Sizing Up The Universe

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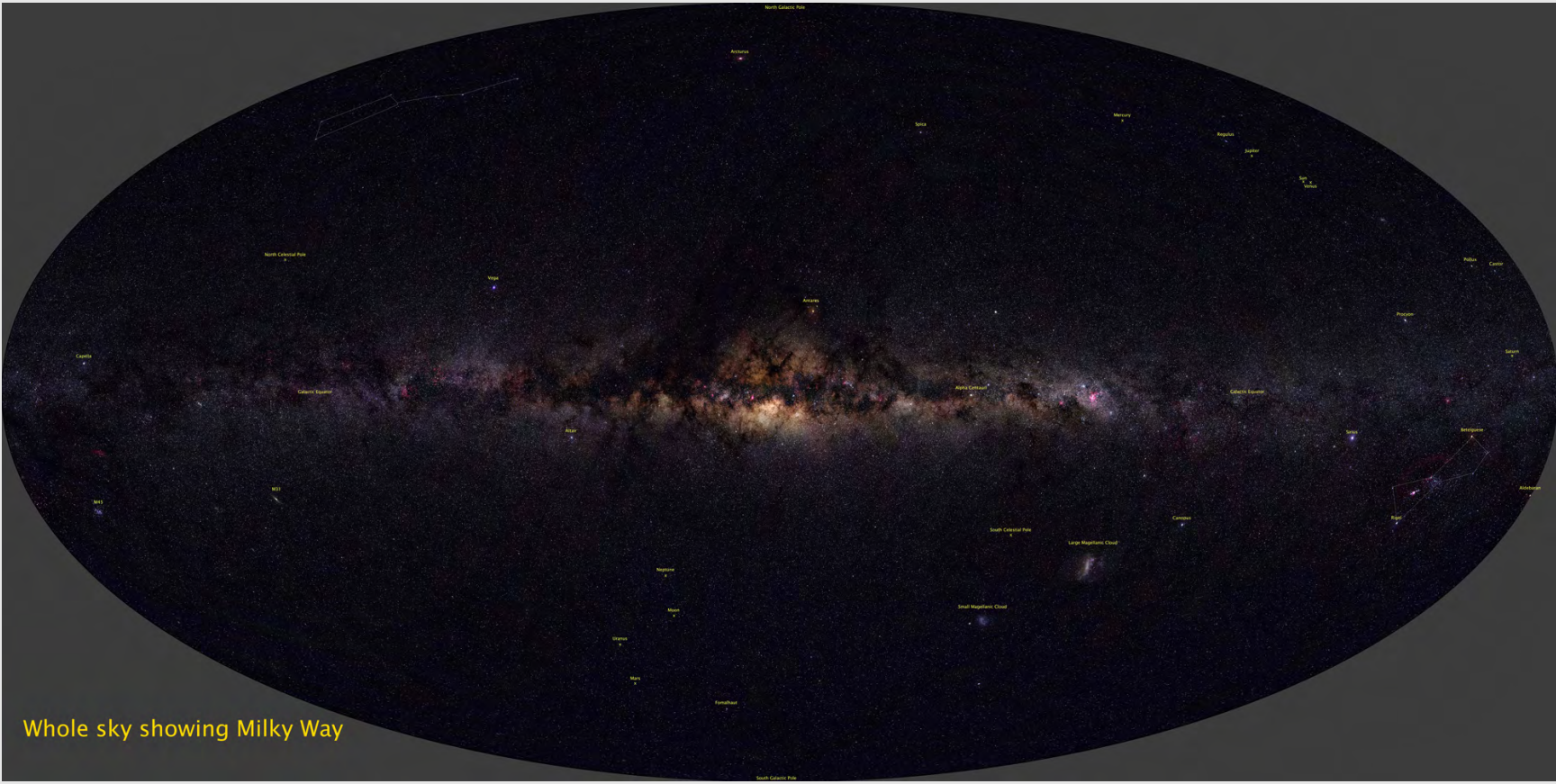
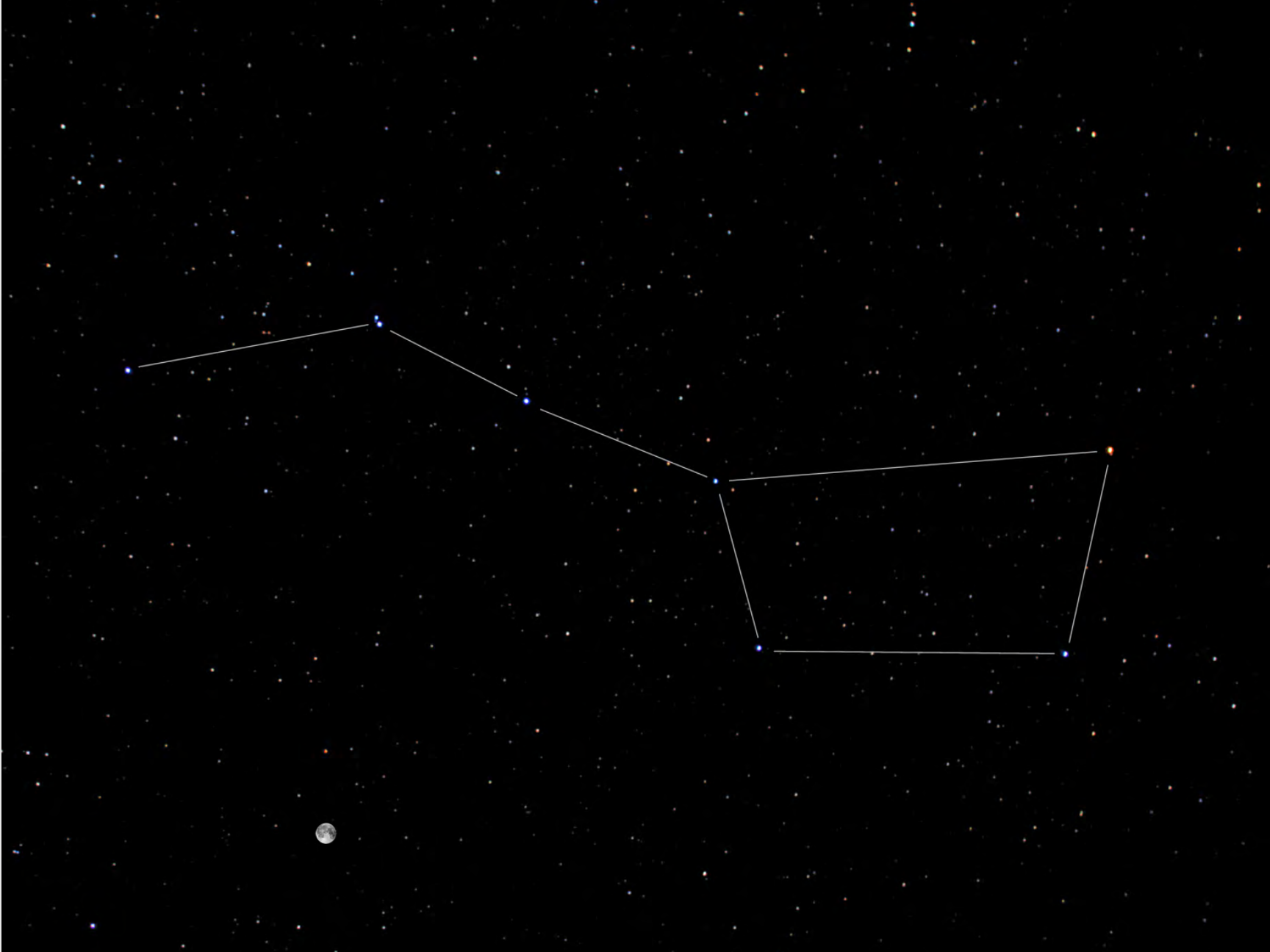
UACNJ at Jenny Jump

