2022 12 19 (Mon) Overview

2022년 12월 17일 토요일 오후 12:02

Introduction to Astrophysics and Cosmology

Lecturer : Bum-Hoon Lee
(Research Distinguished Professor/Emeritus Professor, Sogang University, Seoul, Korea)
Email : bhl@sogang.ac.kr
Mobile : +82-10-6274-8427

Lecture:
December 19~December 30, 2022 From Monday until Friday,
Time : 10:00 ~ 11:40, 14:00~15:40

Home Page for the Lecture : https://indicocquest.sogang.ac.kr/event/20/
Lecture Notes and HomeWorks will be uploaded

Q&A
During the lectures, before or after lectures
You may visit to my office
Email, Zoom, Mobiles, etc.

Reference :
1) Schutz, A First Course in General Relativity (pdf file is available through the internet)
2) Lecture Notes by David Tong, pdf file is available.
3) Teach Astronomy - Galaxy Distance Indicators Teach Astronomy
4) Lecture 11 (uh.edu) ASTR 3131 (uh.edu)

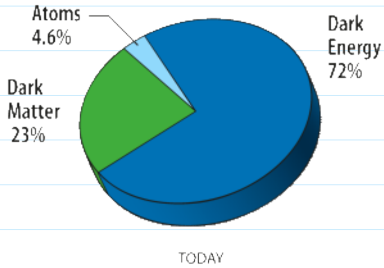
- Some images are through Google.

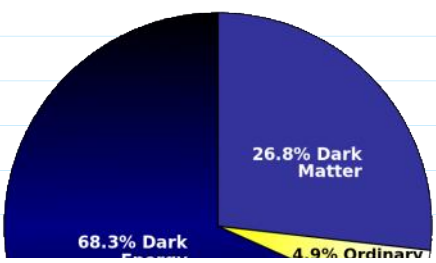
Einstein Equations

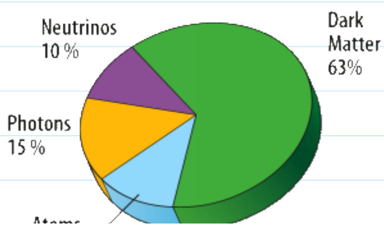
$$\underbrace{R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R}_{\text{spacetime}} = 8\pi G \underbrace{T_{\mu\nu}}_{\text{"matter" energy momentum}}$$

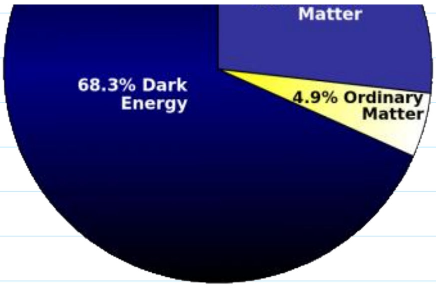
Ordinary Matter : ~5%, mostly H, He
Dark Matter 27%
Dark Energy 68%

{ star, galaxy, galaxy cluster
  은하, 은하단
  gas, dust, ...



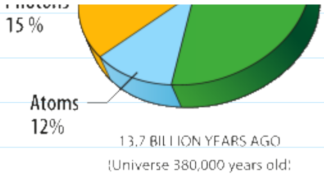






Estimated distribution of matter and energy in the universe

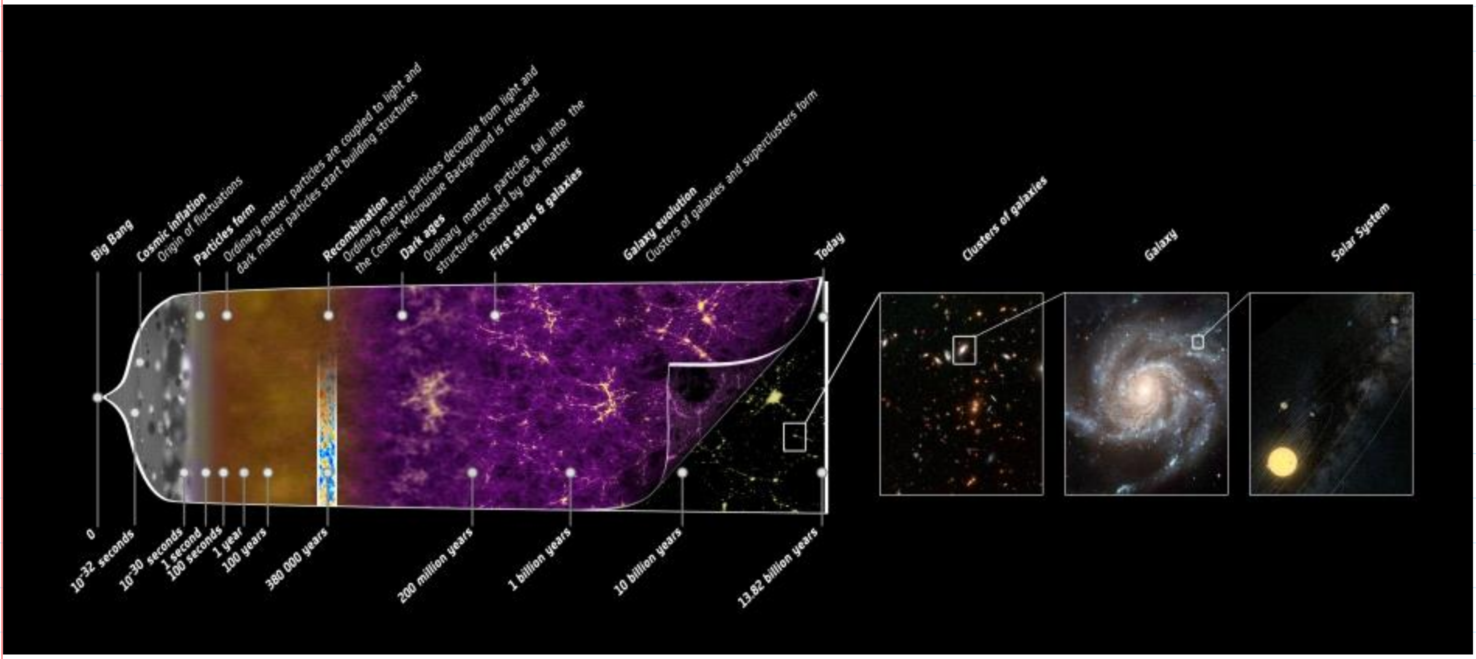
출처: <https://en.wikipedia.org/wiki/Dark_energy#/media/File:DMPie_2013.svg>



Estimated division of total energy in the universe into matter, dark matter and dark energy based on five years of WMAP data.

출처:
<https://en.wikipedia.org/wiki/Dark_energy#/media/File:WMAP_2008_universe_content.png>

The evolution of the Universe



The **Story** of Our Universe

This illustration summarizes the almost 14-billion-year-long history of our universe.
It shows the main events that occurred
between the initial phase of the cosmos - where its properties were almost **uniform** and punctuated only by **tiny fluctuations** -
to the rich variety of cosmic **structure** that we observe today, ranging from **stars** and planets to **galaxies** and **galaxy clusters**.

The Planck mission has made the most precise map ever of the oldest light from our universe, the cosmic microwave background, harking back to less than 400,000 years after the big bang.
Patterns of light in this map reflect not only events that happened just moments after the big bang, but also the light's long journey from the distant universe to Earth. By studying these patterns, scientists can learn about the origins, fate and ingredients of our universe.

Planck is a European Space Agency mission, with significant participation from NASA.
NASA's Planck Project Office is based at NASA's Jet Propulsion Laboratory, Pasadena, Calif.
JPL contributed mission-enabling technology for both of Planck's science instruments.
European, Canadian and U.S. Planck scientists work together to analyze the Planck data.

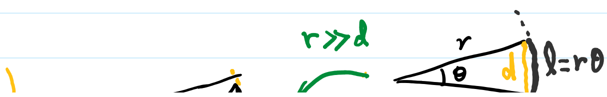
More information is online at http://www.nasa.gov/planck, http://planck.caltech.edu and http://www.esa.int/planck .

출처: <https://www.nasa.gov/mission_pages/planck/multimedia/pia16876b.html#.Y51Ak1HP3_c>

Ⅰ. Measurement

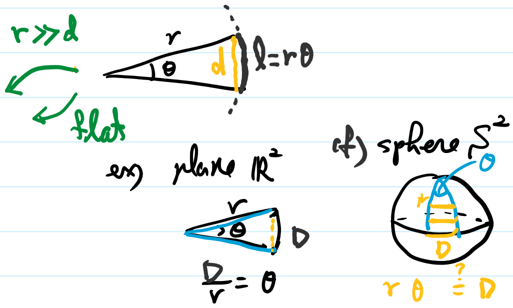
distance, size, mass, spectroscopy, structure, …

1. Angular size θ



1. Angular size θ

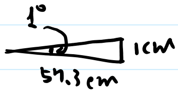
$D \simeq r \cdot \theta$

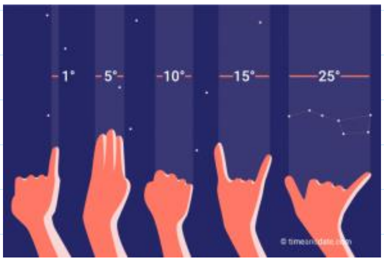


1 rad = 57.3degree

$1° = \frac{1}{57.3}$ rad

$\frac{1}{60}$ rad





1" (arcsec)=1/(57.3x60x60)

=1/206,264.8=1/2.062648x10^5

1"=1/(60x60)° = 0.277 ⋯x10^{-3}°

1(rad)=2.06x10^5arcsec

ex)

$\frac{l}{r} = 10^{-2} \Rightarrow \frac{57.3}{100} = 0.573°$

$10^{-3} \Rightarrow \frac{57.3\times 60}{10^3} = 3.44'$

$10^{-5} \Rightarrow \frac{2\times 10^5}{10^5} = 2''$

Summary:
1° = 1/57.29578
1' = 1/3,437.74677
1'' =1/206,264.806

Ex) Angular diameter

Full moon 0.5° (31 arcminute)

Sun : 1/1.874°=0.53°

Slightly larger than that of the moon

Angular Diameter

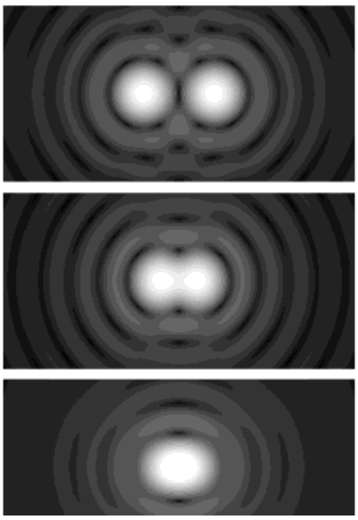
Object	Minimum	Maximum
Sun	31.6'	32.7'
Moon	29.3'	34.1'
Venus	10"	66"
Jupiter	30"	49"
Saturn	15"	20"
Mars	4"	25"
Mercury	5"	13"
Uranus	3"	4"
Neptune		2"
Ceres		0.8"
Pluto		0.1"
Betelgeuse	0.049"	0.060"
Sirius		0.007"

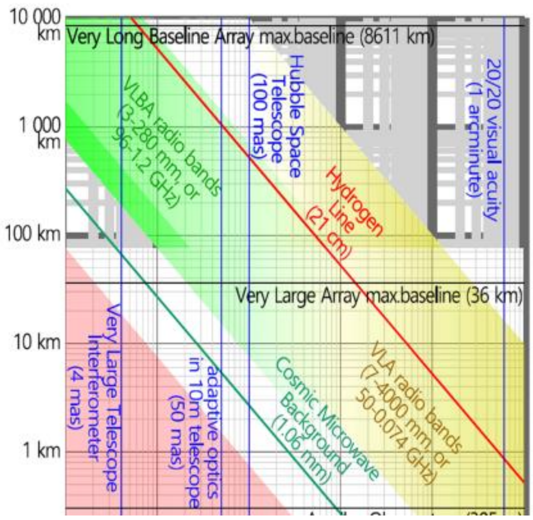
Table 1: Estimated Sizes of Some Prominent Objects

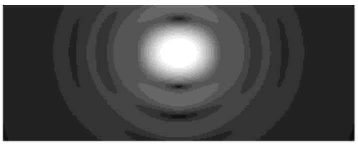
Object Name	Angular Size	Distance (LY)	Diameter (LY)
Mizar (Double Star) Separation	14"	60	0.004*
Ring Nebula (M57)	70"	2,000	0.7
Crab Nebula (M1)	6.5'	6,500	12
M35 (Open Cluster)	0.5°	2,800	24
Great Hercules Cluster (M13)	0.3°	20,000	100
Andromeda Galaxy (M31)	5°	2,000,000	170,000

*This is the approximate distance between the two stars, although the tilt of the orbit with respect to Earth introduces some errors in the calculation. To put the orbit's size in perspective, 0.004 LY is equal to 3.8x10^{10}km, or over six times the mean distance of Pluto from the Sun.

Angular resolution - Diffraction Limit







[Airy diffraction patterns](https://en.wikipedia.org/wiki/Airy_disk) generated by light from two point sources passing through a circular aperture, such as the pupil of the eye.
(top) Points far apart, distinguishable
(middle) meeting the Rayleigh criterion, can be distinguished.
(bottom) Points closer than the Rayleigh criterion are difficult to distinguish.

출처: <https://en.wikipedia.org/wiki/Angular_resolution>

Diffraction through a circular aperture,

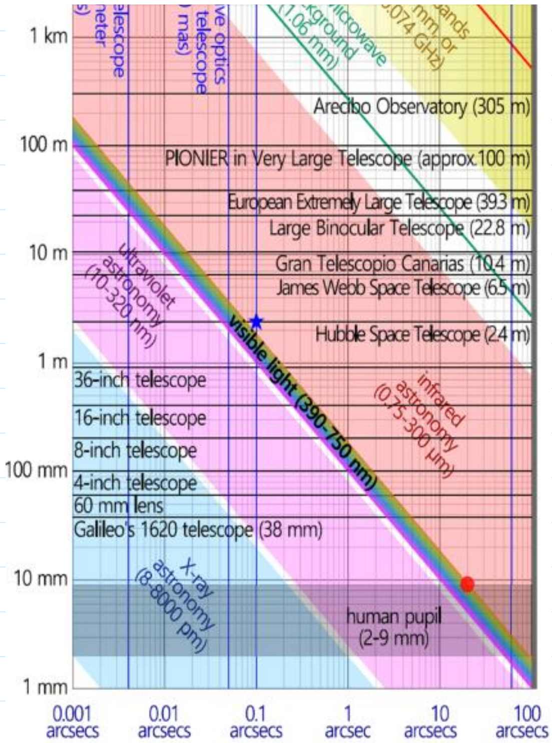
$$\theta \approx 1.22\frac{\lambda}{D}$$

where

θ : the *angular resolution* (radians),

λ : the wavelength of light,

D : the diameter of the lens' aperture.



Log−log plot of aperture diameter vs angular resolution at the diffraction limit for various light wavelengths compared with various astronomical instruments.

For example, the blue star shows that the Hubble Space Telescope is almost diffraction-limited in the visible spectrum at 0.1 arcsecs, whereas the red circle shows that the human eye should have a resolving power of 20 arcsecs in theory, though normally only 60 arcsecs.

