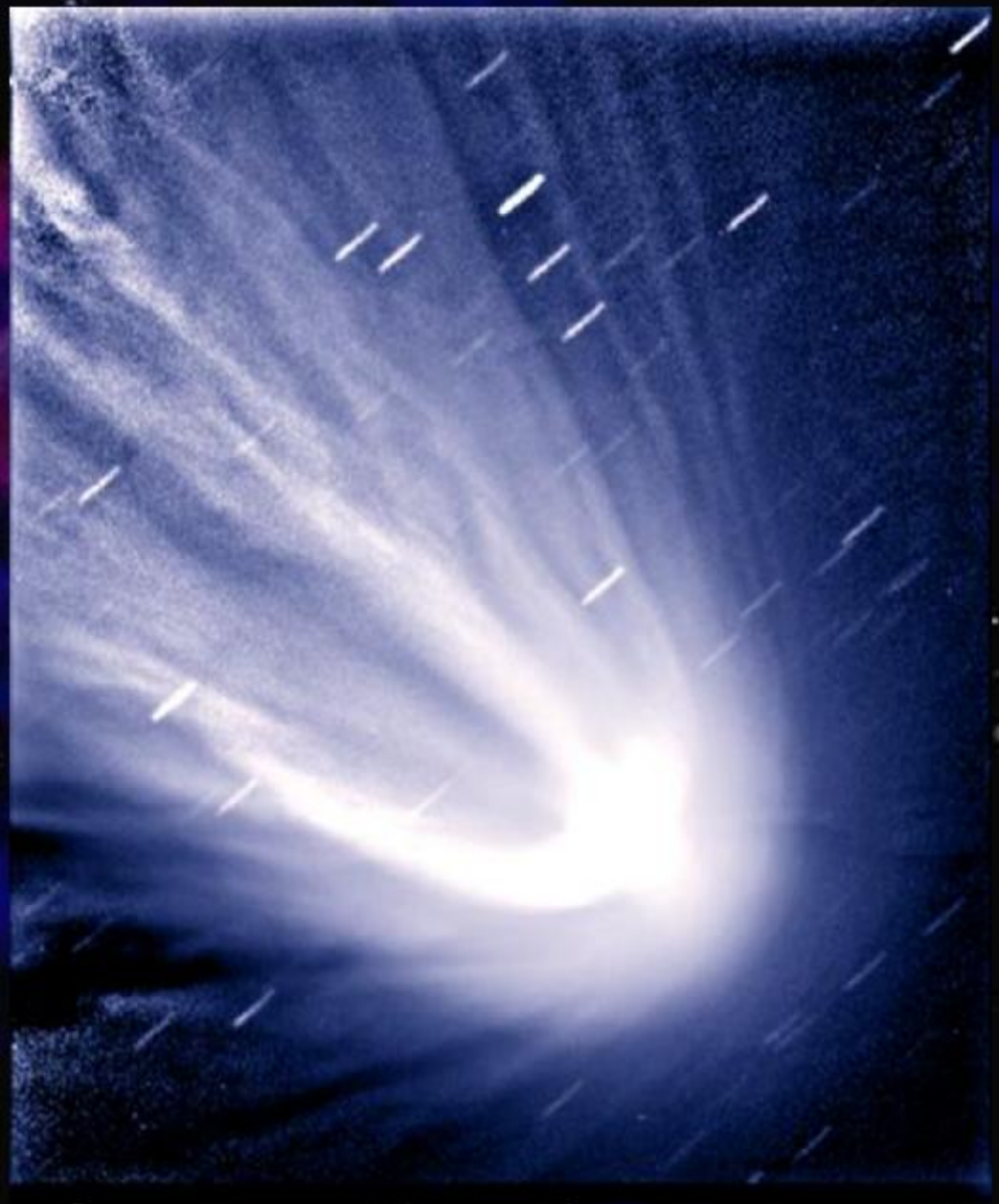

Near Side

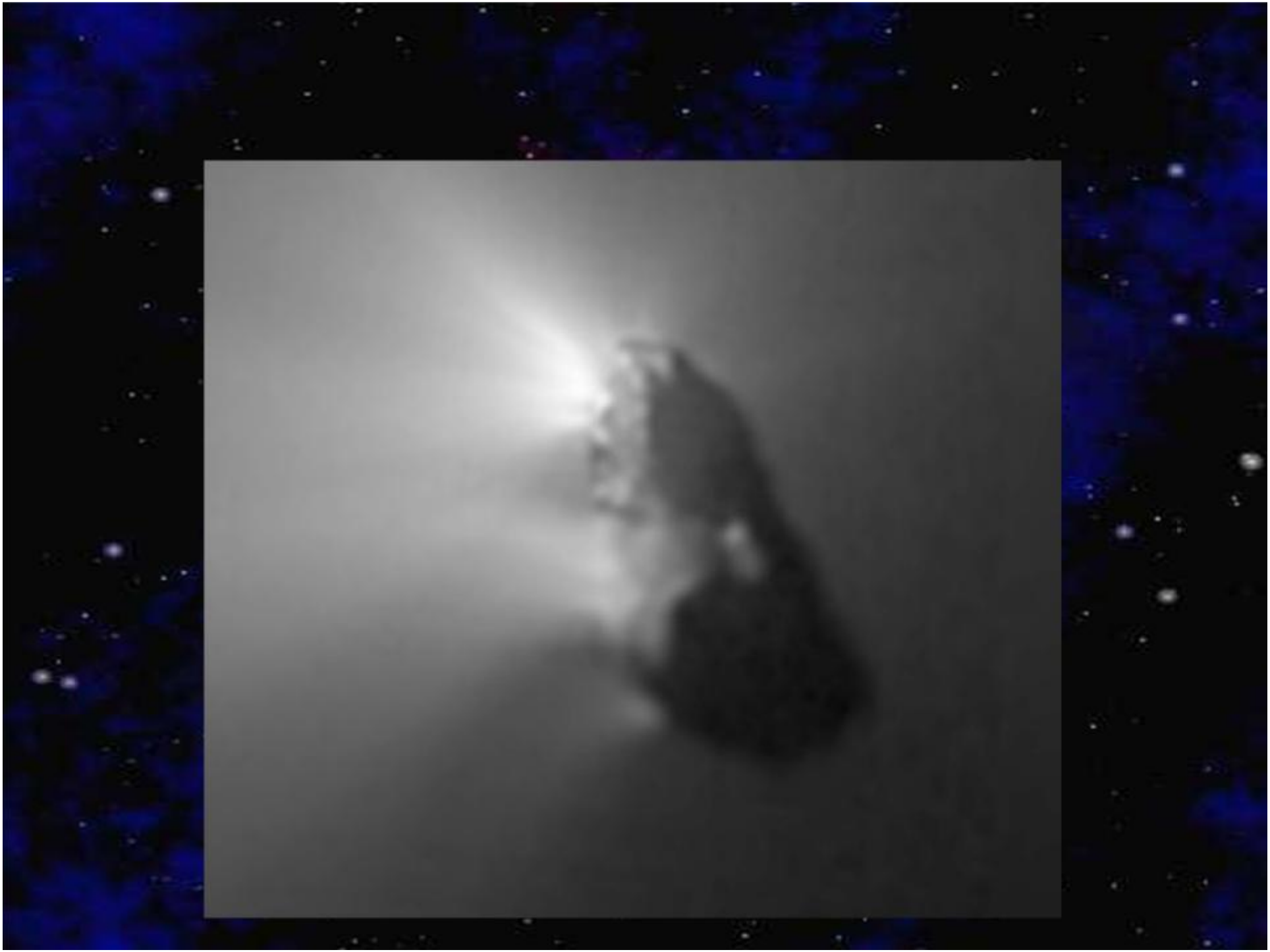

Far Side

Lunar Craters

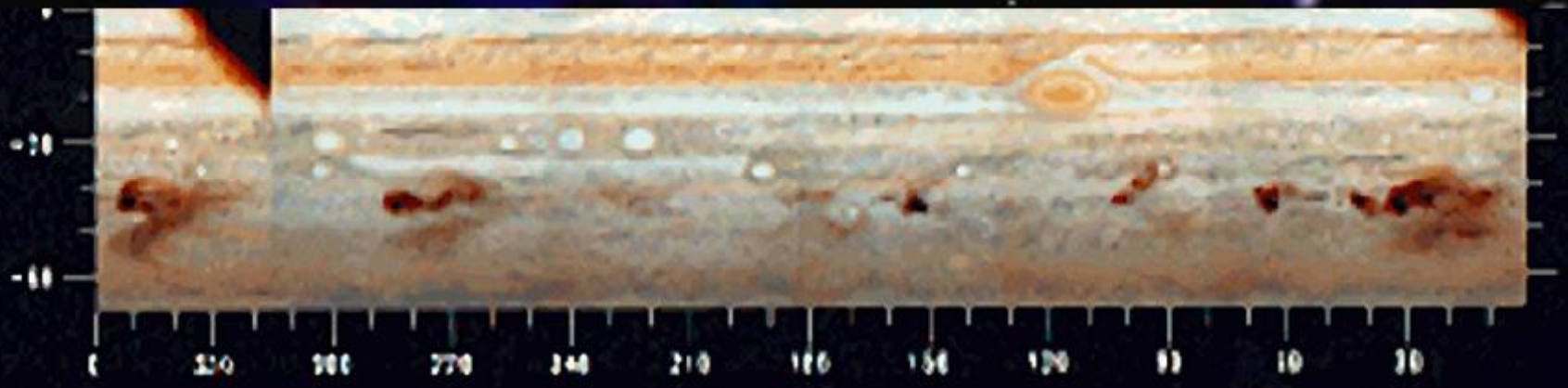

NORTH
PACIFIC
OCEAN
MEXICO

Hale-Bopp, 1996

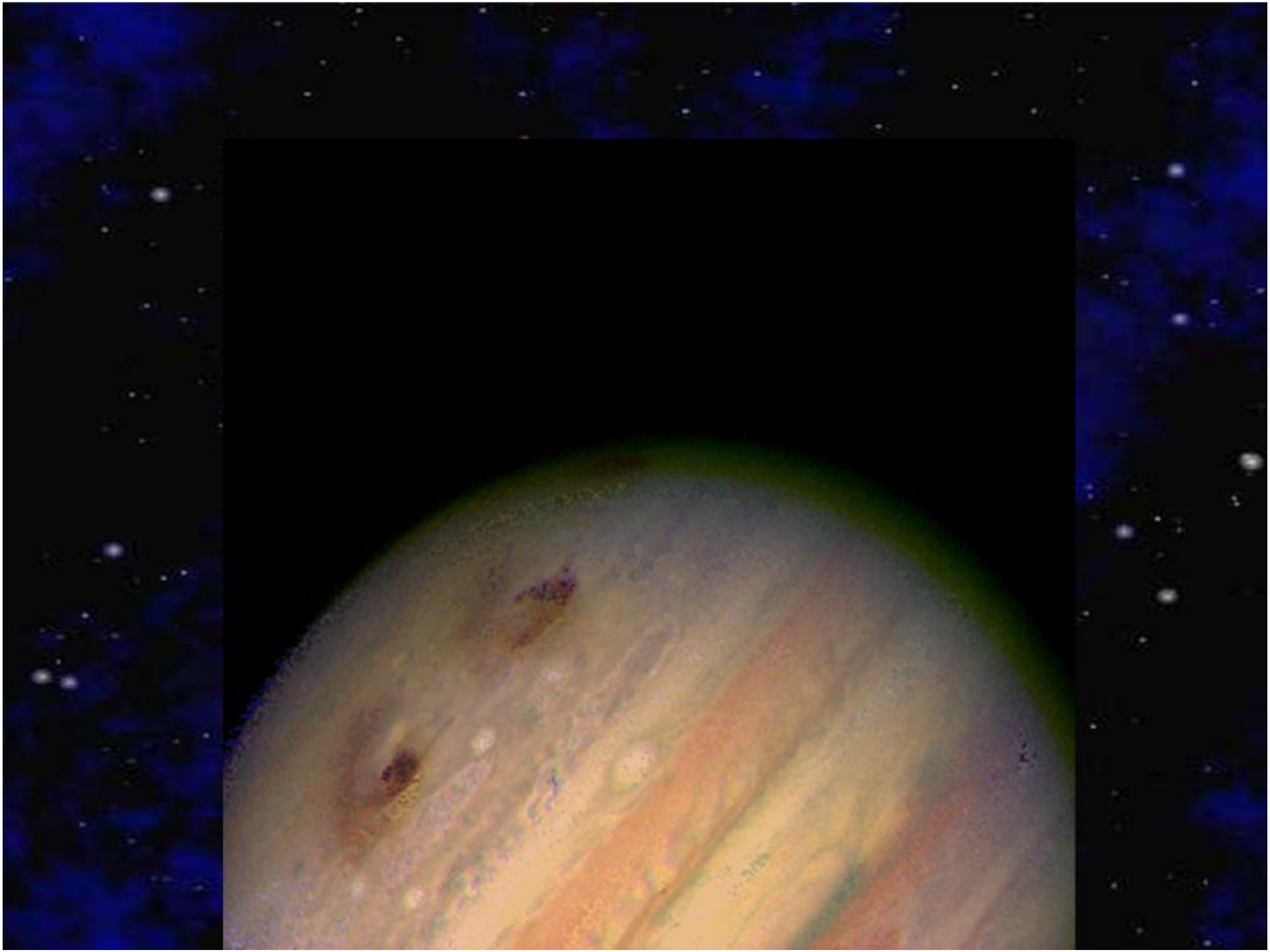


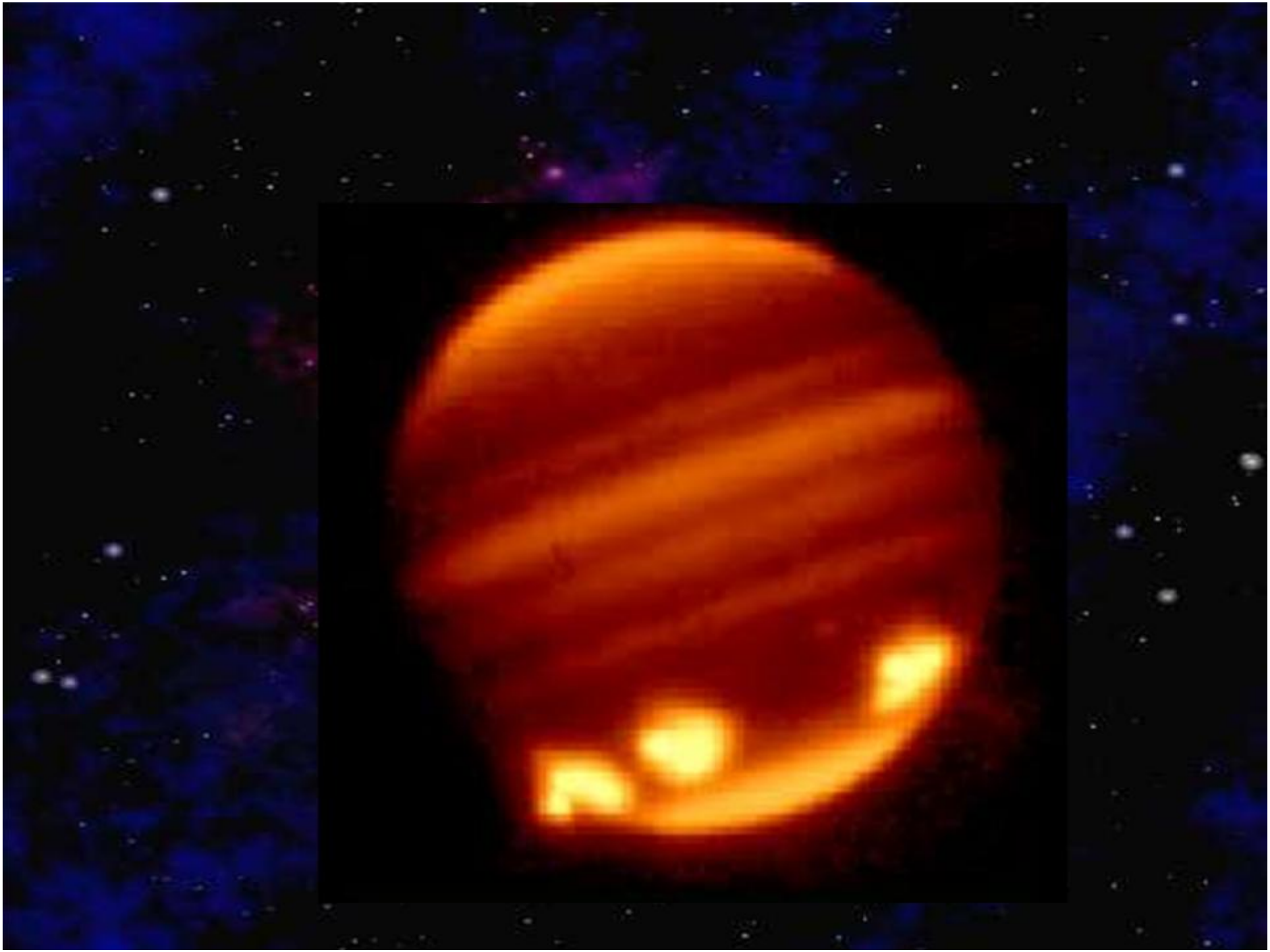


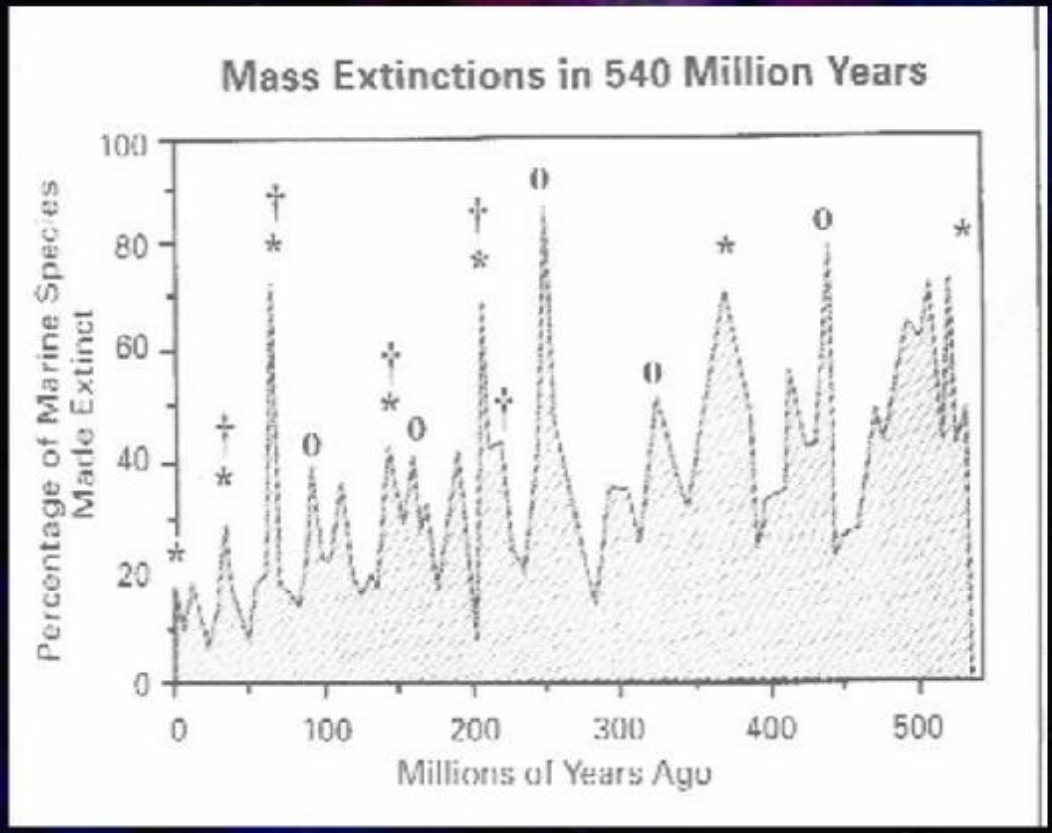
Comet Shoemaker-Levy



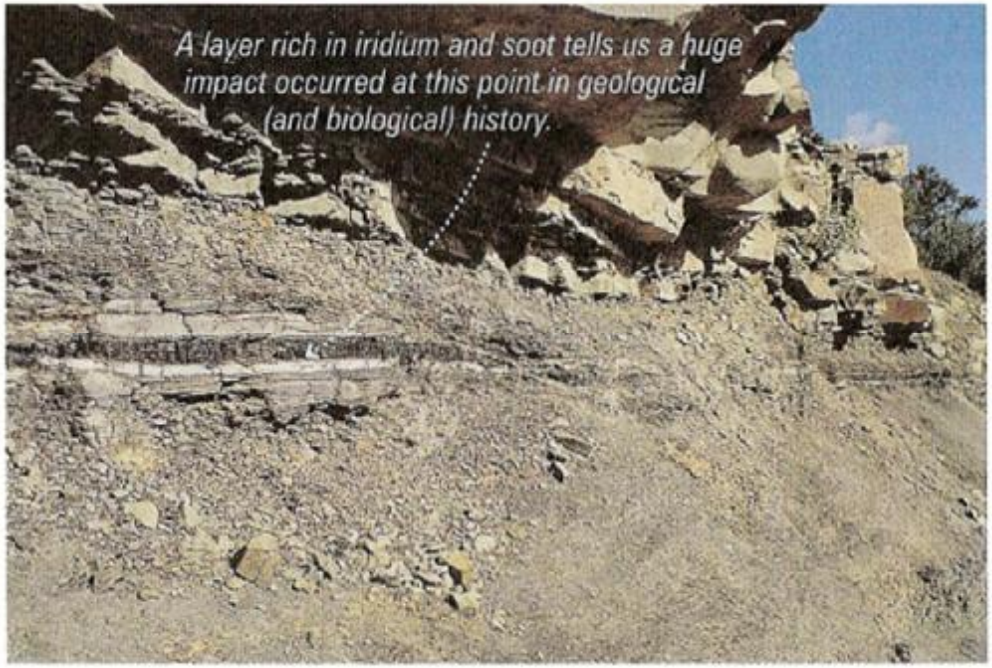
Comet Shoemaker-Levy





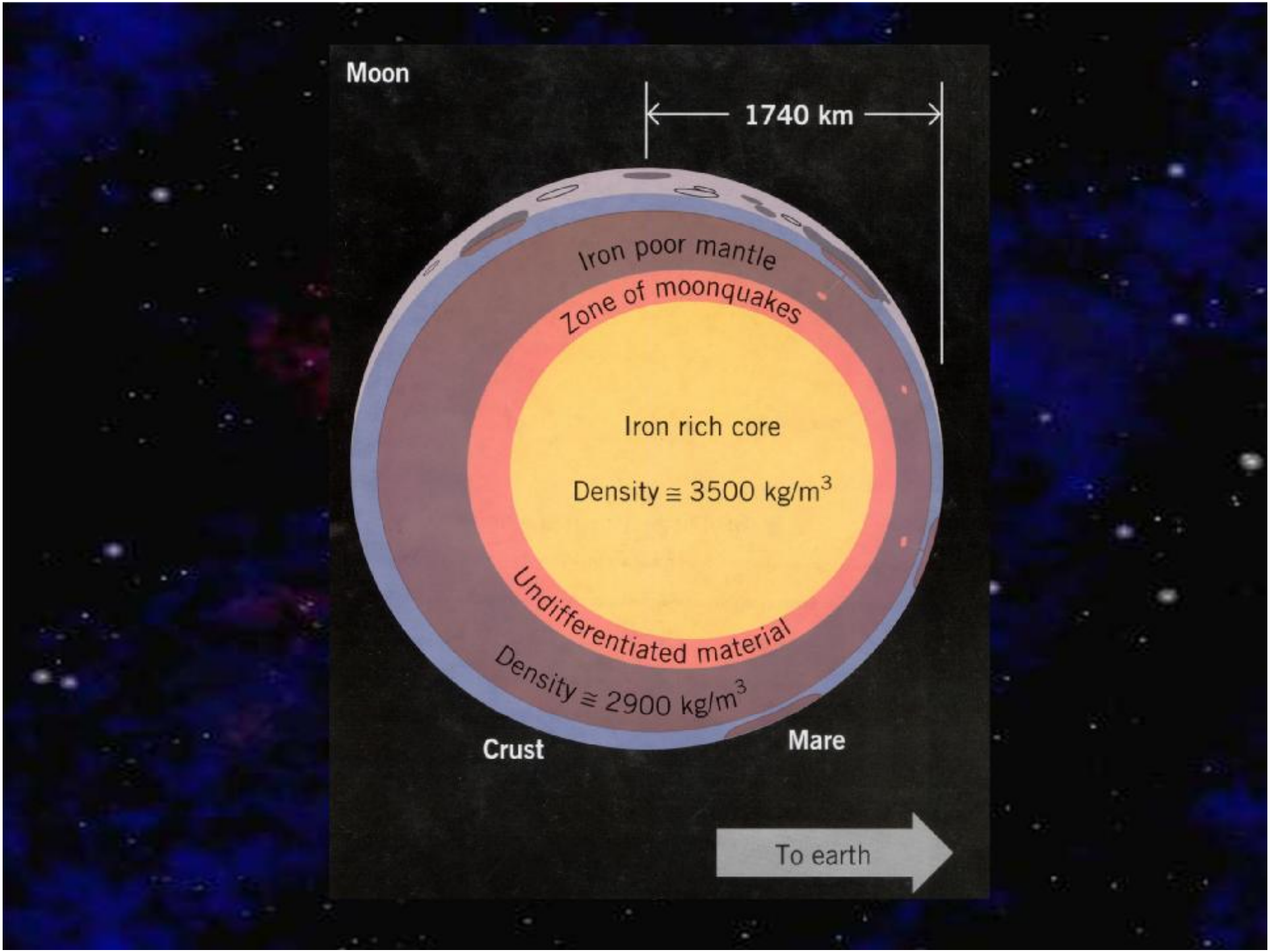

Mass Extinctions in 540 Million Years
Percentage of Marine Species Made Extinct
100
80
60
40
20
0
0
100
200
300
400
500
Millions of Years Ago


Mexico
Chicxulub crater
Yucatán peninsula


A layer rich in iridium and soot tells us a huge impact occurred at this point in geological (and biological) history.

Lunar Maria

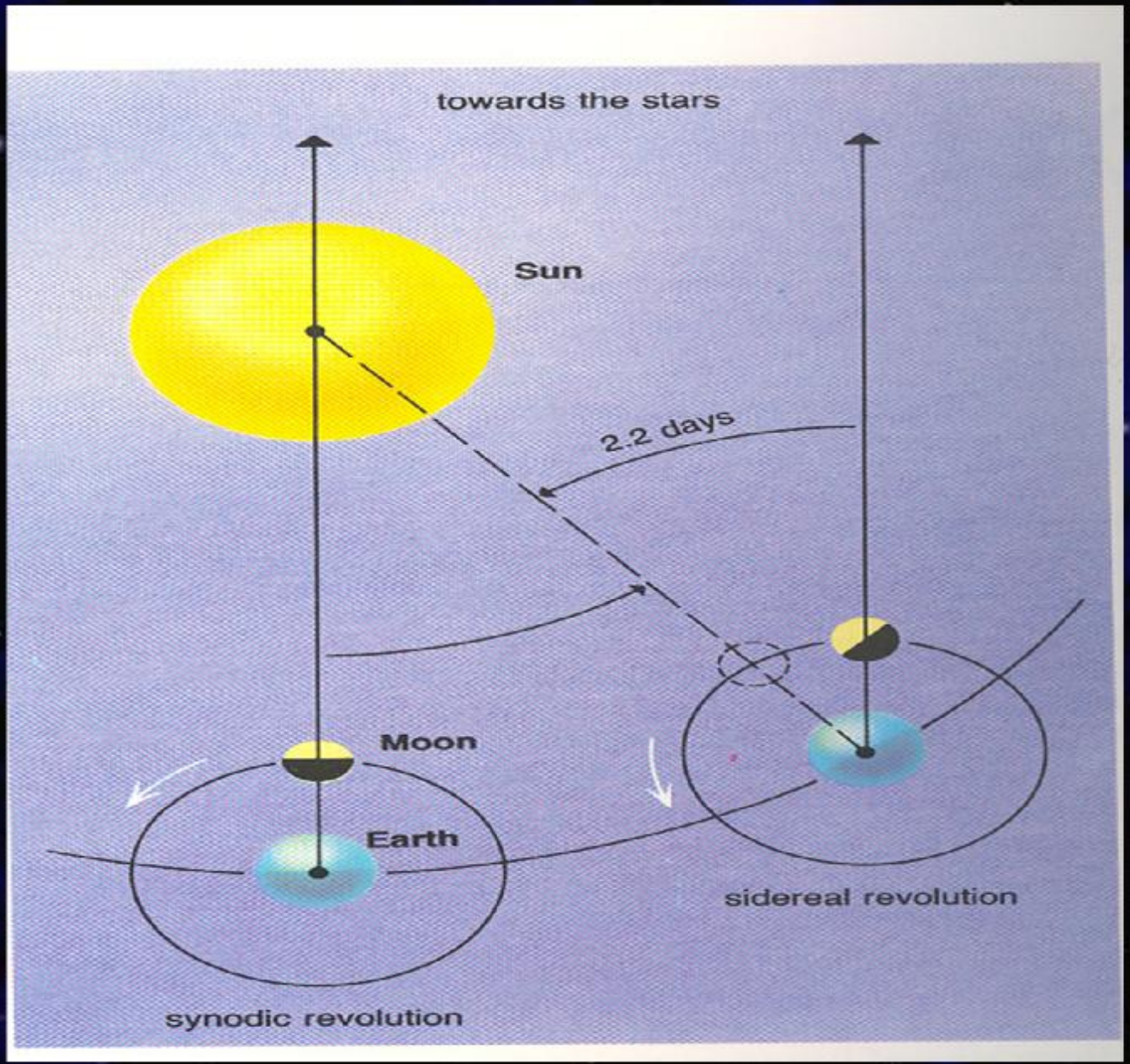

Oceanus
Procellarum
Mare
Tranquillitatis
Mare Imbrium
Mare
Serenitatis
Sinus Iridum


Moon
1740 km
Iron poor mantle
Zone of moonquakes
Iron rich core
Density ≅ 3500 kg/m3
Undifferentiated material
Density ≅ 2900 kg/m3
Crust
Mare
To earth

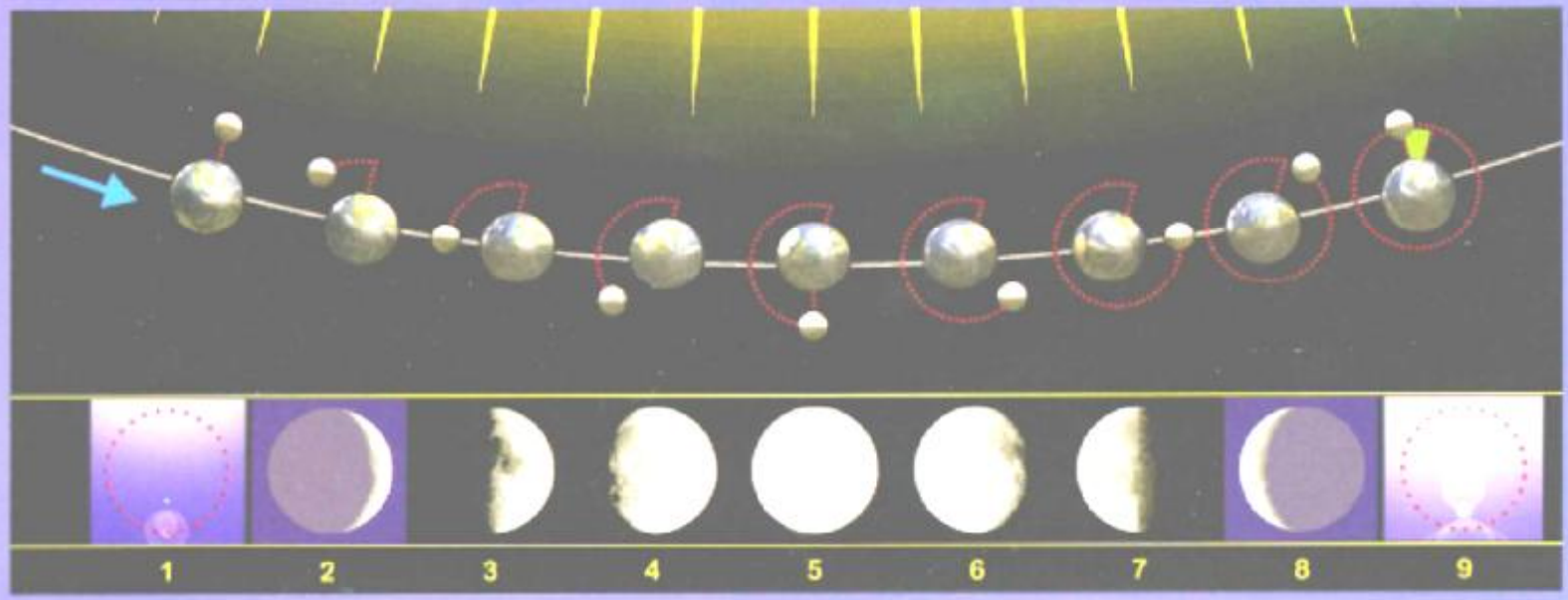
Motion of the Moon with respect to the Celestial Sphere:

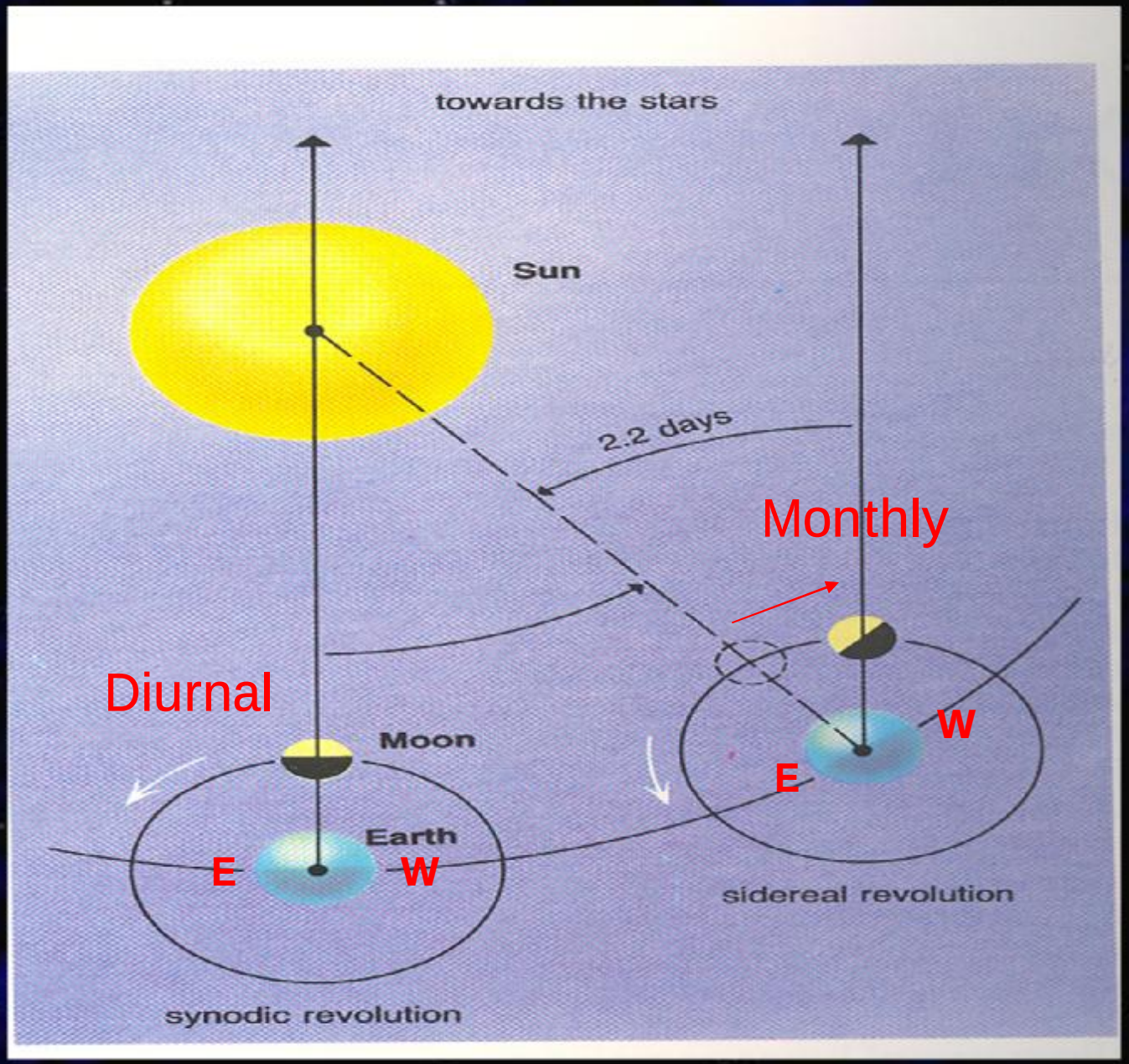
- Diurnal Motion (east –to- west)
- Monthly (west –to- east)
- Moves ~13° each day

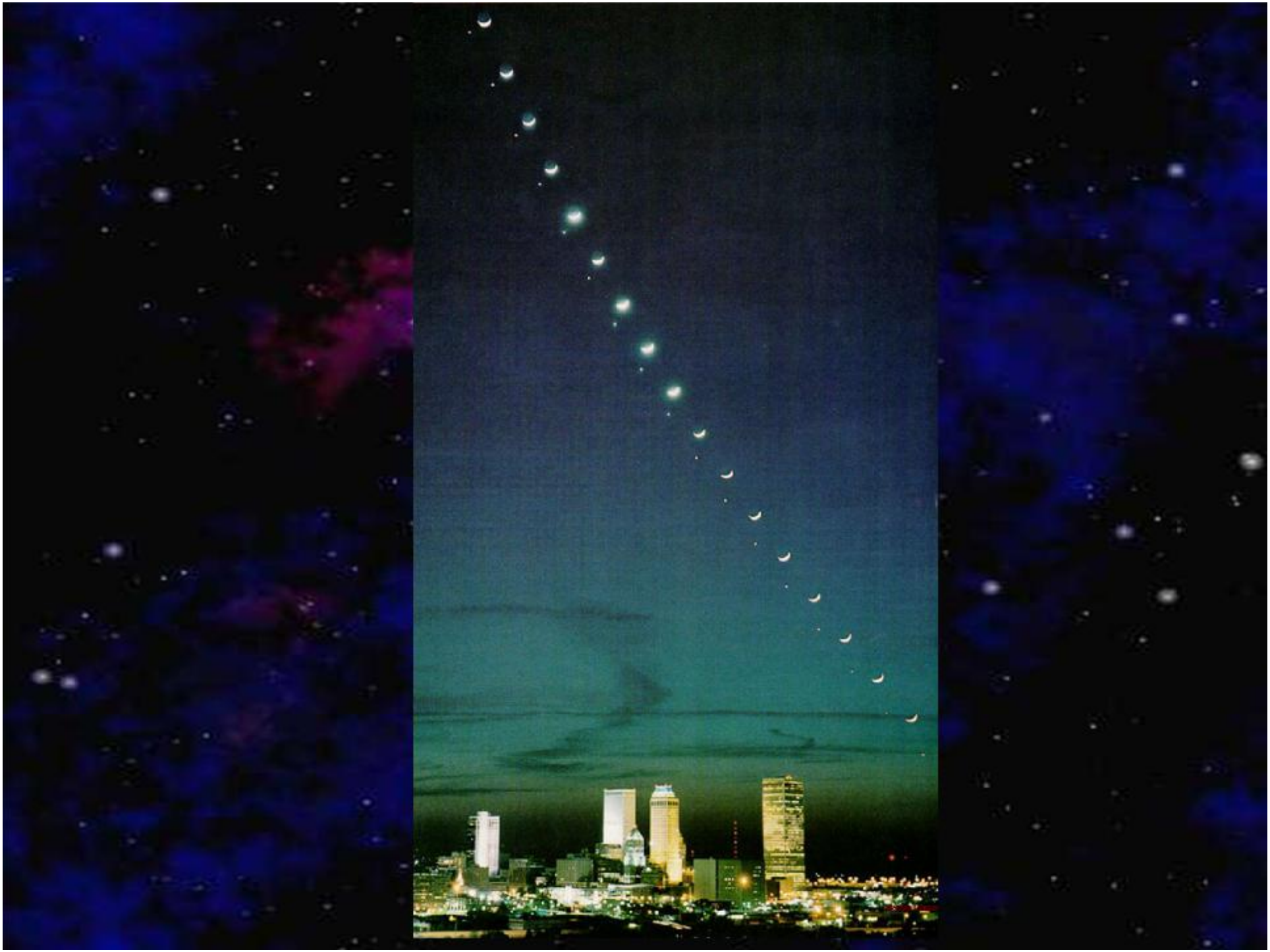
360 degrees in a circle/28 days = 12.9 degrees/day


towards the stars
Sun
2.2 days
Moon
Earth
sidereal revolution
synodic revolution

Moon Phases or Moon Shine?



