Equipped with his five senses, man explores the universe around him and calls the adventure Science.

Before the invention of the telescope, the only information that astronomers could obtain about the stars and planets was their position in the sky. This relied on instruments that typically measured its position in the sky with respect to the horizon at a particular time (azimuth and altitude), or its position with respect to the “fixed stars” (declination or right ascension).
Time Line (1450 – 1750 AD)

- Leonardo da Vinci (1450)
- William Shakespeare (1450–1500)
- Tycho Brahe (1500–1550)
- Johannes Kepler (1550–1600)
- Galileo Galilei (1600–1650)
- Christiaan Huygens (1650–1700)
- Issac Newton (1700–1750)
- Edmund Halley (1750)
- Giordano Bruno (1450–1500)
- Gian Domenico Cassini (1500–1750)

1607 Virginia founded by the English
1608 Quebec founded by the French
1608 Invention of the Telescope
1612 New Amsterdam (New York) founded by the Dutch
Lenses and the telescope were invented by craftsmen, so the history is not clear. By the 1450s, both convex and concave lenses were being made for eyeglasses.

The telescope was first presented in the Netherlands in October of 1608. The Hague reviewed two patents by Hans Lipperhey of Middelburg, and then of Jacob Metius of Alkmaar, for a instrument for "seeing faraway things as though nearby." The instrument used a convex and a concave lens in a tube and magnified the scene 3 to 4 times. No patent was awarded since the construction was simple. But both Lipperhey and Metius made a good bit of money.

http://galileo.rice.edu/sci/instruments/telescope.html
Galileo and the Telescope

By April of 1609, you could buy simple telescopes in Paris.

By June or July, Galileo had heard about the telescope and made his own. By August he had an 8 power telescope.

He heard that a Dutchman was coming down to Venice to sell telescopes to the Venetian Navy. Galileo was not about to be outdone. Galileo arrived before the Dutchman with his 8 power telescope and gave a demonstration to the Venetian Senate. They then placed an order with Galileo.

By late fall, Galileo had perfected a 20 power telescope, which he used to look at the sky.

And what he found changed the world.

http://www.imss.fi.it/
Light

Light has properties of both a particle and a wave. We begin by looking at its wave properties.

Light is an electromagnetic wave

In a vacuum, light travels at a constant speed of:

\[ c = 186,000 \text{ mi/sec} = 3 \times 10^8 \text{ m/sec} \]
Light as a Wave

Properties of a Wave

Amplitude $A$

One Cycle

Wavelength $\lambda$

Frequency $f$ is the number of cycles passing a point per second

Relations: $c = \lambda f$
The Electromagnetic Spectrum

Increasing Frequency
Decreasing Wavelength
Increasing Energy
Light Slows Down in Matter

The frequency stays the same, but the speed slows down. This means that the wavelength has to decrease.

\[ \lambda = \frac{c}{f} \]
Refraction

This also causes the path of a light wave to bend.

This effect is called refraction.
You can better understand how this works by following the rays, which point in the direction the light wave is traveling.

\[ \lambda = \frac{c}{f} \]
You can better understand how this works by following the rays, which point in the direction the light wave is traveling.
Convex (Converging) Lens
Convex (Converging) Lens
Convex (Converging) Lens

Focal Point
Images of a Convex (Converging) Lens
Concave (Diverging) Lens
Concave (Diverging) Lens
Concave (Diverging) Lens
Concave (Diverging) Lens
Telescope

focal point

focal point
First Fifty Years of Telescopes

Please visit The Institute and Museum of the History of Science

Court Scientists

Optical axis

Set of lenses

The telescope with a single divergent lens in the eyepiece was used by Galileo Galilei (1564-1642) from 1609, and empirically perfected by him.
Reflecting Telescopes

A Newtonian Reflecting Telescope relies on curved mirrors to magnify the images.
The Cassegrain design relies on having the light travel through a hole in the primary mirror.
Power and Light Gathering Ability

The two most important characteristics of a telescope are the power and the light gathering ability.

**Power**: Magnification

**Light Gathering Ability**: How much light is collected by the telescope and concentrated onto the eye. This depends on the area of the aperture (or the objective lens in a refractor).
Kitt Peak National Observatory

University of Arizona’s Steward Observatory 90 inch telescope
KPNO’s Mayall 4 meter telescope

Source: NOAO/AURA
Gemini North 8 Meter Optical / Infrared

Gemini North 8 meter telescope
Mauna Kea Hawaii

Source: NOAO/AURA
Gemini North 8 Meter Optical / Infrared

Gemini North interior with open wind vents and observing slit at sunset

Source: NOAO/AURA
Hubble Space Telescope
Spitzer Space Telescope

New infrared observatory
Light as a Particle

Atoms emit light.

The electron orbits the nucleus on a set of discrete orbits.

The atom prefers to be in the ground state, which is the lowest energy state.
An atom can absorb energy by having its electron knocked into a higher orbit.
Falling Back to the Ground State

When the electron falls back to the ground state, it emits a photon.

A photon is a light particle.
Falling Back to the Ground State

The frequency of the photon emitted depends on the energy it loses by falling to a lower energy state.

$$E = hf$$

Where $h$ is Planck’s constant.
Atomic Spectral Lines

Atoms of different elements have distinct sets of orbits. This means that an atom can only emit photons at certain frequencies. These frequencies act like fingerprints allowing us to identify elements.

http://www.daviddarling.info/encyclopedia/H/hydrogen_spectrum.html
Emission Spectrum of Hydrogen

When a gas is excited, it emits an emission spectrum.
Absorption Spectrum of Hydrogen

When light passes through a gas, the gas absorbs the light at certain frequencies. The result is called an absorption spectrum.

Emission and Absorption Spectra

Wavelength in nanometers
Blackbody Radiation

A Blackbody is a theoretical object that absorbs and emits all frequencies of light equally. It reflects no light (which is why it is called a blackbody).

Many real objects are close to being an ideal blackbody.

The hotter the object, the higher the peak frequency of the emitted light.

http://homepages.paradise.net.nz/nickamy/
Blackbody Applet

Click to try: http://webphysics.davidson.edu/alumni/MiLee/java/bb_mjl.htm
Infrared Radiation and Heat

The trash bag is transparent to infrared radiation.
So are you! (to a large degree)

Notice that his glasses are not transparent to infrared radiation.
This is why glass traps heat in a greenhouse (or a car).
All Together Now…

Hot Continuous Light Source

Cool Cloud of Gas

Continuous Blackbody Spectrum

Emission Spectrum

Absorption Spectrum
Molecular Spectra

Vibrations in molecules can give their energy to photons. Different molecules have different vibrations. The energies are usually in the infrared range.

These spectra enable us to identify molecules.
Doppler Shift

If a light source moves toward you, its frequency increases and wavelength decreases (Blue Shift).

If a light source moves away from you, its frequency decreases and its wavelength increases (Red Shift)
Red Shift

Since spectra act as fingerprints, we can use the shift in wavelength as a measure of our relative velocity with respect to an object. Here we see the spectra for an object moving away from us… it is red shifted.
See how Betelgeuse is orange? It is a relatively cool star. Whereas Rigel is bluish. It is very hot!