출처: <https://en.wikipedia.org/wiki/Angular_resolution>

Angular resolution

$$R=\frac{\lambda}{D}$$

Ex)Telescope D=1m λ=1μm,

$R=10^{-6}$(rad) = 0.2" (arcsec)

human eye D=5mm λ=0.5μm,

$R=10^{-4}$(rad) = 20" (arcsec) = 1/180°

or

≈ 0.1m separation at a 1km distance.

출처: <https://en.wikipedia.org/wiki/Naked_eye>

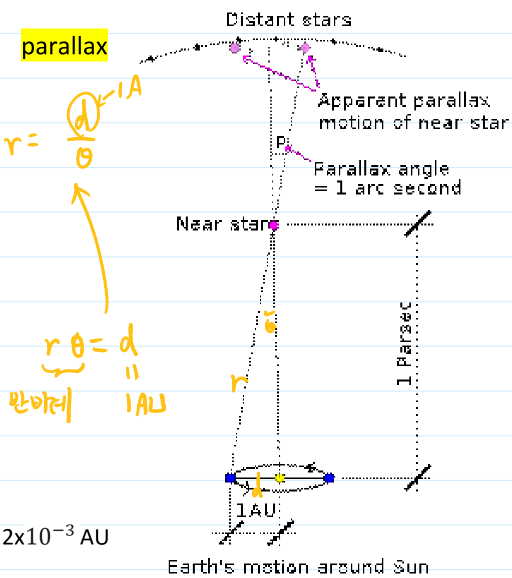
출처: <https://en.wikipedia.org/wiki/Angular_resolution>

2. **Distance** - Unit

parallax

Distanc (in parsec(pc)) = 1/ p (parallex in arcsec)

Distance (in AU) = 2.06265x10^5/p (parallex in ")



1 parsec (pc)

= 3.26 light years(ly)

= 2.06265x10^5AU

=3.09x10^{18}cm =3.09x10^{13}km

Astronomical Unit (AU)

1 AU = 1.496x10^{11} m = 1.496x10^8km

= 0.485x10^{-5} pc = 215 $R_\odot$

=1.58x10^{-5}ly =499 light seconds

1 light year (ly)

= 0.946×10^{13} km

=63,241AU

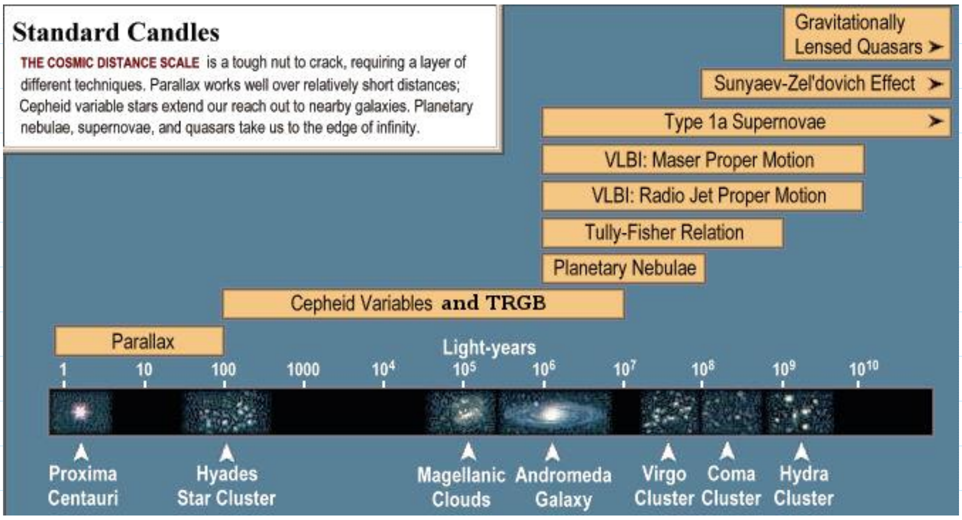
=0.3066pc

Ex) 1 light sec =3x10^5 km = 2x10^{-3} AU

1light hr =7.2AU

1light day = 173AU

Standard Candles



출처: <https://universe-review.ca/R02-07-candle.htm>

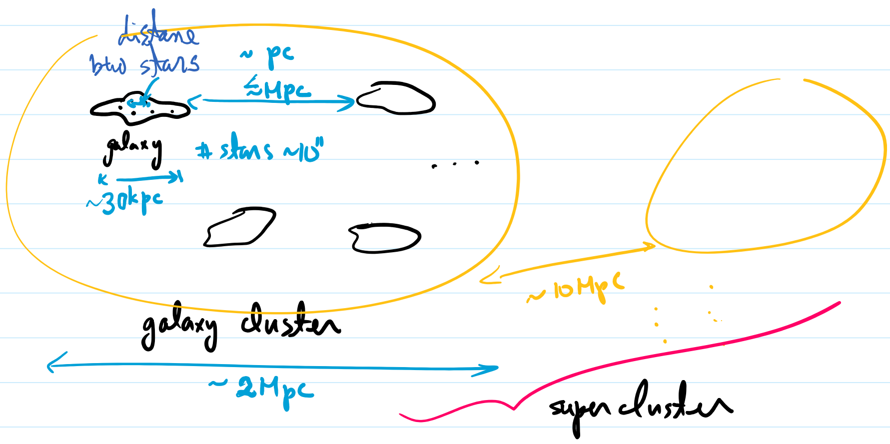
A Rough guideline of scales of star, galaxy, galaxy cluster; galaxy supercluster

Size of a star ~ $R_\odot$ = 6.957 x10^5 km
Size of a galaxy ~ 30kpc
" a galaxy clusters ≈ 2Mpc
" a galaxy superclusters ≲ 50Mpc

Distance to the Nearest star to Earth (Proxima Century)
=0.76" or 1.3 pc = 300,000 AU = 4.1 ly

Distance between stars ~ pc
" " galaxies ~ Mpc
" " galaxy clusters ~ 10Mpc
Ex) distance from the Galaxy(Milky Way)
to Andromeda galaxy(M31) = 0.765Mpc=765kpc
to the Large Magellanic Cloud =49.97kpc

Conversion btw Temperature & Energy : $[k_B T] = [Energy]$
Boltzmann constant
$k_B = 8.617333262 \times 10^{-5}$ eV K^{-1}
1eV=1.16045× 10^4 Kk_B
출처: <https://pdg.lbl.gov/2021/web/viewer.html?file=%2F2021/reviews/rpp2020-rev-phys-constants.pdf>



Ⅱ. Solar system

Sun

Mass $M_\odot$ = 1.9885×10^{30} kg = 1.99×10^{33}g
= 0.333x10^6 $M_\oplus$
Radius $R_\odot$ = 6.957 x10^5 km
= 109 x $R_\oplus$ = 1.8 x (Earth-Moon) distance
Diameter = 1.39 x 10^6 km = 4.6 light-seconds
Luminosity $L_\odot$ = 3.828×10^{26} W =3.828×10^{33} ergs/sec

■Travel Time for 1AU ■
Note) 1 light sec =3x10^5 km
= 2x10^{-3} AU
1light hr =7.2AU
1light day = 173AU

10km/sec (satellite) = 1/(3x10^4 c)

= 109 x $R_\oplus$ = 1.8 x (Earth-Moon) distance

Diameter = 1.39 x 10^6 km = 4.6 light-seconds

Luminosity $L_\odot$ = 3.828×10^{26} W = 3.828×10^{33} ergs/sec

≈3.75×10^{28} lm ≈ 98 lm/W efficacy

Temperature $T_\odot$ = 1.57×10^7 K (Center), (=1.35 keV/k_B)

= 5772 K (Photosphere),

≈ 5×10^6 K (Corona)

Age ≈4.6 Billion years

Velocity ≈ 220 km/s (orbit around the Milky Way Center)

≈ 20 km/s (relative to neighborhood stars)

≈ 370 km/s (relative to Cosmic Microwave Backgound)

v_{escape}=615 km/sec

Average density = 1.408 g/cm^3 = 0.255 x Earth

Surface gravity = 28 x Earth

1light hr = 7.2AU

1light day = 173AU

10km/sec (satellite) = 1/(3x10^4 c)

For 1 AU,

light takes

500 sec

10km/sec satellite takes

500x3x10^4s=1.5x10^7s =0.5 yr

Ex) Satellite

1AU→0.3yr

10AU→ 3yr

100AU →30yrs (Voyager Satellite)

The Earth

$M_\oplus$ = 5.97237×10^{24} kg = 5.97237×10^{27}g =3.0×10^{-6} $M_\odot$

$R_\oplus$ = 6,371 km = 6.371 x 10^3 km (적도 : 6378km, 극: 6356.8km)

Diameter = 12,757 km, Circumference = 40,054 km

Mean density = 5.514 g/cm^3

Distance between ⊙ & ⊕ =1 AU = 1.496x10^{11} m = 1.496x10^8km = 0.485x10^{-5} pc = $\frac{1}{2.06265\times10^5}$ pc

=499 light seconds

속도

자전 속도 0.4651 km/s

공전 속도 29.78 km/s

탈출 속도 11.186 km/s

The Moon

Distance btw the Earth & the Moon = 3.84 x 10^5 km ≈ 30 × 2 $R_\oplus$ ≈1.3 lightseconds

Radius of the Moon =1737.4 km=1.7374× 10^3km

Escape velocity = 2.38km/s

Inner Solar System 출처: <https://en.wikipedia.org/wiki/Solar_System>

- the terrestrial planets (Mercury, Venus, Earth, and Mars) & the asteroid belt .
- Composed of silicates & metals.
- Within the frost line (≲ 5AU (750 million km) from the Sun.

Outer planets

- The 4 outer planets, or giant planets (Jovian planets), (Jupiter,Saturn, Uranus,& Neptune)
- making up 99% of the mass known to orbit the Sun.
- consist overwhelmingly of the gases hydrogen and He,
- are composed primarily of ices, ice giants.

Comparison : Inner Planets and Outer Planets

Parameters	Inner Planets	Outer Planets
Definition	orbits lie btw the Sun & the asteroid belt	orbits lie beyond the asteroid belt
planets	Mercury, Venus, Earth, and Mars	Jupiter,Saturn, Uranus,& Neptune
Composed of	small planets mostly composed of rock	mostly big and composed of gas
from Sun	closer to the Sun	further from the Sun
Moons	Inner planets have very few moons	Outer planets have lots of moons
Rings	no rings around them	rings around them
Surface	a solid surface & are terrestrial planets	No solid surface and are gas giants
Revolution	short periods of revolution	long periods of revolution
Density	Inner planets have great density	Outer planets have less density
Orbits	have close orbits	have separated orbits

출처: <https://askanydifference.com/difference-between-inner-planets-and-outer-planets/>

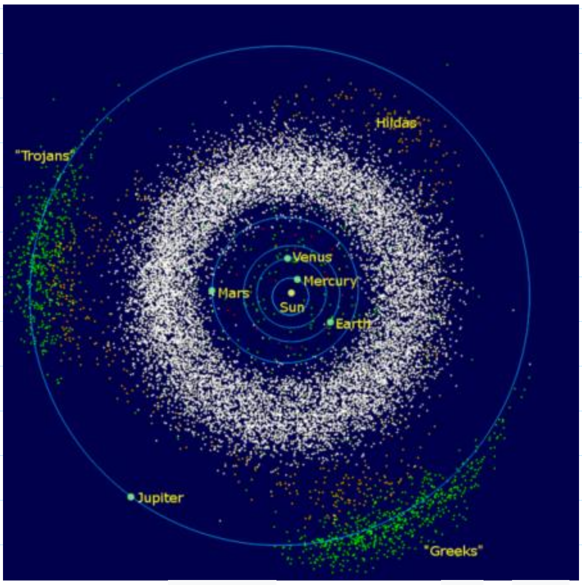
	수성	Venus	Earth	Mars	Jupiter
distance(Mkm)	57.9	108.2	149.6	227.9	778.3
Period revol	88 d	224.7 d	365.2d	687 d	11.86yrs

Saturn	Uranus	Neptune	Pluto5
1,427	2,870	4,497	5,900
29.46 yrs	84 yrs	165 yrs	248 yrs

Period revol	88 d	224.7 d	365.2d	687 d	11.86yrs	29.46 yrs	84 yrs	165 yrs	248 yrs
Rotation period	59 days	243 d retrograde	23 hr 56m4s	24 hr 37 m	9 hr 55m30s	10 hr 40 m24 s	16.8 hr (?) retrograde	16 hr 11 min (?)	6 d 9 hr retrograde
Eccentricity	.206	.007	.017	.093	.048	.056	.047	.009	.254
diameter(km)	4,880	12,100	12,756	6,794	142,800	120,660	51,810	49,528	2,290 (?)
Atmosphere	none	CO_2	N_2 O_2	CO_2	H_2, He	H_2, He	He, H메탄	H_2, He, CH_4	None
Satellites	0	0	1	2	631	562	273	134	36
Rings	0	0	0	0	3	1,000 (?)	11	4	?

출처: <https://www.infoplease.com/math-science/space/solar-system/basic-planetary-data>

Source: Basic NASA data and other sources.



The donut-shaped asteroid belt btw the orbits of Mars & Jupiter.

