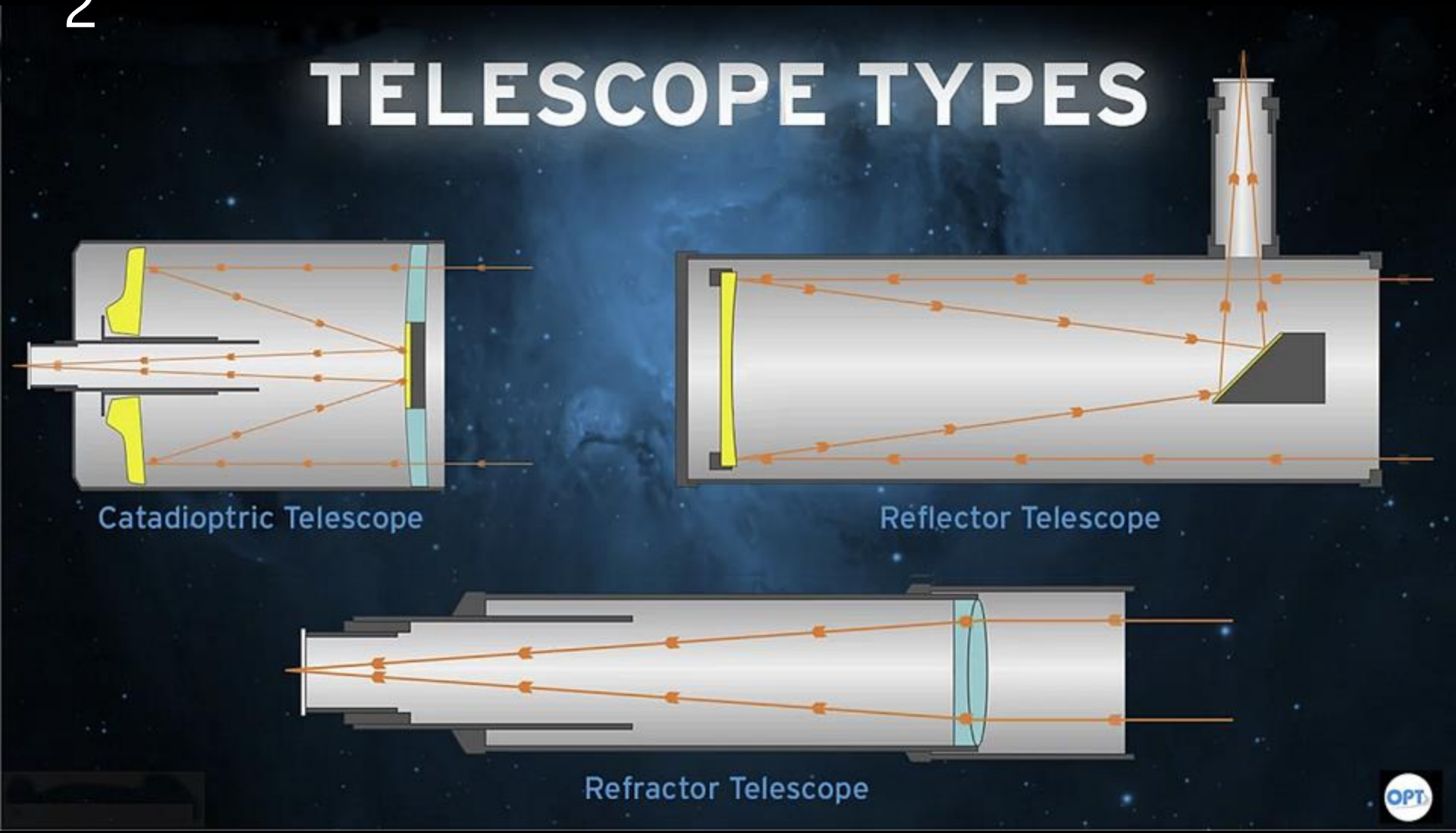
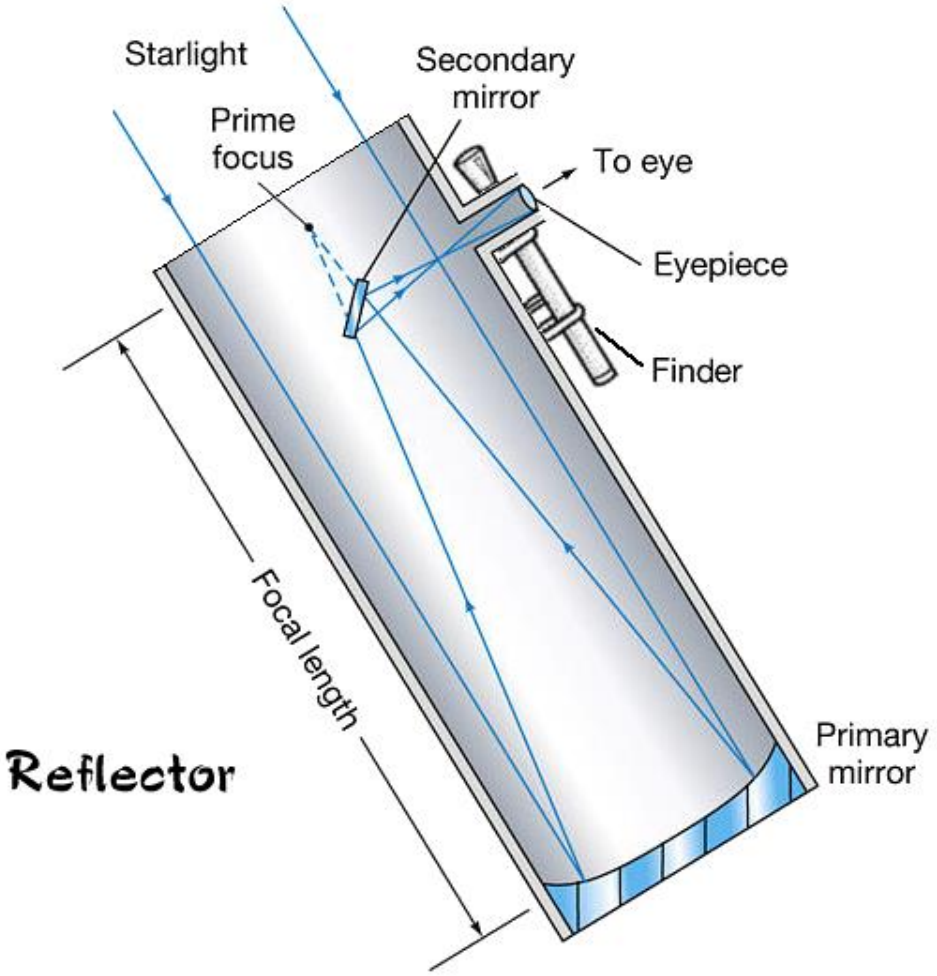
Instrumentation

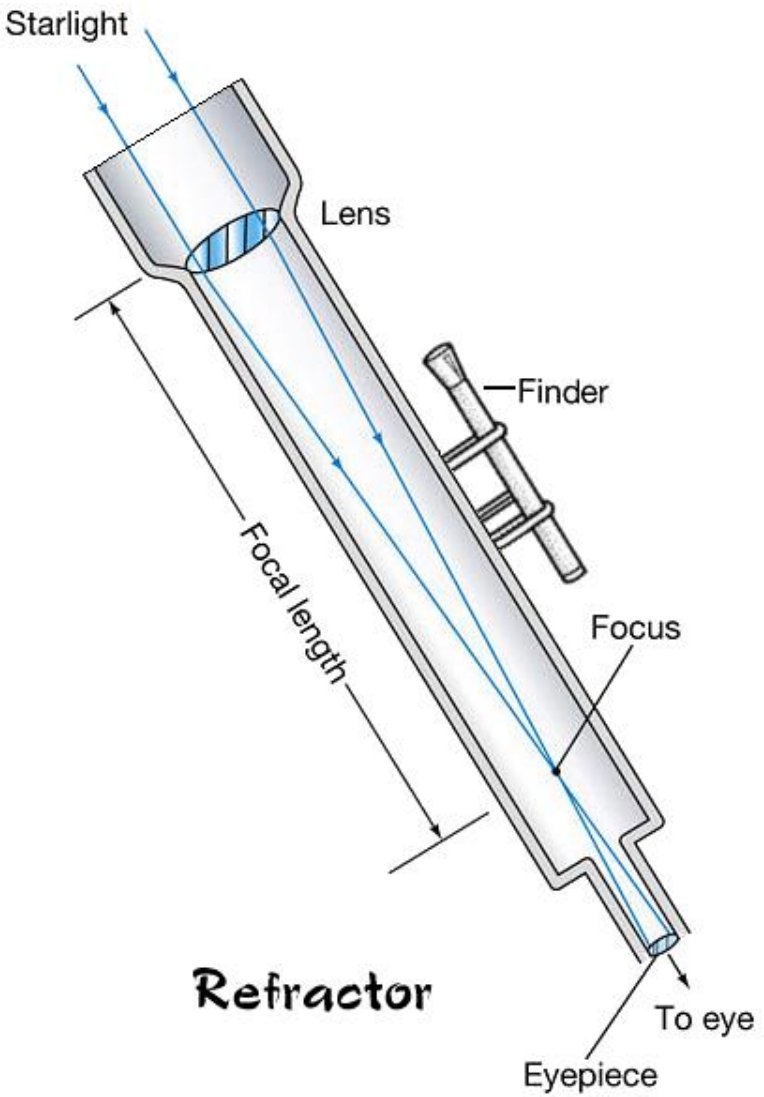
2


TELESCOPE TYPES
Catadioptric Telescope
Reflector Telescope
Refractor Telescope

Telescope Parts Illustrated



Reflector



Refractor

Make a Drawing Through a Telescope

5

PHOTOGRAPH OR DRAW A PICTURE THROUGH A TELESCOPE

(10 points)

Instructions: After constructing your drawing, create a jot list with respect to the problems that you have encountered using your telescope. **What frustrated you?** Many people have the misconception that when they look through a scope, the universe will be revealed to them with the clarity of an image taken through the Hubble Space Telescope. The truth is that with telescopes or binoculars, nothing comes easily. Making useful observations or taking good images of the night sky are not simple tasks. Describe six problems that you experienced while using your telescope, and don't be afraid to speak to others about these difficulties (4 points).

1. **Mounting system of the telescope was nonexistent. Image moved because of the inability to hold the telescope steady making detail difficult to see.**
2. **Finding the object to draw or photograph was difficult.**
3. **The field of view was too small for a handheld telescope.**
4. **Color in the objects being viewed after dark became difficult to discern.**
5. **Image was inverted and perverted making it difficult to move the object to the center of the field of view.**
6. **Focusing was difficult and the tube motions (pull/push) which enabled focusing were uneven, making the best focus location hard to obtain.**
7. **Each observer required a unique focusing position.**
8. **Almost impossible to center and to focus a smart phone to capture an image.**
9. **Internal glare was annoying and created additional difficulty in viewing the object.**
10. **The best focus positions still showed an image had focus issues.**
11. **The magnification was too low. Objects were smaller in the eyepiece than expected.**
12. **Telescope was hard to balance.**
13. **Because the telescope was light in weight, wind gusts moved the telescope and this was an additional factor in losing the image.**
14. **Part of the telescope (eyepiece) became detached.**
15. **Weather conditions were cold and windy adding to the difficulty of manipulating the telescope.**
16. **Images were difficult to draw because of the nighttime conditions.**
17. **Glasses kept fogging up.**

Gary A. Becker

6

PHOTOGRAPH OR DRAW A PICTURE THROUGH A TELESCOPE

(10 points)

Instructions: Based upon the problems that you have experienced observing through your telescope to make your drawing, state four ways in which you would improve the telescope that you were using. How would you make your telescope better? (3 points)

1. **The telescope needs some type of a stand or a tripod.**
2. **Put an erector eyepiece in the telescope so that magnified objects viewed are positioned in the same way that they are seen from afar.**
3. **Provide a more precise focuser to adjust the image.**
4. **Provide an eyepiece of higher quality and lower magnification.**
5. **Provide an eyepiece of higher quality and higher magnification.**
6. **Provide a screw with the eyepiece to stabilize it when the best focus was achieved.**
7. **Incorporate a zoom eyepiece to make detail more easily seen.**
8. **Make the telescope heavier to increase its stability especially in windy situations.**
9. **Baffle the telescope to reduce or prevent internal reflections (glare).**
10. **Provide a devise for imaging through the telescope.**
11. **Incorporate a nightlight on the telescope to make it easier to see as well as complete sketches and photos.**
12. **The telescope needs a better finder to locate objects.**

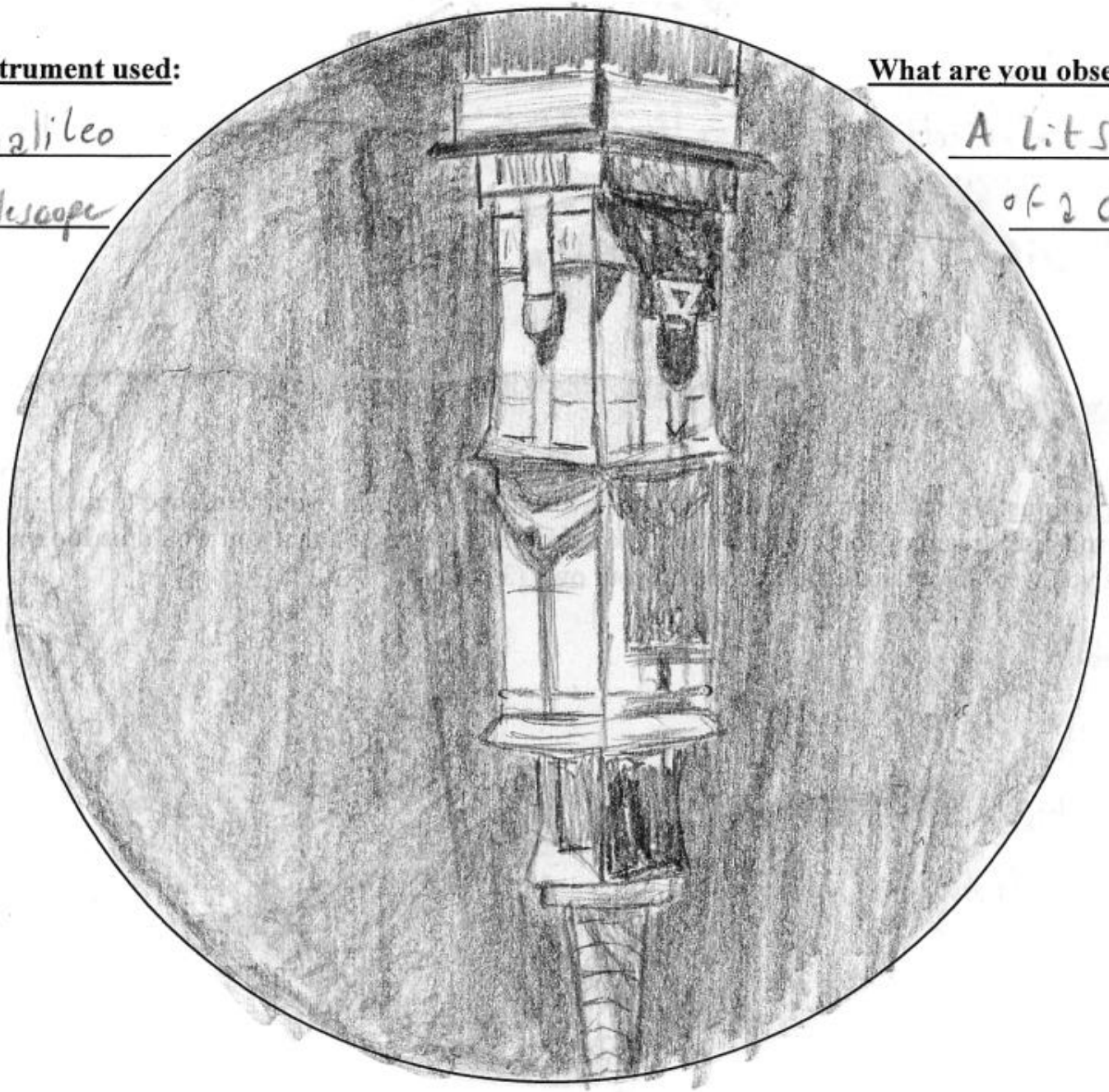
7

Instrument used:

Galileo Telescope

What are you observing?

A lit staple of a church



Hannah Stevens, Spring 2014

8

Instrument used:

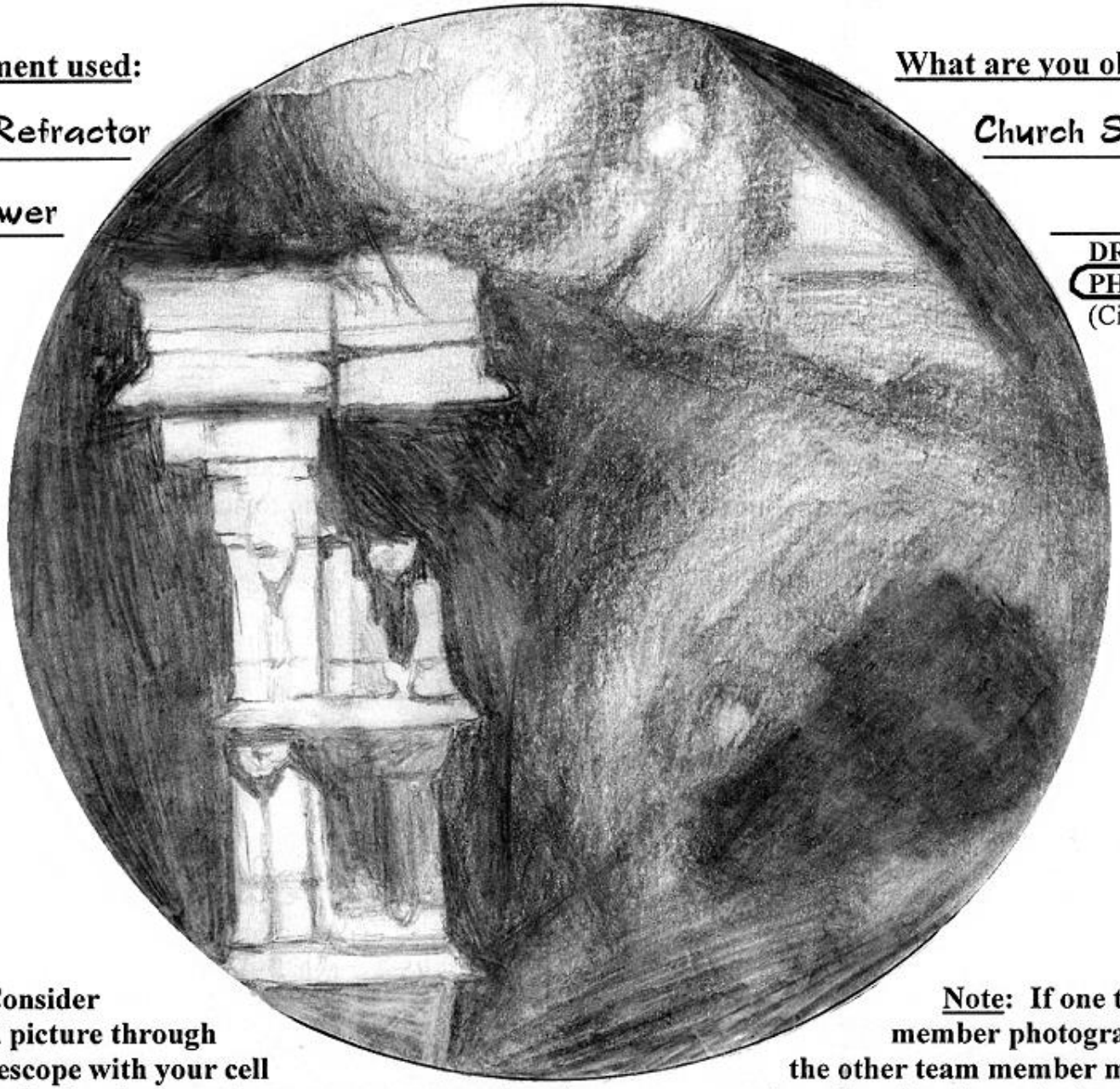
Galileo Refractor

25 Power

What are you observing?

Church Steeple

DRAWING
PHOTO
(Circle One)



Hint: Consider taking a picture through your telescope with your cell phone and using it to render a more accurate drawing.

Note: If one team member photographs, the other team member must make a drawing through the scope.

Kimberly A. Leamon, Fall 2014

9

Instrument used:

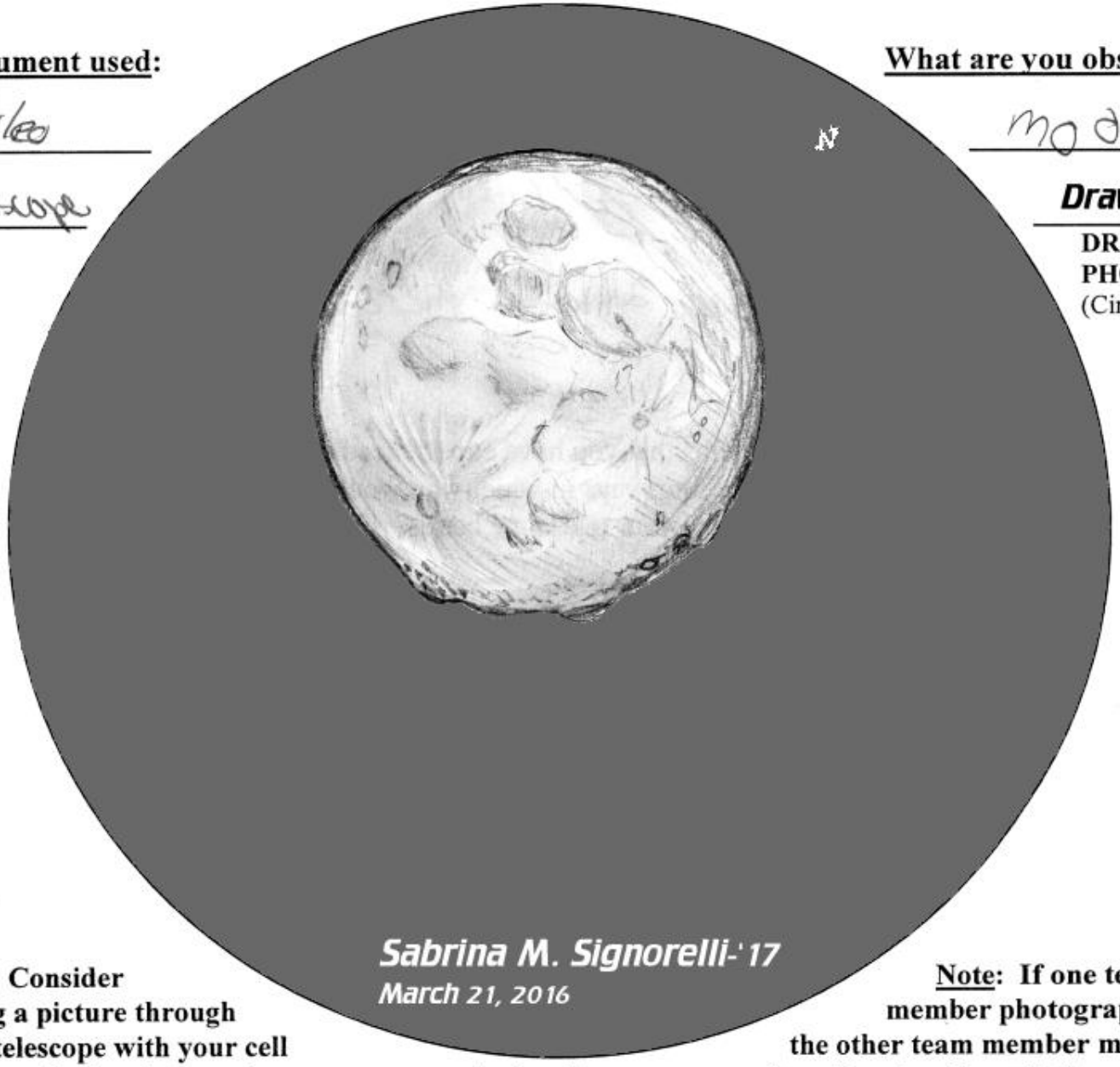
Galileo telescope

What are you observing?

moon

Drawing

DRAWING
PHOTO
(Circle One)



Hint: Consider taking a picture through your telescope with your cell phone and using it to render a more accurate drawing.

