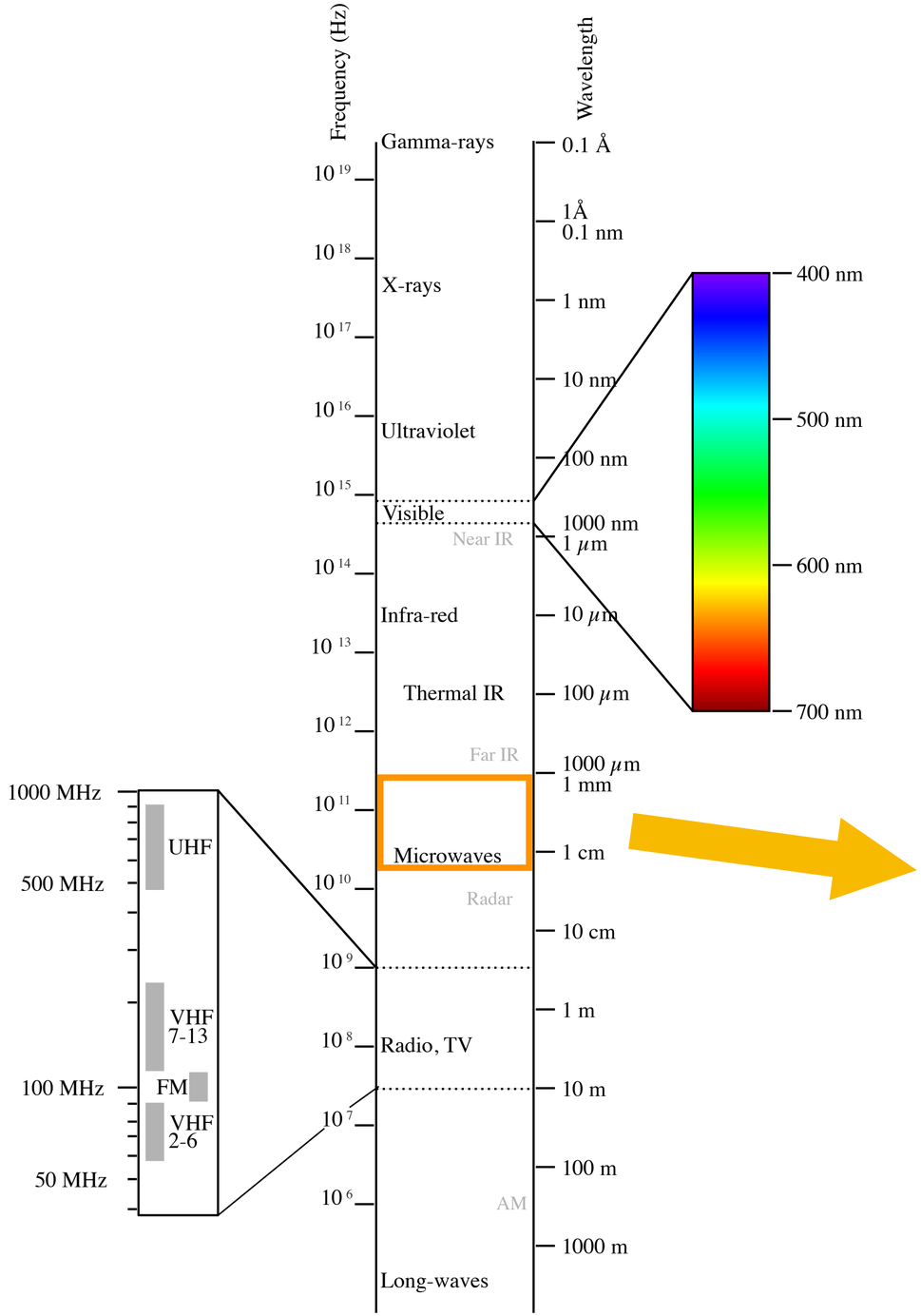
Korea Astronomy and Space Science Institute

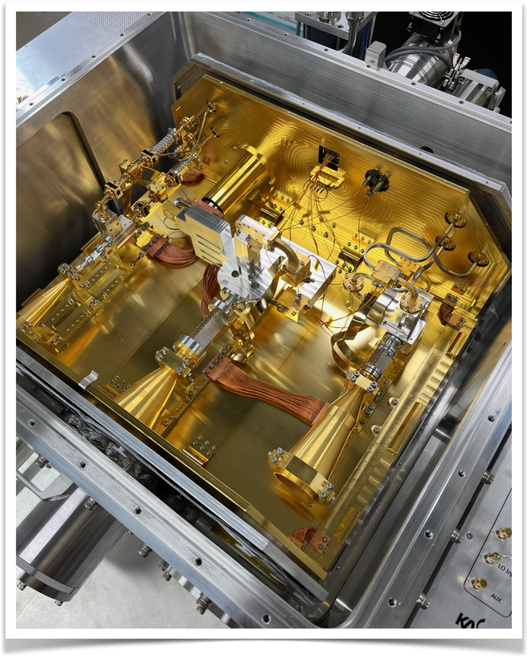
KOREA UNIVERSITY

Optical Telescope

Korea Astronomy and Space Science Institute
Radio Astronomy Division

Jihoon Choi


Frequency (Hz)
Wavelength
Gamma-rays
0.1 Å
10^{19}
1Å
0.1 nm
10^{18}
X-rays
1 nm
10^{17}
10 nm
10^{16}
Ultraviolet
100 nm
10^{15}
Visible
1000 nm
Near IR
1 μm
10^{14}
Infra-red
10 μm
10^{13}
Thermal IR
100 μm
10^{12}
Far IR
1000 μm
1 mm
10^{11}
Microwaves
1 cm
10^{10}
Radar
10 cm
10^{9}
1 m
10^{8}
Radio, TV
10 m
10^{7}
100 m
10^{6}
AM
1000 m
Long-waves
400 nm
500 nm
600 nm
700 nm
1000 MHz
500 MHz
100 MHz
50 MHz
UHF
VHF
7-13
FM
VHF
2-6



Gamma-ray Bursts

The most powerful events in the known universe

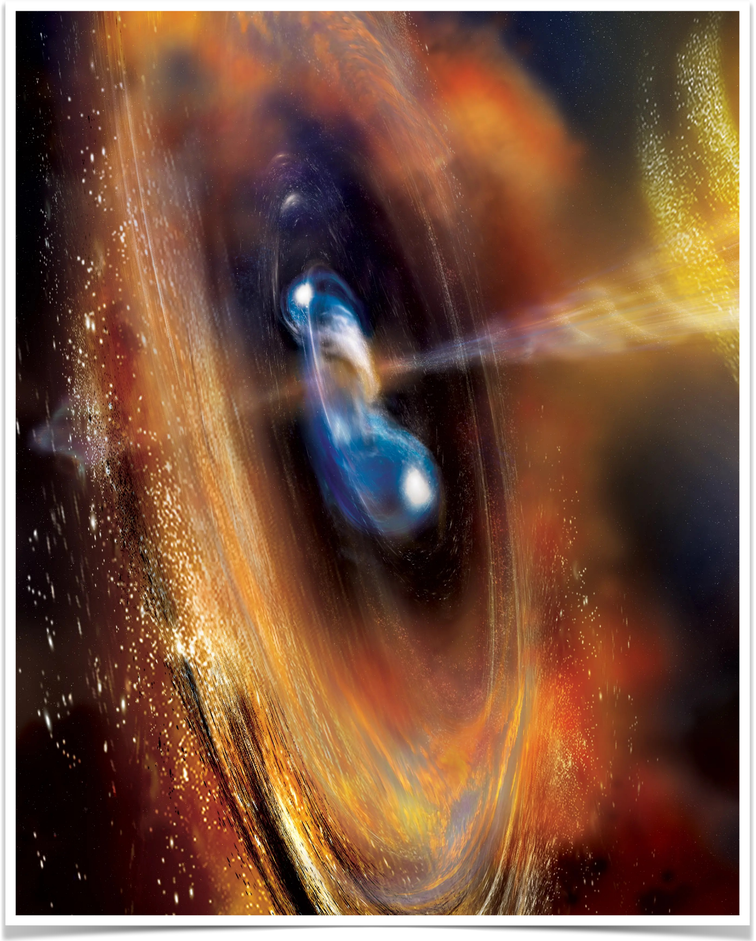


Image from “https://universe.nasa.gov/news/329/gamma-ray-bursts-harvesting-knowledge-from-the-universes-most-powerful-explosions"