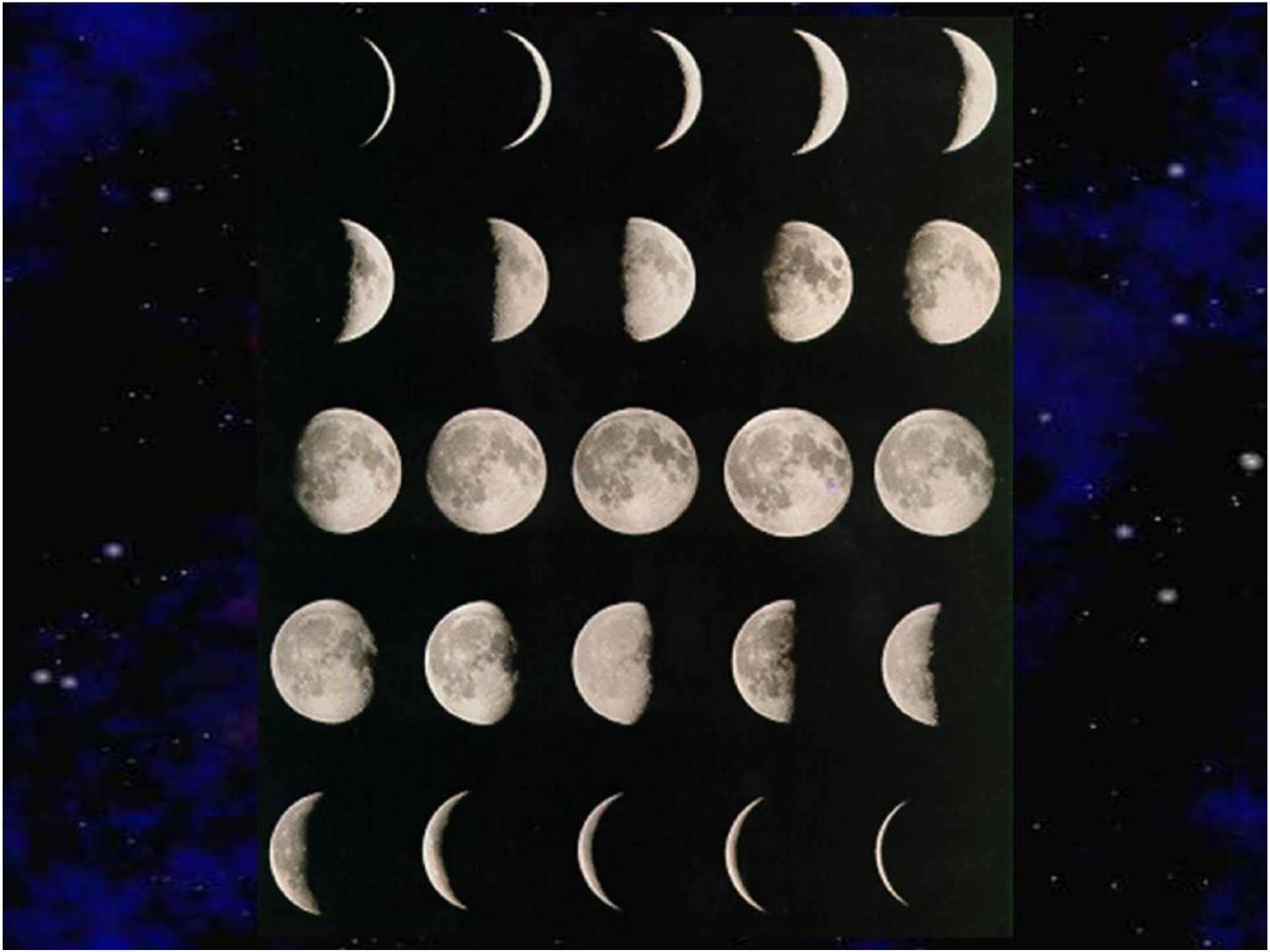

towards the stars
Sun
2.2 days
Monthly
Diurnal
Moon
Earth
E
W
E
W
sidereal revolution
synodic revolution

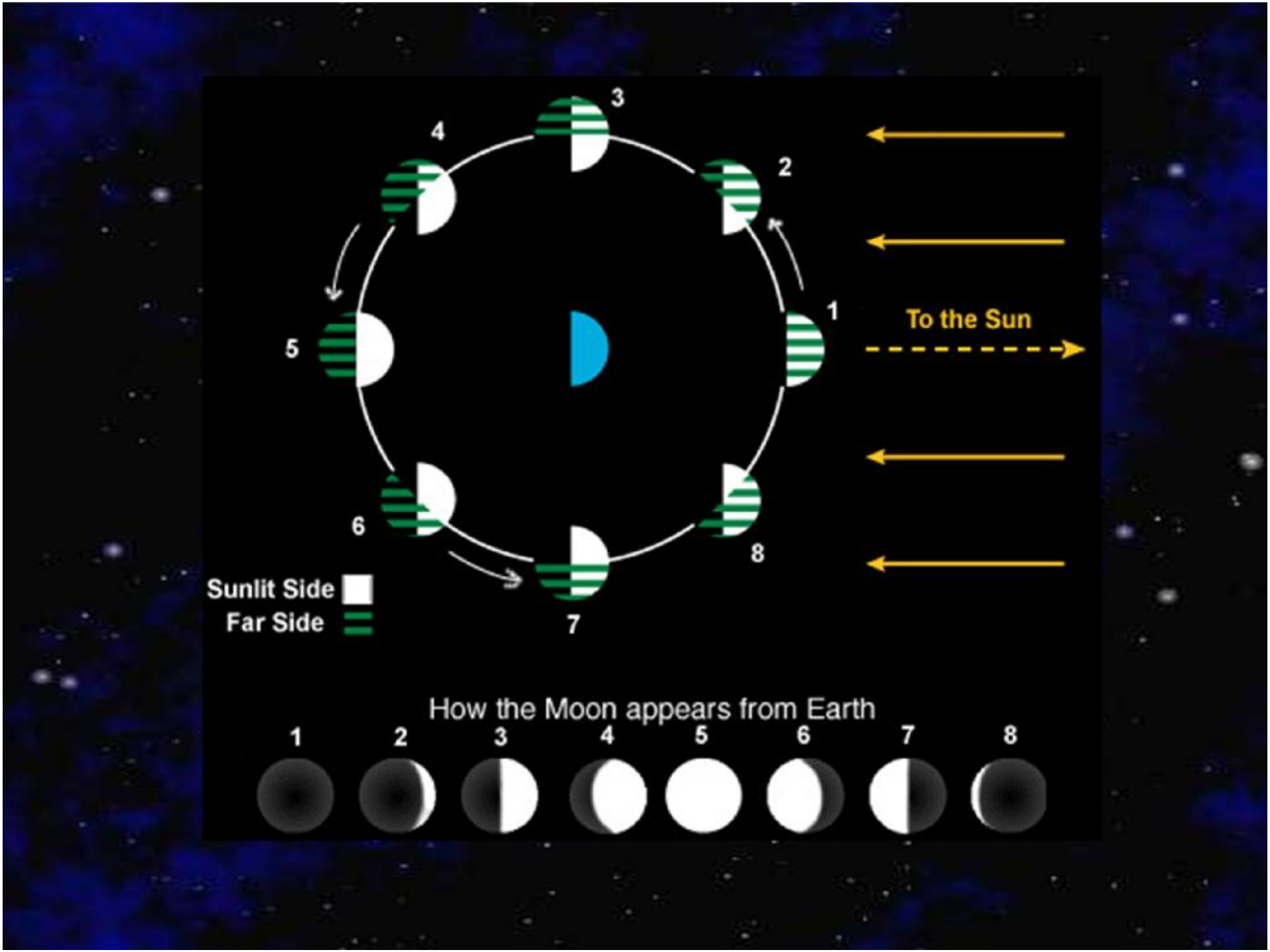


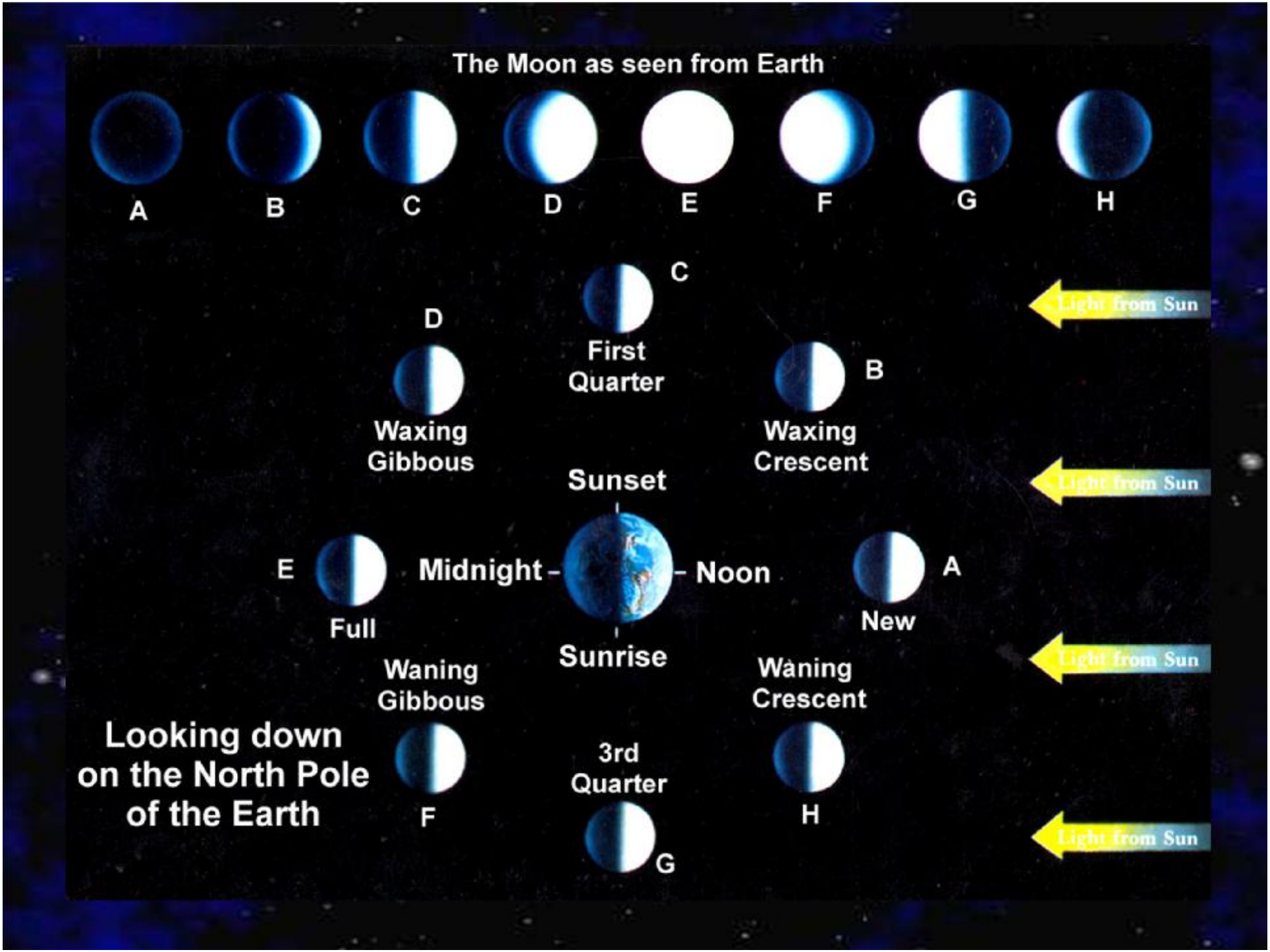
LUNAR PHASES

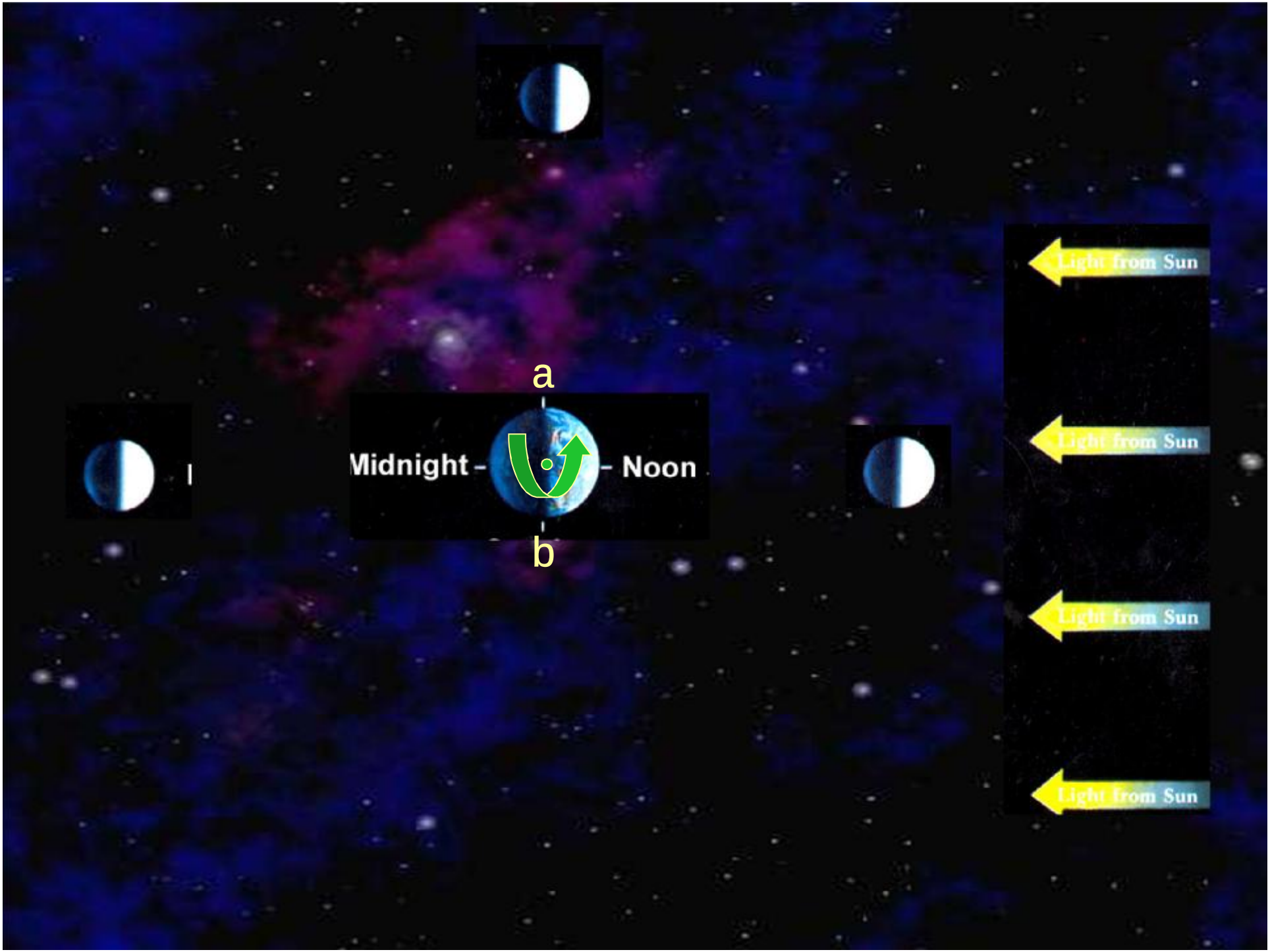
Lunar Phases:

Caused by the change in the orientation between the Earth, Sun, & Moon



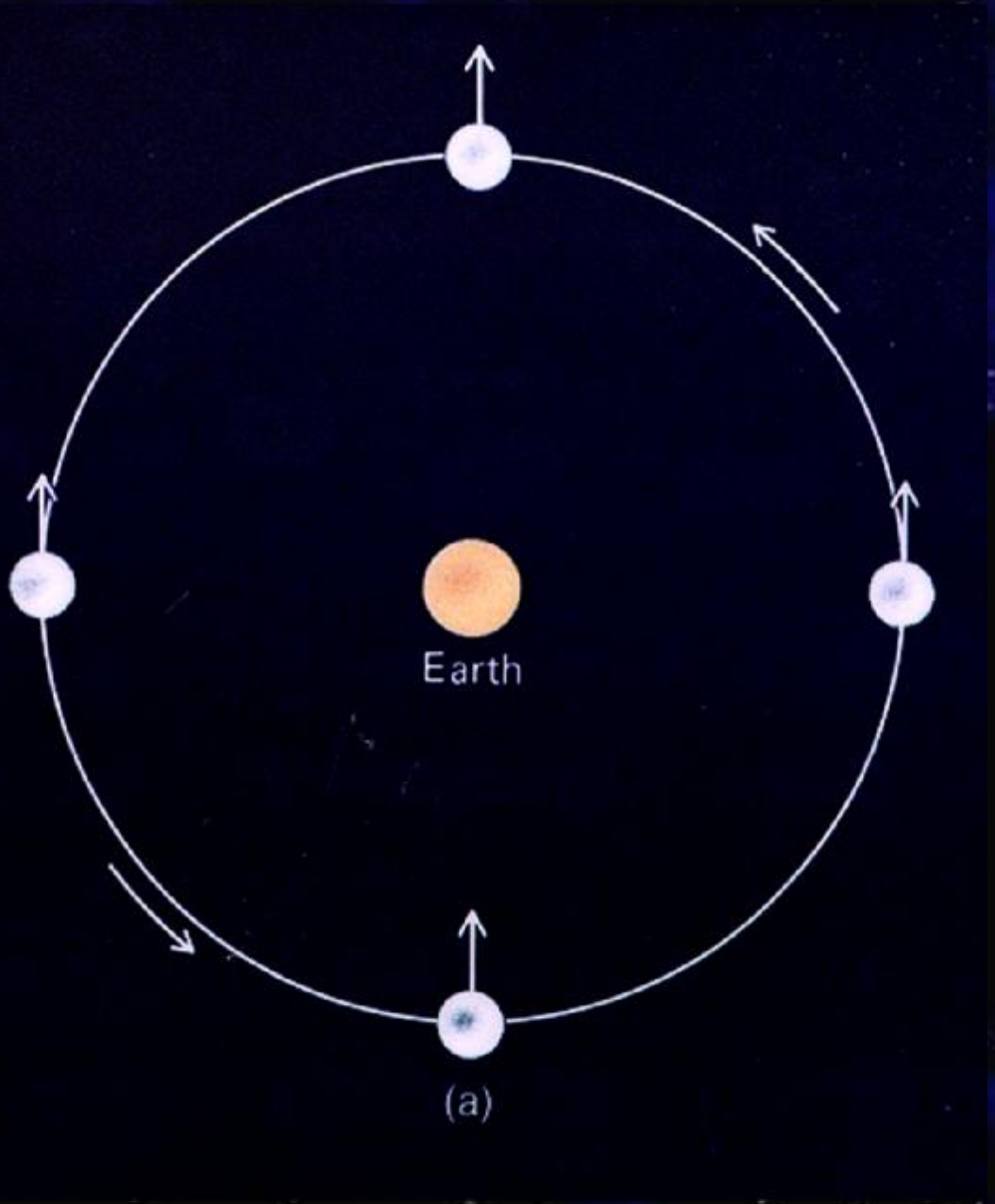

3
4
2
1
5
To the Sun
6
8
7
Sunlit Side
Far Side
How the Moon appears from Earth
1
2
3
4
5
6
7
8


The Moon as seen from Earth
A
B
C
D
E
F
G
H
C
First Quarter
D
Waxing Gibbous
B
Waxing Crescent
Light from Sun
Light from Sun
Sunset
E
Full
Midnight
Noon
A
New
Sunrise
Waning Gibbous
Waning Crescent
Light from Sun
Looking down on the North Pole of the Earth
F
3rd Quarter
H
G
Light from Sun

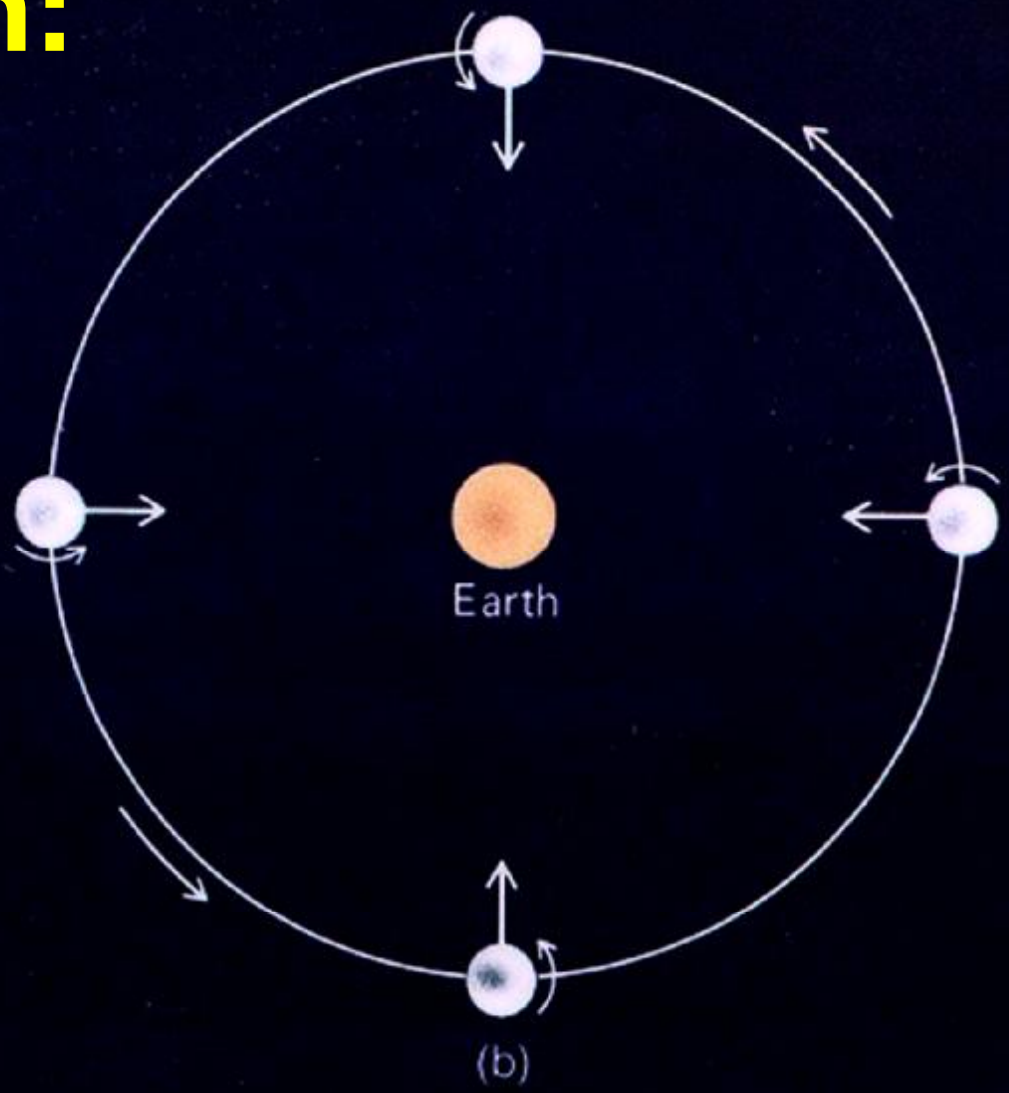

a
Midnight
Noon
b
Light from Sun
Light from Sun
Light from Sun
Light from Sun

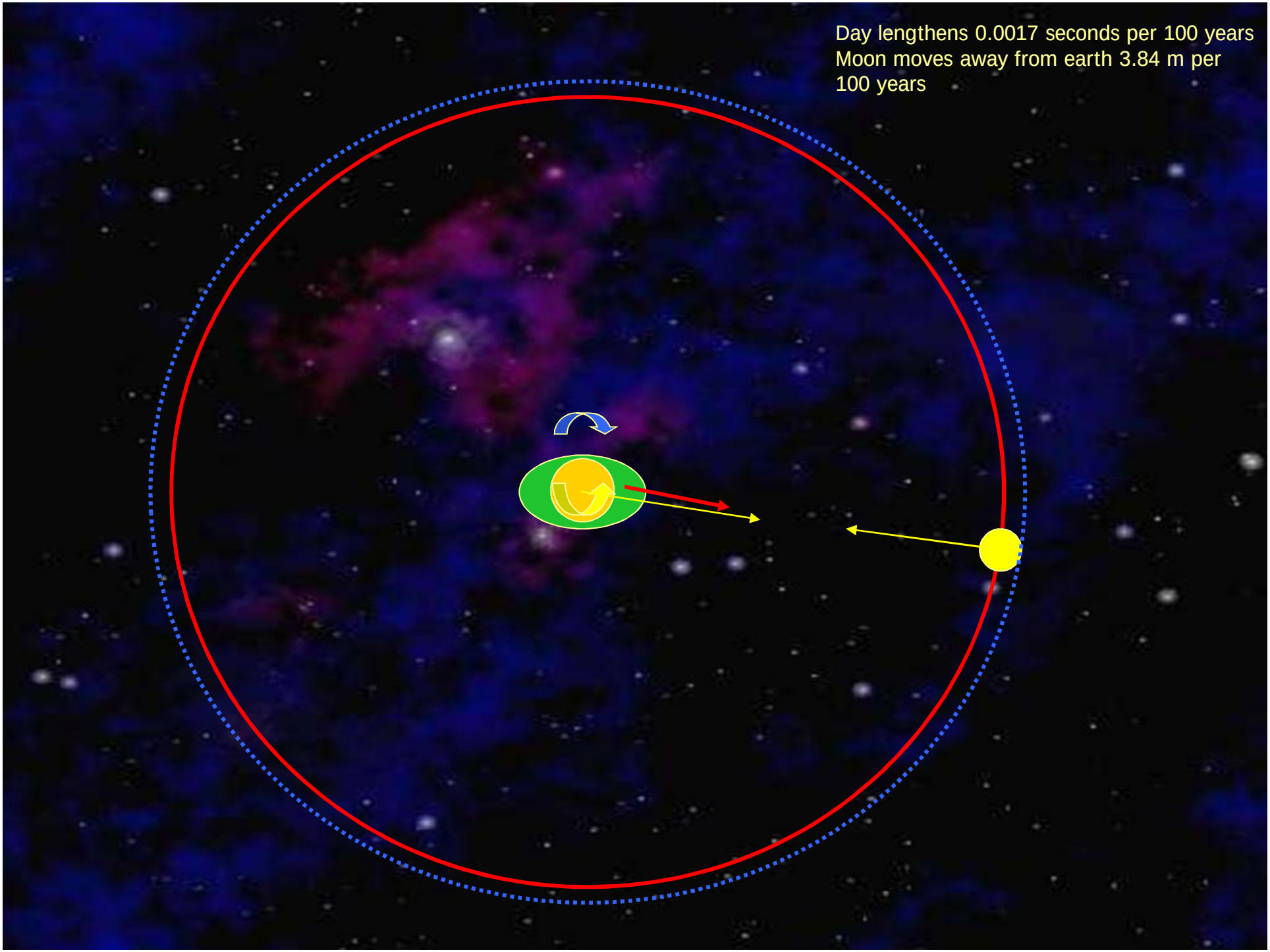
Does the Moon Rotate on its Axis?

No rotation:



With rotation:




Day lengthens 0.0017 seconds per 100 years
Moon moves away from earth 3.84 m per 100 years

SHORT TERM CHANGES

THE SEASONS

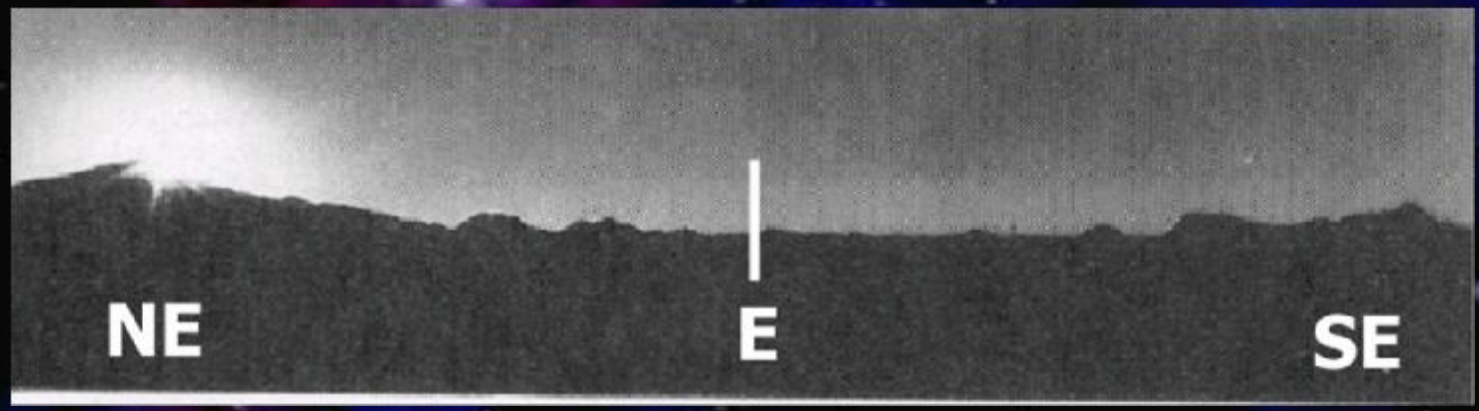
The revolution of the Earth around the Sun:

Tropical Year:

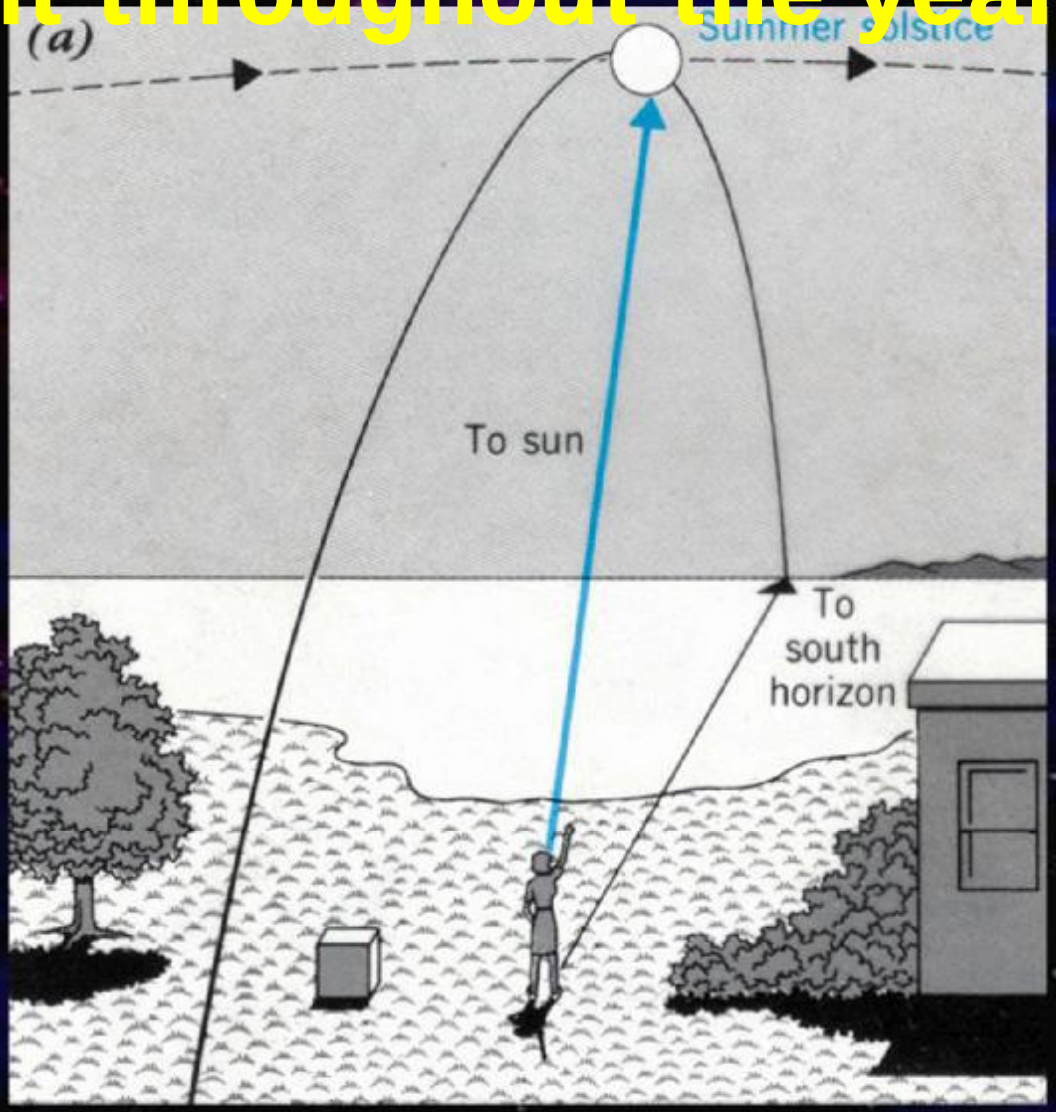
365.2422 days

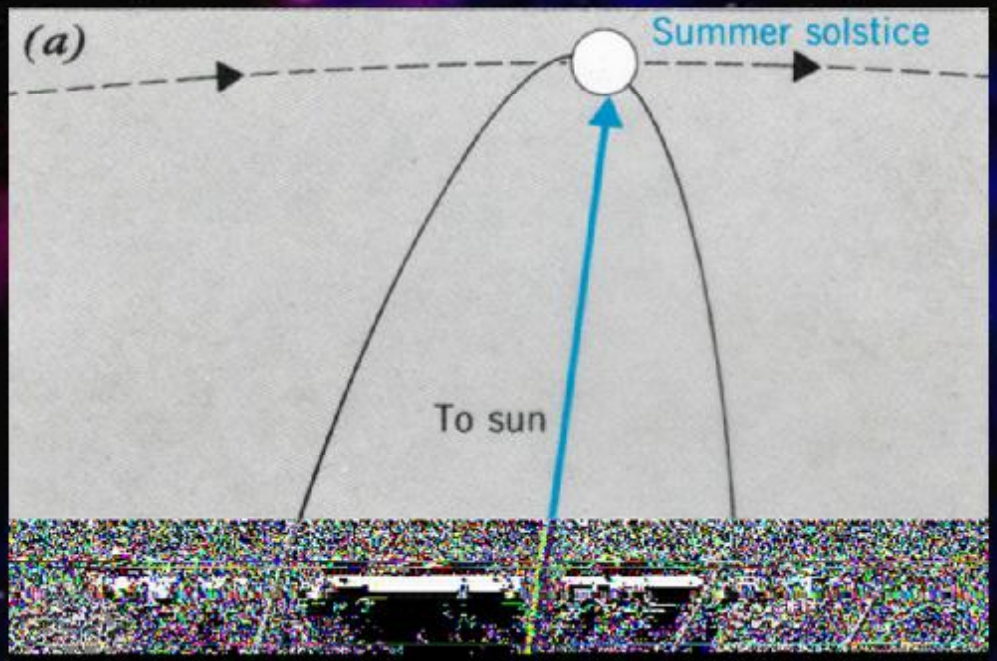
Why does the Earth experience Seasons?

