

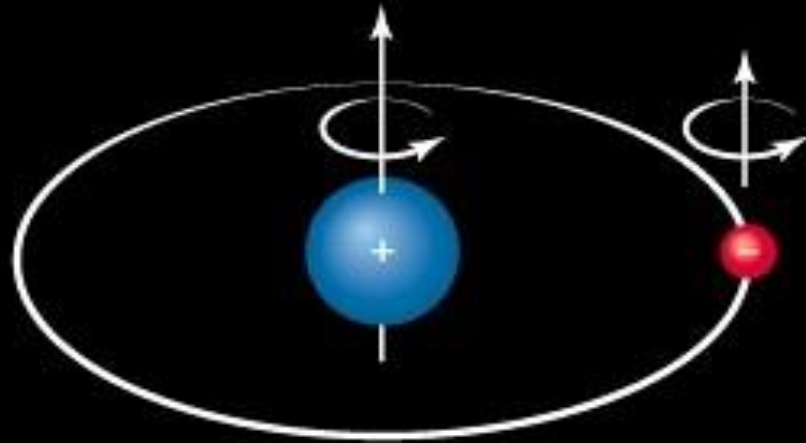
Galactic Exploration with Invisible Light

Infoage Space Exploration Center

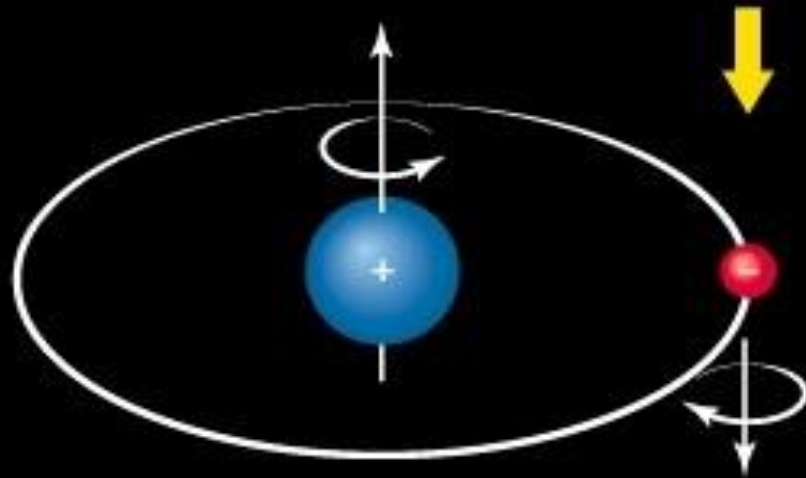


- The TLM18 - Parabolic Dish Antenna
- Army Signal Corps- Tiros, Satellites
- Unused since late 20th century
- Educational Princeton University Students
- Weather Satellites, The Moon, The Sun
- Milky Way Galactic Arms, Pulsars, Galaxies
- Hydrogen -21 Cm Radiation

