Observing and Photographing the Total Lunar Eclipse; May 15/16th, 2022

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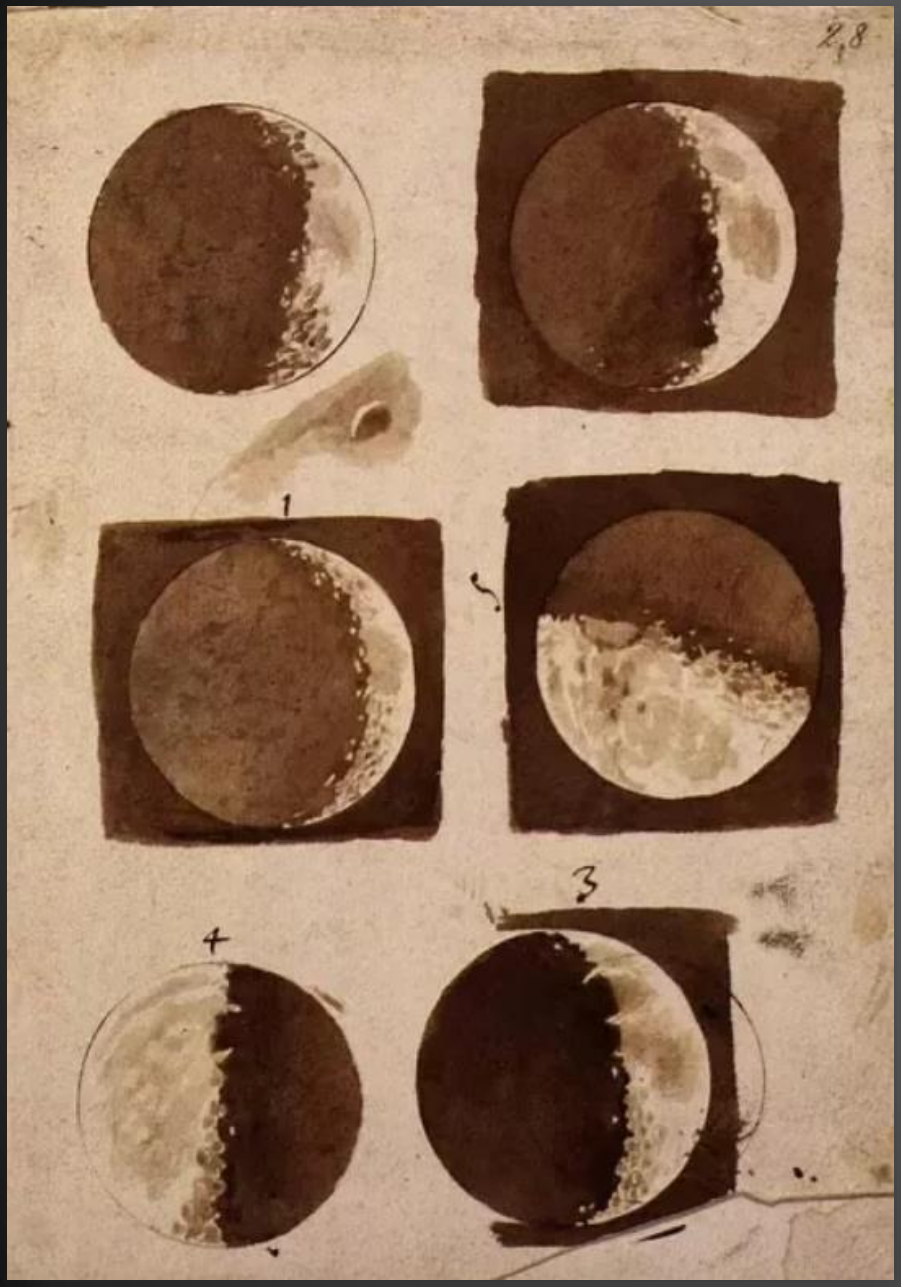
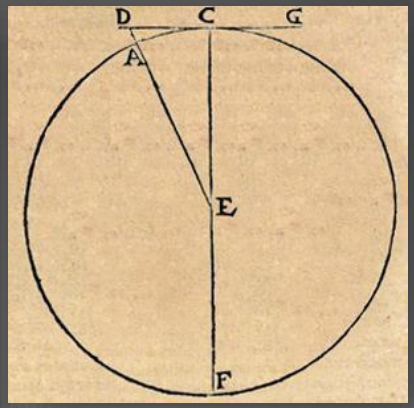
Miami Valley Astronomical Society

October 8, 2022

9/27/15

Celestial Shadows





Galileo used shadows on the moon to estimate the heights of lunar mountains

Shadows near the lunar terminator give clues as to the sizes and shapes of lunar surface features

It can be a lot of fun to try and match shadows on the moon with the land form that cast it

The Shadow of the Earth as Cast During a Lunar Eclipse

During eclipses of the moon it can be fun to visualize what part of the Earth is casting the shadow that you are observing

This example is from a total eclipse of the moon that occurred on the evening October 27, 2004

The image was taken as the moon egressed from the Earth's shadow at 12:15am

The edge of the Earth's shadow was being cast by central Europe, the UK, and the North Atlantic

The Ultimate Shadow Show

Perhaps the ultimate shadow show is the case of NGC 2261, Hubble's Variable Nebula (R Monoceros)

The star at the tip of the nebula isn't a star, but a dense nebula with a star embedded within it

Clouds of dust orbiting the star cast shadows onto the nebula and you can watch these shadows sweep across the nebula over time spans of weeks and months

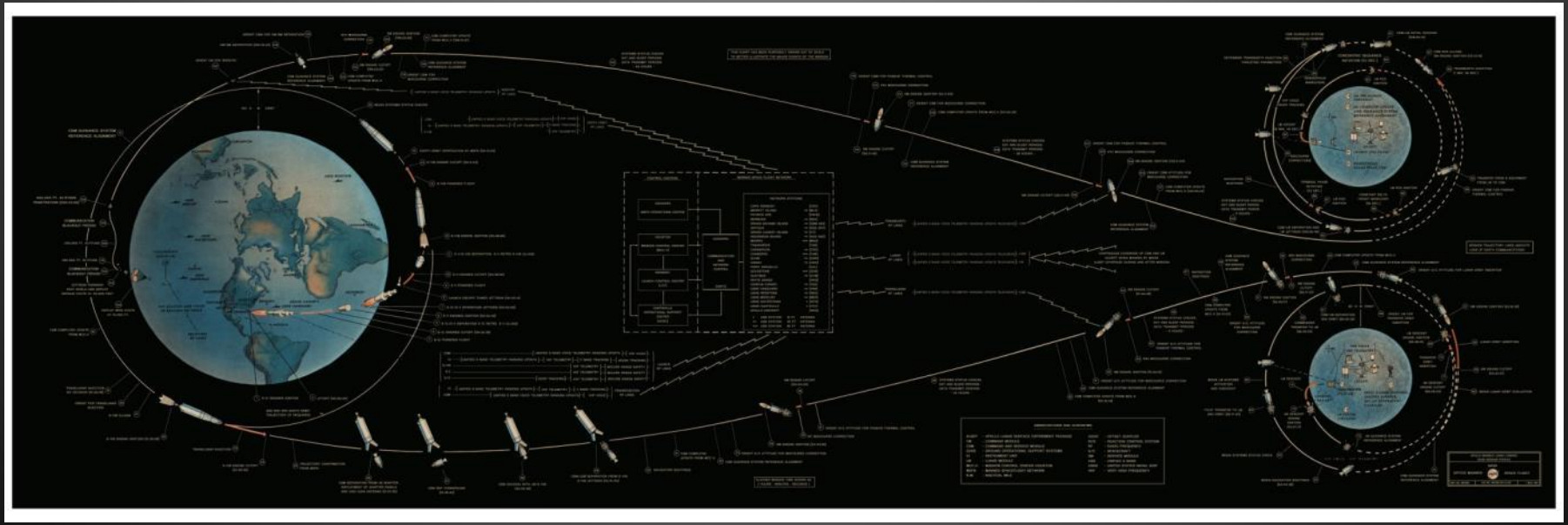
The Shadow of the Moon

Apollos 8, 10, 11, 16, and 17 launched when the moon was a waxing crescent

This means that the moon's shadow was angled towards the Earth and as they climbed towards the moon they also climbed into the moon's shadow

The Apollo 8 flight controllers were a little surprised at the sudden drop in the temperatures onboard the spacecraft before they recalled that this was expected and it was a reminder of how special this journey was

The crew of Apollo 11 gave lengthy descriptions of what they could see out of the Command Module windows as they flew through the shadow of the moon including the visibility of stars, the solar corona, earthshine, and the earthshine terminator