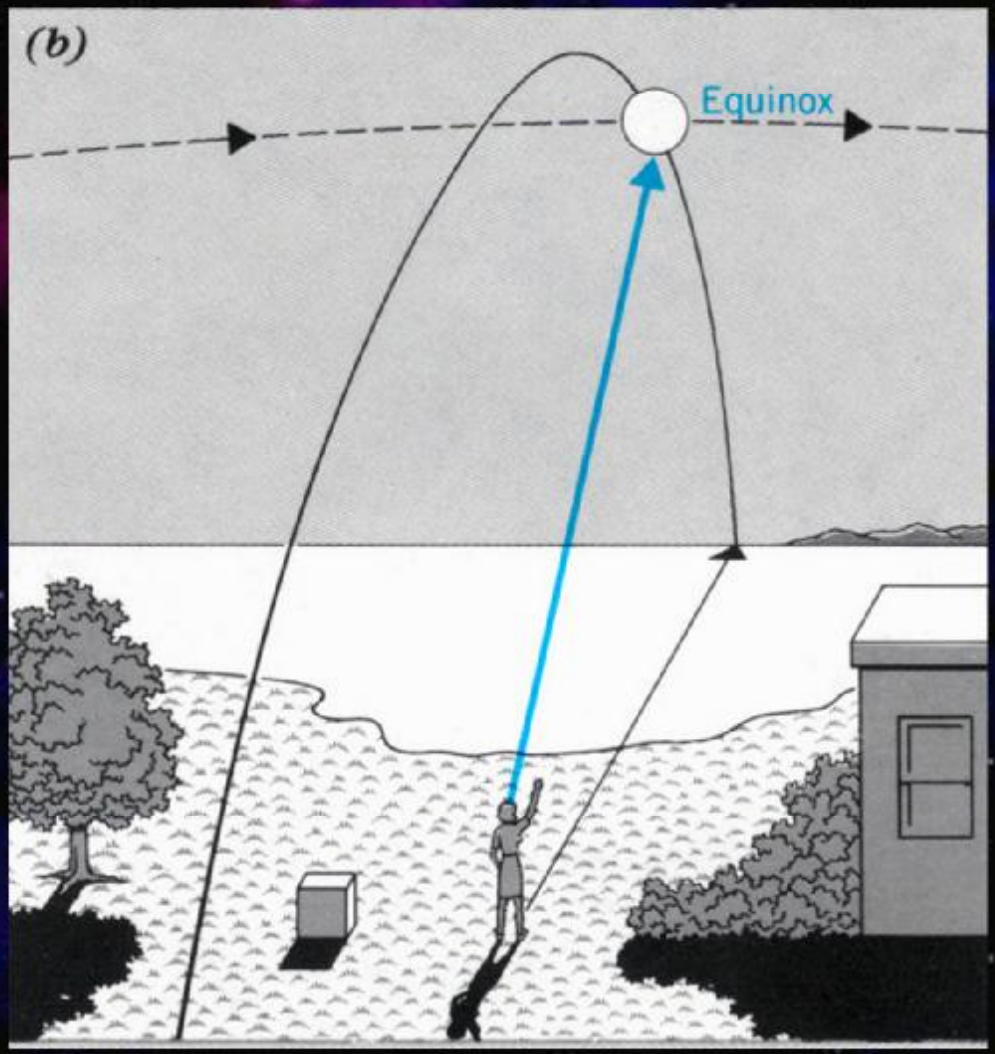
1. The Sun rises and sets at different places along the horizon.

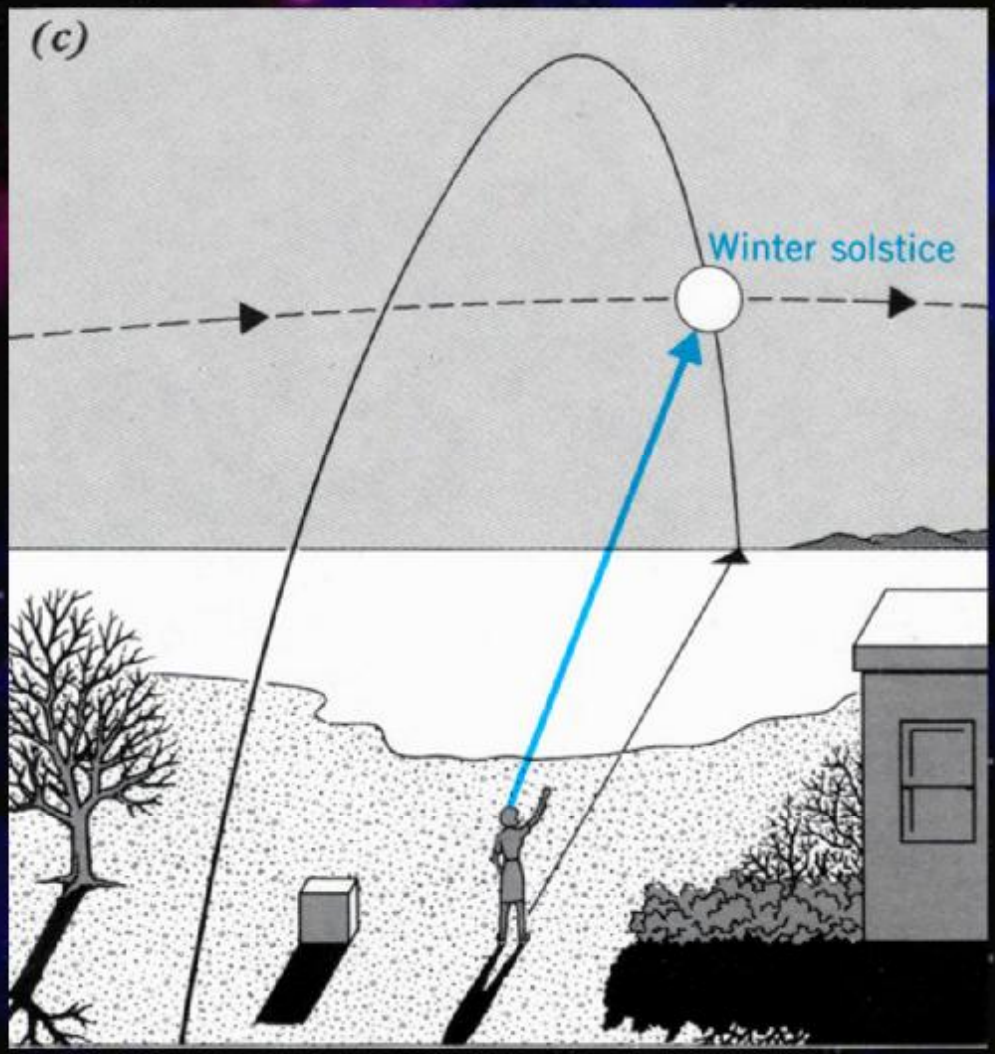


2. The height of the Sun at noon is different throughout the year.

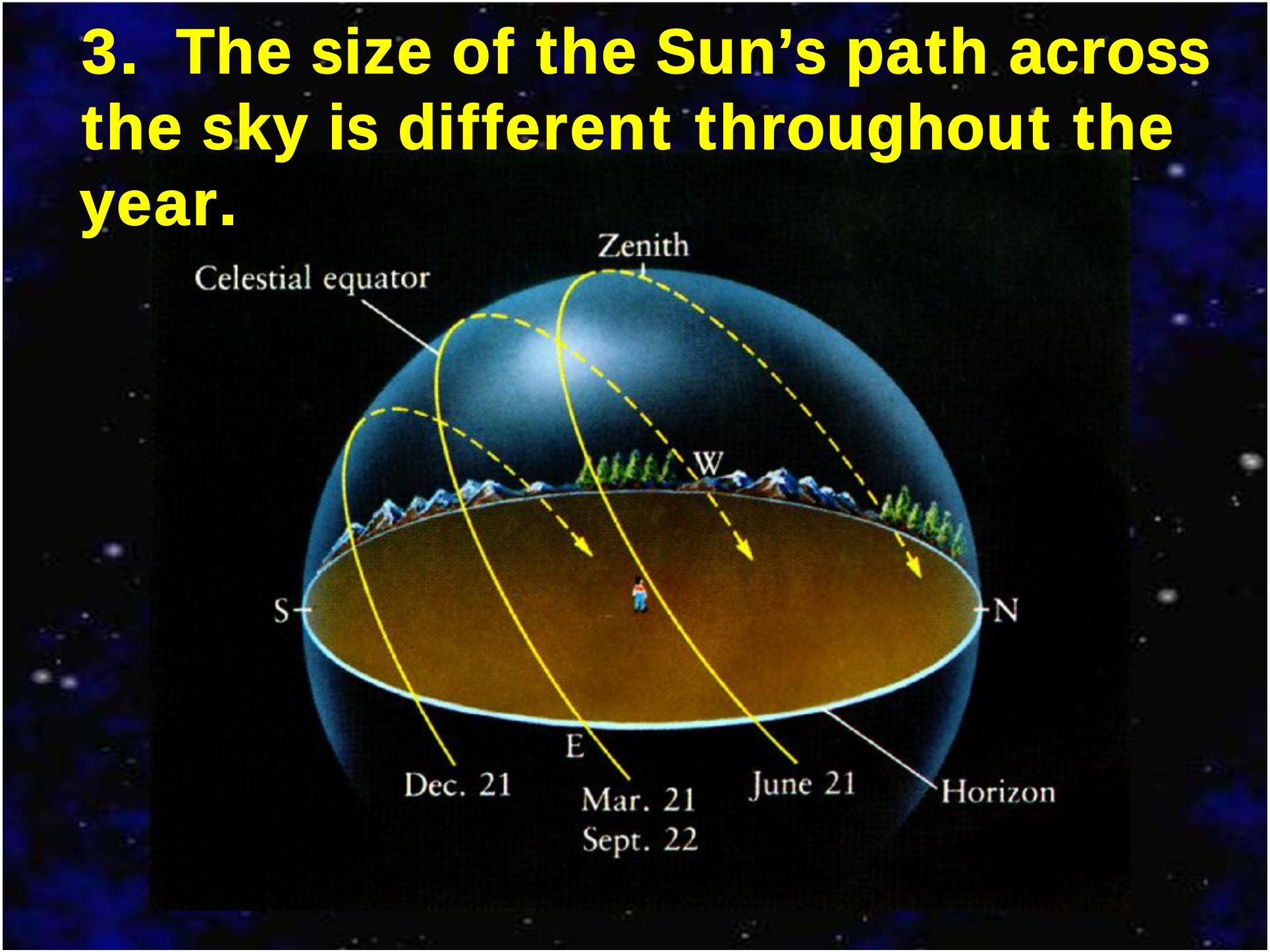



(a)
Summer solstice
To sun

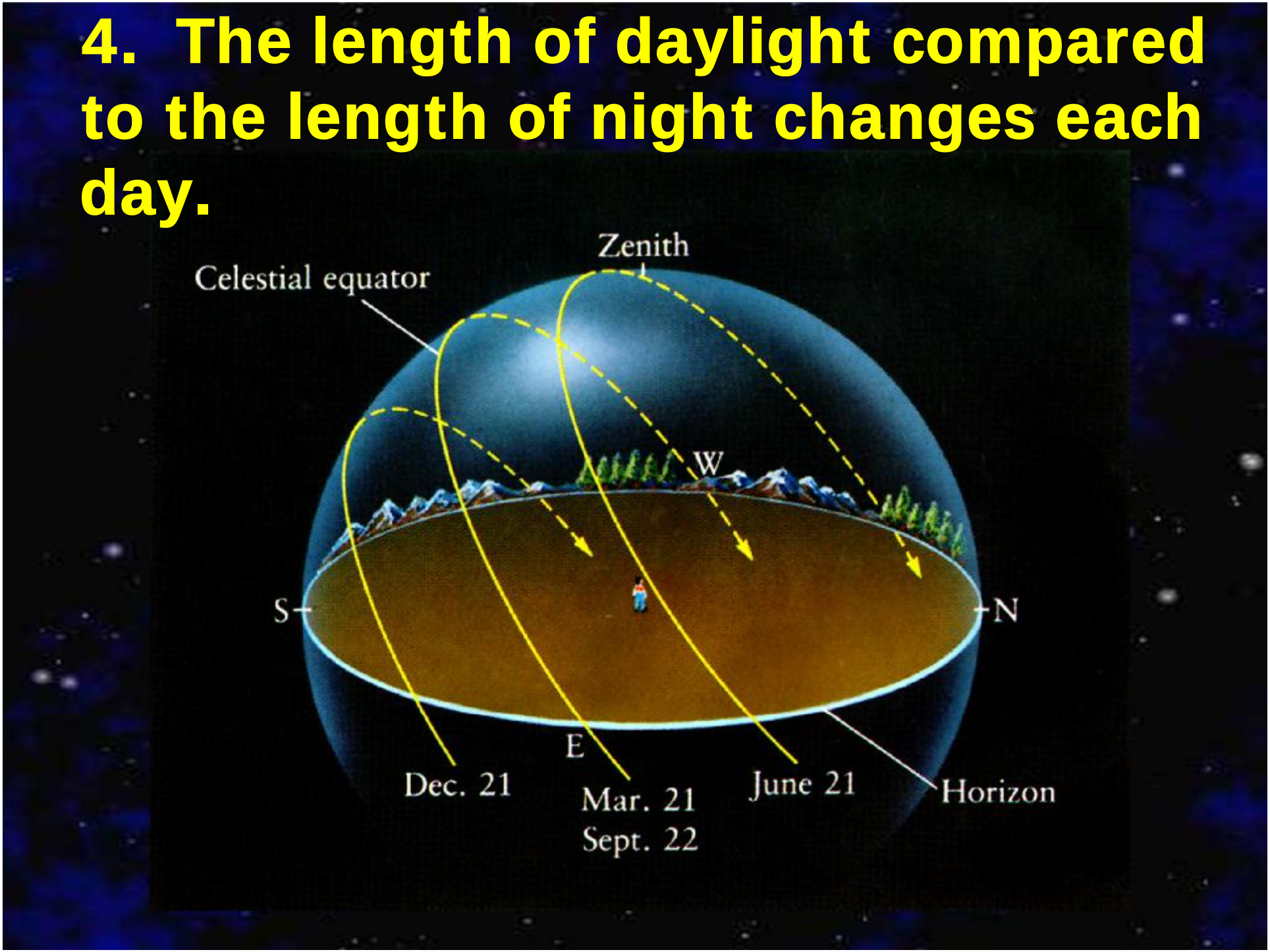

(b)
Equinox

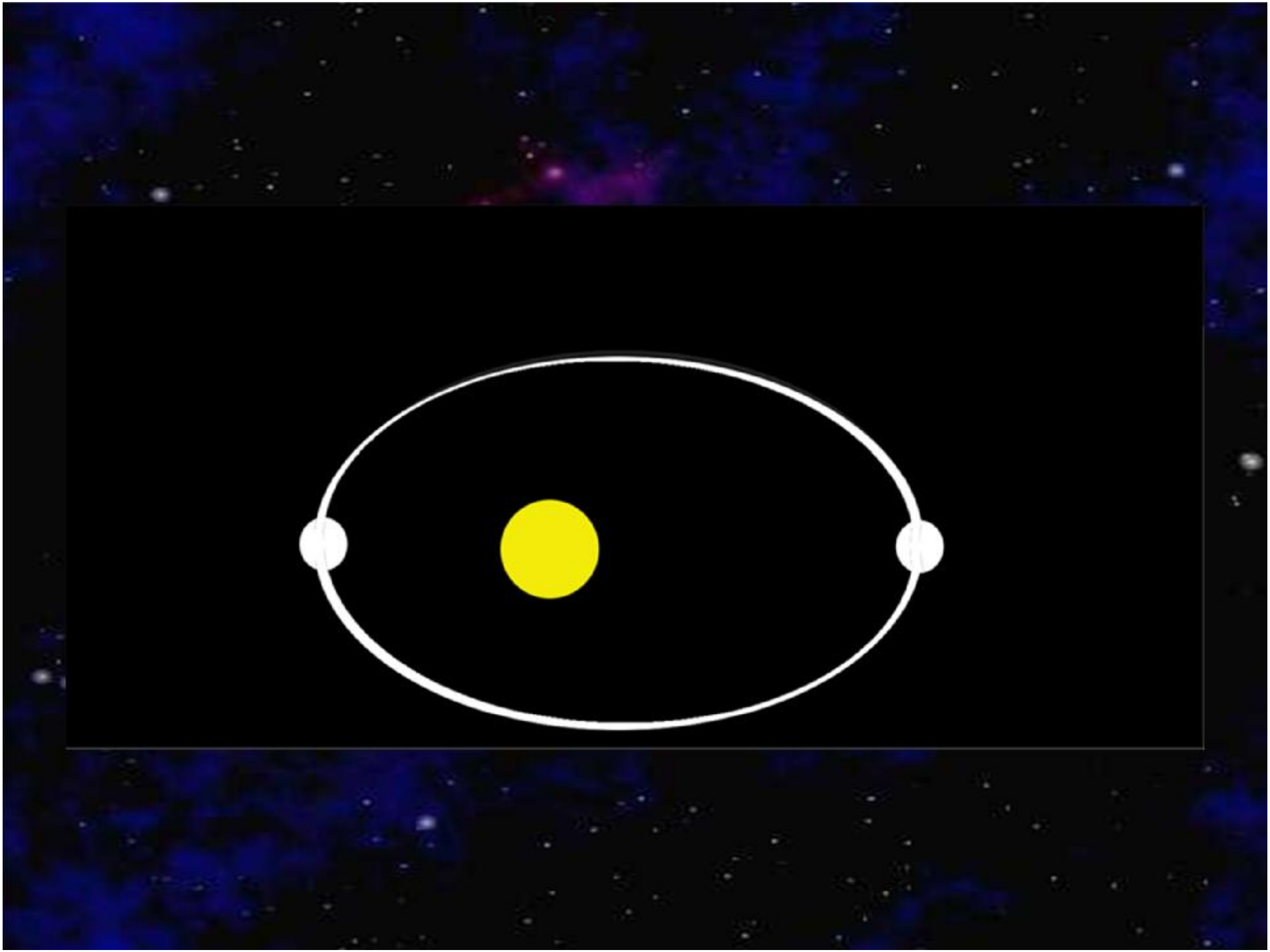

(c)
Winter solstice

3. The size of the Sun's path across the sky is different throughout the year.

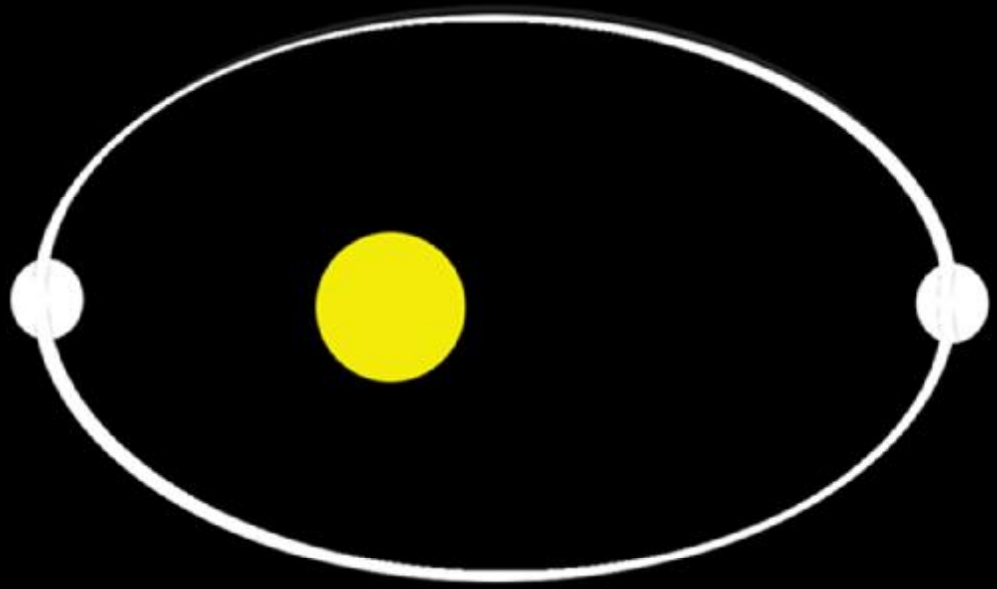


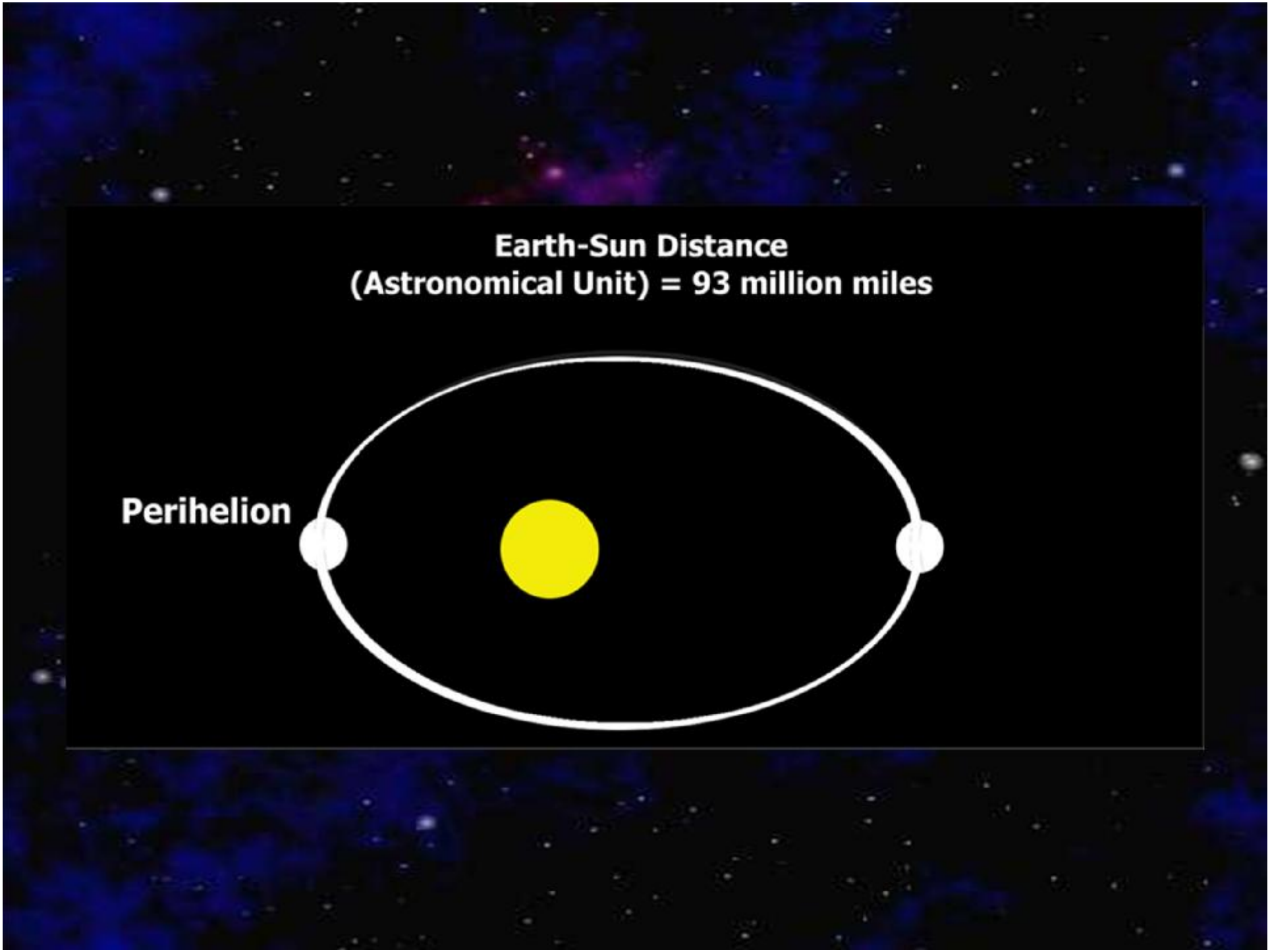
4. The length of daylight compared to the length of night changes each day.

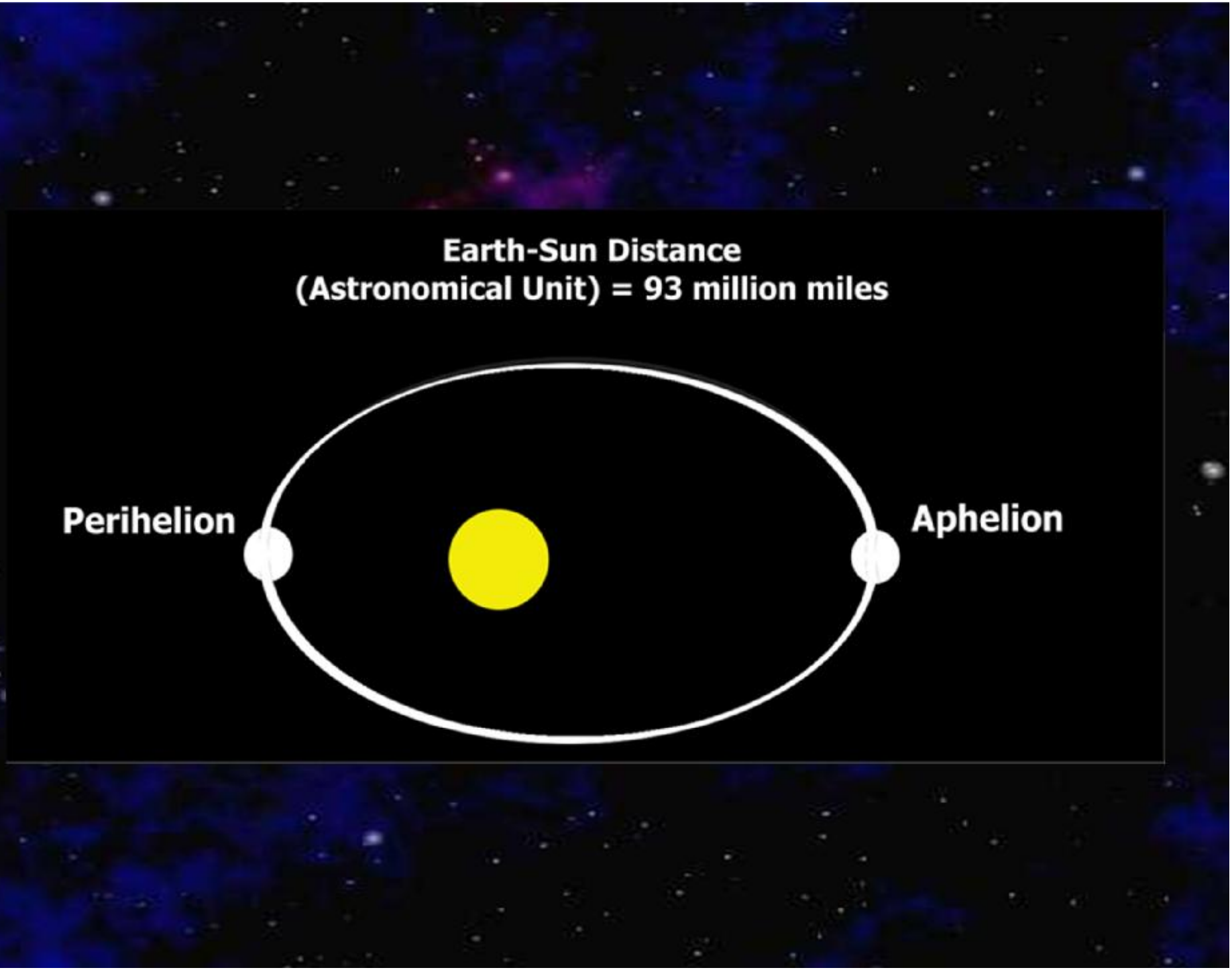


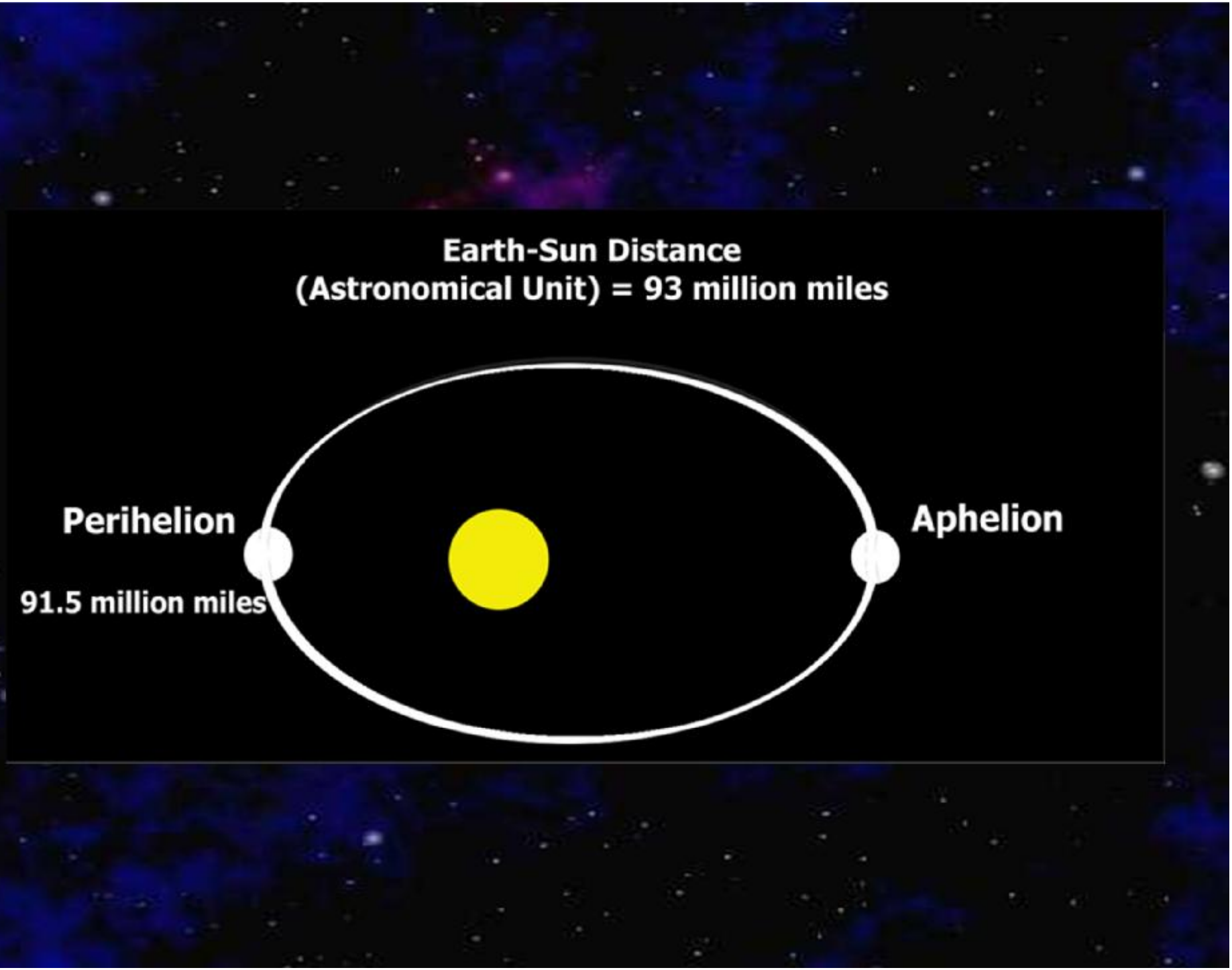


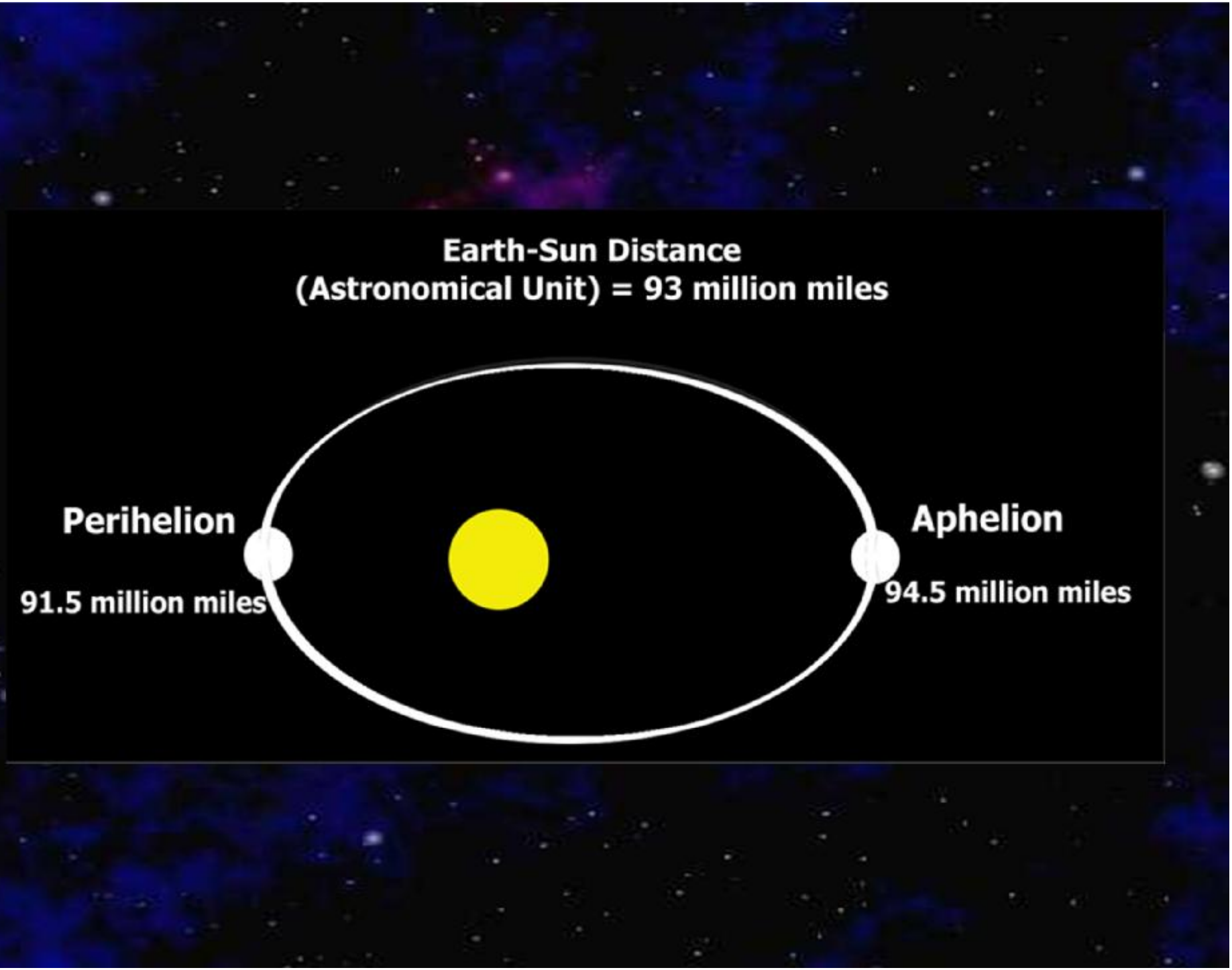
Earth-Sun Distance
(Astronomical Unit) = 93 million miles