The 21cm Line



Parallel spins: higher-energy configuration

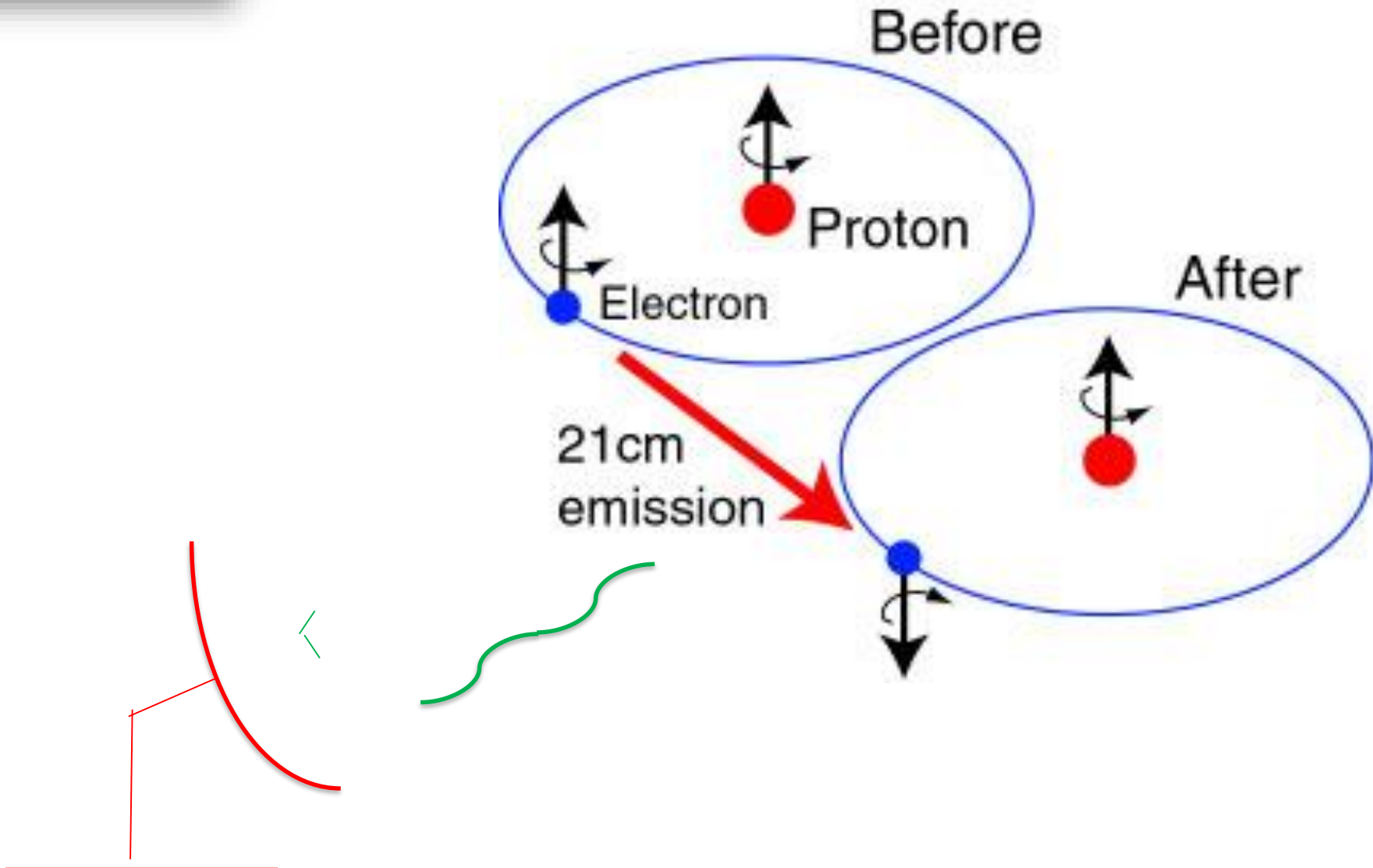


Opposite spins: lower-energy configuration

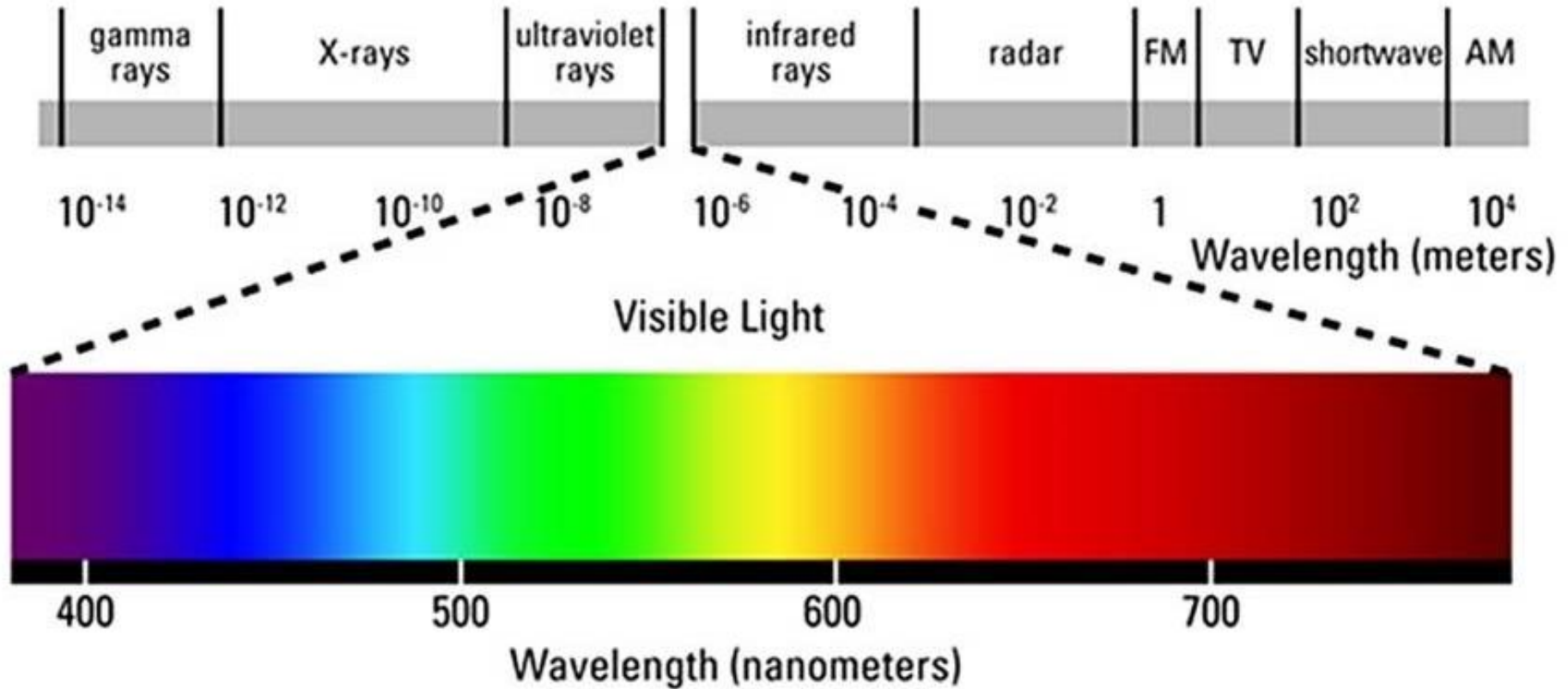
The protons and the electrons that comprise hydrogen atoms are tiny magnets. The energy of these atoms depends on whether these magnets are aligned (N-N) or anti-aligned (N-S).

The atom can flip from one state to the other, emitting or absorbing a small amount of radio energy in the process.

