

# NMR - 2D

## 2. CORRELAZIONI ETERONUCLEARI SHIFT CORRELATE

	Technique	Principal Applications
$^1J$	HSQC	Correlating coupled heteronuclear spins across a single bond and hence identifying directly connected nuclei. Employs detection of high-sensitivity nuclides, for example, $^1\text{H}$ , $^{19}\text{F}$ , $^{31}\text{P}$ (an 'inverse technique'). Favoured over HMQC as it can provide improved resolution.
$^1J$	HMQC	Correlating coupled heteronuclear spins across a single bond and hence identifying directly connected nuclei, most often $^1\text{H}$ - $^{13}\text{C}$ . Employs detection of high-sensitivity nuclides, for example, $^1\text{H}$ , $^{19}\text{F}$ , $^{31}\text{P}$ (an 'inverse technique').
$^2J, ^3J$	HMBC	Correlating coupled spins across multiple bonds. Employs detection of high-sensitivity nuclides, for example, $^1\text{H}$ , $^{19}\text{F}$ , $^{31}\text{P}$ (an 'inverse technique'). This is HMQC tuned for the detection of small couplings. Most valuable in correlating $^1\text{H}$ - $^{13}\text{C}$ over two- or three-bonds. Powerful tool for linking together structural fragments.
$^2J$	H2BC	Used to identify HMBC peaks that equate to two-bond $^1\text{H}$ - $^{13}\text{C}$ correlations and so distinguish them from three-bond correlations. Limited to correlations to protonated carbon centres only.
Long range	HSQMBC	Used for measurement of the magnitudes of long-range heteronuclear coupling constants, most often between proton and carbon centres.
Long range	LR-HSQMBC	Used for the detection of very long-range heteronuclear correlations. For $^1\text{H}$ - $^{13}\text{C}$ systems this may provide correlations over four, five and even six bonds and will likely prove most useful for proton-sparse structures.
$^1J$	HETCOR	Correlating coupled heteronuclear spins across a single bond. Employs detection of the lower- $\gamma$ nuclide, typically $^{13}\text{C}$ , so has significantly lower sensitivity than inverse techniques. Benefits from high resolution in the $^{13}\text{C}$ dimension, so may find use when this is critical, otherwise superseded by the aforementioned methods.

# H,C-COSY

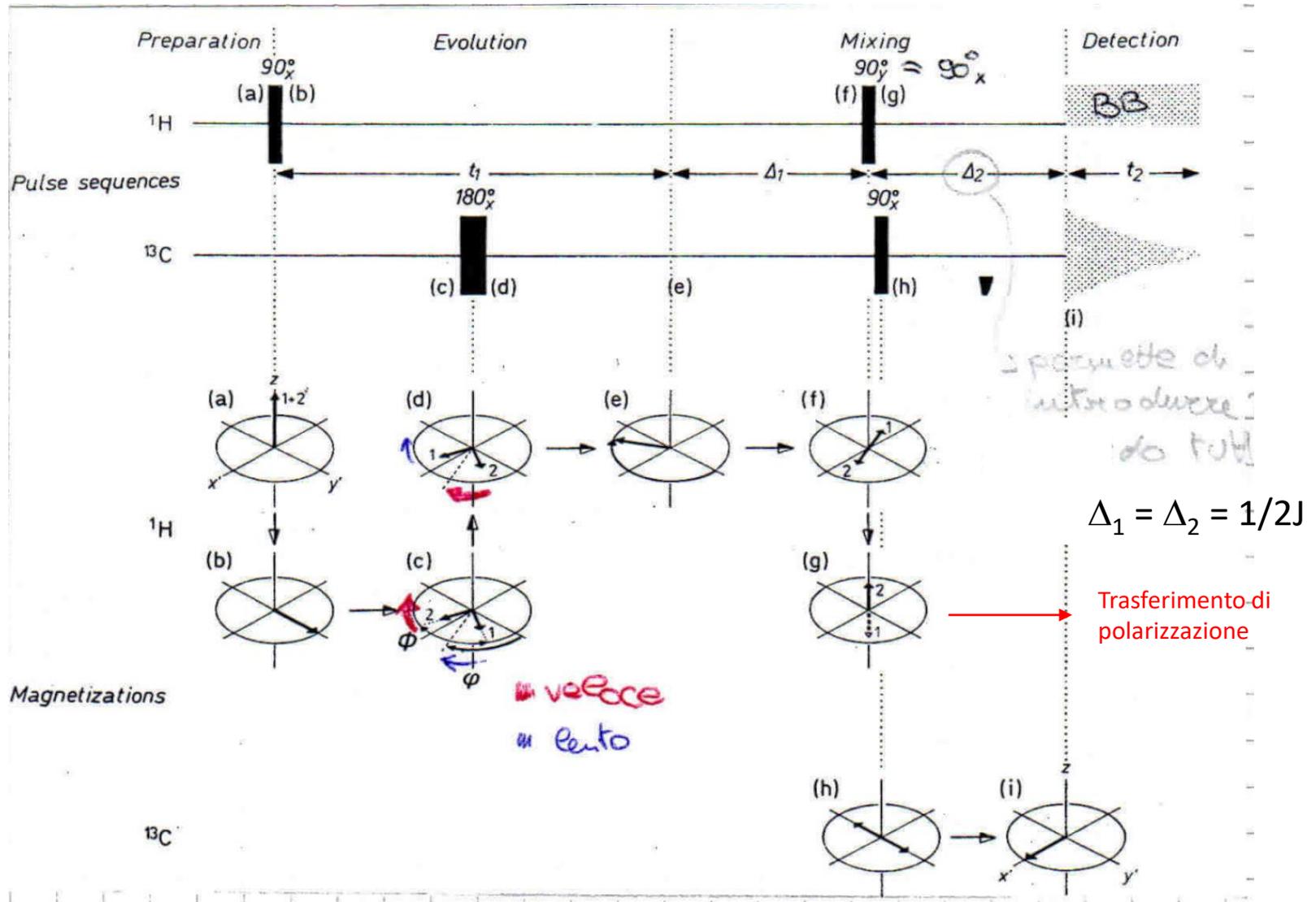
# C,H-COSY

Informazione: quale C è attaccato a quale protone

- Differenza: nel primo caso il nucleo osservato (F2) è il  $^{13}\text{C}$  (poco sensibile) **HETCOR**
- Nel secondo caso il nucleo osservato (F2) è il  $^1\text{H}$  (molto sensibile) = **HSQC, HMQC** TECNICHE INVERSE

# H,C-COSY: HETCOR

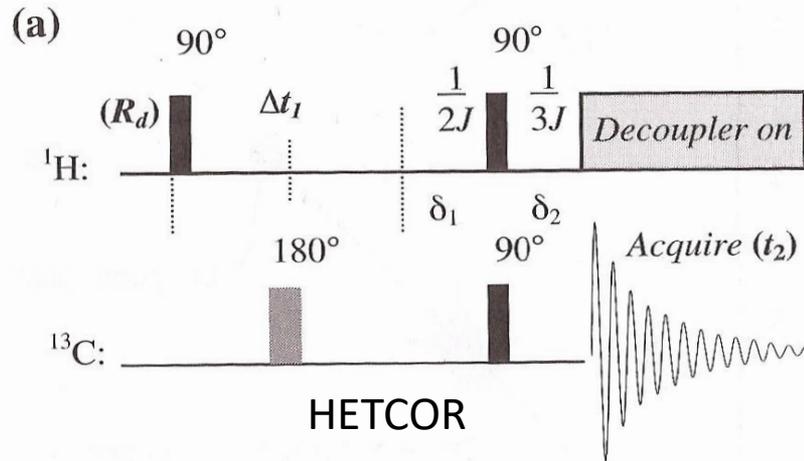
## Heteronuclear Correlation



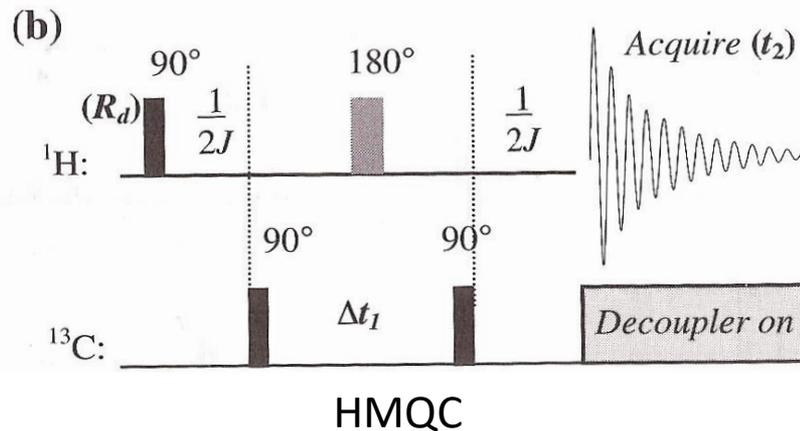


# C,H-COSY: HMQC

## Heteronuclear Multiple Quantum Correlation



Stesse informazioni di HETCOR  
Minor tempo di acquisizione



Procedura inversa.  
Si induce coerenza ( $90^\circ$ ) sul canale  
del nucleo insensibile  
Si rileva il nucleo più sensibile