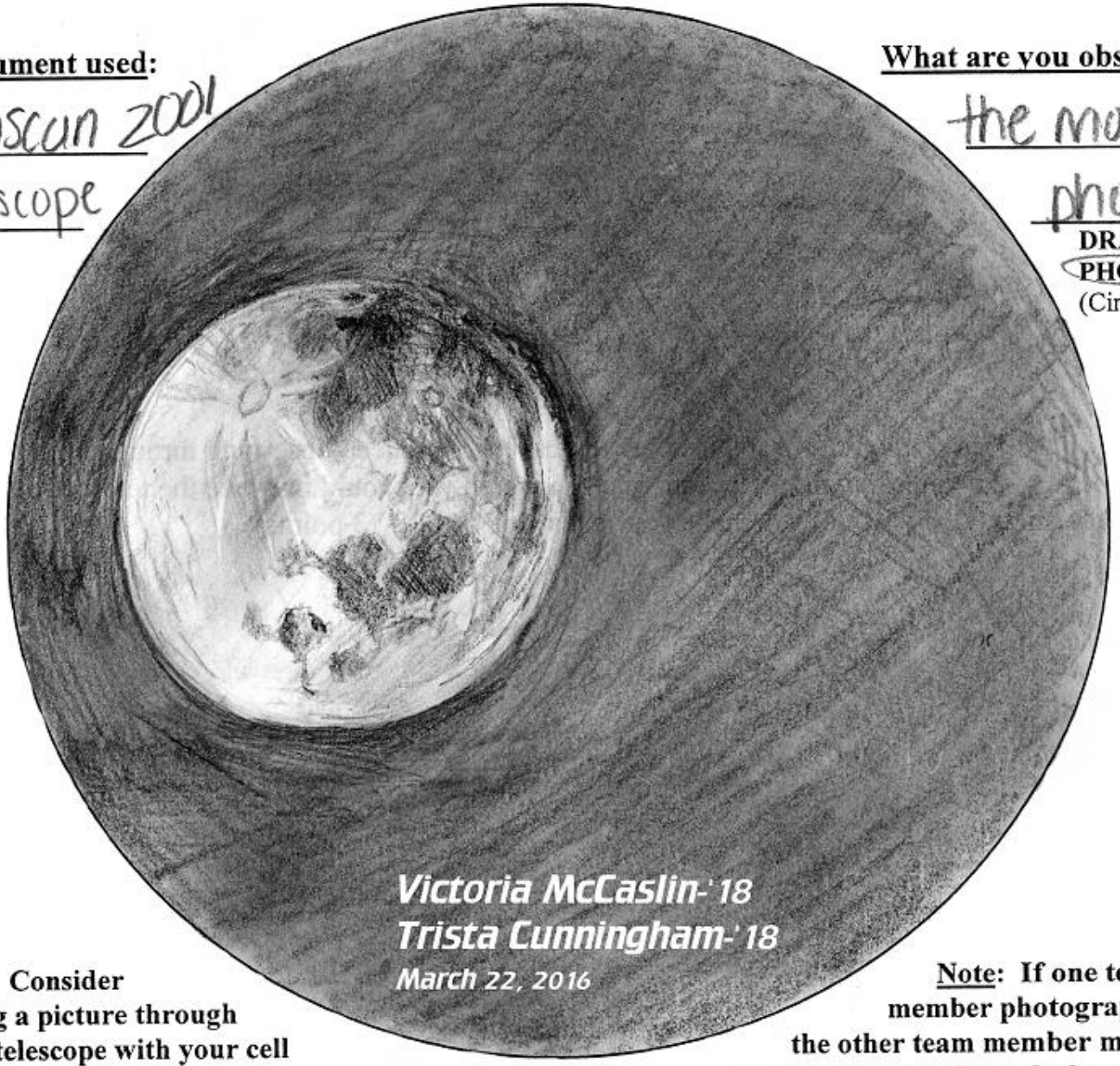
Note: If one team member photographs, the other team member must make a drawing through the scope.

10

Instrument used: Astroscan 2001 telescope

What are you observing? the moon photo

DRAWING
PHOTO
(Circle One)



Victoria McCaslin-'18
Trista Cunningham-'18
March 22, 2016

Hint: Consider taking a picture through your telescope with your cell phone and using it to render a more accurate drawing.

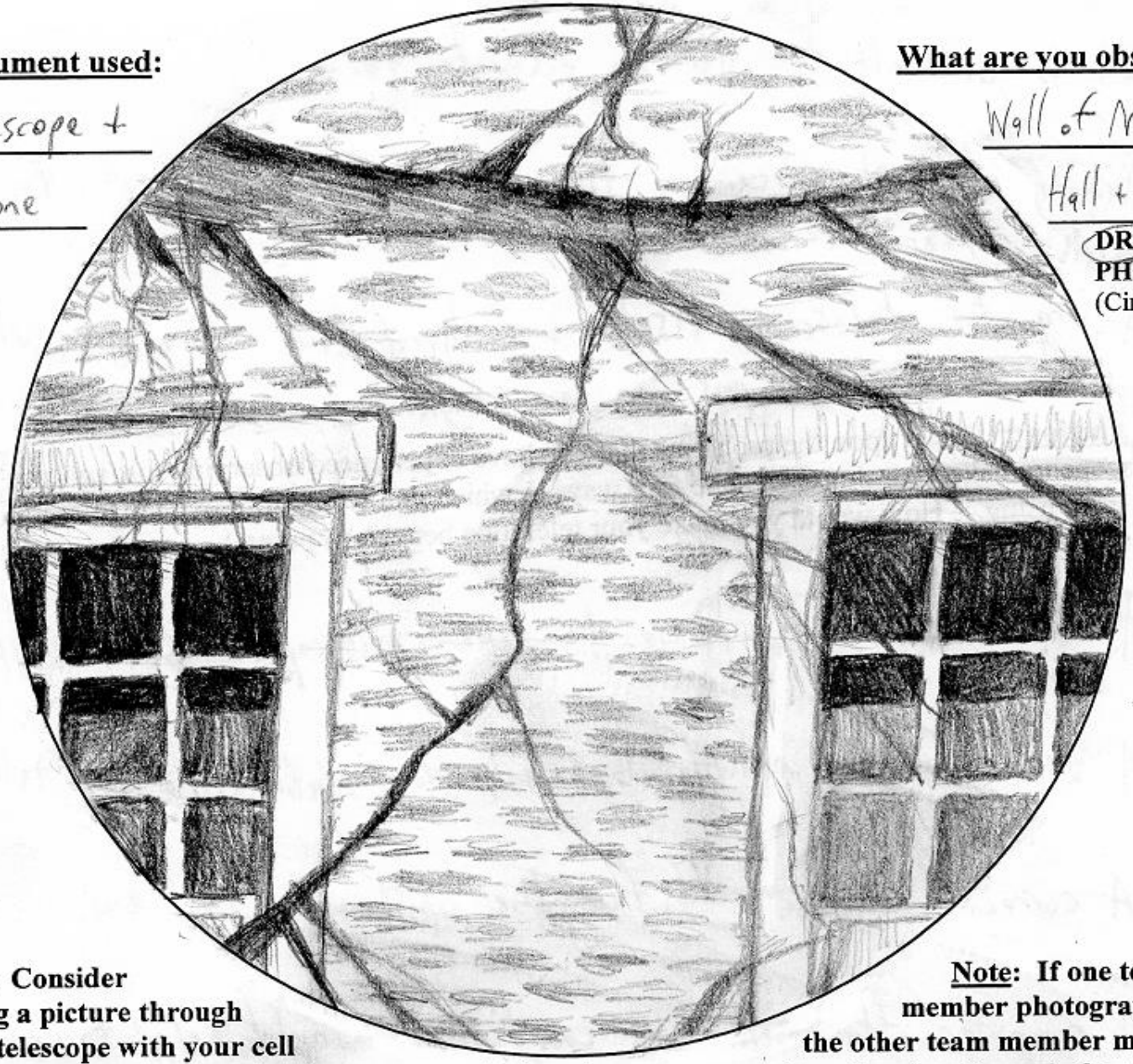
Note: If one team member photographs, the other team member must make a drawing through the scope.

11

Instrument used: Telescope + iPhone

What are you observing? Wall of Memorial Hall + Branches

DRAWING / **PHOTO** (Circle One)



Hint: Consider taking a picture through your telescope with your cell phone and using it to render a more accurate drawing.

Note: If one team member photographs, the other team member must make a drawing through the scope.

Beth Thomas-2020

Instrument used:

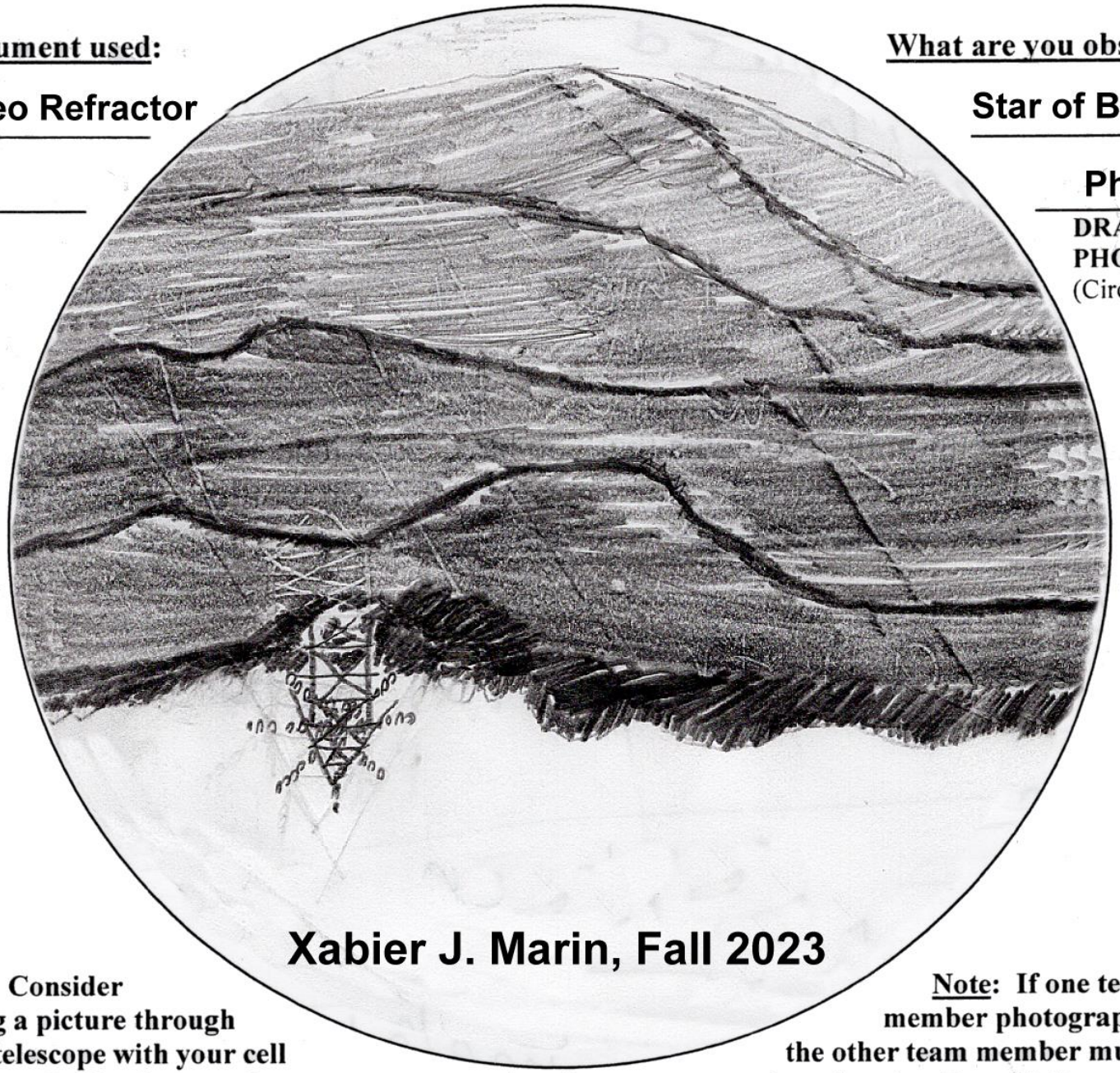
Galileo Refractor

What are you observing?

Star of Bethlehem

Photo

DRAWING
PHOTO
(Circle One)



Xabier J. Marin, Fall 2023

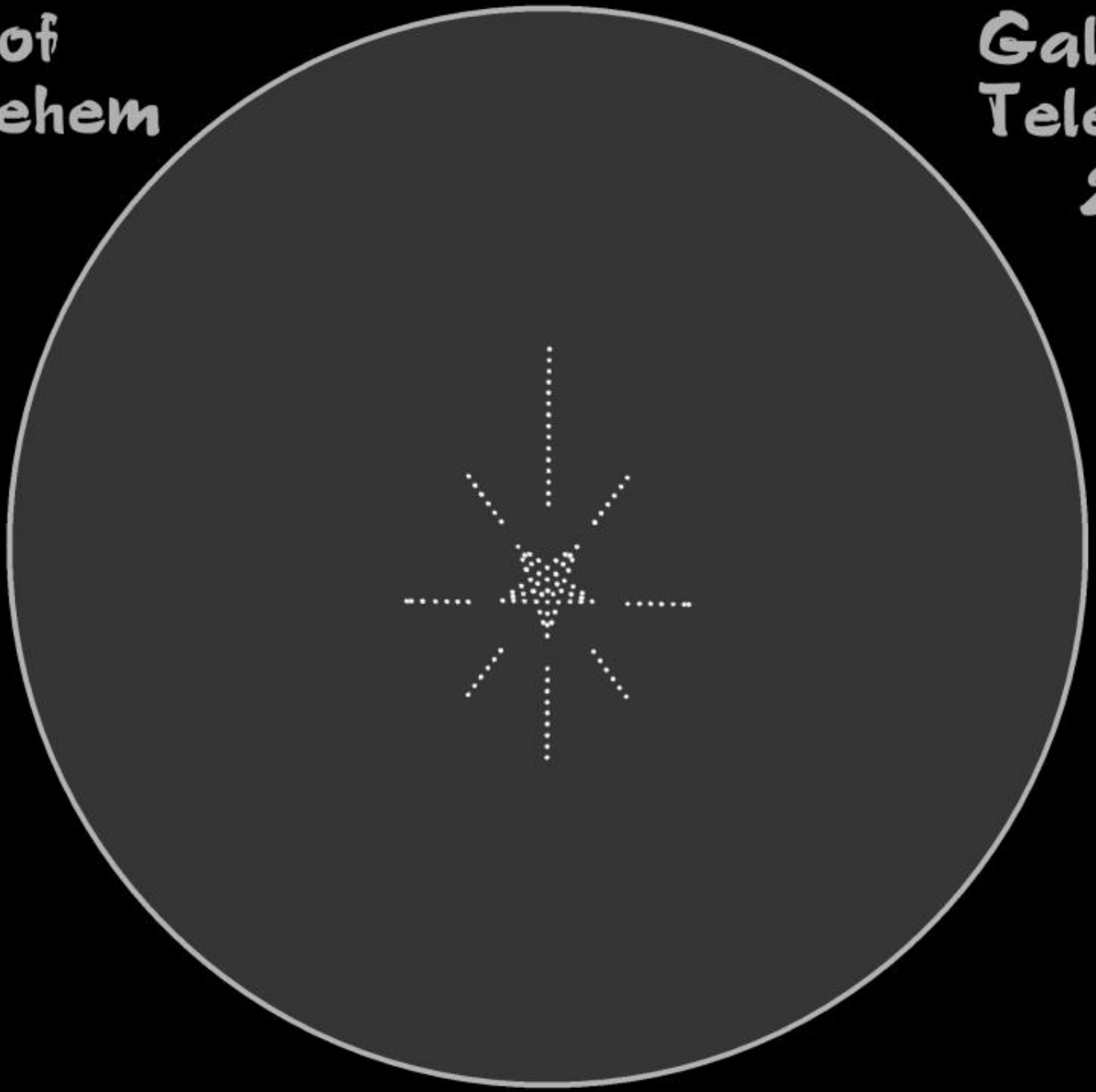
Hint: Consider taking a picture through your telescope with your cell phone and using it to render a more accurate drawing.

Note: If one team member photographs, the other team member must make a drawing through the scope.

Star of Bethlehem

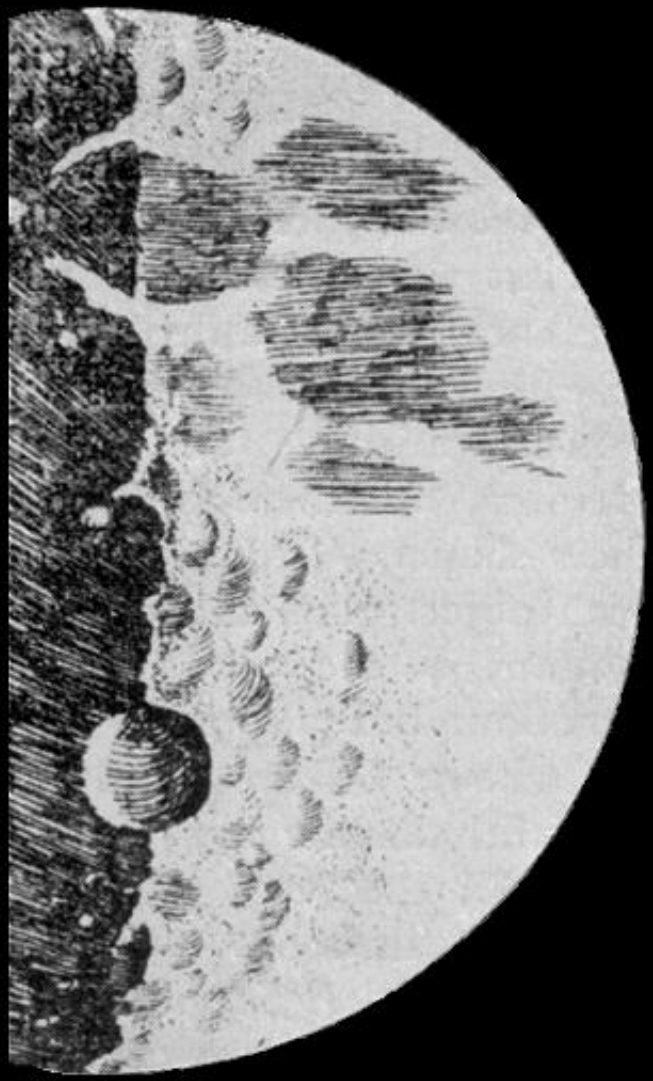
13

Galileo Telescope 25x



Gary A. Becker image

Galileo Galilei



Gary A. Becker

Gary A. Becker image right

15

Gary A. Becker image

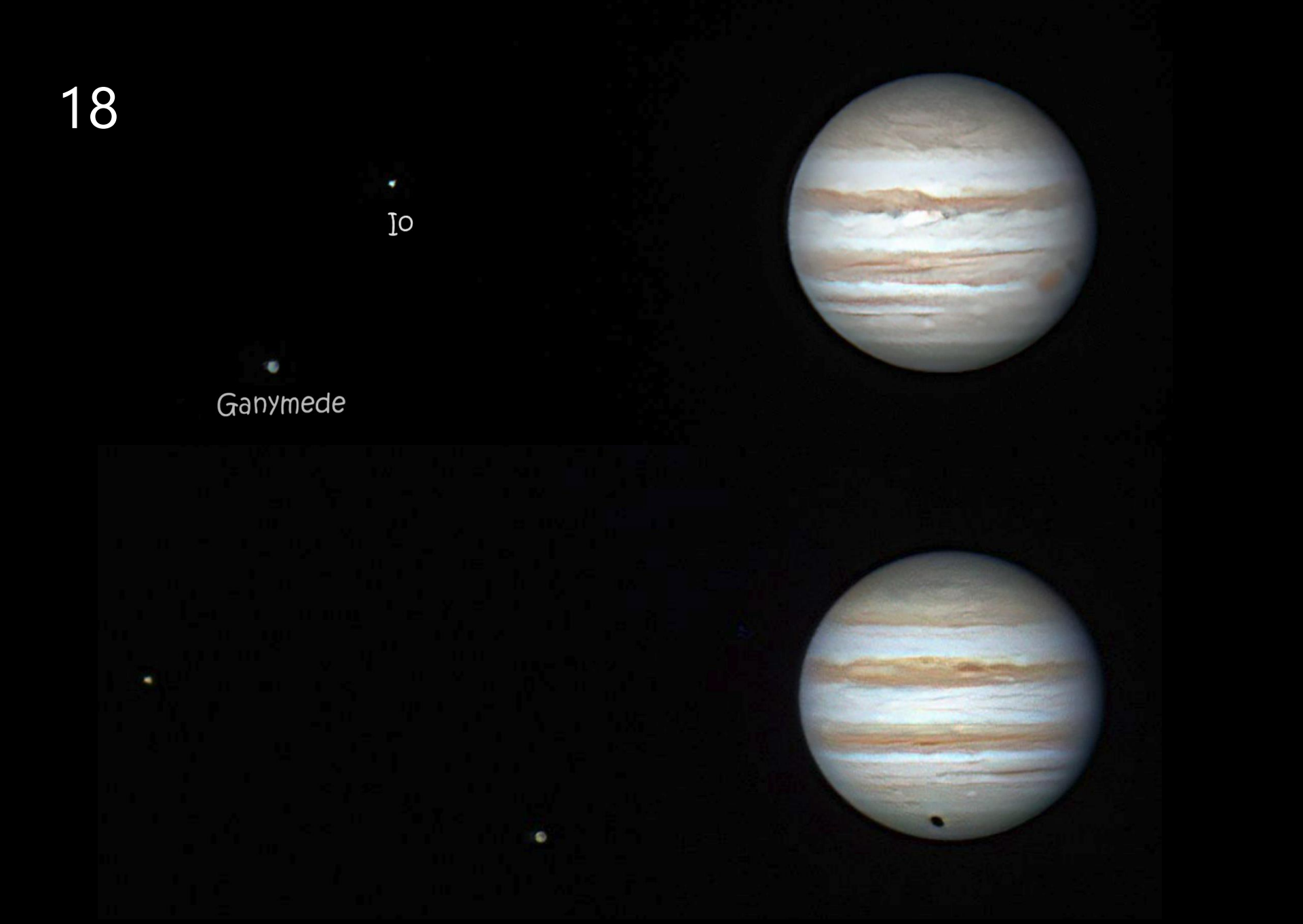
16

Gary A. Becker image

What Planets?