The burst observer and optical transient exploring system in the multi-messenger astronomy era

Y.-D. Hu[1], E. Fernández-García[1], M. D. Caballero-García[1], I. Pérez-García[1], I. M. Carrasco-García[2], A. Castellón[2], C. Pérez del Pulgar[2], A. J. Reina Terol[2] and A. J. Castro-Tirado[1,2]*, on behalf of a larger collaboration[1]

[1]Instituto de Astrofísica de Andalucía (IAA-CSIC), Granada, Spain, [2]Unidad Asociada al CSIC Departamento de Ingeniería de Sistemas y Automática, Escuela de Ingenierías, Universidad de Málaga, Málaga, Spain

- Optical system with wide FOV
  - A telescope with a short focal ratio
  - Wide image sensor
- High light gathering power is required
  - Large aperture window telescope
  - Use of high-sensitivity image sensors
- Precise tracking + fast targeting
  - A high-speed stepping motor is required for 2-axis control

구경이 깡패다

집광력 & 분해능 ⬆

크기 & 무게 & 가격 ⬆

- Light gathering power (집광력)

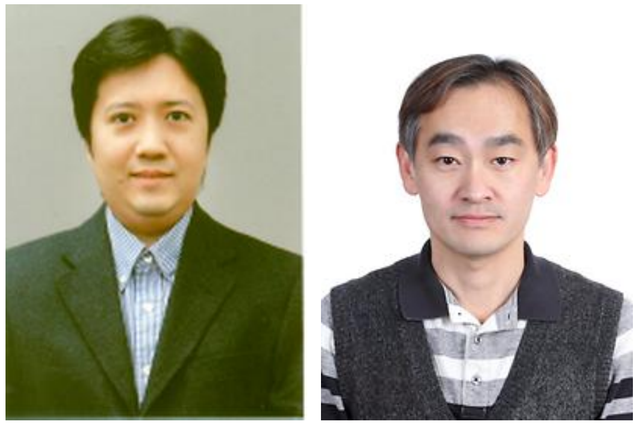
- Resolving power (분해능)

