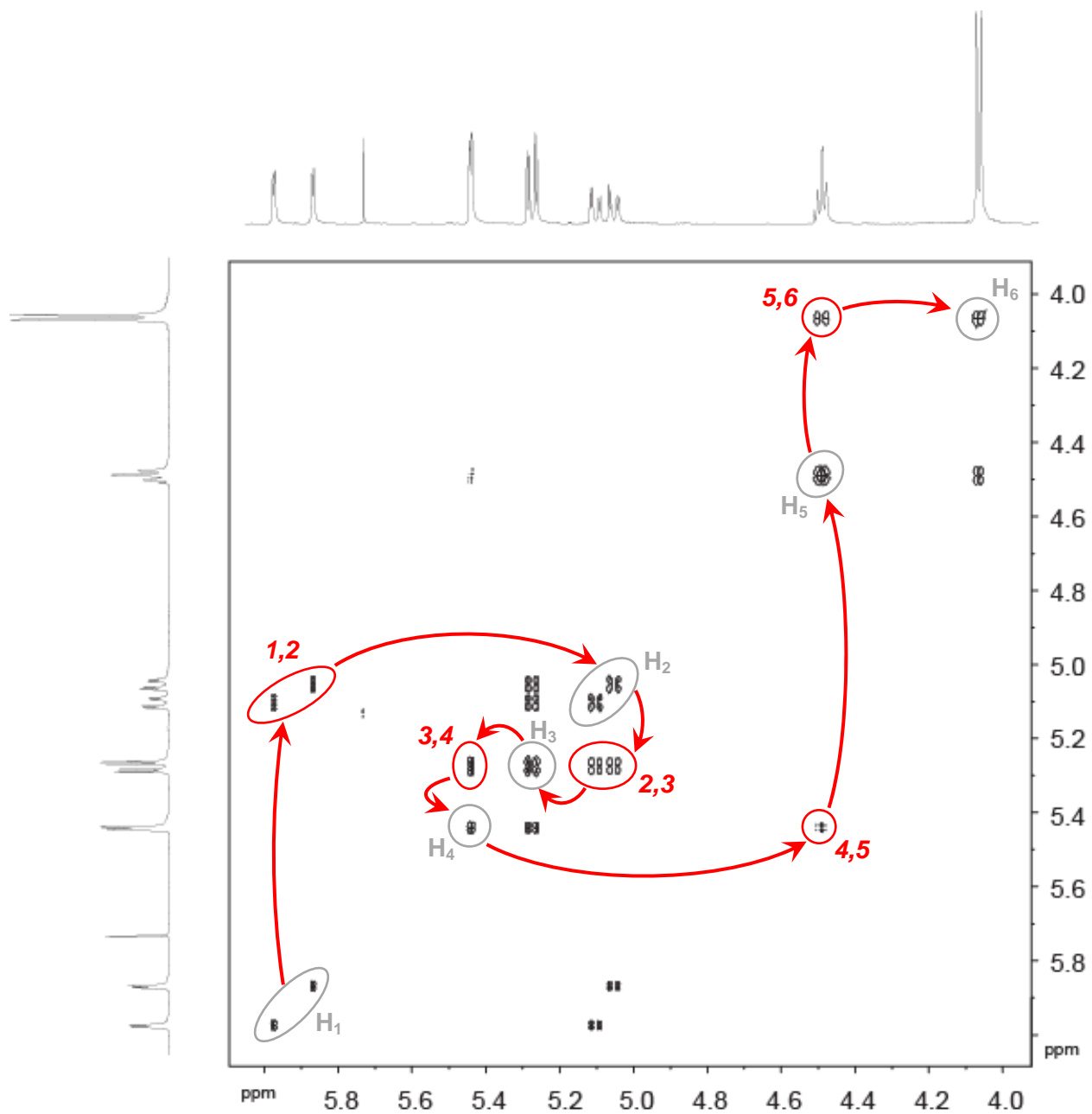


**In-Class Exercise Solutions:
¹H-¹H (Homonuclear) COSY**

- a. In principle, ¹⁹F can couple to both ¹H and ¹³C, but whether that coupling is observed or not depends upon which spectroscopy is being performed. Most ¹⁹F will be attached to ¹²C, not to ¹³C, and so ¹⁹F-¹³C coupling won't be observed in the ¹⁹F NMR spectrum. However, it will be observed in the ¹³C NMR spectrum, because every carbon observed in that spectroscopy is by definition a ¹³C. ¹⁹F-¹H coupling will definitely be observed, with both geminal (²J) and vicinal (³J) coupling relationships.
- b. There were a number of ways to approach this problem, but in my opinion the best way to start was to try to identify one resonance definitively in the 1D spectra, so that we could use that resonance as the start of our "COSY walk". (Another way would be to identify one crosspeak definitively in the COSY, and use that as the starting point.)

Every carbon in our molecule has one electron-withdrawing atom attached to it except one—C₁, which has two. I would expect H₁, as a result, to be downfield of everything else. Looking at the ¹H NMR, there are some features that are immediately clear: 4 tall singlets corresponding to the four acetyl groups, and integrated intensity of 7H for the remaining protons in the molecule. (There are also peaks from CH₂Cl₂ at ~5.7 ppm, and H₂O at 3.3 ppm.) If H₁ is downfield of everything, it must be the dd at δ = 5.9 ppm. This dd has one extremely large coupling constant, J = 53 Hz, which is too large to correspond to ¹H-¹H coupling. Pretsch says, on the other hand, that ²J_{HF} values can be as high as 80 Hz, so fluorine at position 1 could be responsible for the giant splitting pattern. This same coupling constant is also observed in the ¹⁹F NMR dd, confirming that assignment. That same ¹⁹F dd also has a coupling constant of 25 Hz, which we'll keep an eye out for as we look at the problem.

- c. We can analyze the 2D spectrum by "walking" from proton 1 to other, coupled protons in the molecule. Doing that would look something like what is shown on the next page. In each step, you walk off the diagonal, and then you walk back onto the diagonal again at a different frequency; that different frequency is the next proton in the line of coupled nuclei.



Walking from diagonal to crosspeak to diagonal allows us to identify the sequence of coupled protons in this molecule. We can now fill in the chart:

proton	δ (ppm)
H ₁	5.9
H ₂	5.1
H ₃	5.3
H ₄	5.4
H ₅	4.5
H _{6a} & H _{6b}	4.1

Going back to the ddd for H₂, there is indeed a large coupling constant of 24 Hz that matches the J_{HF} we measured in the ¹⁹F spectrum, so some confirmation there.

- d. We can definitely assign some of the ¹³C resonances. All of the peaks at $\delta = 169$ ppm belong to acetyl group carbonyls, and the peaks at $\delta = 20$ ppm to the acetyl group methyls. (There are only three peak labels, but two of the methyls must be overlapping.)

The rest of the spectrum has too many peaks--just 6 carbons, but 9 peaks. We've got to conclude that ¹⁹F-¹³C coupling must be responsible for the extras. We wouldn't see this coupling in the ¹⁹F NMR, because most F's are attached to ¹²C's, but we will see it in the ¹³C NMR. It would explain the two peaks at $\delta = 104$ ppm (d, C₁, $^1J_{CF} = 225$ Hz), the two peaks at $\delta = 66$ ppm (d, C₂, $^2J_{CF} = 24$ Hz), and the two peaks at $\delta = 69$ ppm (d, C₃ or C₅, $^3J_{CF} = 3$ Hz). I'm also going to guess that C₆ is the farthest upfield of the sugar carbons, at $\delta = 61$ ppm. But nothing else can be assigned definitively based on the information in the ¹³C spectrum.