Peter K. Detterline images

18



Peter K. Detterline images

Could this be the…

Star Clusters

Globular
Star Clusters

Open
Star Clusters

21

Double Cluster in Perseus

Open or Globular

Related to each other/11 million yo

Gary A. Becker image

22

M39 in Cygnus

Gary A. Becker image

23

M13 in Hercules

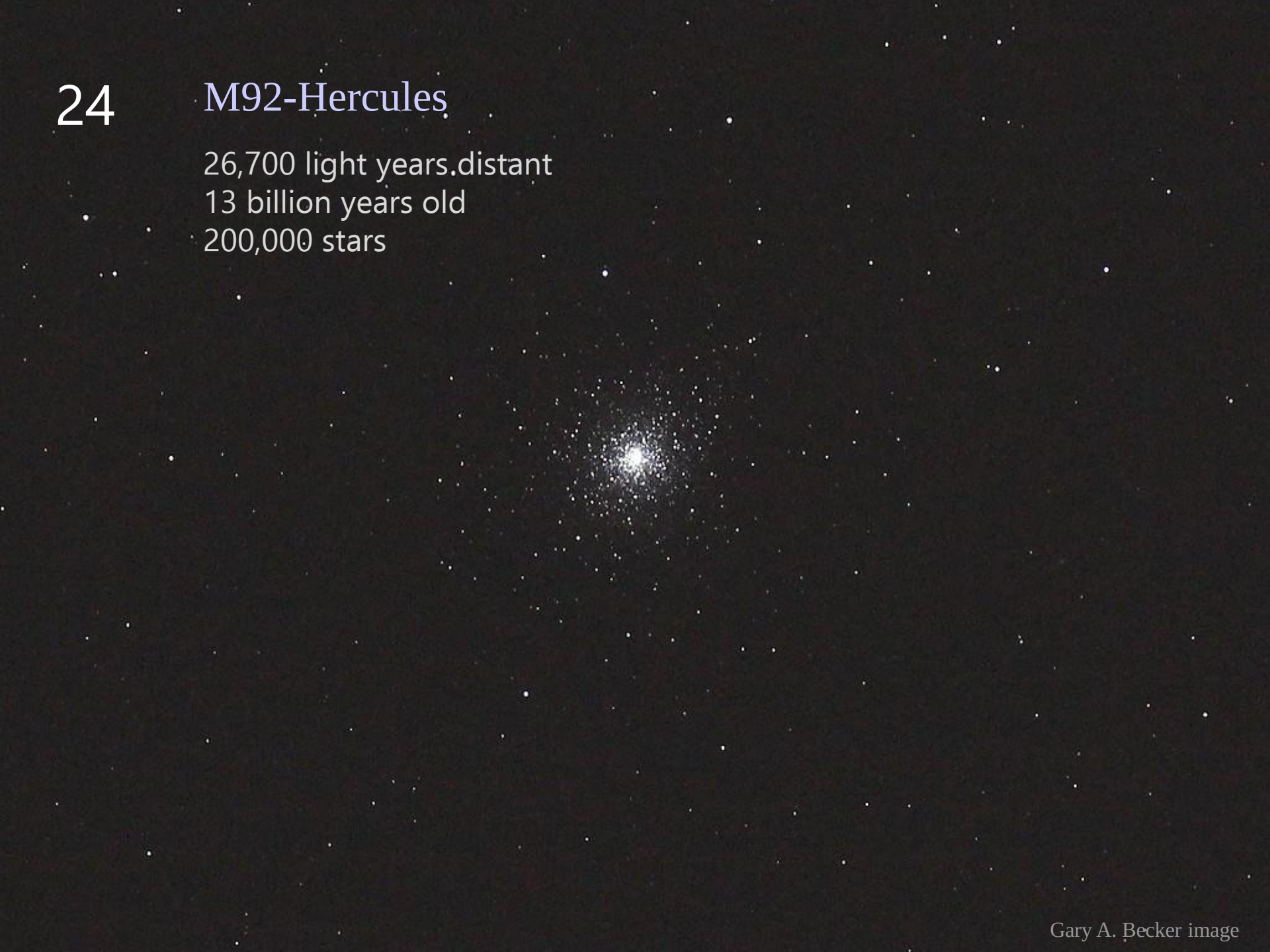
22,200 light years distant
11.6 billion years old
300,000 to 500,000 stars

Dave Moll and Moravian College Students

24

M92-Hercules

26,700 light years.distant
13 billion years old
200,000 stars



Gary A. Becker image

Galaxies

System of millions or billions of stars held together by the gravitational attraction between gas and dust

Spiral

Elliptical

Irregular

https://www.learnthesky.com/

What does the Milky Way Galaxy look like?

Gary A. Becker image

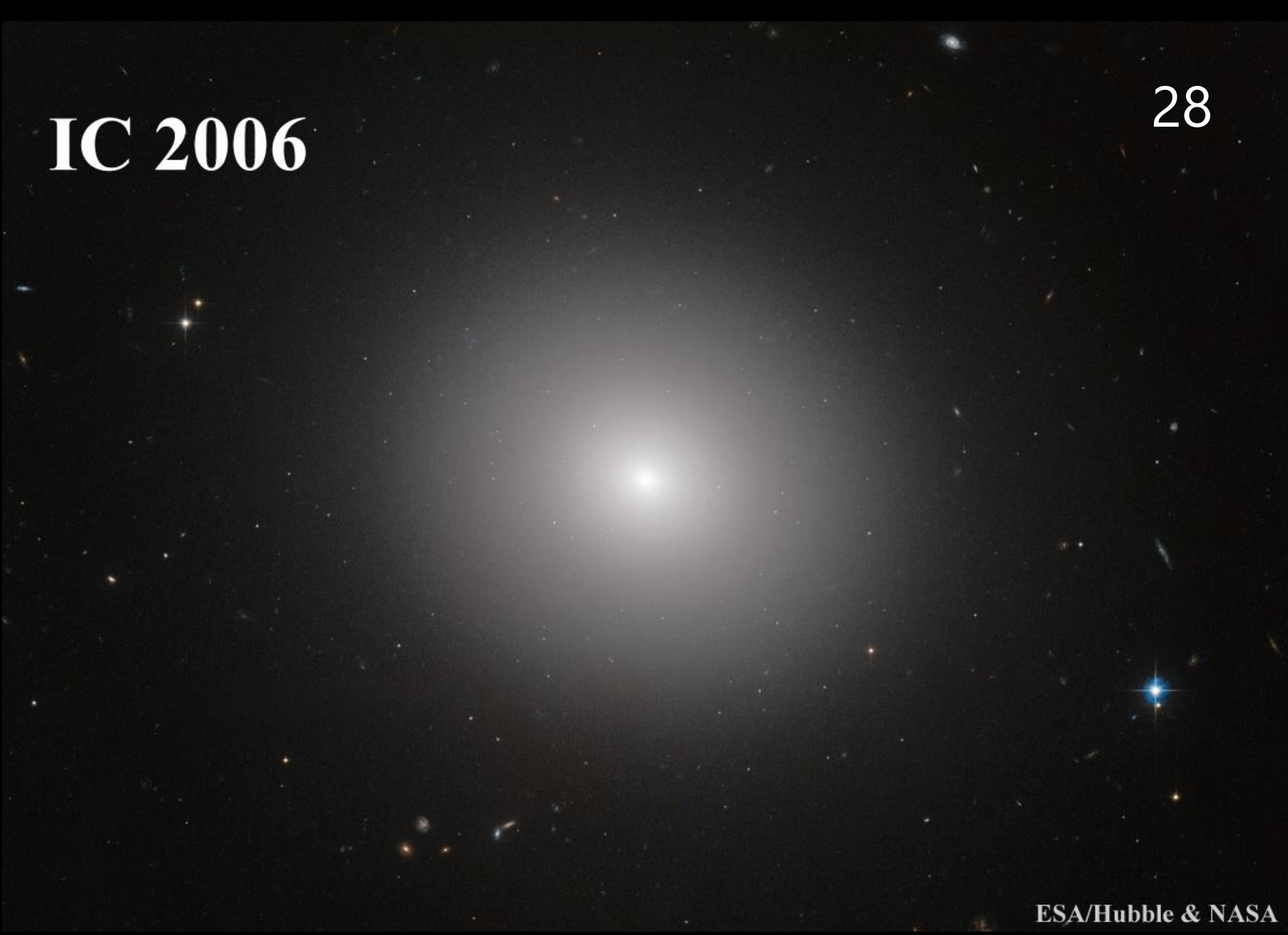
27

M104-Sombrero

Distance: 28 million light-years away in Virgo
Mass: 800 billion suns
One of the most massive objects in the Virgo galaxy cluster.

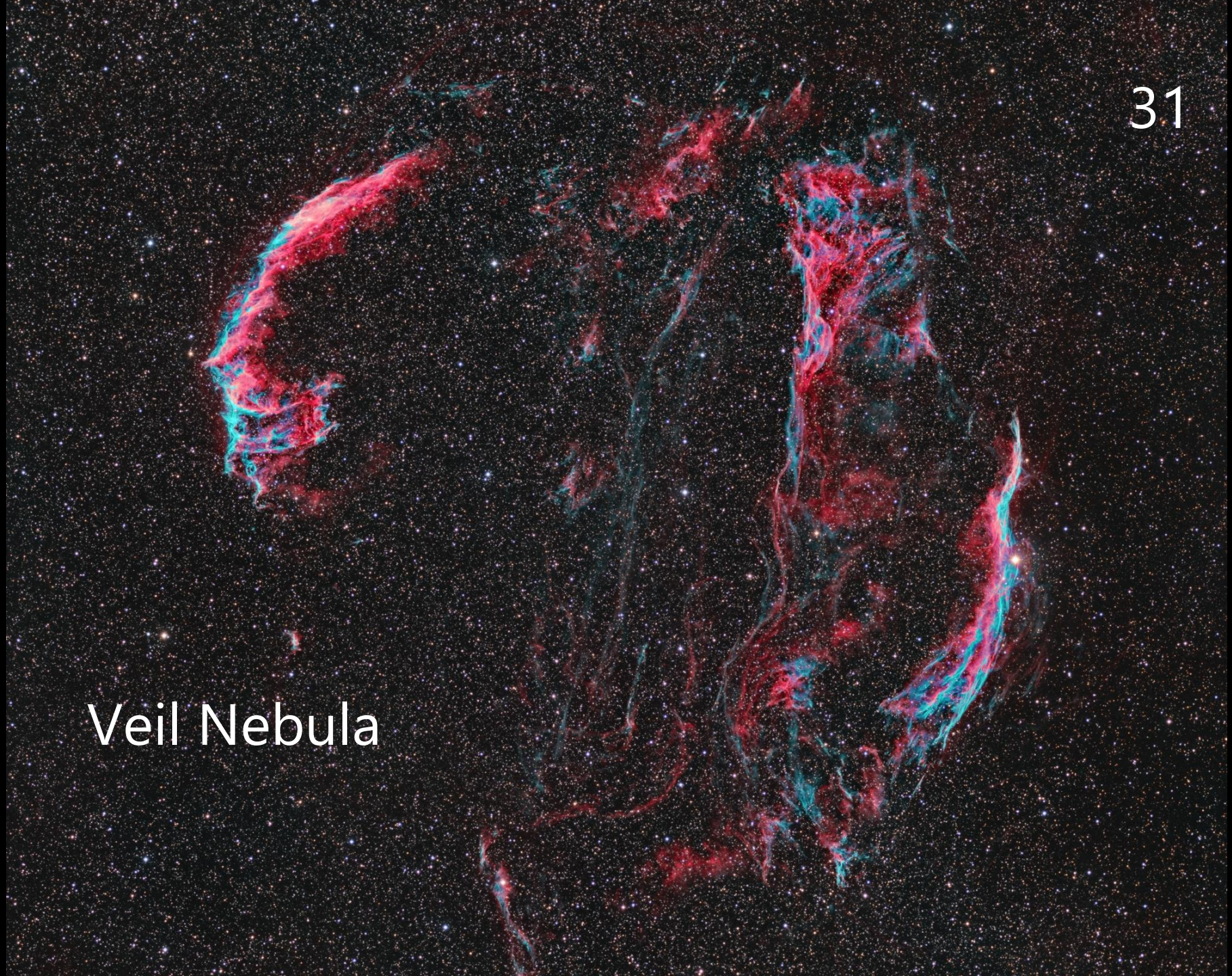
Hubble Space Telescope

IC 2006




NGC 4449
Hubble Space Telescope

What's Happening Here?



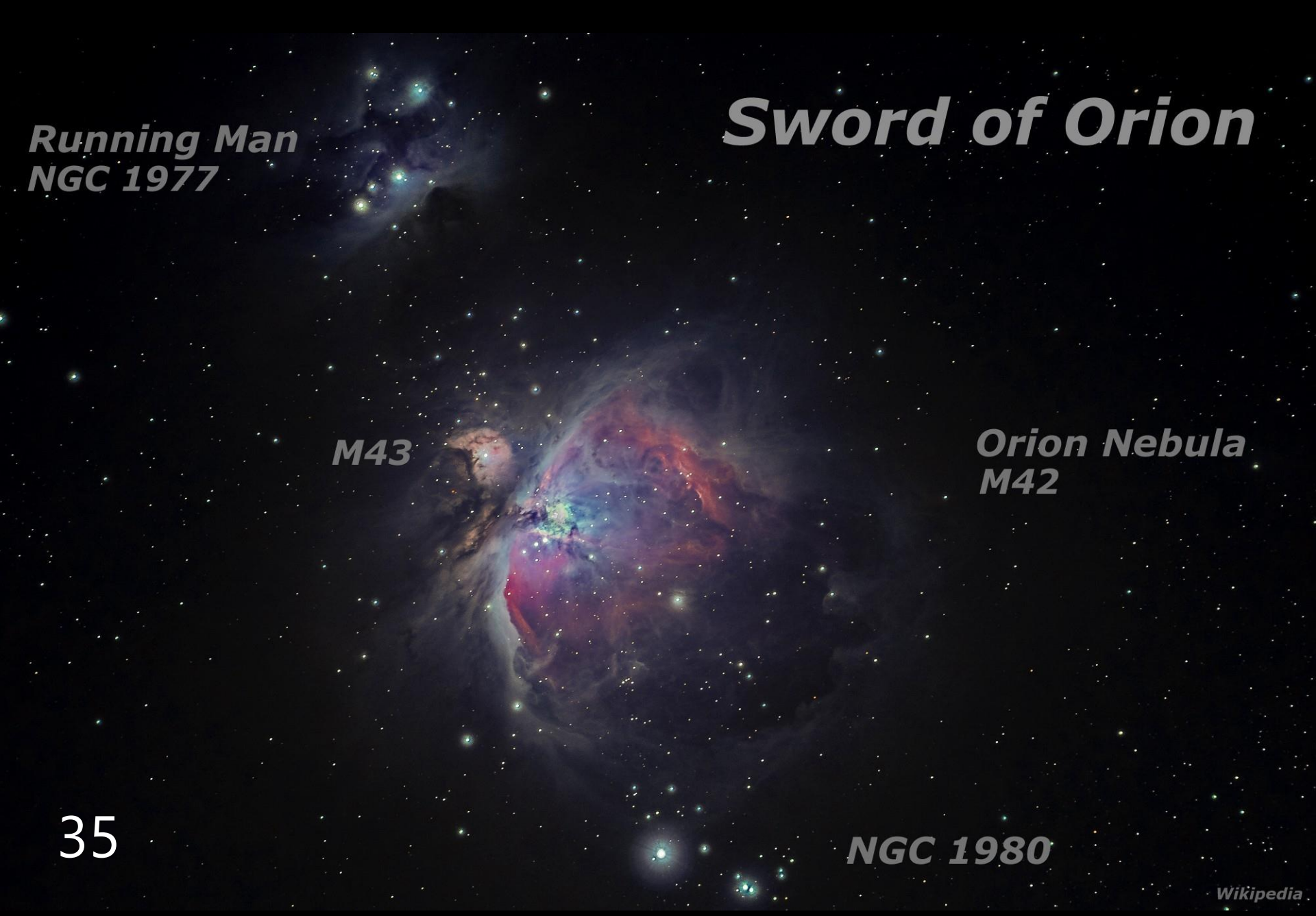
Veil Nebula

Western Portion of Veil

What State Nebula?

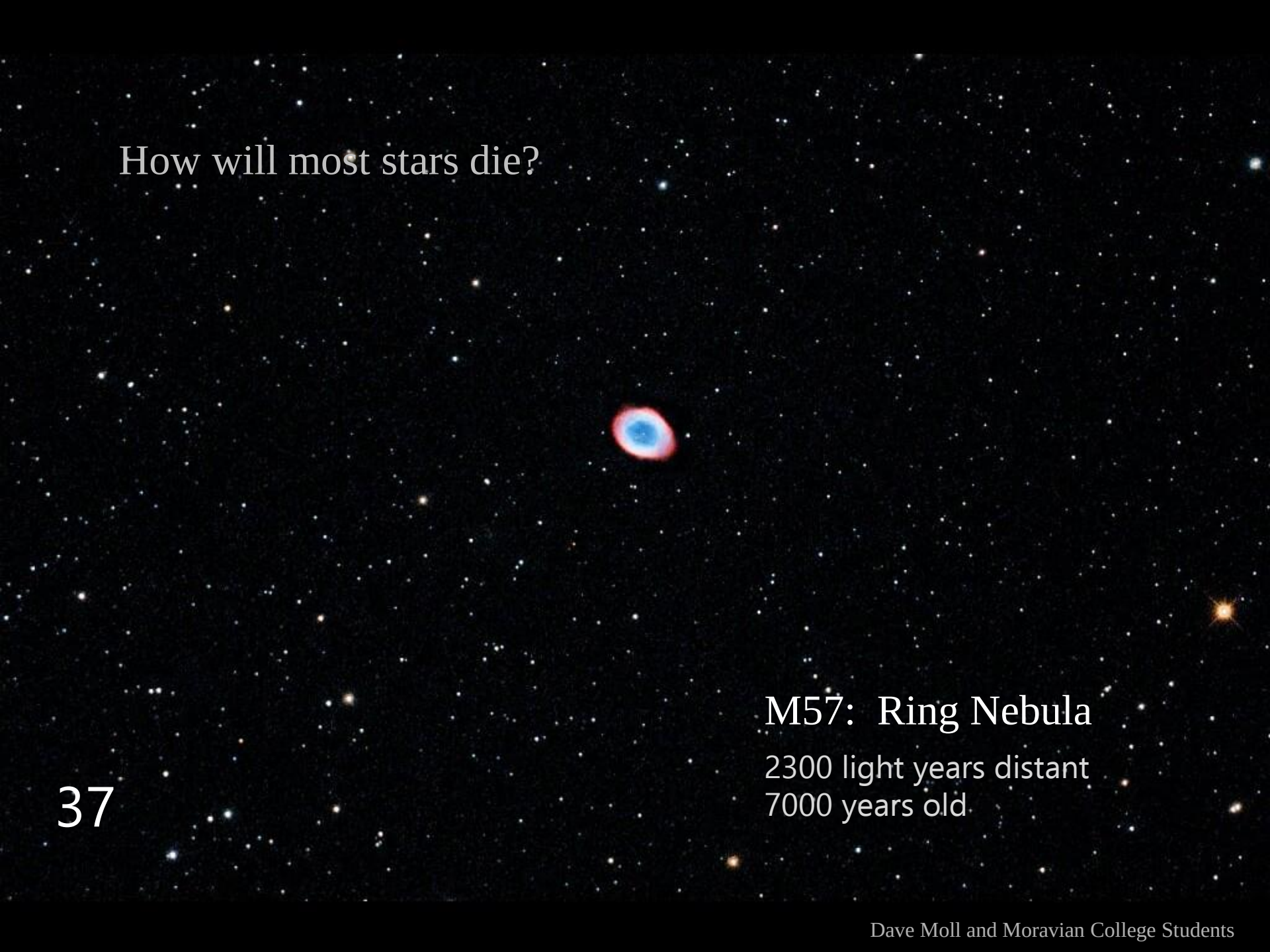
M16-Pillars of Creation

Hubble Space Telescope James Webb Space Telescope


Sword of Orion
Running Man
NGC 1977
M43
Orion Nebula
M42
NGC 1980
Wikipedia

Dumbbell Nebula, M27

How will most stars die?