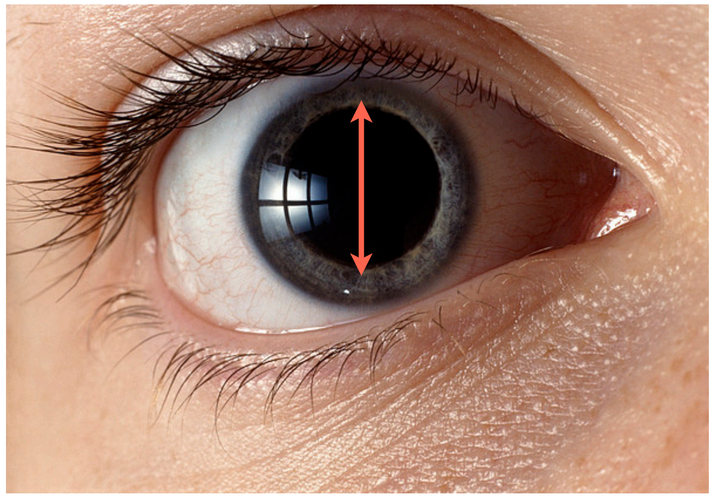
Light gathering power

$$\frac{\pi\left(\frac{D}{2}\right)^2}{\pi\left(\frac{d}{2}\right)^2}$$

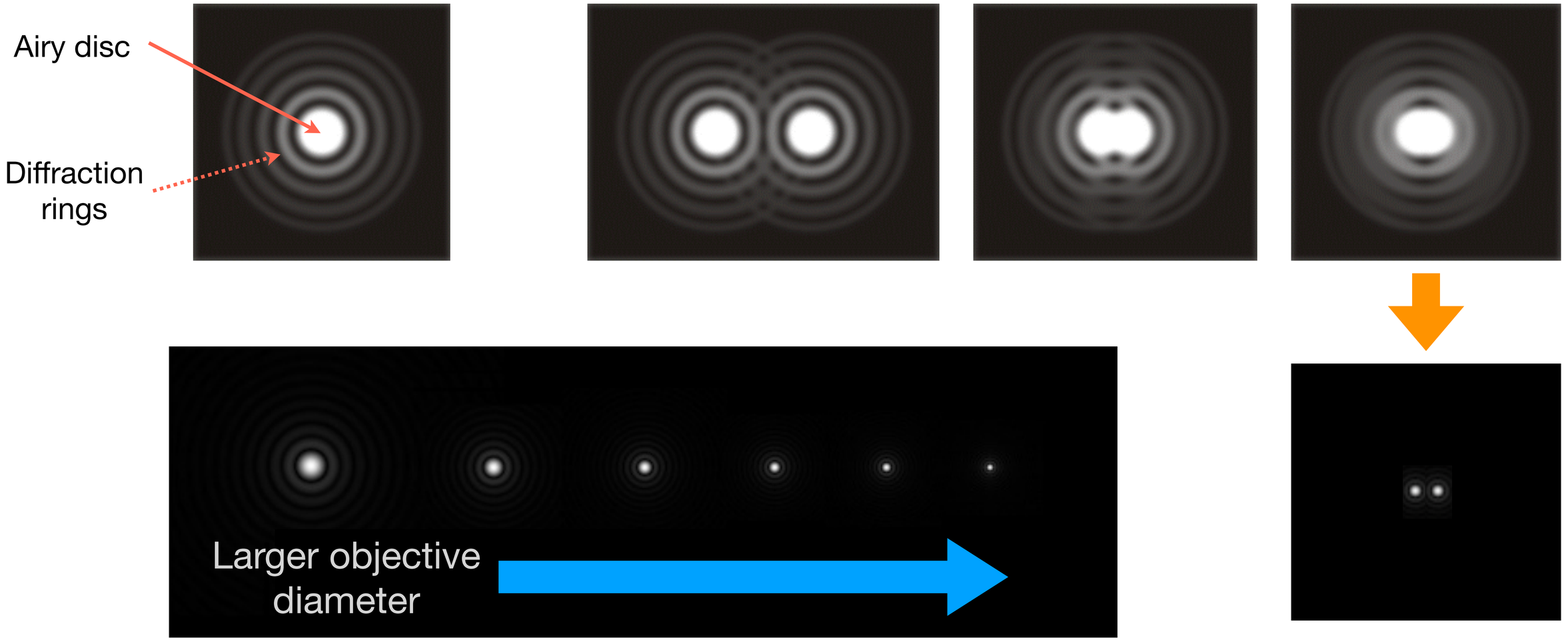
D : Objective diameter

d : Eye pupil diameter = 7 mm





Airy Disc

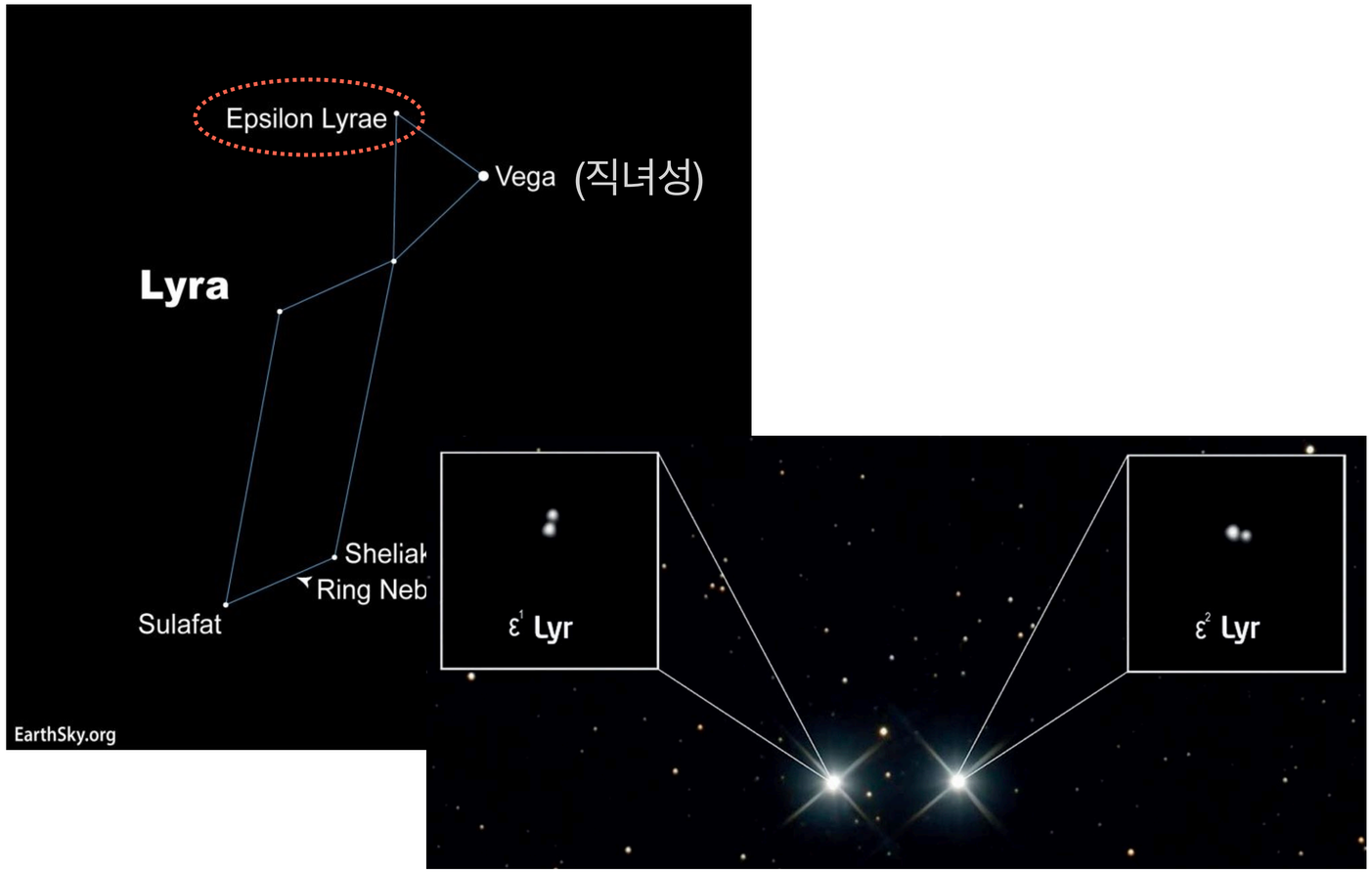


Resolving power

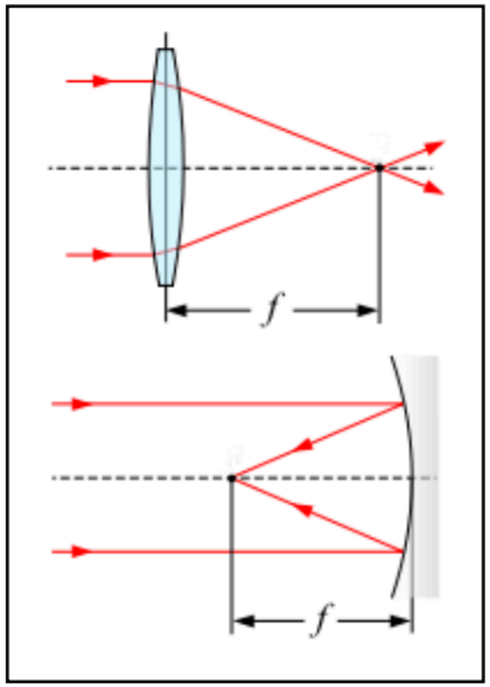
$$\theta_{min} = 1.22\frac{\lambda}{D_O}$$

$$D_O = 100\ mm$$

$$1.25\ \text{arcsec}$$



Focal ratio (F/ number)

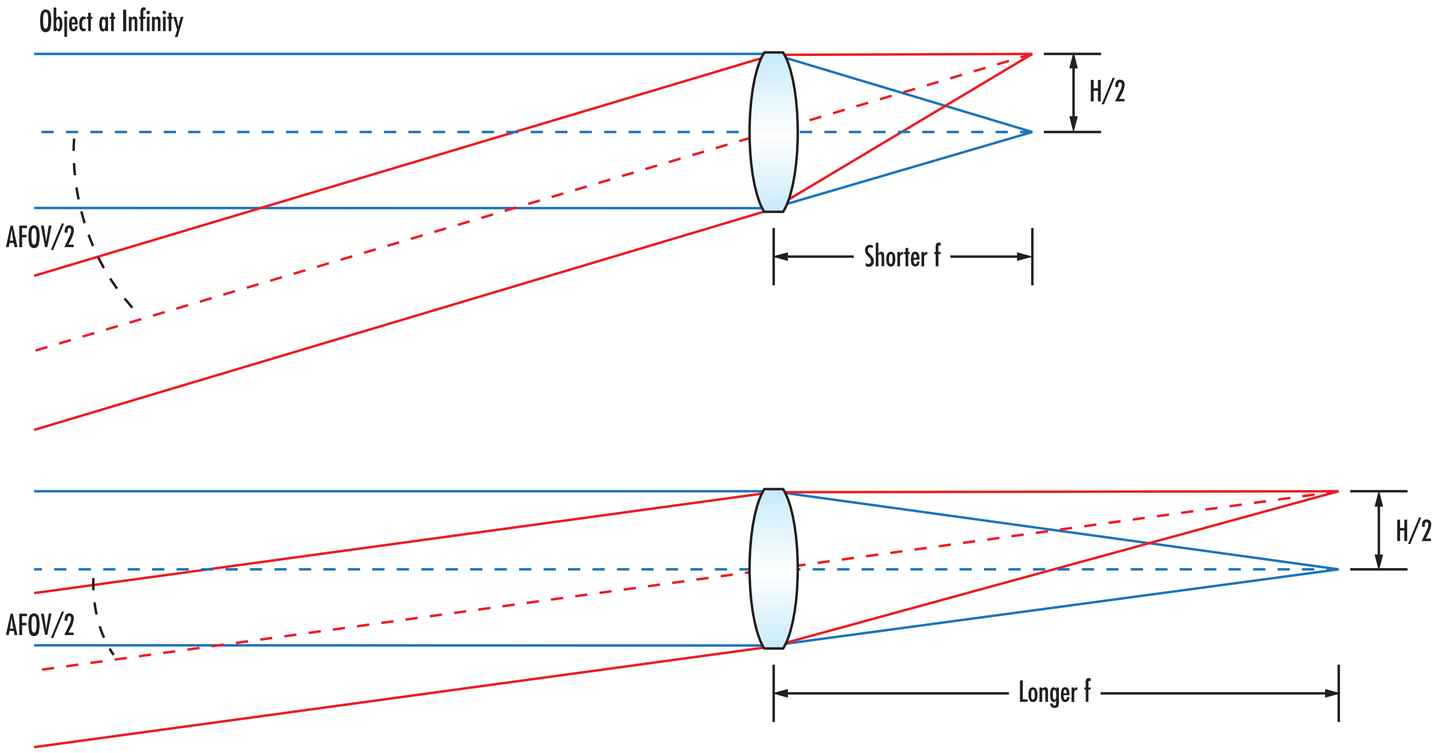


$$\text{Focal ratio} = \frac{f}{D}$$

$$f/\#$$

Meade 6" f/4.1 LX85 Astrograph Reflector Telescope

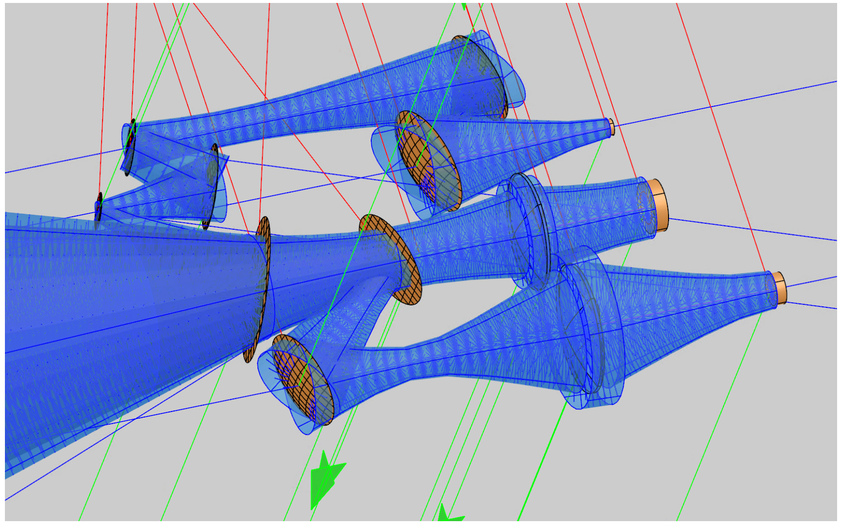
Meade 8" f/10 LX85 ACF Optical Tube Assembly

