Galileo Galilei

. . . And the Optik Tube





1500 1600 1700

Principia Mathematica

Copernicus
Tycho Brahe
Newton
Kepler
Megellan
Columbus
Galileo
Luther
Descartes
Voltaire
Michelangelo
Rembrandt
Bach
Da Vinci
Shakespeare

Galileo's Italy . . .

Pisa

Vincenzo & Guilia Galilei

Born in Pisa, Feb. 15, 1564
Oldest of six kids (four survived)
Baptized in Cathedral of Pisa

Santa Maria di Vallombrosa (monastery)

University of Pisa (1581)

Pendulum Motion

$$T = 2\pi\sqrt{\frac{L}{g}}$$

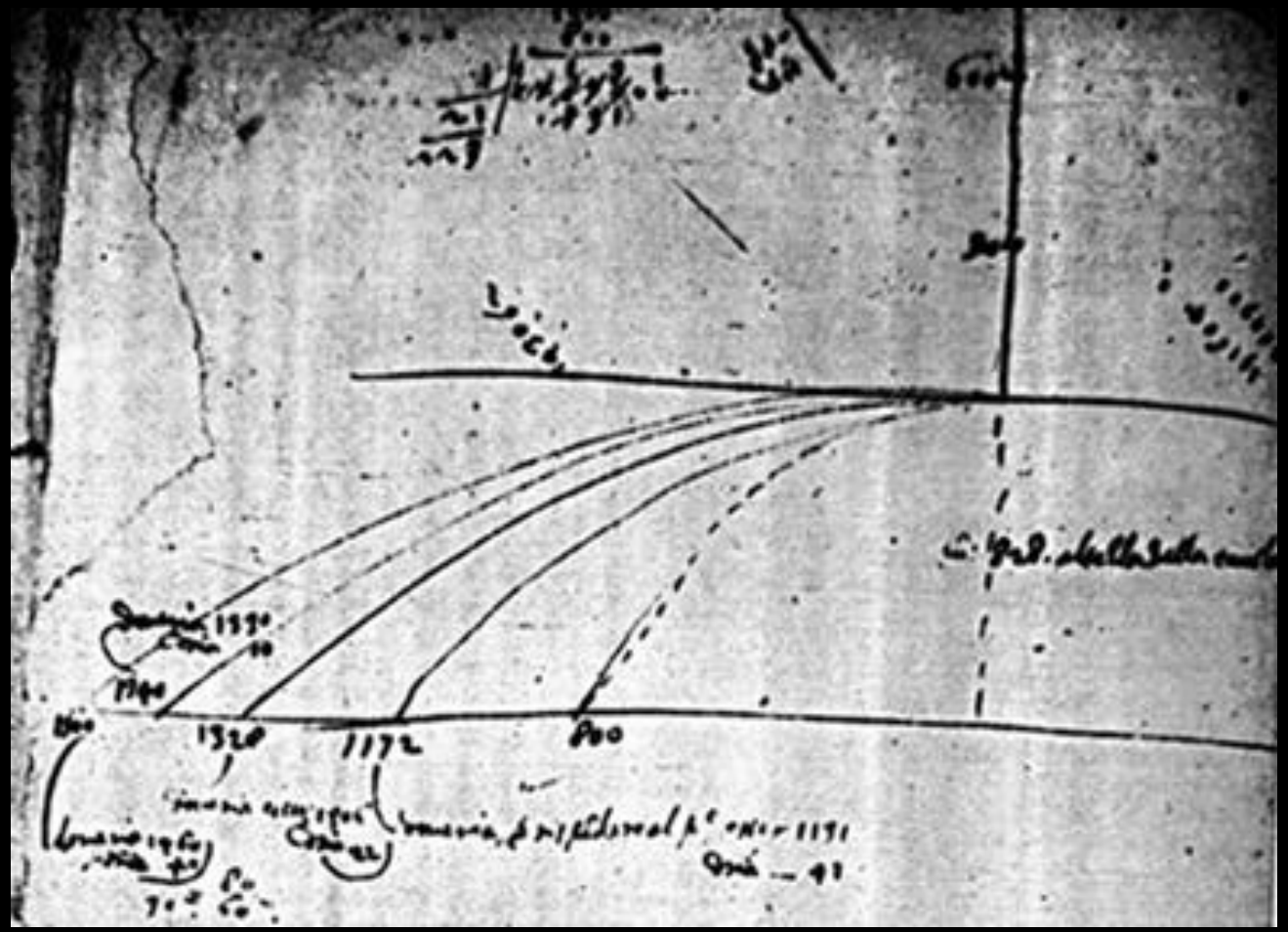

GALILEVS . GALILEIVS
EXPERIMENTIS . E . SVMMA . HAC . TVRRI
SVPER . GRAVIVM . CORPORVM . LAPSV . INSTITVTIS
LEGIBVS . MOTVS . DETECTIS
MECHANICEN . CONDIDIT
INGENIIS . SVIS . POSTERIORVMQE . SOPHORVM . INVENTIS . PRAELVSIT
IN . CVIVS . REI . MEMORIAM
VINCENTIVS . CARMIGNANIVS . EQ . AVR .
AEDITVVS . TEMPLI . MAXIMI . PISANORVM
MARMOR . INSCRIPTVM . DEDICAVIT
KAL . OCTOBR . AN . M . DCCC . XXXVIIII .
QVO . DIE . AVCTORITATE . AVSPICIISQVE
LEOPOLDI . II . MAGNI . DVCIS . ETRVRIAE
STVDIORVM . OPTIMORVM . FAVTORIS . PROVIDENTISSIMI
PRIMORES . DOCTORVM . EX . VNIVERSA . EVROPA
PISIS . AD . CONVENTVM . MAXIMVM . COEVNTES
DISCIPLINIS . ET . ARTIBVS . ITALORVM . FAVSTA . INCREMENTA
POLLICENTVR .

1592 – University of Padua

Hydrostatic Balance

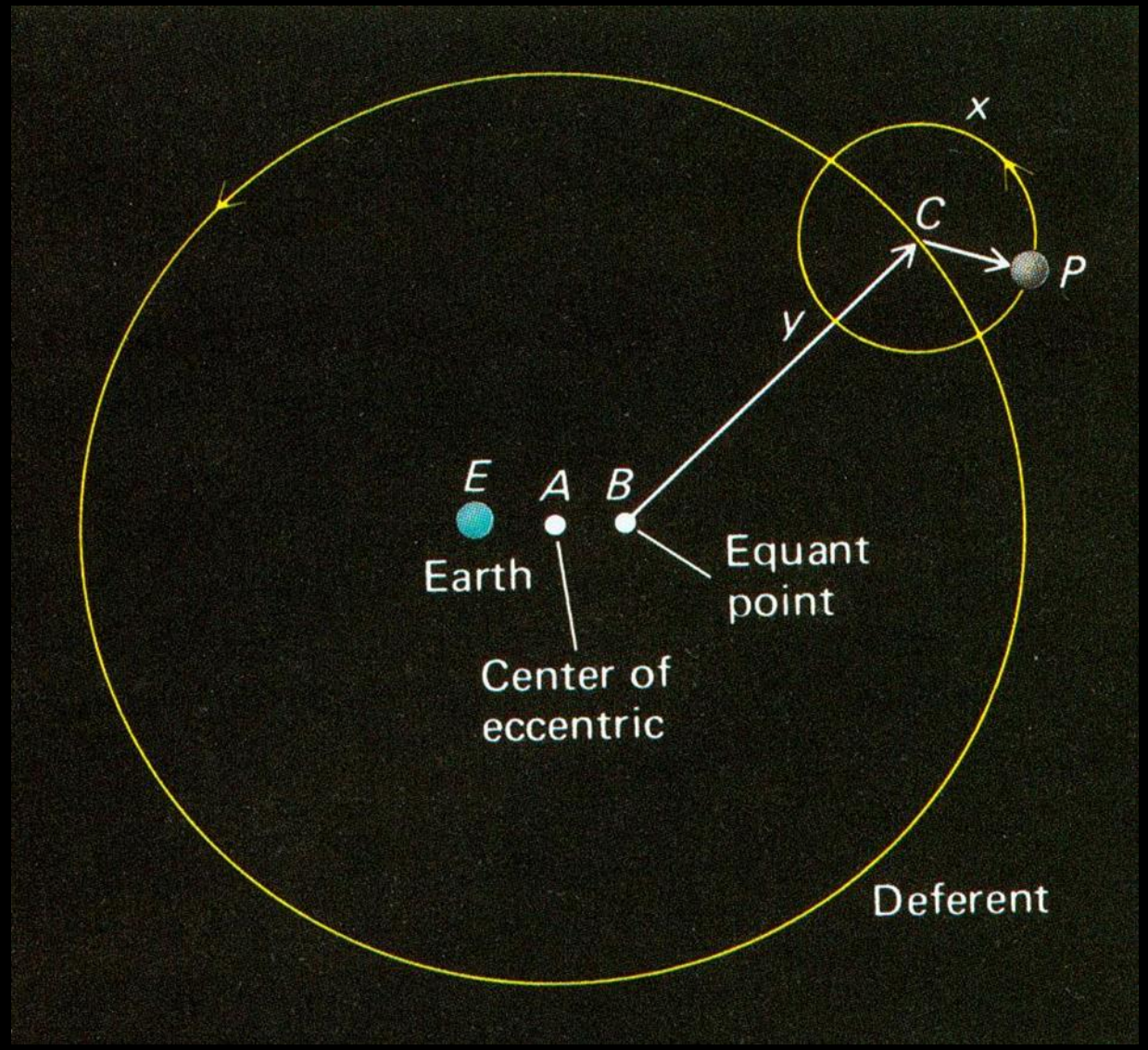
The “Sector”

Marina Gamba



Hans Lippershey (1570-1619)

A quick review . . . .

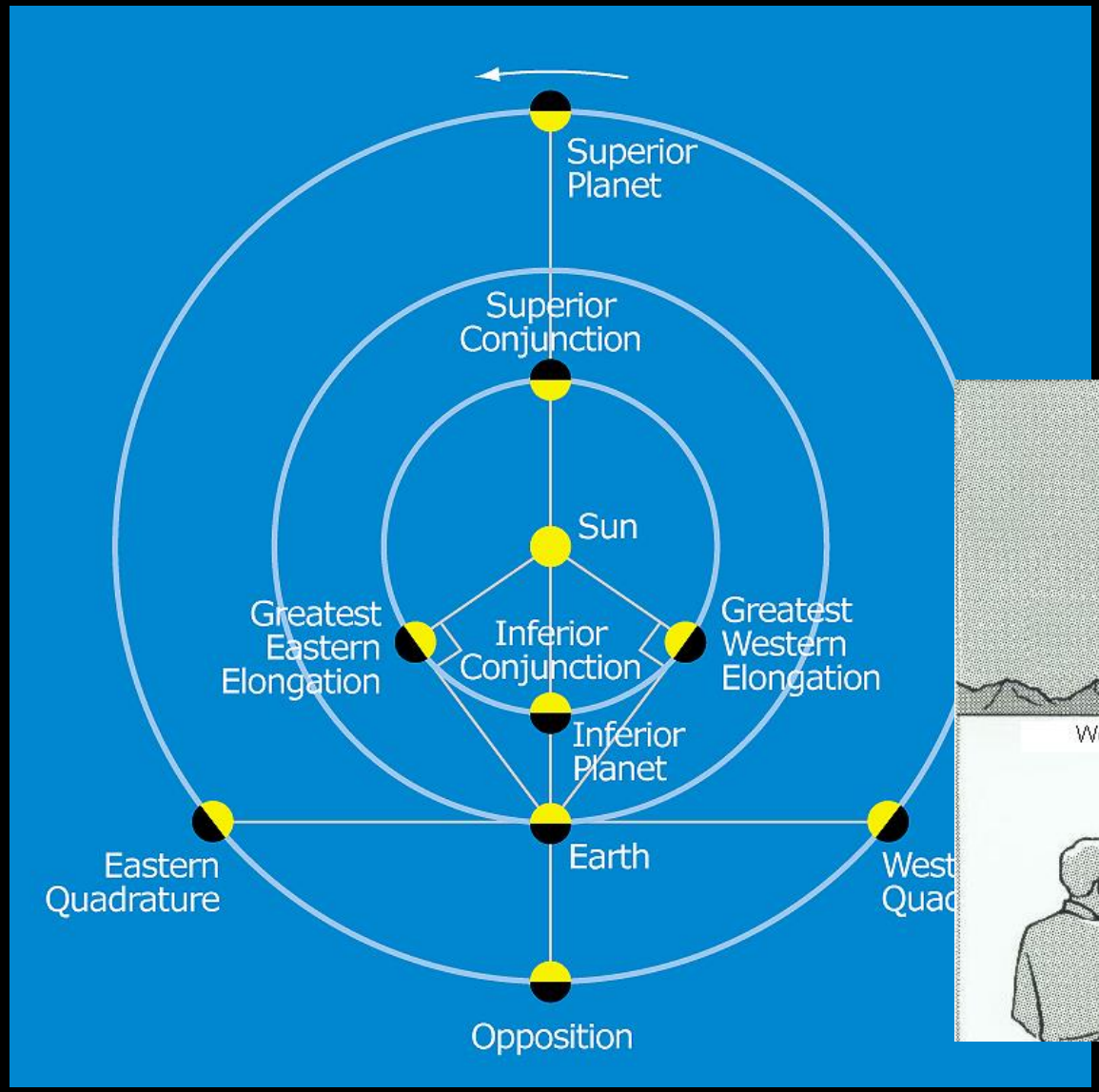


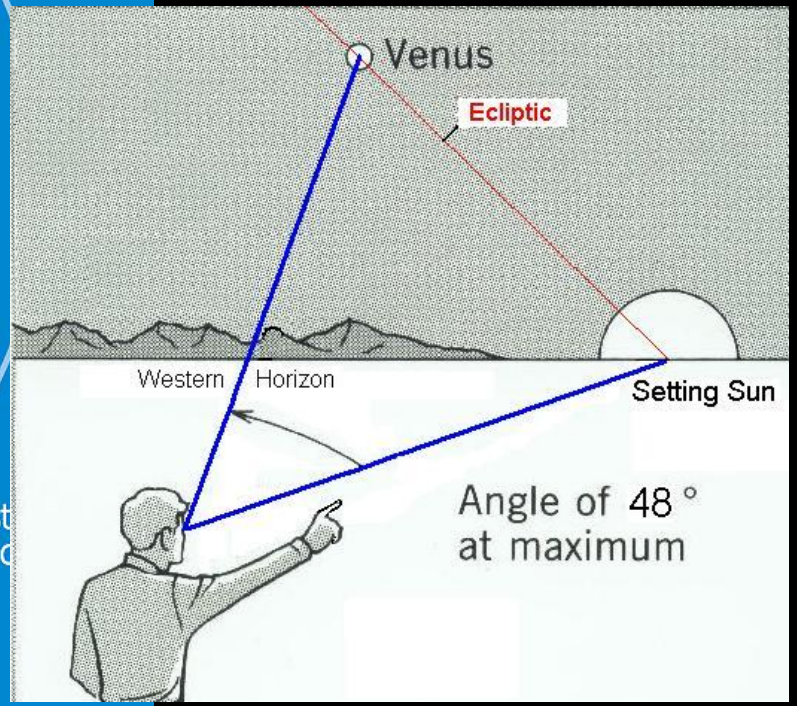
- Heavens are perfect
- Earth is fixed, doesn't move
- Circles are perfect
- Uniform circular motion
- Use of epicycles to explain "retrograde" motion

Geocentric problems

- Planets “orbit” imaginary points. *Why?*
- Why to closer planets always stay near the Sun? What confines them there?
- More distant planets only retrograde when opposite the Sun from Earth.
- What the hell is an “equant?”
- Is it *truly* Geocentric now?
- However . . . . Is this a good *“scientific theory?”*

