1. Who first predicted, and who first observed the 21 cm line from galactic hydrogen? Cite the papers in which the discoveries were reported. (Be impressed that the theorist was a student!)

Also repeat the exercise from class that relates a 21-cm photon wavelength to an energy (in electron volts) and name another physical phenomenon that has a similar energy scale. Do the same for temperature (in K), and frequency (in Hz). Try to find examples that are different to the ones we discussed in class.

We will start problem 2 in class on Friday and you can finish the rest. Problem 3 is really a continuation of problem 2.

2. Construct the matrices for \( S_z, I_z, S_+, I_+, S_-, I_, S^2, I^2 \) in the basis of the 4 kets \( |s = \frac{1}{2}, m_s = \pm \frac{1}{2}; I = \frac{1}{2}, m_I = \pm \frac{1}{2} \rangle \), representing a system of spin-1/2 electron (S) and a spin-1/2 proton (I). Remember that the Coulomb interaction is "turned off" here. We are interested only in the spin part of the quantum system. For notational simplicity, you might prefer to label the states by the \( m \)-quantum numbers only because \( s = \frac{1}{2}, I = \frac{1}{2} \) always. That is, \( |m_s = \pm \frac{1}{2}; m_I = \pm \frac{1}{2} \rangle \). You could use even simpler notation of "+" and "-" if you like, but you must not forget the values that the symbols represent.

3. McIntyre 11.8 (get H' hyperfine)

You do not have to have solved #2 and #3 to do #4, but you do have to know that the hyperfine perturbation Hamiltonian is \( H'_{hf} = const \cdot \vec{S} \cdot \vec{I} \), remember how to use vectors, and remember the basics from the spins paradigm.

4. McIntyre 11.9 (practice with commutators)