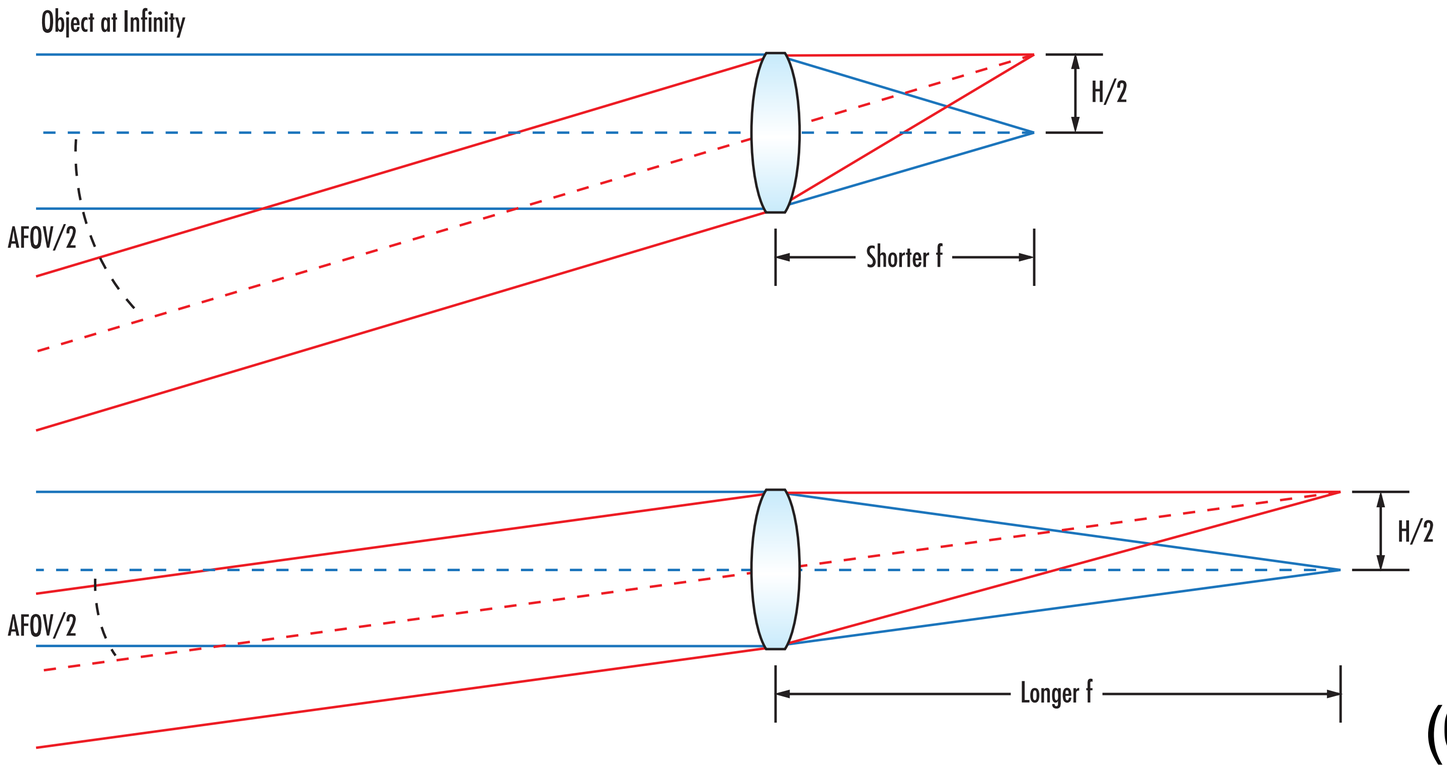


Small focal ratio
(Fast telescope)

$\sim f/6$

Large focal ratio
(Slow telescope)

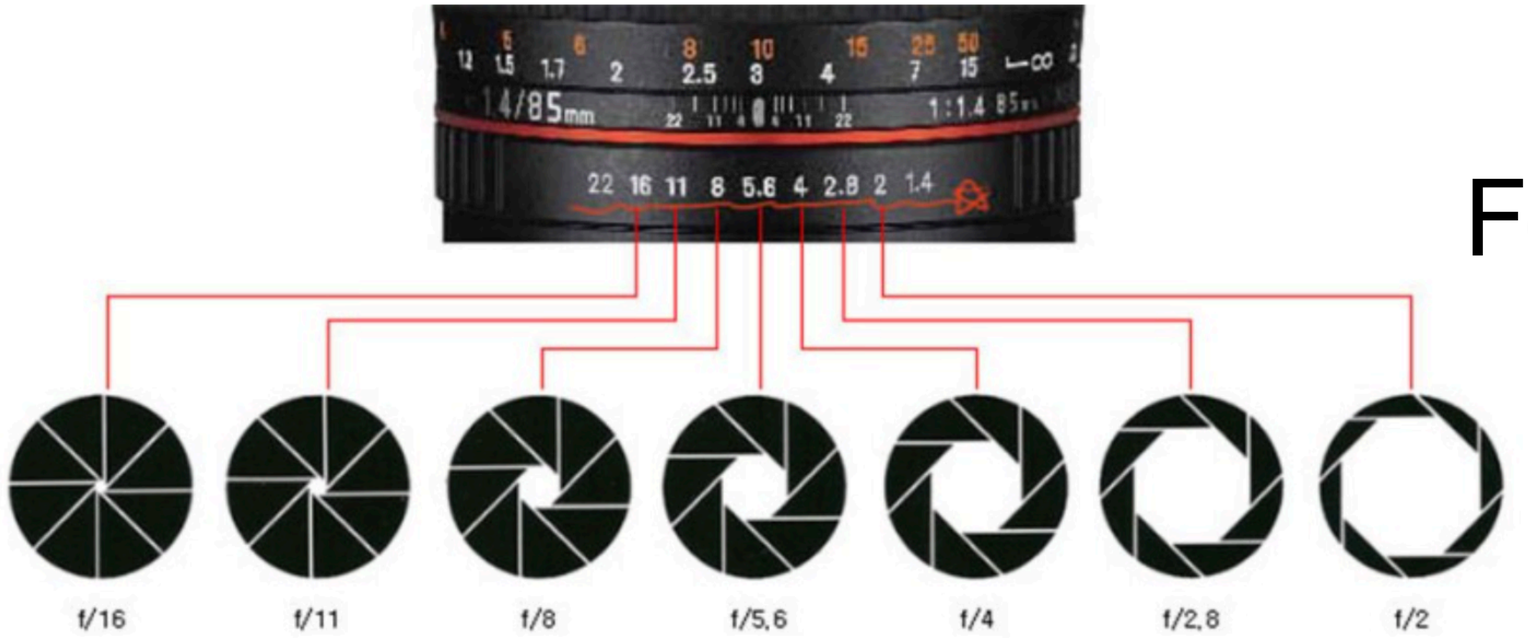




Extender
(1.5X ~ 5.0X)

Reducer
(0.6X ~ 0.8X)

Prime lens for DSLR



$$\text{Focal ratio} = \frac{f}{D}$$

Refracting Telescope

(굴절망원경)