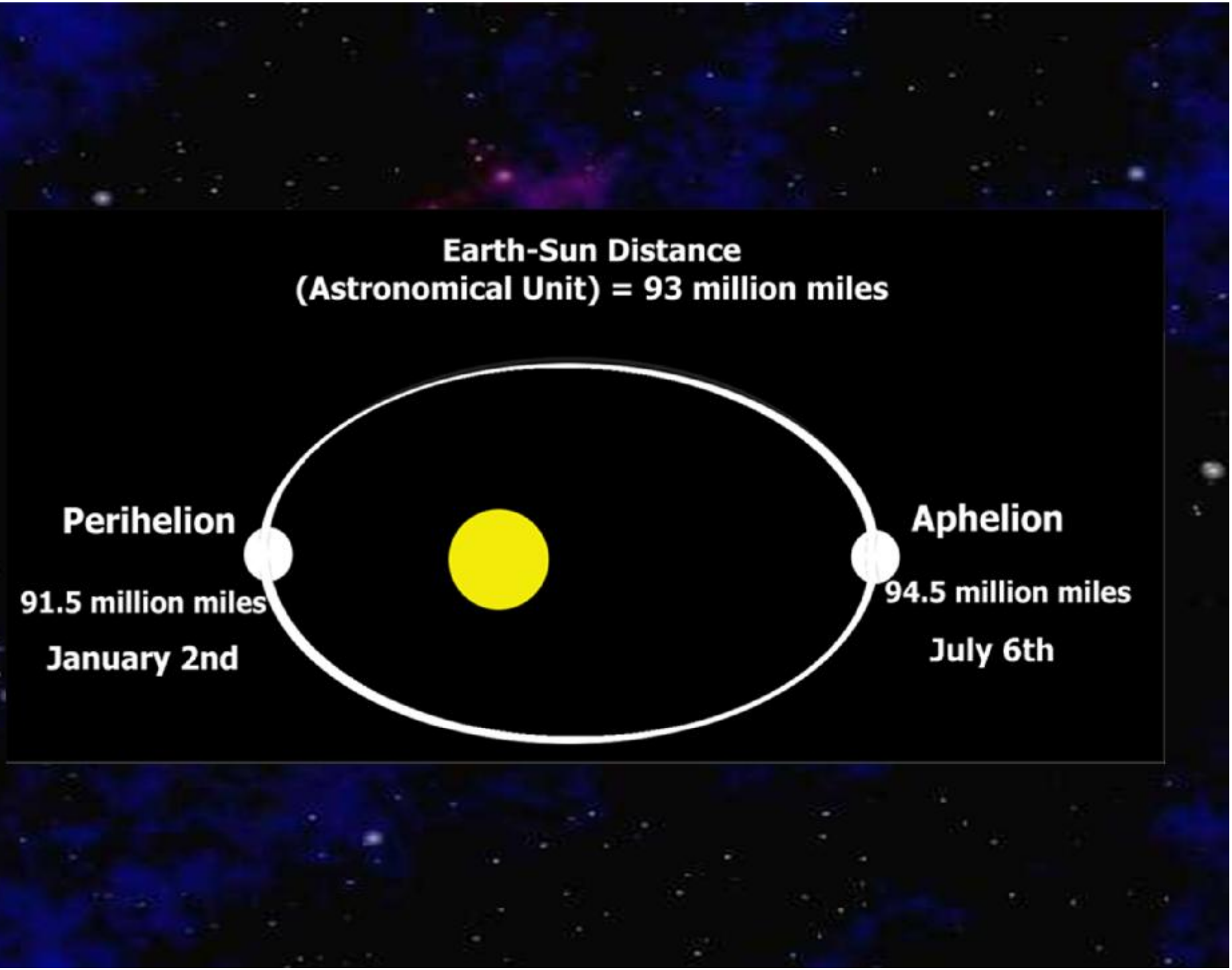


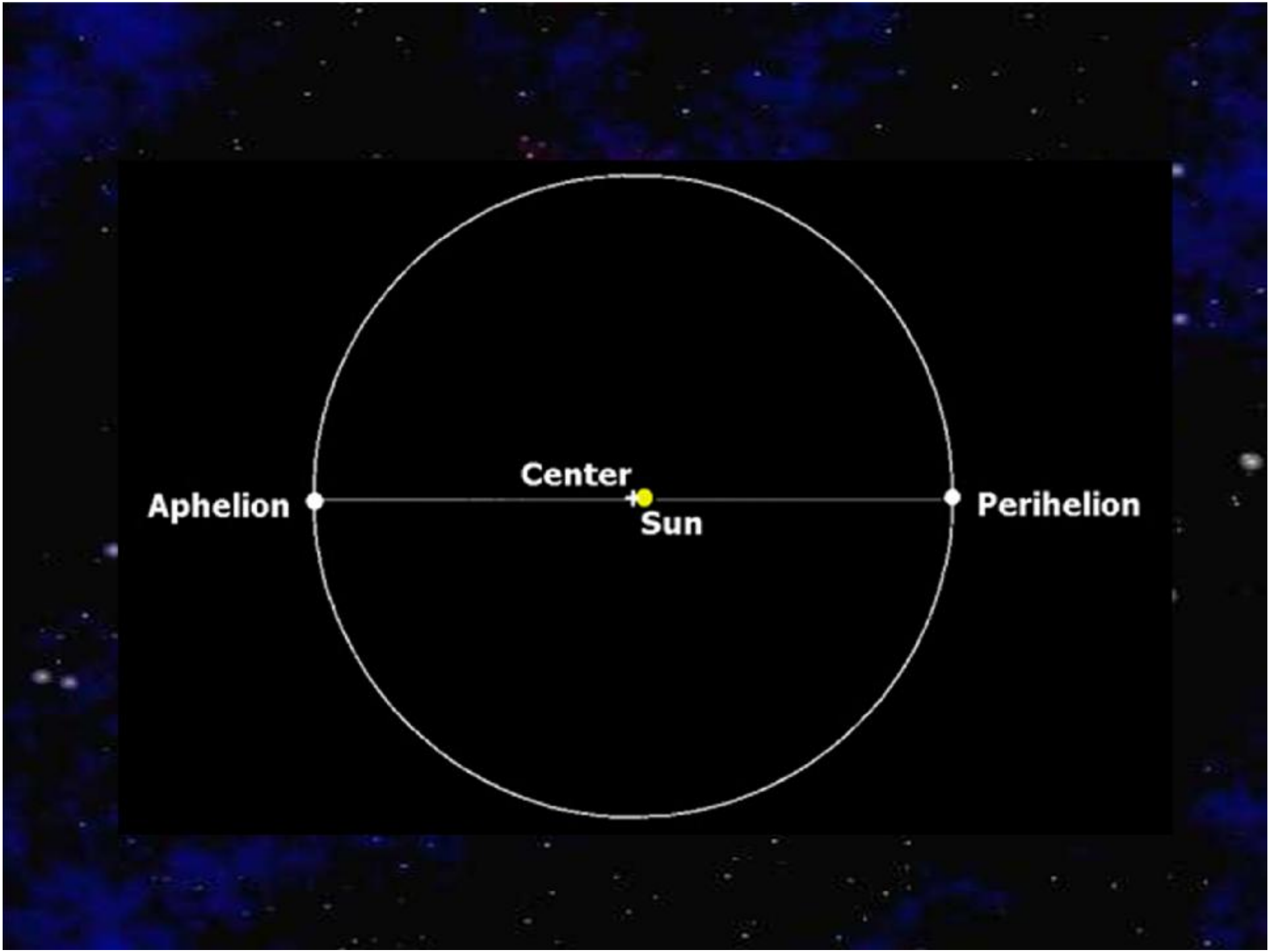

Earth-Sun Distance
(Astronomical Unit) = 93 million miles
Perihelion


Earth-Sun Distance
(Astronomical Unit) = 93 million miles
Perihelion
Aphelion


Earth-Sun Distance
(Astronomical Unit) = 93 million miles
Perihelion
91.5 million miles
Aphelion

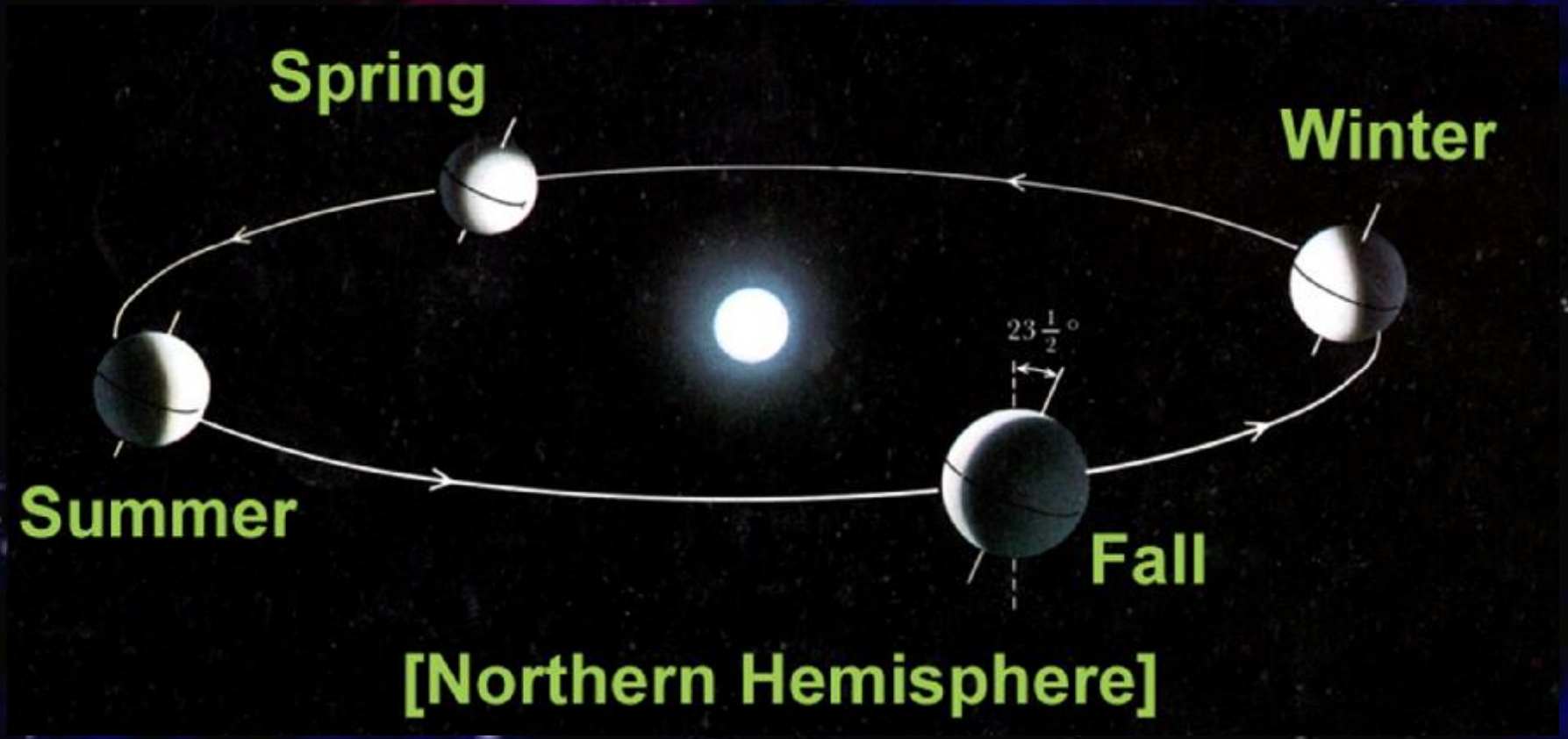

Earth-Sun Distance
(Astronomical Unit) = 93 million miles
Perihelion
91.5 million miles
Aphelion
94.5 million miles

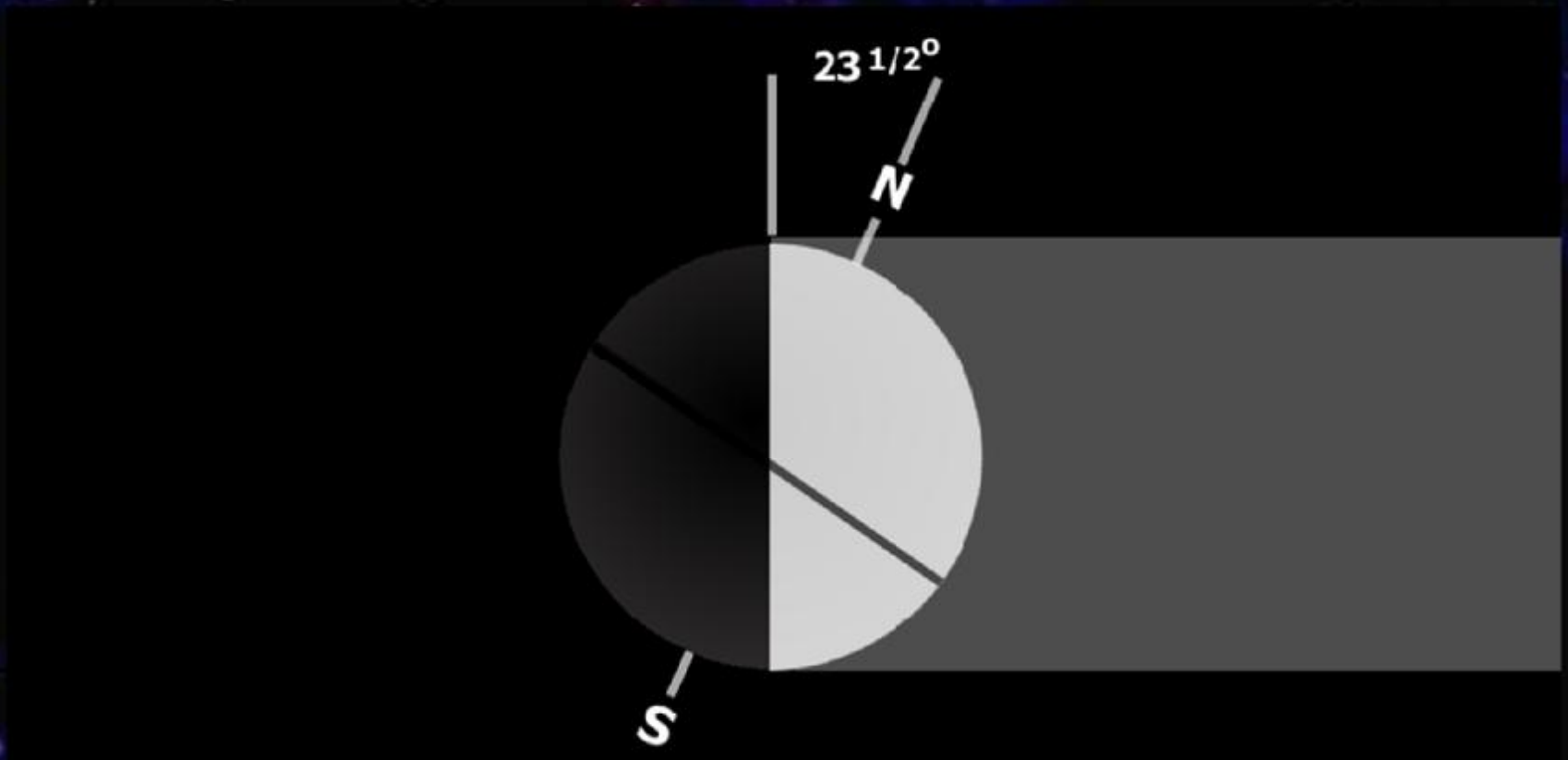

Earth-Sun Distance
(Astronomical Unit) = 93 million miles
Perihelion
91.5 million miles
January 2nd
Aphelion
94.5 million miles
July 6th


Aphelion
Center
Sun
Perihelion

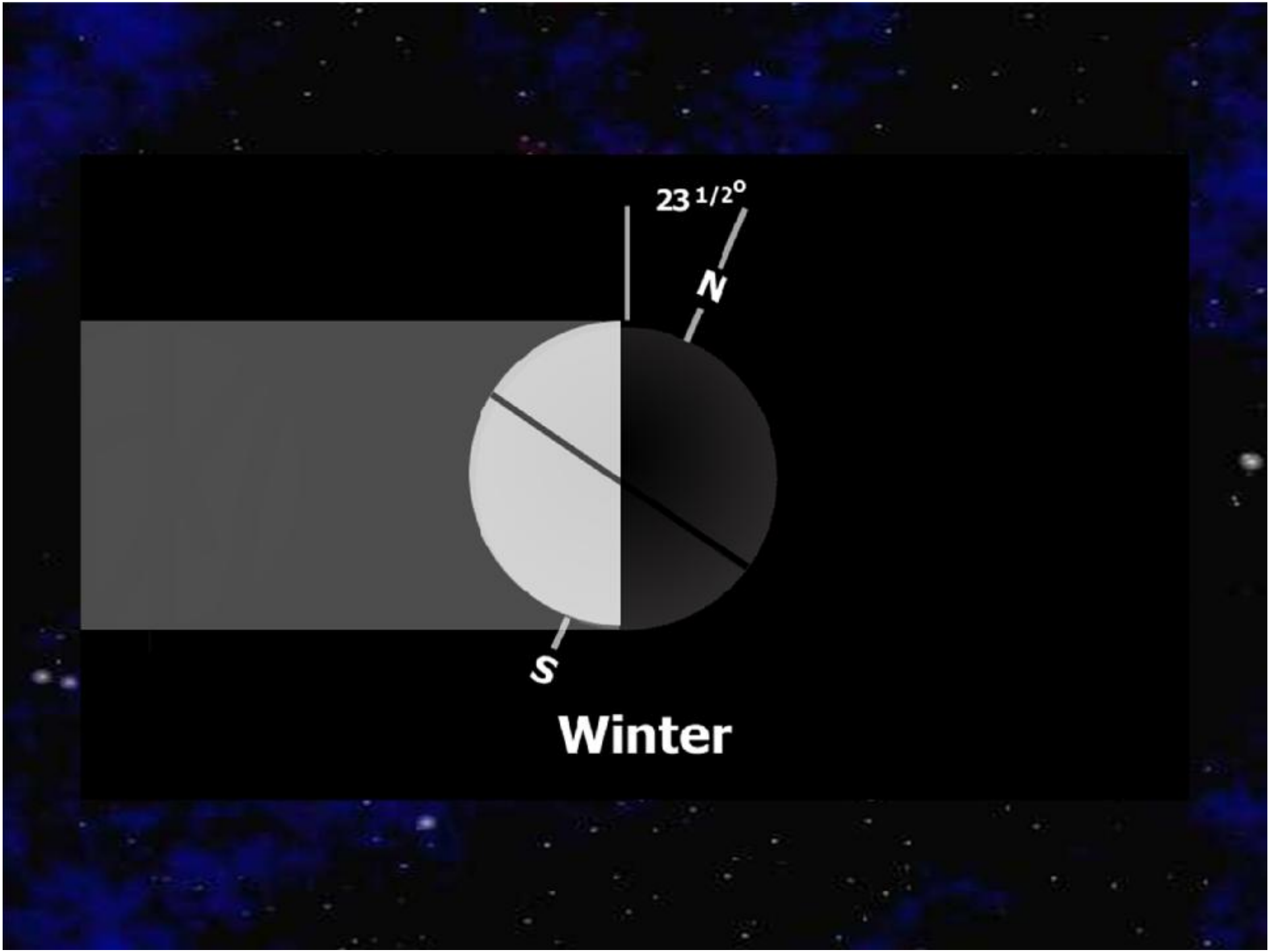

The Earth’s rotational axis is tilted 23½° with respect to its orbital plane.

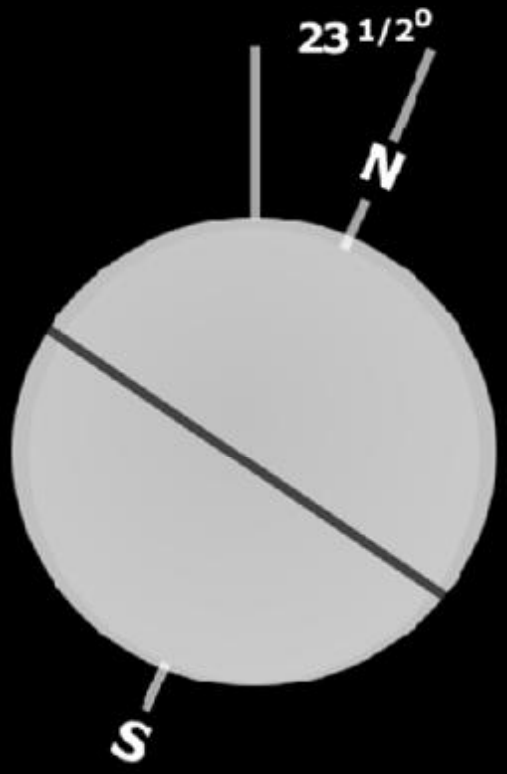
Earth's Orbit



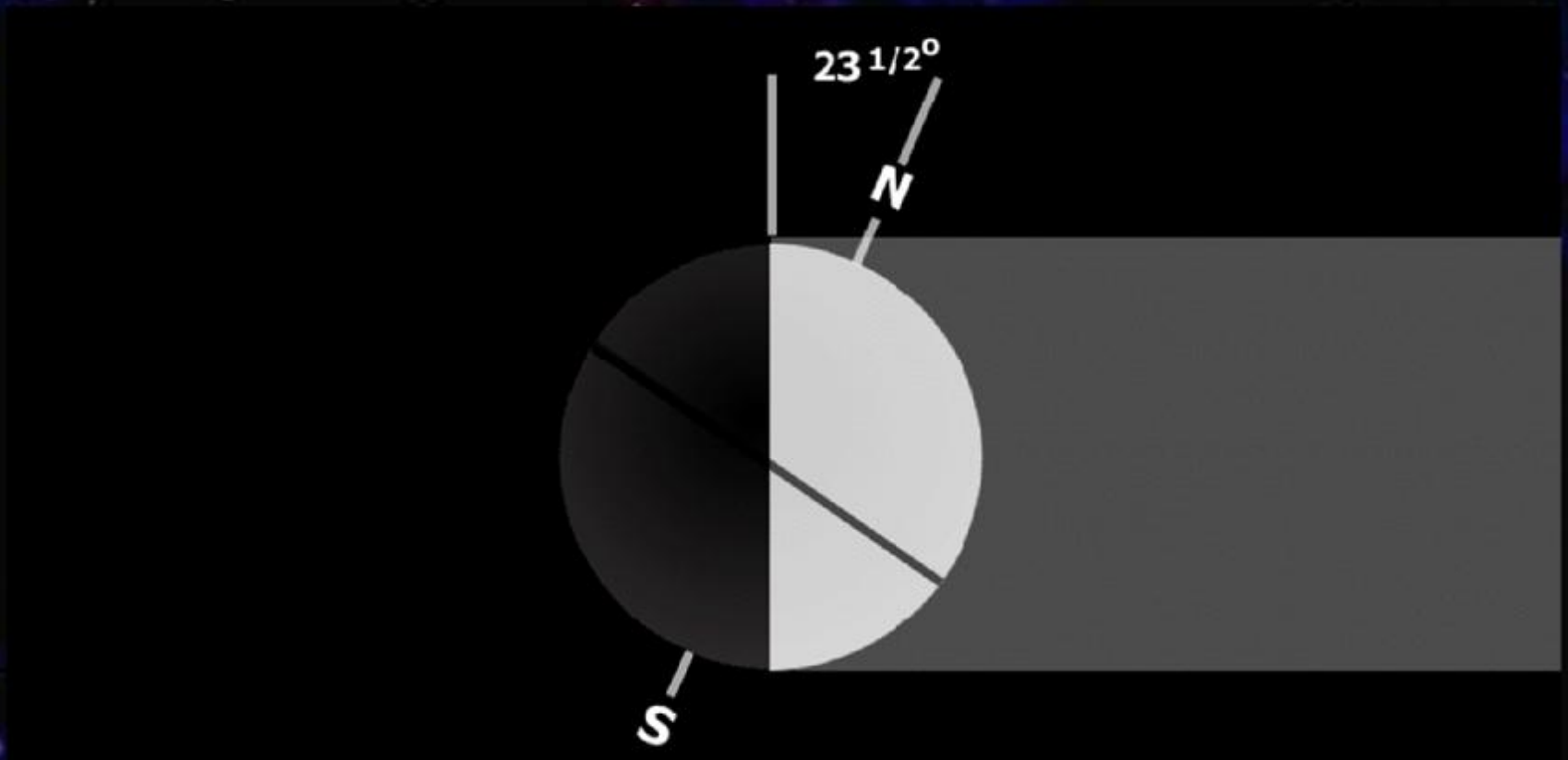


Summer


23 1/2°
N
S
Winter

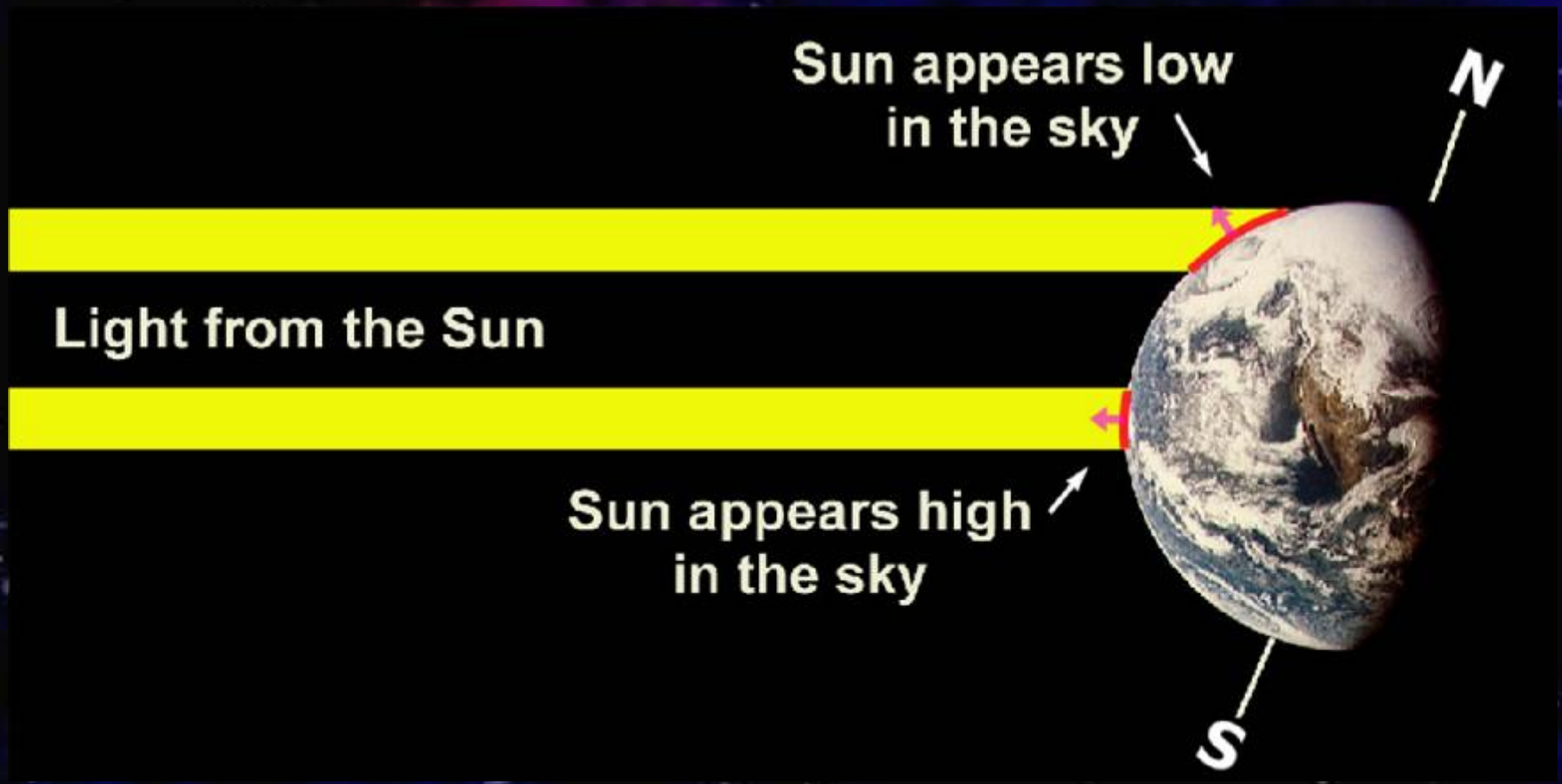


Spring or Fall



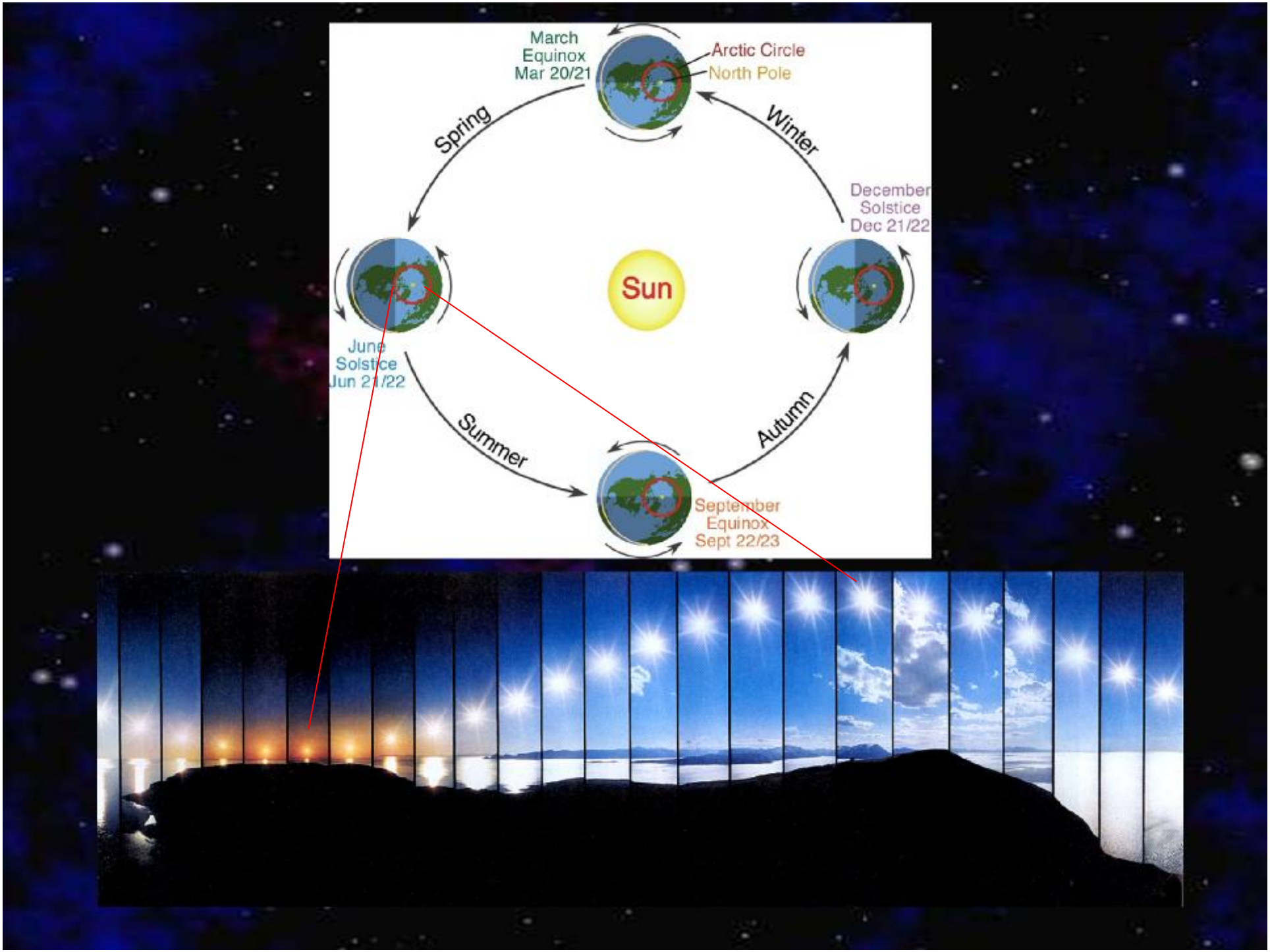
Summer

The intensity of sunlight striking the Earth varies with location:



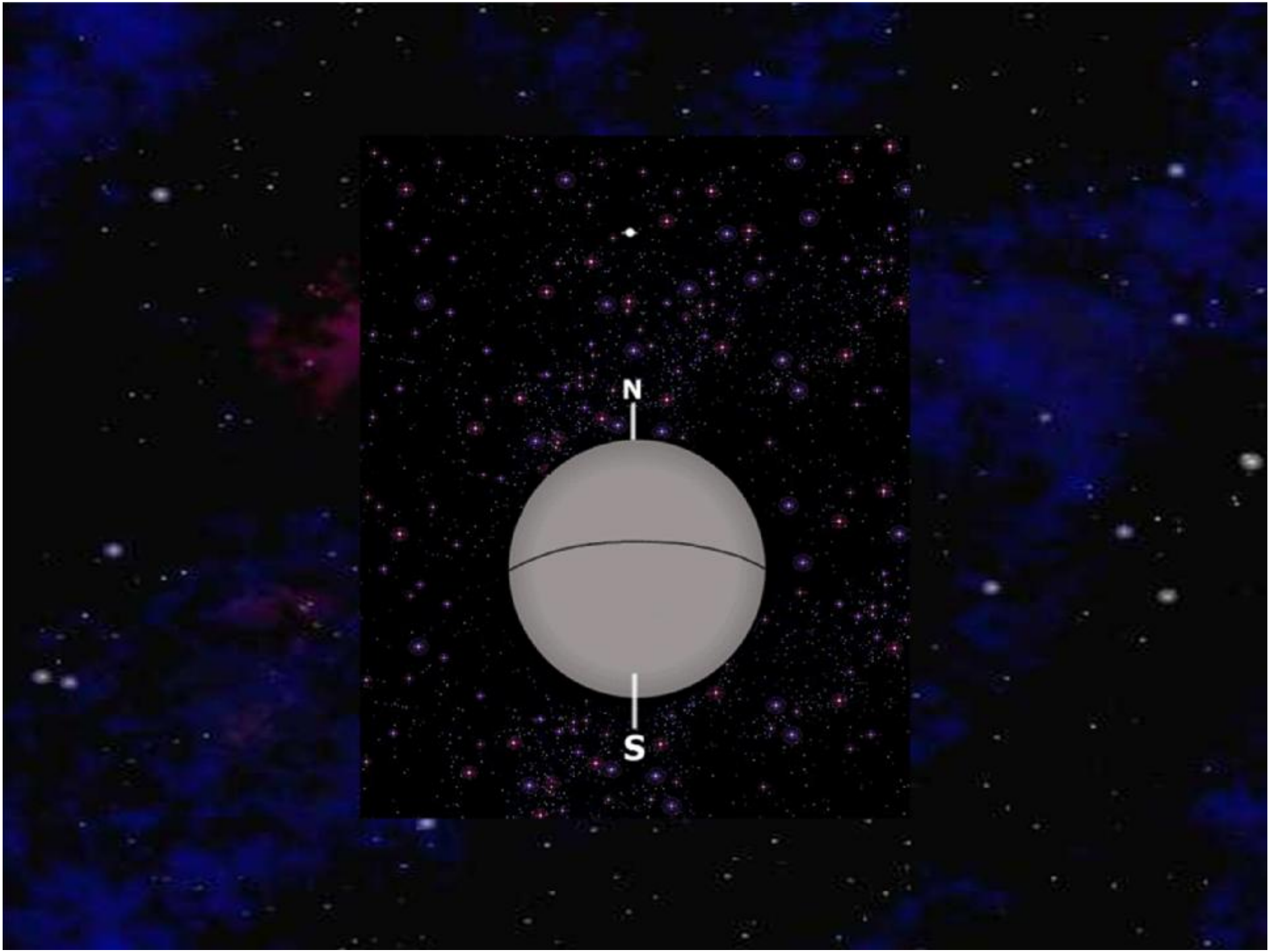
Where on Earth is this photo taken?