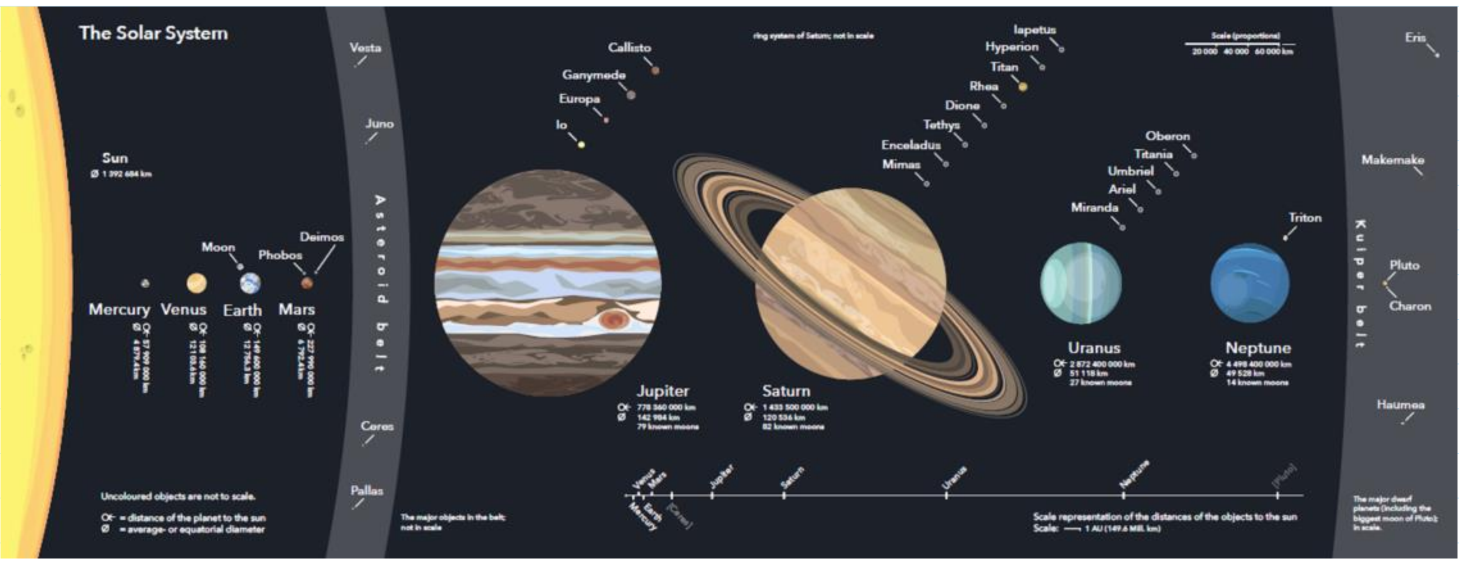
Sun | Jupiter trojans | Planetary orbit
Asteroid belt | Hilda asteroids | NEOs (selection)

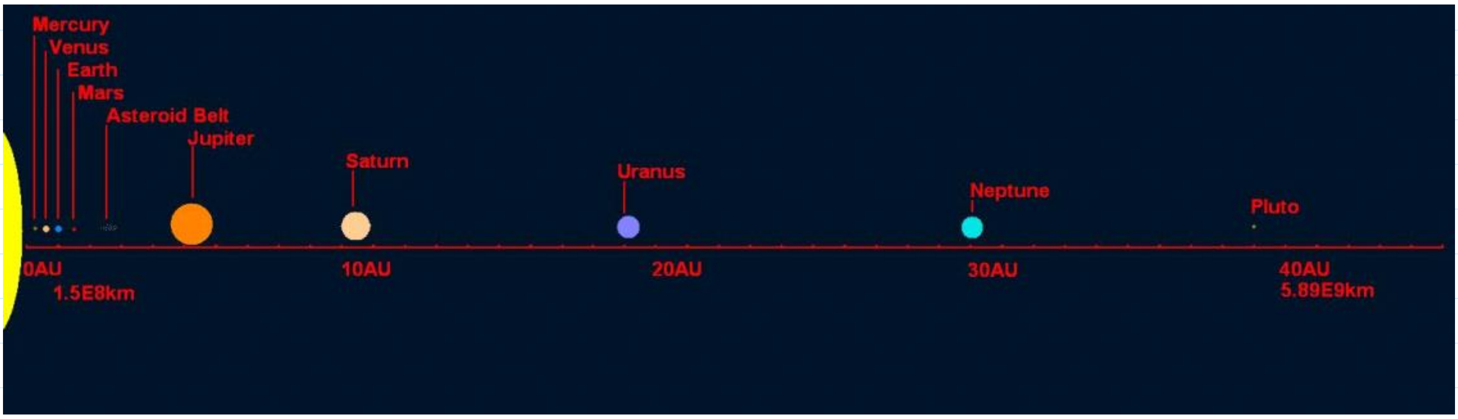
출처: <https://en.wikipedia.org/wiki/Solar_System#Asteroid_groups>

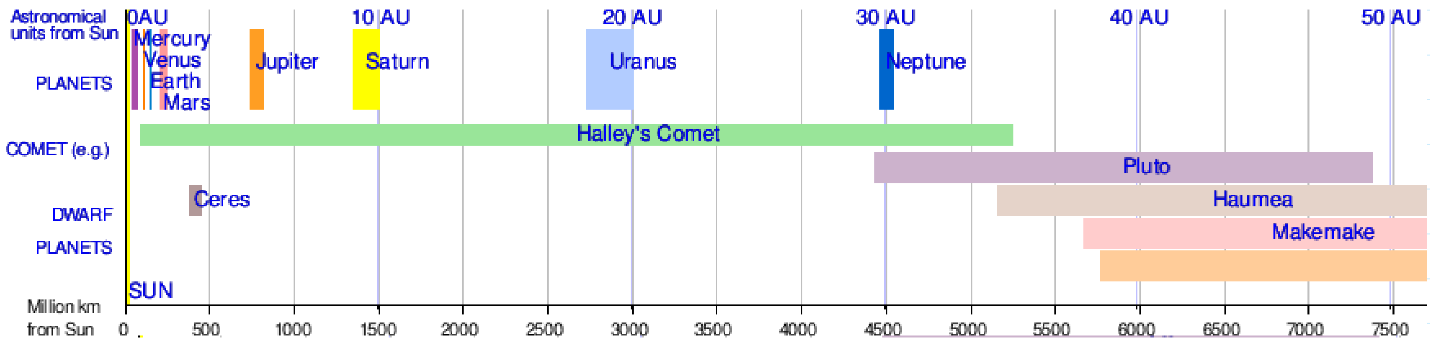
Planet	Distance from the Sun (AU/KM)
Mercury	0.39 (57.9 million)
Venus	0.723 (108.2 million)
Earth	1 (149.6 million)
Mars	1.524 (227.9 million)
Jupiter	5.203 (778.3 million)
Saturn	9.539 (1,427.0 million)
Uranus	19.18 (2,871 million)
Neptune	30.06 (4,497.1 million)

출처: <https://sciencetrends.com/great- planets-order-size-distance-sun/>

Ex) Jupiter
Distance = 5.2 AU
(780 million km)
Radius = 69,911 km
$\approx 11\ R_\oplus$
Mass = 1.8982×10^{27} kg
$= 317.8\ M_\oplus$
$= 1/1047\ M_\odot$



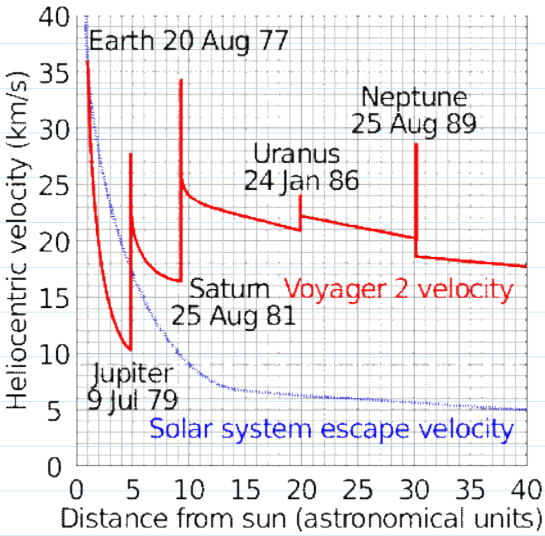




The left & right edges of each bar correspond to the perihelion & aphelion of the body, respectively.

출처: <https://en.wikipedia.org/wiki/Solar_System>

Voyager Satellite



Ex) 10AU↔ 5,000 s
=1 hr 23.33 min.
by light
100AU ↔ 13.88 hr
by light

Ex) By Satellite
10km/sec = 1/(3x10^4 c
10AU→ 3yr
100AU →30yrs
(Voyager Satellite)

Trans-Neptunian region
- Beyond the orbit of Neptune

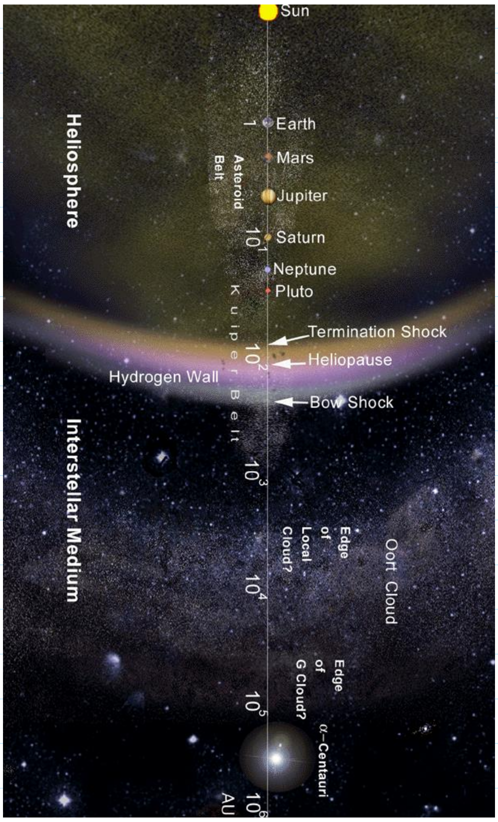
Trans-Neptunian region

- Beyond the orbit of Neptune
- with the doughnut-shaped Kuiper belt,
- home of Pluto & several other dwarf planets,
- and an overlapping disc of scattered objects, which reaches much further out than the Kuiper belt.

The Kuiper belt

- A ring of debris similar to the asteroid belt, but mainly of ice.
- between **30 and 50 AU** from the Sun.
- Contains dwarf planets, short period comets, & other objects
  Ex) Pluto, Haumea, Makemake
  출처: <https://simple.wikipedia.org/wiki/Solar_System>
- Many have multiple satellites, and most have orbits outside the plane of the ecliptic.

출처: <https://en.wikipedia.org/wiki/Solar_System#Asteroid_groups>



From the Sun to the nearest star: The Solar System
출처: <https://en.wikipedia.org/wiki/Solar_System>

The heliosphere

- is a stellar-wind bubble, in which
- the Sun's solar wind at ~ 400 km/s, a stream of charged particles,
- until it collides with the wind of the interstellar medium.

the ***termination shock***,

- Is where the collision occurs
- Located at **80–100 AU** from the Sun upwind of the interstellar medium and
- roughly **200 AU** from the Sun downwind.

the ***heliosheath***

- Here the wind slows dramatically, condenses and becomes more turbulent,
- forming a oval shape.

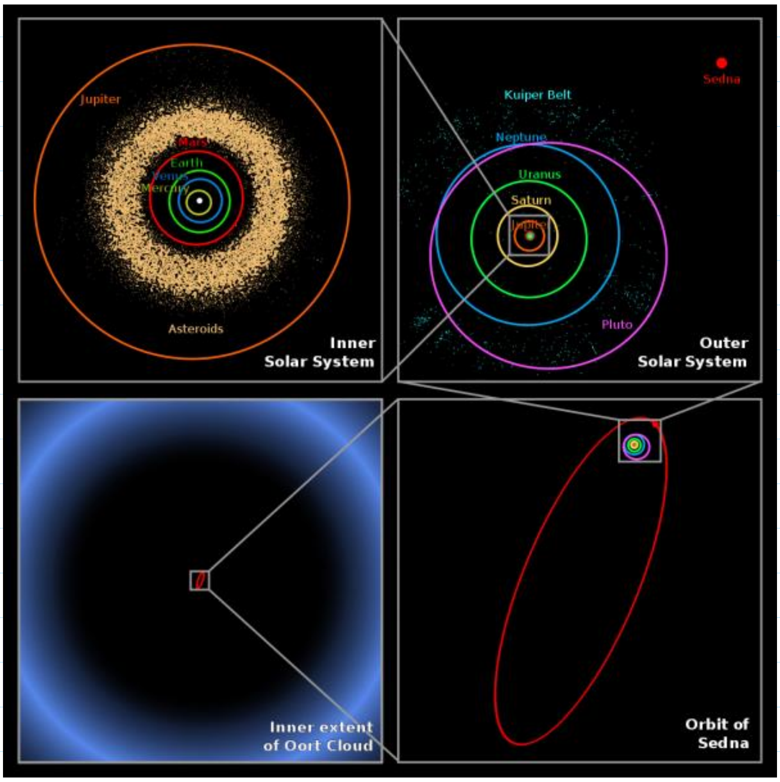
the ***heliopause***

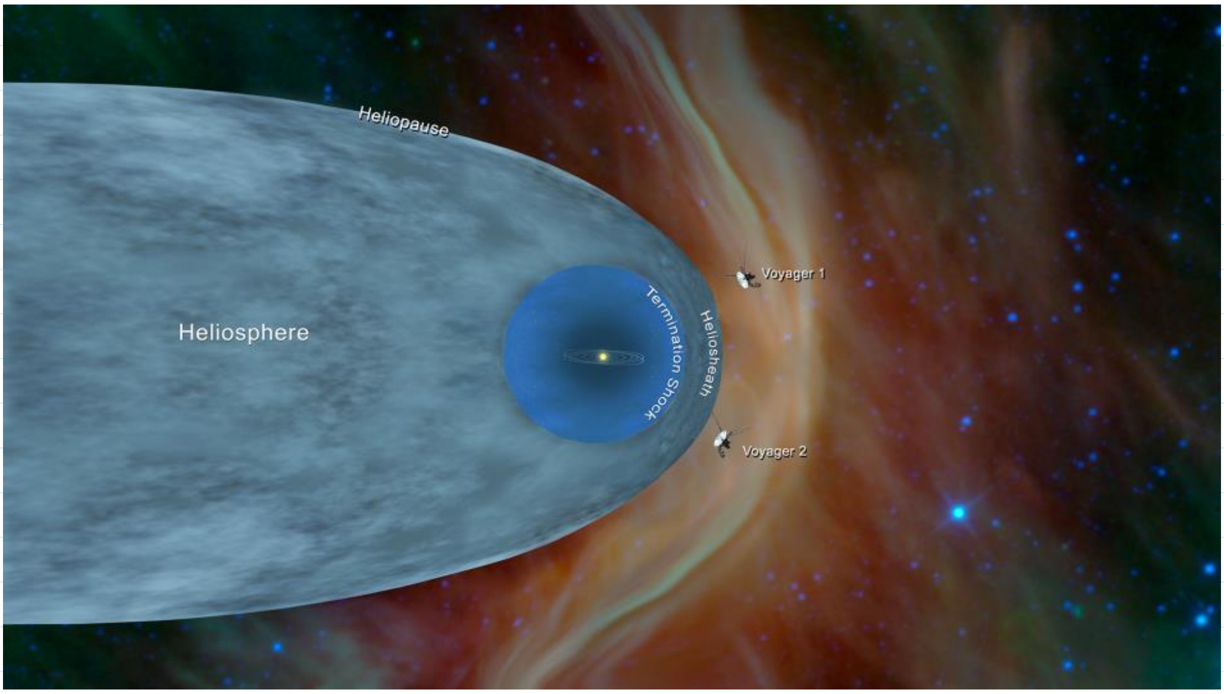
- Is the outer boundary of the heliosphere,
- at which the solar wind finally terminates
- is the beginning of interstellar space.

the bow shock,

- Beyond the heliopause, **at ~230 AU**,
- a plasma "wake" left by the Sun as it travels through the Milky Way.

출처: <https://en.wikipedia.org/wiki/Solar_System#Asteroid_groups>



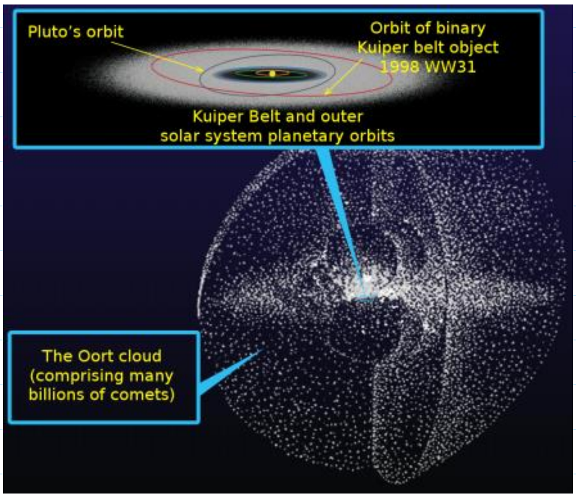


Voyager 1 & *Voyager 2* passed the termination shock and entered the heliosheath, at 94 & 84AU from the Sun, respectively. Voyager 1 has crossed the heliopause in August 2012.

