SUPPORTING INFORMATION

Taming of Furfurylidenes by Chiral Bismuth-Rhodium Paddlewheel Catalysts.

Preparation and Functionalization of Optically Active 1,1-Disubstituted (Trifluoromethyl)cyclopropanes

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Supporting Crystallographic Data

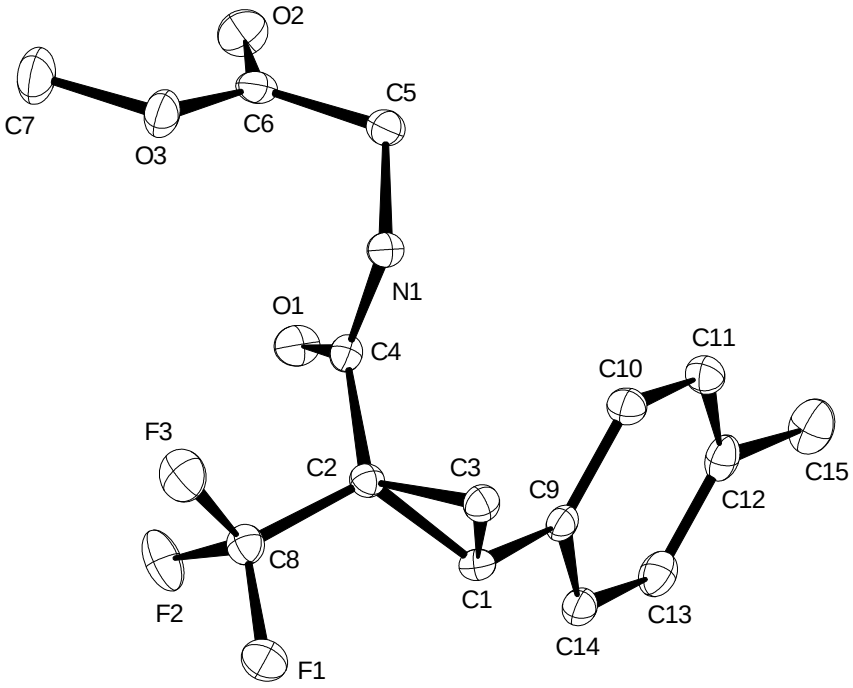


Figure S1. Structure of compound **12** in the solid state. Atomic displacement ellipsoids are shown at the 50% probability level; crystallographic numbering scheme

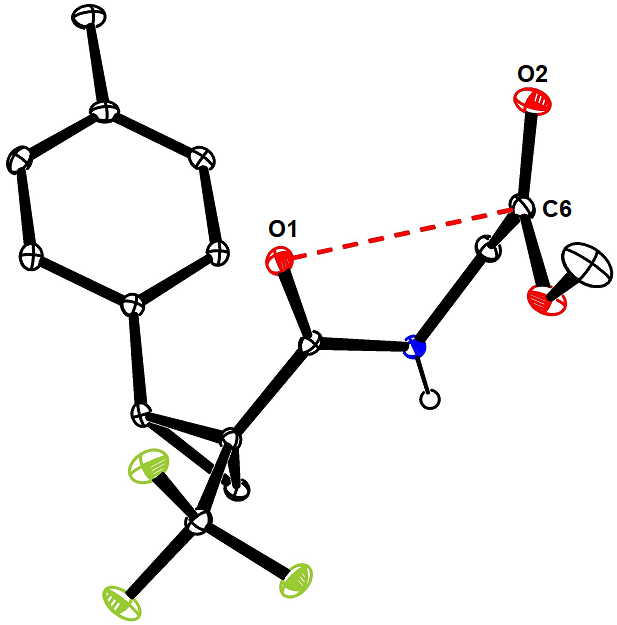
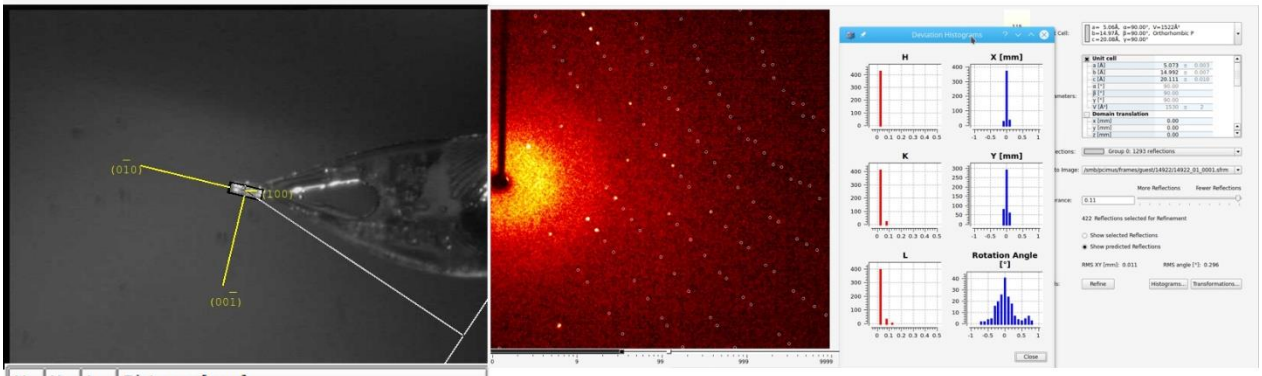