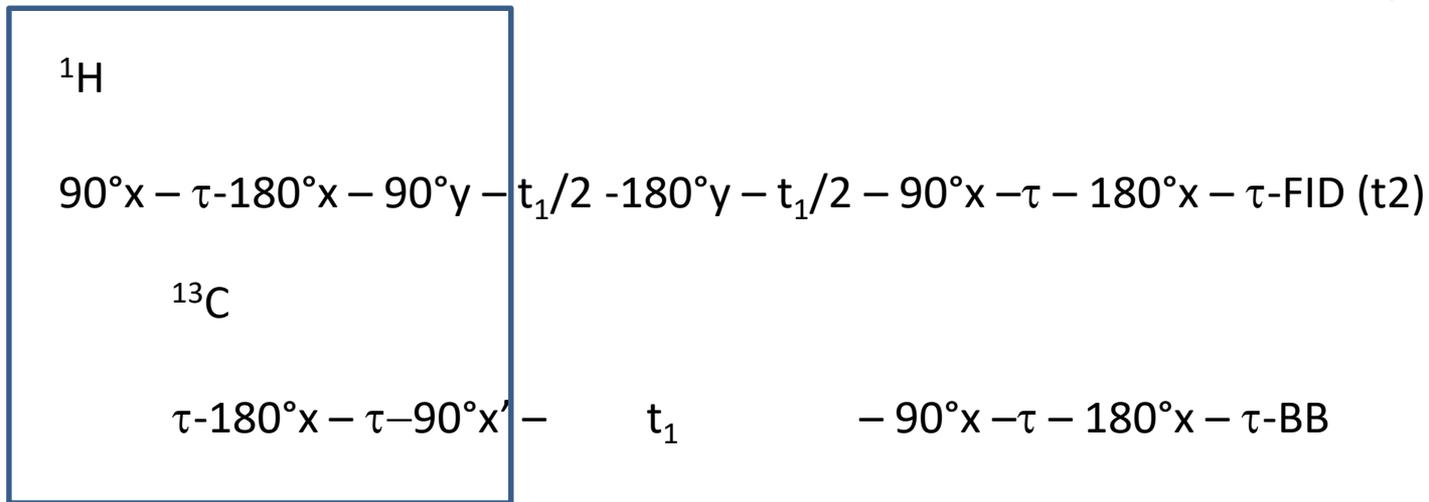
# C,H-COSY: HSQC

## Heteronuclear Single Quantum Correlation

Evolve solo la magnetizzazione del  $^{13}\text{C}$

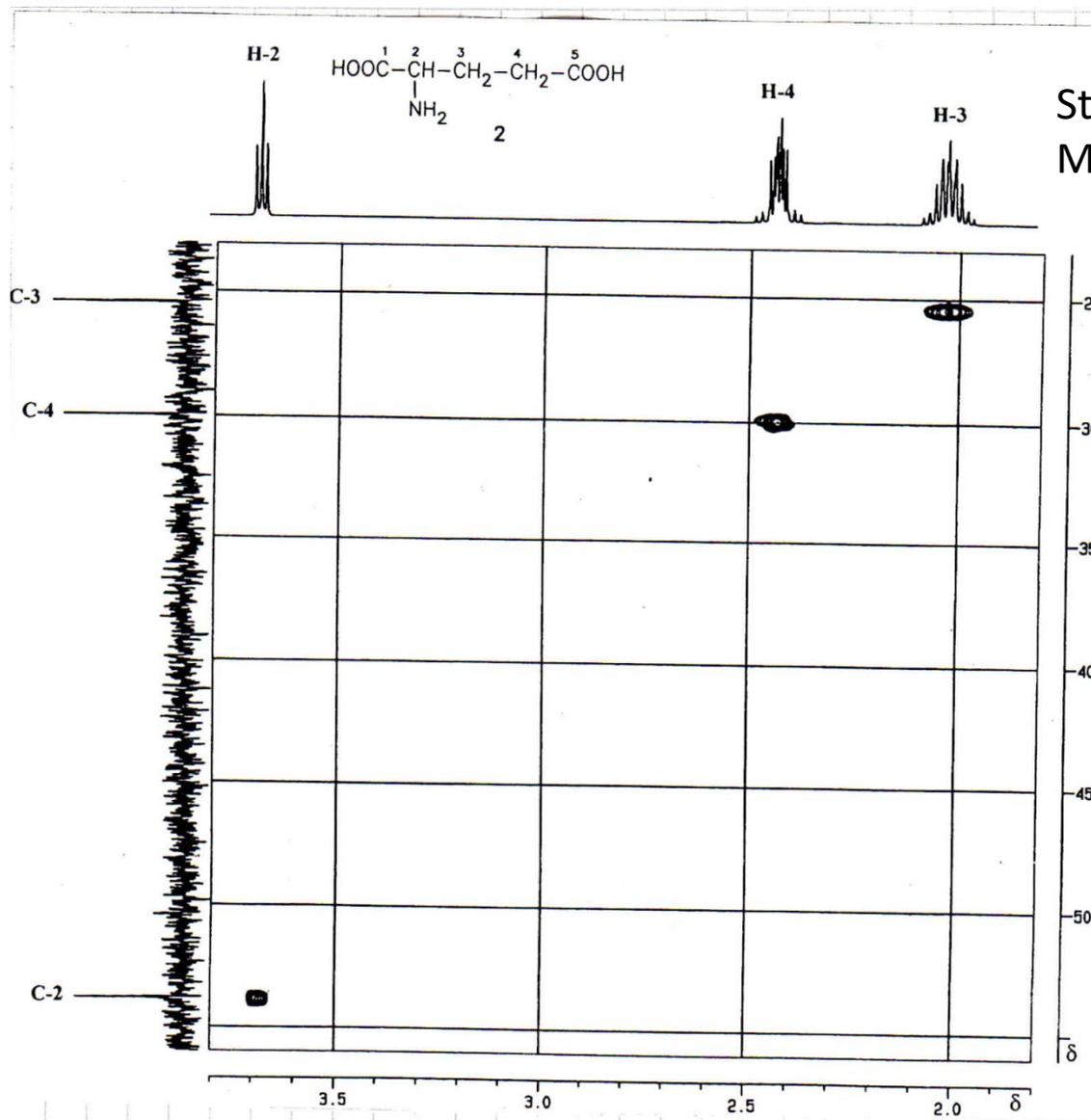
Stesse informazioni  
Minor tempo di acquisizione

INEPT



# C,H-COSY: HSQC

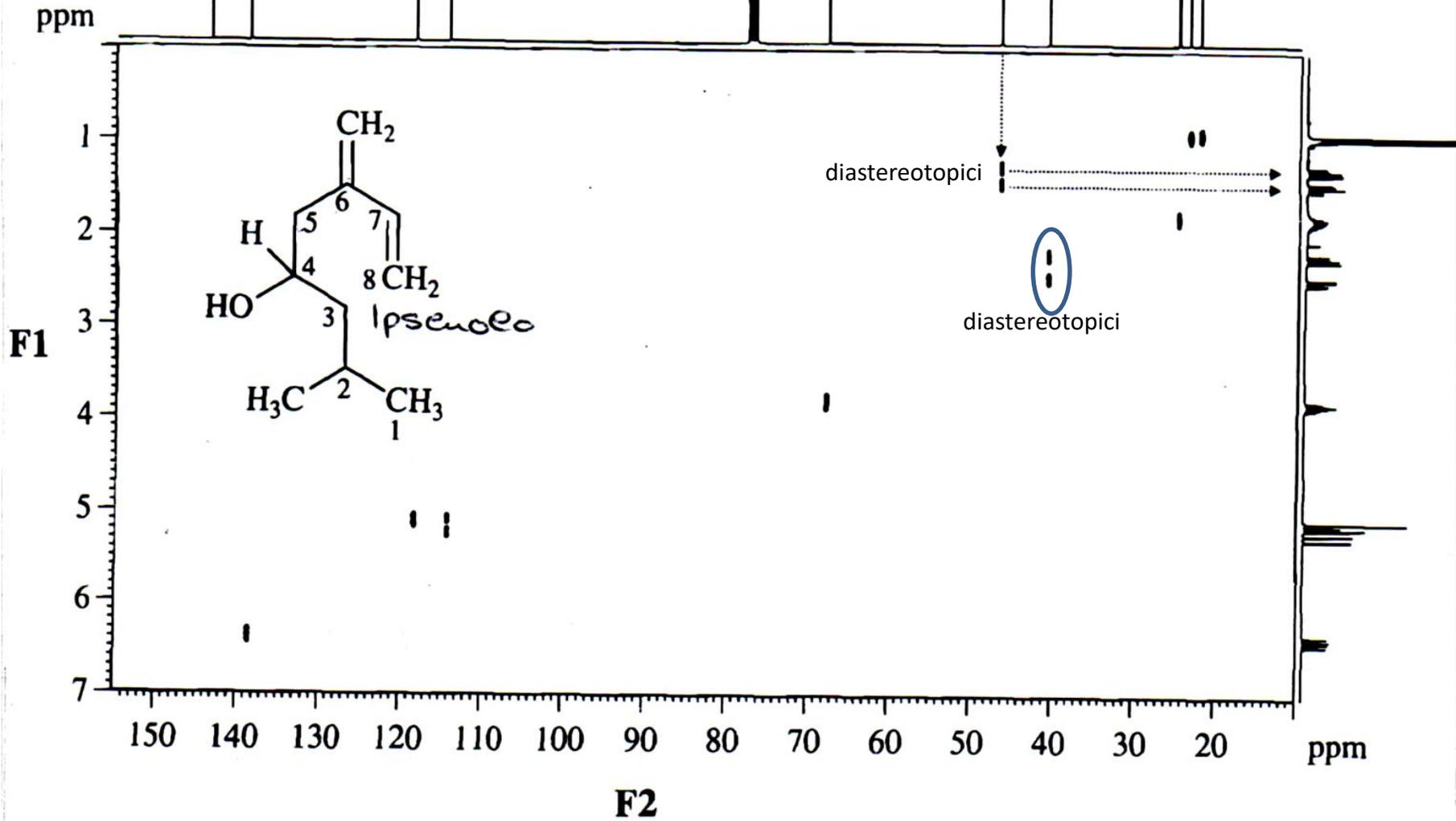
## Heteronuclear Single Quantum Correlation



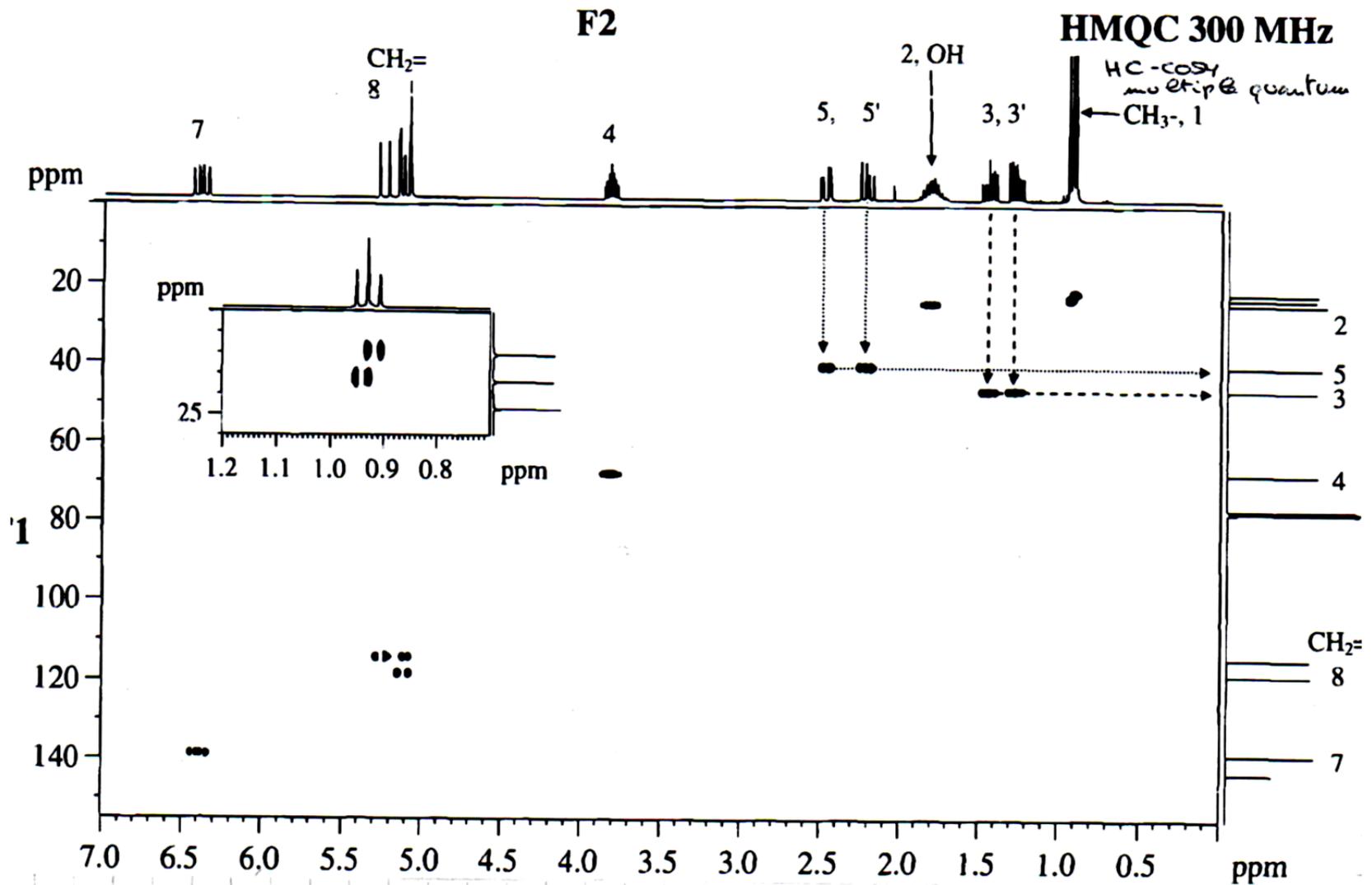
Stesse informazioni  
Minor tempo di acquisizione

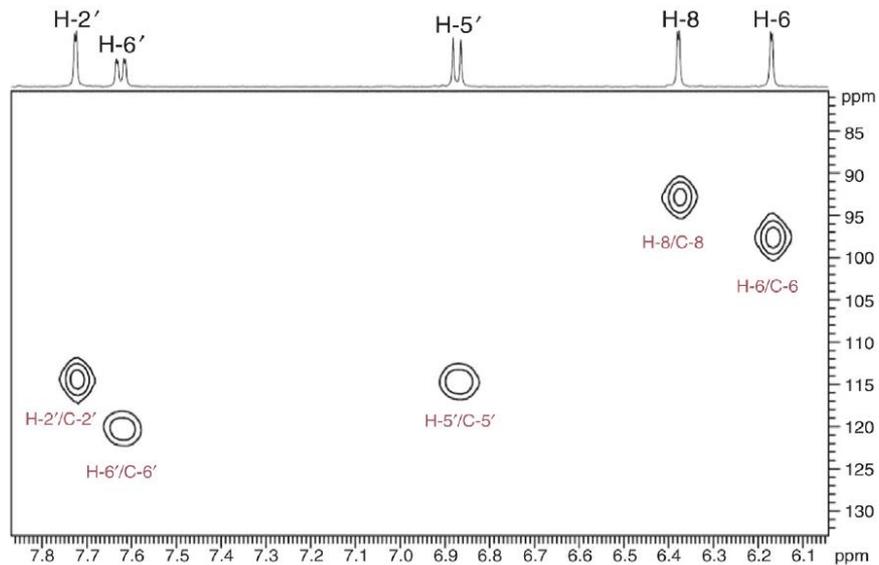
# H,C-COSY

HETCOR 75.5 MHz

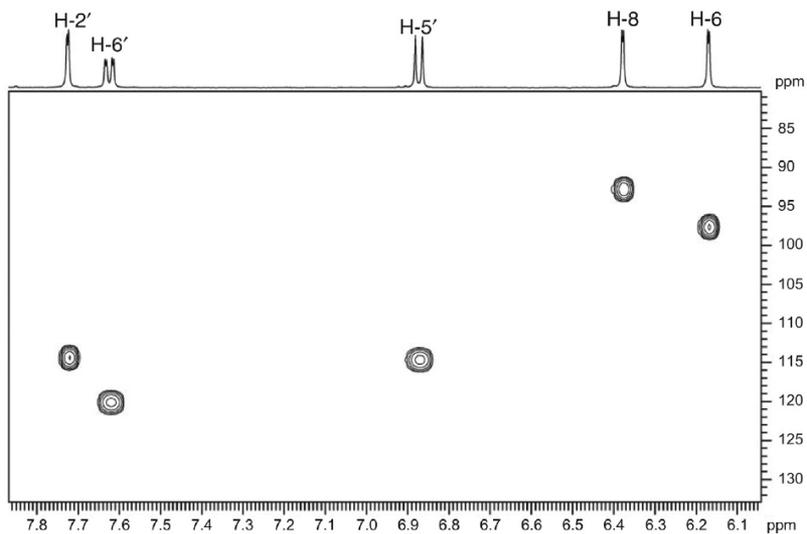
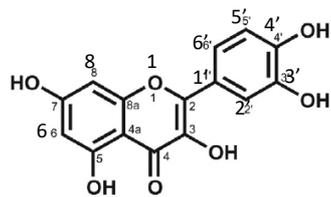