The 21cm Line

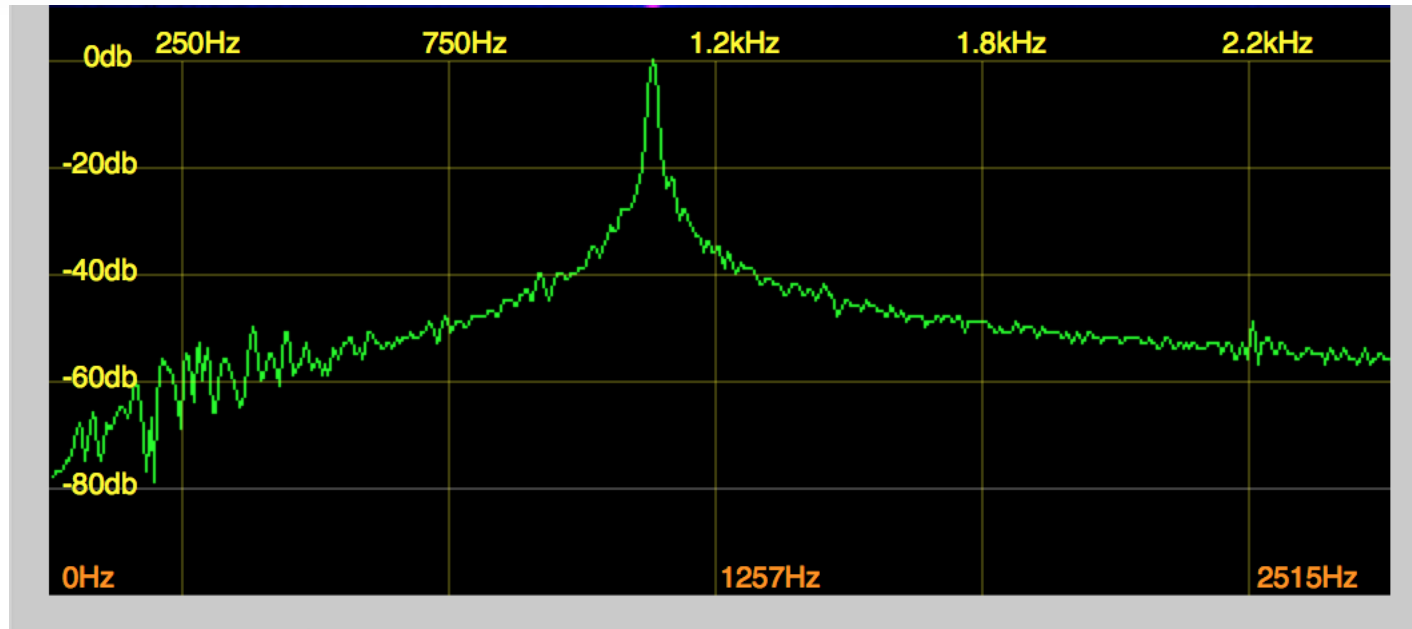


The Radio Spectrum



Light from the Sun and stars and the 21 cm radiation we will observe are both examples of electro-magnetic radiation. From a physics point of view, there is nothing special about the 500 nm visible range that our eyes are adapted to see.