Planetary configurations



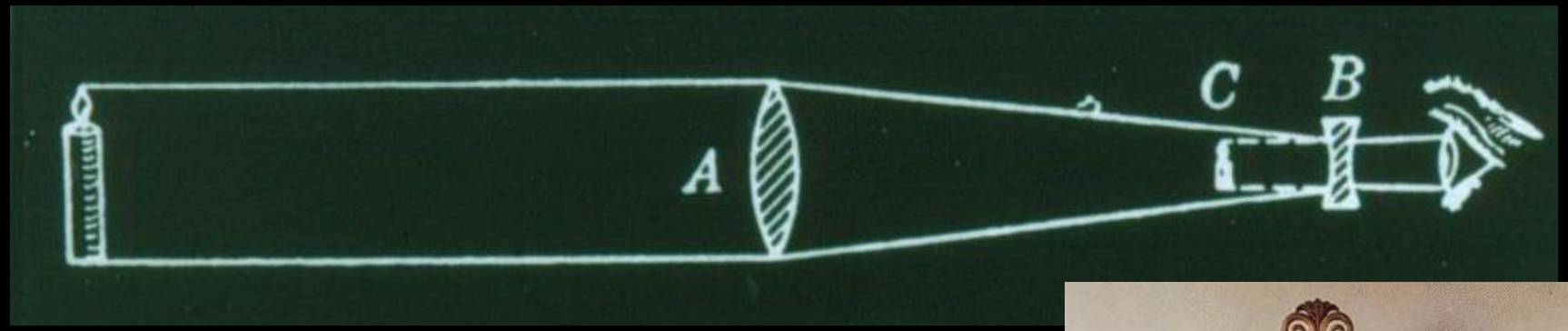


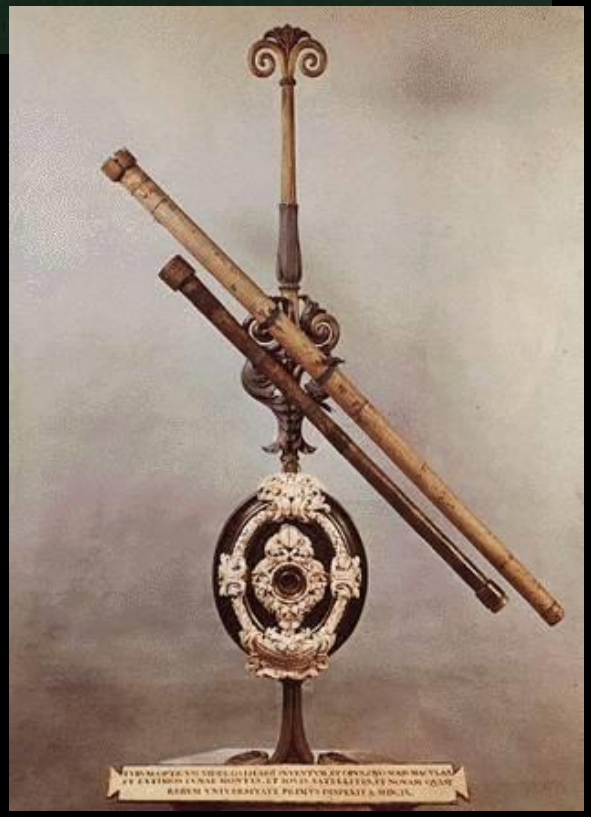
Nicholas Copernicus

- Polish doctor
- Found it “pleasing” that the Earth might orbit the Sun
- Heliocentric idea
- Feared criticism
- Still used perfect circles for orbits

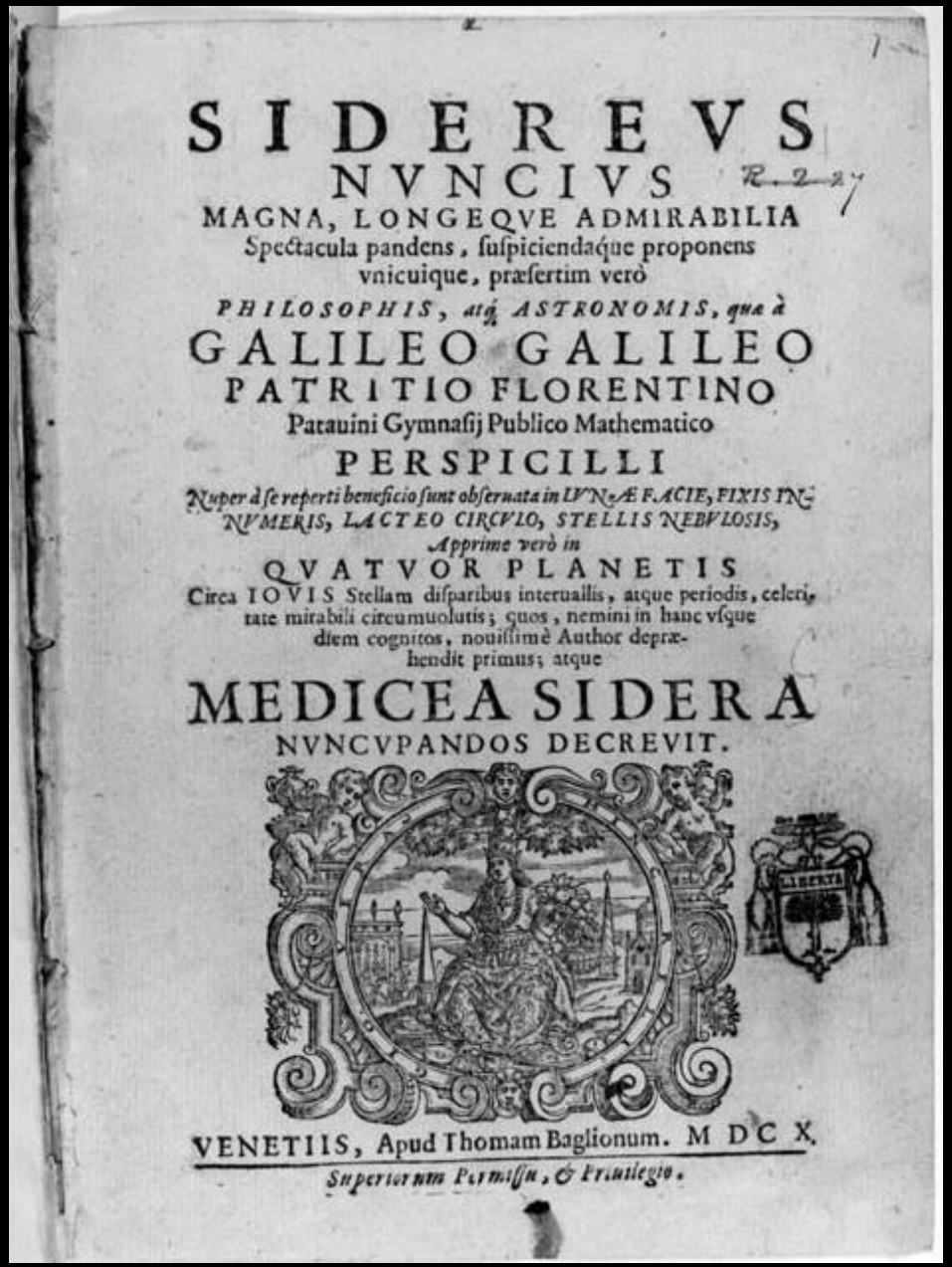
De Revolutionibus, 1543

Galileo's "Optik Tube" (1609)



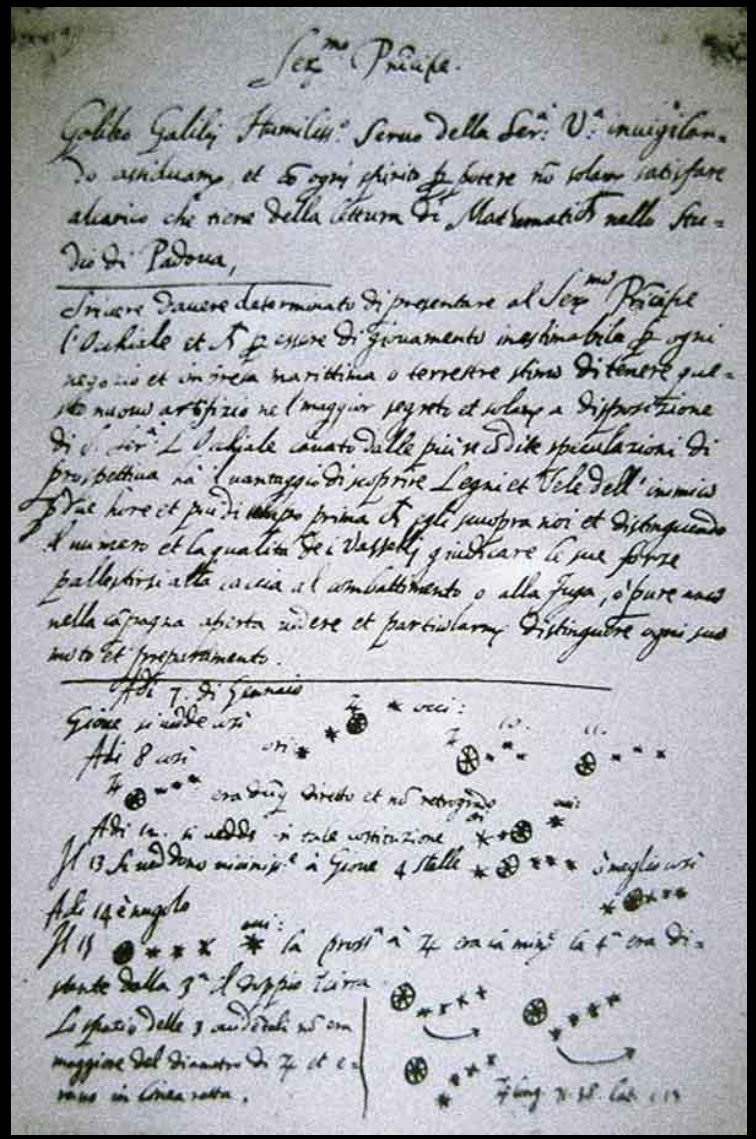


. . . He wrote it down!



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, & Priuilegio.



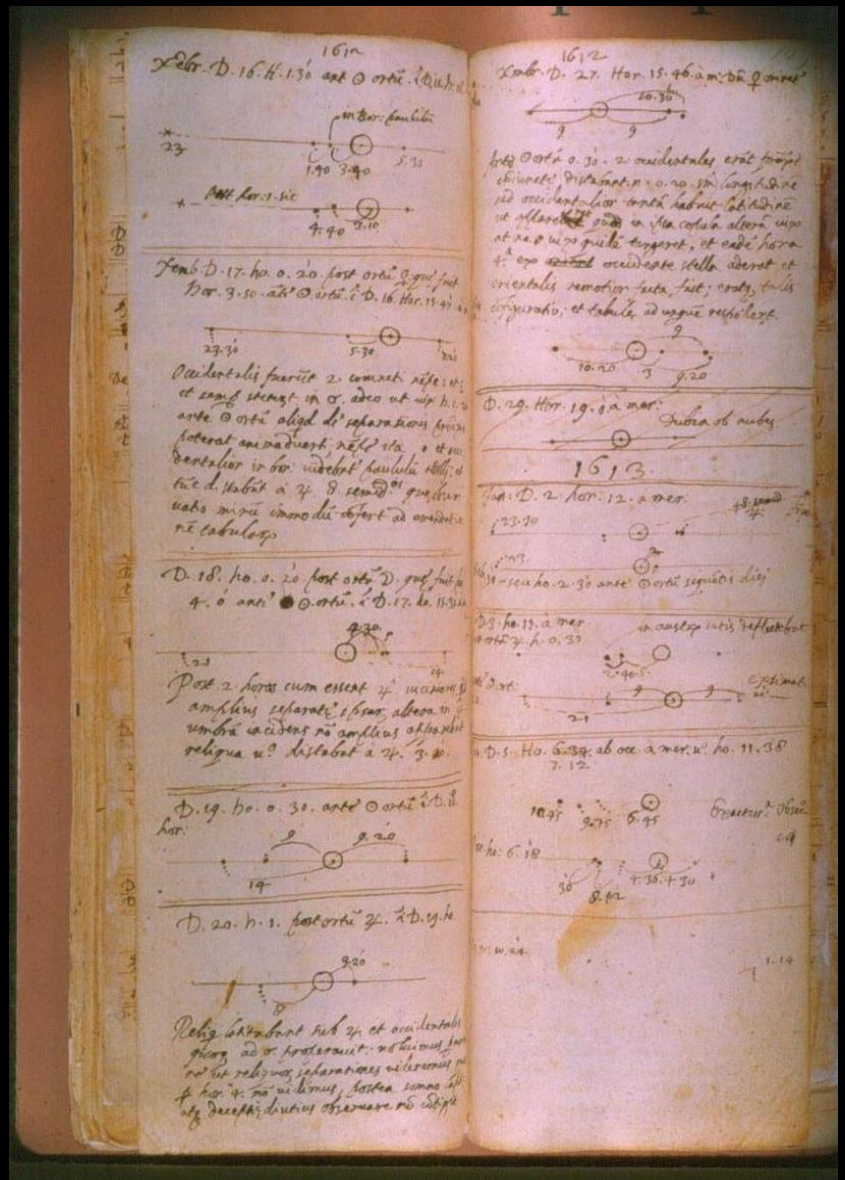
Sen^mo Prencipe.

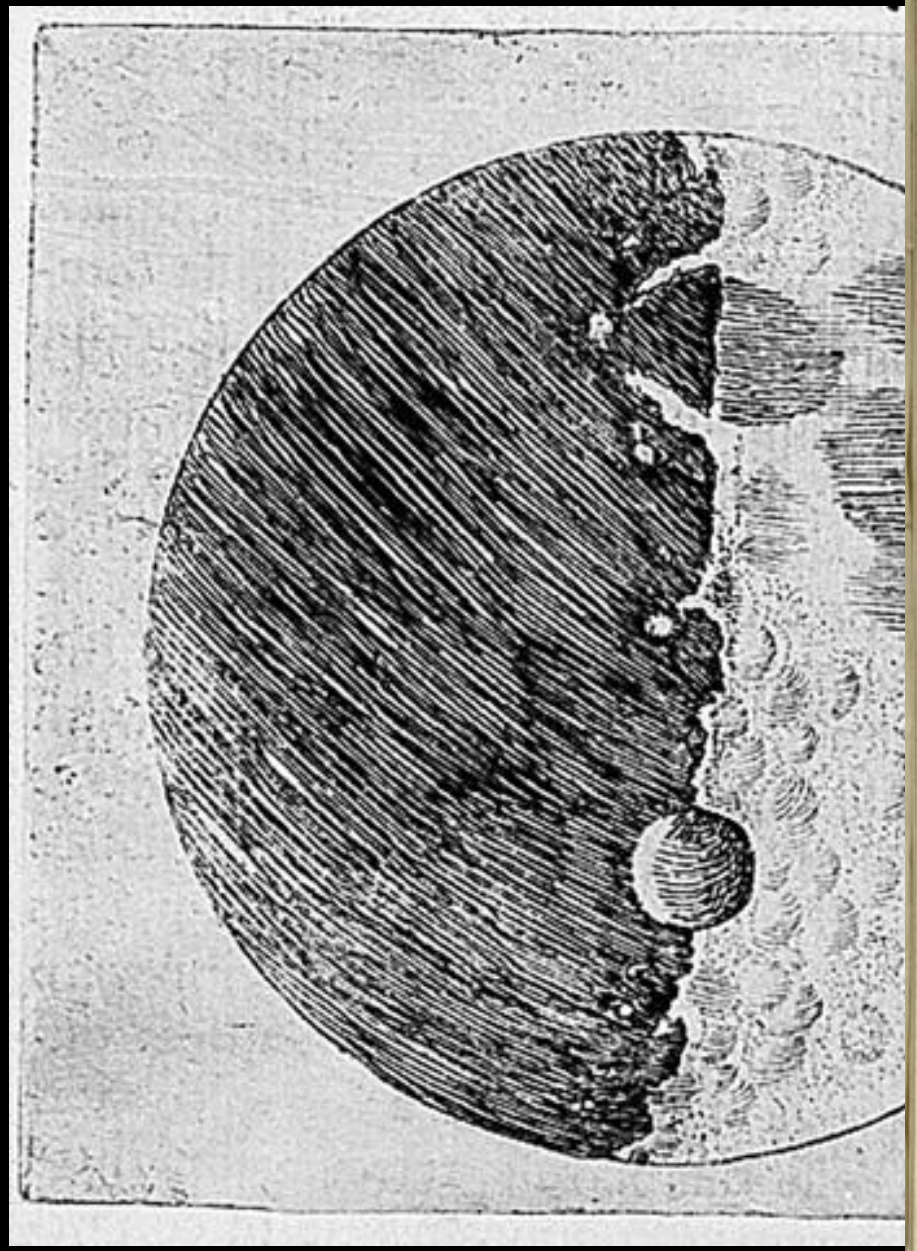
Galileo Galilei Humilis^mo Seruo della Ser^a V^a inuigilando assiduamente et con ogni spirito di deuere non solam^te sabisfare alcuno che resta della Lettura di Mathematica nello Stu-dio di Padoua,

stimare douere determinato di progettare al Ser^mo Prencipe l'Archiale et N^ro essere di giouamento inestimabile in ogni negotio et impresa marittima o terrestre stimo di tenere qual-che nuouo artificio nel maggior segreto et solam^te a dispositione di S^ra L'Archiale causato dalle più sue Dotte speculazioni di pro, pettina nà Quantaggio di scoprire Legni et Vele dell'inimico 2 due hore et più di tempo prima che egli scuopra noi et distinguendo il numero et la qualità de i Vasselli, giudicare le sue forze pallesterie alla caccia al combattimento o alla fuga, o pure anco nella campagna aperta vedere et particolarm^te distinguere ogni suo moto et preparamento.