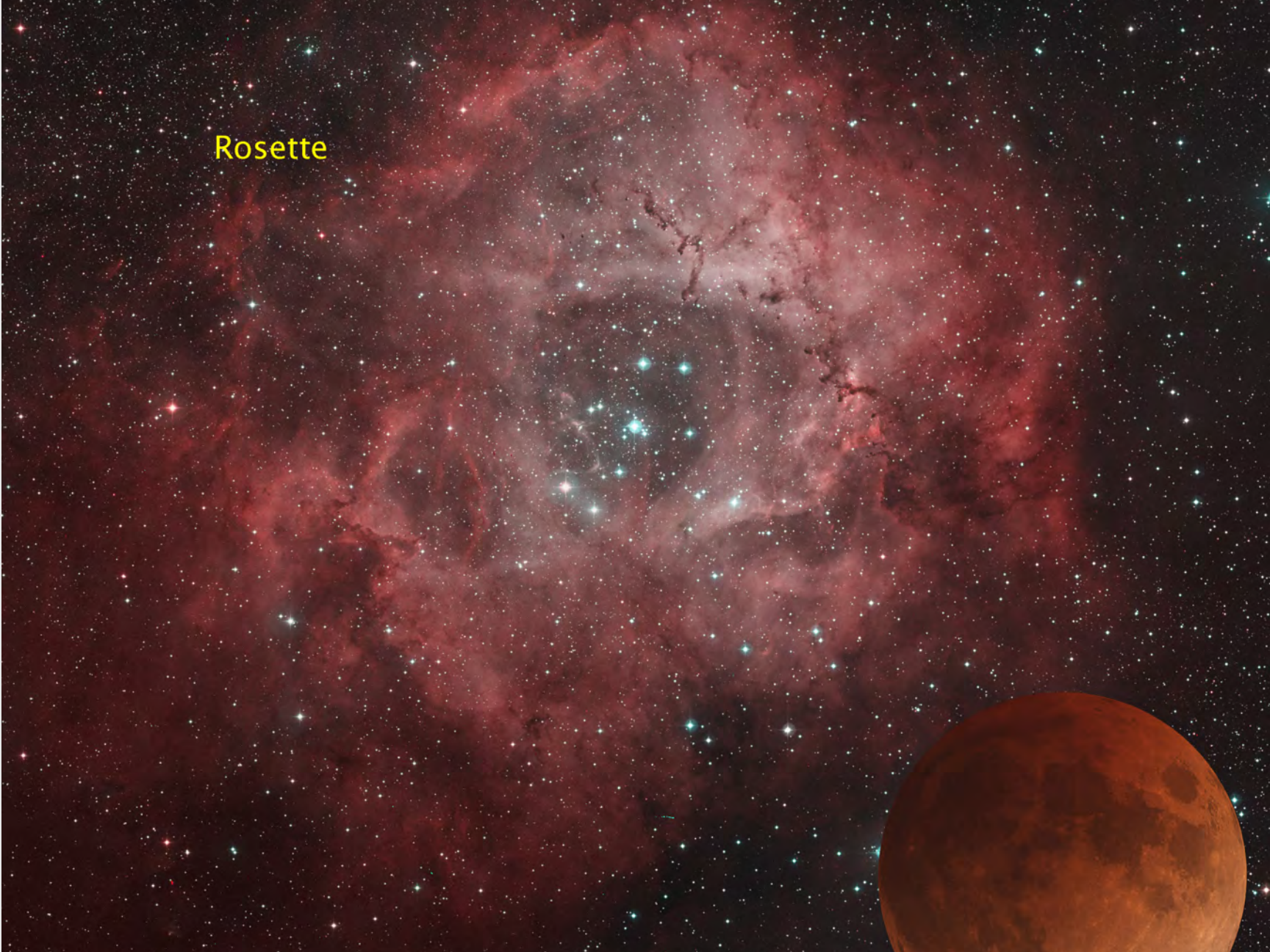
http://www.princeton.edu/∼rvdb

The Whole Sky

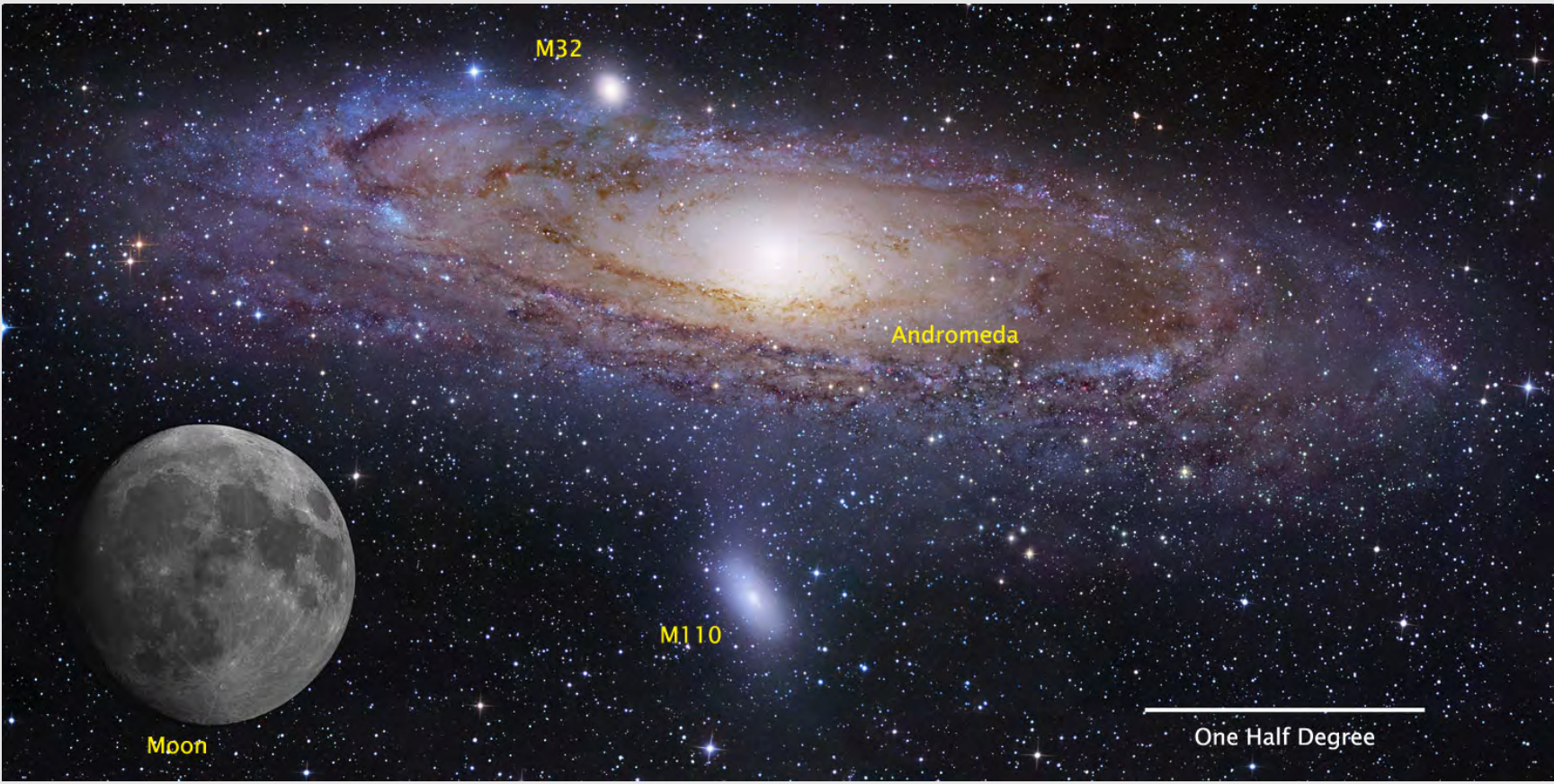


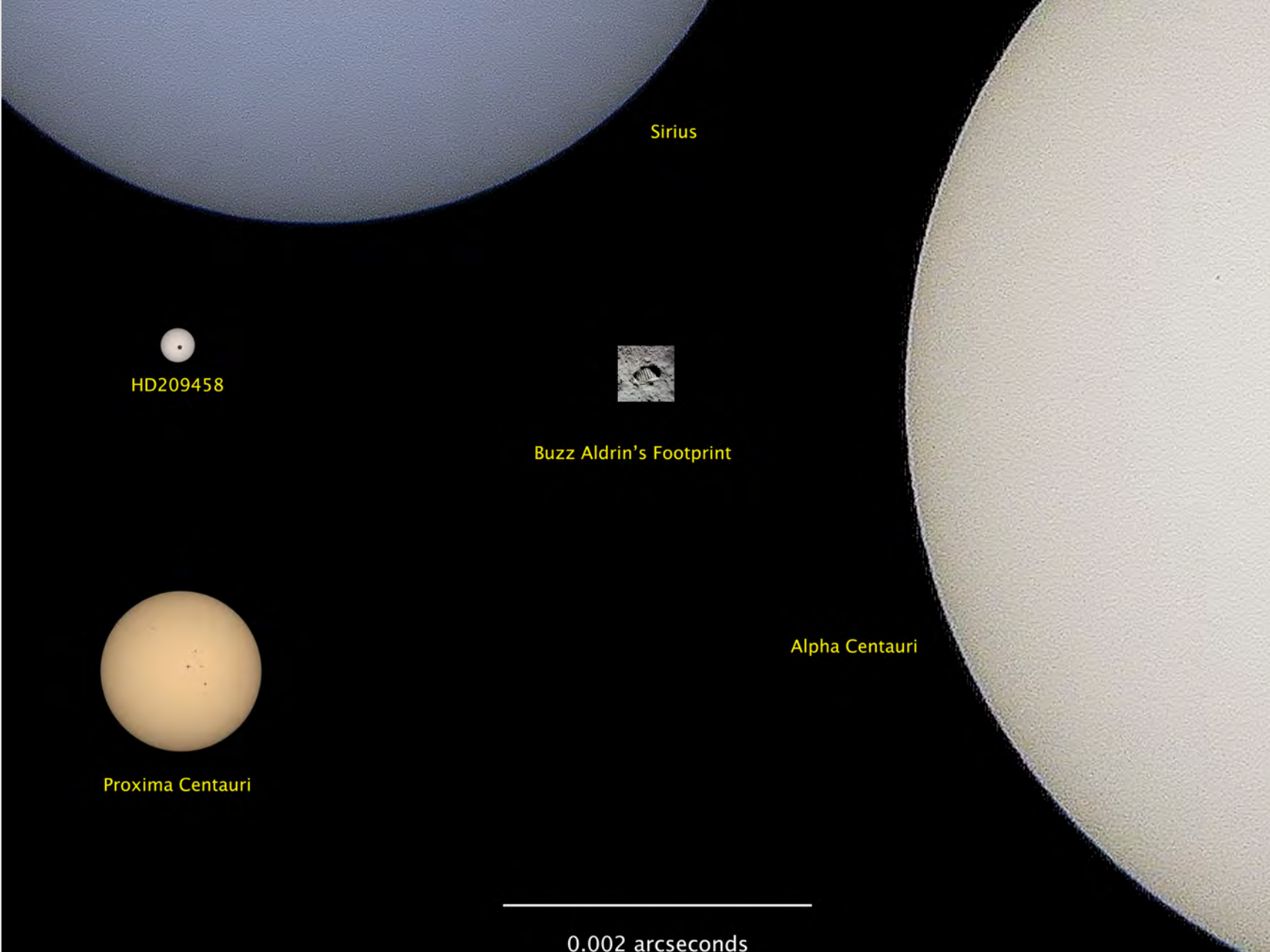
Whole sky showing Milky Way




Rosette

Andromeda and Moon




Sirius
HD209458
Buzz Aldrin's Footprint
Alpha Centauri
Proxima Centauri
0.002 arcseconds

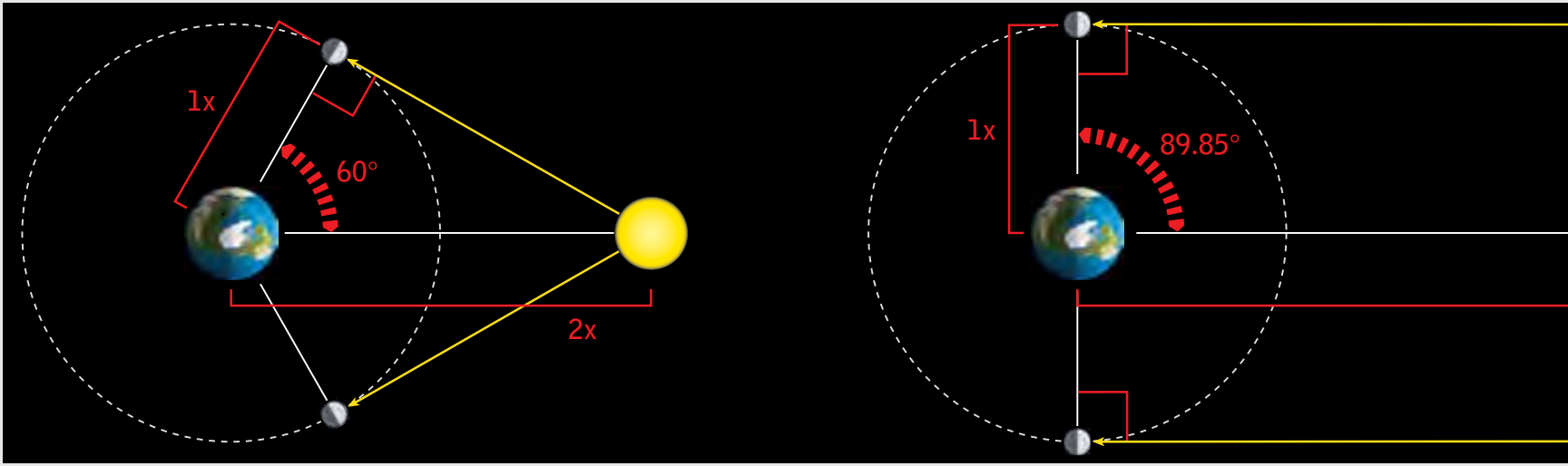

Ursa Minor
Cepheus
Camelopardalis
Draco
Cassiopeia
Ursa Major
Lacerta
Lynx
Perseus
Auriga
Lyra
Cygnus
Canes Venatici
Andromeda
Hercules
Bootes
Leo Minor
Triangulum
Vulpecula
Corona Borealis
Coma Berenices
Gemini
Cancer
Aries
Pegasus
Sagitta
Leo
Taurus
Pisces
Delphinus