Detached objects

90377 Sedna (with an average orbit of 520 AU)

- large, reddish object
- with a gigantic, highly elliptical orbit from about 76 AU at perihelion to 940 AU at aphelion
- and takes 11,400 years to complete.
- discovered in 2003 (by Mike Brown),
- "distant detached objects" (DDOs) also include 2000 CR105, a perihelion of 45 AU, an aphelion of 415 AU, & a period of 3,420 yr.
- Brown terms this population the "inner Oort cloud" Sedna is very likely a dwarf planet.
- The second detached object, with a perihelion farther than Sedna's at roughly 81 AU, is 2012 VP113, discovered in 2012. Its aphelion is only half that of Sedna's, at 400–500 AU.



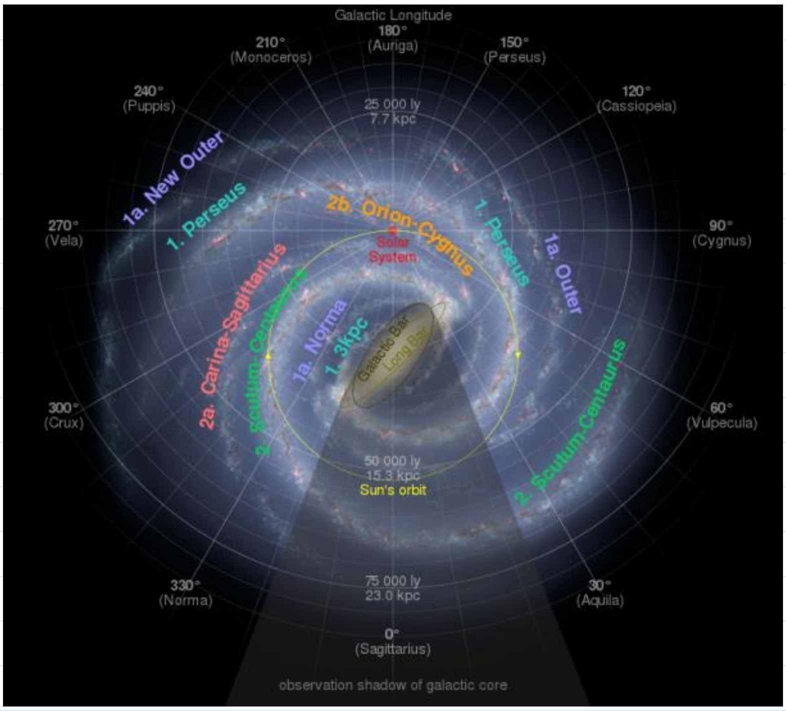
출처: <https://en.wikipedia.org/wiki/Solar_System#Asteroid_groups>

The **Oort cloud**

- is a spherical cloud of up to a trillion icy objects
- the source for all long-period comets
- and to surround the Solar System at 50,000 AU (around 1ly), and to 100,000 AU (1.87 ly).
- composed of comets ejected from the inner Solar System by grav interactions with the outer planets.
- objects move very slowly, can be perturbed by infrequent events, such as collisions, the grav effects of a passing star, or the tidal force by the Milky Way.

출처: <https://en.wikipedia.org/wiki/Solar_System#Asteroid_groups>

Location of the Solar System In the [Universe]



- Observable universe
  - Laniakea Supercluster
    - Virgo Supercluster
      - Local Sheet
        - Local Group
          - Milky Way subgroup
            - Milky Way
              -Orion–Cygnus Arm
                - Gould Belt
                  - Local Bubble
                    - Local Interstellar Cloud – immediate galactic neighborhood of the Solar System.
                      - Alpha Centauri – star system nearest to the Solar System, at about 4.4 light years away
                        - Solar System – star and planetary system where the Earth is located.
                          - Earth – the only planet known to have life, including intelligent life, including humans

출처: <https://en.wikipedia.org/wiki/Outline_of_the_Solar_System>

Mass, Time, size, etc

# of atoms in the universe $\approx 10^{57}$

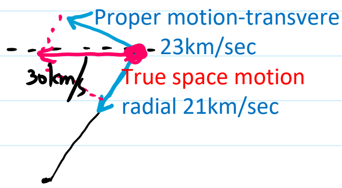
$0.1M_\odot \lesssim M_{\text{Most Stars}} \lesssim 10M_\odot$

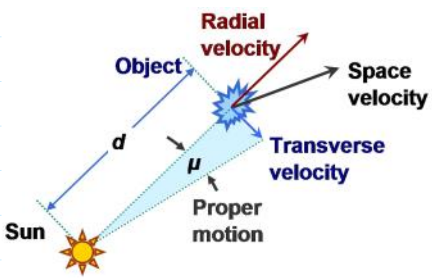
$M_{\text{Most Massive}} \lesssim 150M_\odot$

Ex) Alpha Centuri System
(the closest star system)

V_r = −21 km/s
d=4.37ly=1.34 pc
$\mu = 3.7''$/yr
⇝
$V_t = 23$ km/sec

Alpha Centuri System





Relation between proper motion and velocity components of an object.
A year ago the object was d units of distance from the Sun, and its light moved in a year by angle μ radian/s. If there has been no distortion

Ex) Barnard's Star

d=1.8 pc
$\mu = 10.3''$/yr
(the largest of all stars)
⇝
$V_t = 87$ km/sec

Barnard's Star

Constellation	Ophiuchus
RA	$17^h\ 57^m\ 48.5^s$

A year ago the object was *d* units of distance from the Sun, and its light moved in a year by angle *μ* radian/s. If there has been no distortion by gravitational lensing or otherwise then

$\mu = V_t/d$

출처: <https://en.wikipedia.org/wiki/Proper_motion>

Note : radial velocity measured by the Doppler effect

$V_t = 4.7\, \mu\, d$

where

V_t : km/sec, transverse velocity,
μ : arcsec/yr, angular velocity
d : pc, distance

- Of the stars visible to the naked eye, 61 Cygni A (magnitude V=5.20) has the highest proper motion

$\mu_{61\ Cygni\ A} = 5.281''\ yr^{-1}$

출처: <https://en.wikipedia.org/wiki/Proper_motion>

Constellation	Ophiuchus
RA	$17^h\ 57^m\ 48.5^s$
Declination	+04° 41′ 36″
Appar mag(V)	9.5
Spectral type	M4.0V
Astrometry	
Radial vel (R_v)	−111 km/s
Proper motion (μ)	RA: −803 mas/yr Dec:10,363mas/yr
Parallax (π)	547 mas
Distance	5.96ly (1.83 pc)
Absol mag (M_V)	13.21[2]
Details	
Mass	0.144[6] $M_\odot$
Radius	0.2 $R_\odot$
Luminosity (bol)	0.0035 $L_\odot$
Lumino (vis, L_V)	0.0004 $L_\odot$
Temperature	3,134 ± 102 K
Metallicity	10–32% Sun
Rotation	130.4 d
Age	≈ 10 Gyr

출처: <https://en.wikipedia.org/wiki/Barnard%27s_Star>

Time (시간)

지구 자전(서→ 동)과 공전 같은 방향 ⇒

Solar time (태양시) 출처: <https://en.wikipedia.org/wiki/Solar_time>

apparent solar time (sundial time;시태양시(視太陽時))

mean solar time (clock time 평균태양시(平均太陽時))

An apparent solar day = a mean solar day ±30sec

sidereal time(항성시(恒星時))

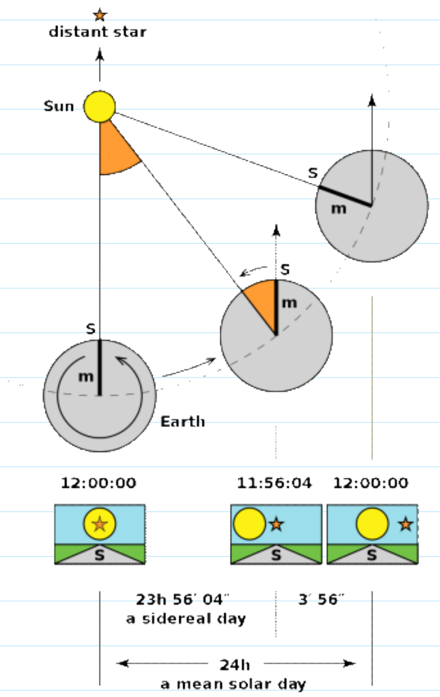
1 평균 항성일(sidereal day)
≈ 23hr 56min 4.0916sec
(in terms of 평균 태양시(solar day))

출처: <https://en.wikipedia.org/wiki/Solar_time>

Time

1 yr = 3.16×10^7s (≈ 3.16×10^7s)= 365 × 24 × 3600
1 d=8.64×10^4s=24 h/d x 3600 s/h
Age of the Universe =1.38×10^{10}yr≈ 5×10^{17}s

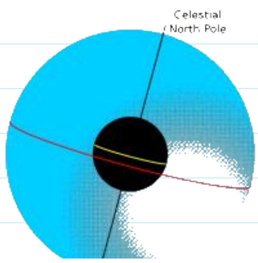
1sidereal day= 23hr 56min(in terms of solar time)
1solar day=24hr
(태양이 자오선 위에 되돌아 오는 시간)
⇒



Sidereal time(항성시) vs solar time (태양시).
좌: 별, 태양 at culmination, on the local meridian m.
중: 별만 at culmination (a mean sidereal day).
우: 태양 on the local meridian again. A solar day.

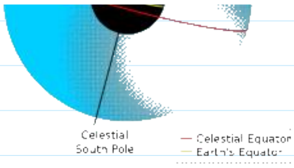
출처: <https://en.wikipedia.org/wiki/Sidereal_time>

Stars : Rises 4 minute earlier every day
Celestial Sphere Rotation : 23hr 56 min.
(infinitely far) stars - fixed in the celestial sphere
Sun - moves eastward 1°/day along the ecliptic
태양- 황도 따라 동쪽으로 1°/day 이동
(연주 운동)

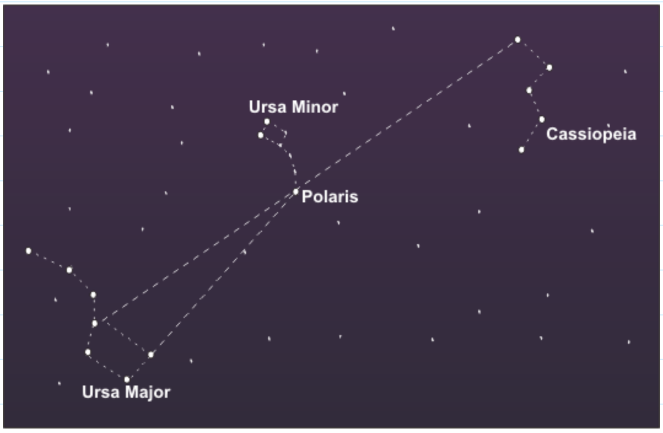


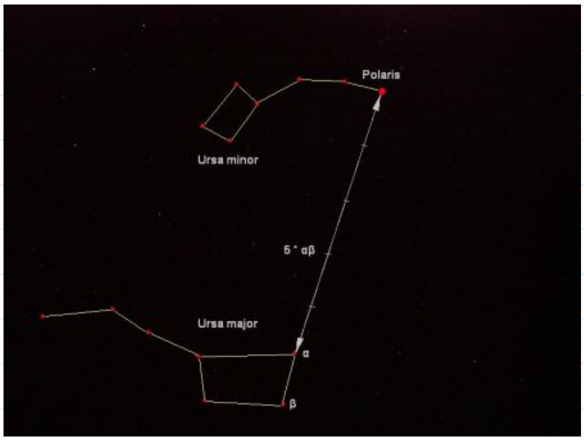
Note : (360° ~ 24hours, 1° ~ 4minutes)

태양- 황도 따라 동쪽으로 1°/day 이동
(연주 운동)
Note : (360° ↔24hours, 1° ↔ 4minutes)