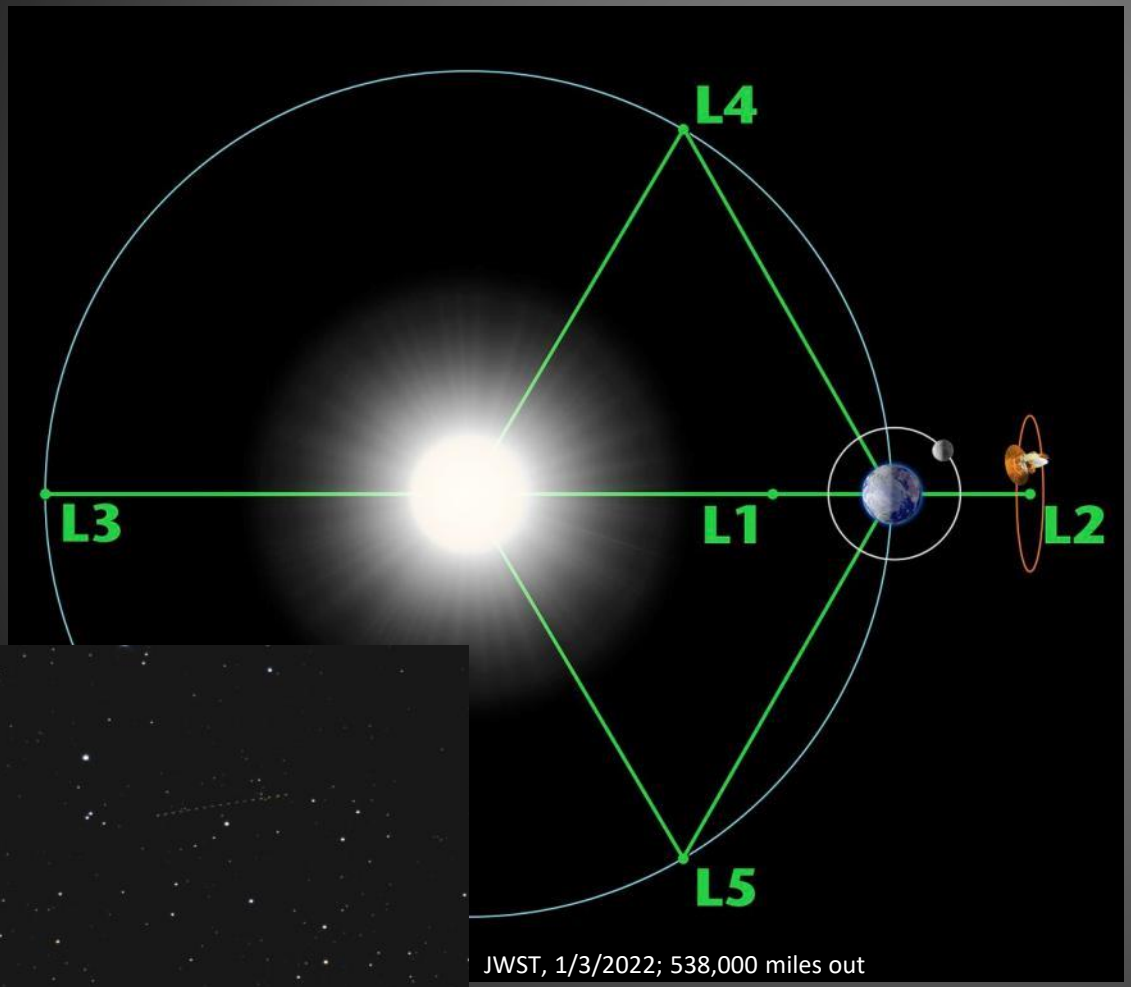


The Shadow of the Earth

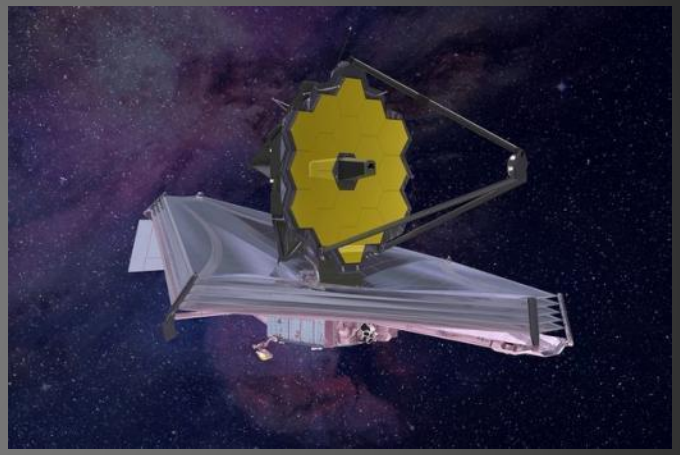
The James Web Space Telescope was launched into a halo orbit around Earth's L2 Lagrange point

Placing the telescope directly at L2 would have potentially been more stable, but it would also put it in the shadow of the Earth and moon

There was some discussion on Cloudy Nights about whether the Earth's shadow actually reaches all the way out to L2 and whether the eclipse at L2 would be total or annular



JWST, 1/3/2022; 538,000 miles out



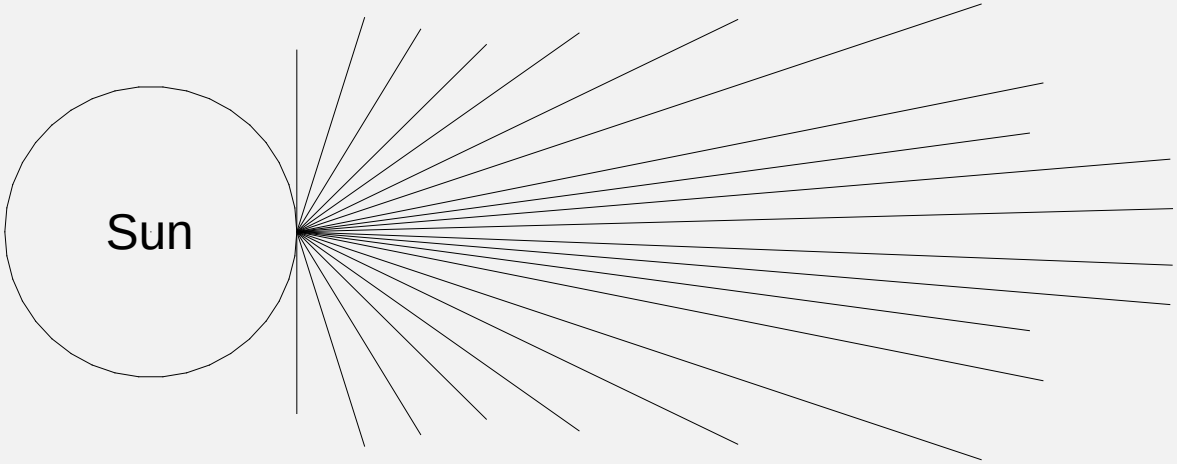
L2 is one of 5 Lagrange points where the gravity of the Earth and sun are balanced

The exact location of L2 isn't fixed and shifts slightly due to the shape of the Earth's orbit along with influences from the moon, Venus, Mars, and Jupiter

L2 is located approximately 900,000 miles distant directly opposite the sun

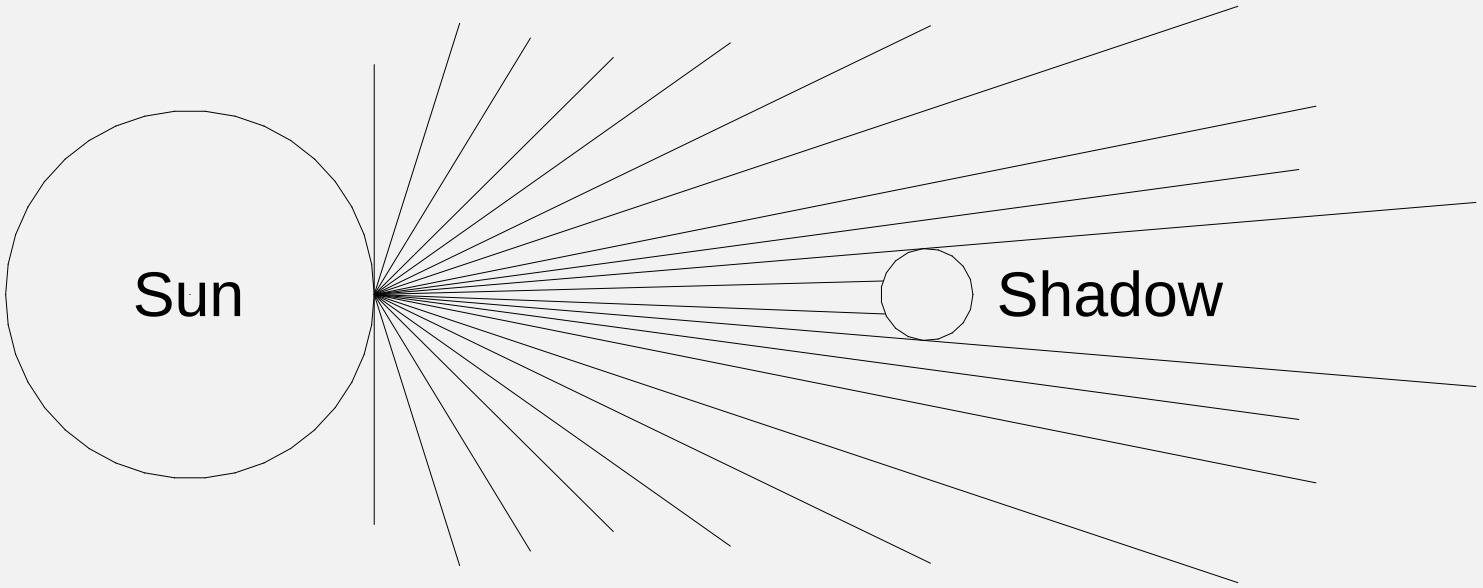
Calculating the Length of the Earth's Shadow