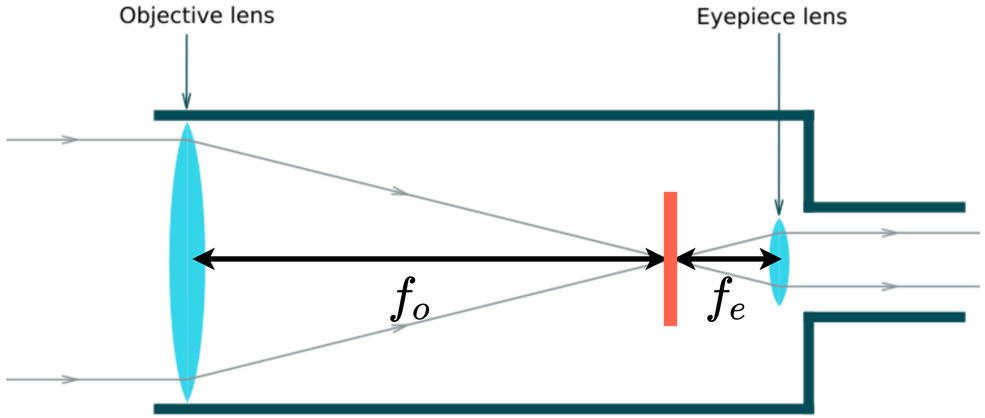
Reflecting Telescope

(반사망원경)

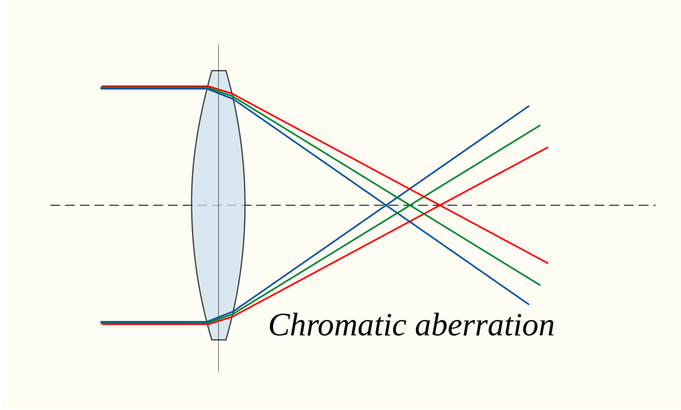
Catadioptric Telescope

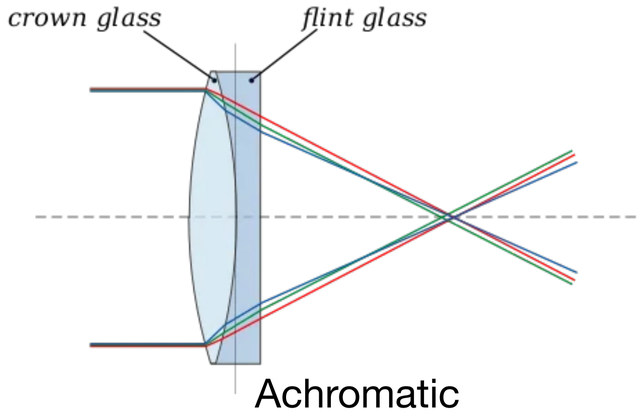
(반사굴절망원경)

Refracting telescope

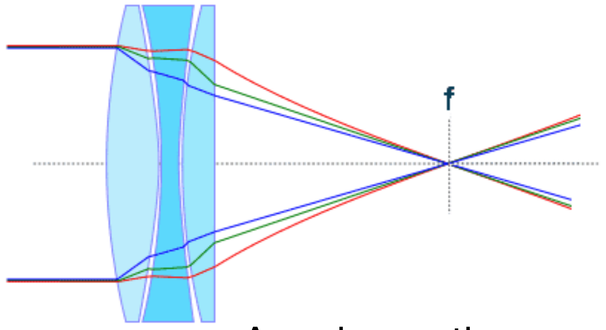


$$M = \frac{f_o}{f_e}$$





Achromatic

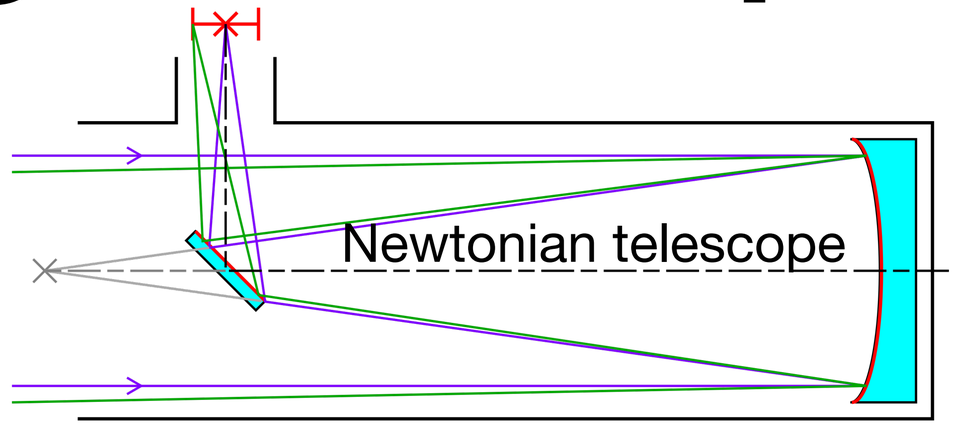


Apochromatic

Refracting telescope

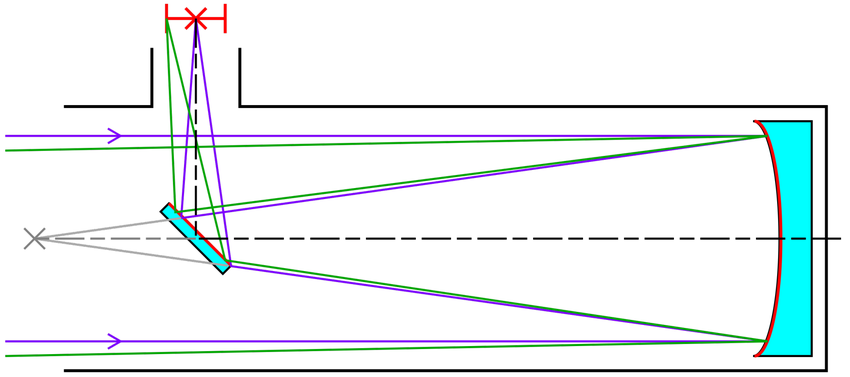
- Advantages
  - All objective lens areas can be used
  - Good optical axis stability
- Disadvantage
  - Difficult to manufacture large diameter
  - Chromatic aberration

Reflecting telescope



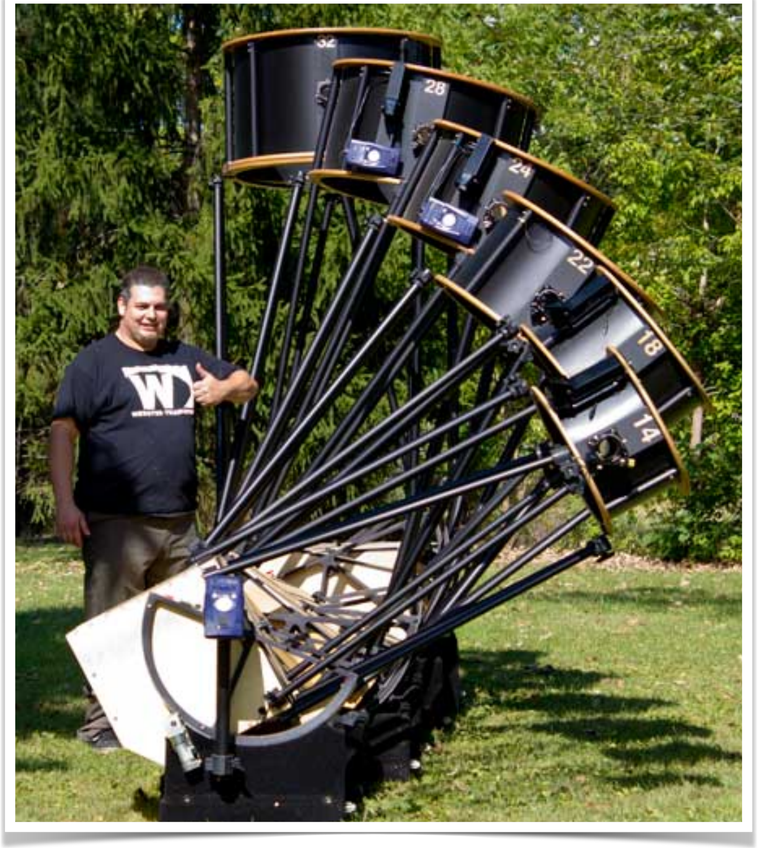
Reflecting telescope

- Advantages
  - Have good value for money
  - No chromatic aberration
- Disadvantage
  - Coma aberration
  - Poor optical axis stability