M57: Ring Nebula

2300 light years distant
7000 years old

Drawings of the Ring Nebula-M57

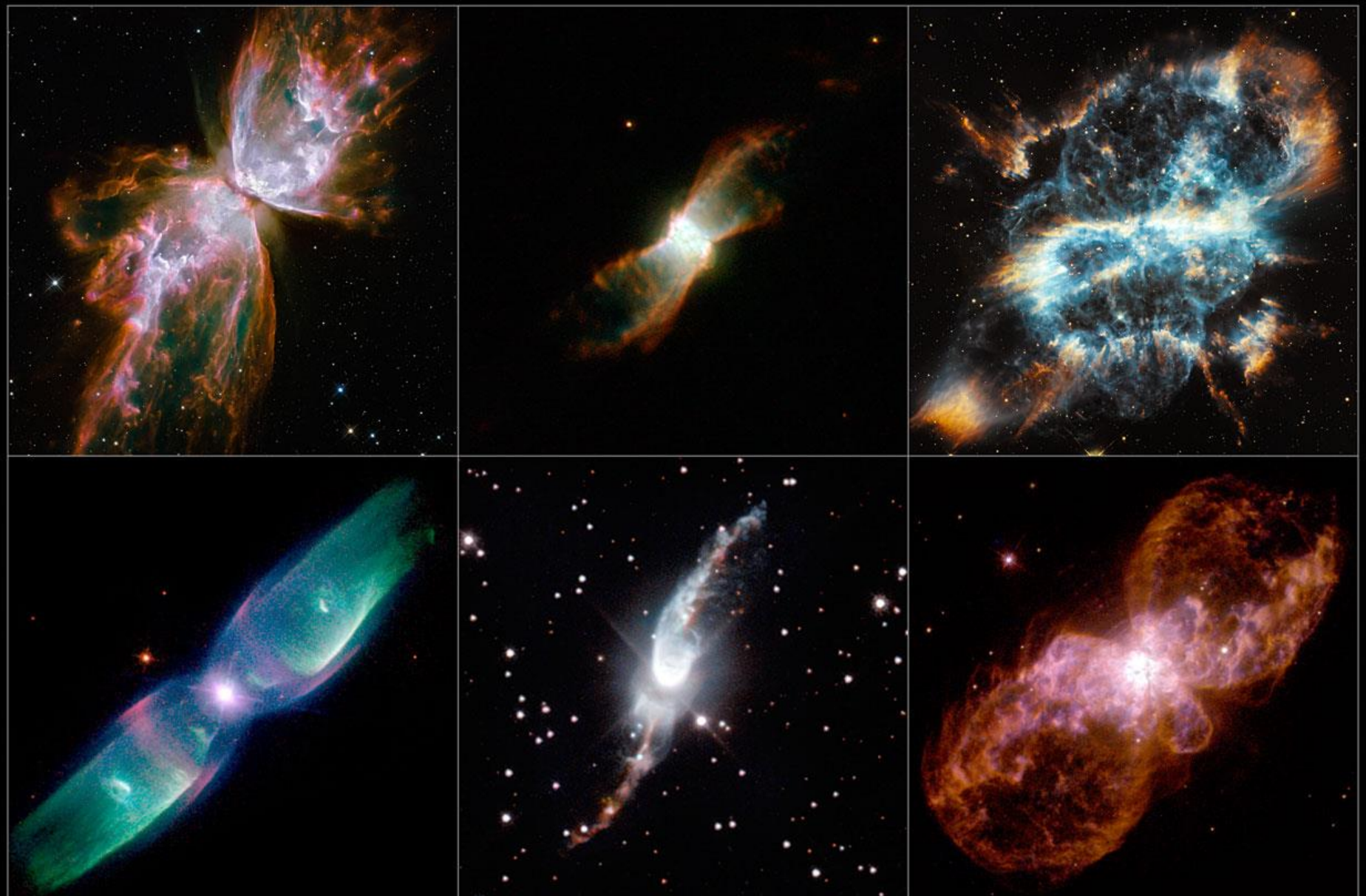
Bert Schwertman

Date: 20/06/2014
Object name: Ring Nebula, M57
Object type: planetary nebula
Location: Ferrara, Italy
Media: HB pencil, photoshop
Silvia

Eskimo

Hubble Space Telescope

Planetary Nebulae Come in All Shapes



41

Gijs de Reijke (left), unknown (right)

Ursa Major's Alcor and Mizar

A Visual Double Star

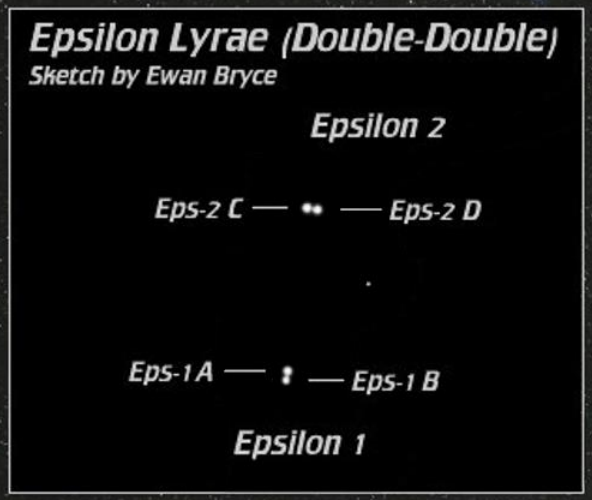
42

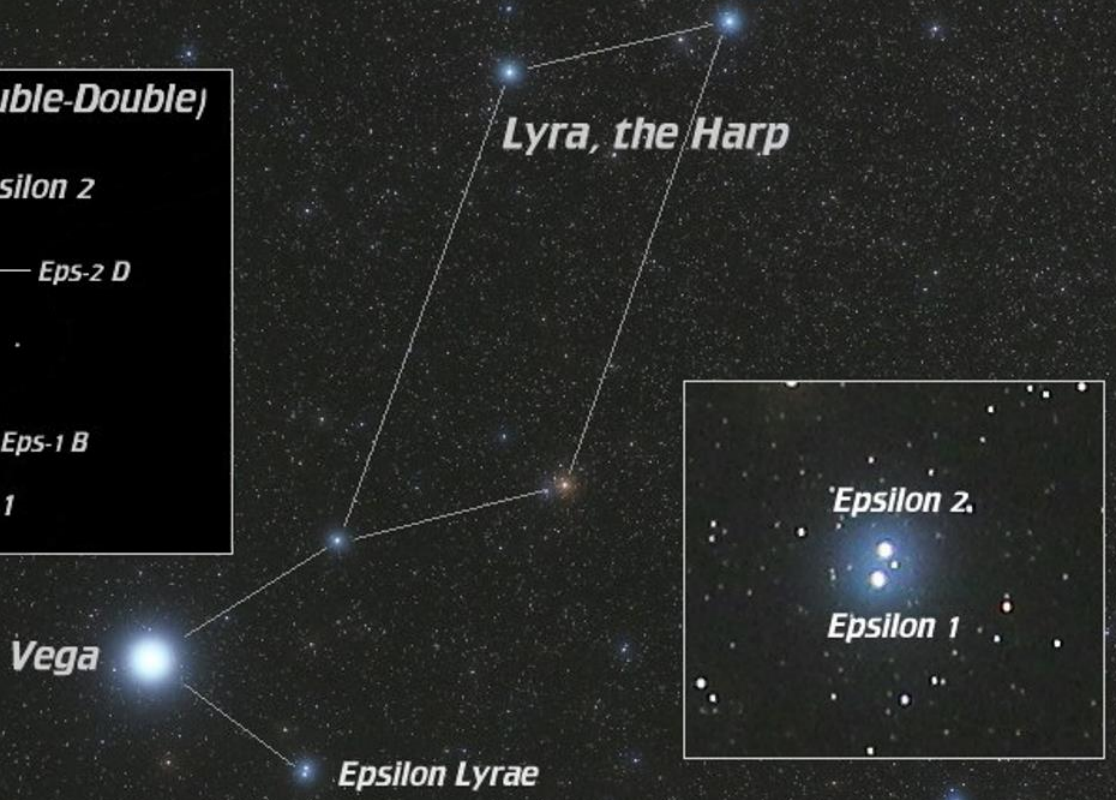
Gary A. Becker image

Alcor and Mizar-Ursa Major

Gary A. Becker image

Epsilon Lyrae: The Double-Double





All are fast spinners	Epsilon-1 A	Epsilon-1 B	Epsilon-2 C	Epsilon-2 D
Apparent Magnitude	+5.1	+6.0	+5.1	+5.4
Spectral Class	A_3	A_7	A_5	A_5
Temperatures	8000 K	7700 K	8200 K	8200 K
Luminosities (Sun = 1)	18	8	17	14
Mass (Sun = 1)	1.9	1.5	1.9	1.8

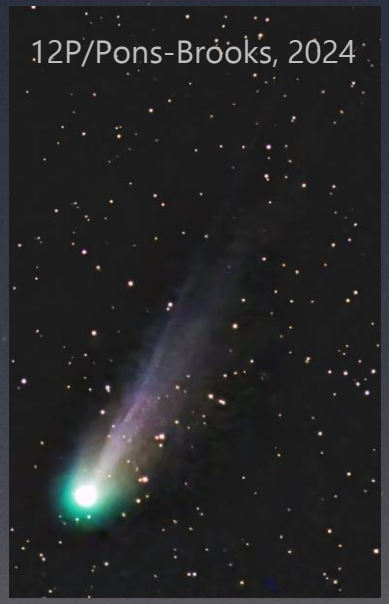
Gary A. Becker image

46

Comet ATLAS
October 21, 2024

Gary A. Becker image

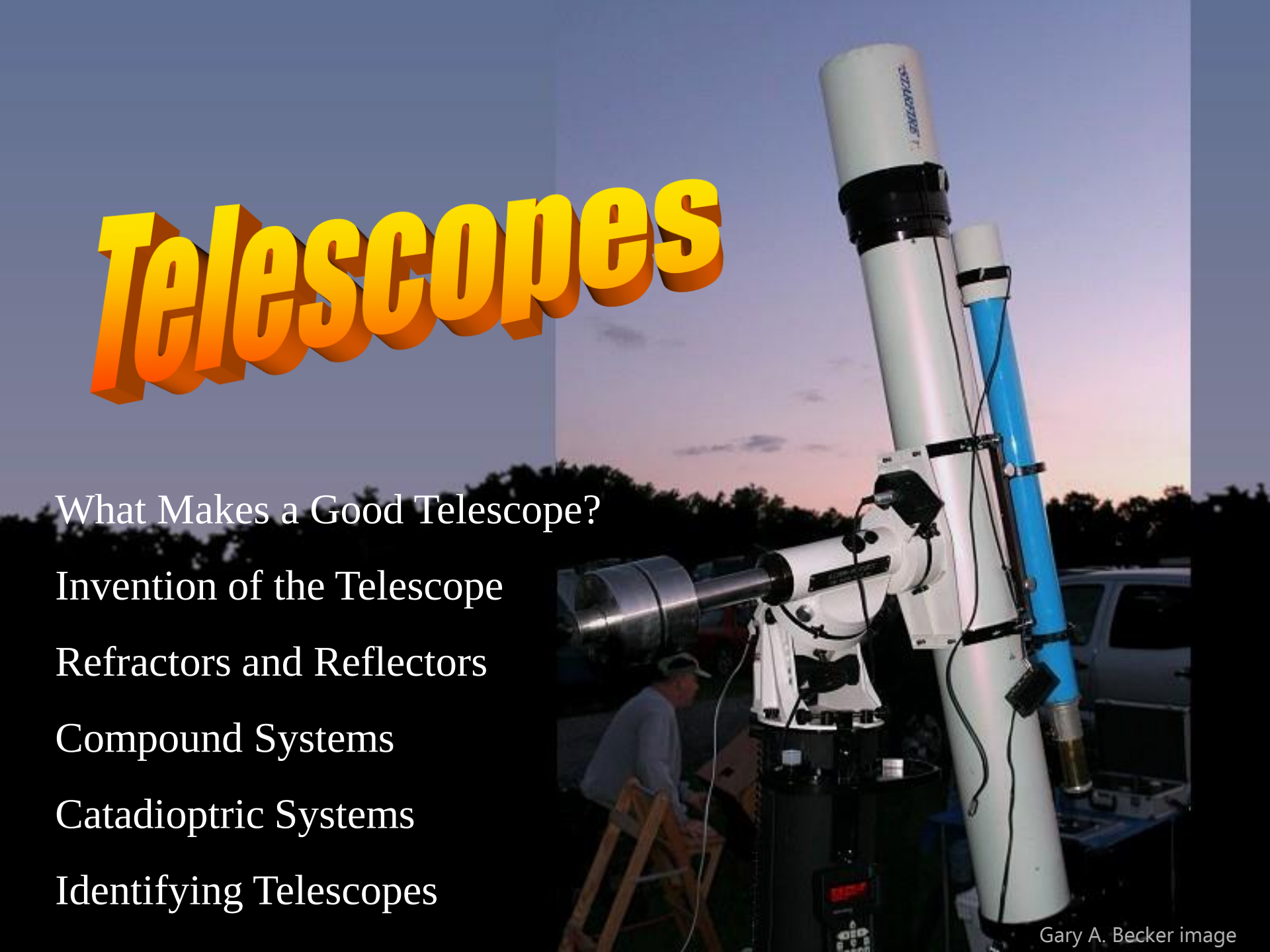
47



Neowise, July 2020

Peter K. Detterline images

Telescopes



What Makes a Good Telescope?

Invention of the Telescope

Refractors and Reflectors

Compound Systems

Catadioptric Systems

Identifying Telescopes

Gary A. Becker image

What Makes a Good Telescope?

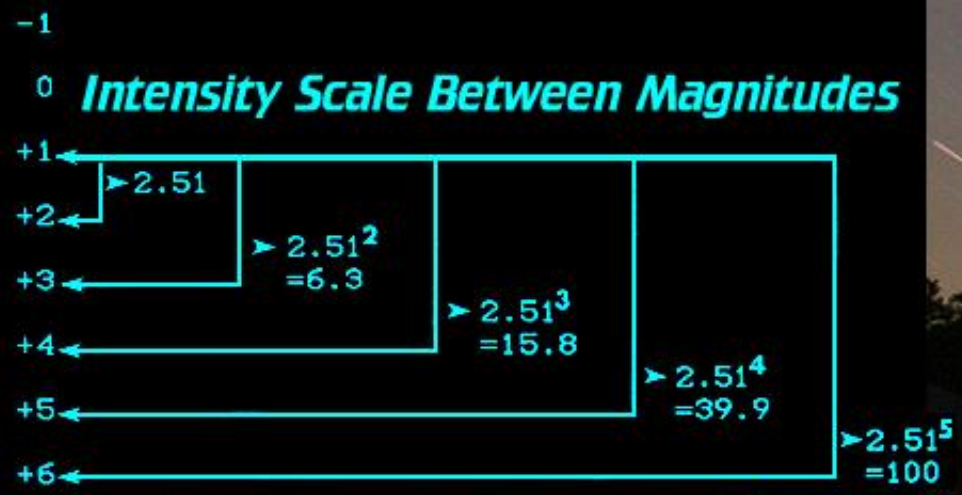
1. **Light Gathering: A telescope must gather a sufficient amount of light to see the object that is to be observed (aperture)**
2. **Resolution: A telescope must differentiate objects of close angular separation (aperture).**
3. **Definition and Contrast: A telescope must produce images which are sharp and distinct and have a good separation of light and dark areas (optical excellence of telescope).**
4. **Magnification: A telescope must make the image look bigger (Inverse Square Rule = $1/d^2$ governs brightness).**
5. **Field of View: A telescope must create a large enough viewing area to see the object of interest (Inverse Square Rule = $1/d^2$ governs angular diameter of field of view).**

Two Important Concepts

Focal length: Distance that light must travel after passing through a lens or reflecting from a mirror before it comes to a focus.

Focal ratio: $\frac{\text{focal length of the telescope}}{\text{diameter of the primary mirror or lens}}$

A telescope must gather a sufficient amount of light to see the object trying to be viewed.



Light Grasp = $7D^2$

D = diameter in inches

Limiting Magnitudes	
D (inches)	*Limiting magnitude*
1	8.8
2	10.3
3	11.2
5	12.3
8	13.3
12	14.2
20	15.3
200	23.0

Light Grasp = $0.63 \times \frac{D^2}{0.3^2}$ = $7D^2$ approximately (older)
= $9D^2$ transmission coatings

Where 0.63 = transmission factor
D = aperture in inches
0.3 = opening of eye in inches

$I = 2.51^x$

Where I = intensity = transmission factor
x = difference in magnitude

Limiting Visual Magnitude = 8.8 + 5 log D

Where D = aperture in inches
8.8 = limiting magnitude of a 1-inch aperture telescope

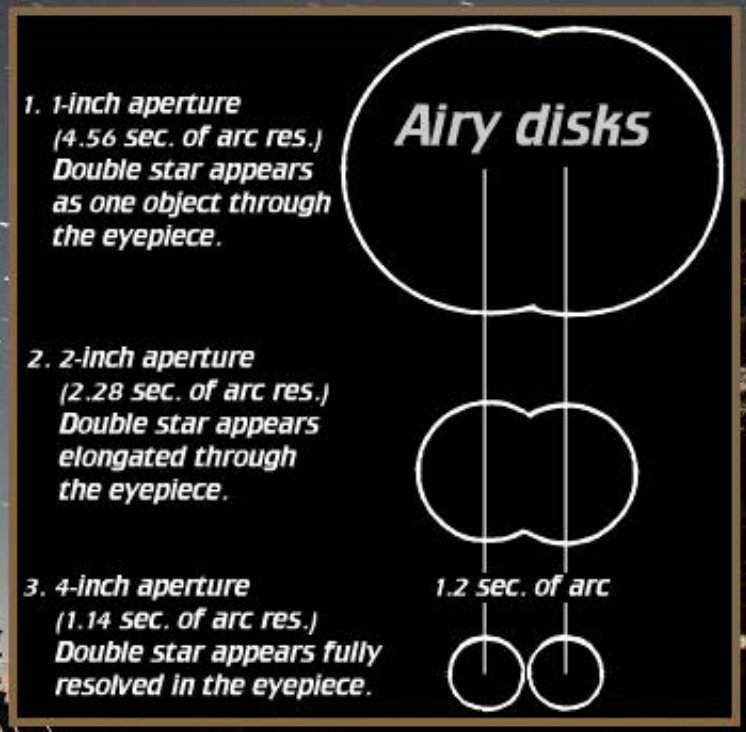
Resolution: A telescope must separate close-together objects.

...also called the spurious disk

Star

Diffraction disk (Airy disk) and rings

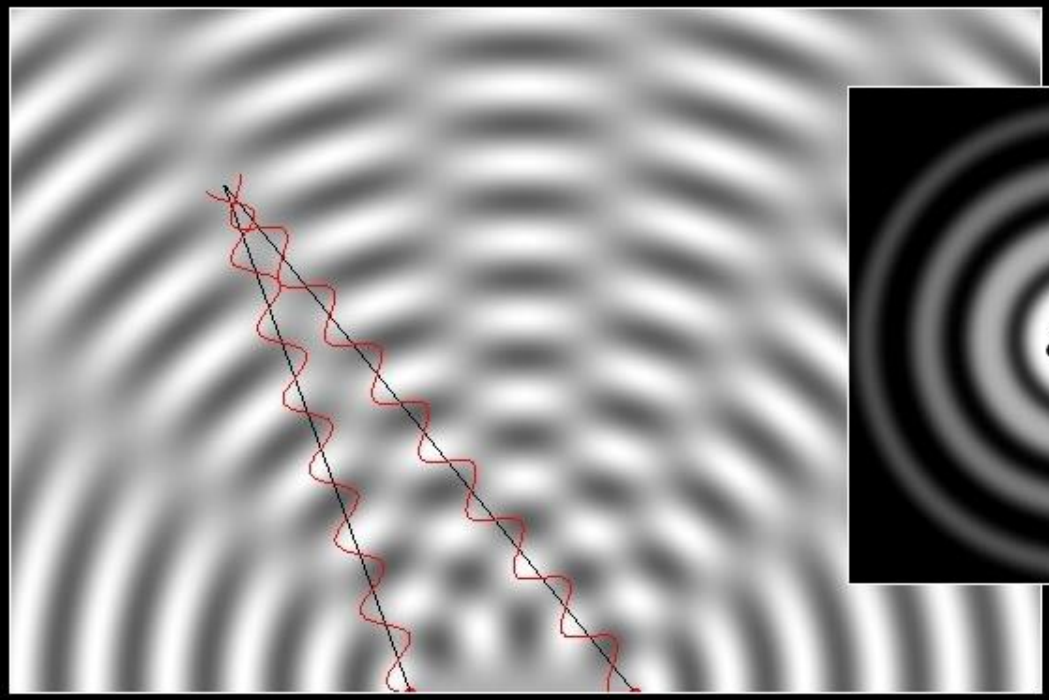
The size of the Airy disk is inversely related to the aperture of the telescope.



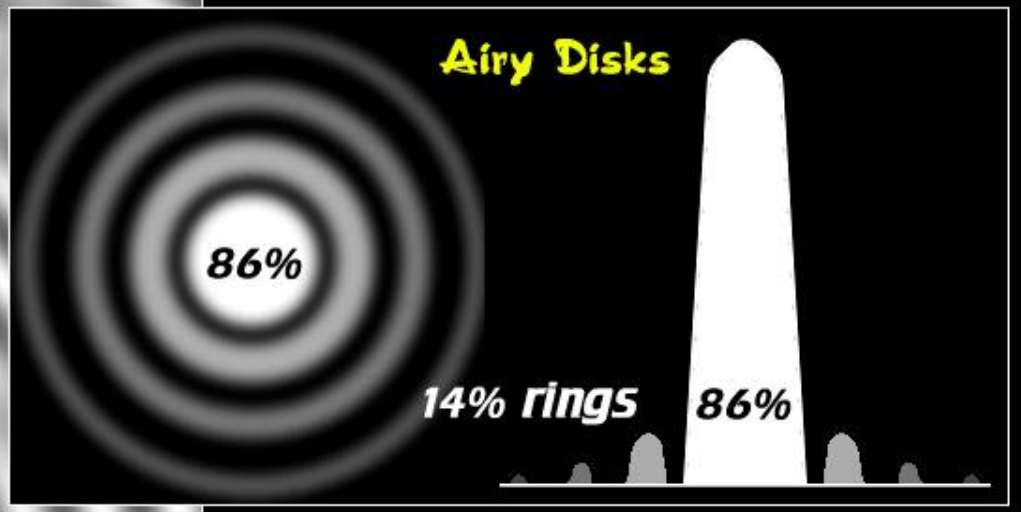
$$\text{Dawe's Limit} = \text{Resolution} = \frac{4.56 \text{ seconds of arc}}{D \text{ (aperture in inches)}}$$