Every point on the sun acts as a point source with light radiating in all directions



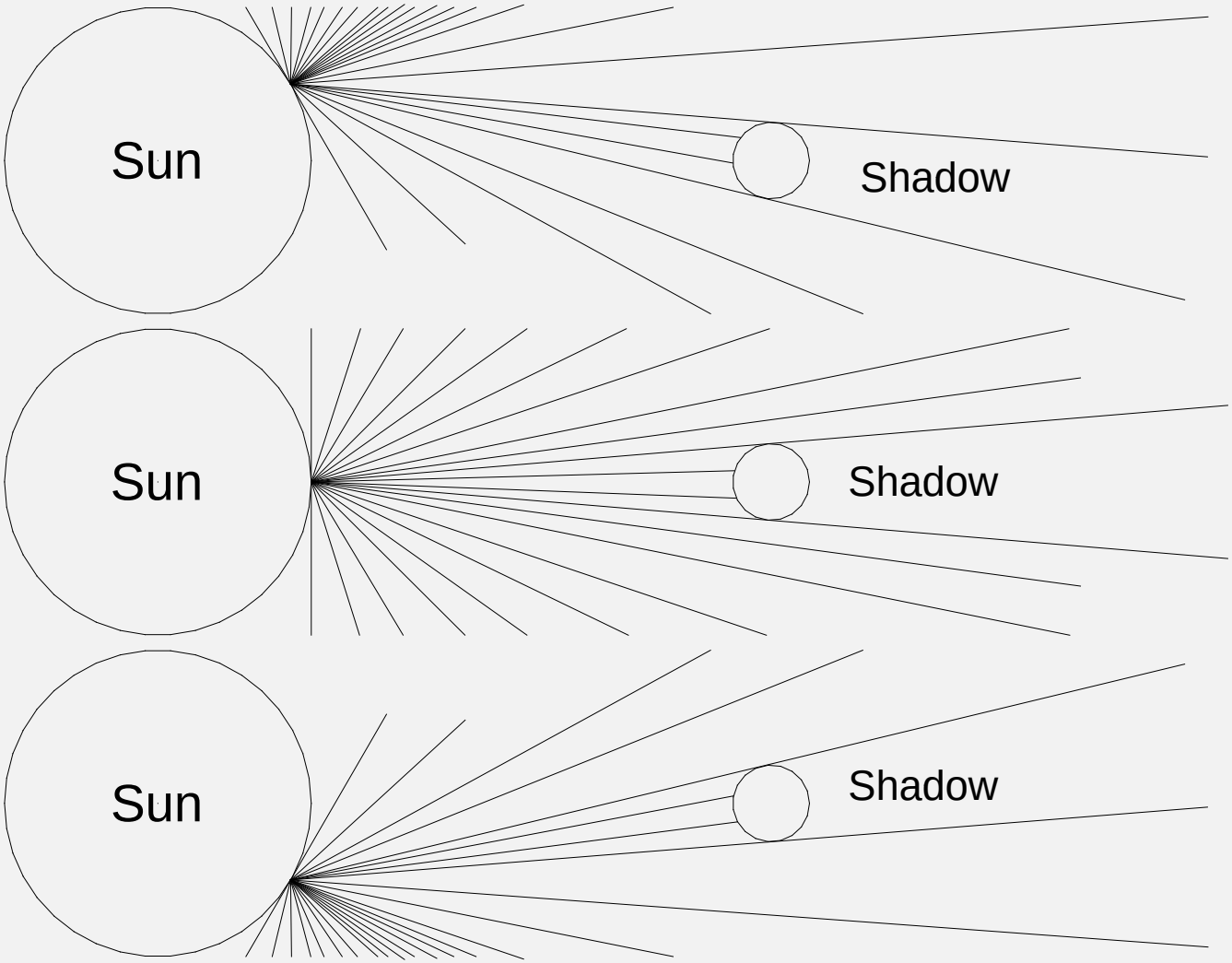
Calculating the Length of the Earth's Shadow

Any solid object placed in front of the sun casts a shadow that expands radially from that point



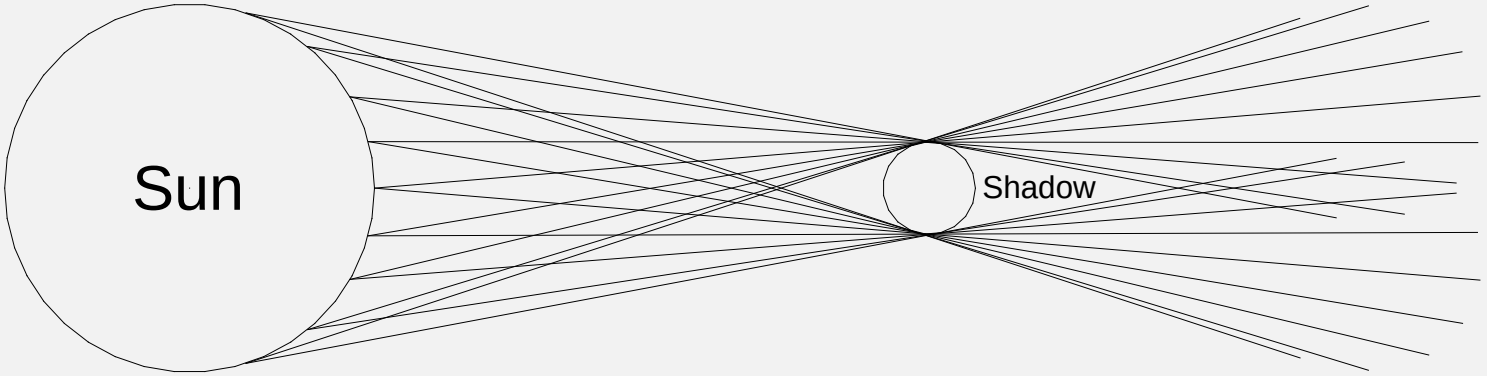
Calculating the Length of the Earth's Shadow

Every point on the sun casts a similar shadow whether it is above or below the centerline between the sun and the object



Calculating the Length of the Earth's Shadow

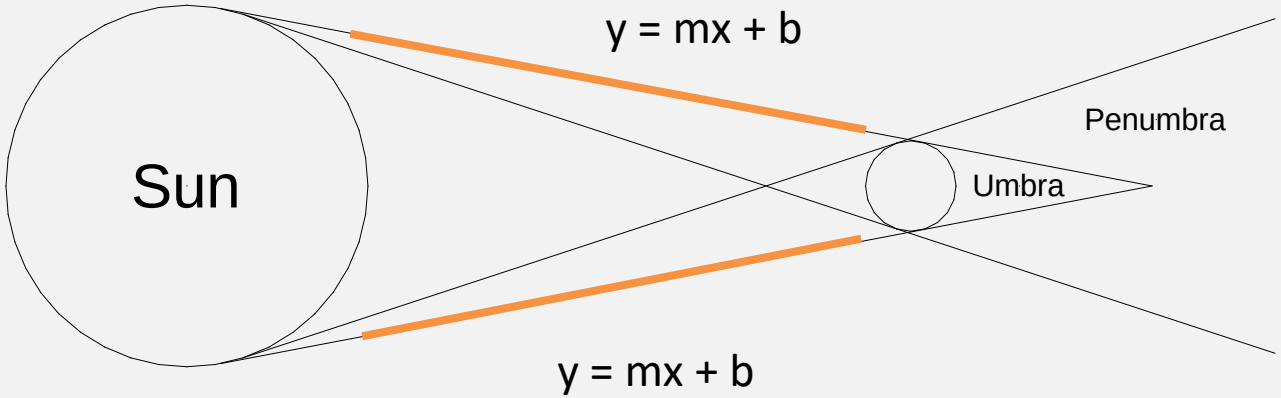
The schematic can be simplified using only the grazing rays…