Spectral Analysis

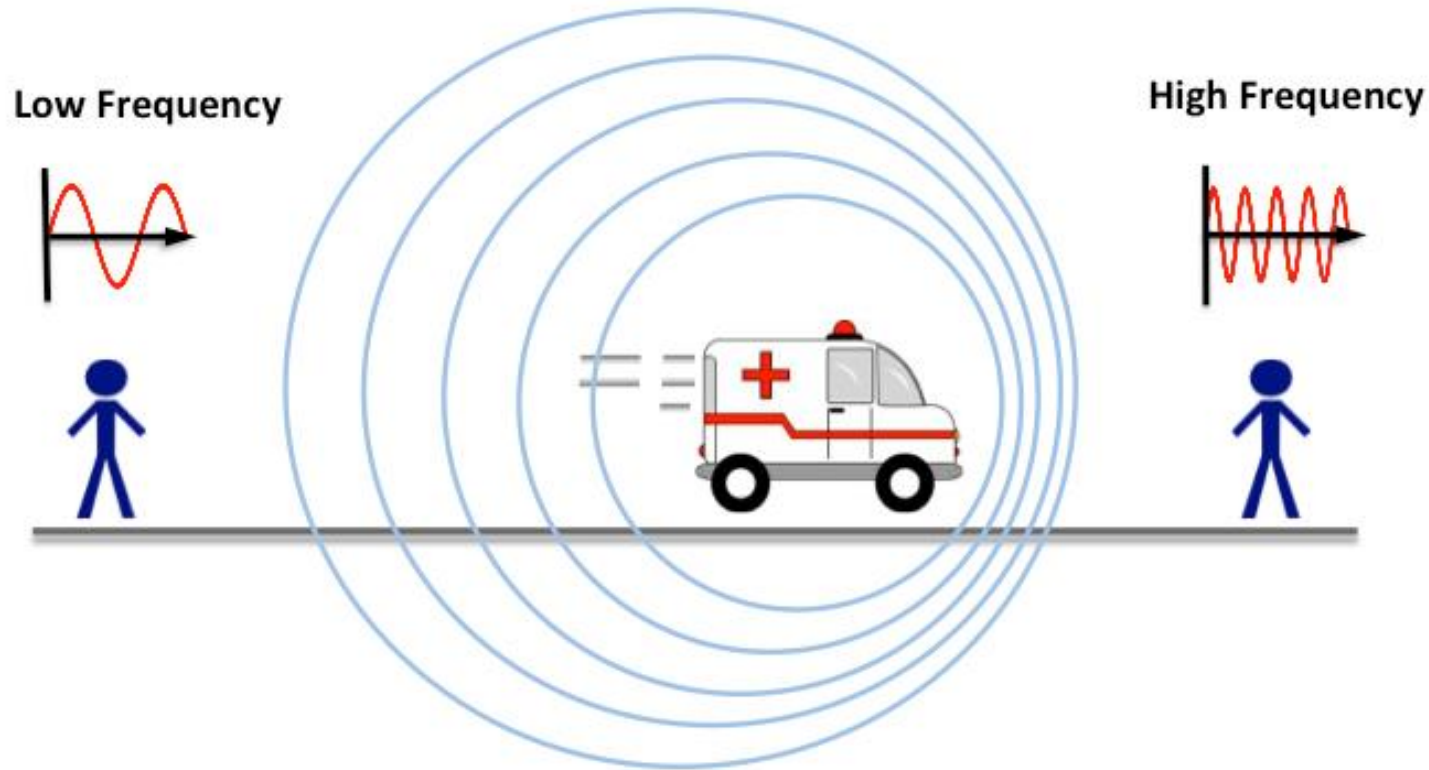


Although the phrase “spectral analysis” can seem mathematical and complicated, it is how our ear-brain system processes sound—we hear “pitch” (a.k.a. frequency) and distinguish different sounds by their “spectral content.”

Galactic Whistle

- The 21 cm signal from a single hydrogen atom is *extremely* weak.
- The density of hydrogen atoms is *tiny* (one per cubic centimeter vs. $\sim 10^{24}/\text{cc}$ in typical liquid water)
- But the galaxy is a (very) big place and taken as a whole, the signal is readily detected with modern radio technology.
- One can think of this signal as a cosmic whistle, detectable throughout the galaxy.

