

## **Supporting Information**

### **Site-Selective, Copper-Mediated *O*-Arylation of Carbohydrate Derivatives**

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## General Information

### Materials

Stainless steel needles and syringes were used to transfer air and moisture-sensitive liquids. Screw cap tubes were purchased from Pyrex® (13 mm x 100 mm, mfr. no. = Corning, 9825-13). Schlenk flasks were dried at 140 °C for at least 24 hours prior to use. Dichloromethane, toluene, acetonitrile, and tetrahydrofuran were HPLC grade and purified using a solvent purification system equipped with columns of activated alumina under nitrogen. (Innovative Technology, Inc.). Acetonitrile was dried further over activated 3 Å molecular sieves prior to use. Anhydrous dimethylformamide and methanol were purchased from Sigma Aldrich and used directly from the SureSeal bottle. 4 Å Powdered molecular sieves were stored for at least 24 hours at 140 °C prior to use. Phenylboronic acid was purchased from Sigma Aldrich and recrystallized from water and dried under high

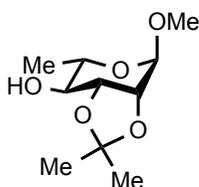
vacuum prior to use. Other reagents and solvents were used without further purification. Flash column chromatography was carried out using neutral silica gel (60 Å, 230–400 mesh, Silicycle). Analytical thin layer chromatography was carried out using aluminum-backed silica gel 60 F<sub>254</sub> plates (EMD), and compounds were visualized through the use of UV light and aqueous basic KMnO<sub>4</sub> stain.

### **Instrumentation**

<sup>1</sup>H and <sup>13</sup>C NMR and 2D NMR spectra were recorded using a Bruker Avance III (400 MHz), Varian Mercury 400 (400 MHz) or Agilent DD2-500 (500 MHz) spectrometer equipped with a XSENS cryoprobe. <sup>1</sup>H NMR are reported in parts per million (ppm) relative to tetramethylsilane and referenced to residual protium in the solvent. Spectral features are tabulated in the following order: chemical shift ( $\delta$ , ppm); multiplicity (s-singlet, d-doublet, t-triplet, q-quartet, m-complex multiplet); number of protons; coupling constant(s) ( $J$ , Hz); assignment. Assignments were made on the basis of coupling constants and 2D NMR spectra. High-resolution mass spectra (HRMS) were obtained on a JEOL AccuTOF JMS-T1000LC mass spectrometer equipped with a DART (direct analysis in real time) ion source. Infrared (IR) spectra were obtained on a Perkin-Elmer Spectrum 100 instrument equipped with a single-bounce diamond/ZnSe ATR accessory as neat samples, or as thin film from CH<sub>2</sub>Cl<sub>2</sub> as indicated. Spectral features are tabulated as follows: wavenumber (cm<sup>-1</sup>); intensity (s-strong, m-medium, w-weak). Specific rotations were measured with a Rudolph Autopol IV digital polarimeter equipped with a sodium lamp source (589 nm) and concentration ( $c$ ) is reported in g/100 mL.

### Preparation of Carbohydrate Substrates

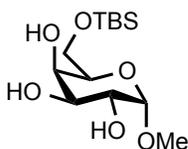
#### **4a – Methyl 2,3-*O*-isopropylidene- $\alpha$ -L rhamnopyranoside**



Prepared from methyl  $\alpha$ -L rhamnopyranoside as previously reported.<sup>1</sup>

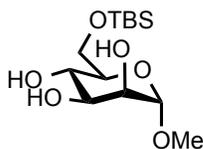
<sup>1</sup>H NMR (400 MHz, CD<sub>3</sub>CN):  $\delta$  (ppm) = 4.79 (d,  $J$  = 0.7 Hz, 1H), 4.06 (dd,  $J$  = 5.7, 0.7 Hz, 1H), 3.88 (dd,  $J$  = 7.5, 5.6 Hz, 1H), 3.52–3.42 (m, 1H), 3.32 (s, 3H), 3.24–3.16 (m, 1H), 1.45 (s, 3H), 1.30 (s, 3H), 1.19 (d,  $J$  = 6.3 Hz, 3H).

#### **1d – Methyl 6-*O*-*tert*-butyldimethylsilyl- $\alpha$ -D-galactopyranoside**



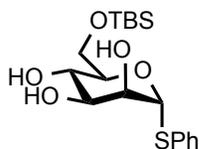
Prepared from methyl  $\alpha$ -D-galactopyranoside as previously reported.<sup>2</sup>

<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>):  $\delta$  (ppm) = 4.82 (d,  $J$  = 3.9 Hz, 1H), 4.10 (dd,  $J$  = 2.3, 2.3 Hz, 1H), 3.95–3.80 (m, 3H), 3.79–3.69 (m, 2H), 3.42 (s,  $J$  = 0.8 Hz, 3H), 3.09 (d,  $J$  = 2.3 Hz, 1H), 2.65 (d,  $J$  = 5.6 Hz, 1H), 2.09 (d,  $J$  = 9.4 Hz, 1H), 0.90 (s, 9H), 0.10 (d,  $J$  = 0.6 Hz, 6H).

**1e – Methyl 6-O-tert-butyldimethylsilyl- $\alpha$ -D-mannopyranoside**

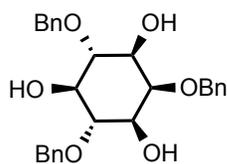
Prepared from methyl  $\alpha$ -D-mannopyranoside as previously reported.<sup>3</sup>

**$^1\text{H NMR}$**  (500 MHz,  $\text{CDCl}_3$ ):  $\delta$  (ppm) = 4.72 (d,  $J$  = 1.7 Hz, 1H), 3.95–3.91 (m, 2H), 3.87–3.76 (m, 3H), 3.59 (ddd,  $J$  = 9.0, 6.5, 4.9 Hz, 1H), 3.38 (s, 3H), 3.28 (s, 1H), 2.65 (s, 1H), 2.37 (s, 1H), 0.91 (s, 9H), 0.11 (s, 3H), 0.11 (s, 3H).

**1f – Phenyl 6-O-tert-butyldimethylsilyl- $\alpha$ -D-thiomannopyranoside**

Prepared from  $\alpha$ -D-thiomannopyranoside as previously reported.<sup>4</sup>

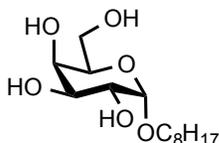
**$^1\text{H NMR}$**  (500 MHz,  $\text{CDCl}_3$ ):  $\delta$  (ppm) = 7.48–7.45 (m, 2H), 7.33–7.26 (m, 3H), 5.54 (dd,  $J$  = 1.5, 0.6 Hz, 1H), 4.21 (d,  $J$  = 2.6 Hz, 1H), 4.16 – 4.09 (m, 1H), 3.93 – 3.87 (m, 3H), 3.84 (dd,  $J$  = 10.3, 6.7 Hz, 1H), 3.37 (br s, 1H), 2.76 (br s, 1H), 2.61 (d,  $J$  = 3.6 Hz, 1H), 0.91 (s, 9H), 0.10 (s, 3H), 0.10 (s, 3H).

**1j – 2,4,6-Tri-O-Bn-*myo*-inositol**

Prepared from *myo*-inositol as previously reported.<sup>5</sup>

$^1\text{H NMR}$  (400 MHz,  $\text{CD}_3\text{OD}$ ):  $\delta$  (ppm) = 7.49–7.41 (m, 6H), 7.37–7.29 (m, 6H), 7.28–7.22 (m, 3H), 4.90 (s, 2H), 4.87 (d,  $J = 4.4$  Hz, 4H), 3.90 (dd,  $J = 2.6, 2.6$  Hz, 1H), 3.70 (dd,  $J = 9.8, 9.1$  Hz, 2H), 3.58 (dd,  $J = 9.8, 2.6$  Hz, 2H), 3.49 (dd,  $J = 9.1, 9.1$  Hz, 1H).

### 1m – Octyl $\alpha$ -D-galactopyranoside



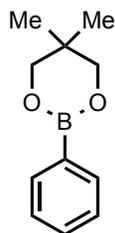
Phenylboronic acid (2 mmol, 1 equiv.),  $\alpha$ -D-galactopyranoside (2 mmol, 1 equiv.) and (1S)-(+)-10-camphorsulphonic acid (0.5 mmol, 0.25 equiv.) were combined in a 50 mL oven-dried round-bottom flask. Anhydrous 1,2-dichloroethane (0.2 M) and *n*-octanol (10 mmol, 5 equiv.) were added to the flask and the reaction mixture was stirred at 80 °C for 24 hours. The reaction mixture was concentrated and then dissolved in a minimum amount of diethyl ether, and then hand shaken vigorously in a separatory funnel with a sorbitol:  $\text{Na}_2\text{CO}_3$  (1M: 1M) solution (100 mL  $\times$  2). The combined aqueous extracts were back-extracted three times with diethyl ether. The combined organic phase was dried over  $\text{MgSO}_4$ , filtered and then concentrated under reduced pressure. The crude material was then acylated with pyridine (10 mL) and acetic anhydride (10 mL) at room temperature for 16 h. The anomers were separated following subjection of the crude reaction mixture to flash chromatography on silica gel (10% to 25% ethyl acetate in hexanes). The  $\alpha$  anomer was deprotected via vigorous stirring with sodium methoxide (0.8 equiv.) in anhydrous methanol (0.1 M) at room temperature under argon for three hours. The reaction was quenched with acid resin, which was then removed by filtration. The titled compound was obtained following concentration under reduced pressure as an amorphous white solid.<sup>6</sup>

$^1\text{H NMR}$  (500 MHz,  $\text{CDCl}_3$ ):  $\delta$  (ppm) = 4.95 (d,  $J$  = 3.8 Hz, 1H), 4.10 (d,  $J$  = 3.3 Hz, 1H), 3.95 (dd,  $J$  = 11.7, 5.2 Hz, 1H), 3.89–3.80 (m, 3H), 3.77 (dd,  $J$  = 9.7, 3.3 Hz, 1H), 3.75–3.68 (m, 1H), 3.51–3.41 (m, 1H), 1.65–1.54 (m, 2H), 1.37–1.21 (m, 10H), 0.92–0.85 (m, 3H).

$^{13}\text{C NMR}$  (126 MHz,  $\text{CDCl}_3$ ):  $\delta$  (ppm) = 98.5, 71.4, 70.6, 69.7, 69.6, 68.7, 63.4, 32.0, 29.6, 29.5, 29.4, 26.3, 22.8, 14.2.

### Preparation of Boronic Esters

#### **2a – 5,5-dimethyl-2-phenyl-1,3,2-dioxaborinane**



Phenylboronic acid (243.9 mg, 2 mmol), neopentyl glycol (208.3 mg, 2 mmol) and toluene (5 mL) were combined in a screw-cap tube. The reaction was heated to reflux for 16 hours and then concentrated under reduced pressure. The resulting material was dried by azeotropic removal of water with small amounts of toluene (0.5 mL  $\times$  3). Spectral features are in agreement with those previously reported.<sup>7</sup>

$^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  (ppm) = 7.83–7.76 (m, 2H), 7.46–7.39 (m, 1H), 7.38–7.32 (m, 2H), 3.77 (s, 4H), 1.03 (s, 6H).

#### **General Procedure A for synthesis of carbohydrate derived boronic esters**

Carbohydrate (0.2 mmol), boronic acid (0.2 mmol) and toluene (2 mL) were combined in a 2 dram vial equipped with a magnetic stir bar. The reaction was heated to reflux for 16 hours and then concentrated under reduced pressure. The resulting material was dried by

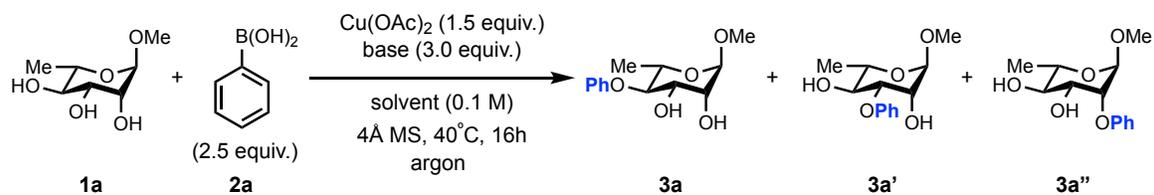
azeotropic removal of water with small amounts of toluene (0.5 mL  $\times$  3). The boronic ester was then dried further under vacuum for at least 6 hours and then used immediately.

### Site-Selective *O*-Arylations

#### **Optimization Procedure**

Methyl  $\alpha$ -L rhamnopyranoside (17.8 mg, 0.1 mmol, 1 equiv.), phenylboronic acid (30.5 mg, 0.25 mmol, 2.5 equiv.), Cu(OAc)<sub>2</sub> (27.2 mg, 0.15 mmol, 1.5 equiv.) and oven dried 4Å MS (30 mg) were combined in a 25 mL Schlenk flask equipped with a magnetic stir bar. The flask was then evacuated and backfilled with argon three times. Solvent and base were added sequentially and the reaction was stirred for 16 h at 40 °C. The mixture was then cooled, filtered through Celite, concentrated under reduced pressure, and then dissolved in ethyl acetate. The crude residue was transferred to a separatory funnel and hand shaken vigorously with a sorbitol: Na<sub>2</sub>CO<sub>3</sub> (1M: 1M) solution for 5 minutes (25 mL  $\times$  2). The combined aqueous extracts were back-extracted with EtOAc, and the organic phase was dried over MgSO<sub>4</sub>. Following concentration, the crude residue was subject to silica gel chromatography to afford the titled compounds. The regioselectivity of each reaction was determined by analysis of the crude <sup>1</sup>H NMR spectrum.

**Table S1: Optimization of Reaction Conditions for *O*-arylation of Carbohydrate 1a with Boronic Acid 2a**



Entry	Solvent	Base	NMR yield <sup>a</sup>	3a: 3a': 3a'' <sup>b</sup>	Bis-arylation <sup>c</sup>
1 <sup>d</sup>	CH <sub>3</sub> CN	<i>i</i> Pr <sub>2</sub> NEt	48 %	7.1: 1.3: 1	5 %
2 <sup>d</sup>	DCM	<i>i</i> Pr <sub>2</sub> NEt	25 %	19: 1: 2	<5 %
3 <sup>d</sup>	PhMe	<i>i</i> Pr <sub>2</sub> NEt	<5 %	-	<5 %
4 <sup>d</sup>	THF	<i>i</i> Pr <sub>2</sub> NEt	<5 %	-	<5 %
5 <sup>d</sup>	DMF	<i>i</i> Pr <sub>2</sub> NEt	24 %	5.7: 1: 1.2	<5 %
6	CH <sub>3</sub> CN	<i>i</i> Pr <sub>2</sub> NEt	71 %	10: 2.3: 1	19 %
7	CH <sub>3</sub> CN	NEt <sub>3</sub>	63 %	4.3: 1.2: 1	9 %
8	CH <sub>3</sub> CN	Pyridine	40%	2.1: 1.4: 1	5 %
9	CH <sub>3</sub> CN	PMP	73 %	5.6: 3.5: 1	11 %
10	CH <sub>3</sub> CN	Proton-sponge	77 %	9.4: 4.9: 1	24 %
11 <sup>e</sup>	CH <sub>3</sub> CN	<i>i</i> Pr <sub>2</sub> NEt	37 %	4.7: 1.4: 1	6 %
12 <sup>f</sup>	CH <sub>3</sub> CN	<i>i</i> Pr <sub>2</sub> NEt	(72 %) <sup>g</sup>	>20: 1: 0.5	27 %

<sup>a</sup>Combined yield of three regioisomers determined from crude <sup>1</sup>H NMR spectrum of the crude reaction mixture (total integration of signals at 4.63ppm (*O*-4 and *O*-3 regioisomers) and 4.75 ppm (*O*-2 regioisomers) relative to 1,3,5-trimethoxybenzene).

<sup>b</sup>Ratios of regioisomers were determined by integration of the <sup>1</sup>H NMR spectrum of the crude reaction mixture in CD<sub>3</sub>CN. *O*-4 (d, 4.63 ppm, H-1): *O*-3 (m, 4.03–3.95 ppm, H-2):

*O*-2 (d, 4.75 ppm, H-1). Integration of *O*-4 (H-1) was determined through subtraction of the integrations of the doublet at 4.63 ppm and the multiplet at 4.03–3.95 ppm due to overlap of anomeric protons of the *O*-4 and *O*-3 regioisomers.

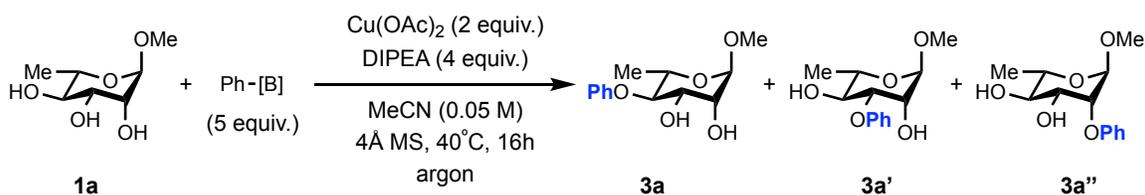
<sup>c</sup>Determined through <sup>1</sup>H NMR analysis of crude reaction mixture.

<sup>d</sup>Boronic ester was formed through condensation of boronic acid (1 equiv.) and carbohydrate (1 equiv.) in toluene (0.2 M) under refluxing conditions for 16 h according to General Procedure A. The compound was dried thoroughly and then added to the reaction flask (no addition of boronic acid). Reactions were run under ambient atmosphere in 2 dram vials.

<sup>e</sup>Reaction was run under ambient atmosphere.

<sup>f</sup>Changes to conditions: increased amount of Cu(OAc)<sub>2</sub> (2 equiv.), *i*Pr<sub>2</sub>NEt (4 equiv.), boronic acid (5 equiv.), 4Å MS (100 mg/mmol of boronic acid) and dilution of the reaction mixture (0.05 M).

<sup>g</sup>Isolated yield

**Table S2: Evaluation of Boron Reagents as Coupling Partners**

Entry	Boron Reagent	Yield	3a: 3a': 3a'' <sup>a</sup>	Bis-arylation <sup>b</sup>
1	Ph-B(OH) <sub>2</sub>	(72 %) <sup>c</sup>	>20: 1: 0.5	27 %
2		64 % <sup>d</sup>	2.1: 1: 1.5	8 %
3 <sup>e</sup>		71 % <sup>d</sup>	>20: 1: 1	13 %
4	Ph-BF <sub>3</sub> K <sup>+</sup>	23 % <sup>d</sup>	19: 2.2: 1	<5 %

<sup>a</sup>Ratios of regioisomers were determined by integration of the <sup>1</sup>H NMR spectrum of the crude reaction mixture in CD<sub>3</sub>CN. *O*-4 (d, 4.63 ppm, H-1): *O*-3 (m, 4.03–3.95 ppm, H-2): *O*-2 (d, 4.75 ppm, H-1). Integration of *O*-4 (H-1) was determined through subtraction of the integrations of the doublet at 4.63 ppm and the multiplet at 4.03–3.95 ppm due to overlap of anomeric protons of the *O*-4 and *O*-3 regioisomers.

<sup>b</sup> Determined through <sup>1</sup>H NMR analysis of crude reaction mixture.

<sup>c</sup> Isolated yield

<sup>d</sup> Combined yield of three regioisomers determined from crude <sup>1</sup>H NMR spectrum of the crude reaction mixture (total integration of signals at 4.63 ppm (*O*-4 and *O*-3 regioisomers) and 4.75 ppm (*O*-2 regioisomers) relative to 1,3,5-trimethoxybenzene).

<sup>e</sup> 1.67 equiv. of phenyl boroxine was used. Boroxine was prepared as previously described.<sup>8</sup>

**General Procedure B for O-arylation of carbohydrate derivatives**

To an oven-dried 50 mL Schlenk flask equipped with a magnetic stir bar was added 1 gram of oven-dried 4 Å molecular sieves, which were then activated under vacuum. The flask was cooled under argon and the carbohydrate (0.2 mmol, 1.0 equiv.), boronic acid (1 mmol, 5.0 equiv.), and Cu(OAc)<sub>2</sub> (72.7 mg, 0.4 mmol, 2.0 equiv.) were added. The flask was then evacuated and backfilled with argon, followed by the addition of both acetonitrile (0.05 M, 4 mL) and *N,N*-diisopropylethylamine (0.14 mL, 0.8 mmol, 4.0 equiv.). The reaction mixture was stirred at 40 °C for 16 hours. The mixture was then cooled, filtered through Celite, concentrated under reduced pressure, and then dissolved in ethyl acetate. The crude residue was transferred to a separatory funnel and hand shaken vigorously with a sorbitol: Na<sub>2</sub>CO<sub>3</sub> (1M: 1M) solution for 5 minutes (2 × 50 mL). The combined aqueous extracts were back-extracted with EtOAc, and the organic phase was dried over MgSO<sub>4</sub>. Following concentration, the crude residue was subject to silica gel chromatography to afford the titled compounds. The regioselectivity of each reaction was determined by analysis of the crude <sup>1</sup>H NMR spectrum prior to column chromatography.

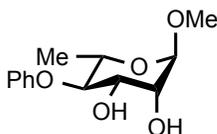
**General Procedure C for mass balance analysis**

To an oven-dried 25 mL Schlenk flask equipped with a magnetic stir bar was added 500 mg of oven-dried 4 Å molecular sieves, which were then activated under vacuum. The flask was cooled under argon and the carbohydrate (0.1 mmol, 1.0 equiv.), boronic acid (0.5 mmol, 5.0 equiv.), and Cu(OAc)<sub>2</sub> (36.6 mg, 0.2 mmol, 2.0 equiv.) were added. The flask was then evacuated and backfilled with argon, followed by the addition of both acetonitrile (0.05 M, 2 mL) and *N,N*-diisopropylethylamine (70 µL, 0.4 mmol, 4.0 equiv.). The reaction mixture was stirred at 40 °C for 16 hours. The mixture was then cooled,

filtered through Celite, concentrated under reduced pressure. Acetic anhydride (1 mL) and pyridine (1 mL) were added and the crude mixture was stirred vigorously for 16 hours. Following concentration under reduced pressure, and then dissolved in ethyl acetate. The crude residue was transferred to a separatory funnel and hand shaken vigorously with a sorbitol:Na<sub>2</sub>CO<sub>3</sub> (1M: 1M) solution for 5 minutes (2 × 25 mL). The combined aqueous extracts were back-extracted with EtOAc, and the organic phase was dried over MgSO<sub>4</sub>. Following concentration, the crude residue was analyzed by NMR spectroscopy.

#### **General Procedure D for pre-stirring of carbohydrate and boronic acid**

To an oven-dried 25 mL Schlenk flask equipped with a magnetic stir bar was added 500 mg of oven-dried 4 Å molecular sieves, which were then activated under vacuum. The flask was cooled under argon and **1a** (17.8 mg, 0.1 mmol, 1.0 equiv.), boronic acid (0.5 mmol, 5.0 equiv.) were added. The flask was then evacuated and backfilled with argon, and the reaction mixture was stirred at 40 °C for 21 h. Cu(OAc)<sub>2</sub> (36.6 mg, 0.2 mmol, 2.0 equiv.) and *N,N*-diisopropylethylamine (70 µL, 0.4 mmol, 4.0 equiv.) were then added. The reaction mixture was stirred at 40 °C for 16 hours. The mixture was then cooled, filtered through Celite, concentrated under reduced pressure, and then dissolved in ethyl acetate. The crude residue was transferred to a separatory funnel and hand shaken vigorously with a sorbitol: Na<sub>2</sub>CO<sub>3</sub> (1M: 1M) solution for 5 minutes (2 × 50 mL). The combined aqueous extracts were back-extracted with EtOAc, and the organic phase was dried over MgSO<sub>4</sub>. The crude mixture was concentrated under reduced pressure.

**3a – Methyl-4-*O*-phenyl-  $\alpha$ -L-rhamnopyranoside**

Prepared according to General Procedure B from methyl  $\alpha$ -L-rhamnopyranoside (**1a**) (35.6 mg, 0.2 mmol, 1 equiv.) and phenylboronic acid (121.9 mg, 1 mmol, 5 equiv.). The titled compound was obtained as an off-white solid (36.4 mg, 72%) after flash chromatography on silica gel (20% to 60% ethyl acetate in hexanes). In addition to the reported product, the crude reaction mixture revealed complete consumption of **1a**, and 27% combined yield of three carbohydrate derived bis-aryl ethers.

**$^1\text{H NMR}$**  (400 MHz,  $\text{CD}_3\text{CN}$ ):  $\delta$  (ppm) = 7.31–7.23 (m, 2H, Ar-H), 7.07–7.01 (m, 2H, Ar-H), 6.97–6.91 (m, 1H, Ar-H), 4.60 (d,  $J = 0.7$  Hz, 1H, H-1), 4.15 (dd,  $J = 9.1, 9.1$  Hz, 1H, H-4), 3.86–3.79 (m, 2H, H-2 and H-3), 3.74 (dq,  $J = 9.4, 6.3$  Hz, 1H, H-5), 3.41–3.36 (m, 2H, OH), 3.34 (s, 3H,  $\text{OCH}_3$ ), 1.16 (d,  $J = 6.3$  Hz, 3H,  $\text{CH}_3$ ).

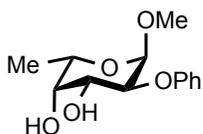
**$^{13}\text{C NMR}$**  (101 MHz,  $\text{CD}_3\text{CN}$ ):  $\delta$  (ppm) = 161.1, 130.3, 122.0, 117.4, 101.7, 81.3, 72.1, 71.4, 67.8, 55.1, 18.3.

**Regioselectivity:** >20: 1: 0.5 (*O*-4 H-1: *O*-3 H-2: *O*-2 H-1)

**IR (neat,  $\text{cm}^{-1}$ ):** 3287 (br, m), 2941 (w), 2906 (w), 1599 (m), 1587 (m), 1495 (s), 1454 (m), 1240 (s), 1134 (s), 1094 (s), 1074 (s), 1044 (s), 984 (s), 968 (s), 832 (m), 779 (m), 751 (s), 686 (s).

**HRMS** (Direct Analysis in Real Time, positive ion mode ( $\text{DART}^+$ ),  $m/z$ ): calculated for  $\text{C}_{13}\text{H}_{22}\text{NO}_5$  [ $\text{M}+\text{NH}_4$ ] $^+$ : 272.14980, found 272.14985.

$[\alpha]_{\text{D}}^{20} = -95.0$  ( $c = 0.99$  g/100  $\text{mL}^{-1}$ ,  $\text{CHCl}_3$ )

**3b – Methyl-2-*O*-phenyl-  $\alpha$ -L-fucopyranoside**

Prepared according to General Procedure B from methyl  $\alpha$ -L-fucopyranoside (**1b**) (35.6 mg, 0.2 mmol, 1 equiv.) and phenylboronic acid (121.9 mg, 1 mmol, 5 equiv.). The titled compound was obtained as a light yellow solid (29.7 mg, 58%) after flash chromatography on silica gel (20% to 60% ethyl acetate in hexanes). An experiment conducted according to General Procedure C indicated that a mixture of bis-aryl ethers (17% combined yield) and unreacted **1b** (9%) made up the mass balance after the O-arylation step.

**$^1\text{H NMR}$**  (400 MHz,  $\text{CD}_3\text{CN}$ ):  $\delta$  (ppm) = 7.31–7.24 (m, 2H, Ar-H), 7.02–6.93 (m, 3H, Ar-H), 4.86 (d,  $J = 3.6$  Hz, 1H, H-1), 4.39 (dd,  $J = 9.8, 3.6$  Hz, 1H, H-2), 4.01–3.95 (m, 1H, H-3), 3.92 (dq,  $J = 6.6, 1.1$  Hz, 1H, H-5), 3.72 (dd,  $J = 3.4, 1.2$  Hz, 1H, H-4), 3.39 (d,  $J = 5.9$  Hz, 1H, OH), 3.28 (s, 3H,  $\text{OCH}_3$ ), 3.10 (d,  $J = 4.2$  Hz, 1H, OH), 1.20 (d,  $J = 6.6$  Hz, 3H, H-6).

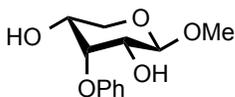
**$^{13}\text{C NMR}$**  (101 MHz,  $\text{CD}_3\text{CN}$ ):  $\delta$  (ppm) = 159.6, 130.5, 122.2, 117.1, 98.2, 76.6, 73.1, 69.7, 66.6, 55.4, 16.6.

**Regioselectivity:** > 20:1

**IR** (neat,  $\text{cm}^{-1}$ ): 3420 (m), 2943 (w), 2914 (w), 1599 (m), 1588 (m), 1496 (s), 1299 (w), 1243 (s), 1192 (m), 1150 (s), 1135 (m), 1089 (m), 1034 (s), 996 (s), 957 (s), 908 (w), 802 (m), 761 (s), 750 (s), 690 (s), 672 (s).

**HRMS** (DART<sup>+</sup>,  $m/z$ ): calculated for  $\text{C}_{13}\text{H}_{22}\text{NO}_5$  [ $\text{M}+\text{NH}_4$ ]<sup>+</sup>: 272.14980, found 272.14997.

$[\alpha]_{\text{D}}^{20} = -74.0$  ( $c = 0.98$  g/100  $\text{mL}^{-1}$ ,  $\text{CHCl}_3$ )

**3c – Methyl-3-*O*-phenyl-  $\beta$ -D-ribofuranoside**

Prepared according to General Procedure B from methyl  $\beta$ -D-ribofuranoside (**1c**) (32.8 mg, 0.2 mmol, 1 equiv.) and phenylboronic acid (121.9 mg, 1 mmol, 5 equiv.). Following sorbitol workup, the crude reaction consisted of a 1:2 mixture of the *O*-3 arylated product and the corresponding *O*-arylated phenylboronic ester. Cleavage of the boronic ester was accomplished through modification of a literature procedure.<sup>9</sup> The crude mixture was dissolved in tetrahydrofuran (0.3 mL) and then aqueous sodium hydroxide (0.3 mL, 2M) was added to the mixture. Hydrogen peroxide (0.3 mL, 30% aqueous solution) was then added slowly. The reaction was stirred for 1.5 hours at 45 °C and then saturated with potassium carbonate. The phases were separated, and the aqueous layer washed with ether ( $\times 3$ ). The organic phase was then washed with brine, dried over  $\text{MgSO}_4$ , and then concentrated. The titled compound was obtained as a light yellow oil (27.8 mg, 58%) after flash chromatography on silica gel (20% to 60% ethyl acetate in hexanes). An experiment conducted according to General Procedure C indicated that no bis- arylation of the carbohydrate occurred, and that the mass balance was not composed of other mono-*O*-arylated regioisomers. Unreacted **1c** or was not observed.

**$^1\text{H}$  NMR** (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  (ppm) = 7.34–7.27 (m, 2H, Ar-H), 7.05–6.99 (m, 3H, Ar-H), 4.83 (d,  $J = 2.1$  Hz, 1H, H-1), 4.46 (dd,  $J = 3.2, 3.2$  Hz, 1H, H-3), 4.13–4.09 (m, 1H, H-4), 4.04–4.00 (m, 1H, H-2), 3.91–3.89 (m, 2H, H-5), 3.51 (br s, 1H, OH), 3.43 (s, 3H,  $\text{OCH}_3$ ), 3.28 (br s, 1H OH).

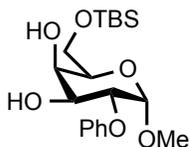
**$^{13}\text{C}$  NMR** (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  (ppm) = 156.5, 129.9, 122.4, 117.1, 102.0, 72.1, 69.0, 68.3, 63.1, 55.5.

**Regioselectivity:** > 20:1

**IR (neat,  $\text{cm}^{-1}$ ):** 3390 (br, m), 2927 (m), 1596 (m), 1492 (s), 1230 (s), 1130 (s), 1107 (s), 1059 (s), 981 (m), 756 (m), 693 (m).

**HRMS (DART<sup>+</sup>, m/z):** calculated for  $\text{C}_{12}\text{H}_{20}\text{NO}_5$   $[\text{M}+\text{NH}_4]^+$ : 258.13415, found 258.13449.

$[\alpha]_{\text{D}}^{20} = -68.9$  ( $c = 0.44 \text{ g}/100 \text{ mL}^{-1}$ ,  $\text{CHCl}_3$ )

**3d – Methyl-2-*O*-phenyl-6-*O*-*tert*-butyldimethylsilyl- $\alpha$ -D-galactopyranoside**

Prepared according to General Procedure B from methyl 6-*O*-*tert*-butyldimethylsilyl- $\alpha$ -D-galactopyranoside (**1d**) (61.7 mg, 0.2 mmol, 1 equiv.) and phenylboronic acid (121.9 mg, 1 mmol, 5 equiv.). The titled compound was obtained as a white solid (44.8 mg, 58%) after flash chromatography on silica gel (20% to 50% ethyl acetate in hexanes). In addition to the reported product, crude reaction mixture contained **1d** (10%) as well as two bis-aryl ethers (10%).

**<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>):  $\delta$  (ppm) = 7.32–7.26 (m, 2H, Ar-H), 7.06–7.02 (m, 2H, Ar-H), 7.02–6.97 (m, 1H, Ar-H), 4.97 (d,  $J$  = 3.5 Hz, 1H, H-1), 4.58 (dd,  $J$  = 9.2, 3.5 Hz, 1H, H-2), 4.23–4.15 (m, 2H, H-3 and H-4), 3.98–3.82 (m, 3H, H-5 and H-6), 3.38 (s, 3H, OCH<sub>3</sub>), 3.10 (dd,  $J$  = 1.8, 0.7 Hz, 1H, OH), 2.56 (d,  $J$  = 4.3 Hz, 1H, OH), 0.91 (s, 9H), 0.11 (s, 3H), 0.11 (s, 3H).

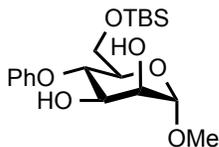
**<sup>13</sup>C NMR** (101 MHz, CDCl<sub>3</sub>):  $\delta$  (ppm) = 158.2, 129.8, 122.2, 116.7, 97.4, 76.2, 69.9, 69.7, 69.4, 63.3, 55.5, 26.0, 18.4, -5.3.

**Regioselectivity:** > 20:1

**IR** (neat, cm<sup>-1</sup>): 3364 (m), 3279 (br, m), 2929 (m), 2885 (w), 2856 (m), 1600 (m), 1588 (m), 1494 (s), 1470 (m), 1463 (m), 1354 (m), 1242 (s), 1106 (s), 1083 (s), 1033 (s), 938 (m), 836 (s), 772 (s), 751 (s), 689 (s).

**HRMS** (DART<sup>+</sup>,  $m/z$ ): calculated for C<sub>16</sub>H<sub>26</sub>NO<sub>7</sub> [M+H]<sup>+</sup>: 385.20464, found 385.20401.

**$[\alpha]_D^{20}$**  = +85.4 (c = 0.92 g/100 mL<sup>-1</sup>, CHCl<sub>3</sub>)

**3e –Methyl-*O*-4-phenyl-6-*O*-*tert*-butyldimethylsilyl- $\alpha$ -D-mannopyranoside**

Prepared according to General Procedure B from methyl 6-*O*-*tert*-butyldimethylsilyl- $\alpha$ -D-mannopyranoside (**1e**) (61.7 mg, 0.2 mmol, 1 equiv.) and phenylboronic acid (121.9 mg, 1 mmol, 5 equiv.). The titled compound was obtained as an off-white solid (51.7 mg, 67%) after flash chromatography on silica gel (20% to 50% ethyl acetate in hexanes). In addition to **3e**, crude reaction mixture contained *O*-3 arylated regioisomer (6%) as well as bis-aryl ethers (12%).

**<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>):  $\delta$  (ppm) = 7.28–7.21 (m, 2H, Ar-H), 7.08–7.03 (m, 2H, Ar-H), 6.98–6.91 (m, 1H, Ar-H), 4.74 (d,  $J$  = 1.8 Hz, 1H, H-1), 4.50 (dd,  $J$  = 9.0 Hz, 1H, H-4), 4.11 – 4.03 (m, 1H, H-3), 3.96 (s, 1H, H-2), 3.82–3.68 (m, 3H, H-5 and H-6), 3.39 (s, 3H, OCH<sub>3</sub>), 2.83–2.74 (m, 2H, OH), 0.84 (s, 9H), 0.00 (s, 3H), –0.05 (s, 3H).

Select peaks for minor regioisomer (*O*-3): 4.83 (d,  $J$  = 1.4 Hz, 0.05H, H-1)

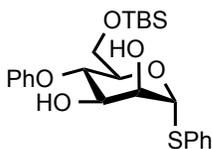
**<sup>13</sup>C NMR** (101 MHz, CDCl<sub>3</sub>):  $\delta$  (ppm) = 159.6, 129.6, 121.7, 116.4, 100.5, 75.0, 72.0, 71.5, 71.1, 62.2, 55.0, 26.0, 18.4, -5.2, -5.4.

**Regioselectivity:** 17.5:1 (*O*-4 H-1: *O*-3 H-1)

**IR** (neat, cm<sup>-1</sup>): 3261 (br, m), 2932 (m), 2856 (w), 2833 (w), 1599 (w), 1507 (s), 1465 (m), 1225 (s), 1135 (s), 1097 (s), 1045 (s), 965 (s), 828 (s), 797 (m), 741 (s), 688 (s).

**HRMS** (DART<sup>+</sup>,  $m/z$ ): calculated for C<sub>19</sub>H<sub>33</sub>O<sub>6</sub>Si [M+H]<sup>+</sup>: 385.20464, found 385.20444.

$[\alpha]_D^{20}$  = +68.6 (c = 0.10 g/100 mL<sup>-1</sup>, CHCl<sub>3</sub>)

**3f – 3-*O*-Phenyl-6-*O*-*tert*-butyldimethylsilyl- $\alpha$ -D-thiophenylmannopyranoside**

Prepared according to General Procedure B from 6-*O*-*tert*-butyldimethylsilyl- $\alpha$ -D-thiophenylmannopyranoside (**1f**) (77.3 mg, 0.2 mmol, 1 equiv.) and phenylboronic acid (121.9 mg, 1 mmol, 5 equiv.). The titled compound was obtained as a light yellow solid (61.6 mg, 65%) after flash chromatography on silica gel (20% to 50% ethyl acetate in hexanes). In addition to the reported product, crude reaction mixture contained bis-aryl ethers (13%).

**<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>):  $\delta$  (ppm) = 7.54–7.49 (m, 2H, Ar-H), 7.34–7.26 (m, 5H, Ar-H), 7.12–7.08 (m, 2H, Ar-H), 7.01–6.95 (m, 1H, Ar-H), 5.56 (dd,  $J$  = 2.1, 0.6 Hz, 1H, H-1), 4.63 (dd,  $J$  = 9.0, 9.0 Hz, 1H, H-4), 4.29–4.23 (m, 2H, H-2 and H-5), 4.19–4.09 (m, 1H, H-3), 3.79 (d,  $J$  = 3.1 Hz, 2H, H-6), 2.50–2.46 (m, 2H, OH), 0.84 (s, 9H), -0.00 (s, 3H), -0.06 (s, 3H).

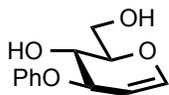
**<sup>13</sup>C NMR** (126 MHz, CDCl<sub>3</sub>):  $\delta$  (ppm) = 159.4, 134.1, 131.6, 129.7, 129.2, 127.6, 122.0, 116.5, 87.5, 75.2, 73.3, 72.4, 72.0, 62.1, 26.0, 18.5, -5.2, -5.4.

**Regioselectivity:** > 20:1

**IR** (neat, cm<sup>-1</sup>): 3279 (br, m), 2952 (m), 2928 (m), 2857 (m), 1600 (m), 1587 (m), 1495 (s), 1480 (s), 1239 (s), 1093 (s), 1077 (s), 1048 (s), 957 (s), 833 (s), 777 (s), 740 (s), 691 (s), 674 (s).

**HRMS** (DART<sup>+</sup>,  $m/z$ ): calculated for C<sub>24</sub>H<sub>38</sub>NO<sub>5</sub>SSi [M+NH<sub>4</sub>]<sup>+</sup>: 480.22399, found 480.22311.

**$[\alpha]_D^{20}$**  = +152.3 ( $c$  = 0.94 g/100 mL<sup>-1</sup>, CHCl<sub>3</sub>)

**3g – Methyl-3-O-phenyl-D-glucal**

Prepared according to General Procedure B from methyl D-glucal (**1g**) (29.2 mg, 0.2 mmol, 1 equiv.) and phenylboronic acid (121.9 mg, 1 mmol, 5 equiv.). The titled compound was obtained as a light yellow solid (25.2 mg, 57%) after flash chromatography on silica gel (20% to 50% ethyl acetate in hexanes).

An experiment conducted according to General Procedure C indicated that an unreacted **1g** (31%) made up the mass balance after the O-arylation step.

**<sup>1</sup>H NMR** (400 MHz, CD<sub>3</sub>OD): δ (ppm) = 7.30–7.22 (m, 2H, Ar-H), 6.99–6.88 (m, 3H, Ar-H), 6.44 (dd, *J* = 6.1, 1.4 Hz, 1H, H-1), 4.84 (dd, *J* = 6.1, 2.3 Hz, 1H, H-2), 4.82–4.78 (m, 1H, H-3), 3.98–3.90 (m, 2H, H-4 and H-5), 3.90–3.87 (m, 2H, H-6).

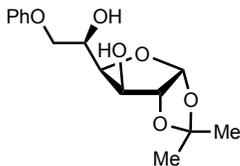
**<sup>13</sup>C NMR** (101 MHz, CD<sub>3</sub>OD): δ (ppm) = 159.2, 146.2, 130.5, 122.0, 117.0, 100.0, 80.3, 76.3, 68.2, 61.9.

**Regioselectivity:** > 20:1

**IR** (neat, cm<sup>-1</sup>): 3444 (br, w), 3307 (br, m), 2960 (w), 2936 (w), 2550 (w), 2460 (br, m), 1642 (s), 1598 (s), 1587 (m), 1494 (s), 1455 (m), 1392 (m), 1243 (s), 1234 (s), 1224 (s), 1156 (m), 1092 (m), 1077 (s), 1065 (s), 1025 (s), 984 (s), 853 (m), 752 (s), 738 (s), 691 (s).

**HRMS** (DART<sup>+</sup>, *m/z*): calculated for C<sub>12</sub>H<sub>18</sub>NO<sub>4</sub> [M+NH<sub>4</sub>]<sup>+</sup>: 240.12358, found 240.12382.

**[α]<sub>D</sub><sup>20</sup>** = -97.9 (c = 0.63 g/100 mL<sup>-1</sup>, CHCl<sub>3</sub>)

**3h – 6-*O*-Phenyl-1,2-*O*-isopropylidene- $\alpha$ -D-glucofuranose**

Prepared according to General Procedure B from 1,2-*O*-isopropylidene- $\alpha$ -D-glucofuranose (**1h**) (44 mg, 0.2 mmol, 1 equiv.) and phenylboronic acid (121.9 mg, 1 mmol, 5 equiv.). The titled compound was obtained as a light yellow oil (37.9 mg, 64%) after flash chromatography on silica gel (20% to 50% ethyl acetate in hexanes). In addition to the reported product, analysis of the crude reaction mixture contained unreacted **1h** (13%).

**<sup>1</sup>H NMR** (500 MHz, CDCl<sub>3</sub>):  $\delta$  (ppm) = 7.32–7.27 (m, 2H, Ar-H), 7.01–6.96 (m, 1H, Ar-H), 6.95–6.91 (m, 2H, Ar-H), 5.99 (d,  $J$  = 3.6 Hz, 1H, H-1), 4.56 (dd,  $J$  = 3.7, 0.6 Hz, 1H, H-2), 4.46–4.43 (m, 1H, H-3), 4.41–4.35 (m, 1H, H-5), 4.28 (dd,  $J$  = 9.8, 3.3 Hz, 1H, H-6a), 4.21 (dd,  $J$  = 6.7, 2.7 Hz, 1H, H-4), 4.11 (dd,  $J$  = 9.8, 6.0 Hz, 1H, H-6b), 3.26 (s, 1H, OH), 3.04 (s, 1H, OH), 1.49 (s, 3H, CH<sub>3</sub>), 1.33 (s, 3H, CH<sub>3</sub>).

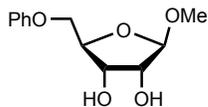
**<sup>13</sup>C NMR** (126 MHz, CDCl<sub>3</sub>):  $\delta$  (ppm) = 158.4, 129.7, 121.6, 114.8, 112.0, 105.2, 85.3, 85.2, 79.7, 75.9, 69.3, 27.0, 26.3.

**Regioselectivity:** > 20:1

**IR** (neat, cm<sup>-1</sup>): 3406 (br, m), 2987 (w), 2935 (w), 1599 (s), 1588 (m), 1495 (s), 1457 (m), 1378 (m), 1242 (s), 1216 (s), 1164 (s), 1071 (s), 1012 (s), 913 (m), 883 (m), 754 (s), 691 (s).

**HRMS** (DART<sup>+</sup>,  $m/z$ ): calculated for C<sub>15</sub>H<sub>24</sub>NO<sub>6</sub> [M+NH<sub>4</sub>]<sup>+</sup>: 314.16036, found 314.16008.

$[\alpha]_D^{20}$  = -1.5 (c = 0.67 g/100 mL<sup>-1</sup>, CHCl<sub>3</sub>)

**3i – Methyl-5-O-phenyl-β-D-ribofuranoside**

Prepared according to General Procedure B from methyl β-D-ribofuranoside (**1i**) (32.8 mg, 0.2 mmol, 1 equiv.) and phenylboronic acid (121.9 mg, 1 mmol, 5 equiv.). The titled compound was obtained as a white solid (19.2 mg, 40%) after flash chromatography on silica gel (20% to 60% ethyl acetate in hexanes).

An experiment conducted according to General Procedure C indicated exclusive formation of **3i**. Acetylated **1i** was likely lost in the aqueous workup.

<sup>1</sup>H NMR (400 MHz, CD<sub>3</sub>OD): δ (ppm) = 7.31–7.23 (m, 2H, Ar-H), 6.98–6.90 (m, 3H, Ar-H), 4.80 (s, 1H, H-1), 4.27–4.20 (m, 2H, H-3 and H-4), 4.20–4.15 (m, 1H, H-5a), 4.04–3.98 (m, 1H, H-5b), 3.95–3.92 (m, 1H, H-2), 3.32 (s, 3H, OCH<sub>3</sub>).

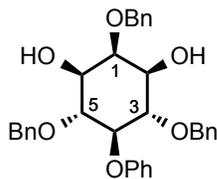
<sup>13</sup>C NMR (101 MHz, CD<sub>3</sub>OD): δ (ppm) = 160.4, 130.4, 121.9, 115.7, 109.9, 82.5, 76.0, 72.8, 70.5, 55.3.

**Regioselectivity:** > 20:1

**IR (neat, cm<sup>-1</sup>):** 3345 (br, w), 2985 (w), 2935 (m), 2917 (m), 2499 (m), 2464 (br, m), 1605 (m), 1589 (m), 1494 (s), 1450 (m), 1235 (s), 1125 (s), 1079 (s), 1055 (s), 1042 (s), 977 (s), 950 (s), 887 (m), 805 (m), 758 (s), 693 (s).

**HRMS (DART<sup>+</sup>, m/z):** calculated for C<sub>12</sub>H<sub>20</sub>NO<sub>5</sub> [M+NH<sub>4</sub>]<sup>+</sup>: 258.13415, found 258.13420.

[α]<sub>D</sub><sup>20</sup> = -29.0 (c= 0.43 g/100 mL<sup>-1</sup>, CHCl<sub>3</sub>)

**3j – 4-*O*-Phenyl-2,4,6-tri-*O*-benzyl-*myo*-inositol**

Prepared according to General Procedure B, but at 60 °C, from 2,4,6-tri-*O*-benzyl-*myo*-inositol (**1j**) (90.1 mg, 0.2 mmol, 1 equiv.) and phenylboronic acid (121.9 mg, 1 mmol, 5 equiv.). The titled compound was obtained as an orange oil (40.5 mg, 38%) after flash chromatography on silica gel (20% to 50% ethyl acetate in hexanes). The remainder of the mass balance consisted of **1j**, which was recovered in 48% (43.2 mg).

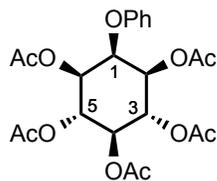
<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ (ppm) = 7.45–7.26 (m, 13H, Ar-H), 7.20–7.10 (m, 6H, Ar-H), 7.04–6.98 (m, 1H, Ar-H), 4.86 (s, 2H, CH<sub>2</sub>Ph), 4.80 (d, *J* = 10.8 Hz, 2H, CH<sub>2</sub>Ph), 4.64 (d, *J* = 10.8 Hz, 2H, CH<sub>2</sub>Ph), 4.41 (dd, *J* = 9.1, 9.1 Hz, 1H, H-4), 4.05 (dd, *J* = 2.7, 2.7 Hz, 1H, H-1), 3.94 (dd, *J* = 9.5 Hz, 2H, H-3 and H-5), 3.61 (ddd, *J* = 9.7, 4.8, 2.6 Hz, 2H, H-2 and H-6), 2.38 (d, *J* = 5.1 Hz, 2H, OH).

<sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>): δ (ppm) = 159.3, 138.7, 138.1, 129.7, 128.6, 128.6, 128.5, 128.0, 127.9, 121.5, 116.2, 82.4, 81.7, 78.8, 75.6, 75.4, 72.4.

**Regioselectivity:** >20:1

**IR (neat, cm<sup>-1</sup>):** 3438 (br, w), 3063 (w), 3030 (w), 2931 (w), 2908 (w), 2876 (w), 1598 (m), 1587 (m), 1492 (s), 1454 (m), 1239 (s), 1123 (s), 1064 (s), 1027 (s), 1007 (s), 991 (s), 934 (w), 751 (s), 737 (s), 692 (s).

**HRMS (DART<sup>+</sup>, *m/z*):** calculated for C<sub>33</sub>H<sub>38</sub>NO<sub>6</sub> [M+NH<sub>4</sub>]<sup>+</sup>: 544.26991, found 544.26873.

**3k – 1-*O*-Phenyl-2,3,4,5,6-acetyl-*myo*-inositol**

To an oven-dried 50 mL Schlenk flask was added 2 grams of oven-dried 4 Å molecular sieves, which were then activated under vacuum. The flask was cooled under argon and *myo*-inositol (**1k**) (36 mg, 0.2 mmol, 1 equiv.), phenylboronic acid (243.9 mg, 2 mmol, 10 equiv.), and Cu(OAc)<sub>2</sub> (72.7 mg, 0.4 mmol, 2.0 equiv.) were added. The flask was then evacuated and backfilled with argon, followed by the addition of both acetonitrile (0.025 M, 8 mL) and *N,N*-diisopropylethylamine (0.14 mL, 0.8 mmol, 4.0 equiv.). The reaction mixture was stirred at 60 °C for 16 hours. The mixture was then cooled, filtered through Celite, and concentrated under reduced pressure. Pyridine (1 mL) and acetic anhydride (1 mL) were added to the crude mixture, which was then stirred for 16 hours at room temperature. The mixture was then concentrated and the crude residue was transferred to a separatory funnel and hand shaken vigorously with a sorbitol:Na<sub>2</sub>CO<sub>3</sub> (1M: 1M) solution for 5 minutes (2 × 50 mL). The combined aqueous layers were back-extracted with EtOAc, and the organic phase was dried over MgSO<sub>4</sub> and then concentrated. The titled compound was obtained as white solid (40.3 mg, 43%) after flash chromatography on silica gel (20% to 50% ethyl acetate in hexanes). The remainder of the mass balance consisted of **1k**, which was recovered in 46% (38.7 mg).

<sup>1</sup>H NMR (400 MHz, C<sub>6</sub>D<sub>6</sub>): δ (ppm) = 6.97–6.90 (m, 2H, Ar-H), 6.77–6.70 (m, 3H, Ar-H), 6.16 (dd, *J* = 10.4, 9.8 Hz, 2H, H-3 and H-5), 5.48 (dd, *J* = 9.7, 9.7 Hz, 1H, H-4), 5.19

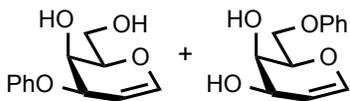
(dd,  $J = 2.7, 2.7$  Hz 1H, H-1), 5.14 (dd,  $J = 10.4, 2.6$  Hz, 2H, H-2 and H-6), 1.76–1.72 (m, 9H), 1.41 (s, 6H).

$^{13}\text{C}$  NMR (101 MHz,  $\text{C}_6\text{D}_6$ ):  $\delta$  (ppm) = 169.7, 169.7, 169.3, 159.7, 129.8, 122.3, 117.0, 75.0, 71.9, 71.0, 70.4, 20.3, 20.2, 19.9.

**Regioselectivity:** >20:1

**IR (neat,  $\text{cm}^{-1}$ ):** 1738 (s), 1492 (m), 1382 (m) 1366 (m), 1255 (s), 1226 (s), 1212 (s), 1070 (m), 1031 (s), 942 (m), 928 (m), 754 (m), 687 (m).

**HRMS (DART $^+$ ,  $m/z$ ):** calculated for  $\text{C}_{22}\text{H}_{30}\text{NO}_{11}$   $[\text{M}+\text{NH}_4]^+$ : 484.18188, found 484.18176.

**3I and 3I' – Methyl-3-*O*-phenyl D-glucal and methyl-6-*O*-phenyl D-glucal**

Prepared according to General Procedure B from methyl D-glucal (**1I**) (29.2 mg, 0.2 mmol, 1 equiv.) and phenylboronic acid (121.9 mg, 1 mmol, 5 equiv.). An inseparable mixture of regioisomers was obtained as a light brown solid (23.2 mg, 52%, 2.5:1) after flash chromatography on silica gel (20% to 50% ethyl acetate in hexanes).

Analysis of the crude reaction mixture according to General Procedure C confirmed formation of **3I** and **3I'** as well as tri-*O*-acetyl-D-galactal (14%).

Major regioisomer (*O*-6):

<sup>1</sup>H NMR (600 MHz, CD<sub>3</sub>OD): δ (ppm) = 7.29–7.24 (m, 2H, Ar-H), 6.96–6.91 (m, 3H, Ar-H), 6.36 (dd, *J* = 6.2, 1.8, 1.8 Hz, 1H, H-1), 4.69 (ddd, *J* = 6.2, 1.9, 1.9 Hz, 1H, H-2), 4.38 (ddd, *J* = 4.3, 1.8, 1.8 Hz, 1H, H-3), 4.28–4.24 (m, 1H, H-5), 4.24–4.21 (m, 2H, H-6), 3.99 (ddd, *J* = 4.7, 1.5, 1.5 Hz, 1H, H-4).

<sup>13</sup>C NMR (151 MHz, CD<sub>3</sub>OD): δ (ppm) = 160.1, 144.9, 130.5, 122.0, 115.6, 104.1, 76.6, 67.9, 66.5, 65.0.

Select peaks for *O*-3 regioisomer:

<sup>1</sup>H NMR (600 MHz, MeOD): δ (ppm) = 7.29–7.24 (m, 0.91H, Ar-H), 7.01–6.97 (m, 0.84 H, Ar-H), 6.96–6.91 (m, 0.51H, Ar-H), 6.45 (dd, *J* = 6.3, 1.8 Hz, 0.4H, H-1), 5.06–5.03 (m, 0.43H, H-3), 4.78 (ddd, *J* = 6.3, 1.9, 1.9 Hz, 0.44H, H-2), 4.21–4.18 (m, 0.49H, H-4), 4.06–4.03 (m, 0.43H, H-5), 3.88–3.77 (m, 0.9H, H-6).

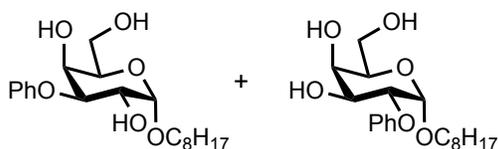
<sup>13</sup>C NMR (151 MHz, MeOD): δ (ppm) = 158.8, 146.2, 130.5, 122.2, 117.1, 100.0, 78.8, 71.6, 64.3, 62.2.

**Regioselectivity:** 2.3:1 (*O*-6 H-1: *O*-3 H-1)

**IR (neat,  $\text{cm}^{-1}$ ):** 3312 (br, w), 2946 (w), 2887 (w), 2474 (br, m), 1644 (m), 1599 (m), 1587 (m), 1497 (m), 1455 (m), 1226 (s), 1154 (m), 1079 (s), 1031 (s), 976 (m), 798 (m), 754 (s), 691 (s).

**HRMS (DART<sup>+</sup>, m/z):** calculated for  $\text{C}_{12}\text{H}_{18}\text{NO}_5$   $[\text{M}+\text{NH}_4]^+$ : 240.12358, found 240.12374.

**3m and 3m' – Octyl-3-*O*-phenyl- $\alpha$ -D-galactopyranoside and octyl-2-*O*-phenyl- $\alpha$ -D-galactopyranoside**



To an oven-dried 25 mL Schlenk flask was added 800 mg of oven-dried 4 Å molecular sieves, which were then activated under vacuum. The flask was cooled under argon and the octyl- $\alpha$ -D-galactopyranoside (**1m**) (23.5 mg, 0.08 mmol, 1 equiv.), phenylboronic acid (97.5 mg, 0.8 mmol, 10 equiv.), and Cu(OAc)<sub>2</sub> (29.1 mg, 0.16 mmol, 2.0 equiv.) were added. The flask was then evacuated and backfilled with argon, followed by the addition of both acetonitrile (0.023 M, 3.5 mL) and *N,N*-diisopropylethylamine (56  $\mu$ L, 0.32 mmol, 4.0 equiv.). The reaction mixture was stirred at 40 °C for 16 hours. The mixture was then cooled, filtered through Celite, concentrated under reduced pressure, and then dissolved in diethyl ether. The crude residue was transferred to a separatory funnel and hand shaken vigorously with a sorbitol:Na<sub>2</sub>CO<sub>3</sub> (1M: 1M) solution for 5 minutes (2  $\times$  50 mL). The combined aqueous layers were back-extracted with diethyl ether, and the organic phase was dried over MgSO<sub>4</sub> and then concentrated. The *O*-2 regioisomer was obtained as a white solid (12.2 mg, 41%) and the *O*-3 regioisomer was obtained as a colourless oil (10.7 mg, 36%) after flash chromatography on silica gel (20% to 100% ethyl acetate in hexanes). Two bis-aryl ethers were additionally isolated in a combined yield of 25% (8.9 mg).

**Regioselectivity:** 1.2:1 (*O*-3 H-3: *O*-2 H-2)

**3m'** (*O*-2 regioisomer)

**<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>): δ (ppm) = 7.30–7.24 (m, 2H, Ar-H), 7.05–6.95 (m, 3H, Ar-H), 5.06 (d, *J* = 3.5 Hz, 1H, H-1), 4.57 (dd, *J* = 9.5, 3.5 Hz, 1H, H-2), 4.27–4.16 (m, 2H, H-3 and H-4), 3.98–3.80 (m, 3H, H-5 and H-6), 3.64 (ddd, *J* = 9.9, 6.7, 6.7 Hz, 1H, -OCH<sub>2</sub>-), 3.35 (ddd, *J* = 9.9, 6.6, 6.6 Hz, 1H, -OCH<sub>2</sub>-), 3.27 (br s, 1H, OH), 2.88 (br s, 1H, OH), 2.61 (br s, 1H, OH), 1.58–1.48 (m, 2H, OCH<sub>2</sub>-CH<sub>2</sub>-), 1.31 – 1.19 (m, 10H, CH<sub>2</sub>), 0.87 (t, *J* = 6.9 Hz, 3H, CH<sub>3</sub>).

**<sup>13</sup>C NMR** (101 MHz, CDCl<sub>3</sub>): δ (ppm) = 157.9, 129.8, 122.2, 116.6, 96.1, 75.6, 70.8, 69.4, 69.0, 68.6, 63.3, 31.9, 29.5, 29.4, 29.3, 26.2, 22.8, 14.2.

**IR (neat, cm<sup>-1</sup>):** 3399 (br, m), 2953 (m), 2924 (s), 2855 (s), 1599 (m), 1587 (m), 1493 (s), 1466 (w), 1456 (w), 1229 (s), 1148 (s), 1051 (s), 1034 (s), 974 (m), 883 (w), 752 (s), 690 (s).

**HRMS** (DART<sup>+</sup>, *m/z*): calculated for C<sub>20</sub>H<sub>36</sub>NO<sub>6</sub> [M+NH<sub>4</sub>]<sup>+</sup>: 386.25426, found 386.25308.

[α]<sub>D</sub><sup>20</sup> = +100.6 (c = 0.28 g/100 mL<sup>-1</sup>, CHCl<sub>3</sub>)

**3m** (*O*-3 regioisomer)

**<sup>1</sup>H NMR** (400 MHz, CDCl<sub>3</sub>): δ (ppm) = 7.35–7.27 (m, 2H, Ar-H), 7.08–6.99 (m, 3H, Ar-H), 5.05 (d, *J* = 3.9 Hz, 1H, H-1), 4.41 (dd, *J* = 9.6, 3.2 Hz, 1H, H-3), 4.27–4.23 (m, 1H, H-4), 4.19 (ddd, *J* = 9.5, 9.5, 3.9 Hz, 1H, H-2), 3.96 (ddd, *J* = 11.2, 5.4, 3.9 Hz, 1H, H-6a), 3.92–3.87 (m, 1H, H-5), 3.83 (ddd, *J* = 11.2, 8.2, 4.2 Hz, 1H, H-6b), 3.76 (ddd, *J* = 9.7, 6.9, 6.9 Hz, 1H, -OCH<sub>2</sub>-), 3.51 (ddd, *J* = 9.7, 6.6, 6.6 Hz, 1H, -OCH<sub>2</sub>-), 2.60 (dd, *J* = 1.5

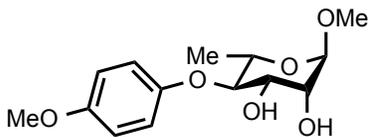
Hz, 1H, OH), 2.21 (dd,  $J = 8.3, 3.9$  Hz, 1H, OH), 2.08 (d,  $J = 9.3$  Hz, 1H, OH), 1.64 (p,  $J = 6.9$  Hz, 2H, OCH<sub>2</sub>-CH<sub>2</sub>-), 1.44–1.20 (m, 10H, CH<sub>2</sub>), 0.95–0.81 (m, 3H, CH<sub>3</sub>).

<sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>):  $\delta$  (ppm) = 157.6, 129.9, 122.7, 117.3, 98.7, 78.9, 69.6, 68.8, 68.6, 68.1, 63.2, 32.0, 29.6, 29.5, 29.4, 26.3, 22.8, 14.2.

**IR** (neat, cm<sup>-1</sup>): 3525 (br, m), 3409 (br, m), 2951 (m), 2921 (m), 2871 (m), 1599 (m), 1586 (m), 1494 (s), 1467 (m), 1370 (m), 1230 (s), 1143 (s), 1091 (s), 1032 (s), 972 (s), 894 (s), 846 (s), 751 (s), 694 (s).

**HRMS** (DART<sup>+</sup>,  $m/z$ ): calculated for C<sub>20</sub>H<sub>36</sub>NO<sub>6</sub> [M+NH<sub>4</sub>]<sup>+</sup>: 386.25426, found 386.25380.

$[\alpha]_{\text{D}}^{20} = +80.2$  ( $c = 0.42$  g/100 mL<sup>-1</sup>, CHCl<sub>3</sub>)

**6a – Methyl-4-O-(4-methoxyphenyl)-  $\alpha$ -L-rhamnopyranoside**

Prepared according to General Procedure B from methyl  $\alpha$ -L-rhamnopyranoside (**1a**) (35.6 mg, 0.2 mmol, 1 equiv.) and 4-methoxyphenylboronic acid (152 mg, 1 mmol, 5 equiv.). The titled compound was obtained as an off-white solid (43.2 mg, 76%) after flash chromatography on silica gel (20% to 60% ethyl acetate in hexanes). The crude reaction mixture contained 12% combined yield of three carbohydrate derived bis-aryl ethers.

**$^1\text{H NMR}$**  (400 MHz,  $\text{CD}_3\text{CN}$ ):  $\delta$  (ppm) = 7.01–6.95 (m, 2H, Ar-H), 6.84–6.79 (m, 2H, Ar-H), 4.57 (d,  $J$  = 1.1 Hz, 1H, H-1), 3.96 (dd,  $J$  = 9.1, 9.1 Hz, 1H, H-4), 3.81–3.77 (m, 2H, H-2 and H-3), 3.77–3.68 (m, 1H, H-5), 3.73 (s, 3H, Ar-OCH<sub>3</sub>), 3.33 (s, 3H, OCH<sub>3</sub>), 3.31 (d,  $J$  = 6.3 Hz, 1H, OH), 3.26 (d,  $J$  = 4.2 Hz, 1H, OH), 1.17 (d,  $J$  = 6.3 Hz, 3H, CH<sub>3</sub>).

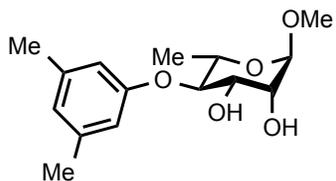
**$^{13}\text{C NMR}$**  (101 MHz,  $\text{CD}_3\text{CN}$ ):  $\delta$  (ppm) = 155.2, 155.1, 118.7, 115.3, 101.7, 82.6, 72.2, 71.4, 67.9, 56.2, 55.1, 18.4.

**Regioselectivity:** >20:1

**IR** (neat,  $\text{cm}^{-1}$ ): 3245 (br, m), 2938 (m), 2831 (w), 1593 (w), 1507 (s), 1465 (m), 1451 (m), 1304 (w), 1289 (w), 1223 (s), 1135 (s), 1097 (s), 1051 (s), 985 (s), 965 (s), 826 (s), 797 (s), 624 (m).

**HRMS** (DART<sup>+</sup>,  $m/z$ ): calculated for  $\text{C}_{14}\text{H}_{24}\text{NO}_6$  [ $\text{M}+\text{NH}_4$ ]<sup>+</sup>: 302.16036, found 302.16092.

$[\alpha]_{\text{D}}^{20}$  = -97.9 ( $c$  = 0.16 g/100  $\text{mL}^{-1}$ ,  $\text{CHCl}_3$ )

**6b – Methyl-4-*O*-(3,5-dimethylphenyl)-  $\alpha$ -L-rhamnopyranoside**

Prepared according to General Procedure B from methyl  $\alpha$ -L-rhamnopyranoside (**1a**) (35.6 mg, 0.2 mmol, 1 equiv.) and 3,5-dimethylphenylboronic acid (150 mg, 1 mmol, 5 equiv.). The titled compound was inseparable from the *O*-2 isomer and was obtained as a light brown solid (35.7 mg, 63%, 16: 1 (*O*-4: *O*-2)) after flash chromatography on silica gel (20% to 50% ethyl acetate in hexanes). The crude reaction mixture contained 5% combined yield of three carbohydrate derived bis-aryl ethers. The *O*-3 arylated regioisomer was present in the crude mixture in < 5%.

**$^1\text{H NMR}$**  (400 MHz,  $\text{CD}_3\text{CN}$ ):  $\delta$  (ppm) = 6.67–6.64 (m, 2H, Ar-H), 6.61–6.58 (m, 1H, Ar-H), 4.58 (d,  $J$  = 1.1 Hz, 1H, H-1), 4.12 (dd,  $J$  = 9.2 Hz, 1H, H-4), 3.82–3.74 (m, 2H, H-2 and H-3), 3.74–3.66 (m, 1H, H-5), 3.33 (s, 3H,  $\text{OCH}_3$ ), 2.24 (s, 7H, Ar- $\text{CH}_3$ ), 1.15 (d,  $J$  = 6.3 Hz, 3H,  $\text{CH}_3$ ).

**$^{13}\text{C NMR}$**  (101 MHz,  $\text{CD}_3\text{CN}$ ):  $\delta$  (ppm) = 161.2, 140.1, 123.6, 115.0, 101.8, 81.0, 72.1, 71.4, 67.9, 55.1, 21.4, 18.3.

Select peaks for minor regioisomer (*O*-2):

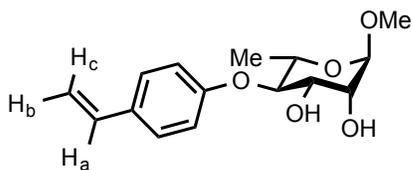
**$^1\text{H NMR}$**  (400 MHz,  $\text{CD}_3\text{CN}$ ):  $\delta$  (ppm) = 4.69 (d,  $J$  = 1.5 Hz, 0.06H, H-1), 4.41 (dd,  $J$  = 3.6, 1.6 Hz, 0.06H, H-2), 3.57–3.50 (m, 0.09H, H-5), 3.44 (dd,  $J$  = 9.4, 4.6 Hz, 0.09H, H-4), 3.25 (d,  $J$  = 4.7 Hz, 0.06H, OH), 3.14 (m, 0.06H, OH).

**$^{13}\text{C}$  NMR** (101 MHz,  $\text{CD}_3\text{CN}$ ):  $\delta$  (ppm) = 140.4, 124.0, 114.7, 99.0, 78.0, 74.0, 71.7, 69.1, 18.1.

**Regioselectivity:** 15: 1 (*O*-4 H-1: *O*-2 H-1)

**IR (neat,  $\text{cm}^{-1}$ ):** 3384 (br, m), 2974 (w), 2913 (m), 2833 (w), 1593 (s), 1467 (m), 1449 (m), 11387 (m), 1318 (s), 1296 (s), 1153 (s), 1132 (s), 1057 (s), 1032 (s), 980 (s), 968 (s), 836 (s), 806 (s), 688 (s), 631 (s).

**HRMS** (DART<sup>+</sup>,  $m/z$ ): calculated for  $\text{C}_{15}\text{H}_{26}\text{NO}_5$  [ $\text{M}+\text{NH}_4$ ]<sup>+</sup>: 300.18110, found 300.18150.

**6c – Methyl-4-*O*-(4-vinylphenyl)-  $\alpha$ -L-rhamnopyranoside**

Prepared according to General Procedure B from methyl  $\alpha$ -L-rhamnopyranoside (**1a**) (35.6 mg, 0.2 mmol, 1 equiv.) and 4-vinylphenylboronic acid (148 mg, 1 mmol, 5 equiv.). The titled compound was inseparable from the *O*-2 isomer and was obtained as an off white solid (30 mg, 54%, 13: 1 (*O*-4: *O*-2)) after flash chromatography on silica gel (20% to 50% ethyl acetate in hexanes). The crude reaction mixture contained 5% combined yield of three carbohydrate derived bis-aryl ethers. The *O*-3 arylated regioisomer was present in the crude mixture in < 5%.

When **1a** and 4-vinylphenylboronic acid were subject to conditions according to General Procedure D, a combined yield of 44% and a product distribution of 11.6: 2.7: 1 (*O*-4: *O*-3: *O*-2) were observed (See **Table S3**).

**<sup>1</sup>H NMR** (400 MHz, CD<sub>3</sub>CN):  $\delta$  (ppm) = 7.38–7.33 (m, 2H, Ar-H), 7.03–6.97 (m, 2H, Ar-H), 6.68 (dd,  $J$  = 17.7, 11.0 Hz, 1H, H<sub>a</sub>), 5.65 (dd,  $J$  = 17.7, 1.1 Hz, 1H, H<sub>c</sub>), 5.12 (dd,  $J$  = 10.9, 1.1 Hz, 1H, H<sub>b</sub>), 4.59 (dd,  $J$  = 0.7 Hz, 1H, H-1), 4.14 (dd,  $J$  = 9.1, 9.1 Hz, 1H, H-4), 3.84–3.77 (m, 2H, H-2 and H-3), 3.77–3.69 (m, 1H, H-5), 3.33 (s, 3H, OCH<sub>3</sub>), 3.32 (d,  $J$  = 4.1 Hz, 1H, OH), 3.30 (d,  $J$  = 4.3 Hz, 1H, OH), 1.16 (d,  $J$  = 6.3 Hz, 3H, CH<sub>3</sub>).

**<sup>13</sup>C NMR** (101 MHz, CD<sub>3</sub>CN):  $\delta$  (ppm) = 161.0, 137.1, 131.8, 128.2, 117.4, 112.3, 101.8, 81.4, 72.1, 71.4, 67.8, 55.1, 18.2.

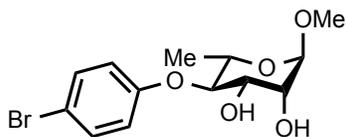
Select peaks for minor regioisomer (*O*-2):

**<sup>1</sup>H NMR** (400 MHz, CD<sub>3</sub>CN): δ (ppm) = 4.71 (d, *J* = 1.5 Hz, 0.08H, H-1), 4.46 (dd, *J* = 3.6, 1.6 Hz, 0.08H, H-2), 3.58–3.50 (m, 0.09H, H-5), 3.45 (dd, *J* = 9.5, 4.5 Hz, 0.06H, H-4), 3.22 (d, *J* = 4.8 Hz, 0.08H, OH), 3.15 (d, *J* = 4.6 Hz, 0.09H, OH).

**Regioselectivity:** 16: 1 (*O*-4 H-1: *O*-2 H-1)

**IR (neat, cm<sup>-1</sup>):** 3244 (br, m), 2936 (w), 2991 (m), 2830 (w), 1627 (w), 1605 (m), 1509 (s), 1452 (w), 1243 (s), 1134 (m), 1097 (s), 1075 (s), 1051 (s), 986 (s), 967 (s), 895 (m), 796 (m).

**HRMS (DART<sup>+</sup>, *m/z*):** calculated for C<sub>15</sub>H<sub>24</sub>NO<sub>5</sub> [M+NH<sub>4</sub>]<sup>+</sup>: 298.16545, found 298.16511.

**6d – Methyl-4-*O*-(4-bromophenyl)-  $\alpha$ -L-rhamnopyranoside**

Prepared according to General Procedure B from methyl  $\alpha$ -L-rhamnopyranoside (**1a**) (35.6 mg, 0.2 mmol, 1 equiv.) and 4-bromophenylboronic acid (200.8 mg, 1 mmol, 5 equiv.). The titled compound was inseparable from the *O*-2 isomer and was obtained as an off white solid (40.7 mg, 61%, 6.5: 1 (*O*-4: *O*-2)) after flash chromatography on silica gel (20% to 50% ethyl acetate in hexanes). The crude reaction mixture contained 8% combined yield of three carbohydrate derived bis-aryl ethers. The *O*-3 arylated regioisomer was present in the crude mixture in < 5%.

When **1a** and 4-bromophenylboronic acid were subject to conditions according to General Procedure D, a combined yield of 53% and a product distribution of 12.6: 1.9: 1 (*O*-4: *O*-3: *O*-2) were observed (See **Table S3**).

**<sup>1</sup>H NMR** (400 MHz, CD<sub>3</sub>CN):  $\delta$  (ppm) = 7.41–7.36 (m, 2H, Ar-H), 7.01–6.95 (m, 2H, Ar-H), 4.58 (d,  $J$  = 0.6 Hz, 1H, H-1), 4.09 (dd,  $J$  = 9.2, 9.2 Hz, 1H, H-4), 3.84–3.76 (m, 2H, H-2 and H-3), 3.76–3.68 (m, 1H, H-5), 3.33 (s, 3H, OCH<sub>3</sub>), 1.15 (d,  $J$  = 6.3 Hz, 3H, CH<sub>3</sub>).