Calculating the Length of the Earth's shadow

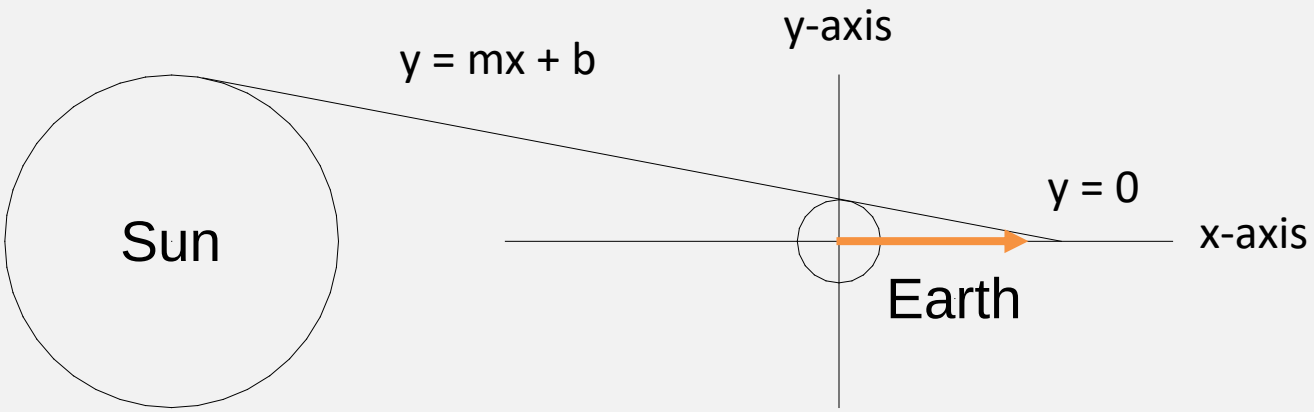
All of the rays can be described as straight lines of the form y = mx + b

Where m is the slope (rise/run) and b is the y intercept (y when x = 0)



Calculating the Length of the Earth's shadow

We can simplify things by placing the origin of the coordinate system at the center of the Earth and recognizing that the length of the Earth's shadow is where y = 0



Calculating the Length of the Earth's shadow

Solve y = mx + b for x when y = 0

$0 = mx + b$

$-mx = b$

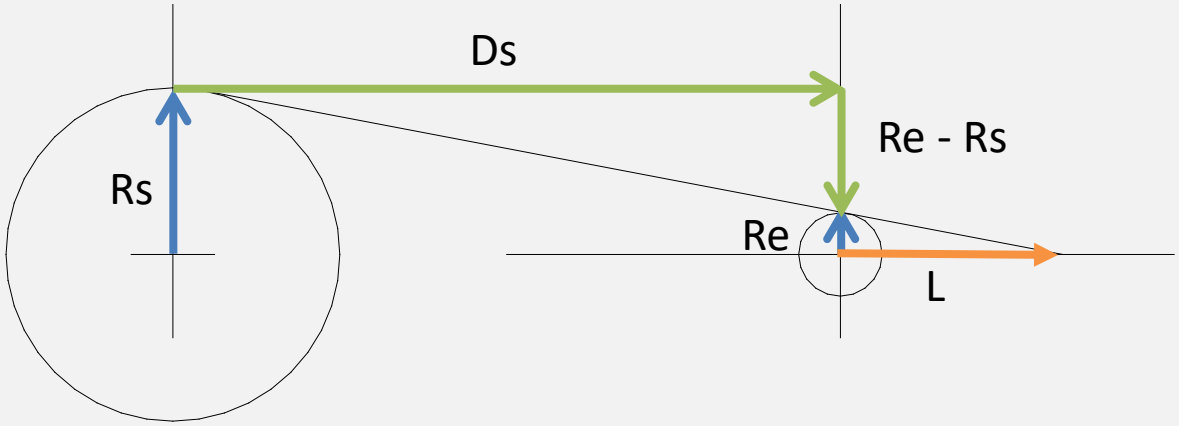
$x = -b/m$

From the schematic...

$b = Re$

$m = (Re - Rs)/Ds$

$L = -Re/[(Re - Rs)/Ds]$



Re = Radius of the Earth = 3,959 mi

Rs = Radius of the Sun = 432,690 mi

Ds = Distance to the Sun = 92,955,902 mi

Length of the Earth's Shadow: 858,332 mi

Distance to L2: approximately 900,000 mi

So, the Earth's shadow doesn't quite reach L2, but it would show a significant annular eclipse

Calculating the Length of the Moon's shadow

Solve y = mx + b for x when y = 0

$0 = mx + b$

$-mx = b$

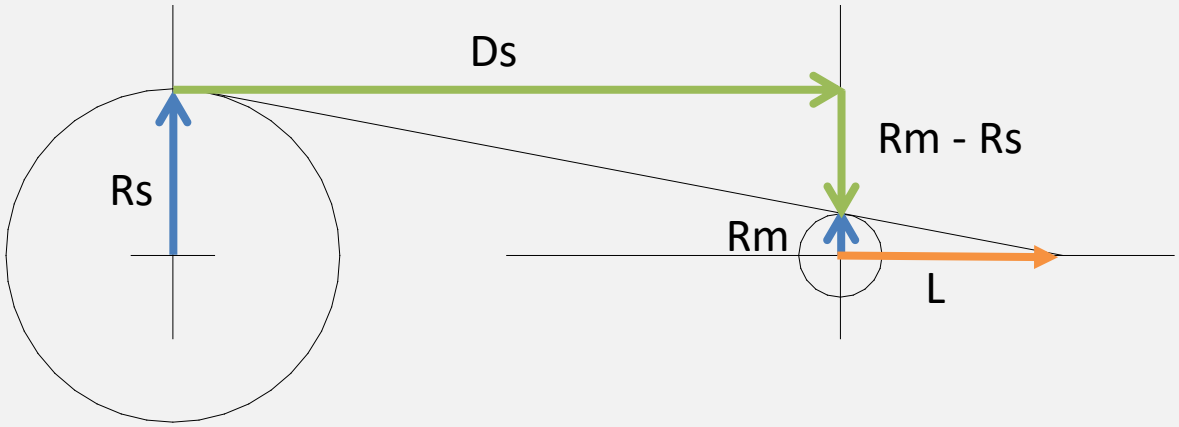
$x = -b/m$

From the schematic...

$b = Rm$

$m = (Rm - Rs)/Ds$

$L = -Rm/[(Rm - Rs)/Ds]$



Rm = Radius of the Moon = 1,080 mi

Rs = Radius of the Sun = 432,690 mi

Ds = Distance to the Sun = 92,721,006 mi

Length of the Moon's Shadow: 231,926 mi

Altitude of the Moon: 221,350 to 247,945 mi

The moon's shadow doesn't always reach the surface of the Earth

Calculating the Length of Other Planetary Shadows

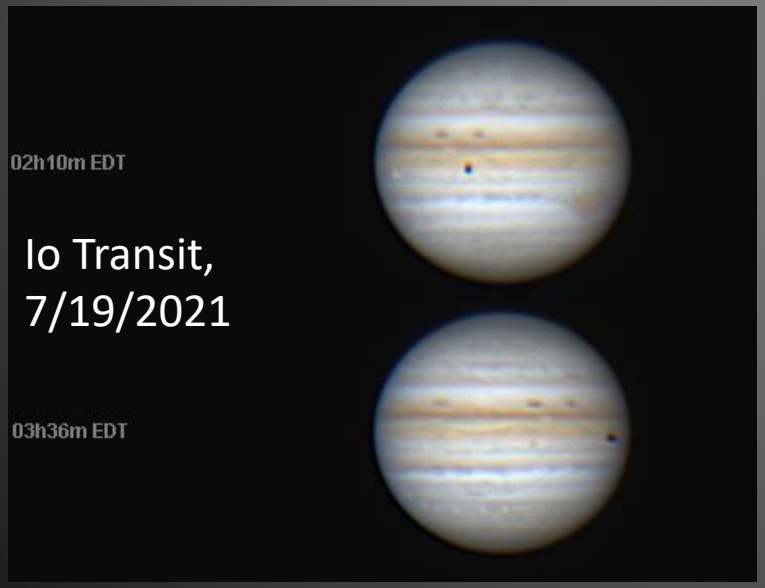
Object	Radius, mi	Solar Distance, mi	Shadow, mi
Mercury	1,516	35,983,044	126,512
Venus	3,760	67,237,979	589,474
Earth	3,959	92,955,902	858,332
Mars	2,106	141,634,852	692,786
Jupiter	43,441	483,779,696	53,990,823
Saturn	36,184	890,759,227	81,288,131
Uranus	15,759	1,783,940,884	67,429,681
Neptune	15,299	2,795,183,973	102,457,127
Pluto	459	2,965,546,207	3,147,891

Planetary shadows tend to get longer the farther you get from the sun

This is in part due to the planets getting bigger, but also because the apparent size of the sun gest smaller

Calculating the Length of Other Moon Shadows

Object	Radius, mi	Shadow, mi	Altitude, mi
Phobos	7	1,482	3,720
Deimos	4	841	12,471
Moon	1,080	232,513	234,648
Io	1,132	1,268,856	218,591
Europa	970	1,086,785	373,520
Ganymede	1,637	1,836,962	621,682
Callisto	1,498	1,680,346	1,126,420
Titan	1,600	3,305,492	723,051