# C,H-COSY

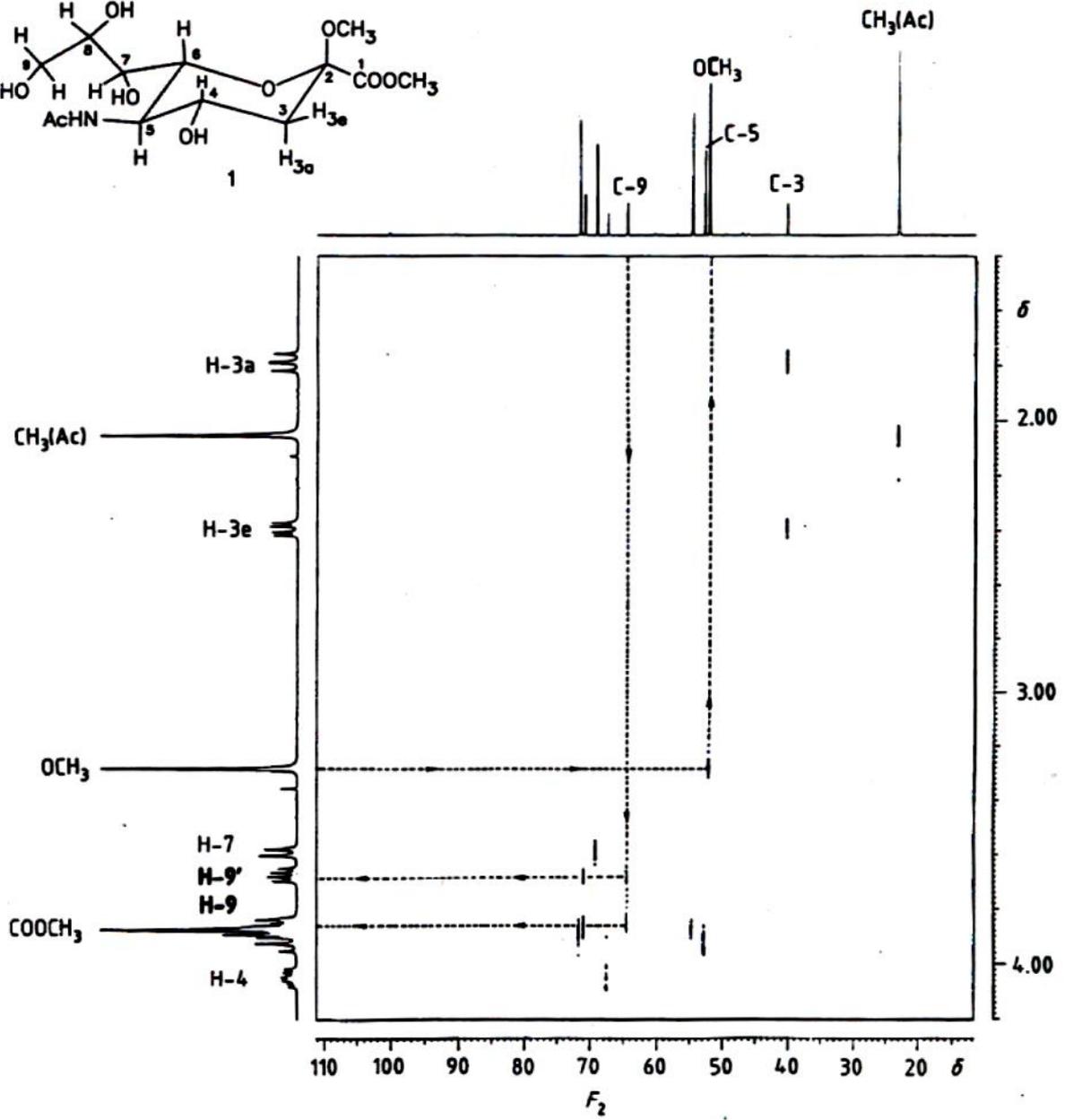
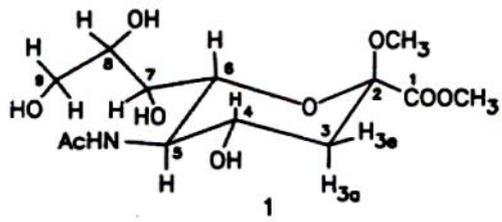




HMQC

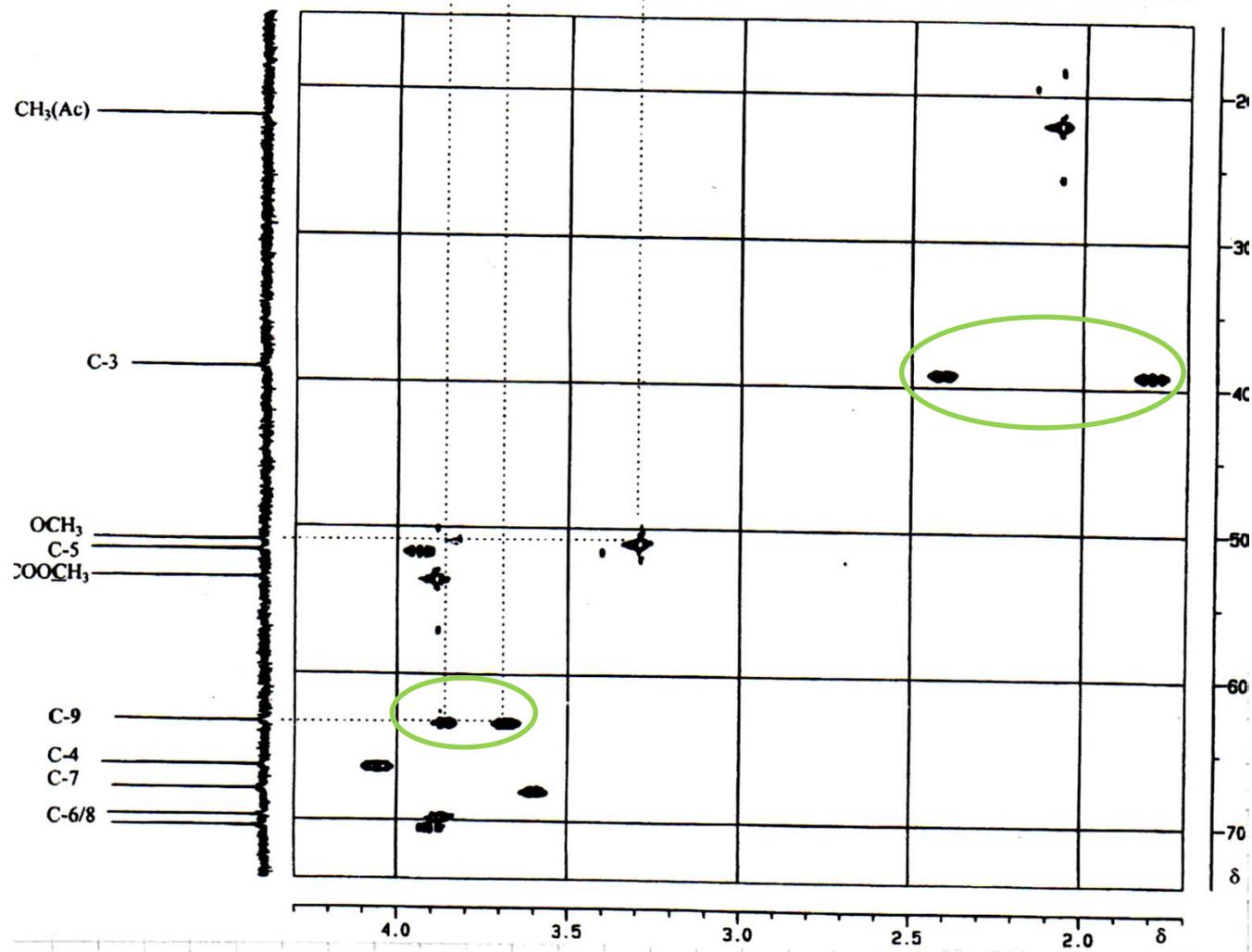
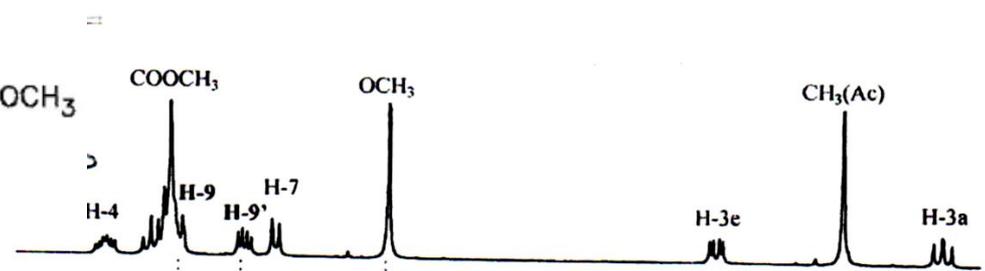
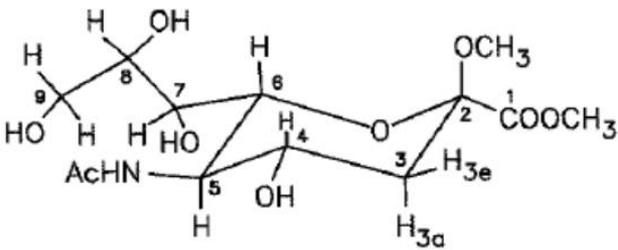


HSQC



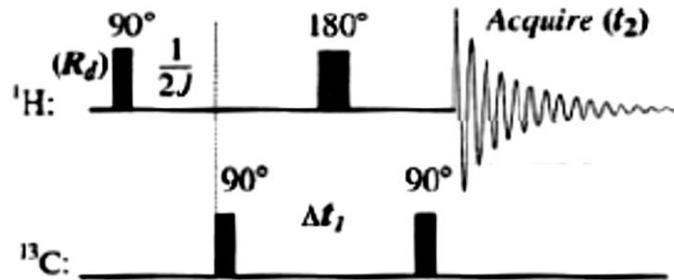
HETCOR

# HSQC



# HMBC

## Heteronuclear Multiple Bond Coherence

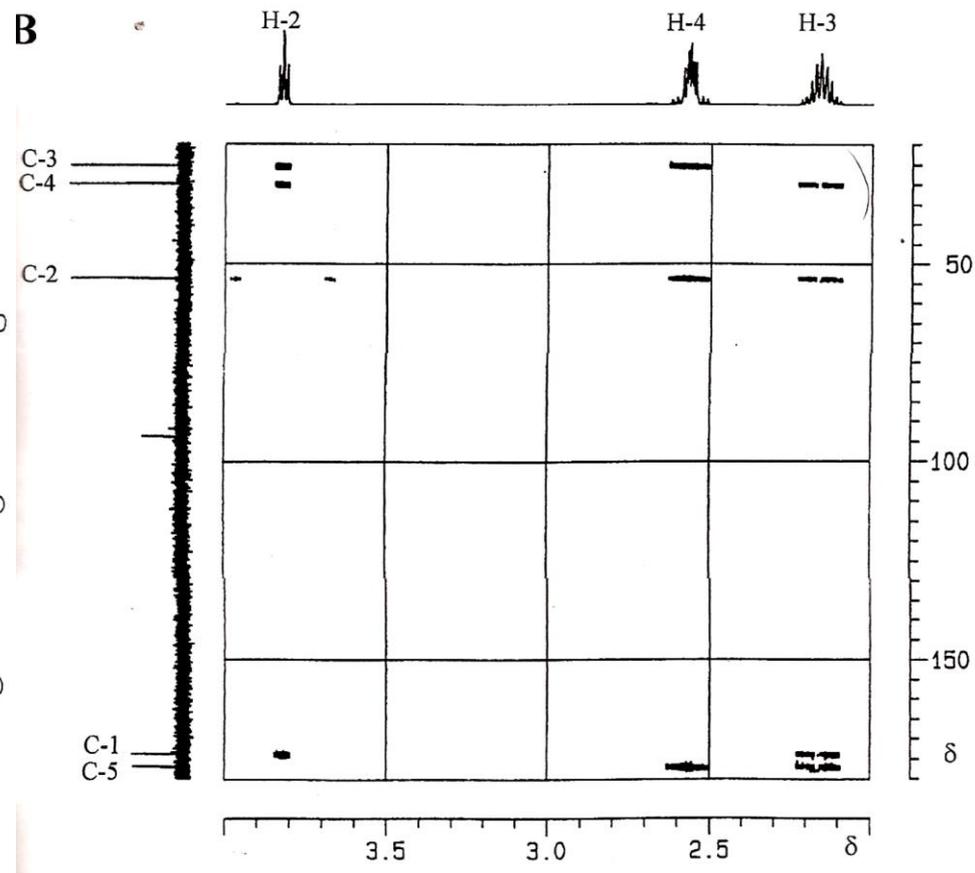
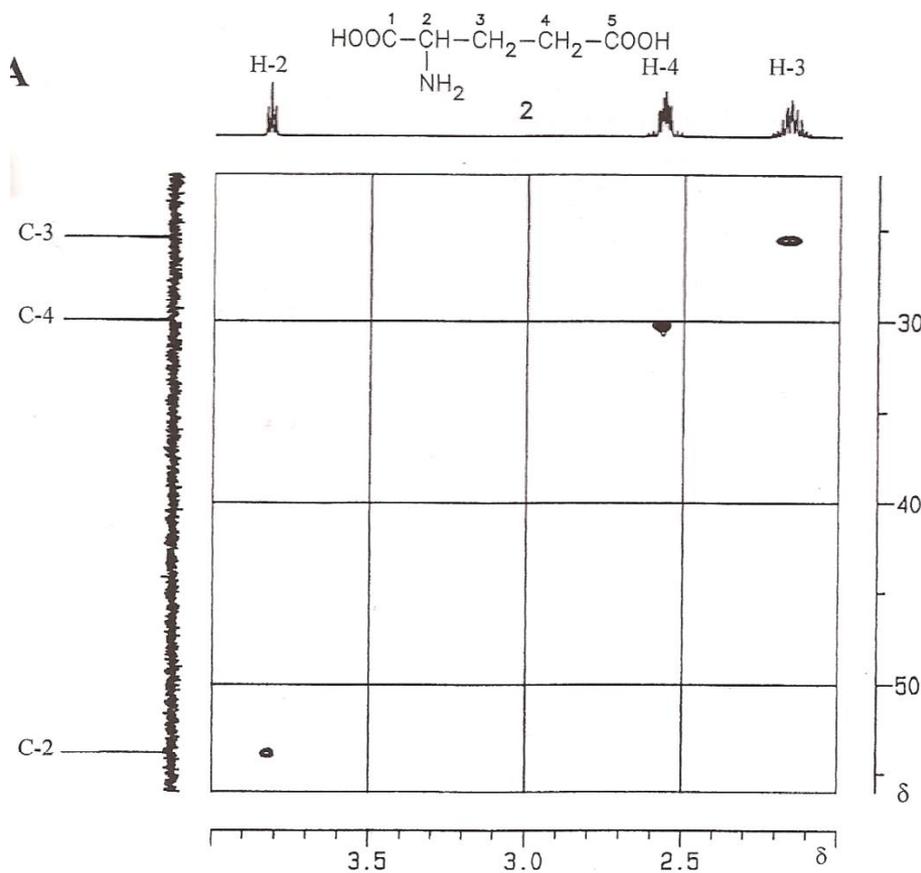