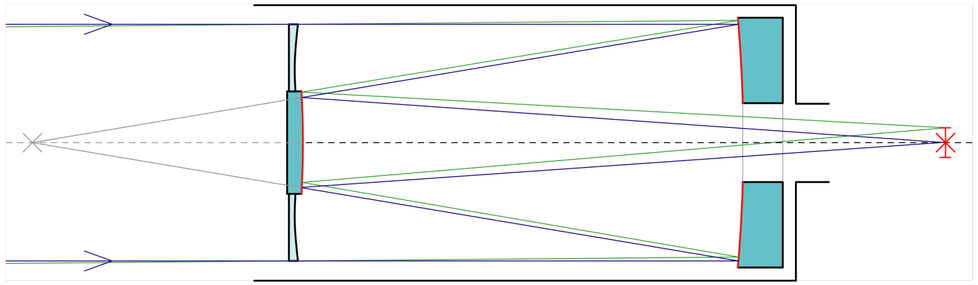


Dobsonian telescope

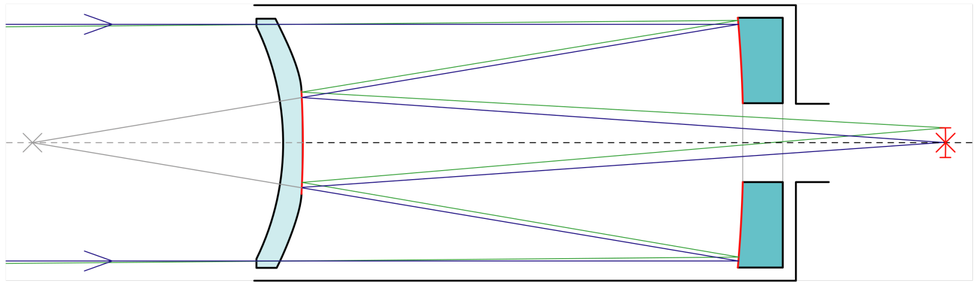
Design popularized by John Dobson in 1965



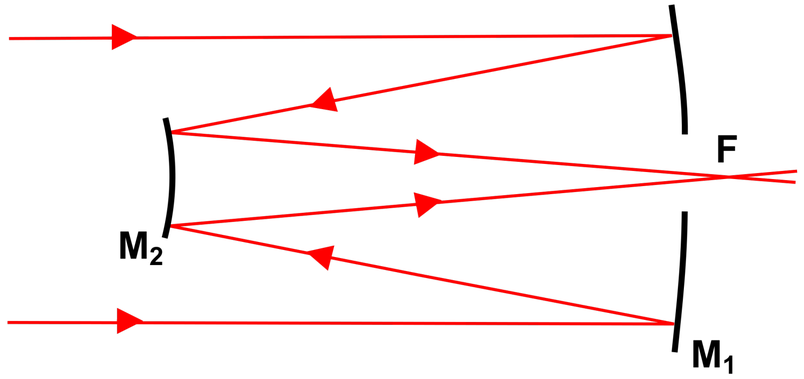
Catadioptric telescope



Schmidt–Cassegrain telescope



Maksutov–Cassegrain telescope



Ritchey–Chrétien telescope

Short barrel size compared to diameter

Many types of aberrations are well suppressed

Amateur user

Schmidt–Cassegrain telescope

Research telescope

Ritchey–Chrétien telescope

Site	B1A	B1B	B2	B3/4/5/6/7	CASANDRA
Type[a]	Ph	SC	RC	RC	Ph
Lens	400 mm + 135 mm	-	-	-	16 mm
Mirror	-	30 cm	60 cm	60 cm	-
Focus[b]	-	Ca	Ca	Ca	-
Focal ratio	f/2.8 + f/2	f/10	f/8	f/8	f/2.8
CCD	4096x4096	512x512	1024x1024	1024x1024	4096x4096
Pixel size	9 μm	16 µm	13 µm	13 µm	9 µm
Angular Resolution	4.39”+13.2′′	2′′	0.59′′	0.59′′	2.2′
FOV	5 °× 5°+15 °× 15°	17′x17′	10′x10′	10′x10′	180°
Filter[c]	C	C	g’r’i’ C R ZY	u’g’r’i’ C ZY	C
Mount	Paramount ME	Paramount MX+	Astelco NTM-500	Astelco NTM-500	-
Camera[d]	MG4	A887	A888	A888	MG4
Spectrograph	-	-	COLORES	-	-

Mount and tracking

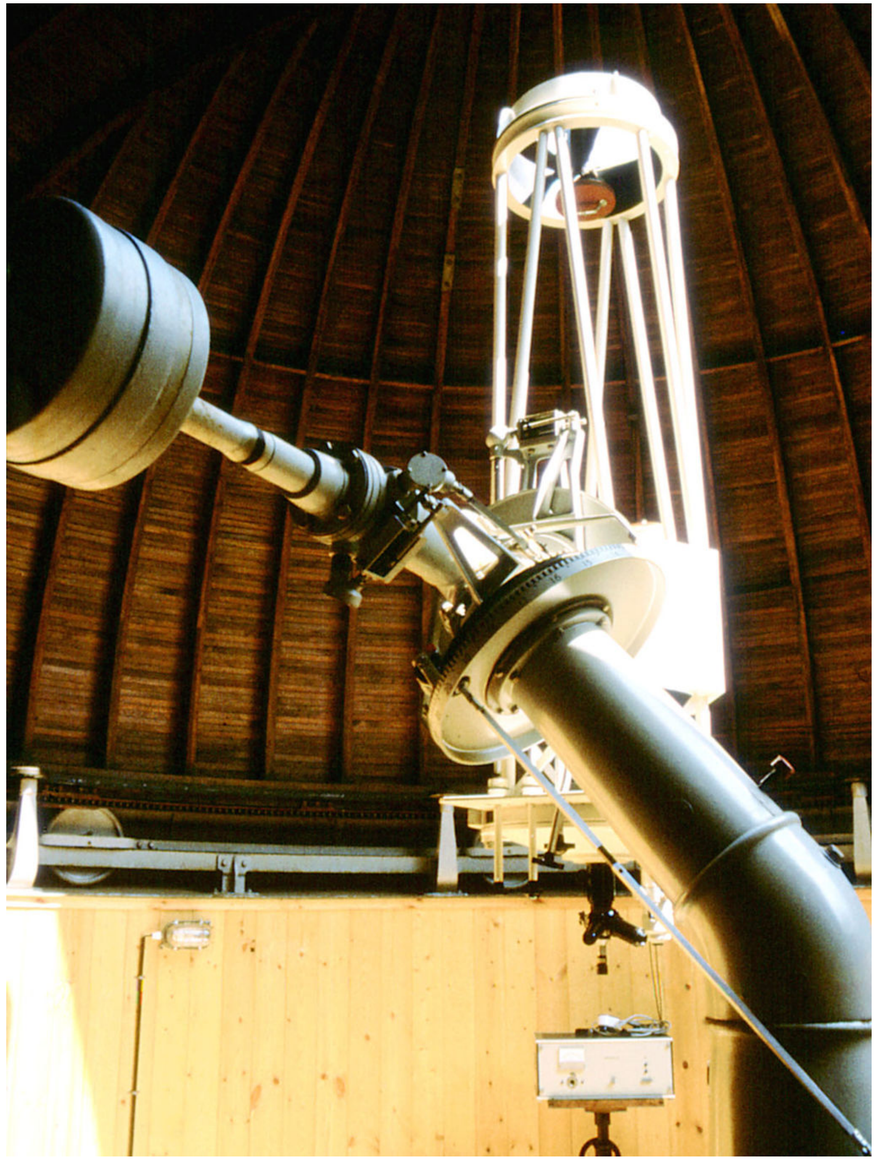
Altazimuth mount
(경위대식)