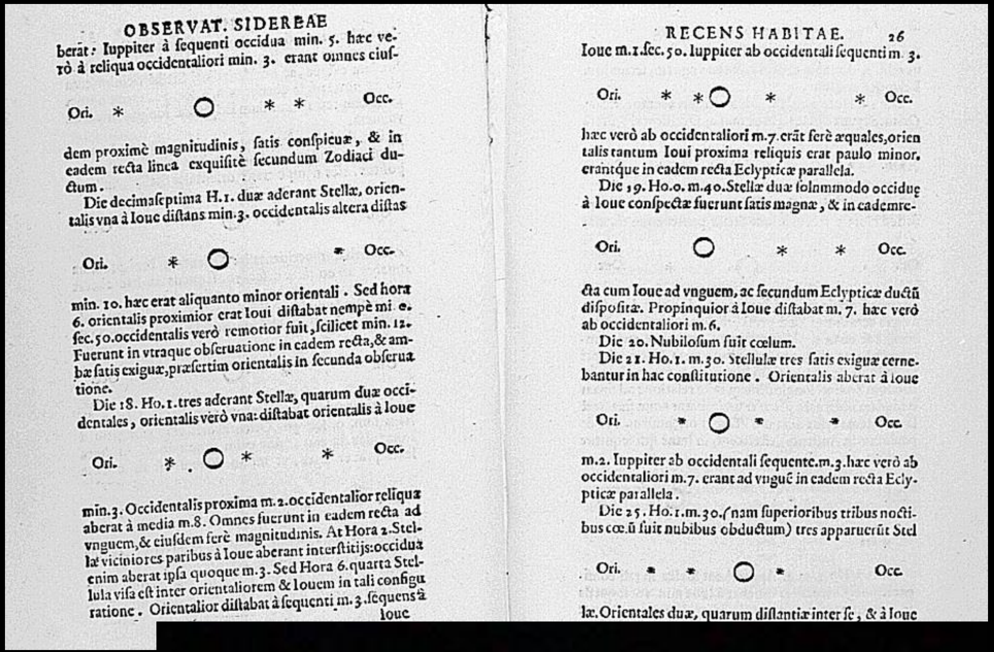
Adì 7. di Genaro
Giove si vedde così
Adì 8 così
Adì 11. si vedde in tale costituzione
Adì 13 si vedono insieme à Giove 4 stelle
Adì 14 è longo
Adì 15 la prossa à 4 era à mezo la 4ta era di-stante della 3za il doppio di terra
Lo spatio della 3 and^a si vedeva assai maggiore del diametro di 4 et e-rano in linea retta.

“Sidereus Nuncius” (Mar. 1610)






2,8
1
3
4



OBSERVAT. SIDEREAE

berat: Iuppiter à ſequenti occidua min. 5. hæc ve-
rò à reliqua occidentaliori min. 3. erant omnes eiuſ-

Ori. * ○ * * Occ.

dem proximè magnitudinis, ſatis conſpicuæ, & in
eadem recta linea exquiſitè ſecundum Zodiaci du-
ctum.

Die decimaſeptima H.1. duæ aderant Stellæ, orien-
talis vna à Ioue diſtans min.3. occidentalis altera diſtas

Ori. * ○ * Occ.

min. 10. hæc erat aliquanto minor orientali. Sed hora
6. orientalis proximior erat Ioui diſtabat nempè mi. e.
ſec.50.occidentalis verò remotior fuit, ſcilicet min. 12.
Fuerunt in vtraque obſeruatione in eadem recta, & am-
bæ ſatis exiguæ, præſertim orientalis in ſecunda obſerua
tione.

Die 18. Ho.1.tres aderant Stellæ, quarum duæ occi-
dentales, orientalis verò vna: diſtabat orientalis à Ioue

Ori. * . ○ * * Occ.

min.3. Occidentalis proxima m.2.occidentalior reliqua
aberat à media m.8. Omnes fuerunt in eadem recta ad
vnguem, & eiuſdem ferè magnitudinis. At Hora 2.Stel-
læ viciniores paribus à Ioue aberant interſtitijs: occidua
enim aberat ipſa quoque m.3. Sed Hora 6.quarta Stel-
lula viſa eſt inter orientaliorem & Iouem in tali configu
ratione. Orientalior diſtabat à ſequenti m.3.ſequens à
Ioue

RECENS HABITAE. 26

Ioue m.1.ſec.50. Iuppiter ab occidentali ſequenti m. 3.

Ori. * * ○ * * Occ.

hæc verò ab occidentaliori m.7. erāt ferè æquales, orien
talis tantum Ioui proxima reliquis erat paulo minor,
erantque in eadem recta Eclypticæ parallela.

Die 19. Ho.0. m.40.Stellæ duæ ſolummodo occiduę
à Ioue conſpectæ fuerunt ſatis magnæ, & in eademre-

Ori. ○ * * Occ.

cta cum Ioue ad vnguem, ac ſecundum Eclypticæ ductū
diſpoſitæ. Propinquior à Ioue diſtabat m. 7. hæc verò
ab occidentaliori m.6.

Die 20. Nubiloſum fuit cœlum.

Die 21. Ho.1. m.30. Stellulæ tres ſatis exiguæ cerne-
bantur in hac conſtitutione. Orientalis aberat à Ioue

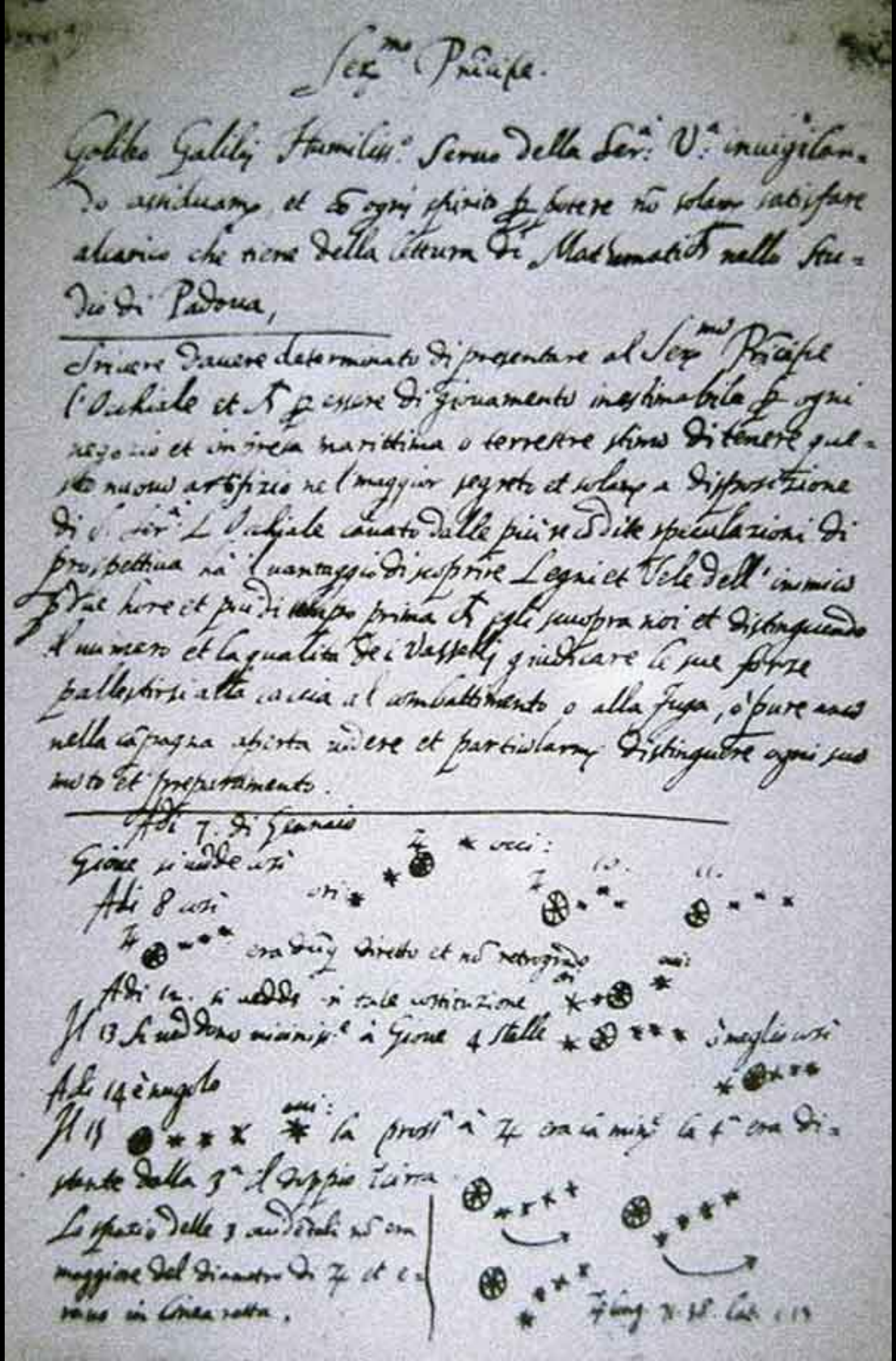
Ori. * ○ * * Occ.

m.2. Iuppiter ab occidentali ſequente.m.3.hæc verò ab
occidentaliori m.7. erant ad vnguē in eadem recta Ecly-
pticæ parallela.

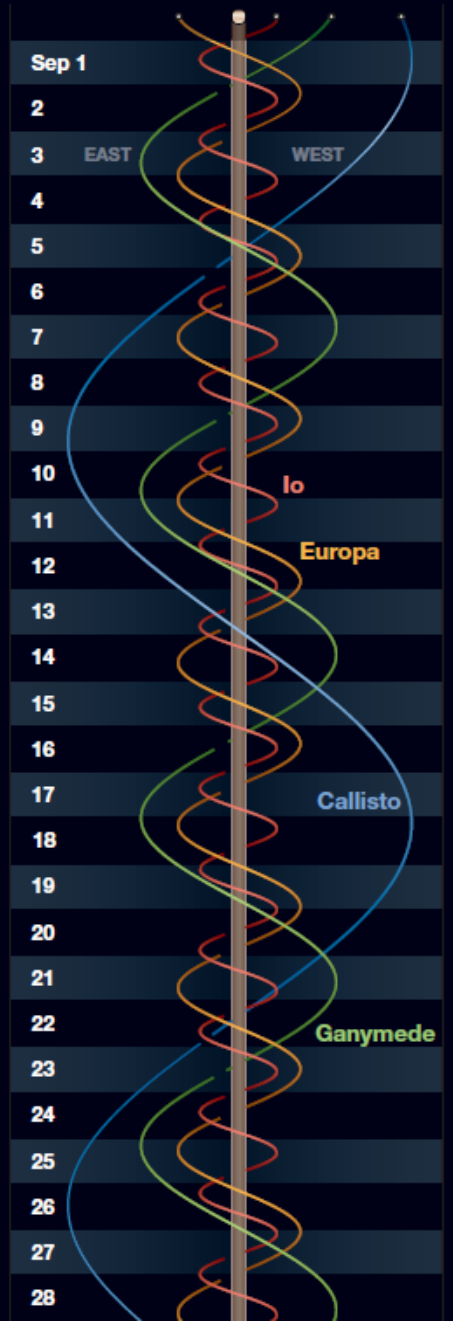
Die 25. Ho.1.m.30.(nam ſuperioribus tribus nocti-
bus cœlū fuit nubibus obductum) tres apparuerūt Stel

Ori. * * ○ * Occ.

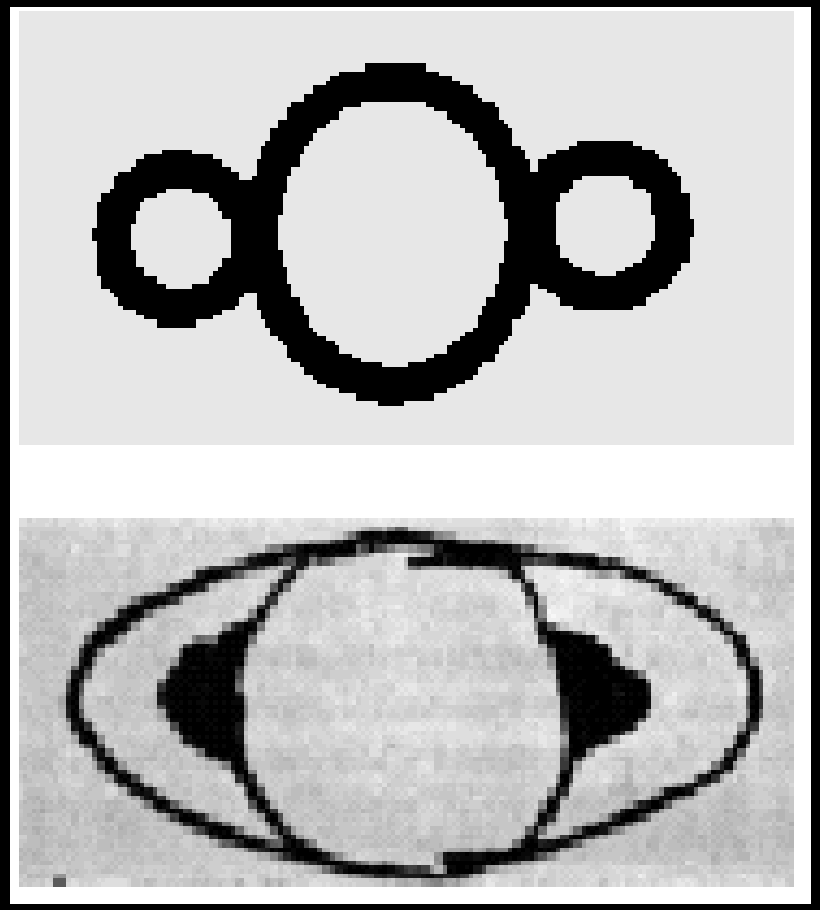
læ. Orientales duæ, quarum diſtantiæ inter ſe, & à Ioue