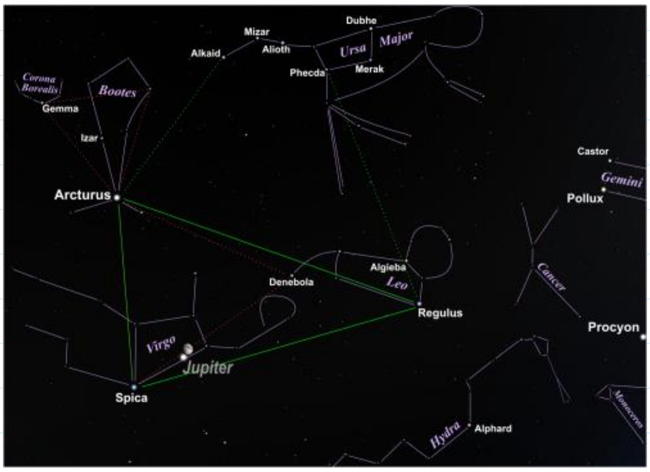
Stars and Constellations





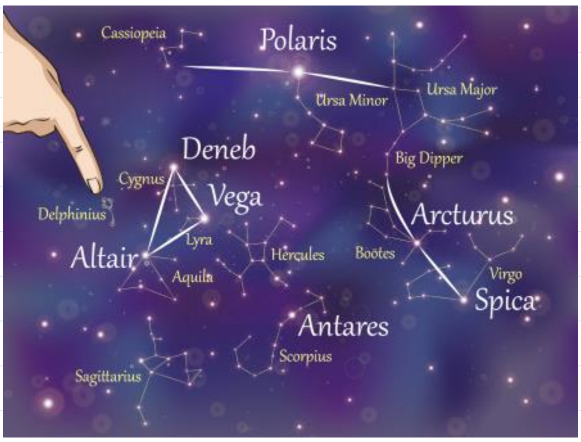
Seasonal Constellation

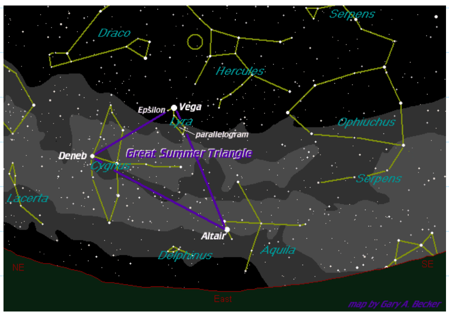
Spring

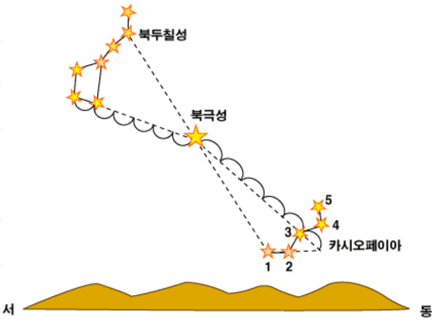


봄의 삼각형

Summer





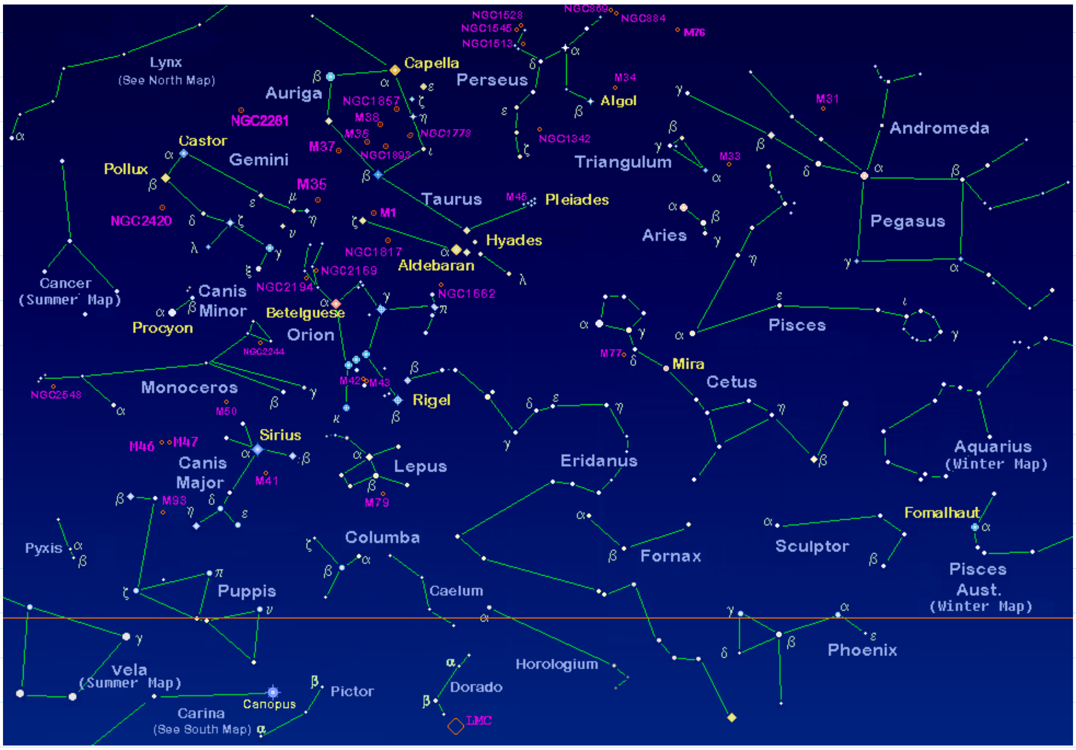


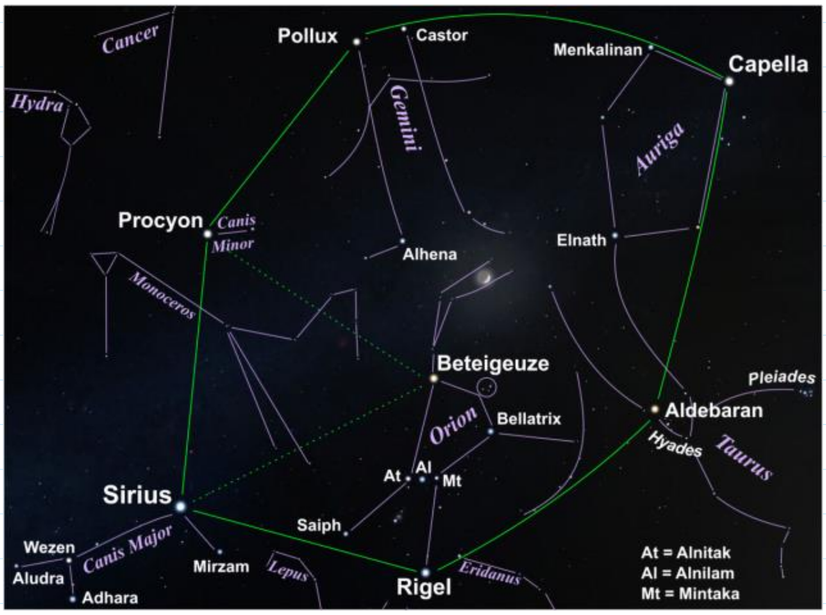
출처: <http://scienceorc.net/science/study/jigu/g11-3.html>

Autumn

Winter Constellations

출처: <http://huntingtonnightlife.blogspot.com/2011/11/winter-constellations.html>



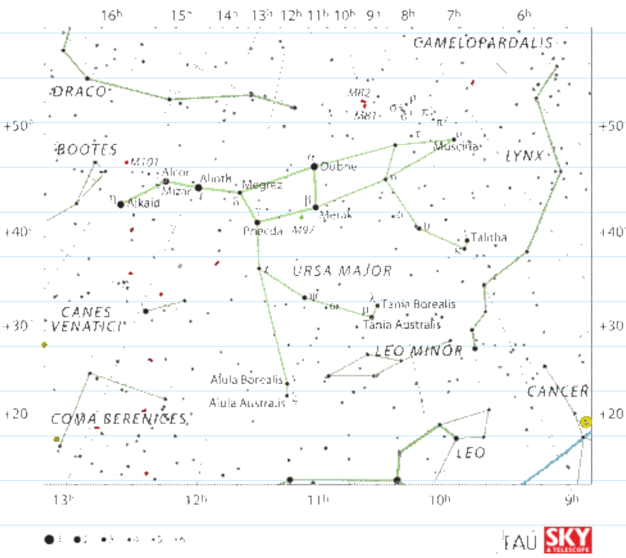


Constellation (별자리)

The whole sky is covered with
Constellations = 88

The stars in the constellation is named in the order of the brightness, α, β, γ, δ etc.
Some bright stars are also called by the historical names.

Ex) Ursa Major (Big Dipper) 북두칠성



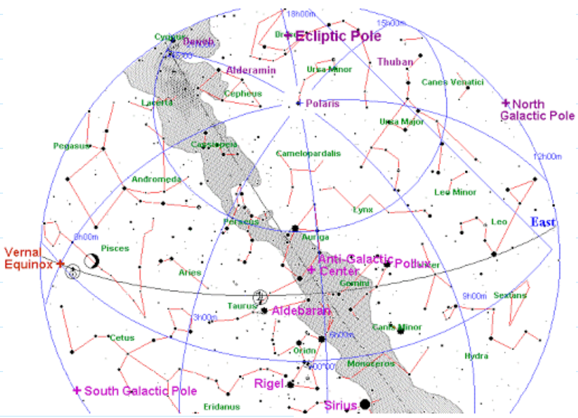
The celestial sphere and Astronomical coordinate system

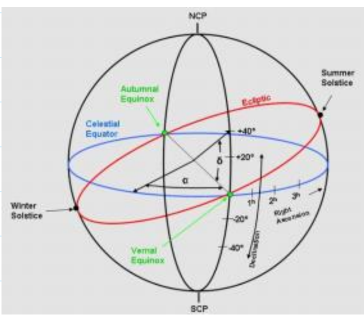
출처: <https://en.wikipedia.org/wiki/Astronomical_coordinate_systems>

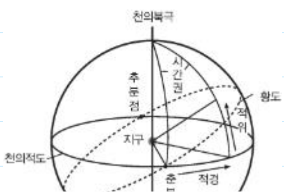
1) Equatorial coordinates

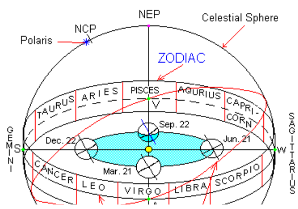
α, right ascension

δ, declination

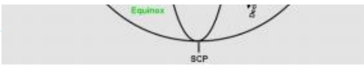


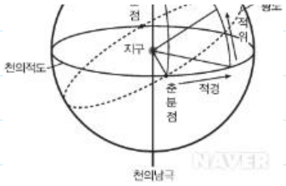


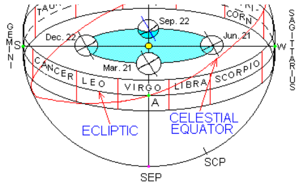




An **equinox** is either of two places

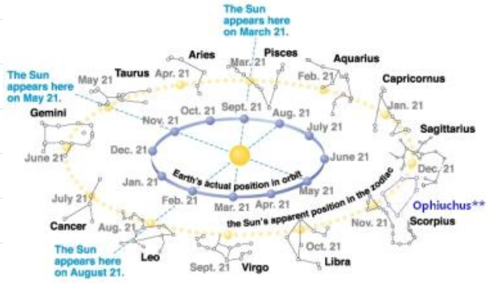






An **equinox** is either of two places on the celestial sphere at which the ecliptic intersects the celestial equator.

The equinox associated with the Sun's ascending node is used as the origin of celestial coordinate systems and referred to simply as "the equinox". 출처: <https://en.wikipedia.org/wiki/Equinox_(celestial_coordinates)>



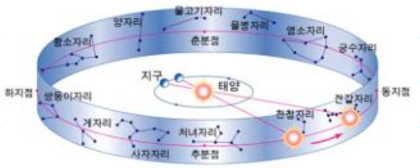
Original © Addison Wesley corrected by Larry McNish

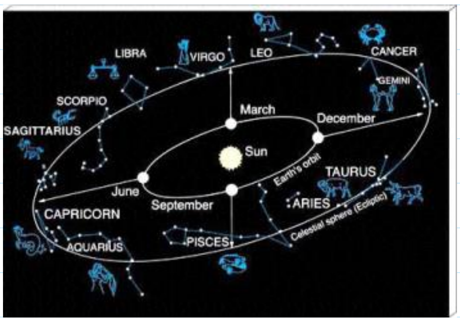
The south celestial pole lies in the constellation Octans.

the south pole star: Sigma Octantis,

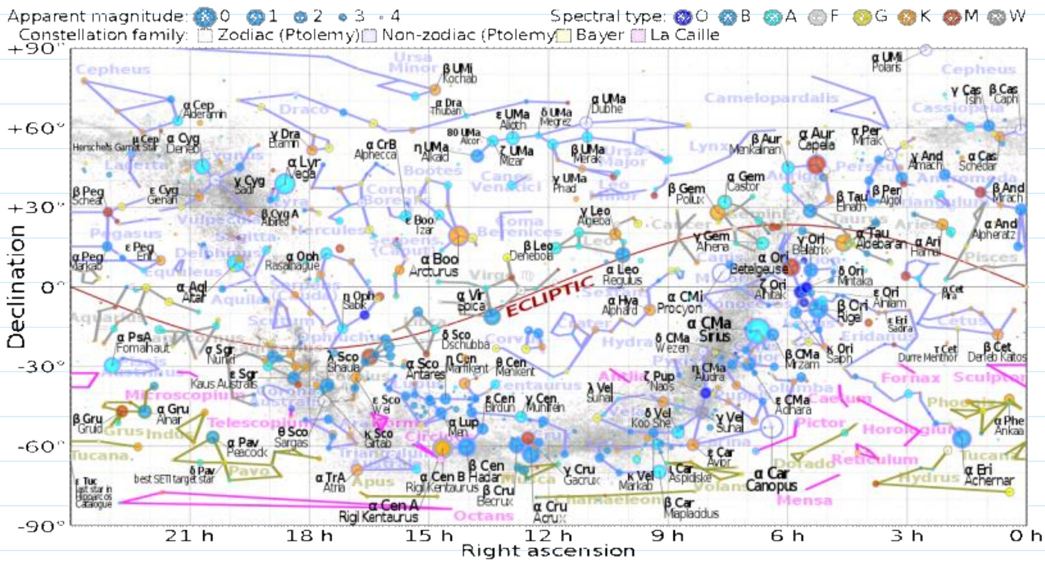
more than 1° away from the pole, with m_v = 5.5.

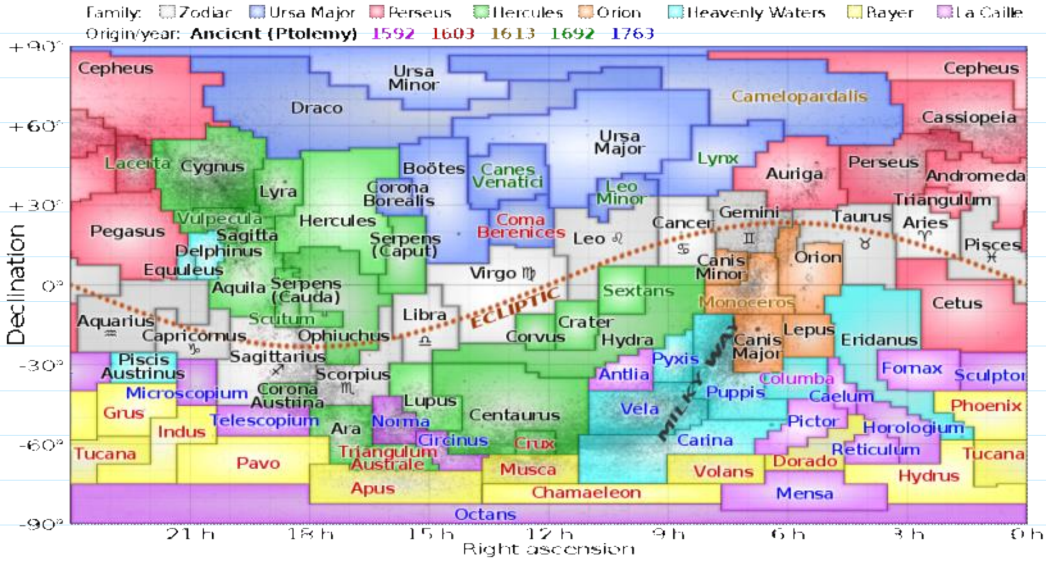
출처: <https://en.wikipedia.org/wiki/Celestial_pole>





All the constellations in the sky (equatorial coordinates)

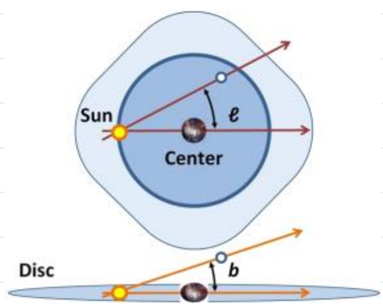




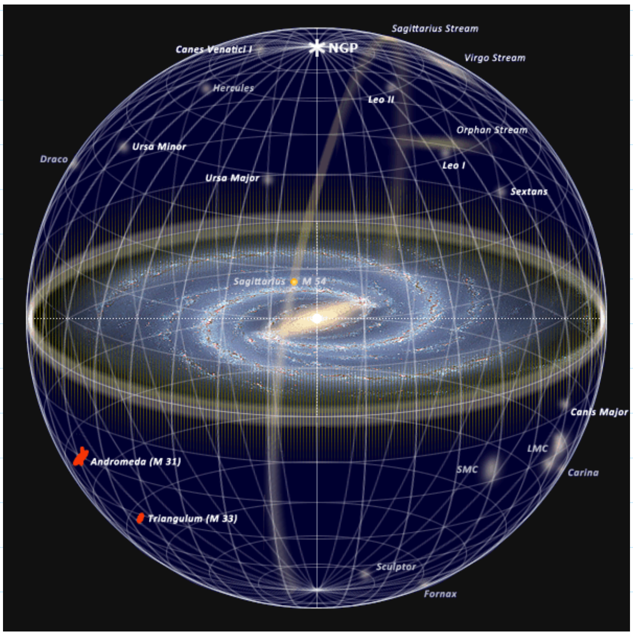
Constellation along the Milky Way in the Sky :
0[Scorpius, Sagittarius];40 Aquila, 80 Cygnus,100 Cepheus,Cassiopeia 120, 150 Perseus; (Auriga170)
Orion200,220Monoceros,230Canis Major(Puppis250); [270Vela, Carina];300Crux; 315Centaurus;330[Lupus Norma];