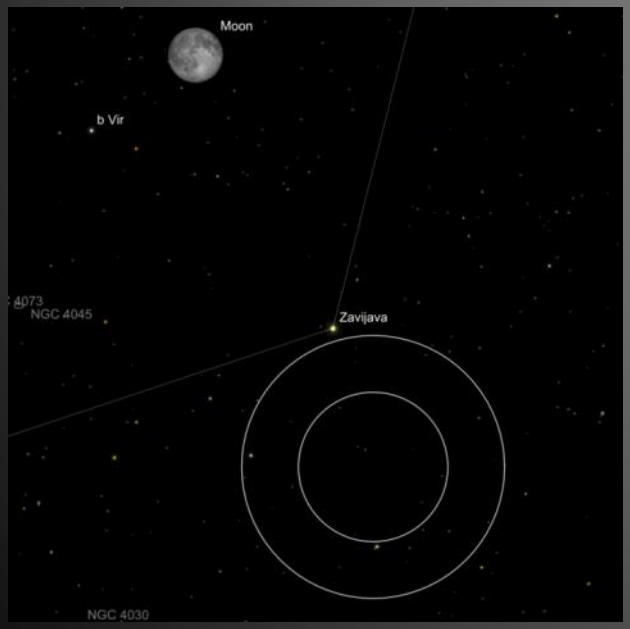
Io Transit, 7/19/2021


Saturn, 7/25/2020

The moon usually passes above (north) or below (south) the Earth's shadow

If you look closely you can see a razor thin terminator sweeping over the opposite lunar pole

The terminator passes over the south pole with the moon is passing north of the Earth's shadow and over the north pole when the moon is passing south of the Earth's shadow



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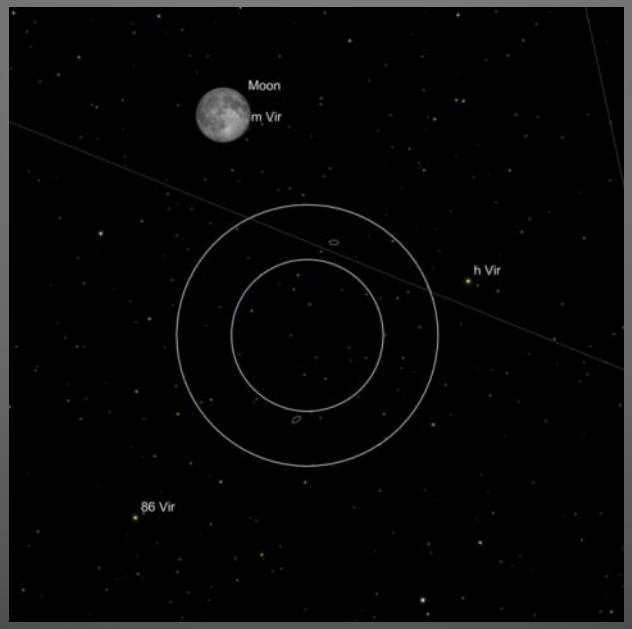
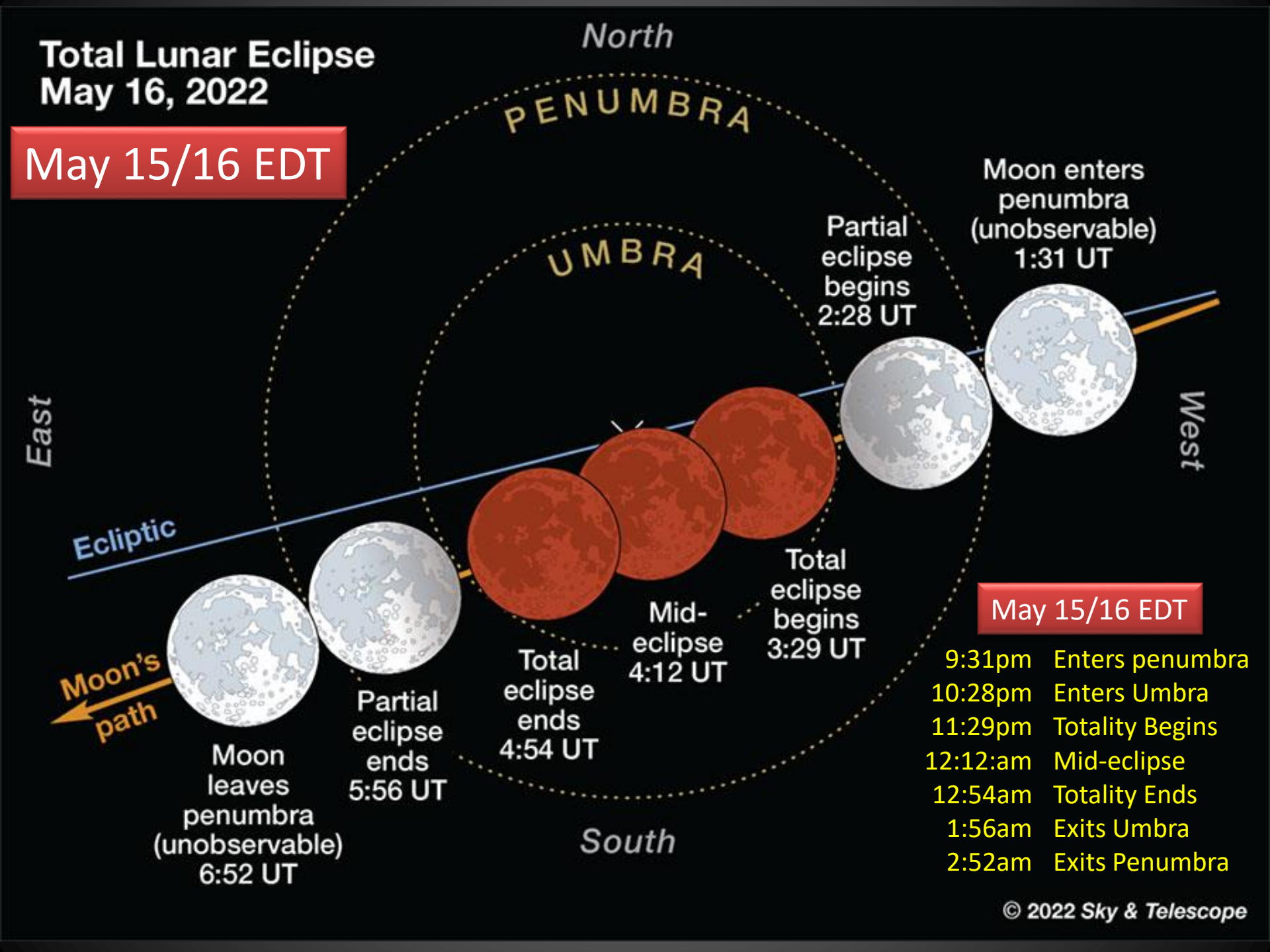


April 16, 2022

May 16, 2022


Total Lunar Eclipse
May 16, 2022
May 15/16 EDT
North
PENUMBRA
UMBRA
Moon enters penumbra (unobservable) 1:31 UT
Partial eclipse begins 2:28 UT
East
West
Ecliptic
Total eclipse begins 3:29 UT
Mid-eclipse 4:12 UT
Total eclipse ends 4:54 UT
Partial eclipse ends 5:56 UT
Moon leaves penumbra (unobservable) 6:52 UT
Moon's path
South
May 15/16 EDT
9:31pm Enters penumbra
10:28pm Enters Umbra
11:29pm Totality Begins
12:12:am Mid-eclipse
12:54am Totality Ends
1:56am Exits Umbra
2:52am Exits Penumbra
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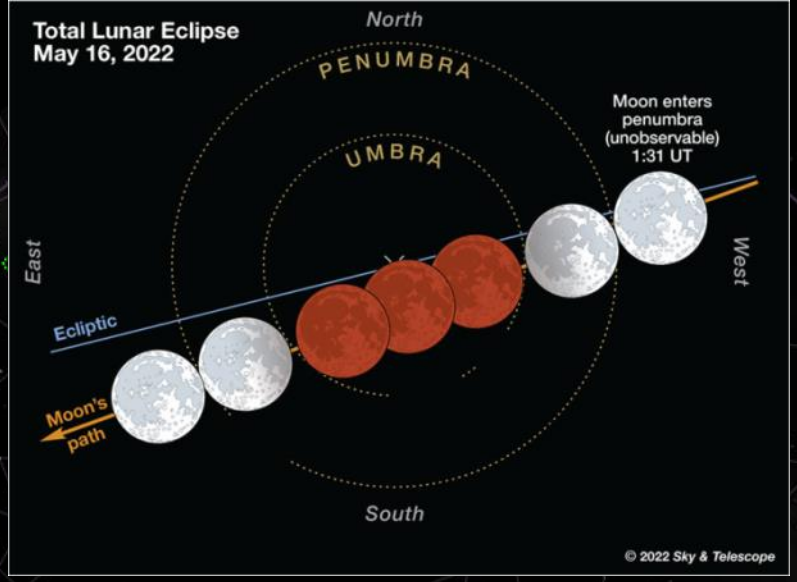
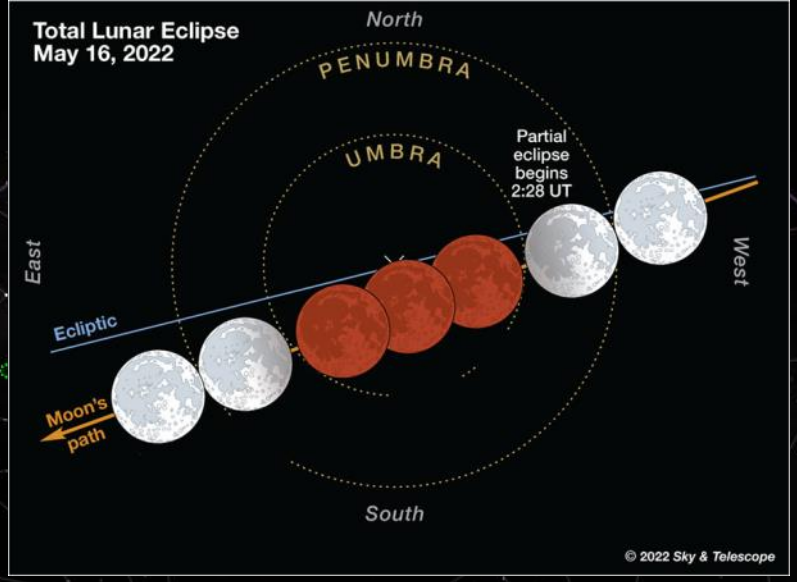