Equatorial mount
(적도의식)

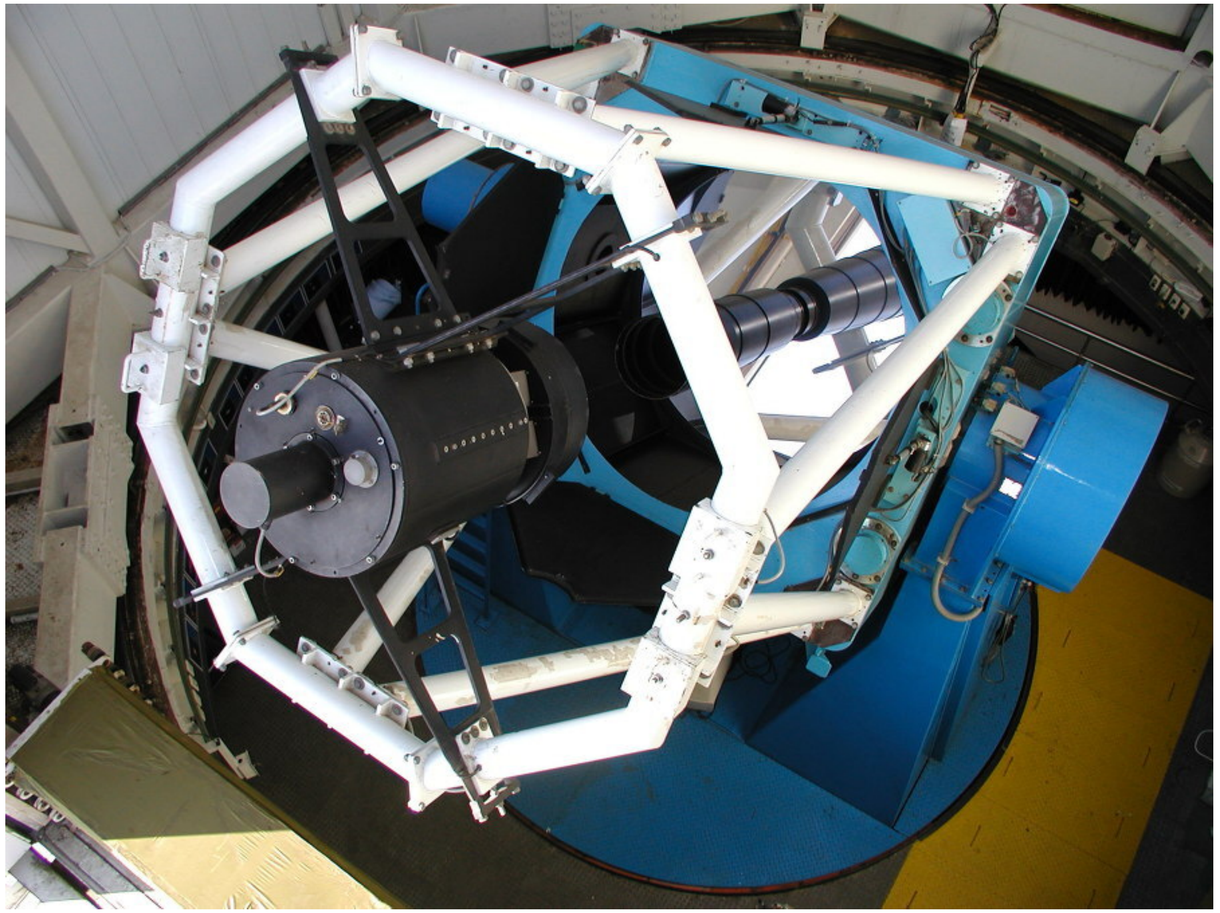
Altaz mount

Equatorial mount

B2	B3/4/5/6/7
RC	RC
-	-
60 cm	60 cm
Ca	Ca
f/8	f/8
1024x1024	1024x1024
13 µm	13 µm
0.59′′	0.59′′
10′x10′	10′x10′
g’r’i’ C R ZY	u’g’r’i’ C ZY
Astelco NTM-500	Astelco NTM-500
A888	A888
COLORES	-



Forststernwarte Jena
50cm Cassegrain reflector telescope

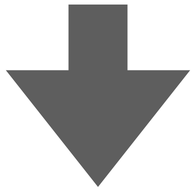


보현산 천문대 1.8m telescope

Imaging sensor

CCD Image Sensor
(Charge-Coupled Device)

CMOS Image Sensor
(Complementary Metal Oxide Semiconductor)