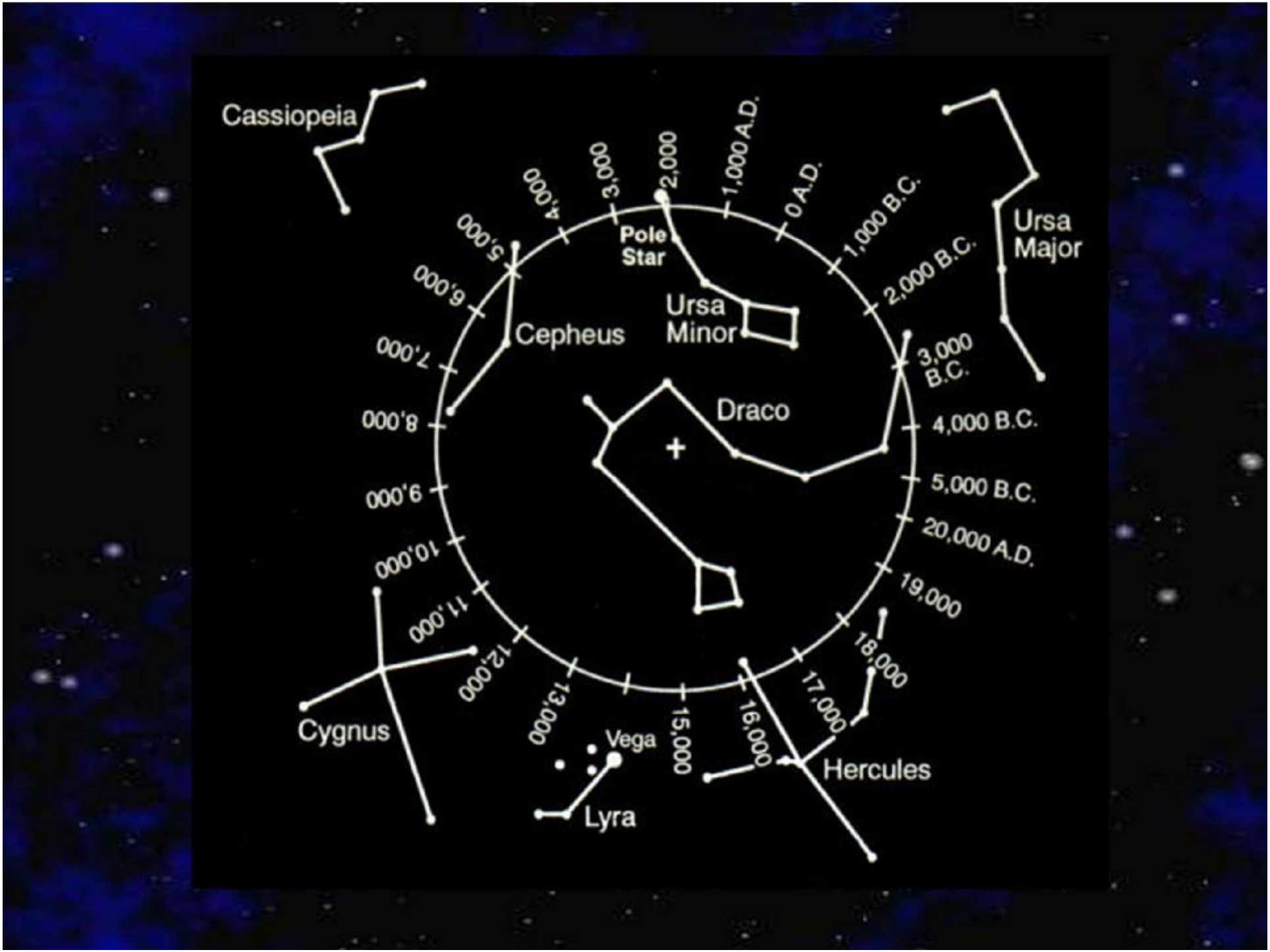
What was the calendar date?

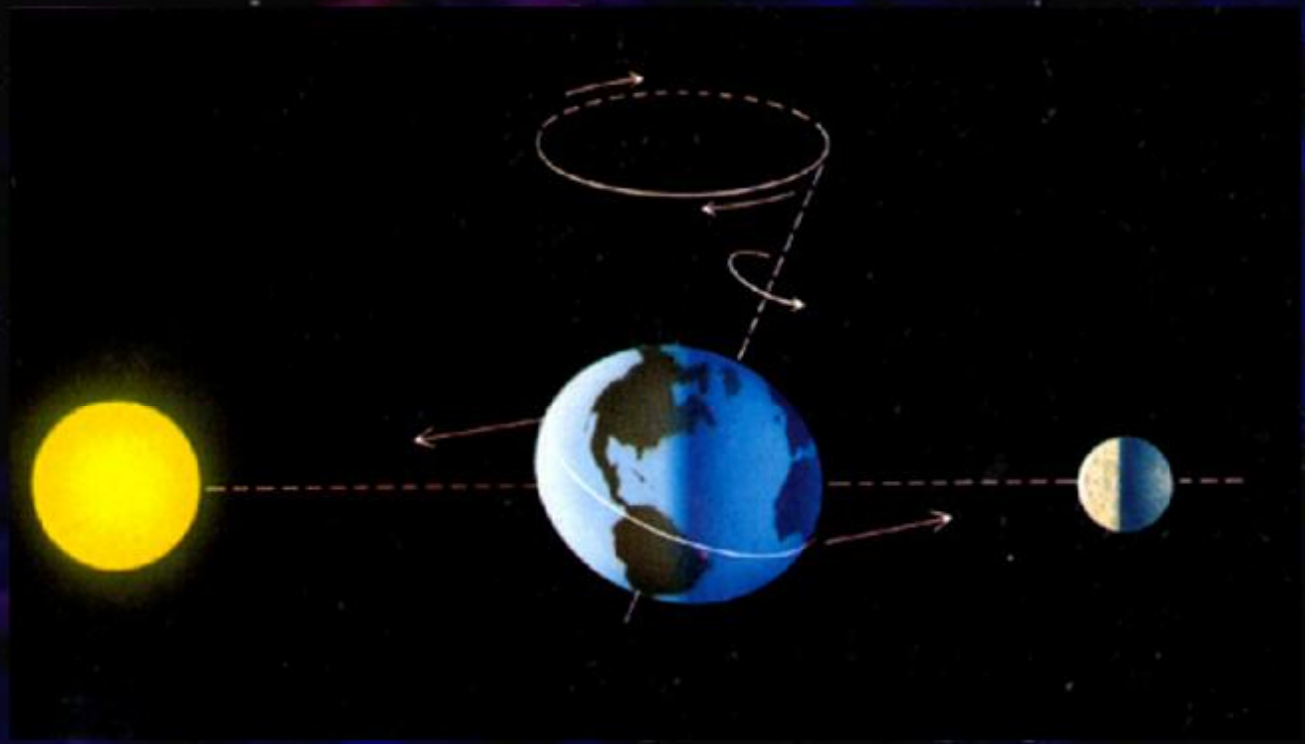

March
Equinox
Mar 20/21
Arctic Circle
North Pole
Spring
Winter
December
Solstice
Dec 21/22
Sun
June
Solstice
Jun 21/22
Summer
Autumn
September
Equinox
Sept 22/23

LONG TERM CHANGES

PRECESSION


N
S


Cassiopeia
4,000
3,000
2,000
1,000 A.D.
0 A.D.
1,000 B.C.
2,000 B.C.
3,000 B.C.
4,000 B.C.
5,000 B.C.
20,000 A.D.
19,000
18,000
17,000
16,000
15,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
Pole Star
Ursa Minor
Ursa Major
Cepheus
Draco
Cygnus
Vega
Lyra
Hercules



PRECESSION

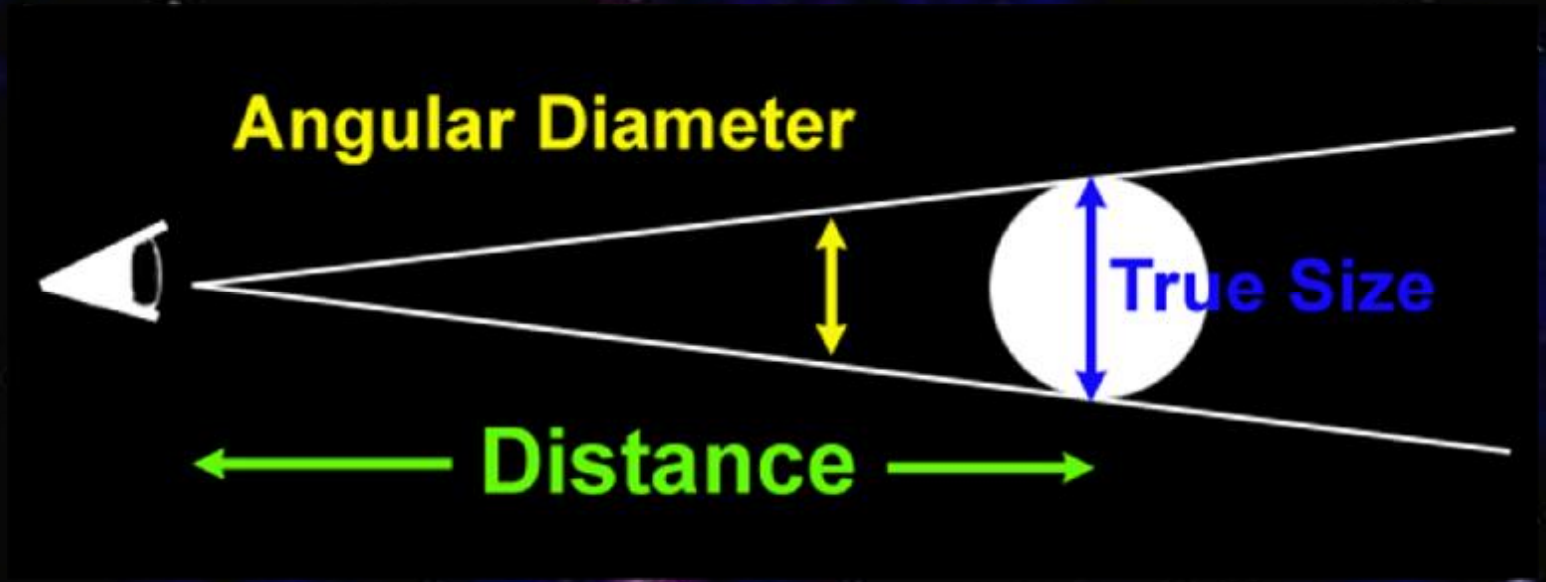
Slow change in the orientation of the Earth's axis of rotation.

- Caused by the gravitational interaction between the Sun, Earth, and Moon.
- Tilt of the Earth remains 23½° -BUT- changes orientation.
- Period of precession ~ 26,000 years

Precession of the Equinoxes


ECLIPSES

Angular Diameter



Angular diameter of the Sun and Moon are approximately the same.

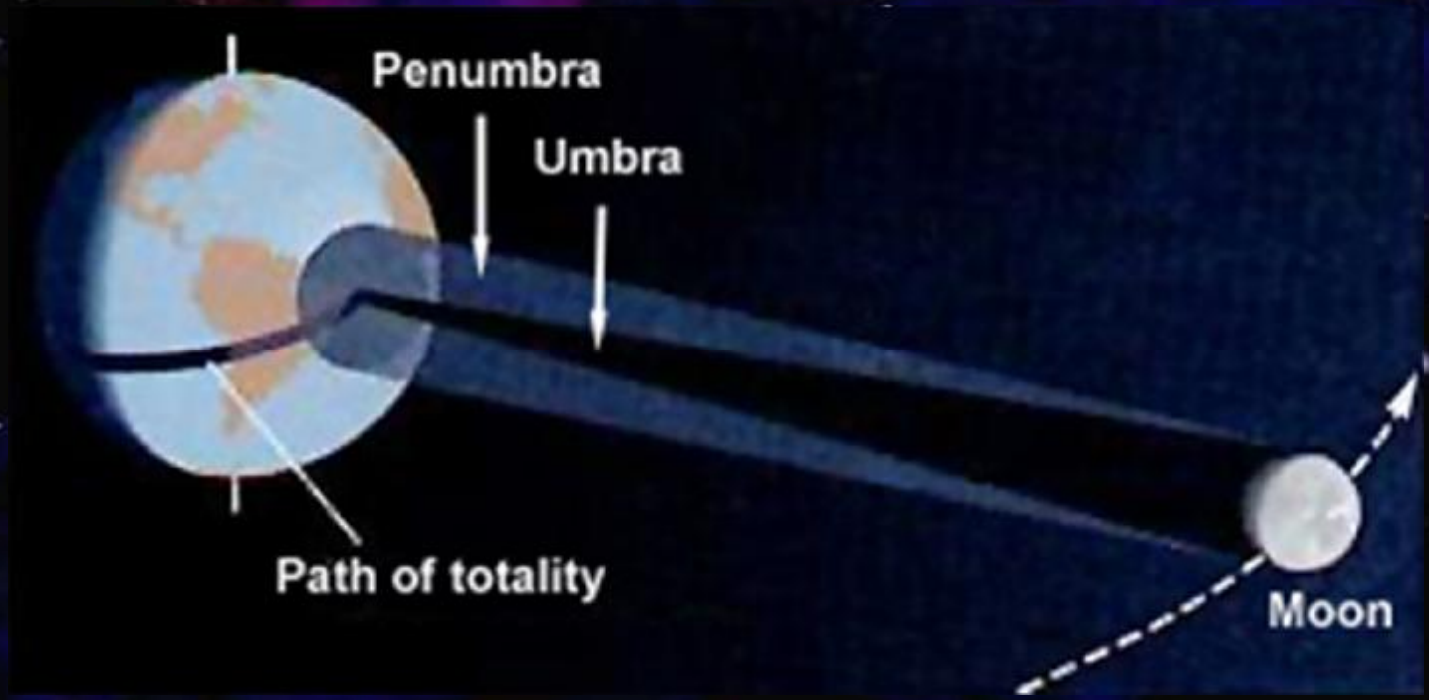
Both Appear to be ~ 1/2°

Solar Eclipses

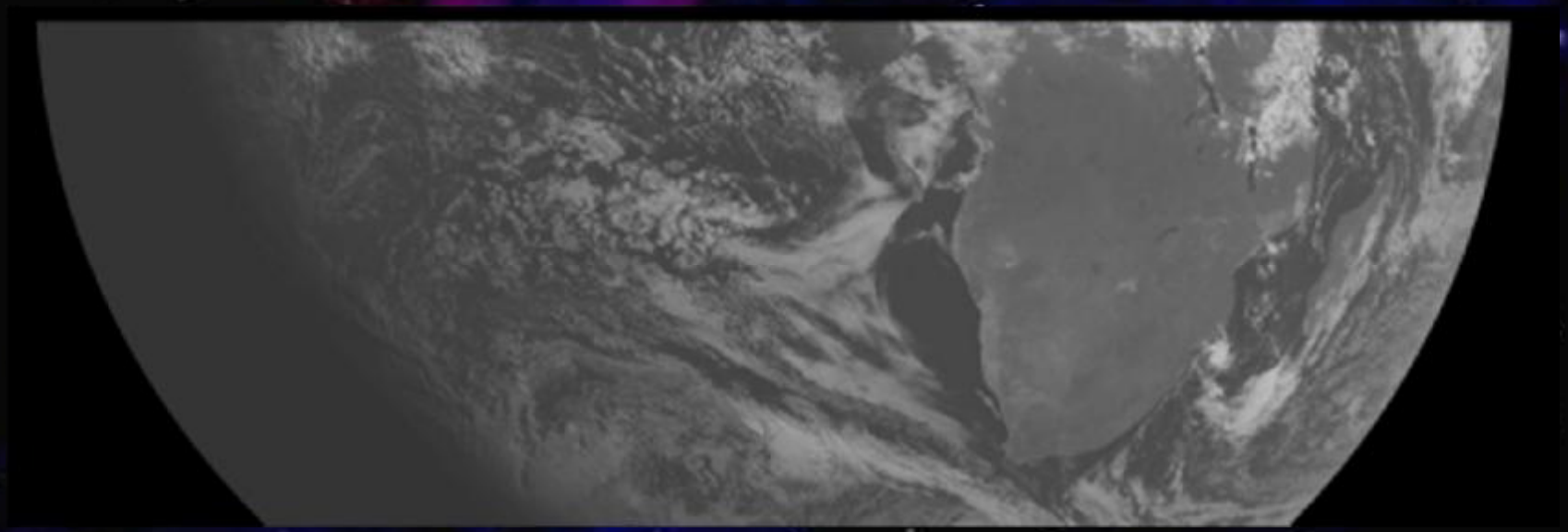
Occurs when the shadow of the Moon is cast upon the Earth.

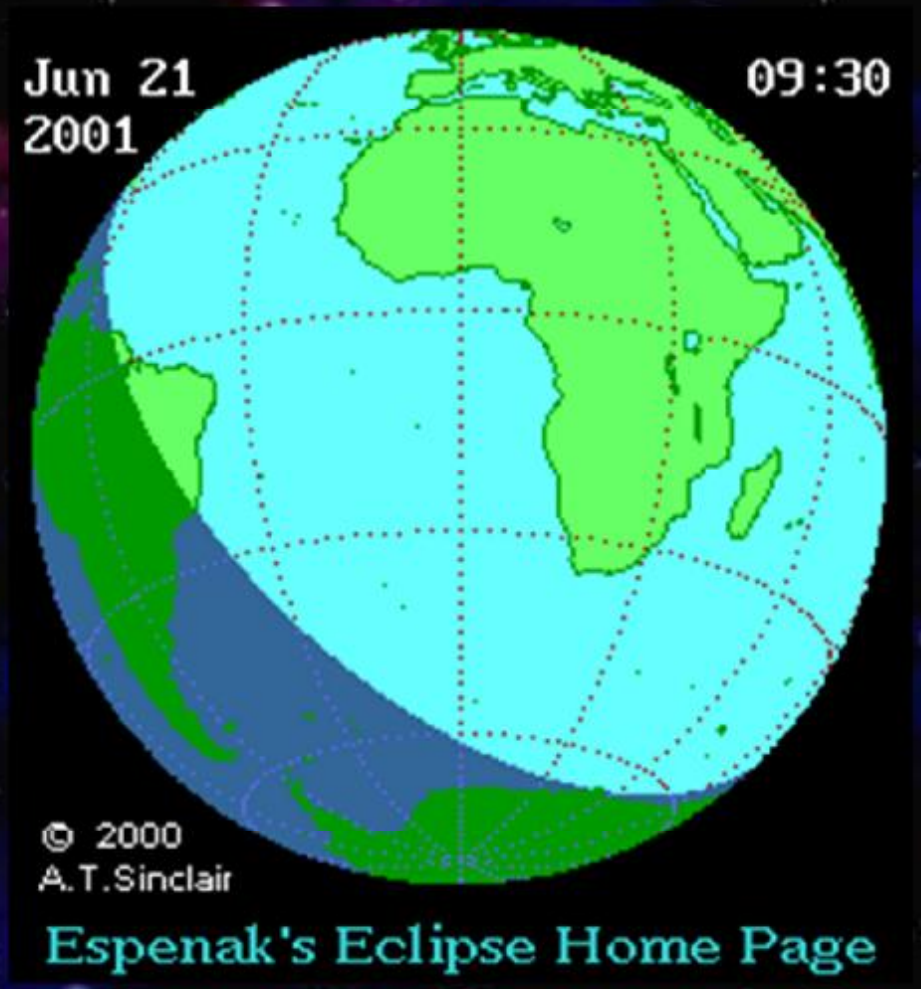
Can only occur at NEW MOON

Anatomy of a Solar Eclipse

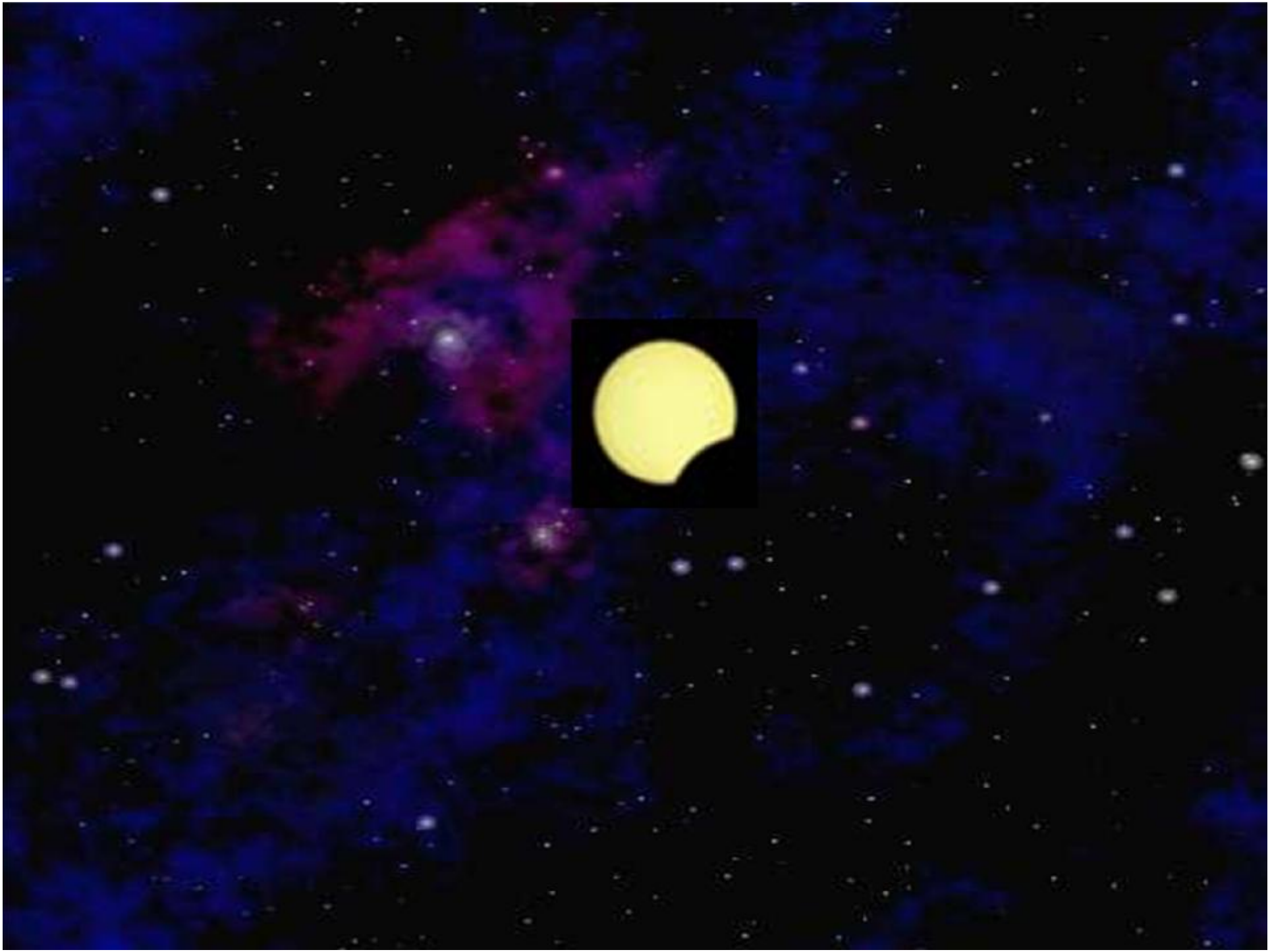


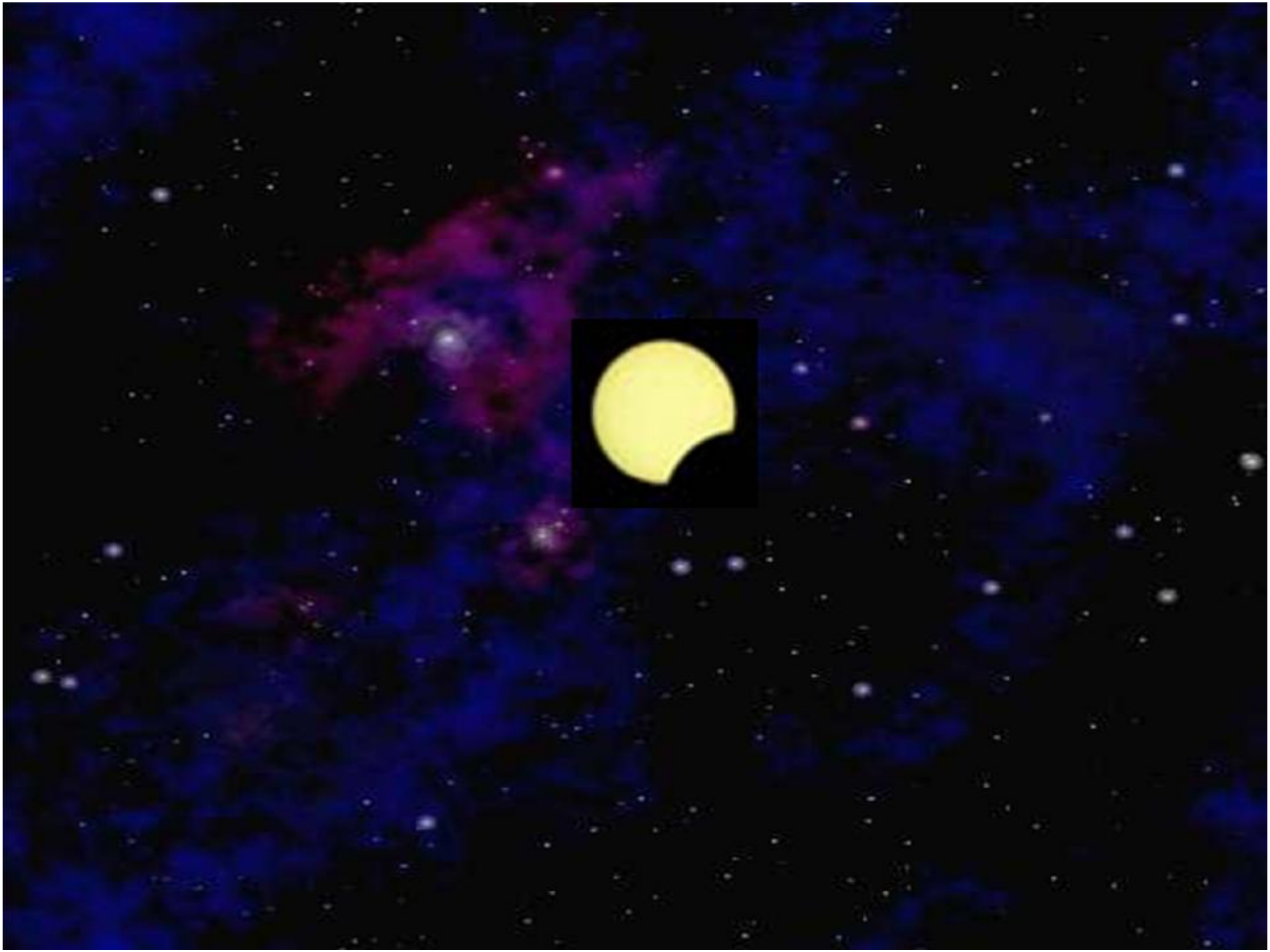
Solar Eclipse seen from space:

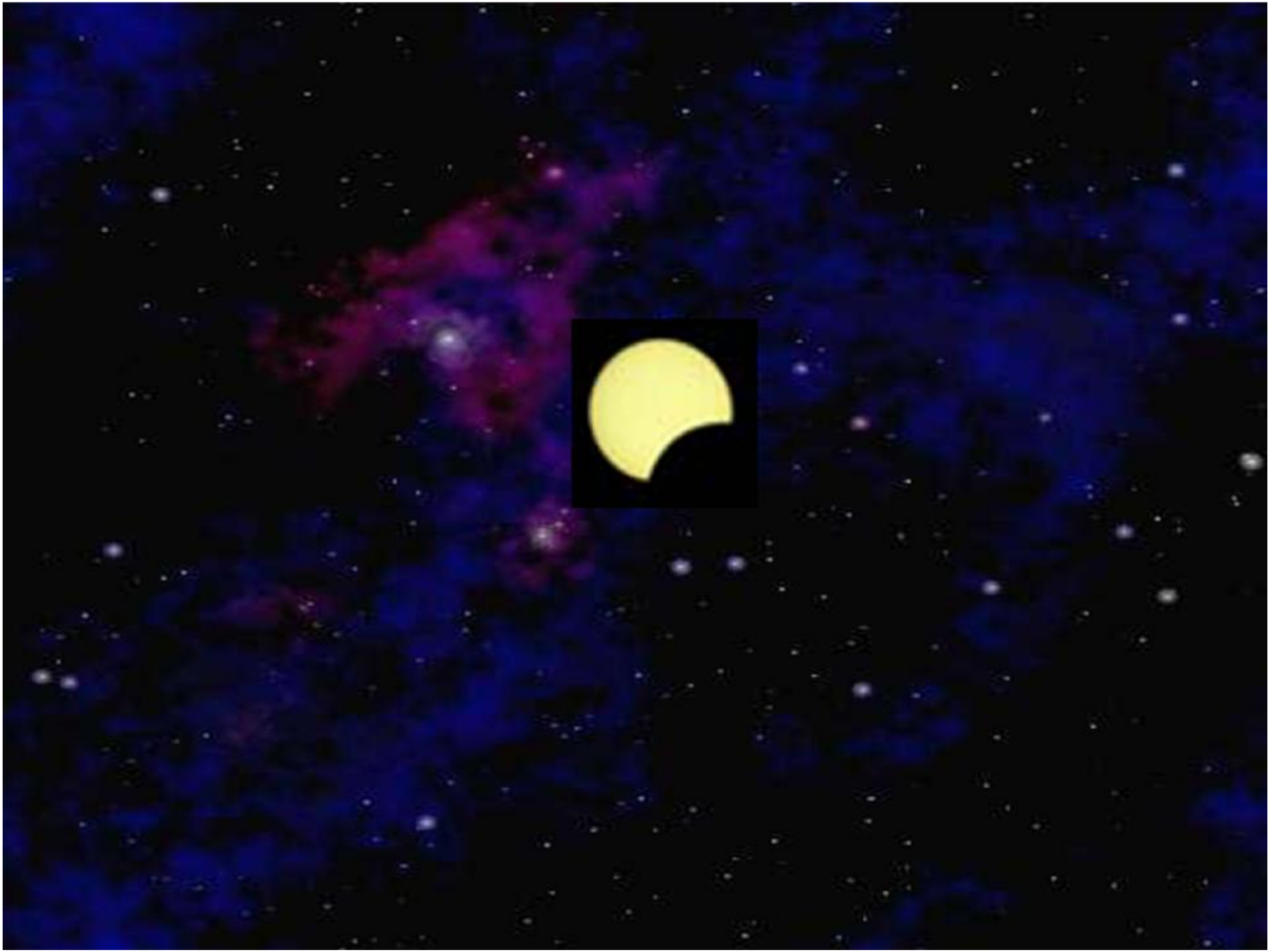


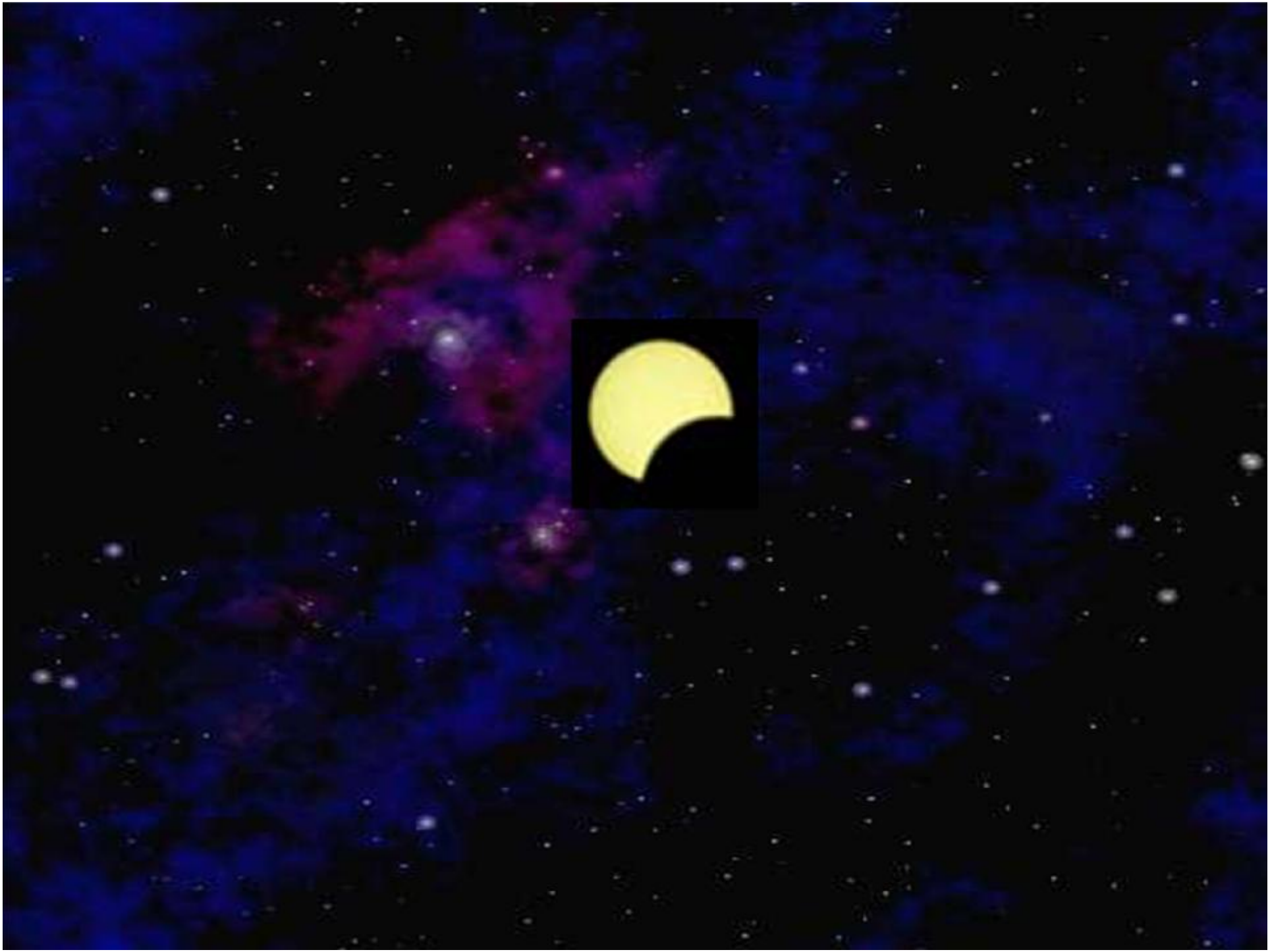

Jun 21
2001
09:30
© 2000
A.T.Sinclair
Espenak's Eclipse Home Page

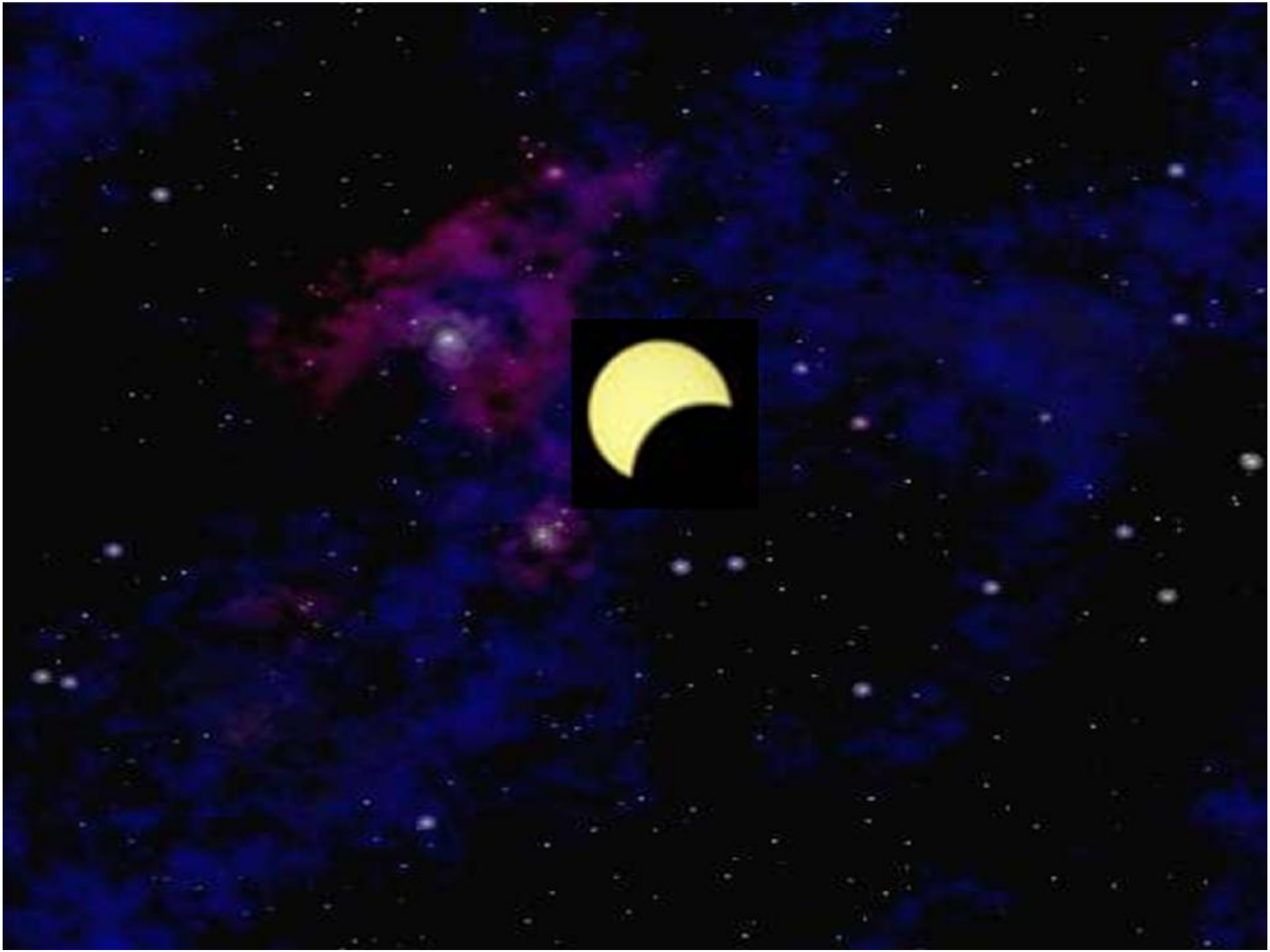
Solar Eclipse seen from Earth:

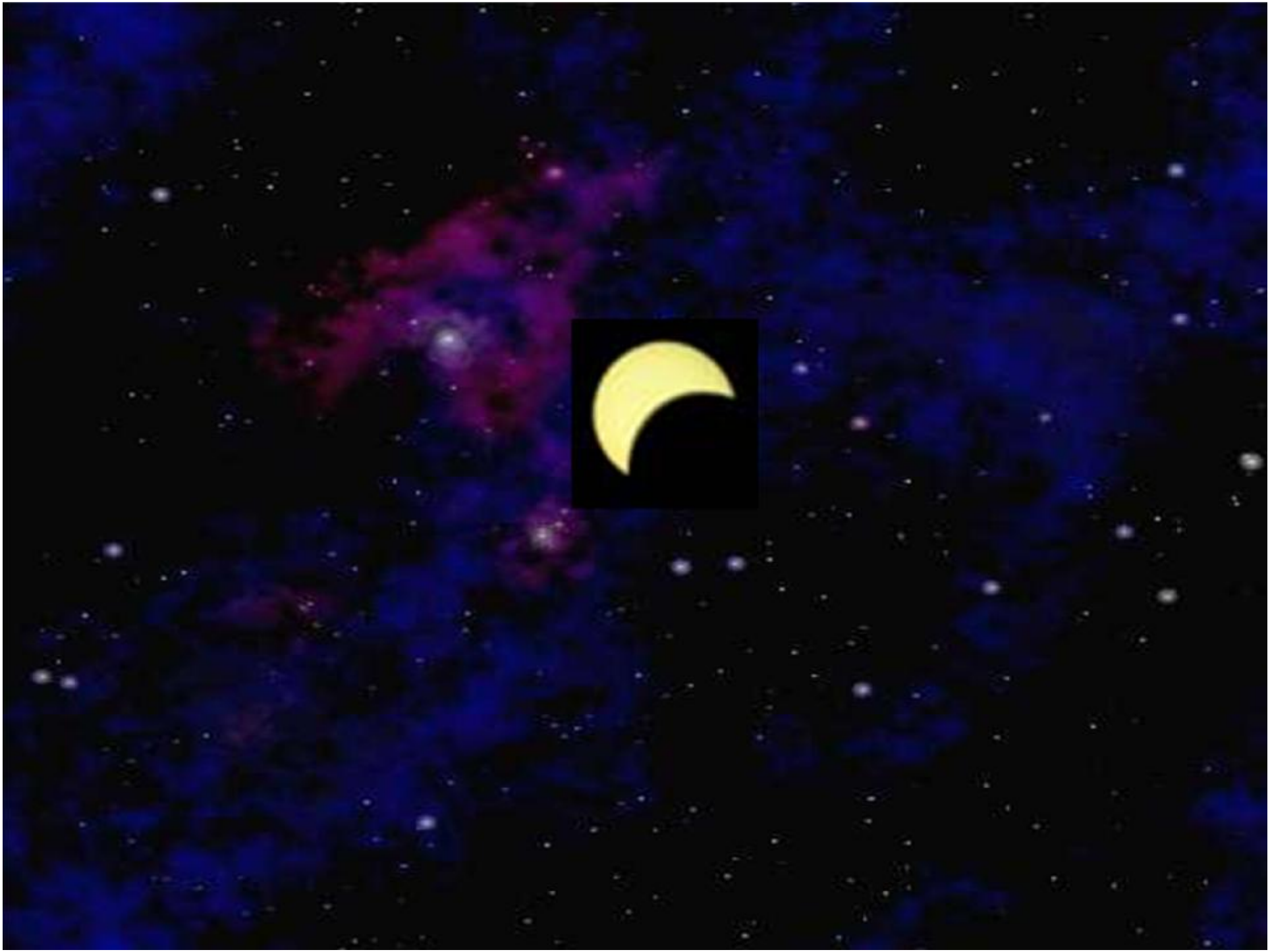


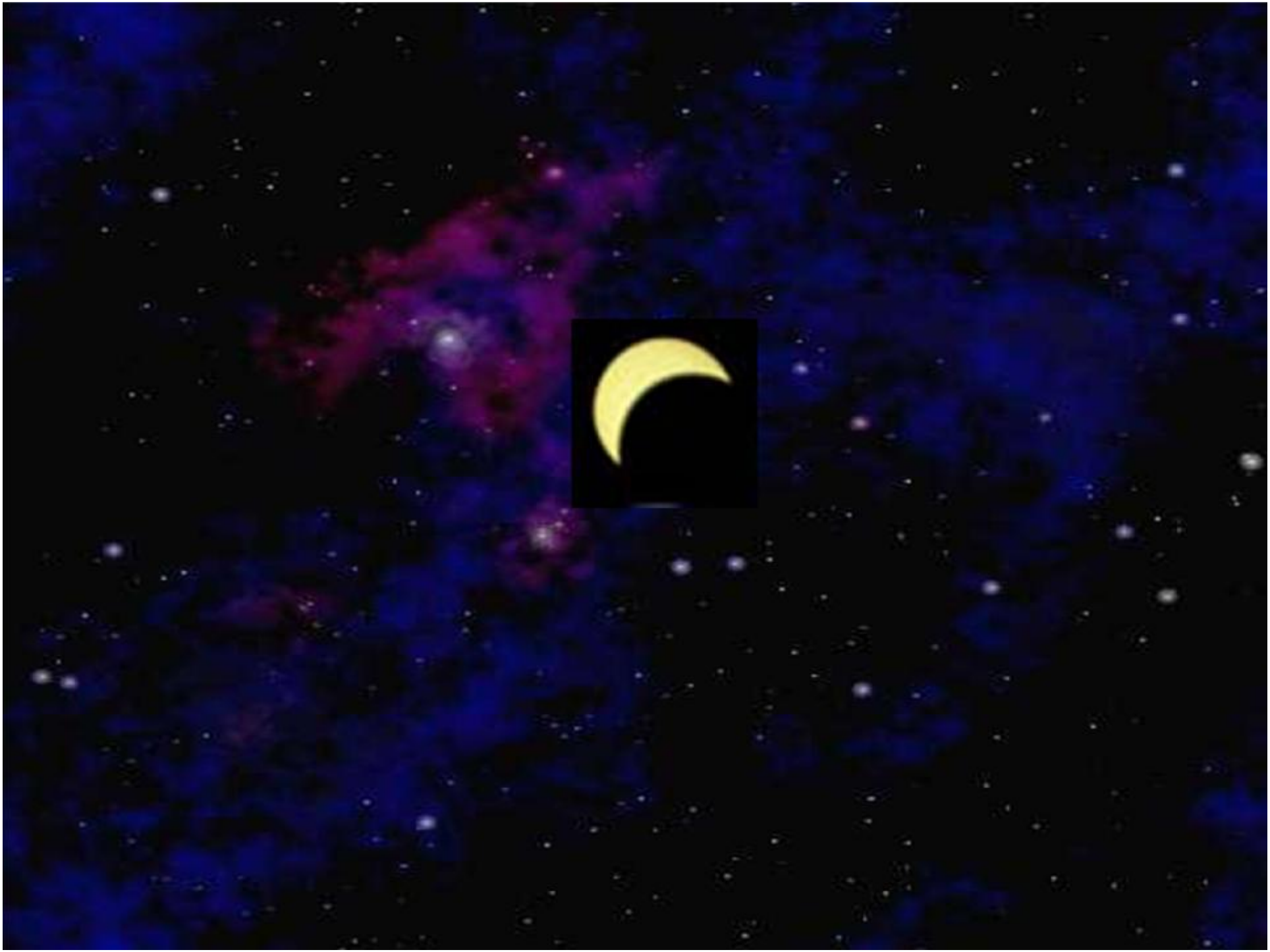


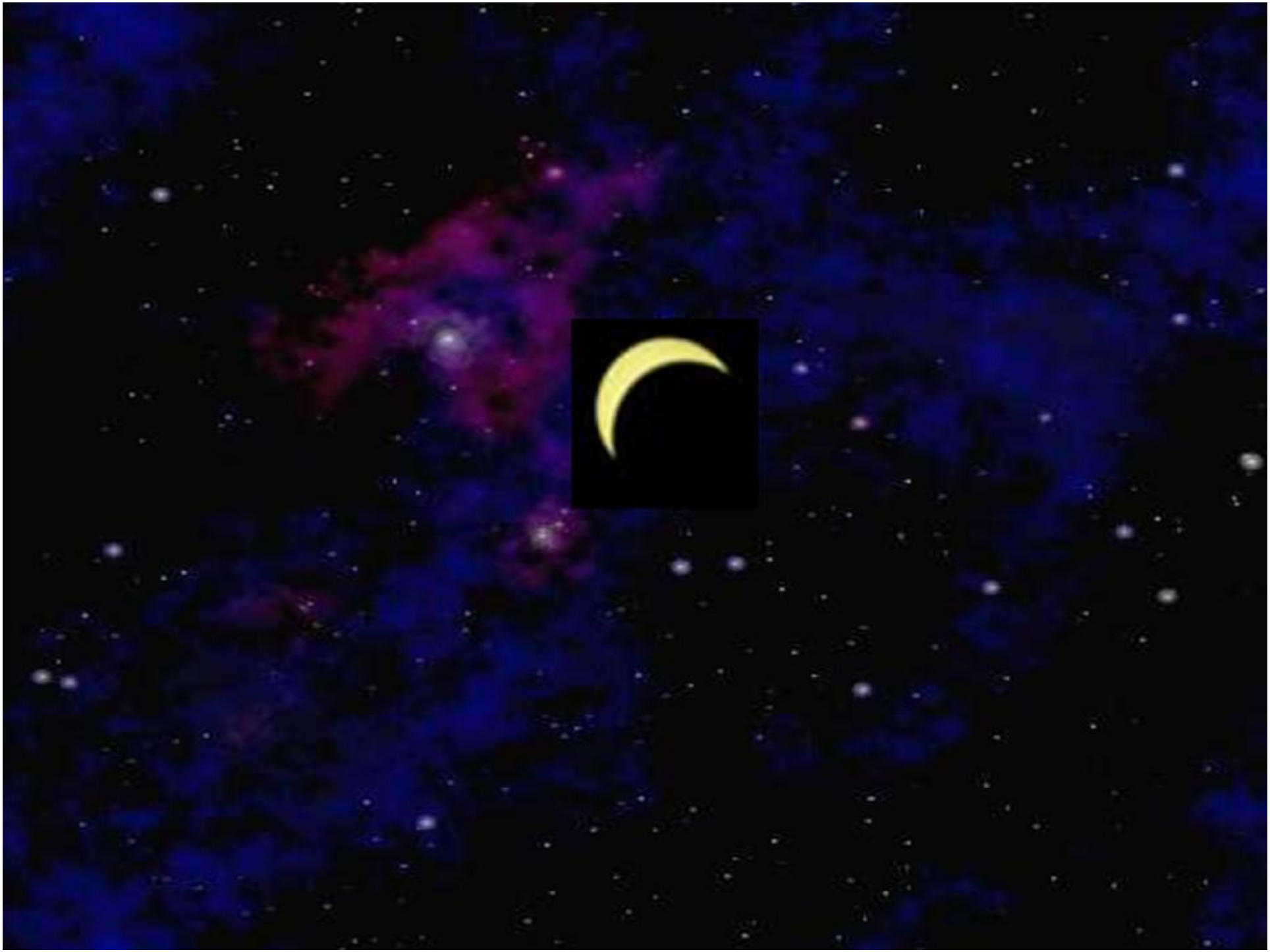


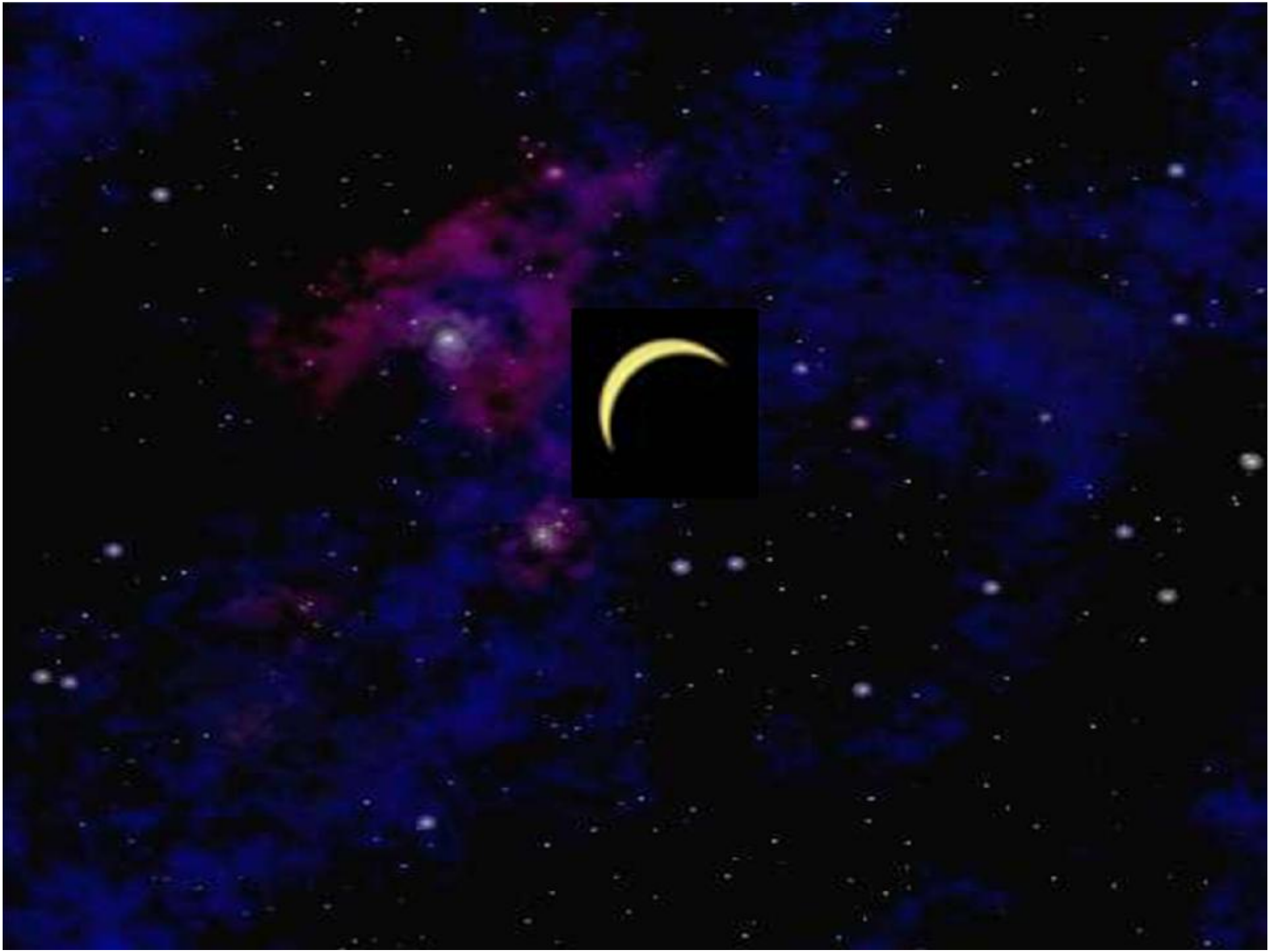


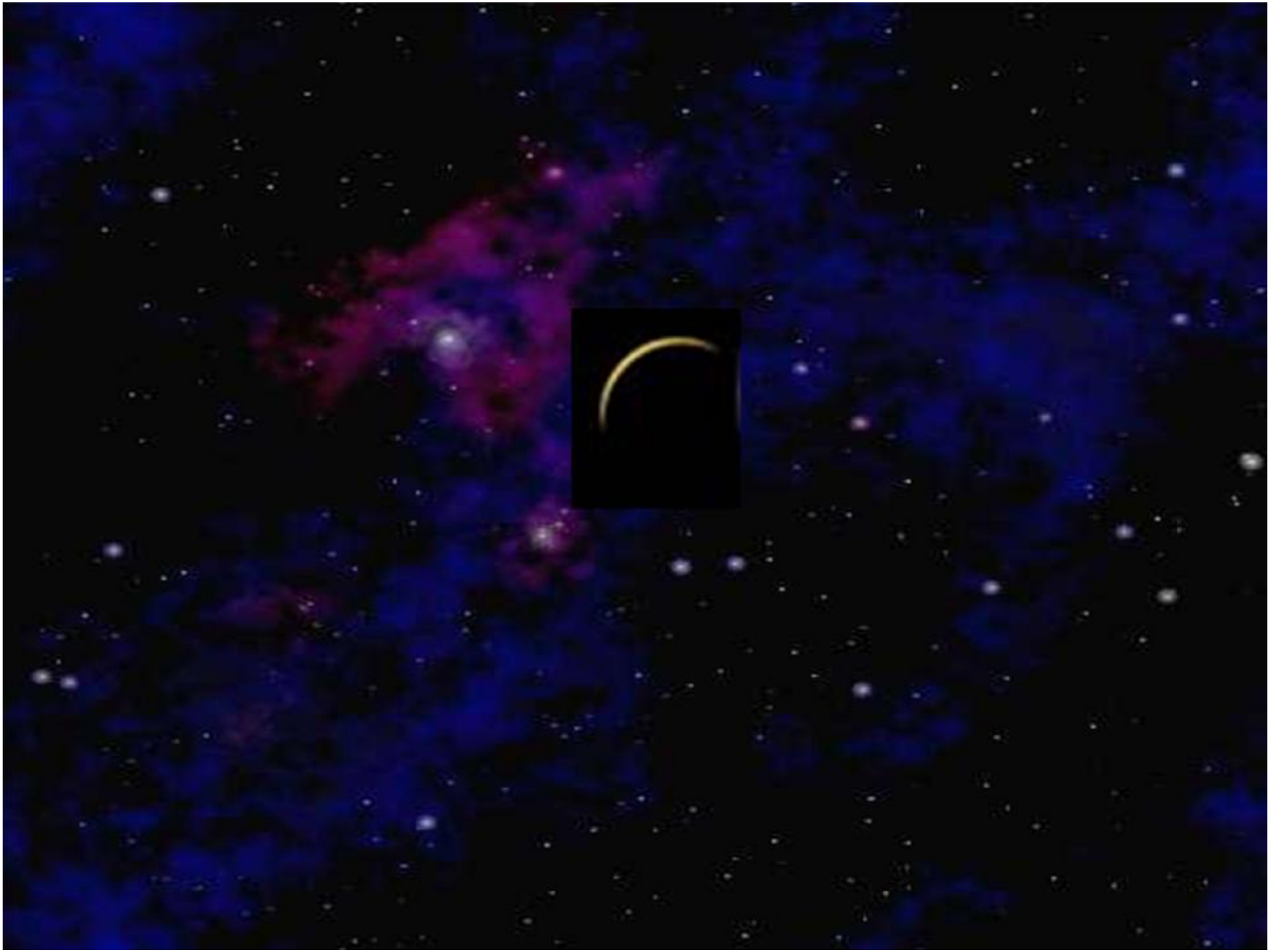


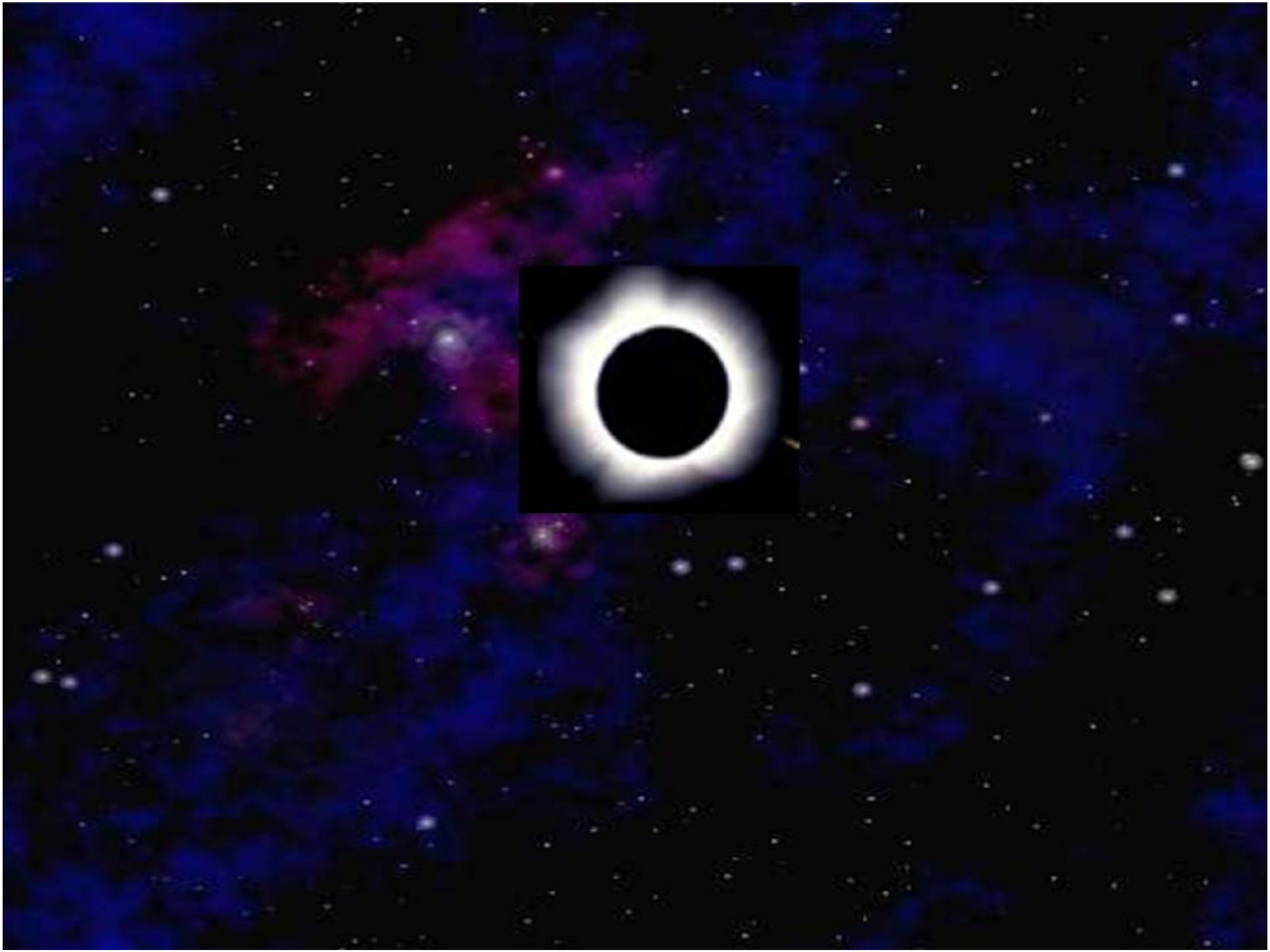


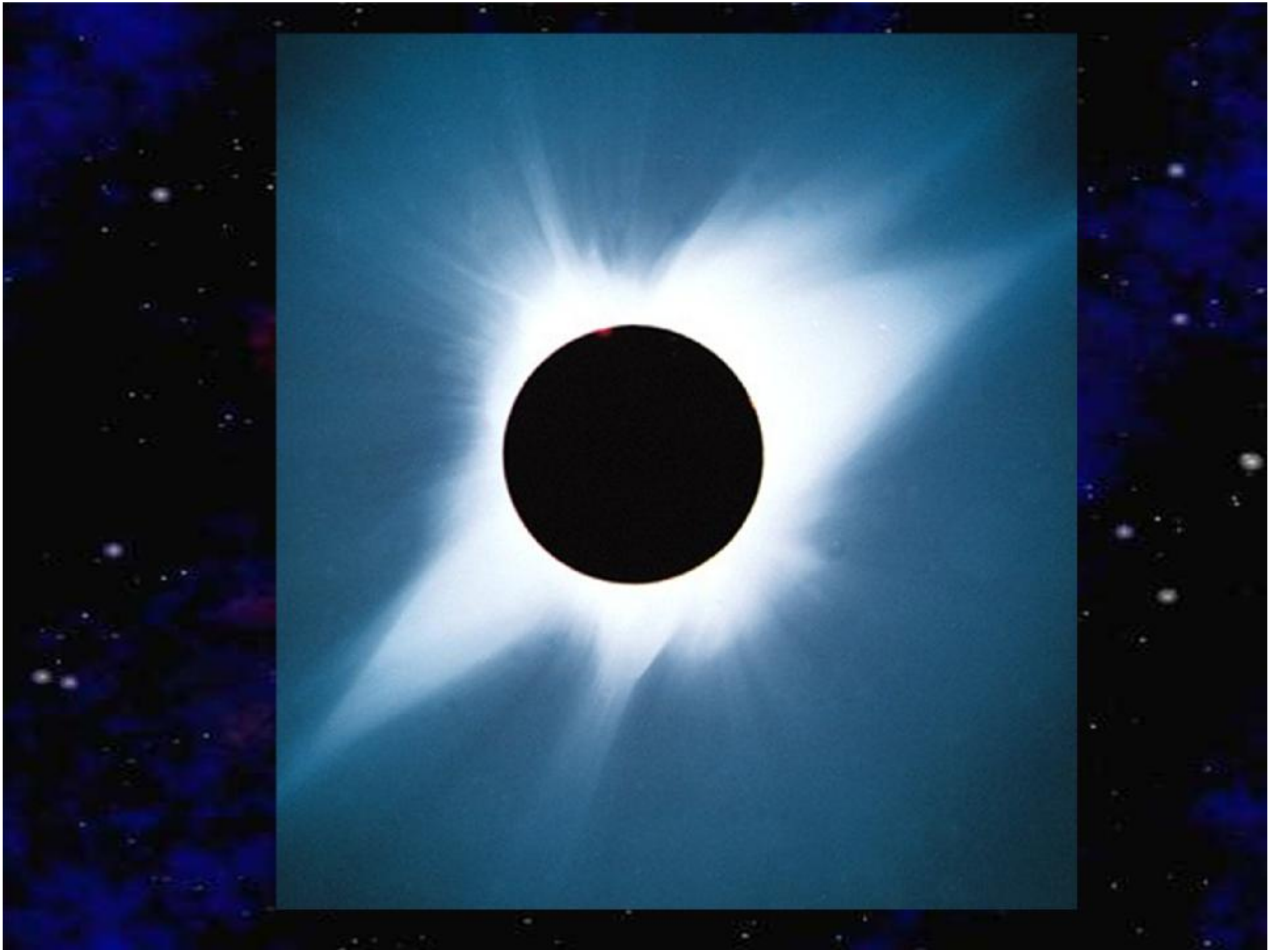


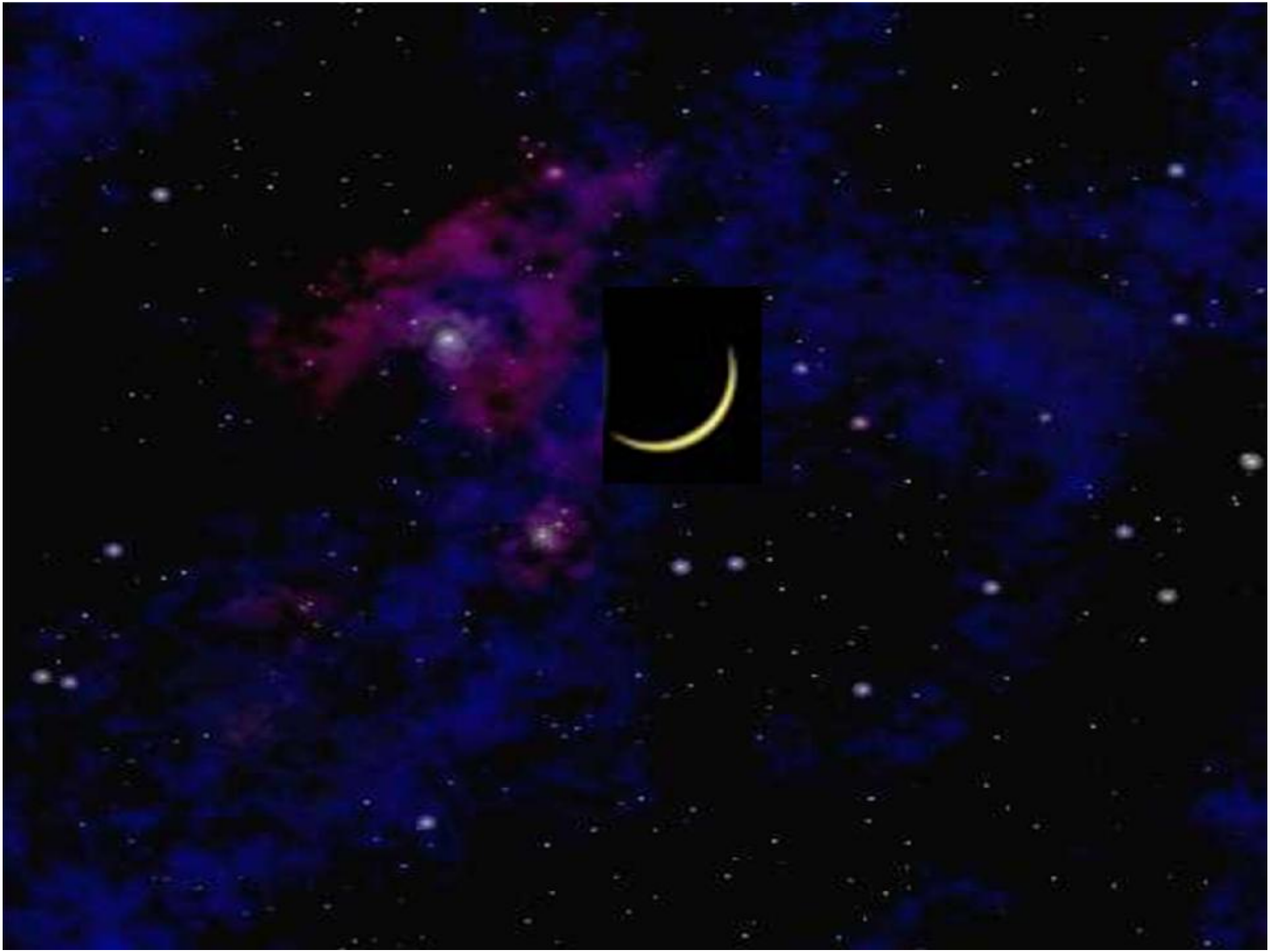


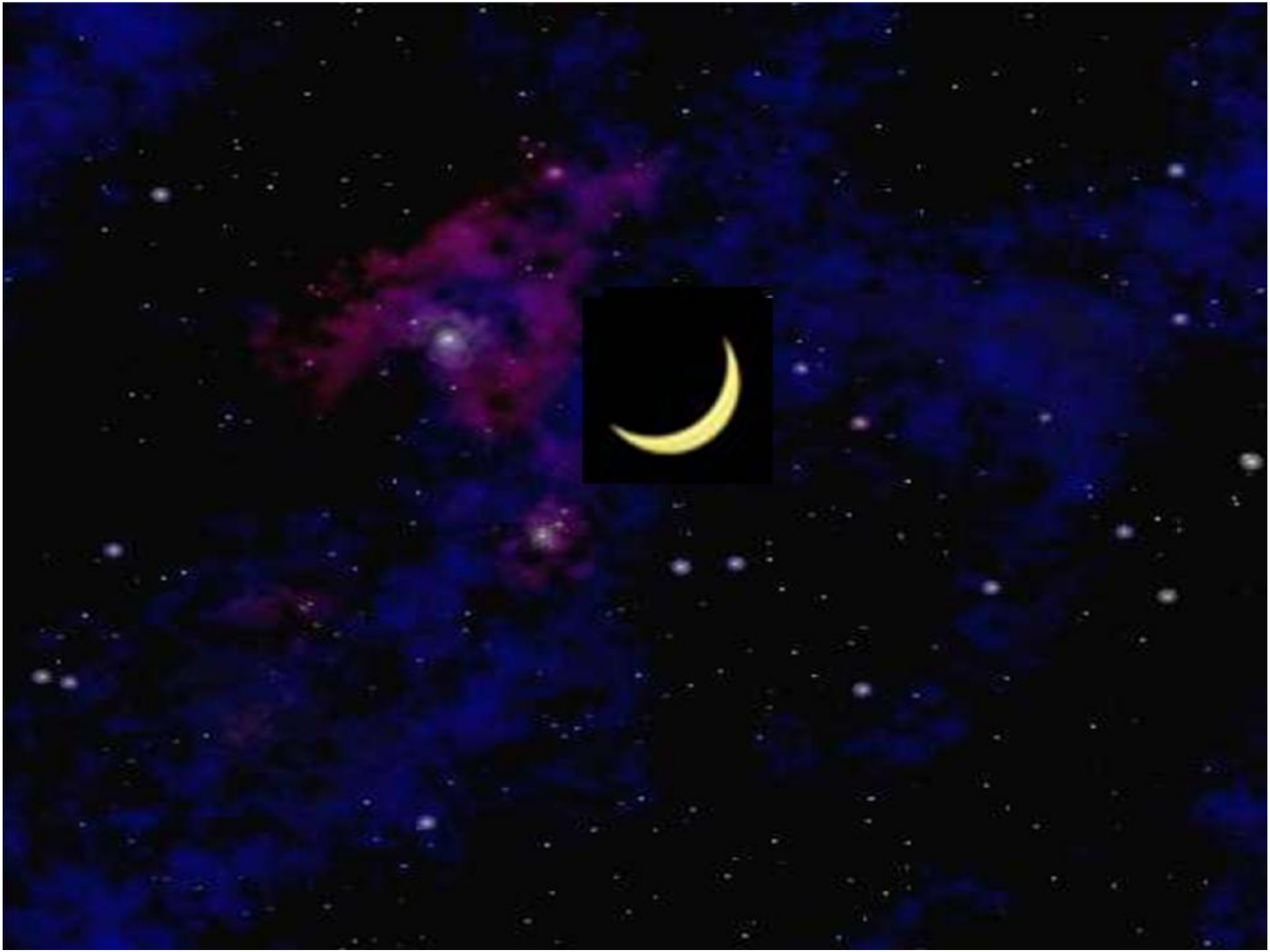


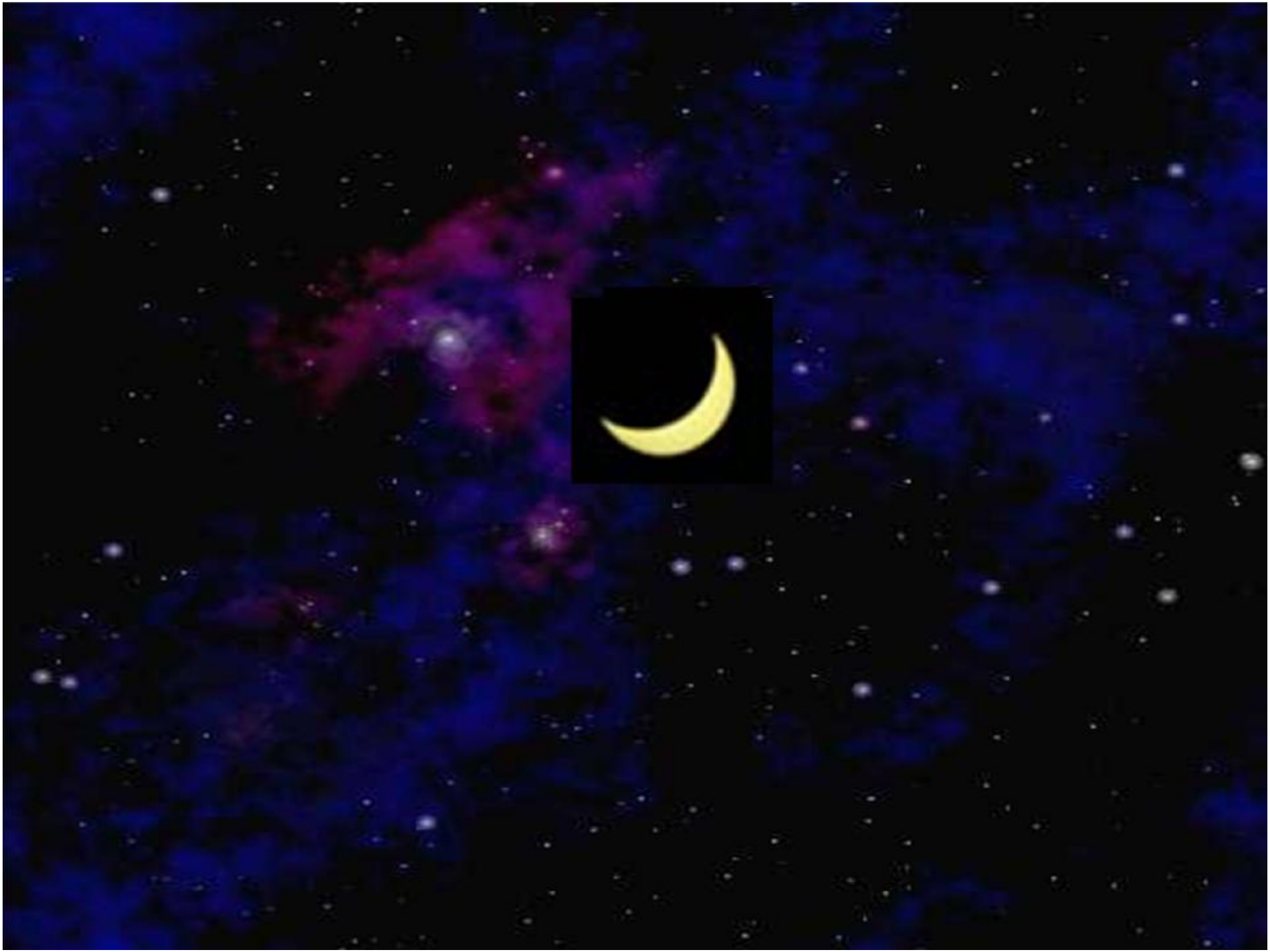


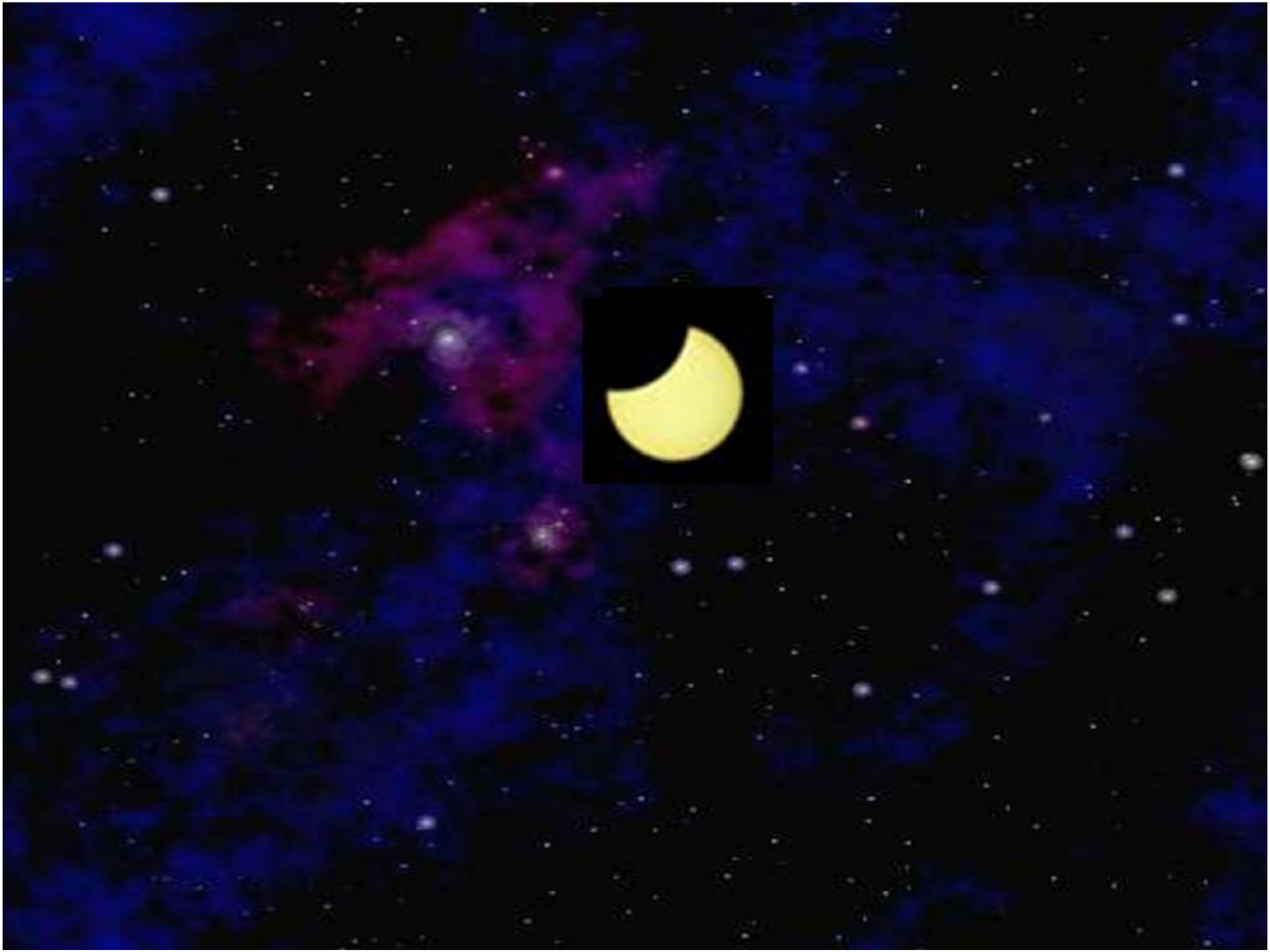


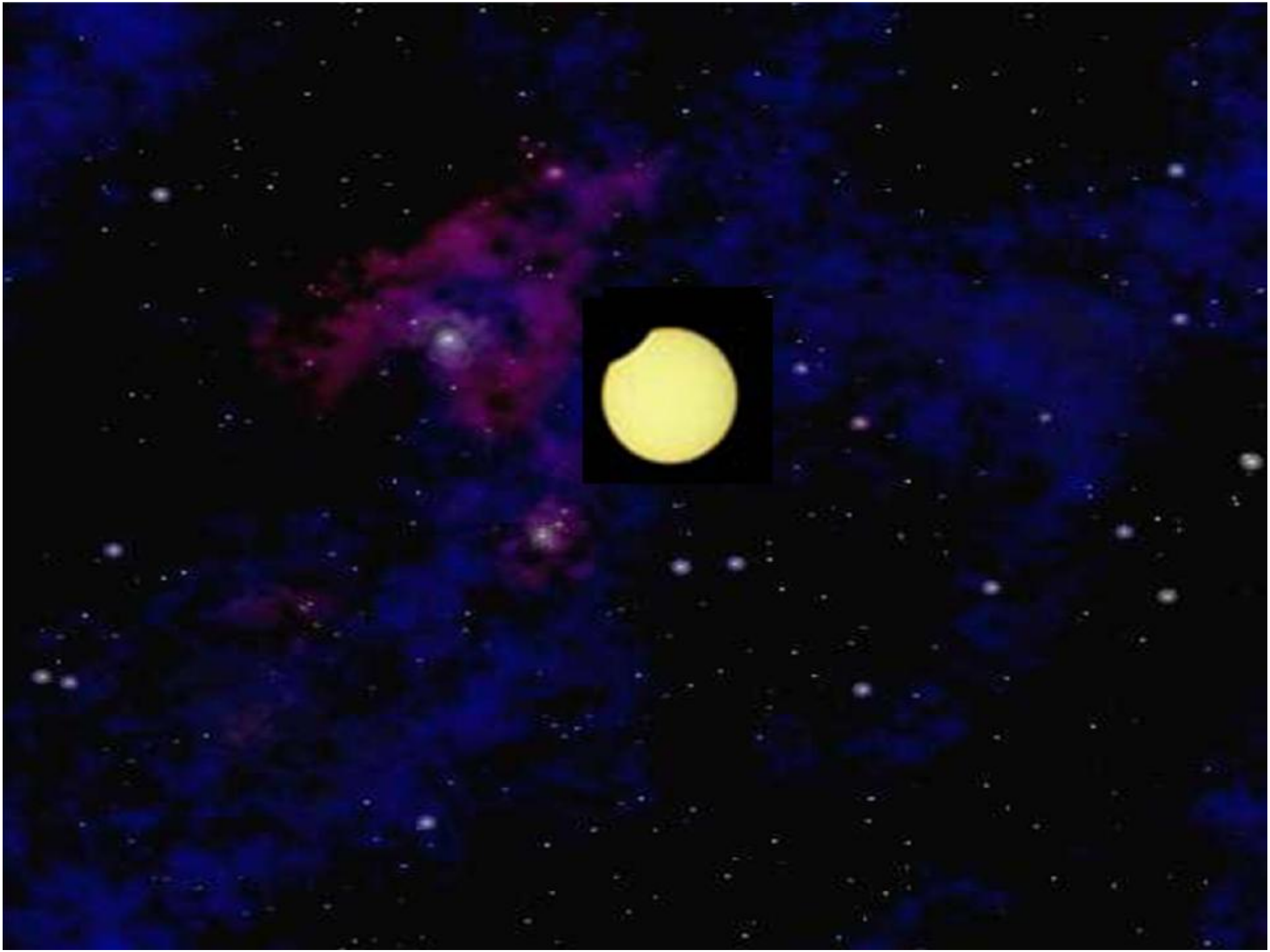