Serpens Caput
Equuleus
Canis Minor
Aquila
Orion
Ophiuchus
Virgo
Sextans
Monoceros
Cetus
Scutum
Aquarius
Serpens Cauda
Hydra
Crater
Libra
Corvus
Capricornus
Lepus
Eridanus
Canis Major
Piscis Australis
Sagittarius
Antlia
Pyxis
Puppis
Fornax
Sculptor
Scorpius
Columba
Caelum
Microscopium
Corona Australis
Lupus
Grus
Centaurus
Vela
Indus
Telescopium
Ara
Norma
Pictor
Horologium
Phoenix
Crux
Tucana
Carina
Reticulum
Dorado
Pavo
Triangulum Australe
Circinus
Musca
Volans
Hydrus
Apus
Mensa
Octans
Chamaeleon

Measuring Distances...

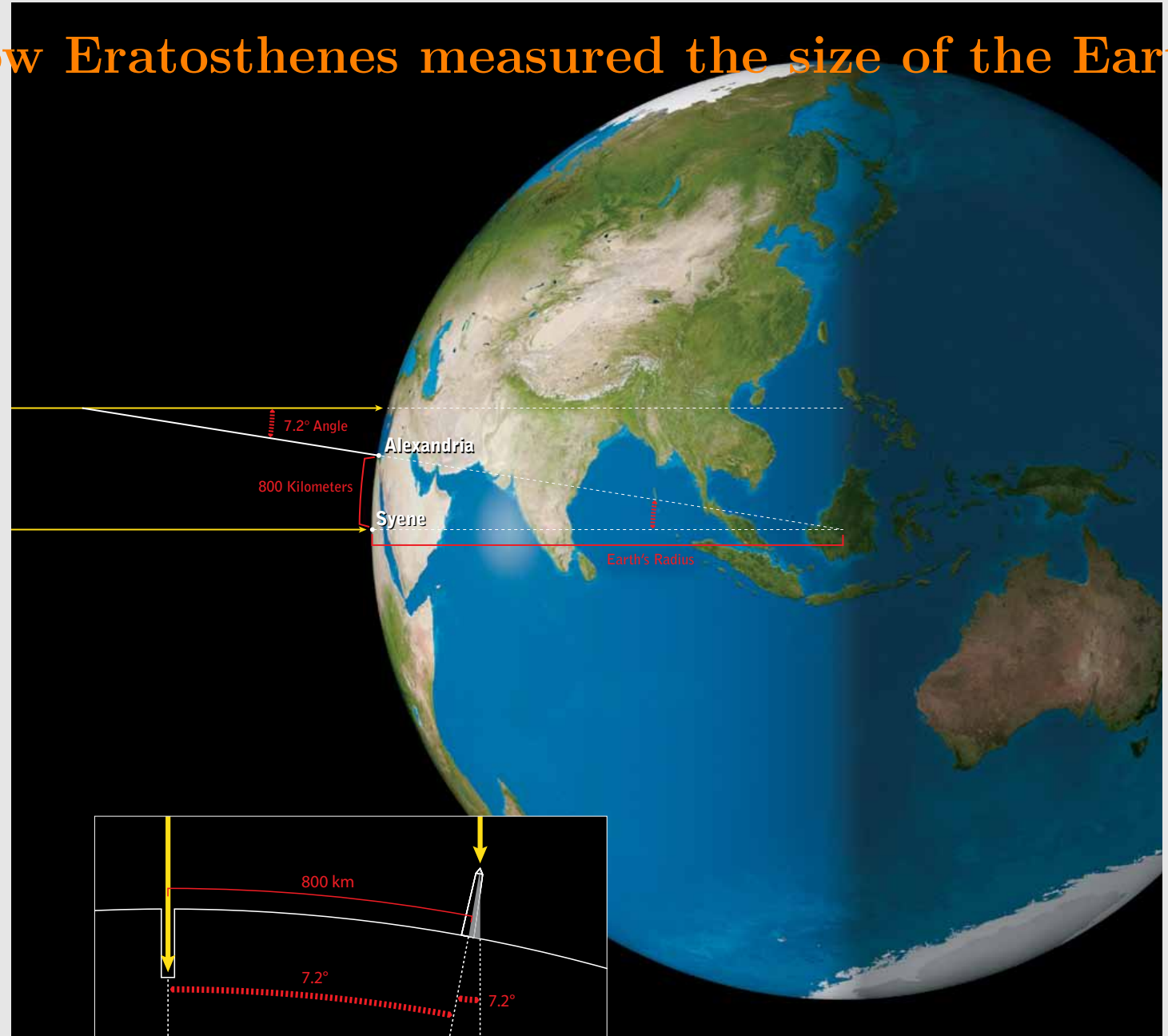
Cleverness Required

The Sun is farther away than the Moon...