Jupiter's Moons

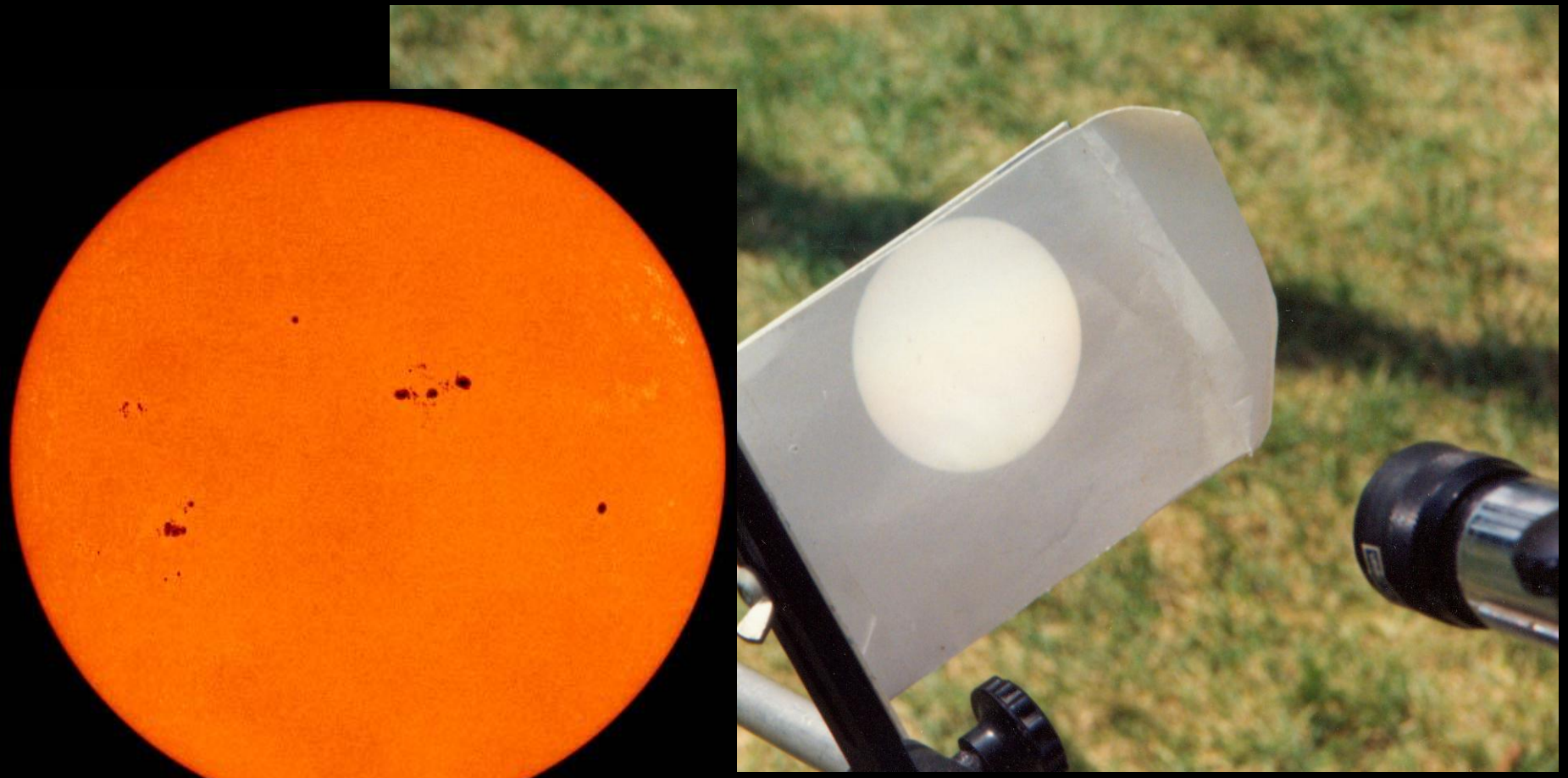


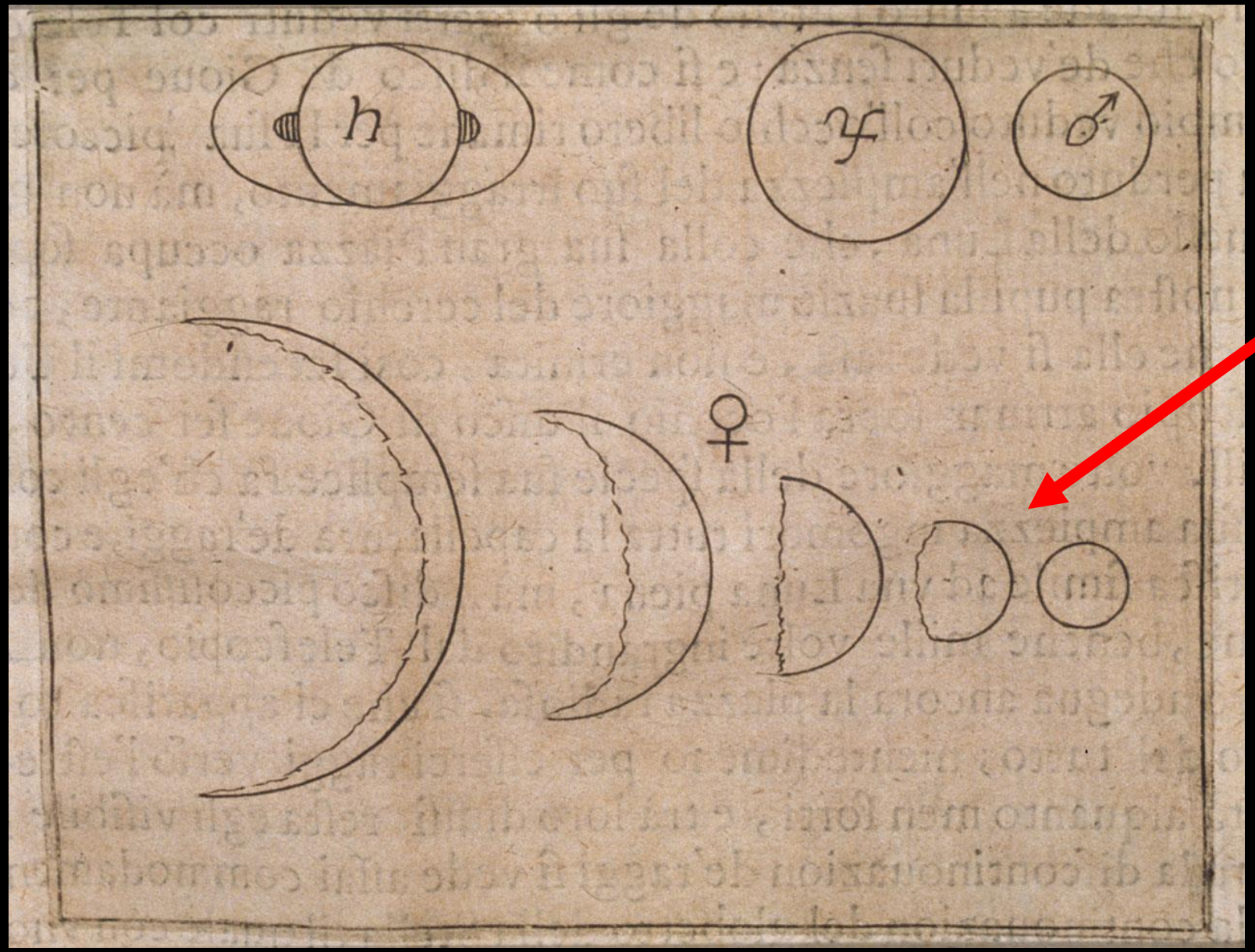
Saturn has “ears”



“smaismrmilmepoetaleumibunenugttausras”

How do you “look” at the Sun?

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♃
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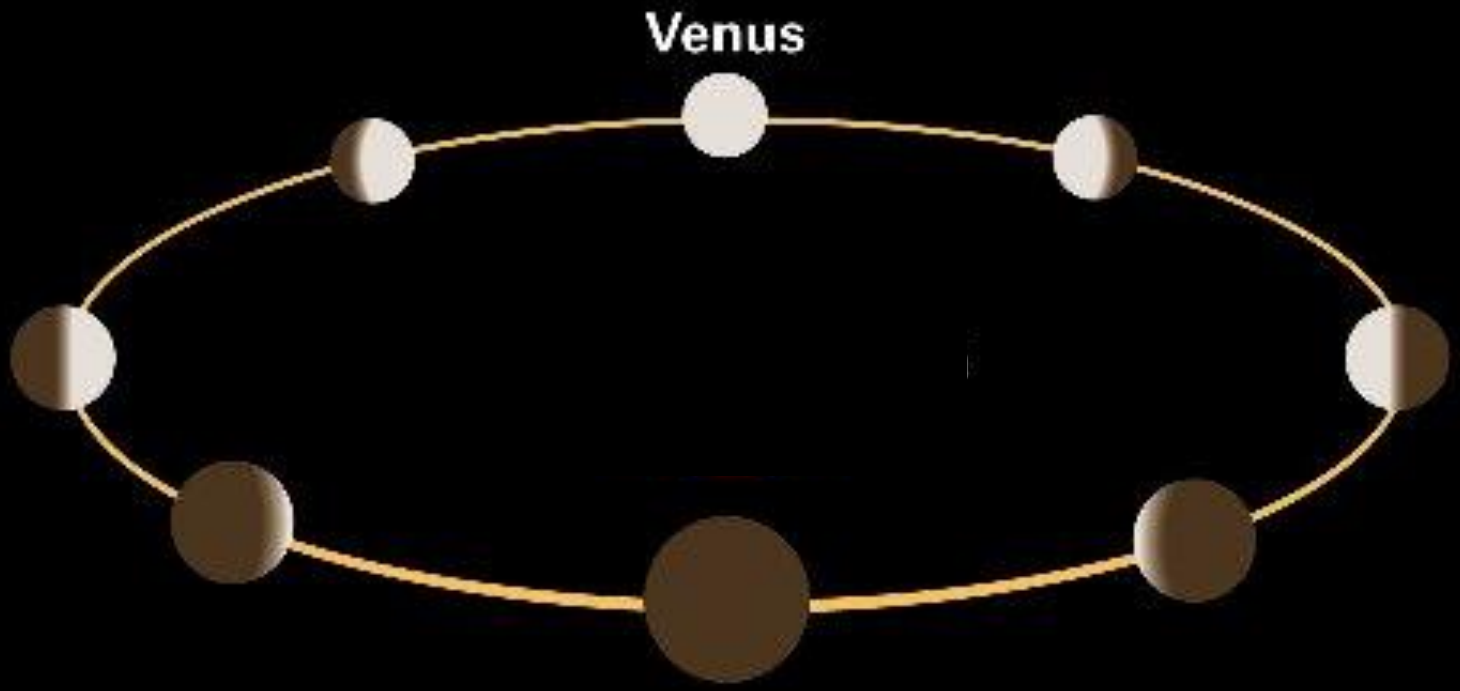

Venus

December 1615 – Heads to Rome

1616 decree . . .

Cardinal Bellarmine


IL SAGGIATORE
Nel quale
Con bilancia esquisita e giusta
si ponderano le cose contenute
nella
LIBRA·ASTRONOMICA·E·FILOSOFICA
DI LOTARIO·SARSI·SIGENSANO
Scritto in forma di lettera
All'Ill.mo et Rever.mo Mons.re D.
VIRGINIO·CESARINI
Acc.o Linceo M.o di Camera di N.S.
Dal Sig.
GALILEO GALILEI
Acc.o Linceo Nobile Fiorentino
Filosofo e Matematico Primario
del
Ser.mo Gran Duca di Toscana
FILOSOFIA NATVRALE
MATE MA
IN ROMA·MD·C·XX III
Appresso Giacomo Mascardi
F. Villamoena Fecit.

Pope Urban VIII

DIALOGO
DI
GALILEO GALILEI LINCEO

MATEMATICO SOPRAORDINARIO

DELLO STVDIO DI PISA.

E Filosofo, e Matematico primario del

SERENISSIMO

GR. DVCA DI TOSCANA.

Doue ne i congressi di quattro giornate si discorre sopra i due

MASSIMI SISTEMI DEL MONDO
TOLEMAICO, E COPERNICANO;

Proponendo indeterminatamente le ragioni Filosofiche, e Naturali tanto per l'vna, quanto per l'altra parte.

CON PRI VILEGI.

IN FIORENZA, Per Gio: Batista Landini MDCXXXII.

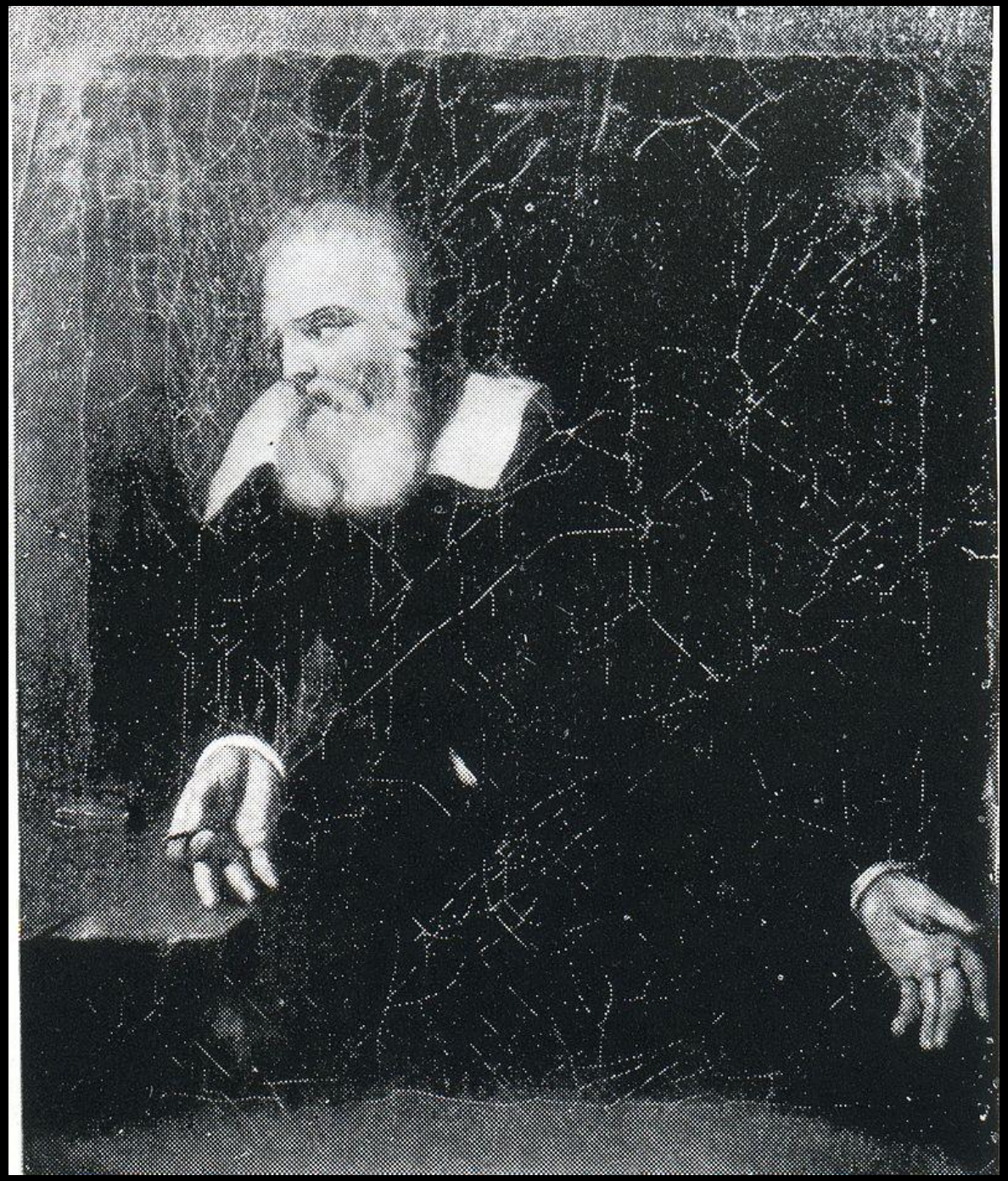
CON LICENZA DE' SVPERIORI.

Santa Maria Sopra Minerva

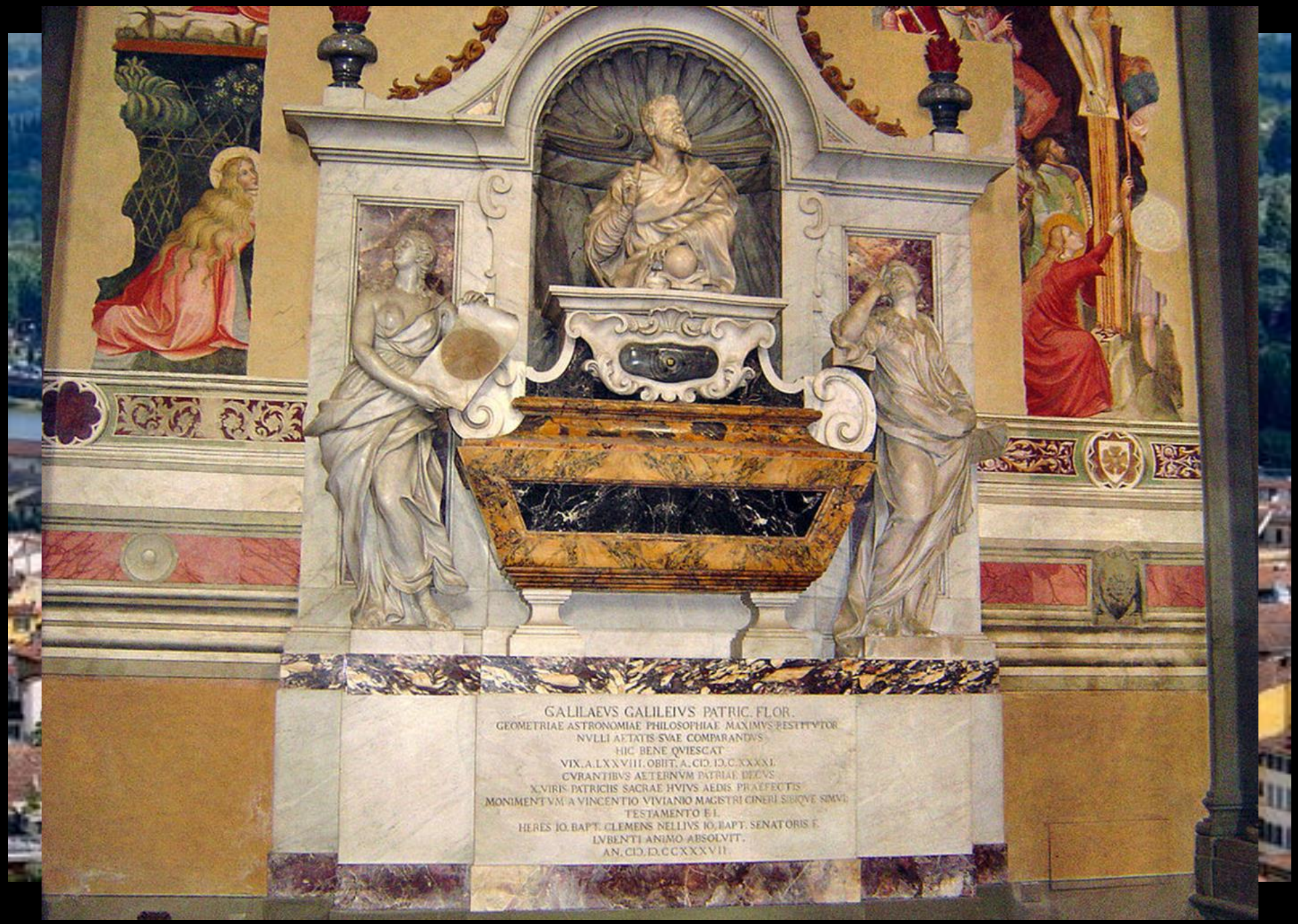
“Discourse and Mathematical Demonstrations Relating to Two New Sciences”

DISCORSI
E
DIMOSTRAZIONI
MATEMATICHE,
intorno à due nuoue ſcienze
Attenenti alla
MECANICA & I MOVIMENTI LOCALI,
del Signor
GALILEO GALILEI LINCEO,
Filoſofo e Matematico primario del Sereniſſimo
Grand Duca di Toſcana.
Con vna Appendice del centro di grauità d'alcuni Solidi.