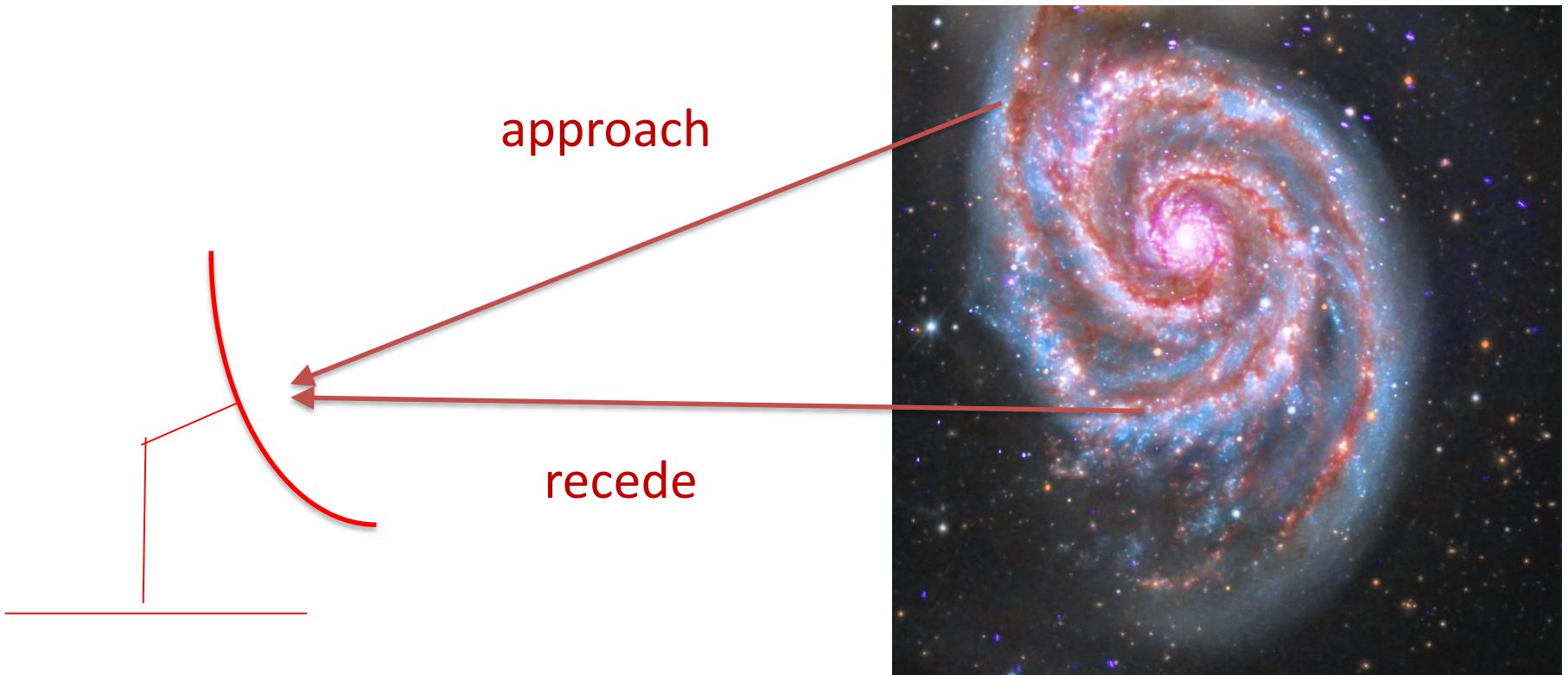
The Doppler Effect



The pitch of sirens, train whistles, and the whines of motors are all affected by their motion relative to the listener: the pitch goes from high to low as the whistle goes from approaching to receding.

Galactic Whistle Doppler Effect

Radio waves also enjoy a Doppler effect (think Doppler radar and speed traps). The pitch of the 21 cm whistle depends on whether the telescope is pointing at hydrogen that is approaching or receding from us.