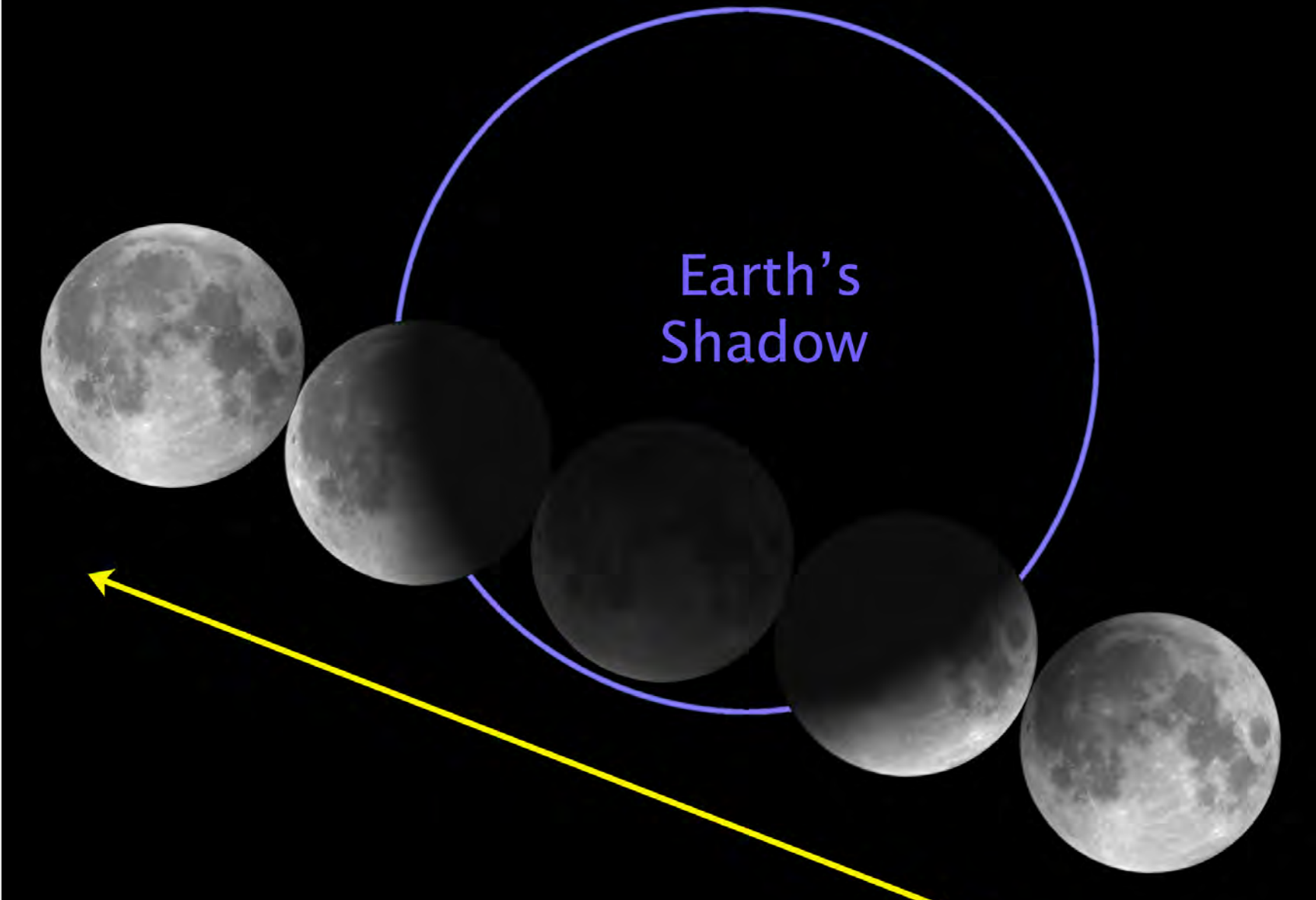
... 400 times farther away



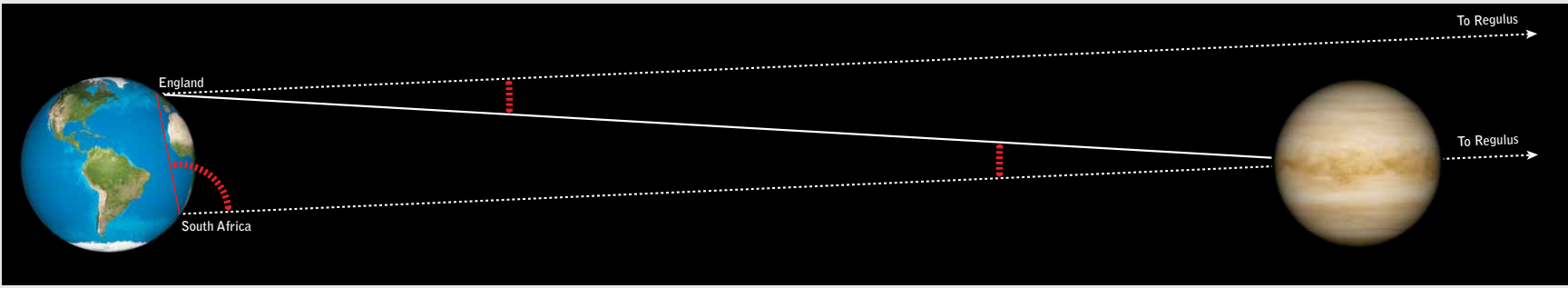
How Eratosthenes measured the size of the Earth



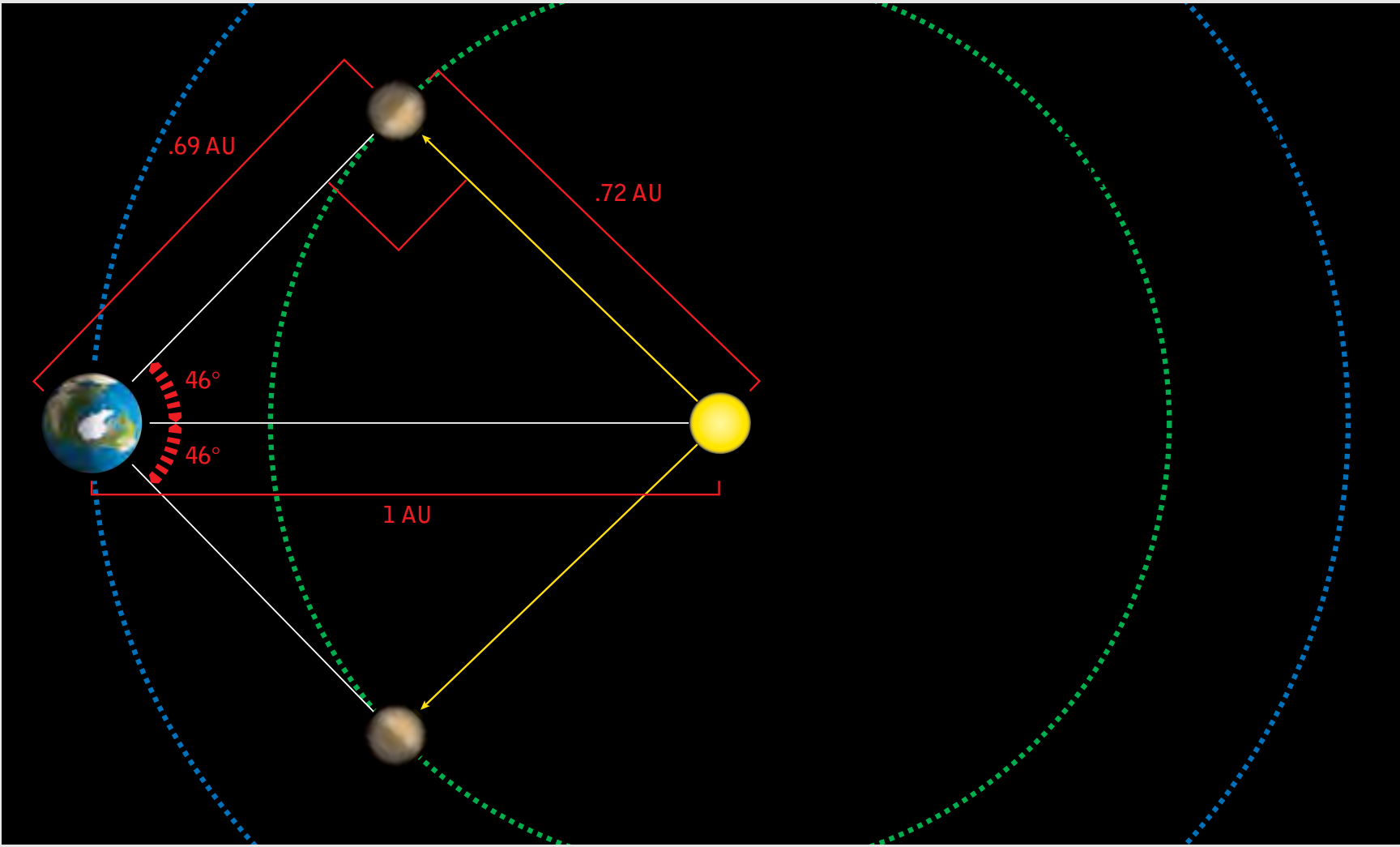
How Aristarchus measured the size of the Moon