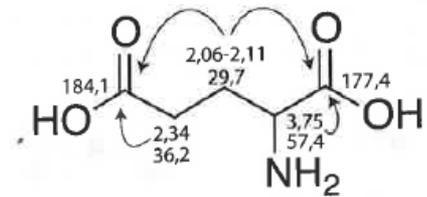
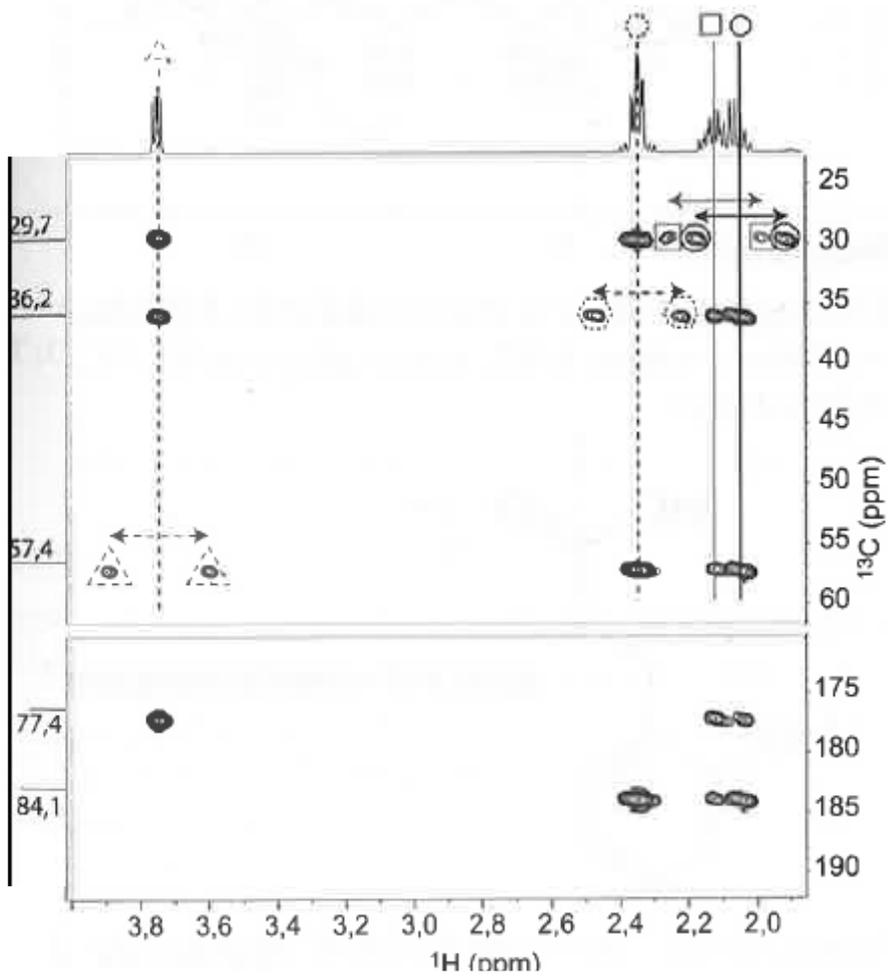
FILTRA GLI ACCOPPIAMENTI  $^1J_{\text{CH}}$

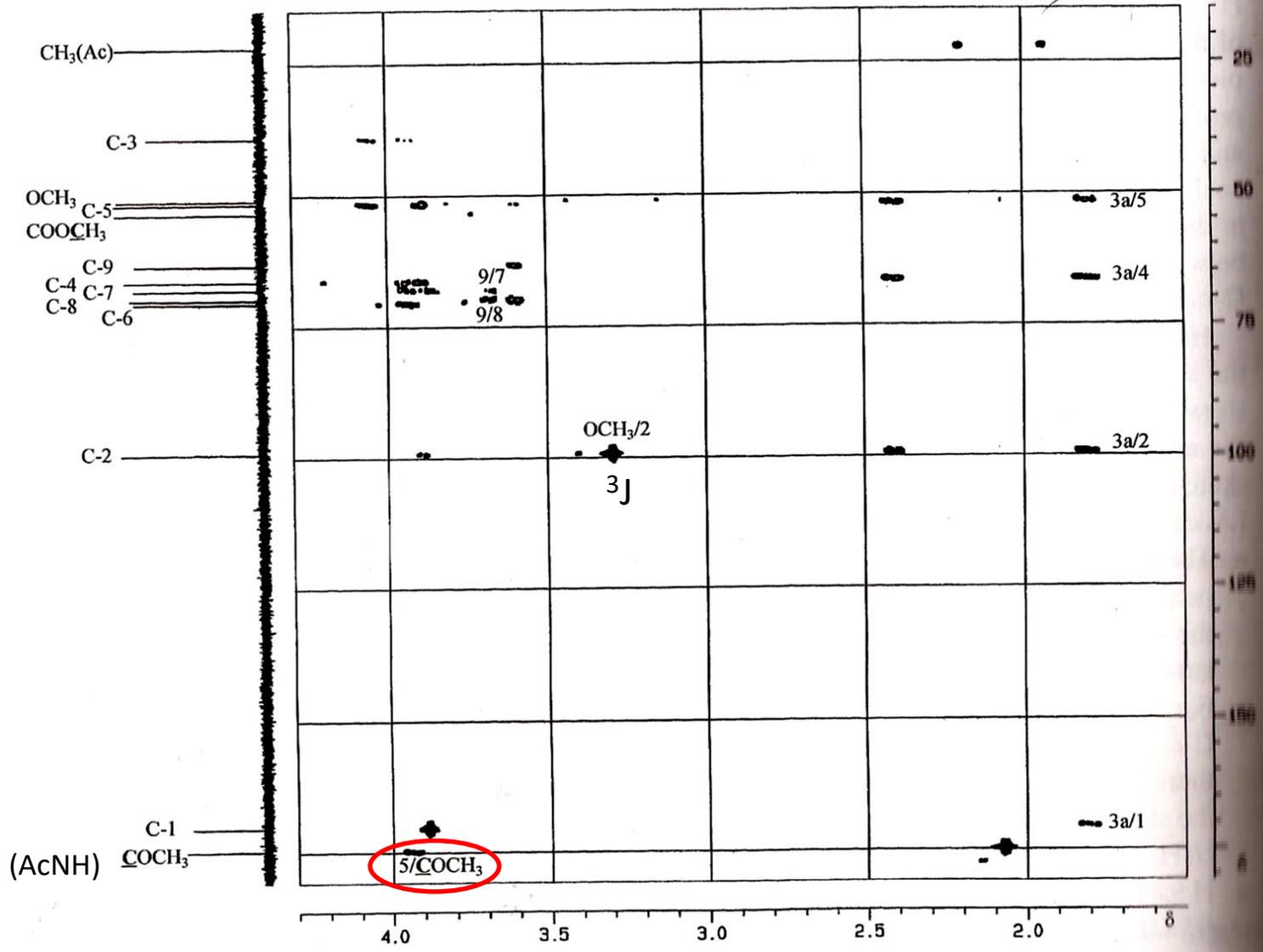
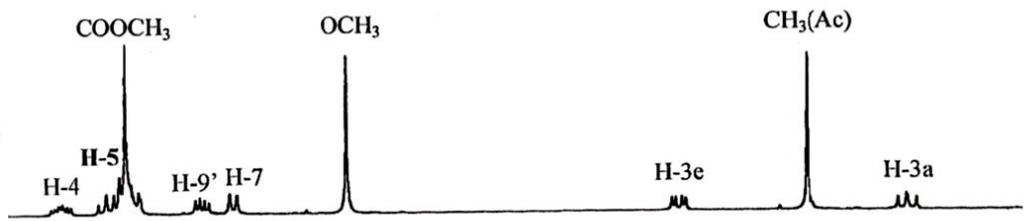
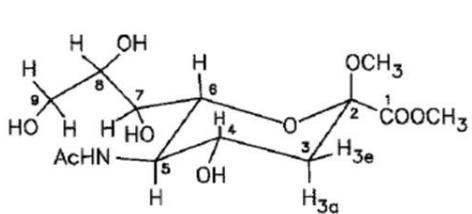
SI VEDONO GLI ACCOPPIAMENTI  $^2J_{\text{CH}}$  e  $^3J_{\text{CH}}$

# HMBC

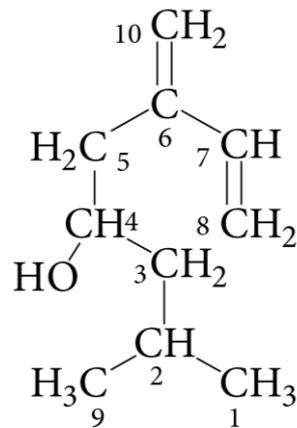
## Heteronuclear Multiple Bond Coherence







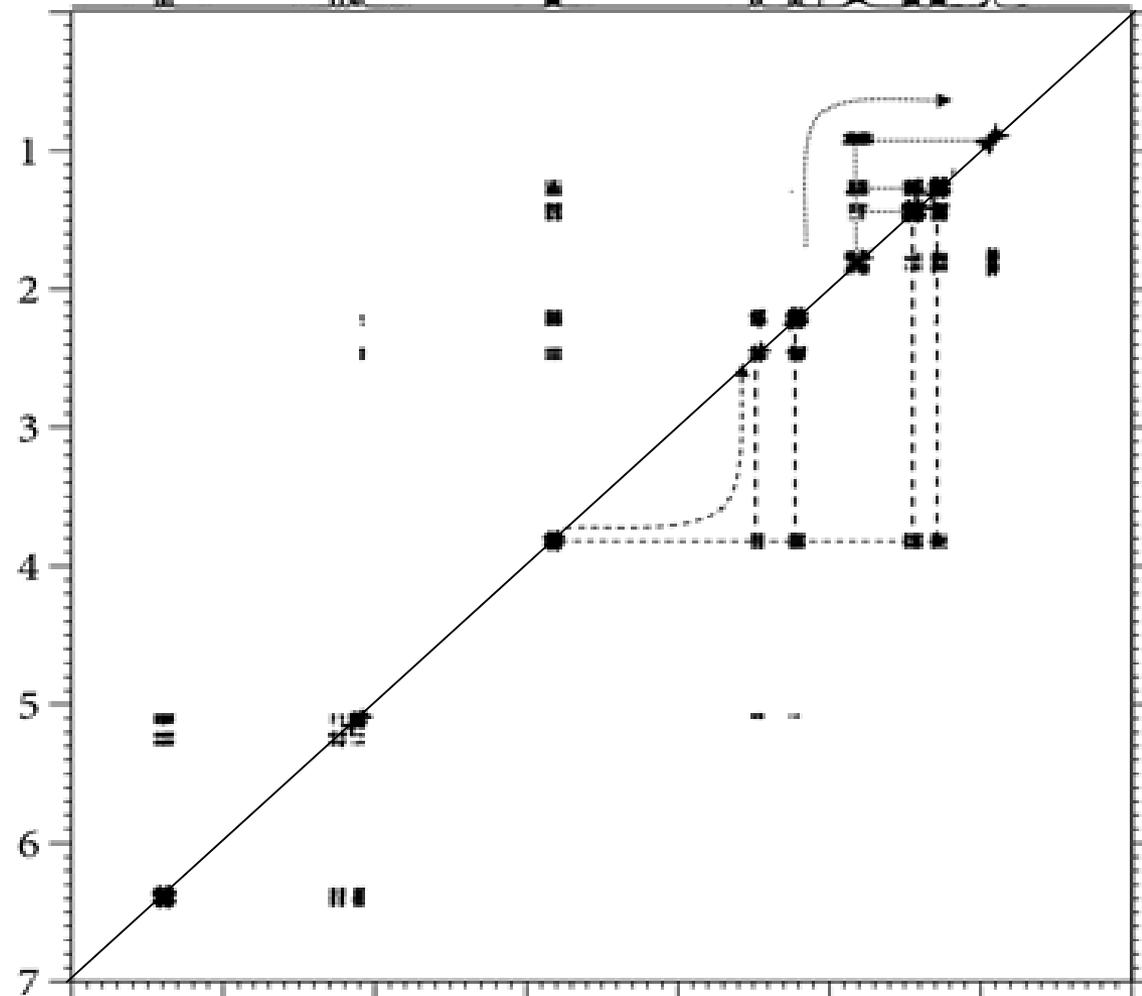
Esercizio: identificare i segnali dei =CH<sub>2</sub> nelle posizioni 8 e 10.