9:31pm
Enters Penumbra
Az: 125° Alt: 9°

The full moon right before and after a lunar eclipse is exceptionally ***bright***!

The entrance into the penumbra itself is not visible, but over the next hour the eastern limb of the moon will *slowly* take on an amber hue

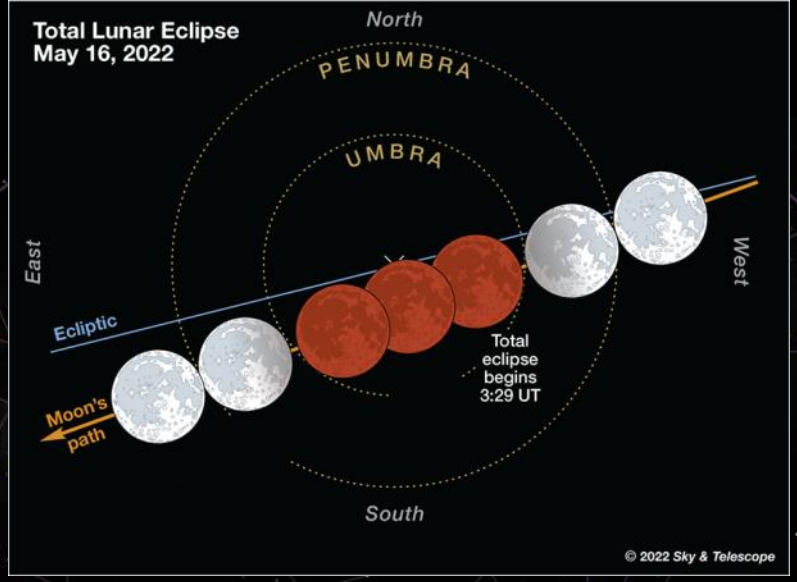


10:28pm
Enters Umbra
Az: 135° Alt: 17°

The partial eclipse begins!

Although the edge of the Earth's shadow is a tad soft, the entrance into the umbra occurs sharp and fast with the sudden appearance of a dark 'bite' out of the eastern limb of the moon

The next few minutes will seem to pass quickly as the dark edge of the shadow grows



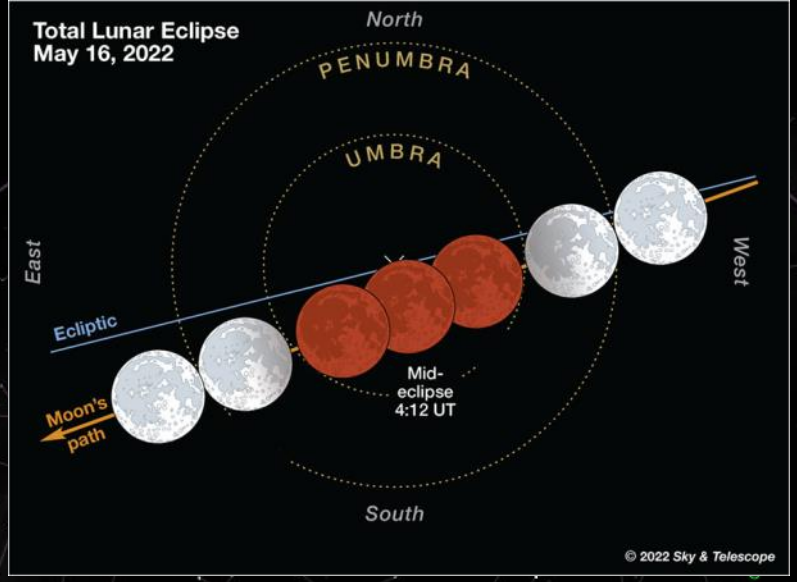
11:29pm
Totality Begins
Az: 148° Alt: 24°

The total eclipse begins!

The last sliver of the western limb in sunlight will appear silvery white as it fades to a dark amber

The exact time that totality begins may be hard to detect, but it's obvious once the last bit of direct sunlight disappears

This phase of the eclipse passes quickly, and then time seems to slow down as the moon crosses the Earth's shadow



12:12am
Mid-Eclipse

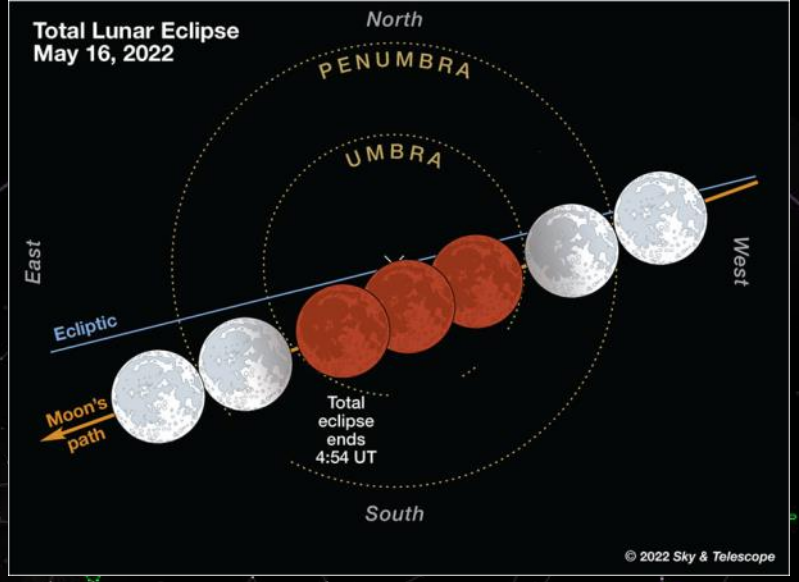
12:12am
Mid-Eclipse
Az: 158° Alt: 27°

The show is halfway over and moon's northern limb is just touching the center of the Earth's shadow

However, this may not be the darkest part of the eclipse

The density and color of the Earth's shadow is hard to predict and depends on the atmospheric conditions around the perimeter of the globe

So, it may be difficult to see clear evidence that the show is half over



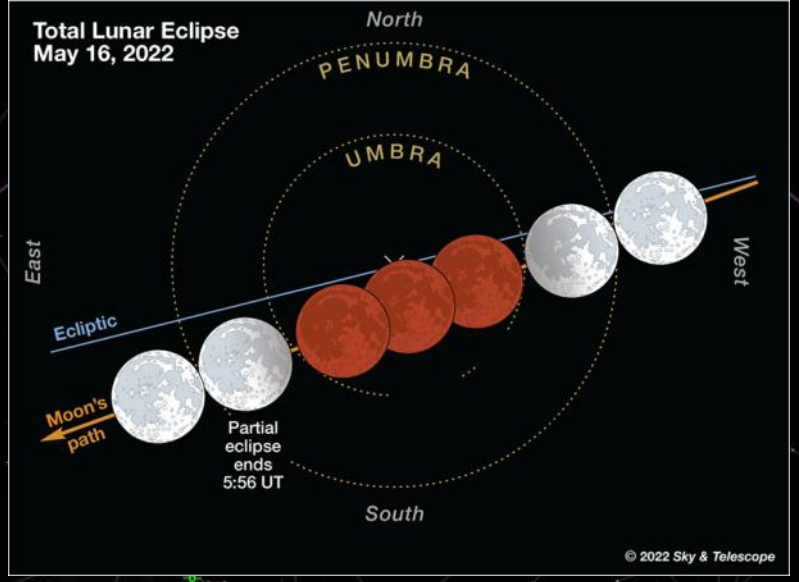
12:54am
Totality Ends

12:54am
Totality Ends
Az: 169° Alt: 29°

As the moon's eastern limb approaches the edge of the Earth's shadow it will begin to brighten with a beautiful silvery glow

Your eyes have become accustomed to seeing the darkened amber moon and the emergence into sunlight will happen quickly