**<sup>13</sup>C NMR** (101 MHz, CD<sub>3</sub>CN):  $\delta$  (ppm) = 160.4, 133.0, 119.5, 113.5, 101.7, 81.9, 72.1, 71.3, 67.6, 55.1, 18.2.

Select peaks for minor regioisomer (*O*-2):

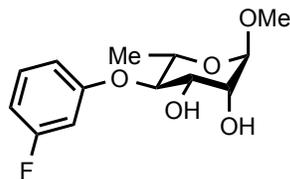
**<sup>1</sup>H NMR** (400 MHz, CD<sub>3</sub>CN):  $\delta$  (ppm) = 4.69 (d,  $J$  = 1.5 Hz, 0.15H, H-1), 4.43 (dd,  $J$  = 3.5, 1.6 Hz, 0.16H, H-2), 3.58–3.50 (m, 0.17H, H-5), 3.43 (dd,  $J$  = 9.4, 4.7 Hz, 0.14H, H-4), 3.23 (d,  $J$  = 4.8 Hz, 0.14H, OH), 3.19 (d,  $J$  = 7.1 Hz, 0.14, OH), 1.25 (d,  $J$  = 6.2 Hz, 0.54H, CH<sub>3</sub>).

**$^{13}\text{C}$  NMR** (101 MHz,  $\text{CD}_3\text{CN}$ ):  $\delta$  (ppm) = 133.2, 132.6, 121.9, 119.2, 98.9, 78.6, 73.8, 71.6, 69.2.

**Regioselectivity:** 5.7: 1 (*O*-4 H-1: *O*-2 H-1)

**IR (neat,  $\text{cm}^{-1}$ ):** 3261 (br, m), 2931(m), 2856 (w), 2833 (w), 1599 (m), 1588 (m), 1490 (s), 1239 (s), 1134 (s), 1097 (s) 1075 (s), 1049 (s), 1004 (m), 984 (s), 965 (s), 821 (s), 780 (m), 751 (m), 687 (s), 631 (s).

**HRMS** (DART<sup>+</sup>,  $m/z$ ): calculated for  $\text{C}_{13}\text{H}_{21}\text{BrNO}_5$   $[\text{M}+\text{NH}_4]^+$ : 350.06031, found 350.06053.

**6e – Methyl-4-*O*-(3-fluorophenyl)- $\alpha$ -L-rhamnopyranoside**

Prepared according to General Procedure B from methyl  $\alpha$ -L-rhamnopyranoside (**1a**) (35.6 mg, 0.2 mmol, 1 equiv.) and 3-fluorophenylboronic acid (139.9 mg, 1 mmol, 5 equiv.). The titled compound was inseparable from the *O*-2 isomer and was obtained as a light brown solid (32.6 mg, 60%, 4.8: 1 (*O*-4: *O*-2)) after flash chromatography on silica gel (20% to 50% ethyl acetate in hexanes). The crude reaction mixture contained 5% combined yield of three carbohydrate derived bis-aryl ethers. The *O*-3 arylated regioisomer was present in the crude mixture in < 5%.

When **1a** and 3-fluorophenylboronic acid were subject to conditions according to General Procedure D, a combined yield of 57% and a product distribution of 11.5: 2.4: 1 (*O*-4: *O*-3: *O*-2) were observed (See **Table S3**).

**<sup>1</sup>H NMR** (400 MHz, CD<sub>3</sub>CN):  $\delta$  (ppm) = 7.29–7.22 (m, 1H, Ar-H), 6.88–6.80 (m, 2H, Ar-H), 6.73–6.65 (m, 1H, Ar-H), 4.59 (d,  $J$  = 0.7 Hz, 1H, H-1), 4.14 (dd,  $J$  = 9.2, 9.2 Hz, 1H, H-4), 3.85–3.78 (m, 2H, H-2 and H-3), 3.78–3.70 (m, 1H, H-5), 3.42–3.36 (m, 2H, OH), 3.33 (s, 3H, OCH<sub>3</sub>), 1.17 (d,  $J$  = 6.3 Hz, 3H, CH<sub>3</sub>).

**<sup>13</sup>C NMR** (101 MHz, CD<sub>3</sub>CN):  $\delta$  (ppm) = 165.5, 163.1, 162.6, 162.5, 131.4, 131.3, 113.4, 113.4, 108.6, 108.4, 104.9, 104.7, 101.8, 81.7, 72.1, 71.3, 67.6, 55.1, 18.2.

Select peaks for minor regioisomer (*O*-2):

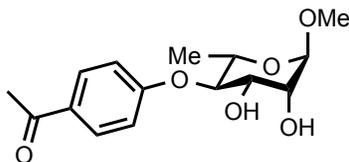
**<sup>1</sup>H NMR** (400 MHz, CD<sub>3</sub>CN): δ (ppm) = 4.71 (d, *J* = 1.6 Hz, 0.21H, H-1), 4.47 (dd, *J* = 3.5, 1.6 Hz, 0.22H, H-2), 3.62–3.49 (m, 0.25H, H-5), 3.29 (d, *J* = 4.7 Hz, 0.23H, OH), 3.25 (d, *J* = 7.1 Hz, 0.22H, OH), 1.26 (d, *J* = 6.2 Hz, 0.95H, CH<sub>3</sub>).

**<sup>13</sup>C NMR** (101 MHz, CD<sub>3</sub>CN): δ (ppm) = 165.6, 163.2, 161.0, 160.9, 131.6, 131.5, 113.0, 112.9, 109.0, 108.8, 104.6, 104.4, 98.9, 78.5, 73.9, 71.6, 69.2, 55.2, 18.1.

**Regioselectivity:** 4.7: 1 (*O*-4 H-1: *O*-2 H-1)

**IR (neat, cm<sup>-1</sup>):** 3247 (br, m), 2932 (m), 2833 (w), 1607 (s), 1592 (s), 1489 (s), 1455 (m), 1279 (s), 1264 (m), 1132 (s), 1097 (s), 1075 (s), 1051 (s), 987 (s), 968 (s), 947 (s), 844 (s), 806 (m), 762 (s), 716 (m), 675 (s), 625 (s).

**HRMS** (DART<sup>+</sup>, *m/z*): calculated for C<sub>13</sub>H<sub>21</sub>FNO<sub>5</sub> [M+NH<sub>4</sub>]<sup>+</sup>: 290.14038, found 290.14086.

**6f – Methyl-4-*O*-(3-acetylphenyl)-  $\alpha$ -L-rhamnopyranoside**

Prepared according to General Procedure B from methyl  $\alpha$ -L-rhamnopyranoside (**1a**) (35.6 mg, 0.2 mmol, 1 equiv.) and 4-acetylphenylboronic acid (164 mg, 1 mmol, 5 equiv.). The titled compound was inseparable from the *O*-2 isomer and was obtained as a light brown solid (20.8 mg, 35%, 3.3: 1 (*O*-4: *O*-2)) after flash chromatography on silica gel (20% to 50% ethyl acetate in hexanes). The *O*-3 arylated regioisomer was present in the crude mixture in < 5%.

**<sup>1</sup>H NMR** (400 MHz, CD<sub>3</sub>CN):  $\delta$  (ppm) = 7.93–7.88 (m, 2H, Ar-H), 7.12–7.07 (m, 2H, Ar-H), 4.61 (d,  $J$  = 1.0 Hz, 1H, H-1), 4.30 (dd,  $J$  = 9.2, 9.2 Hz, 1H, H-4), 3.88–3.80 (m, 2H, H-2 and H-3), 3.80–3.71 (m, 1H, H-5), 3.44–3.38 (m, 2H, OH), 3.34 (s, 3H, OCH<sub>3</sub>), 2.50 (s, 3H, COCH<sub>3</sub>), 1.16 (d,  $J$  = 6.3 Hz, 3H, CH<sub>3</sub>).

**<sup>13</sup>C NMR** (101 MHz, CD<sub>3</sub>CN):  $\delta$  (ppm) = 197.4, 164.8, 131.4, 131.3, 116.7, 101.8, 81.0, 72.1, 71.3, 67.6, 55.2, 26.7, 18.1.

Select peaks for minor regioisomer (*O*-2):

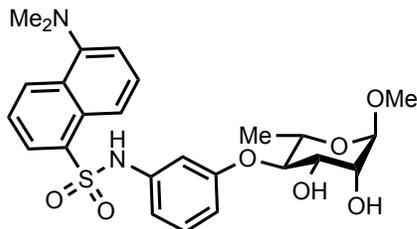
**<sup>1</sup>H NMR** (400 MHz, CD<sub>3</sub>CN):  $\delta$  (ppm) = 7.06–7.02 (m, 1H, Ar-H), 4.72 (d,  $J$  = 1.5 Hz, 0.28H, H-1), 3.61–3.53 (m, 0.31H, H-5), 3.47 (dd,  $J$  = 9.5, 4.8 Hz, 0.25H, H-4), 3.28 (m, 0.61H, OH), 1.26 (d,  $J$  = 6.2 Hz, 0.91H, CH<sub>3</sub>).

**<sup>13</sup>C NMR** (101 MHz, CD<sub>3</sub>CN):  $\delta$  (ppm) = 163.3, 131.8, 131.6, 116.3, 99.0, 78.0, 73.8, 71.6, 69.2, 55.2, 26.7, 18.1.

**Regioselectivity:** 3: 1 (*O*-4 H-4: *O*-2 H-1)

**IR (neat,  $\text{cm}^{-1}$ ):** 3249 (br, m), 2934 (m), 2836 (w), 1674 (s), 1598 (s), 1509 (m), 1451 (w), 1359 (m), 1272 (m), 1248 (s), 1178 (s), 1073 (s), 1048 (s), 984 (s), 961 (s), 827 (s), 788 (m), 706 (m), 623 (m).

**HRMS (DART<sup>+</sup>, m/z):** calculated for  $\text{C}_{15}\text{H}_{21}\text{O}_6$   $[\text{M}+\text{H}]^+$ : 297.13381, found 297.13416.

**6g– Methyl-4-*O*-(3-dansylaminophenyl)-  $\alpha$ -L-rhamnopyranoside**

Prepared according to General Procedure B from methyl  $\alpha$ -L-rhamnopyranoside (**1a**) (8.9 mg, 0.05 mmol, 1 equiv.) and 3-(dansylamino)phenylboronic acid (92.5 mg, 0.25 mmol, 5 equiv.). The titled compound was inseparable from the *O*-2 and *O*-3 regioisomers and was obtained as a green oil (12.5 mg, 50%, 4.2: 1.3: 1 (*O*-4: *O*-3: *O*-2)) after flash chromatography on silica gel (2% to 5% methanol in dichloromethane). In addition to the isolated product, bis-aryl ethers were observed in a combined yield of 30% (12.6 mg).

**$^1\text{H NMR}$**  (600 MHz,  $\text{CD}_3\text{CN}$ ):  $\delta$  (ppm) = 8.50–8.47 (m, 1H, Ar-H), 8.35–8.32 (m, 1H, Ar-H), 8.24–8.22 (m, 1H, Ar-H), 7.64–7.61 (m, 1H, Ar-H), 7.54–7.49 (m, 1H, Ar-H), 7.26–7.23 (m, 1H, Ar-H), 6.99 (dd,  $J = 8.2, 8.2$  Hz, 1H, Ar-H), 6.71–6.68 (m, 1H, Ar-H), 6.63 (ddd,  $J = 8.3, 2.5, 0.9$  Hz, 1H, Ar-H), 6.58–6.55 (m, 1H, Ar-H), 4.56 (d,  $J = 1.7$  Hz, 1H, H-1), 3.90 (dd,  $J = 9.3, 9.3$  Hz, 1H, H-4), 3.78 (dd,  $J = 3.5, 1.7$  Hz, 1H, H-2), 3.71 (dd,  $J = 9.2, 3.5$  Hz, 1H, H-3), 3.65–3.60 (m, 1H, H-5), 3.31 (s, 3H,  $\text{OCH}_3$ ), 2.82 (s, 6H,  $\text{N}(\text{CH}_3)_2$ ), 0.93 (d,  $J = 6.3$  Hz, 3H,  $\text{CH}_3$ ).

**$^{13}\text{C NMR}$**  (151 MHz,  $\text{CD}_3\text{CN}$ ):  $\delta$  (ppm) = 161.6, 153.1, 139.2, 135.1, 131.7, 131.7, 130.8, 130.5, 130.3, 129.5, 124.3, 119.5, 116.4, 113.6, 113.6, 109.1, 101.7, 81.6, 72.0, 71.1, 67.6, 55.1, 45.7, 18.2.

Select peaks for minor regioisomer (*O*-2):

**<sup>1</sup>H NMR** (600 MHz, CD<sub>3</sub>CN): δ (ppm) = 4.49 (d, *J* = 1.6 Hz, 0.24H, H-1), 4.20 (dd, *J* = 3.6, 1.6 Hz, 0.23H, H-2), 3.28 (s, 0.68H, OCH<sub>3</sub>), 1.23 (d, *J* = 6.2 Hz, 0.68H, CH<sub>3</sub>).

Select peaks for minor regioisomer (*O*-3):

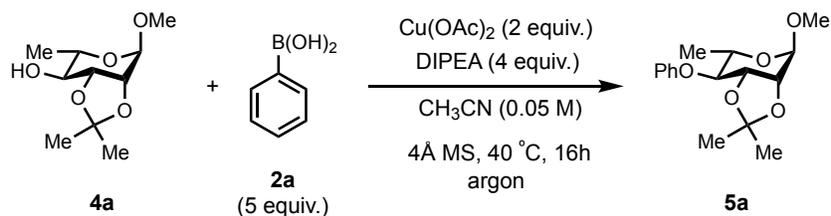
**<sup>1</sup>H NMR** (600 MHz, CD<sub>3</sub>CN): δ (ppm) = 4.06 (dd, *J* = 9.1, 3.1 Hz, 0.31H, H-3), 3.75–3.73 (m, 0.22H, H-2), 3.38 (s, 0.70H, OCH<sub>3</sub>), 1.25 (d, *J* = 6.1 Hz, 0.90H, CH<sub>3</sub>).

**Regioselectivity:** 8.2: 1.5: 1 (*O*-4 H-4: *O*-3 H-3: *O*-2 H-1)

**IR (thin film, cm<sup>-1</sup>):** 3500 (br, m), 3260 (br, w), 2916 (w), 2839 (w), 1603 (s), 1578 (m), 1485 (m), 1465 (m), 1394 (m), 1330 (s), 1273 (s), 1049 (s), 973 (s), 834 (s), 793 (s), 734 (s), 692 (s).

**HRMS (DART<sup>+</sup>, *m/z*):** calculated for C<sub>25</sub>H<sub>31</sub>N<sub>2</sub>O<sub>7</sub>S [M+H]<sup>+</sup>: 503.18520, found 503.18469.

**Background reactivity of 4a towards copper mediated *O*-arylation: Methyl-4-*O*-phenyl-2,3-*O*-isopropylidene- $\alpha$ -rhamnopyranoside**



Prepared according to General Procedure B from methyl 2,3-isopropylidene- $\alpha$ -L-rhamnopyranoside (**4a**) (37.9 mg, 0.17 mmol, 1 equiv.) and phenylboronic acid (103.6 mg, 0.85 mmol, 5 equiv.). **5a** was obtained as a yellow solid (9.4 mg, 19%) after flash chromatography on silica gel (20% to 50% ethyl acetate in hexanes).

$^1\text{H NMR}$  (400 MHz,  $\text{CD}_3\text{CN}$ ):  $\delta$  (ppm) = 7.33–7.24 (m, 2H, Ar-H), 7.12–7.04 (m, 2H, Ar-H), 7.01–6.92 (m, 1H, Ar-H), 4.87 (s, 1H, H-1), 4.26–4.14 (m, 2H, H-2 and H-3), 4.01 (dd,  $J = 9.8, 6.7$  Hz, 1H, H-4), 3.83–3.70 (m, 1H, H-5), 3.36 (s, 3H), 1.54 (s, 3H,  $\text{CH}_3$ ), 1.32 (s, 3H,  $\text{CH}_3$ ), 1.21 (d,  $J = 6.3$  Hz, 3H,  $\text{CH}_3$ ).

$^{13}\text{C NMR}$  (101 MHz,  $\text{CD}_3\text{CN}$ ):  $\delta$  (ppm) = 160.2, 130.5, 122.5, 117.7, 110.1, 98.8, 82.6, 78.3, 77.0, 65.2, 55.2, 28.1, 26.4, 18.0.

**IR** (neat,  $\text{cm}^{-1}$ ): 2979 (w), 2933 (w), 2903 (w), 1595 (m), 1586 (m), 1492 (s), 1450 (w), 1457 (w), 1381 (m), 1369 (m), 1235 (s), 1223 (s), 1172 (m), 1140 (s), 1120 (s), 1077 (s), 1018 (s), 980 (s), 866 (s), 827 (s), 799 (s), 770 (s), 698 (s).

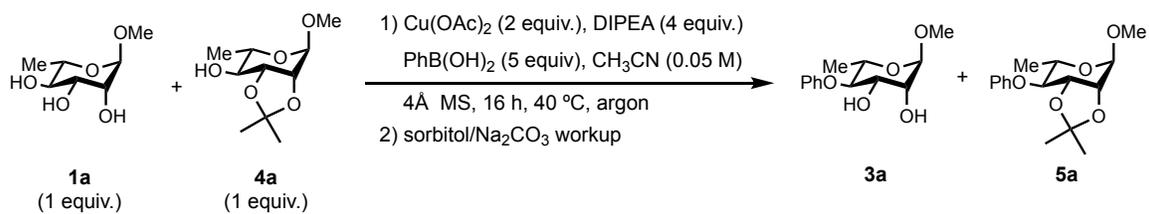
$[\alpha]_{\text{D}}^{20} = -54.3$  ( $c = 0.14$  g/100  $\text{mL}^{-1}$ ,  $\text{CHCl}_3$ )

### Competition Experiments

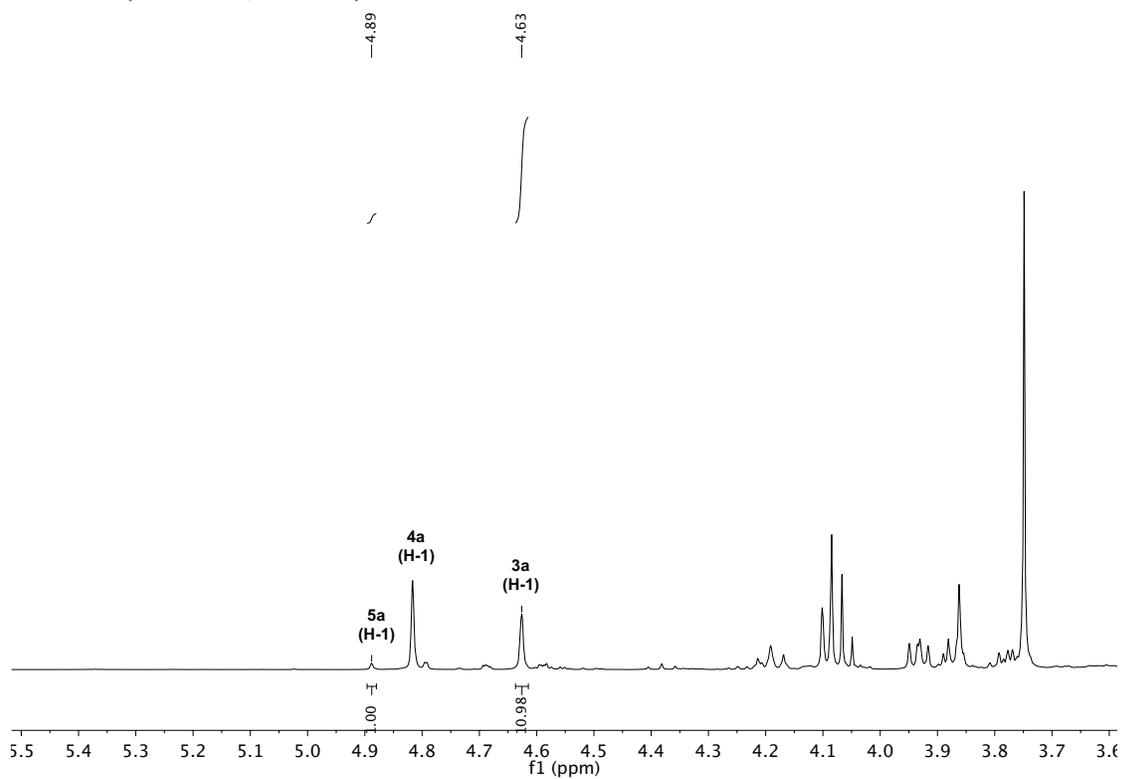
#### **General Procedure E for O-arylation competition experiments**

To an oven-dried 50 mL Schlenk flask equipped with a magnetic stir bar was added 1 gram of oven-dried 4 Å molecular sieves, which were then activated under vacuum. The flask was cooled under argon and the carbohydrates were added (0.2 mmol of each), followed by boronic acid (1 mmol, 5.0 equiv.), and Cu(OAc)<sub>2</sub> (72.7 mg, 0.4 mmol, 2.0 equiv.). The flask was then evacuated and backfilled with argon, followed by the addition of both acetonitrile (0.05 M, 4 mL) and *N,N*-diisopropylethylamine (0.14 mL, 0.8 mmol, 4.0 equiv.). The reaction mixture was stirred at 40 °C for 16 hours. The mixture was then cooled, filtered through Celite, concentrated under reduced pressure, and then dissolved in ethyl acetate. The crude residue was transferred to a separatory funnel and hand shaken vigorously with a sorbitol: Na<sub>2</sub>CO<sub>3</sub> (1M: 1M) solution for 5 minutes (2 × 50 mL). The combined aqueous extracts were back-extracted with EtOAc, and the organic phase was dried over MgSO<sub>4</sub>, and then concentrated. The crude reaction mixture was analyzed by <sup>1</sup>H NMR spectroscopy.

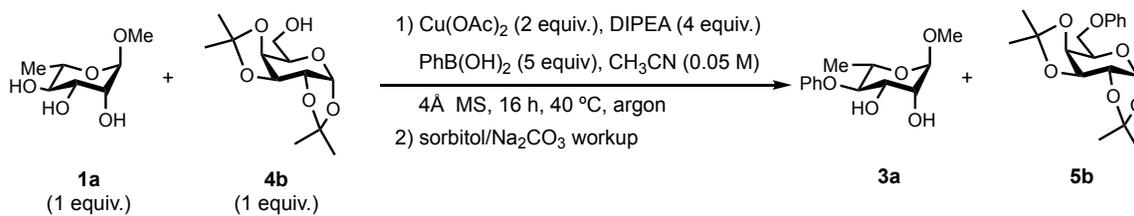
**Figure S1: Competition between of unprotected carbohydrate (1a) and protected, secondary alcohol (4a) under optimized coupling conditions**



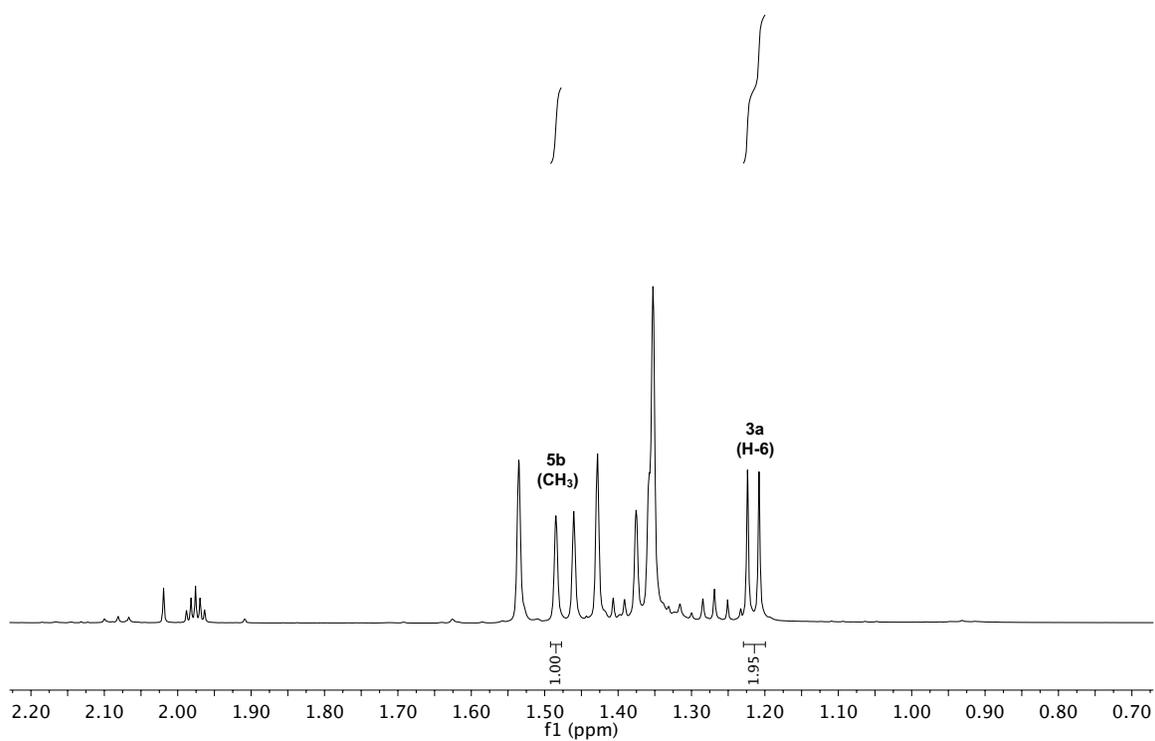
<sup>1</sup>H NMR (400 MHz, CD<sub>3</sub>CN)



**Figure S2: Competition between of unprotected carbohydrate (1a) and protected, primary alcohol (4b) under optimized coupling conditions**

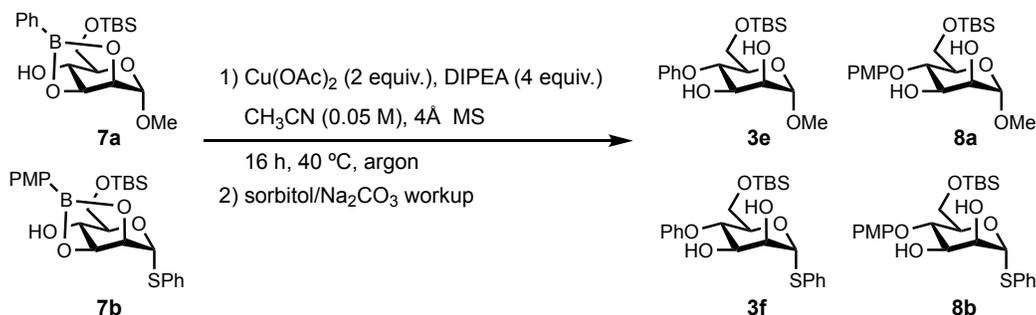


**<sup>1</sup>H NMR (400 MHz, CD<sub>3</sub>CN)**



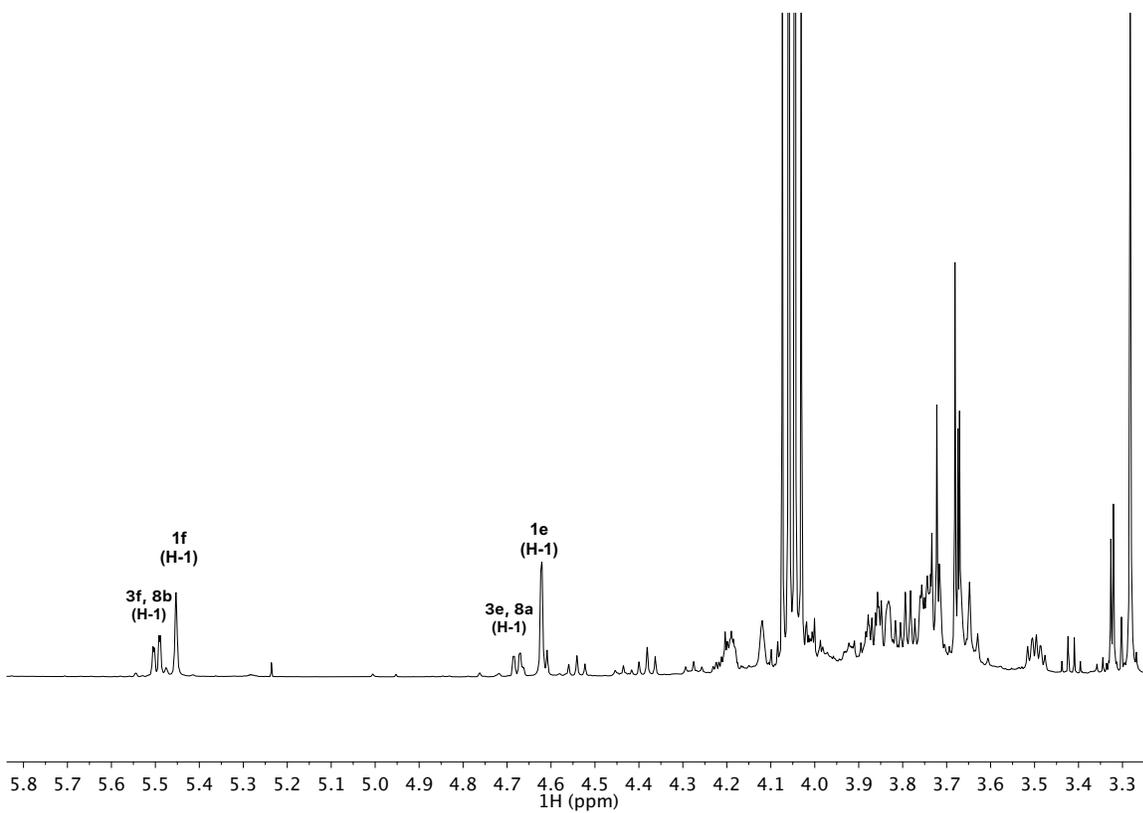
### Crossover and Transesterification Experiments

#### Crossover experiment between of boronic esters **7a** and **7b** under optimized reaction conditions

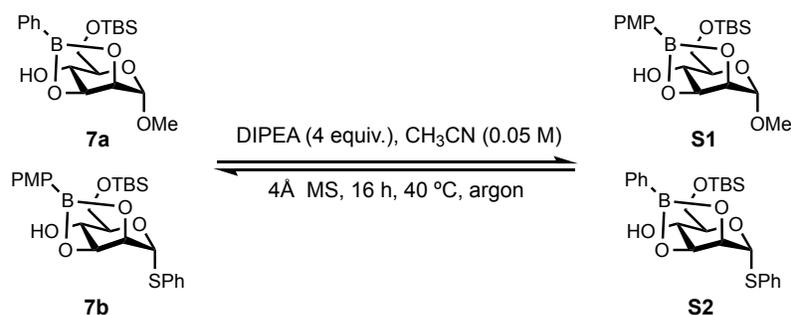


To an oven-dried 25mL Schlenk flask equipped with a magnetic stir bar was added 1 gram of oven-dried 4 Å molecular sieves, which were then activated under vacuum. The flask was cooled under argon and Cu(OAc)<sub>2</sub> (72.7 mg, 0.4 mmol) was added. The flask was then evacuated and backfilled with argon. **7a** (0.1 mmol) and **7b** (0.1 mmol) (prepared according to General Procedure A) were transferred into the reaction flask using acetonitrile (0.05 M, 4 mL). *N,N*-Diisopropylethylamine (0.14 mL, 0.8 mmol, 4.0 equiv.) was then added. The reaction mixture was stirred at 40 °C for 16 hours. The mixture was then cooled, filtered through Celite, concentrated under reduced pressure, and then dissolved in ethyl acetate. The crude residue was transferred to a separatory funnel and hand shaken vigorously with a sorbitol: Na<sub>2</sub>CO<sub>3</sub> (1M: 1M) solution for 5 minutes (2 × 50 mL). The combined aqueous extracts were back-extracted with EtOAc, and the organic phase was dried over MgSO<sub>4</sub>, and then concentrated under reduced pressure. Four carbohydrate derived aryl ethers were observed in the crude <sup>1</sup>H NMR spectrum.

**Figure S3: Crude  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ ) for crossover experiment between 7a and 7b**

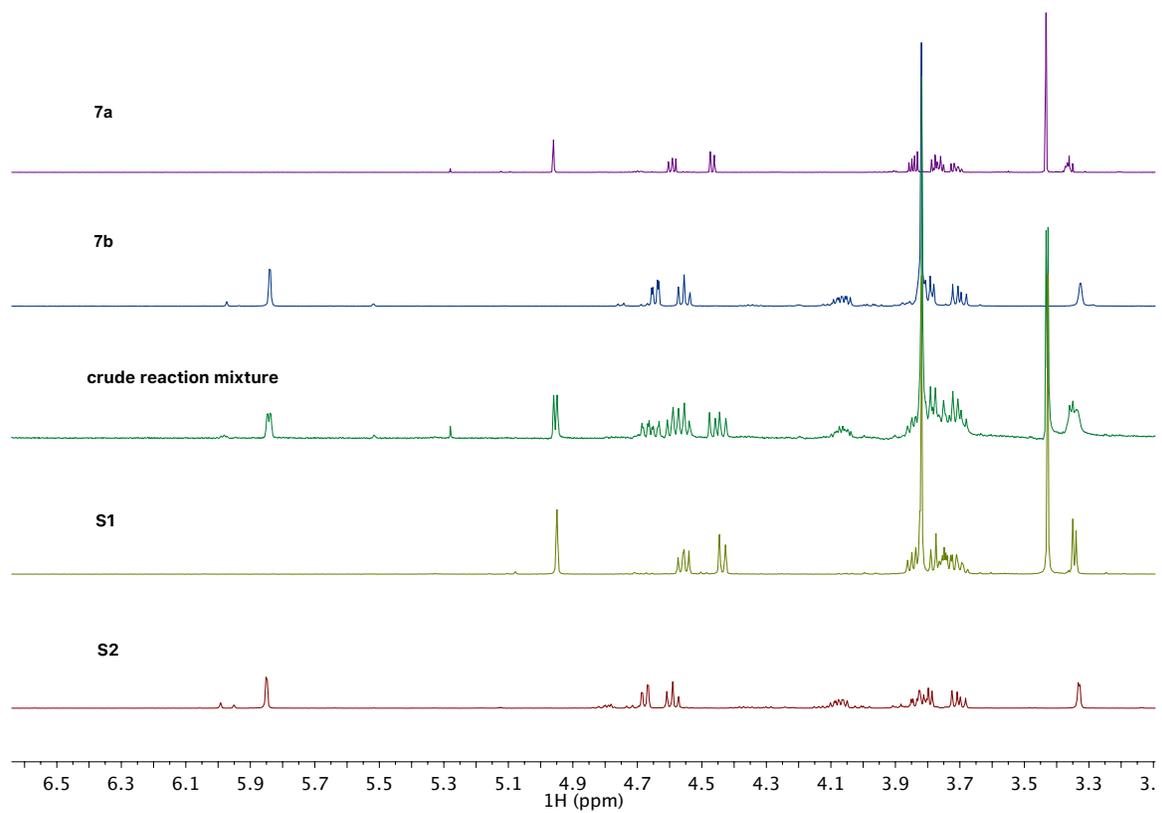


**Transesterification experiment between boronic esters **7a** and **7b** under optimized reaction conditions in the absence of  $\text{Cu}(\text{OAc})_2$**

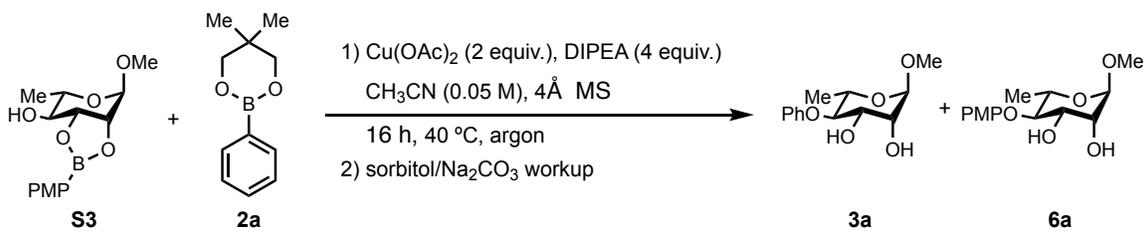


To an oven-dried 25mL Schlenk flask equipped with a magnetic stir bar was added 1 gram of oven-dried 4 Å molecular sieves which were then activated under vacuum. The flask was cooled under argon. **7a** (0.1 mmol) and **7b** (0.1 mmol) (prepared according to General Procedure A) were transferred into the reaction flask using acetonitrile (0.05 M, 4 mL). *N,N*-diisopropylethylamine (0.14 mL, 0.8 mmol, 4.0 equiv.) was then added. The reaction mixture was stirred at 40 °C for 16 hours. The mixture was then cooled, filtered through Celite, concentrated under reduced pressure. Four carbohydrate derived aryl ethers were observed in the crude <sup>1</sup>H NMR spectrum.

**Figure S4: Crude  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) for transesterification experiment between 7a and 7b**

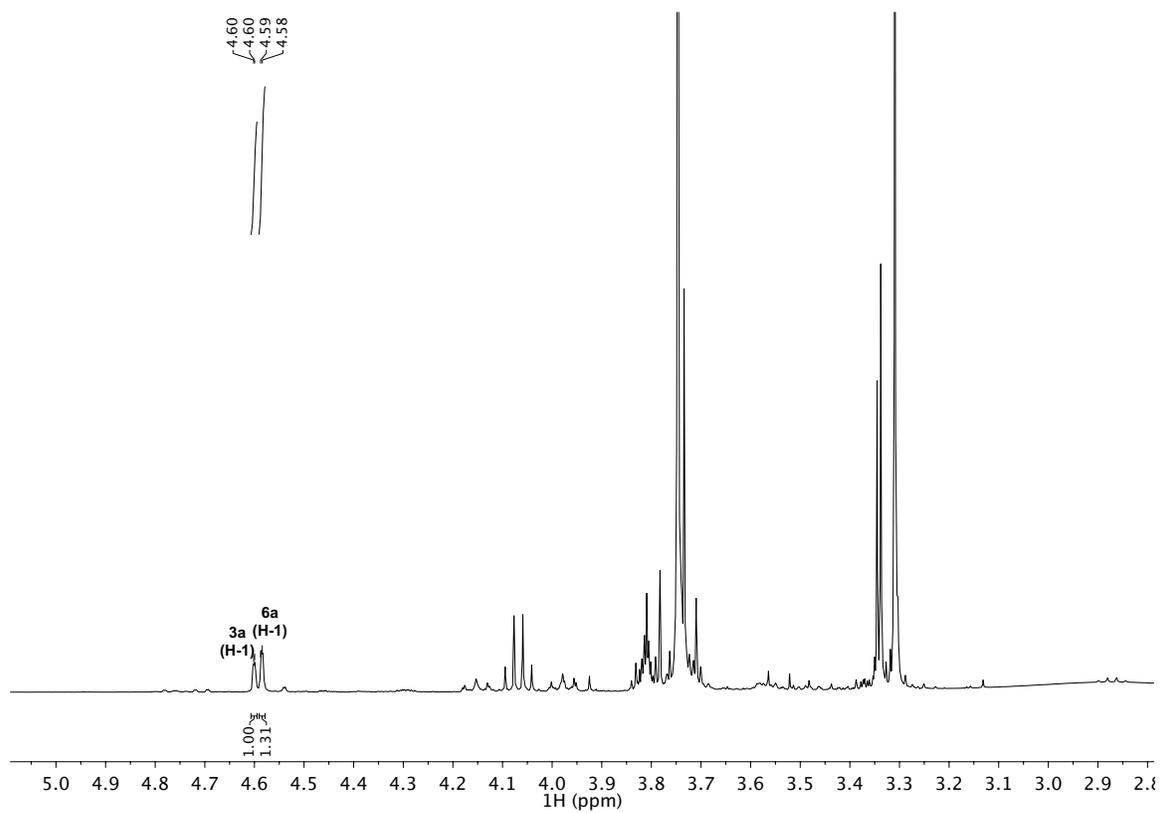


**Crossover experiment between of boronic esters **S3** and **2a** under optimized reaction conditions**

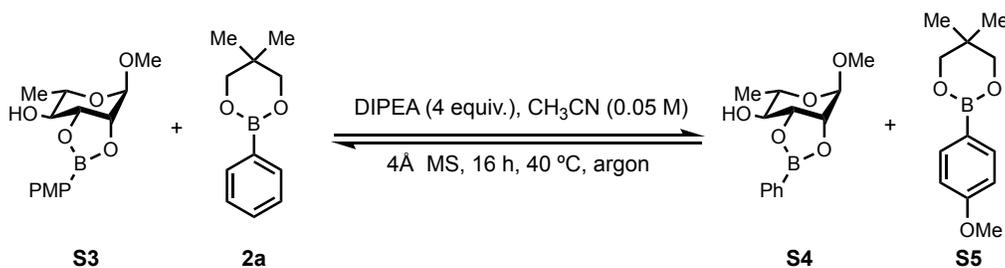


To an oven-dried 25mL Schlenk flask equipped with a magnetic stir bar was added 500 mg of oven-dried 4 Å molecular sieves, which were then activated under vacuum. The flask was cooled under argon and both **2a** (0.1 mmol) and  $\text{Cu}(\text{OAc})_2$  (36.6 mg, 0.2 mmol) was added. The flask was then evacuated and backfilled with argon. **S3** (0.1 mmol, prepared according to General Procedure A) was transferred into the reaction flask using acetonitrile (0.05 M, 2 mL). *N,N*-Diisopropylethylamine (70  $\mu\text{L}$ , 0.4 mmol, 4.0 equiv.) was then added. The reaction mixture was stirred at 40 °C for 16 hours. The mixture was then cooled, filtered through Celite, concentrated under reduced pressure, and then dissolved in ethyl acetate. The crude residue was transferred to a separatory funnel and hand shaken vigorously with a sorbitol:  $\text{Na}_2\text{CO}_3$  (1M: 1M) solution for 5 minutes ( $2 \times 20$  mL). The combined aqueous extracts were back-extracted with EtOAc, and the organic phase was dried over  $\text{MgSO}_4$ , and then concentrated under reduced pressure. **3a** and **6a** were observed in the crude  $^1\text{H}$  NMR spectrum in a (1:1.3, **3a:6a**).

**Figure S5: Crude  $^1\text{H}$  NMR (400 MHz,  $\text{CD}_3\text{CN}$ ) for crossover experiment between S3 and 2a**

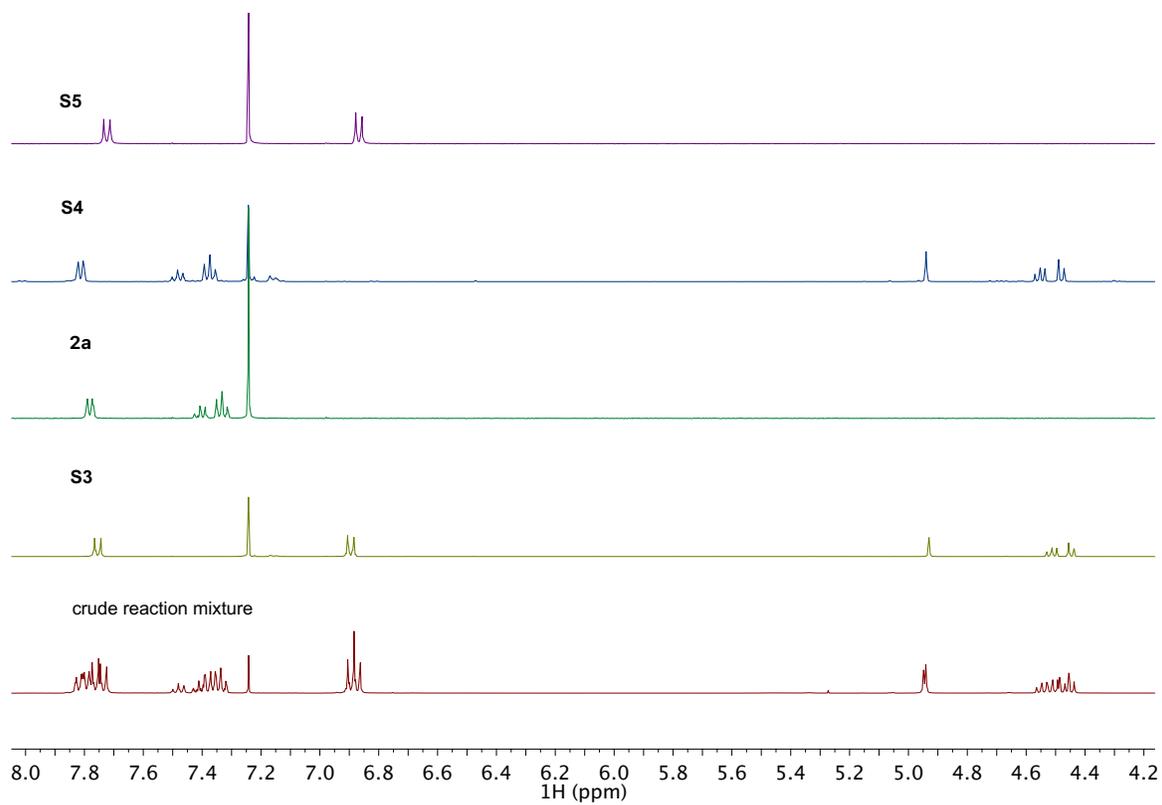


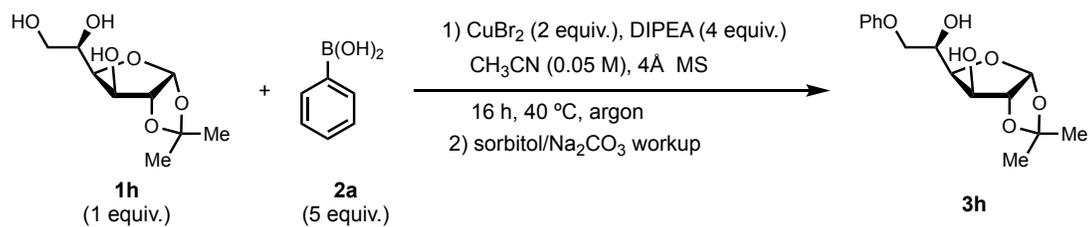
**Transesterification experiment between boronic esters **S3** and **2a** under optimized reaction conditions in the absence of  $\text{Cu}(\text{OAc})_2$**



To an oven-dried 25mL Schlenk flask equipped with a magnetic stir bar was added 1 gram of oven-dried 4 Å molecular sieves which were then activated under vacuum. The flask was cooled under argon and **2a** (0.1 mmol) was added. The flask was then evacuated and backfilled with argon. **S3** (0.1 mmol, prepared according to General Procedure A) was transferred into the reaction flask using acetonitrile (0.05 M, 2 mL). *N,N*-Diisopropylethylamine (70 μL, 0.4 mmol, 4.0 equiv.) was then added. The reaction mixture was stirred at 40 °C for 16 hours. The mixture was then cooled, filtered through Celite, concentrated under reduced pressure. Two carbohydrate derived aryl ethers were observed in the crude  $^1\text{H}$  NMR spectrum.

**Figure S6: Crude  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) for transesterification experiment between S3 and 2a**



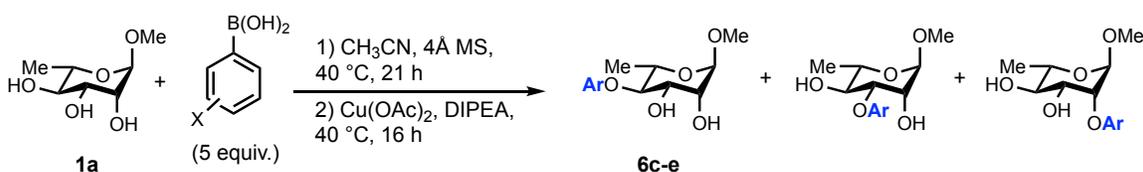
**Reaction in the absence of proposed bridging acetate**

**1h** (22 mg, 0.1 mmol, 1.0 equiv.) and **2a** (61 mg, 0.5 mmol, 5.0 equiv.) were subject to reaction conditions according to General Procedure B, but with the replacement of  $\text{Cu}(\text{OAc})_2$  with  $\text{CuBr}_2$  (44.7 mg, 0.2 mmol, 2.0 equiv.). **3h** was observed in <5% yield by crude  $^1\text{H}$  NMR.

### Pre-Stirring Experiments

The electronic properties of the arylboronic acid employed could influence the extent to which polyol-derived boronic esters are formed and the resulting product distribution. When electron deficient arylboronic acids were employed under optimized reaction conditions, increased amounts of a minor *O*-2 regioisomer (and *O*-3 regioisomer in the case of **6g**) were observed. Experiments in which **1a** and arylboronic acids from **Figure 4** were pre-stirred in the presence of 4 Å molecular sieves (in an attempt to maximize boronic ester formation) according to General Procedure D are summarized in **Table S3**. In each case, all three regioisomers were observed. The formation of the *O*-3 regioisomer under these reaction conditions may be attributed to different intermediate polyol-derived boronic esters or an alternative reaction pathway.

**Table S3: Yields and product distributions resulting from pre-stirring 1a with arylboronic acids**



Entry	X	NMR yield	<i>O</i> -4: <i>O</i> -3: <i>O</i> -2	Bis-arylation <sup>d</sup>
<b>6c<sup>a</sup></b>	4-(CH) <sub>2</sub>	44 %	11.6: 2.7: 1	15 %
<b>6d<sup>b</sup></b>	4-Br	53 %	12.6: 1.9: 1	20 %
<b>6e<sup>c</sup></b>	3-F	57 %	11.5: 2.4: 1	16 %

<sup>a</sup>Combined yield of three regioisomers determined from crude <sup>1</sup>H NMR spectrum of the crude reaction mixture (total integration of signals at 4.59 ppm (*O*-4 and *O*-3 regioisomers) and 4.71 ppm (*O*-2 regioisomers) relative to 1,3,5-trimethoxybenzene). Ratios of

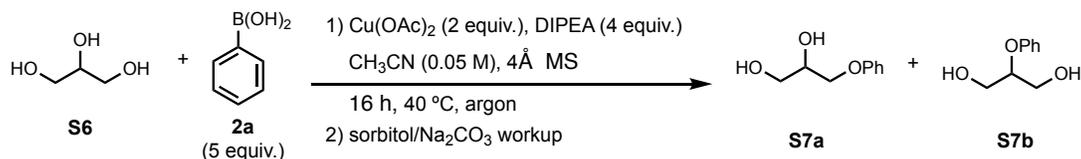
regioisomers were determined by integration of the  $^1\text{H}$  NMR spectrum of the crude reaction mixture in  $\text{CD}_3\text{CN}$ . O-4 (d, 4.59 ppm, H-1): O-3 (m, 4.02–3.99 ppm, H-2): O-2 (d, 4.71 ppm, H-1). Integration of O-4 (H-1) was determined through subtraction of the integrations of the doublet at 4.59 ppm and the multiplet at 4.02–3.99 ppm due to overlap of anomeric protons of the O-4 and O-3 regioisomers.

<sup>b</sup> Combined yield of three regioisomers determined from crude  $^1\text{H}$  NMR spectrum of the crude reaction mixture (total integration of signals at 4.58 ppm (O-4 and O-3 regioisomers) and 4.69 ppm (O-2 regioisomers) relative to 1,3,5-trimethoxybenzene). Ratios of regioisomers were determined by integration of the  $^1\text{H}$  NMR spectrum of the crude reaction mixture in  $\text{CD}_3\text{CN}$ . O-4 (d, 4.58 ppm, H-1): O-3 (m, 3.98–3.95 ppm, H-2): O-2 (d, 4.69 ppm, H-1). Integration of O-4 (H-1) was determined through subtraction of the integrations of the doublet at 4.58 ppm and the multiplet at 3.98–3.95 ppm.

<sup>c</sup> Combined yield of three regioisomers determined from crude  $^1\text{H}$  NMR spectrum of the crude reaction mixture (total integration of signals at 4.59 ppm (O-4 and O-3 regioisomers) and 4.71 ppm (O-2 regioisomers) relative to 1,3,5-trimethoxybenzene). Ratios of regioisomers were determined by integration of the  $^1\text{H}$  NMR spectrum of the crude reaction mixture in  $\text{CD}_3\text{CN}$ . O-4 (d, 4.58 ppm, H-1): O-3 (m, 4.01–3.98 ppm, H-2): O-2 (d, 4.69 ppm, H-1). Integration of O-4 (H-1) was determined through subtraction of the integrations of the doublet at 4.58 ppm and the multiplet at 4.01–3.98 ppm.

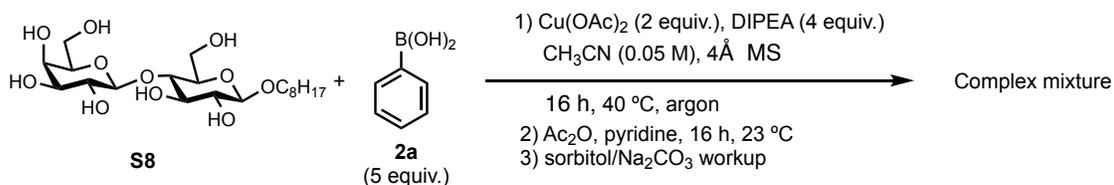
<sup>d</sup> Determined through  $^1\text{H}$  NMR analysis of crude reaction mixture.

**Preliminary application of optimized conditions to acyclic polyol**



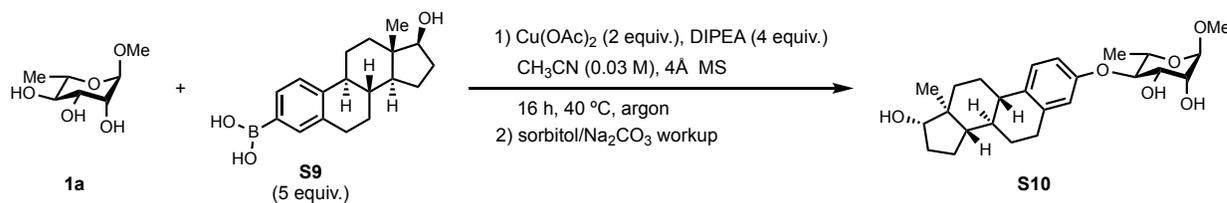
Glycerol (**S6**) (0.2 mmol, 1 equiv.) and phenylboronic acid (**2a**) were subject to optimized reaction conditions for cyclic carbohydrate derivatives according to General Procedure B. The composition of the crude reaction mixture in  $\text{CD}_3\text{CN}$  was analyzed. **S7a** (m, 3.67–3.59 ppm) and **S7b** (m, 4.39–4.31 ppm) were present in a 3.4: 1 ratio (**S7a**: **S7b**) with a combined  $^1\text{H}$  NMR yield of 33% (determined via total integration of aforementioned signals relative to 1,3,5-trimethoxybenzene).

**Preliminary application of optimized conditions to a disaccharide**



Octyl- $\beta$ -D-lactopyranoside (**S8**) and phenylboronic acid (**2a**) were subject to optimized reaction conditions according to General Procedure C. Column chromatography was performed on the crude reaction mixture, and complex mixtures of both mono- and bis-*O*-arylation of **S8** were identified.

**Preliminary application of optimized conditions to synthesis of estradiol-linked carbohydrate**



Prepared according to General Procedure B from methyl  $\alpha$ -L-rhamnopyranoside (**1a**) (8.7 mg, 0.049 mmol, 1 equiv.) and **S9** (73 mg, 0.243 mmol, 5 equiv.), in 1.5 mL (0.03 M) of acetonitrile. Analysis of the crude  $^1\text{H}$  NMR spectrum indicated that the *O*-4 arylated regioisomer (**S10**) was present, along with two other mono-*O*-aryl regioisomers, in a 2: 1: 1 (*O*-4: *O*-3: *O*-2) ratio. The three isomers were isolated in a combined yield of approximately 40% after column chromatography.

## Computational Studies

### Method

All ground state quantum chemical calculations were performed using the Gaussian 09 program.<sup>10</sup> DFT calculations were carried out using the B97-D3<sup>11</sup> functional with all stationary points optimized using the Def2-TZVP<sup>12</sup> basis set. Solvation was modeled using a self-consistent reaction field by means of the PCM<sup>13</sup> method. Vibrational frequency calculations were performed to characterize each stationary point as a minimum (no imaginary frequencies) or saddle point (one imaginary frequency) on the potential energy surface. The intrinsic reaction coordinate method was used to check all transition states structures.<sup>14</sup> All frequency calculations were carried out at 1 atm and 298.15 K. All structures were visualized using GaussView 5.0.8. Reaction coordinates were created in Origin 9.0.0 SR2.

**Table S4: Ligand Exchange Without Solvent**

	LE_SM	LE_TS	LE_P	LE_P-AcOH	AcOH
Energy (hartree)	-3236.291432	-3236.275116	-3236.277768	-3007.193344	-229.0606331
ZP corr	0.477538	0.472501	0.476437	0.41537	0.059932
E corr	0.51281	0.507173	0.511553	0.444539	0.064662
H corr	0.513754	0.508117	0.512497	0.445484	0.065606
G corr	0.406599	0.402623	0.405291	0.352825	0.031515
Imaginary Frequency		-666.5592			

**Table S5: Ligand Exchange With Solvent**

	LE_SM	LE_TS	LE_P	LE_P-ACN	ACN
Energy (hartree)	-3236.291432	-3236.275116	-3236.277768	-3139.938321	-132.72837
ZP corr	0.477538	0.472501	0.476437	0.461193	0.044238
E corr	0.51281	0.507173	0.511553	0.49557	0.047858
H corr	0.513754	0.508117	0.512497	0.496514	0.048803
G corr	0.406599	0.402623	0.405291	0.392594	0.021254
Imaginary Frequency		-666.5592			

**Table S6: Transmetalation Without Solvent**

	TM_SM	TM_TS	TM_P
Energy (hartree)	-2775.610334	-2775.587295	-2775.635344
ZP corr	0.327318	0.326536	0.326369
E corr	0.350704	0.349481	0.350861
H corr	0.351648	0.350425	0.351806
G corr	0.273371	0.274294	0.269303
Imaginary Frequency		-280.2094	

**Table S7: Transmetalation With One Solvent Molecule**

	TM-S_ACN	TM-S_SM	TM-S_PRC	TM-S_TS	TM-S_P
Energy (hartree)	-132.7283661	-2908.37827	-2908.378695	-2908.345654	-2908.389067
ZP corr	0.044238	0.37295	0.371139	0.370299	0.37193
E corr	0.047858	0.401804	0.400425	0.399399	0.401765
H corr	0.048803	0.402748	0.40137	0.400344	0.402709
G corr	0.021254	0.309769	0.307681	0.307019	0.306246
Imaginary Frequency				-224.6293	

**Table S8: Transmetalation With Two Solvent Molecules**

	TM-2S_SM	TM-2S_TS	TM-2S_P
Energy (hartree)	-3041.128093	-3041.084133	-3041.124718
ZP corr	0.417689	0.415538	0.417314
E corr	0.452018	0.450081	0.452656
H corr	0.452962	0.450081	0.4536
G corr	0.347467	0.345557	0.342947
Imaginary Frequency		-333.0888	

## Geometries

## Ligand Exchange

AcOH

	LE_SM	LE_TS	LE_P
C	0.089103	0.124767	0.000004
O	0.631639	1.211831	-0.000001
O	0.790146	-1.039991	0.000001
H	1.736715	-0.808106	-0.000012
C	-1.394861	-0.121633	0.000001
H	-1.928418	0.828560	0.000110
H	-1.674022	-0.706891	-0.882250
H	-1.674007	-0.707096	0.882119

ACN

	LE_SM	LE_TS	LE_P
N	-0.000000	-0.000000	1.436376
C	-0.000000	-0.000000	0.276707
C	0.000000	0.000000	-1.177056
H	-0.000000	1.028379	-1.550846
H	0.890602	-0.514190	-1.550846
H	-0.890602	-0.514190	-1.550846

	LE_SM	LE_TS	LE_P
C	-2.647369	-2.417617	-0.794862
C	-1.546159	-0.596916	0.500687
C	-1.412000	-1.513130	-0.711237
H	-2.787815	-2.959828	0.151574
H	-1.393038	-1.160679	1.425560
H	-1.421655	-0.904869	-1.620615
O	-3.777086	-1.533298	-1.014045
C	-4.059134	-0.652261	0.060190
H	-4.852827	0.002079	-0.329315
O	-4.499970	-1.335231	1.217835
C	-5.718581	-2.060151	1.022789
H	-5.584366	-2.888091	0.316518
H	-6.004674	-2.455782	1.999964
H	-6.510351	-1.394398	0.649339
C	-2.604864	-3.391822	-1.954022
H	-1.764481	-4.080604	-1.832264
H	-3.531293	-3.972934	-1.995095
H	-2.481418	-2.855169	-2.901390
O	-0.565862	0.462436	0.440168
C	-2.855040	0.189535	0.507042
H	-3.065500	0.550613	1.524333
O	-2.605153	1.292067	-0.357181
C	-0.699089	3.016309	0.216387
C	-0.892920	4.195163	-0.525564
C	-0.087194	3.138605	1.475240
C	-0.498342	5.440963	-0.034354
H	-1.357082	4.138753	-1.508612
C	0.316810	4.380355	1.973846
H	0.079186	2.246250	2.074225
C	0.111646	5.537090	1.219716
H	-0.661450	6.337055	-0.629399
H	0.792613	4.445100	2.950177
H	0.424968	6.505099	1.603674
B	-1.177877	1.588265	-0.340613
C	3.091721	-0.797265	-0.167966
C	4.139097	-0.082020	0.374363
C	3.220432	-1.913000	-0.970697
C	5.435990	-0.504601	0.041806
H	3.985778	0.767964	1.031514
C	4.528939	-2.320135	-1.278843
H	2.362853	-2.446965	-1.364746
C	5.624896	-1.618464	-0.776872
H	6.286099	0.042496	0.441265
H	4.670128	-3.189978	-1.915500
H	6.632338	-1.945204	-1.019598
O	1.576646	-0.628873	1.897990
C	1.324110	-1.821303	2.365371
C	1.672689	-1.953423	3.836813
H	2.744797	-2.169862	3.913285
H	1.477634	-1.023495	4.375249
H	1.111224	-2.778709	4.277853
O	0.868353	-2.775392	1.722298
O	-0.152404	-2.184086	-0.710851
H	0.075574	-2.511932	0.195948
Cu	1.291083	-0.143721	0.102902
H	0.748247	2.591051	-3.863609
C	0.668311	1.502942	-3.759833
C	0.422382	1.182456	-2.310460
H	1.584643	1.032531	-4.114943
H	-0.188366	1.175709	-4.355540
O	1.363079	0.625495	-1.669883
O	-0.725323	1.512198	-1.853606
C	0.552145	3.322063	-0.666423
C	1.092865	1.158652	0.448096
C	0.121430	1.863866	-0.480250
H	0.690078	3.808108	0.309355
H	0.993831	1.527240	1.472903
H	1.094899	1.408939	-1.476527
O	1.828074	3.236020	-1.352039
C	2.875383	2.607408	-0.624776
H	3.694683	2.531793	-1.354596
O	3.273022	3.361664	0.501176
C	3.792407	4.654061	0.168979
H	3.016547	5.299257	-0.259708
H	4.157634	5.090426	1.101234
H	4.622616	4.565406	-0.546596
C	-0.386989	4.130729	-1.535202
H	-1.364474	4.207995	-1.050629
H	0.009188	5.139169	-1.688295
H	-0.518673	3.648743	-2.510087
O	0.766866	-0.249940	0.423171
C	2.520271	1.211509	-0.078615
H	3.236610	0.983362	0.724580
O	2.547910	0.194924	-1.069998
C	2.453415	-2.166008	0.076537
C	3.650290	-2.660151	-0.469288
C	1.918861	-2.842263	1.185595
C	4.289230	-3.780704	0.066439
H	4.092465	-2.155076	-1.326440
C	2.548470	-3.965800	1.728070
H	0.999096	-2.480315	1.639373
C	3.737360	-4.439174	1.168811
H	5.216917	-4.140983	-0.373391
H	2.114443	-4.469743	2.589205
H	4.232116	-5.311441	1.589658
B	1.714044	-0.895940	-0.580725
C	-3.082349	-0.370906	-0.344452
C	-3.920321	-1.135184	0.441887
C	-3.460431	0.293395	-1.494198
C	-5.256282	-1.247216	0.021750
H	-3.580057	-1.632944	1.342952
Cu	-1.208952	-0.368477	0.120136
C	-4.800265	0.161084	-1.892558
H	-2.768703	0.895974	-2.071737
C	-5.689504	-0.602583	-1.136326
H	-5.942962	-1.844034	0.616947
H	-5.130913	0.668402	-2.795442
H	-6.725953	-0.693566	-1.449758
O	-1.620397	-0.333970	2.281518
C	-1.724998	0.751726	2.901473
C	-1.978478	0.737808	4.391135
H	-2.927014	1.244491	4.598801
H	-2.014783	-0.283363	4.771656
H	-1.188268	1.299085	4.900028
O	-1.632434	1.921258	2.358216
O	-1.208861	1.644641	-0.010640
H	-1.391892	1.838696	1.191730
H	0.427206	-3.972915	-2.698512
C	-0.305059	-3.173247	-2.861433
C	-0.137777	-2.153259	-1.772483
H	-1.312170	-3.589189	-2.860945
H	-0.078330	-2.714048	-3.827953
O	-1.028528	-2.064604	-0.881124
O	0.934000	-1.439837	-1.824622
C	-0.241717	3.338347	-0.315673
C	0.885719	1.270791	0.515675
C	-0.342086	1.814055	-0.195977
H	-0.040702	3.788458	0.666119
H	0.887545	1.568614	1.568454
H	-0.324635	1.458609	-1.237620
O	0.897095	3.550375	-1.191488
C	2.152728	3.099553	-0.699094
H	2.831889	3.228278	-1.554591
O	2.593230	3.856236	0.409960
C	2.801145	5.240892	0.110561
H	1.859760	5.740679	-0.146256
H	3.222066	5.693182	1.011238
H	3.508554	5.354875	-0.723721
C	-1.448680	3.981392	-0.963328
H	-2.330119	3.831726	-0.333279
H	-1.285871	5.055993	-1.090408
H	-1.641870	5.532431	-1.943782
O	0.821465	-0.169541	0.430207
C	2.167623	1.634585	-0.222664
H	3.040858	1.516209	0.435936
O	2.216554	0.687507	-1.281341
C	2.873387	-1.603740	-0.185542
C	4.124215	-1.689206	-0.818520
C	2.629232	-2.473650	0.890483
C	5.093555	-2.603556	-0.398566
H	4.344550	-1.023563	-1.651209
C	3.589931	-3.394436	1.316379
H	1.675098	-2.422980	1.410523
C	4.827428	-3.461747	0.671482
H	6.056331	-2.647532	-0.903616
H	3.377065	-4.055193	2.154219
H	5.579645	-4.174166	1.002206
B	1.753513	-0.570630	-0.707691
C	-2.971847	-0.629950	-0.502867
C	-3.933820	-1.179113	0.322046
C	-3.203574	-0.189653	-1.792267
C	-5.224304	-1.329401	-0.212654
H	-3.713981	-1.495580	1.335779
Cu	-1.156823	-0.559986	0.140161
C	-4.498990	-0.352143	-2.304958
H	-2.427330	0.263871	-2.402088
C	-5.501752	-0.918640	-1.516050
H	-6.001714	-1.768689	0.407641
H	-4.709883	-0.024345	-3.319763
H	-6.504791	-1.034083	-1.917571
O	-1.406137	-1.147289	2.413807
C	-1.519728	-0.275570	3.279183
C	-1.540492	-0.587345	4.751065
H	-2.366615	-0.062297	5.239070
H	-1.626344	-1.662527	4.908560
H	-0.609376	-0.226950	5.203297
O	-1.622155	1.019640	3.011727
O	-1.500640	1.293389	0.444667
H	-1.560101	1.176152	1.996132
H	1.025304	-3.960515	-2.474773
C	0.107142	-3.383274	-2.634953
C	0.090136	-2.246180	-1.657507
H	-0.763709	-4.025969	-2.509826
H	0.146256	-2.983726	-3.652797
O	-0.766101	-2.256725	-0.726411
O	0.971804	-1.323630	-1.838831

LE_P-AcOH			LE_P-ACN			Transmetallation Without Solvent			TM_TS						
C	0.293735	3.313097	-0.007838	C	2.122806	-2.839143	0.147744	TM_SM			C	2.795011	0.633921	1.119347	
C	-0.803045	1.209639	-0.791745	C	1.468389	-0.640924	-0.810646	C	2.604193	0.432363	1.190254	C	1.299656	-1.253208	0.503980
C	0.449517	1.793794	-0.158328	C	1.051206	-1.736664	0.151596	C	0.935865	-1.250742	0.474425	C	1.334020	0.158309	1.115602
H	0.010283	3.766196	-0.967649	H	2.301583	-3.188410	-0.878447	C	1.105932	0.095571	1.160209	H	3.474752	-0.139038	1.504928
H	-0.884257	1.516218	-1.838351	H	1.326921	-0.992223	-1.838948	C	3.185353	-0.396321	1.619054	H	1.880504	-1.978784	1.079189
O	-0.793344	3.467083	0.943259	H	1.063917	-1.339805	1.177354	H	1.281140	-2.060056	1.125633	H	0.932285	0.822519	0.348157
C	-2.058588	2.962801	0.535803	O	3.313228	-2.181850	0.654045	H	2.958426	-0.167980	0.489713	O	3.080892	0.857450	-0.298036
H	-2.679492	3.051039	1.439445	C	3.856038	-1.156620	-0.169331	O	2.937366	0.582910	-0.220460	C	2.951163	-0.259443	-1.167176
O	-2.613378	3.709661	-0.528386	H	4.661285	-0.726637	0.444305	C	2.823750	-0.568695	-1.051357	H	2.959992	0.186420	-2.172631
C	-2.857263	5.081039	-0.197847	O	4.371704	-1.666605	-1.383455	H	2.958426	-0.167980	0.489713	O	4.025489	-1.171109	-1.017505
H	-1.921231	5.621782	-0.014967	C	5.439594	-2.601875	-1.202437	O	3.819602	-1.529533	-0.756110	C	5.303222	-0.603649	-1.323887
H	-3.371997	5.519976	-1.055447	H	5.091298	-3.519123	-0.712810	C	5.153915	-1.044361	-0.938490	H	5.573628	0.183360	-0.610399
C	-3.496754	5.157330	0.693579	H	5.816817	-2.840347	-2.199586	H	5.395862	-0.254613	-0.217672	H	6.027164	-1.419304	-1.261587
C	1.511491	4.000137	0.570490	H	6.246437	-2.158249	-0.600731	H	5.818010	-1.897832	-0.783833	H	5.308219	-0.185136	-2.341063
H	2.357528	3.890263	-0.113953	C	1.813094	-4.004015	1.062291	H	5.288557	-0.653513	-1.957679	C	3.018084	1.948049	1.833323
H	1.134325	5.066477	0.717828	H	0.904302	-4.507710	0.720133	C	2.939114	1.736702	1.878501	H	2.823051	1.824473	2.902601
H	1.782027	3.552737	1.533178	H	2.636965	-4.724693	1.059714	H	2.685461	1.667466	2.940731	H	4.051266	2.284301	1.701213
O	-0.658802	-0.231022	-0.727447	H	1.651573	-3.653701	2.087806	H	4.007173	1.957627	1.786638	H	2.341414	2.716551	1.444481
C	-2.043584	1.503910	0.040166	O	0.569466	0.455473	-0.558400	H	2.366735	2.559885	1.437023	O	-0.053558	-1.689474	0.414566
H	-2.957648	1.354176	-0.553039	C	2.848859	-0.055370	-0.572997	H	2.685461	1.667466	2.940731	C	1.695378	-1.134075	-0.964906
O	-1.973499	0.542041	1.086098	H	3.237653	0.403848	-1.494176	H	4.007173	1.957627	1.786638	H	1.907006	-2.114386	-1.406075
C	-2.666592	-1.708975	-0.051058	O	2.659284	0.938518	0.420047	H	2.366735	2.559885	1.437023	O	0.477049	-0.621289	-1.577078
C	-3.998689	-1.556361	0.361691	C	0.895350	2.879527	0.144533	O	-0.470429	-1.382346	0.266293	C	-1.497750	0.934757	-0.349381
C	-2.371784	-2.784455	-0.907442	C	0.236598	3.756935	1.018763	C	1.482678	-1.342246	-0.946858	C	-2.893315	1.143230	-0.438733
C	-4.998954	-2.439667	-0.055500	C	1.227692	3.376680	-1.129062	H	1.699495	-2.383346	-1.213917	C	-0.688180	2.016440	-0.743676
H	-4.255187	-0.727879	1.018948	C	-0.076209	5.069355	0.648637	O	0.427835	-0.860269	-1.794814	C	-3.438424	2.346752	-0.894817
C	-3.361195	-3.675347	-1.327234	H	-0.041512	3.415047	2.012949	C	-1.079871	1.018114	-0.938880	H	-3.593105	0.366836	-0.151790
H	-1.351507	-2.927755	-1.259712	C	0.925045	4.684001	-1.511864	C	-2.181446	1.614040	-0.292298	C	-1.219933	3.216931	-1.213841
C	-4.681644	-3.504811	-0.900661	H	1.728479	2.721274	-1.839704	C	-0.166111	1.901079	-1.547038	H	0.395274	1.930265	-0.746501
H	-6.024785	-2.297481	0.278188	C	0.268796	5.538589	-0.619969	C	-2.331958	3.002597	-0.208659	C	-2.603620	3.392628	-1.282561
H	-3.106510	-4.499655	-1.990125	H	-0.592112	5.723501	1.348302	H	-2.967276	1.004805	0.143251	H	-4.518976	2.460570	-0.941102
H	-5.455784	-4.195071	-1.227633	H	1.193410	5.038086	-2.505026	C	-0.316734	3.287700	-1.489083	H	-0.549652	4.012518	-1.530776
B	-1.523546	-0.689021	0.450318	H	0.025260	6.556699	-0.914300	H	0.693754	1.483948	-2.061310	H	-3.022460	4.331338	-1.636361
C	3.249340	-0.531680	-0.329803	B	1.244067	1.340523	0.494591	C	-1.396051	3.848196	-0.803490	B	-0.602913	-0.939173	-0.705952
C	4.010468	-0.613292	-1.483163	C	-2.785575	-1.645957	-0.340141	H	-3.190643	3.419215	0.312789	O	0.501132	0.305541	2.225491
C	3.781325	-0.563636	0.948083	C	-2.969828	-2.545230	-1.372976	H	0.415408	3.931356	-1.971797	Cu	-1.228038	-0.151941	1.510939
C	5.394304	-0.795032	-1.338257	C	-3.687495	-1.443613	0.687600	H	-1.510574	4.927499	-0.741161	H	-3.413247	-3.715217	-1.244532
H	3.568465	-0.543790	-2.472756	C	-4.162438	-3.284032	-1.382485	B	-0.777200	-0.592023	-1.014586	C	-3.834376	-2.807797	-0.801251
Cu	1.340964	-0.475968	-0.527053	H	-2.221739	-2.694340	-2.145014	O	0.333746	0.089937	2.339388	C	-2.730238	-1.939792	-0.280205
C	5.167655	-0.735628	1.071008	C	-4.869171	-2.202037	0.663196	Cu	-1.403913	-0.440499	1.692548	H	-4.529556	-3.062283	-0.001990
H	3.161007	-0.473534	1.834905	H	-3.498783	-0.731745	1.483776	H	-3.946423	-3.050198	-1.774767	H	-4.362010	-2.269294	-1.596476
C	5.966906	-0.853176	-0.067305	C	-5.104374	-3.112831	-0.366914	C	-4.244576	-2.209195	-1.142955	O	-2.720364	-1.533073	0.897030
H	6.012851	-0.878079	-2.228423	H	-4.337086	-3.995564	-2.185862	C	-3.027976	-1.537556	-0.569260	O	-1.810901	-1.634530	-1.181675
H	5.609683	-0.775545	2.063480	H	-5.597756	-2.066157	1.458922	H	-4.912154	-2.543382	-0.348819				
H	7.040886	-0.981640	0.036898	H	-6.022593	-3.693945	-0.376623	H	-4.771296	-1.488393	-1.779382				
O	1.568907	1.334538	-0.897309	O	-0.248816	-2.152601	-0.210957	O	-3.019396	-1.228557	0.652638				
H	-0.458171	-4.140675	2.001637	Cu	-1.202499	-0.527490	-0.378694	O	-2.080255	-1.308904	-1.436773				
C	0.397918	-3.477204	2.172556	H	0.010581	1.690351	4.333228								
C	0.280362	-2.311227	1.237193	C	-0.329480	0.717897	3.964093								
H	1.326834	-4.022576	2.008871	C	-0.305040	0.693269	2.452320								
H	0.335323	-3.122555	3.205345	H	-1.332658	0.504429	4.334982								
O	1.095544	-2.223625	0.271634	O	0.367722	-0.037292	4.344348								
O	-0.662925	-1.471193	1.491466	H	-1.294050	0.340358	1.798188								
				O	0.847946	1.045126	1.949408								
				N	-2.154795	1.036144	-0.997341								
				C	-2.438776	2.124355	-1.250529								
				C	-2.771597	3.494970	-1.557443								
				H	-3.660393	3.794687	-0.994199								
				H	-1.927235	4.134173	-1.275931								
				H	-2.967649	3.598477	-2.628774								