# Ipsenolo - COSY

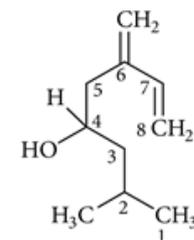
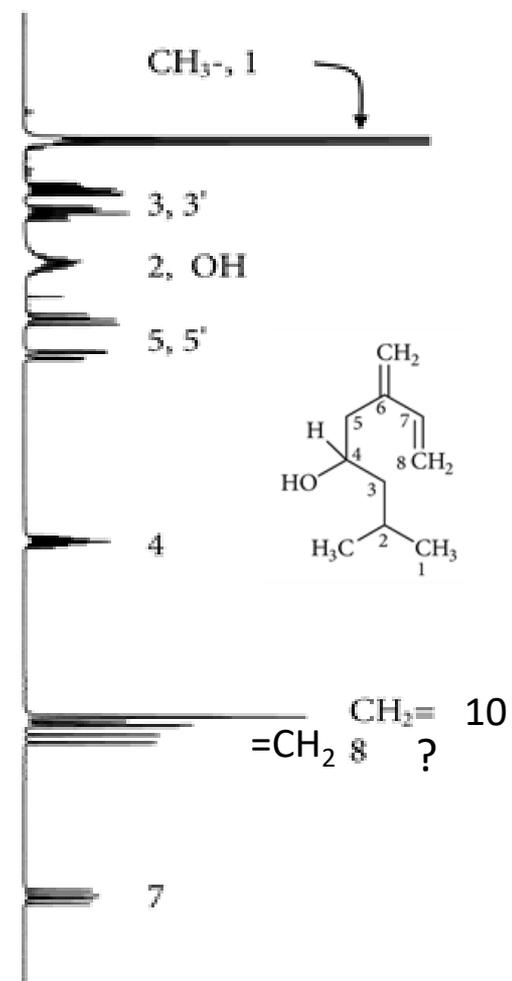
F2

ppm



F2

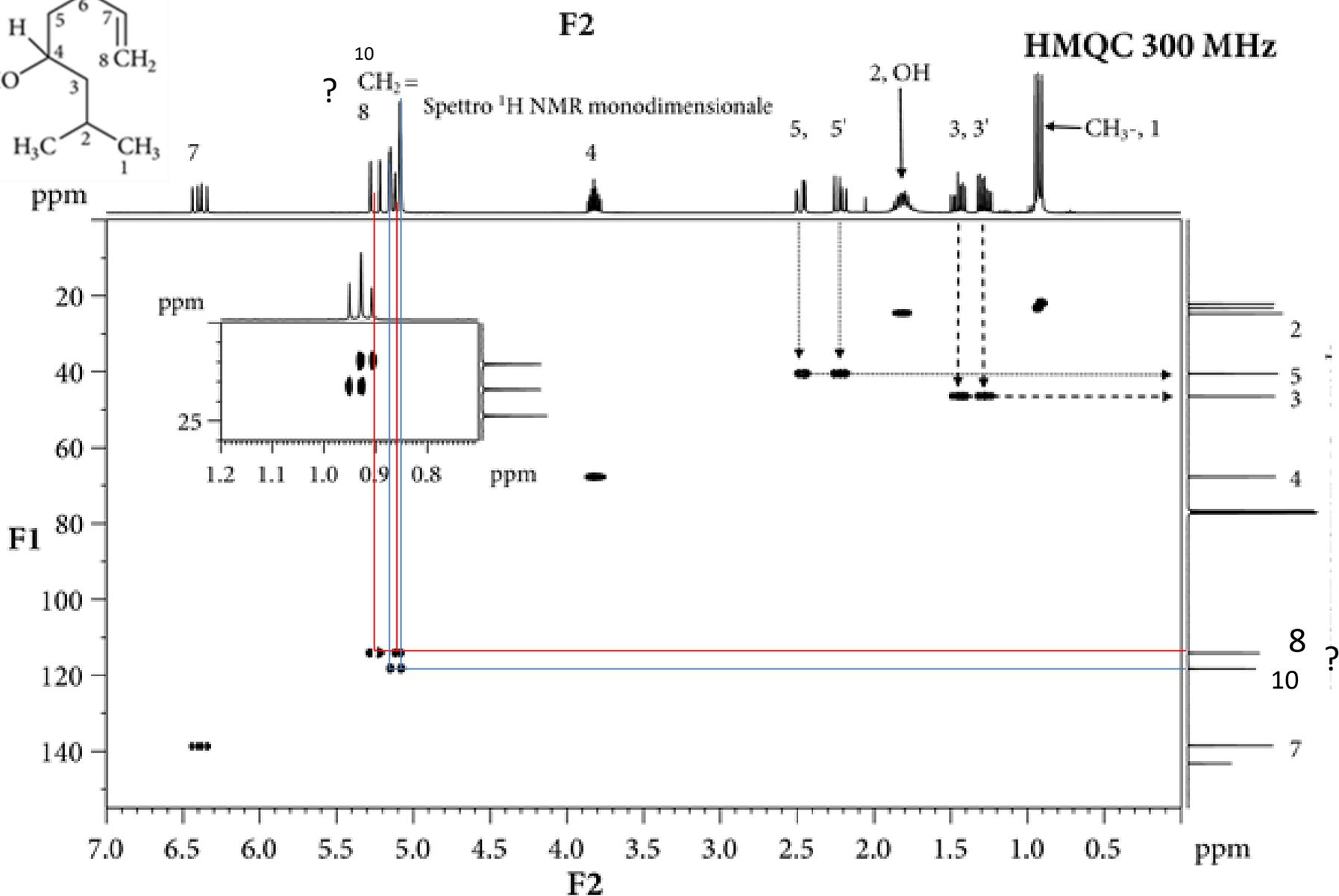
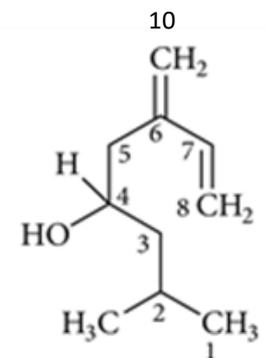
DQF-COSY 300 MHz



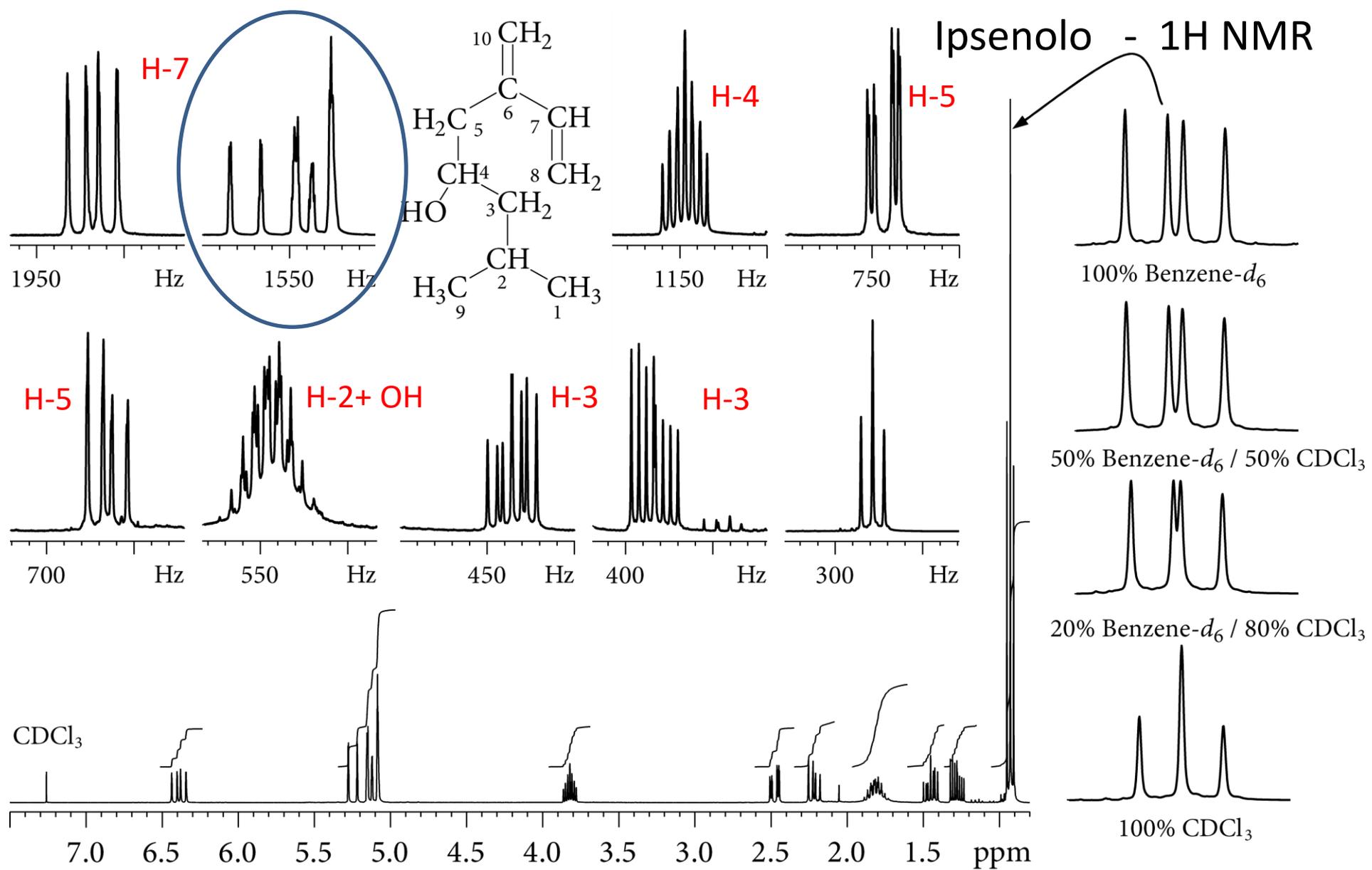
CH<sub>2</sub>= 10  
=CH<sub>2</sub> 8 ?