Figure S2. Different projection, which shows that the structure of compound **12** in the solid state is likely stabilized by a n→π* interaction[1] between the amide carbonyl group and the ester terminus; O1-C6 2.791Å, O1-C6-O2 107.4°

X-ray Crystal Structure Analysis of Compound 12: C_{15} H_{16} F_3 N O_3, M_r = 315.29 g mol^{-1}, colourless needle, crystal size 0.113 x 0.046 x 0.032 mm^3, orthorhombic, space group $P2_12_12_1$ [19], a = 5.0016(2) Å, b = 14.7658(8) Å, c = 19.8117(10) Å, V = 1463.15(12) Å^3, T = 100(2) K, Z = 4, D_{calc} = 1.431 g·cm^3, λ = 0.71073 Å, μ(*Mo-K*α) = 0.124 mm^{-1}, analytical absorption correction (T_{min} = 0.99, T_{max} = 1.00), Bruker-AXS Kappa Mach3 with APEX-II detector and IμS microfocus source, 1.720 < θ < 31.024°, 49169 measured reflections, 4666 independent reflections, 3892 reflections with $I > 2\sigma(I)$, R_{int} = 0.0528, absolute structure parameter = 0.1(2). The structure was solved by *SHELXT* and refined by full-matrix least-squares (*SHELXL*) against F^2 to R_1 = 0.035 [$I > 2\sigma(I)$], wR_2 = 0.077, 209 parameters. **CCDC 2287213**



H	K	L	Distance [mm]
0	-1	0	0.055
0	1	0	0.055
1	0	0	0.015
-1	0	0	0.010
0	0	1	0.015
0	0	-1	0.020

The quality of the dataset allowed for the experimental localization of the hydrogen atoms at C1 and N1. The other hydrogen atoms were refined in ideal positions.

To determine the absolute configuration, three different crystals were measured; the outcome was the same for each crystal.

INTENSITY STATISTICS FOR DATASET # 1 14922sadabs.raw

Resolution	#Data	#Theory	%Complete	Redundancy	Mean I	Mean I/s	Rmerge	Rsigma
Inf - 2.86	73	73	100.0	17.44	174.41	150.01	0.0159	0.0047
2.86 - 1.90	163	163	100.0	18.57	82.31	116.50	0.0202	0.0062
1.90 - 1.50	235	235	100.0	18.51	39.85	82.69	0.0314	0.0094
1.50 - 1.30	240	240	100.0	19.06	26.04	60.65	0.0436	0.0126
1.30 - 1.18	238	238	100.0	18.01	23.38	52.23	0.0531	0.0152
1.18 - 1.10	231	231	100.0	16.99	20.84	44.88	0.0616	0.0179
1.10 - 1.03	238	238	100.0	13.39	18.61	33.59	0.0732	0.0233
1.03 - 0.98	229	229	100.0	11.08	10.71	20.99	0.1069	0.0394
0.98 - 0.93	281	281	100.0	9.80	9.88	18.30	0.1153	0.0460
0.93 - 0.90	202	202	100.0	8.72	9.80	16.52	0.1231	0.0519
0.90 - 0.87	226	226	100.0	8.20	6.67	11.24	0.1563	0.0730
0.87 - 0.84	238	238	100.0	7.77	5.42	9.68	0.1869	0.0927
0.84 - 0.81	308	308	100.0	7.46	4.59	7.49	0.2172	0.1089
0.81 - 0.79	241	241	100.0	7.25	4.66	7.60	0.2121	0.1148
0.79 - 0.77	247	247	100.0	7.02	4.56	7.19	0.2260	0.1224
0.77 - 0.76	127	127	100.0	6.80	4.35	6.80	0.2424	0.1322
0.76 - 0.74	288	288	100.0	6.74	3.94	6.08	0.2582	0.1475
0.74 - 0.72	312	312	100.0	6.55	3.68	5.24	0.2885	0.1669
0.72 - 0.71	165	165	100.0	6.43	3.37	4.81	0.2918	0.1827