Sadly, the best part of the show is over

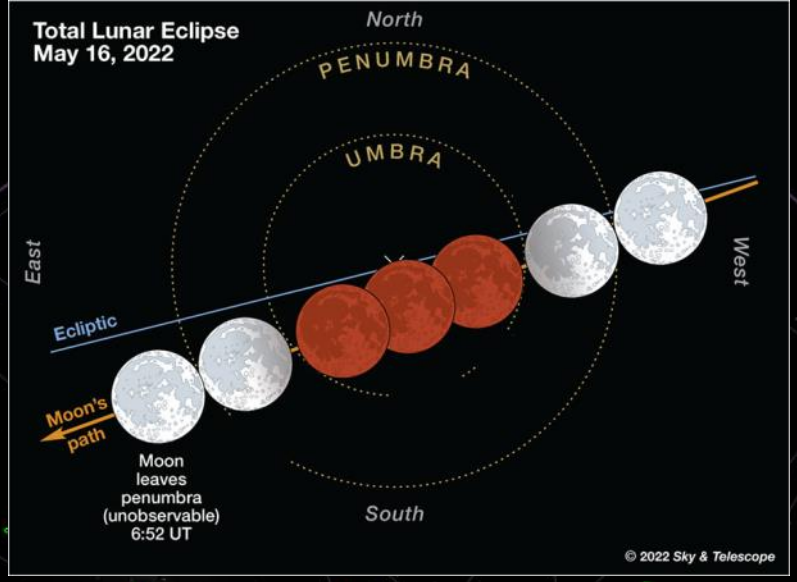


1:56am
Exits Umbra

1:56am
Exits Umbra
Az: 185° Alt: 30°

The last sliver of the Earth's shadow exits the moon's western limb, leaving a soft amber glow behind that slowly fades

The visible portion of the eclipse is over



2:52am
Exits Penumbra

2:52am
Exits Penumbra
Az: 199° Alt: 30°

Between the time the moon exits the umbra and finally exits the penumbra you will once again be treated to an exceptionally ***bright*** full moon

It may appear even more dazzling as it is now high in the south and your eyes have become accustom to the amber moon

It's almost a surreal experience to watch the moon pass from full to full with an earthlit moon in between over the space of a few hours


October 27-28, 2004
Total Lunar Eclipse
Top: 00h15m, 00h00m, 23h43m
Middle: 01h00m, 00h45m, 00h30m
Bottom: 01h30m, 01h15m

Camera Options

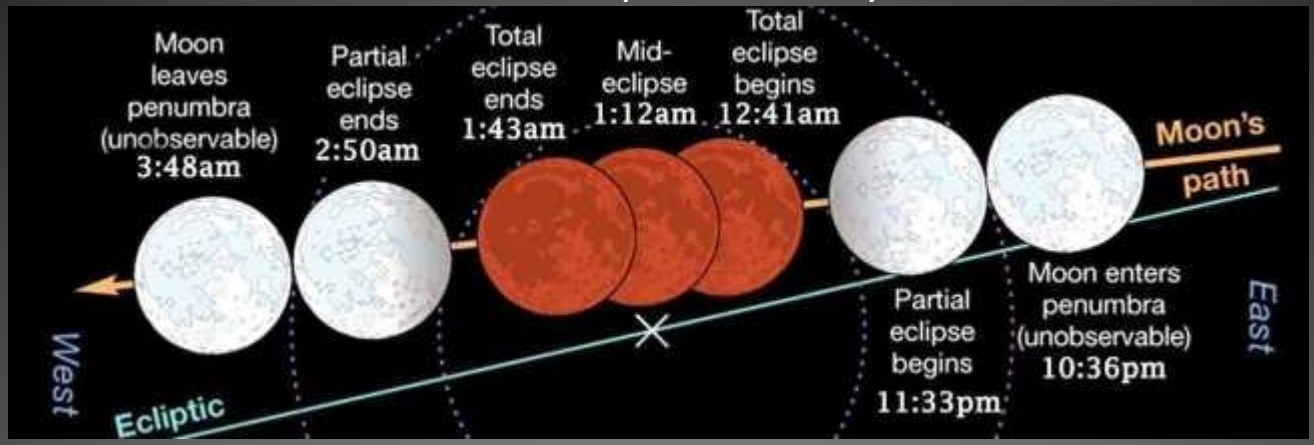
Stand-alone

Afocal

Prime Focus

- Stand-alone cameras including cell phone or tablet cameras, point and shoot cameras, and DSLRs
- Afocal includes cell phone and point and shoot cameras with adapters to attach them to an eyepiece
- Prime Focus includes DSLRs adapted for use in place of an eyepiece and dedicated astro cameras

Total Lunar Eclipse – January 20, 2019



Regardless of the type of camera that you are planning to use the challenges are basically the same

Over the space of a couple of hours you will be imaging the moon as it passes from being the brightest full moon that you will ever see, fading into a beautiful amber shadow, and back again

The key is being flexible, and taking a lot of pictures with various settings to give yourself the best source images for post-eclipse processing

Tips for using a stand-alone camera

- Consider using a tripod, this will hold your camera steady and allow you to compose your image
- Become familiar with your camera's Pro or Manual mode
  - ➢ Gain (ISO)
  - ➢ Exposure Time
  - ➢ Focus
- Your camera may have a Night Mode
  - ➢ Automatically stacks images to reduce noise and increase dynamic range
- Use the Self-Timer to allow vibrations to settle
- Auto-focus should work when the moon is bright, though you may have to switch to manual focus as the moon darkens

- If using a DSLR consider using a remote switch, interval timer, or even a notebook computer
- Use the mirror lock-up function to allow vibrations to settle
- Save your source images as RAW to give you the best options in post-processing
- If using auto-focus, set the focus while the moon is bright, and then switch to manual focus to keep it from changing as the moon darkens.

Tips for using an afocal camera

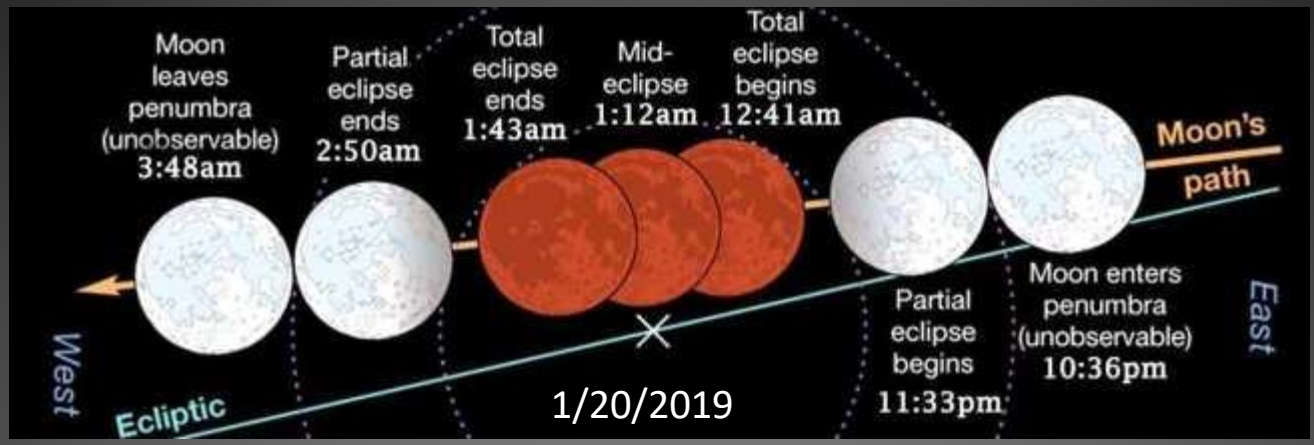
- Become familiar with your camera's Pro or Manual mode
  - Gain (ISO)
  - Exposure Time
  - Focus
- Your camera may have a Night Mode
  - Automatic ally stacks images to reduce noise and increase dynamic range
- Use the Self-Timer to allow vibrations to settle
- The auto-focus usually helps to adjust the focus
- During totality you may have to set the focus manually
- During the partial phase concentrate on taking images where the sunlit moon is not over-exposed
- You may want to experiment taking images that show the umbra while the penumbra is over-exposed

- As the eclipse approaches totality be prepared to use longer exposures and/or higher gain
- Totality itself is fairly long, pace yourself, try different camera settings, and enjoy the view!
- The trickiest time is catching the last rays of the sun as totality begins, and the first rays of the sun as totality ends

Tips for using a prime focus camera

- Set the focus on a bright star using a Bahtinov mask
- During the partial phase concentrate on using short exposures (<1/1000 sec) and low gain (ISO 200-800 for DSLRs, Gain 100-200 for ZWO cameras)
- Save your source images as RAW
- Use a remote switch, interval timer, or computer to trigger the shutter
- Take short series of 8-16 images each for stacking
- During the partial phase concentrate on taking images where the sunlit moon is not over-exposed
- You may want to experiment taking images that show the umbra while the penumbra is over-exposed
- As the eclipse approaches totality be prepared to use longer exposures and/or higher gain
- Learn how to use your mirror lock-up when using exposures that are longer than 1/250 sec and pause long enough to allow vibrations to settle

- Totality itself is fairly long, pace yourself, try different camera settings, and enjoy the view!
- The trickiest time is catching the last rays of the sun as totality begins, and the first rays of the sun as totality ends
- Visually these times are also quite beautiful, don’t forget to look!