TM_P			With One Solvent Molecule			TM-S_PRC			TM-S_TS						
C	2.343898	-1.840525	0.536380	C	2.577348	-1.772603	-0.333993	C	3.103813	-1.616288	-0.131789	C	2.861000	-1.653644	0.286400
C	1.588921	0.033053	-0.901322	C	1.336671	0.201136	-1.179181	C	1.497768	0.245069	-0.883746	C	1.507691	-0.189264	-1.173687
C	1.154905	-0.913115	0.218368	C	1.181348	-1.131193	-0.469015	C	1.621344	-1.309673	-0.361389	C	1.415955	-1.147722	0.041512
H	2.698304	-2.334976	-0.378541	C	3.070262	-1.826010	-1.314946	H	3.695755	-1.356291	-1.019762	H	3.338034	-1.963501	-0.654529
H	1.598695	-0.474920	-1.866727	H	1.545326	0.038040	-2.241805	H	1.925536	0.262201	-1.890992	H	1.850394	-0.722212	-2.064748
H	1.054119	-0.302348	1.141680	H	0.900353	-0.938926	0.577720	H	1.136339	-1.230082	0.625837	H	1.246385	-0.538346	0.937787
O	3.392495	-0.971921	1.051143	O	3.301539	-0.852884	0.526301	O	3.512204	-0.800192	0.986751	O	3.564032	-0.506920	0.829149
C	3.920856	-0.042392	0.127768	C	3.542645	0.452818	0.011938	O	3.510461	0.594381	0.728575	C	3.655793	0.621668	-0.025381
H	4.579304	0.599152	0.731510	H	3.966586	0.995605	0.869630	H	3.715901	1.050571	1.707584	H	3.980252	1.436583	0.638494
O	4.644729	-0.660987	-0.917697	O	4.455080	0.434344	-1.069111	O	4.493225	0.967404	-0.214859	O	4.600767	0.422256	-1.063135
C	5.776151	-1.410795	-0.458432	C	5.742373	-0.085192	-0.721477	C	5.832056	0.696887	0.216870	C	5.931347	0.200369	-0.586524
H	5.465566	-2.272609	0.143170	H	5.690397	-1.151007	-0.469376	H	6.016598	-0.380606	0.297712	H	6.004766	-0.738930	-0.025848
H	6.300453	-1.756008	-1.351956	H	6.380278	0.052953	-1.597547	H	6.493772	1.126044	-0.538590	H	6.573090	0.151098	-1.469220
H	6.444814	-0.774970	0.139555	H	6.165680	0.464945	0.131736	H	6.027406	1.170113	1.189944	H	6.256846	1.030324	0.057960
C	2.037670	-2.864070	1.607858	H	2.573454	-3.125762	0.341400	H	4.402218	-3.231492	0.459466	C	2.939238	-2.760034	1.315802
H	1.247810	-3.535377	1.259910	H	2.022669	-3.842711	-0.274869	H	4.202184	-3.326877	1.144808	H	2.422666	-3.648332	0.941247
H	2.929064	-3.456610	1.836664	H	3.596003	-3.492318	0.477172	H	2.760502	-3.326877	1.144808	H	3.983514	-3.017674	1.520444
H	1.695498	-2.369568	2.523890	O	2.290382	1.188562	-0.523980	O	0.175041	0.599229	-0.869544	H	2.460974	-2.448864	2.251078
O	0.553620	1.084046	-0.940047	H	2.086124	-3.062162	1.320675	C	2.180400	1.122902	0.174491	O	0.236585	0.416239	-1.454455
C	2.862527	0.809097	-0.591982	O	0.060612	0.843193	-1.045917	H	2.407184	2.089902	-0.309670	C	2.358255	1.002483	-0.755842
H	3.320108	1.231421	-1.491859	C	2.290382	1.188562	-0.523980	O	1.184432	1.266551	1.152900	H	2.649389	1.611561	-1.621423
O	2.381521	1.929409	0.216792	H	2.647519	1.929229	-1.252554	C	-1.334874	0.662432	1.248422	O	1.416734	1.762255	0.044055
C	-3.026690	-0.838683	-0.172455	O	1.520126	1.842567	0.482350	C	-2.658988	1.126084	1.170203	C	-1.067003	0.655755	1.104987
C	-4.179537	-0.043048	-0.118078	C	-0.523932	0.777648	1.599111	C	-1.115013	-0.499471	2.012675	C	-2.468552	0.844839	1.075697
C	-3.157428	-2.231100	-0.124203	C	-1.887466	0.462383	1.763707	C	-3.711444	0.456251	1.797419	C	-0.422980	0.675870	2.353701
C	-5.446331	-0.636080	-0.031411	C	0.345432	0.343728	2.619005	H	-2.880149	2.018506	0.593022	C	-3.197403	1.004462	2.263604
H	-4.105128	1.041955	-0.143617	C	-2.350521	-0.273101	2.858496	H	-2.159574	-1.184547	2.637017	H	-2.998817	0.909138	0.128224
C	-4.422650	-2.823994	-0.037176	H	-2.614456	0.796464	1.030766	H	-0.100371	-0.870033	2.138602	C	-1.144538	0.865328	3.533600
H	-2.269848	-2.858941	-0.153598	C	-0.106467	-0.380063	3.723428	H	-4.725357	0.841894	1.714774	H	0.656172	0.552277	2.411114
C	-5.568912	-2.026301	0.009181	H	1.403645	0.571305	2.529064	H	-1.952480	-2.083346	3.213790	C	-2.534326	1.019036	3.489668
H	-6.334345	-0.007701	0.006592	C	-1.460434	-0.701854	3.843810	H	-4.287652	-1.240579	3.004532	H	-4.274588	1.147066	2.219580
H	-4.511366	-3.908355	-0.003496	H	-3.409840	-0.506841	2.941976	C	-3.467753	-0.710844	2.525239	H	-0.624659	0.881027	4.488855
H	-6.552065	-2.485892	0.079677	H	0.598665	-0.698533	4.488476	H	-4.725357	0.841894	1.714774	H	-3.095386	1.156297	4.410600
B	1.057258	2.072249	-0.102933	H	-1.817130	-1.274791	4.696537	H	-1.952480	-2.083346	3.213790	B	0.126570	1.466774	-0.497076
O	-0.044682	-1.526319	-0.116260	O	0.159551	-1.838902	-1.107558	H	-4.287652	-1.240579	3.004532	O	0.416186	-2.082425	-0.094358
Cu	-1.282993	-0.008540	-0.356526	Cu	-1.345067	-0.469273	-1.121289	B	-0.118821	1.346175	0.439996	Cu	-1.258974	-1.094568	0.038075
H	-1.197485	5.281074	0.107357	H	-1.832715	4.807955	-1.268973	O	0.955473	-2.095811	-1.229237	H	-1.562399	4.801398	-1.853996
C	-1.567374	4.519781	0.802486	C	-2.537374	4.097160	-0.826382	Cu	-0.897004	-1.825530	-1.157571	H	-2.341529	4.085316	-1.575852
C	-1.056036	3.178621	0.384095	C	-1.868846	2.756830	-0.640434	H	0.041400	5.126518	-1.064020	C	-1.779572	2.686726	-1.522347
H	-2.656461	4.518745	0.818212	H	-3.421347	4.001396	-1.457431	C	-1.000228	4.819817	-0.920527	H	-3.169316	4.132326	-2.283976
H	-1.171689	4.766563	1.793230	H	-2.827711	4.491136	0.154067	C	-1.090861	3.306876	-0.862439	H	-2.697569	4.362442	-0.576666
O	-1.760087	2.228410	0.094131	O	-2.392611	1.717769	-1.079758	H	-1.614898	5.207629	-1.734195	O	-2.277415	1.724964	-2.077312
O	0.310570	3.137748	0.381412	O	-0.736470	2.827065	0.023644	H	-1.336147	5.247024	0.030729	O	-0.668065	2.637294	-0.760810
				N	-2.908702	-1.554806	-1.163062	O	-1.785171	2.653515	-1.631809	N	-2.604095	-2.246815	-0.785505
				C	-3.851765	-2.218838	-1.128224	O	-0.341110	2.807379	0.111612	C	-3.427425	-2.897963	-1.267951
				C	-5.033820	-3.048434	-1.082951	N	-2.735360	-1.667801	-1.138006	C	-4.459160	-3.711732	-1.871547
				H	-5.136526	-3.593526	-2.026241	C	-3.867381	-1.477076	-1.010061	H	-4.739720	-3.289475	-2.841383
				H	-4.947471	-3.763232	-0.258773	C	-5.284603	-1.243093	-0.865121	H	-4.087692	-4.731065	-2.014544
				H	-5.916781	-2.420781	-0.928250	H	-5.480901	-0.167384	-0.904075	H	-5.337597	-3.735074	-1.219434
								H	-5.827352	-1.743037	-1.673301				
								H	-5.622033	-1.633990	0.099387				

TM-S_P			With Two Solvent Molecules			TM-2S_TS			TM-2S_P						
C	-2.996812	-0.093942	1.462886	C	-3.147296	1.437116	-0.693109	C	3.056909	1.383411	0.875517	C	1.927336	-0.814994	0.807002
C	-1.711334	0.905424	-0.440230	C	-1.617527	-0.572078	-0.790905	C	1.662406	0.711690	0.813731	C	1.662406	0.711690	0.813731
C	-1.589341	0.144216	0.887313	C	-1.688054	0.960092	-0.729436	H	3.689503	0.921984	1.647965	C	-2.047842	0.500988	0.932664
H	-3.524043	0.863203	1.582060	C	-3.696466	1.027981	-1.553650	H	2.407979	-1.128059	1.738361	C	-1.652015	-0.822073	0.259441
H	-1.898708	1.966187	-0.258042	H	-1.956205	-0.927671	-1.770720	H	1.327024	0.987564	-0.194010	H	-3.443595	-1.840545	0.956711
H	-1.220367	-0.871353	0.640089	H	-1.280622	1.246509	0.257656	C	3.648062	1.153856	-0.430991	H	-2.224701	0.344119	1.999397
O	-3.714896	-0.919107	0.505297	O	-3.713638	0.904501	0.532287	C	3.867344	-0.203055	-0.769628	H	-1.275286	-0.573153	-0.751541
C	-3.964803	-0.300346	-0.738251	C	-3.729272	-0.511611	0.628869	H	4.081075	-0.183297	-1.848779	O	-3.777703	-0.900381	-0.880319
H	-4.398414	-1.097326	-1.360457	O	-4.070956	-0.702350	1.657418	O	4.966302	-0.755672	-0.061161	C	-4.284899	0.292958	-0.325665
O	-4.858107	0.792981	-0.638975	O	-4.614479	-1.105063	-0.303772	C	6.202671	-0.084015	-0.317564	H	-4.813586	0.781411	-1.157831
C	-6.155782	0.422878	-0.160515	C	-5.979957	-0.723640	-0.115379	H	6.188315	0.943041	0.066009	O	-5.169301	0.065491	0.756751
H	-6.114385	0.069240	0.876409	H	-6.129335	0.344583	-0.313508	H	6.979312	-0.655620	0.196006	C	-6.328479	-0.690779	0.391389
H	-6.774594	1.321096	-0.216903	H	-6.569039	-1.312124	-0.822728	H	6.417035	-0.061111	-1.396466	H	-6.063645	-1.714881	0.103196
C	-6.591802	-0.364701	-0.792215	H	-6.308467	-0.946805	0.910545	C	2.982809	2.882065	1.074954	H	-6.974166	-0.713506	1.272031
H	-2.979675	-0.849130	2.775600	H	-2.888973	3.386528	-1.556664	C	2.553757	3.101789	2.056511	H	-6.859282	-0.208537	-0.442371
H	-2.448717	-0.265171	3.531446	H	-4.348628	3.222675	-0.554489	H	3.981941	3.326518	1.017602	H	-2.621686	-2.978405	-0.681460
H	-4.001072	-1.033293	3.123674	H	-2.746677	3.352743	0.214150	H	2.346365	3.339529	0.309083	H	-1.956110	-3.580877	-0.058521
H	-2.468005	-1.811095	2.656570	O	-0.256160	-0.951455	-0.584842	O	0.717335	-1.567285	0.636799	H	-3.547510	-3.536045	-0.855524
O	-0.439887	0.770659	-1.150204	C	-2.366165	-1.177257	0.390798	C	2.697904	-1.149993	-0.465492	H	-2.130492	-2.801057	-1.645064
C	-2.710837	0.268409	-1.409664	H	-2.546065	-2.251548	0.224417	H	3.113831	-2.165425	-0.423168	O	-0.937586	1.442500	0.779166
H	-3.027826	0.977478	-2.182399	O	-1.464002	-0.974906	1.462966	C	-1.014404	0.112090	-0.949673	C	-3.202980	1.222501	0.231291
O	-1.920765	-0.769354	-2.057635	C	0.980227	-0.175299	1.592188	C	-2.370564	-0.271339	-0.954393	O	-2.531972	1.971506	-0.821813
C	2.045635	-0.694812	1.137730	C	2.367373	-0.321743	1.399974	C	-0.595349	1.100993	-1.852746	C	1.733387	-0.622427	-0.740003
C	3.435921	-0.688159	0.970714	C	0.555931	0.933293	2.347132	C	-3.285515	0.347268	-1.812956	C	2.796511	0.218707	-1.081172
C	1.385792	-1.921753	1.253931	C	3.282219	0.588150	1.933355	H	-2.720202	-1.063658	-0.298526	C	1.214649	-1.488690	-1.708114
C	4.153307	-1.889637	0.916612	H	2.729224	-1.159486	0.812135	C	-1.506781	1.717418	-2.713201	C	3.333864	0.190773	-2.375205
H	3.977895	0.249702	0.873245	C	1.462343	1.848164	2.887429	H	0.449423	1.402709	-1.888257	H	3.220893	0.902785	-0.350202
C	2.098821	-3.126097	1.191831	H	-0.508757	1.076436	2.515934	C	-2.854354	1.346327	-2.687019	C	1.750497	-1.513539	-3.001010
H	0.308051	-1.963251	1.395161	H	2.833257	1.678110	2.682049	H	-4.329671	0.042342	-1.802217	H	0.395860	-2.159100	-1.460174
C	3.485311	-3.110888	1.024931	H	4.348001	0.450375	1.761412	H	-1.167833	2.493135	-3.396604	C	2.812333	-0.670282	-3.336763
H	5.232972	-1.867480	0.781003	H	1.100862	2.694829	3.467889	H	-3.564855	1.833684	-3.350081	H	4.158443	0.861323	-2.627300
H	1.568246	-4.072536	1.276268	H	3.543219	2.388869	3.098622	B	0.463238	-1.521710	-0.748236	H	1.339791	-2.196353	-3.742640
H	4.040306	-4.044592	0.975951	O	-0.884900	1.497658	-1.725465	O	0.737535	1.094960	1.757461	H	3.230520	-0.689286	-4.340307
B	-0.608088	-0.358560	-1.925449	Cu	0.860141	0.743842	-1.459896	Cu	-1.046623	0.768872	1.063427	B	-1.232351	2.129528	-0.376901
O	-0.719492	0.775816	1.767500	B	-0.101372	-1.178879	0.932908	H	-1.232720	-4.616327	-2.599721	O	-0.680210	-1.499822	0.989643
Cu	1.035473	1.020862	1.142231	O	0.920666	-4.875130	1.087265	C	-1.968614	-4.105336	-1.971759	Cu	0.972624	-0.623301	1.099536
H	2.333171	-2.662745	-3.229594	C	1.103565	-3.440404	0.601867	C	-1.281925	-3.291113	-0.903911	H	1.288716	4.364716	-2.541434
C	2.646301	-1.907343	-2.502394	H	0.011284	-5.281062	0.815178	H	-2.647896	-4.827837	-1.518456	C	1.763949	3.570488	-1.956100
C	1.725965	-0.726610	-2.557667	C	0.992066	-4.875130	1.087265	H	-2.535281	-3.426450	-2.620172	C	0.919121	3.256062	-0.756376
H	3.672352	-1.593915	-2.693862	H	1.776789	-5.490898	0.644750	O	-1.570963	-3.325164	0.277135	H	2.760769	3.879570	-1.642020
H	2.579246	-2.359697	-1.506784	H	1.065163	-4.909033	2.179415	O	-0.321187	-2.508227	-1.435136	H	1.831226	2.684025	-2.594278
O	2.047104	0.429743	-2.683445	O	1.935523	-3.093436	-0.231062	N	-2.111382	-0.330149	2.439963	O	1.258609	3.343979	0.398565
O	0.405419	-1.125149	-2.473714	O	0.212242	-2.656458	1.178506	C	-2.553252	-1.321332	2.842788	O	-0.350153	2.879569	-1.140648
N	2.300884	2.390468	0.607211	N	1.766636	2.386125	-0.790666	C	-3.097244	-2.575563	3.317390	N	2.218963	0.388458	2.174080
C	3.091592	3.124064	0.191146	C	2.179994	3.291223	-0.205649	H	-2.908138	-3.346612	2.563887	C	2.897826	1.234434	2.575339
C	4.082924	4.037514	-0.332350	C	2.696940	4.435407	0.512328	H	-2.615283	-2.859947	4.257645	C	3.739033	2.306090	3.058057
H	4.355112	3.737628	-1.349192	H	2.690323	5.314709	-0.138972	H	-4.174999	-2.479424	3.479924	H	3.513755	3.216098	2.492699
H	3.678227	5.054080	-0.351779	H	2.072109	4.626090	1.389557	N	-2.216153	2.558401	0.823610	H	3.547858	2.483200	4.120851
H	4.974985	4.015620	0.301018	H	3.720393	4.232481	0.840300	C	-2.724005	3.342170	0.139202	H	4.792355	2.043971	2.919193
				N	2.353390	-0.344148	-2.112254	C	-3.358676	4.327764	-0.711883	N	2.561734	-3.292495	1.871779
				C	3.162454	-1.149662	-2.280409	H	-3.601986	5.222313	-0.130398	C	3.186891	-3.252680	0.895377
				C	4.165158	-2.172299	-2.468865	H	-2.682310	4.599258	-1.527768	C	3.971451	-3.199953	-0.325243
				H	4.192818	-2.481019	-3.518200	H	-4.277258	3.911054	-1.135336	H	3.415908	-3.667748	-1.142841
				H	5.147989	-1.788363	-2.179219					H	4.162094	-2.156271	-0.592050
				H	3.901328	-3.026939	-1.838443					H	4.921125	-3.724614	-0.184144

## Reaction Coordinates (Gibbs Free Energies)

Figure S7: Reaction Coordinate for Ligand Exchange Without solvent

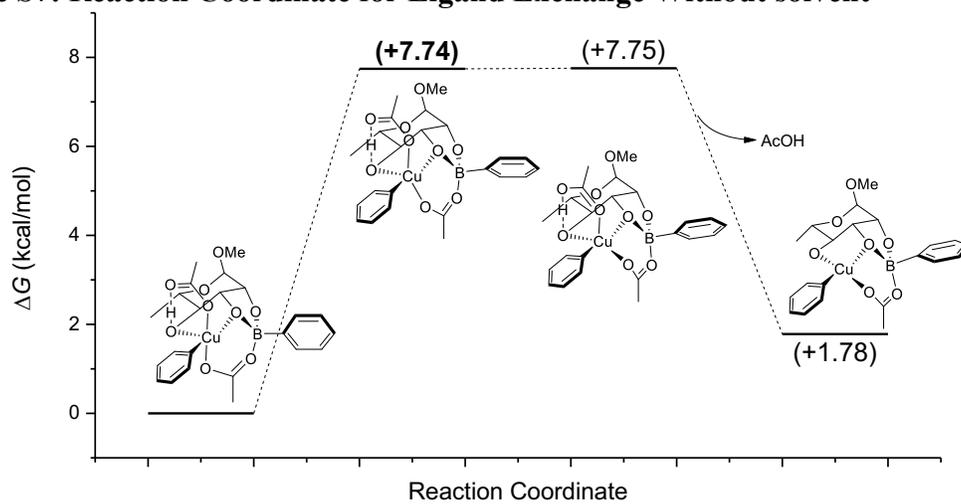
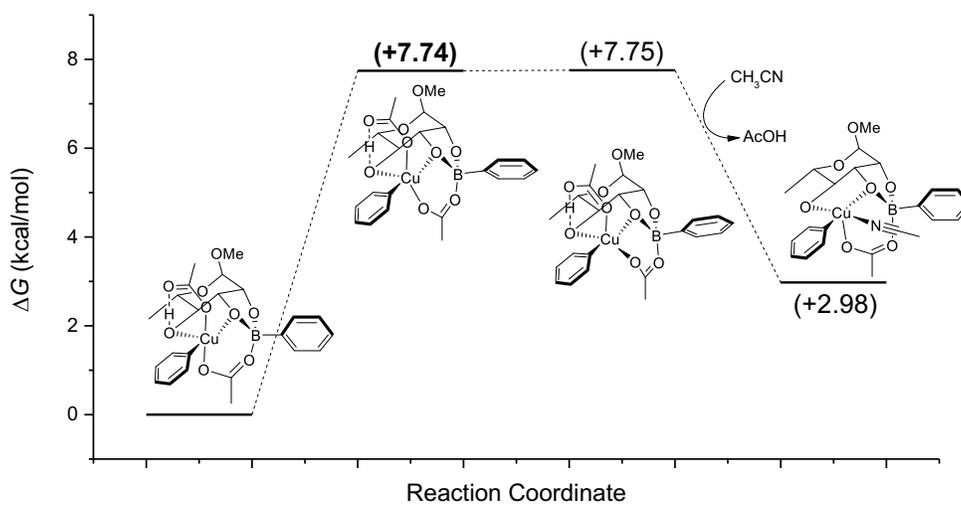
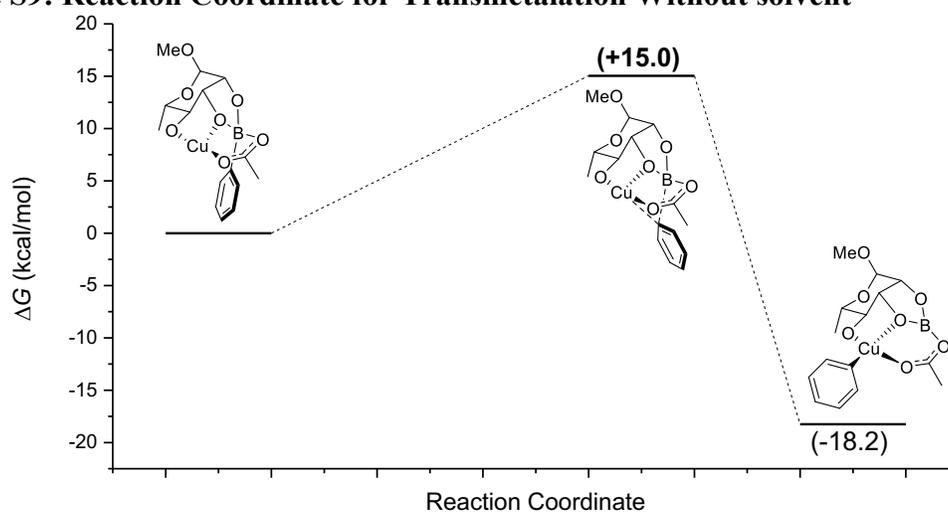
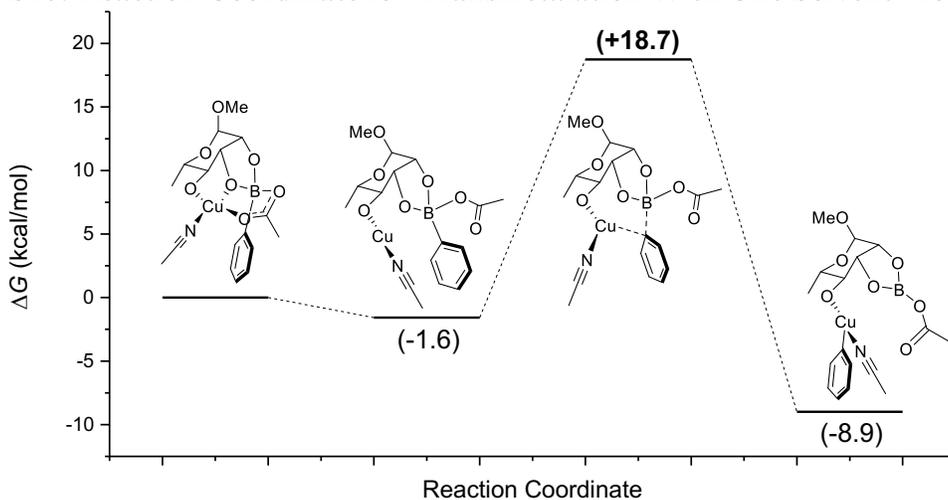
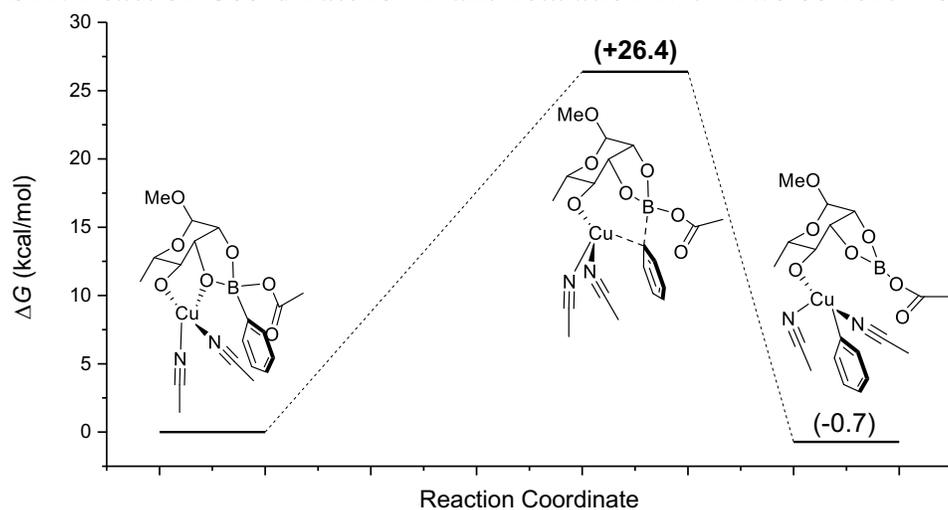
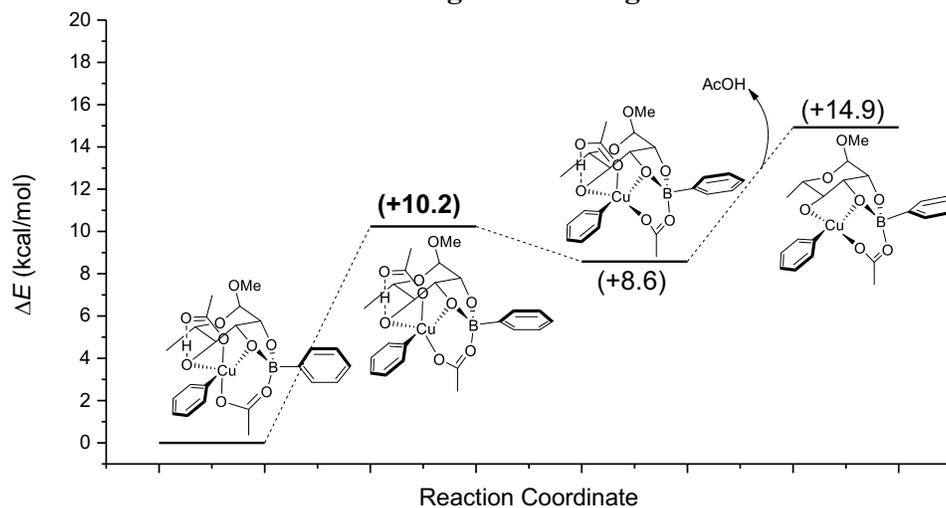
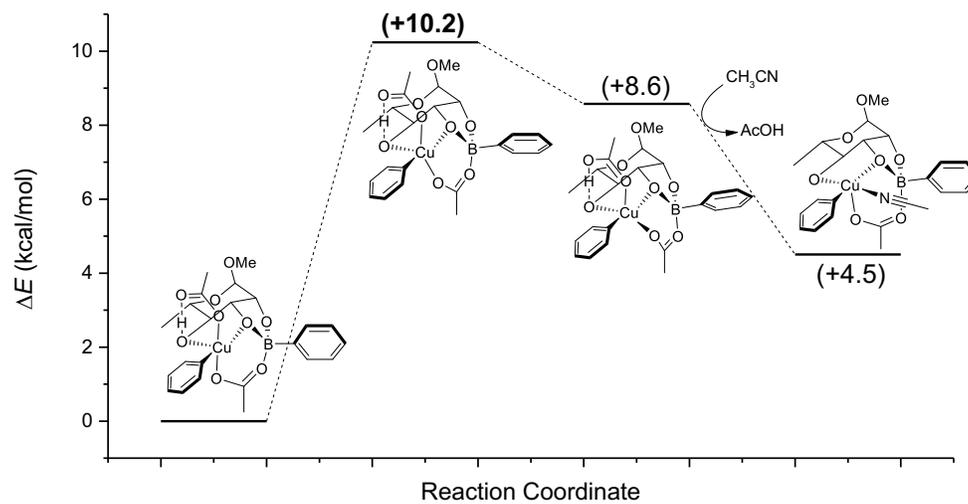
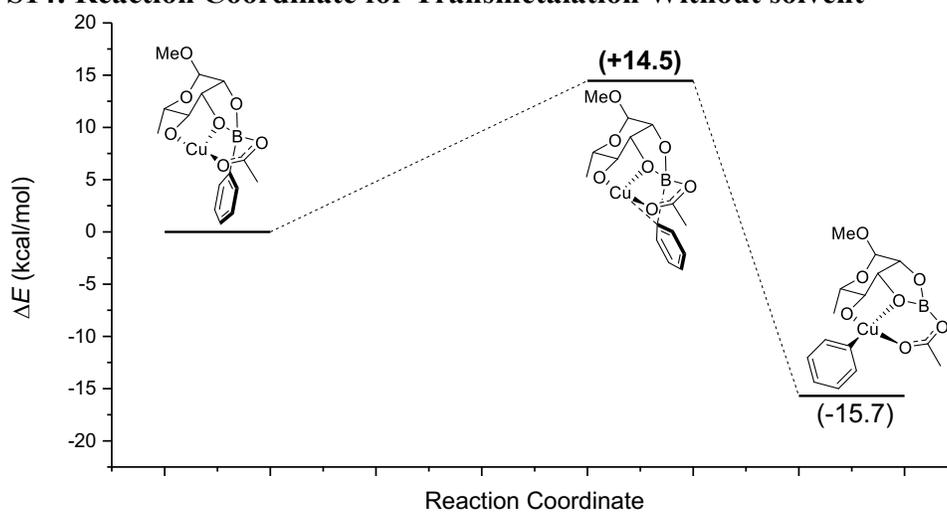
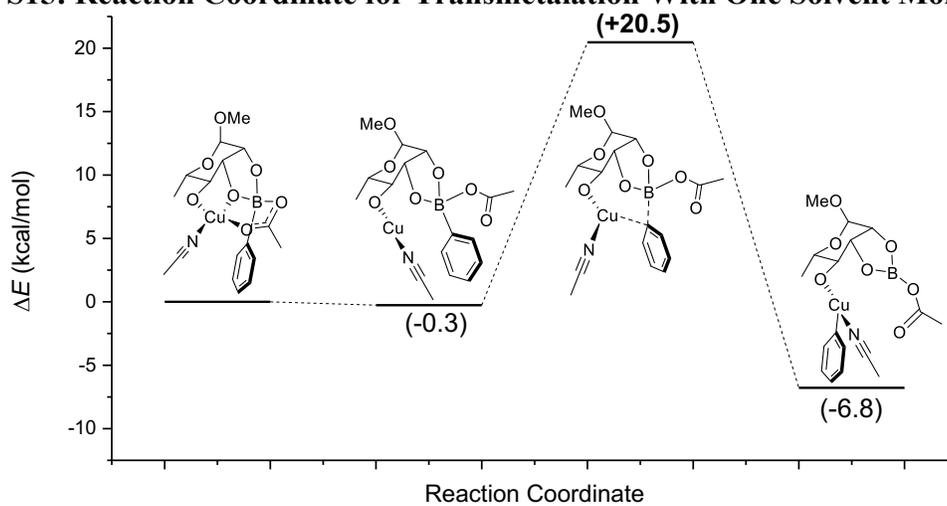
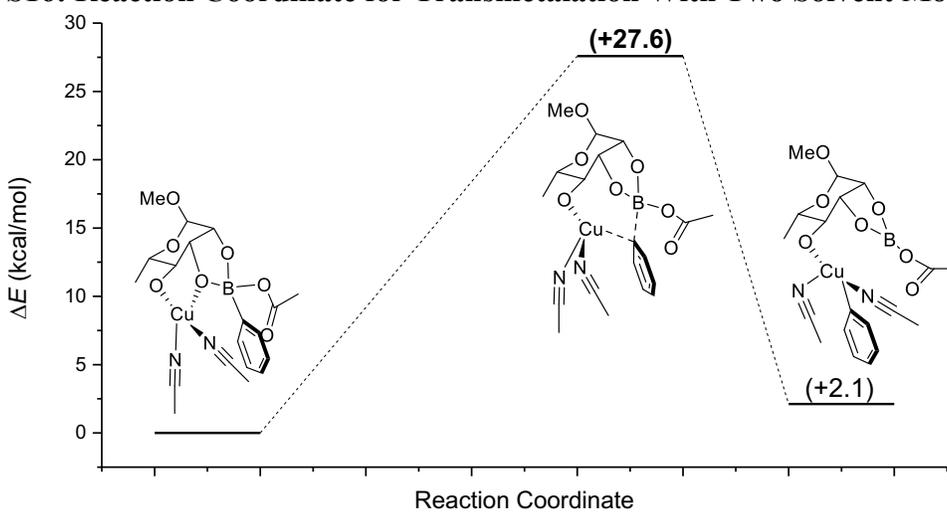


Figure S8: Reaction Coordinate for Ligand Exchange With solvent



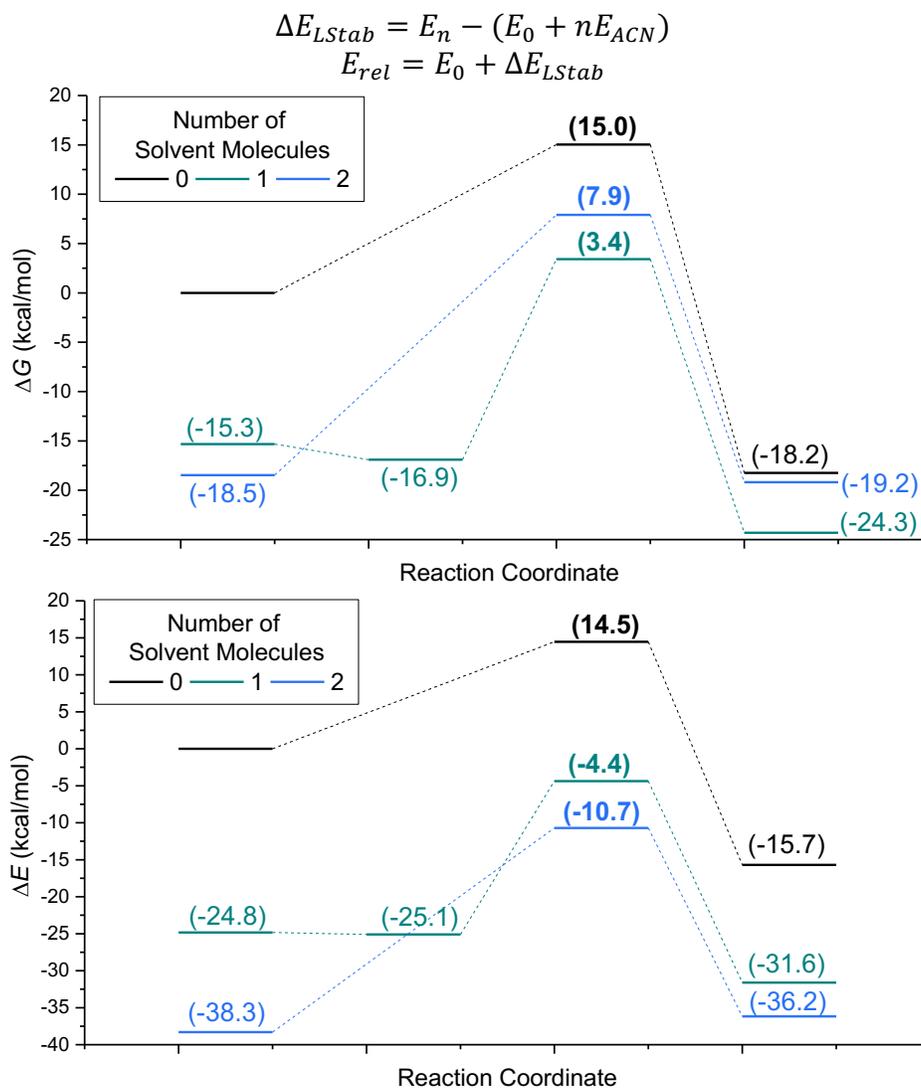
**Figure S9: Reaction Coordinate for Transmetalation Without solvent****Figure S10: Reaction Coordinate for Transmetalation With One Solvent Molecule****Figure S11: Reaction Coordinate for Transmetalation With Two Solvent Molecules**

**Reaction Coordinates (Uncorrected Electronic Energies)****Figure S12: Reaction Coordinate for Ligand Exchange Without Solvent****Figure S13: Reaction Coordinate for Ligand Exchange With Solvent**

**Figure S14: Reaction Coordinate for Transmetalation Without solvent****Figure S15: Reaction Coordinate for Transmetalation With One Solvent Molecule****Figure S16: Reaction Coordinate for Transmetalation With Two Solvent Molecules**

### Figure S17: Relative Transmetalation Energies

These values were calculated by comparing the energy (or free energy) differences between the stationary points without solvation to those with solvation to obtain ligand stabilization energies ( $\Delta E_{LStab}$ ). To plot all the data on one plot, the ligand stabilization energies were applied to the stationary points without solvation ( $E_{rel}$ ).

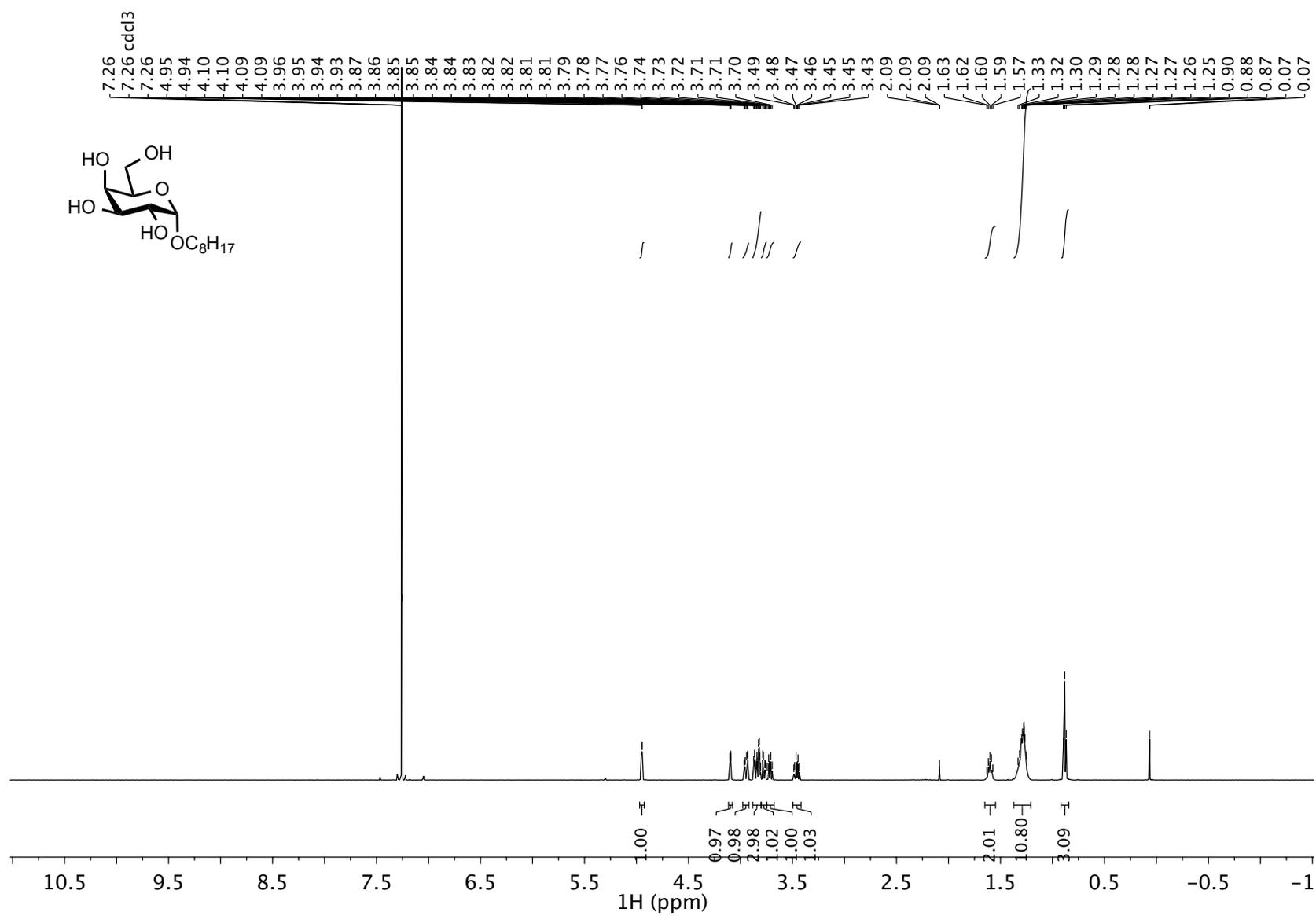


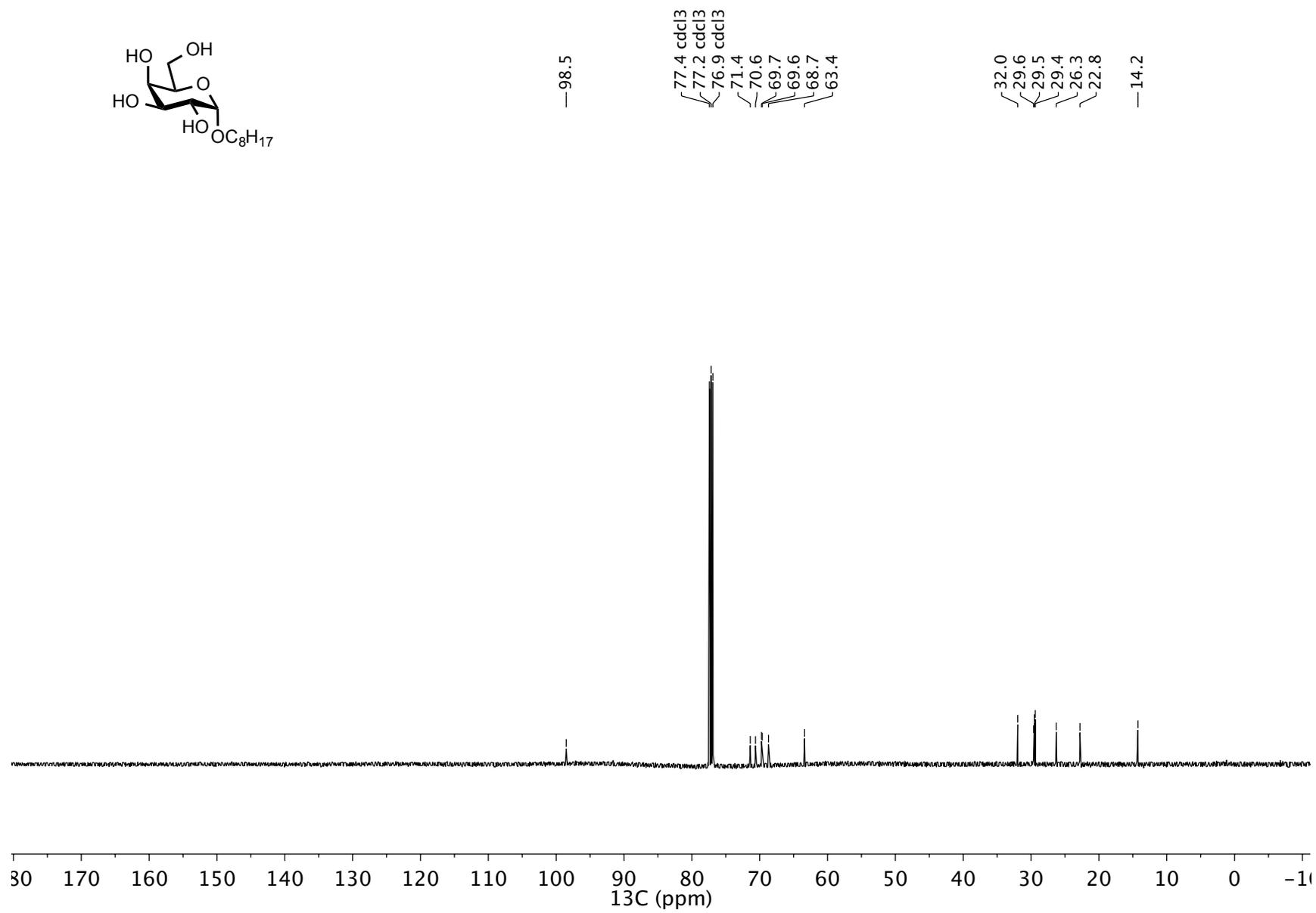
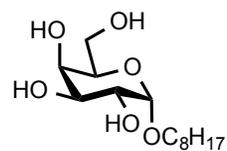
## References

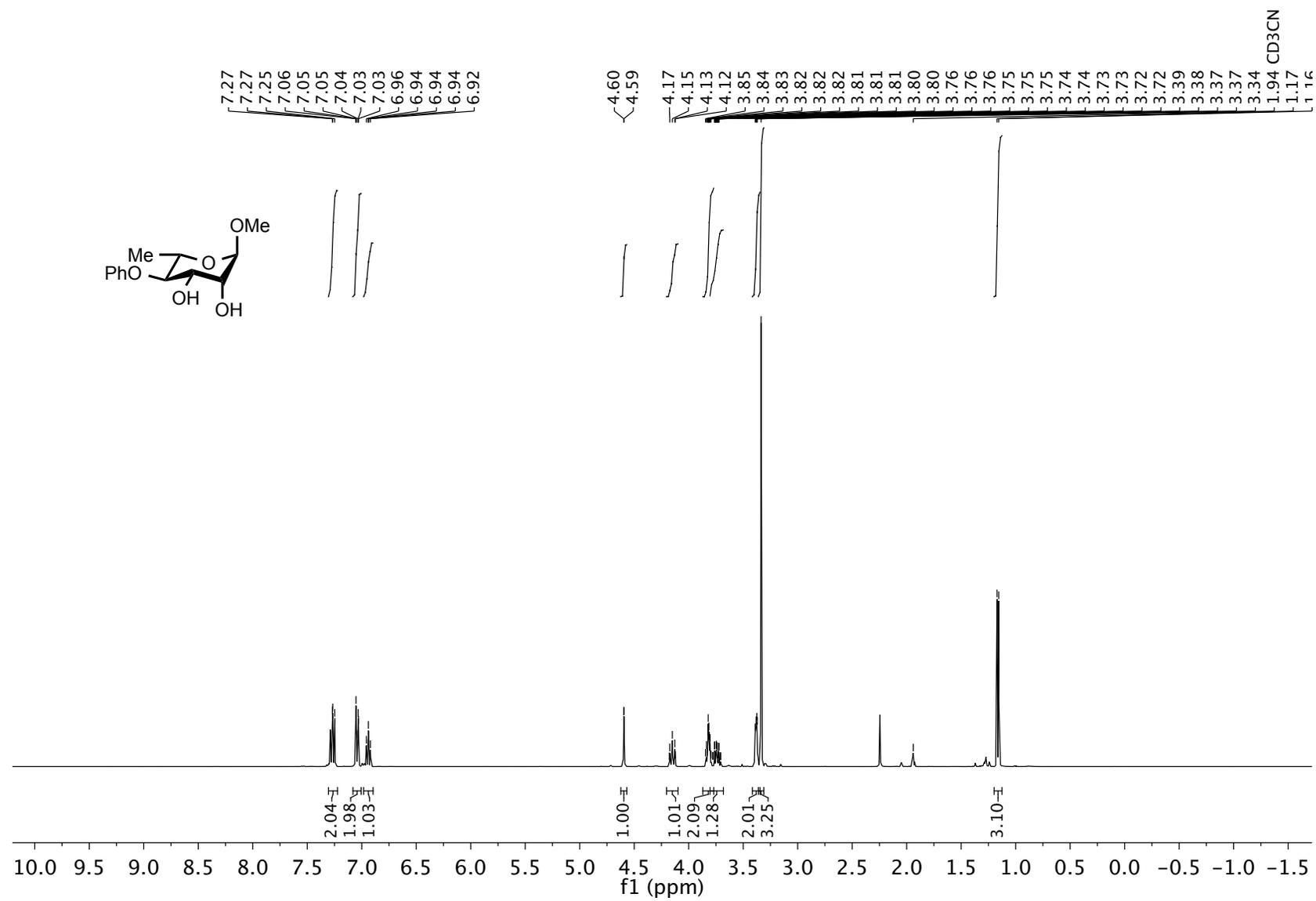
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- (2) Chambers, D. J.; Evans, G. R.; Fairbanks, A. J. *Tetrahedron.* **2005**, *61*, 7184–7192.
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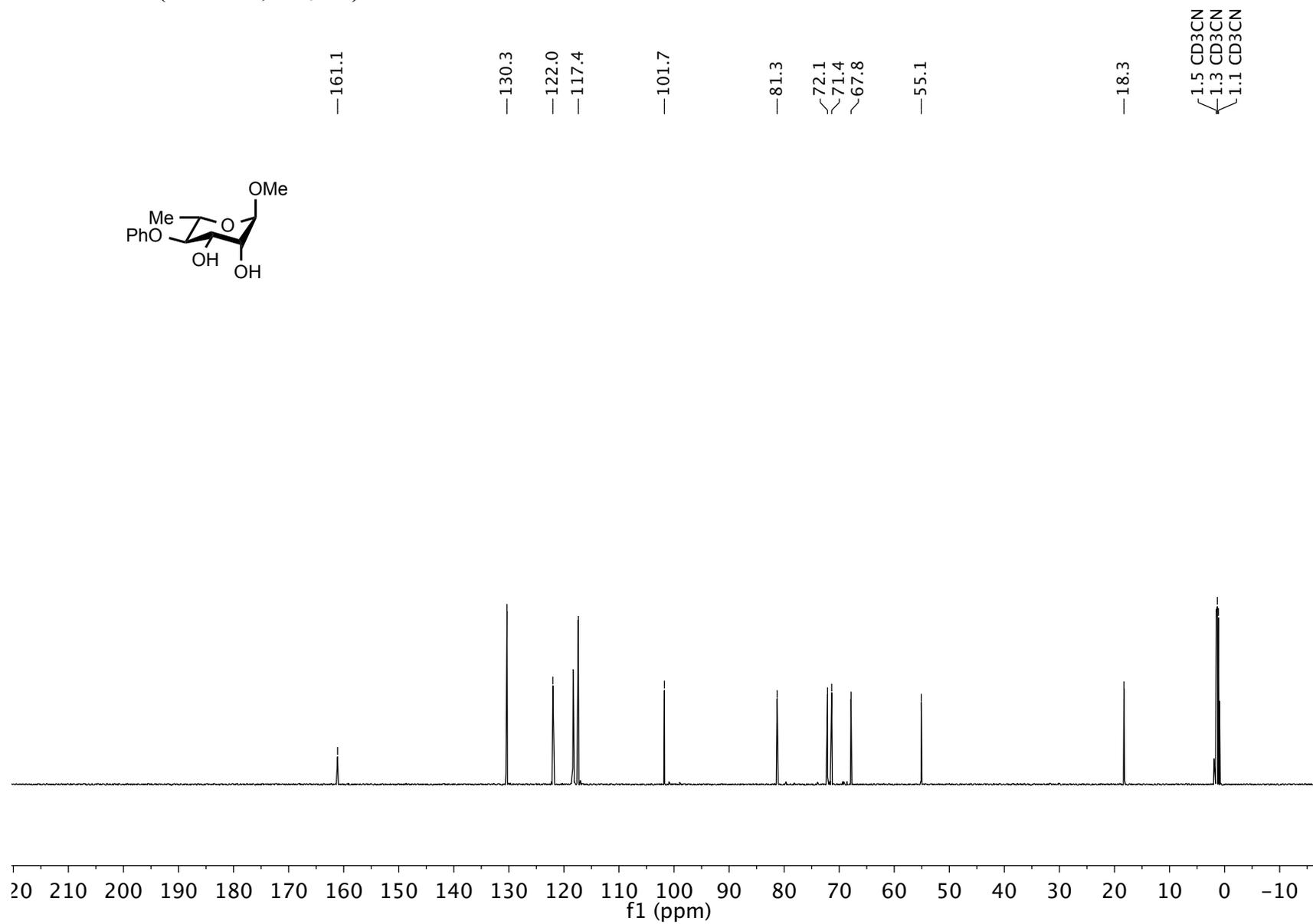
**$^1\text{H}$ ,  $^{13}\text{C}$  and 2D NMR Spectra**

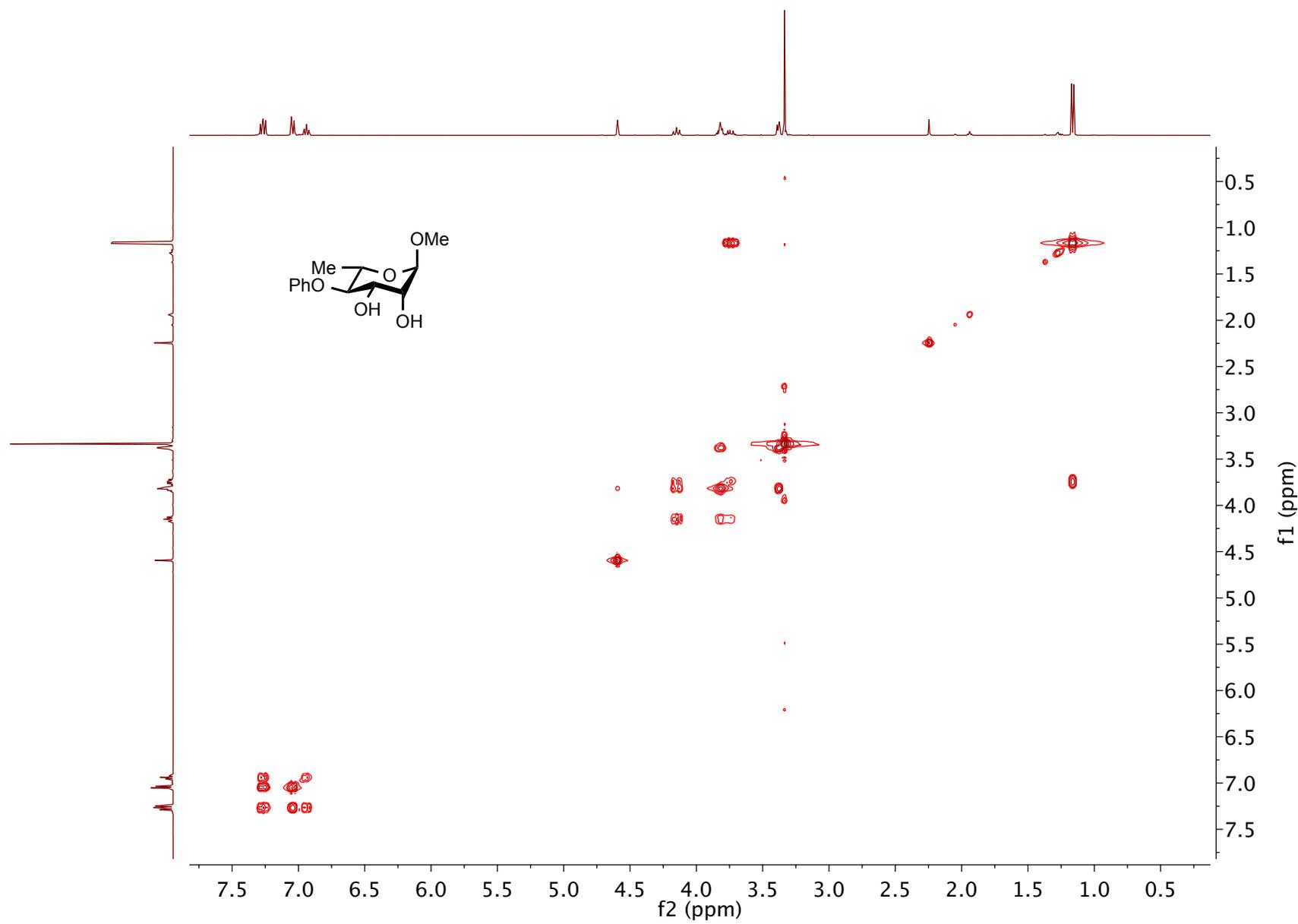
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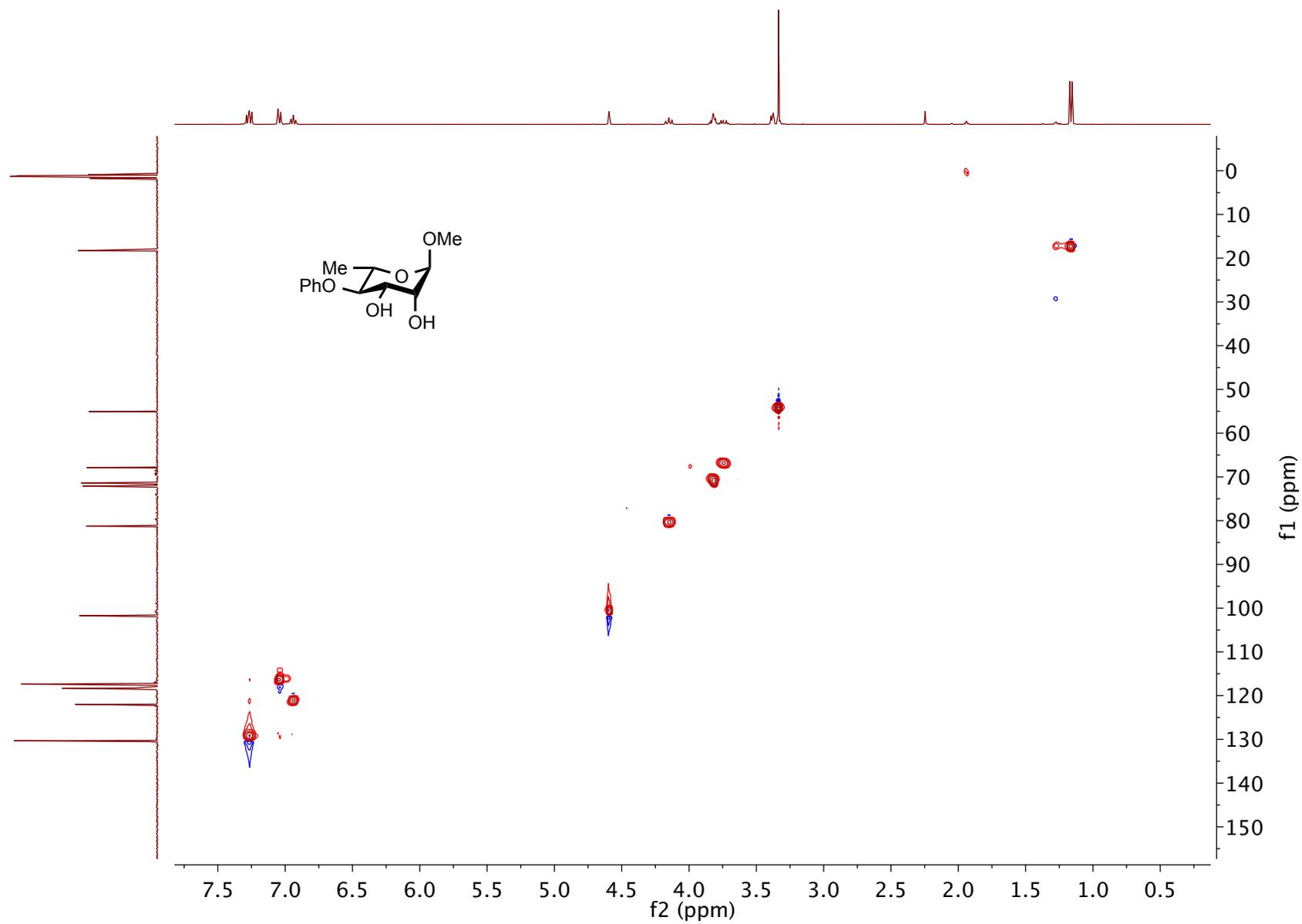
**1m – <sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>)**

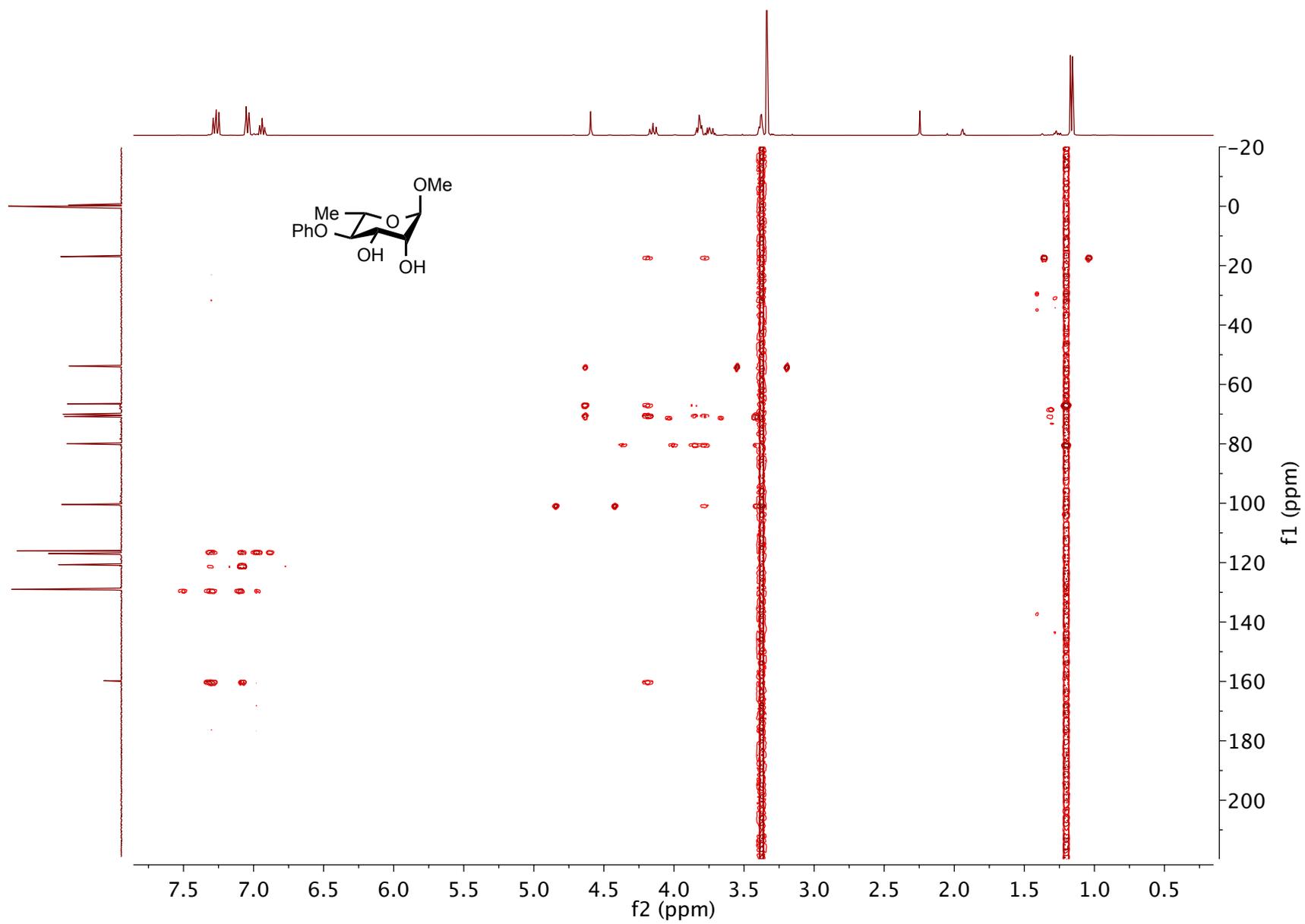
**1m –  $^1\text{H}$  NMR (126MHz,  $\text{CDCl}_3$ )**

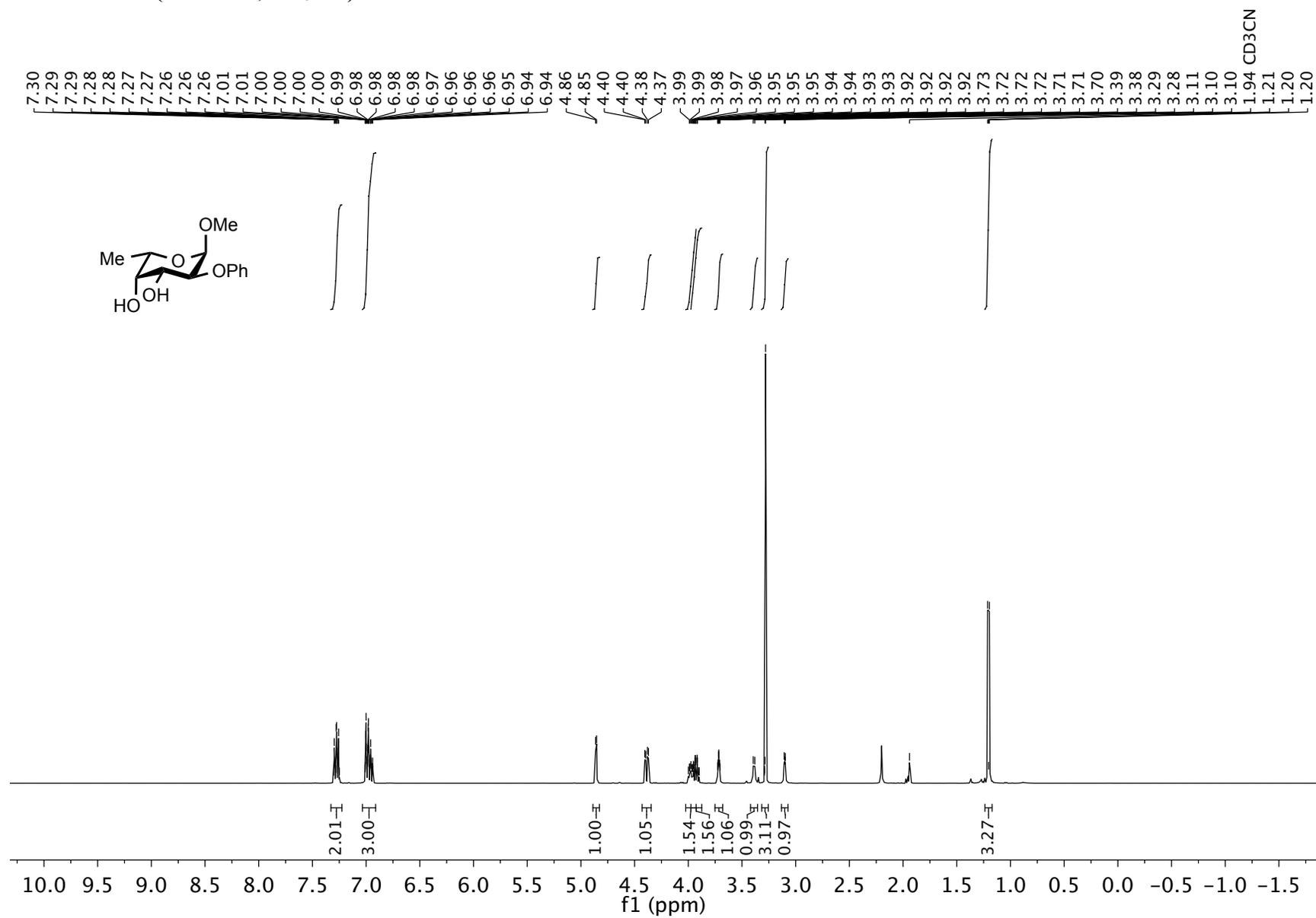
**3a – <sup>1</sup>H NMR (400 MHz, CD<sub>3</sub>CN)**

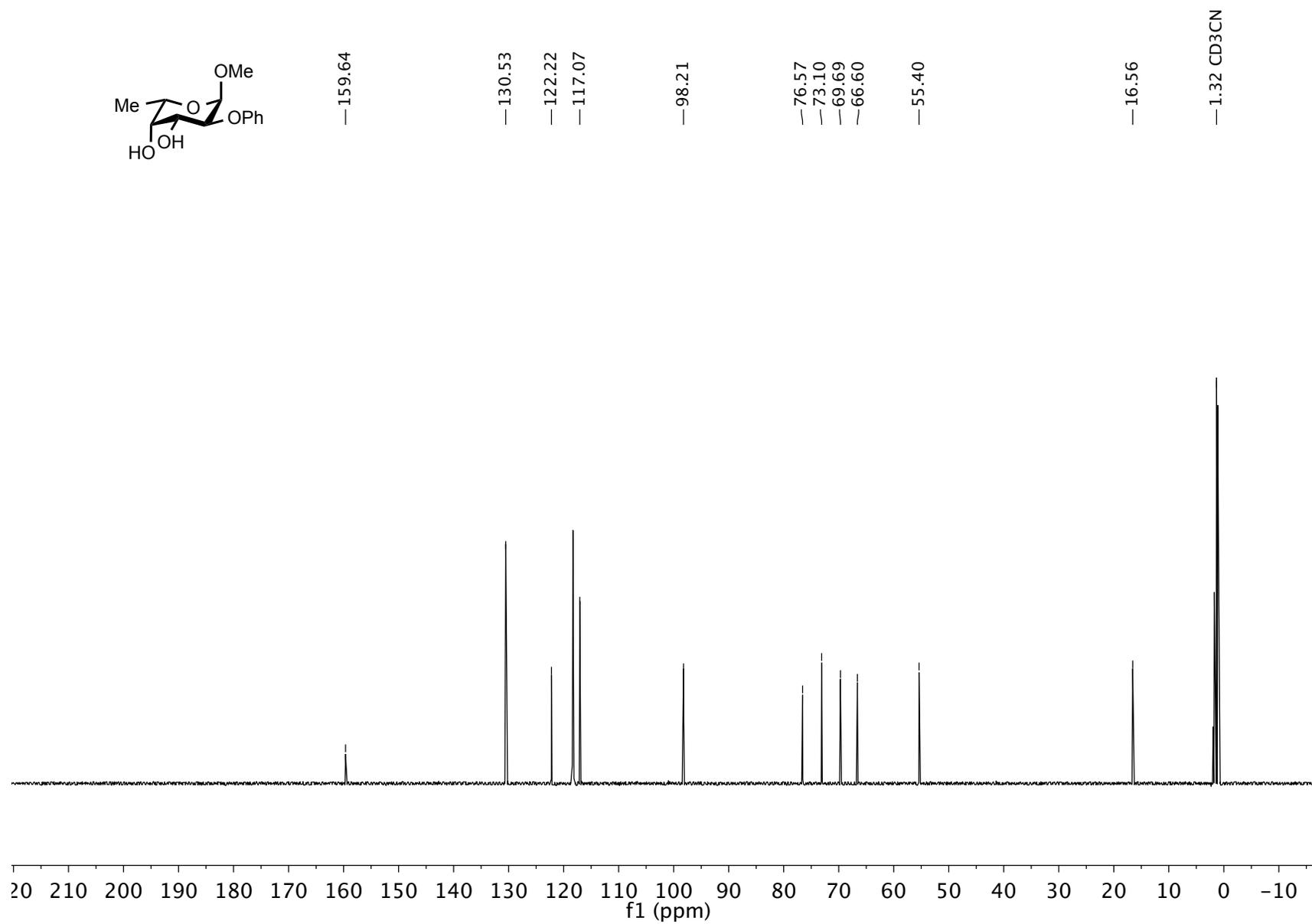
**3a – <sup>1</sup>H NMR (101 MHz, CD<sub>3</sub>CN)**

