Possible sources of information about the Universe

(1) In situ (on site) measurements and samples (e.g. Moon rocks). This is possible only for the Solar System.

(2) Meteorites, and interplanetary or sometimes interstellar dust (collected by high-flying airplanes).

(3) Cosmic rays: About as much energy as is in starlight is delivered to Earth by cosmic rays, or high-energy subatomic particles. Above Earth's atmosphere, these are mostly electrons and protons. Near sea level, reactions with the nuclei in air molecules turn them into mostly muons and alpha particles (or helium nuclei). Cosmic rays have yielded interesting information, for example that the Universe is probably mostly made of matter and not half matter/half antimatter, since cosmic rays are almost all matter. The information content of cosmic rays is limited, however, since their directions get randomized in the magnetic field of the Galaxy.

(4) Other particle radiation from the Sun, called "The Solar Wind," although the really energetic ones are called "Solar cosmic rays." These can be trapped by Earth's magnetic field (also called the Van Allen belts). As with cosmic rays, these include protons, electrons, and alpha particles.

(5) Neutrinos: these are nearly massless, neutral particles that are the direct products of nuclear reactions. They have been detected from the Sun and from Supernova 1987A. They're difficult to observe, requiring giant detectors.

(6) Gravitational waves: since 2015, the LIGO project has been detecting gravitational waves from merging black holes and merging neutron stars.

(7) Tachyons: these hypothetical faster-than-light particles may or may not exist. Many physicists are skeptical that they can exist, since they might have very strange properties, such as traveling backwards in time, and having imaginary rest masses. (What does either mean, anyway?)

(8) LIGHT, including radio waves, X-rays, etc. Since "light" is often taken to mean "visible light," when talking about light at all wavelengths, both visible and invisible, we often use the term "electromagnetic radiation."

The electromagnetic spectrum

Visible and invisible light are electromagnetic radiation, or the e/m spectrum.
Visible light, which human eyes can see, makes up only a tiny portion of the possible kinds of e/m radiation, the difference between which is their wavelength (and energies):

Region of the spectrum	Effect of Earth's atmosphere	Wavelength (λ)	Photon Energy (eV)	Typical Objects and Temperatures
Gamma rays	Absorbed by ozone	$< 10^{-13}$ m	$> 10^6$	T = 10^9 K: from nuclear reactions
X-rays	Absorbed by ozone	10^{-10} m = 1 Ångström	1000	10^6 – 10^7 K: near black holes, and from inner-electron transitions.
Ultraviolet radiation	Absorbed by ozone	0.01 – 0.4 microns		10^4 – 10^5 K: from the hottest stars
Visible light		0.4-0.78 microns	1	T = 5800 K: from the Sun, and from outer-electron transitions.
Infrared Radiation	Absorbed by water vapor	0.78-100 microns		T = 310 K: human bodies, planets, molecular transitions.
Microwaves		millimeters	10^{-3}	T = 2.7K: Cosmic background
Radio waves		centimeters & longer	Low	From cold gas between the stars, and from non-thermal processes.

Wavelength units: 1 Å = 1 Ångström = 10^{-8} cm = 10^{-10} m = 10^{-4} microns = 10 nm.

Photon energies: Recall that, for each photon,

$E = hf = hc/\lambda$ where λ = wavelength of light,
f = frequency of light,
c = the speed of light (and of course, $\lambda f = c$),
and h = Planck's constant.

For visible light photons, E ≈ 1 eV = 1 electron volt = 1.602×10^{-19} Joules = 1.602×10^{-12} ergs.

1 keV = 10^3 eV (Soft X-rays are 0.1-1 keV. Hard X-rays are 1-100 keV.)
1 MeV = 10^6 eV (soft gamma rays)
1 GeV = 10^9 eV (hard gamma rays)

Very High Energy (VHE) gamma rays have E ≈ 10 TeV = 10^{13} eV.
The highest-energy cosmic rays known have E = 10^{20} eV. (!)

Thermal radiation (also called blackbody radiation): opaque objects (that aren't transparent to light) radiate a distinctive spectrum, with its maximum energy at the wavelength $\lambda(\max) = 2.9\times10^{-3}$ m · K / T(K).

This isn't the only way objects can make light, though. **Line radiation** can come from inner electron transitions in atoms (which make X-rays), or outer electron transitions (which make visible light).

Ultraviolet (UV), X-rays, most gamma rays, and most infrared (IR) radiation are absorbed by Earth's atmosphere, so spacecraft are needed to observe them. Spacecraft are expensive, though: much worthwhile observing, especially in the optical, near-IR, and radio, can be done from ground-based telescopes.