2) Galactic coordinate system

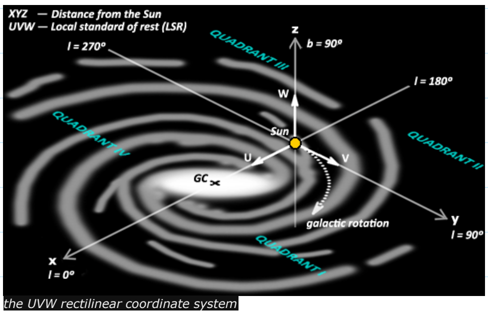
출처:
<https://en.wikipedia.org/wiki/Galactic_coordinate_system>



출처:
<https://en.wikipedia.org/wiki/Galactic_coordinate_system>

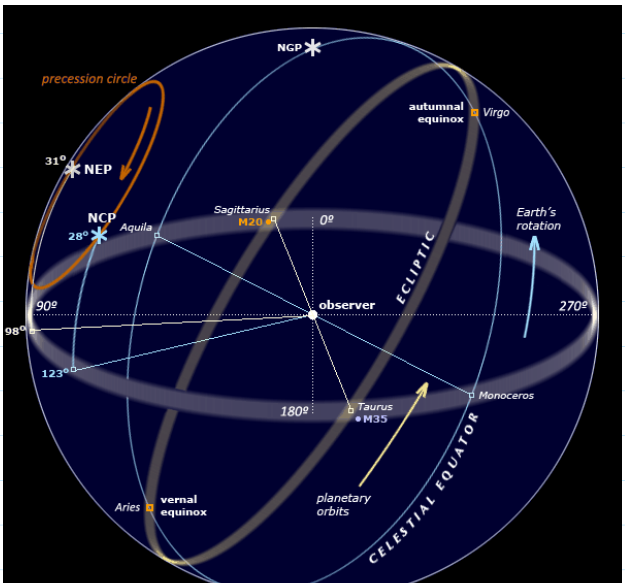


The galactic north pole at
RA= 12h 51.4m, Dec= +27°07’
the galactic centre at
RA= 17h 45.6m, Dec = -28°56’



the UVW rectilinear coordinate system

출처: <https://www.handprint.com/ASTRO/galaxy.html>

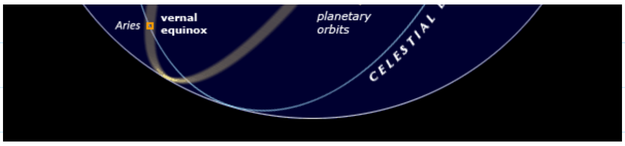


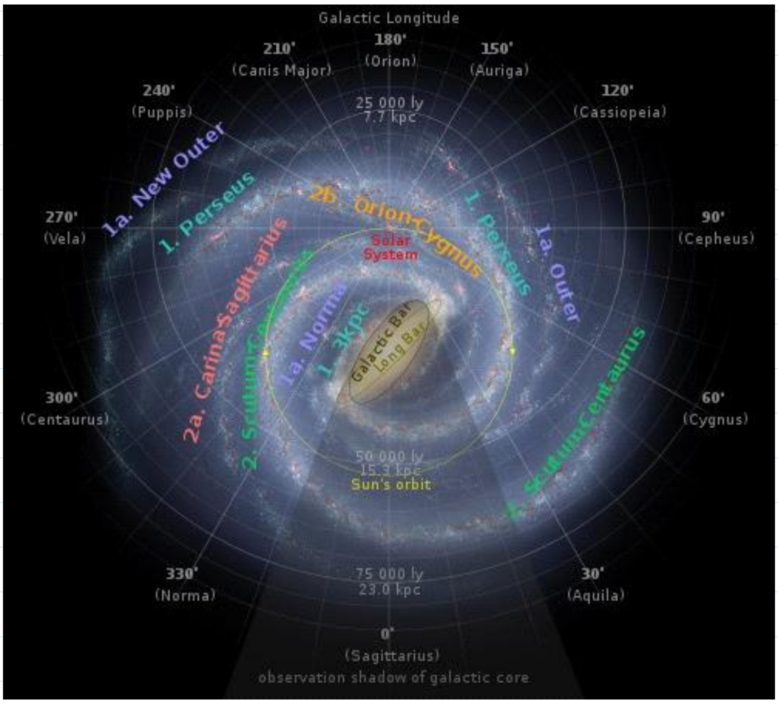
NEP in Draco
(at the Cat's Eye Nebula, NGC 6543),
NCP in Ursa Minor,
ecliptic & celestial equator in relation
to NGP & galactic longitude.

출처: <https://www.handprint.com/ASTRO/galaxy.html>

ecliptic & celestial equator in relation to NGP & galactic longitude.

출처: <https://www.handprint.com/ASTRO/galaxy.html>





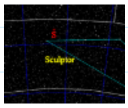
Equatorial coordinates

of galactic reference points

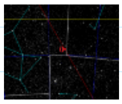
	RA	Dec	Constellation
North Pole +90° latitude	$12^h51.4^m$	+27.13°	Coma Berenices (near 31 Com)
South Pole −90° latitude	$0^h51.4^m$	−27.13°	Sculptor (near NGC 288)
Center 0° longitude	$17^h45.6^m$	−28.94°	Sagittarius (in Sagittarius A)
Anticenter 180° longitude	$5^h45.6^m$	+28.94°	Auriga (near HIP 27180)

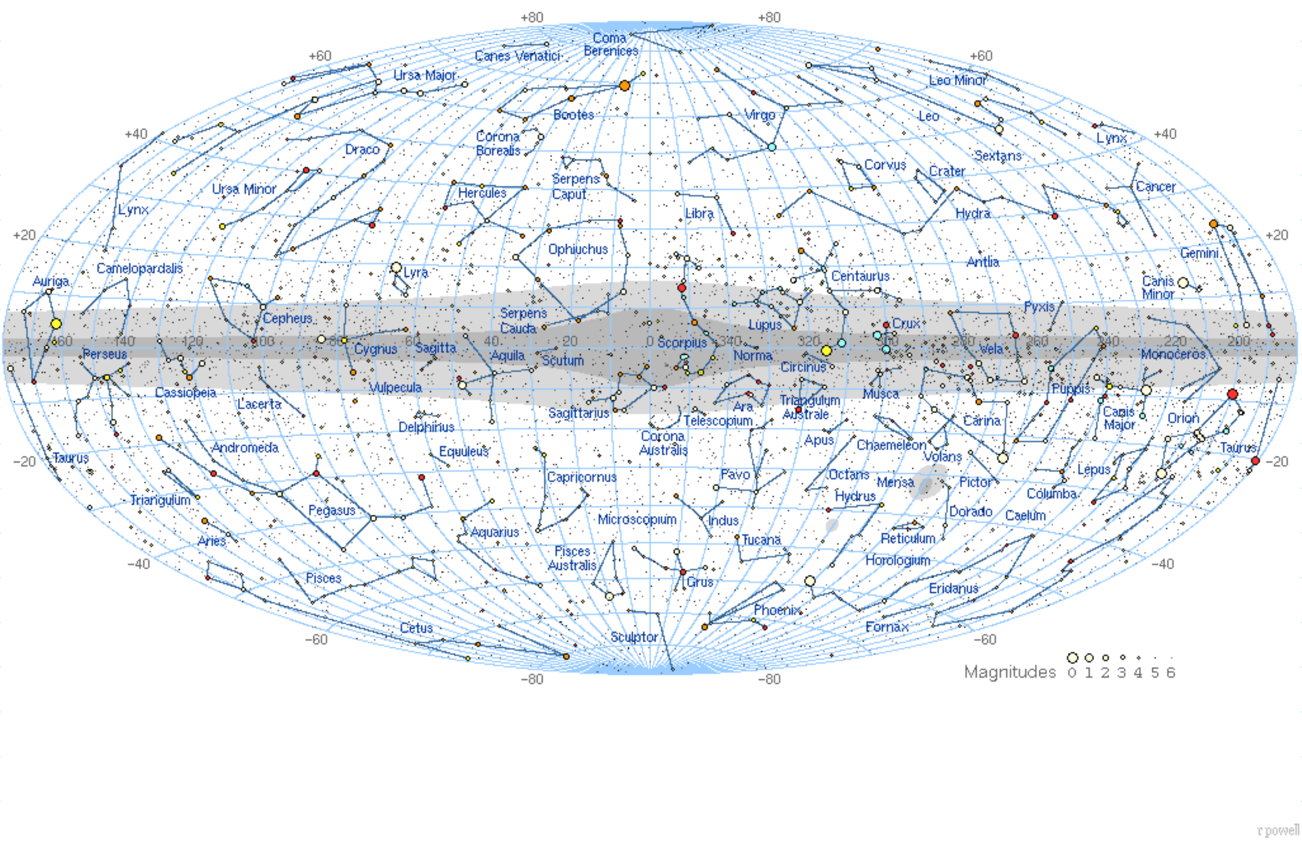
출처: <https://en.wikipedia.org/wiki/Galactic_coordinate_system>

Galactic north



Galactic south


Galactic center



Constellation along the Milky Way in the Sky :
0[Scorpius, Sagittarius];40 Aquila, 80 Cygnus,100 Cepheus,Cassiopeia 120, 150 Perseus; (Auriga170)
Orion200,220Monoceros,230Canis Major(Puppis250); [270Vela, Carina];300Crux; 315Centaurus;330[Lupus Norma];

별 - 밝기와 거리 출처: <https://en.wikipedia.org/wiki/Absolute_magnitude>

Apparent magnitude (*m*) is a measure of the brightness.

The scale is reverse logarithmic: the brighter an object is, the lower its magnitude number.

$\Delta m = 1.0 \leftrightarrow \sqrt[5]{100} \approx 2.512.$ $\Delta m = 2.0 \leftrightarrow (\sqrt[5]{100})^2 \approx 6.31$

Absolute magnitude (M) = a measure of the intrinsic luminosity

= the apparent magnitude at 10 pc (32.6 ly) or a parallax of 0.1″ (100 milliarcsec)

Ex) the **absolute visual magnitude** M_V in V(visual) band (in the UBV photometric system).

An absolute *bolometric* magnitude (M_{bol}) = total luminosity over all wavelengths,

Examples) -26.7(Sun) $\le m \le$ +31.5 (by Hubble Space Telescope)

$m(\odot)$=-26.7 $M_V(\odot)$ =+4.83. $M_{bol}(\odot)$ = 4.75

m(Venus) = -4.2

m(Sirius) = -1.46. M_V (Sirius) =+ 1.4,

m_V(Rigel) = 0.12, M(Rigel)=-7.0 distance= 860 light-years:

m_V(Vega) = 0.03 parallax = 0.129″,

The faintest stars visible with the naked eye ≈ +6.5.

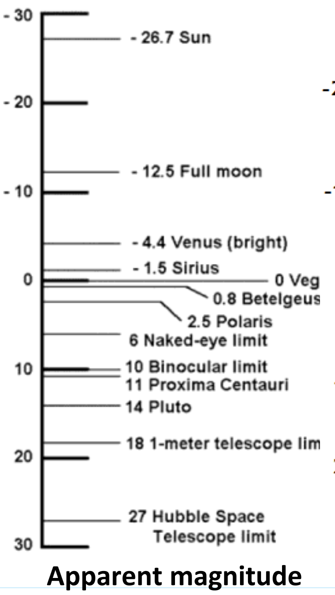
$-10 \le M$(star) $\le$ +17 M(Deneb) =-7.2, M(Naos)=-6.0, M(Betelgeuse)=-5.6

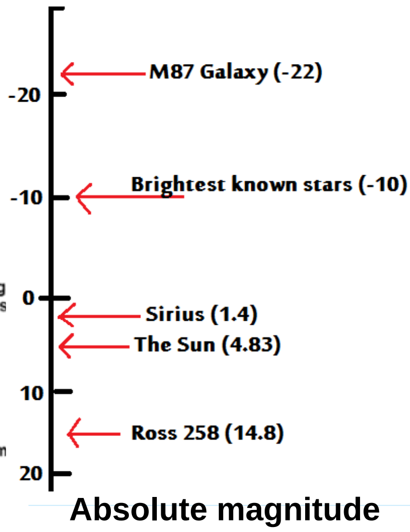
M_B (Milky Way) ≈ -20.8. M_V (M87, giant elliptical galaxy) =-22

M_V (CTA-102, AGN(quasar)) =-32, the most luminous objects

Apparent magnitude

Extinction rates within the Milky Way galaxy $\Delta m \approx 1 \sim 2$ /kpc





LIST OF BRIGHTEST STARS

Name	Bayer designation	Apparent magnitude	Distance (lys)	Spectral class
1. Sirius	Alpha Canis Majoris	-1.46	8.60	A1V+DA
2. Canopus	Alpha Carinae	-0.73	310	A9II
3. Rigil Kentaurus	Alpha Centauri	-0.29	4.37	G2V+K1V
4. Arcturus	Alpha Boötis	-0.05	36.7 ± 0.2	K0 III
5. Vega	Alpha Lyrae	0.03	25.04 ± 0.07	A0Va
6. Capella	Alpha Aurigae	0.07	42.92± 0.05	K0III+G1III
7. Rigel	Beta Orionis	0.15	860 ± 80	B8Ia
8. Procyon	Alpha Canis Minoris	0.36	11.46 ± 0.05	F5IV-V + DQZ
9. Achernar	Alpha Eridani	0.45	139 ± 3	B6 Vep
10. Betelgeuse	Alpha Orionis	0.55	700	M2Ib
11. Hadar	Beta Centauri	0.61	390 ± 20	B1III
12. Altair	Alpha Aquilae	0.77	16.73 ± 0.05	A7V
13. Acrux	Alpha Crucis	0.79	320 ± 20	B0.5IV+B1V
14. Aldebaran	Alpha Tauri	0.86	65.3 ± 1.0	K5III
15. Antares	Alpha Scorpii	0.95	550	M1Ib+B4V
16. Spica	Alpha Virginis	0.97	250 ± 10	B1V
17. Pollux	Beta Geminorum	1.14	33.78 ± 0.09	K0III
19. Deneb	Alpha Cygni	1.24	2,615 ± 215	A2Ia
46. Mirzam	Beta Canis Majoris	1.98	490 ± 20	B1II–III
48. Polaris	Alpha Ursae Minoris	1.99	323–433	F7Ib+F6V+F3V

출처: <https://www.star-facts.com/brightest-stars/>

List of nearest stars and brown dwarfs

78 objects within 5.0 pc

(9 visible to the naked eye)

----

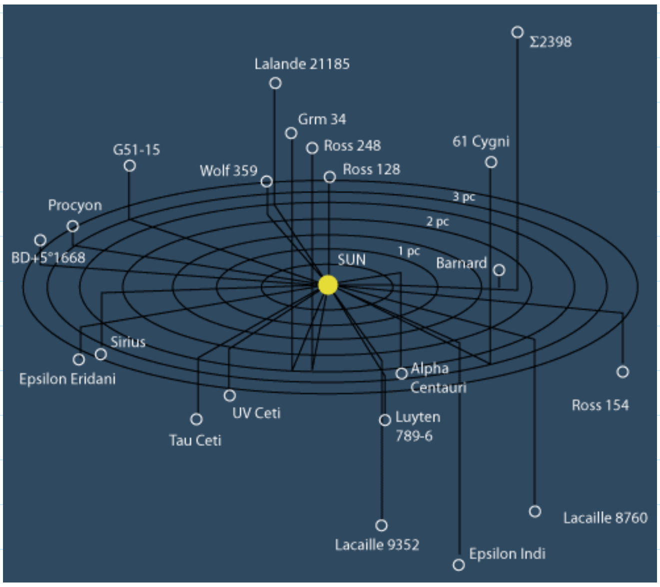
63 stars = 50 red dwarfs + 13 more massive

11 brown dwarfs (no H-fusion)

4 white dwarfs

All of these objects are currently moving in the Local Bubble, a region within the Orion–Cygnus Arm of the Milky Way.