IN LEIDA,
Appreſſo gli Elſevirii. M. D. C. XXXVIII.



“E pur si muove”



Died: January 8, 1642


ANA NE SPERNAS DIGITI QVO DEXTERA
VIAS NVMQVAM VISOS MORTALIBVS
AVIT PARVO FRAGILIS MOLIMINE VIS
PRIOR FACINVS CVI NON TITANIA QVO
FECIT PVBES CONGESTIS MONTIBVS AC
QVIDQVAM SVPERAS CONATA ASCENDER
THOMAS


©IMSS - Firenze

Galileo Museum, Florence

Top 10 National Apologies

On June 15, British Prime Minister David Cameron offered an apology before the House of Commons for the 1972 "Bloody Sunday" killings of 14 unarmed protesters in Northern Ireland. TIME looks back on other apologies for national misdeeds

MEA MAXIMA CULPA

The Galileo Case

By Dan Fastenberg | Thursday, June 17, 2010

His only crime was to claim that planet Earth revolved around the Sun. That was enough cause for the Catholic Church to persecute Galileo. The Vatican condemned Galileo in 1633 for his putatively subversive views, and threatened the scientist with a burning at the stake. Galileo took back his statement, but still lived under house arrest for the rest of his life. It took 359 years and the leadership of Pope John Paul II (left) to recognize the wrong. On October 31, 1992, he formally apologized for the "Galileo Case" in the first of many famous apologies during his papacy.

GARY HERSHORN / Reuters / Corbis

POWER!!!

The “nasty five-letter word”

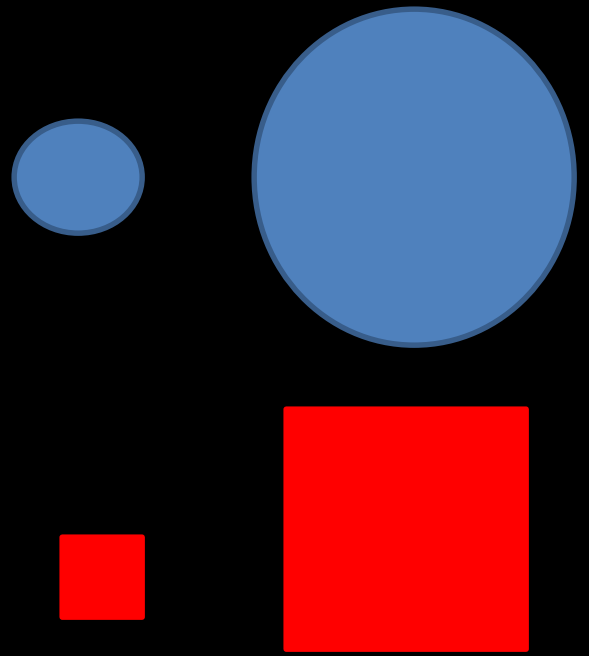
Different “powers”

- **Magnification** – “making things larger”
- **Light Gathering** – “collecting more light than your eye.” Depends on “aperture,” or diameter of light collector.
- **Resolving** – “the ability to see fine detail.” Depends on quality, aperture & sky conditions. Measured in arc seconds.

A little diddy . . .bout Jack & Diane . . . .

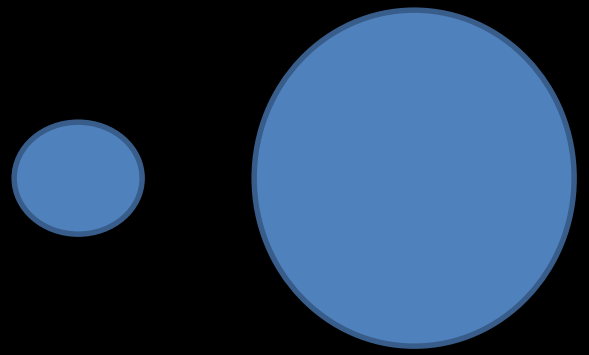
Follow this . . . . .

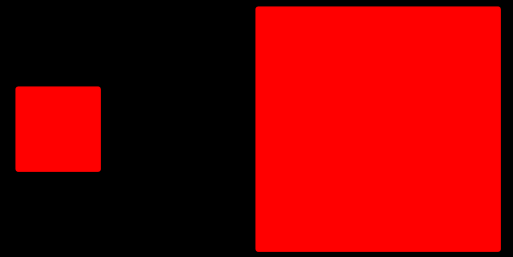
- Diane . . . 2” telescope, 7x
- 2” is 8x larger than eye (1/4”)
- Think “areas” 8 x 8 = 64x more light
- Magnify 7x, spread out light 7 x 7 = 49x
- 64/49 = 1.3x brighter



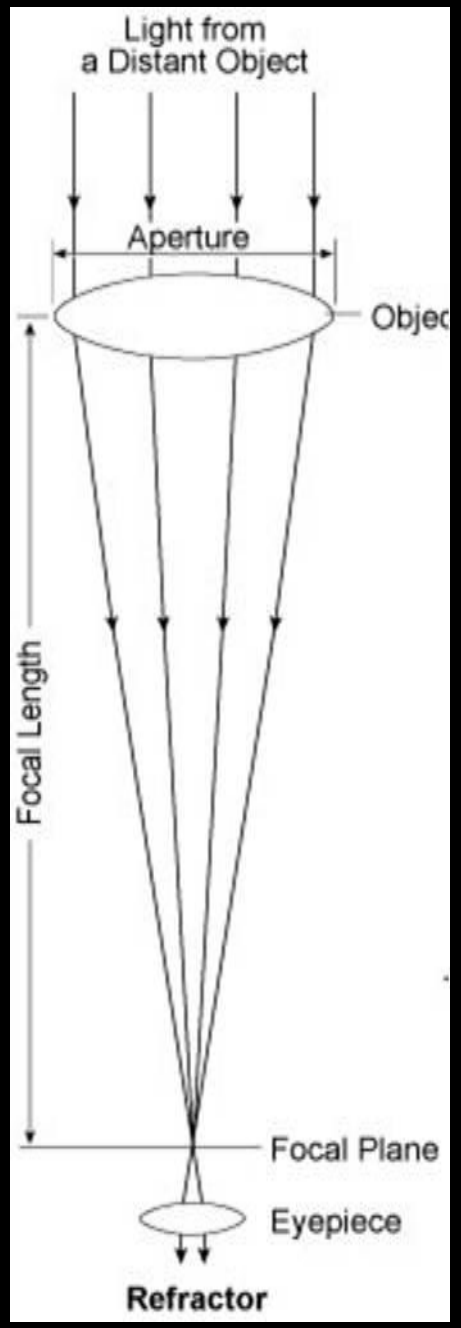
Follow this . . . . .

- Jack . . . 3” telescope, 500x
- 3” is 12x larger than eye (1/4”)
- Think “areas” 12 x 12 = 144x more light
- Magnify 500x, spread out light
  500 x 500 = 250,000x
- 144/500,000 = 0.0003x brighter
  (3500x fainter!)

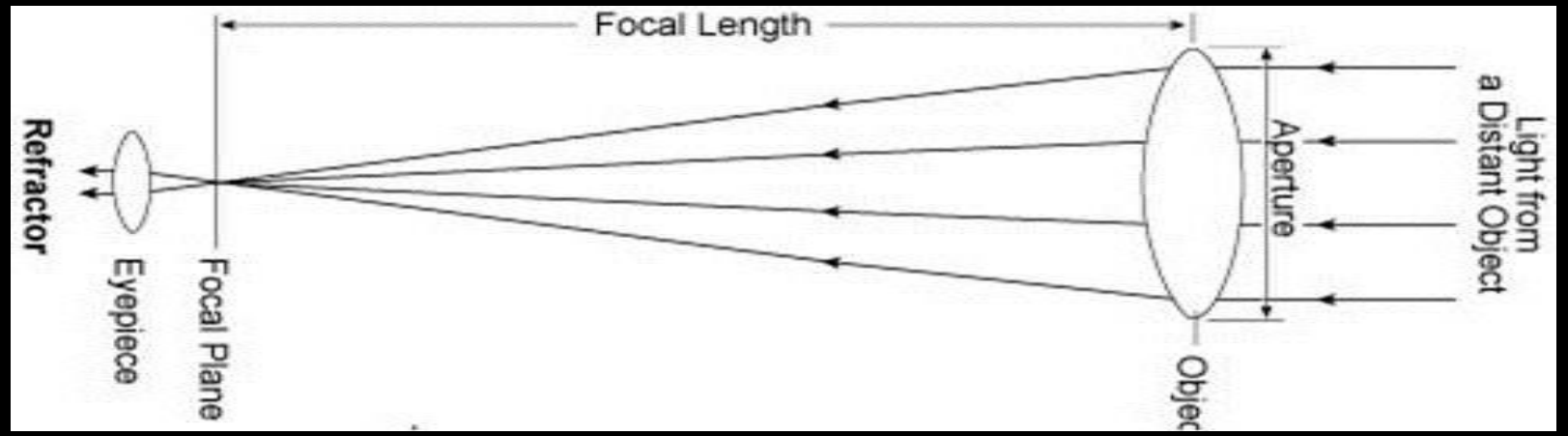




The Main Purpose
of a Telescope is to
Collect Light
. . . .*period!*


Light from
a Distant Object
Aperture
Objec
Focal Length
Focal Plane
Eyepiece
Refractor

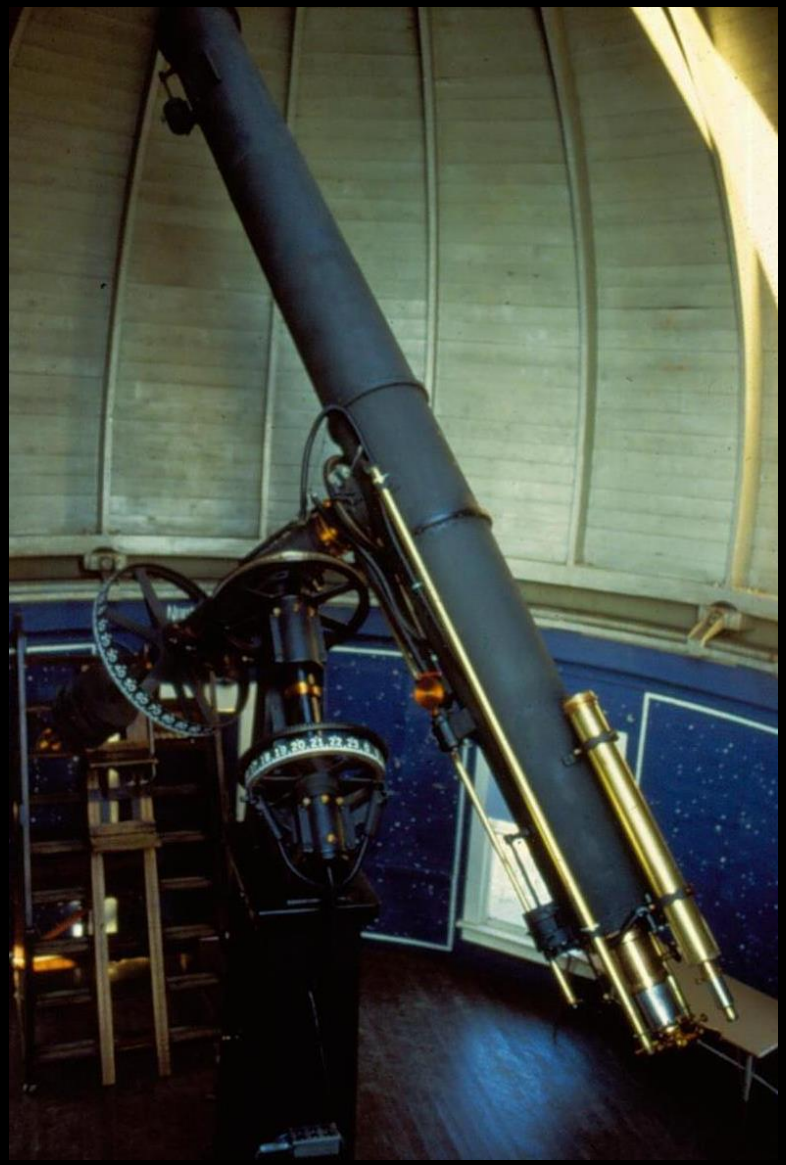
Some useful definitions

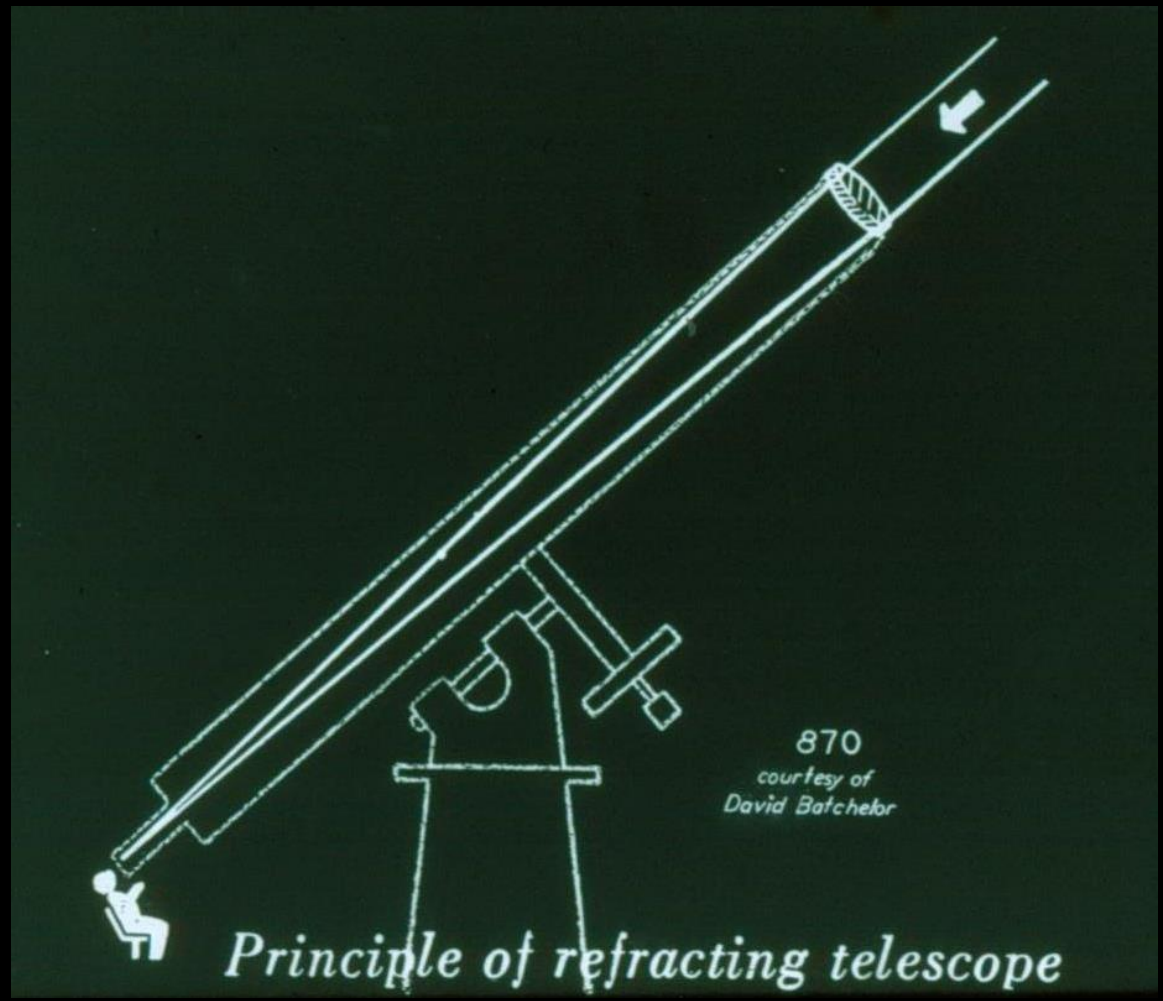


"Objective" – whatever is doing the collecting (lens or mirror)
"Aperture" – diameter of whatever is collecting the light (lens or mirror)
"Focal Point" – the spot where the light comes to a focus, the light rays come together.
"Focal length" – the distance from the lens (or mirror) to the focal point.
"Eyepiece" – what you look into. This does the magnifying. You can change eyepieces and change the magnification.