0.71 - 0.70	216	216	100.0	6.02	3.44	4.68	0.3049	0.1877
0.70 - 0.69	197	209	94.3	4.88	3.25	4.06	0.3144	0.2402
0.79 - 0.69	1552	1564	99.2	6.37	3.80	5.56	0.2695	0.1635
Inf - 0.69	4695	4707	99.7	10.49	15.98	26.76	0.0515	0.0318

Table S1. Crystal data and structure refinement.

Empirical formula	$C_{15}H_{16}F_3NO_3$	
Color	colourless	
Formula weight	315.29 $g \cdot mol^{-1}$	
Temperature	100(2) K	
Wavelength	0.71073 Å	
Crystal system	ORTHORHOMBIC	
Space group	**$P2_12_12_1$, (no. 19)**	
Unit cell dimensions	a = 5.0016(2) Å	α= 90°.
	b = 14.7658(8) Å	β= 90°.
	c = 19.8117(10) Å	γ = 90°.
Volume	1463.15(12) $Å^3$	
Z	4	
Density (calculated)	1.431 $Mg \cdot m^{-3}$	
Absorption coefficient	0.124 mm^{-1}	
F(000)	656 e	
Crystal size	0.113 x 0.046 x 0.032 mm^3	
θ range for data collection	1.720 to 31.024°.	
Index ranges	$-7 \le h \le 7$, $-21 \le k \le 21$, $-28 \le l \le 28$	
Reflections collected	49169	
Independent reflections	4666 [R_{int} = 0.0528]	
Reflections with I>2σ(I)	3892	
Completeness to θ = 25.242°	100.0 %	
Absorption correction	Gaussian	
Max. and min. transmission	1.00 and 0.99	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	4666 / 0 / 209	
Goodness-of-fit on F^2	1.025	
Final R indices [I>2σ(I)]	R_1 = 0.0353	wR^2 = 0.0714
R indices (all data)	R_1 = 0.0508	wR^2 = 0.0772
Absolute structure parameter	0.1(2)	
Largest diff. peak and hole	0.3 and -0.2 e $\cdot Å^{-3}$	

Bond lengths [Å] and angles [°].

F(1)-C(8)	1.336(2)	F(2)-C(8)	1.339(2)
F(3)-C(8)	1.3432(19)	O(1)-C(4)	1.229(2)
O(2)-C(6)	1.204(2)	O(3)-C(6)	1.333(2)
O(3)-C(7)	1.446(2)	N(1)-H(1)	0.84(2)
N(1)-C(4)	1.334(2)	N(1)-C(5)	1.448(2)
C(1)-H(1A)	0.94(2)	C(1)-C(2)	1.535(2)
C(1)-C(3)	1.504(2)	C(1)-C(9)	1.491(2)
C(2)-C(3)	1.500(2)	C(2)-C(4)	1.513(2)
C(2)-C(8)	1.493(2)	C(5)-C(6)	1.510(2)
C(9)-C(10)	1.397(2)	C(9)-C(14)	1.395(2)
C(10)-C(11)	1.387(2)	C(11)-C(12)	1.392(3)
C(12)-C(13)	1.389(3)	C(12)-C(15)	1.503(2)
C(13)-C(14)	1.384(2)		