출처: <https://en.wikipedia.org/wiki/List_of_nearest_stars_and_brown_dwarfs>



Common Name	**Scientific Name**	**거리 (ly)**	**Appar Mag**	**Absol Mag**	**Spec Type**
1. Sun		-	-26.72	4.8	G2V
2. α Centauri					
Proxima Centauri	V645 Cen	4.2	11.05 (var.)	15.5	M5.5Vc
Rigil Kentaurus	α Cen A	4.3	-0.01	4.4	G2V
	α Cen B	4.3	1.33	5.7	K1V
3. Barnard's Star		6.0	9.54	13.2	M3.8V
7. Sirius					
Sirius A	α CMa A	8.6	-1.46	1.4	A1Vm
Sirius B	α CMa B	8.6	8.3	11.2	DA
10.	ε Eri	10.8	3.73	6.1	K2Vc
12.	61 Cyg A	11.1	5.2var	7.6	K3.5Vc
	61 Cyg B	11.1	6.03	8.4	K4.7Vc
16. Procyon					
Procyon A	α CMi A	11.4	0.38	2.6	F5IV-V
Procyon B	α CMi B	11.4	10.7	13.0	DF

17. 61 Cygni star sys

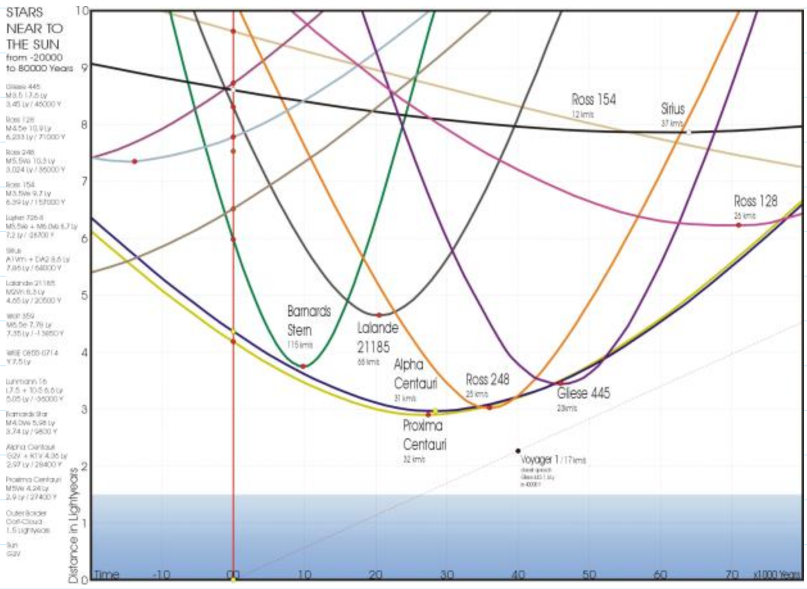
61 Cygni A – 11.4 ly

61 Cygni B – 11.4 ly

출처: <https://simple.wikipedia.org/wiki/List_of_nearest_stars>

Kruger 60 (BD+56°2783)	A	13	M3.0V[5]	mass 0.271	겉보기등급 9.79	절대등급11.76	Par mas 250	B flare star
	B (DO Cep)		M4.0V[5]	0.176	11.41	13.38		

출처: <https://en.wikipedia.org/wiki/List_of_nearest_stars_and_brown_dwarfs>

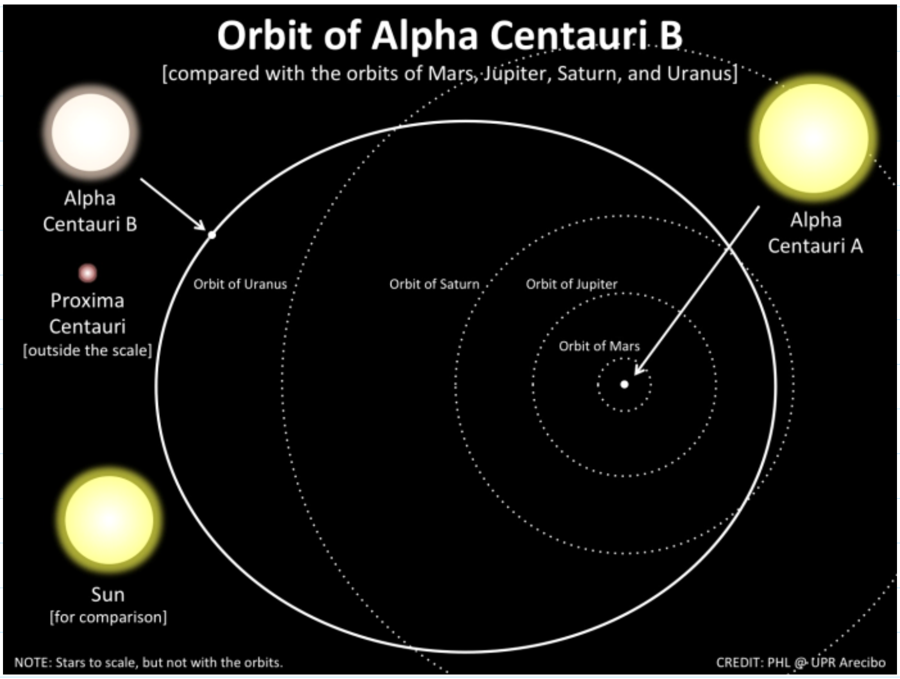


What can we learn from this information? Quite a lot.

- they are distributed more or less randomly.
- We live very close (500 lightseconds) to a star. This is probably a necessary condition for the originination and maintenance of life.
- Stars are very far apart (average about 8 lightyears for the closest dozen), compared to their size (about 2 lightseconds for the Sun); by a factor of 250 million or so.
- Many stars occur in multiple systems.
- Most of the nearby stars are dimmer than our Sun, by factors of 100 to 10,000.

출처: <http://www.astro.wisc.edu/~dolan/constellations/extra/nearest.html>

α Centauri – a triple star system



α Centauri A and
α Centauri B
is
a binary component

The two bright stars are (left) Alpha Centauri AB and (right) Beta Centauri. The faint red star in the center of the red circle is Proxima Centauri.

출처: <https://en.wikipedia.org/wiki/Centaurus#/media/File:Alpha,_Beta_and_Proxima_Centauri_(1).jpg>

Alpha Centauri (α Centauri, Alpha Cen or α Cen)

at 4.37 light-years (1.34 parsecs) from the Sun.

a triple star system of the 3 closest stars (& exoplanets)

- α Centauri A (officially **Rigil Kentaurus**),[15]
- α Centauri B (officially **Toliman**),[15]
- α Centauri C (officially Proxima Centauri, the closest star)

Alpha Centauri A and B

form the binary star Alpha Centauri AB

α Centauri A : 1.1× $M_\odot$ 1.519× $L_\odot$ G2V M_V =4.38, m_V =+0.01

α Centauri B : 0.9× $M_\odot$ 0.445× $L_\odot$ K1V M_V = 5.71 m_V =+1.33

To the naked eye, the two appear to be a single star with an apparent magnitude m_V =−0.27,
the brightest star in the southern constellation of Centaurus
and the third-brightest, outshone only by Sirius and Canopus.
The pair's orbital period is 79.91 years.
The distance between A and B in their elliptical orbit varies from 35.6 AU to 11.2 AU.

Alpha Centauri C, or Proxima Centauri,

a red dwarf (M5.5Ve; M_V =4.38, m_V =10.43 ~ 11.11)
the closest star at a distance of 4.24 light-years (1.30 pc), slightly closer than Alpha Centauri AB.
The distance between Proxima Centauri and α Centauri AB

≈ 13,000 AU (0.21 ly), ≈ 430 × the Neptune's orbit radius.

planets

Proxima Centauri has two planets:

Proxima b,

an Earth-sized exoplanet in the habitable zone

discovered in 2016;

Proxima c,

a super-Earth 1.5 AU away,

possibly surrounded by a huge ring system,

discovered in 2019.

Alpha Centauri A

may have a Neptune-sized habitable-zone planet,

not yet known to be planetary

could be an artifact of the discovery mechanism.

Alpha Centauri B

has no known planets:

planet Bb, purportedly discovered in 2012, was found to be an artifact

출처: <https://en.wikipedia.org/wiki/Alpha_Centauri> 출처: <https://en.wikipedia.org/wiki/Proxima_Centauri>

Astronomical Naming conventions

Stars *Main article: Stellar designation*

visible to the naked eye (an apparent magnitude of 6): ten thousand stars.
the number of stars named by ancient cultures.
With the telescope, far too many to all be given names.

There have been many historical star catalogues, and new star catalogues are set up on a regular basis as new sky surveys are performed.

All designations of objects in recent star catalogues
start with an "initialism", which is kept globally unique by the IAU.
Different star catalogues then have different naming conventions for what goes after the initialism,
but modern catalogs tend to follow a set of generic rules for the data formats used.

Proper names[edit]

See also: Stellar designation § Proper names, and List of proper names of stars

There are about 300 to 350 stars with traditional or historical proper names.
Most such names are derived from the Arabic language.
They tend to be the brightest stars and are often the most prominent ones of the constellation.
Examples : Betelgeuse, Rigel and Vega.

Stars may have multiple proper names, as many different cultures named them independently.
Example) Polaris has also been known by the names *Alruccabah*, *Angel Stern, Cynosura*,
the *Lodestar*, *Mismar*, *Navigatoria*, *Phoenice*, the *Pole Star*, the *Star of Arcady*, *Tramontana* and *Yilduz* at various times and places by different cultures in human history.

Named after people[edit]

There are about two dozen stars
Ex) Barnard's Star and Kapteyn's Star that have historic names and named in honor after astronomers.

- *Star catalogue*

With the telescope, far too many to all be given names.
Instead, they have designations assigned to them by a variety of different star catalogues.
Older catalogues either assigned an arbitrary number to each object,
or used a simple systematic naming scheme based on the constellation the star lies in.
The variety of sky catalogues now in use makes most bright stars have multiple designations.

- **1. Bayer designation**

The earliest naming system which is still popular
using the name of constellations to identify the stars within them.
about 1,500 brightest stars, first published in 1603.
a star is identified by a lower-case letter of the Greek alphabet, followed by the possessive(genitive) form(, which in almost every case ends in *is*, *i* or *ae*, *um* if plural) of the Latin name of its parent constellation(a 3-letter abbreviation often used. (in order of apparent brightness)

.
Examples
Alpha Andromedae (*α And*) in the constellation of Andromeda,
Alpha Centauri (*α Cen*), in the constellation Centaurus,
Alpha Crucis (*α Cru*) and Beta Crucis (*β Cru*), the two brightest stars in the constellation Crux, the Southern Cross,
Epsilon Carinae (*ε Car*) in Carina, Lambda Scorpii (*λ Sco*) in Scorpius
and Sigma Sagittarii (*σ Sgr*) in Sagittarius.

After all twenty-four Greek letters have been assigned, upper and lower case Latin letters are used,
such as for A Centauri (*A Cen*), D Centauri (*D Cen*), G Scorpii (*G Sco*), P Cygni (*P Cyg*),
b Sagittarii (*b Sgr*), d Centauri (*d Cen*) and s Carinae (*s Car*).

numeric superscripts were added to distinguish those previously unresolved stars.
Examples
Theta Sagittarii (*θ Sgr*) later distinguished as
Theta^1 Sagittarii (*θ^1 Sgr*) and Theta^2 Sagittarii (*θ^2 Sgr*), each being their own (physical) star system with two and three stars, respectively.

- **2. Flamsteed designation** (the numbers now in use appeared in 1783)

Flamsteed designations consist of a number (in order of increasing right ascension) and the Latin genitive of the constellation the star lies in.
Were assigned to 2554 stars.
Flamsteed's catalogue covered only the stars visible from Great Britain,
and therefore stars of the far southern constellations have no Flamsteed numbers.

They are commonly used when no Bayer designation exists
Examples) 51 Pegasi and 61 Cygni.
or when the Bayer designation uses numeric superscripts
Ex) Instead of Rho^1 Cancri, the simpler Flamsteed designation, 55 Cancri, is often preferred.
출처: <https://en.wikipedia.org/wiki/Flamsteed_designation#List_of_constellations_using_Flamsteed_star_designations>
출처: <https://en.wikipedia.org/wiki/Flamsteed_designation#List_of_constellations_using_Flamsteed_star_designations>

- **3. Modern catalogues**

Most modern catalogues are generated by computers, using high-resolution, high-sensitivity telescopes, and as a result describe very large numbers of objects.

Example) the Guide Star Catalog II has entries on over 998 million distinct astronomical objects.
assign designations to these objects based on their position in the sky.

Example) *SDSSp J153259.96−003944.1*,
SDSSp : from the "Sloan Digital Sky Survey preliminary objects",
the other characters : celestial coordinates
(epoch 'J', right ascension 15^{h}32^{m}59.96^s, declination −00°39′44.1″).

HD/HDE[edit]

Main article: Henry Draper Catalogue

- The Henry Draper Catalogue was published in the period 1918–1924.
- It covers the whole sky down to about ninth or tenth magnitude, and is notable as the first large-scale attempt to catalogue spectral types of stars.

- The catalogue was named in honour of Henry Draper, whose widow donated the money required to finance it.
- HD numbers are widely used today for stars which have no Bayer or Flamsteed designation.
- Stars numbered 1–225300 are from the original catalogue and are numbered in order of right ascension for the 1900.0 epoch.
- Stars in the range 225301–359083 are from the 1949 extension of the catalogue.
  The notation HDE can be used for stars in this extension, but they are usually denoted HD as the numbering ensures that there can be no ambiguity.