Measuring the distance to Venus

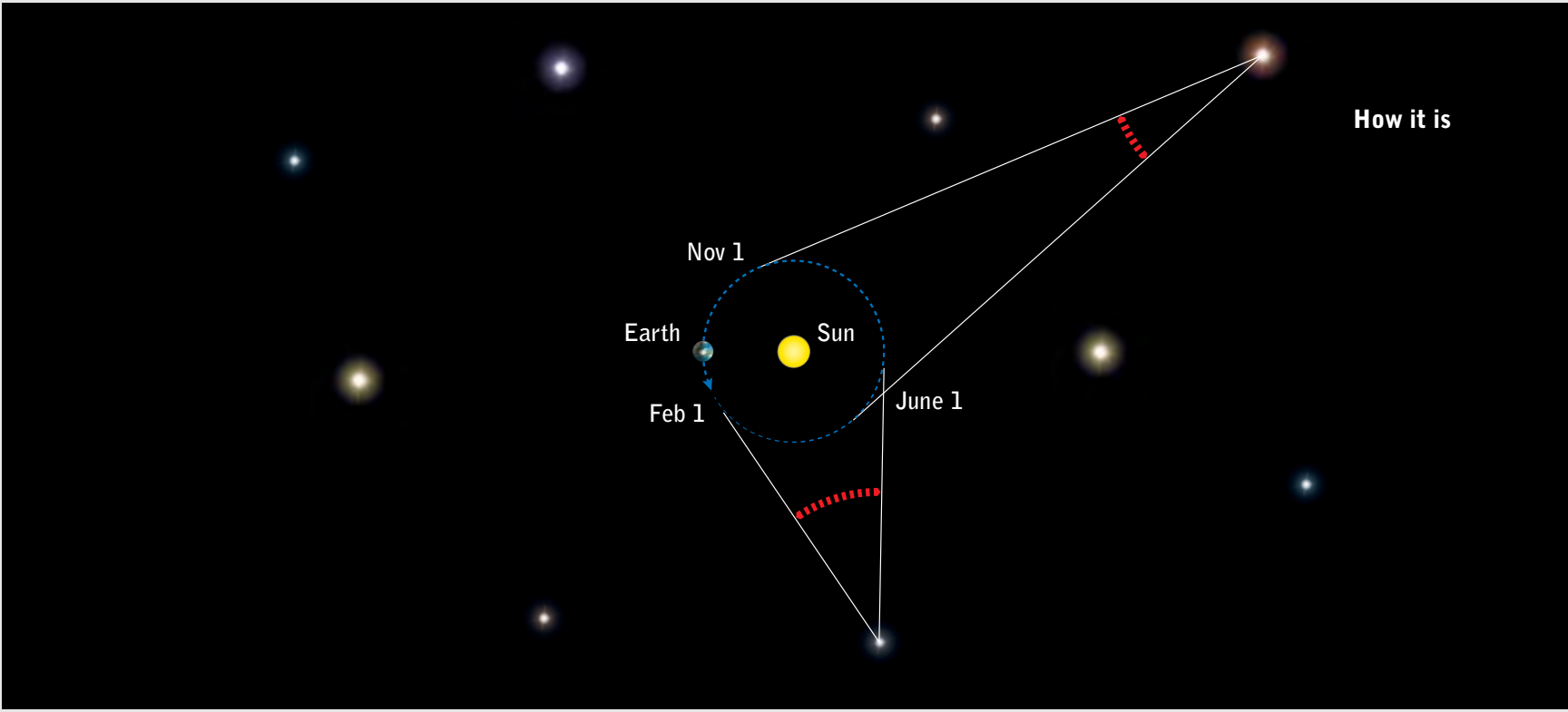


Measuring the distance to the Sun




Venus Transit

Parallax: Distance to the Stars

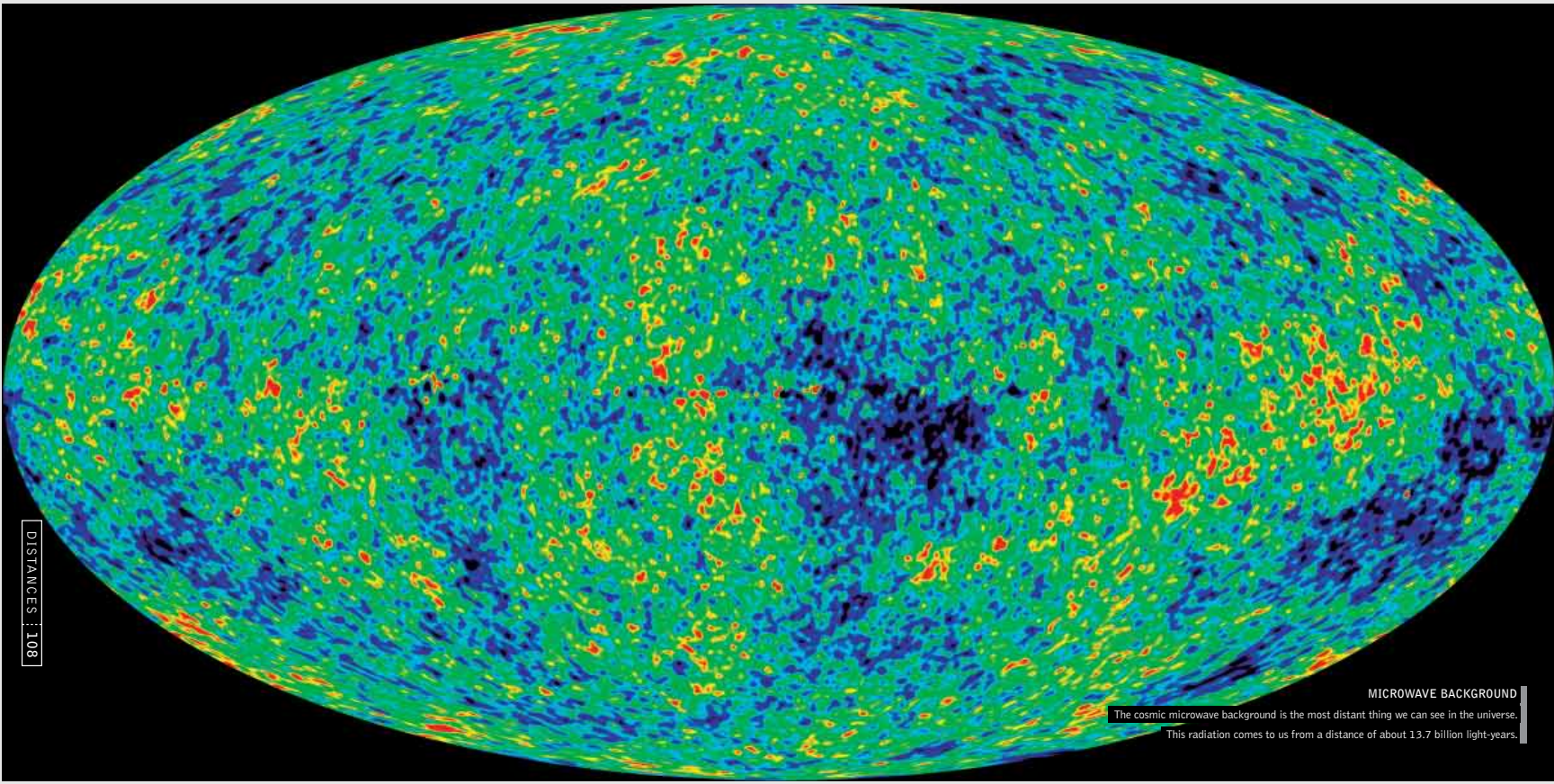


Cepheid Variable Stars: Distance to Andromeda

Supernovae: Distance to Remote Galaxies

Looking Out is Looking Back

13.7 Billion Years Ago



MICROWAVE BACKGROUND

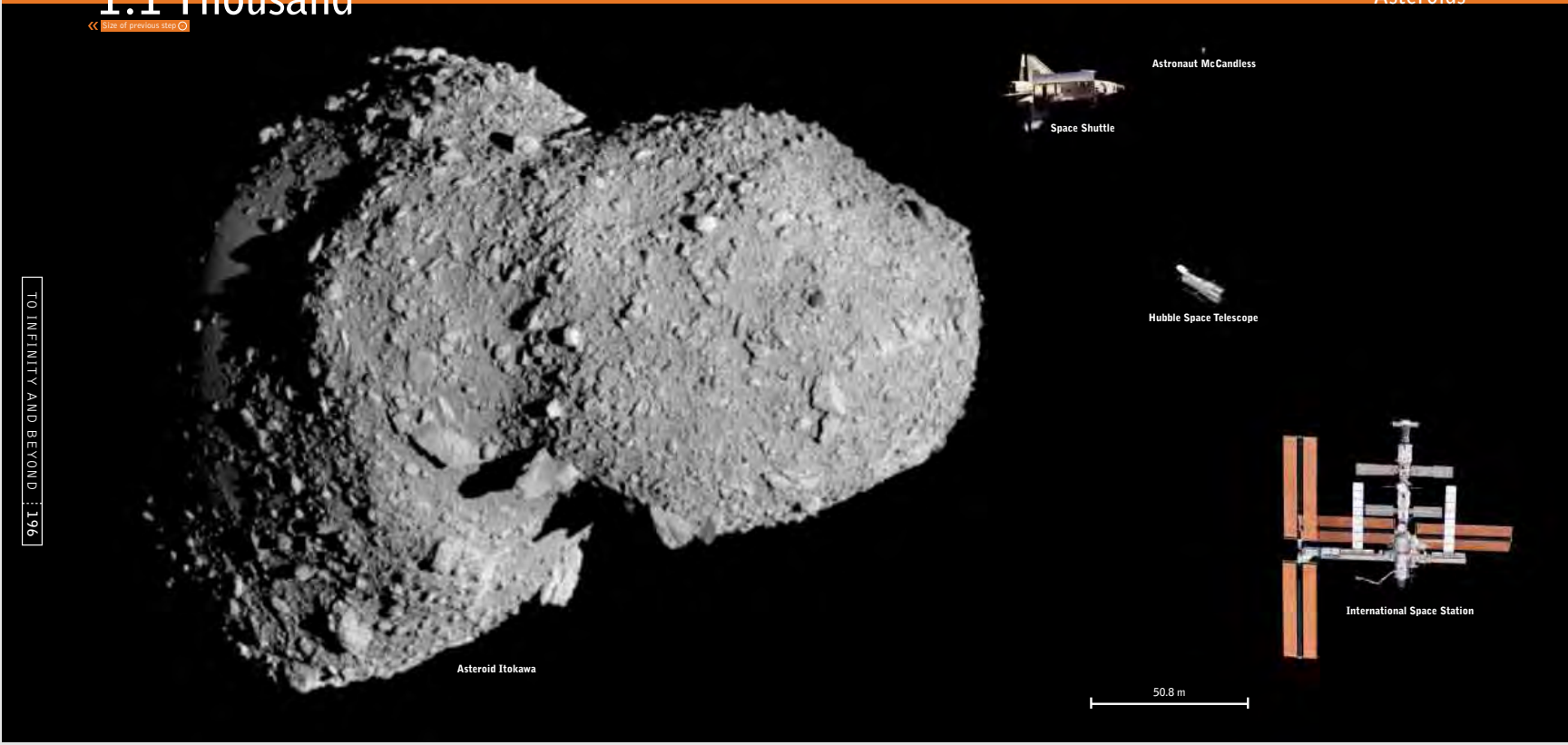
The cosmic microwave background is the most distant thing we can see in the universe. This radiation comes to us from a distance of about 13.7 billion light-years.