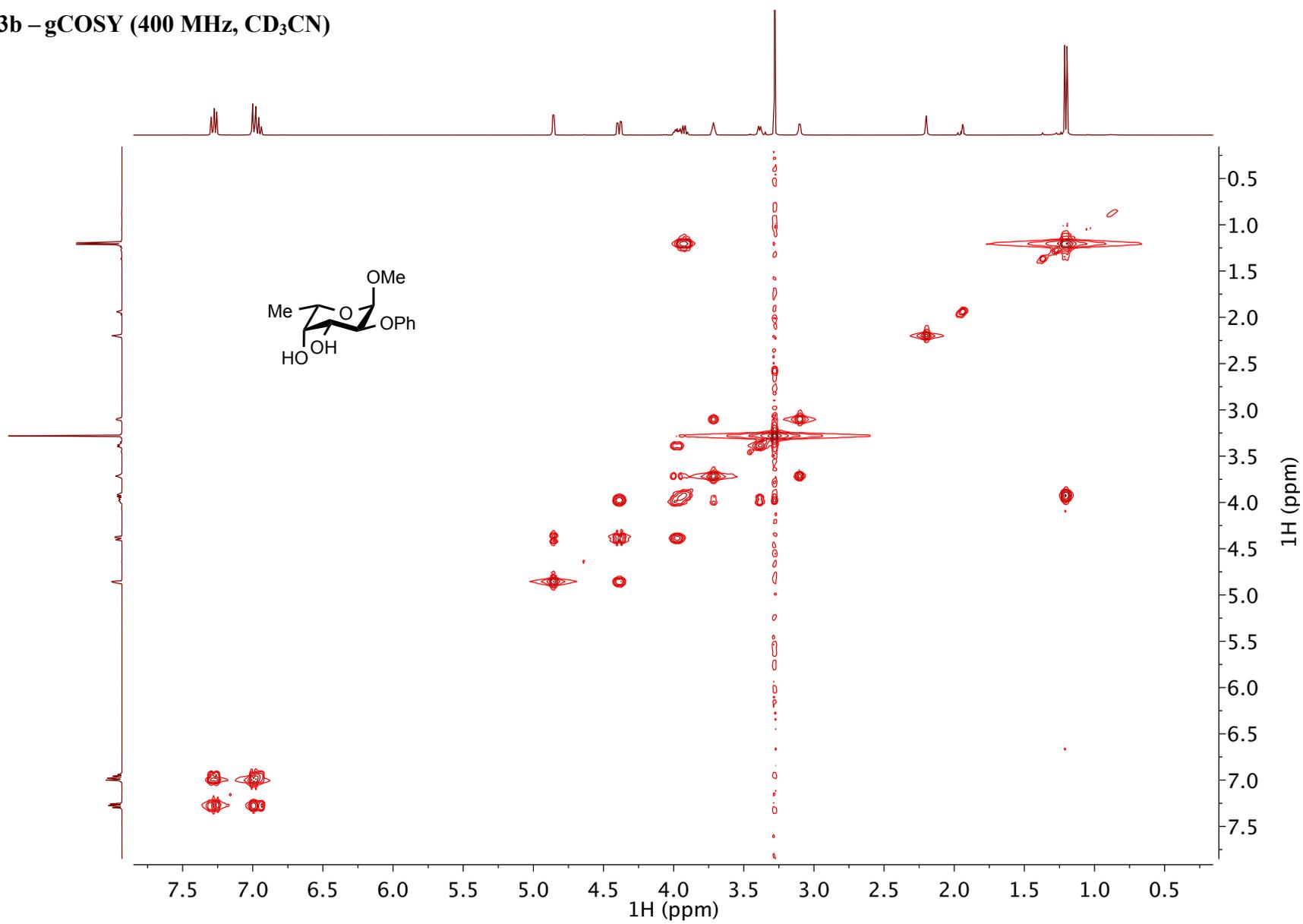
**3a – gCOSY (400 MHz, CD<sub>3</sub>CN)**

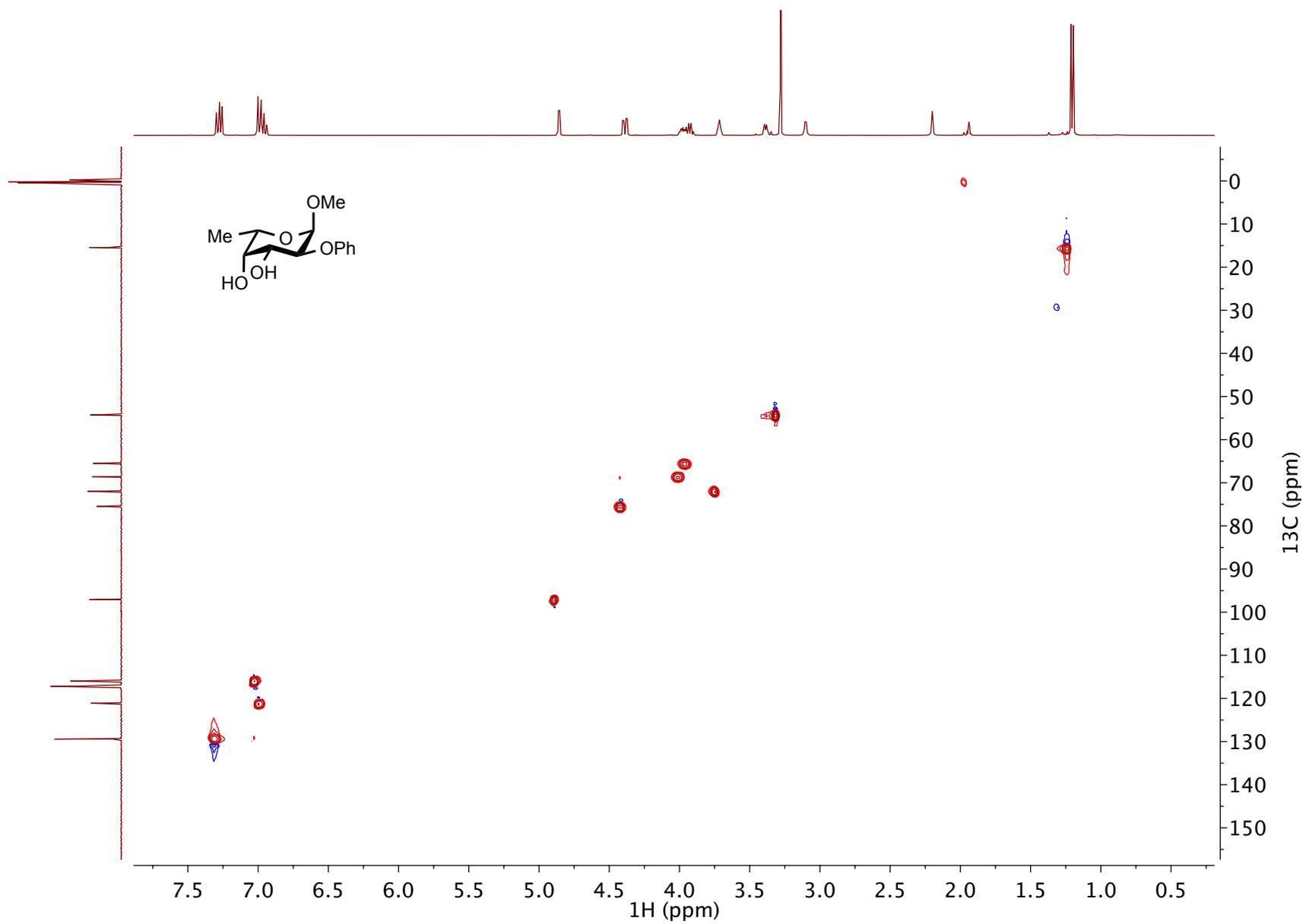
3a – HSQC (400 MHz, CD<sub>3</sub>CN)

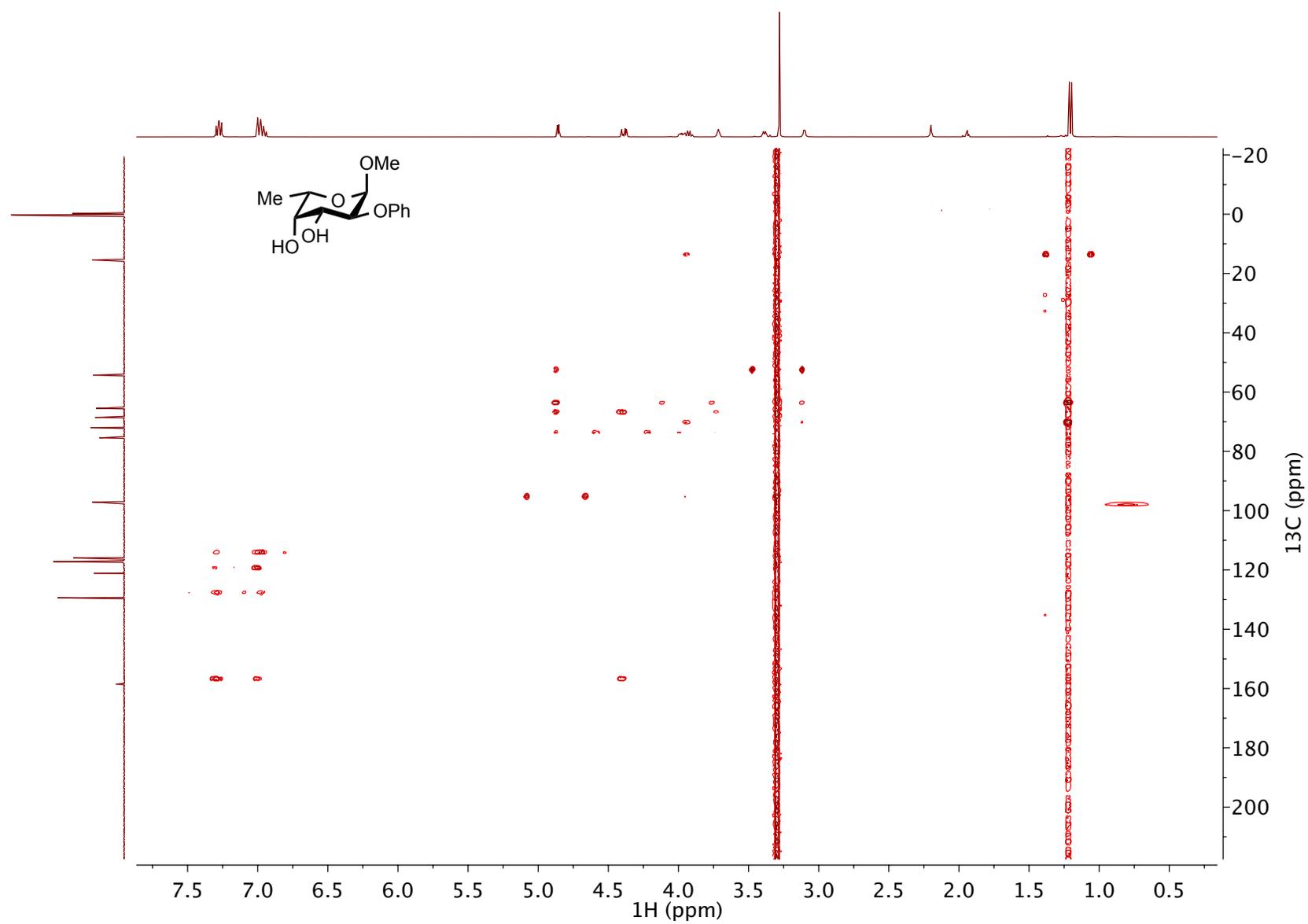
3a – HMBC (400 MHz, CD<sub>3</sub>CN)

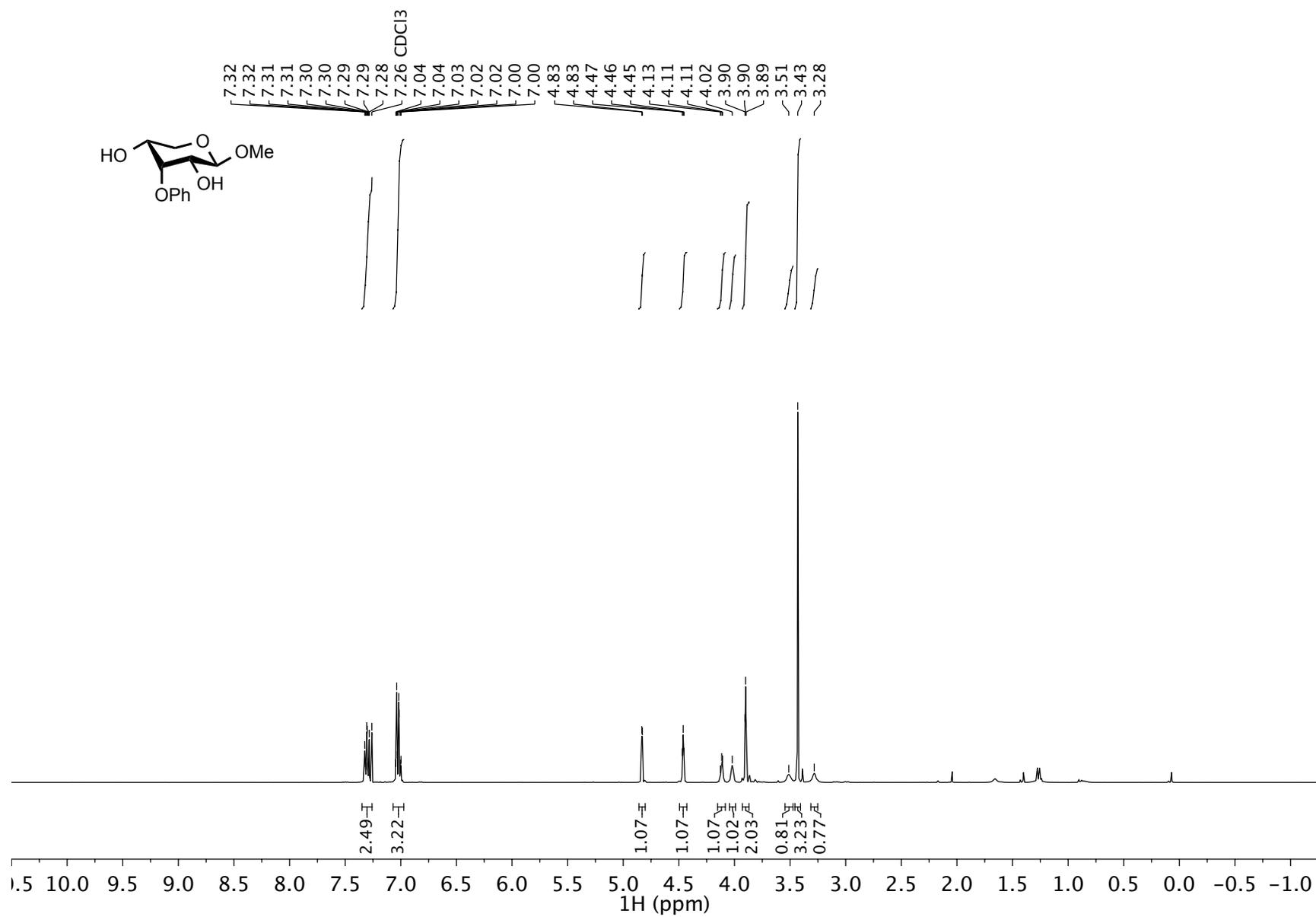
**3b** –  $^1\text{H}$  NMR (400 MHz,  $\text{CD}_3\text{CN}$ )

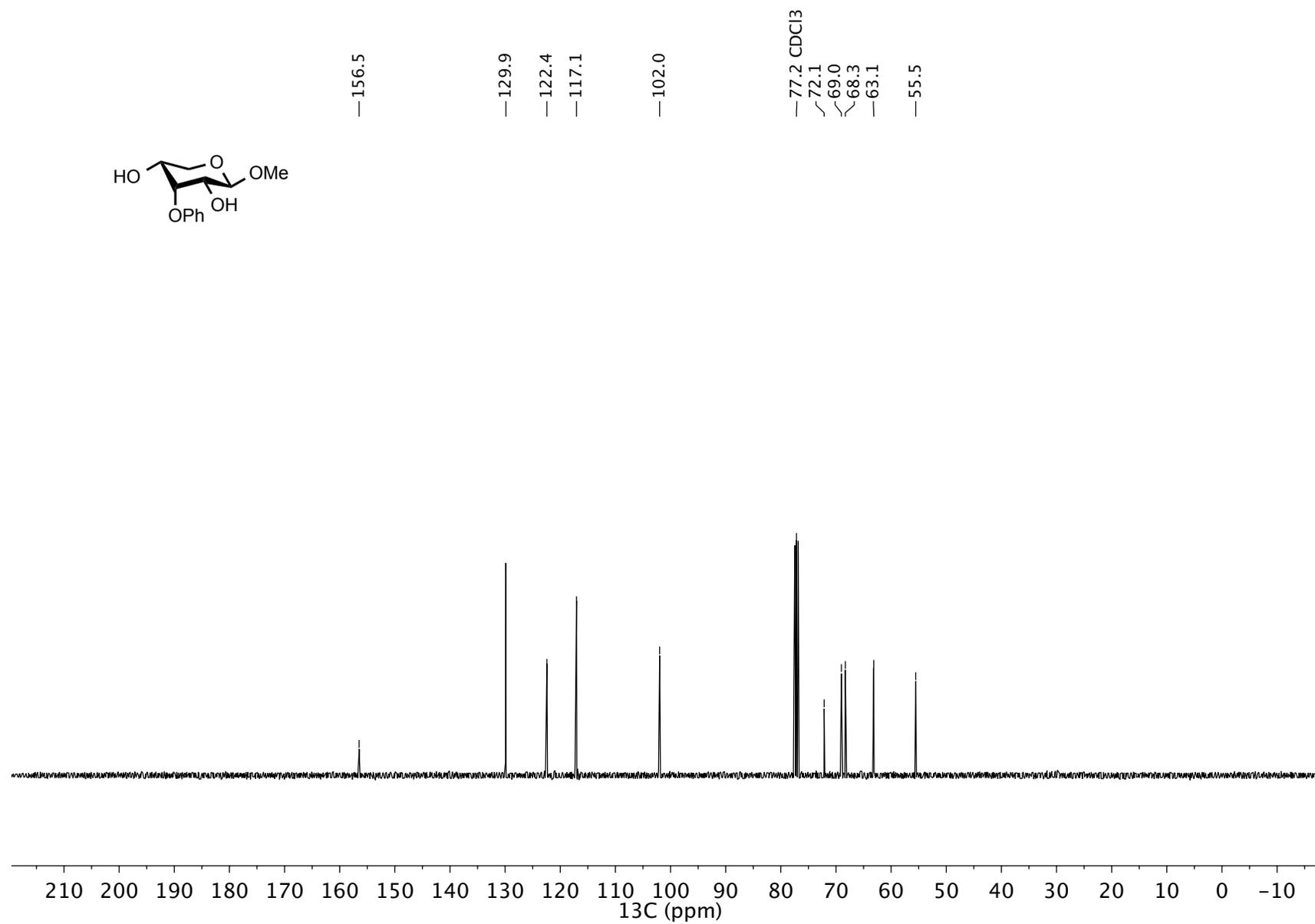
**3b** –  $^{13}\text{C}$  NMR (400 MHz,  $\text{CD}_3\text{CN}$ )

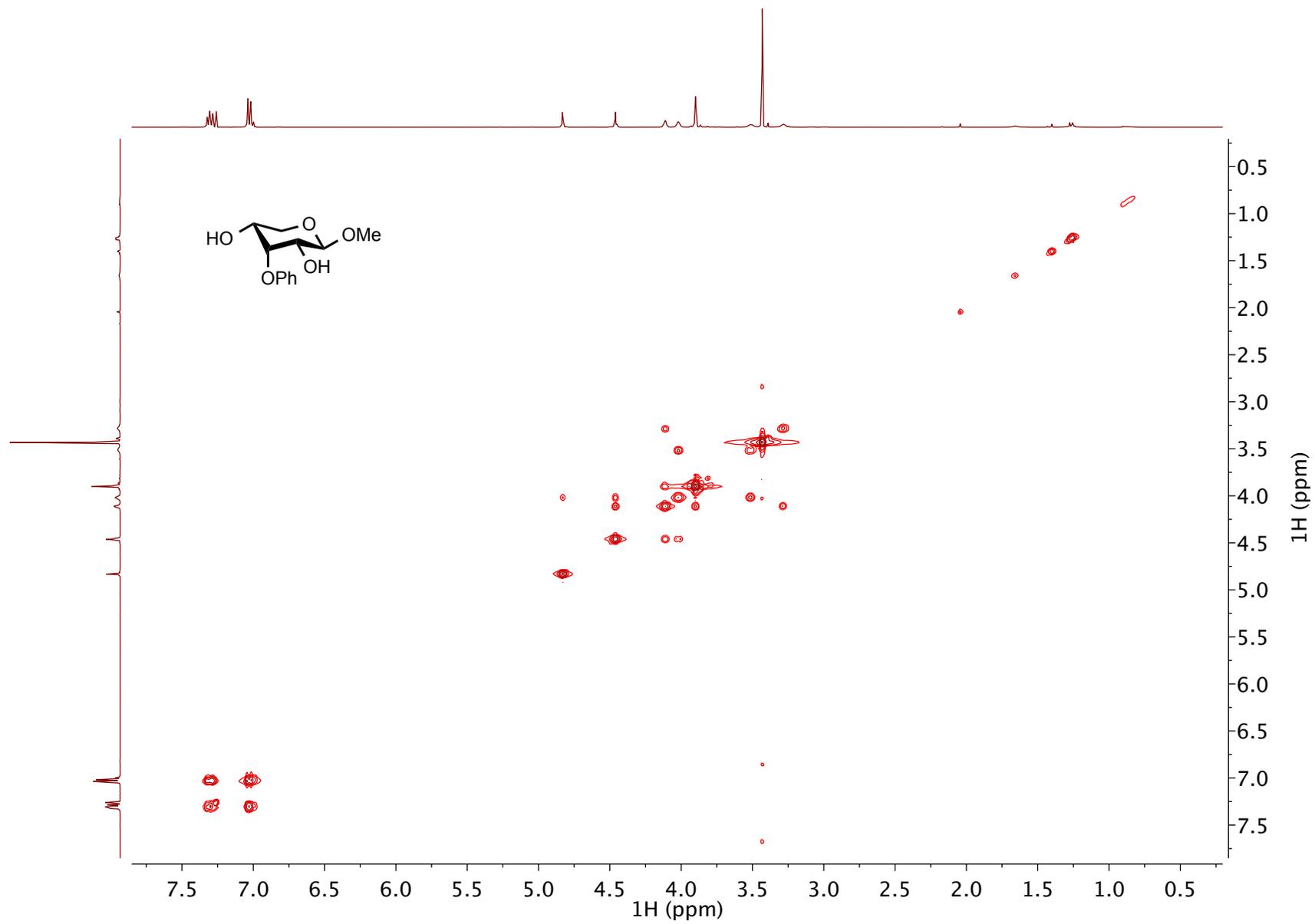
**3b – gCOSY (400 MHz, CD<sub>3</sub>CN)**

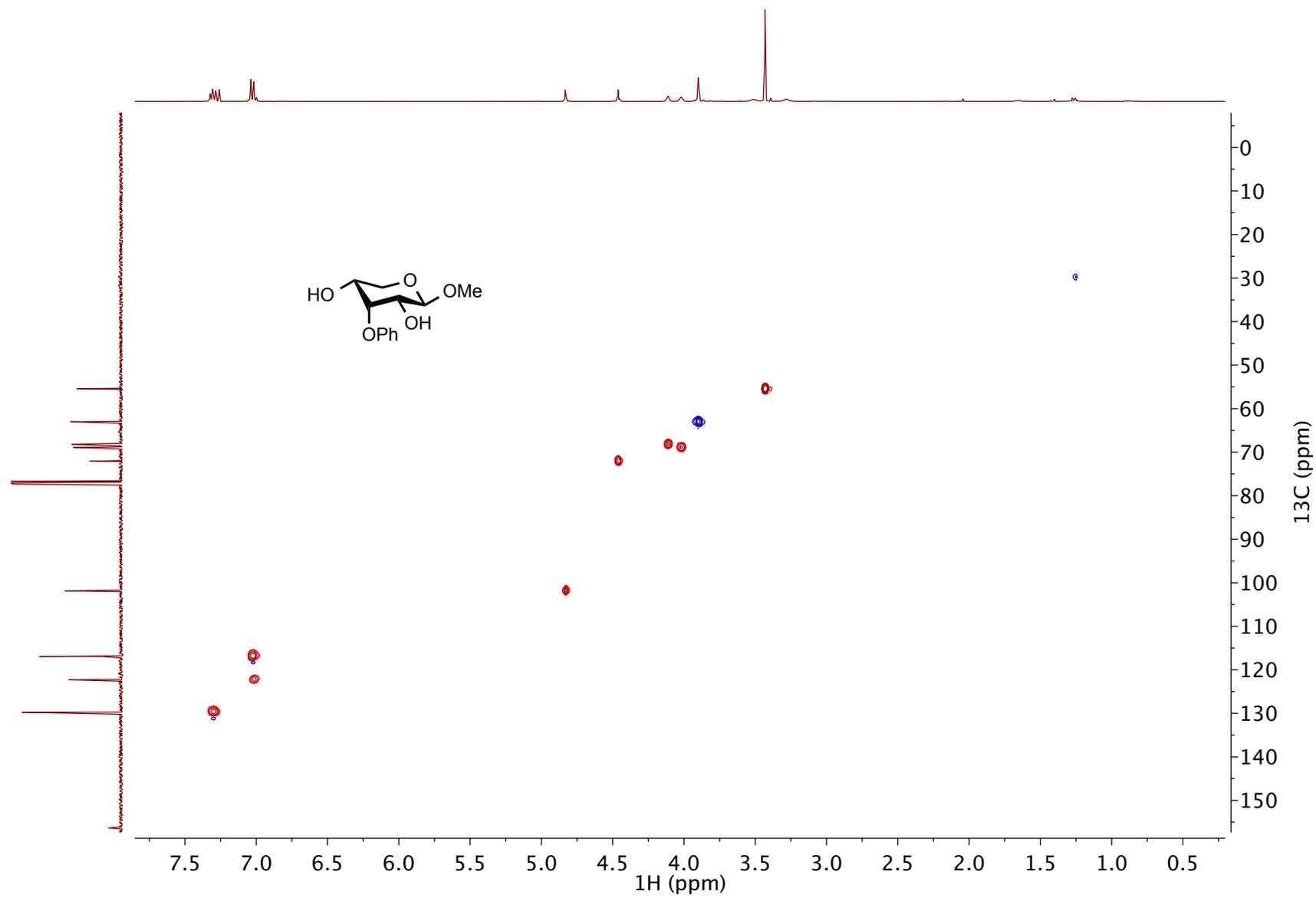
**3b – HSQC (400 MHz, CD<sub>3</sub>CN)**

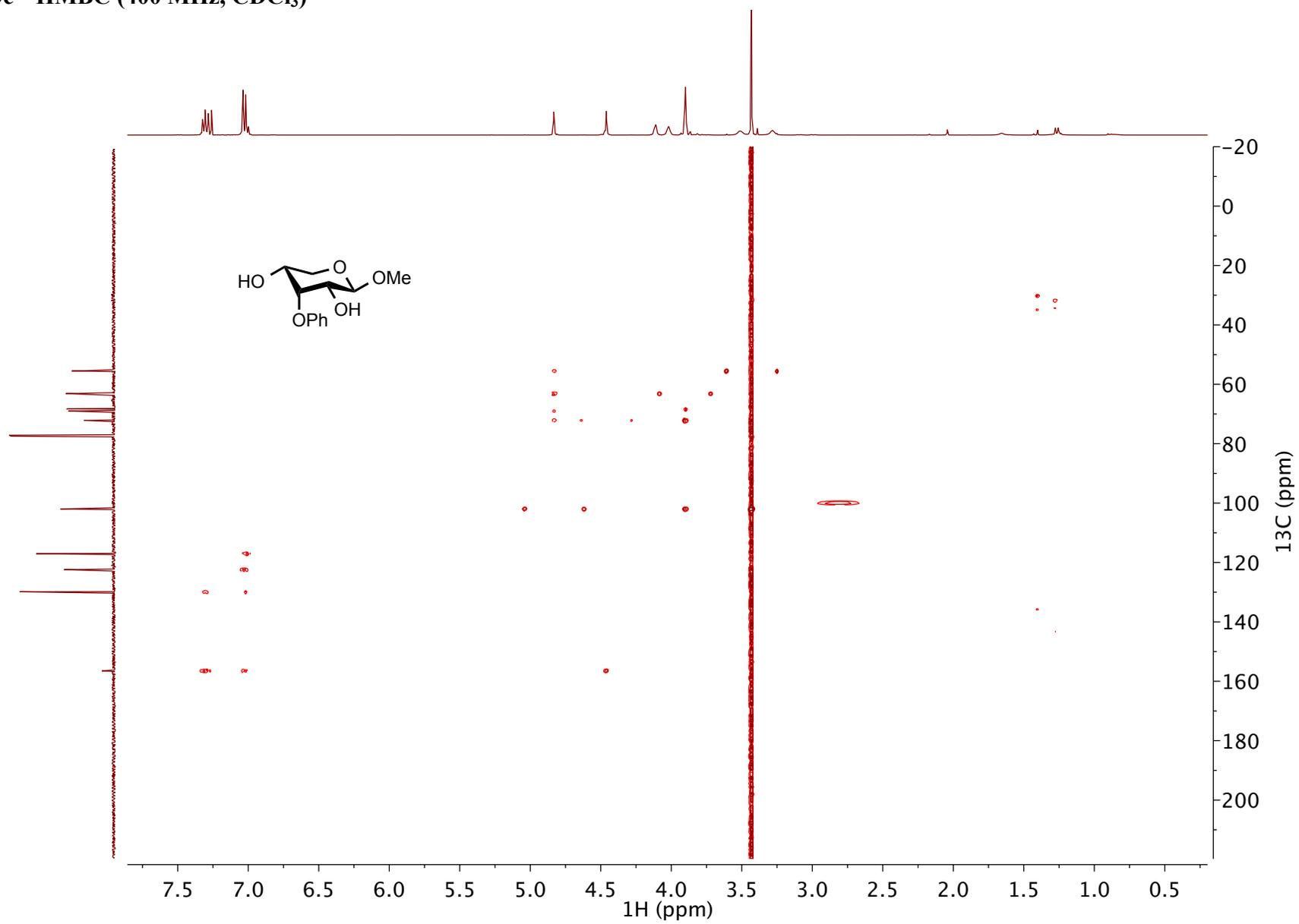
**3b – HMBC (400 MHz, CD<sub>3</sub>CN)**

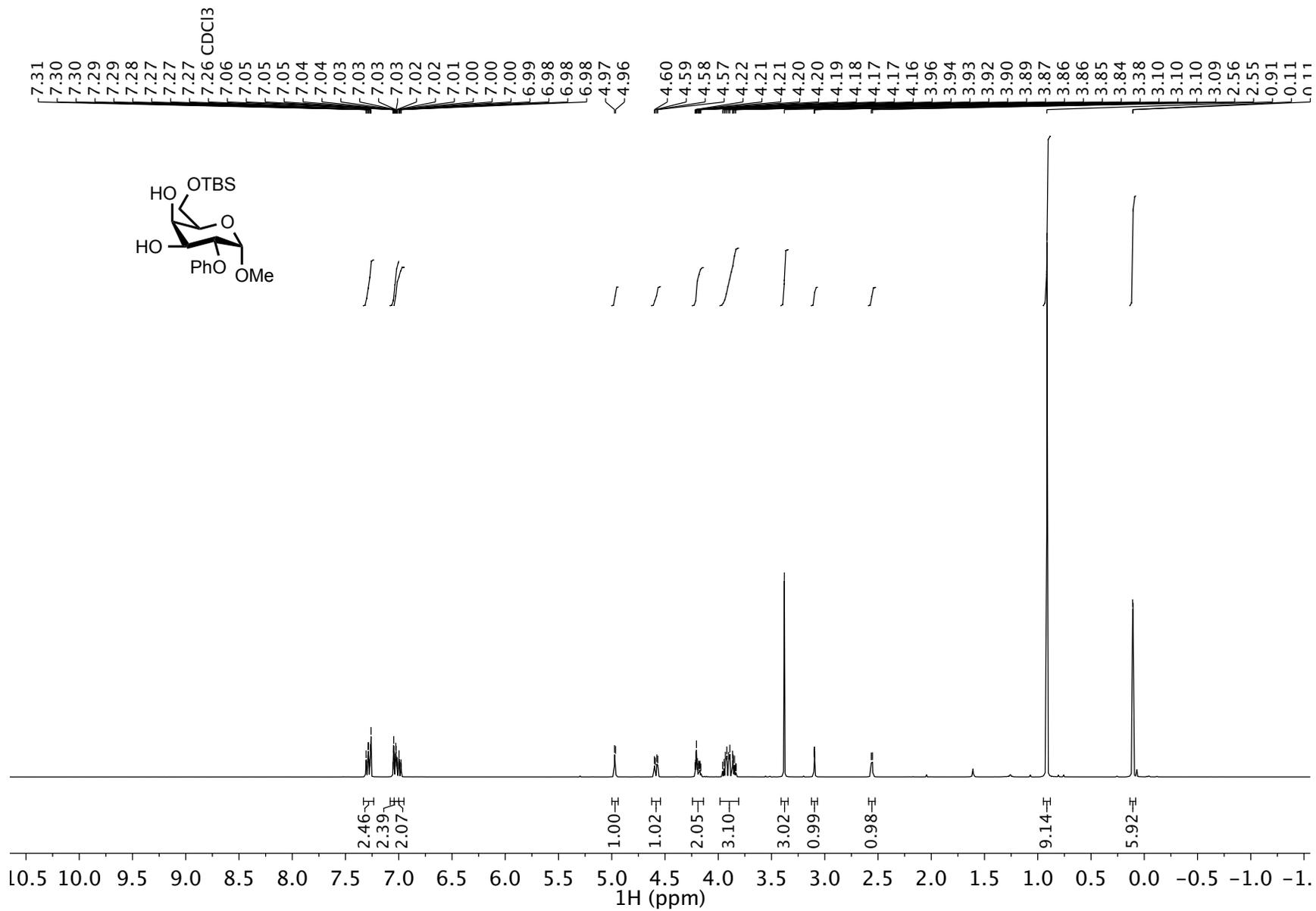
**3c –  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )**

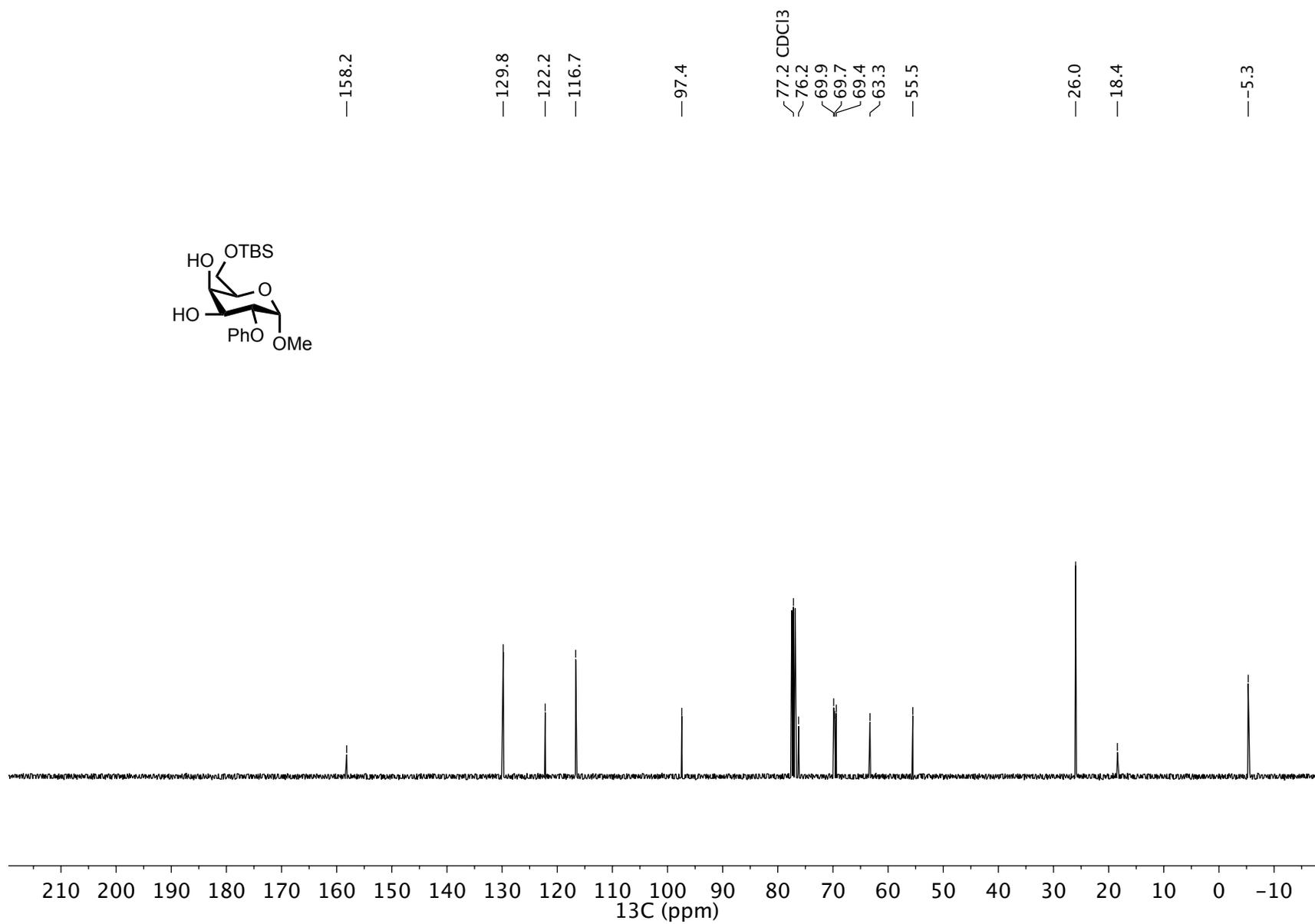
**3c –  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )**

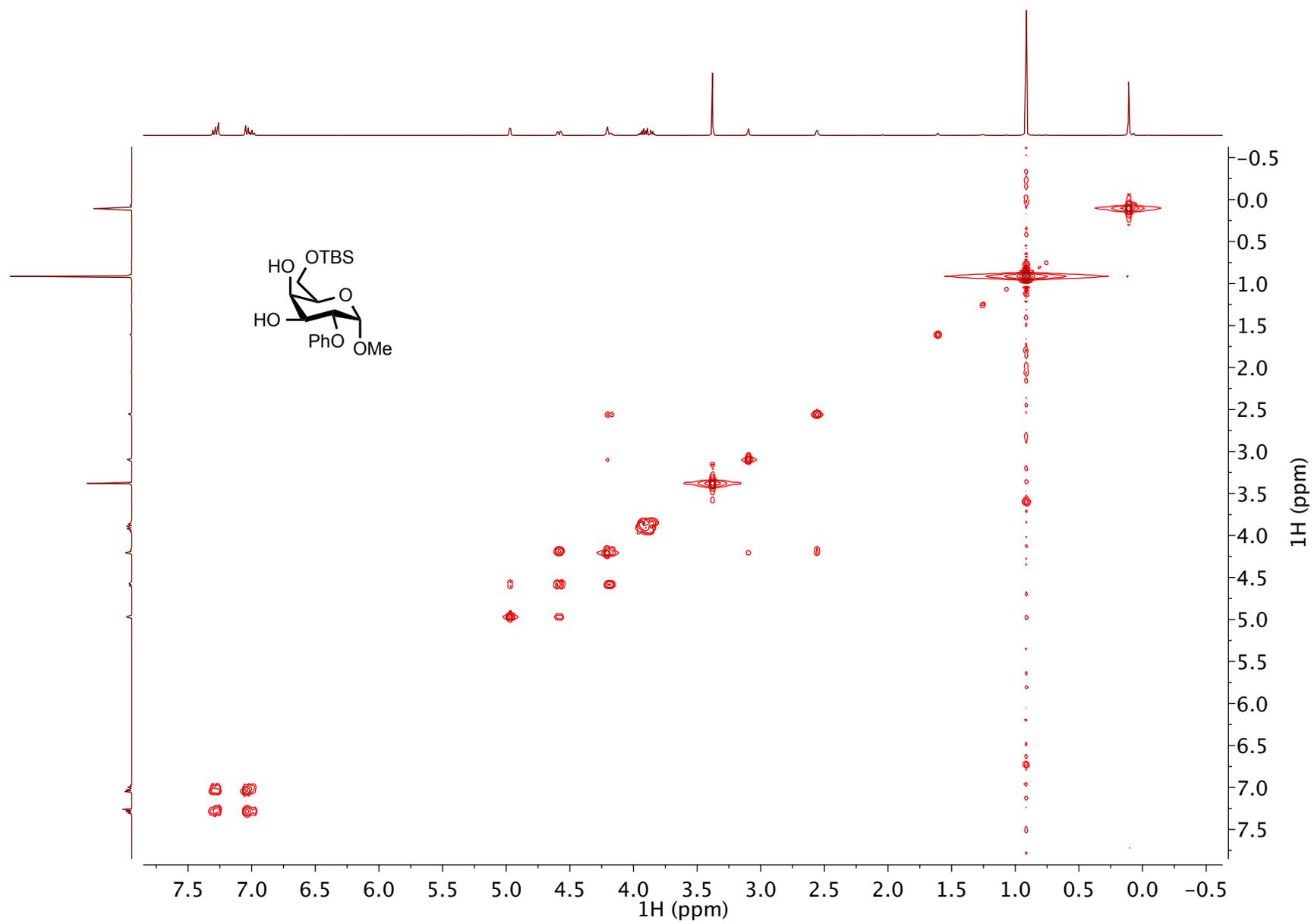
**3c – gCOSY (400 MHz, CDCl<sub>3</sub>)**

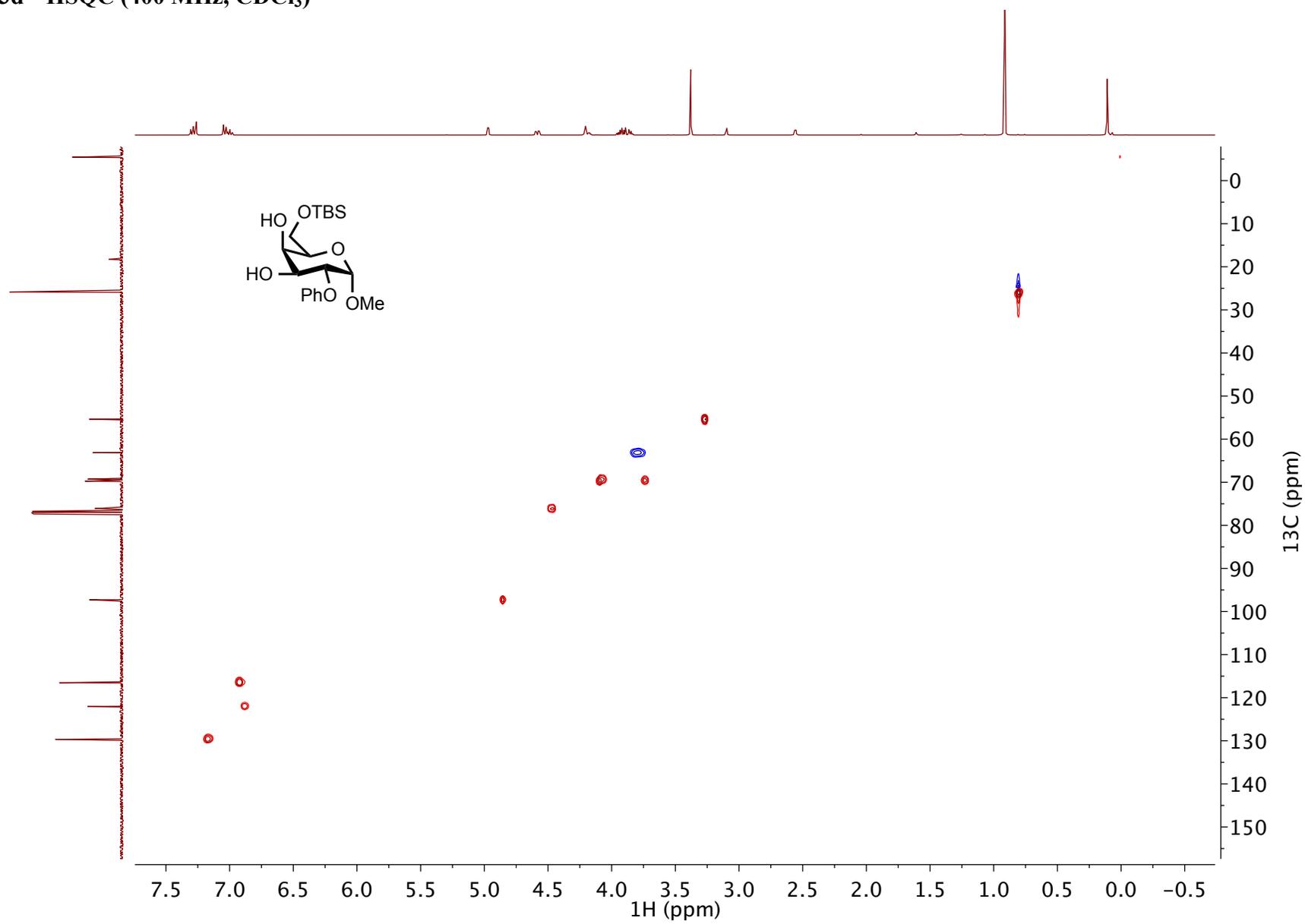
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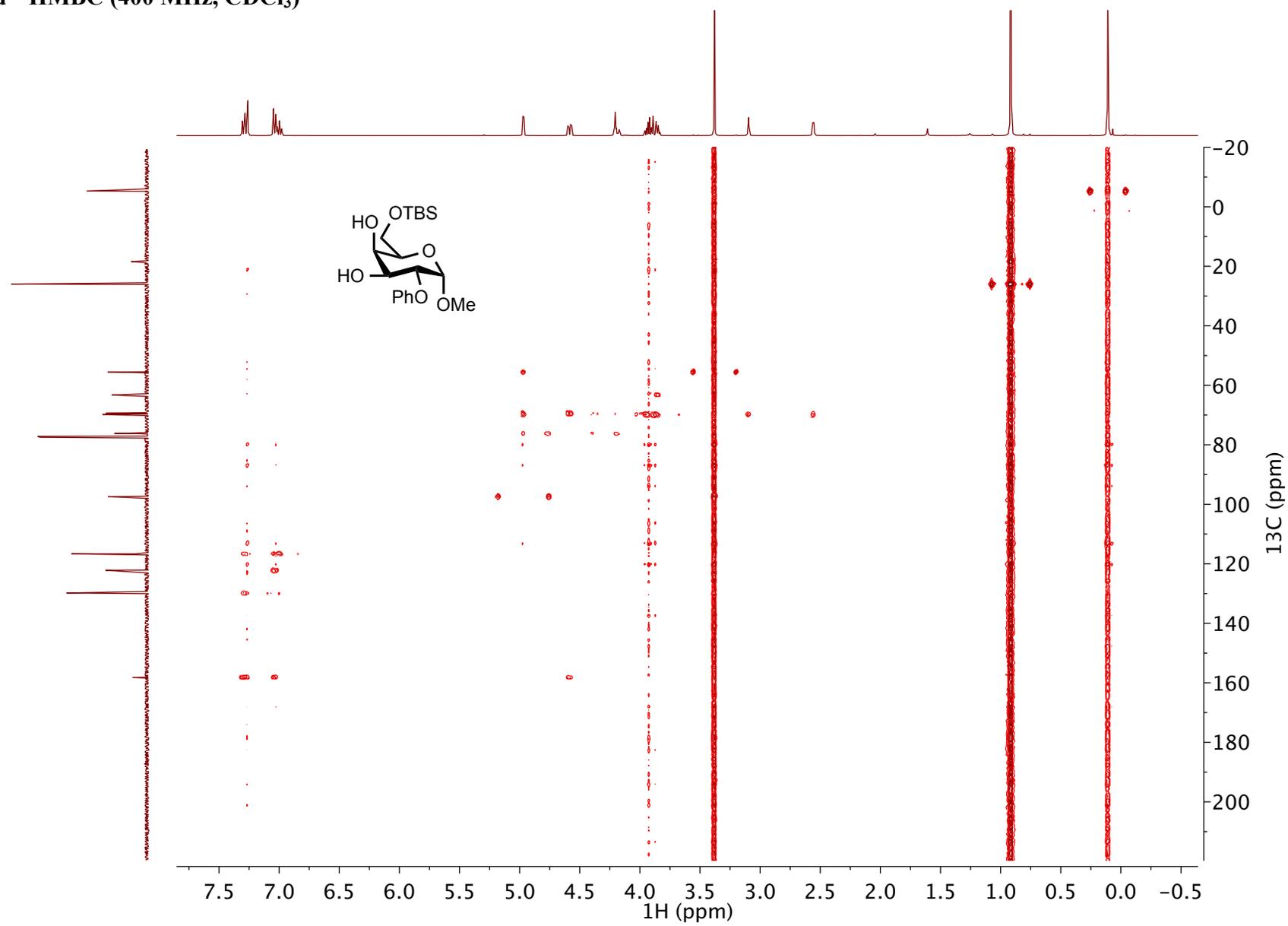
**3c – HMBC (400 MHz, CDCl<sub>3</sub>)**

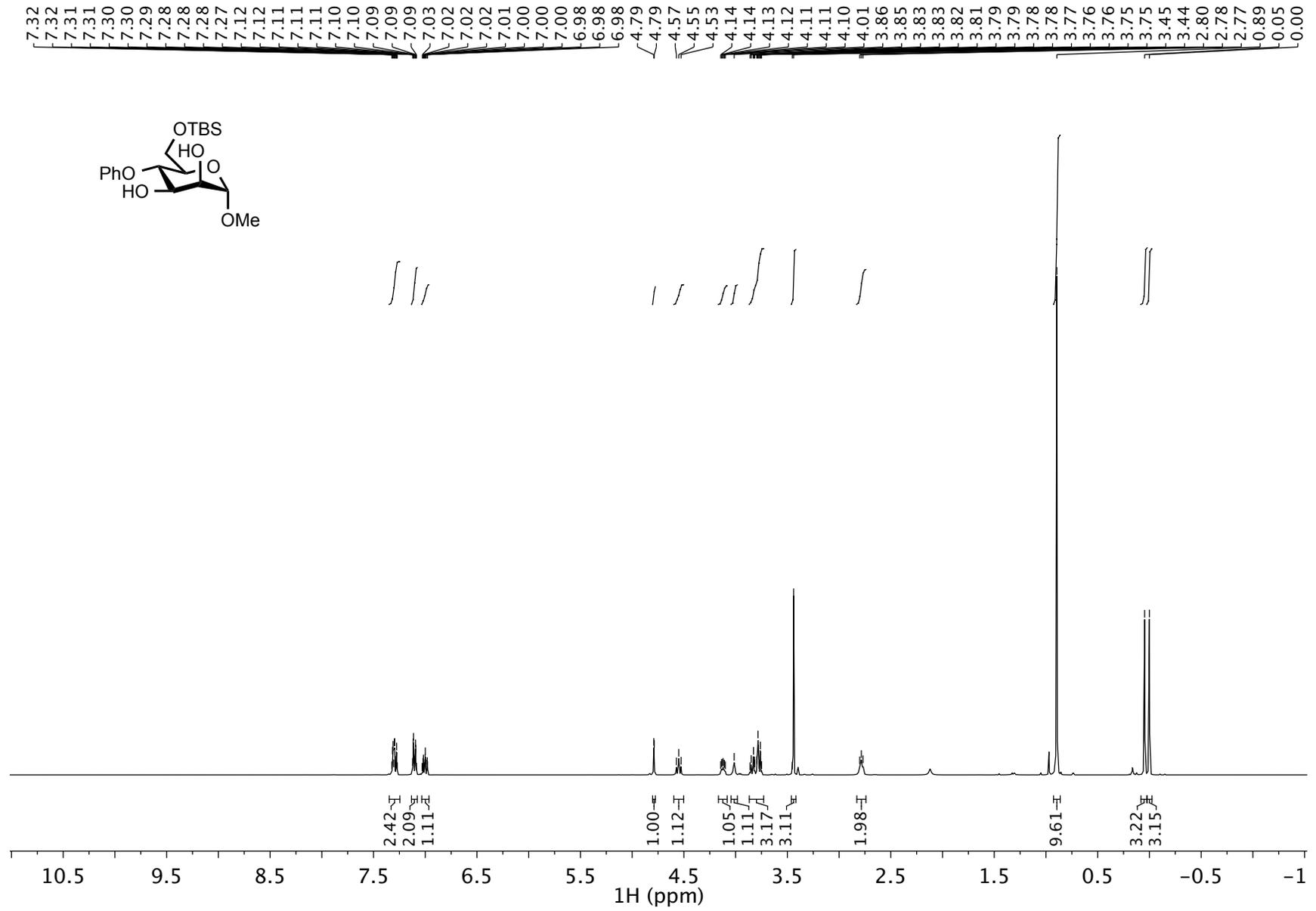
**3d –  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )**

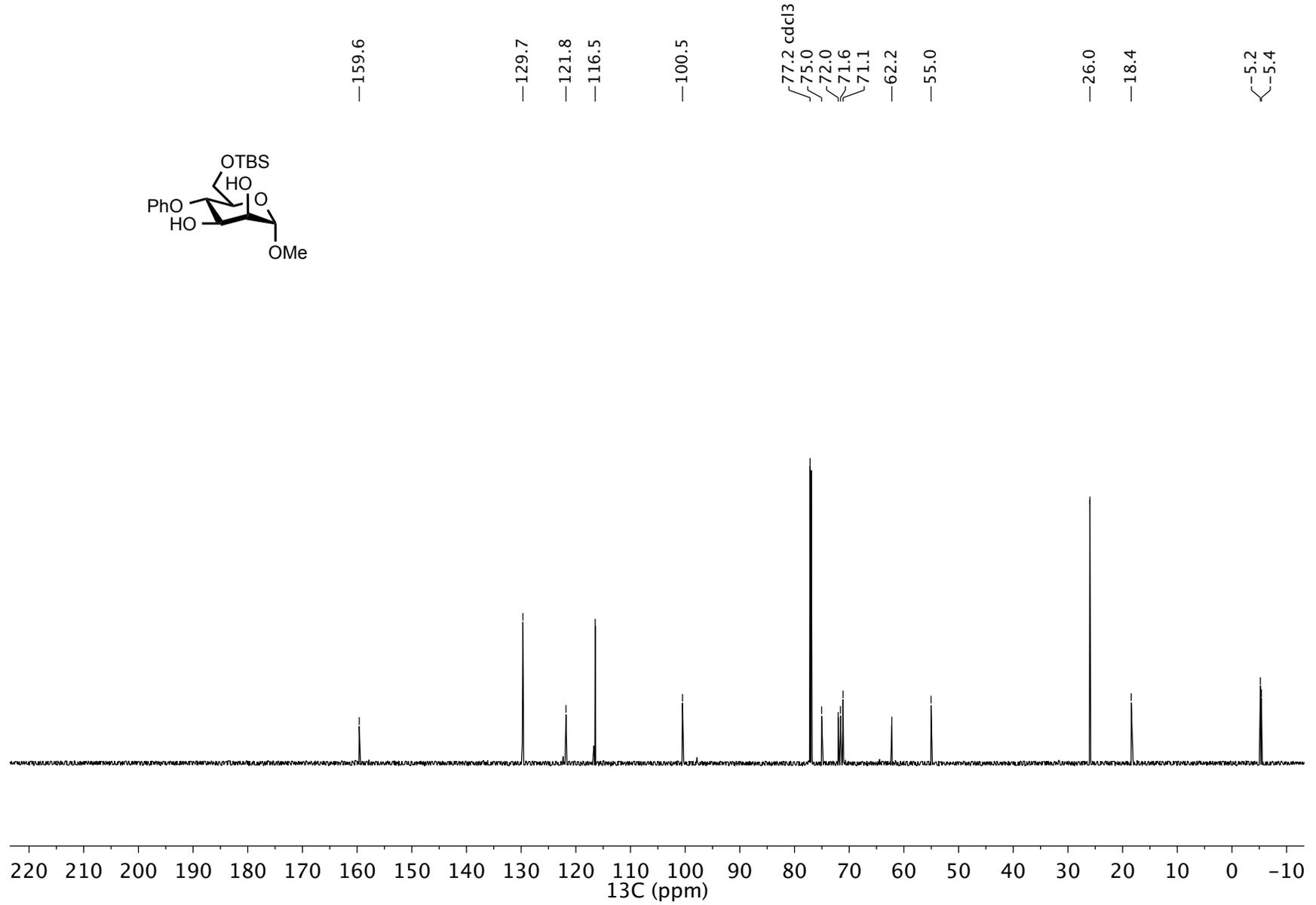
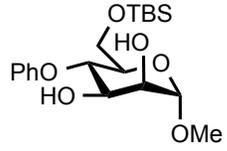
**3d** –  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )

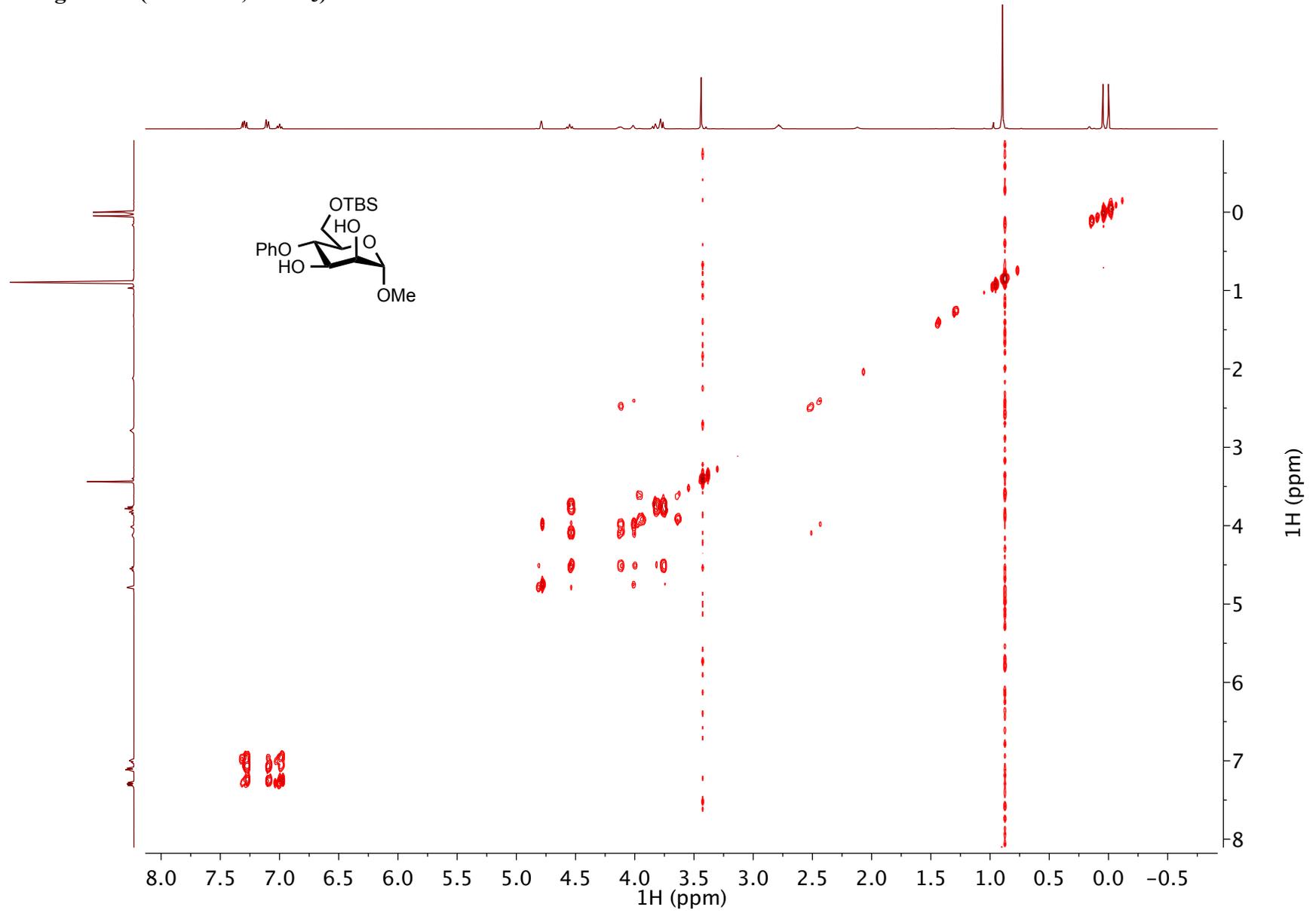
3d – gCOSY (400 MHz, CDCl<sub>3</sub>)

**3d – HSQC (400 MHz, CDCl<sub>3</sub>)**

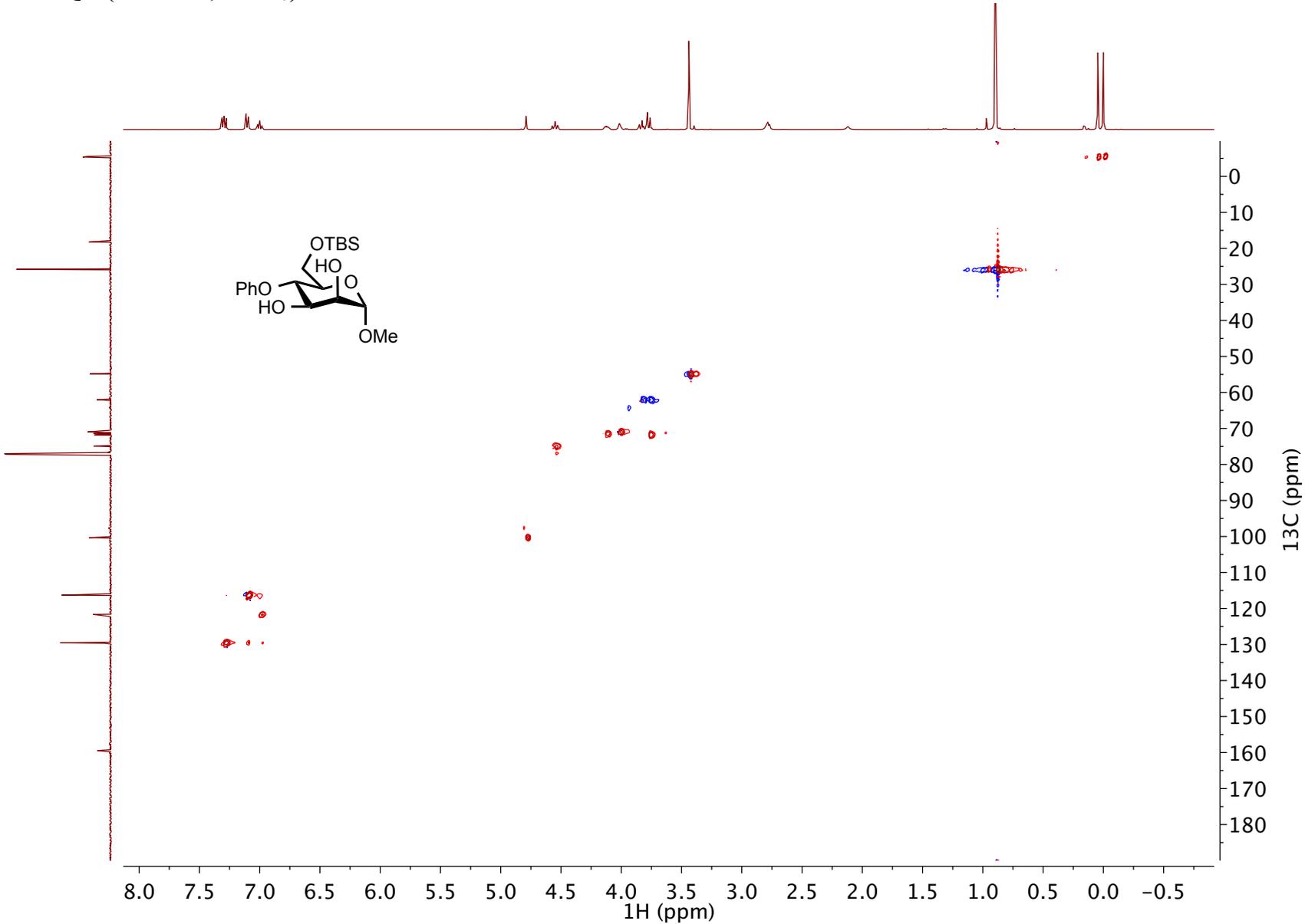
3d – HMBC (400 MHz, CDCl<sub>3</sub>)

**3e - <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)**

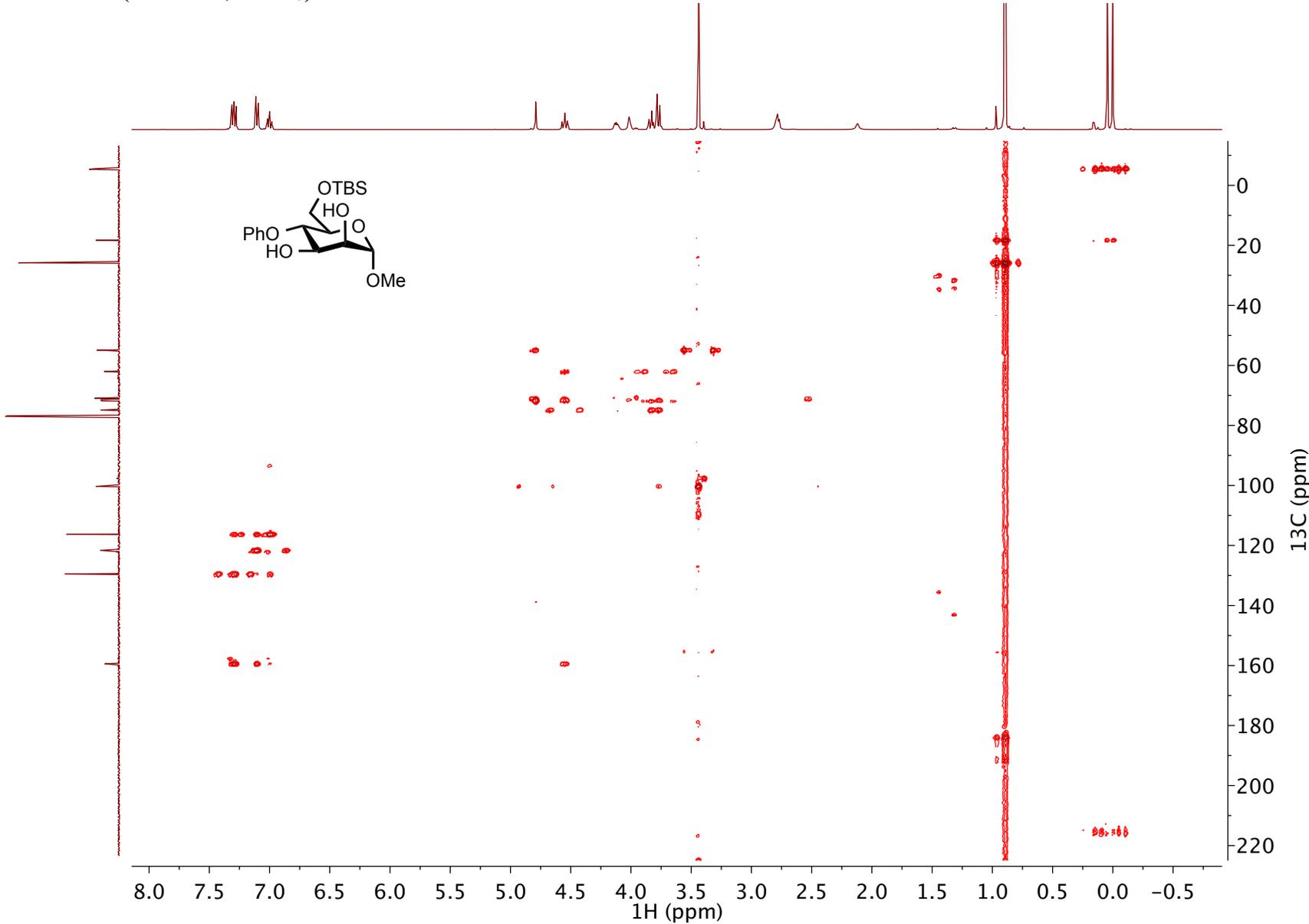
**3e –  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )**

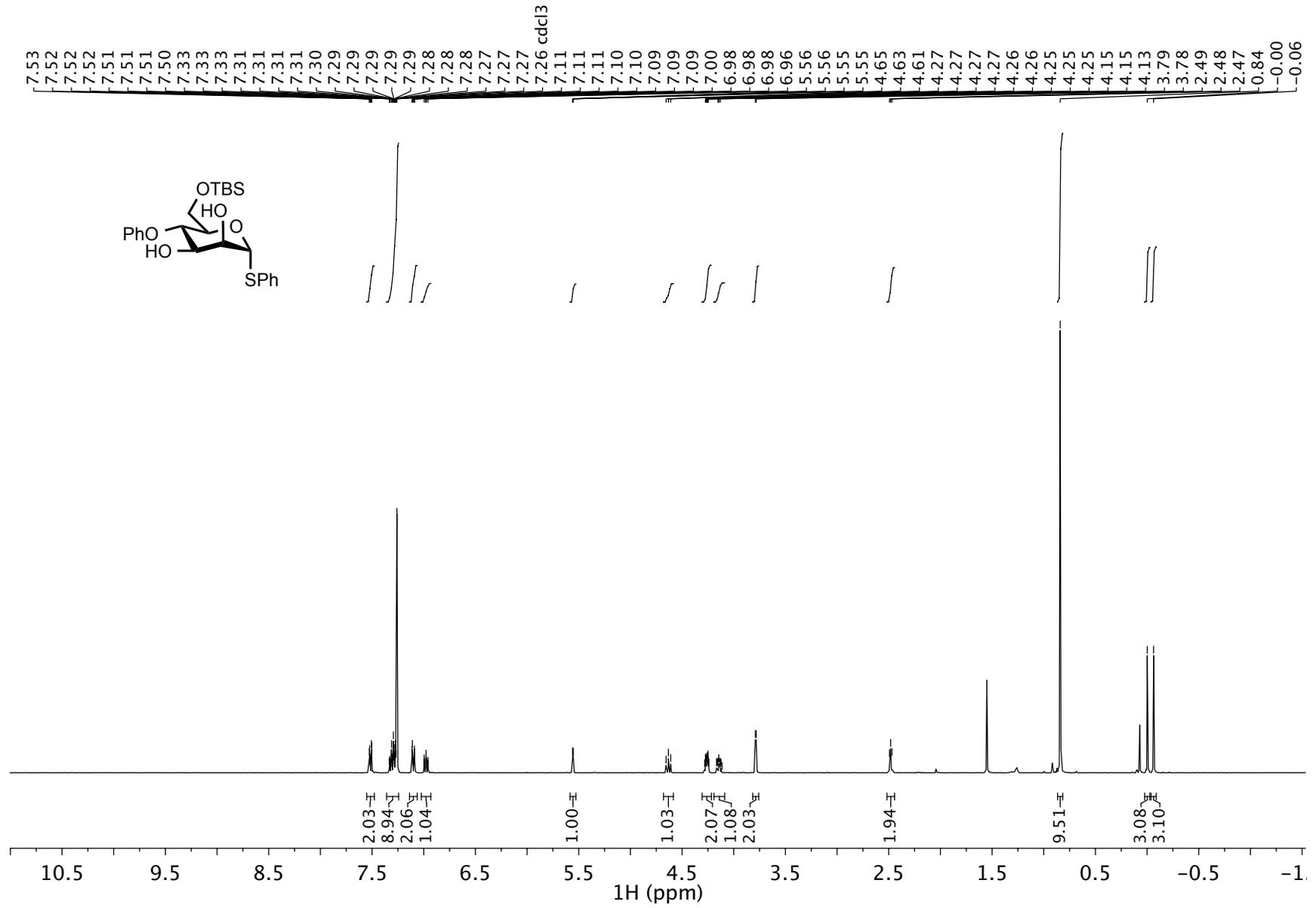
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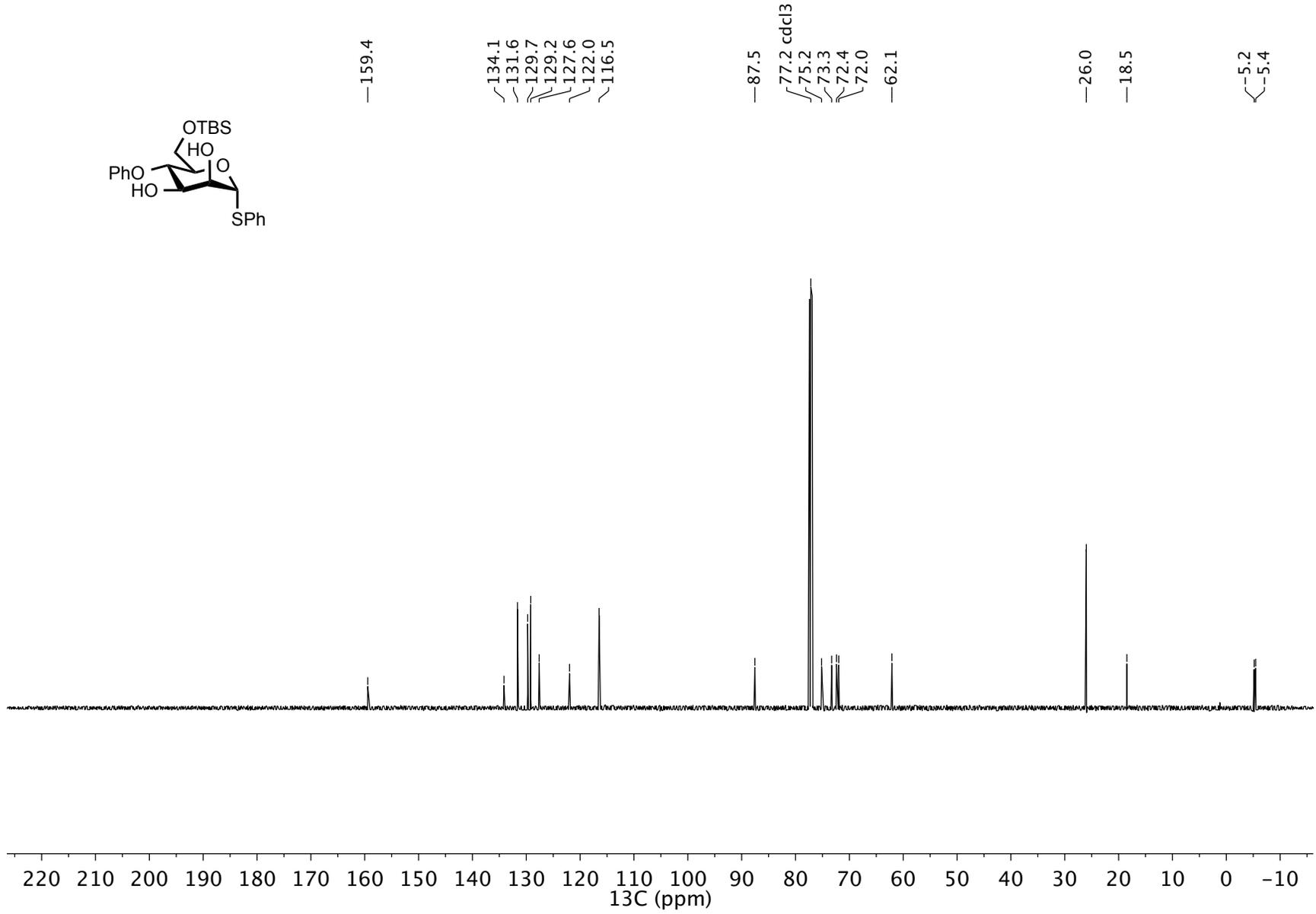
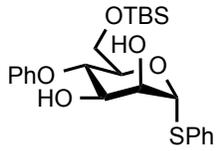
3e – HSQC (400 MHz, CDCl<sub>3</sub>)