C(6)-O(3)-C(7)	114.72(15)	C(4)-N(1)-H(1)	120.6(14)
C(4)-N(1)-C(5)	118.75(14)	C(5)-N(1)-H(1)	119.8(14)
C(2)-C(1)-H(1A)	112.8(12)	C(3)-C(1)-H(1A)	117.0(12)
C(3)-C(1)-C(2)	59.14(11)	C(9)-C(1)-H(1A)	113.5(12)
C(9)-C(1)-C(2)	121.42(14)	C(9)-C(1)-C(3)	122.38(14)
C(3)-C(2)-C(1)	59.41(11)	C(3)-C(2)-C(4)	121.13(14)
C(4)-C(2)-C(1)	118.08(14)	C(8)-C(2)-C(1)	118.07(14)
C(8)-C(2)-C(3)	117.02(14)	C(8)-C(2)-C(4)	113.16(13)
C(2)-C(3)-C(1)	61.45(11)	O(1)-C(4)-N(1)	121.84(15)
O(1)-C(4)-C(2)	121.63(15)	N(1)-C(4)-C(2)	116.52(14)
N(1)-C(5)-C(6)	114.27(14)	O(2)-C(6)-O(3)	124.40(16)
O(2)-C(6)-C(5)	123.16(16)	O(3)-C(6)-C(5)	112.37(14)
F(1)-C(8)-F(2)	106.57(14)	F(1)-C(8)-F(3)	106.50(14)
F(1)-C(8)-C(2)	112.76(14)	F(2)-C(8)-F(3)	105.77(14)
F(2)-C(8)-C(2)	113.67(14)	F(3)-C(8)-C(2)	111.05(14)
C(10)-C(9)-C(1)	123.96(15)	C(14)-C(9)-C(1)	118.08(15)
C(14)-C(9)-C(10)	117.95(15)	C(11)-C(10)-C(9)	120.55(16)
C(10)-C(11)-C(12)	121.58(16)	C(11)-C(12)-C(15)	121.63(17)
C(13)-C(12)-C(11)	117.49(16)	C(13)-C(12)-C(15)	120.83(17)
C(14)-C(13)-C(12)	121.55(16)	C(13)-C(14)-C(9)	120.88(16)

General

Unless stated otherwise, all reactions were carried out under argon atmosphere in flame-dried Schlenk glassware, ensuring inert conditions. The solvents were purified by distillation over the indicated drying agents and were transferred under argon: THF, Et_2O (Mg/anthracene); pentane, toluene (Na/K); CH_2Cl_2, chlorobenzene (CaH_2). MeCN, Et_3N and DMF were dried by an absorption solvent purification system based on molecular sieves. *t*-BuOH was dried over 3 Å molecular sieves. Flash chromatography: Merck Geduran silica gel 60 (40 – 63 μm). Preparative TLC plates: Macherey-Nagel 1.00 mm silica gel 60 coated plate with fluorescent indicator UV_{254}.

NMR spectra were recorded on Bruker DPX 300, AV 400, AV 500 or AV III 600 spectrometers in the solvents indicated; chemical shifts are given in ppm relative to TMS, coupling constants (*J*) in Hz. The solvent signals were used as references and the chemical shifts converted to the TMS scale ($CDCl_3$: δ_C = 77.2 ppm; residual $CHCl_3$: δ_H = 7.26 ppm; CD_2Cl_2: δ_C = 54.0 ppm; residual $CHDCl_2$: δ_H = 5.32 ppm; CD_3CN: δ_C = 1.3, 118.3 ppm; residual CHD_2CN: δ_H = 1.94 ppm). Signal assignments were established using HSQC, HMBC, NOESY and HOESY experiments.

IR: Alpha Platinum ATR (Bruker), wavenumbers ($\tilde{\nu}$) in cm^{-1}; medium and weak resonances are omitted.

MS (EI): Finnigan MAT 8200 (70 eV), ESI-MS: ESQ 3000 (Bruker) or Thermo Scientific LTQ-FT or Thermo Scientific Exactive Spectrometer. HRMS: Bruker APEX III FT-MS (7 T magnet), MAT 95 (Finnigan), Thermo Scientific LTQ-FT or Thermo Scientific Exactive Spectrometer. GC-MS spectra were measured on a Shimadzu GCMS-QP2010 Ultra instrument.

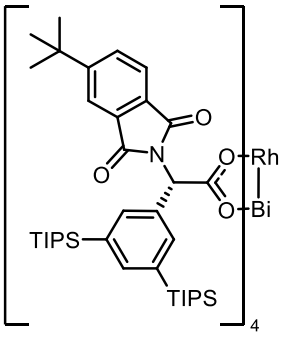
LC analyses were conducted on a Shimadzu LC 2020 instrument equipped with a Shimadzu SPD-M20A UV/VIS detector. GC analyses were conducted on an Agilent technologies 7890B instrument with a FID detector.

Melting points were measured on a Büchi B-540 (uncalibrated). Optical rotations were measured with an A-Krüss Otronic Model P8000-t polarimeter at a wavelength of 589 nm. The values are given as specific optical rotation with exact temperature, concentration (c in g/100 mL) and solvent.

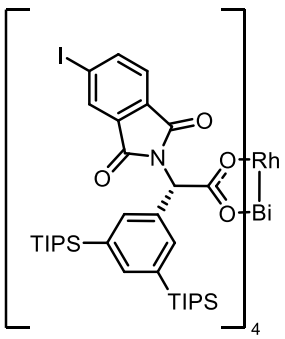
Unless stated otherwise, all commercially available compounds (abcr, Acros, Aldrich, Alfa Aesar, FluoroChem, Strem, TCI) were used as received.