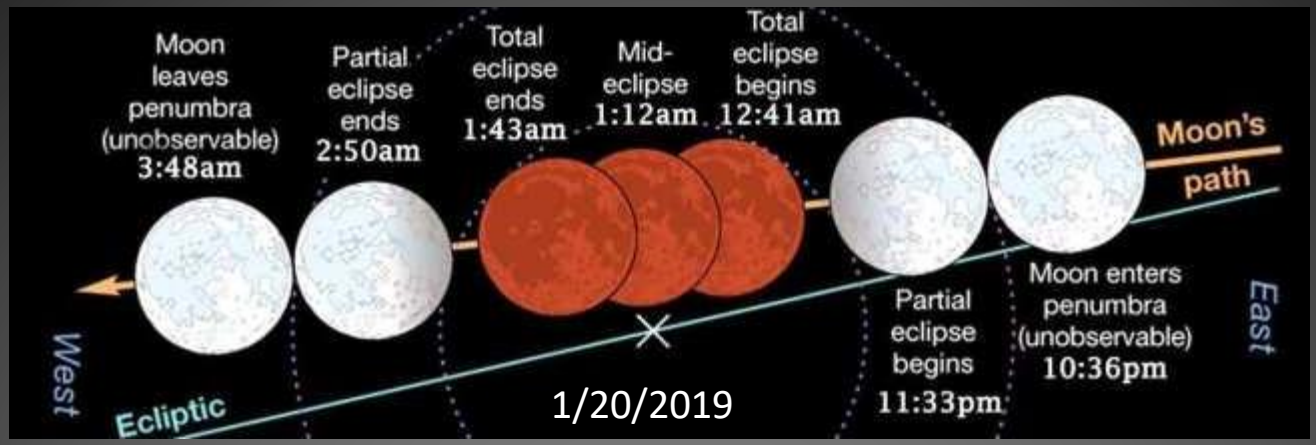
1/20/2019

When imaging the full moon check the histogram to make sure that none of the moon is saturated

Ideally, no part of the image should be over 90% full-scale (about 225 on the scale of 0-255)

If in doubt, err on the side of slightly under-exposing the moon, you can fix the brightness later in processing

1/20/2019, 10:30pm
Telescope: Meade SN8
Camera: ZWO ASI294MC (Uncooled)



1/20/2019

As the moon approaches the umbra the eastern limb will begin to darken with a soft amber hue

You may want to use slightly longer exposures to capture the darkening limb, but avoid over-exposing the sunlit moon

First contact with the umbra is fairly obvious visually, but more subtle photographically

1/20/2019, 11:35pm
Telescope: Meade SN8
Camera: ZWO ASI294MC (Uncooled)

9/27/2015 Telescope: Meade SN10 Camera: Stock Canon 550D

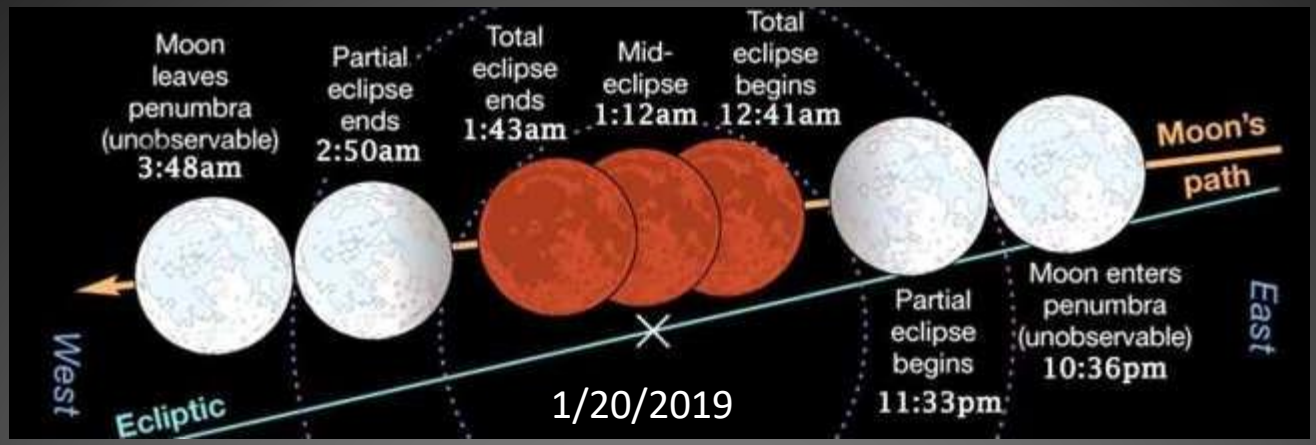
Things will start to pick up speed as totality approaches and you will want to capture the last sliver of sunlit moon against the amber glow of the umbra

I find the most beautiful part of the eclipse occurs as the last sliver of sunlight fades from the moon's western limb, and just begins to catch the eastern limb as totality ends

As the moon enters the umbra the moon will progressively darken and you will want to use steadily increasing exposures to balance the section of the moon in shadow with the moon remaining in sunlight

The trade-off is that higher gain allows shorter exposures, but the image may become noisy, lower gain gives a cleaner image, but long exposures may begin to blur

These are stacks of 16 frames each and if you look closely you can see stars that trailed during each sequence

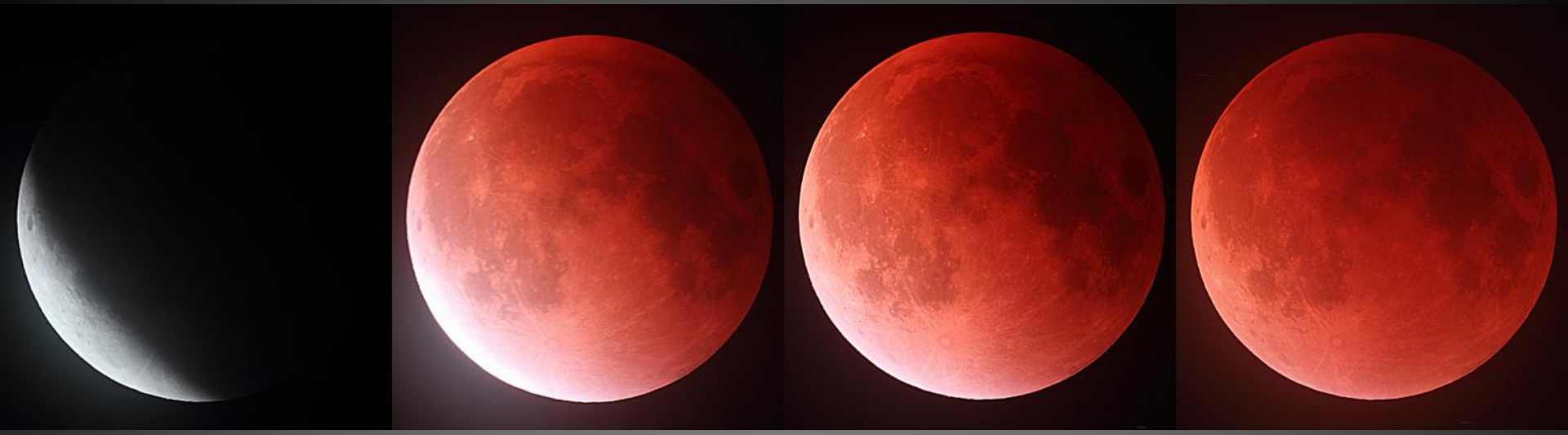


1/20/2019

During totality time seems to slow down and you will have time to take a series of images as the moon crosses the umbra

Note that the Earth's shadow may be uneven in color an brightness and the darkest part of the eclipse may not be at the mid point

1/20/2019, 1:22am
Telescope: Meade SN8
Camera: ZWO ASI294MC (Uncooled)



9/27/2015 Telescope: Meade SN10 Camera: Stock Canon 550D

- The pace picks up again as the moon approaches the eastern edge of the umbra
- The emergence of the moon's eastern limb into sunlight happens relatively quickly and is quite beautiful
- As the moon exits the shadow you will get this feeling that the main event is over

1/20/2019 Telescope: Meade SN8 Camera: ZWO ASI 294MC

- It’s worth hanging in there to capture the entire eclipse so that you can compose a balanced image of the event
- It’s also fun to compose an image that shows the size and shape of the Earth’s shadow.

Practice, Practice Practice...

The key to making viewing and imaging a total eclipse of the moon is to be relaxed, take your time, and enjoy the show

If you have not photographed a lunar eclipse before you can practice by imaging the moon as often as you can before the date of the eclipse

Imaging Earthshine is good practice for imaging the partial and total eclipse

Surprisingly, you can photograph Earthshine as late as the waxing and waning gibbous moon

Imaging the full moon allows you to practice imaging the brilliant full moon that will bracket the eclipse

If in doubt, set the camera aside, and enjoy the show!

Questions?