Gary A. Becker image

Constructive and Destructive Interference

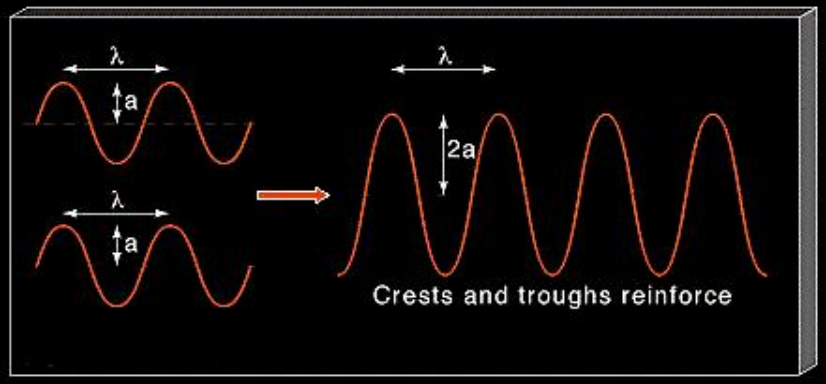


CONTRAST

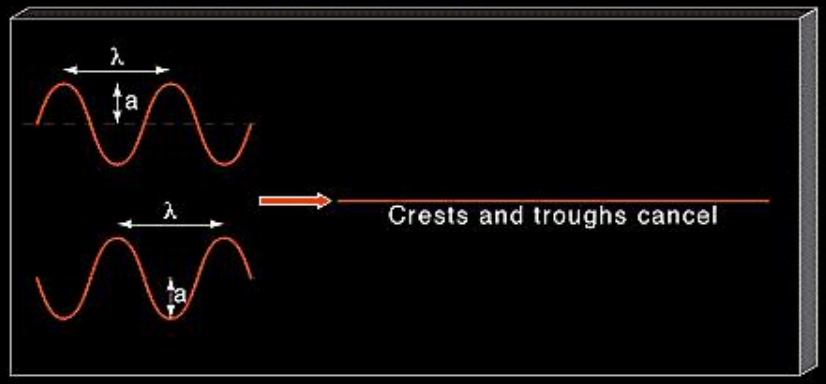


DEFINITION

Constructive Interference



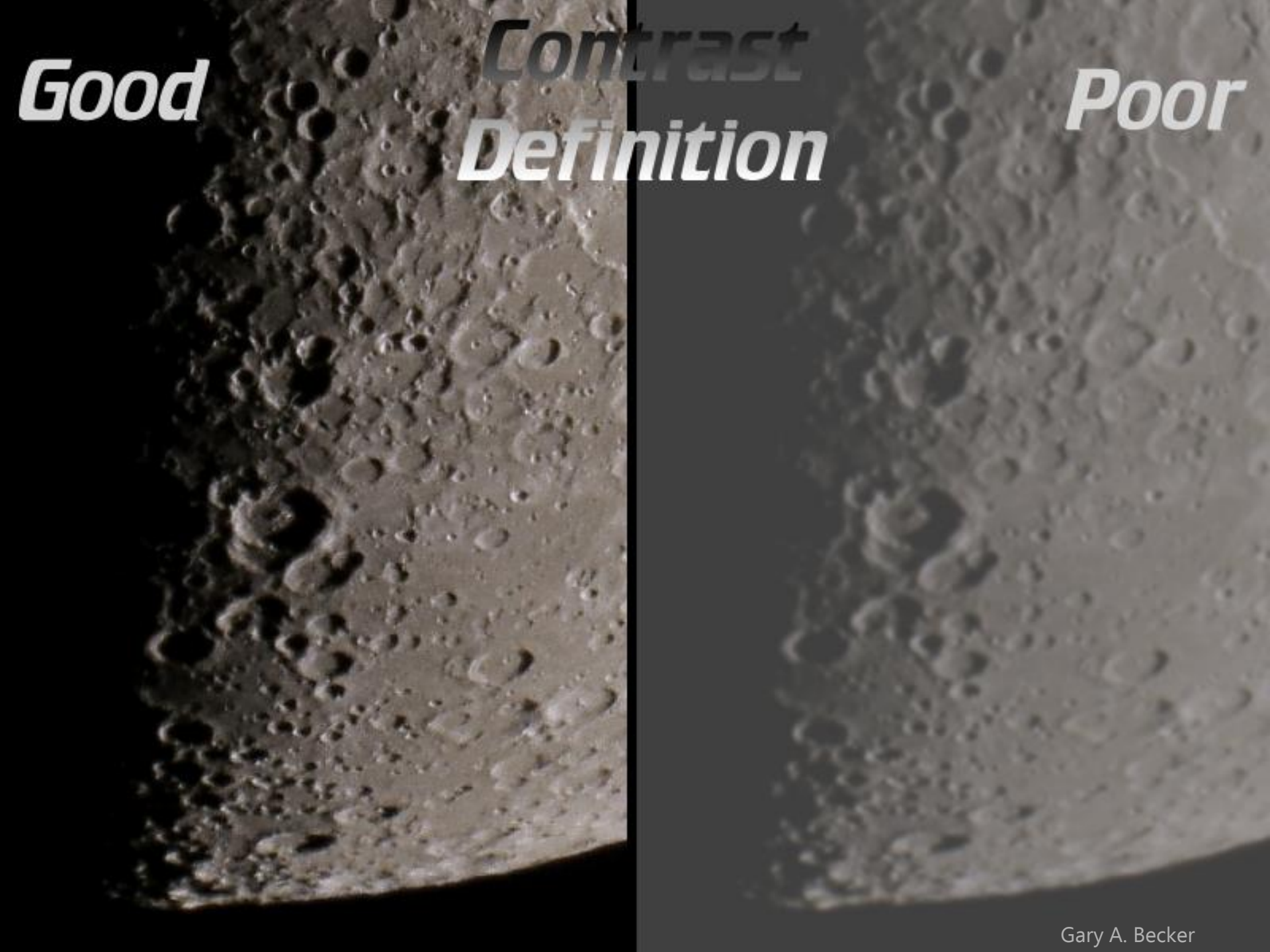
Destructive Interference



Contrast: The Weeders, Jules Breton (1827-1906), French

Gary A. Becker image


Weeders
Low
Contrast
High
Gary A. Becker images


Good
Contrast
Definition
Poor
Gary A. Becker

Magnification

$$M = \frac{\text{focal length of telescope}}{\text{focal length of eyepiece}}$$

Larger aperture telescopes produce smaller Airy disks and therefore can tolerate higher magnifications.

1X

2X

4X

Limits: 6X-60X per inch

Gary A. Becker image

Empty Magnification

Gary A. Becker image

Use your smart phone to take a picture of the previous Harrison Ford image showing empty magnification.

Look at the amount of detail on the photo you have taken. Is it more or less?

Explain why the slide and your picture are so different.

Finally, enlarge the image to produce empty magnification once again.

Spring 2014: Sarah K. Durham and Amanda Van Fleet

Magnification

$$M = \frac{\text{focal length of telescope}}{\text{focal length of eyepiece}}$$

Larger aperture telescopes produce smaller Airy disks and therefore can tolerate higher magnifications.

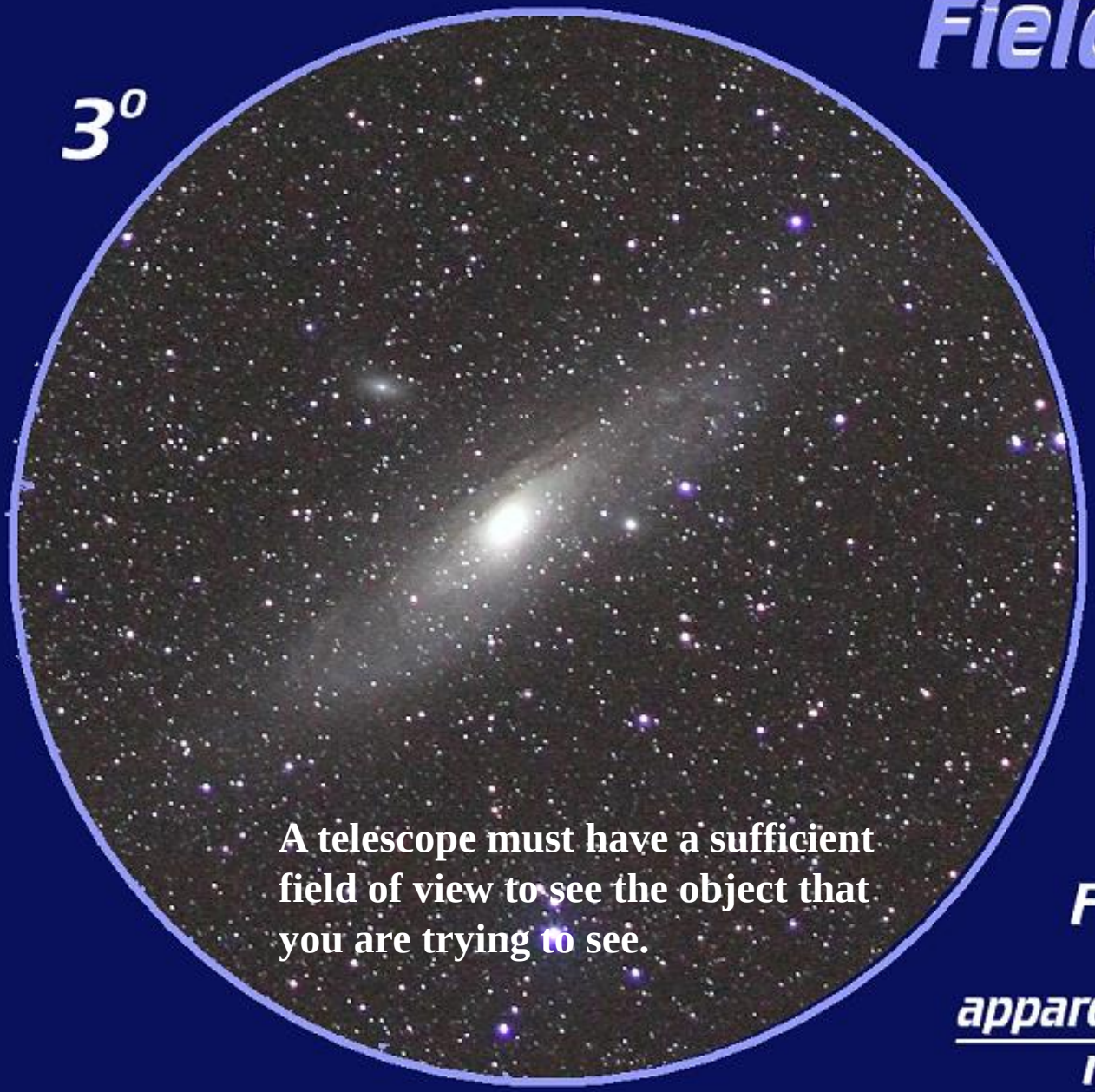
1X

2X

4X

Gary A. Becker image

Field of View



A telescope must have a sufficient field of view to see the object that you are trying to see.

$$\text{Field of View} = \frac{\text{apparent field of eyepiece}}{\text{magnification}}$$

large image, Gary A. Becker

Camera Lens with Diaphragm

Diffraction

Diffraction: A deflection or bending which light undergoes when passing the edges of narrow openings or opaque bodies.

Gary A. Becker image


Venus and Jupiter, March 15, 2012
Gary A. Becker image

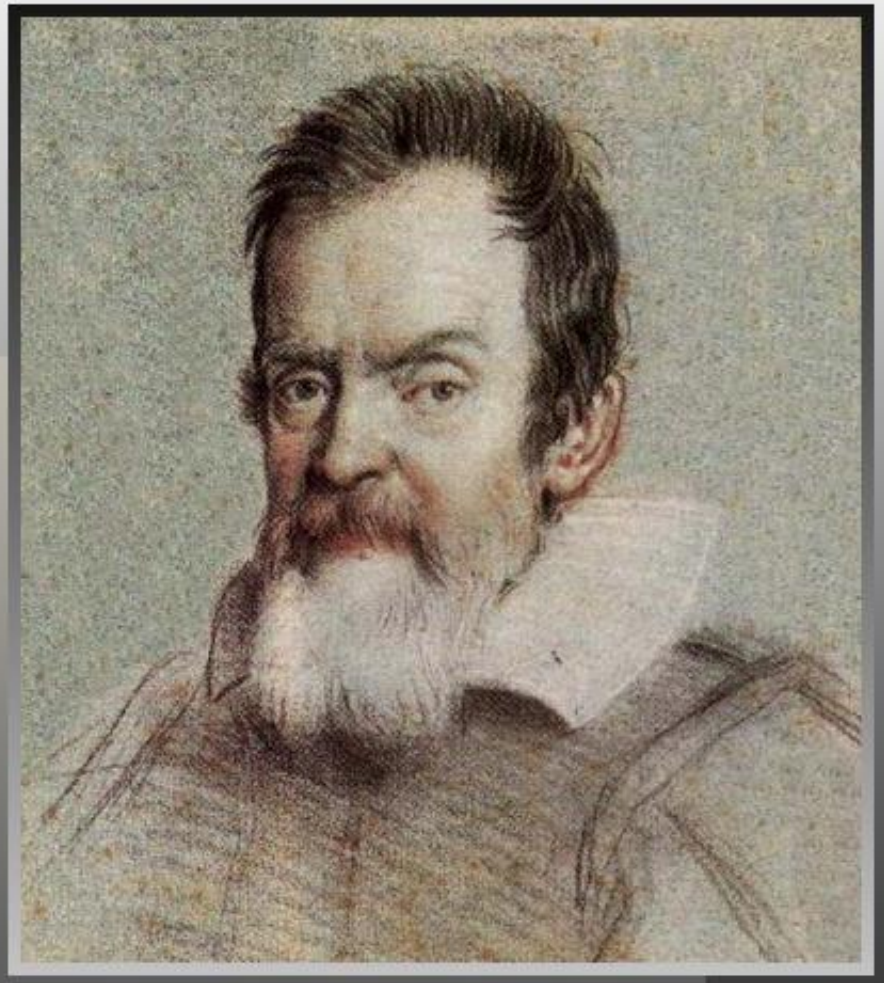
Pleiades or Seven Sisters

What is missing in this picture of the Pleiades?

What kind of telescope imaged the Pleiades?

Who Invented the Telescope?

Hans Lippershey 1570-1619



Galileo Galilei 1564-1642

Hans Lippershey—Dutch Optician

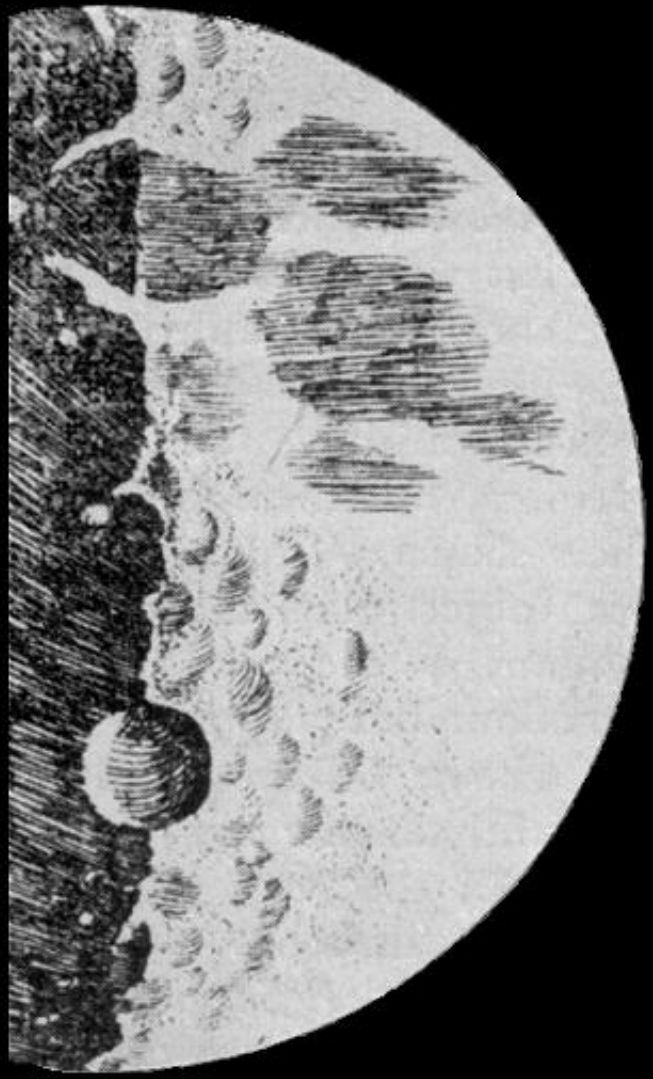
Galileo-First to Publish Starry Messenger-1610

Laughing Galileo from Opere di Galileo Galilei-1666

SIDEREVS
NVNCIVS
MAGNA, LONGEQVE ADMIRABILIA
Spectacula pandens, suspiciendaque proponens
vnicuique, præsertim verò
PHILOSOPHIS, atq; ASTRONOMIS, quæ à
GALILEO GALILEO
PATRITIO FLORENTINO
Patauini Gymnasij Publico Mathematico
PERSPICILLI
Nuper à se reperti beneficio sunt obseruata in LVNÆ FACIE, FIXIS IN-NVMERIS, LACTEO CIRCVLO, STELLIS NEBVLOSIS,
Apprime verò in
QVATVOR PLANETIS
Circa IOVIS Stellam disparibus interuallis, atque periodis, celeritate mirabili circumuolutis; quos, nemini in hanc vsque diem cognitos, nouissimè Author deprehendit primus; atque
MEDICEA SIDERA
NVNCVPANDOS DECREVIT.

VENETIIS, Apud Thomam Baglionum. M DC X.
Superiorum Permissu, & Privilegio.

Galileo Galilei

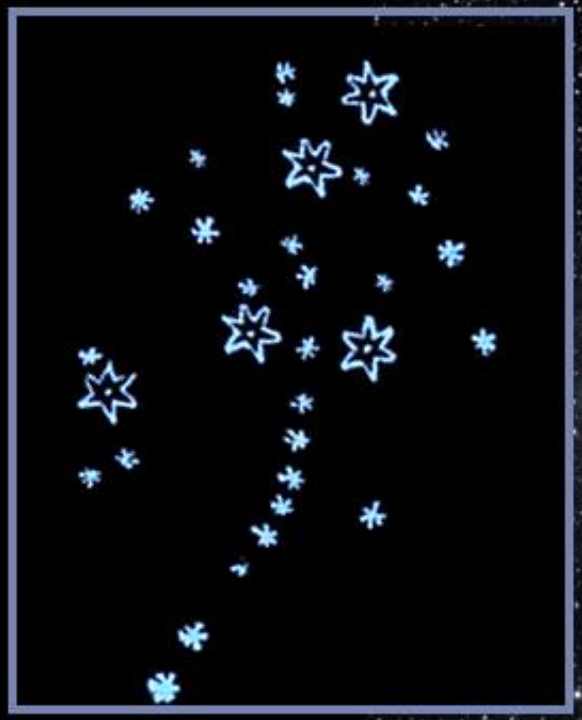


Gary A. Becker

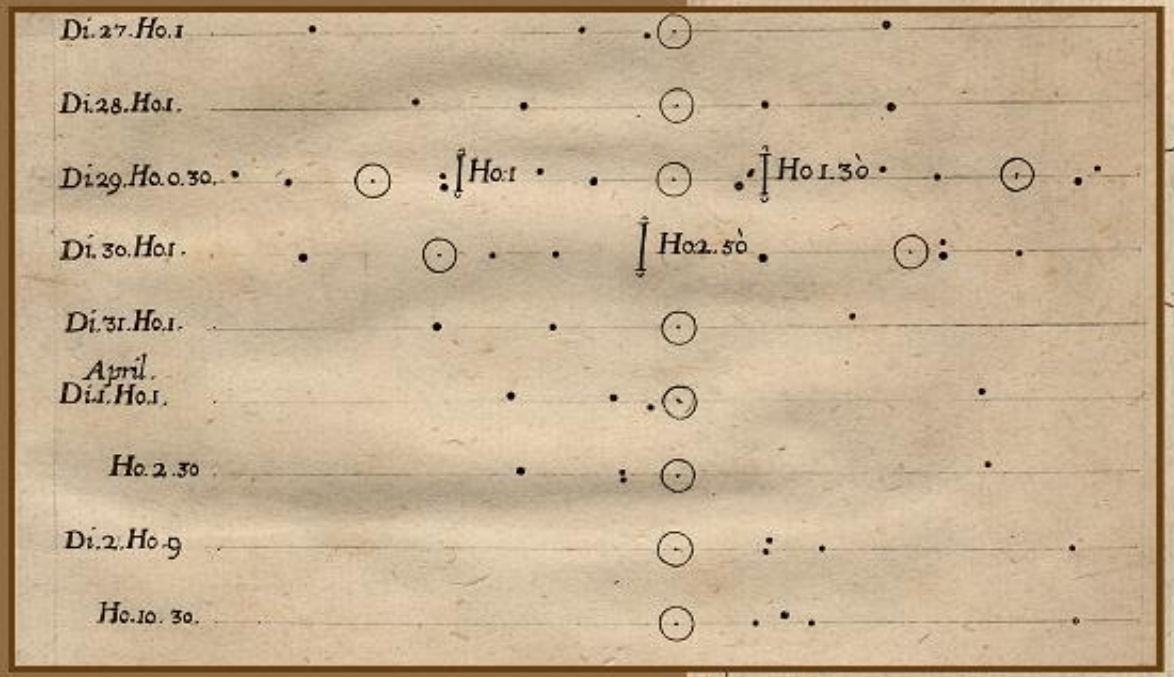
Gary A. Becker image right

Galileo Draws the Pleiades

Sidereus Nuncius-1610



Galileo Galilei

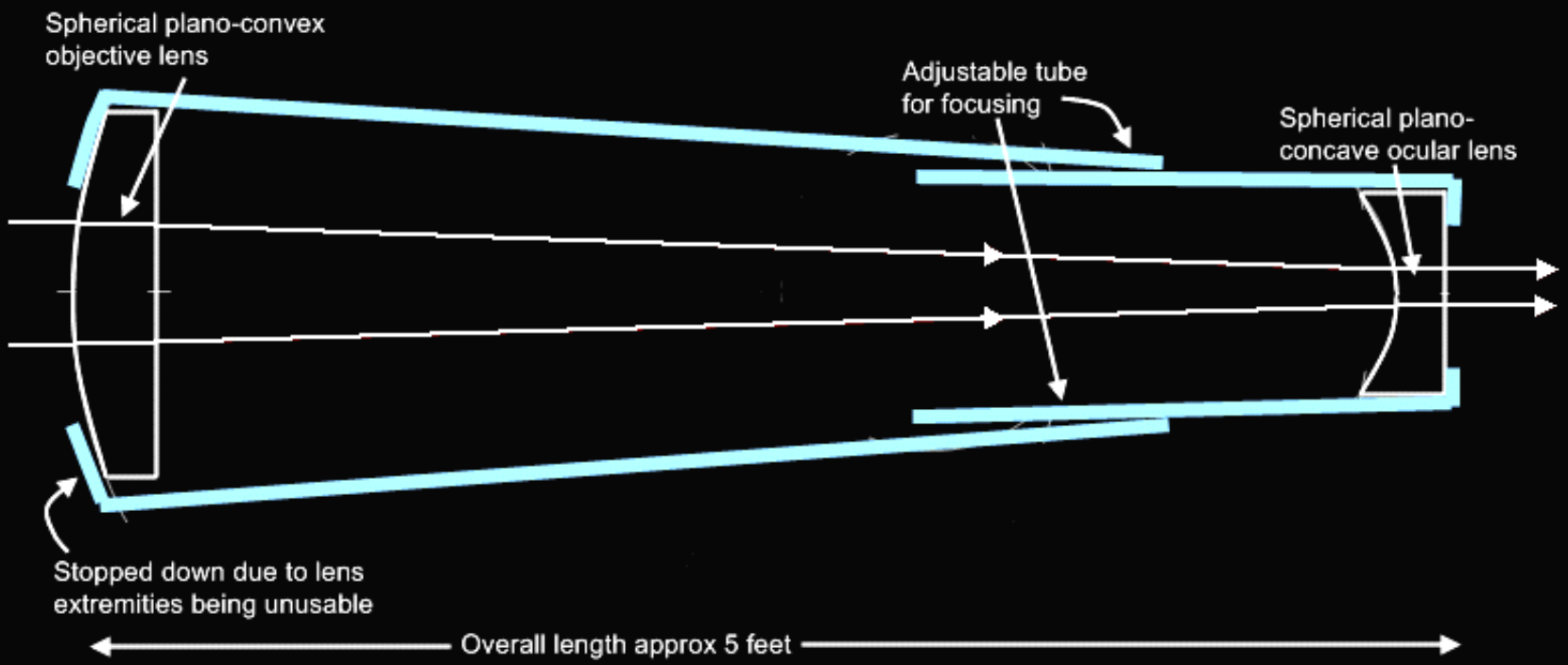


Galileo's History and Demonstrations-1613

pone Apelle del moſtrarſi Saturno hora oblongo, & hor' accompagnato con due ſtelle à i fianchi, creda pur V. S. ch'è ſtata imperfezzione dello ſtrumento, ò dell'occhio del riguardante, perche ſendo la figura di Saturno così ,come moſtrano alle perfette viſte i perfetti ſtrumenti, doue manca tal perfezzione appariſce così non ſi diſtinguendo perfettamente la ſeparazione, e figura delle tre ſtelle; ma io che mille volte in diuerſi tempi con eccellente ſtrumento l'hò riguar-