Boc-protected 2-vinylpyrrole[2] and *o*-trifluoromethylbenzenesulfonyl hydrazide ($TfsNHNH_2$)[3] were prepared according to the literature.

The following heterobimetallic paddlewheel catalysts were prepared as previously described by our laboratory.[4,5]



7a



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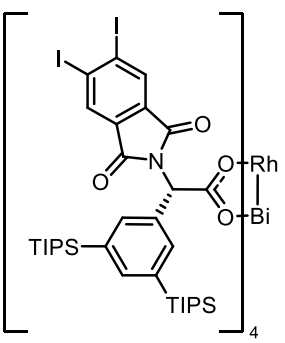


7c

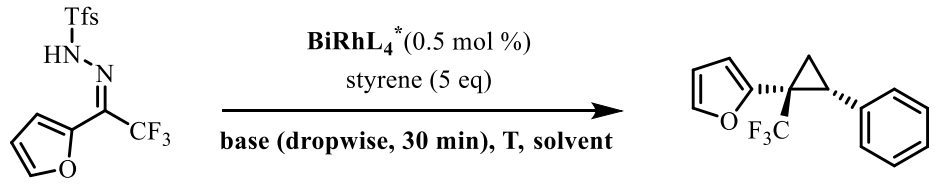
Substrates

2,2,2-Trifluoro-1-(furan-2-yl)ethan-1-one (S1). *n*-BuLi (1.6 M solution in hexanes, 27.5 mL, 44 mmol) was added dropwise over 20 min to a stirred solution of furan (2.90 mL, 40 mmol) in THF (80.0 mL) at 0 °C (ice bath). Once the addition was complete, stirring was continued for 30 min before the solution was cooled to –78 °C. Ethyl trifluoroacetate (7 mL, 58 mmol) was added dropwise at this temperature to the reaction mixture. The solution was then allowed to warm to ambient temperature and stirring was continued overnight. The reaction was quenched with sat. aq. NH_4Cl and the aqueous layer was extracted with diethyl ether. The combined organic phases were dried over $MgSO_4$, filtered and concentrated. The residue was purified by flash chromatography (hexanes/EtOAc 95:5) to afford the title compound as a yellow oil (53 %, 3.5 g). The spectral data were consistent with those previously reported in literature.[6]

N'-(2,2,2-Trifluoro-1-(furan-2-yl)ethylidene)-2-(trifluoromethyl)benzenesulfonohydrazide (8). A round bottom flask was charged with trifluoromethyl ketone **S1** (5.4 g, 31.55 mmol) and trifluorotoluene (TFT):EtOAc (30:1, 62 mL). *o*-Trifluoromethylbenzenesulfonyl hydrazide ($TfsNHNH_2$, 6.3 g, 26.3 mmol) and $Et_2O{\bullet}BF_3$ (3.9 mL, 31.55 mmol) were then added and the resulting mixture was stirred at room temperature until a clear solution had formed (~2 h). The mixture was then stirred at 40 °C (bath temperature) for 16 h. The mixture was concentrated under reduced pressure and the residue was purified by flash chromatography (hexane/EtOAc, 6:1) to give a brown solid. The solid was recrystallized from hexane/EtOAc to afford the title compound as a crystalline white solid material (5.77 g, 57 %). M.p. = 142-143°C. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 10.37 (s, 1H), 8.47 – 8.37 (m, 1H), 7.94 – 7.84 (m, 1H), 7.83 – 7.68 (m, 3H), 6.88 (ddt, *J* = 3.7, 1.8, 0.9 Hz, 1H), 6.62 (dd, *J* = 3.8, 1.8 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 145.5, 144.0, 136.3, 134.0, 133.7, 132.7, 128.8 (d, *J* = 35.7 Hz), 128.6 (q, *J* = 6.3 Hz), 128.1 (d, *J* = 33.1 Hz), 122.9 (q, *J* = 273.8 Hz), 120.0 (q, *J* = 275.0 Hz), 116.2 (q, *J* = 2.6 Hz), 112.4. ^{19}F NMR (282 MHz, $CDCl_3$) δ = –68.3, –66.4; IR (ATR): ṽ = 3317, 1394, 1361, 1309, 1274, 1243, 1181, 1148, 1119, 1082, 1033, 997, 864, 759, 583, 562 cm^{-1}; HRMS (ESI$^+$) for $[M+Na]^+$: calcd: 409.00520, found: 409.00546.