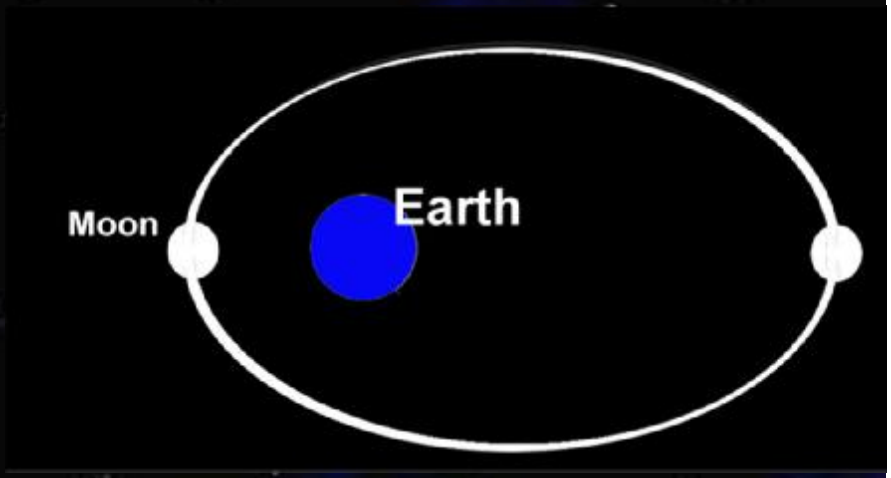






Annular Eclipses

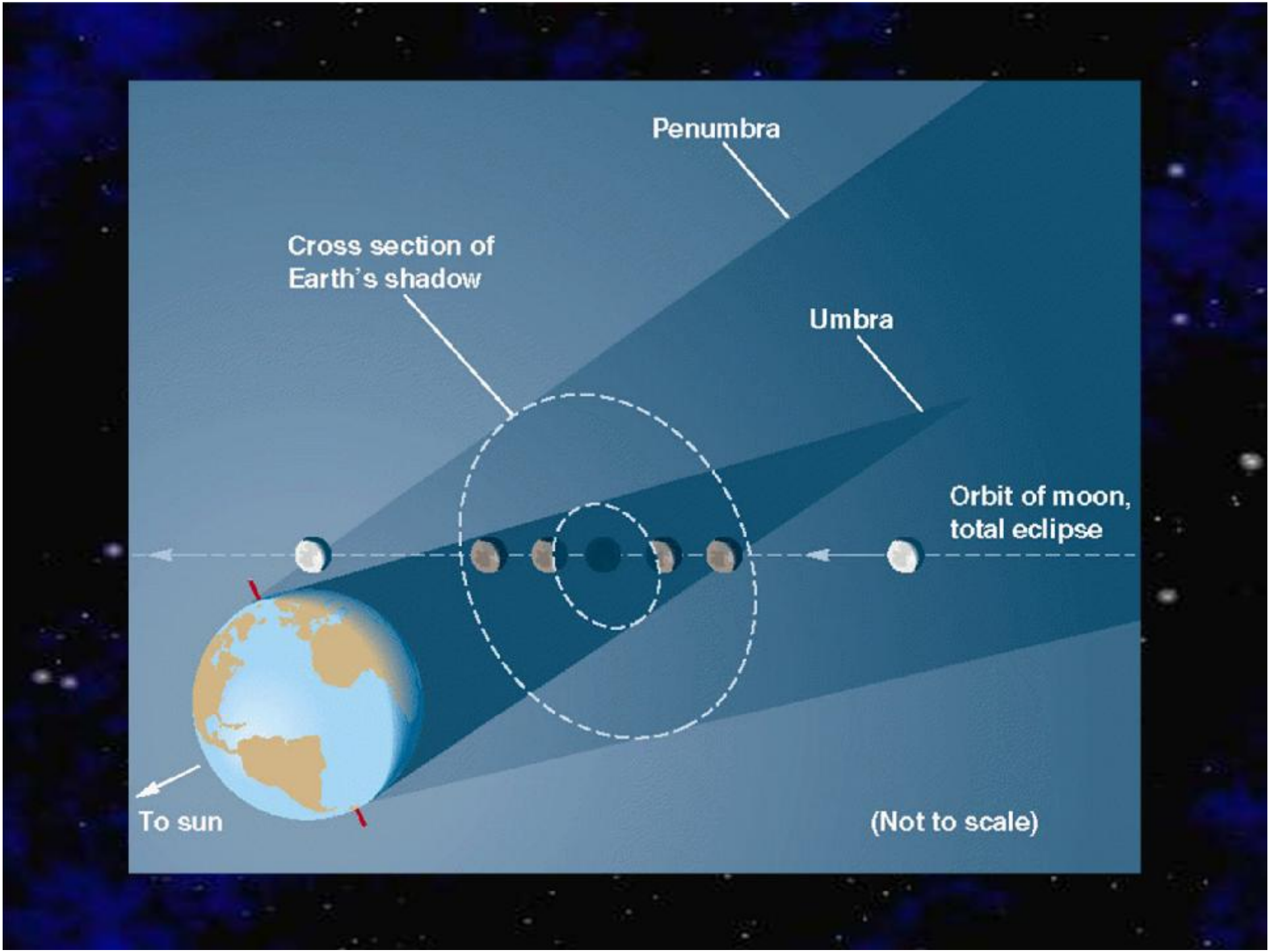
- The angular size of the Moon can appear smaller than the angular size of the Sun.
- The Moon's orbit is not a circle, but instead is an *ellipse.*

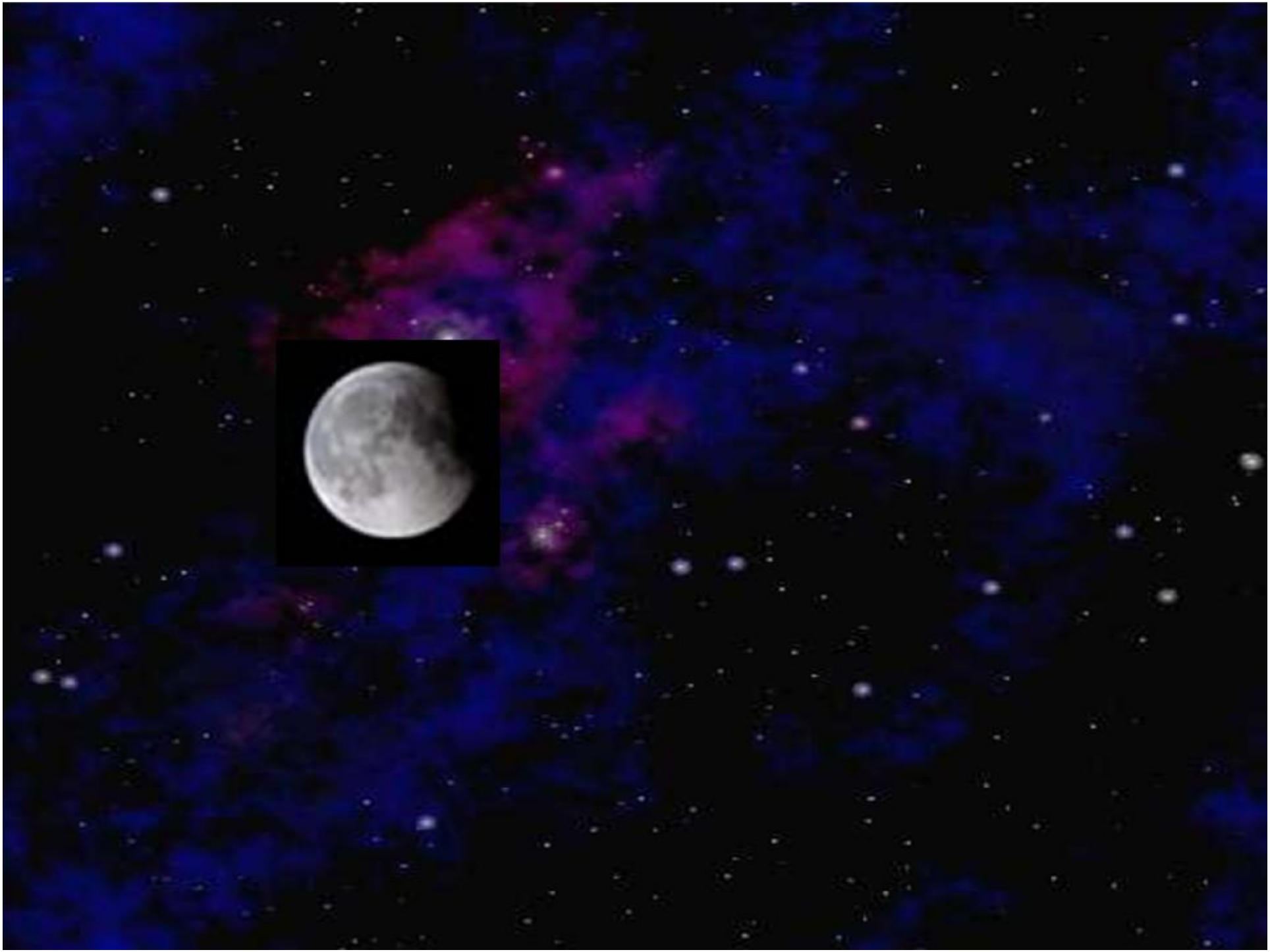


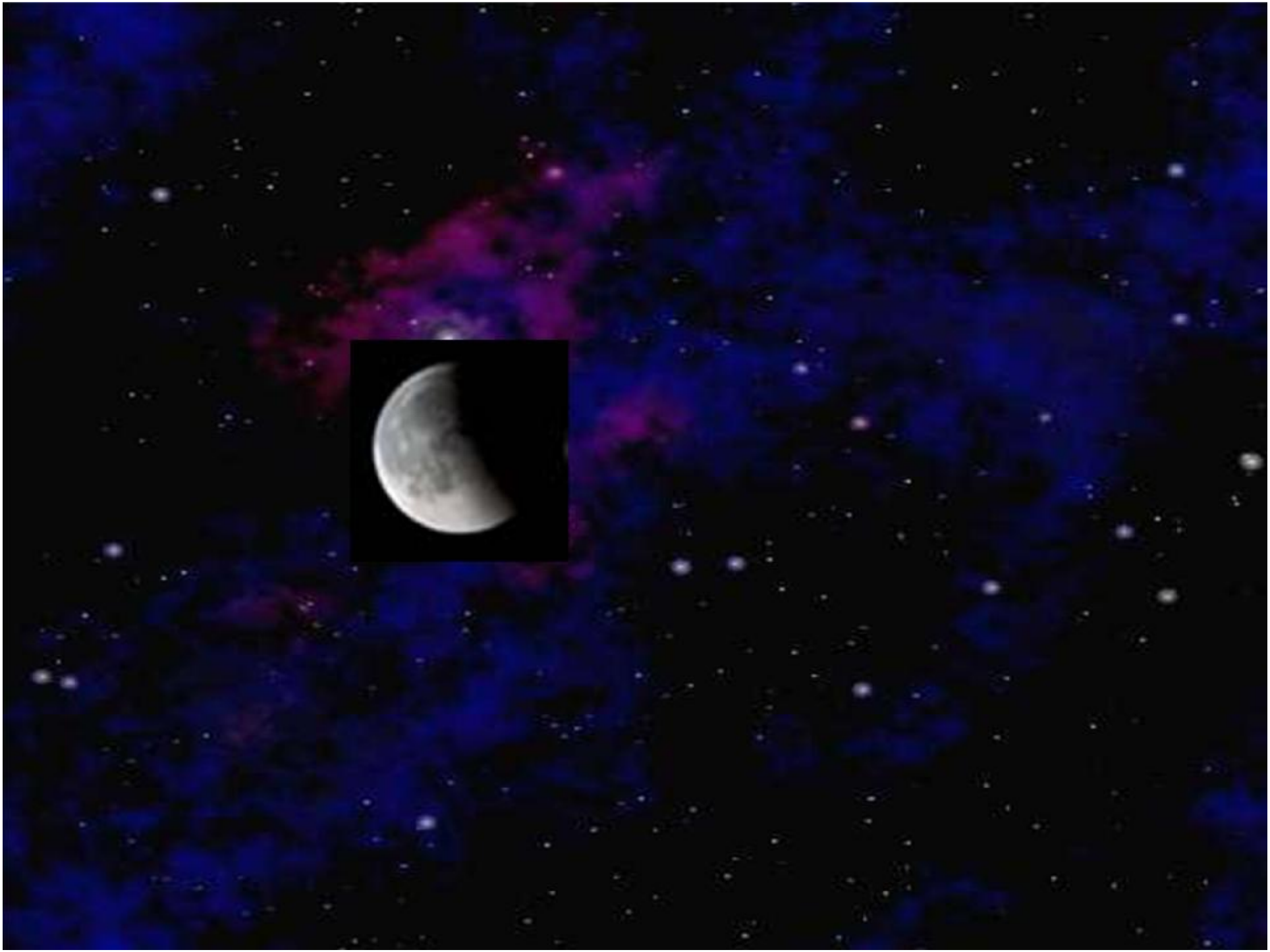
Lunar Eclipses

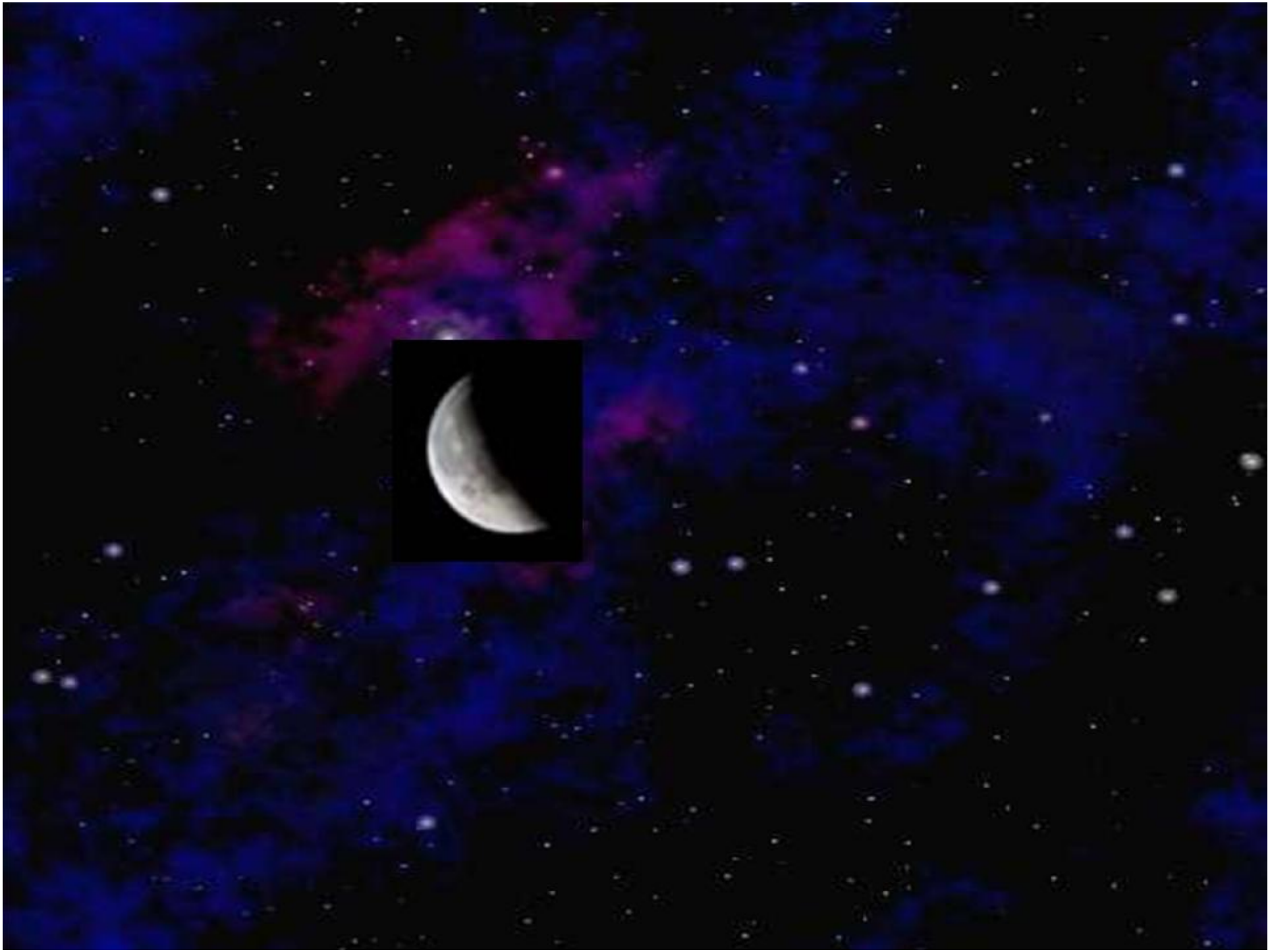
Occurs when the Moon passes through the shadow cast by the Earth.

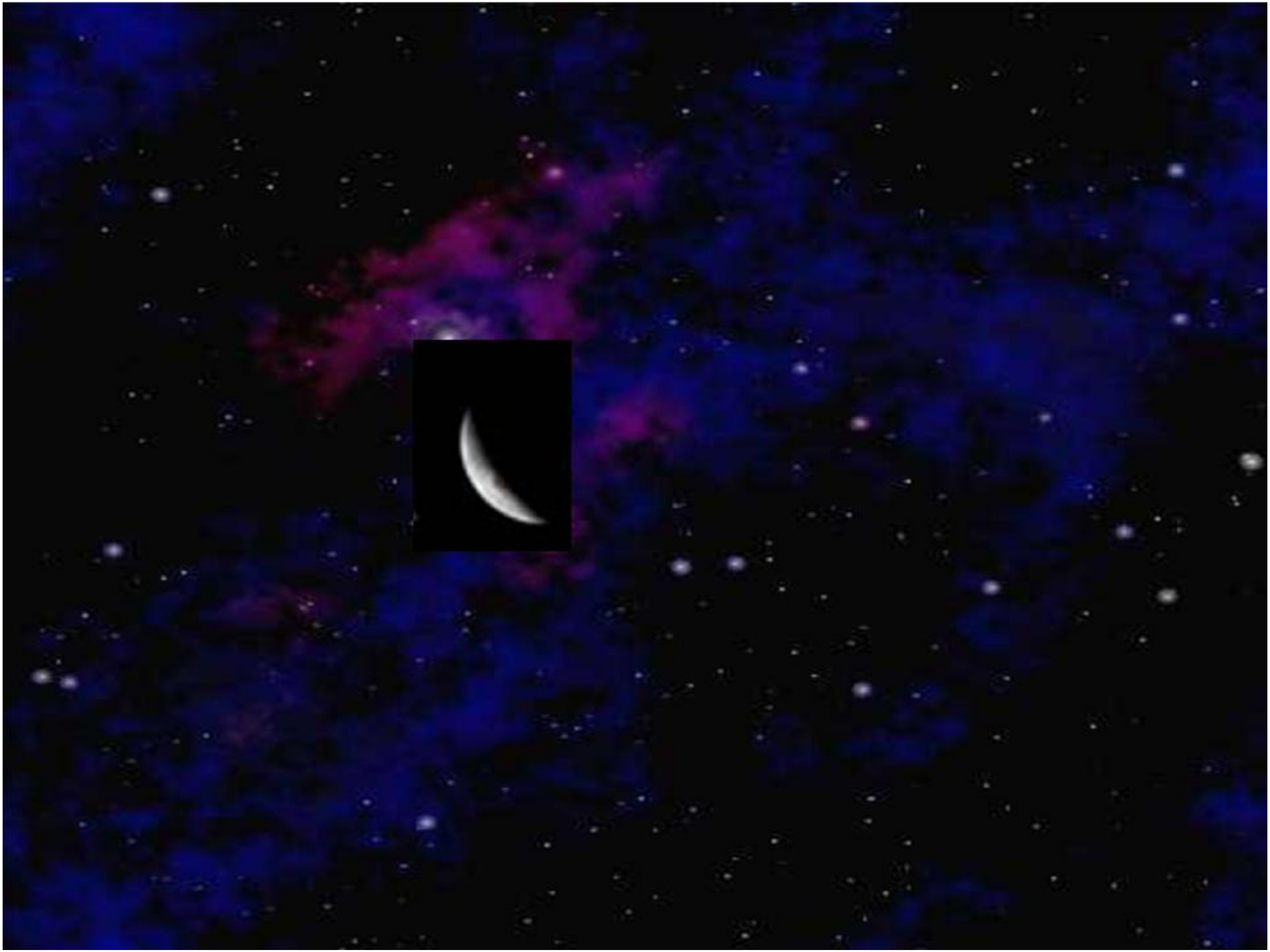
Can only occur at FULL MOON.