ppm

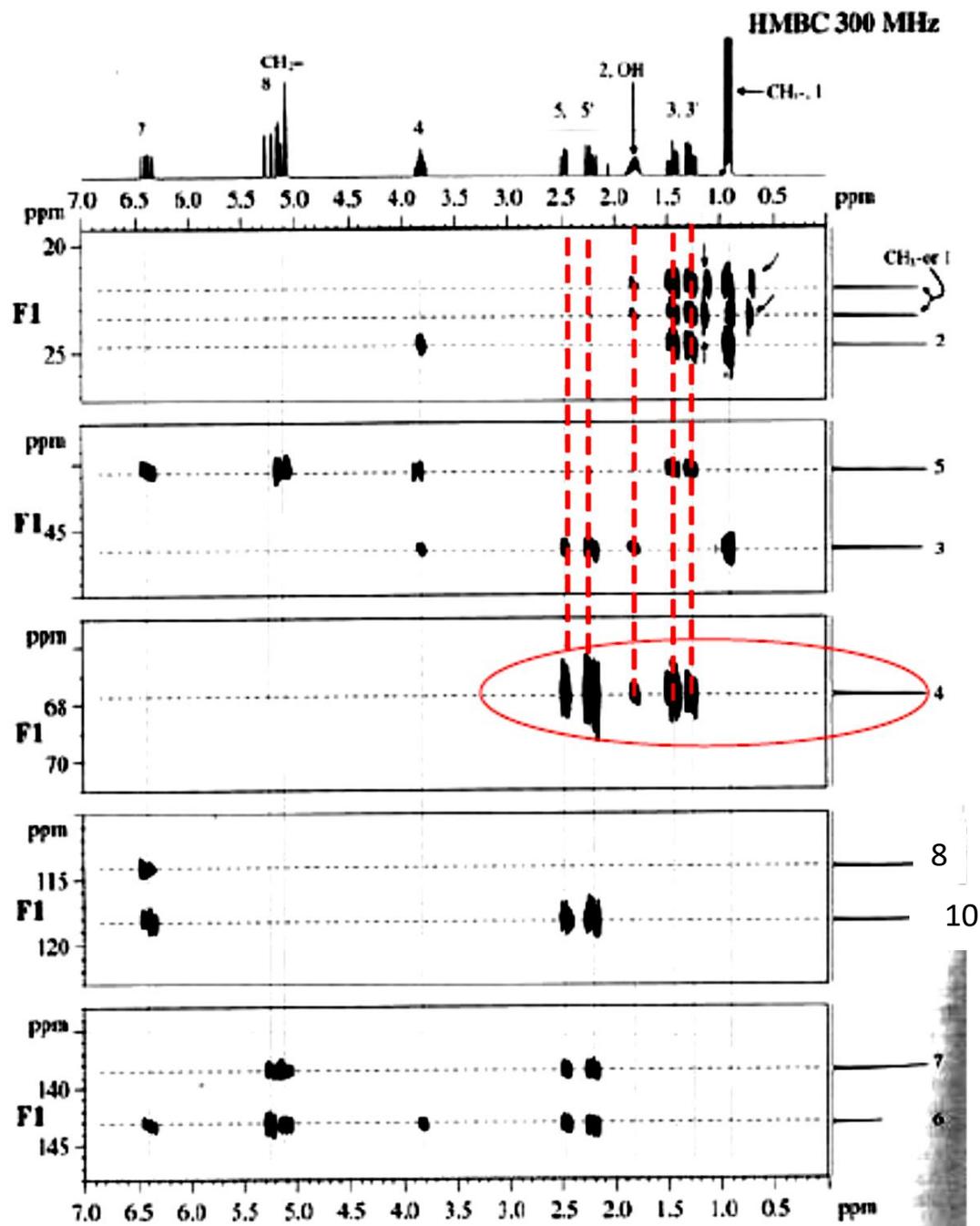
# Ipsenolo - HMQC



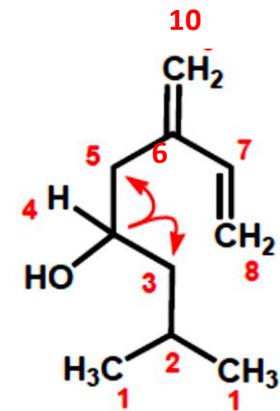
# Ipsenolo - 1H NMR



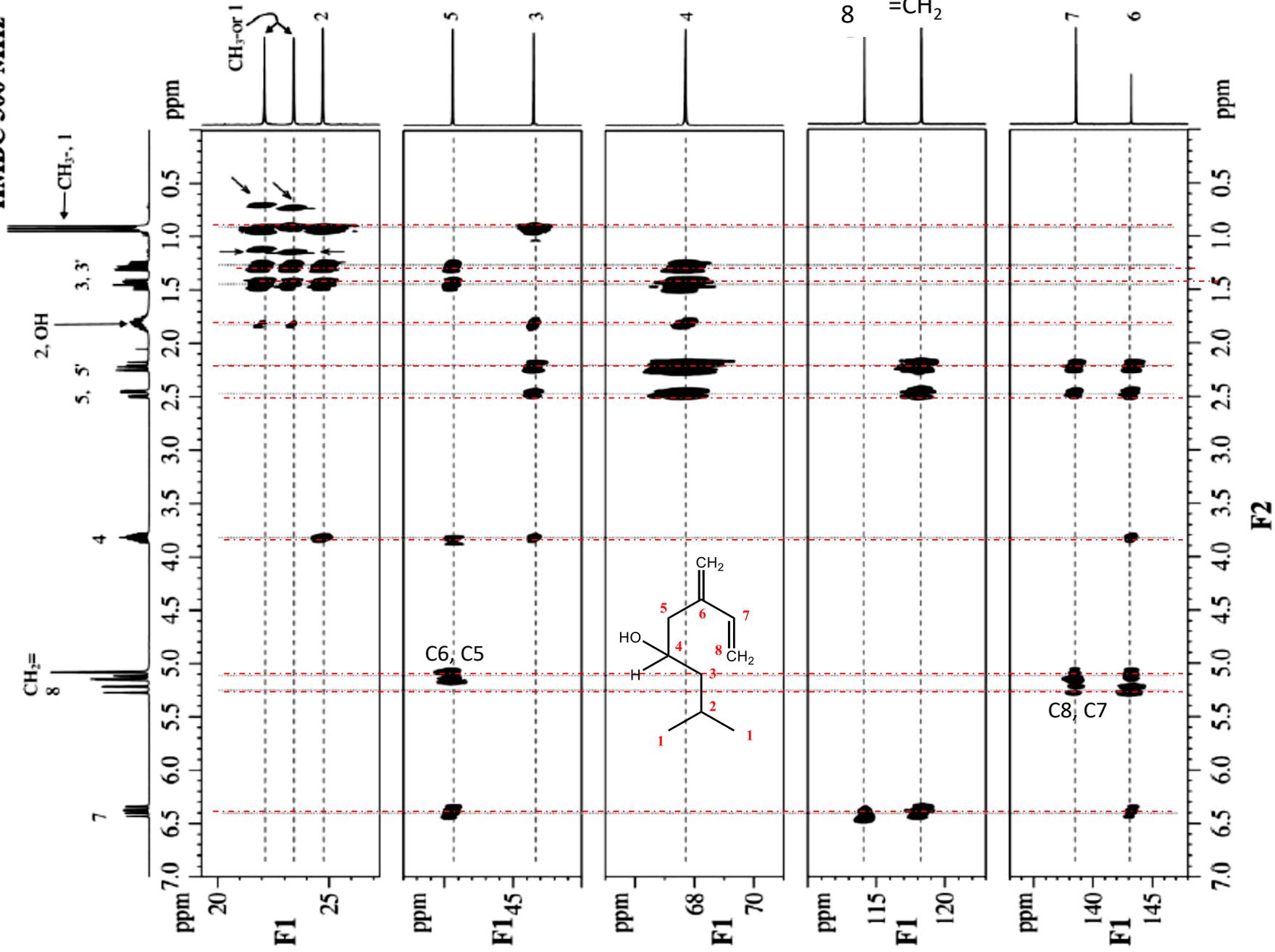
Spettro protonico NMR di 2-metil-6-metilen-7-otten-4-olo (ipesenolo) in CDCl<sub>3</sub> a 300 MHz ed effetto della titolazione con benzene-d<sub>6</sub>.



Non si osservano costanti dirette



# HMBC 300 MHz



# J RESOLVED NMR 2D

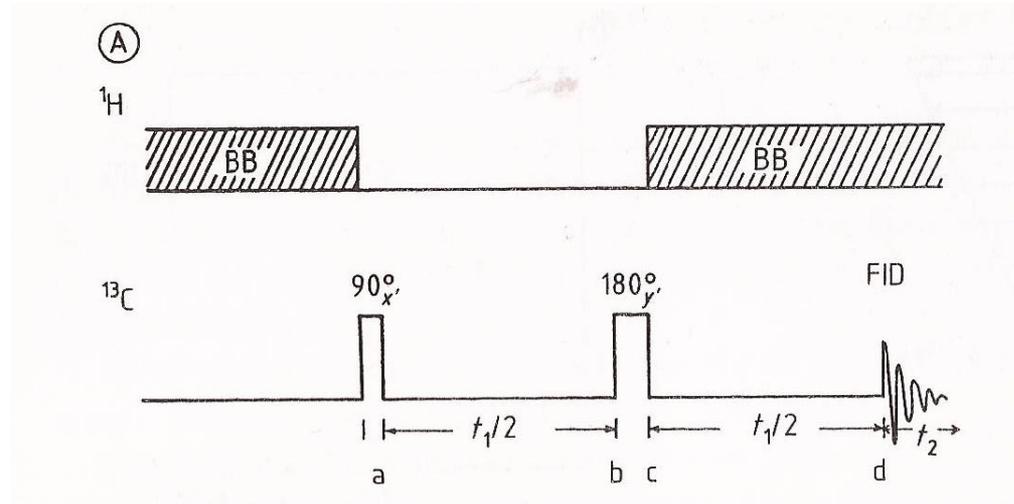
Gli esperimenti J resolved separano l'informazione del chemical shift ( $\nu_1$ ) da quella della  $J$  ( $\nu_2$ ) lungo le due dimensioni dello spettro consentendo l'assegnazione esatta di chemical shift e  $J$  di multipletti sovrapposti nello spettro 1D.

Versioni omo- ed eteronucleari

## 1. HETERONUCLEAR (C-H) J-RESOLVED 2D

Derivano dalla variazione periodica del segnale del  $^{13}\text{C}$  durante  $t_1$  ad opera della  $J_{\text{CH}}$  (frequenza di modulazione)

Si usa una sequenza uguale alla 1D J-MODULATED SPIN ECHO, con  $t_1$  variabile in maniera incrementale. Il decoupler è acceso ad intermittenza, in particolare viene spento durante la prima metà del  $t_1$ .



# J RESOLVED NMR 2D

Seconda trasformata di Fourier in  $t_1$  dà, per il sistema AX ( $\text{CHCl}_3$ ) due segnali separati da  $J/2$