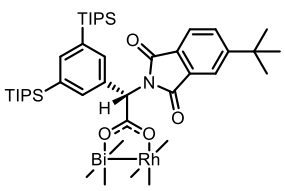
N'-(1-(Benzofuran-2-yl)-2,2,2-trifluoroethylidene)-2-(trifluoromethyl)benzenesulfonohydrazide (10). Prepared analogously from 1-(benzofuran-2-yl)-2,2,2-trifluoroethan-1-one.[7] Purification by flash chromatography (hexane/EtOAc, 8:1 to 6:1) afforded the desired product as a yellow solid. The yellow impurity was removed by washing the product thrice with ice-cold pentane to leave the title compound as a white solid (133 mg, 41%). M.p. = 173-174 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.74 (s, 1H), 8.49 – 8.39 (m, 1H), 7.94 – 7.86 (m, 1H), 7.83 – 7.74 (m, 2H), 7.69 (ddd, *J* = 7.8, 1.3, 0.7 Hz, 1H), 7.52 (ddd, *J* = 8.5, 7.2, 1.3 Hz, 1H), 7.38 (ddd, *J* = 8.1, 7.2, 1.0 Hz, 1H), 7.22 (qd, *J* = 1.8, 0.9 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 154.8, 144.4, 136.3, 134.0, 133.6, 132.8, 128.7 (q, *J* = 6.3 Hz), 128.3, 126.0, 125.0, 123.0 (q, *J* = 274.4 Hz), 121.1 (q, *J* = 275.7 Hz), 112.4 (q, *J* = 2.6 Hz), 111.9. ^{19}F NMR (282 MHz, $CDCl_3$) δ –58.3, –66.0. IR (ATR): ṽ = 1387, 1341, 1308, 1271, 1251, 1177, 1160, 1141, 1086, 1037, 1007, 862, 751, 728, 584, 561 cm^{-1}. HRMS (ESI$^+$) for $[M+H]^+$: calcd: 437.03891, found: 437.03874.

Screening results



#	Catalyst	Solvent	Base	T (°C)	Yield % (^{1}H NMR)	% *ee*
1	**7a**	C_6F_6	DIPEA	r.t.	36	90
2	**7a**	pentane	DIPEA	r.t.	(<5)	nd
3	**7a**	DCM	DIPEA	r.t.	59 (60)	89
4	**7a**	DCM	DBU	r.t.	52	89
5	**7a**	DCM	DIPEA	-10	0	nd
6	**7a**	DCM	DIPEA	40	95	88
7	**7b**	DCM	DIPEA	40	75	90
8	**7c**	DCM	DIPEA	40	74	91
9	**7c**	DCM	DIPEA	r.t.	84	92
10	**7c**	DCE	DIPEA	r.t.	46	92
11	**7c**	Toluene	DIPEA	r.t.	52	92
12	**7c**	DCM	DIPEA	10	(60)	93

Screening reactions were performed on a 0.1 mmol scale. Yields in brackets are determined via crude ^{1}H NMR analysis with triphenylmethane as internal standard. All other yields are isolated yields.



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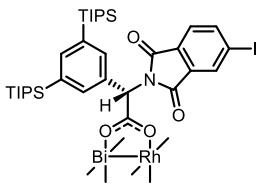

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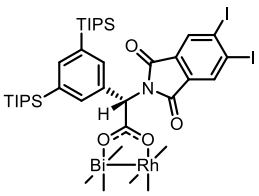
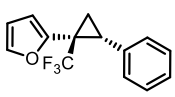