The Universe in Ten Steps

Actual Size

1:1 Thousand

« Size of previous step



1:1 Million

« Size of previous step

Comet Wild 2

Halley's Comet

951 Gaspra

Phobos

Deimos

Dactyl

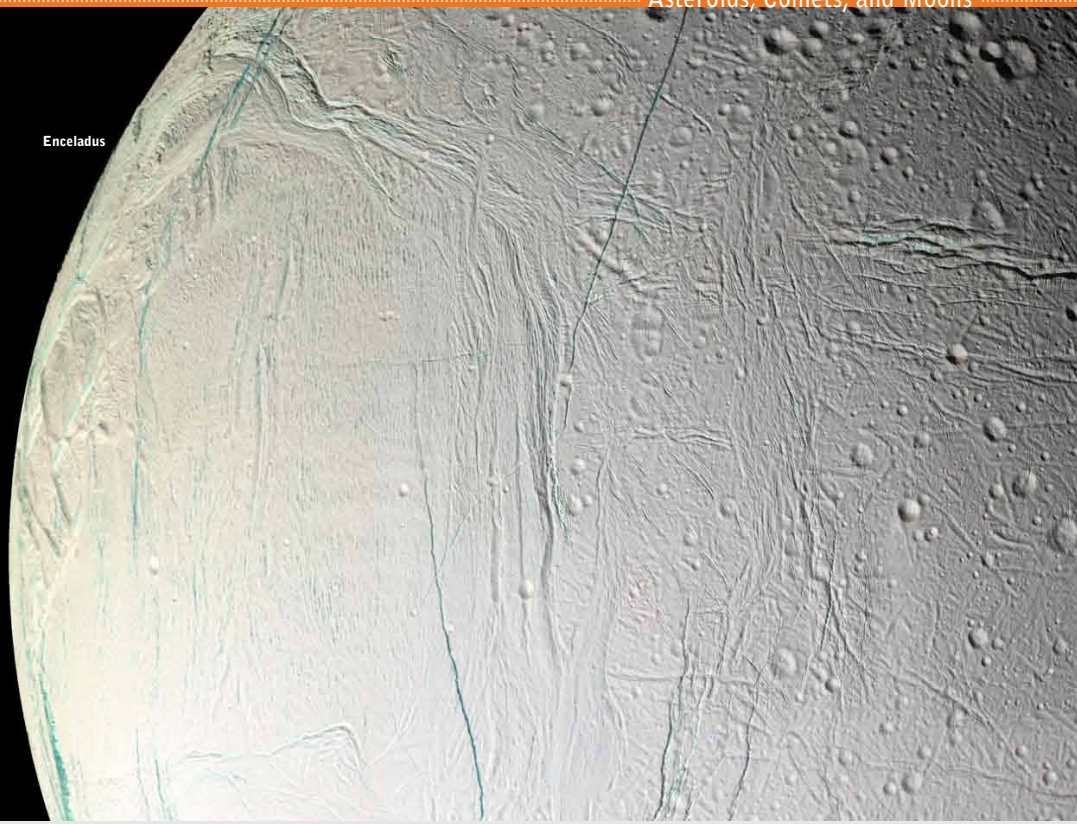
Eros

Ida

Cygnus X-1 Black Hole

Neutron Star

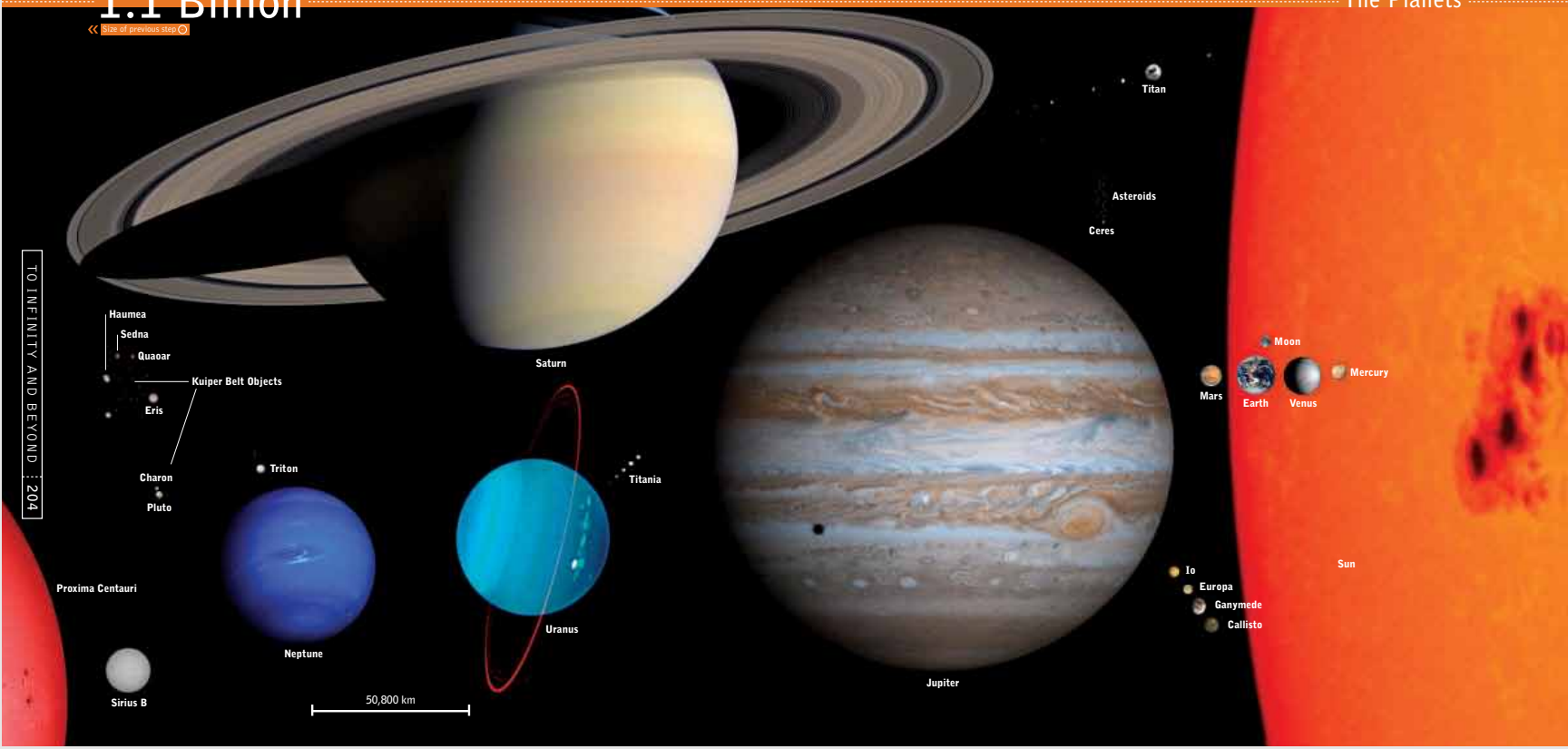
50.8 km

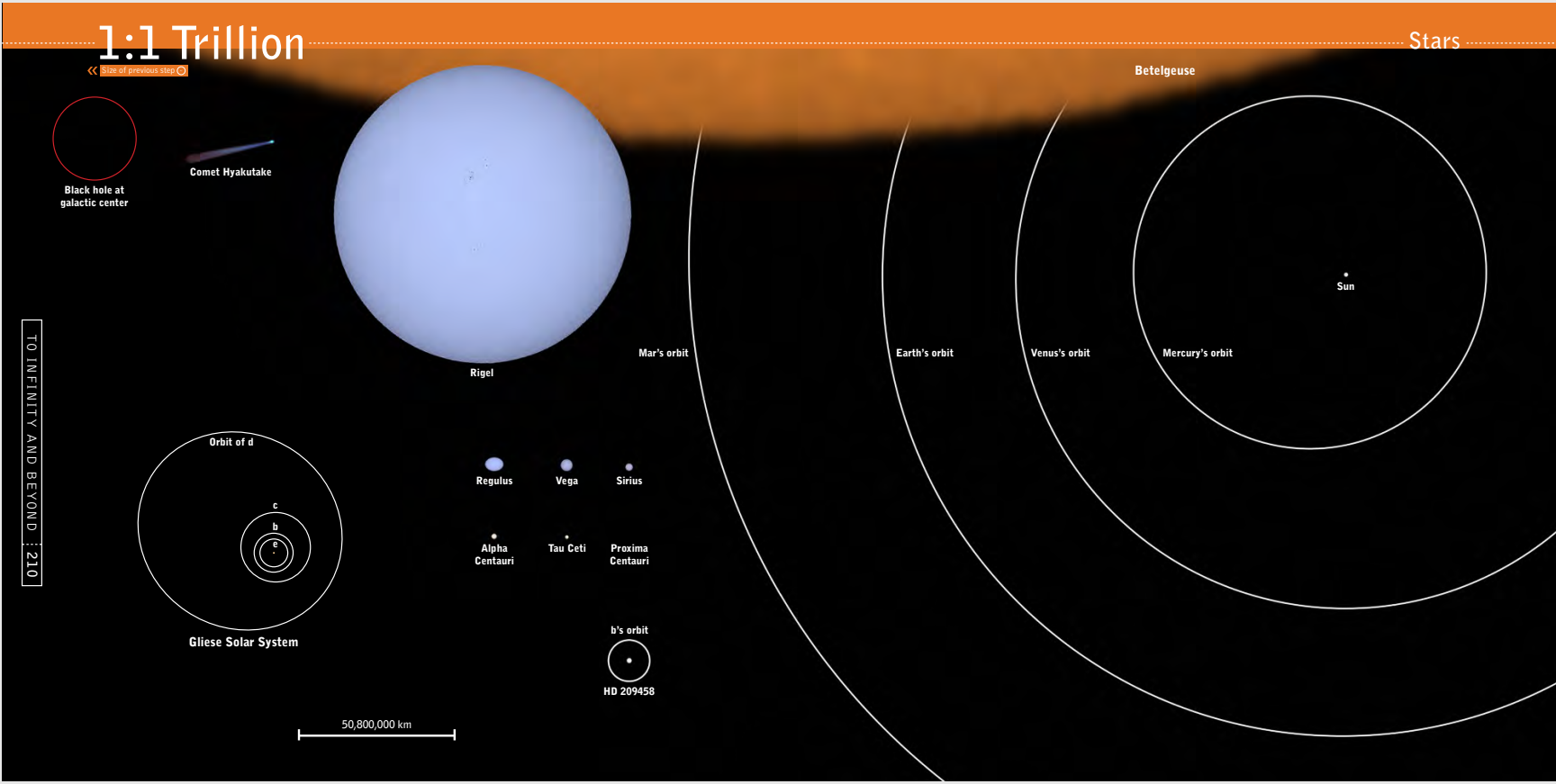