출처: <https://en.wikipedia.org/wiki/Star_catalogue>

Nomenclature for Variable star 출처: <https://en.wikipedia.org/wiki/Variable_star>

Main article: Variable star designation

The current naming system is:[1]

출처: <https://en.wikipedia.org/wiki/Variable_star_designation>

- Stars with existing Greek letter Bayer designations are not given new designations.
- In a given constellation, the first variable stars discovered were designated with letters R through Z, e.g. R Andromedae. R xxx, ..., Z xxx (# 9)
- This system of nomenclature was developed by Friedrich W. Argelander, who gave the first previously unnamed variable in a constellation the letter R, the first letter not used by Bayer.
- Letters RR through RZ, SS through SZ, up to ZZ are used for the next discoveries, e.g. RR Lyrae.
  RRxxx, RSxxx,..., RYxxx, RZ xxx (# 9)
  SSxxx,..., SYxxx, SZ xxx (# 8)
  ...
  ZZ xxx (# 1)
  (9+(9+8+... +1)=54)
- Later discoveries, Use AA...AZ, BB...BZ, CC...CZ and up to QQ...QZ, omitting J in both the 1st and 2nd positions.[2]
  AAxxx, ABxxx, ...AIxxx, AKxxx, AIxxx, ... ,AQxxx, ARxxx, ... AYxxx, AZ xxx (# 26-1=25)
  BBxxx,..., BIxxx, BKxxx, BLxxx, ... ,BQxxx, BRxxx, ... BYxxx, BZ xxx (# 23)
  ....
  IIxxx, IKxxx, ILxxx,..., IQxxx, IRxxx, ... IYxxx, IZxxx
  KKxxx, KLxxx, ...,KQxxx, KRxxx, ... KYxxx, KZxxx
  ....
  QQxxx, QRxxx, ... QYxxx, QZxxx (# 10)
  (25+24+...+10+9+8+...+1)+9= 325+9=334)
  The second letter is never nearer the beginning of the alphabet than the first, e.g., no star can be BA, CA, CB, DA and so on.
- Once those 334 combinations are exhausted, abandon the Latin script, and start naming stars with V335, V336, and so on in order of discovery.

Catalogues for various objects

1) NGC, IC I, IC II (NGC xxxx)

2) Messier Catalogue (M1 ~M110)

The ***New General Catalogue of Nebulae and Clusters of Stars*** (abbreviated **NGC**)

- is an astronomical catalogue of deep-sky objects compiled by John Louis Emil Dreyer in 1888 using observations from William Herschel and his son John, among others. The NGC contains 7,840 objects, including galaxies, star clusters, emission nebulae and absorption nebulae.
- The first major update to the NGC is the ***Index Catalogue*** *of Nebulae and Clusters of Stars* (abbreviated as *IC*), published in two parts by Dreyer in 1895 (IC I, containing 1,520 objects) and 1908 (IC II, containing 3,866 objects).
  It serves as a supplement to the NGC, containing an additional 5,386 objects, collectively known as the IC objects. It summarizes the discoveries of galaxies, clusters and nebulae between 1888 and 1907, most of them made possible by photography.
- Thousands of these objects are best known by their NGC or IC numbers, which remain in widespread use.
- The NGC expanded and consolidated the cataloguing work of William and Caroline Herschel, and John Herschel's *General Catalogue of Nebulae and Clusters of Stars*. Objects south of the celestial equator are catalogued somewhat less thoroughly, but many were included based on observation by John Herschel or James Dunlop.
- A *Revised New General Catalogue and Index Catalogue* (abbreviated as RNGC/IC) was compiled in 2009 by Wolfgang Steinicke and updated in 2019 with 13,957 objects.[1]

출처: <https://en.wikipedia.org/wiki/New_General_Catalogue>

The **Messier objects**

- are a set of 110 astronomical objects catalogued by the French astronomer Charles Messier in his *Catalogue des Nébuleuses et des Amas d'Étoiles* (*Catalogue of Nebulae and Star Clusters*). Because Messier was only interested in finding comets, he created a list of those non-comet objects that frustrated his hunt for them. The compilation of this list, in collaboration with his assistant Pierre Méchain, is known as *the Messier catalogue*. This catalogue of objects is one of the most famous lists of astronomical objects, and many Messier objects are still referenced by their Messier number.
- The catalogue includes most of the astronomical deep-sky objects that can easily be observed from Earth's Northern Hemisphere; many Messier objects are popular targets for amateur astronomers.
- A preliminary version first appeared in 1774 in the *Memoirs* of the French Academy of Sciences for the year 1771.[3][4][5] The first version of Messier's catalogue contained 45 objects which were not yet numbered. Eighteen of the objects were discovered by Messier, the rest being previously observed by other astronomers.[6] By 1780 the catalogue had increased to 70 objects.[7] The final version of the catalogue containing 103 objects was published in 1781 in the *Connaissance des Temps* for the year 1784.[8][4] However, due to what was thought for a long time to be the incorrect addition of Messier 102, the total number remained 102. Other astronomers, using side notes in Messier's texts, eventually filled out the list up to 110 objects.
- The catalogue consists of a diverse range of astronomical objects, from star clusters and nebulae to galaxies. For example, Messier 1 is a supernova remnant, known as the Crab Nebula, and the great spiral Andromeda Galaxy is M 31. Further inclusions followed, the first addition came from Nicolas Camille Flammarion in 1921, who added Messier 104 after finding Messier's side note in his 1781 edition exemplar of the catalogue. M 105 to M 107 were added by Helen Sawyer Hogg in 1947, M 108 and M 109 by Owen Gingerich in 1960, and M 110 by Kenneth Glyn Jones in 1967.[10]

- The first edition of 1774 covered 45 objects (M1 to M45). The total list published by Messier in

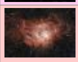
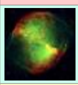
1781 contained 103 objects, but the list was expanded through successive additions by other astronomers, motivated by notes in Messier's and Méchain's texts indicating that at least one of them knew of the additional objects. The first such addition came from Nicolas Camille Flammarion in 1921, who added Messier 104 after finding a note Messier made in a copy of the 1781 edition of the catalogue. M 105 to M 107 were added by Helen Sawyer Hogg in 1947, M 108 and M 109 by Owen Gingerich in 1960, and M 110 by Kenneth Glyn Jones in 1967.[11] M 102 was observed by Méchain, who communicated his notes to Messier. Méchain later concluded that this object was simply a re-observation of M 101, though some sources suggest that the object Méchain observed was the galaxy NGC 5866 and identify that as M 102.

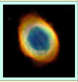
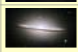
- Messier's final catalogue was included in the *Connaissance des Temps pour l'Année 1784* [*Knowledge of the Times for the Year 1784*], the French official yearly publication of astronomical ephemerides.
- Messier lived and did his astronomical work at the Hôtel de Cluny (now the Musée national du Moyen Âge), in Paris, France. The list he compiled contains only objects found in the sky area he could observe: from the north celestial pole to a celestial latitude of about $-35.7°$. He did not observe or list objects visible only from farther south, such as the Large and Small Magellanic Clouds.[13]

Observations

- The Messier catalogue comprises nearly all the most spectacular examples of the five types of deep-sky object – diffuse nebulae, planetary nebulae, open clusters, globular clusters, and galaxies – visible from European latitudes. Furthermore, almost all of the Messier objects are among the closest to Earth in their respective classes, which makes them heavily studied with professional class instruments that today can resolve very small and visually spectacular details in them. A summary of the astrophysics of each Messier object can be found in the *Concise Catalog of Deep-sky Objects*.
- Since these objects could be observed visually with the relatively small-aperture refracting telescope (approximately 100 mm ≈ 4 inches) used by Messier to study the sky, they are among the brightest and thus most attractive astronomical objects (popularly called deep-sky objects) observable from Earth, and are popular targets for visual study and astrophotography available to modern amateur astronomers using larger aperture equipment. In early spring, astronomers sometimes gather for "Messier marathons", when all of the objects can be viewed over a single night.[15][16]

출처: <https://en.wikipedia.org/wiki/Messier_object>

Messier number	NGC/IC number	Common name	Picture	Object type	거리 (kly)	Constellation	App mag	Right ascension	Declination
M1[17]	NGC 1952	*Crab Nebula*		Supernova remnant	4.9–8.1	Taurus	8.4	05^h 34^m 31.94^s	+22° 00′ 52.2″
M8[24]	NGC 6523	*Lagoon Nebula*		Nebula with cluster	4.1	Sagittarius	6.0	18^h 03^m 37^s	−24° 23′ 12″
M27[43]	NGC 6853	*Dumbbell Nebula*		Planetary nebula	1.148–1.52	Vulpecula	7.5	19^h 59^m 36.340^s	+22° 43′ 16.09″
M31[47]	NGC 224	*Andromeda Galaxy*		Spiral galaxy	2,430–2,650	Andromeda	3.4	00^h 42^m 44.3^s	+41° 16′ 9″
M32[48]	NGC 221	*Small Andromeda Galaxy*		Dwarf elliptical galaxy	2,410–2,570	Andromeda	8.1	00^h 42^m 41.8^s	+40° 51′ 55″
M33[49]	NGC 598	*Triangulum/Pinwheel Galaxy*		Spiral galaxy	2,380–3,070	Triangulum	5.7	01^h 33^m 50.02^s	+30° 39′ 36.7″

M42[58]	NGC 1976	*Orion Nebula*		H II region nebula	1.324–1.364	Orion	4.0	05ʰ 35ᵐ 17.3	−05° 23′ 28″
M45[61]	–	*Pleiades*		Open cluster	0.39–0.46	Taurus	1.6	03ʰ 47ᵐ 24ˢ	+24° 07′ 00″
M51[67]	NGC5194, NGC 5195	*Whirlpool Galaxy*		Spiral galaxy	19,000 –27,000	Canes Venatici	8.4	13ʰ 29ᵐ 52.7ˢ	+47° 11′ 43″
M57[73]	NGC 6720	*Ring Nebula*		Planetary nebula	1.6–3.8	Lyra	8.8	18ʰ 53ᵐ 35.079ˢ	+33° 01′ 45.03″
M81[98]	NGC 3031	*Bode's Galaxy*		Spiral galaxy	11,400 –12,200	Ursa Major	6.9	09ʰ 55ᵐ 33.2ˢ	+69° 3′ 55″
M87	NGC 4486	*Virgo A*		Elliptical galaxy	51,870 –55,130	Virgo	9.6	12ʰ 30ᵐ 49.423 38ˢ	+12° 23′ 28.0439″
M101	NGC 5457	*Pinwheel Galaxy*		Spiral galaxy	19,100 –22,400	Ursa Major	7.9	14ʰ 03ᵐ 12.6ˢ	+54° 20′ 57″
M102	NGC 5866	*Spindle Galaxy*		Lenticular galaxy	50,000	Draco	10.7	15ʰ 06ᵐ 29.5ˢ	+55° 45′ 48″
M104	NGC 4594	*Sombrero Galaxy*		Spiral galaxy	28,700 –30,900	Virgo	9.0	12ʰ 39ᵐ 59.4ˢ	−11° 37′ 23″
M109	NGC 3992	–		Barred Spiral galaxy	59,500 –107,500	Ursa Major	10.6	11ʰ 57ᵐ 36.0ˢ	+53° 22′ 28″
M110	NGC 205	–		Dwarf elliptical galaxy	2,600–2,780	Andromeda	9.0	00ʰ 40ᵐ 22.1ˢ	+41° 41′ 07″

출처: <https://en.wikipedia.org/wiki/Messier_object>

Names for X-ray sources

X-ray sources get their names from the constellations, from famous catalogs, from the satellites that discovered them and their coordinates in Right Ascension and Declination (like longitude and latitude), other coordinate systems and the year they were discovered, just to name a few.

In the early days of X-ray astronomy, new objects were named after the constellation they were in. Objects like Cygnus X-1, LMC X-4, and Cen X-3 have this form.

After it became obvious that there were going to be more than 20 or 30 X-ray sources, this naming convention was abandoned.

Unfortunately, a single convention has never been agreed upon. Following are some examples of X-ray source names and where they came from.

Sco X-1 The first cosmic X-ray source ever discovered (after the Sun). It's in the constellation Scorpius. Each new X-ray source in a constellation gets an X-#. There is a Cygnus X-1, Cygnus X-2, and a Cygnus X-3. The Large Magellanic Cloud also has several sources with names of this form, they're called LMC X-1, LMC X-2, LMC X-3, and LMC X-4.

U Gem This is another source that's named after its constellation. Usually, names of this form use a letter of the alphabet to order the stars in a constellation by optical brightness. However, this only applies to stars up through the letter Q. Names of this form that start after Q are *variable stars*. U Gem is a Cataclysmic Variable in the constellation Gemini.

Many of the X-ray sources have names that come from a combination of a catalog abbreviation and the Right Ascension (RA) and Declination (Dec) of the object.
Those funny things that look like backward phone numbers (0748-676) really list the location of the object. The above example source is at an RA of 07 hours, 48 minutes and a Dec of -67.6 degrees.

Here are some other examples of this form of naming X-ray sources:

4U 0115+63 4th Uhuru catalog - one of the earliest X-ray satellites
3S 1820-30 SAS-3 discovery - another early X-ray satellite
EXO 0748-676 EXOSAT discovery

PKS 2155-304	Parkes catalog
H 2252-035	HEAO-1 A2 satellite survey
A 1916-05	Ariel catalog
2A 1822-371	2nd Ariel catalog
GS 2000+25	Ginga satellite discovery
G 21.5-0.9	Lowell Proper Motion Surveys of optical stars
MSH 15-52	Mills, Slee & Hill (1958) catalog of radio sources
PSR 1855-09	PSR=Pulsar (normally radio pulsars)
X 1608-52	X-ray source (general)
GX 301-2	This name describes the Galactic coordinates of this X-ray source. In this coordinate system, the center of our Galaxy is defined as 0,0. To find this source, you would go 301 degrees around the plane of the Galaxy (as seen from Earth) and then 2 degrees below the plane. If the source was called GX 4+1, you would go 4 degrees around the plane and 1 degree above the plane. GX 4+1 is very close to the center of our Galaxy (as seen from Earth).

Many objects get their names from a reference number in a catalog. Although these catalogs are often ordered by RA and Dec, one can't tell from the reference number where the object is in the sky. Some objects of this form are:

HD 93162	Henry Draper Catalog (1919-1925)
SS 433	The Stephenson & Sanduleak catalog
M 15	Messier catalog of non-stellar objects
NGC 6624	New General Catalog of Nebulae and Clusters of Stars (published 1888 by Dreyer)
IC 443	Index Catalogue (published 1895 by Dreyer)
Mrk 297	Appears in B. E. Markarian's ultraviolet catalog of galaxies. Sometimes listed as Mkn instead of Mrk.
Abell 2256	George Abell's catalog of clusters of galaxies
3C 273	The 3rd Cambridge catalogue
CTB 109	Cal Tech radio observation reports (catalog B)
AC 211	Auriere and Cordoni catalog of stars in M15
W 44	Westerhout (1958) catalog of radio sources
HZ 43	Humason & Zwicky (1946)
RCW 103	Rodgers, Campbell & Whiteoak catalog of HII regions (1960)
MCG 6-30-15	Morphological Catalogue of Galaxies (a compilation of information for approximately 34,000 galaxies found and examined on the Palomar Observatory Sky Survey (POSS)). The numbers correspond to the zone of the POSS.
I Zw 18	First Zwicky Catalogue of Clusters of Galaxies. The Zwicky clusters were identified by F. Zwicky in 560 POSS fields. They are rich clusters, each having at least 50 members within 3 magnitudes of the brightest member. There are II Zw and III Zw sources, as well.
SN 1987a	This is an object that was in the news in 1987. The SN means that it is a supernova. 1987 is the year it appeared and the letter "a" denotes that that it was the first supernova found in that year. Can you guess which supernova of 1993 was named SN 1993j? Did you know the Chinese have records of the supernova, SN 1006? When there are more supernovae than letters of the alphabet, they add a letter: SN 1995aa, SN 1995ab, *etc*. The last supernova discovered in 1995 was given the name SN 1995bd!
Tycho	Another supernova (observed by Tycho Brahe in 1572). Can you guess who discovered the Kepler supernova?

출처: <https://imagine.gsfc.nasa.gov/science/toolbox/xray_names.html>