7c

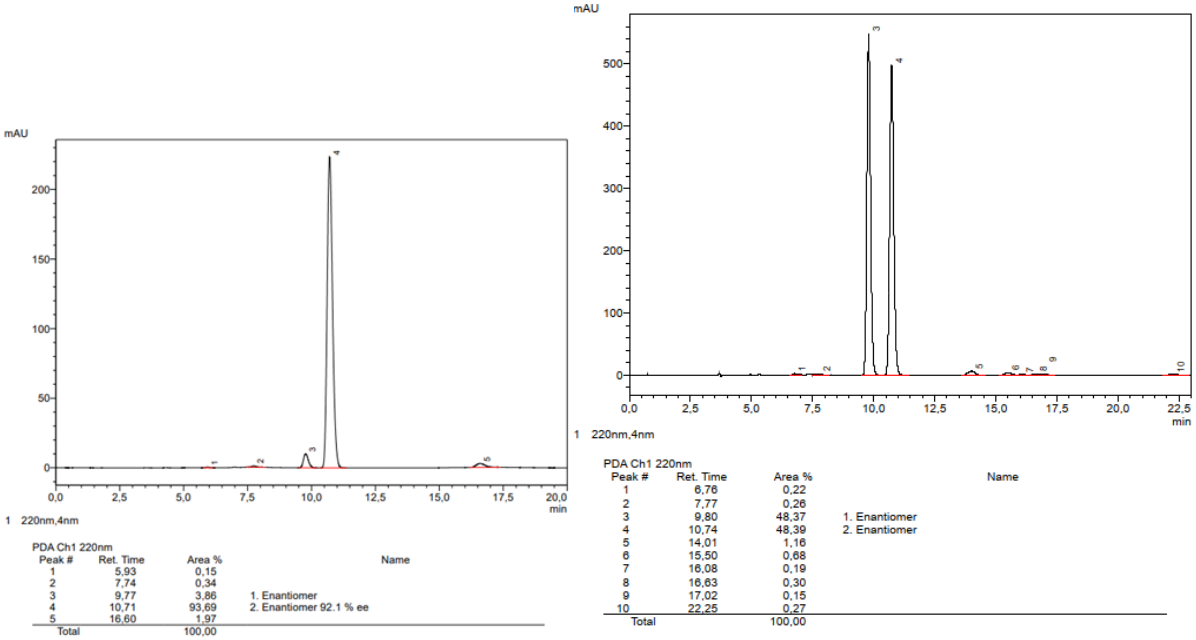
[BiRh] Catalyzed [2+1] Cycloaddition Reactions

General Procedure. An oven-dried Schlenk flask equipped with a magnetic stir bar was charged with the bismuth-rhodium paddlewheel complex **7c** (0.5 mol %) under argon. Alkene or alkyne (0.45-0.9 mmol), the triftosylhydrazone (0.09 mmol) and CH_2Cl_2 (1 mL) were added and the resulting mixture was stirred at room temperature. A solution of diisopropylethylamine (0.18 mmol) in CH_2Cl_2 (3 mL) was added dropwise over 0.5 h. The resulting mixture was stirred until TLC showed complete consumption of the hydrazone (ca. 16-20 h). The mixture was concentrated and the residue purified by either flash chromatography or preparative thin layer chromatography to obtain the cyclopropane or cyclopropene product.

The corresponding racemates were prepared analogously using $Rh_2(esp)_2$ (2 mol%) as the catalyst.