Enceladus

1:1 Billion

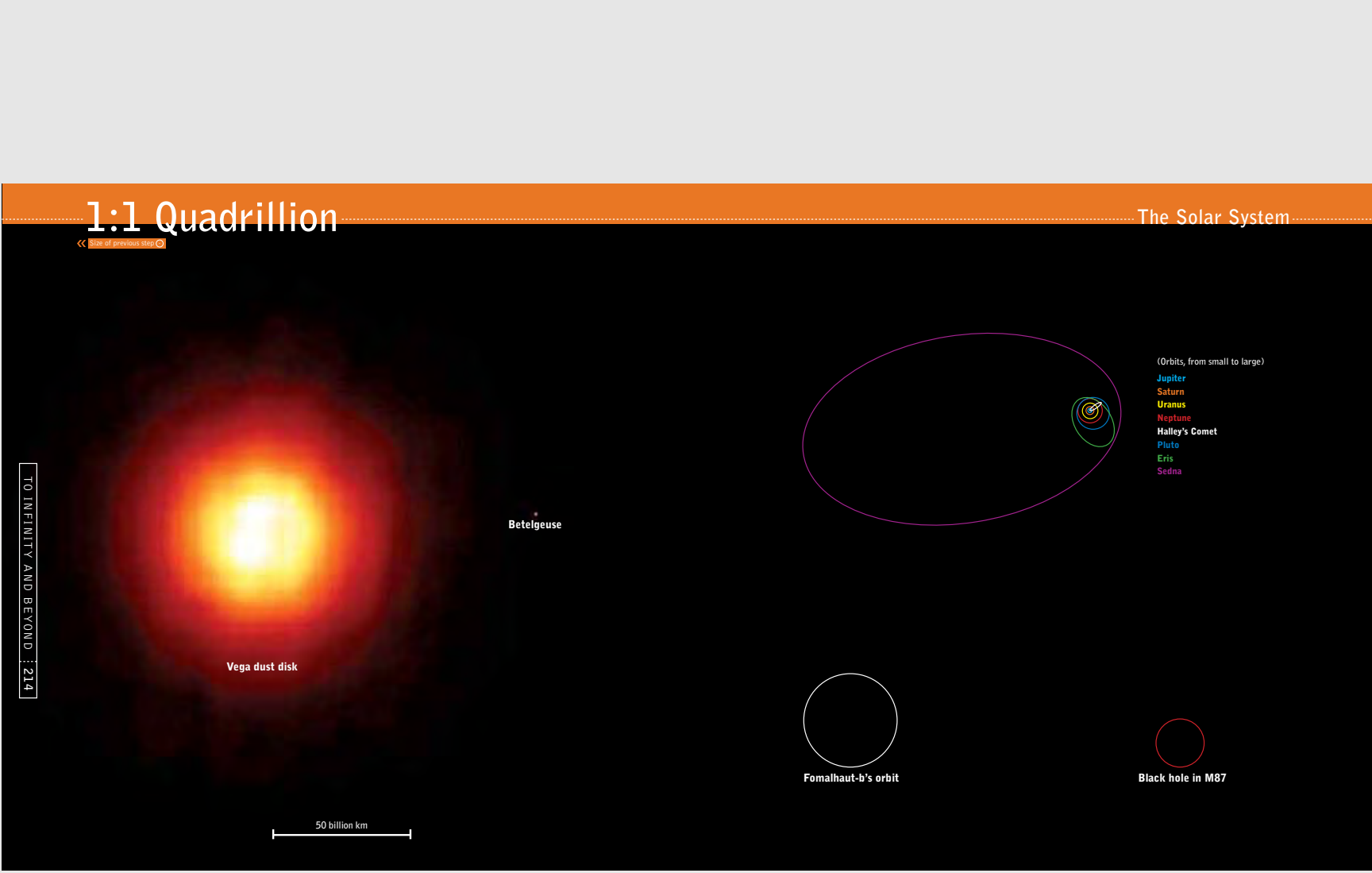
« Size of previous step




« Size of previous step
Black hole at galactic center
Comet Hyakutake
Rigel
Betelgeuse
Sun
Mercury's orbit
Venus's orbit
Earth's orbit
Mar's orbit
Orbit of d
c
b
e
Gliese Solar System
Regulus
Vega
Sirius
Alpha Centauri
Tau Ceti
Proxima Centauri
b's orbit
HD 209458
50,800,000 km