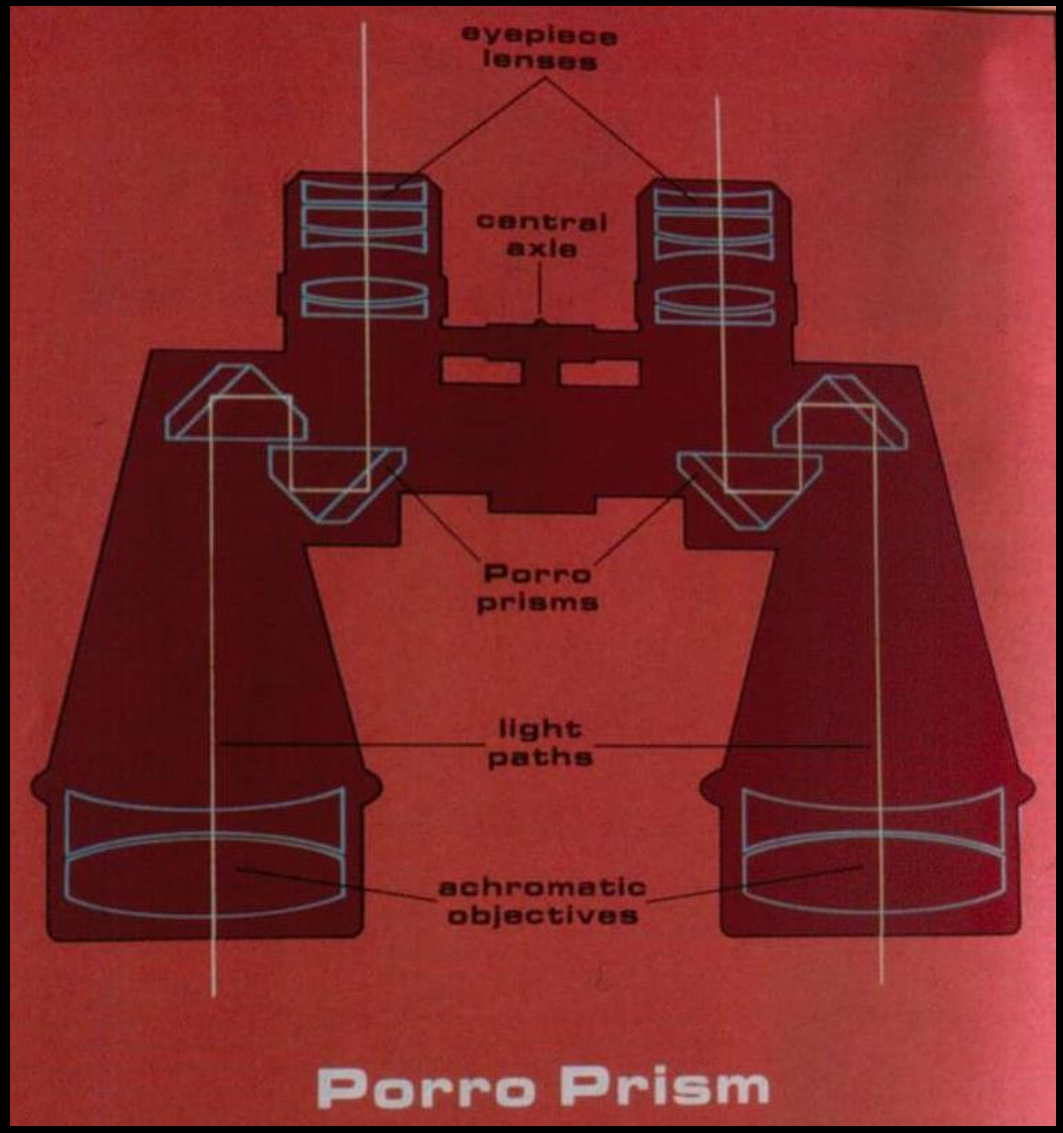
$$\text{Magnification} = \frac{\text{Focal length of objective}}{\text{Focal length of eyepiece}}$$

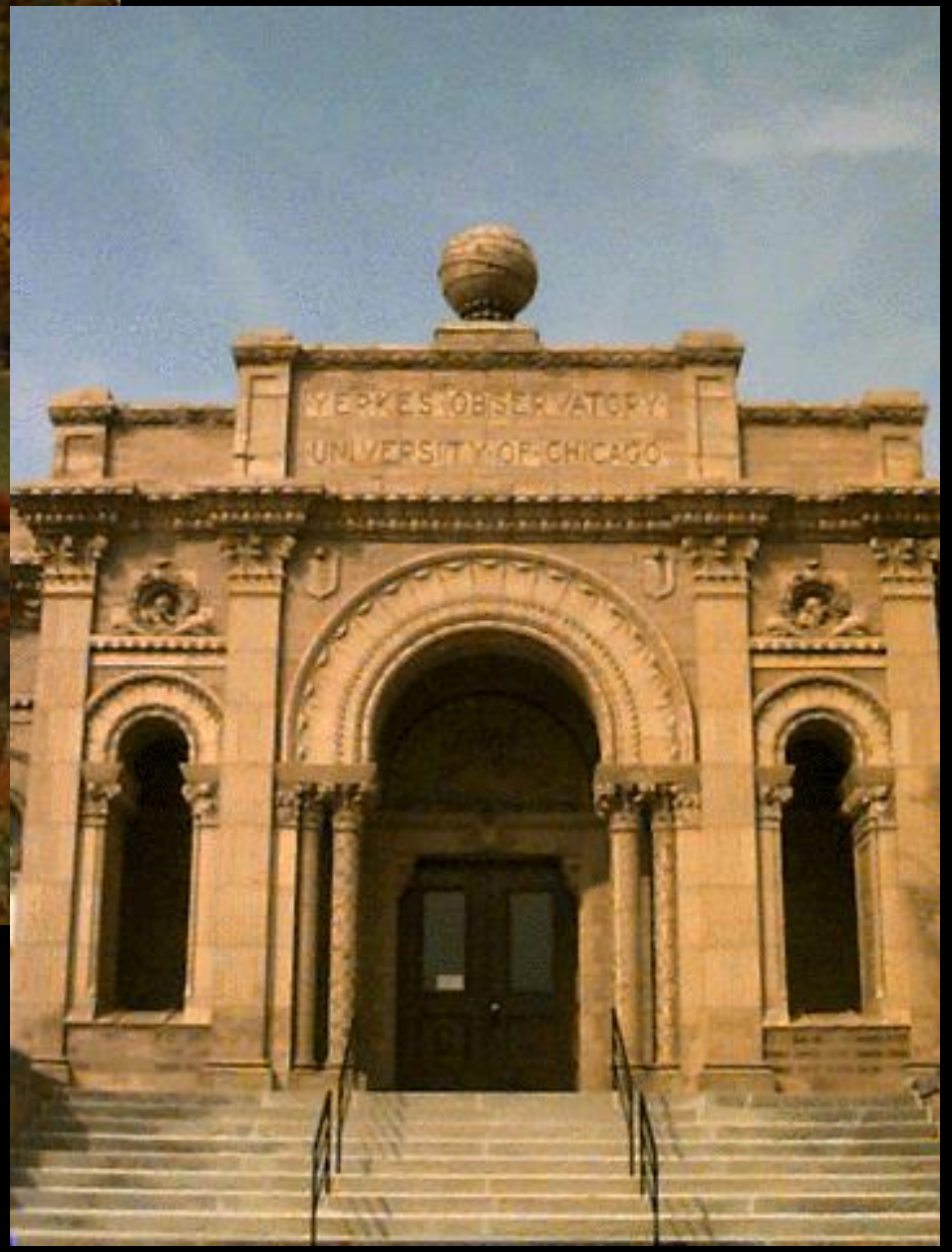
The Refractor



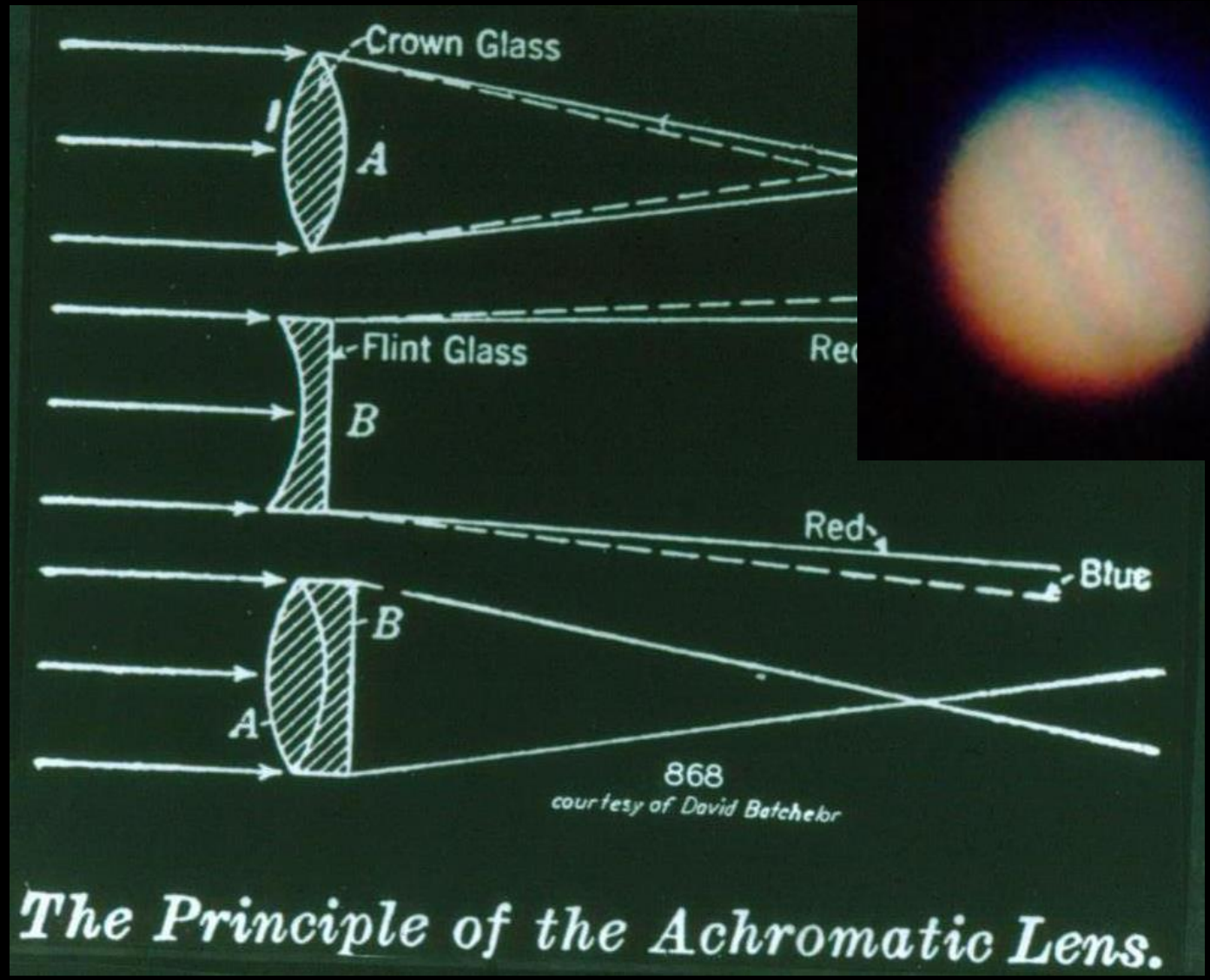


Binoculars

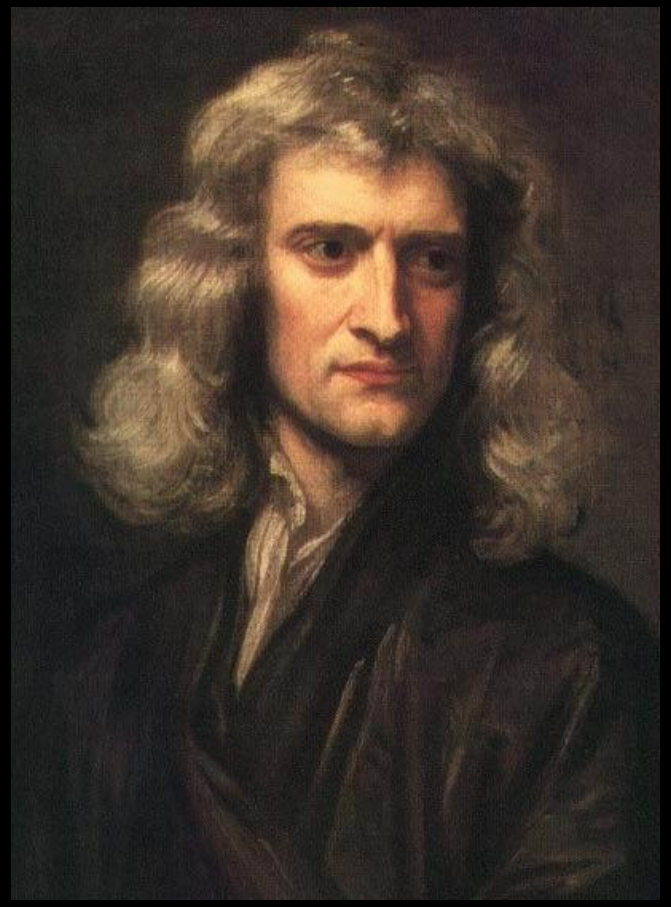

eyepiece lenses
central axle
Porro prisms
light paths
achromatic objectives
Porro Prism