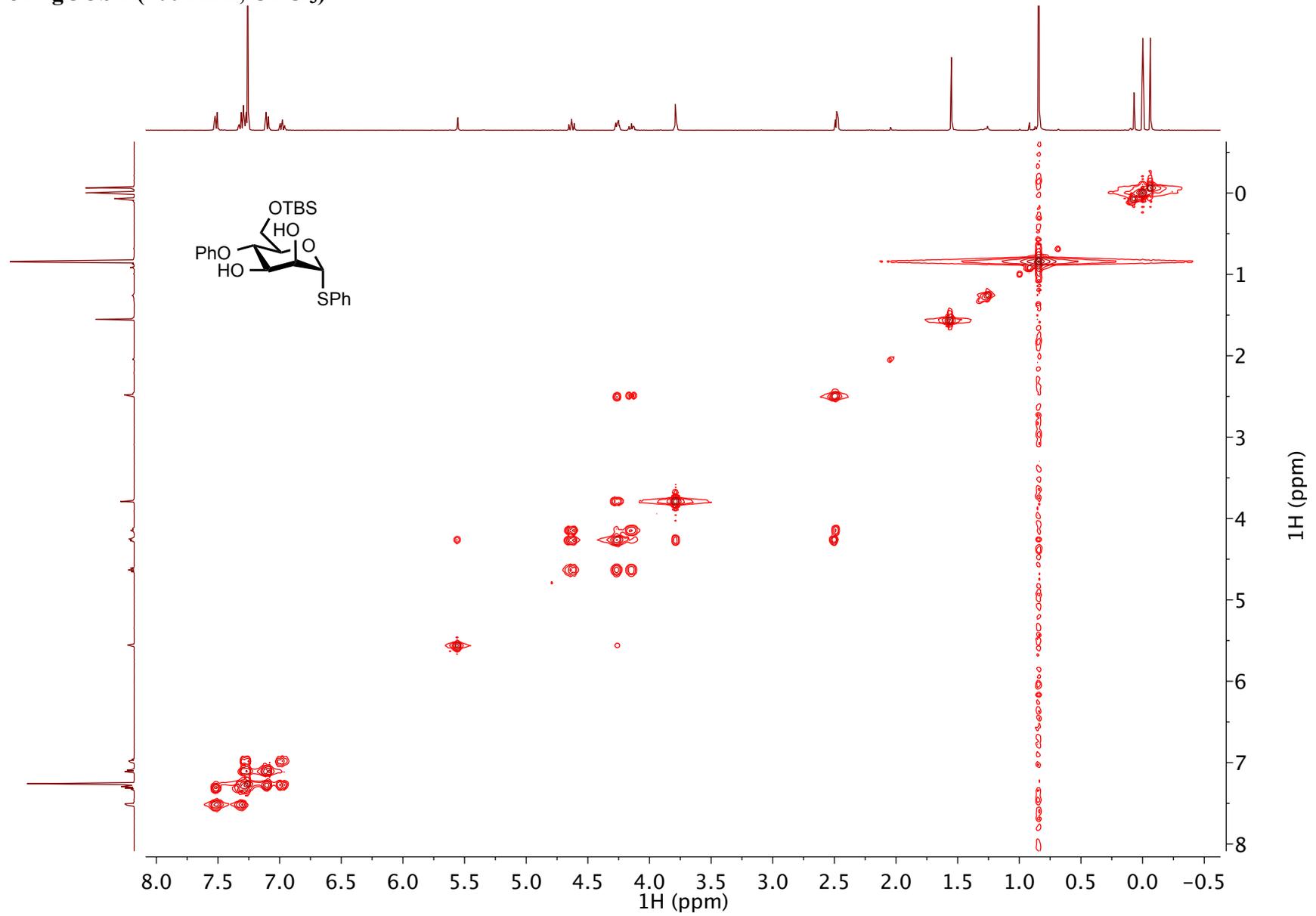


3e – HMBC (400 MHz, CDCl<sub>3</sub>)

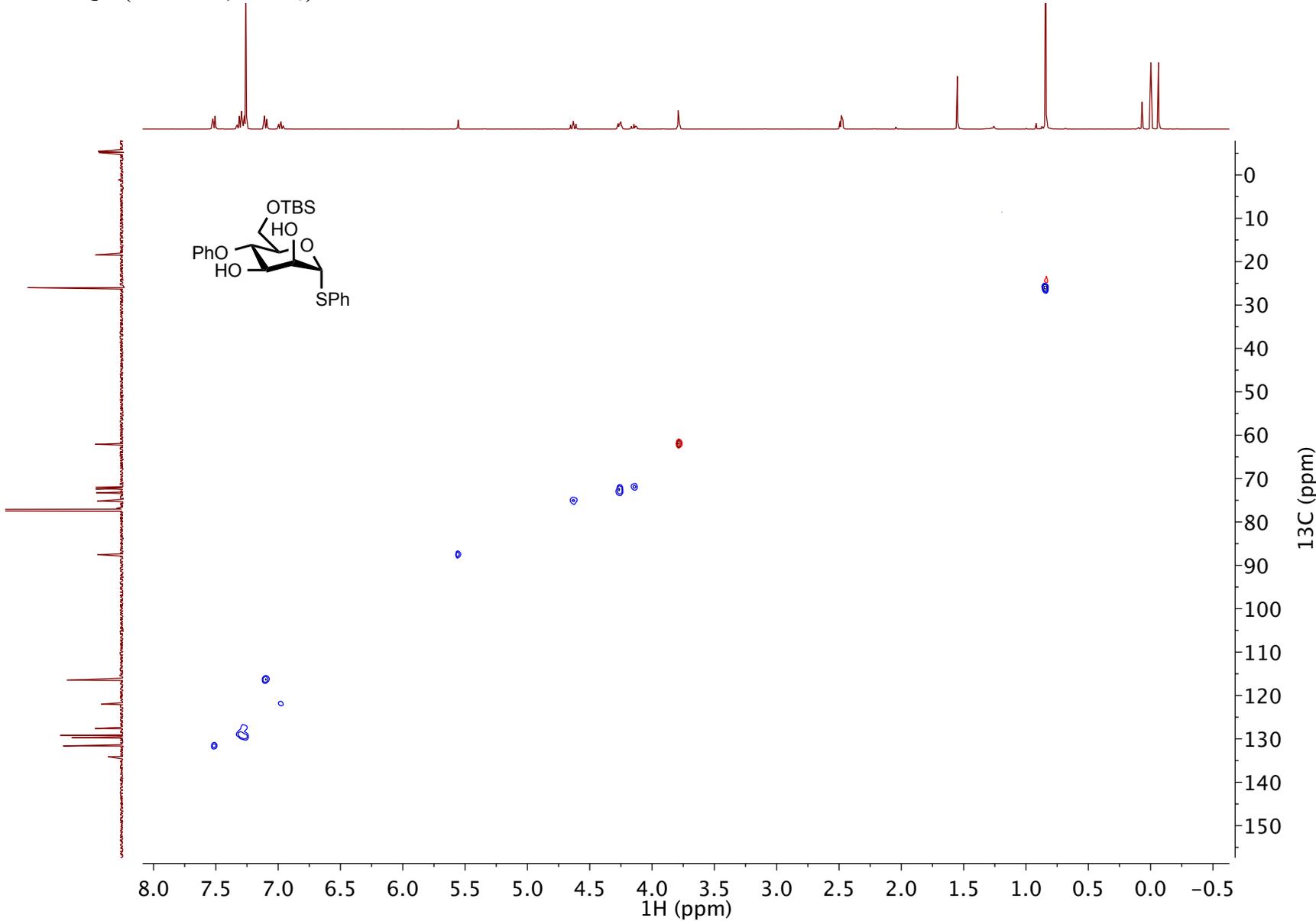


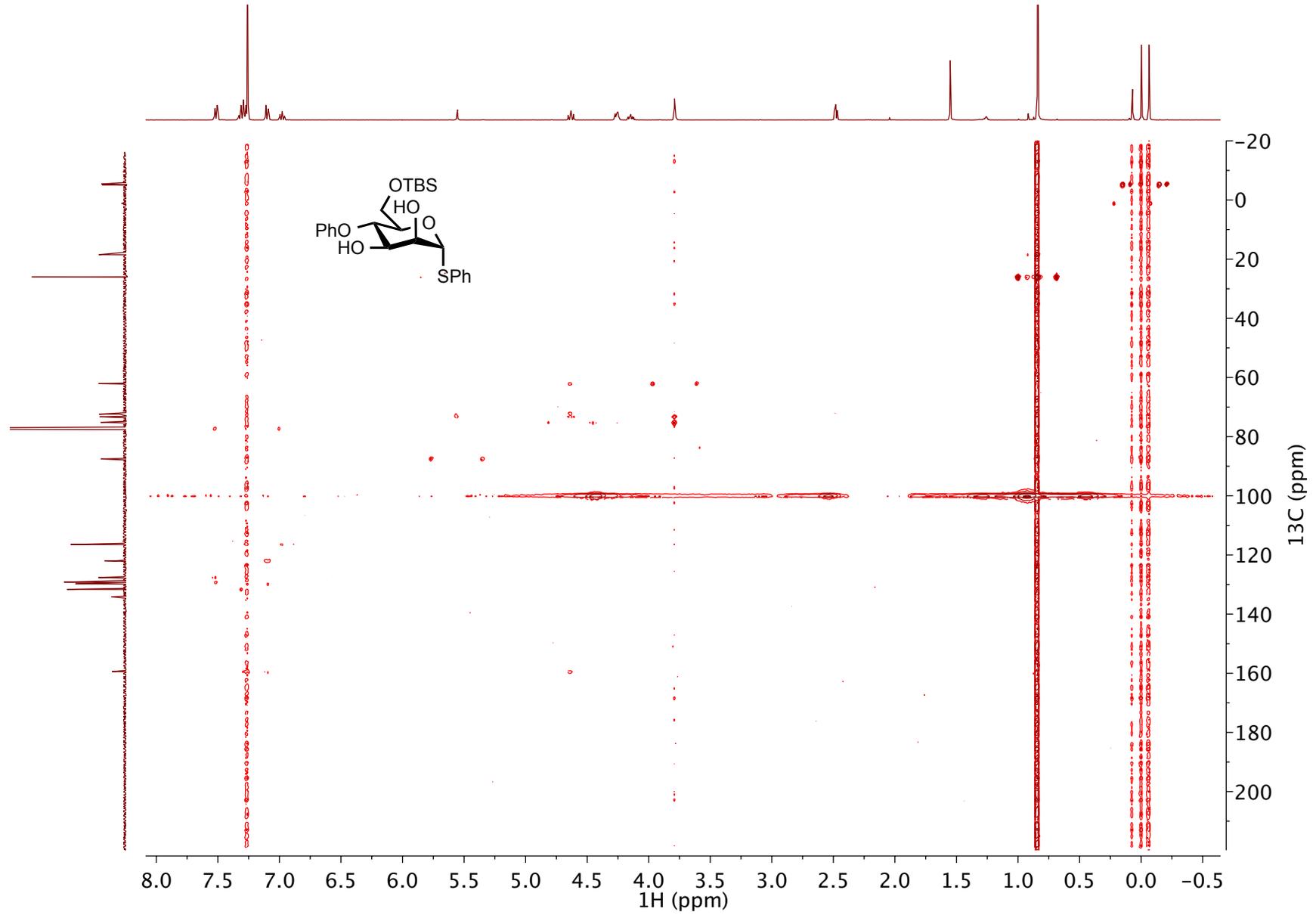
**3f – <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)**

**3f –  $^{13}\text{C}$  NMR (126 MHz,  $\text{CDCl}_3$ )**

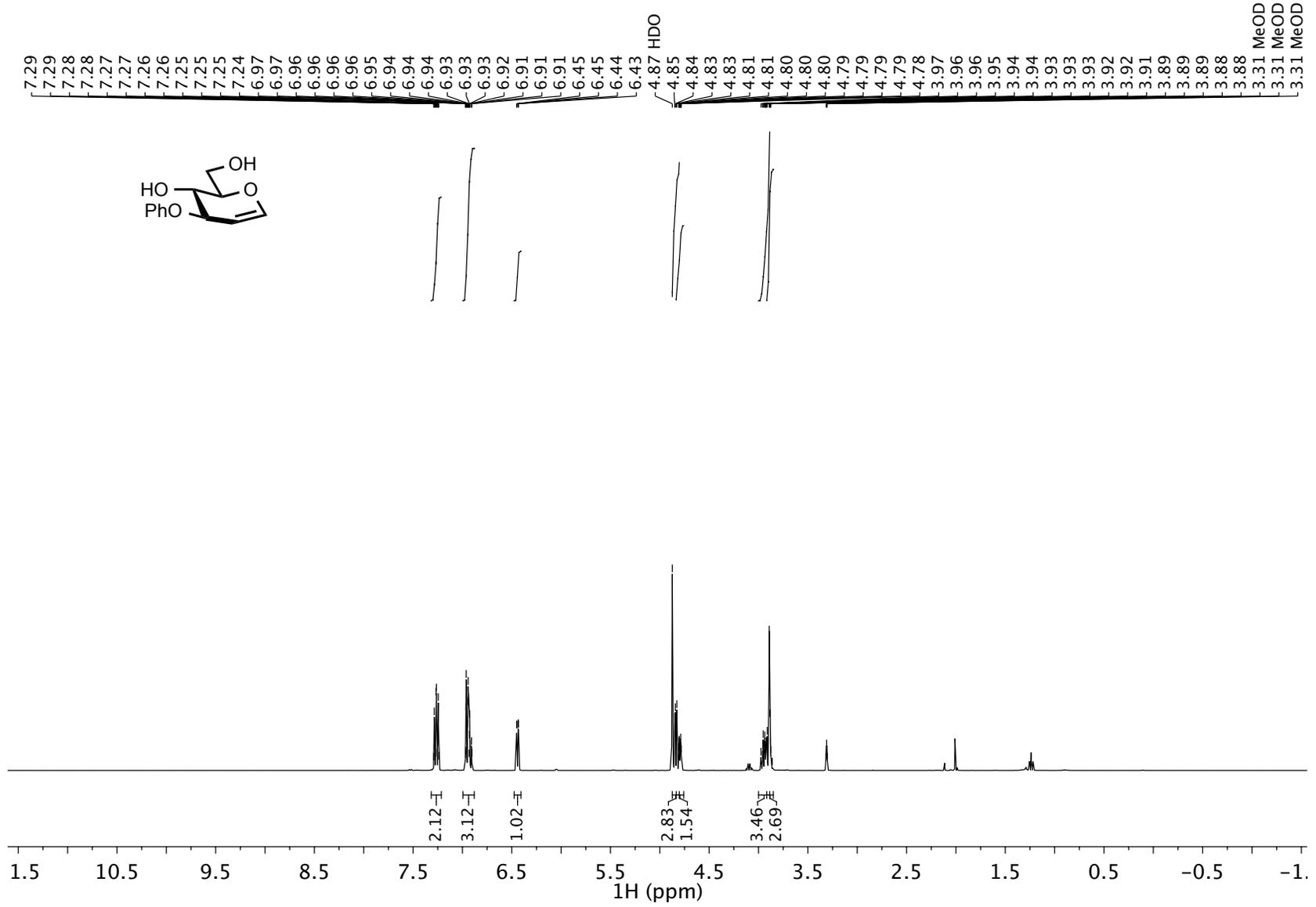
3f-gCOSY (400 MHz, CDCl<sub>3</sub>)

3f – HSQC (400 MHz, CDCl<sub>3</sub>)

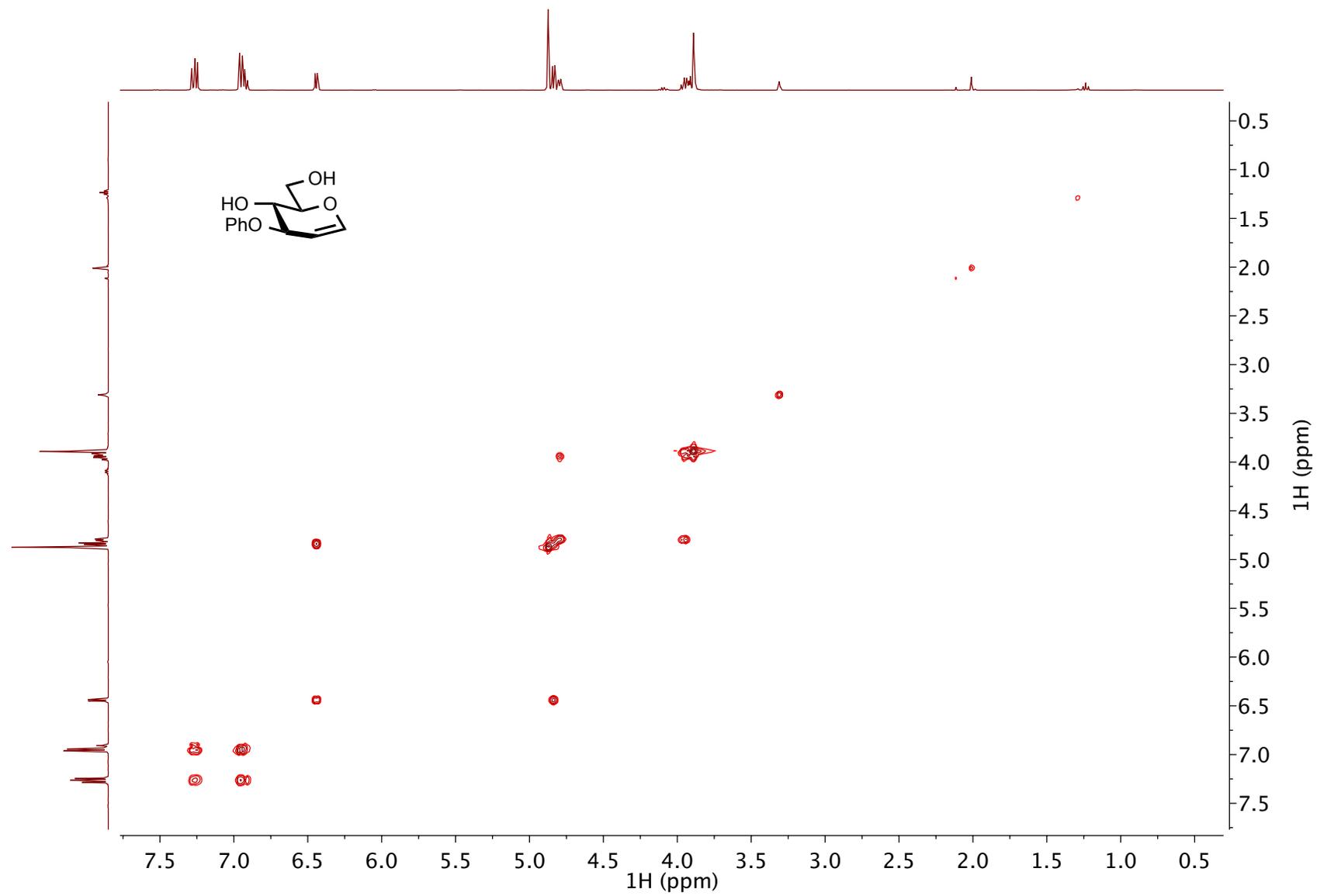


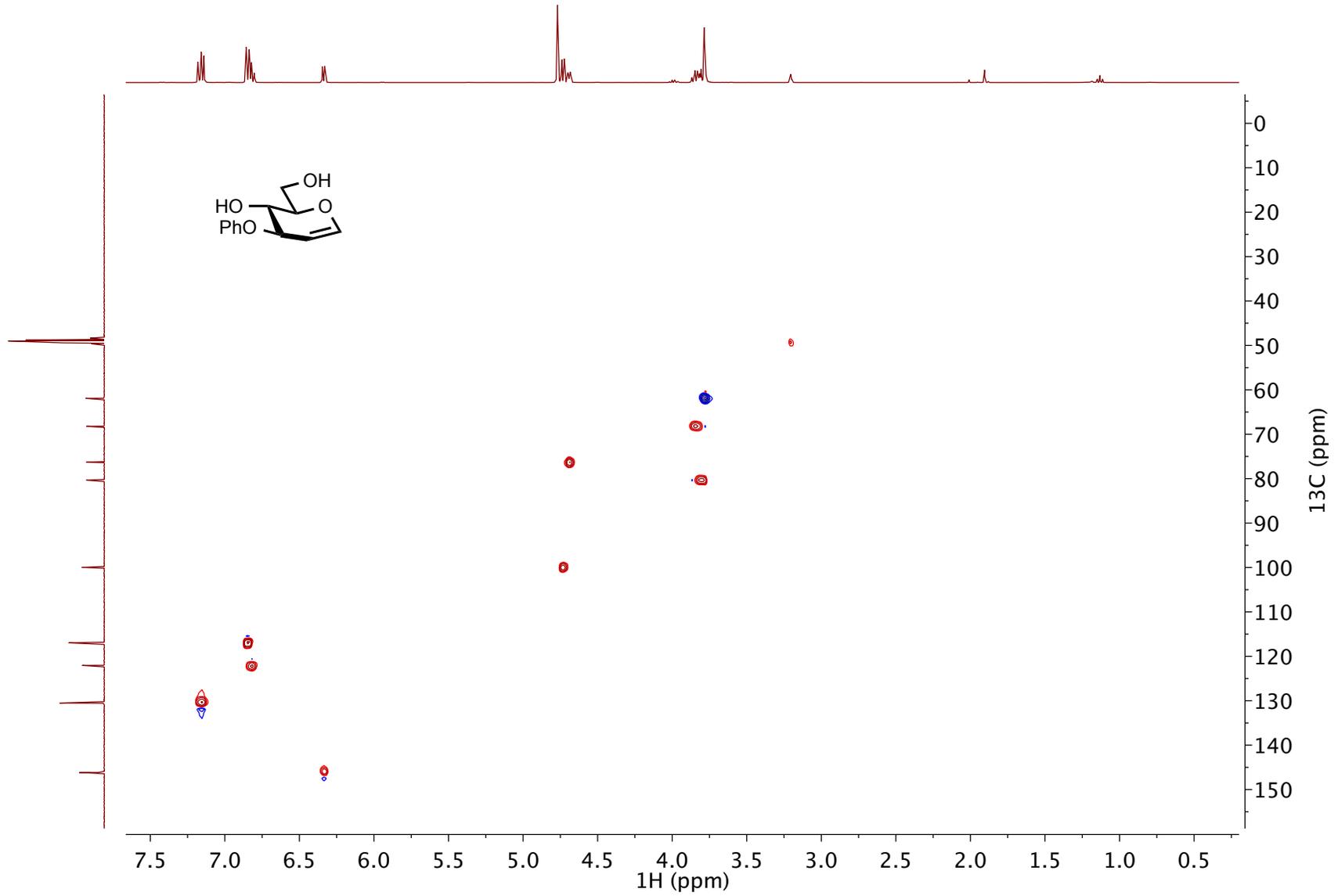
3f – HMBC (400 MHz, CDCl<sub>3</sub>)

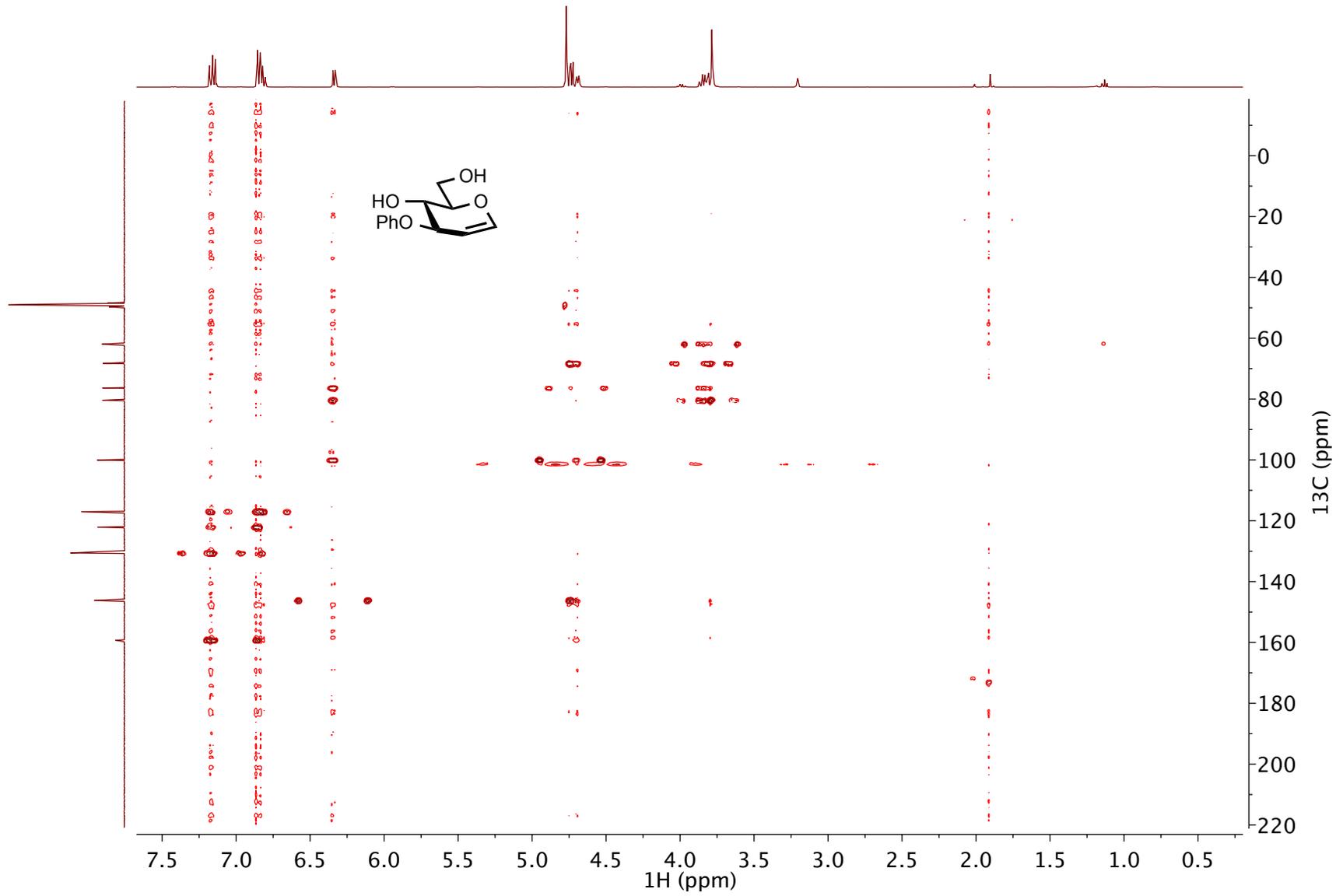
**3g –  $^1\text{H}$  NMR (400 MHz,  $\text{CD}_3\text{OD}$ )**



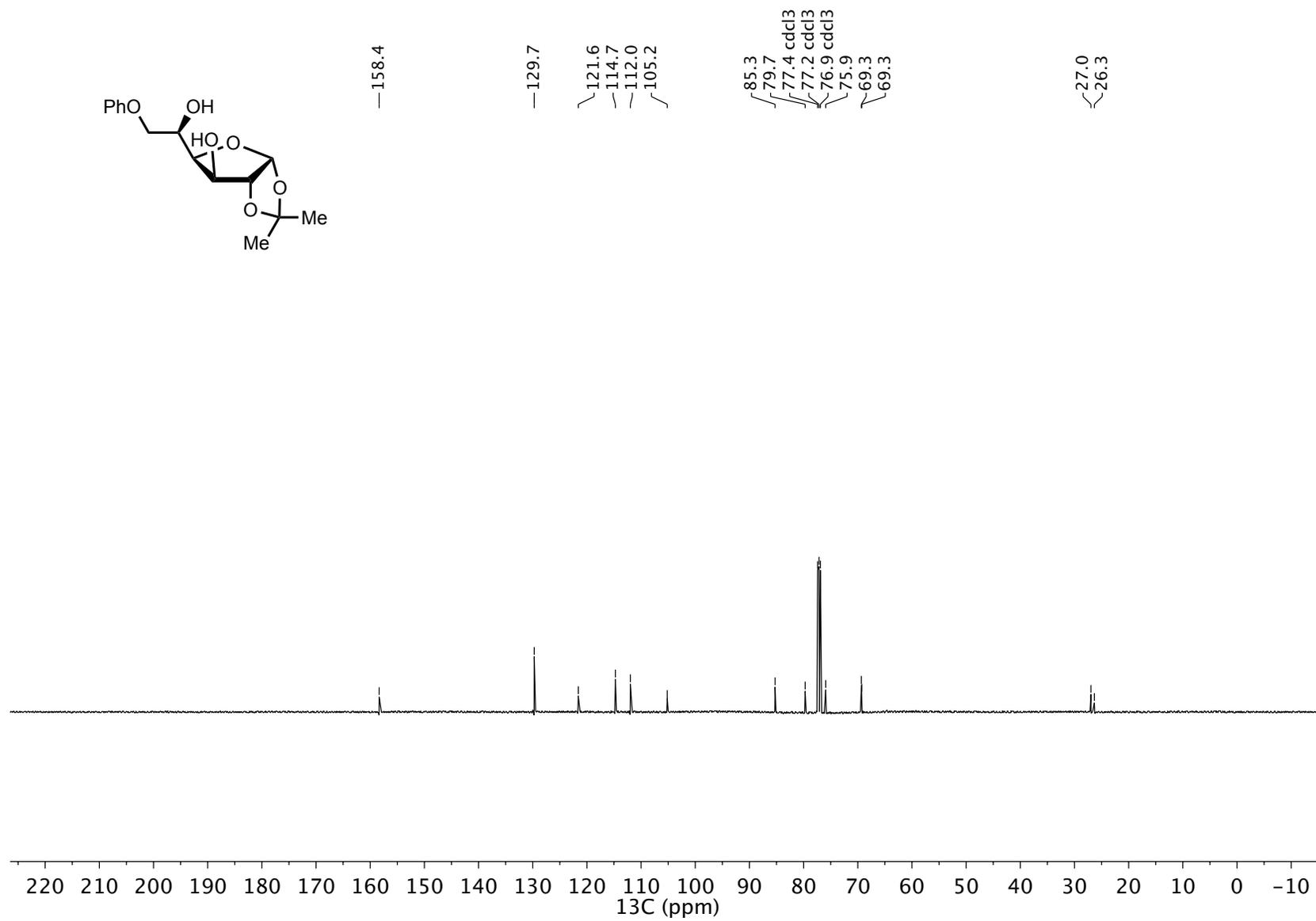


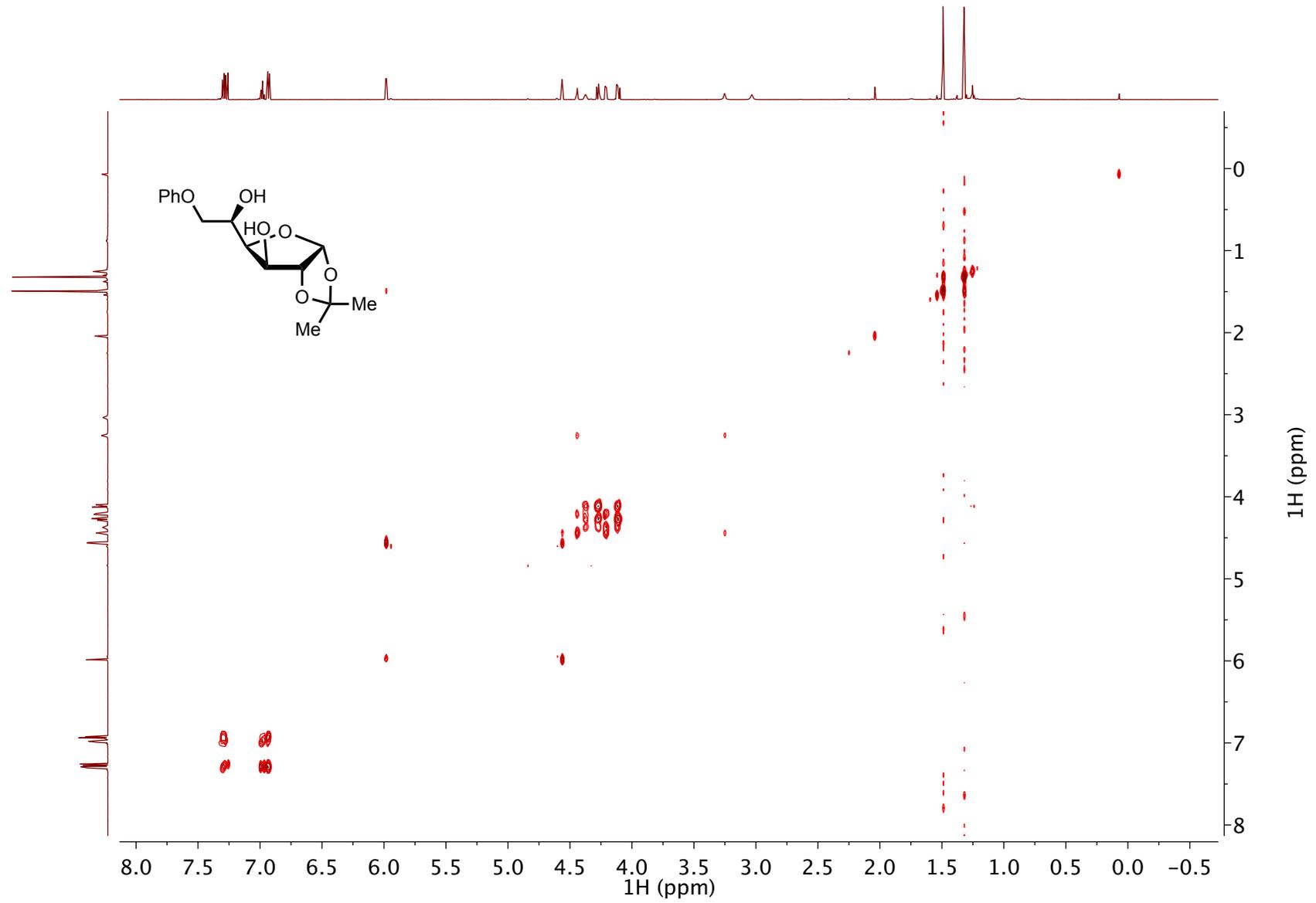
3g – gCOSY (400 MHz, CD<sub>3</sub>OD)

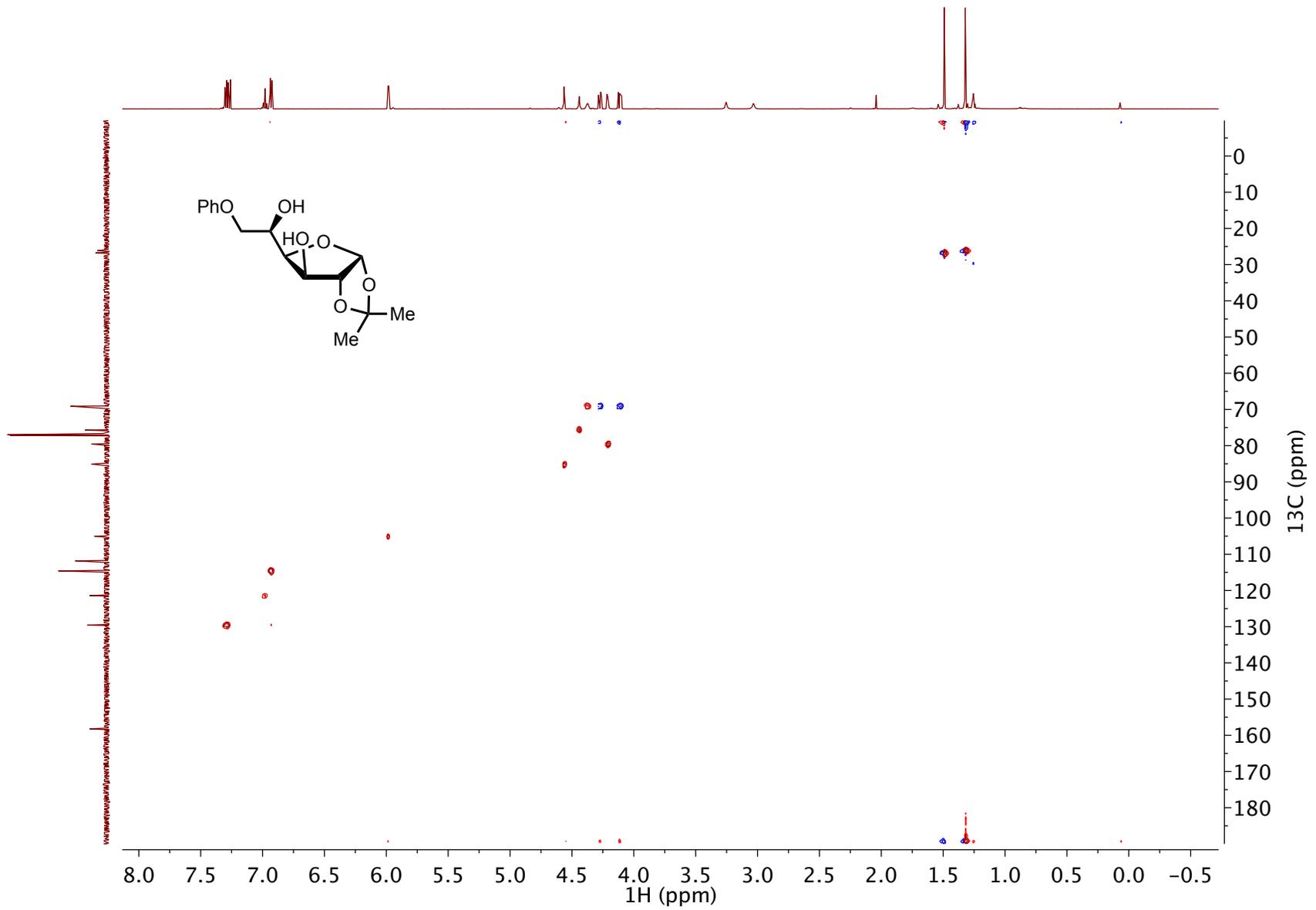
3g – HSQC (400 MHz, CD<sub>3</sub>OD)

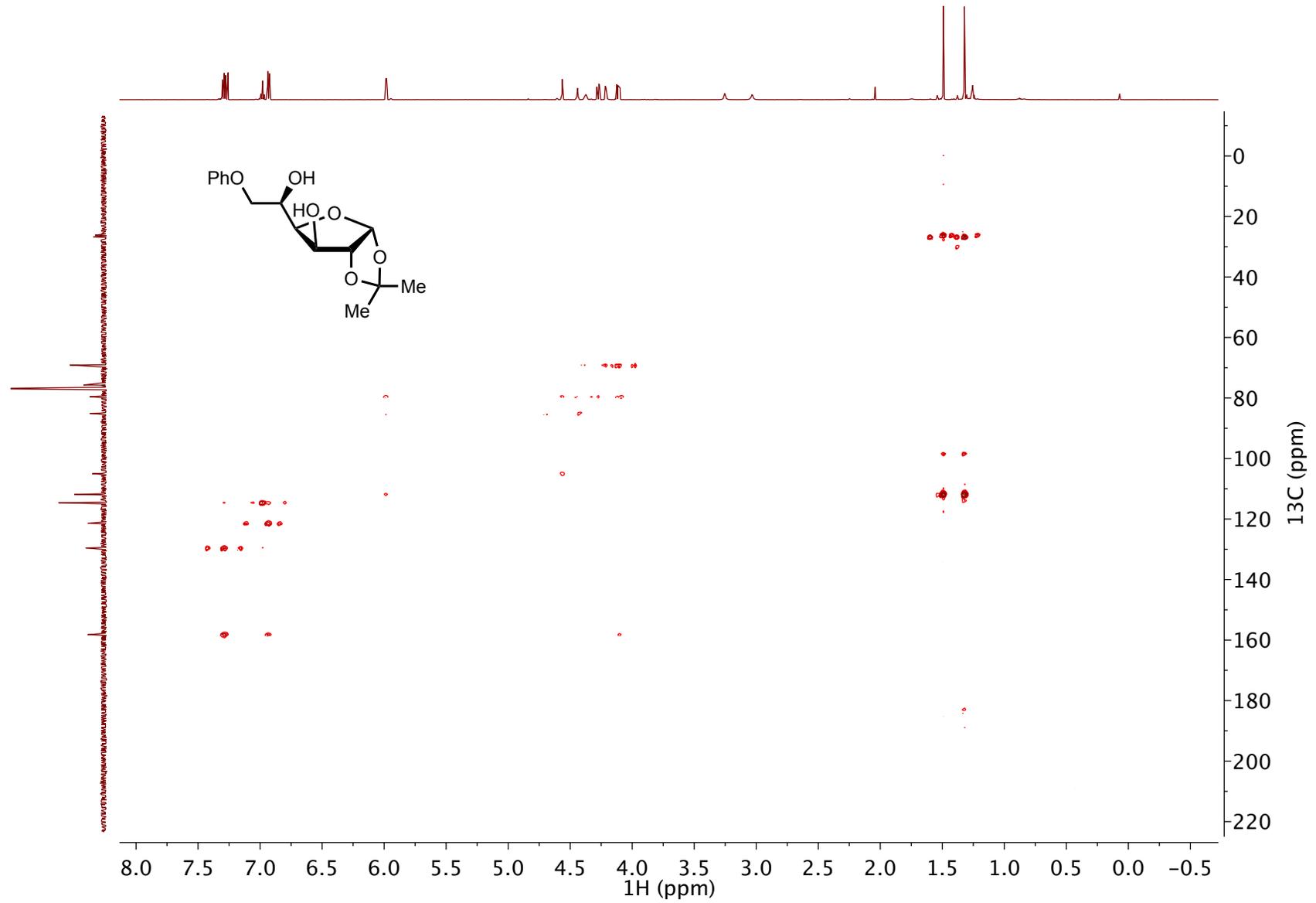
3g – HMBC (400 MHz, CD<sub>3</sub>OD)

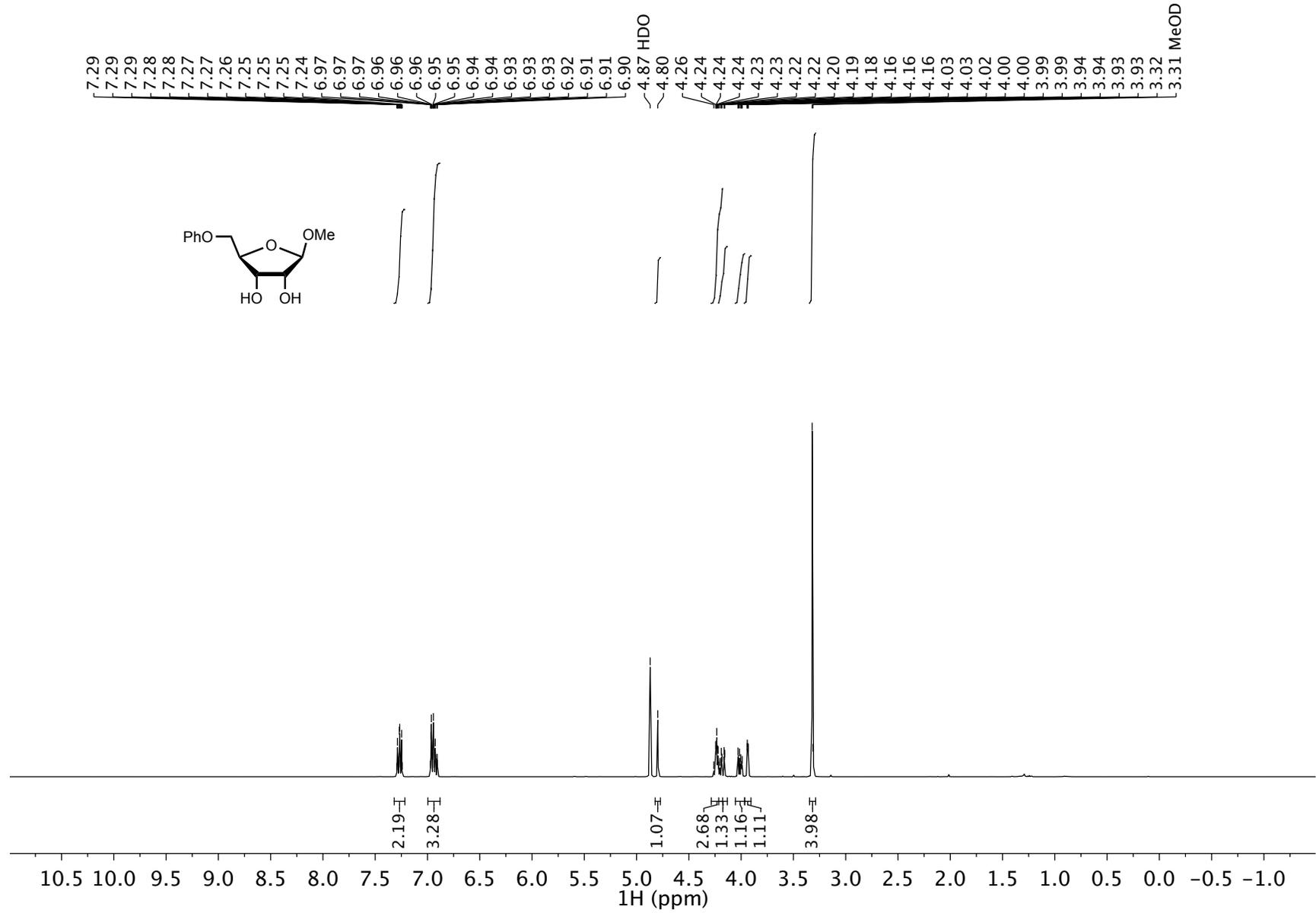


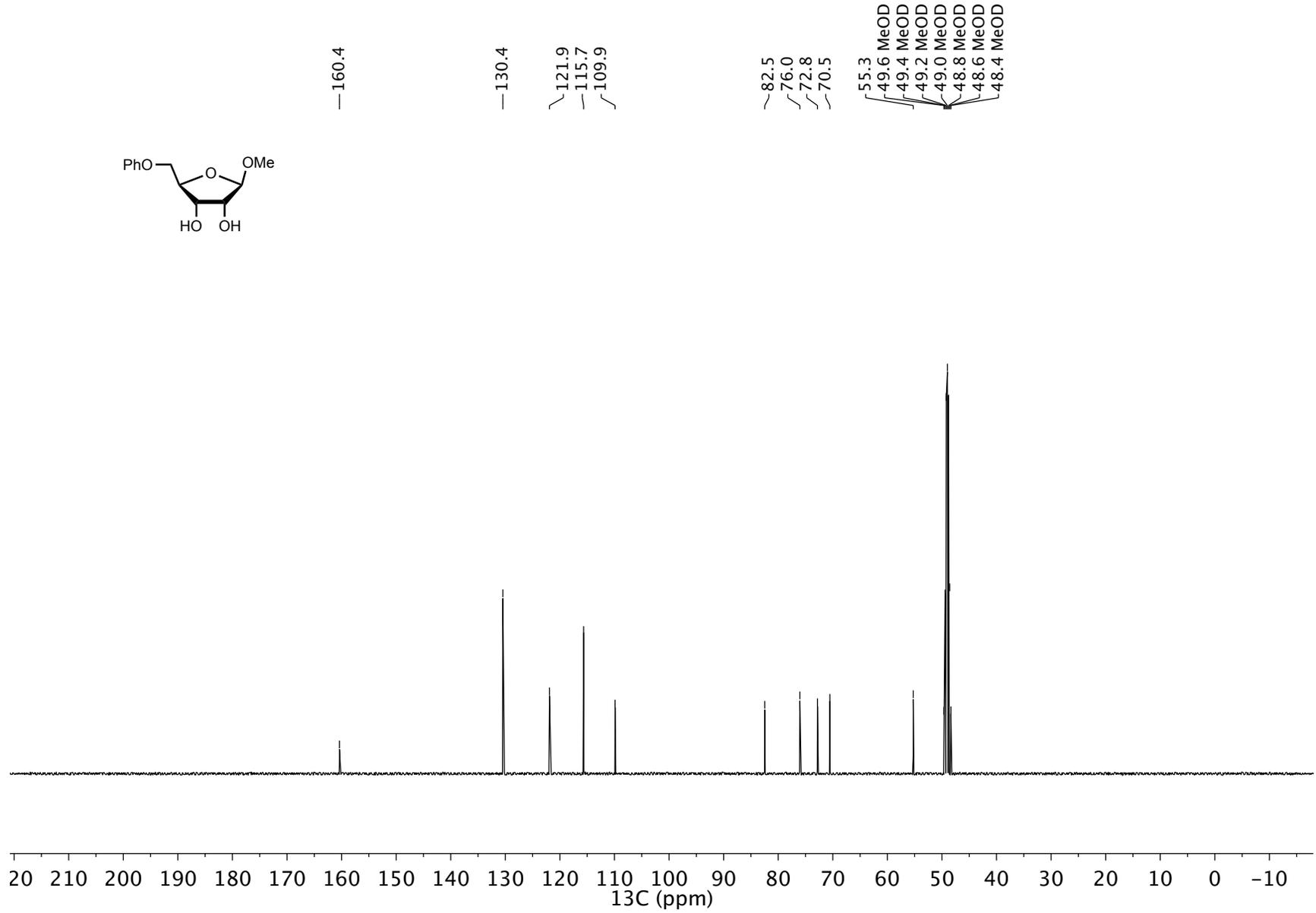
**3h** –  $^{13}\text{C}$  NMR (126 MHz,  $\text{CDCl}_3$ )

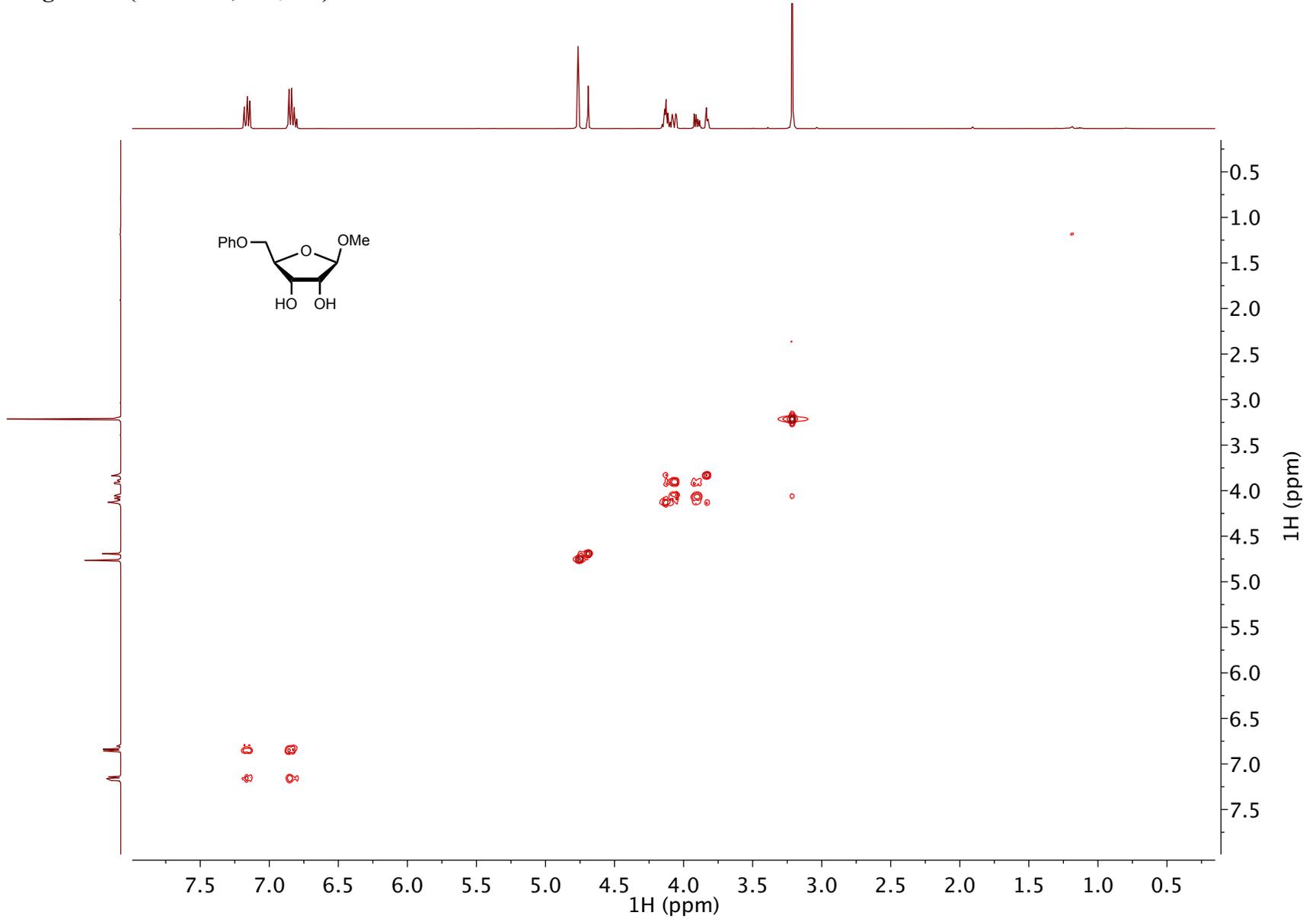
3h – gCOSY (400 MHz, CDCl<sub>3</sub>)

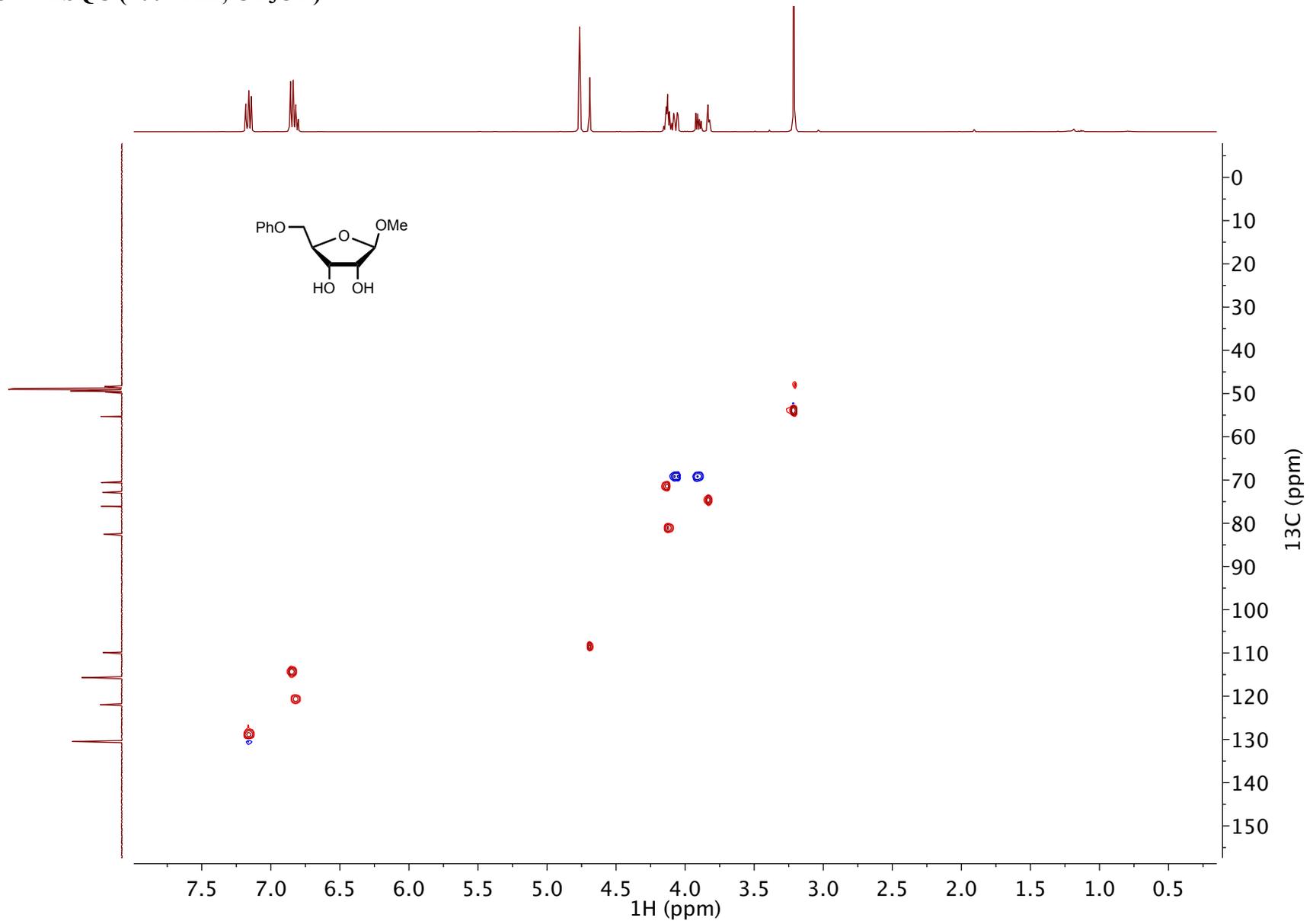
3h – HSQC (400 MHz, CDCl<sub>3</sub>)

3h – HMBC (400 MHz, CDCl<sub>3</sub>)

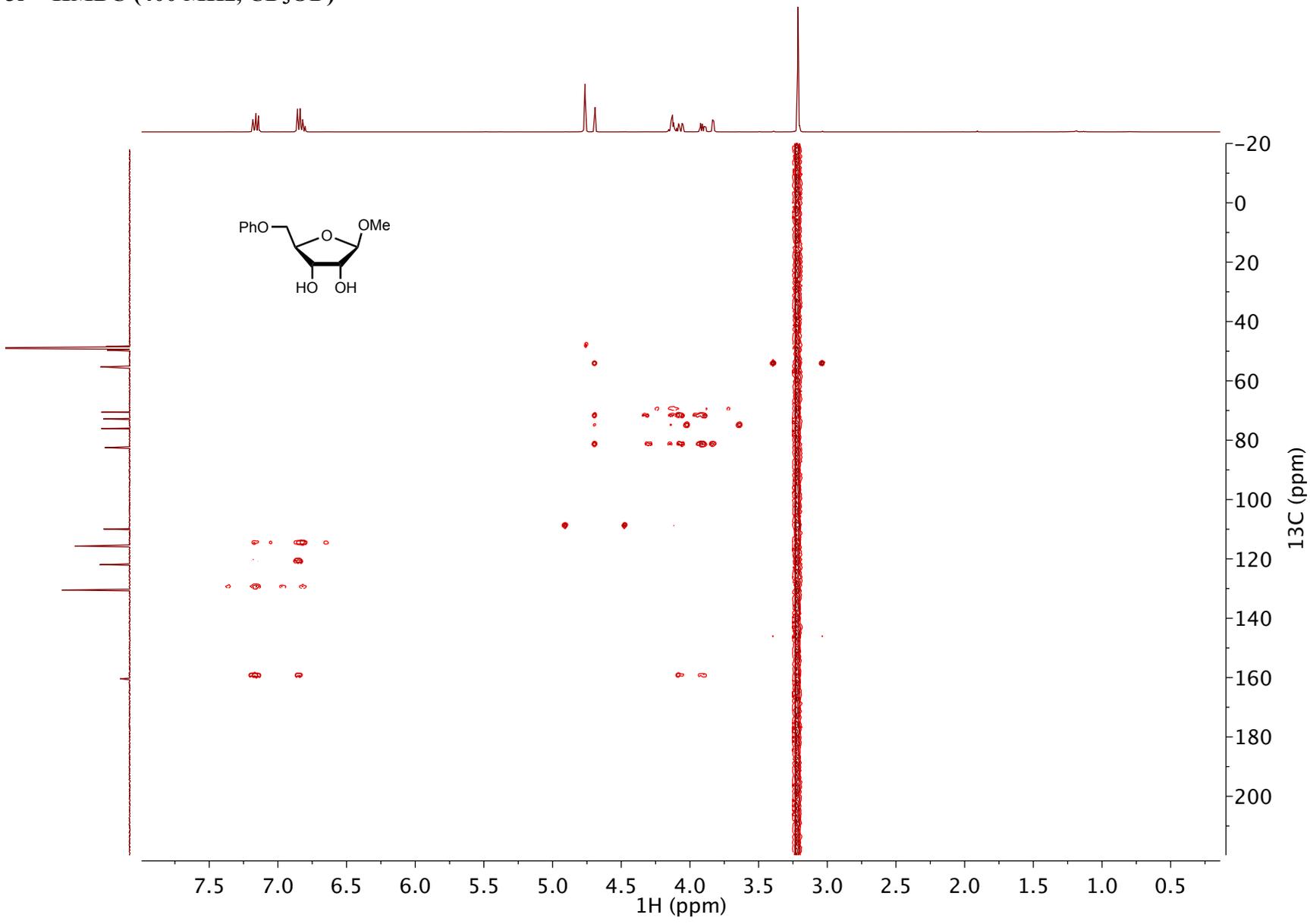
**3i – <sup>1</sup>H NMR (400 MHz, CD<sub>3</sub>OD)**

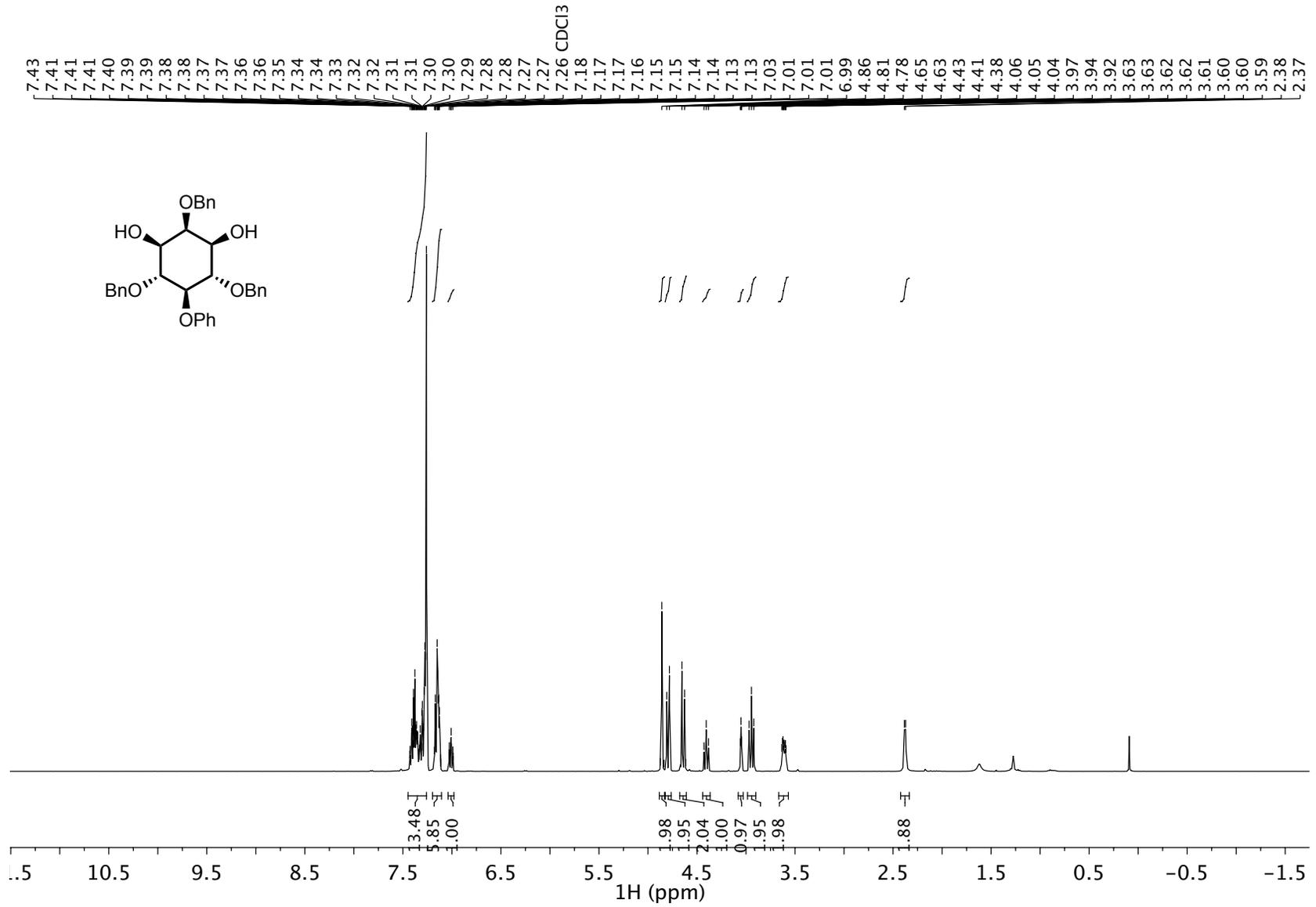
**3i –  $^{13}\text{C}$  NMR (101 MHz,  $\text{CD}_3\text{OD}$ )**

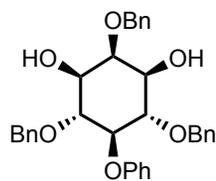
**3i – gCOSY (400 MHz, CD<sub>3</sub>OD)**

3i – HSQC (400 MHz, CD<sub>3</sub>OD)

3i – HMBC (400 MHz, CD<sub>3</sub>OD)



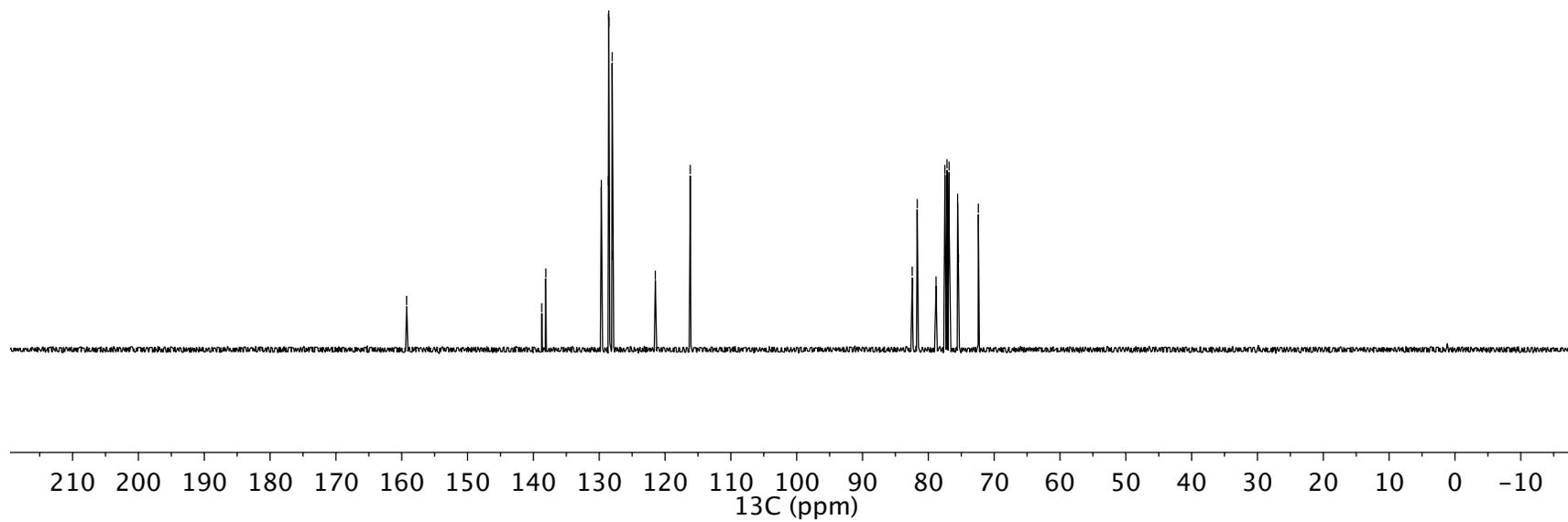
3j –  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )

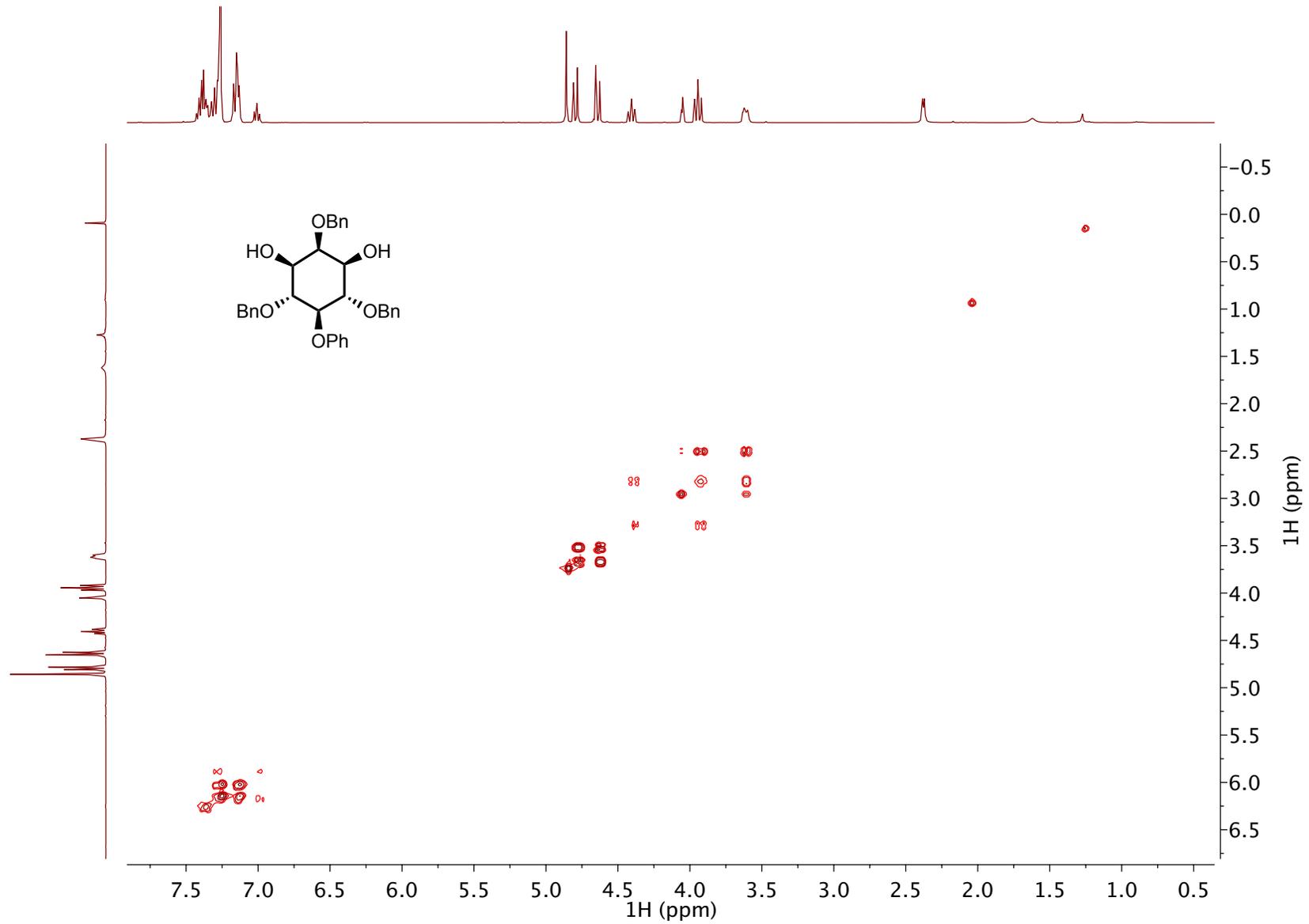
**3j** –  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )

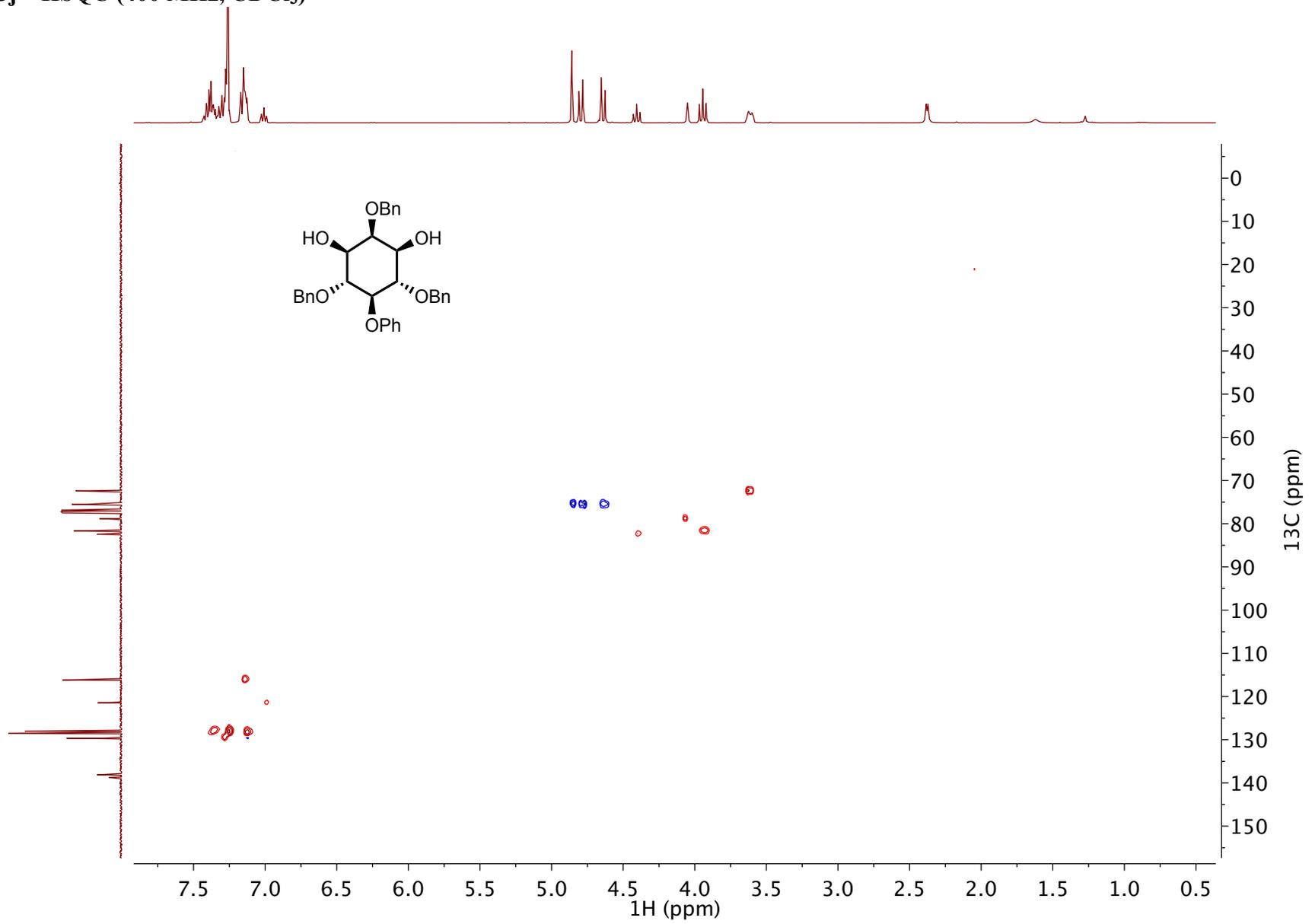
—159.3

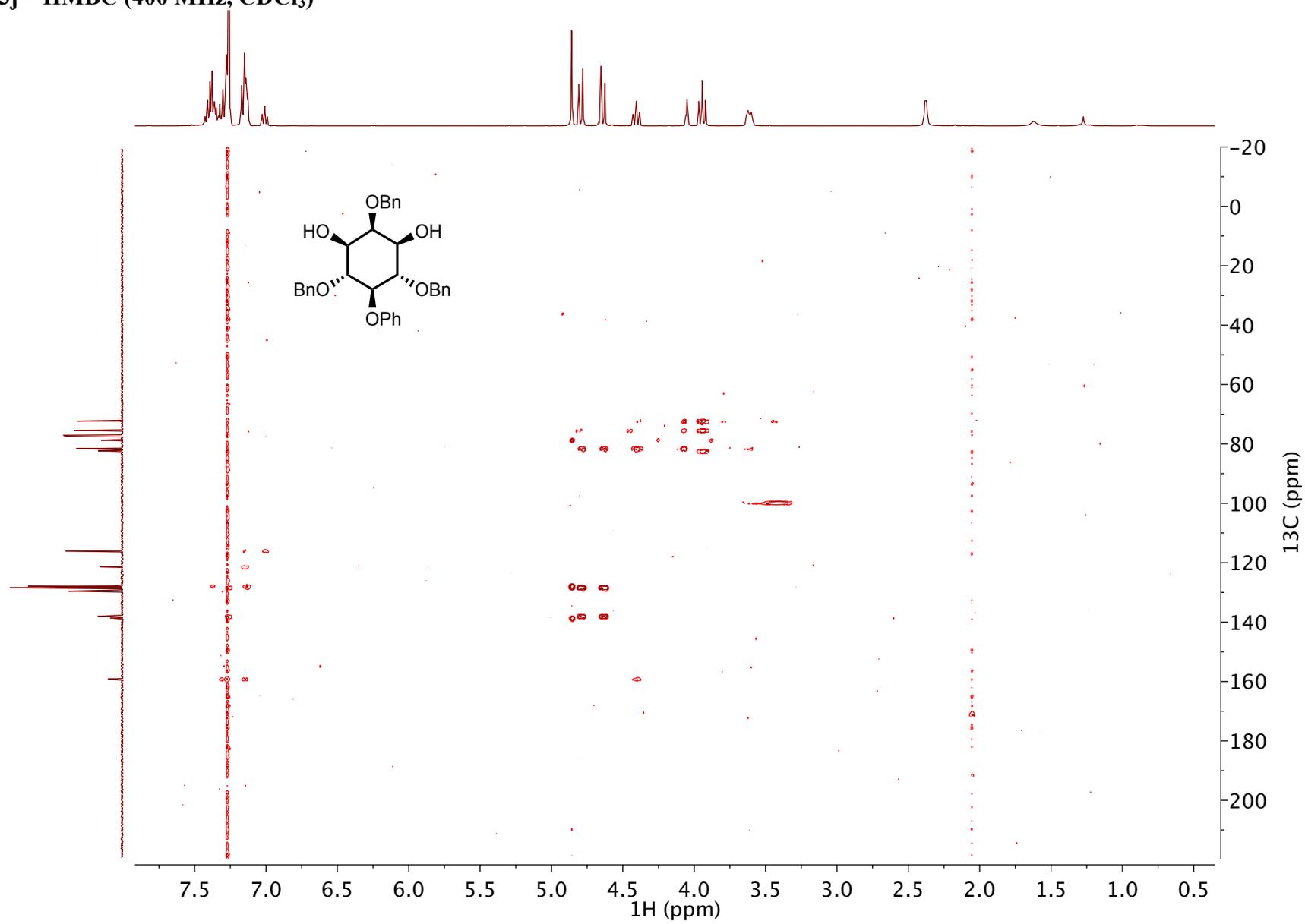
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138.1  
129.7  
128.6  
128.5  
128.0  
127.9  
121.5  
116.2

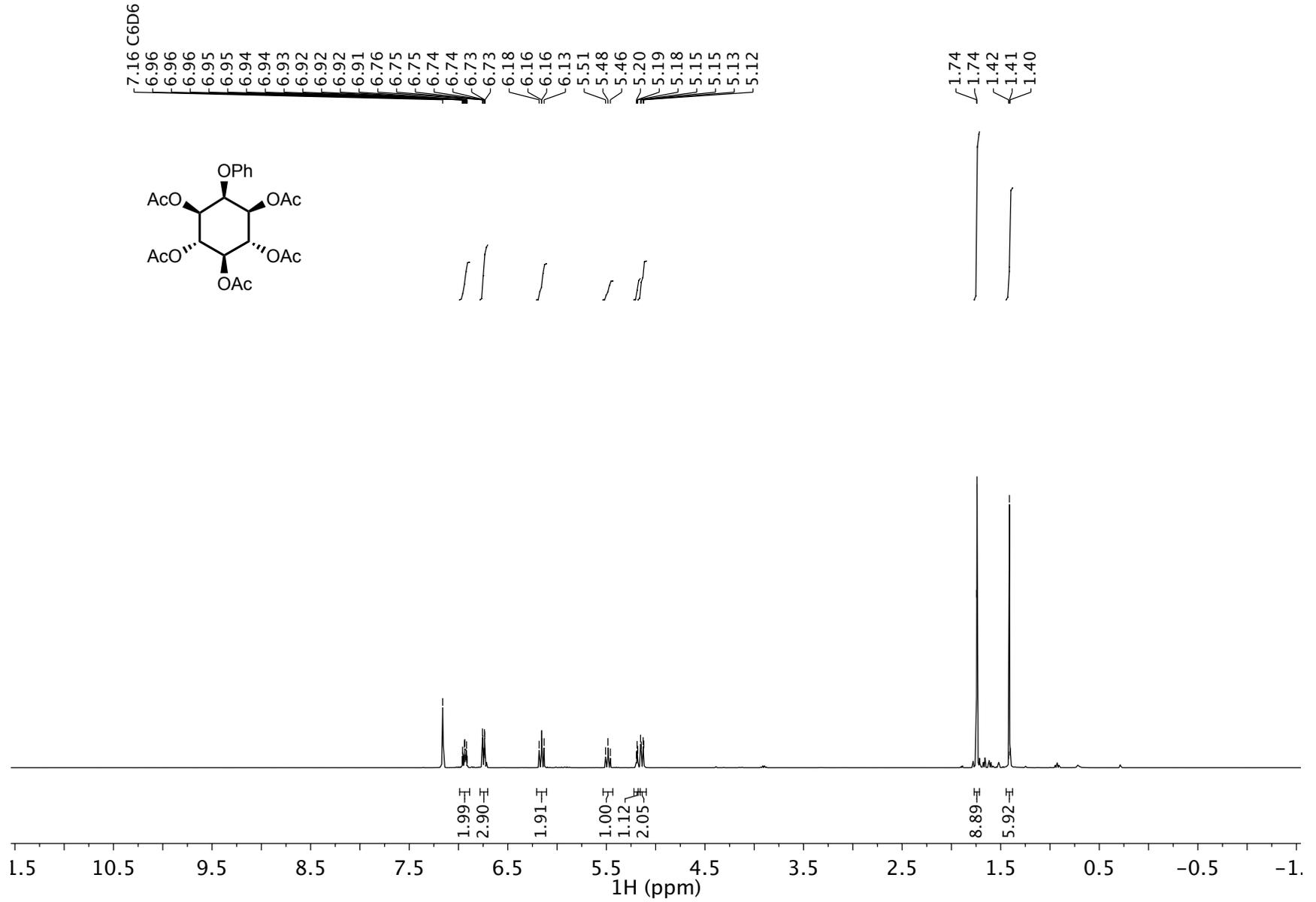
82.4  
81.7  
78.8  
77.5 CDC13  
77.2 CDC13  
76.8 CDC13  
75.6  
75.4  
72.4

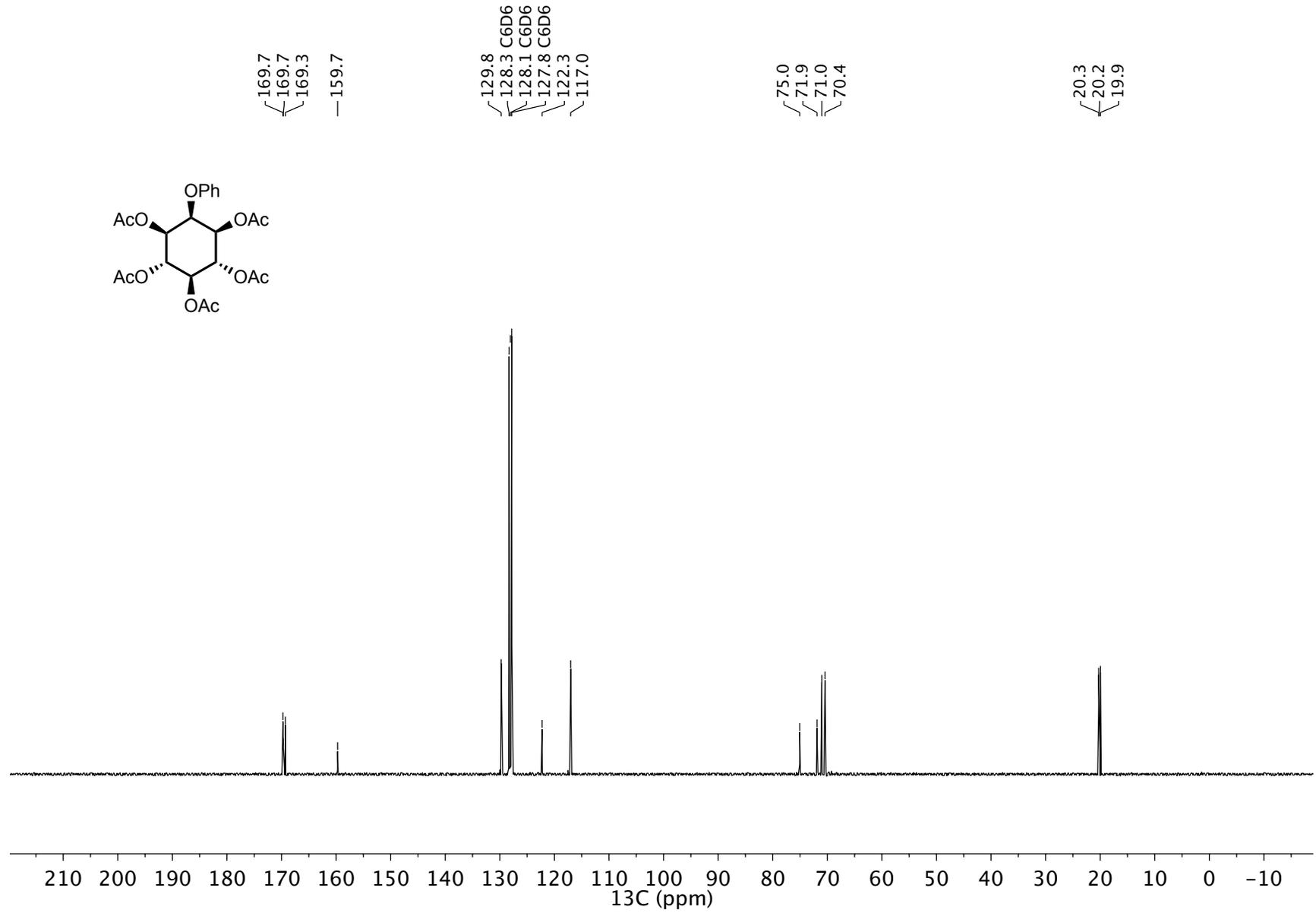


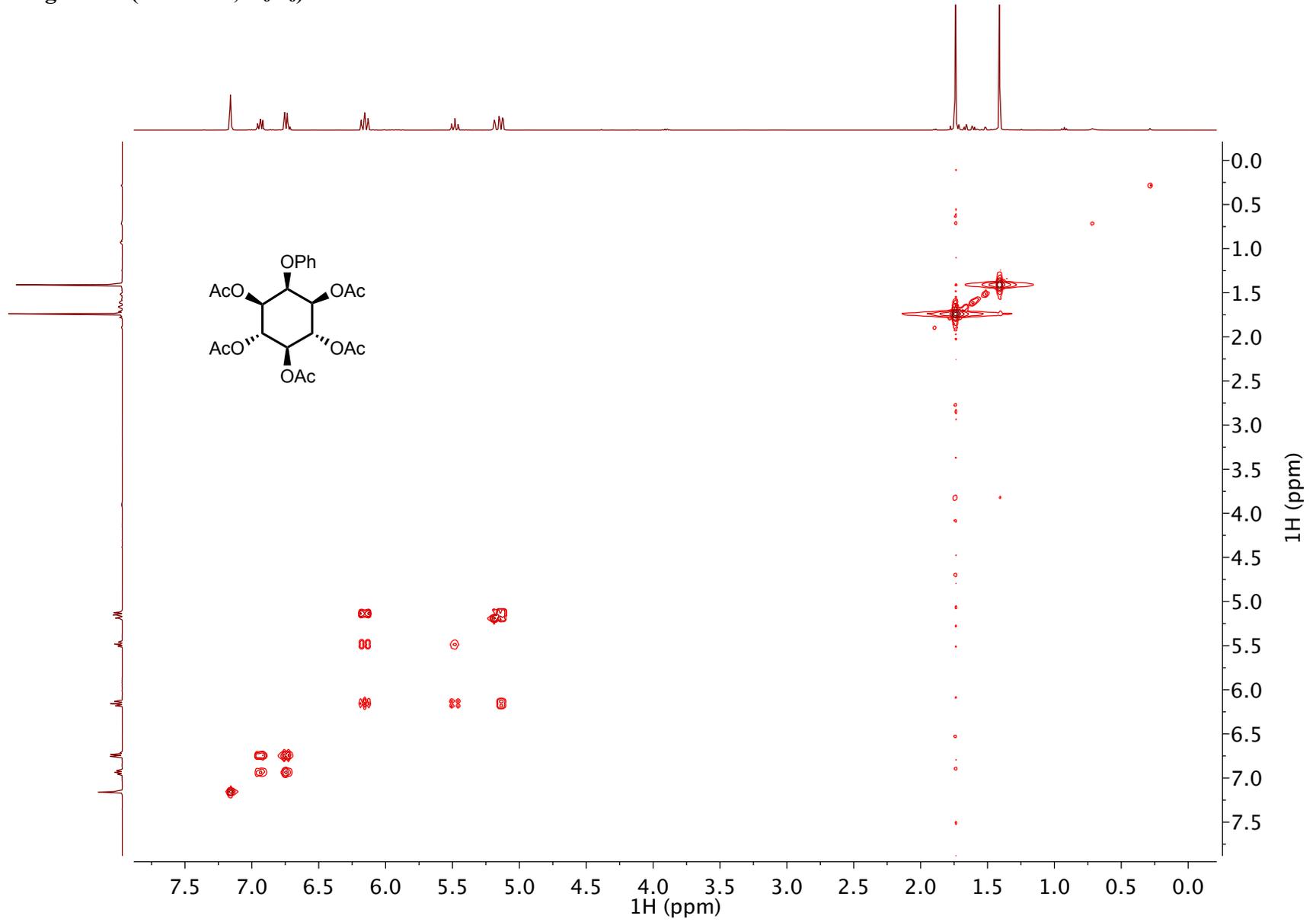
**3j –gCOSY (400 MHz, CDCl<sub>3</sub>)**

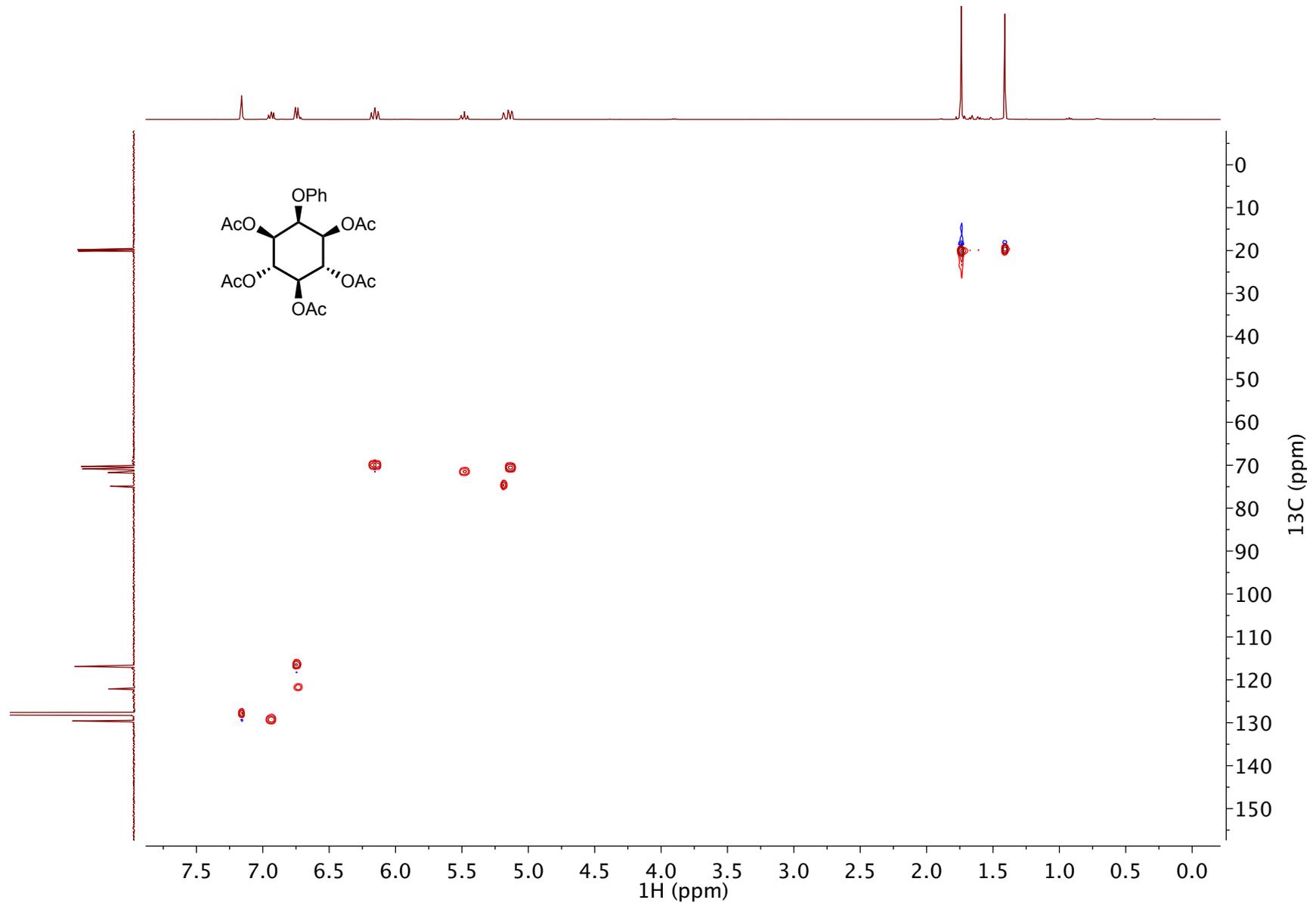
3j – HSQC (400 MHz, CDCl<sub>3</sub>)

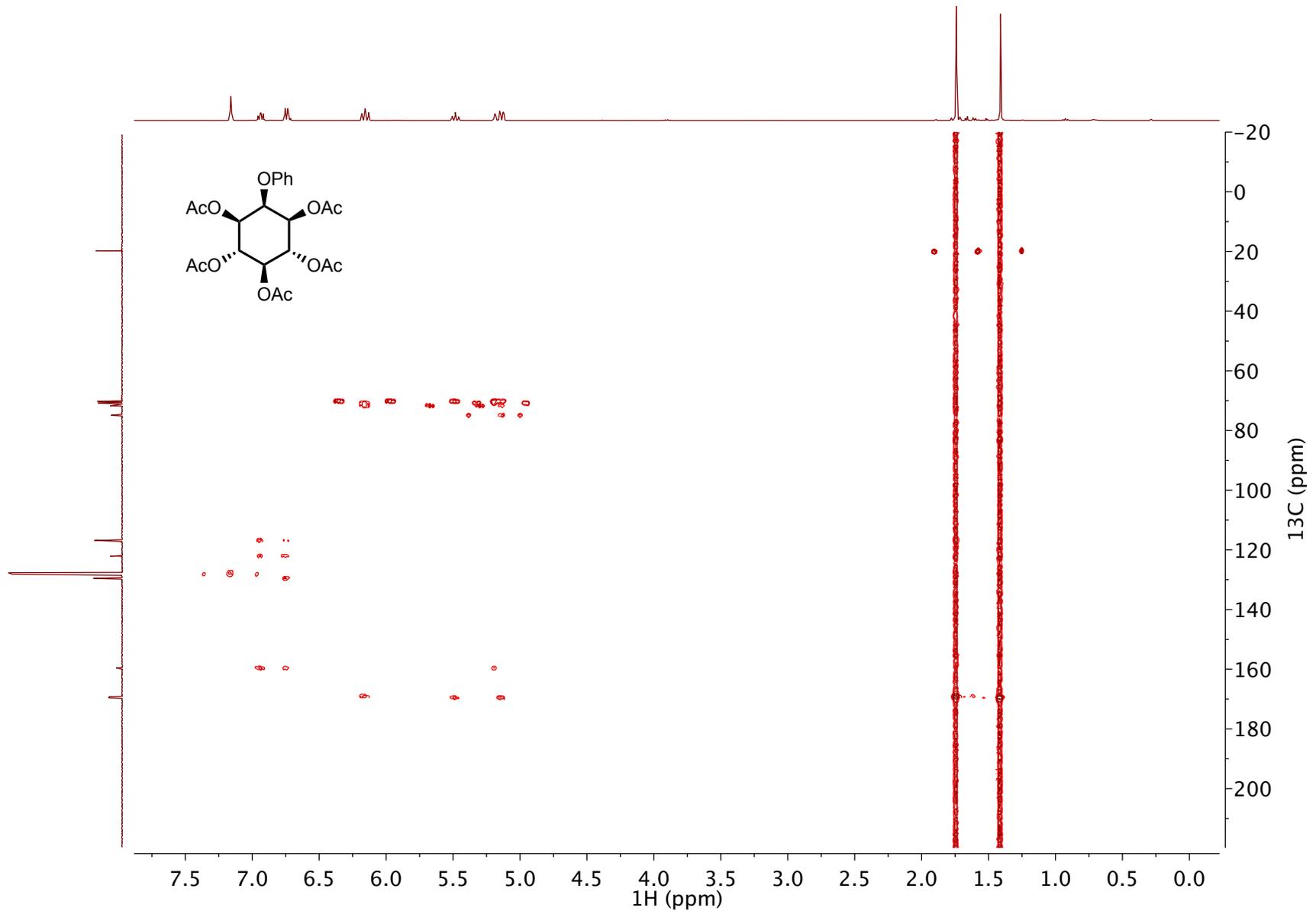
3j – HMBC (400 MHz, CDCl<sub>3</sub>)

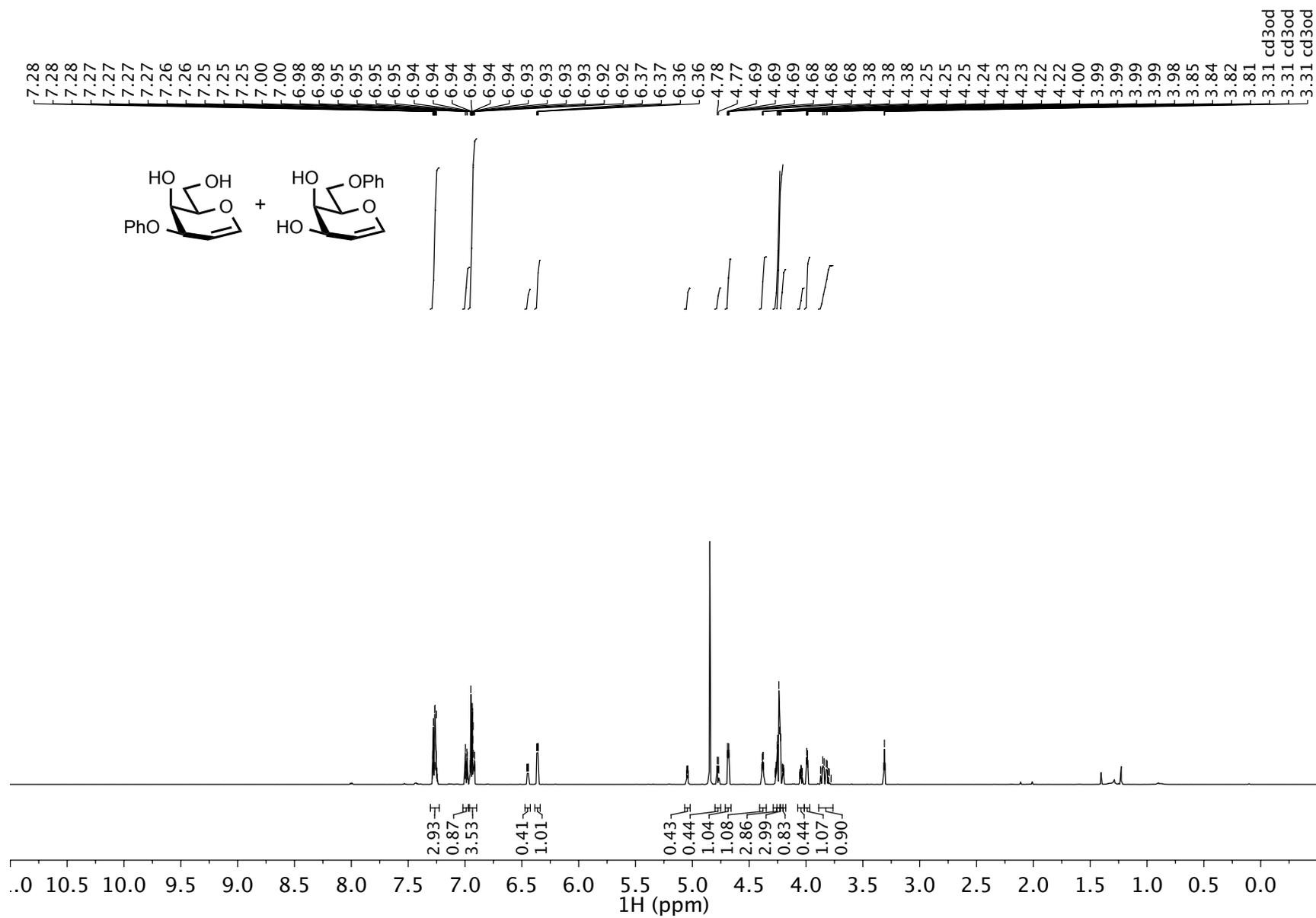
3k –  $^1\text{H}$  NMR (400 MHz,  $\text{C}_6\text{D}_6$ )

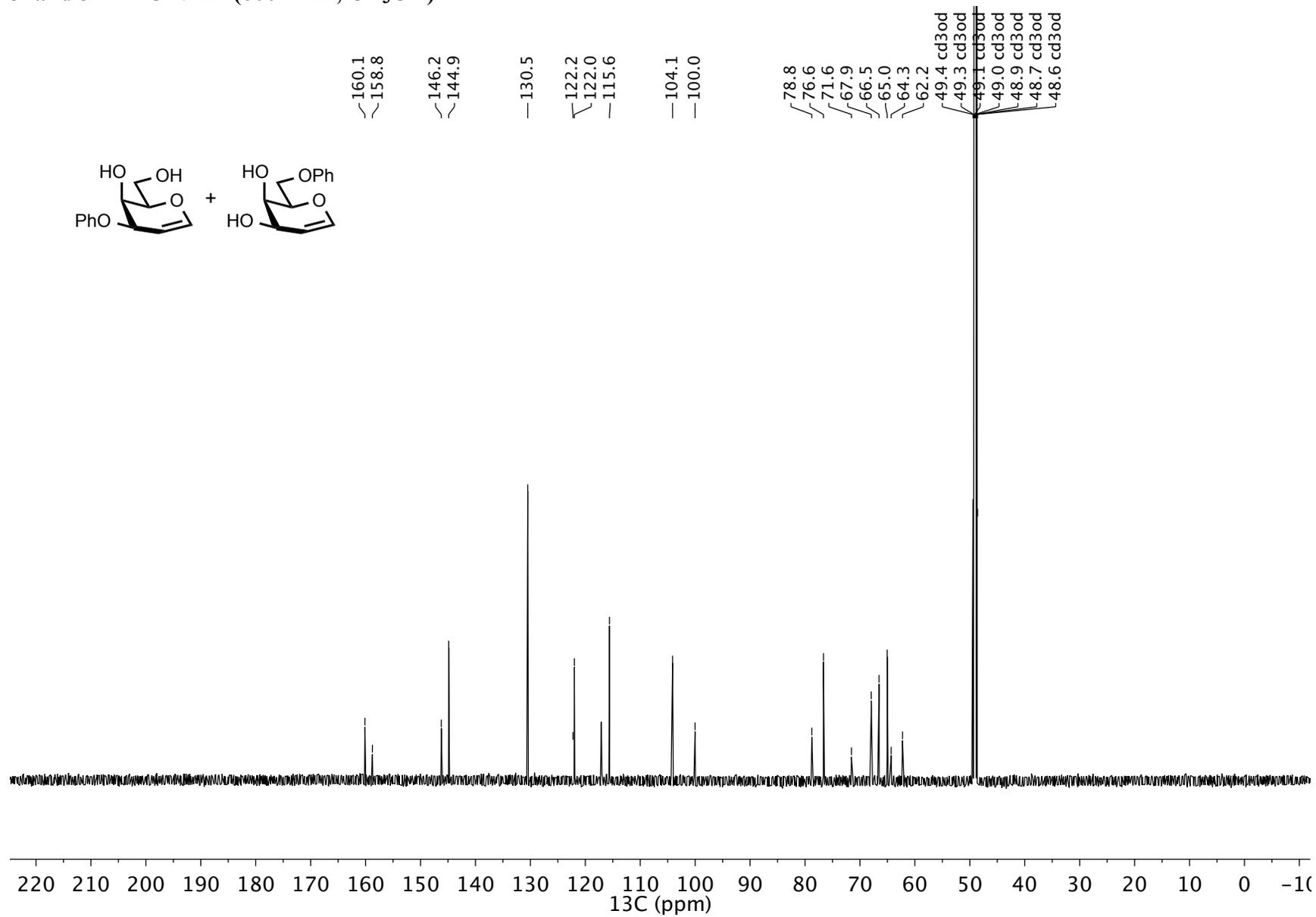
**3k** –  $^{13}\text{C}$  NMR (400 MHz,  $\text{C}_6\text{D}_6$ )

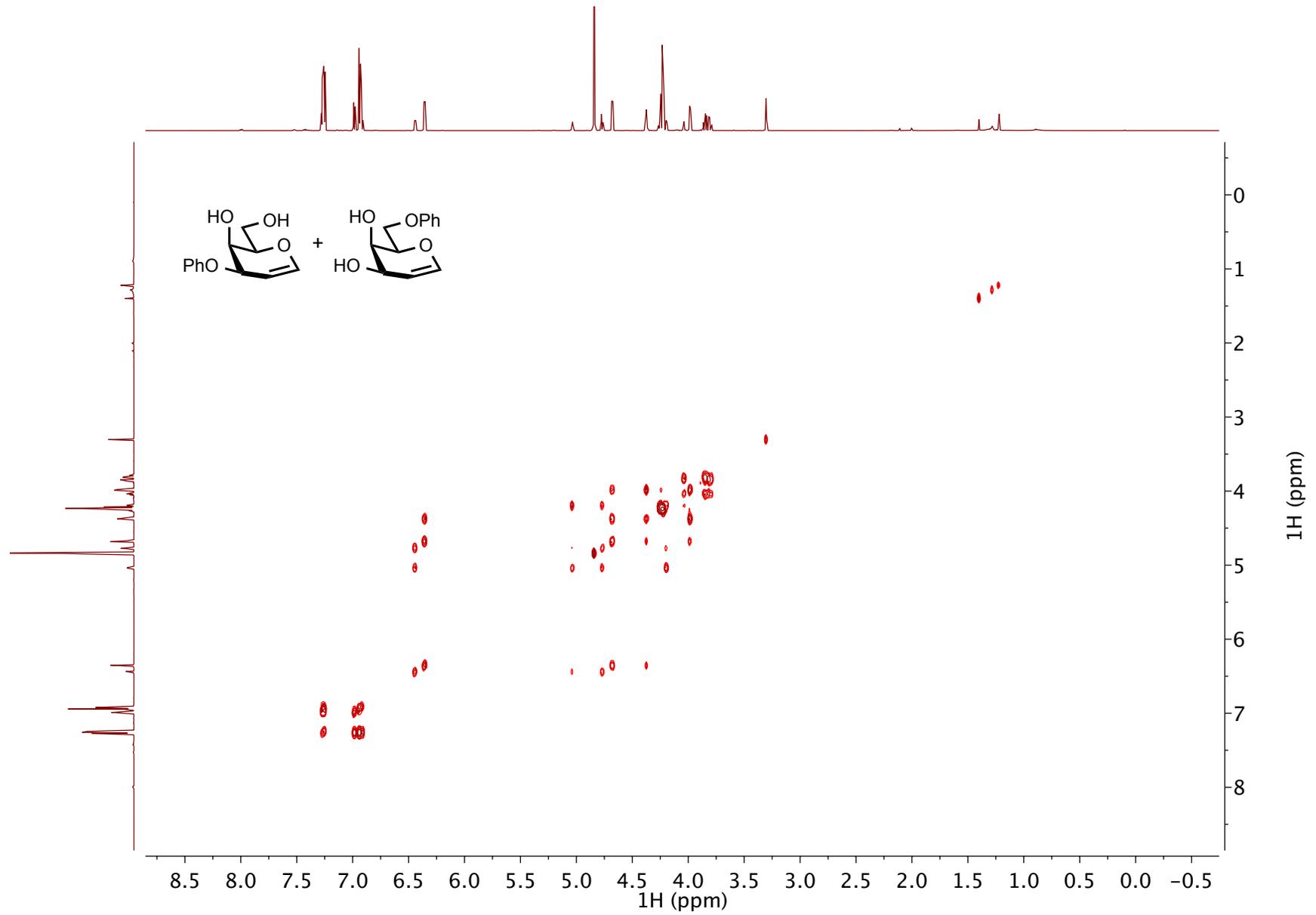
3k – gCOSY (400 MHz, C<sub>6</sub>D<sub>6</sub>)

3k - HSQC (400 MHz, C<sub>6</sub>D<sub>6</sub>)

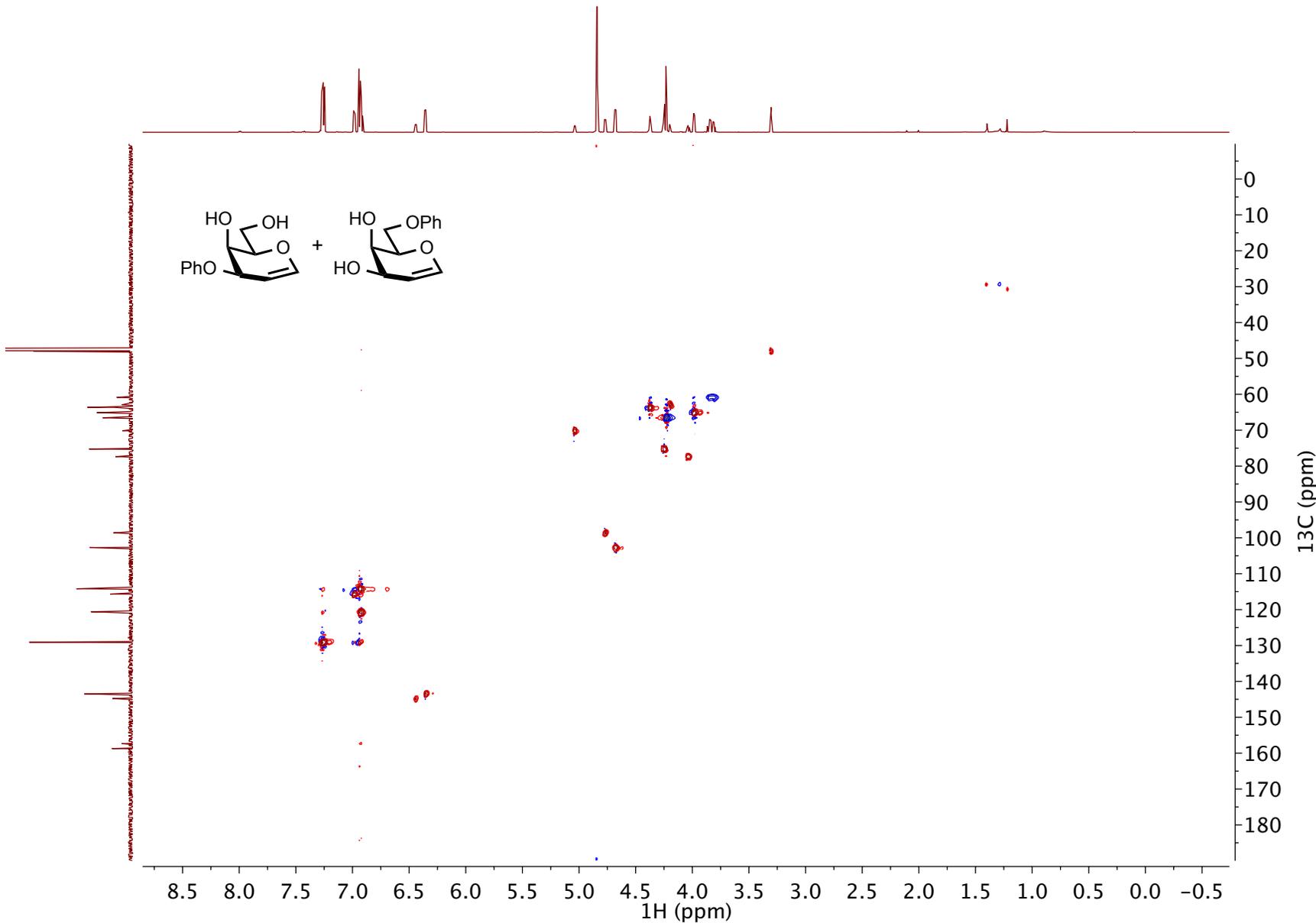
3k – HMBC (400 MHz, C<sub>6</sub>D<sub>6</sub>)

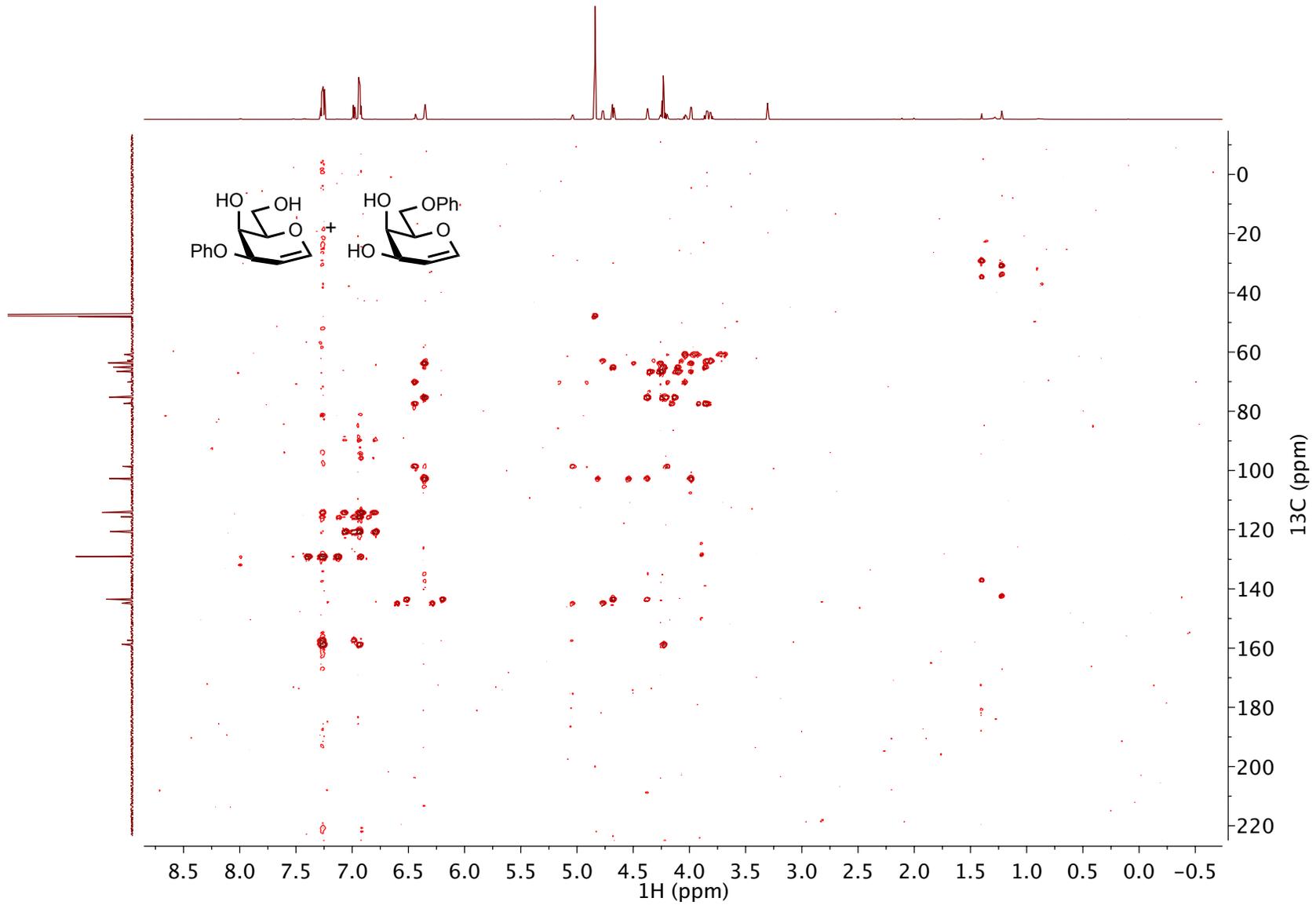
3l and 3l' –  $^1\text{H}$  NMR (600 MHz,  $\text{CD}_3\text{OD}$ )

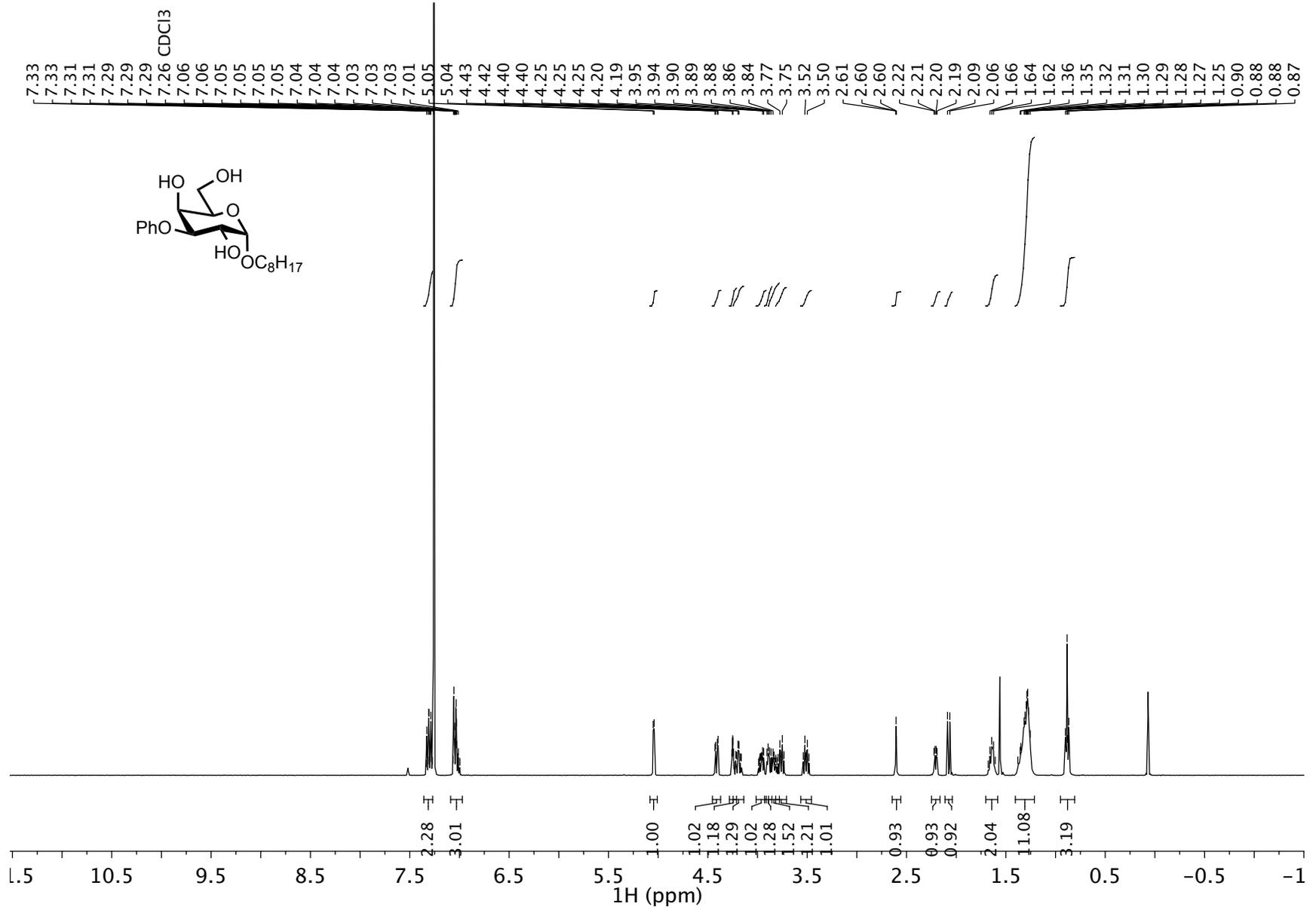
**3l and 3l' –  $^{13}\text{C}$  NMR (600 MHz,  $\text{CD}_3\text{OD}$ )**

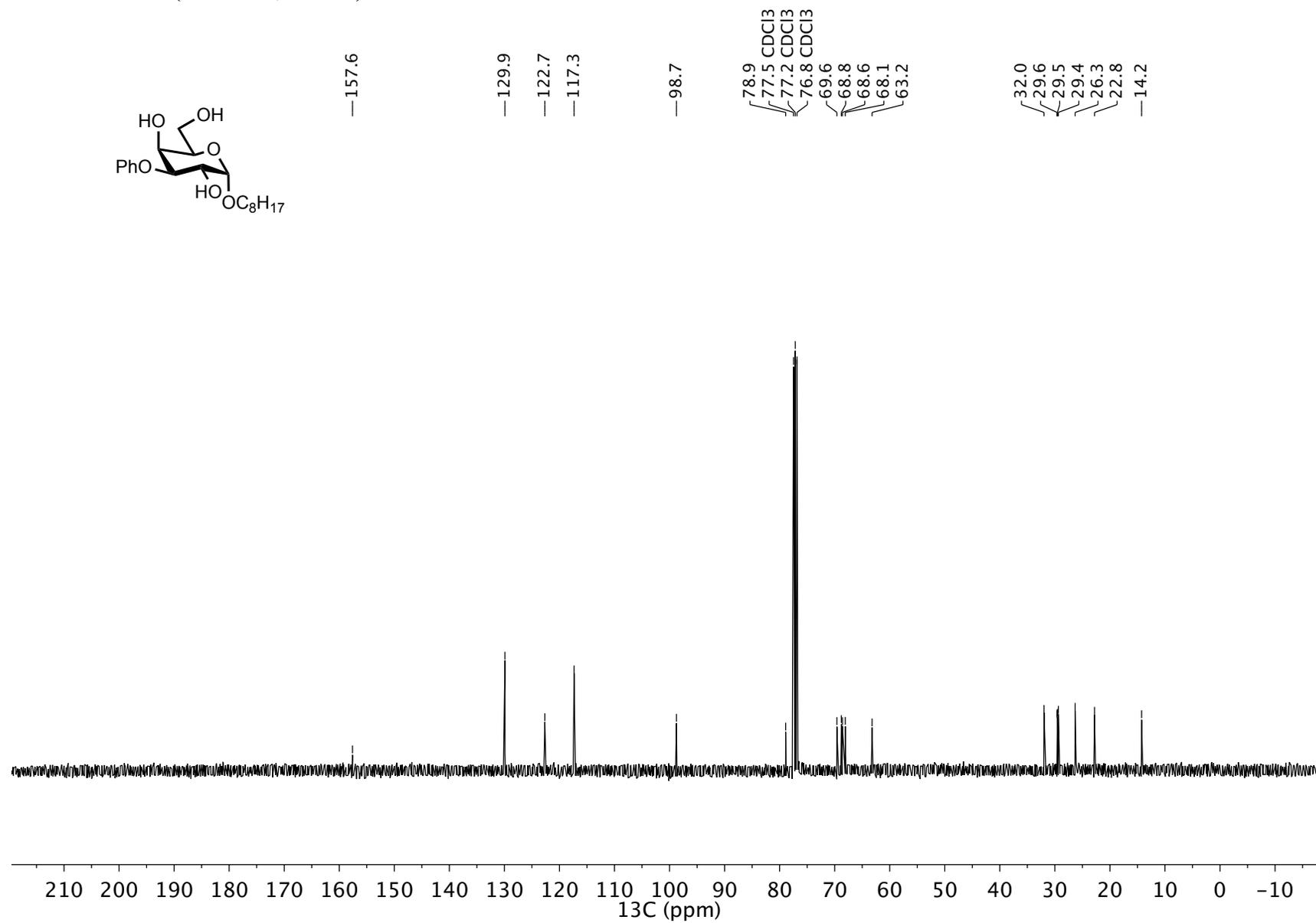
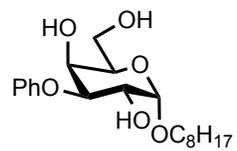
**3l and 3l' – gCOSY (600 MHz, CD<sub>3</sub>OD)**

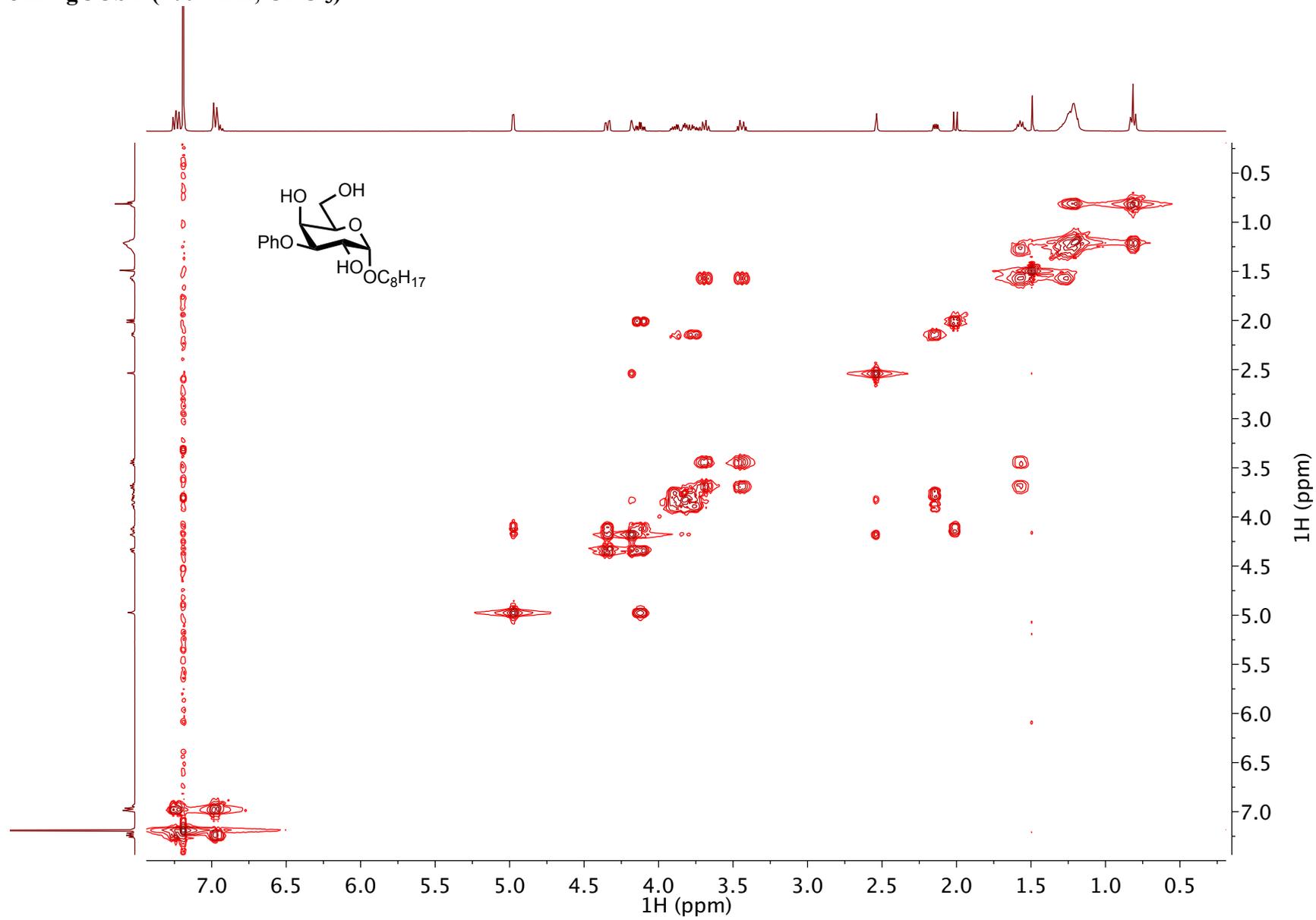
3l and 3l' – HSQC (600 MHz, CD<sub>3</sub>OD)



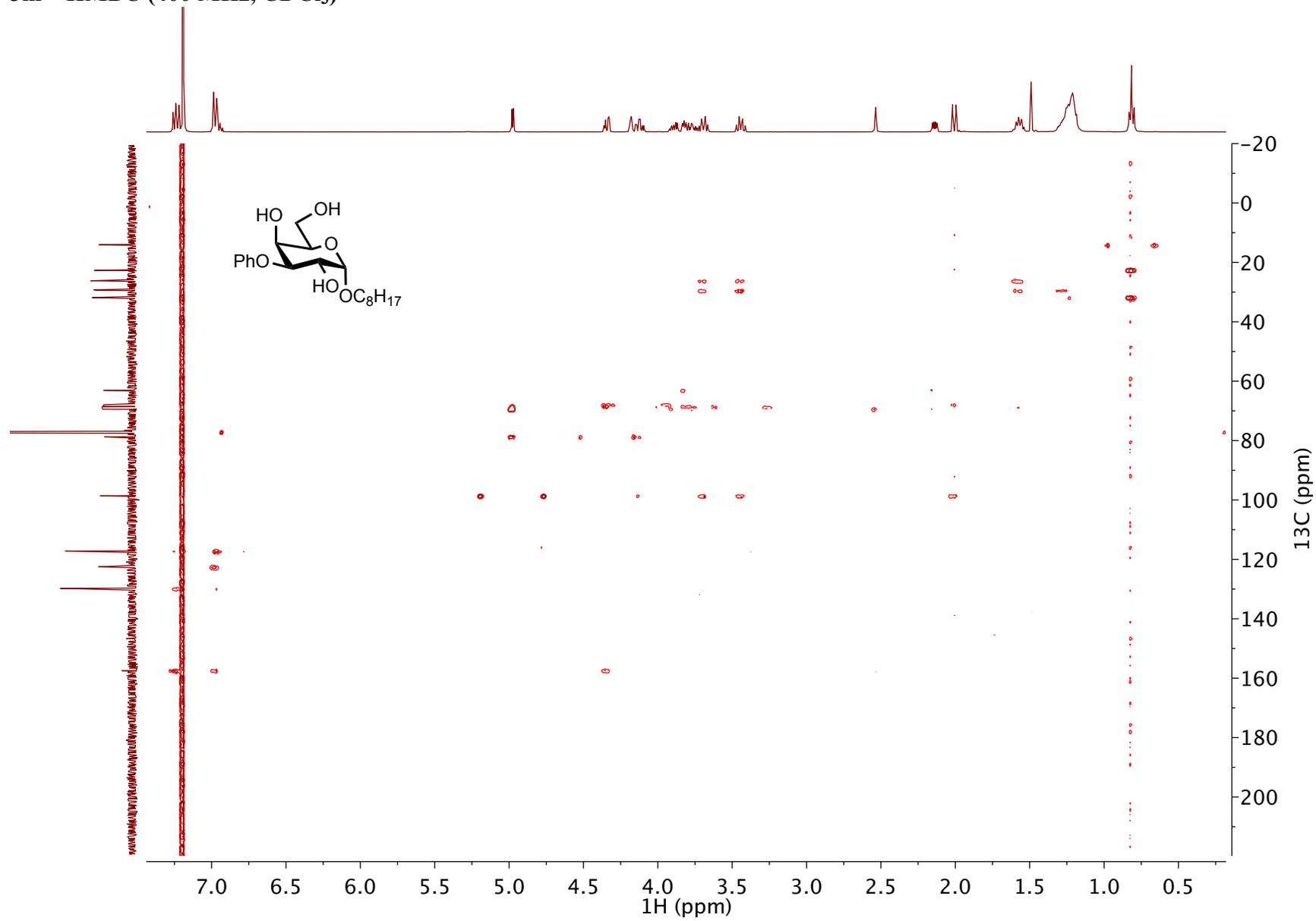
3l and 3l' – HMBC (600 MHz, CD<sub>3</sub>OD)

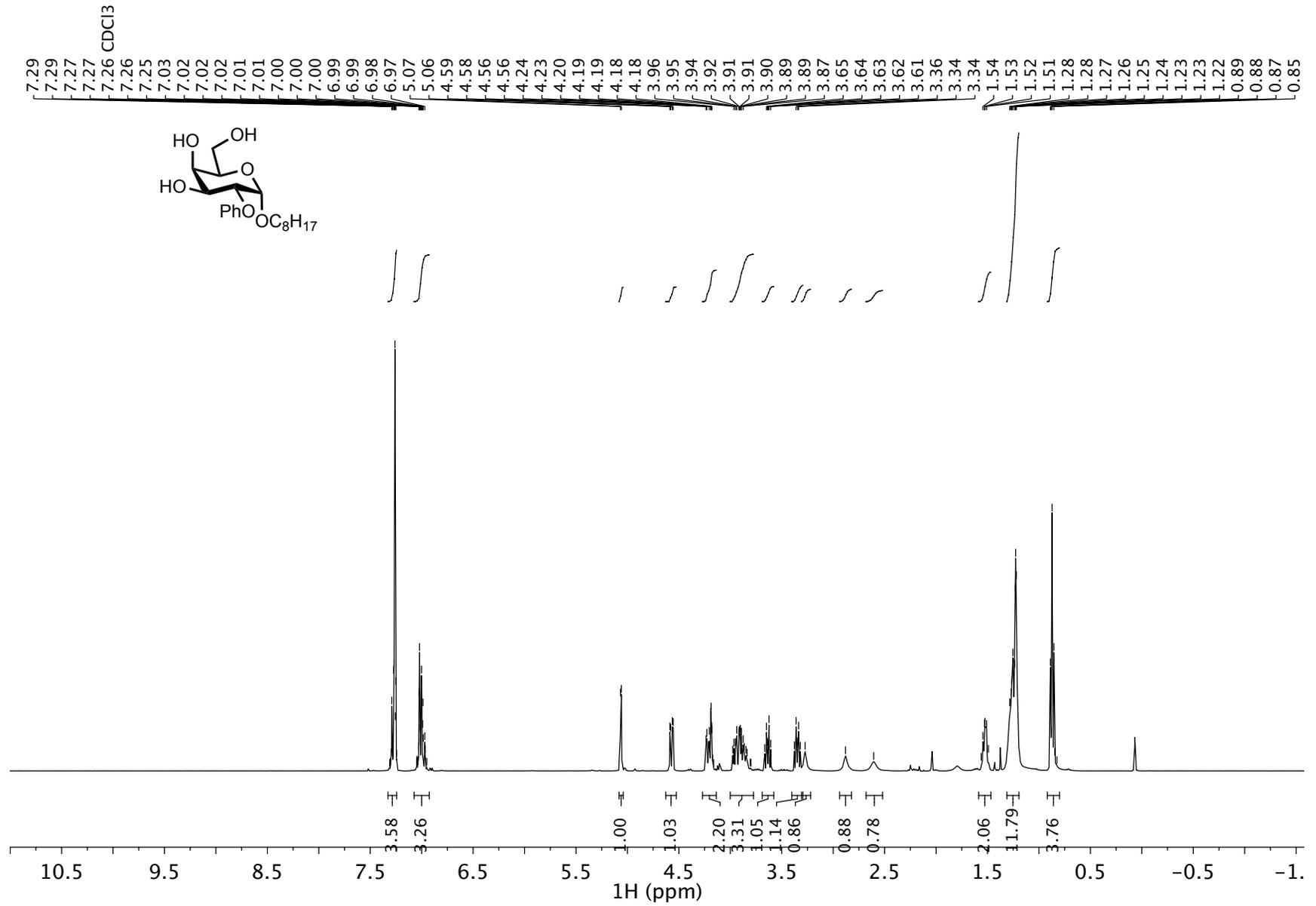
**3m –  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )**

**3m –  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )**

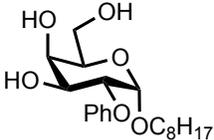
3m – gCOSY (400 MHz, CDCl<sub>3</sub>)



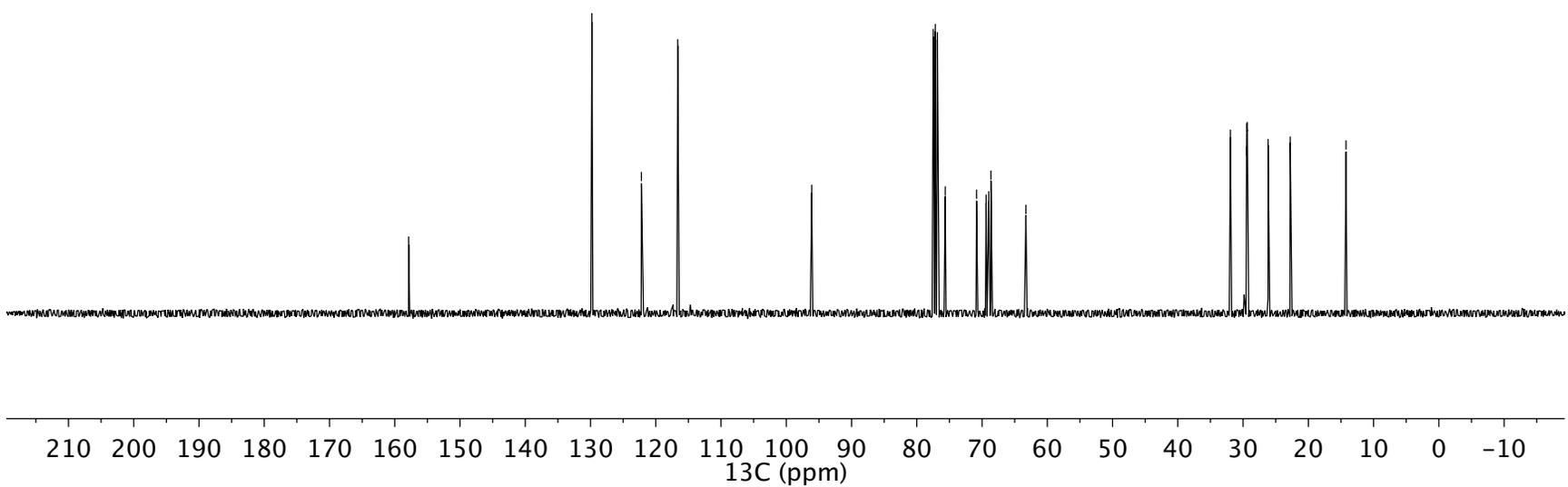
3m – HMBC (400 MHz, CDCl<sub>3</sub>)

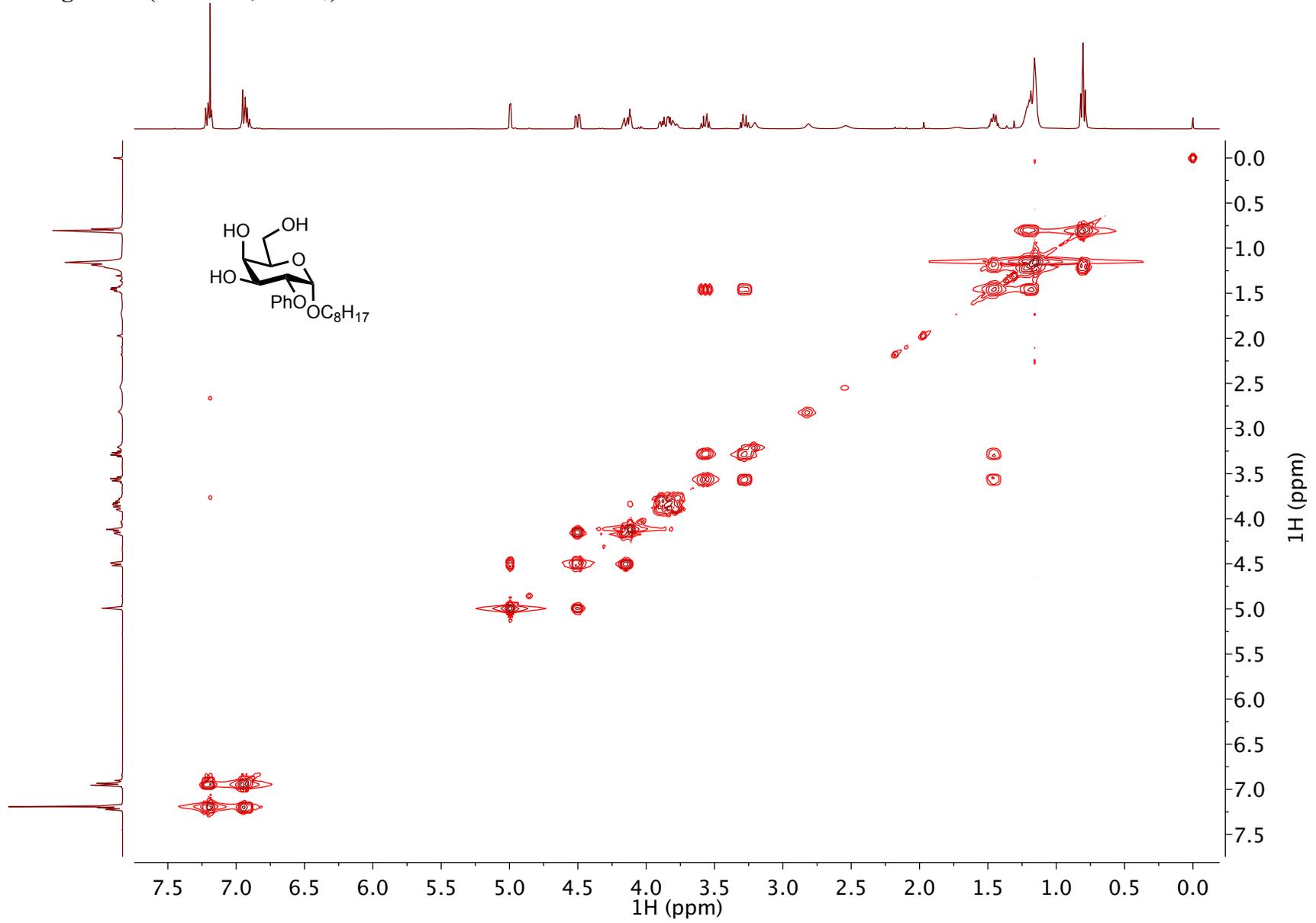
**3m' –  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )**

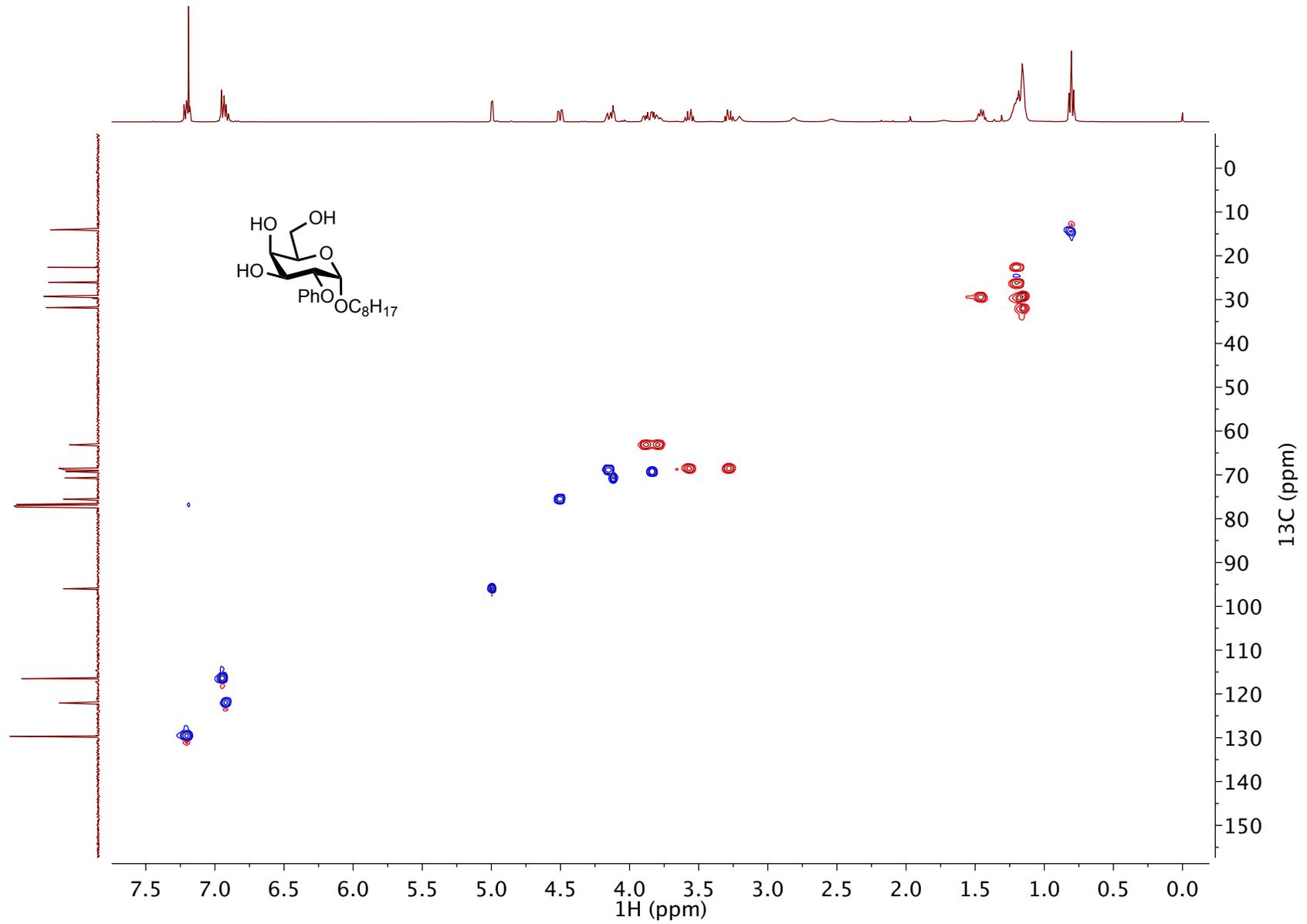
3m' - <sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)