1:1 Quadrillion

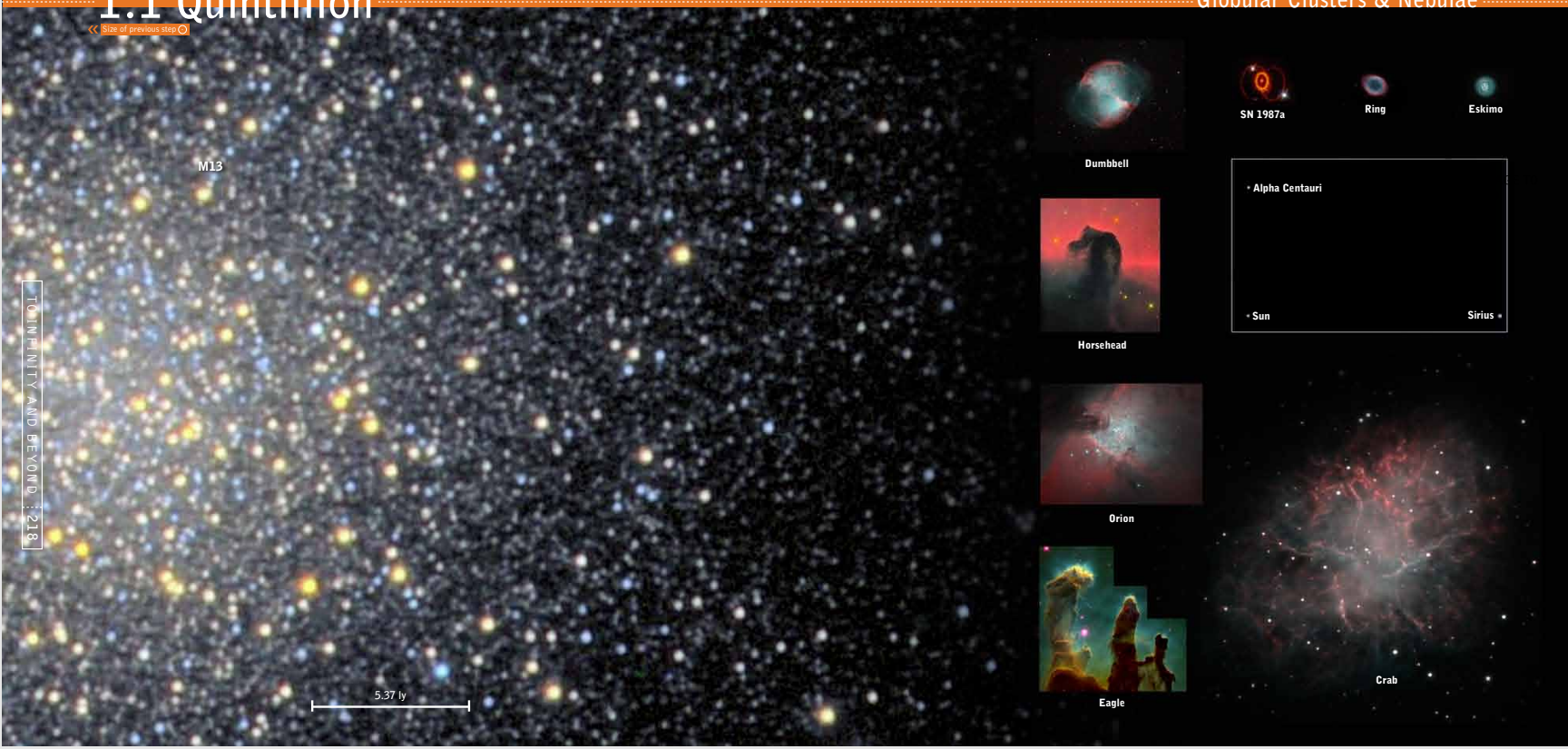
« Size of previous step



1:1 Quintillion

« Size of previous step

Globular Clusters & Nebulae

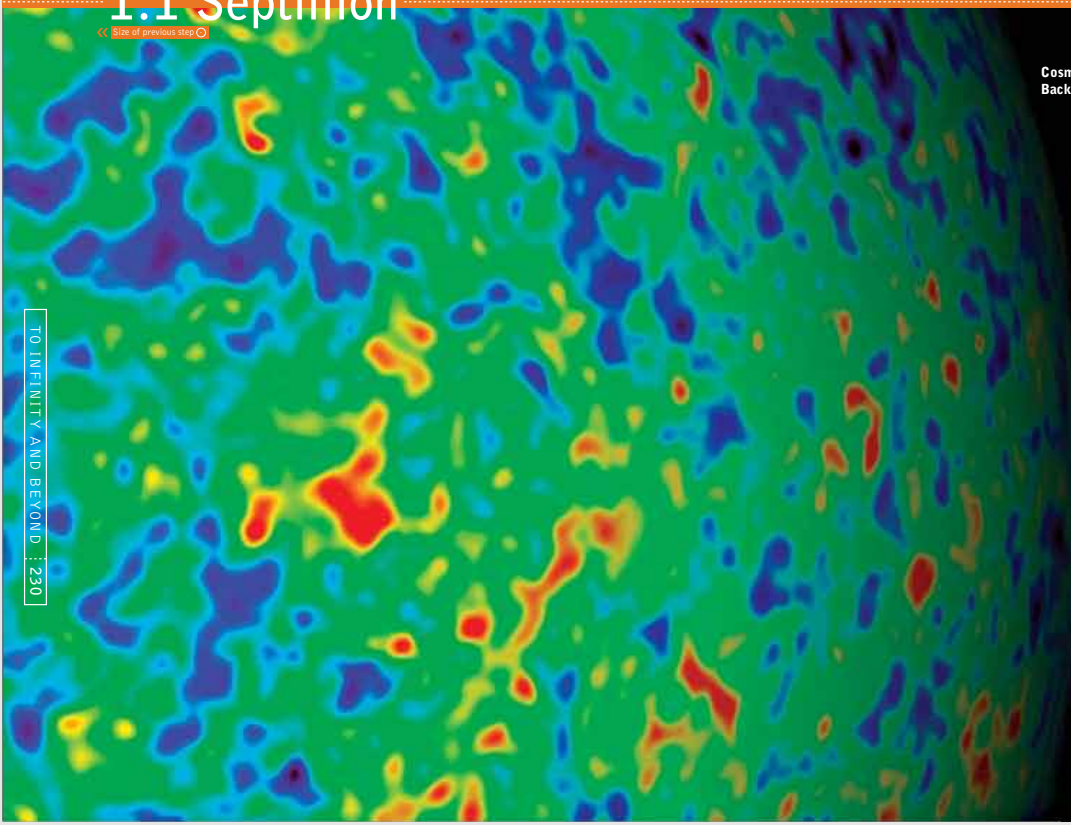


1:1 Sextillion

« Size of previous step

1:1 Septillion

« Size of previous step



Cosmic Microwave Background

Perseus Cluster

M31

M33

Milky Way

Local Group

Coma Cluster

Bullet Cluster

5.37 million ly

Step Ten

ONE LAST JUMP by a factor of a thousand, and we can see the extent of the entire visible universe—everything we can see. We are looking here at the equatorial slice of the Sloan Survey containing 126,594 galaxies and quasars. It is a cross-sectional slice of the universe extending outward from Earth's Equator. Earth is in the center of the picture. Galaxies are shown as green dots, and quasars as orange dots. The two large, blank regions are zones of avoidance, where our galaxy blocks the distant view. The scale shows the look-back-time distance in billions of light-years.

When we look out in space, because of the finite velocity of light, we look back in time. A galaxy five billion light-years away we see as it was five billion years ago. We can see out to a radius of just 13.7 billion light-years in any direction, because the universe began in a big bang explosion 13.7 billion years ago. The farthest thing we can see is the cosmic microwave background radiation left over after the big bang, which encircles the visible universe.

Earth is at the center of the visible universe. This does not mean that we are in a special location. If you look out from the top of the Empire State Building in New York City, the region you can see, out to the horizon, is circular and centered on the Empire State Building. Looking out from the top of a different building, you would see a different circular region—one centered on it. An observer in a distant galaxy would see a different visible region of the universe, one centered on his galaxy instead of ours. Most of the galaxies visible are less than 5 billion light-years away, while most of the quasars are between 5 and 12 billion light-years away. Near Earth, many voids and walls of galaxies are visible. These also appear in the Map of the Universe shown on pages 123-126.

The Sloan Great Wall (highlighted by a detailed, same-size inset that points to its location in the map) is the largest structure we have found in the universe so far. Its length stretches 1.37 billion light-years, one-tenth the radius of the visible universe.

The visible universe is very large because gravity is such a weak force. In 1961, physicist Robert Dicke pointed out that it is no accident we live about one stellar main-sequence lifetime after the big bang—after some stars have died (to make the carbon needed for life) but before all the stars have burned out, making it too cold for life. If gravity were stronger, main-sequence lifetimes of stars would be shorter, we would live closer in time to the big bang, and the radius of the visible universe would be smaller. Since gravity is weak, we carbon-based life-forms, orbiting our main-sequence star, are treated to a truly grand view.

FYI We are now observing a scale a billion, billion, billion times larger than Buzz Aldrin's footprint. And that footprint is a billion times larger than a hydrogen atom.

Just think: After the end of inflation, the process that produced the big bang explosion 13.7 billion years ago, all the matter we can see in the visible universe today was still inside a region smaller than Buzz Aldrin's footprint.

A computer-generated representation of the visible universe. Sloan Survey galaxies (green) and quasars (orange) are plotted at their look-back-time distances—black wedges are regions obscured by our galaxy and not covered by the Sloan Survey. Around the perimeter is the cosmic microwave background.