Distances in the Universe

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Syllabus:

1. The rules and units
2. Distances in the Solar system
3. Stars and Galaxy
4. Beyond our Galaxy

Cosmic rules and units

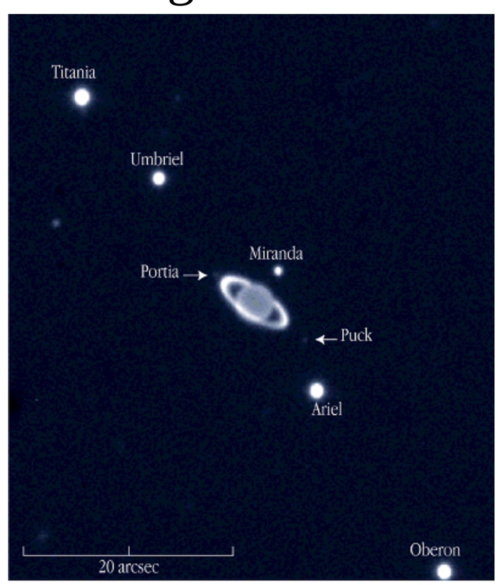
kilometer: too small unit to use it in astronomy

Astronomical unit (AU): The mean distance of the Earth from the Sun (original definition)
1 AU = 149 597 870 km = 499.005 light seconds

Light year (ly): The distance crossed by the light during one year. Light speed c = 299 792 km/s $\Rightarrow$
1 ly = 63 240 AU = 9.450 . 10^{12} km

Parsec: (parallax + second)
Parallax: distance indicator. Annual parallax of a star - the angle, under which we could see the the Earth orbit from the star.
Parsec: the distance, from which the big axis of the Earth orbit can be seen under the angle of 1 arcsec.

Giant Planet Saturn (H+K-band composite)
(VLT YEPUN + NAOS-CONICA)
ESO PR Photo 04a/02 (31 January 2002) © European Southern Observatory



Uranus with Rings and Moons
(VLT ANTU + ISAAC)
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The solar system

How to measure the distances?

Today: radar and laser measurements with very high accuracy

Historically: using trigonometric relations, however, we need to know one (as long as possible) distance in the triangle - (AU determined from the Venus transit!), the third Kepler law.

Distances:

Earth - Moon	380 400 km	0.003 AU
- -		
Sun - Mercury		0.383 AU
Sun - Venus		0.723 AU
Sun - Earth		1.000 AU
Sun - Mars		1.524 AU
Sun - Jupiter		5.200 AU
Sun - Saturn		9.539 AU
Sun - Uranus		19.18 AU
Sun - Pluto		39.2 AU
Oort's comet cloud		3 000 - 135 000 AU

Stars and Galaxy

- **How to measure the distances?**

  1. (annual) parallaxes: thanks to the Hubble telescope and Hipparcos, we know trigonometric parallaxes of stars up to $\approx$1000 ly
  2. from the brightness and luminosity (derived from the H-R diagram)
  3. from periodic variations of pulsating stars, e.g. Cepheids. There exist an accurate relation between their luminosity and period - the slower is the pulsation, the higher is the luminosity.
  4. from the maximum brightness of supernovae - for the given type of supernovae the maximum brightness during the outburst is almost constant.

- **Closest stars:** a few light years
- **Diameter of the Milky Way:**
  Huge flattened disk containing $\approx$ 150 milliards of stars:

large semi-axis of the disk	50 000 ly
halo radius	100 000 ly
distance to the Galaxy center	30 000 ly

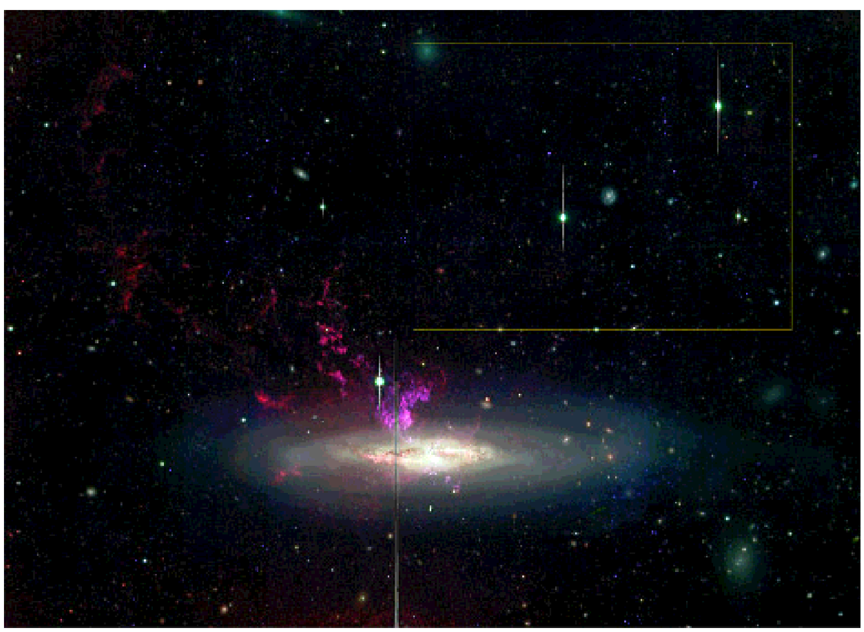
Extragalactic distances

- **How to measure the distances?**

1. Cepheids - permit to measure distances up to 100 000 000 ly - first used by Hubble to derive the distance of the Andromeda galaxy (M31 - the most distant object seen with a naked eye) and many other galaxies.

2. so called redshift - the spectral lines are more shifted for more distant galaxies (Hubble law).
   A galaxy at a distance of 1 000 000 ly has velocity 20 km/s (the value of the Hubble constant)
   Virgo cluster (60 000 000 ly) - velocity 1200 km/s

3. Supernovae - (of type Ia) up to milliard of light years



Spiral Galaxy NGC 4388 in Virgo Cluster
(Subaru + Suprime-Cam)

ESO PR Photo 04c/05 (16 January 2005)

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Let's travel with light through the Universe

Earth	0.00
Moon	1.2 s
Sun	8 minutes 20 seconds
Pluto	6.5 hours
Proxima Centauri	4.3 years
Sirius	8.6 years
Polaris	432 years
Galaxy center	30 000 years
M 31 (Andromeda galaxy)	2 400 000 years
Virgo cluster of galaxies	60 000 000 years
2C273 quasar	2 500 000 000 years

Learning more about distances in the universe and its structure the people may get more respect to the nature and a bird's eye view of their "big" daily problems.