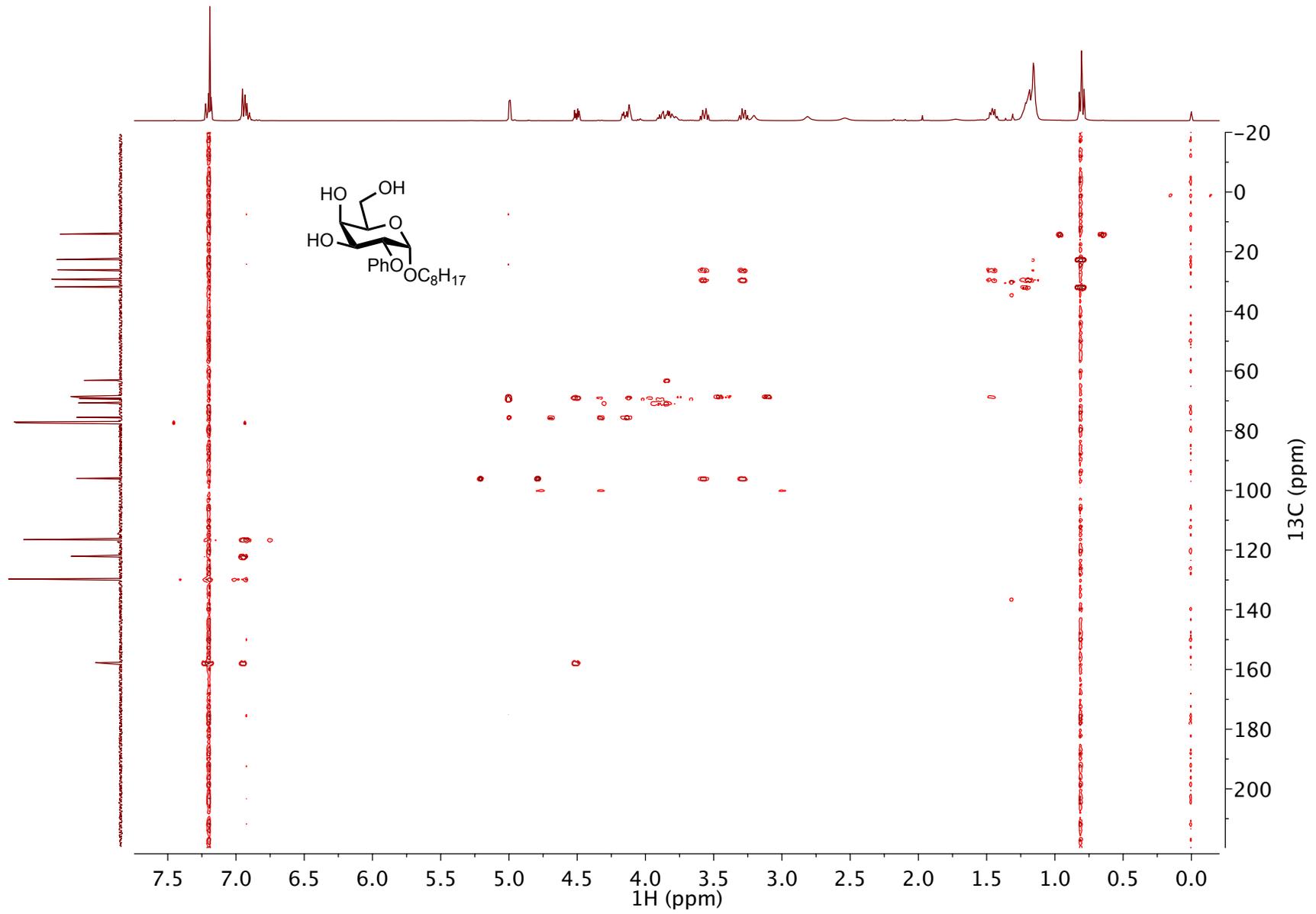


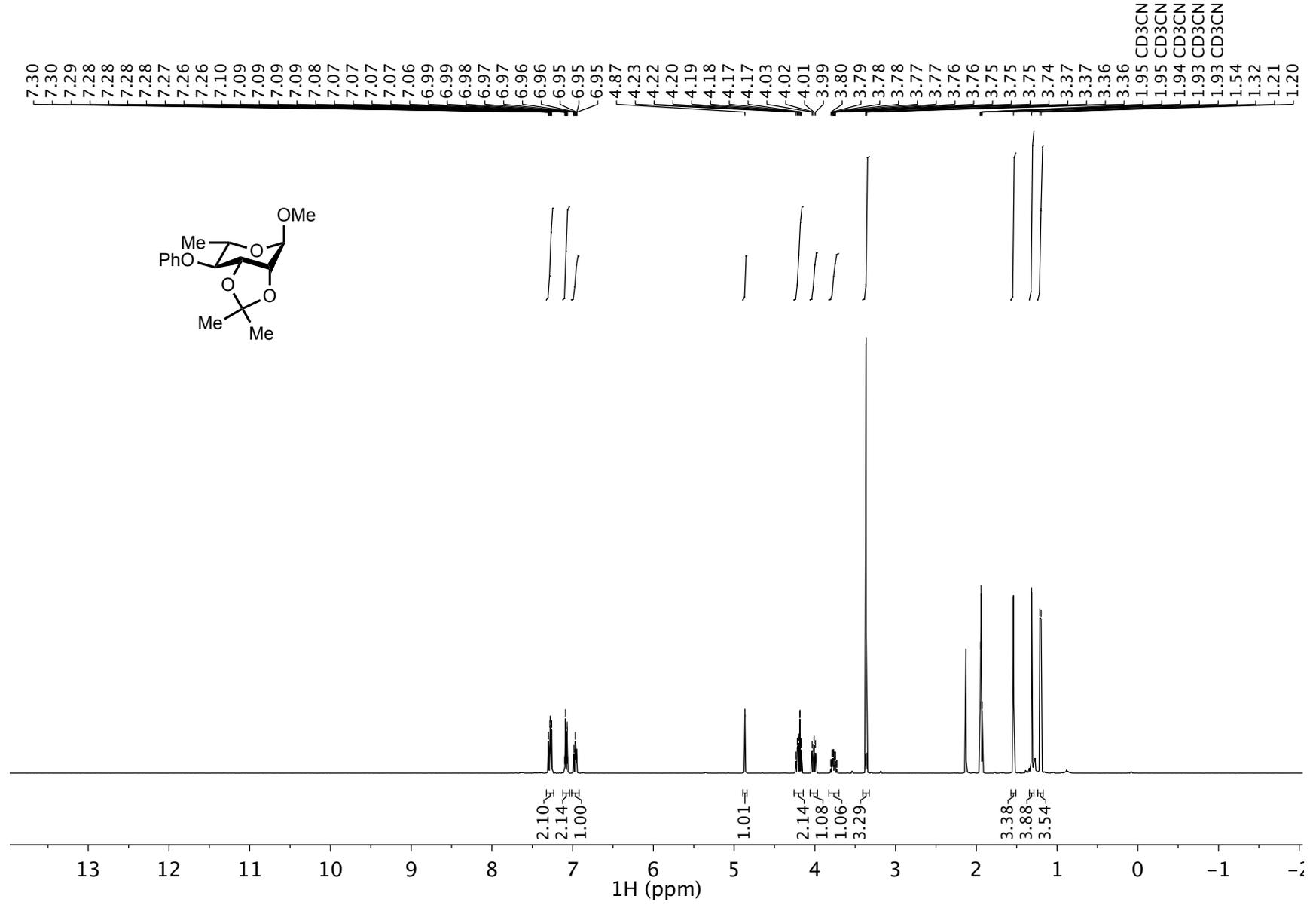
- 157.9
- 129.8
- 122.2
- 116.6
- 96.1
- 77.5 CDCl<sub>3</sub>
- 77.2 CDCl<sub>3</sub>
- 76.8 CDCl<sub>3</sub>
- 75.6
- 70.8
- 69.4
- 69.0
- 68.6
- 63.3
- 31.9
- 29.5
- 29.4
- 29.3
- 26.2
- 22.8
- 14.2

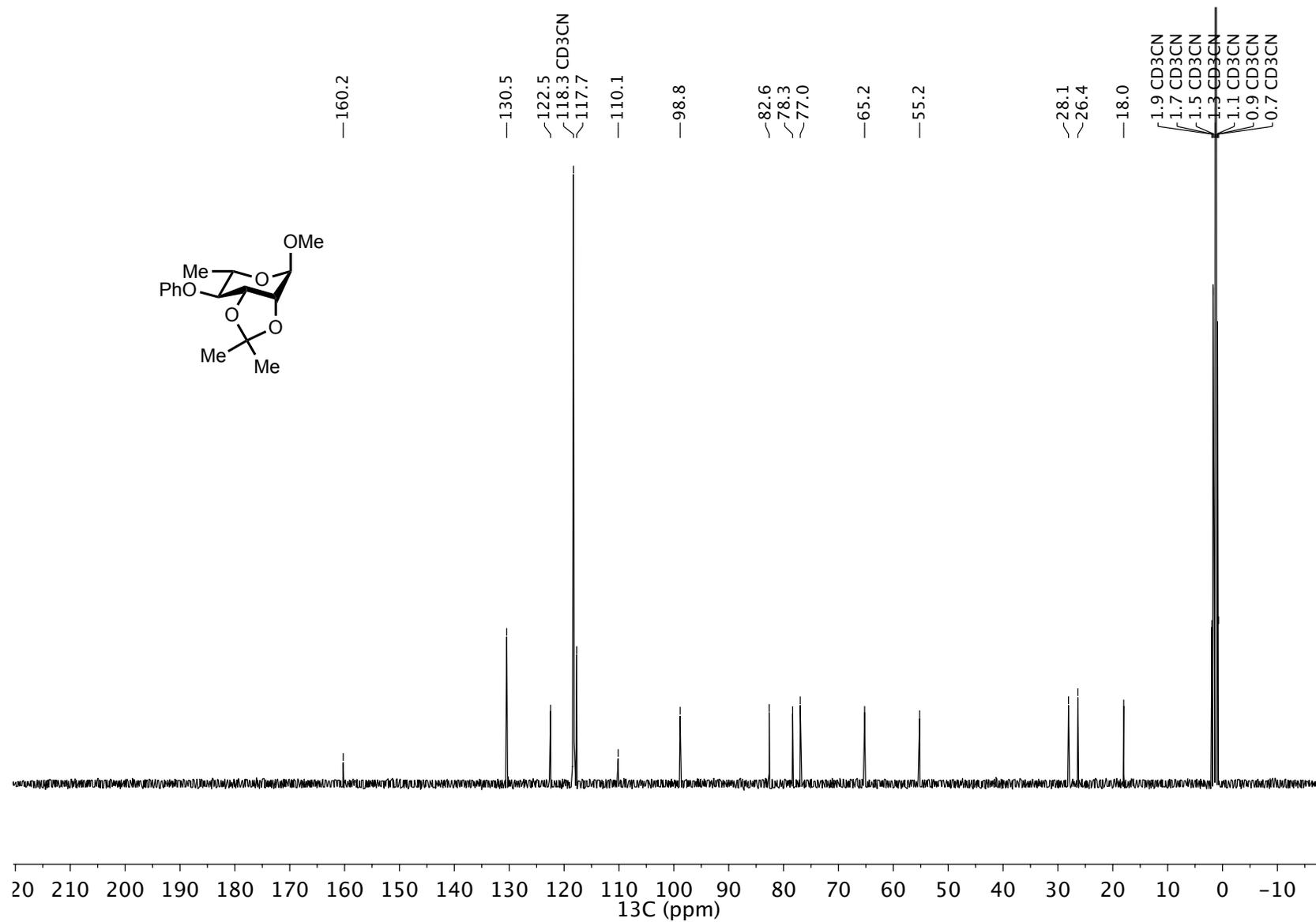


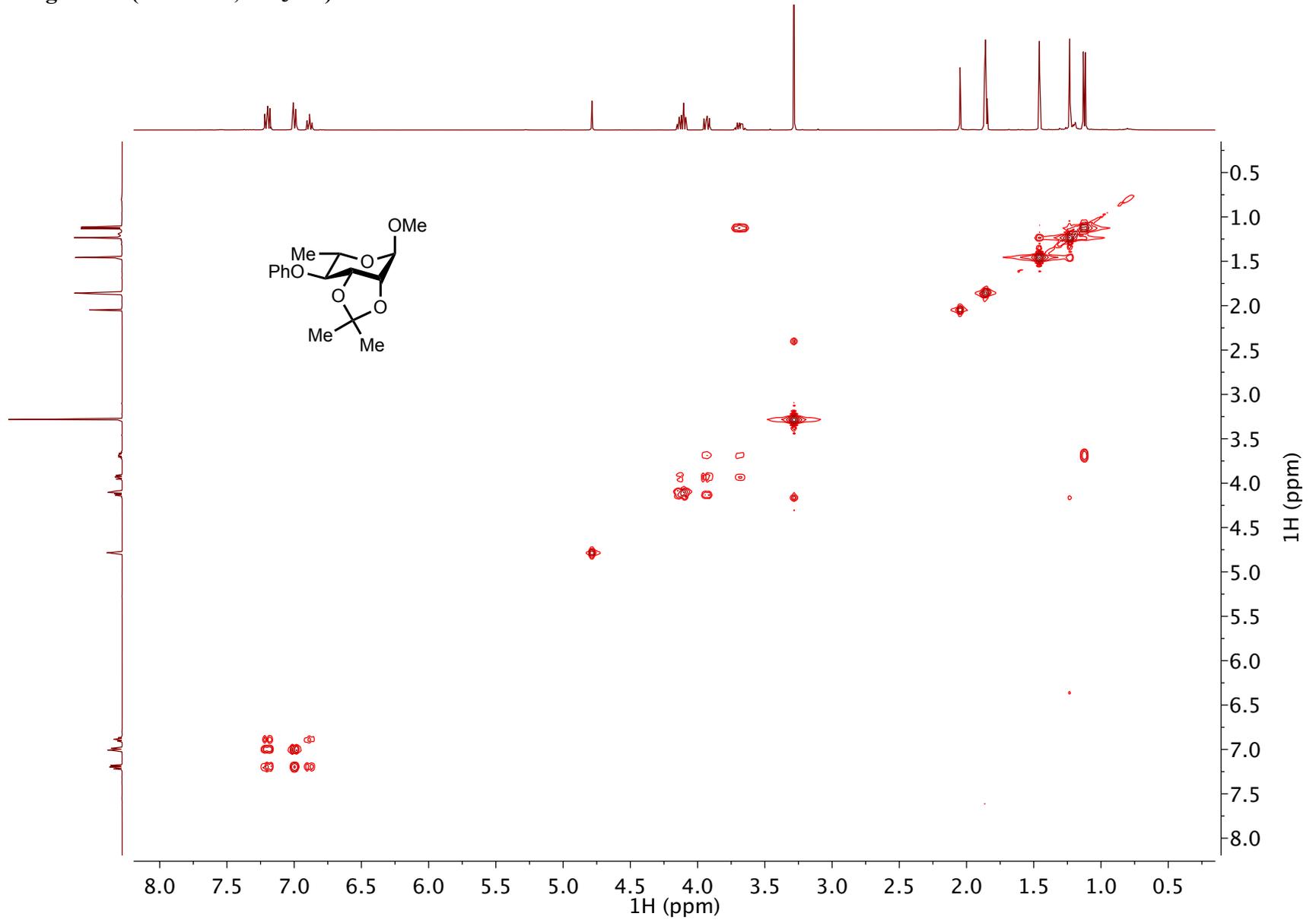
**3m' – gCOSY (400 MHz, CDCl<sub>3</sub>)**

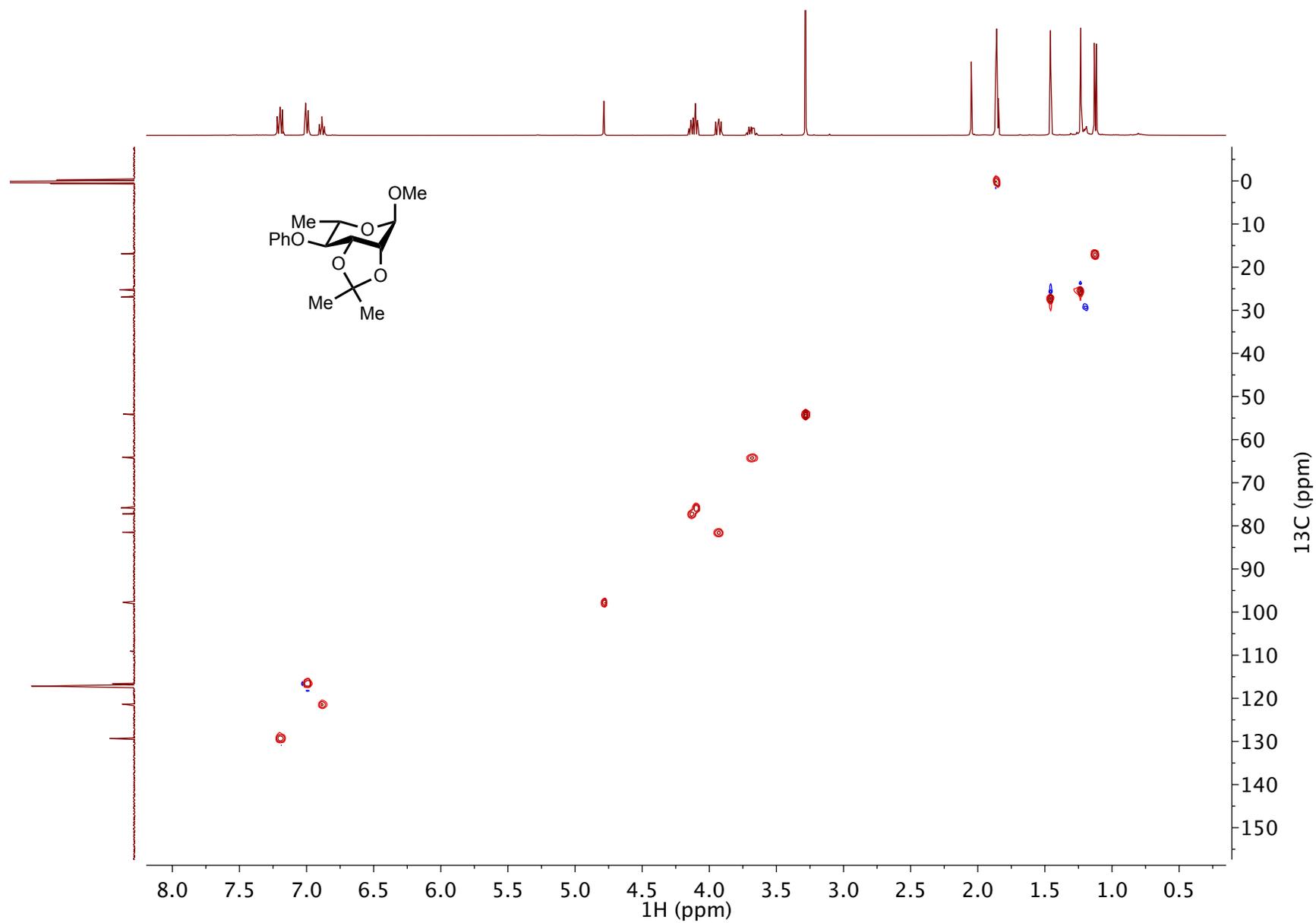
3m' – HSQC (400 MHz, CDCl<sub>3</sub>)

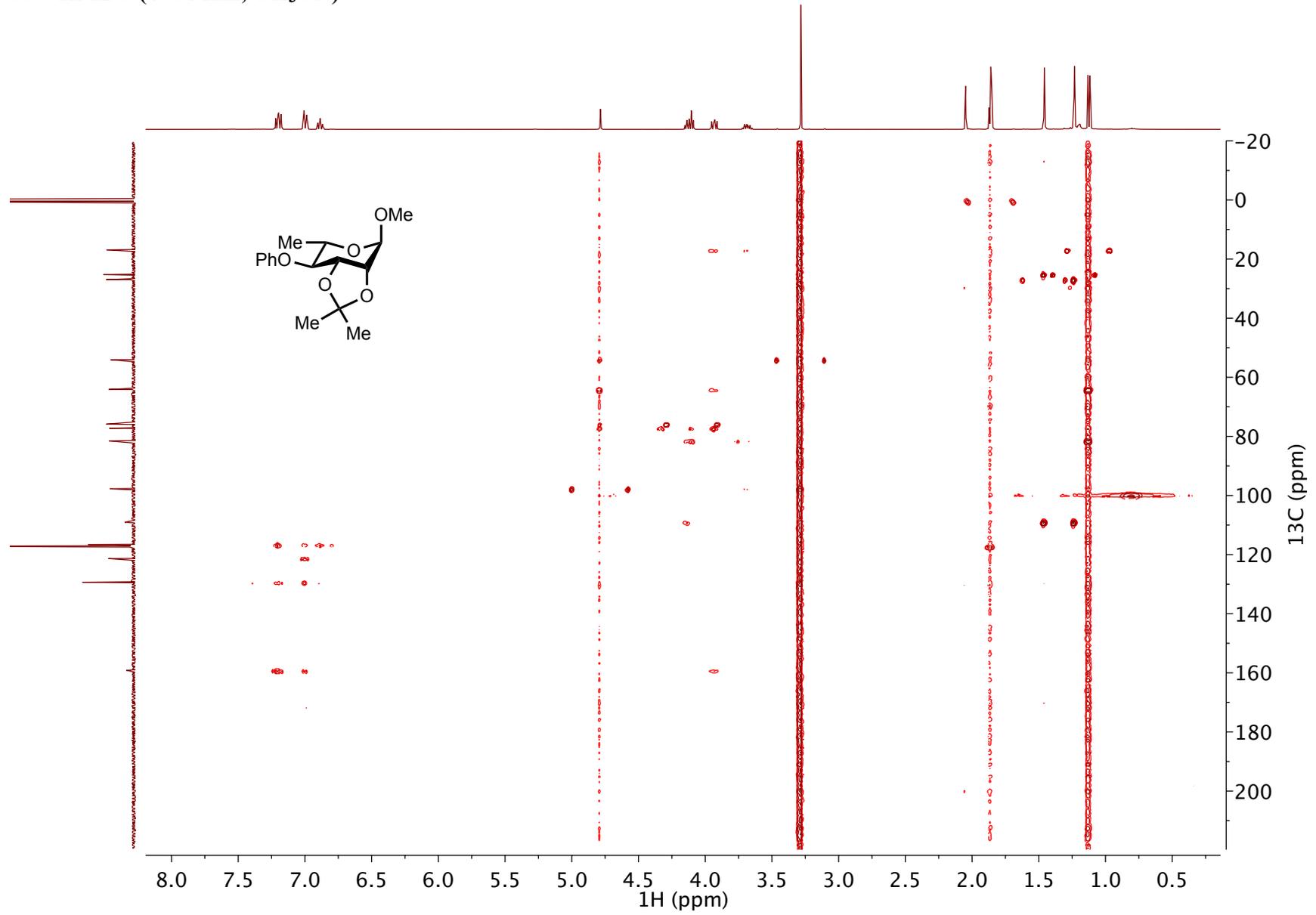
**3m' – HMBC (400 MHz, CDCl<sub>3</sub>)**

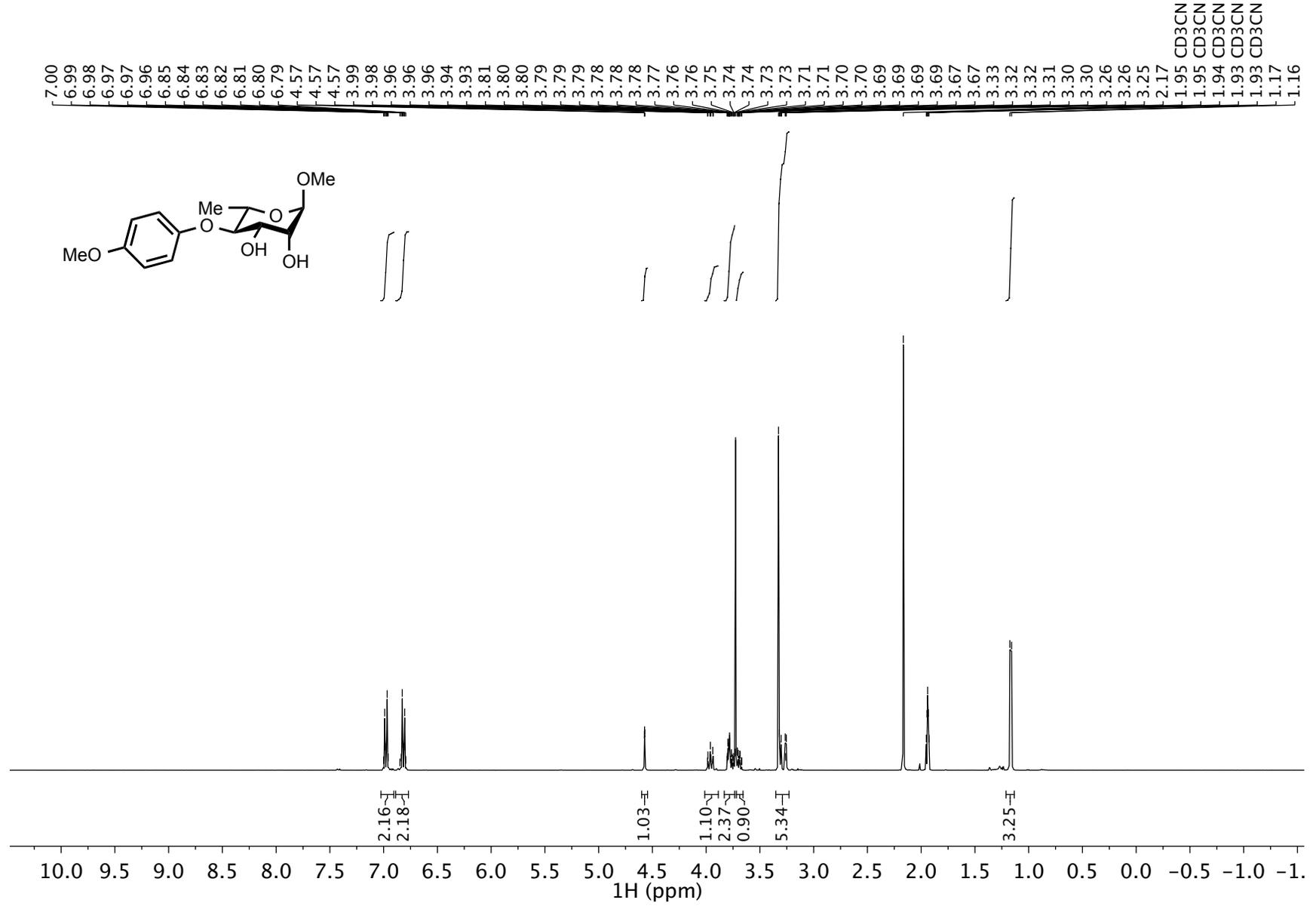
5a –  $^1\text{H}$  NMR (400 MHz,  $\text{CH}_3\text{CN}$ )

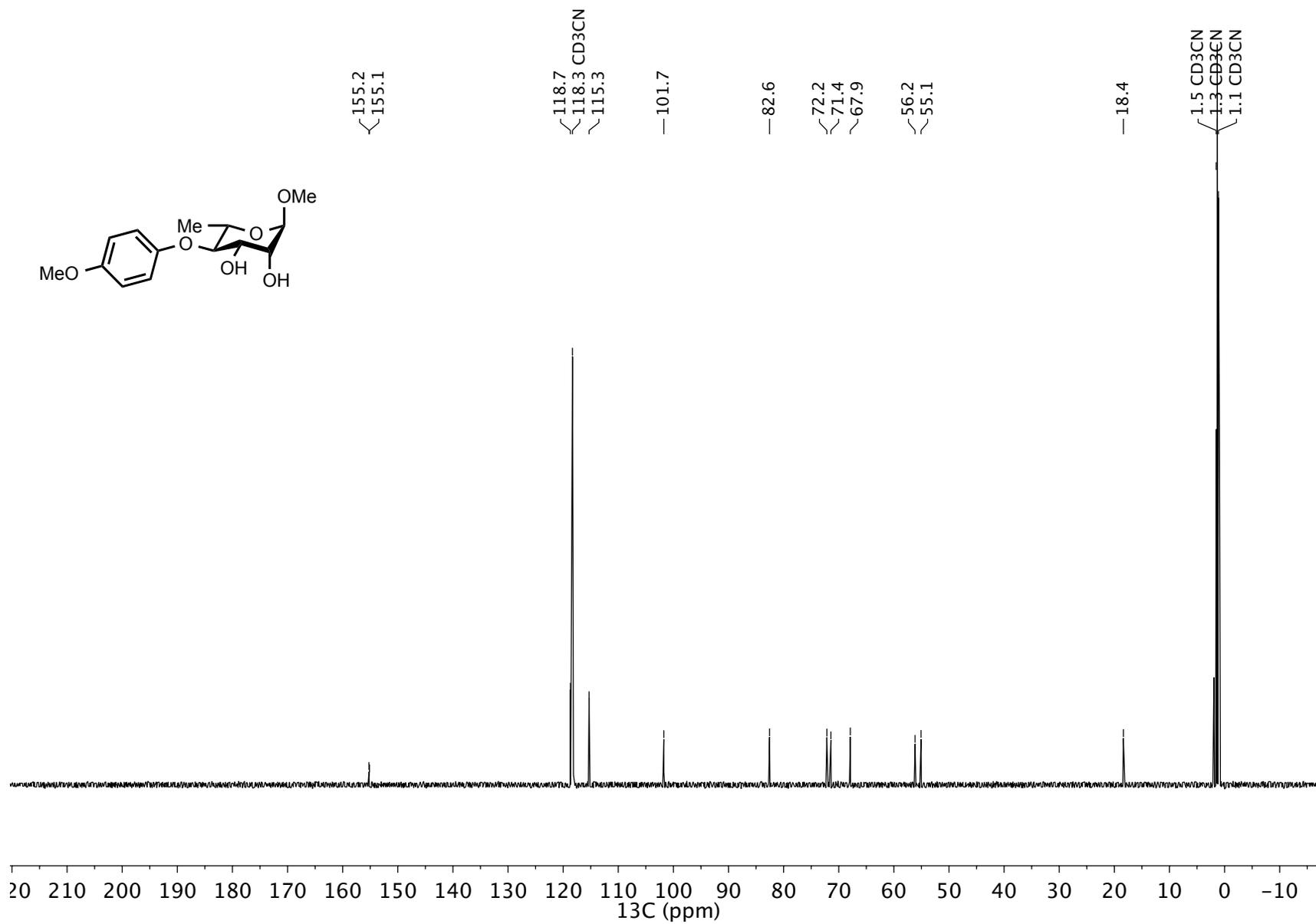
**5a** –  $^{13}\text{C}$  NMR (101 MHz,  $\text{CH}_3\text{CN}$ )

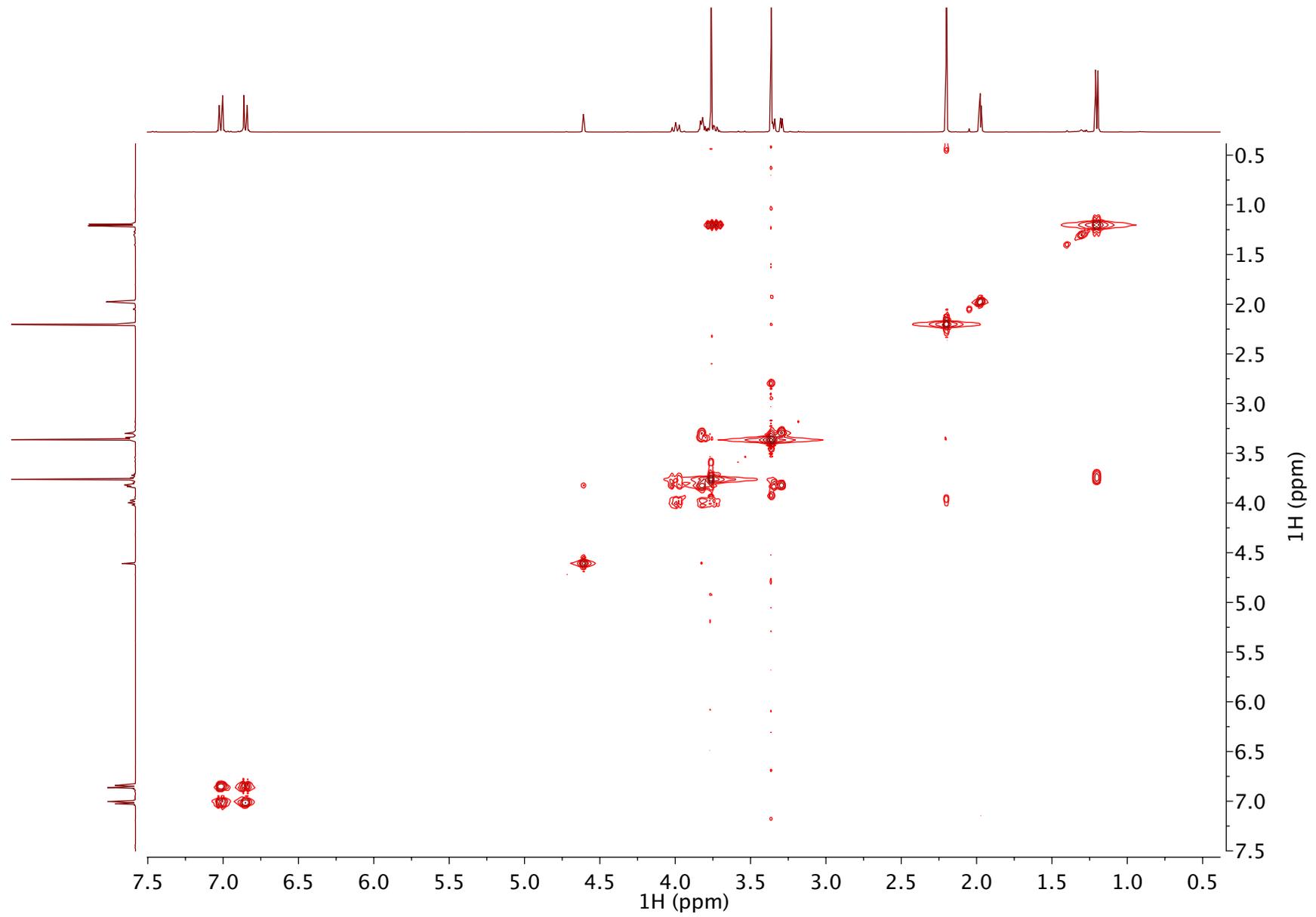
**5a – gCOSY (400 MHz, CH<sub>3</sub>CN)**

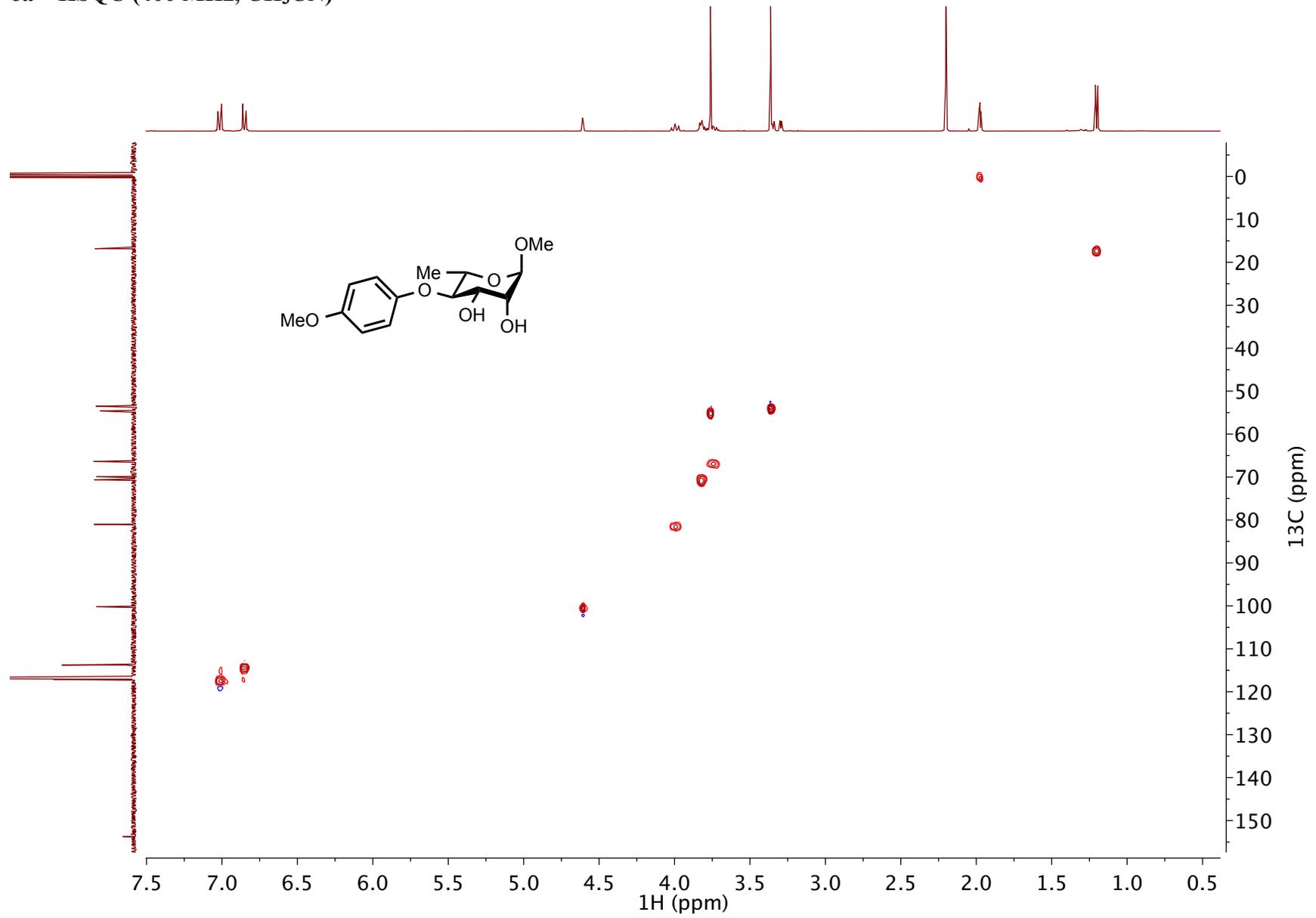
5a – HSQC (400 MHz, CH<sub>3</sub>CN)

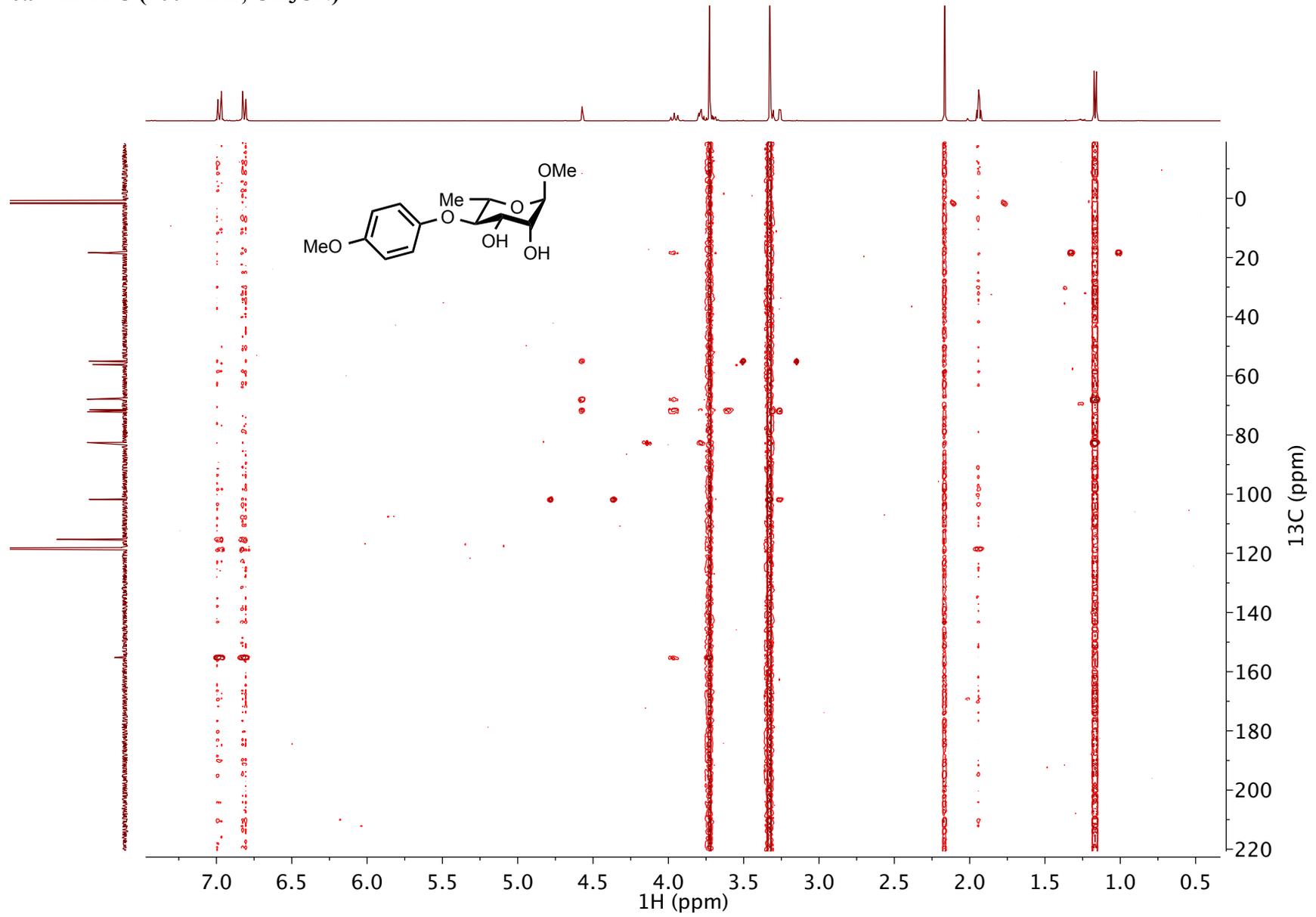
5a – HMBC (400 MHz, CH<sub>3</sub>CN)

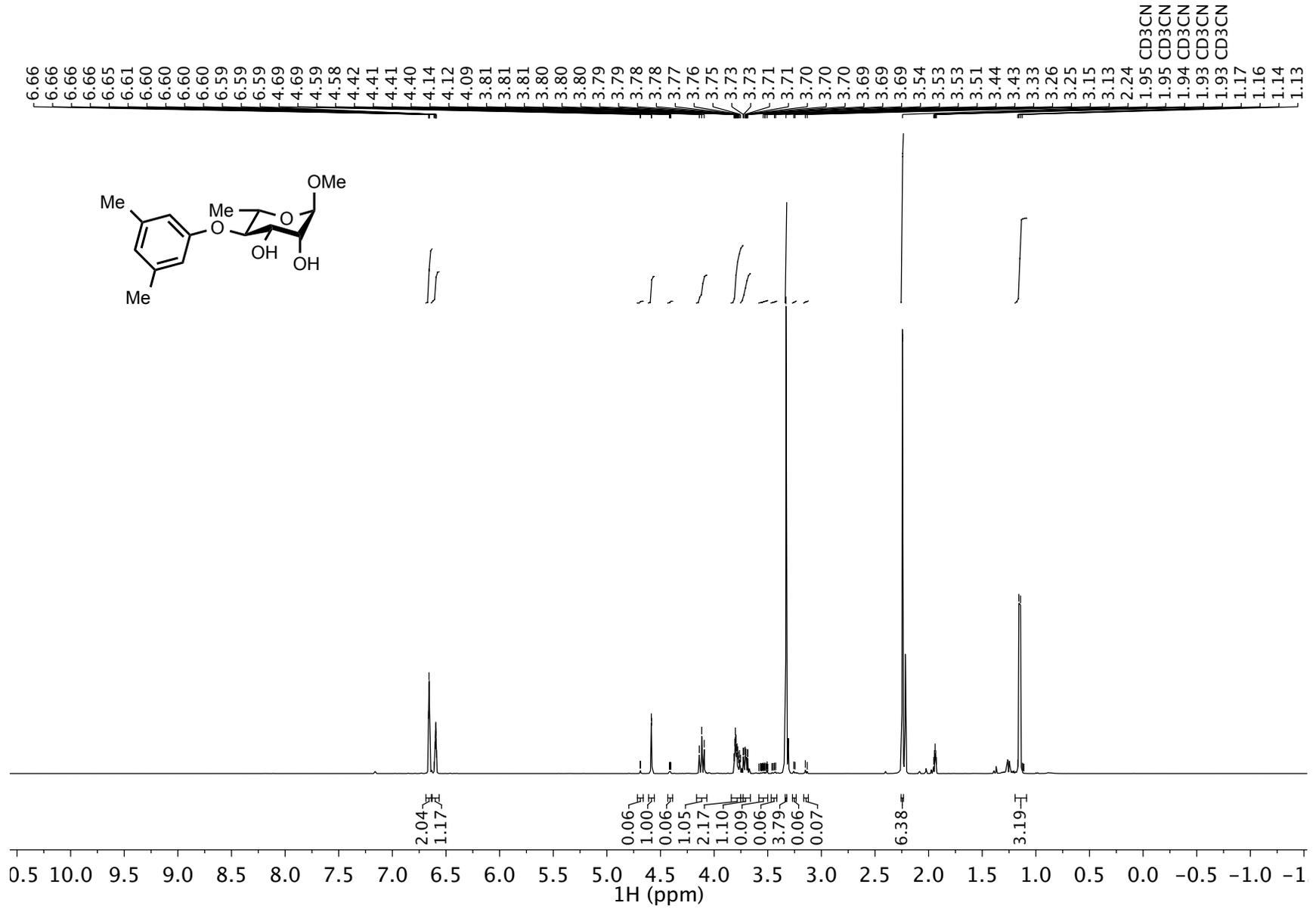
6a –  $^1\text{H}$  NMR (400 MHz,  $\text{CH}_3\text{CN}$ )

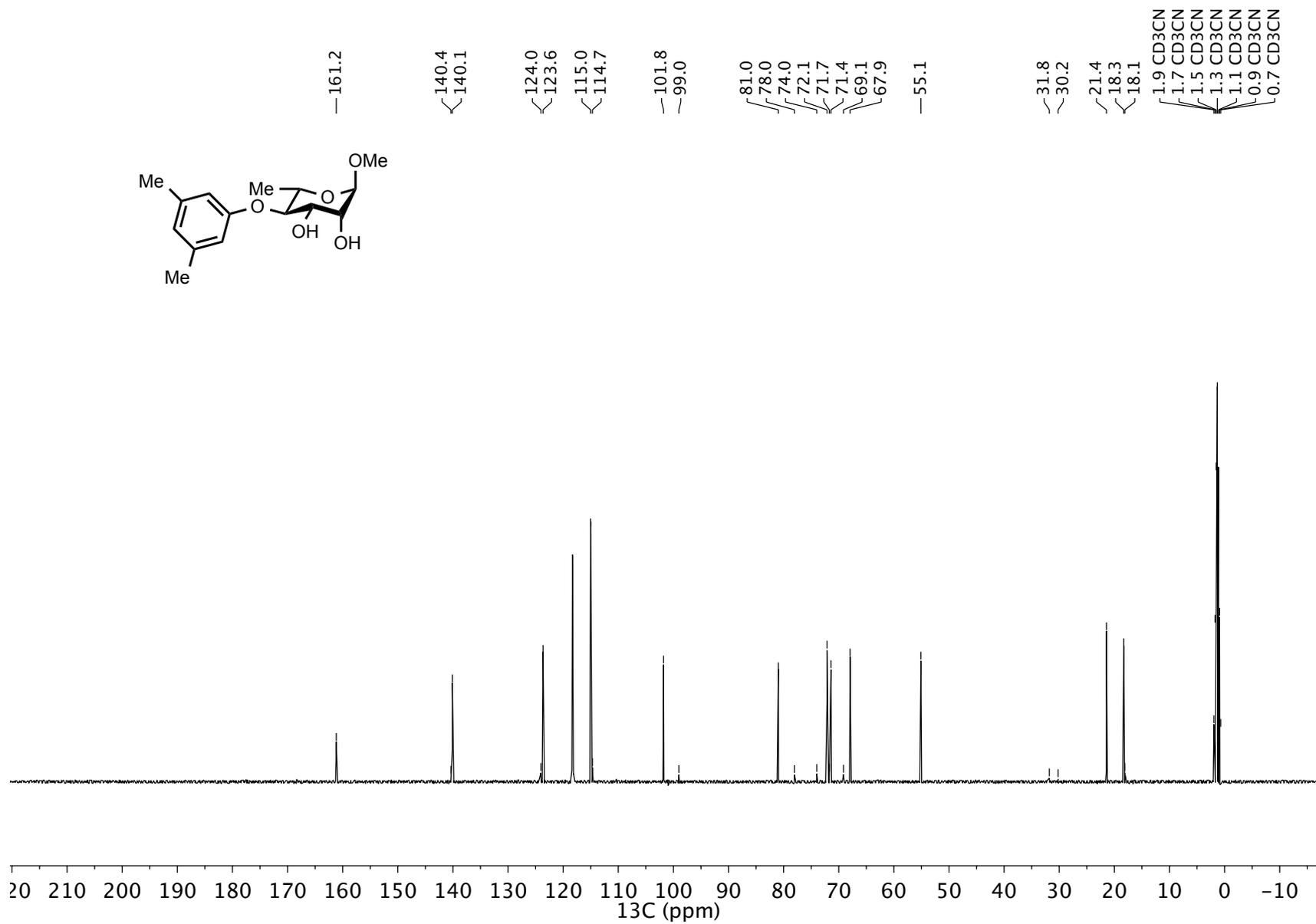
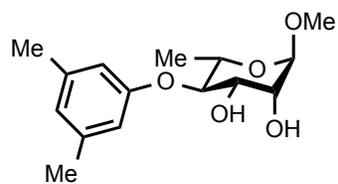
**6a** –  $^{13}\text{C}$  NMR (101 MHz,  $\text{CH}_3\text{CN}$ )

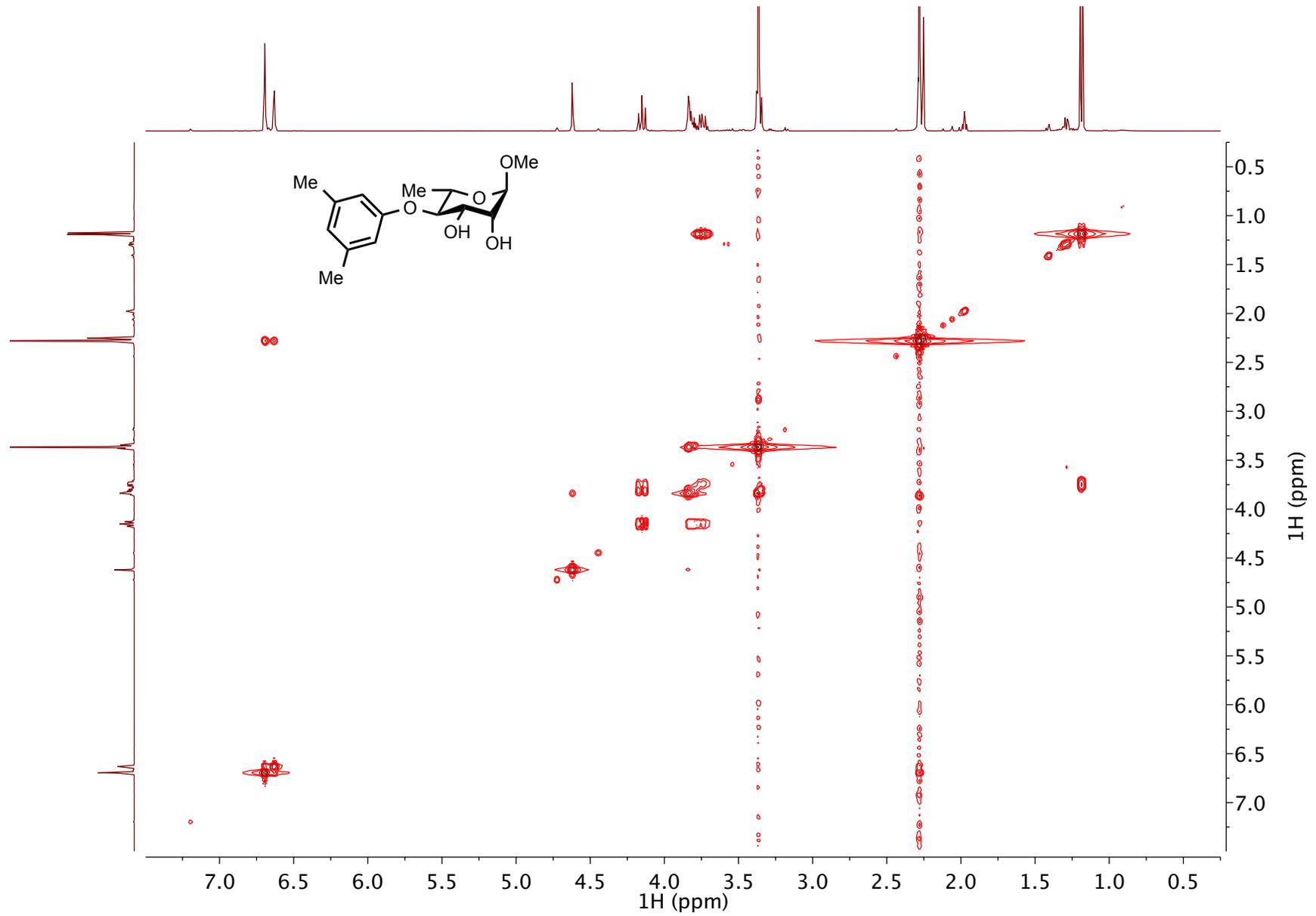
6a – gCOSY (400 MHz, CH<sub>3</sub>CN)

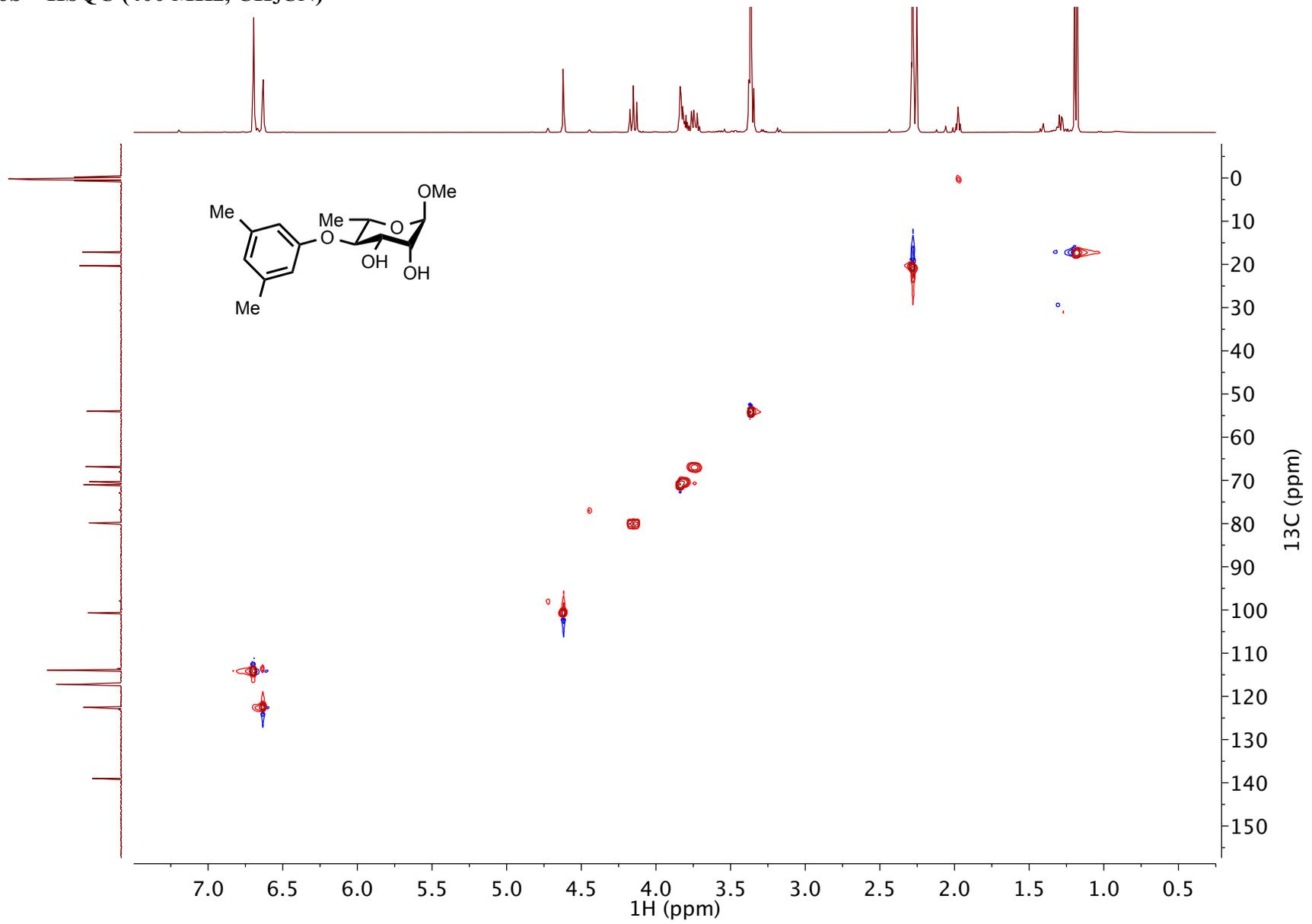
6a – HSQC (400 MHz, CH<sub>3</sub>CN)

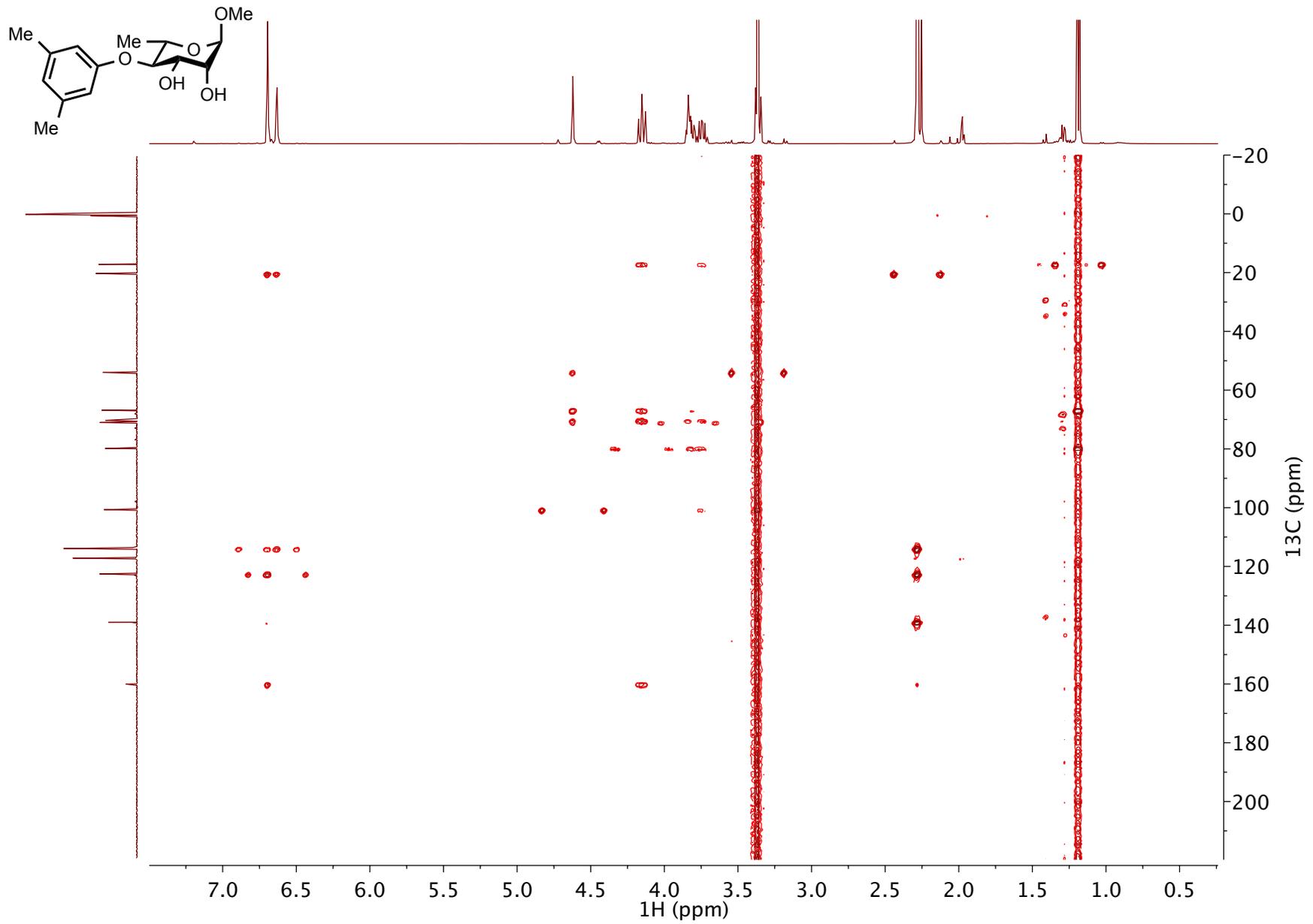
6a – HMBC (400 MHz, CH<sub>3</sub>CN)

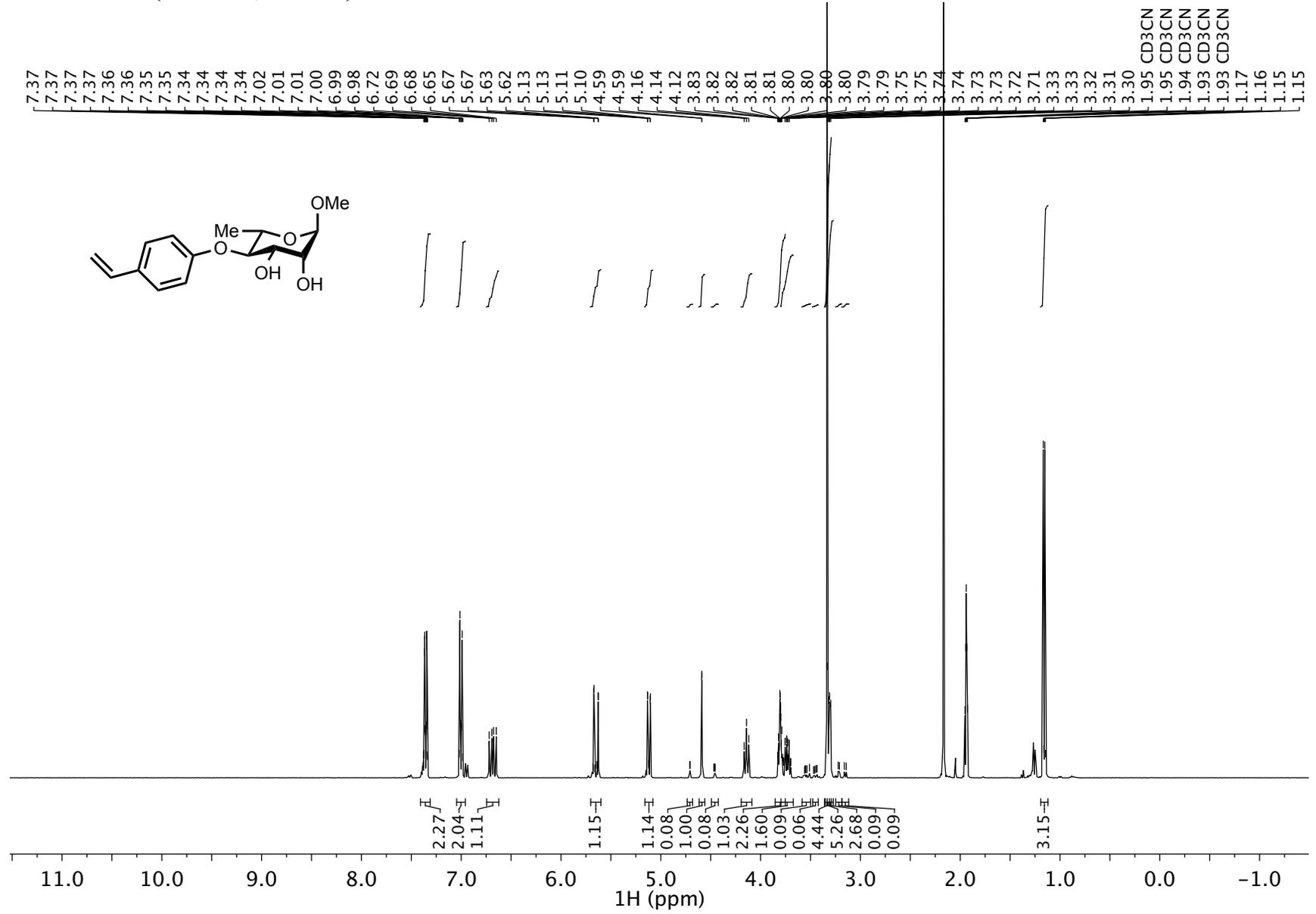
6b – <sup>1</sup>H NMR (400 MHz, CH<sub>3</sub>CN)

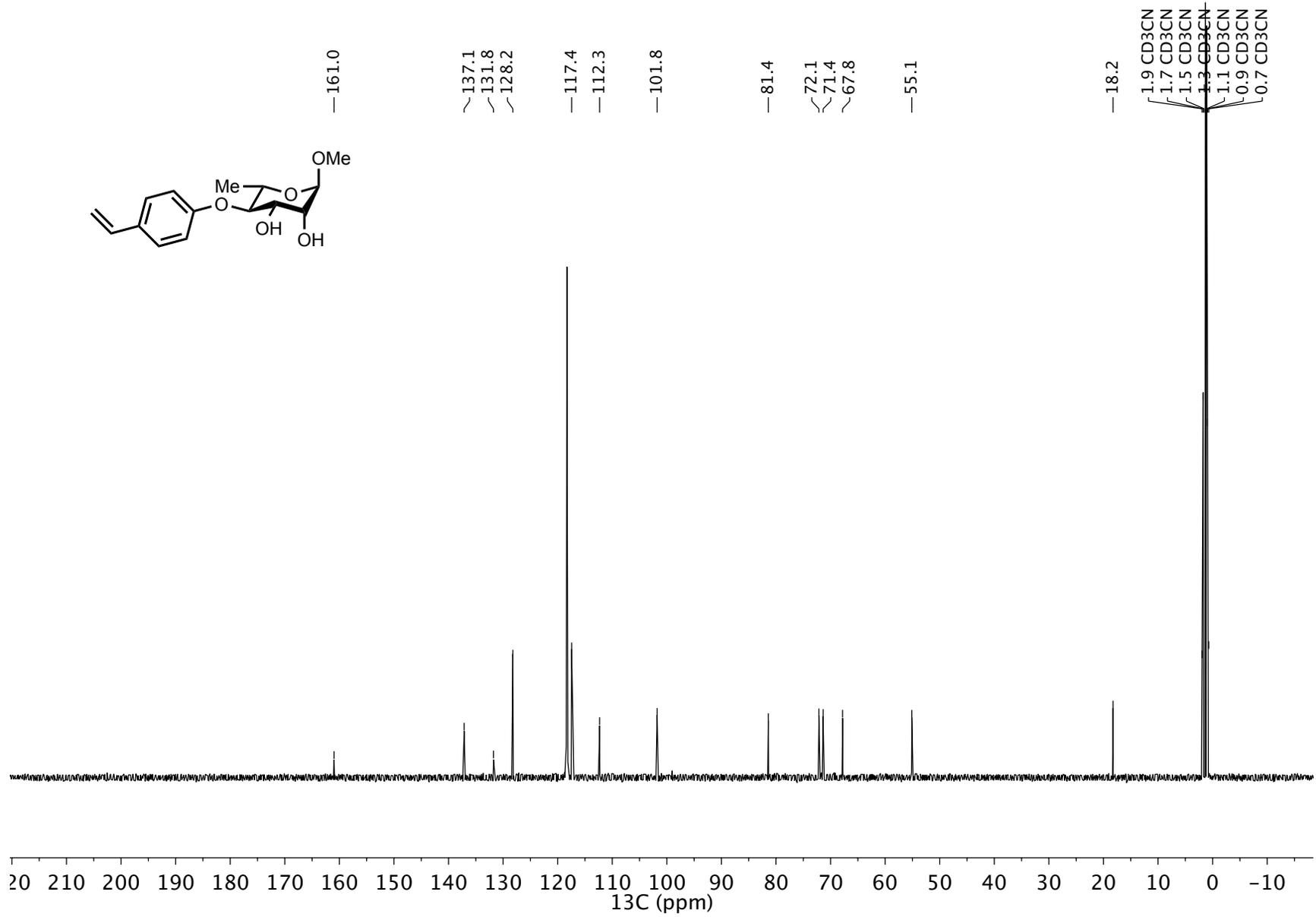
**6b** –  $^{13}\text{C}$  NMR (101 MHz,  $\text{CH}_3\text{CN}$ )

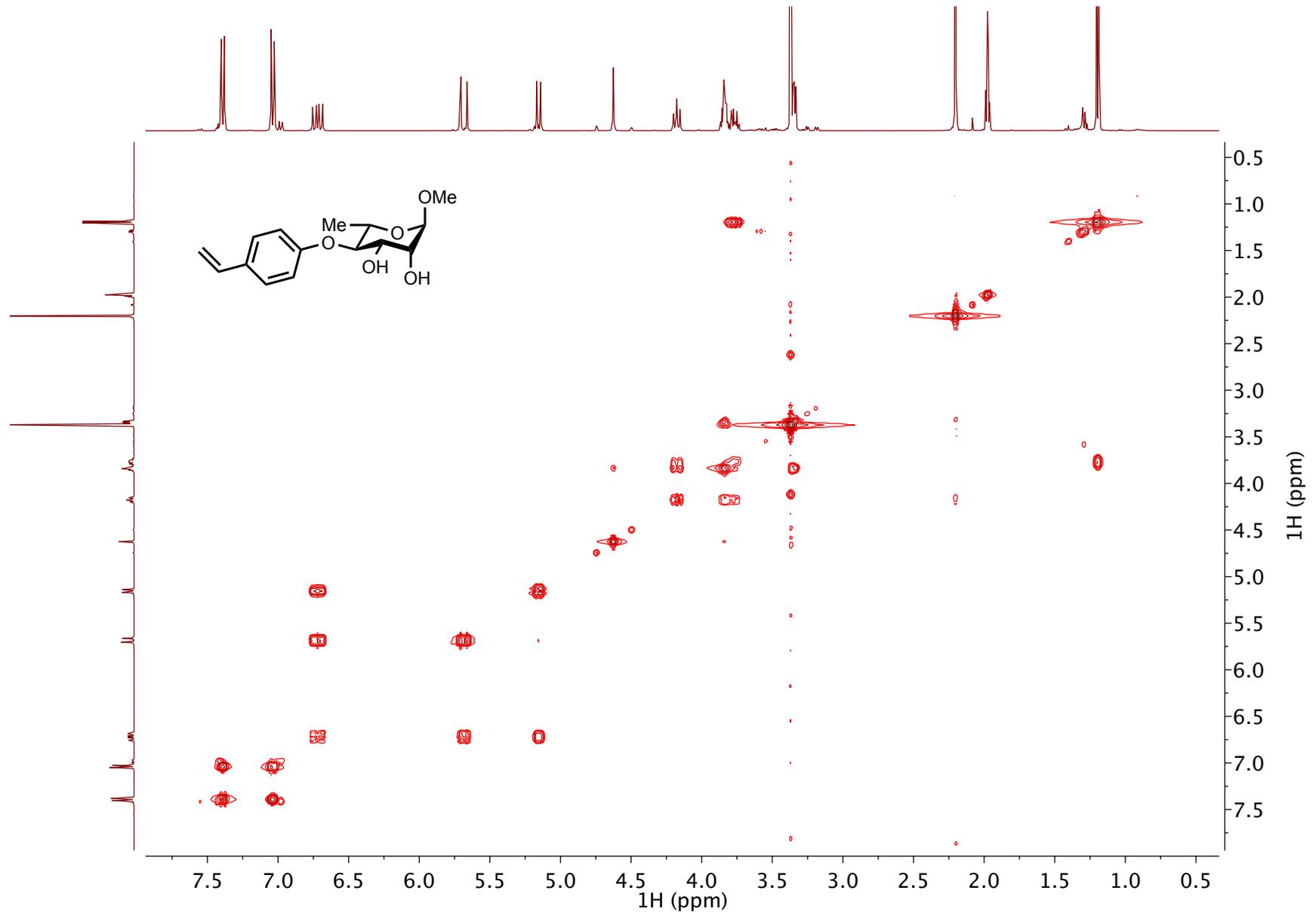
**6b – gCOSY (400 MHz, CH<sub>3</sub>CN)**

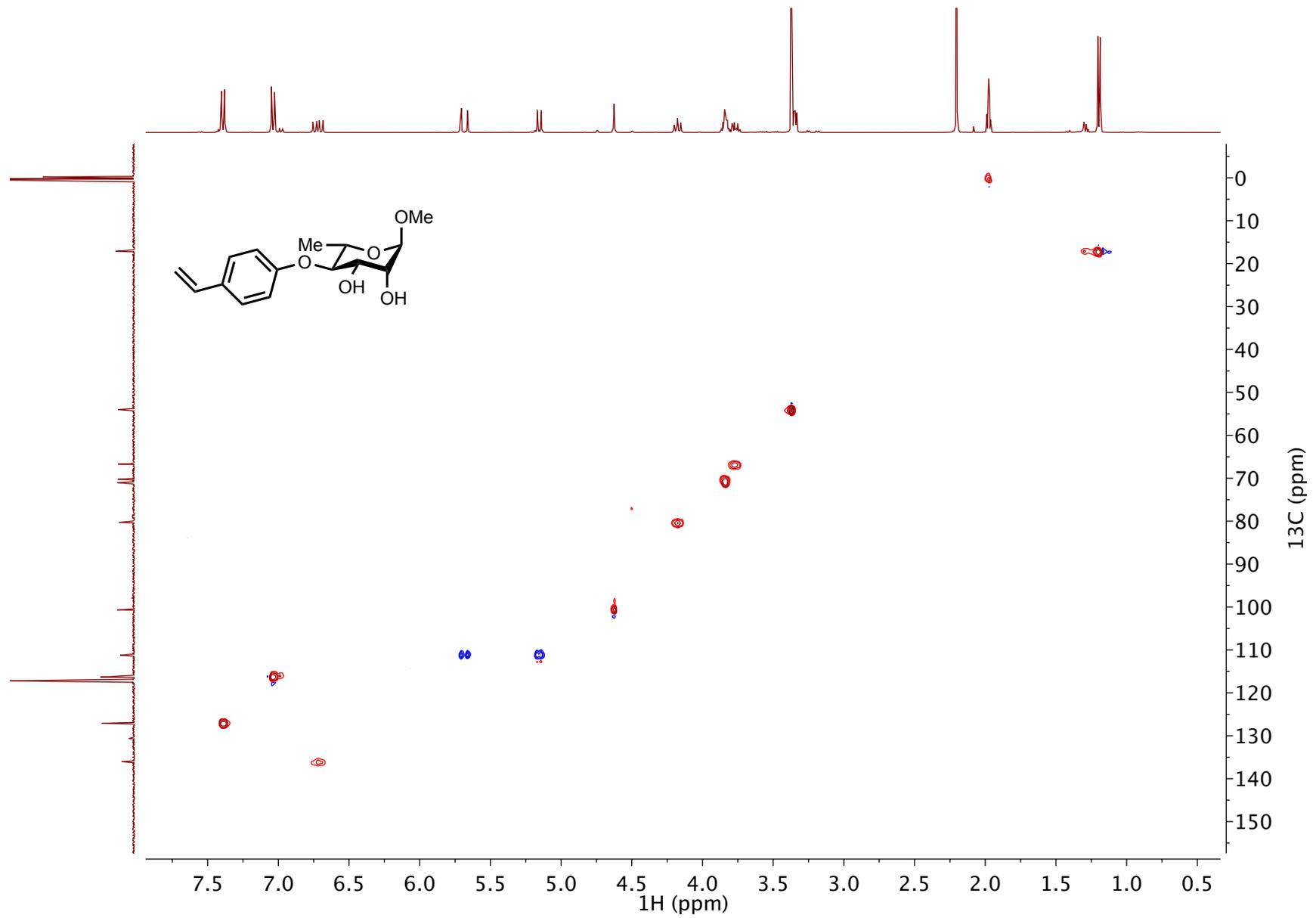
**6b – HSQC (400 MHz, CH<sub>3</sub>CN)**