La dimensione  $\nu_2$  contiene il  $^{13}\text{C}$  chemical shift

La dimensione  $\nu_1$  contiene le costanti di accoppiamento

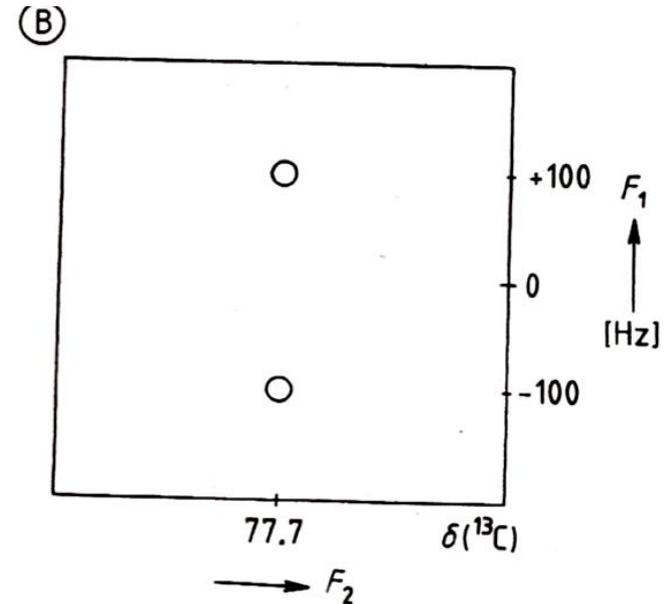
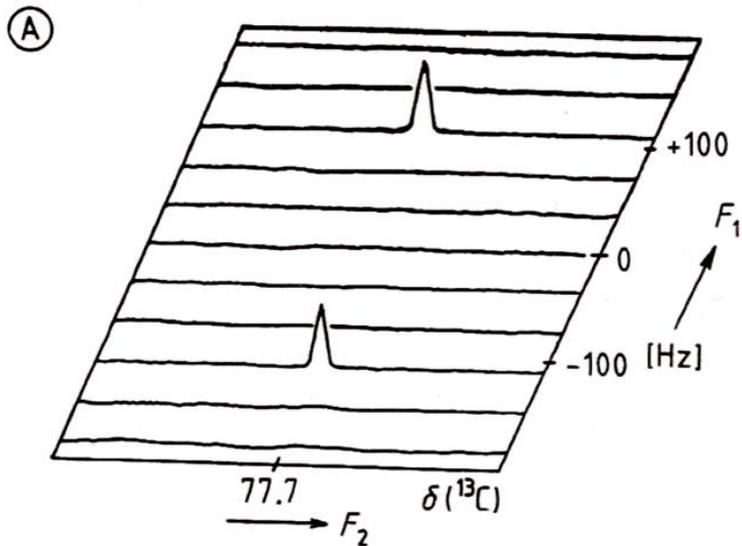
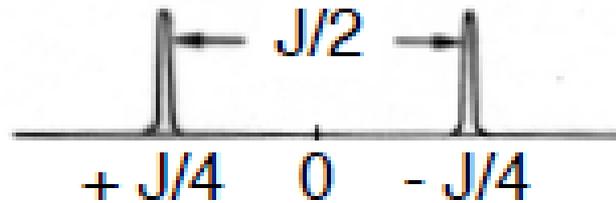
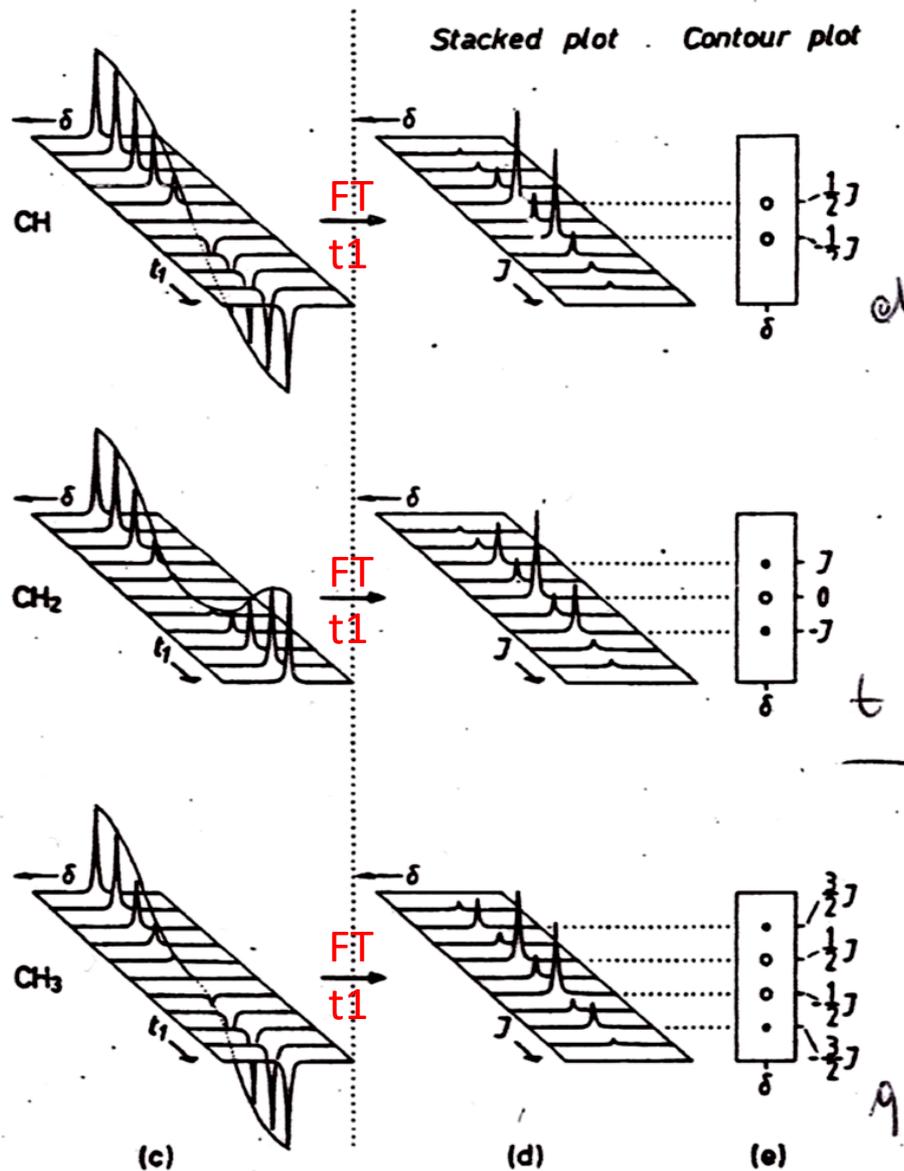
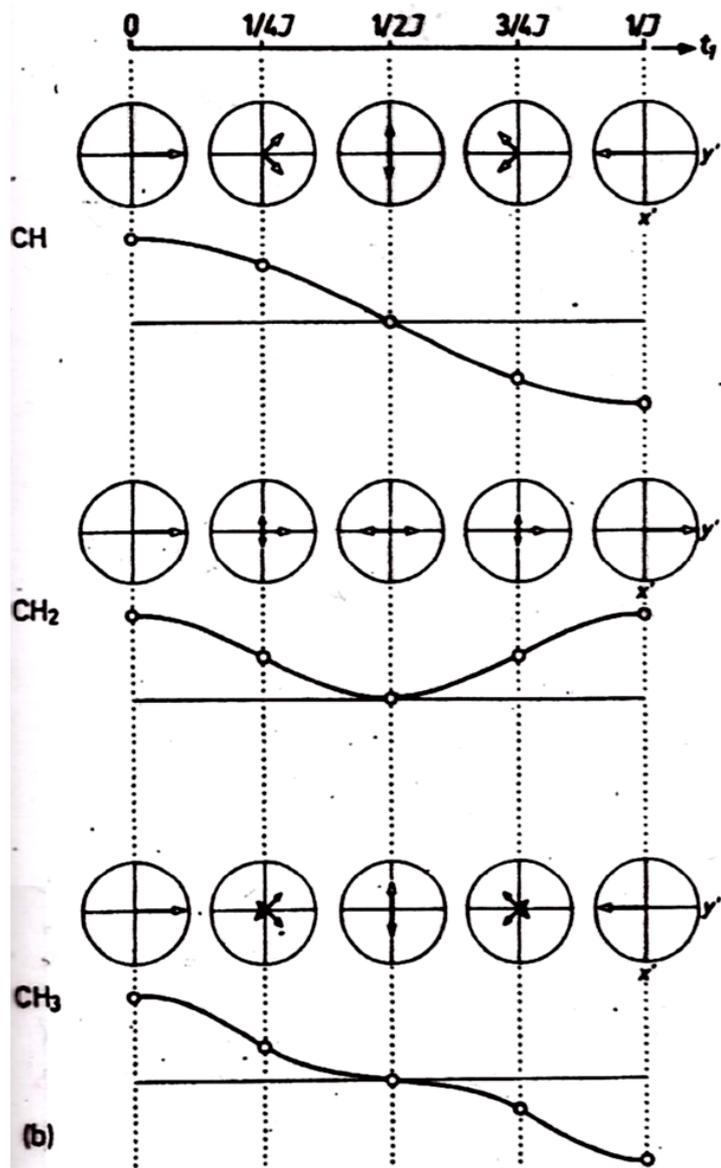
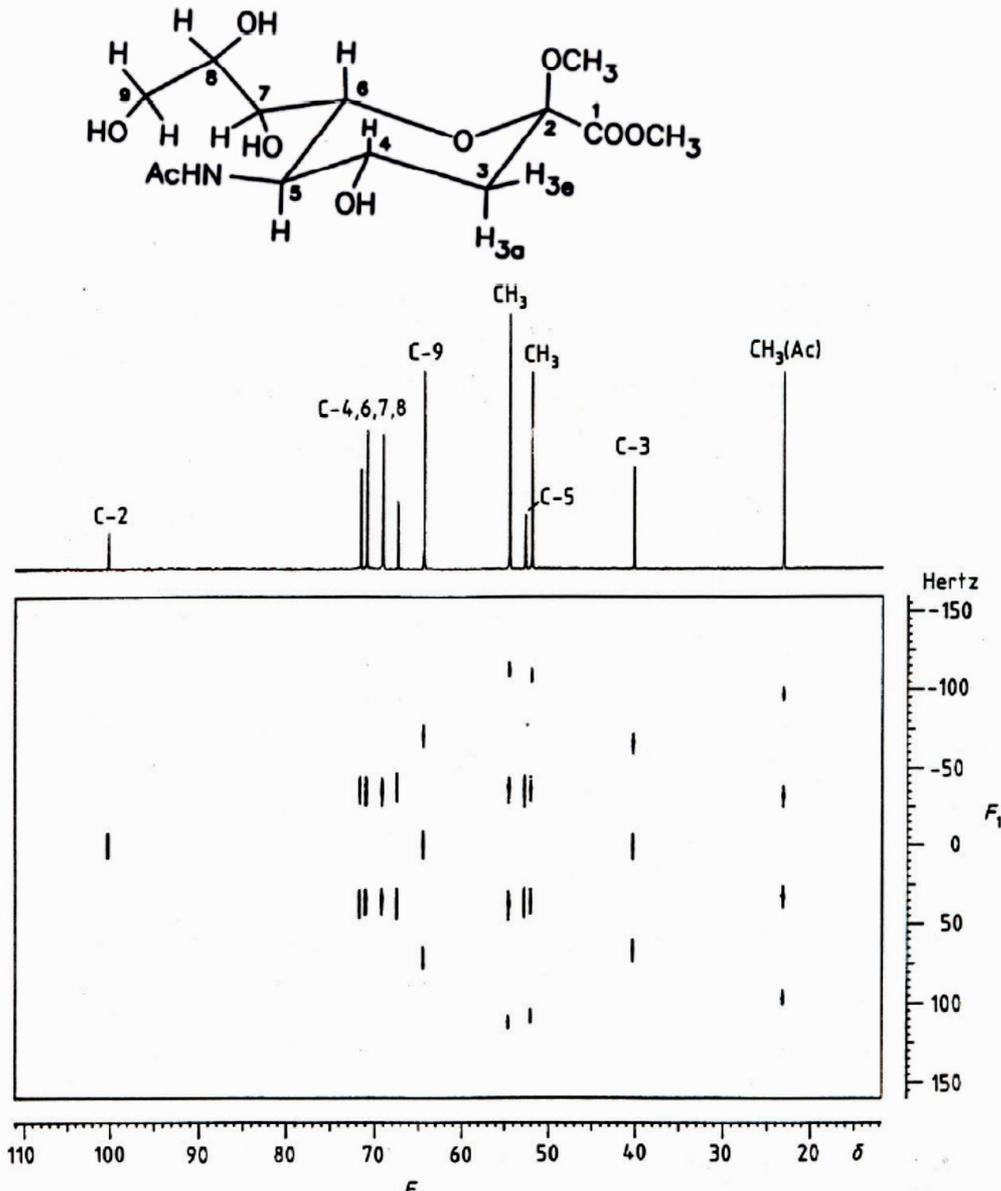


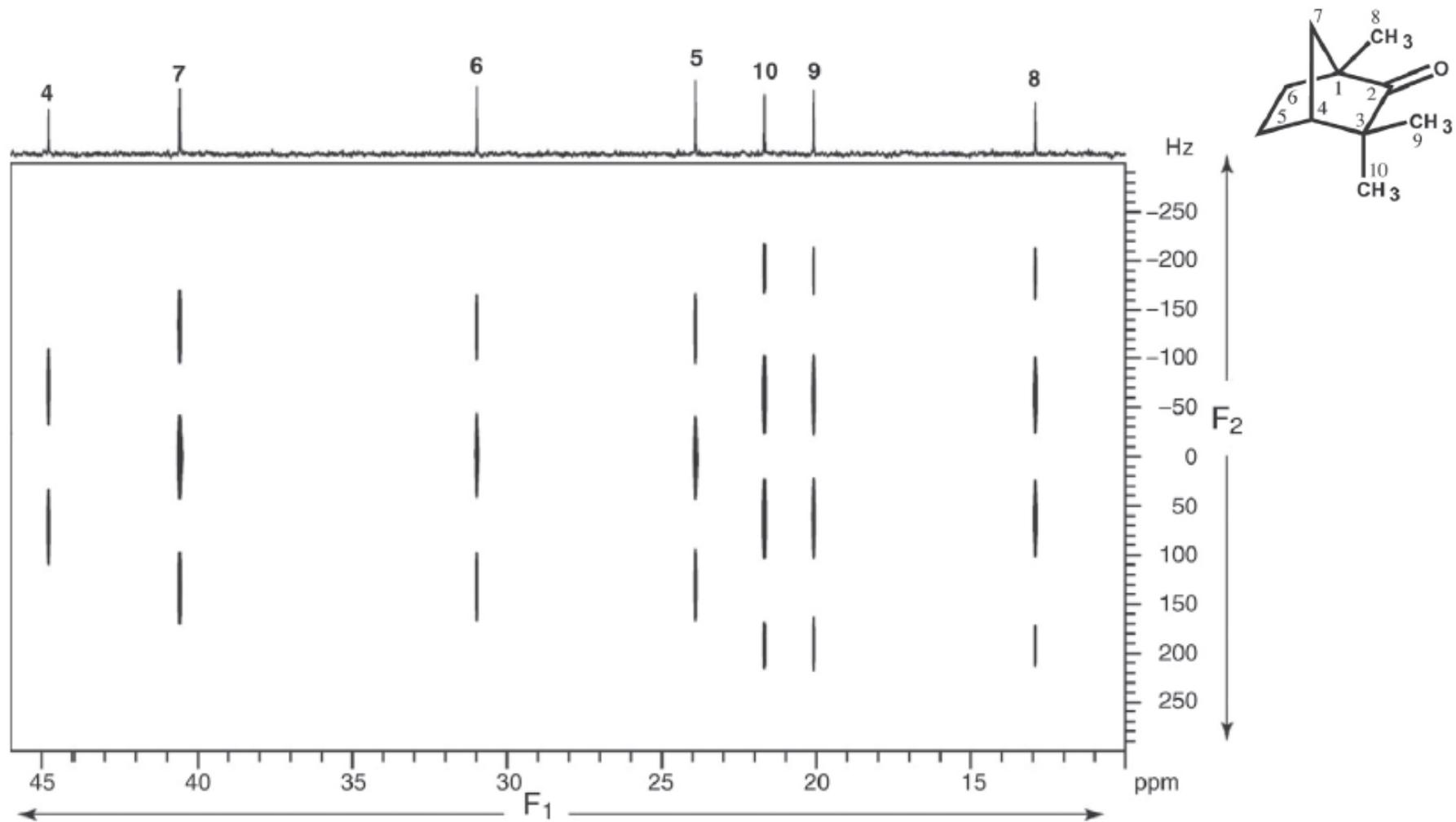
Figure 9-3.