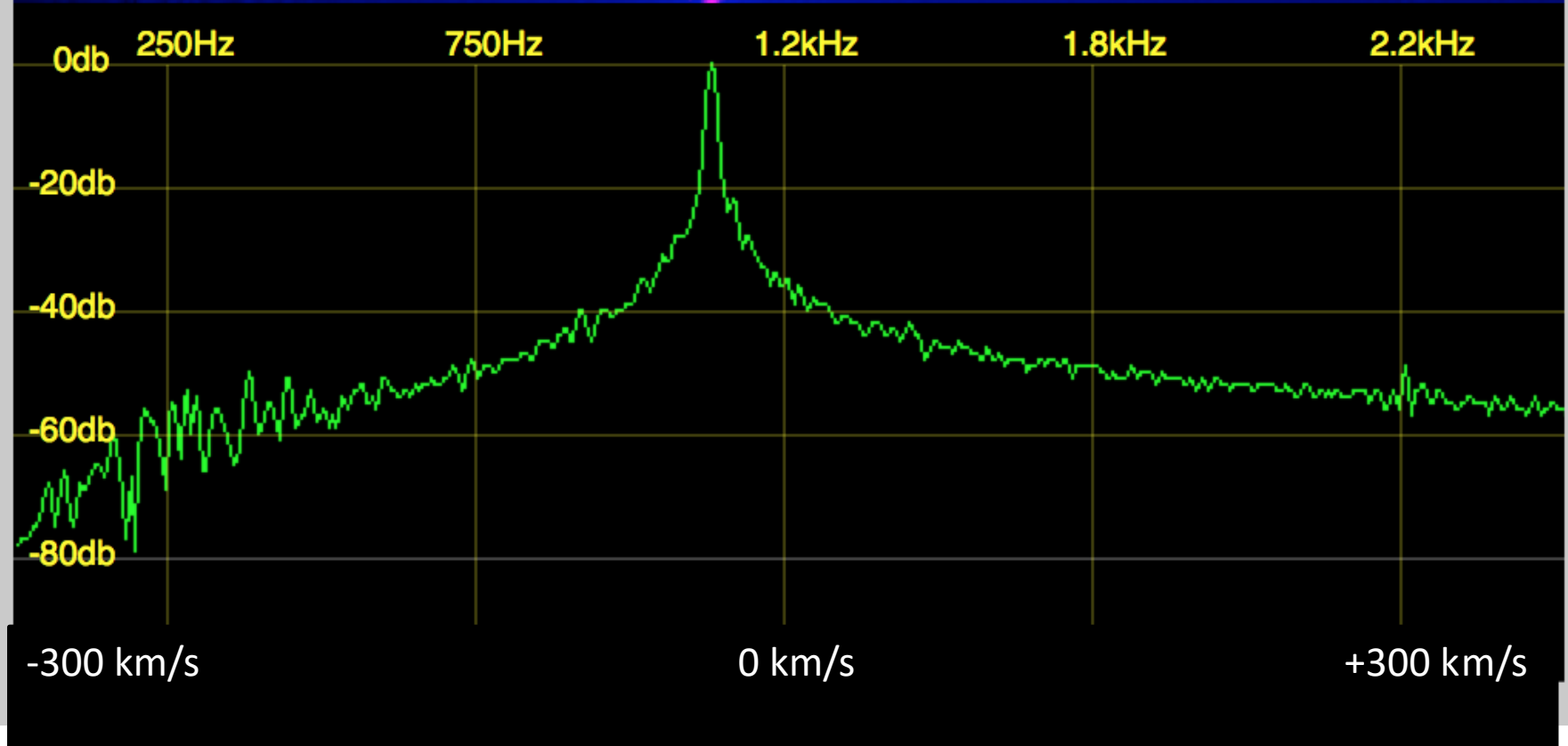
Galactic Whistle Doppler Effect

In fact, we are in the galaxy, so the situation is more like this.

We are here



Galactic Whistle Doppler Effect



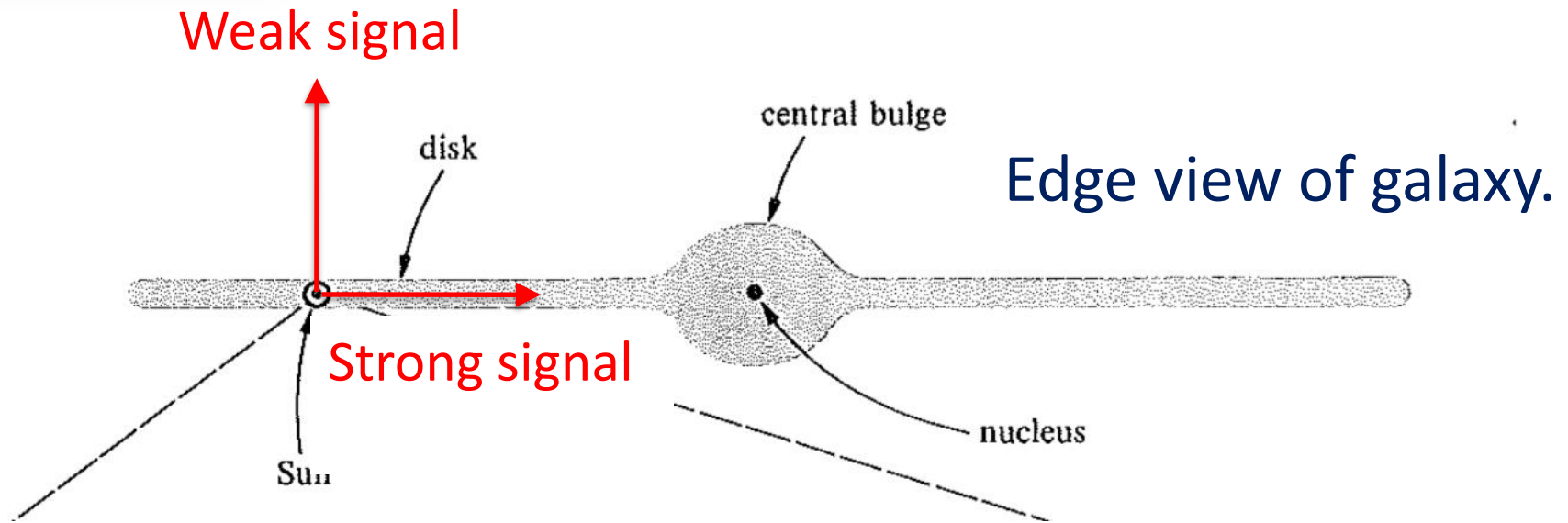
Instead of frequency, we plot our spectrum in terms of Doppler velocity, where higher frequencies correspond to approach hydrogen clouds and lower frequencies correspond to receding clouds.

Galactic Whistle Doppler Effect



If the beam of the telescope passes through multiple arms of the galaxy, which in general will be moving at different speeds with respect to us, we will see (hear) multiple whistles, which appear as multiple peaks in the spectrum.