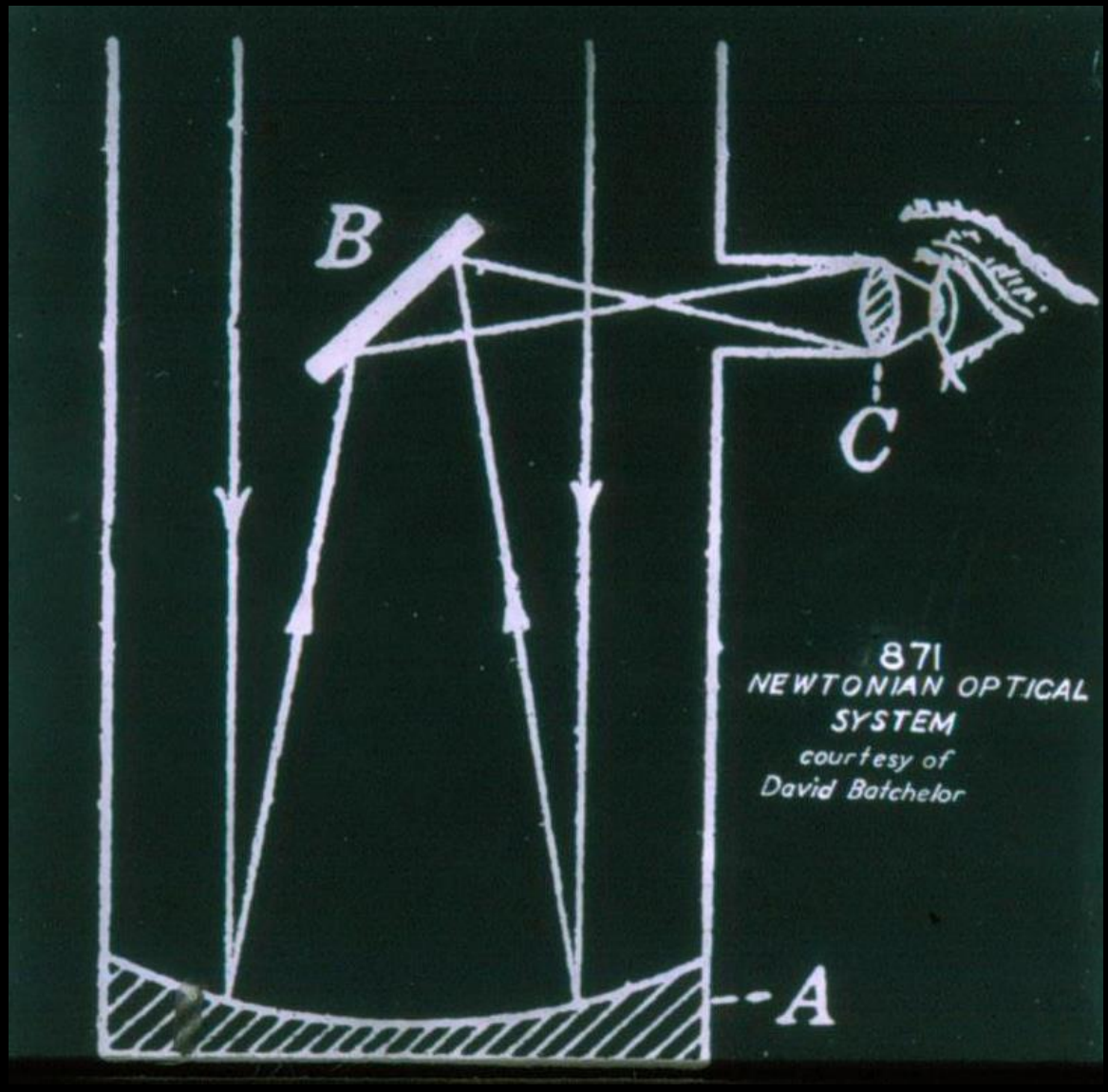

YERKES OBSERVATORY
UNIVERSITY OF CHICAGO

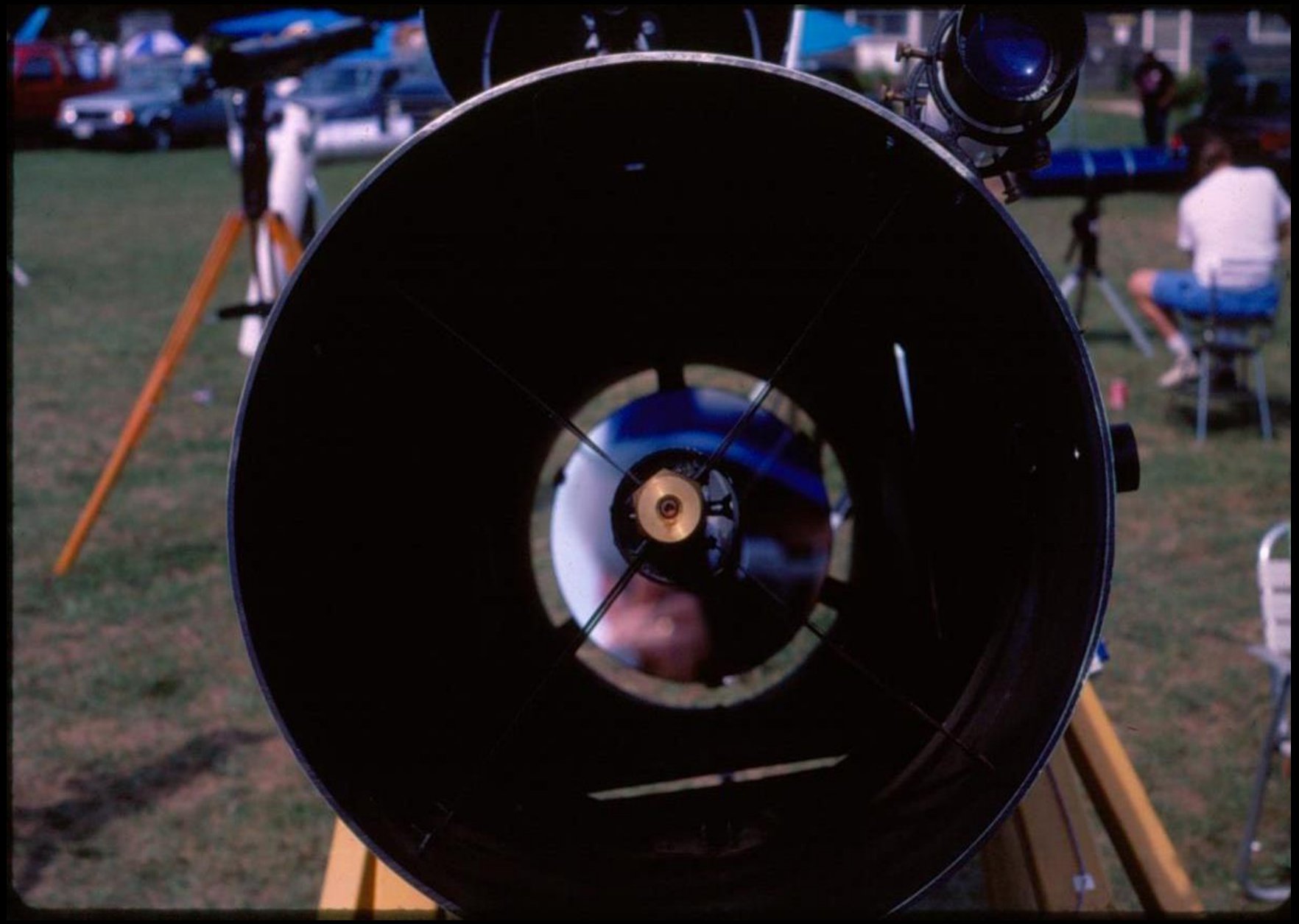
Refractor problems



Isaac to the rescue!

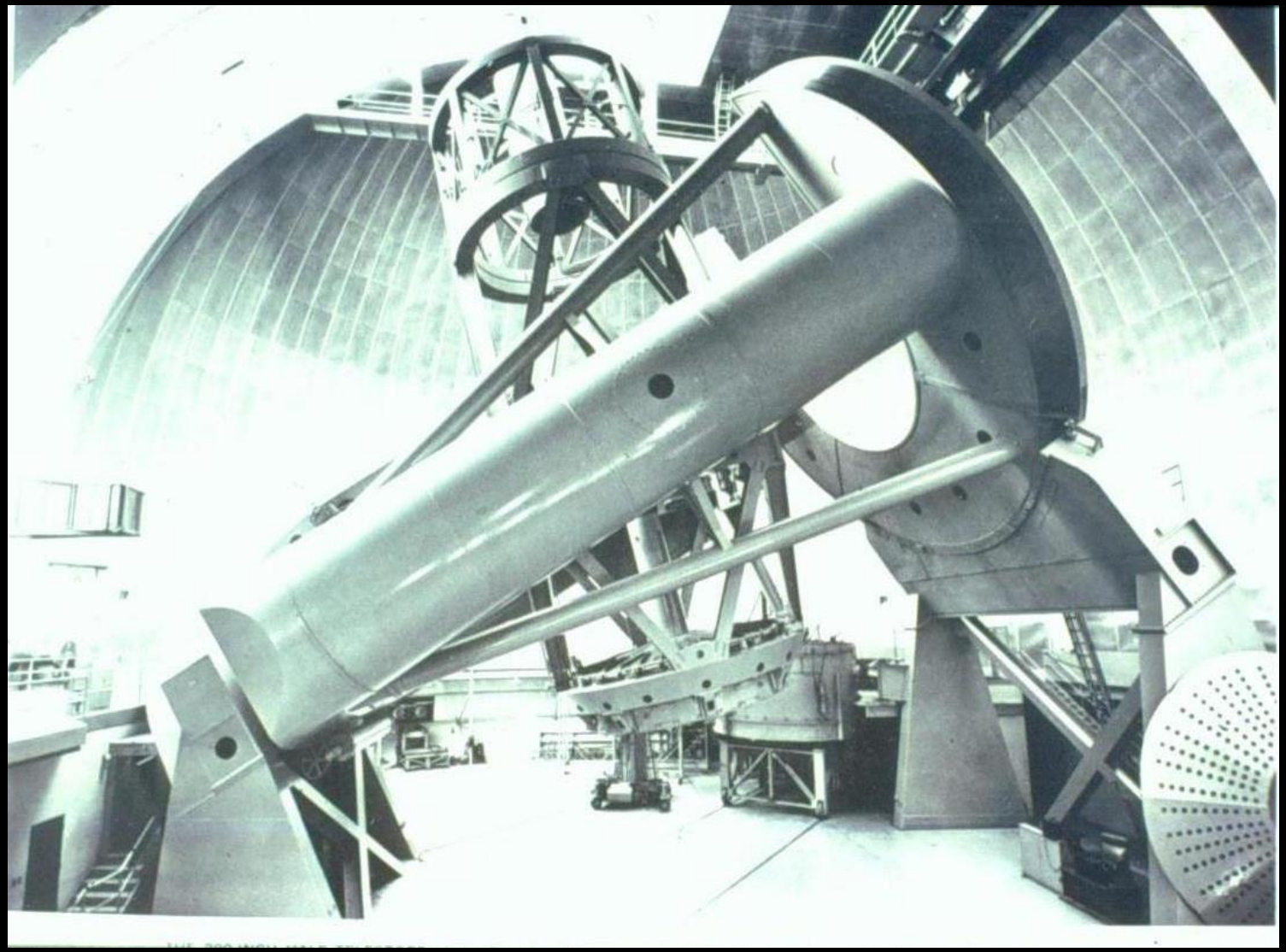




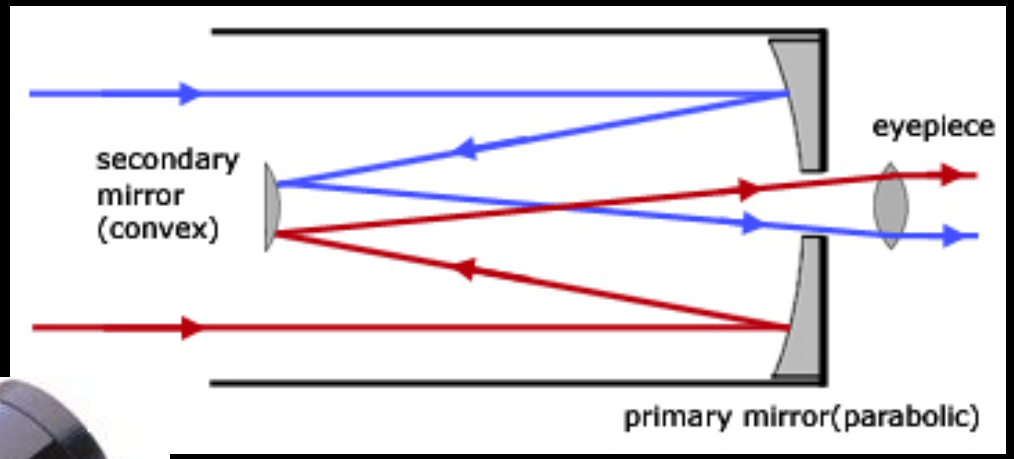


So . . . what's wrong with this?

200-inch Mt. Palomar



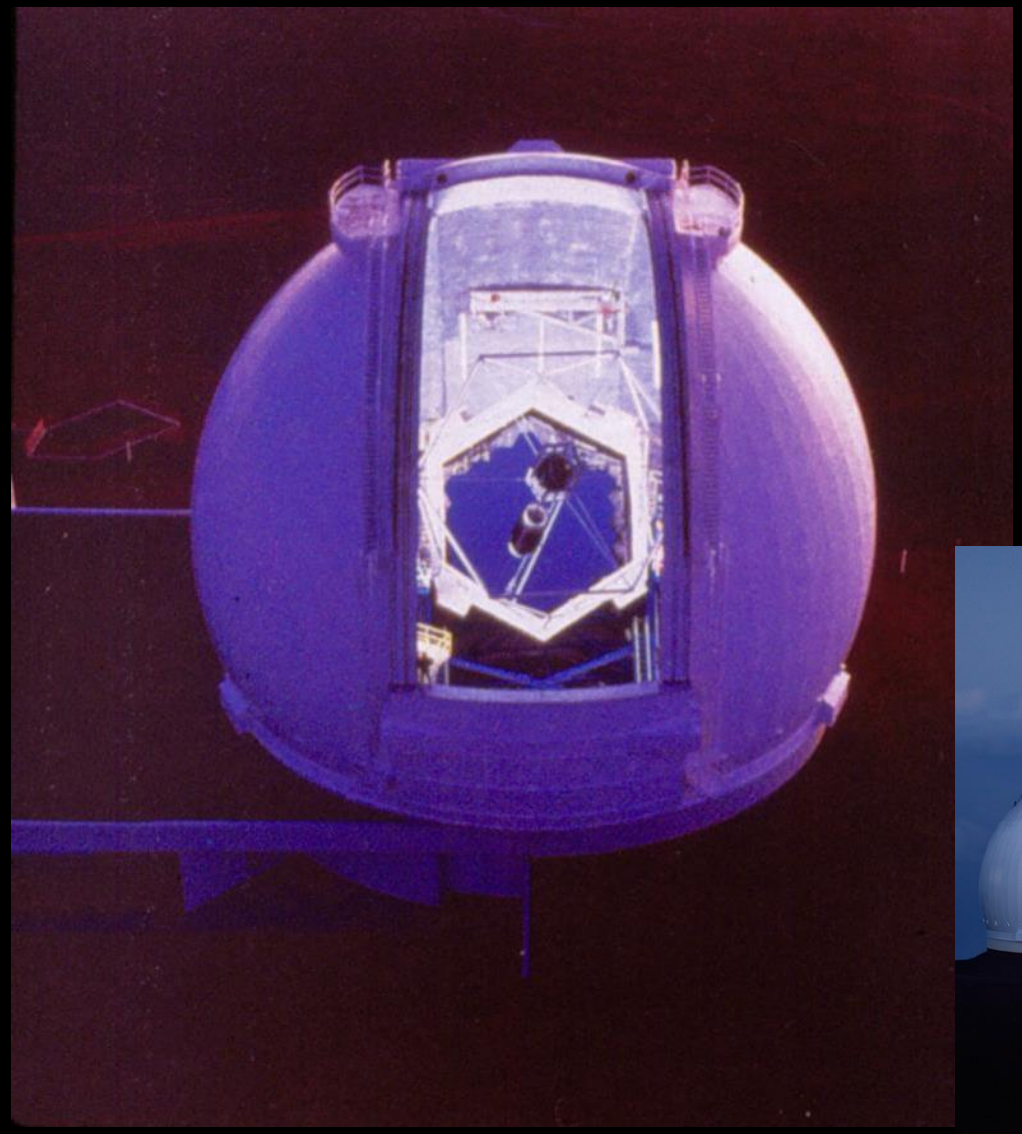
“Folded Telescopes” (Cassegrains)

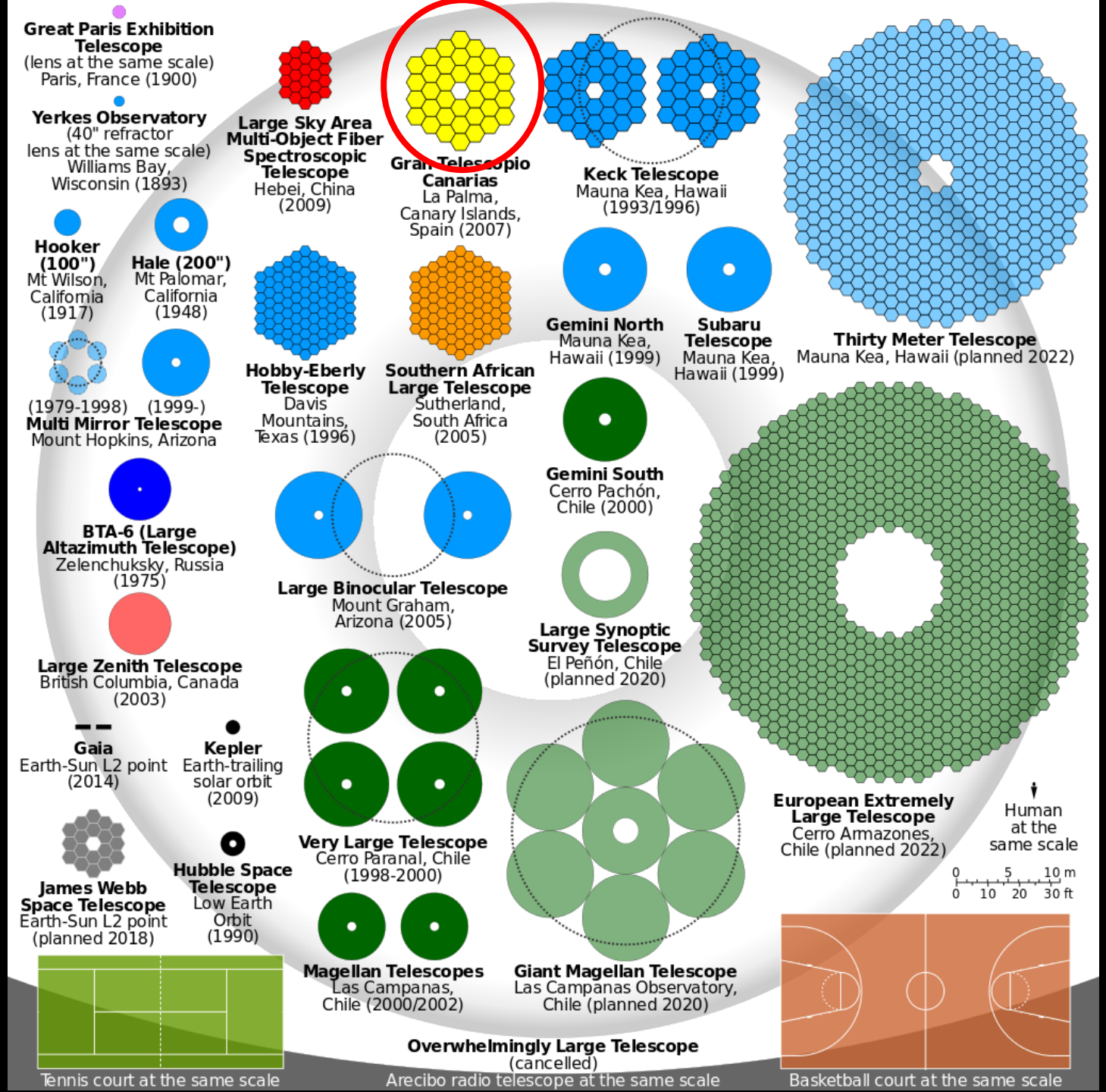


“Go To”
Technology

John Dobson

Keck 10-meter




Great Paris Exhibition Telescope
(lens at the same scale)
Paris, France (1900)
Yerkes Observatory
(40" refractor
lens at the same scale)
Williams Bay,
Wisconsin (1893)
Hooker (100")
Mt Wilson,
California
(1917)
Hale (200")
Mt Palomar,
California
(1948)
(1979-1998)
(1999-)
Multi Mirror Telescope
Mount Hopkins, Arizona
BTA-6 (Large Altazimuth Telescope)
Zelenchuksky, Russia
(1975)
Large Zenith Telescope
British Columbia, Canada
(2003)
Gaia
Earth-Sun L2 point
(2014)
Kepler
Earth-trailing
solar orbit
(2009)
James Webb Space Telescope
Earth-Sun L2 point
(planned 2018)
Hubble Space Telescope
Low Earth
Orbit
(1990)
Large Sky Area Multi-Object Fiber Spectroscopic Telescope
Hebei, China
(2009)
Gran Telescopio Canarias
La Palma,
Canary Islands,
Spain (2007)
Keck Telescope
Mauna Kea, Hawaii
(1993/1996)
Hobby-Eberly Telescope
Davis
Mountains,
Texas (1996)
Southern African Large Telescope
Sutherland,
South Africa
(2005)
Gemini North
Mauna Kea,
Hawaii (1999)
Subaru Telescope
Mauna Kea,
Hawaii (1999)
Thirty Meter Telescope
Mauna Kea, Hawaii (planned 2022)
Gemini South
Cerro Pachón,
Chile (2000)
Large Binocular Telescope
Mount Graham,
Arizona (2005)
Large Synoptic Survey Telescope
El Peñón, Chile
(planned 2020)
European Extremely Large Telescope
Cerro Armazones,
Chile (planned 2022)
Human at the same scale
0 5 10 m
0 10 20 30 ft
Very Large Telescope
Cerro Paranal, Chile
(1998-2000)
Magellan Telescopes
Las Campanas,
Chile (2000/2002)
Giant Magellan Telescope
Las Campanas Observatory,
Chile (planned 2020)
Overwhelmingly Large Telescope
(cancelled)
Arecibo radio telescope at the same scale
Tennis court at the same scale
Basketball court at the same scale