Diuerſità nel veder Saturno cagionata da difetto

Galilean Refractor



Good Attributes

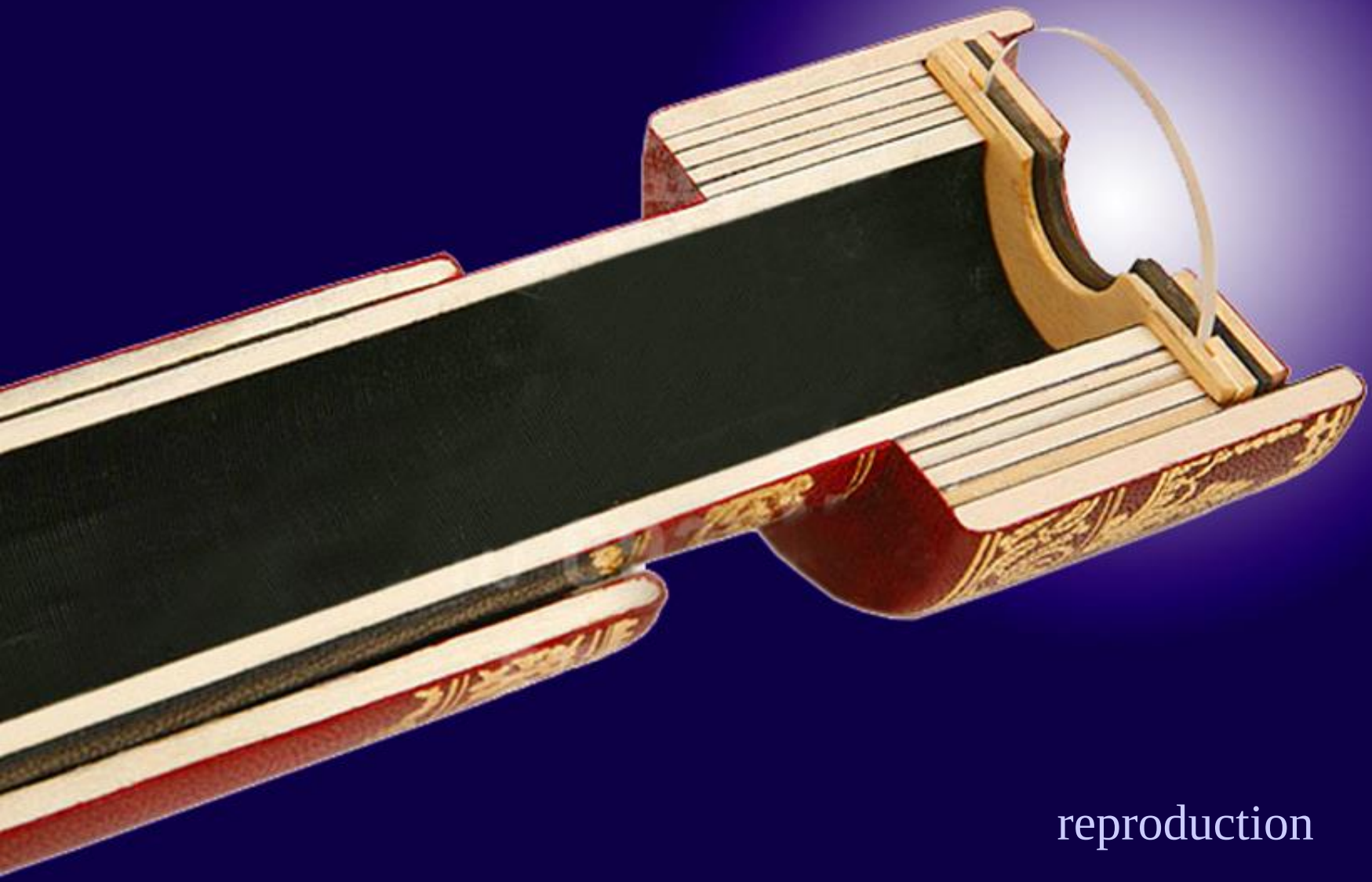
Cheap, simple and easy to produce.
Tolerant of bad lenses

Bad Attributes

Dull image due to poor aperture
Narrow field of view limits magnification <30x
Spherical aberration
Doesn't get much better even if lenses do

Telescopes Built by Galileo

Galilean Telescope Cutaway



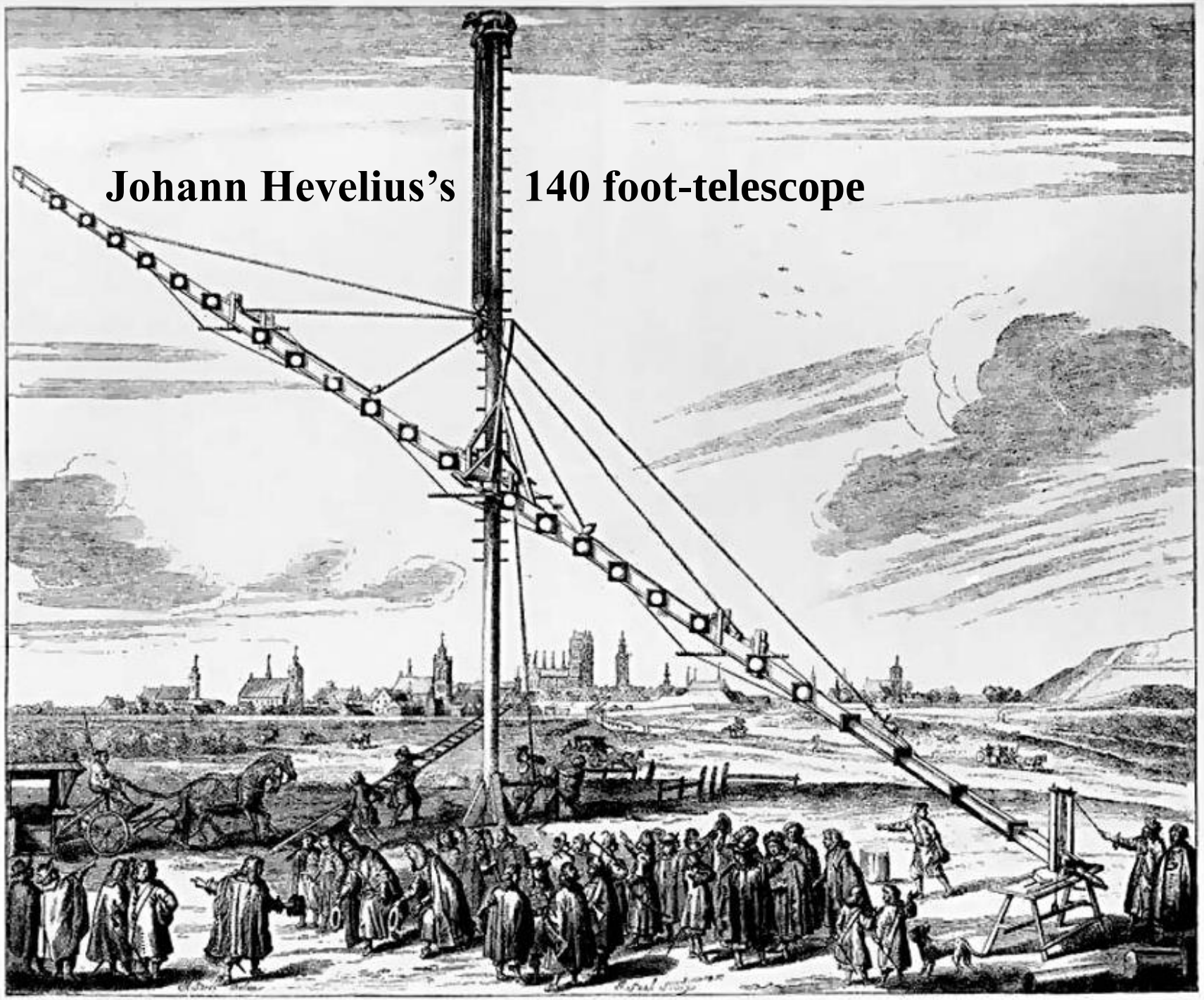
reproduction

Refraction

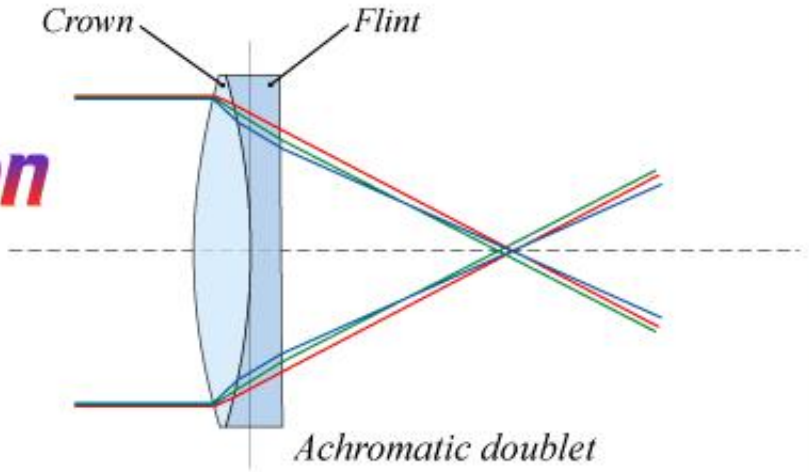
Chromatic Aberration

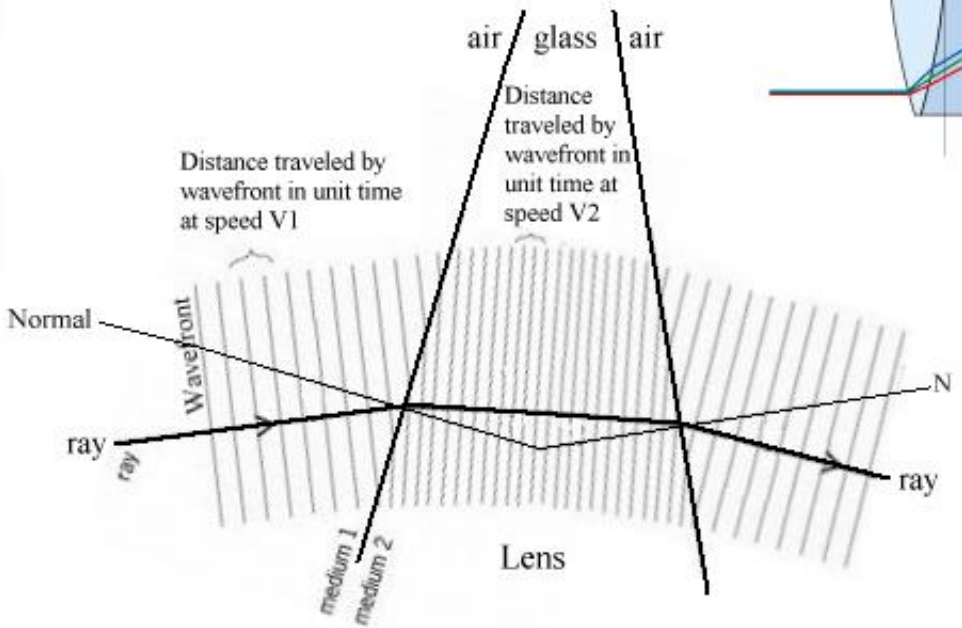
Hevelius's Long Refracting Telescope (ca: 1647)

German: 1611-1687


Johann Hevelius's 140 foot-telescope

Refraction and Color Correction





REFRACTIVE INDEX

The refractive index of water is 1.33, meaning that light travels at the speed of light divided by/1.33 slower in water than in a vacuum.

186,000 mi. per sec. /1.33 = 140,000 mi. per sec.

Law of Refraction

Dutch astronomer
Willebrord Snellius (1580-1626)

Snell's Law:

Snell's law states that the ratio of the sines of the angles of incidence and refraction is equivalent to the ratio of phase velocities in the two media.

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1}$$

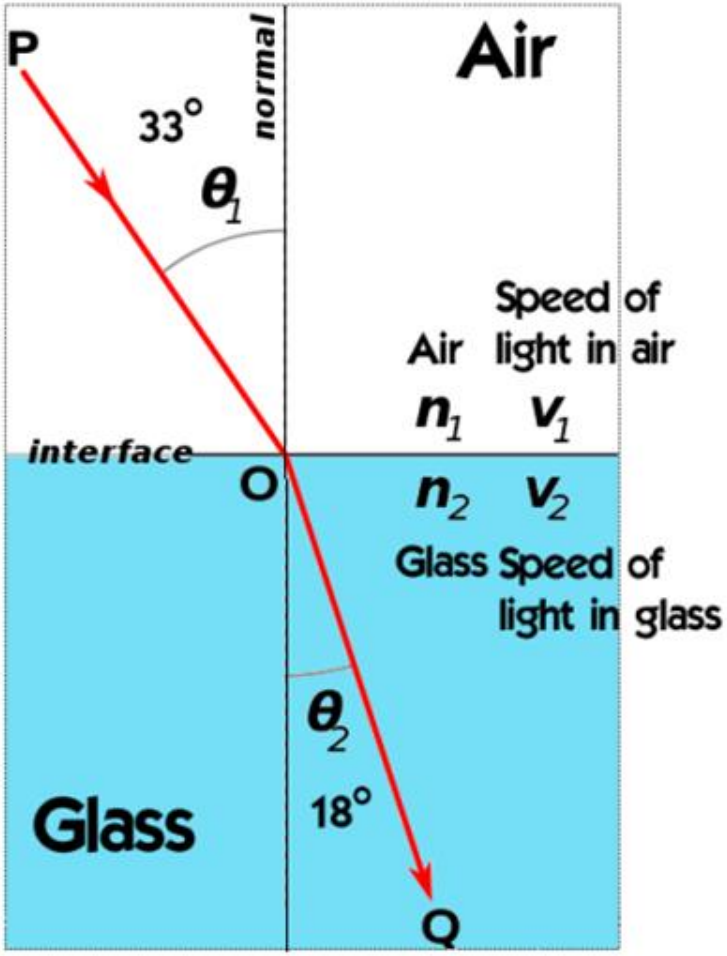
n_2 = refractive index of glass

$n_1 = 1$ refractive index of air is 1.

$$\frac{\text{Sin } 33^\circ}{\text{Sin } 18^\circ} = \frac{0.54}{0.31} = \frac{n_2}{1}$$

$$n_2 = \frac{0.54}{0.31} = 1.7 \text{ (index of refraction)}$$

In the n_2 medium the speed of light is reduced from 3.00×10^5 km/sec to $\frac{3.00 \times 10^5 \text{ km/sec}}{1.7}$ or 1.8×10^5 km/sec

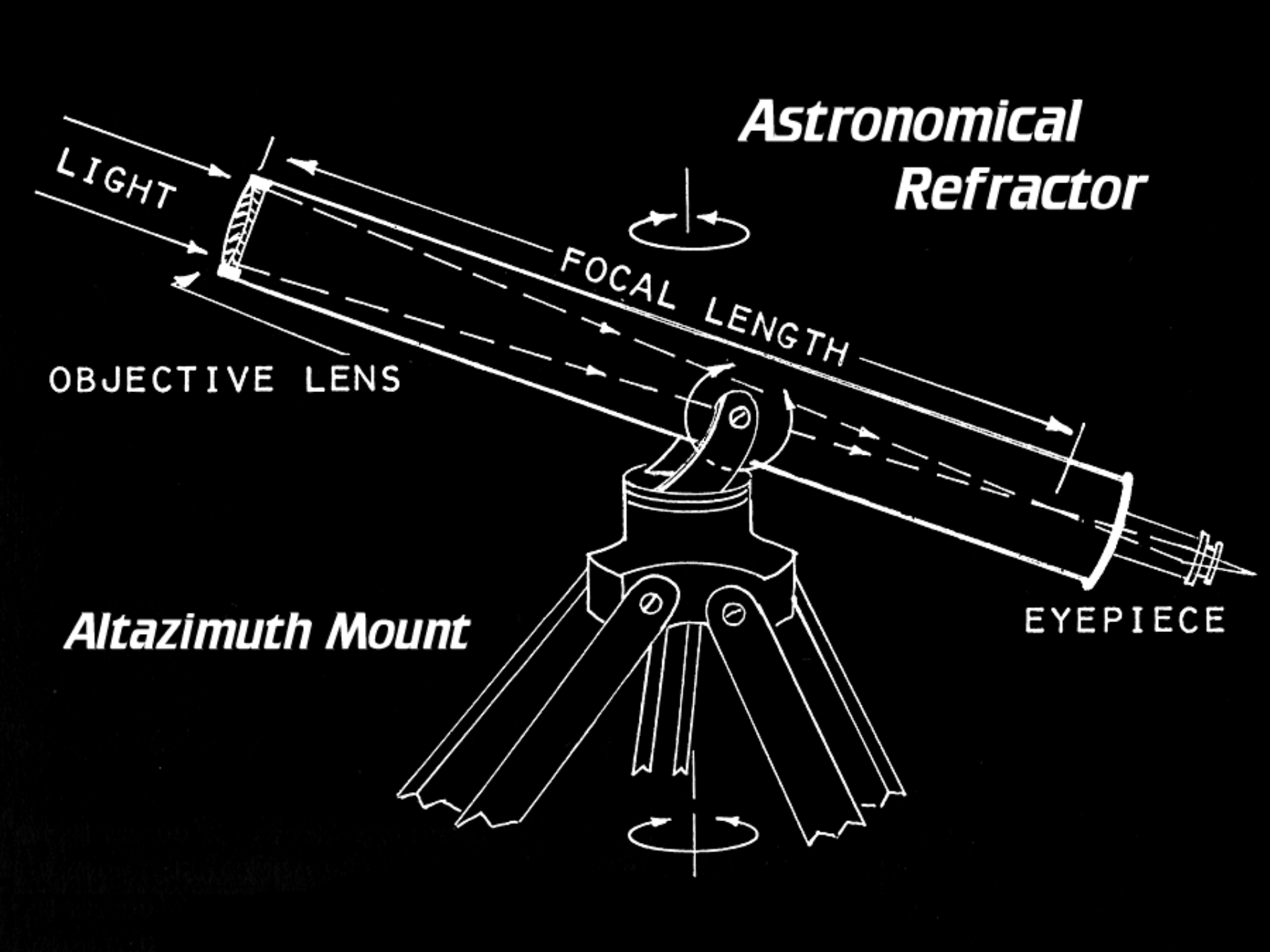


adapted from Wikipedia, the free encyclopedia

Two Basic Mounting Systems

Altazimuth: A mounting system, such as a tripod, which utilizes directions along the horizon and angular measurement above the horizon to find objects in the sky. A Dobsonian mount is altazimuth.

Equatorial: A mounting system which has one axis which can be made to rotate around the North Celestial Pole, the polar axis, and the other axis offset from it by an angle of 90 degrees, the declination axis.

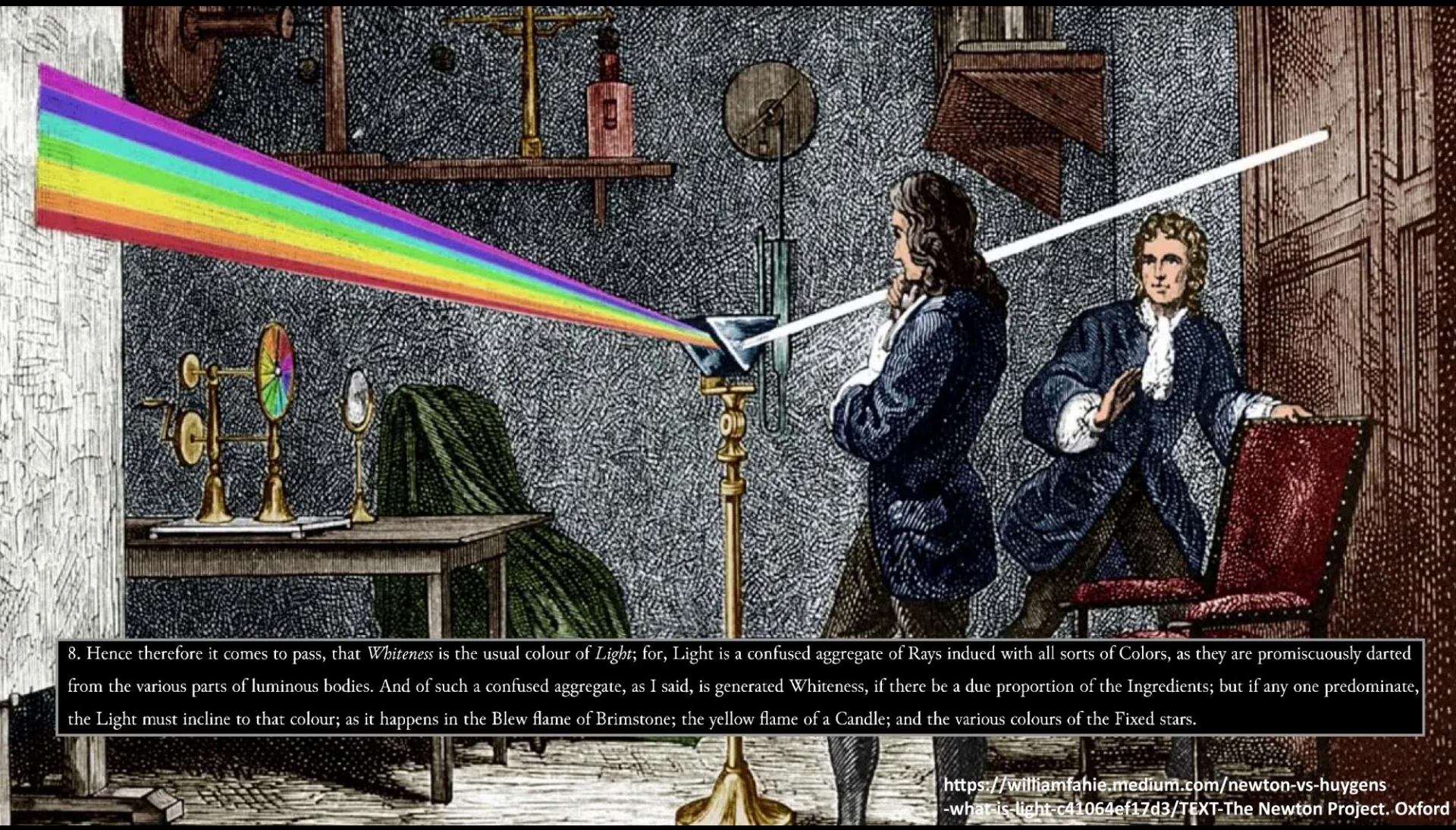

Astronomical
Refractor
LIGHT
FOCAL LENGTH
OBJECTIVE LENS
EYEPIECE
Altazimuth Mount

Isaac Newton

1642-1727

Quantified Gravity, Invented the Calculus,
Considered light as a particle not a wave.

