# Instrument Scientist

## Instrument selection

The instruments on board a satellite will dictate the type of science that can be carried out by the telescope. Different wavelengths will observe different objects in the universe, as shown in the table below. The light from objects in the distant Universe is stretched by a phenomenon called redshift. This means that a given wavelength is sensitive to different objects in the nearby and distant Universe.

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| --- | --- | --- | --- |
| Type | Wavelength | Our Galaxy and nearby galaxies | Distant Universe |
| Sub-mm | 300–1000 m | Birth of stars Very cold dust | Birth of stars Cool dust |
| Far-IR | 30–300 m | Cool dust  Birth of stars  Outermost regions of the solar system (Uranus, Neptune, Kuiper Belt, comets) | Birth of stars  Warm dust around young stars |
| Mid-IR | 3–30 m | Warm dust around young stars  Formation of planets  Inner Solar System (Mars, Jupiter, Saturn, Asteroids) | The first stars (100 million years after Big Bang) |
| Near-IR | 0.8 – 3 m | Cool stars (red dwarfs, red giants)  Near-Earth objects | The first galaxies in the Universe (400 million years after the Big Bang) |
| Optical | 0.4–0.8 m | Most Stars  Nearby galaxies | Hot, young stars |
| UV | 0.1–0.4 m | Hot, young stars | Very hot regions |

The variation of objects studied at different wavelengths is largely due to their different temperatures. An object of a given temperature will typically emit light at a broad range of frequencies, but the strongest emission will be at a wavelength given by Wen’s Displacement Law:

whereis the wavelength (in metres) at which the emission is brightest, *T* is the object temperature in Kelvin, and *w* is Wein’s displacement constant, which has a value of 0.0029 m.K.

The Kelvin temperature scale is similar to the Celsius temperature scale, but begins at –273oC. This is known as absolute zero, and is the coldest temperature it is physically possible for an object to achieve. To convert from Celsius to Kelvin, simply add 273.

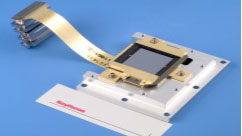
There are two general types of instruments in astronomy. One is a “camera”, which takes pictures of objects. The other is a “spectrometer”, which splits the light into a range of wavelengths in order to look for the signatures of specific atoms and molecules.

Example using the Sun

The surface of the Sun is around 5800 K. If we wanted to convert from Kelvin to Celsius we would subtract 273, so the surface of the Sun is at a temperature of just over 5500oC.

From Wein’s displacement law, the wavelength at which the Sun is brightest is given by:

That means that the Sun is brightest in the visible part of the spectrum.

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An infrared detector chip

### Questions

1. Convert the following temperatures from degrees Celsius to Kelvin:  
   a) 20oC, b) 75oC, c) –50oC
2. Using Wein’s displacement law, do colder objects typically emit at longer or shorter wavelengths.
3. Given the temperature of the following 3 objects, calculate the wavelength at which they are brightest using Wien’s law: a) A Person (37oC), b) Jupiter (160K), c) a hot young star (10,000oC)
4. The light from very distant objects is stretched to longer wavelengths. Does this make them appear warmer or cooler?