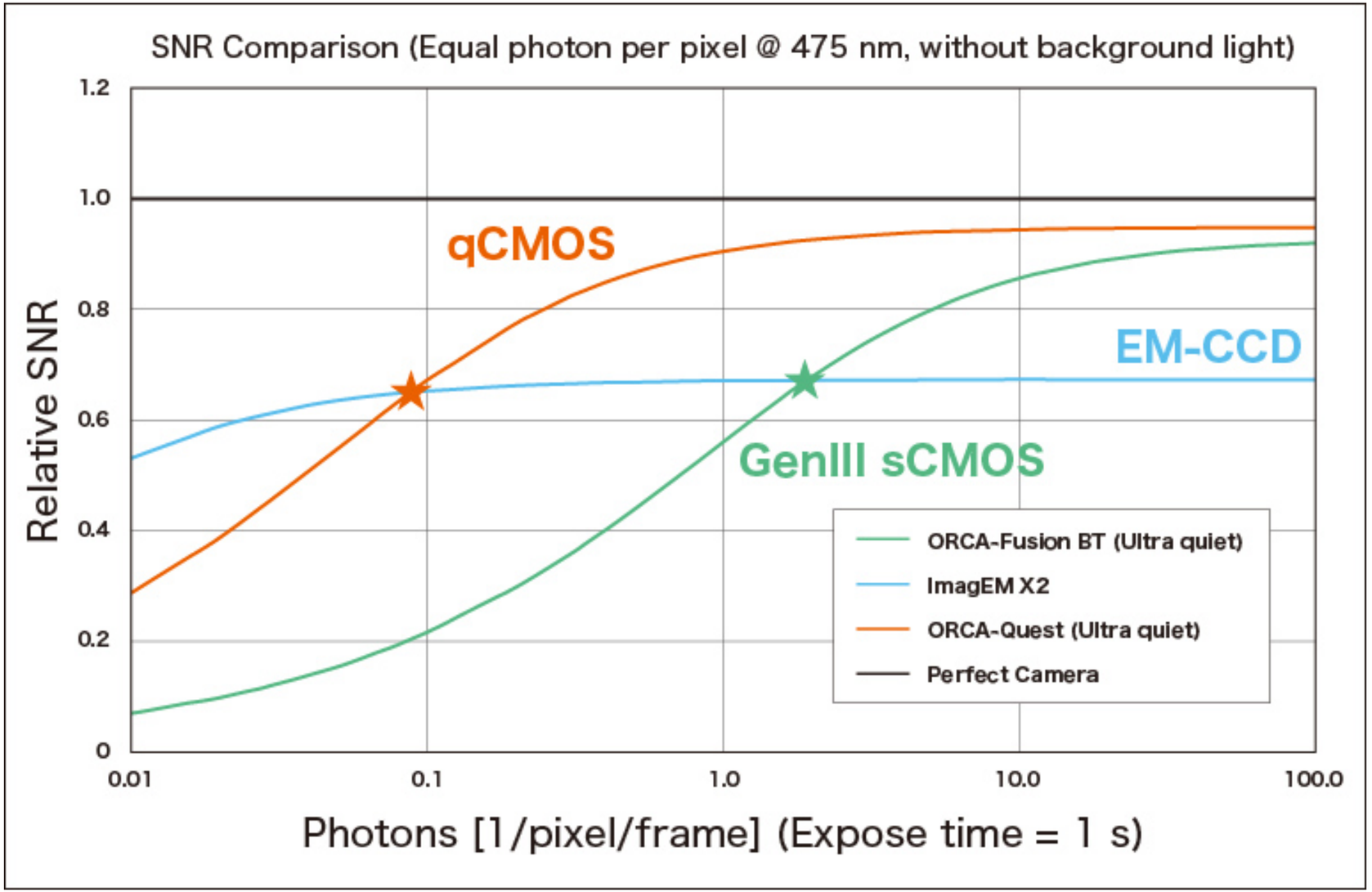


Cooled
Thermoelectric cooling

Non-cooled

OXFORD INSTRUMENTS

CCD		EMCCD	sCMOS		
16.8 MP	4.2 MP	2 MP	16.9 MP	4.2 MP	5.5 & 4.2 MP
					
iKon-XL	iKon-L	iXon-Ultra	Balor	Marana	ZL41 Wave
Dynamic Range	Dynamic Range	Dynamic Range	Dynamic Range	Dynamic Range	Dynamic Range
Back-illuminated QE	Back-illuminated QE	Back-illuminated QE	Front-illuminated QE	Back-illuminated QE	Front-illuminated QE
Low Noise	Low Noise	Low Noise	Low Noise	Low Noise	Low Noise
Resolution	Resolution	Resolution	Resolution	Resolution	Resolution
FOV	FOV	FOV	FOV	FOV	FOV
Speed	Speed	Speed	Speed	Speed	Speed
Budget	Budget	Budget	Budget	Budget	Budget



https://camera.hamamatsu.com/jp/en/learn/technical_information/camera_articles/qcmos_vs_emccd.html

Summary

Telescope

200 mm (or 8”)
Schmidt–Cassegrain telescope

Mount

Equatorial Mount
(Motor drive part modification)

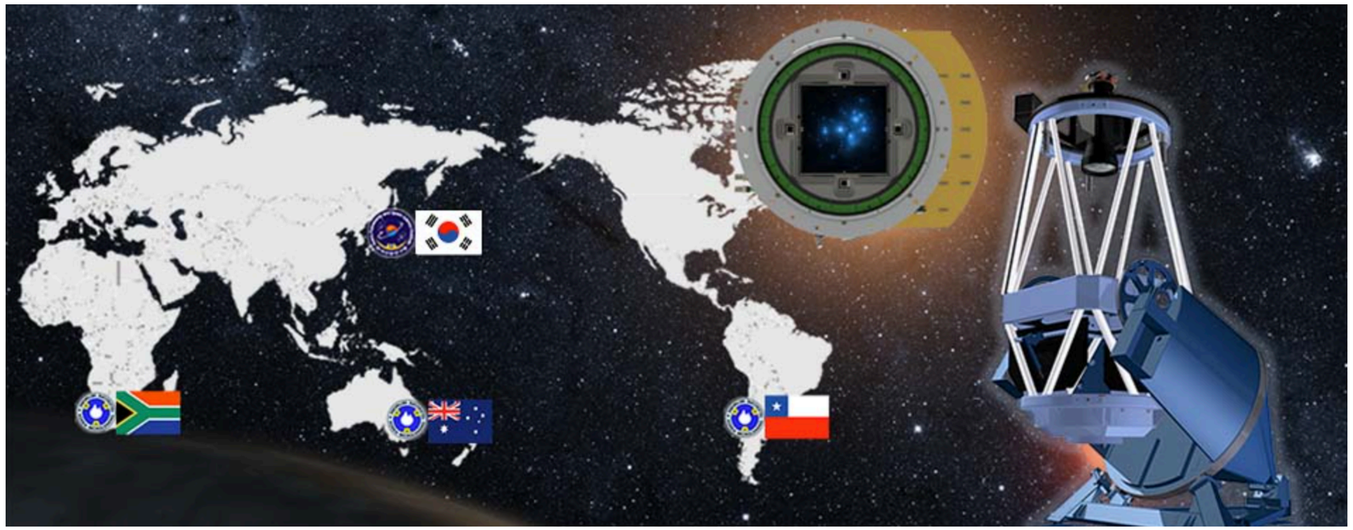
(High speed stepping motor
with FPGA control)

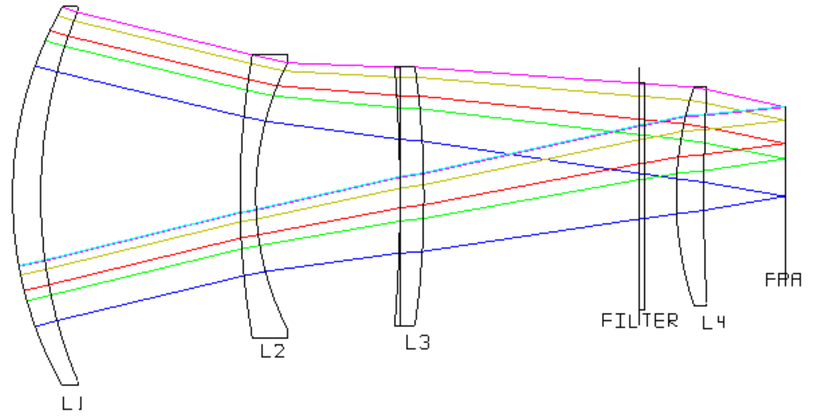
Image
sensor

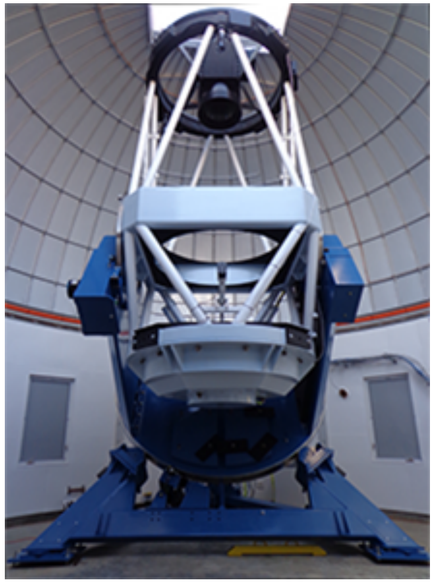
Commercial DRSL
or Mirrorless body
(CMOS image sensor)

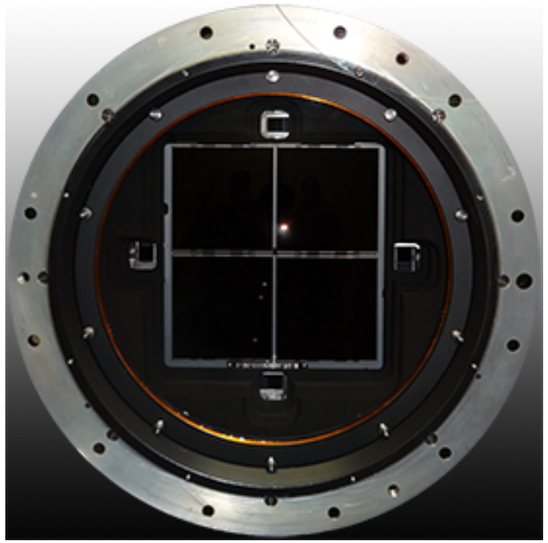
ork)

KMTNet (외계행성탐색)









Wide-field Photometric Systems

Telescope	Camera	FOV	Site	Target
PanSTARRS 1.8m × 4	1400M pixel CCD	7.0 deg^2	Haleakala, USA	All sky survey
MOA 1.8m	80M pixel CCD	2.4 deg^2	Mt. John, New Zealand	Galactic Bulge
KMTNet 1.6m × 3	340M pixel CCD	4.0 deg^2	CTIO - SAAO - SSO	Galactic Bulge
SkyMapper 1.35m	268M pixel CCD	5.7 deg^2	SSO, Australia	All sky survey
OGLE-IV 1.3m	268M pixel CCD	1.4 deg^2	LCO, Chile	Galactic Bulge