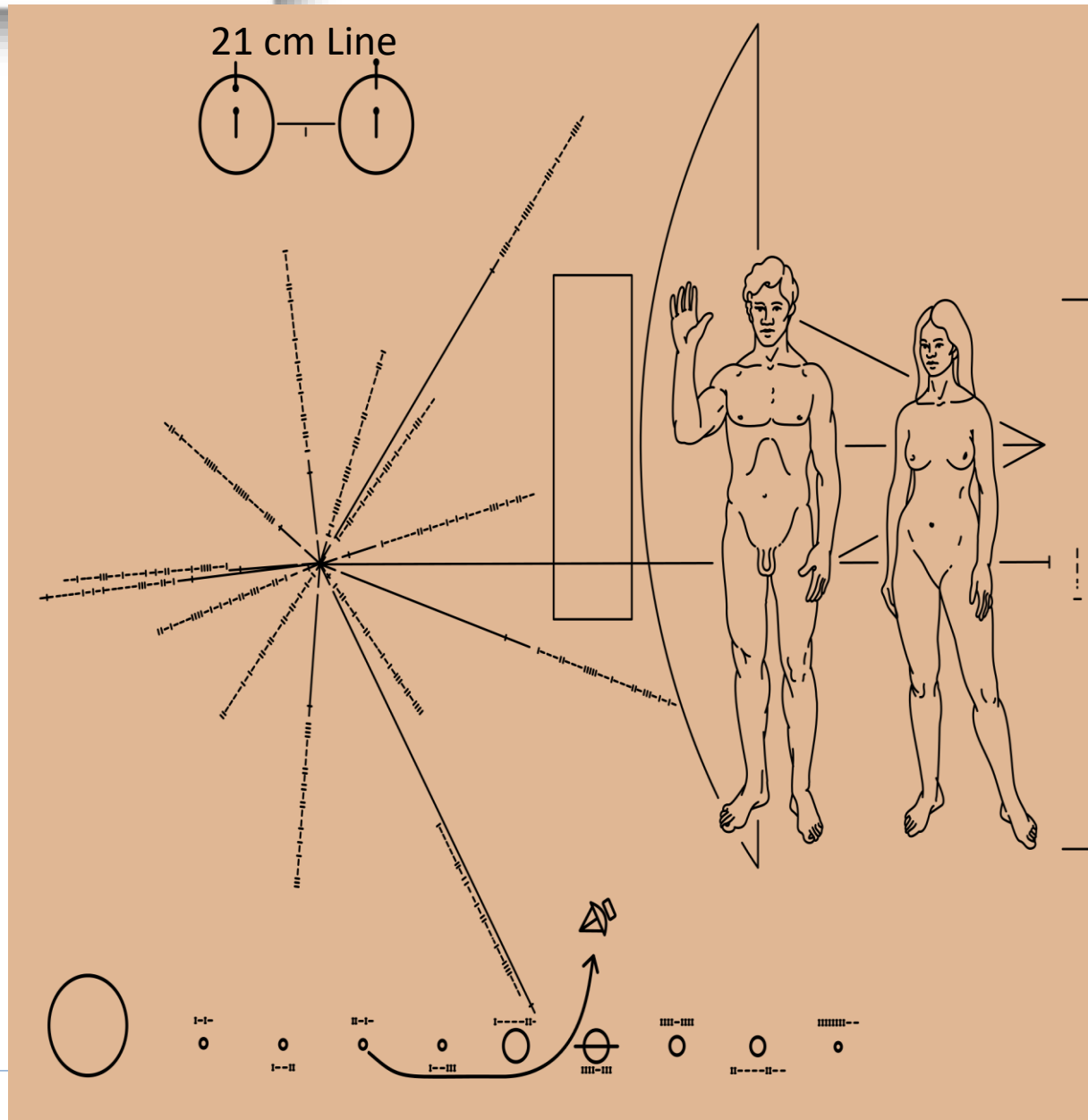
Galactic Whistle Doppler Effect



In general, we see a much bigger signal if we beam the telescope along the thin part of the galaxy.

Let's have a look at some live data!

The Pioneer Plaque



A plaque mounted on the Pioneer deep space probe uses the 21 cm line to set the scale for the drawing of the humans engraved on the plaque. Bright radio pulsars can be used to help extra-terrestrials who find the plaque to locate the earth through triangulation.