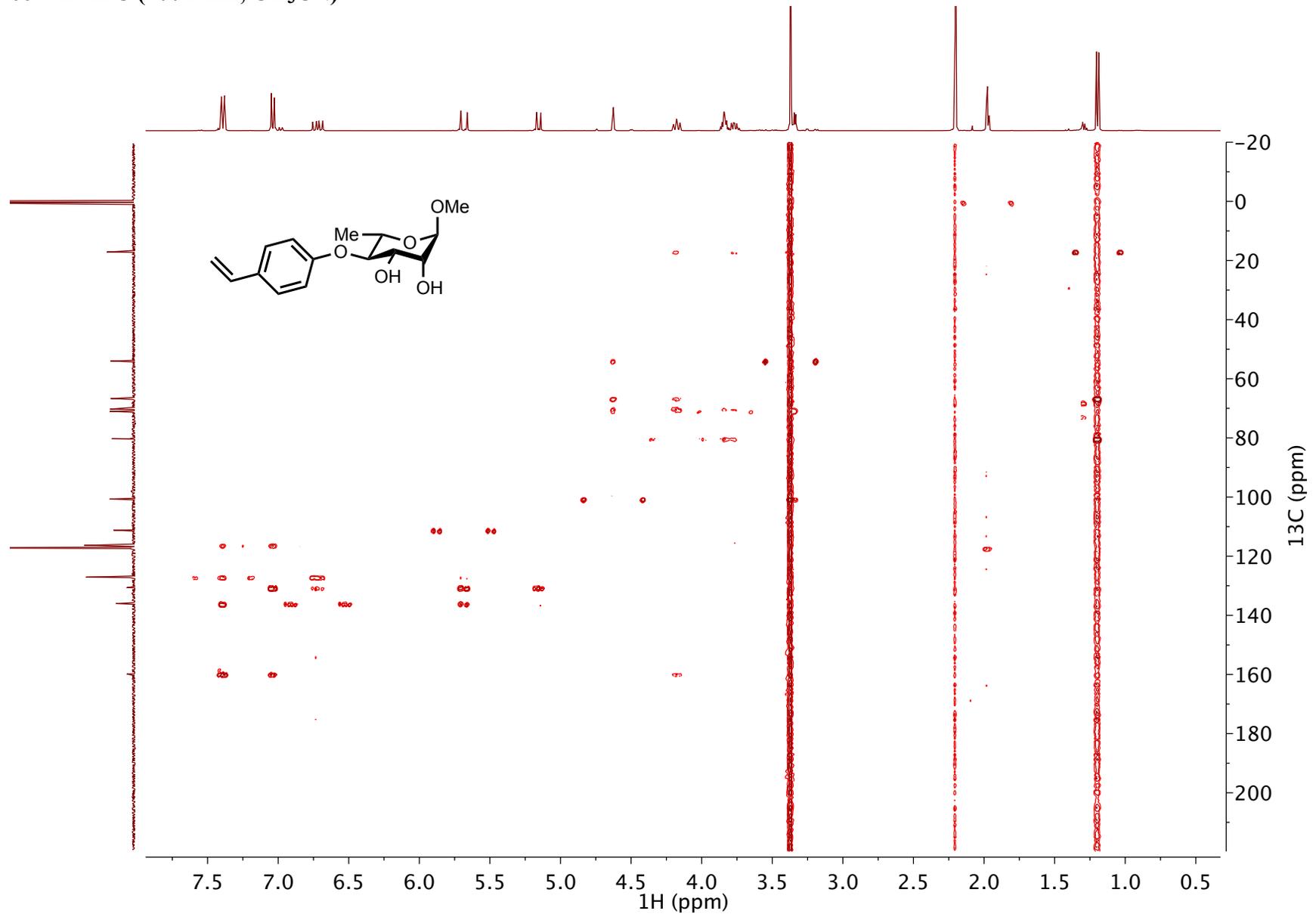
**6b – HMBC (400 MHz, CH<sub>3</sub>CN)**

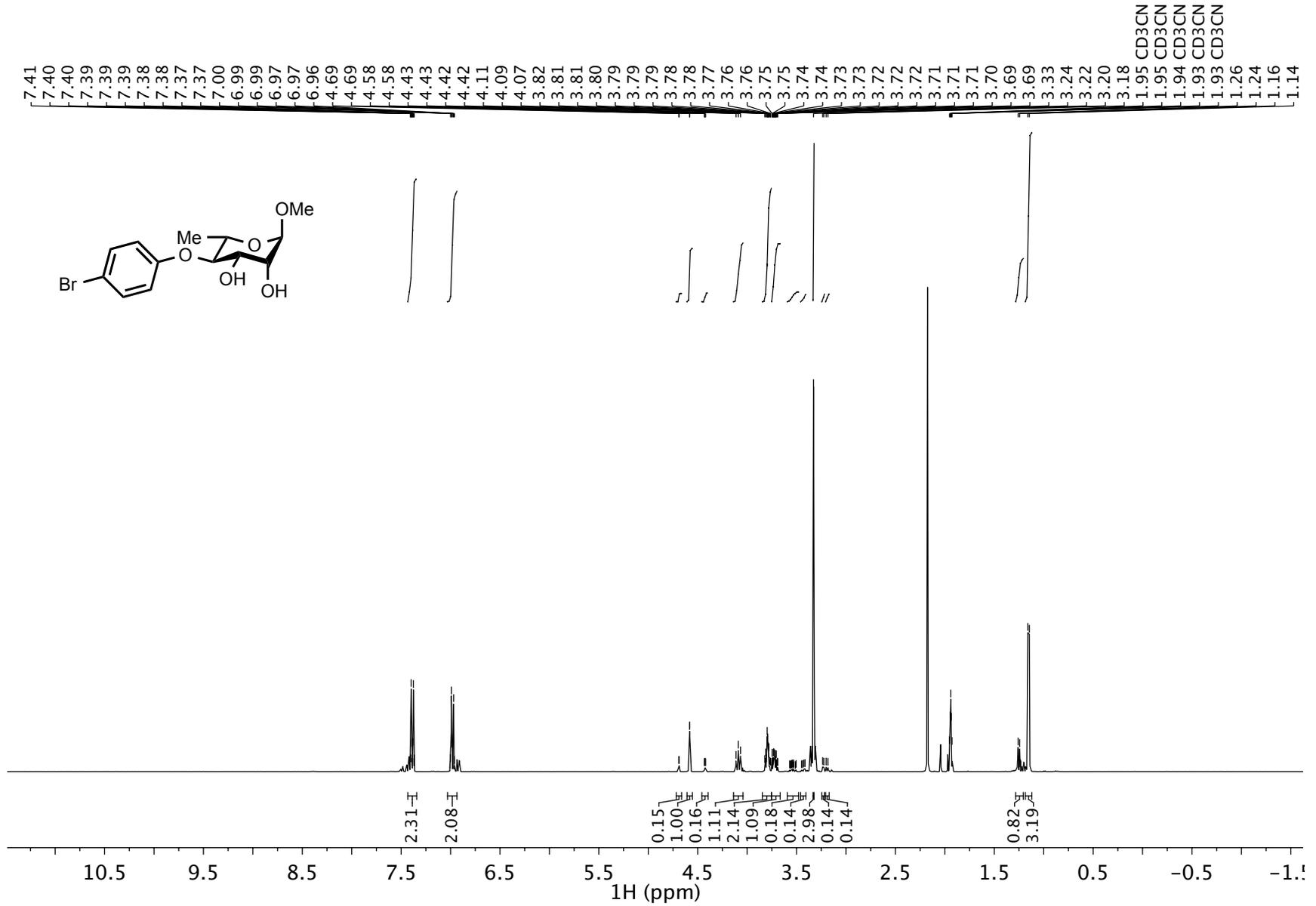
6c –  $^1\text{H}$  NMR (400 MHz,  $\text{CH}_3\text{CN}$ )

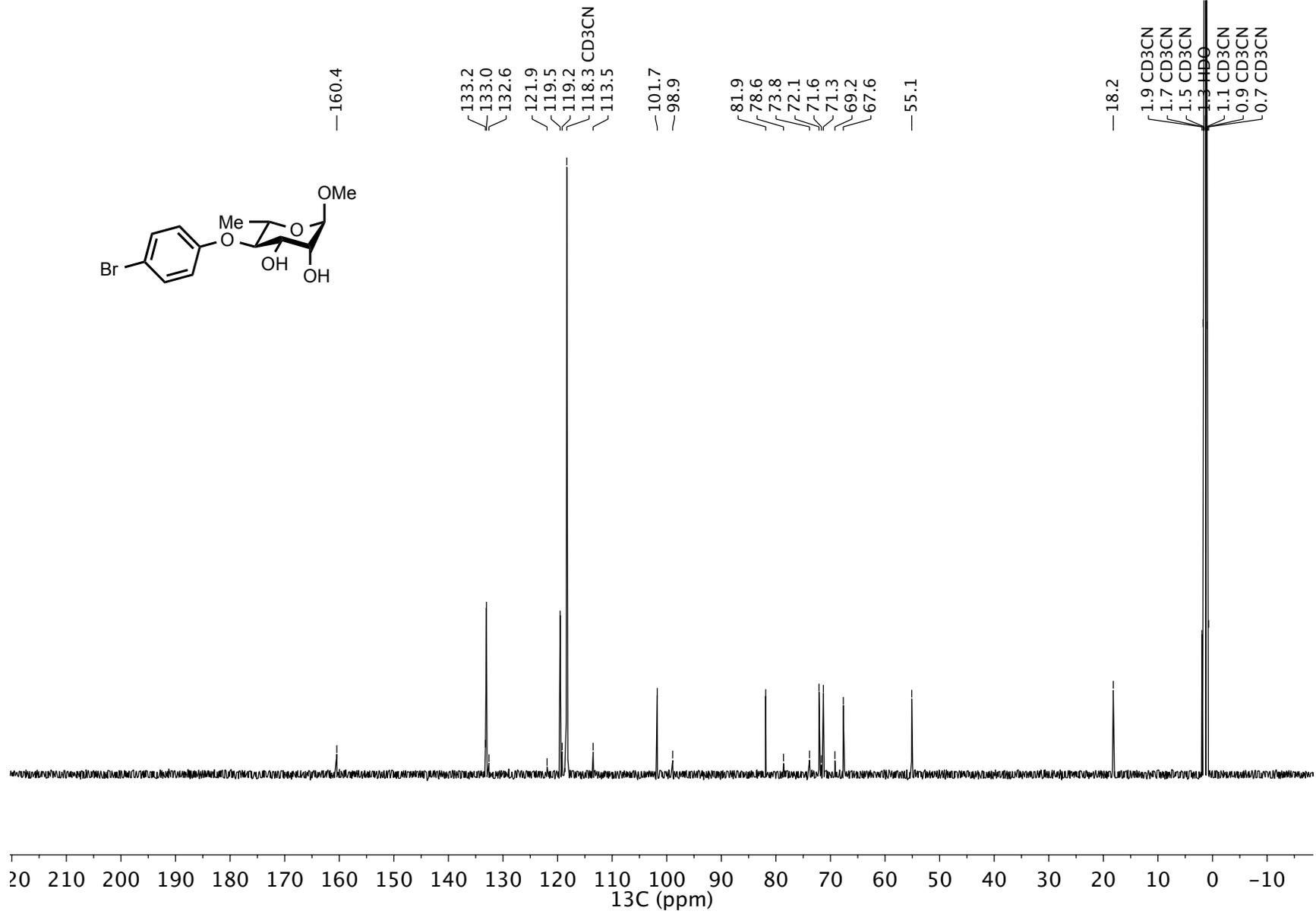
**6c** –  $^{13}\text{C}$  NMR (400 MHz,  $\text{CH}_3\text{CN}$ )

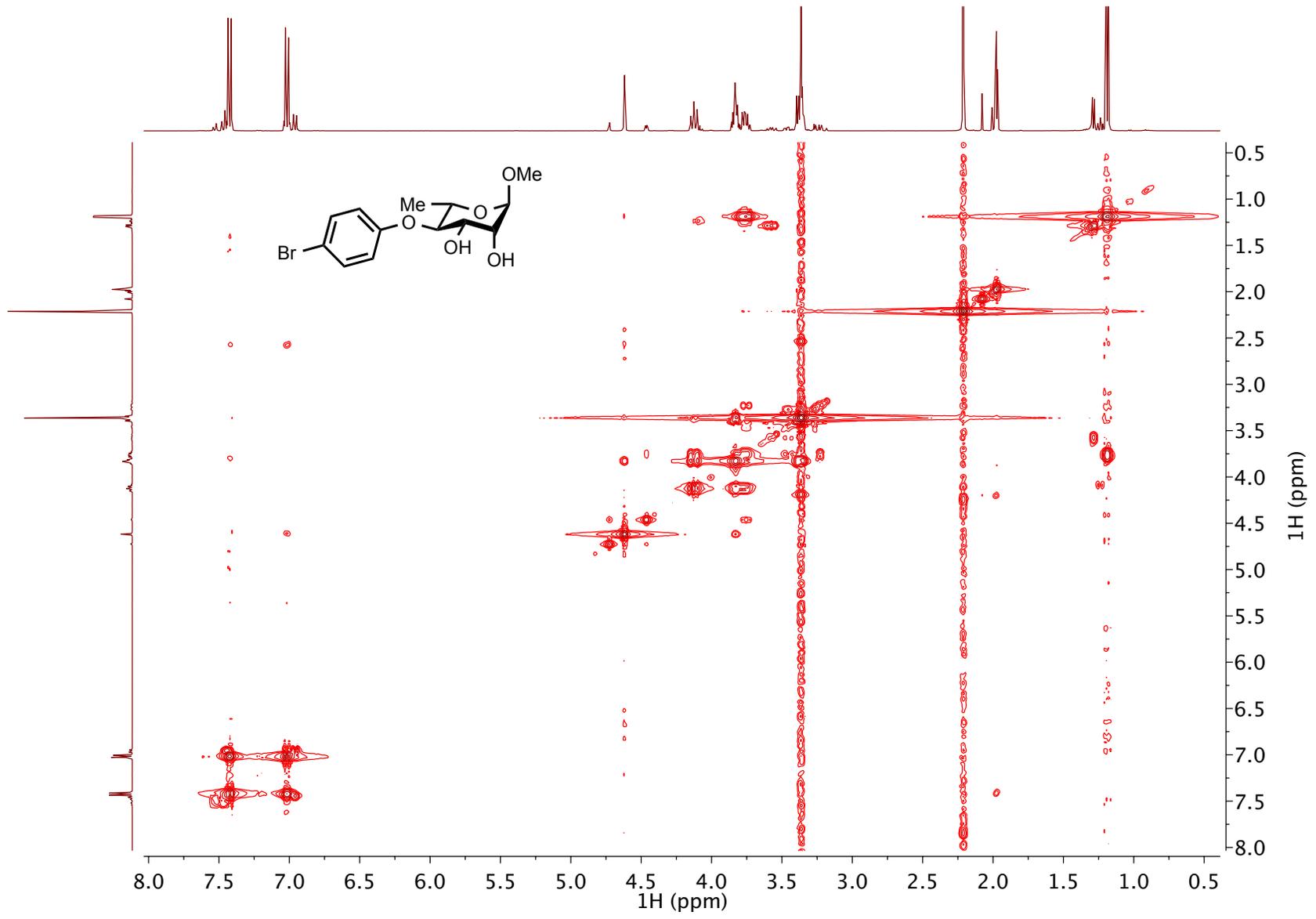
**6c – gCOSY (400 MHz, CH<sub>3</sub>CN)**

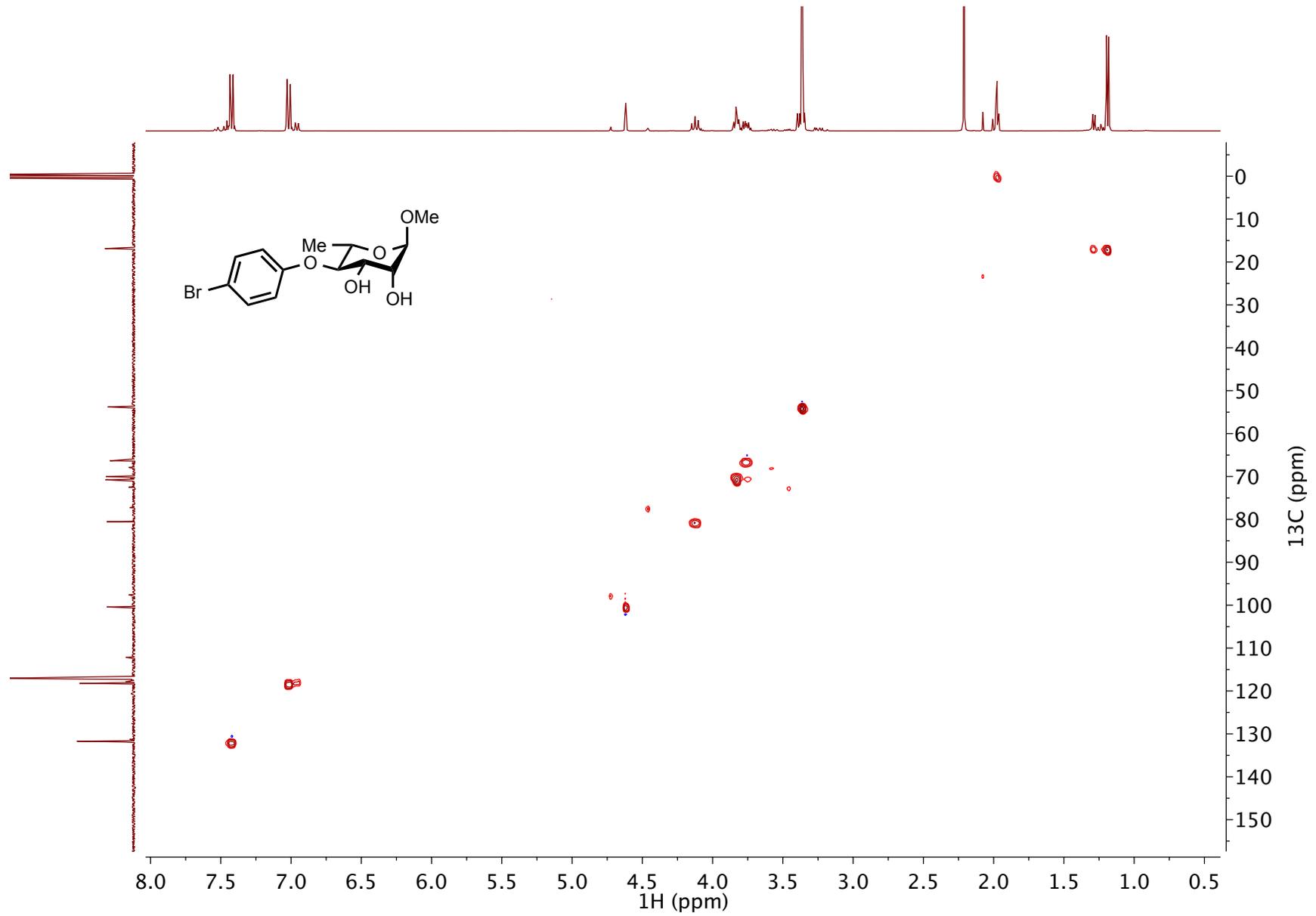
**6c – HSQC (400 MHz, CH<sub>3</sub>CN)**

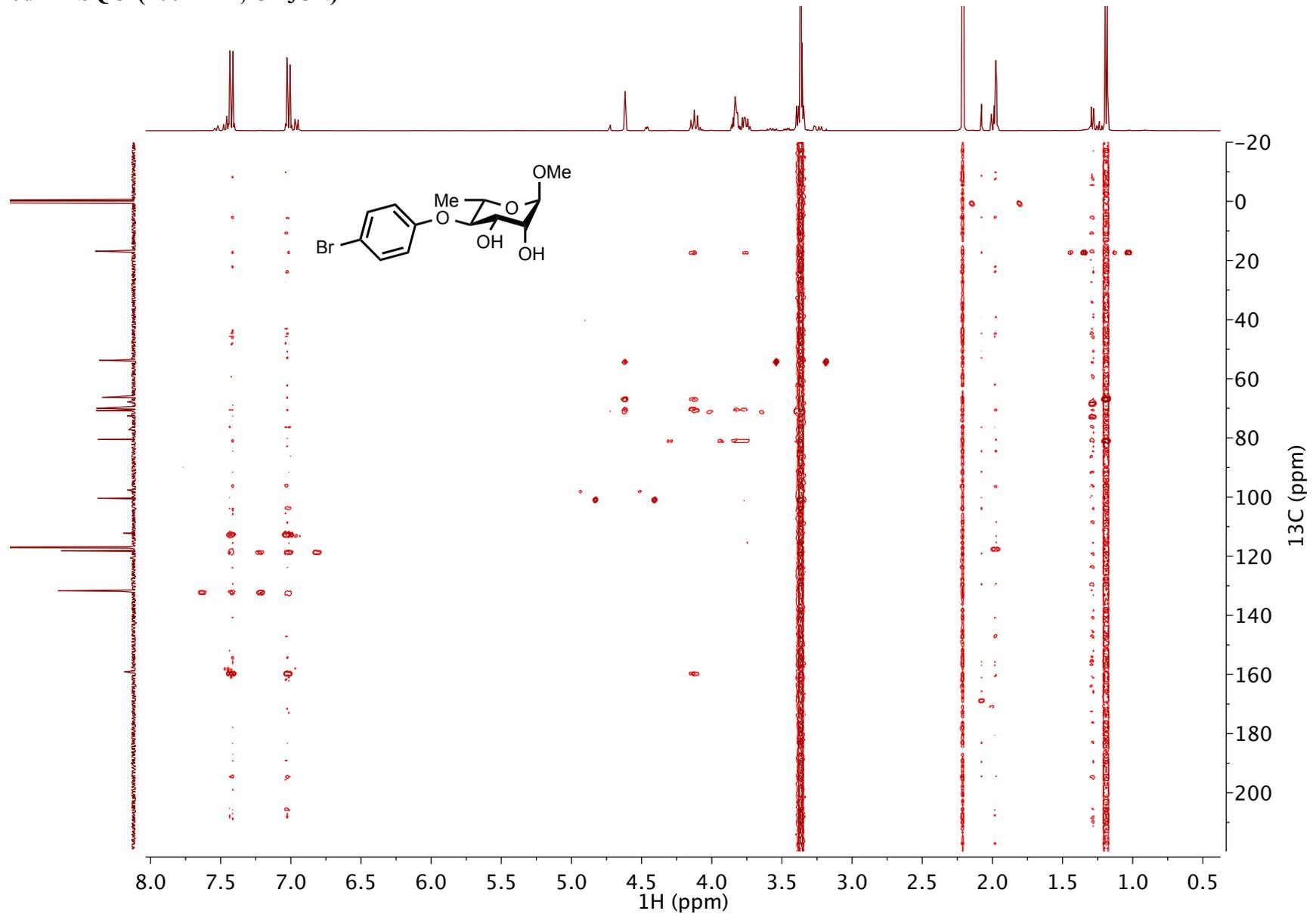
**6c – HMBC (400 MHz, CH<sub>3</sub>CN)**

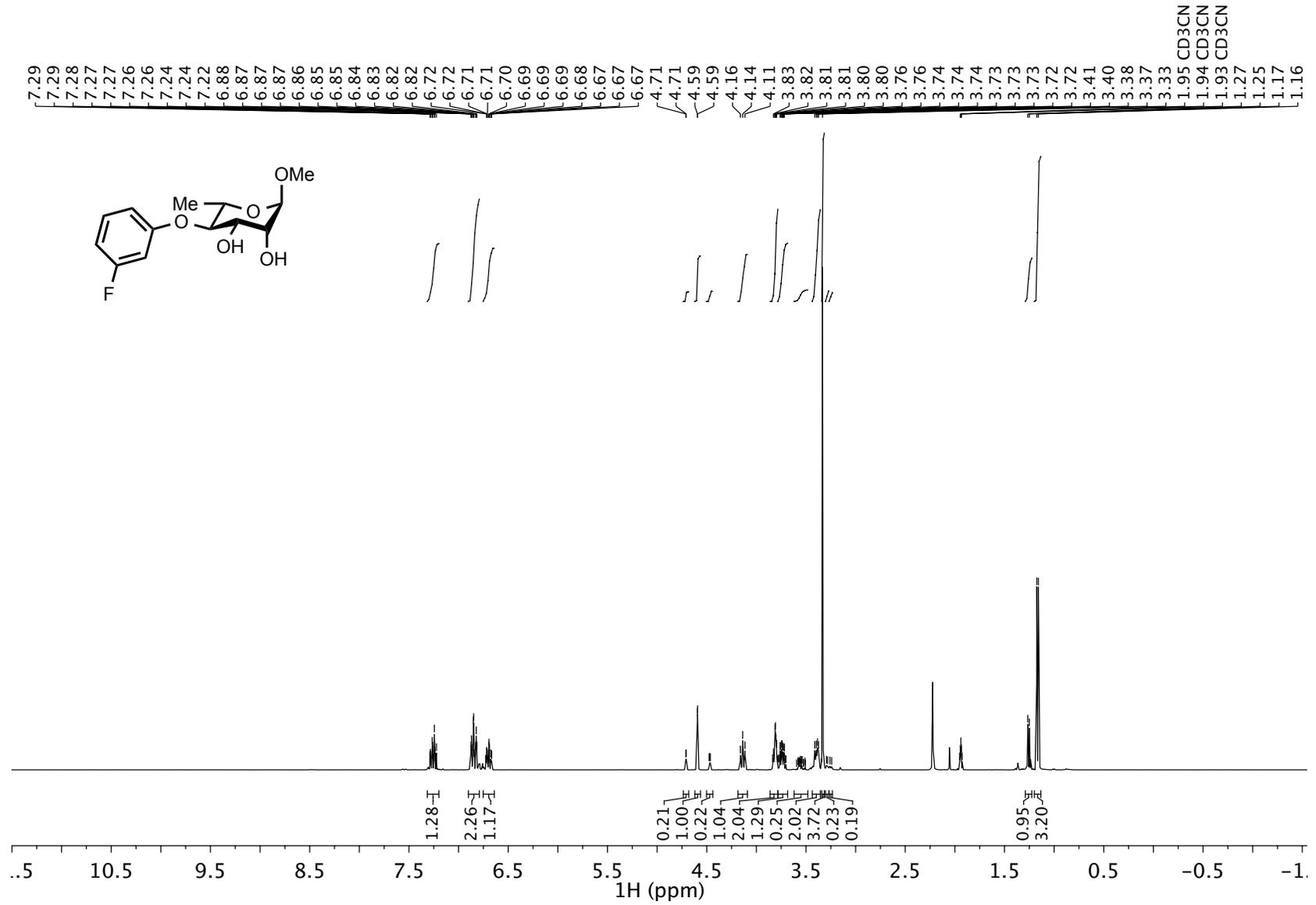
6d –  $^1\text{H}$  NMR (400 MHz,  $\text{CH}_3\text{CN}$ )

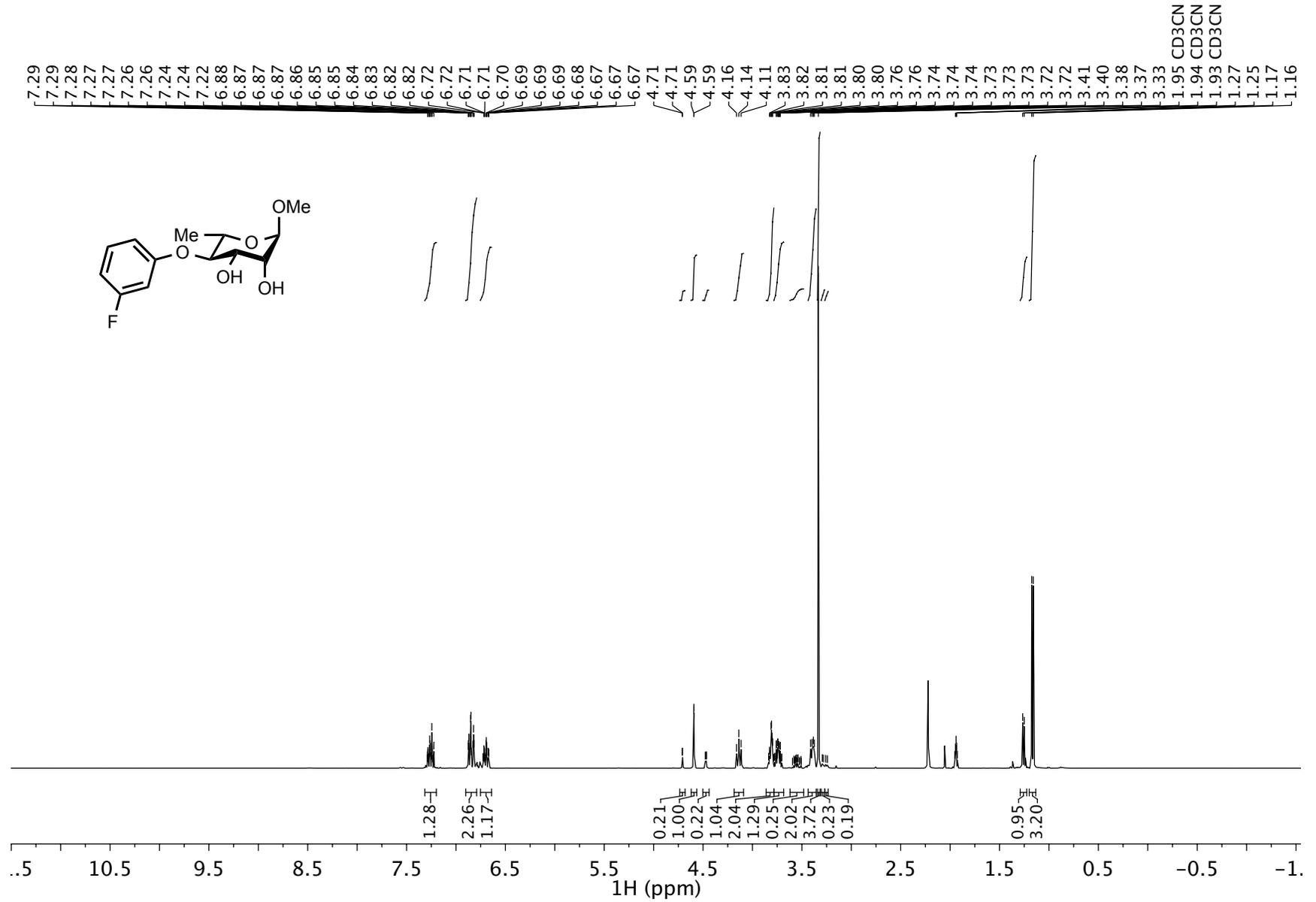
**6d –  $^{13}\text{C}$  NMR (101 MHz,  $\text{CH}_3\text{CN}$ )**

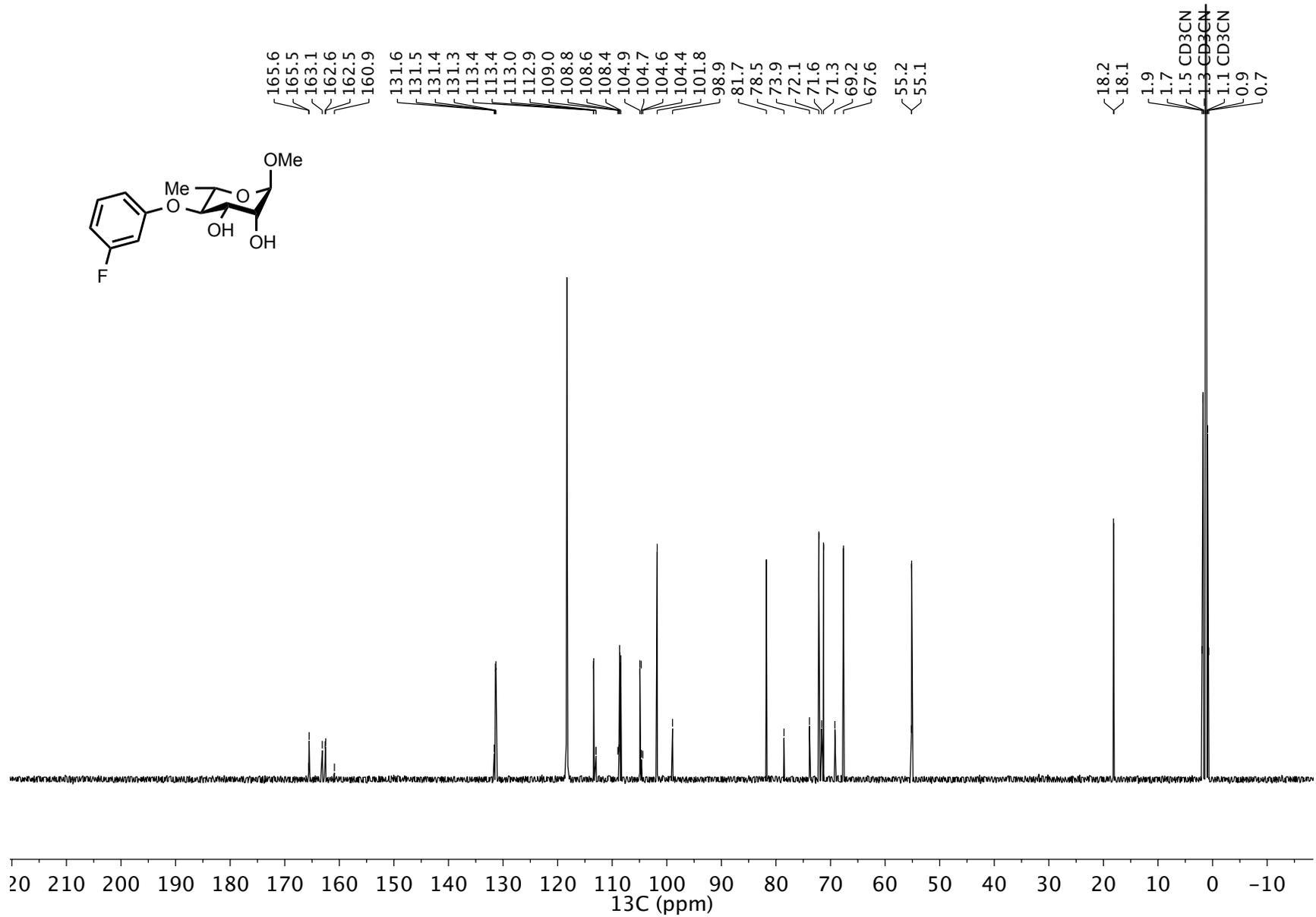
6d – gCOSY (400 MHz, CH<sub>3</sub>CN)

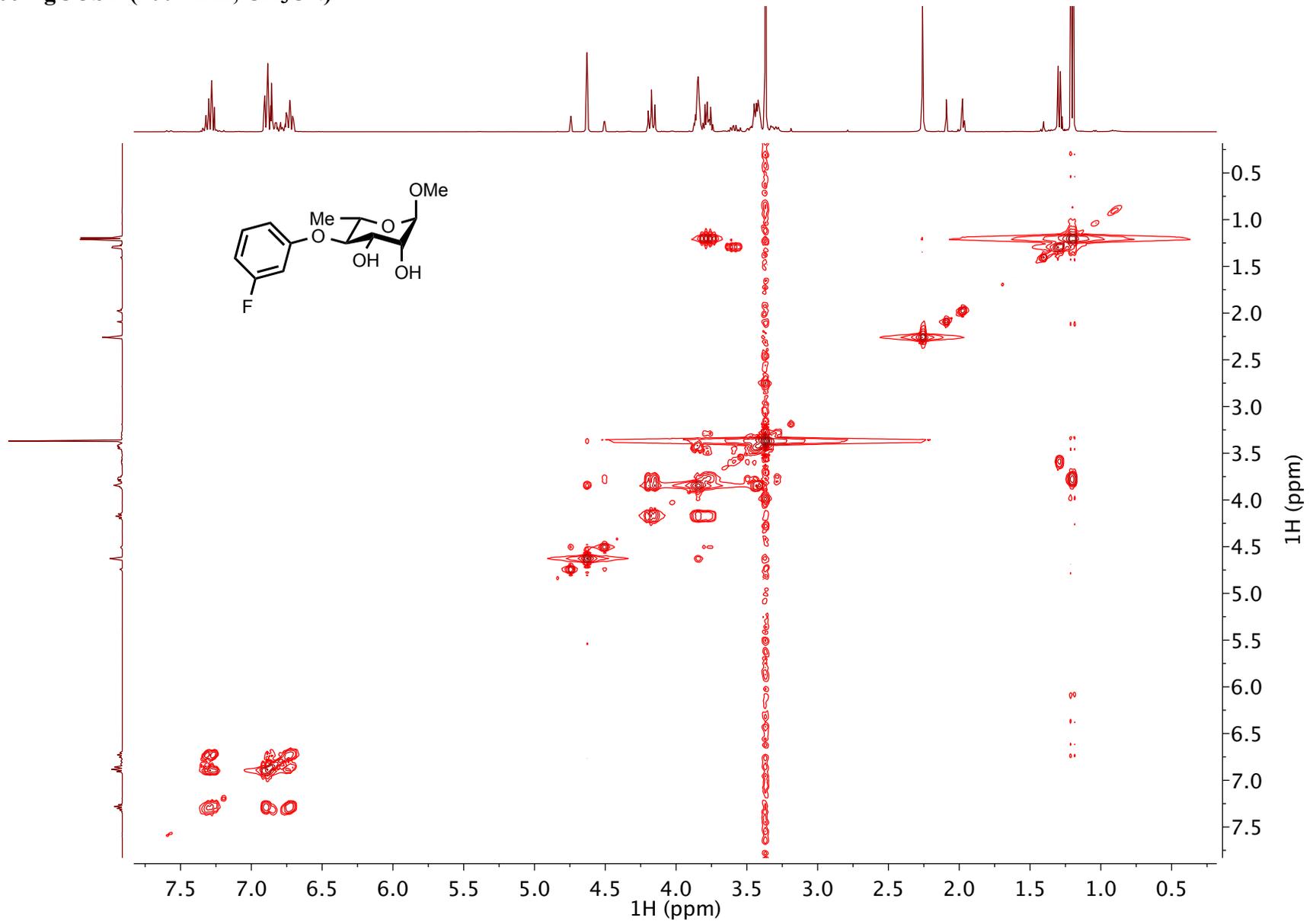
6d – HSQC (400 MHz, CH<sub>3</sub>CN)

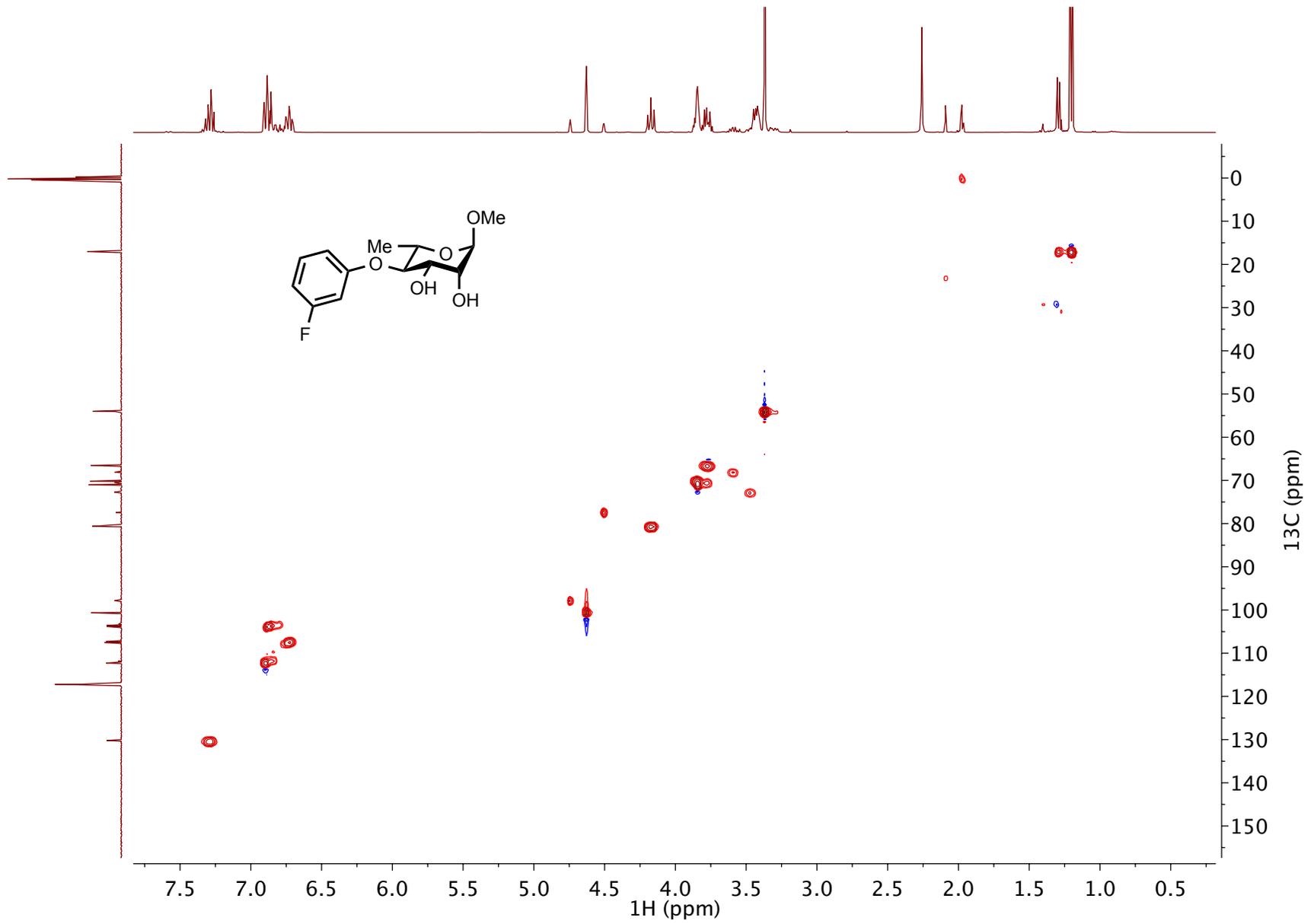
6d – HSQC (400 MHz, CH<sub>3</sub>CN)

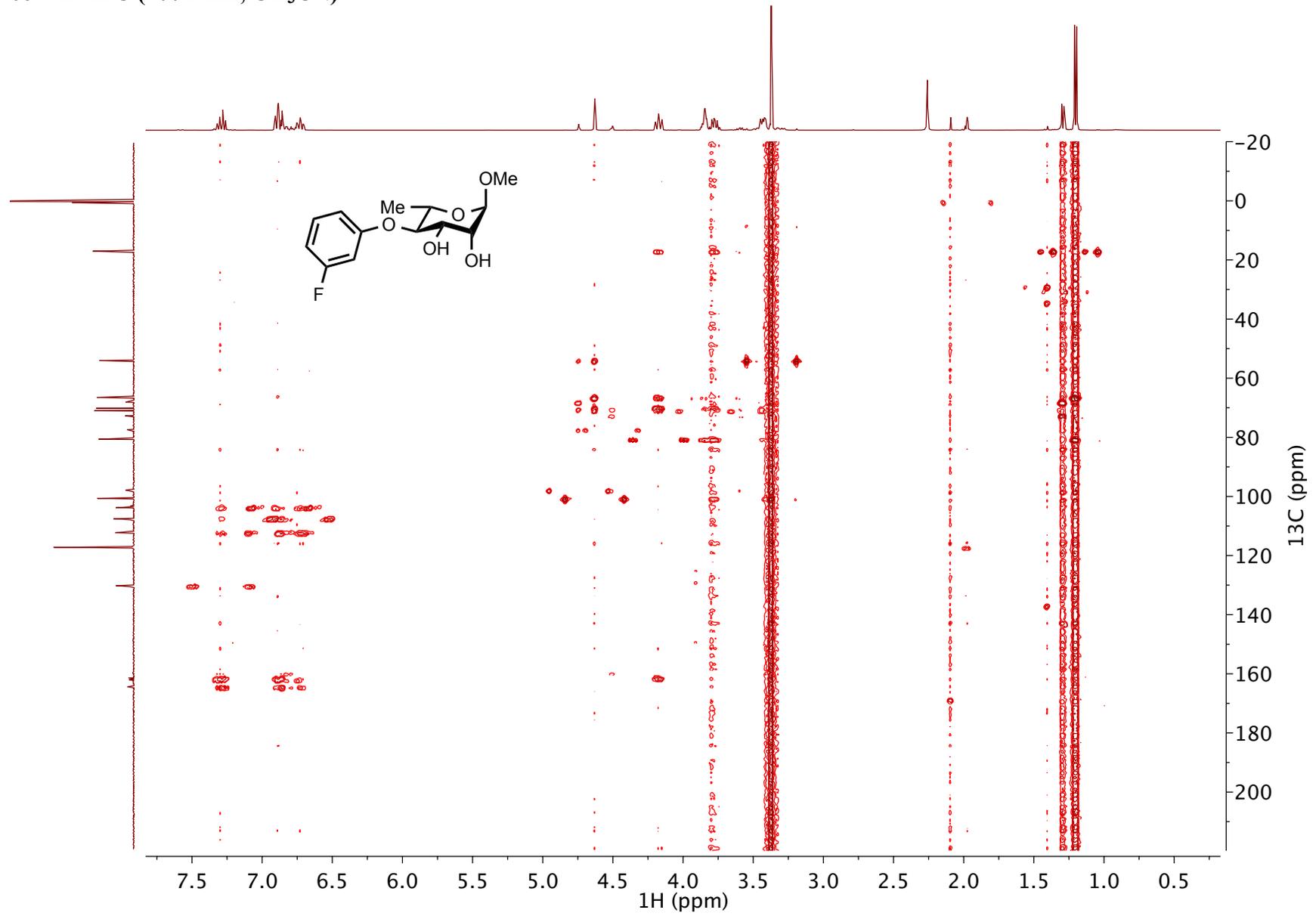
6e –  $^1\text{H}$  NMR (400 MHz,  $\text{CH}_3\text{CN}$ )

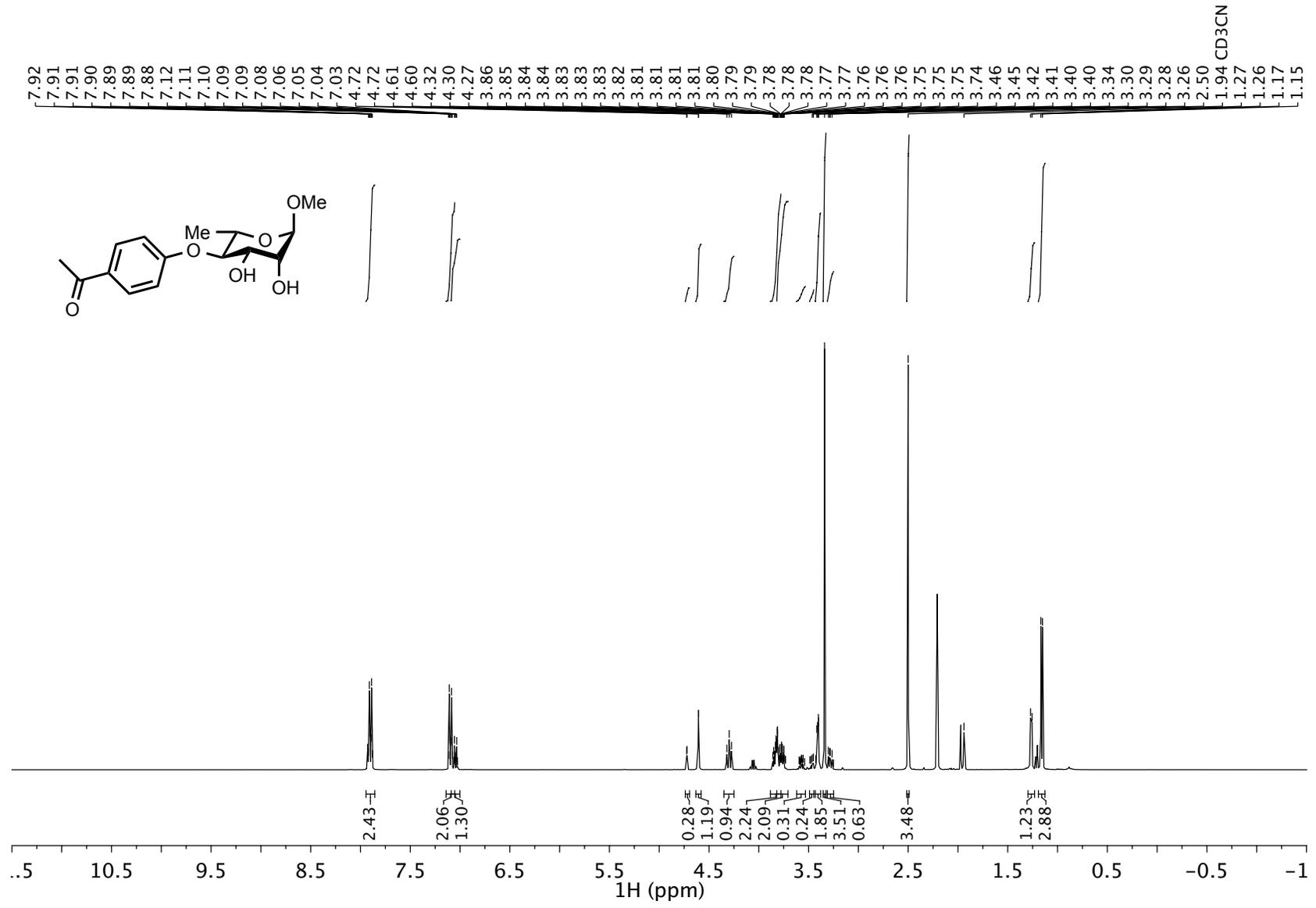
**6e – <sup>1</sup>H NMR (400 MHz, CH<sub>3</sub>CN)**

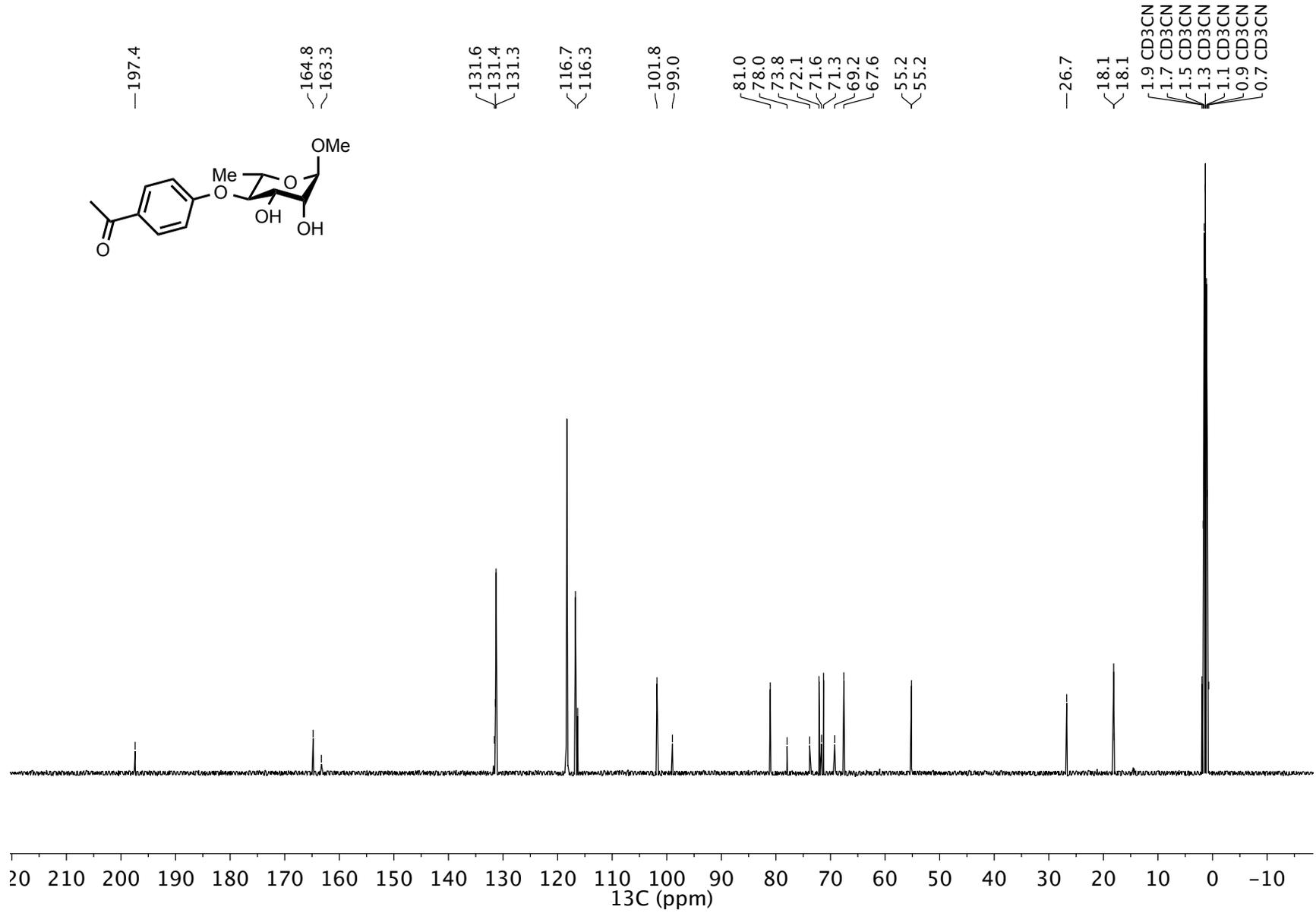
**6e –  $^{13}\text{C}$  NMR (101 MHz,  $\text{CH}_3\text{CN}$ )**

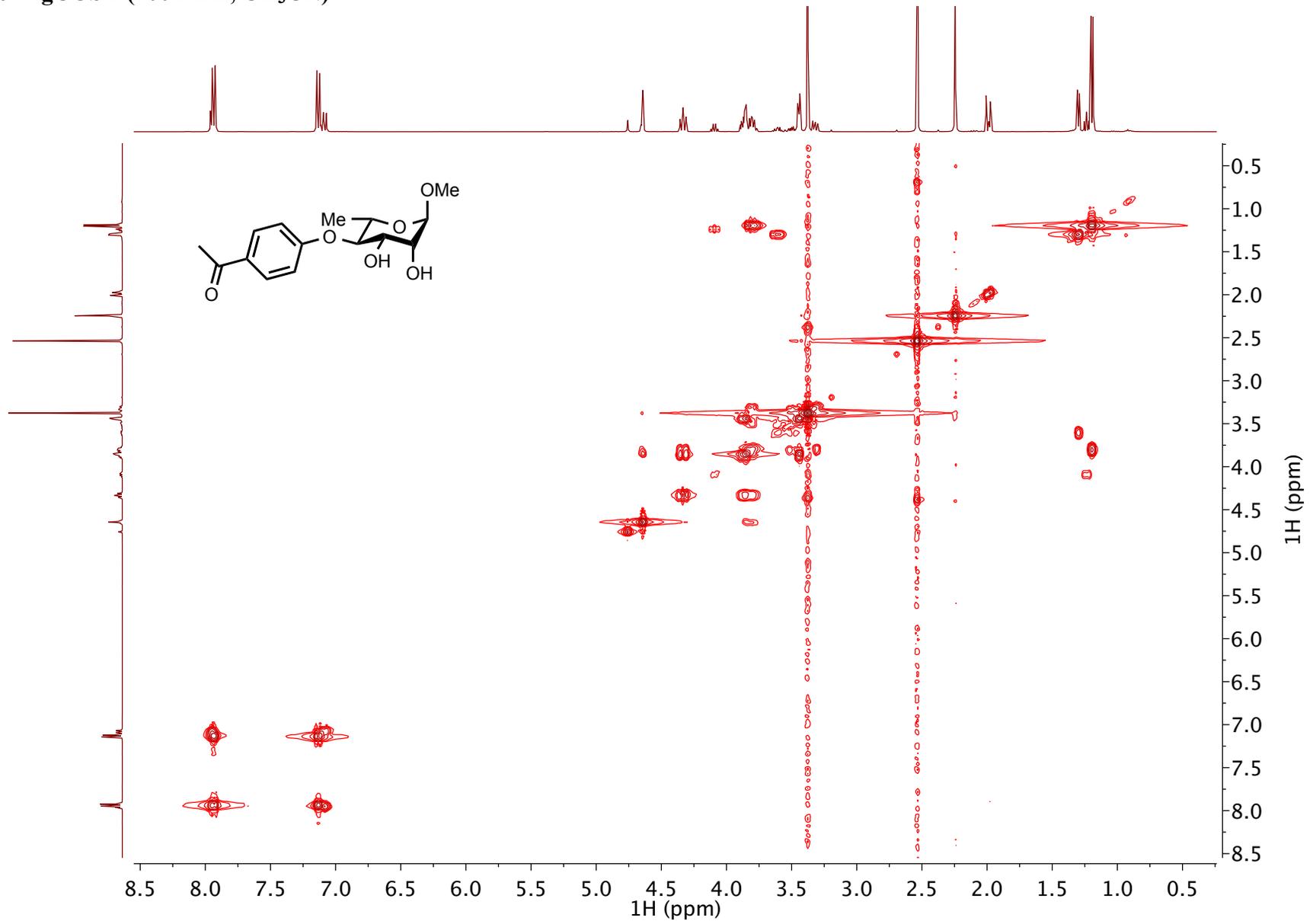
6e – gCOSY (400 MHz, CH<sub>3</sub>CN)

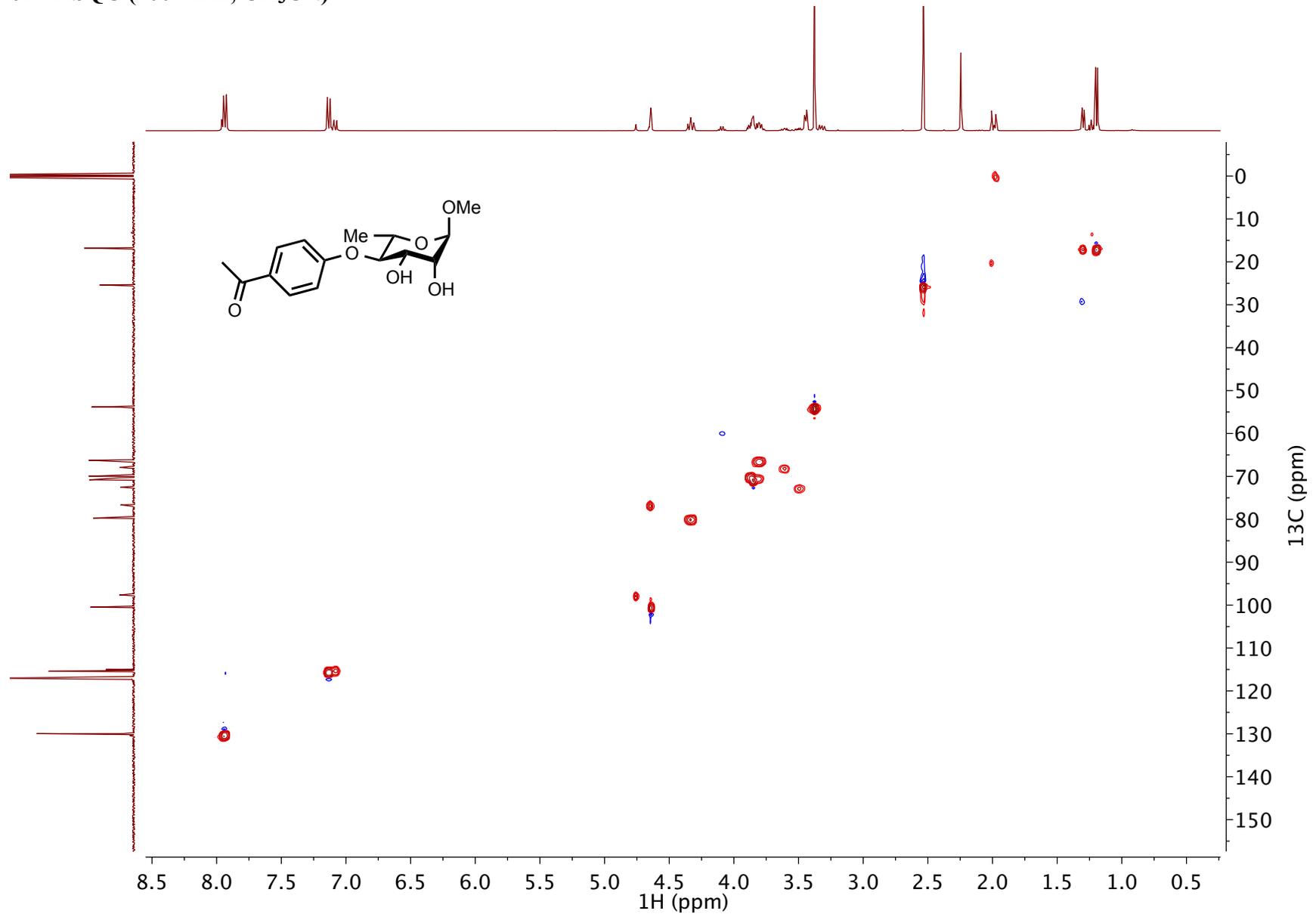
6e – HSQC (400 MHz, CH<sub>3</sub>CN)

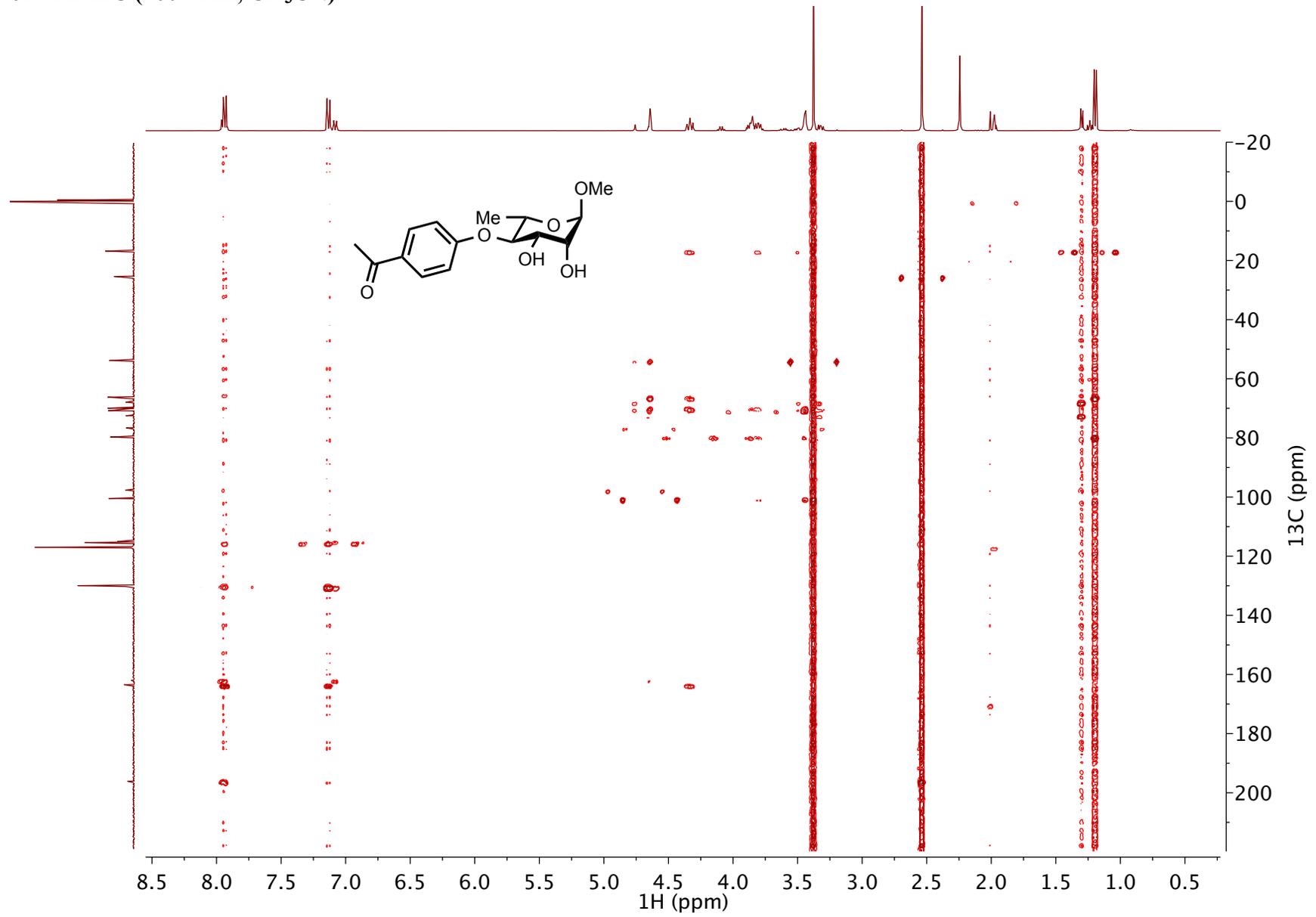
6e – HMBC (400 MHz, CH<sub>3</sub>CN)

6f –  $^1\text{H}$  NMR (400 MHz,  $\text{CH}_3\text{CN}$ )

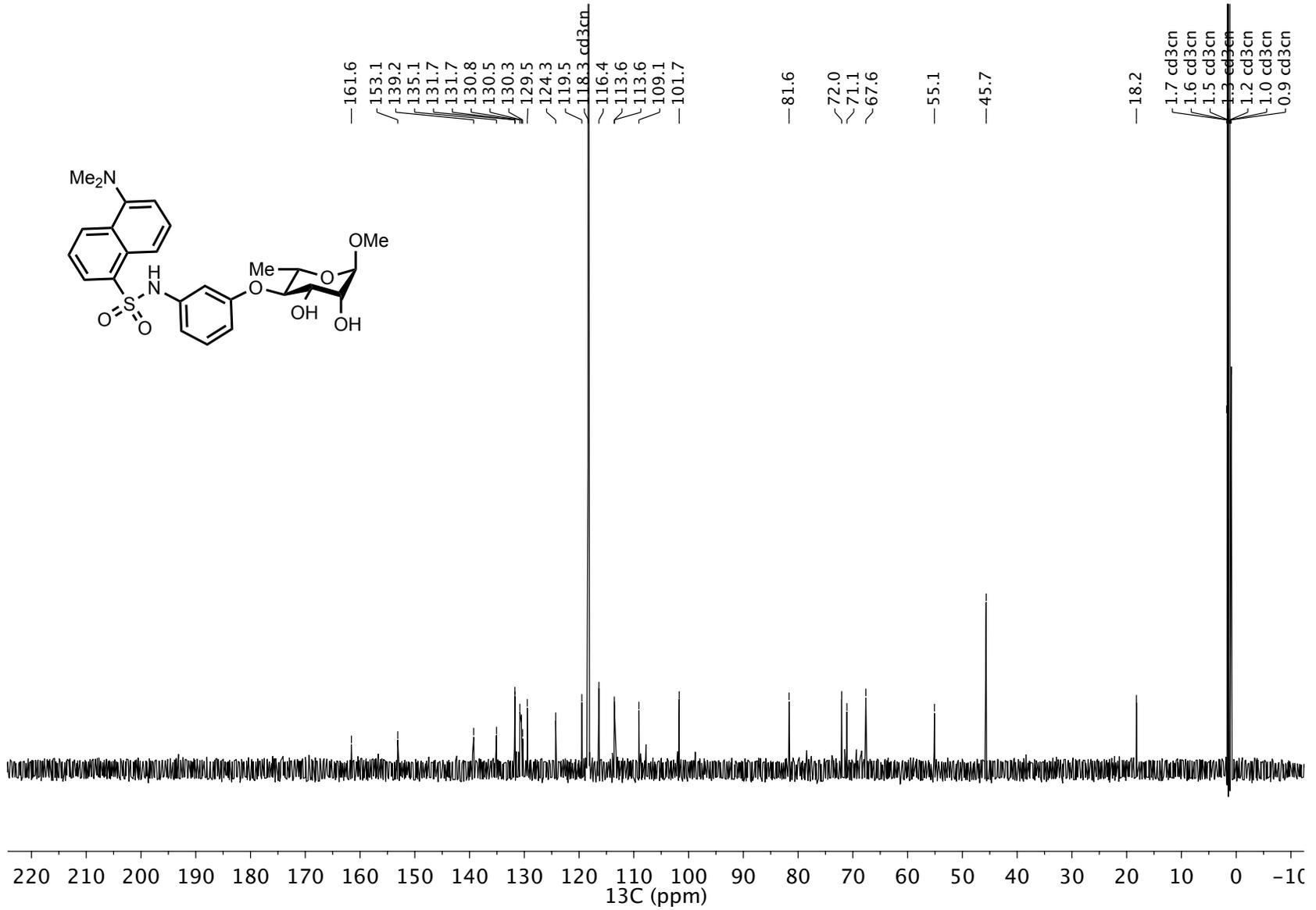
**6f –  $^{13}\text{C}$  NMR (101 MHz,  $\text{CH}_3\text{CN}$ )**

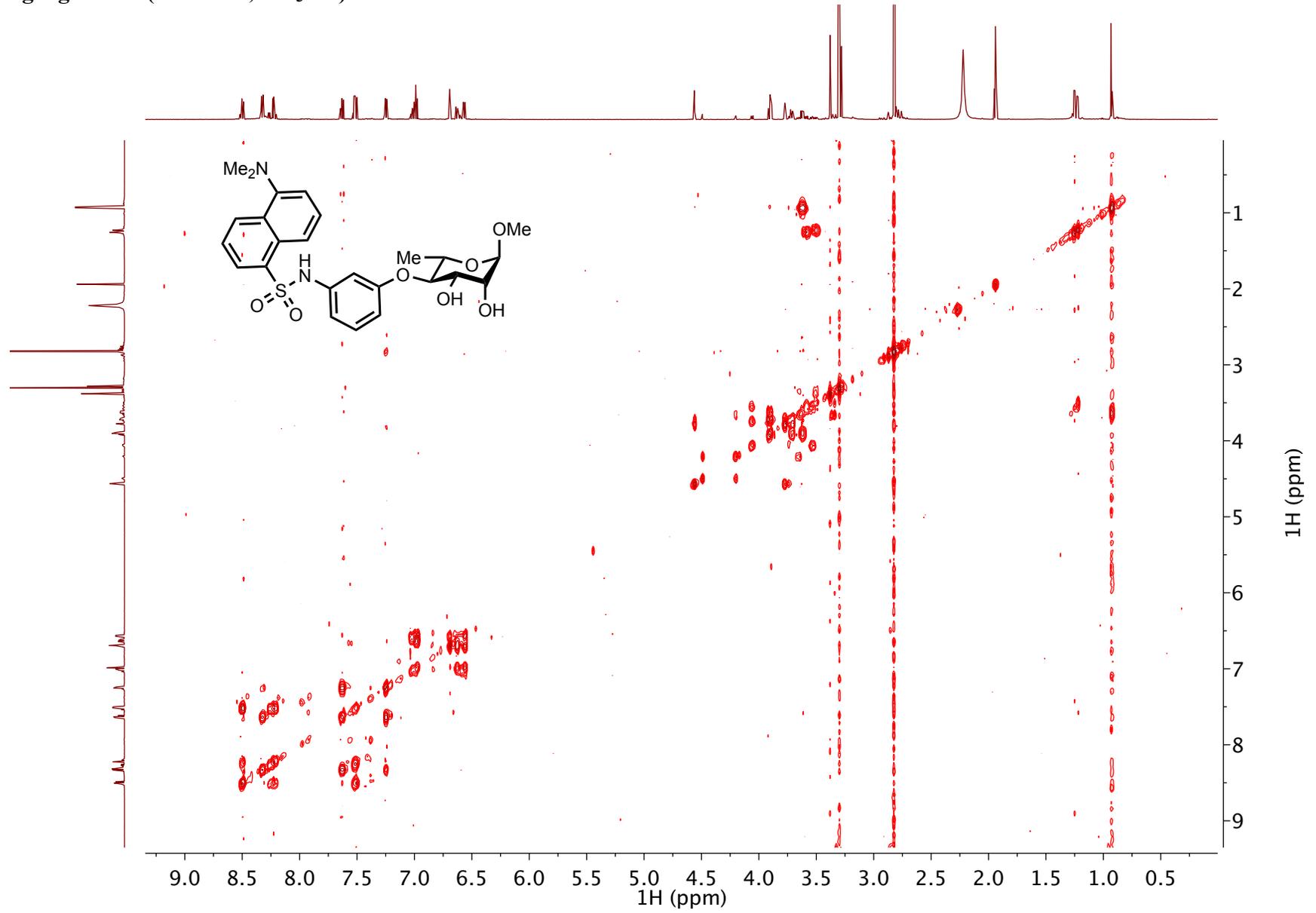
6f – gCOSY (400 MHz, CH<sub>3</sub>CN)

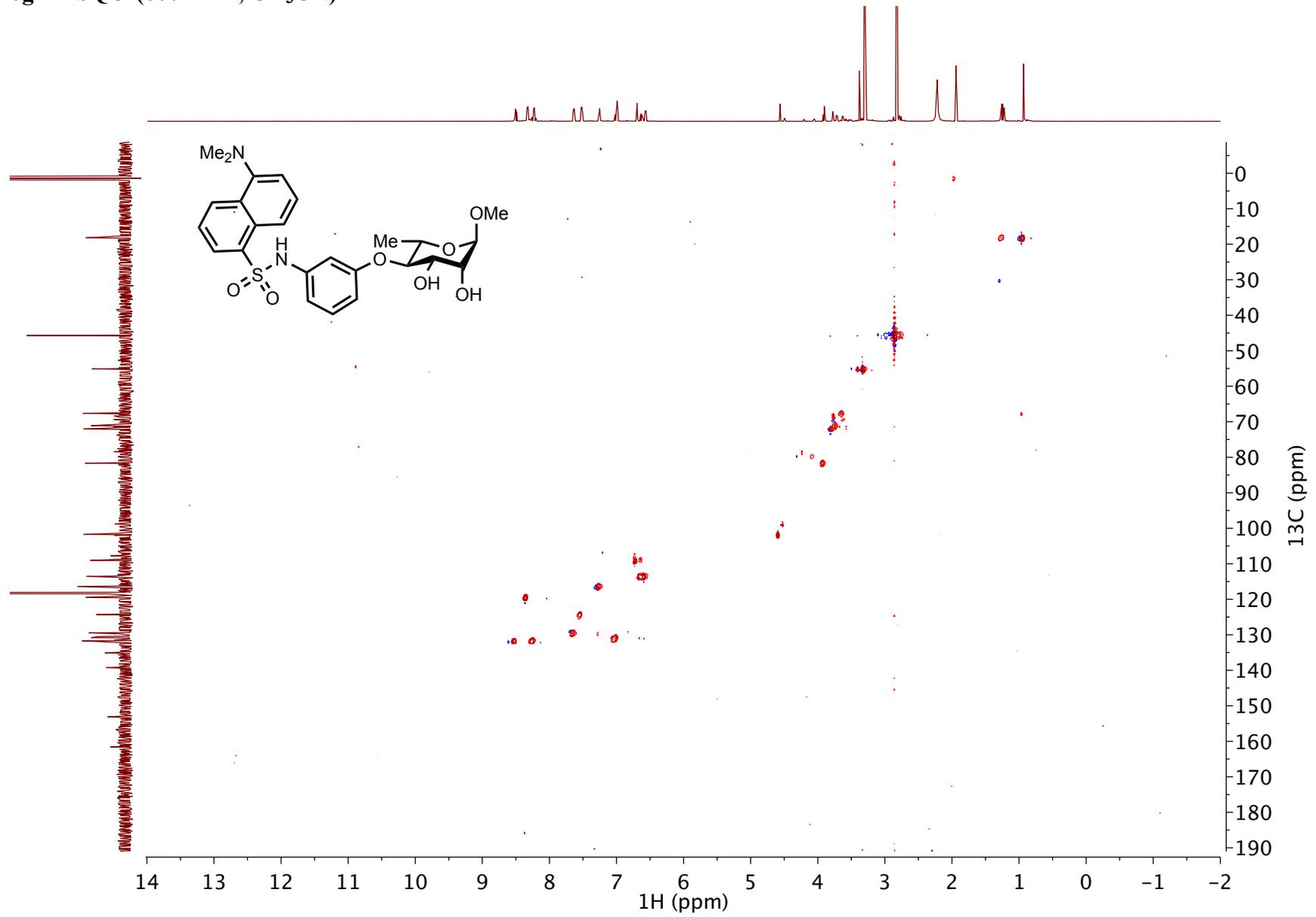
6f – HSQC (400 MHz, CH<sub>3</sub>CN)

6f – HMBC (400 MHz, CH<sub>3</sub>CN)



**6g** –  $^{13}\text{C}$  NMR (151 MHz,  $\text{CH}_3\text{CN}$ )

6g – gCOSY (600 MHz, CH<sub>3</sub>CN)

6g – HSQC (600 MHz, CH<sub>3</sub>CN)

6g – HMBC (600 MHz, CH<sub>3</sub>CN)