Reflecting Telescope-1668/9

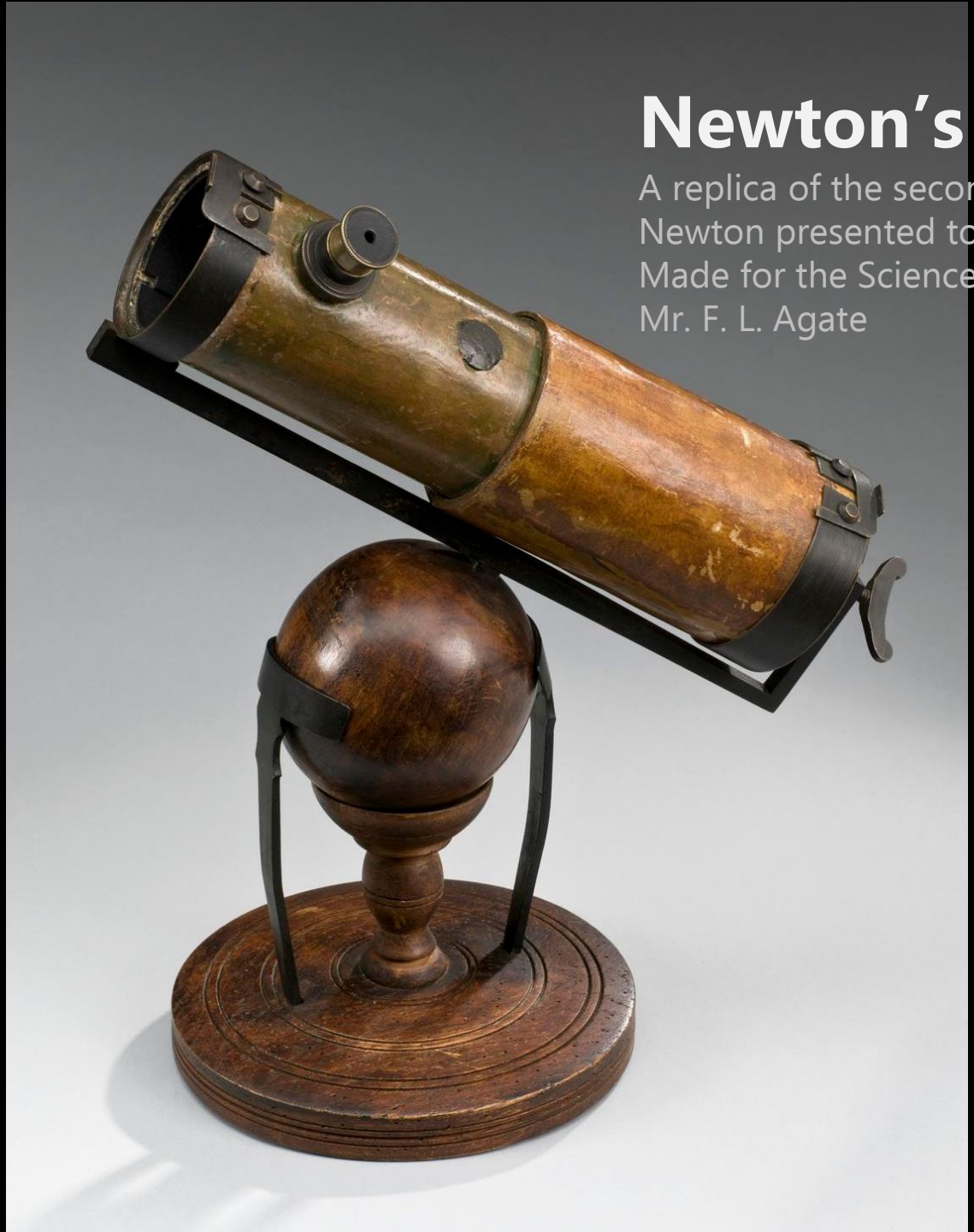


8. Hence therefore it comes to pass, that *Whiteness* is the usual colour of *Light*; for, Light is a confused aggregate of Rays indued with all sorts of Colors, as they are promiscuously darted from the various parts of luminous bodies. And of such a confused aggregate, as I said, is generated Whiteness, if there be a due proportion of the Ingredients; but if any one predominate, the Light must incline to that colour; as it happens in the Blew flame of Brimstone; the yellow flame of a Candle; and the various colours of the Fixed stars.

https://williamfahie.medium.com/newton-vs-huygens-what-is-light-c41064ef17d3/TEXT-The Newton Project. Oxford

Newton's Telescope

A replica of the second reflecting telescope Newton presented to the Royal Society
Made for the Science Museum in 1924 by Mr. F. L. Agate



Wikipedia

The Real Deal

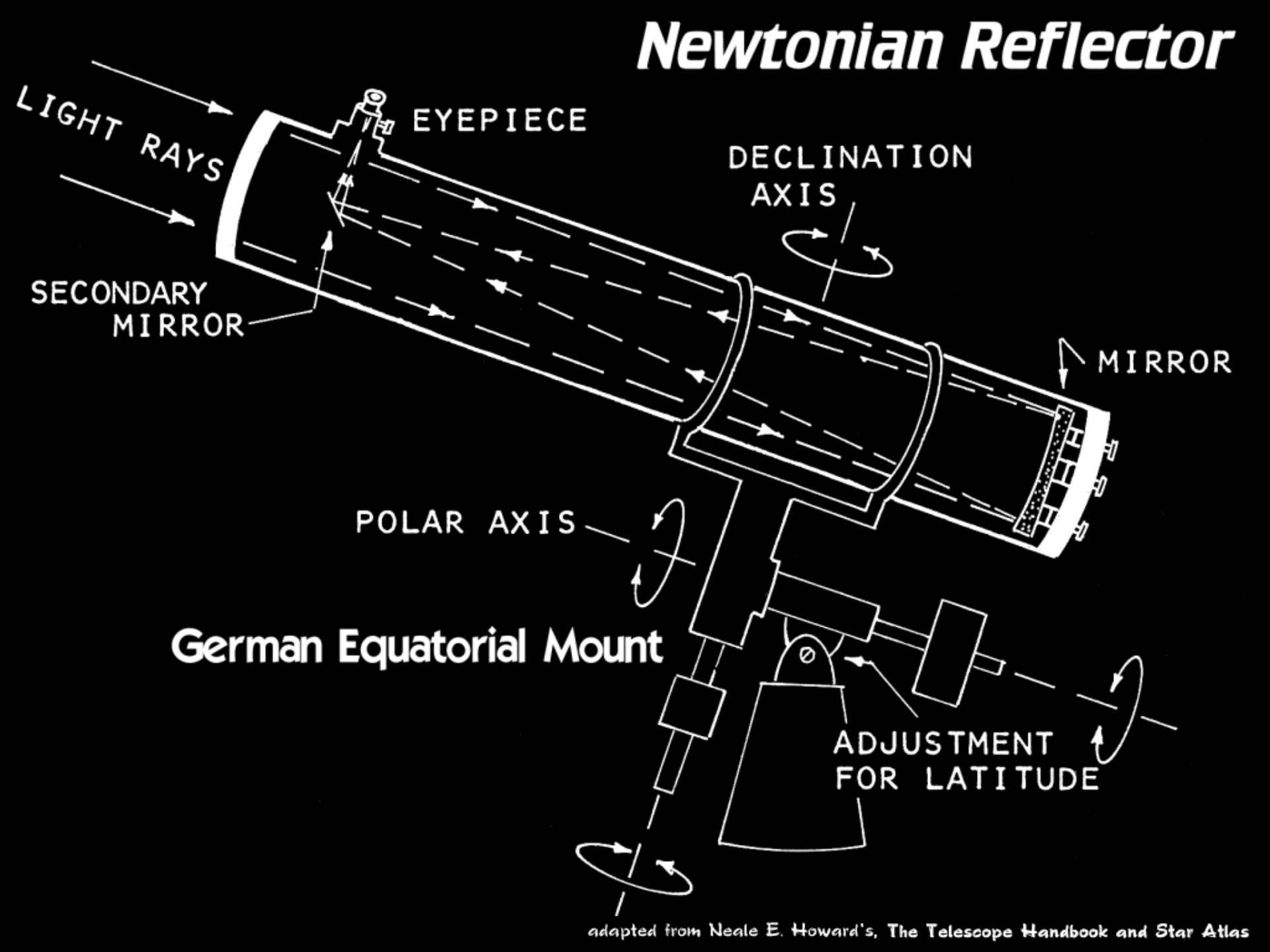
1668/9, 1671

Newton's first reflector was much smaller with a tube length of about six inches. It was lost. Newton then built a second larger telescope which he presented to the Royal Society in 1671. This is the one that can be seen in the picture.

Isaac, meet Susan.

Gary A. Becker images

Newtonian Reflector

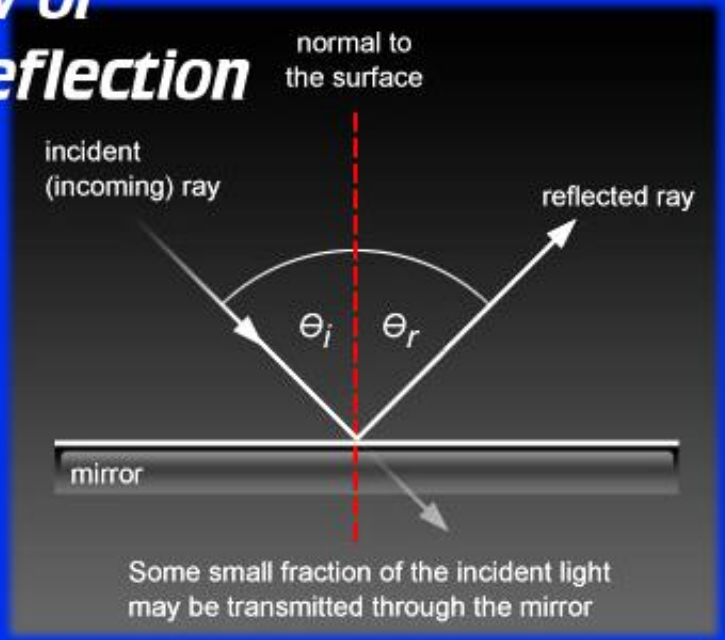


adapted from Neale E. Howard's, The Telescope Handbook and Star Atlas

Principals of a Reflecting Telescope

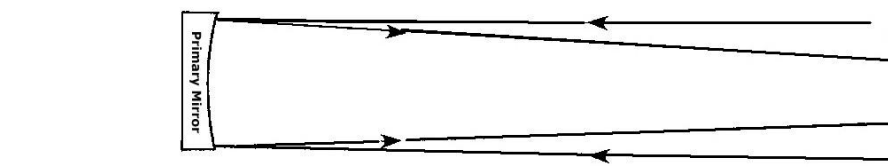
Parabolic Mirror

Law of Reflection

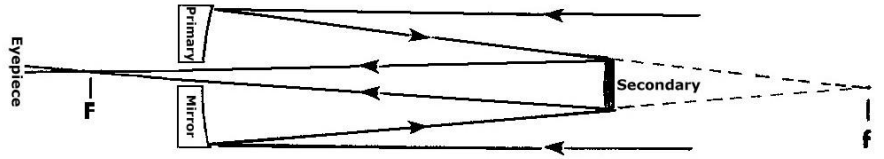


Newtonian Reflector

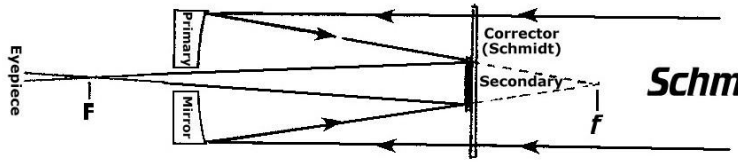
Economizing the Size of a Telescope



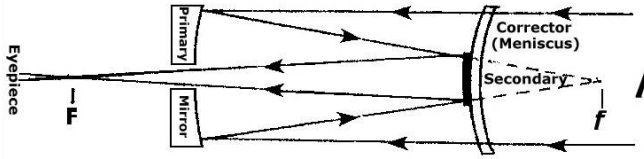
Newtonian



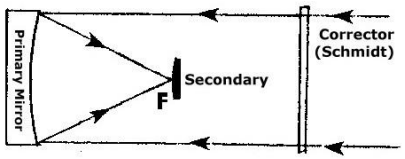
Cassegrain



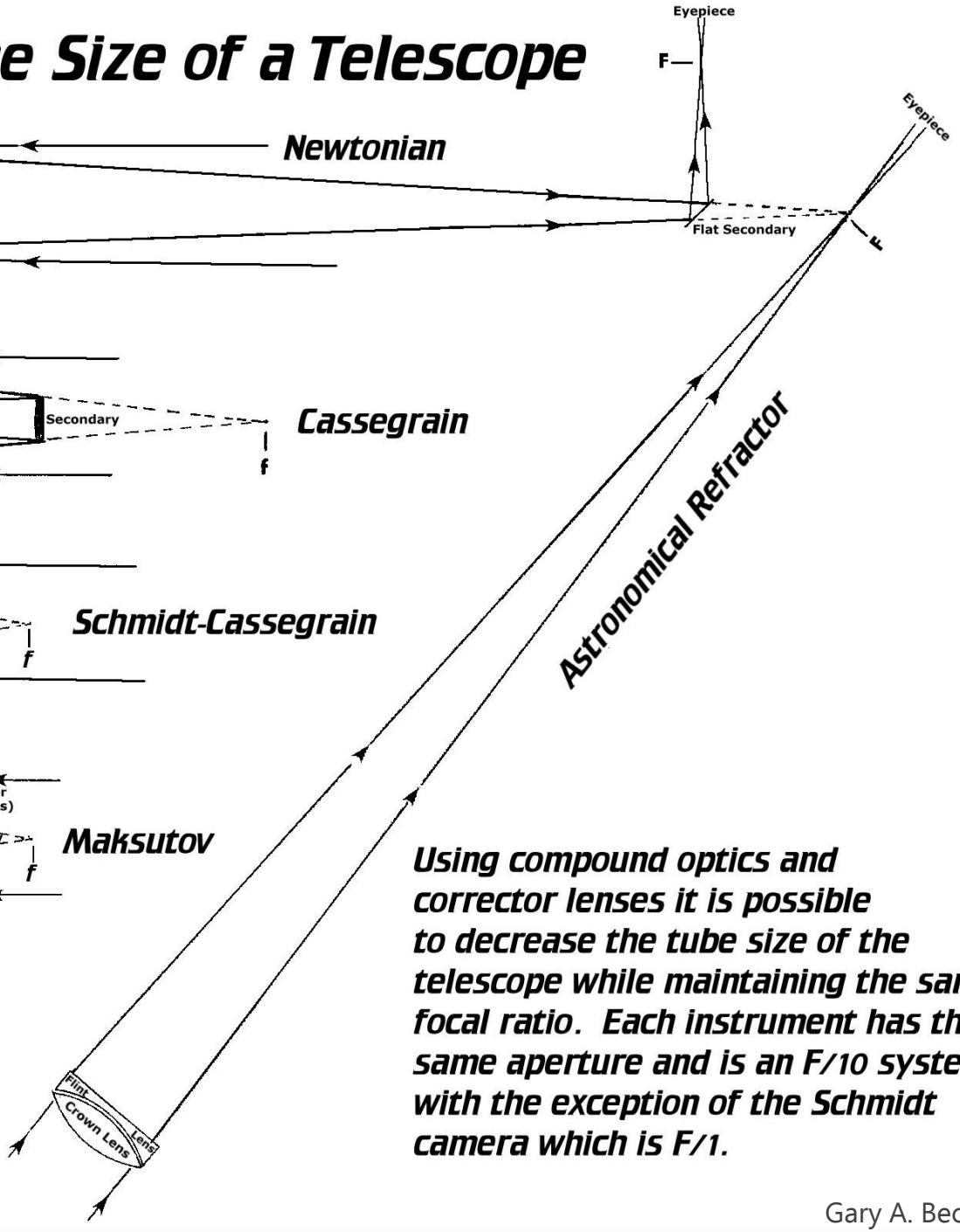
Schmidt-Cassegrain



Maksutov



Schmidt camera



Astronomical Refractor

Using compound optics and corrector lenses it is possible to decrease the tube size of the telescope while maintaining the same focal ratio. Each instrument has the same aperture and is an F/10 system with the exception of the Schmidt camera which is F/1.

Gary A. Becker

Newtonians

Dobsonian Mounts

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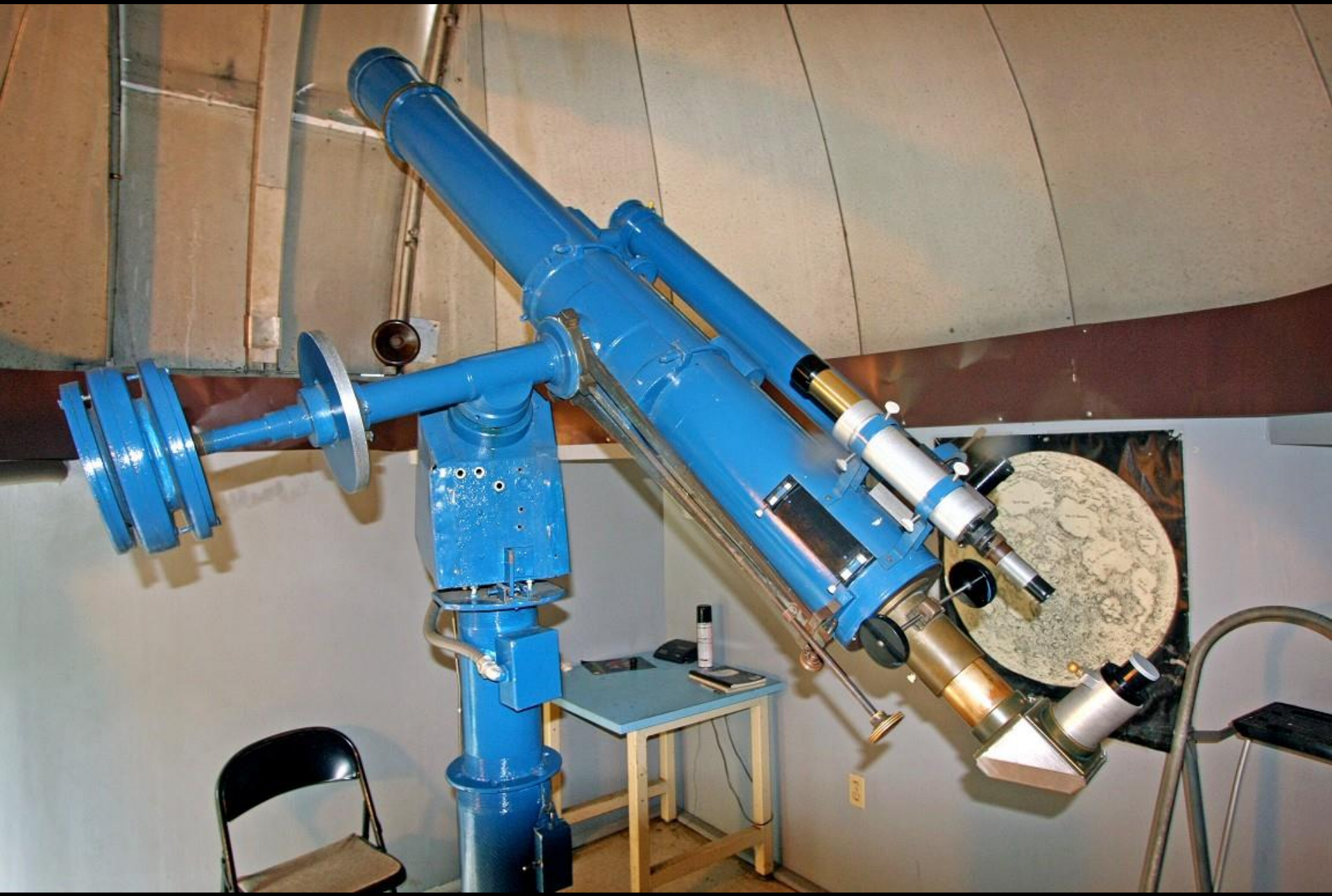

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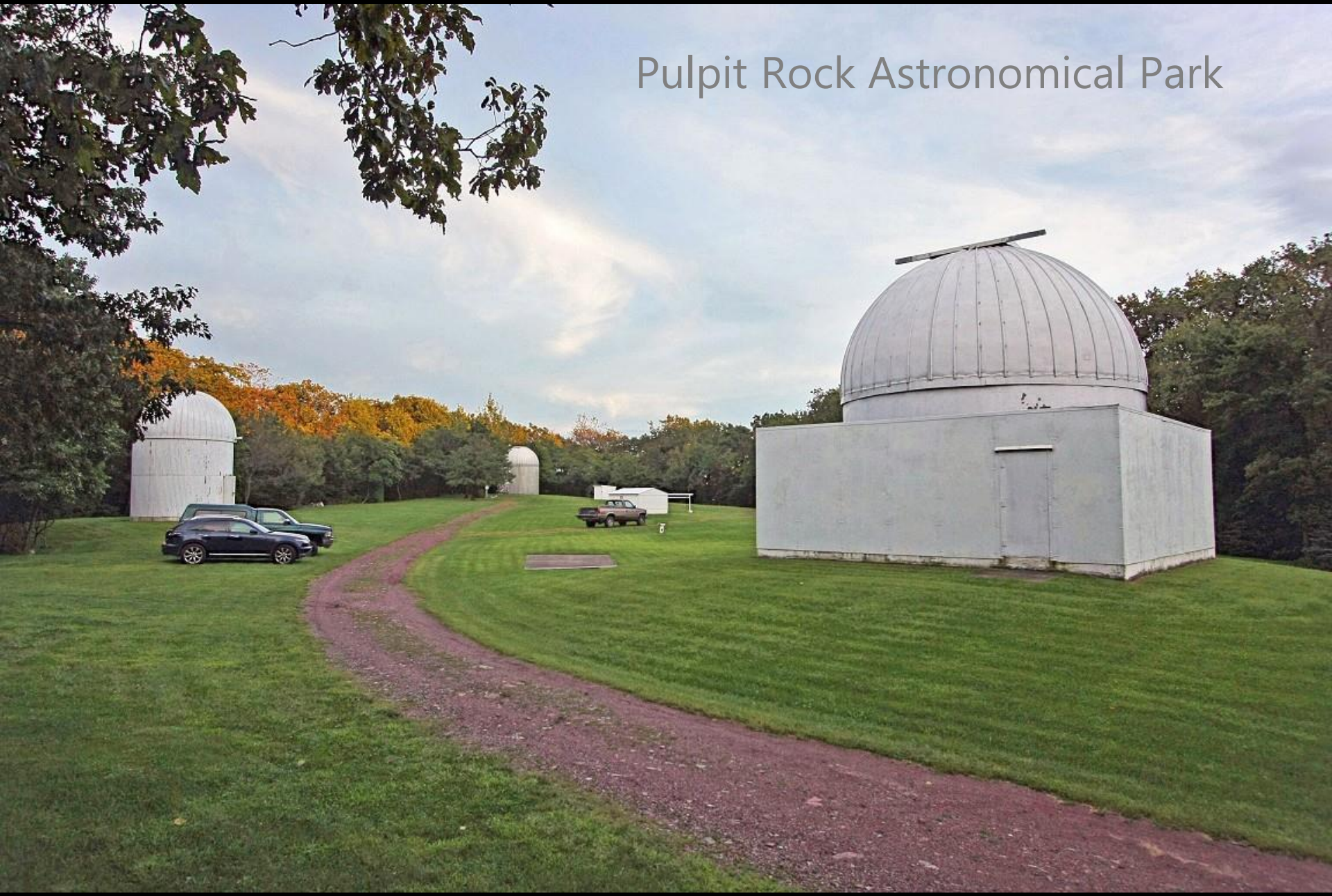