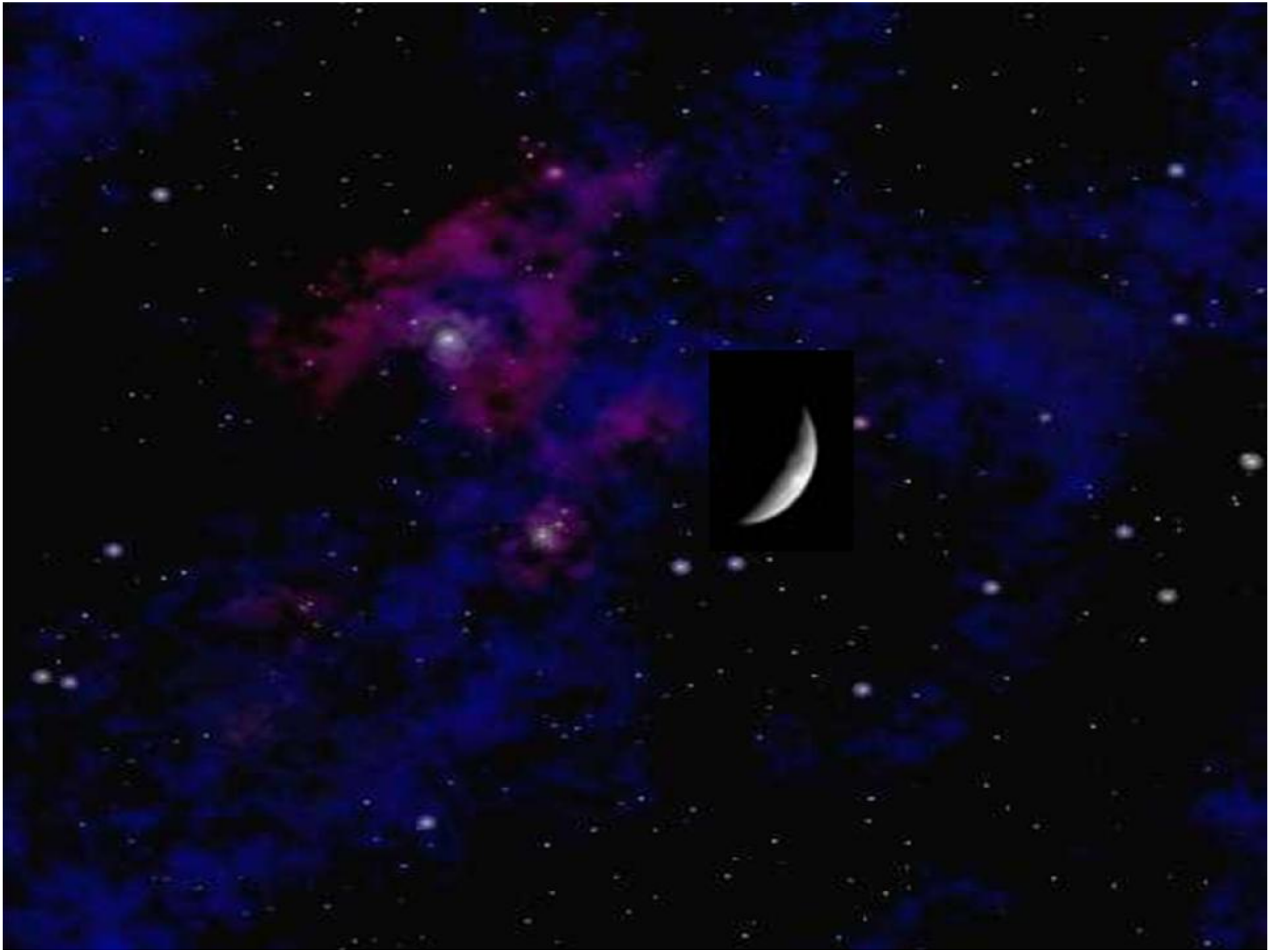

Penumbra
Cross section of
Earth's shadow
Umbra
Orbit of moon,
total eclipse
To sun
(Not to scale)

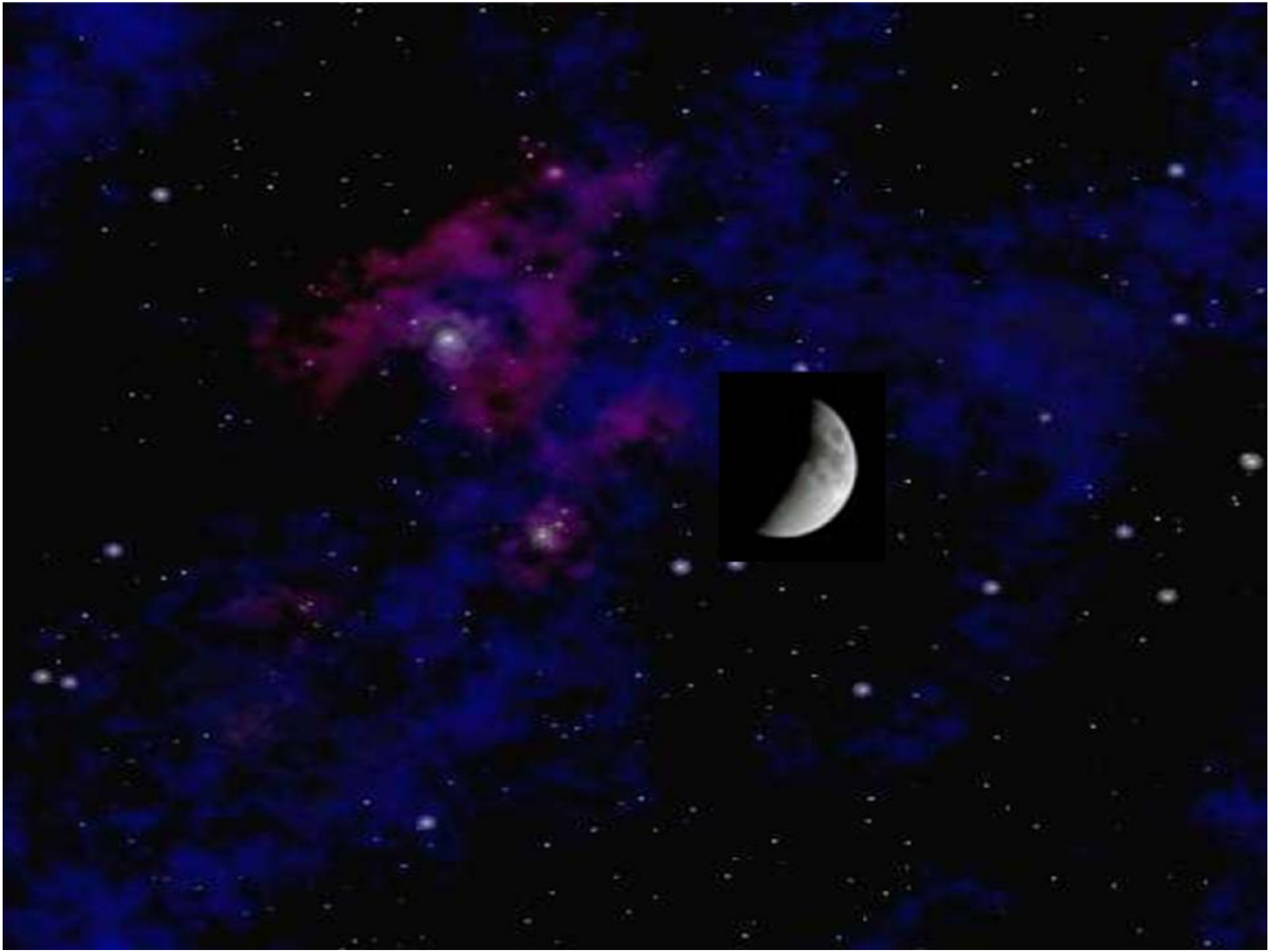


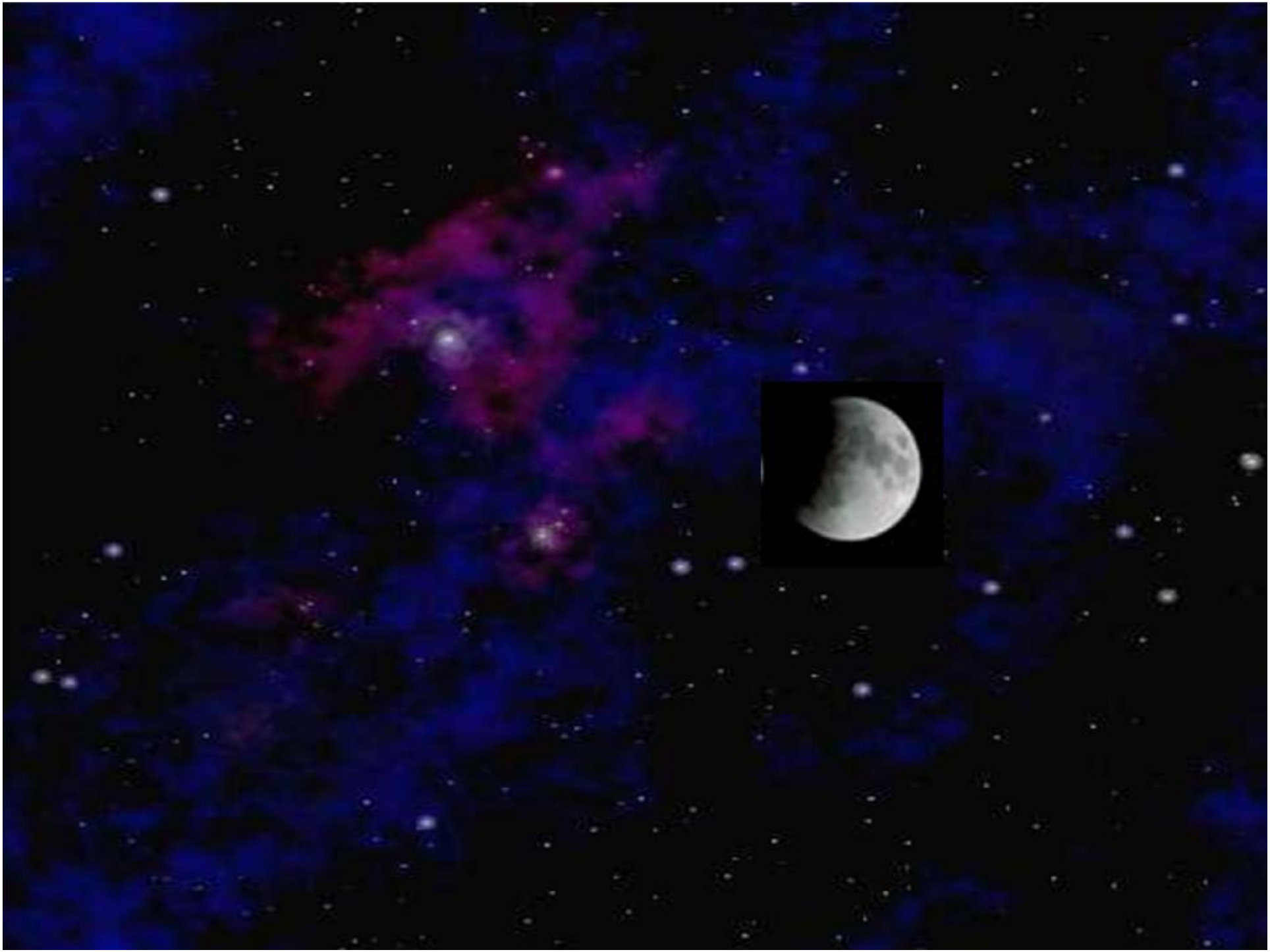


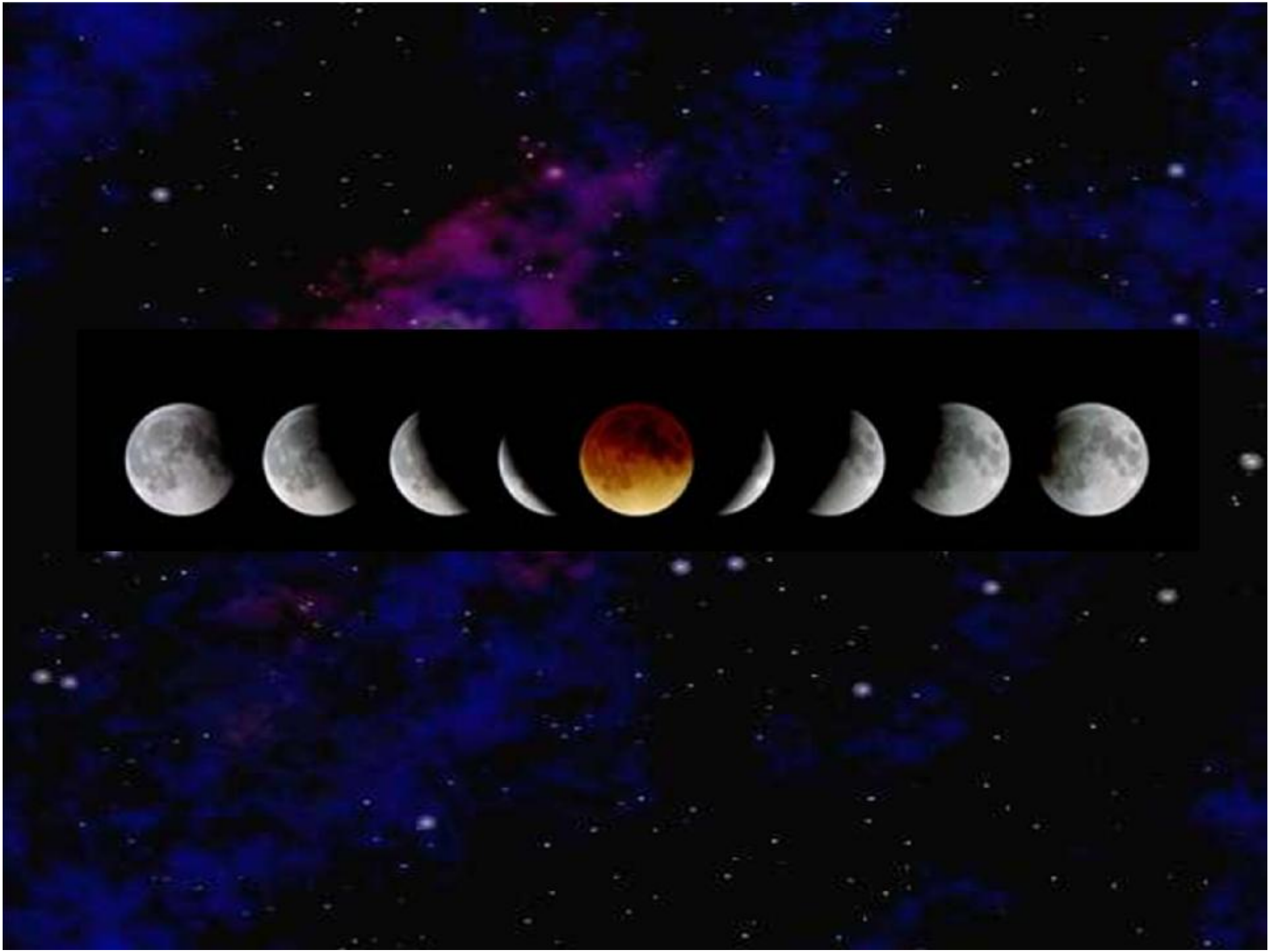












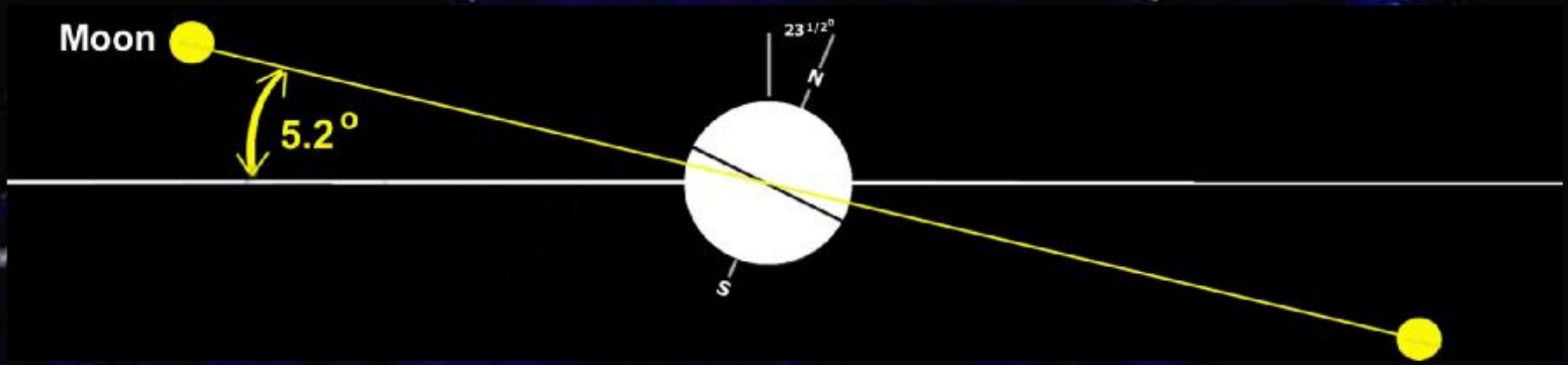
If a LUNAR ECLIPSE occurs during FULL MOON…

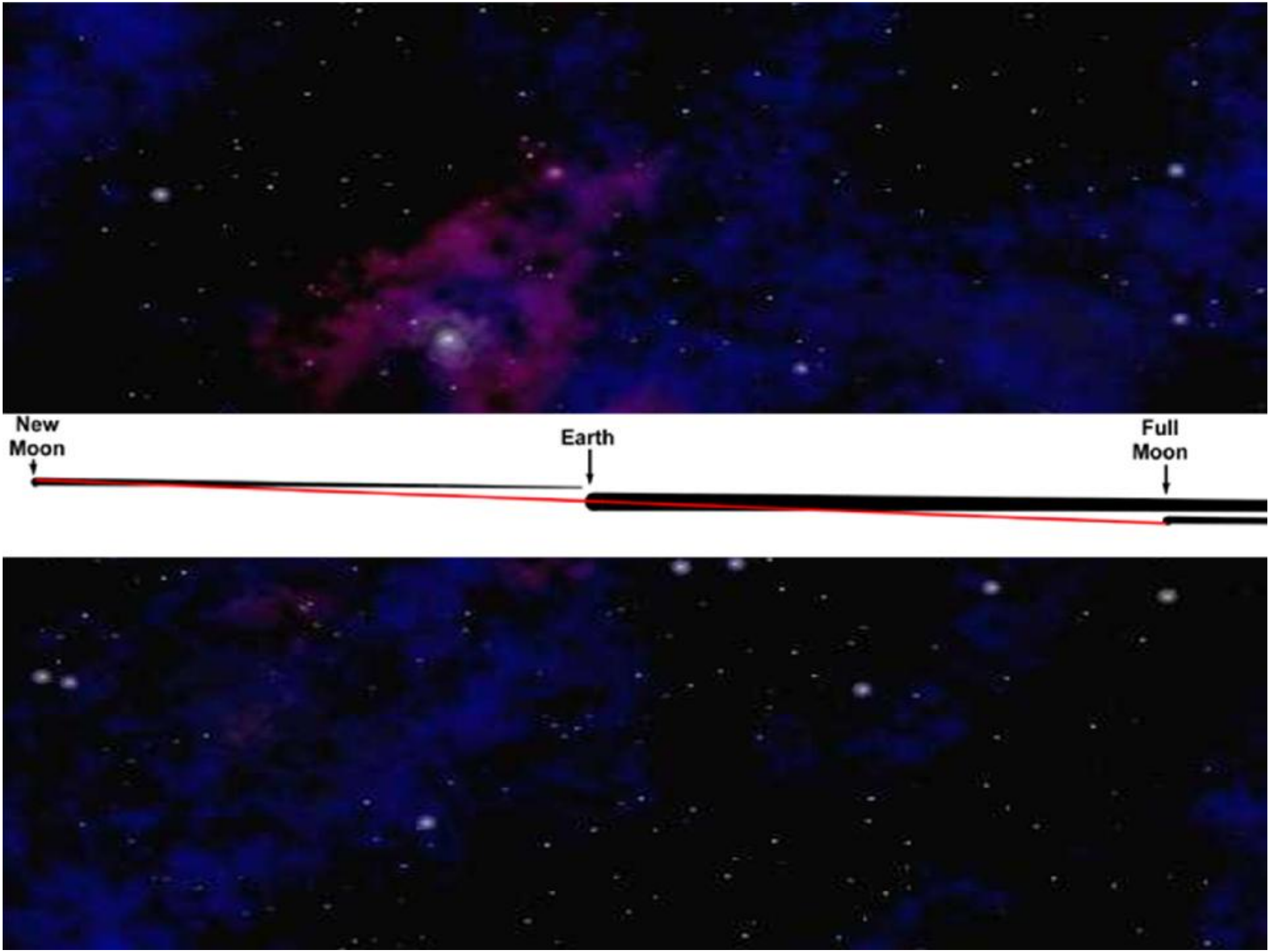
And a SOLAR ECLIPSE occurs during NEW MOON…

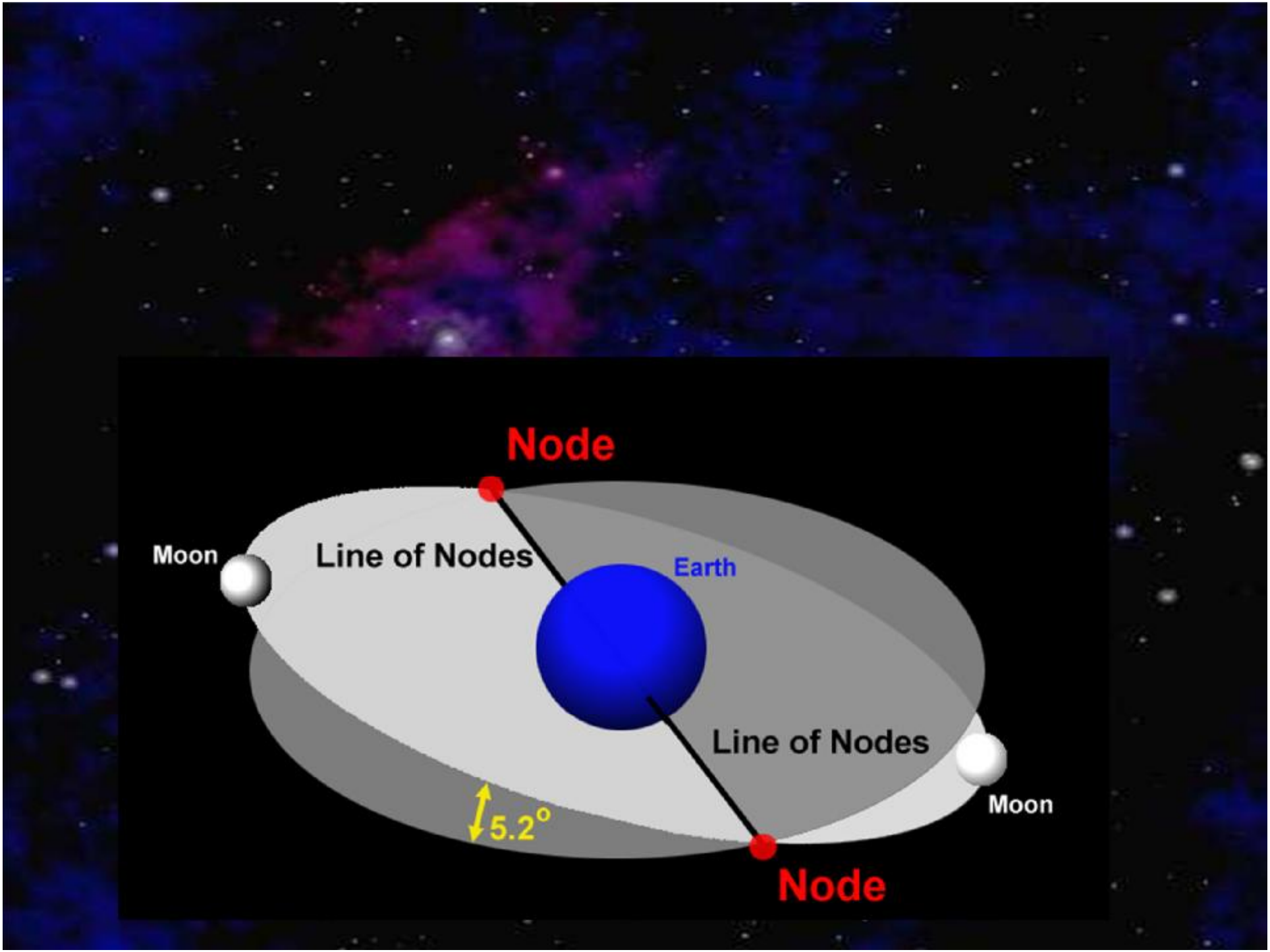
If there is a FULL MOON and a NEW MOON every month…

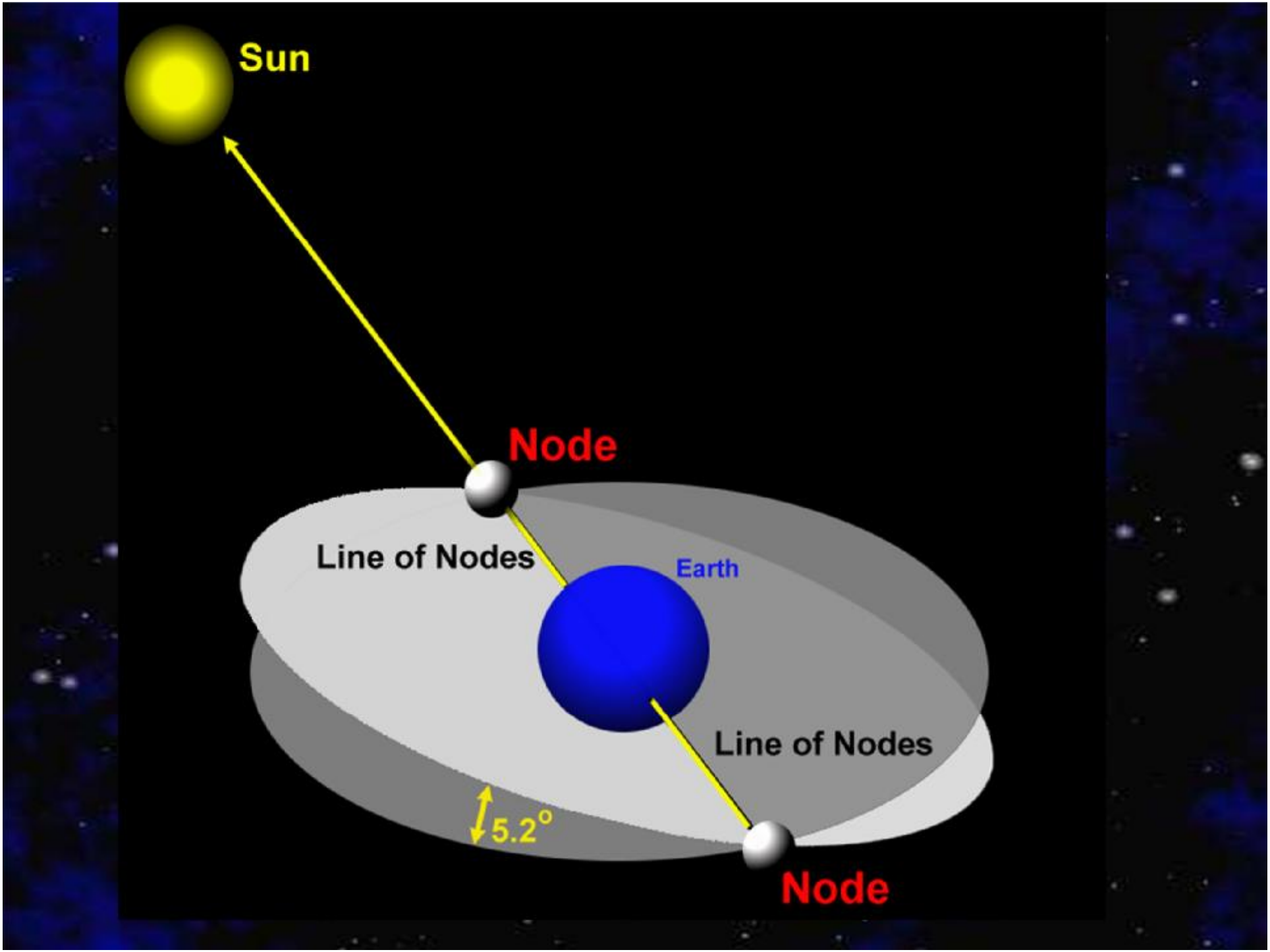
Then why don’t we experience eclipses every month??

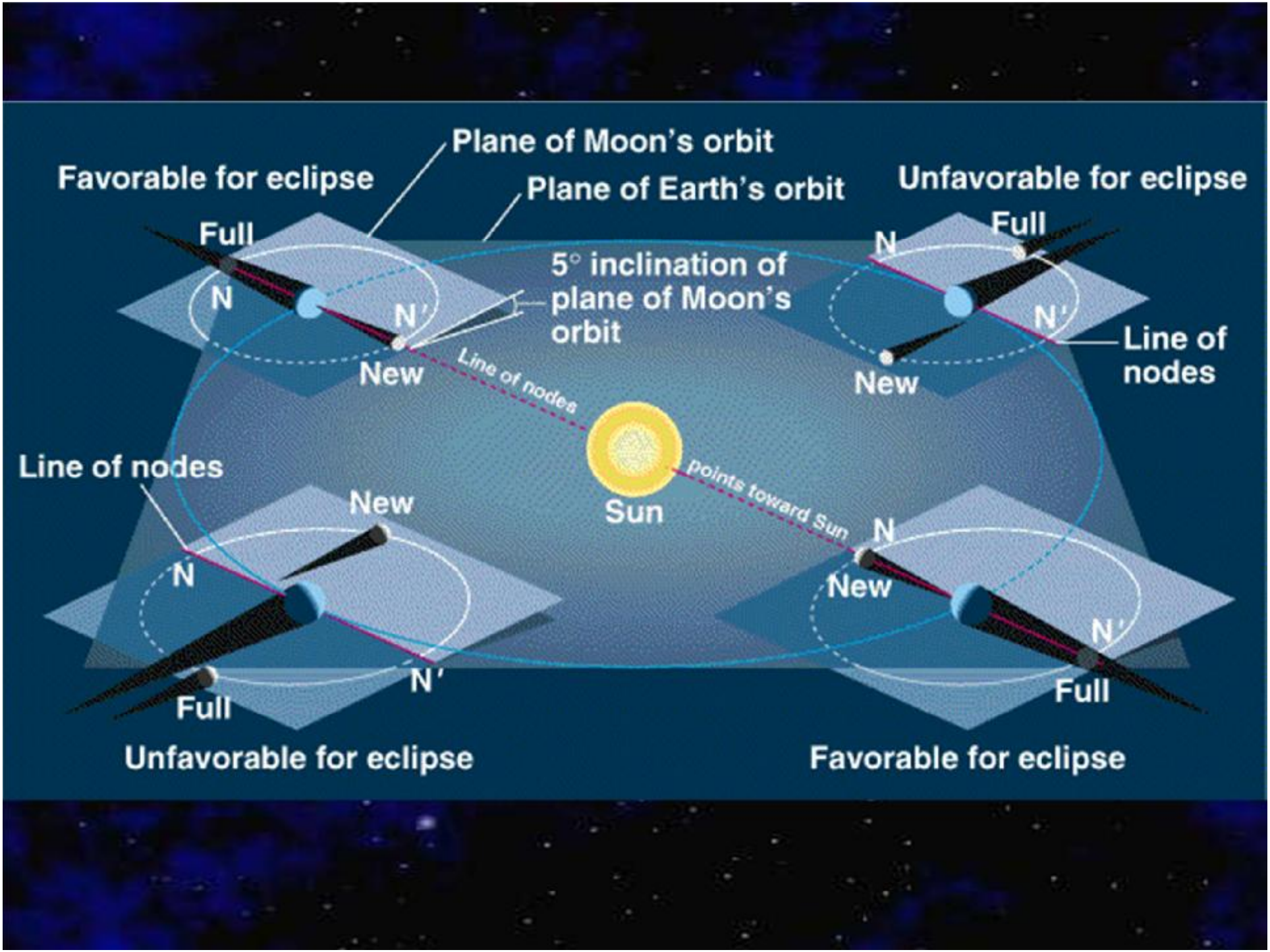
The Moon's orbit is inclined to the Earth's orbit by 5.2°




New
Moon
Earth
Full
Moon


Node
Moon
Line of Nodes
Earth
Line of Nodes
Moon
5.2°
Node


Sun
Node
Line of Nodes
Earth
Line of Nodes
5.2°
Node


Plane of Moon's orbit
Favorable for eclipse
Plane of Earth's orbit
Unfavorable for eclipse
Full
N
5° inclination of plane of Moon's orbit
N'
Full
N
N'
Line of nodes
New
Line of nodes
New
Line of nodes
points toward Sun
Sun
New
N
N
New
N'
Full
N'
Full
Unfavorable for eclipse
Favorable for eclipse

Eclipse Predictions

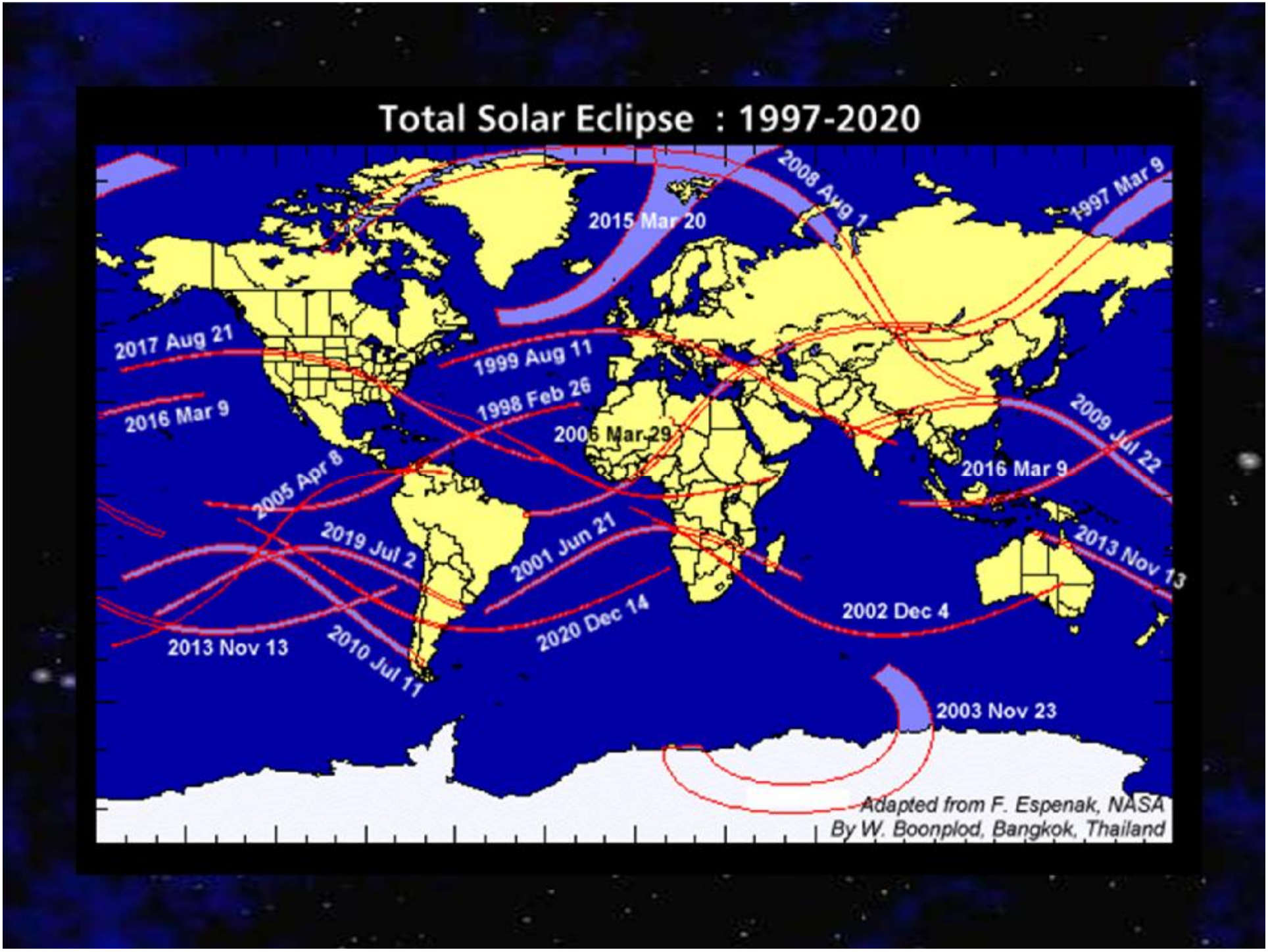
How do we know how long an eclipse will last?

How do we know *where* eclipses will occur?

Length of Totality

The shortest time totality can last is a brief moment.

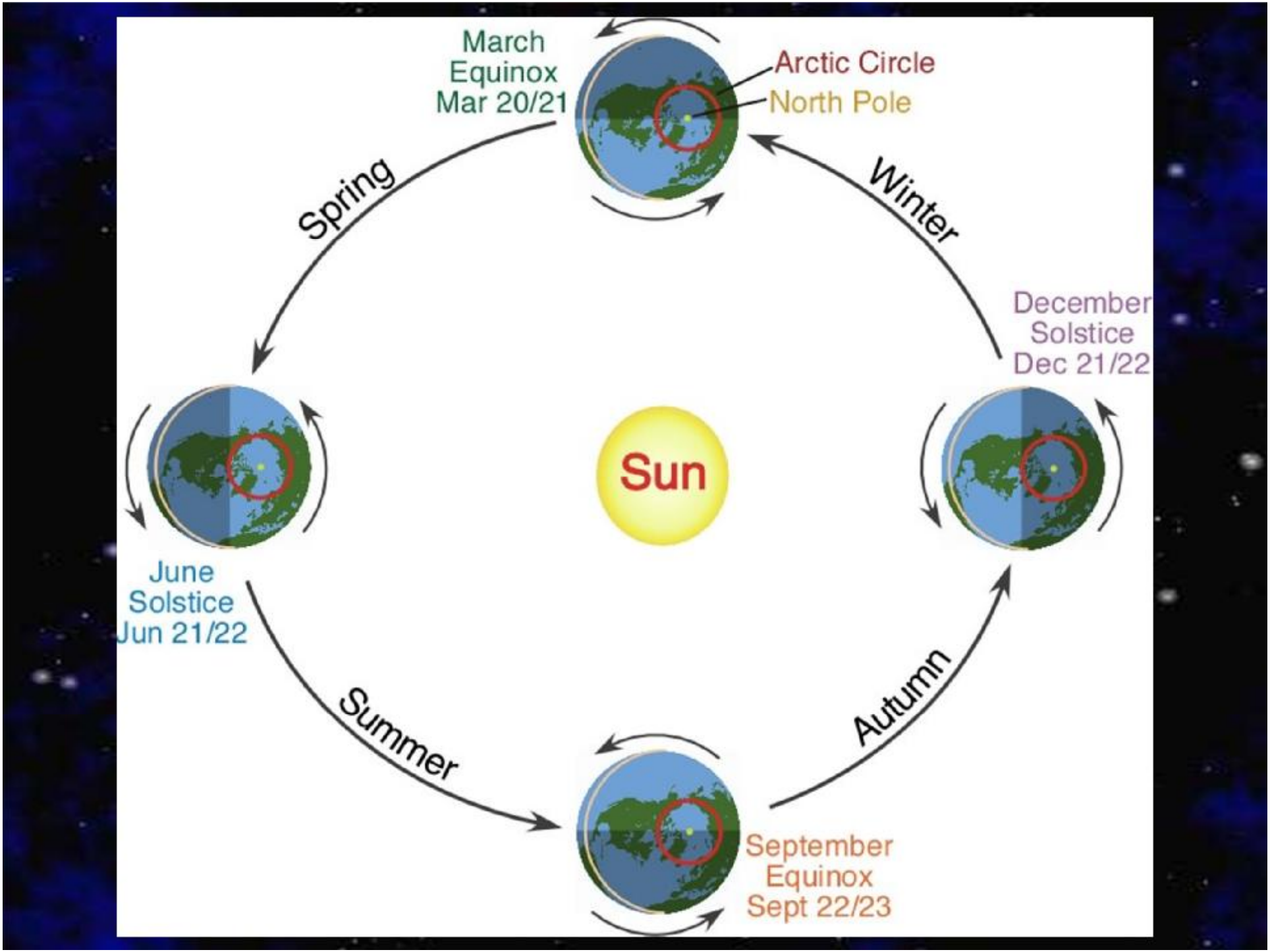
The longest time totality can last is 7½ minutes


Total Solar Eclipse : 1997-2020
2008 Aug 1
1997 Mar 9
2015 Mar 20
2017 Aug 21
1999 Aug 11
1998 Feb 26
2016 Mar 9
2006 Mar 29
2009 Jul 22
2005 Apr 8
2016 Mar 9
2019 Jul 2
2001 Jun 21
2013 Nov 13
2020 Dec 14
2002 Dec 4
2013 Nov 13
2010 Jul 11
2003 Nov 23
Adapted from F. Espenak, NASA
By W. Boonplod, Bangkok, Thailand

Eclipses generally come in twos:

July 11, 1991 LONG total solar eclipse

Jan 4, 1992 Annular solar eclipse


March
Equinox
Mar 20/21
Arctic Circle
North Pole
Spring
Winter
December
Solstice
Dec 21/22
Sun
June
Solstice
Jun 21/22
Summer
Autumn
September
Equinox
Sept 22/23