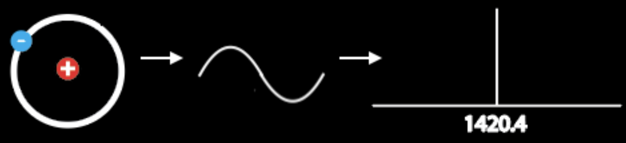
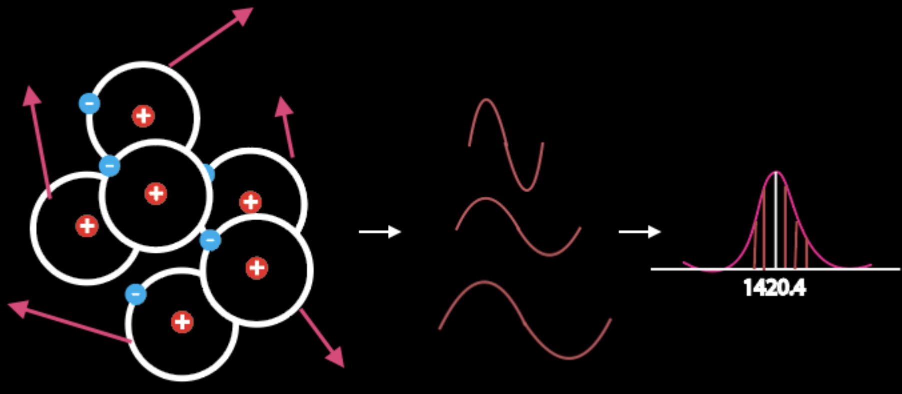
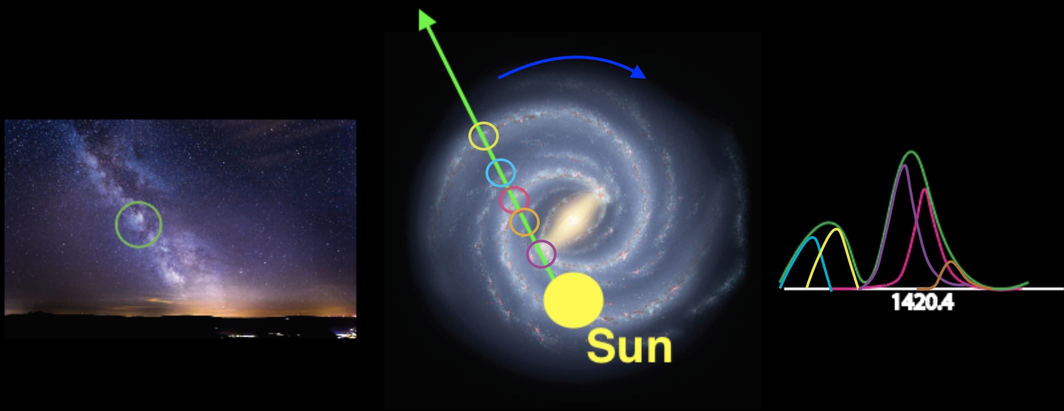


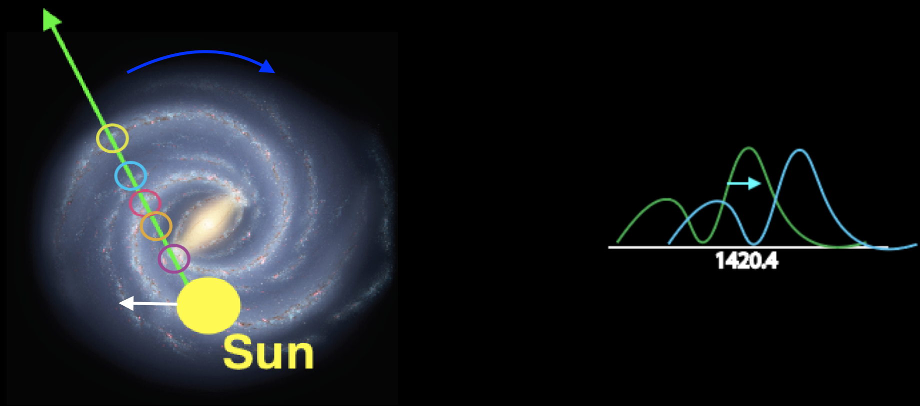
A single Hydrogen atom at rest undergoing the spin-flip transition will produce a photon with a frequency of 1420.4 MHz, which would appear as a sharp spectral line if it could be detected with our telescope. If the atom were moving, the spectral line will appear shifted from the rest frequency due to the Doppler effect.



Within a cloud of Hydrogen gas, there will be many atoms of Hydrogen undergoing this transition, producing many photons. These gas clouds have some temperature, which causes the atoms to have some motion that we see as a slight Doppler shift Now, instead of a sharp spectral line, we have a broad peak from the combination of many spectral lines.



However, in reality the telescope captures many of these clouds within its field-of-view (what we call a “beam”). The telescope observes a patch of sky with many clouds moving with different overall velocities. The telescope observes a “line-of-sight”out into space, and gas observed along the line of sight will come from multiple arms and structures within the Milky Way. These gas clouds, in addition to their Doppler broadening, will have an overall Doppler shift applied if they are moving with respect to the observer. This creates many peaks in your data that combine to form a more complex profile. The green profile represents the combination.



The Earth and Sun are also moving with respect to the Hydrogen as they orbit, causing another Doppler shift effect. Instead of broadening the spectral line, or creating extra features, this creates a shift of the whole spectrum. If we want to know how fast the gas is moving with respect to the Galactic Center instead of with respect to an observer on the Earth, we have to compensate for this motion.