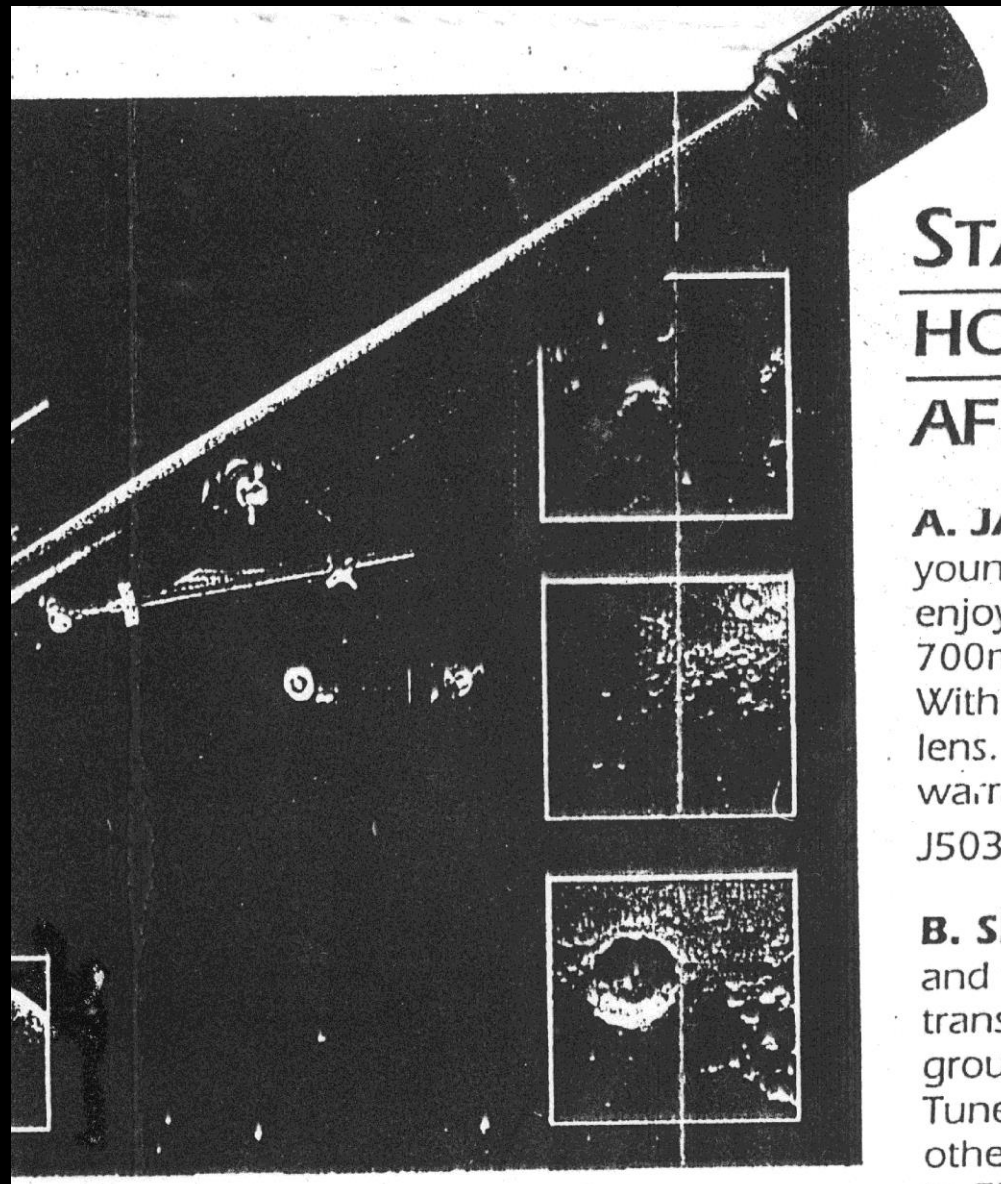
Canary Islands – 10.4 meters

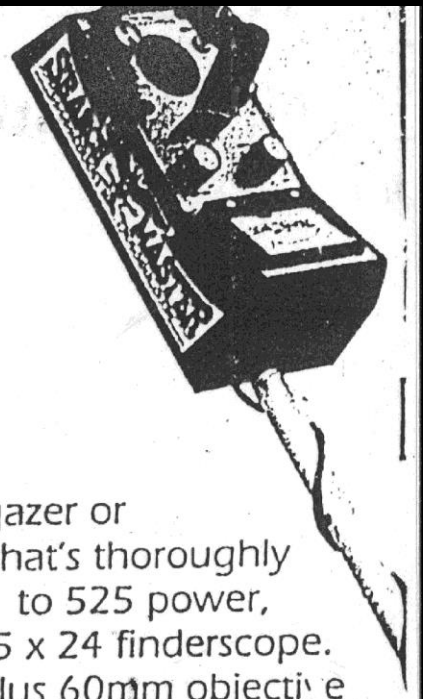
Chile

Las Campanas

VLT

The “ELT”





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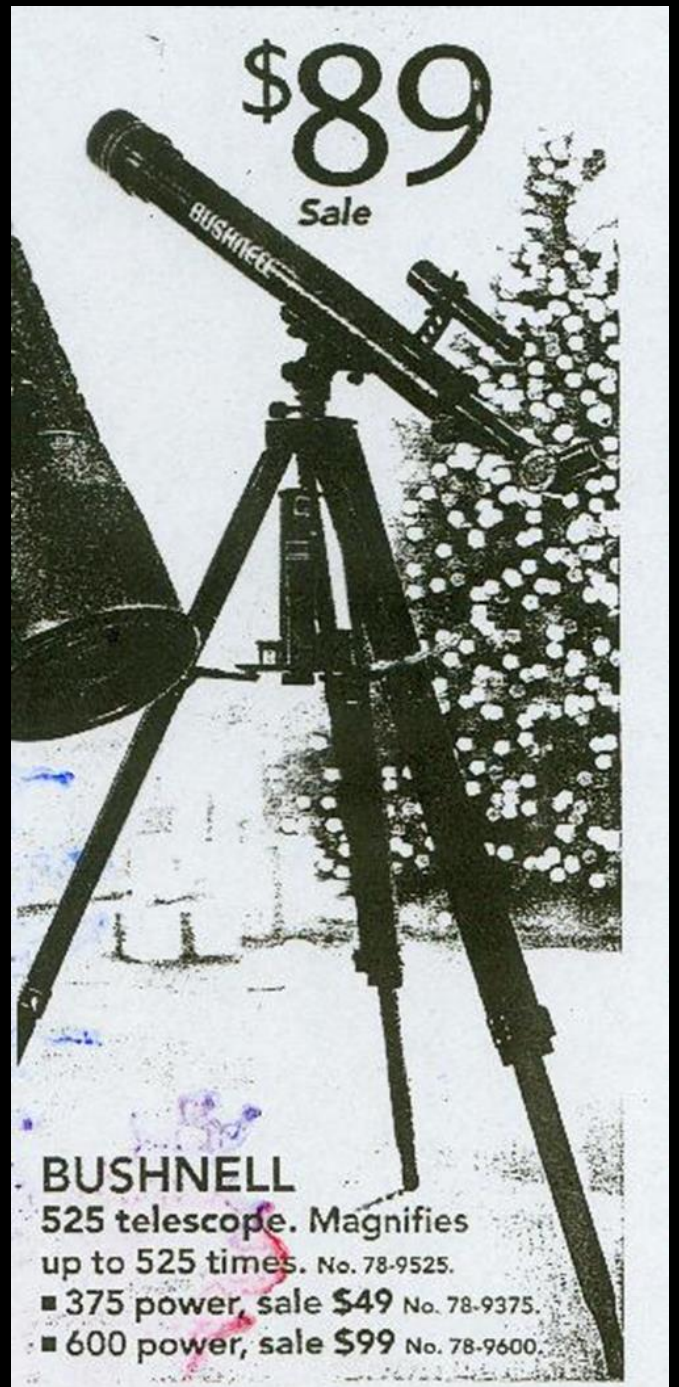

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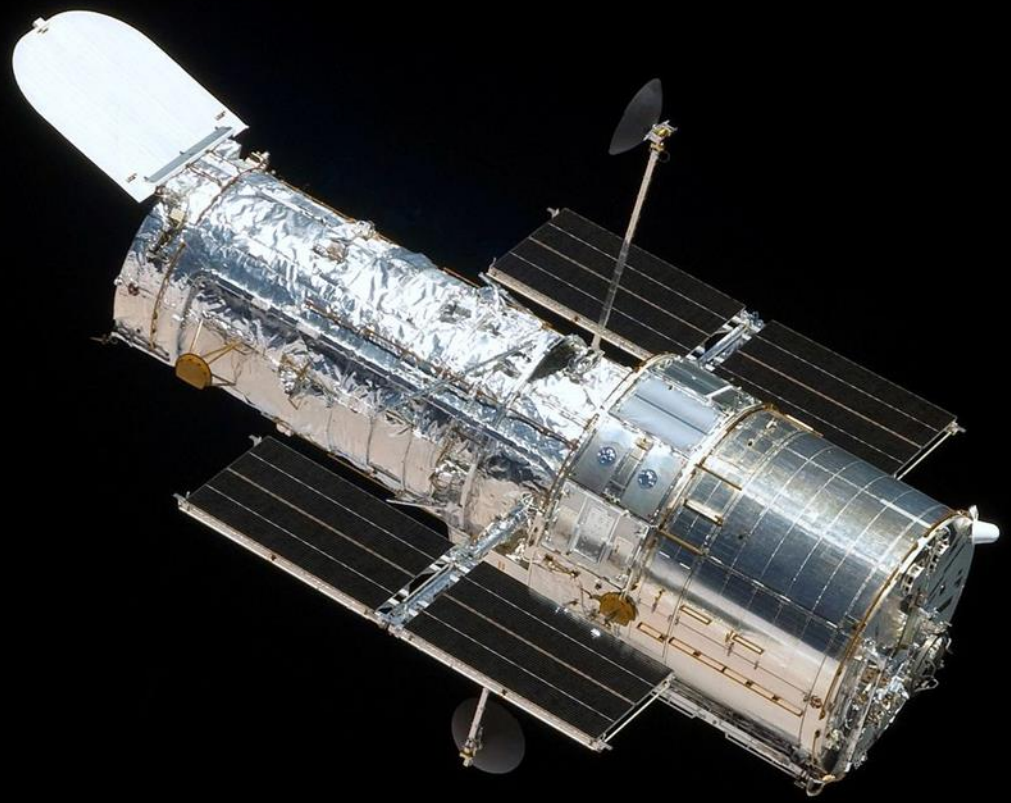
- Began at the Champaign Park District in 1986 (Halley's Comet)
- Built an observatory southwest of town in 1992 & 2017
- Currently 60 members
- Outreach to the community ("Market at the Square," public open houses, observing in the parks & preserves, dome open houses, etc)

Q: Is the Hubble Space Telescope the largest telescope?

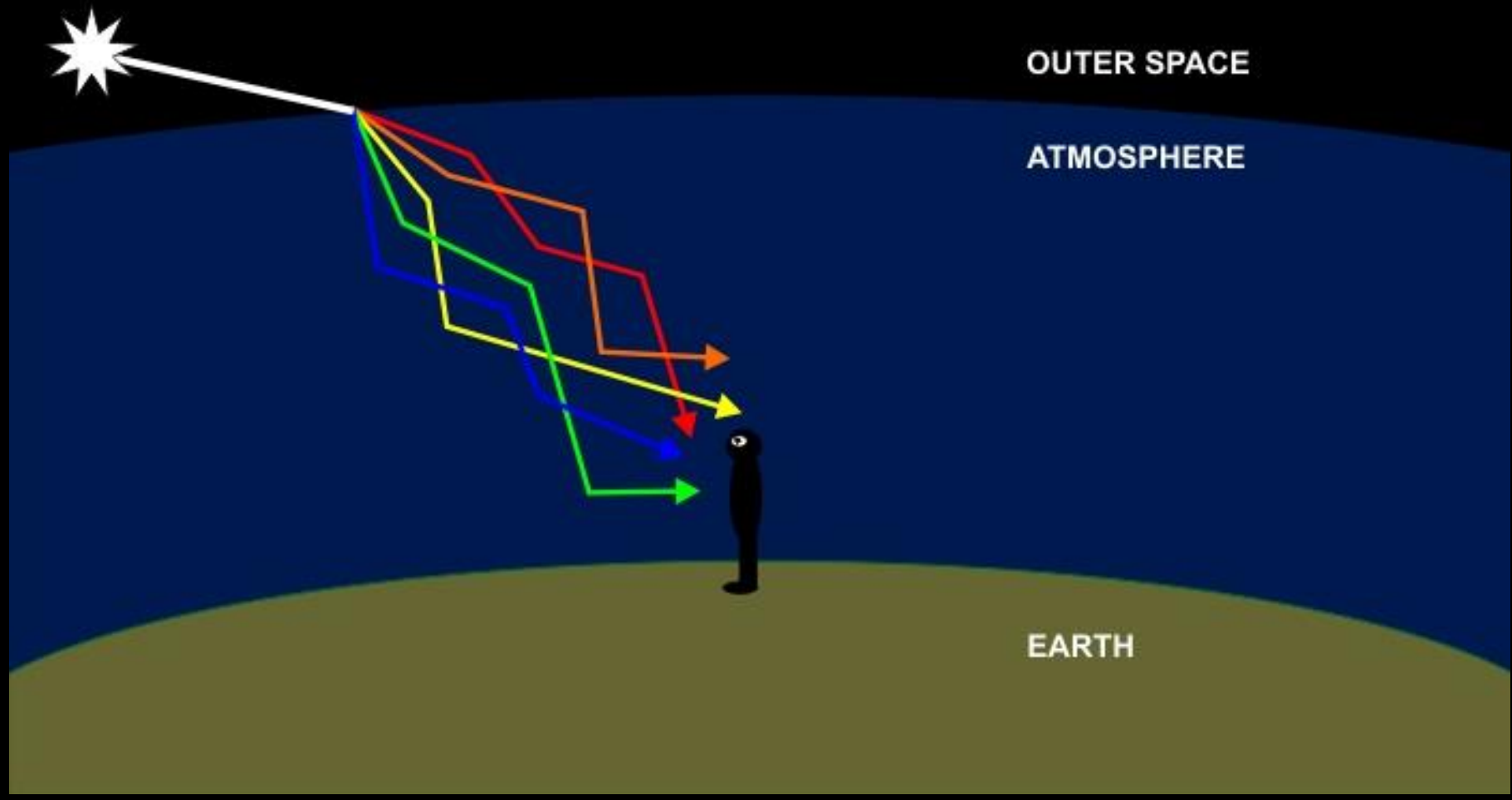


A: NO! 94-inch primary mirror

Q: . . .So . . What makes Hubble so good?

A: Two things:
1) “Windows”
2) “Seeing”

“Star twinkling” (“Seeing”)



“Father of Modern Science” – Albert Einstein