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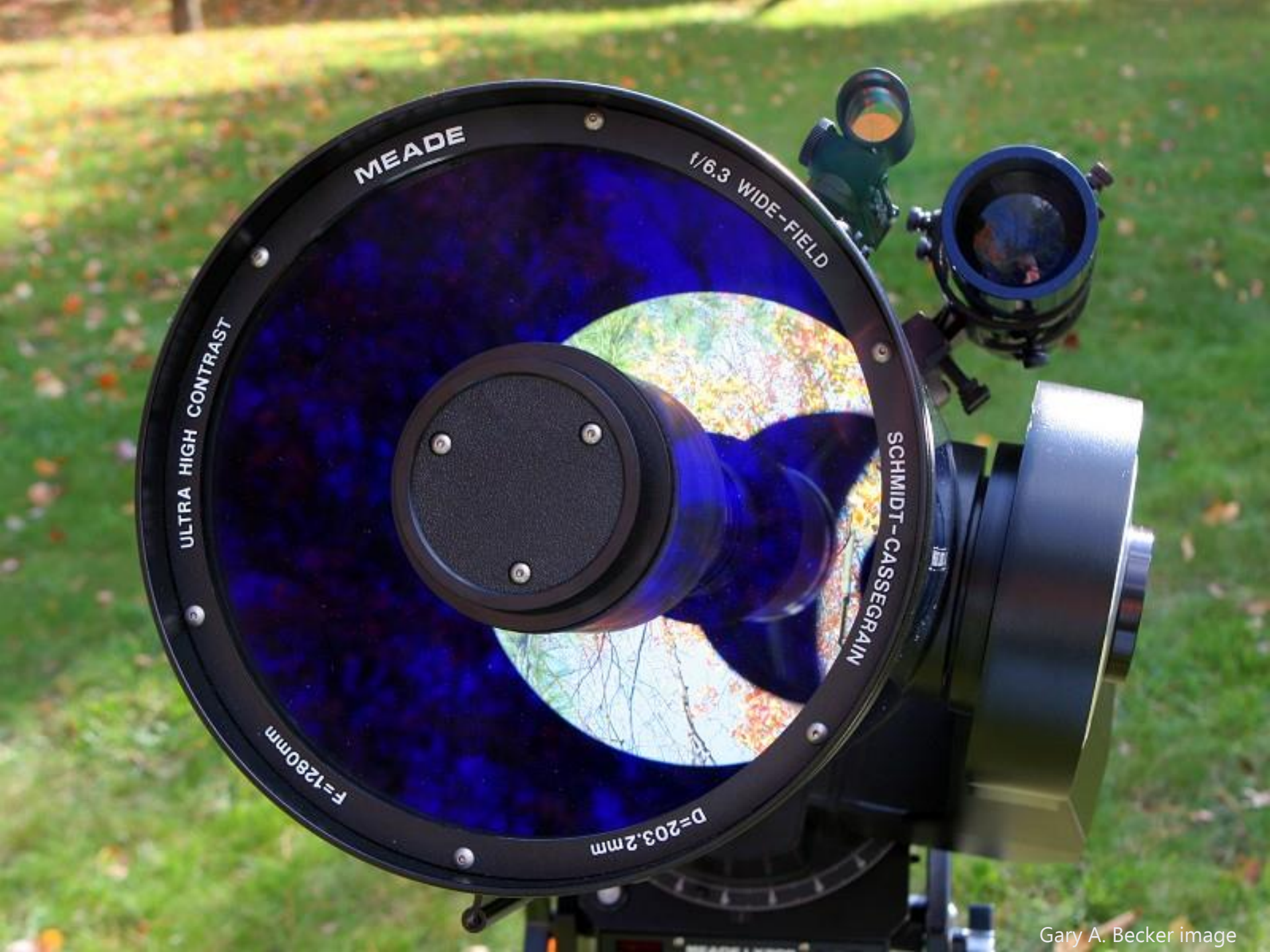

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Schmidt-Cassegrain Reflector

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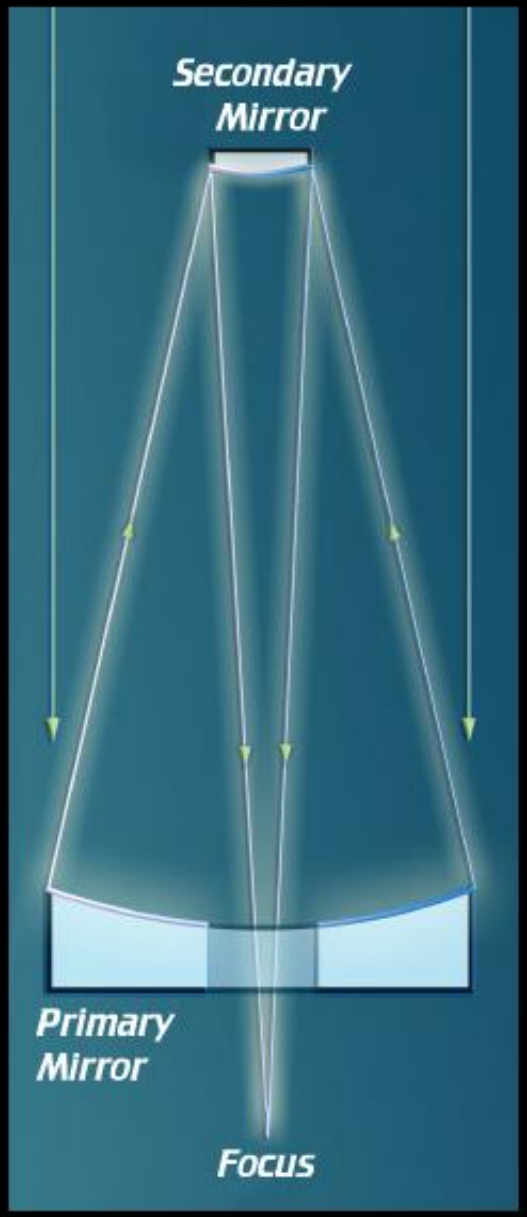
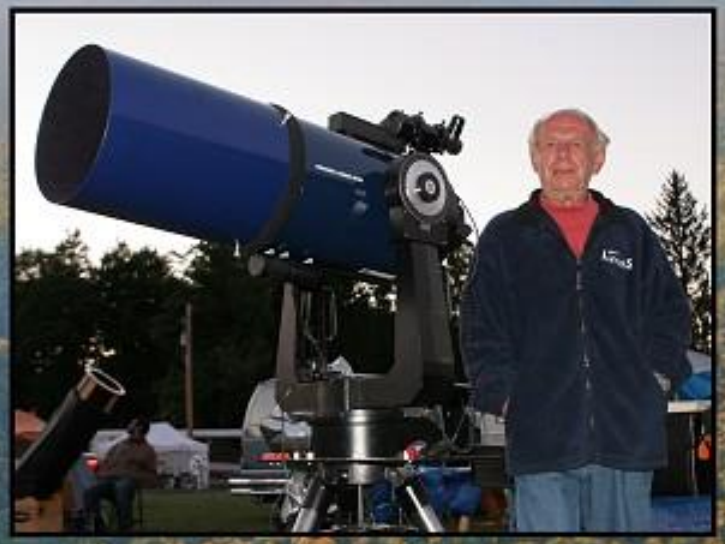
Cassegrain Reflectors



200-inch Hale Telescope

Black Forest Star Party



2005

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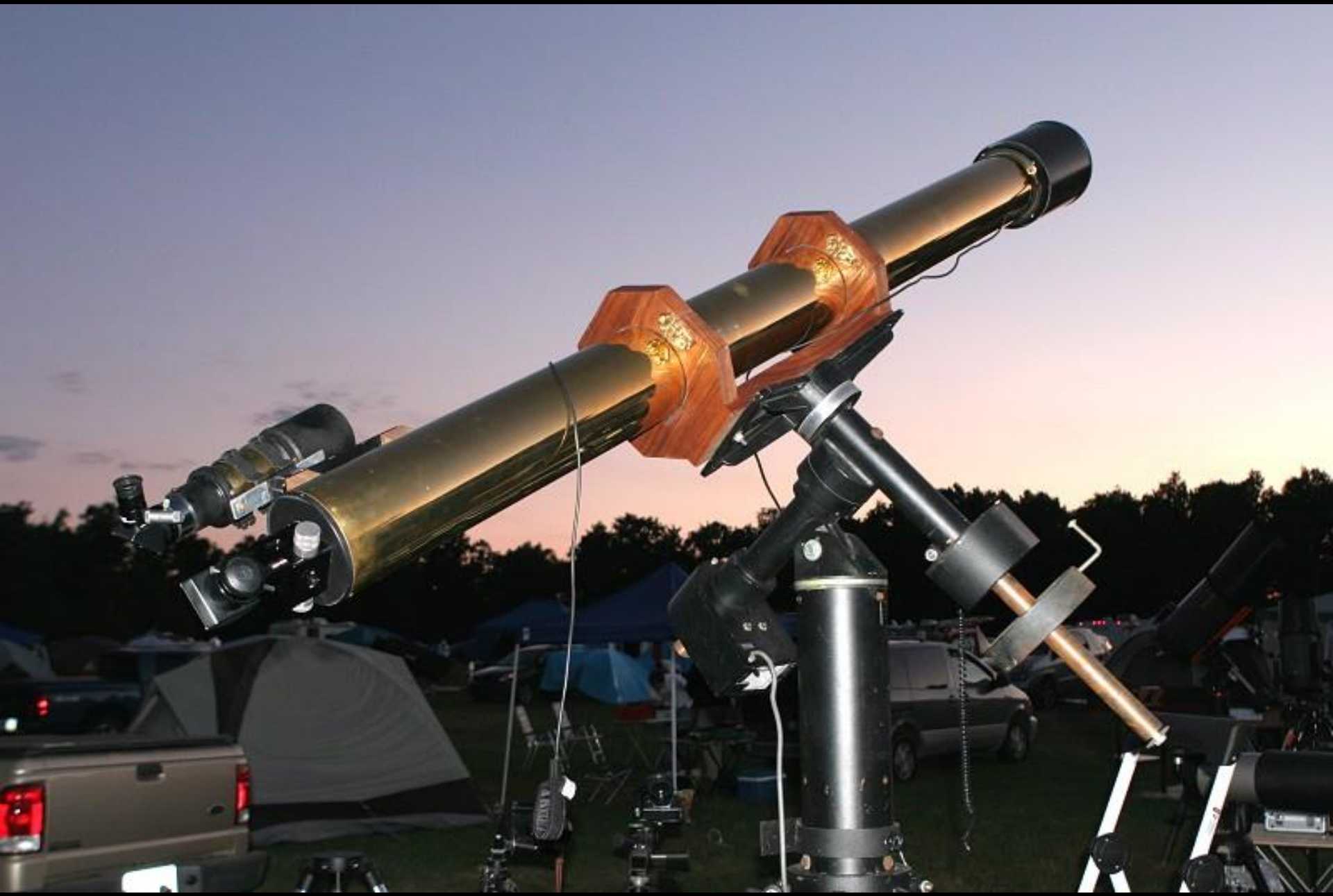

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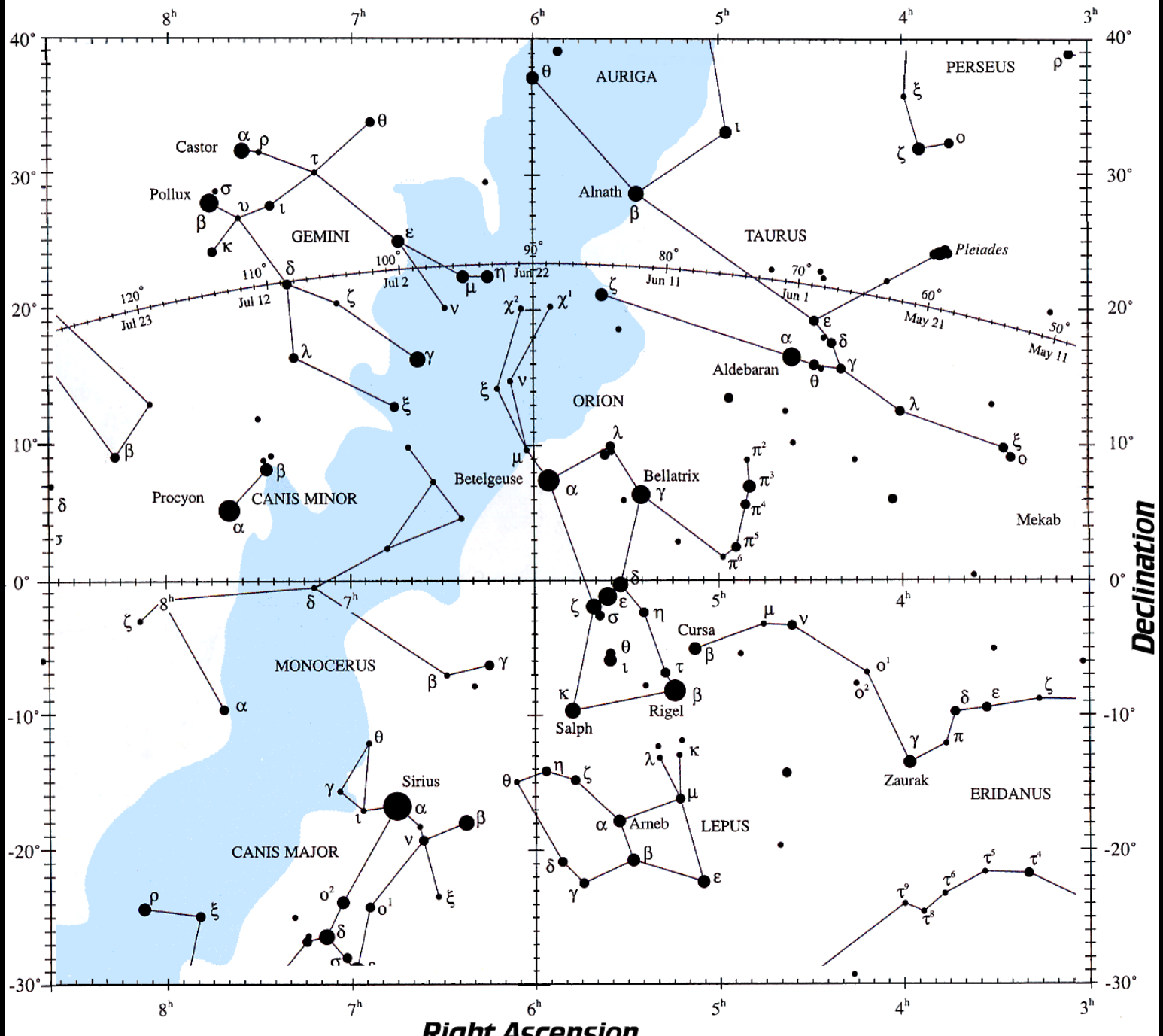
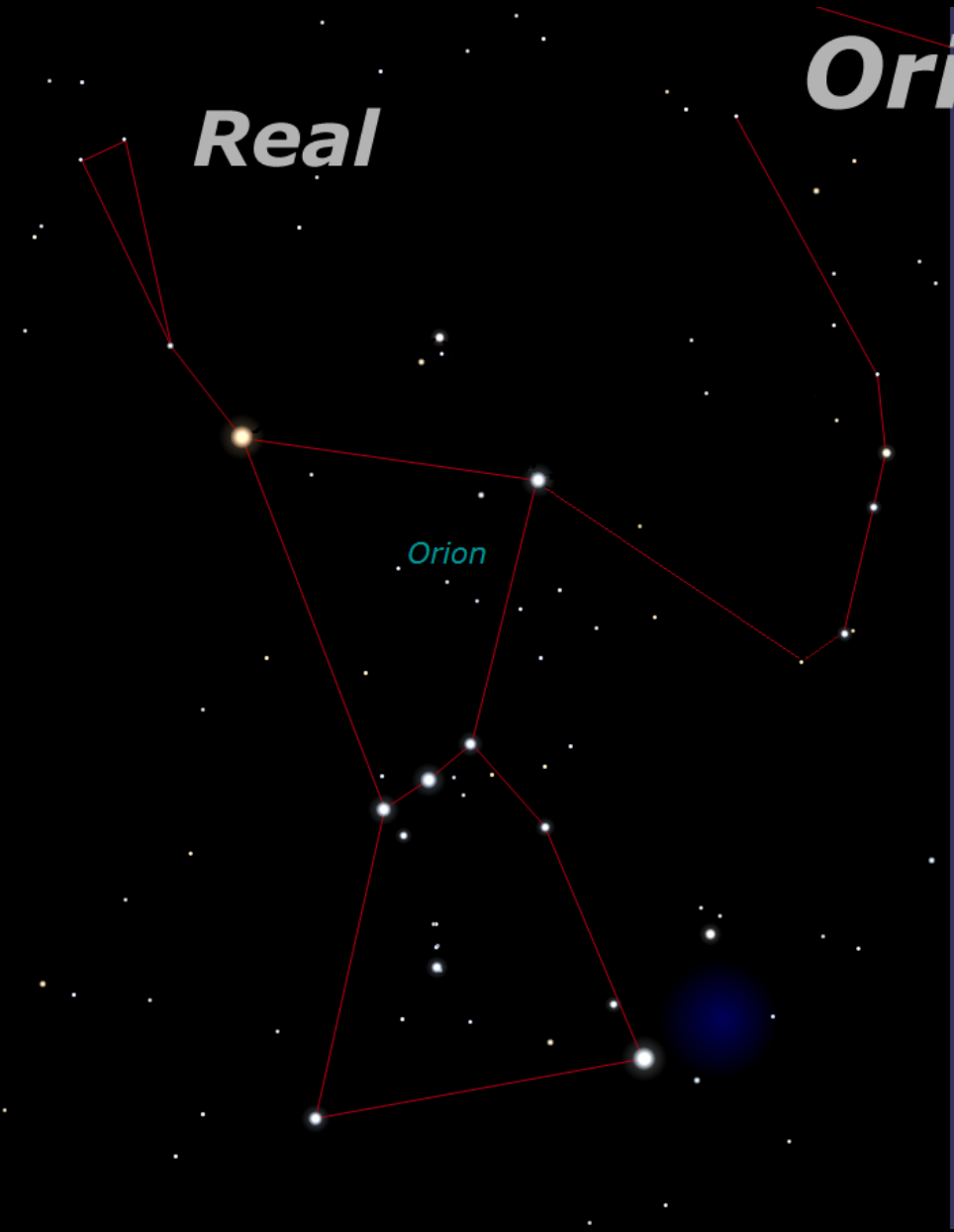
Finished

Bart's Comet

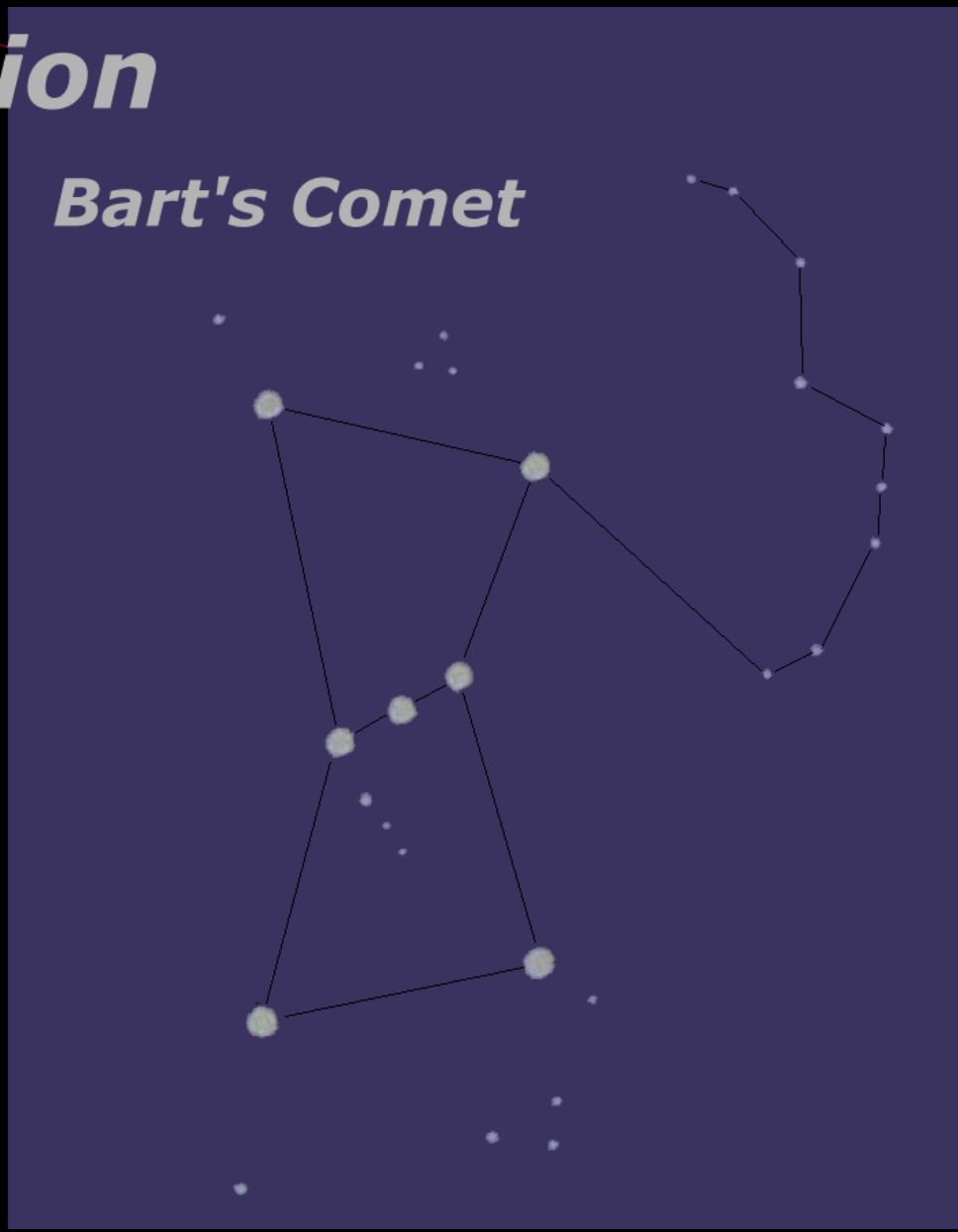

8h
7h
6h
5h
4h
3h
40°
30°
20°
10°
0°
-10°
-20°
-30°
AURIGA
PERSEUS
Castor
Pollux
GEMINI
Alnath
TAURUS
Pleiades
Jul 23
Jul 12
Jul 2
Jun 22
Jun 11
Jun 1
May 21
May 11
Aldebaran
ORION
Betelgeuse
Bellatrix
Mekab
Procyon
CANIS MINOR
MONOCEROS
Cursa
Rigel
Salph
Zaurak
ERIDANUS
Sirius
CANIS MAJOR
Arneb
LEPUS
Declination
Right Ascension
Define the scale. How many minutes are in an hour?

Orion

Real



Bart's Comet



La Fin