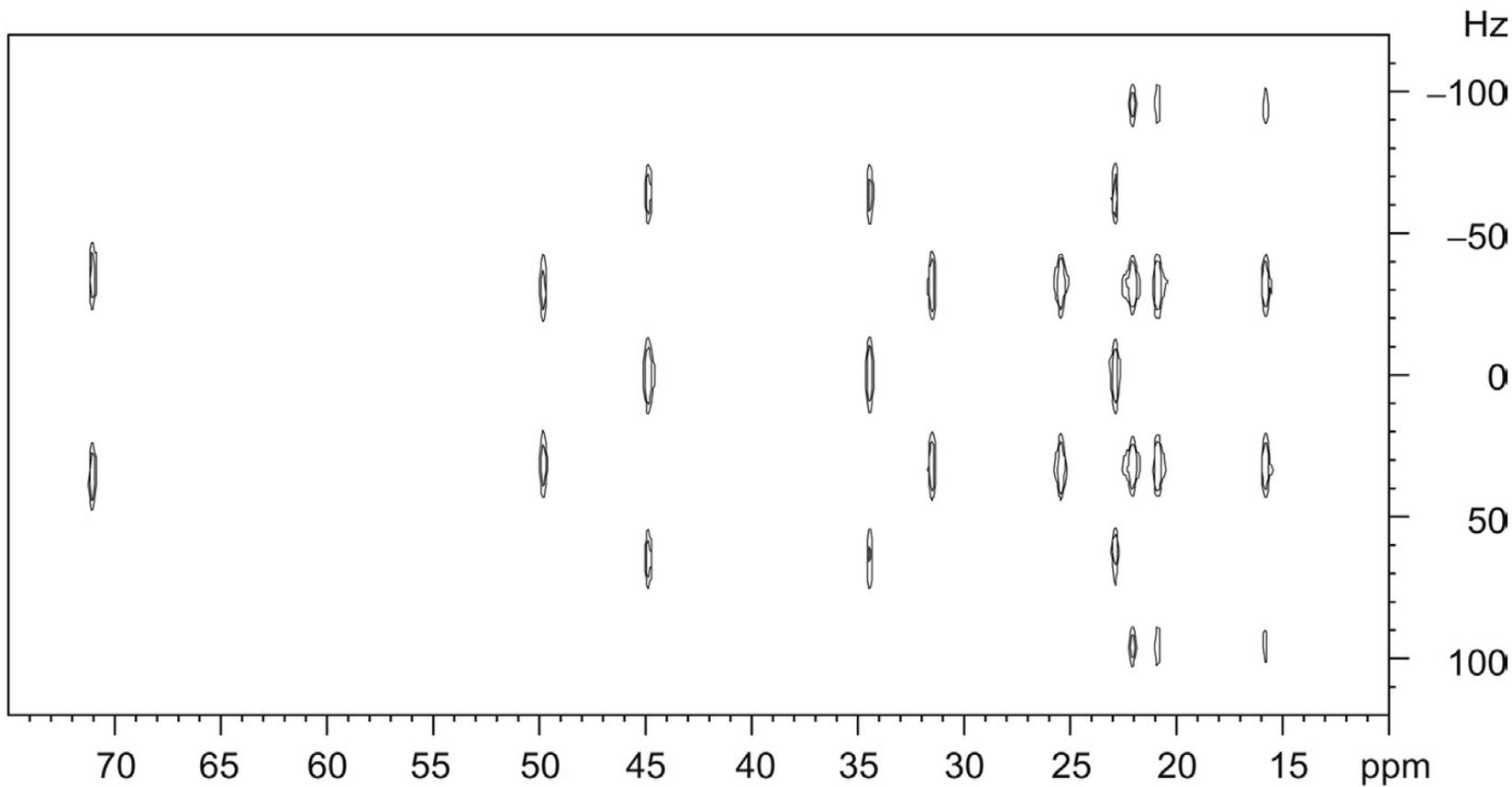
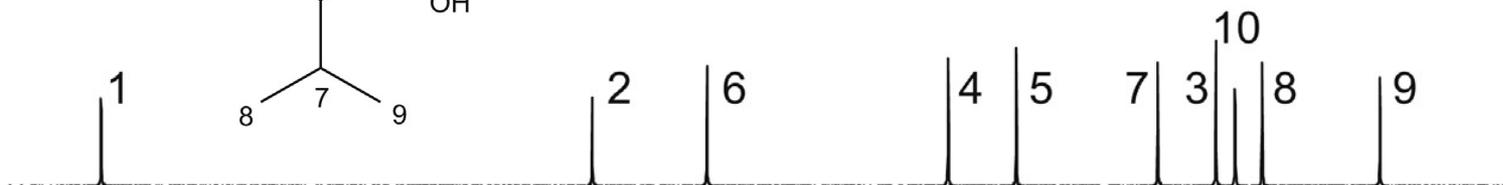
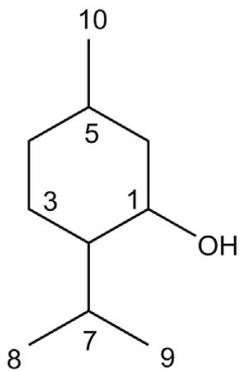
# EVOLUZIONE DEI MULTIPLETTI CH<sub>x</sub> SOTTO L'INFLUENZA DELLA J



# J RESOLVED NMR 2D



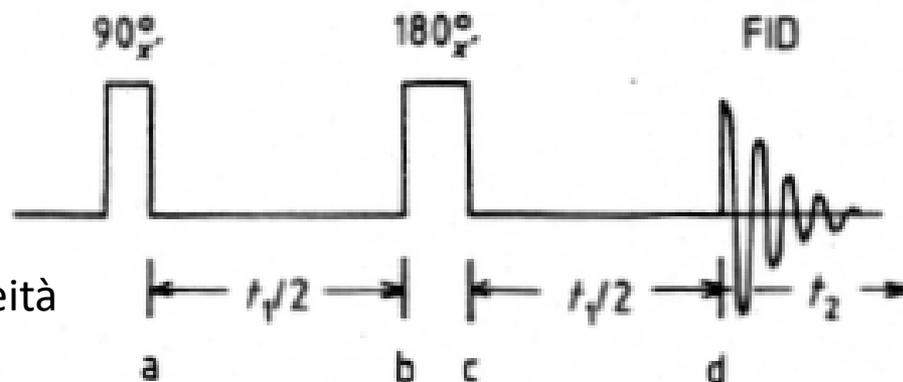




# J RESOLVED NMR 2D

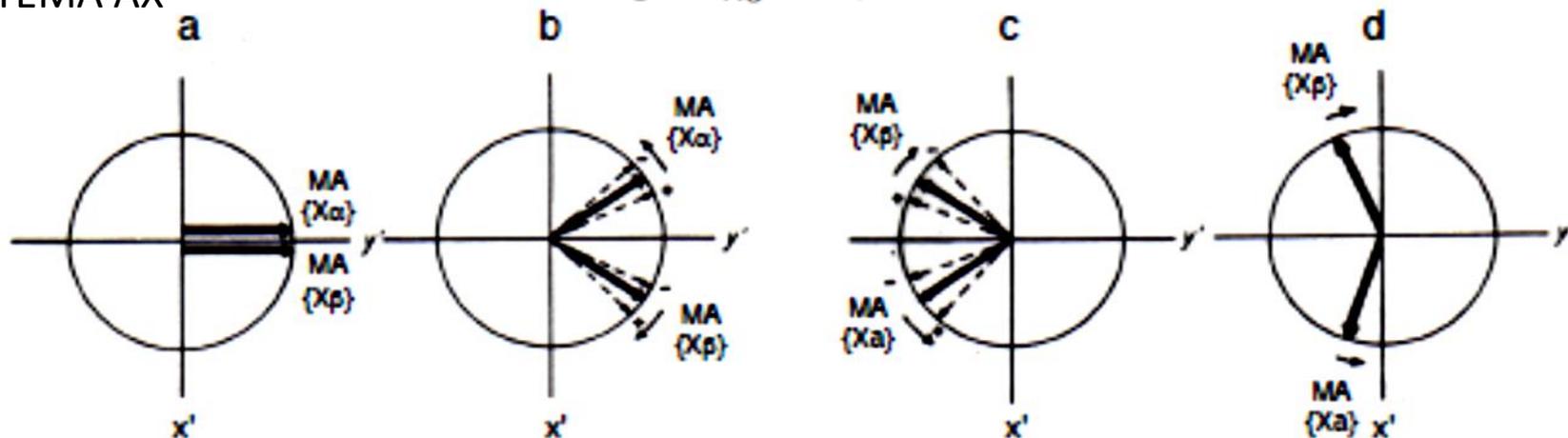
## 2. HOMONUCLEAR (HH) J-RESOLVED 2D

- Esperimento simile a J-MOD spin echo con  $t_1$  variabile
- Ovviamente non si può usare il BB
- Gli impulsi sono applicati su entrambi gli spin A e X
- J coupling evolvono durante entrambi i  $t_1/2$
- Evoluzione del chemical shift e le inomogeneità sono rifocalizzate con  $180^\circ$



SISTEMA AX

$$\Theta = 2\pi J_{AX} t_1$$



# J RESOLVED NMR 2D

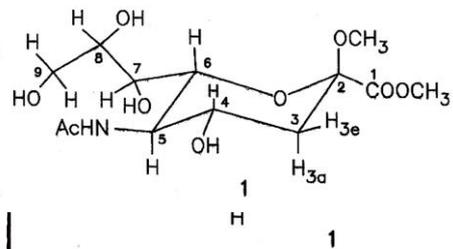
## 2. HOMONUCLEAR (HH) J-RESOLVED 2D

Per un sistema  $^1\text{H}$  AX:

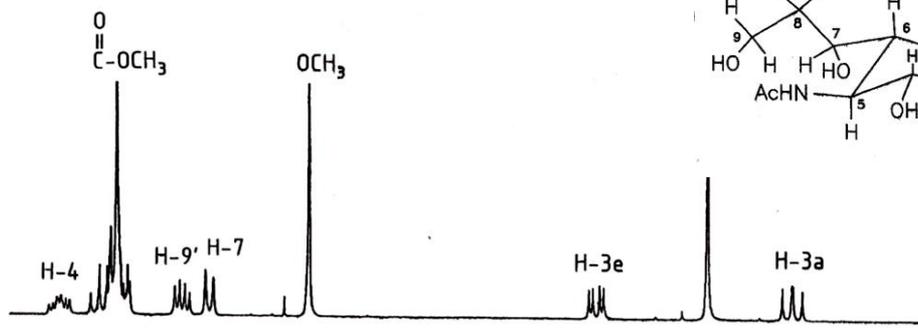
Il segnale nel receiver dipende dalla somma dei due vettori, che dipende da  $J_{AX}$ .

Dopo FT( $t_2$ ) otteniamo 1 picco in  $\nu_2$

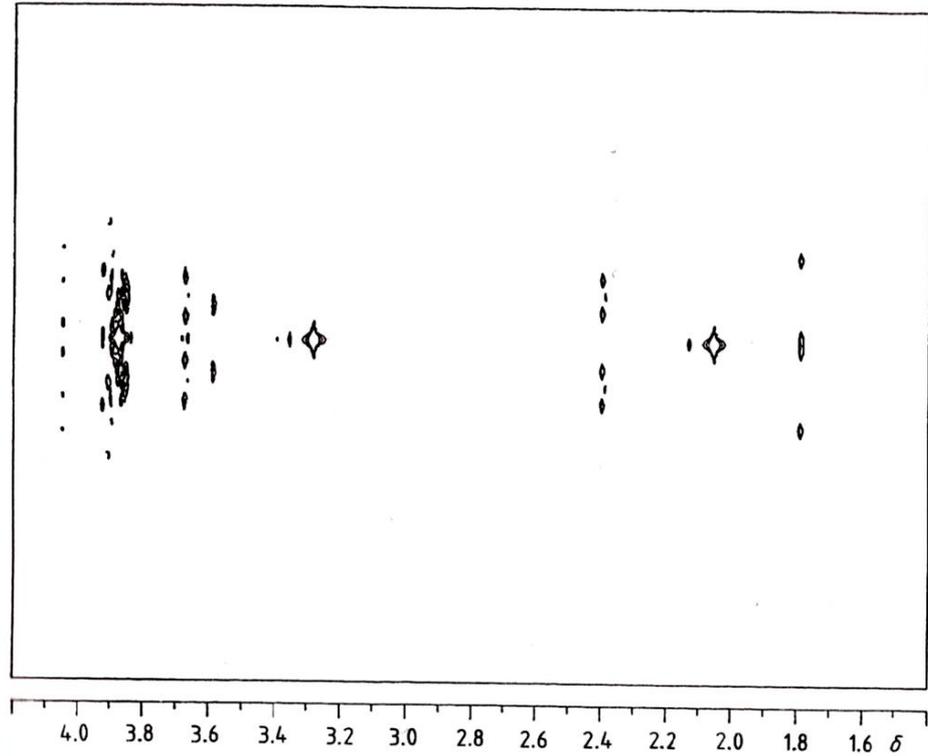
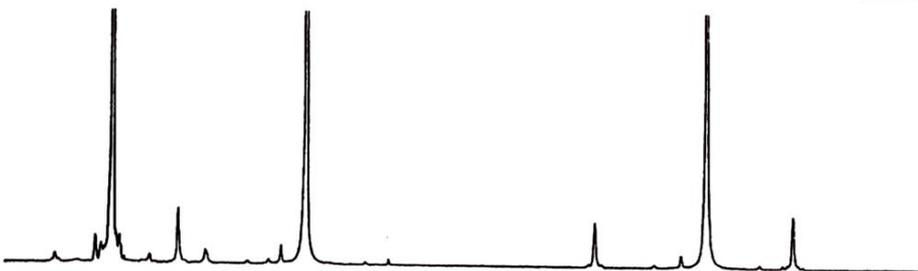
I segnali  $^1\text{H}$  NMR sono modulati da  $J_{AX}$  in  $t_1$ . Dopo FT( $t_1$ ) si osserva un doppietto in  $t_1$  con separazione  $J_{AX}$



B)



A)



J RESOLVED HH-2D