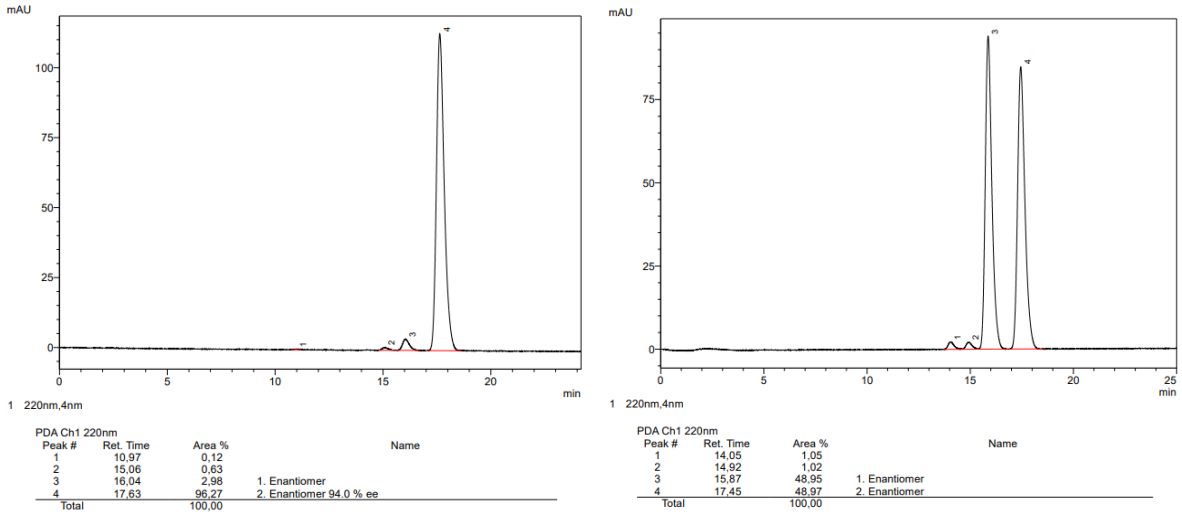


2-((1*S*,2*R*)-2-Phenyl-1-(trifluoromethyl)cyclopropyl)furan (3a). Prepared according to the general procedure with 0.45 mmol of styrene. Purification by flash chromatography (hexanes/ *tert*-butyl methyl ether, 98:2) afforded the title compound as a colorless liquid (19.5 mg, 85% yield, 92% *ee*). [The *ee* was determined by HPLC analysis: Daicel 150 mm Chiralcel OJ-3R, Ø 4.6 mm, acetonitrile/water = 60/40, v = 0.5 mL/min, λ = 220 nm, t(minor) = 9.81 min, t(major) = 10.75 min]. $[\alpha]_D^{20}$ = –23.1 (c = 0.43, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.21 (dd, *J* = 1.9, 0.8 Hz, 1H), 7.20 – 7.08 (m, 3H), 7.04 – 6.88 (m, 2H), 6.17 (dd, *J* = 3.3, 1.9 Hz, 1H), 6.10 (dd, *J* = 3.3, 0.8 Hz, 1H), 2.86 (dd, *J* = 9.5, 7.3 Hz, 1H), 1.96 – 1.89 (m, 1H), 1.85 (dd, *J* = 9.5, 6.0 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$): δ = 142.8, 135.2, 128.1 (2C), 127.0, 125.23 (q, *J* = 274.0 Hz), 112.2, 110.6, 29.7 (d, *J* = 34.8 Hz), 27.2 (d, *J* = 2.0 Hz), 14.0 (d, *J* = 2.3 Hz). ^{19}F NMR (282 MHz, $CDCl_3$) δ –69.4; IR (ATR): ṽ = 3033, 2865, 1501, 1334, 1288, 1138, 1054, 1014, 740, 695 cm^{-1}; HRMS (ESI$^+$) for $[M+H]^+$: calcd: 252.07565, found: 252.07605.



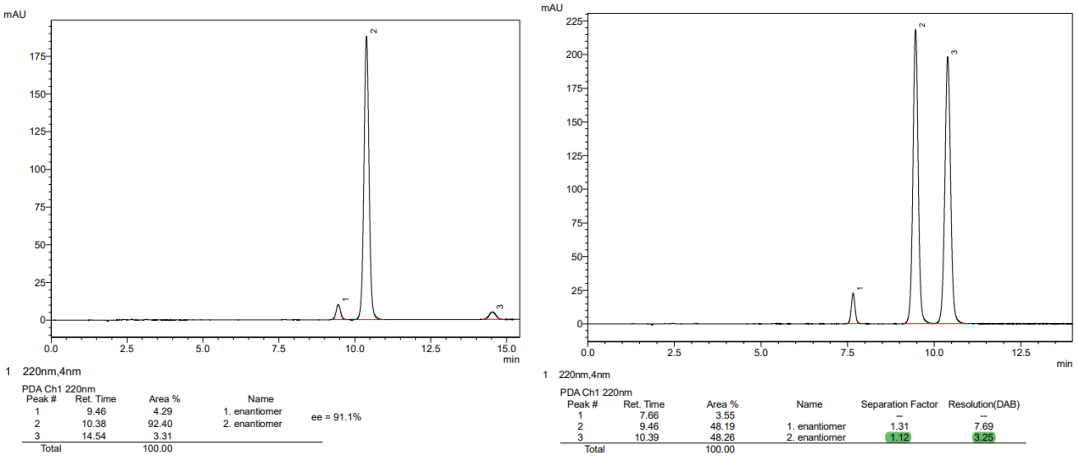
HPLC traces of **3a** (left) and the corresponding racemate (right).

2-((1*S*,2*R*)-2-(*p*-Tolyl)-1-(trifluoromethyl)cyclopropyl)furan (3b). Prepared according to the general procedure with 0.9 mmol of 4-methylstyrene. Purification by flash chromatography (pentane:EtOAc, 75:1) afforded the title compound as a colorless oil (19.9 mg, 83%, 94% *ee*). [The *ee* was determined by HPLC analysis: 150 mm Chiralpak OJ-3R, Ø 4.6 mm i.D., acetonitrile/water = 50:50, v = 1.0 mL/min, λ = 220 nm, t(minor) = 16.04 min, t(major) = 17.63 min]. $[\alpha]_D^{20}$ = –58.1 (c = 1.2, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.23 (dd, *J* = 1.9, 0.9 Hz, 1H), 7.01 – 6.94 (m, 2H), 6.89 – 6.81 (m, 2H), 6.18 (dd, *J* = 3.3, 1.9 Hz, 1H), 6.11 (dd, *J* = 3.3, 0.8 Hz, 1H), 2.83 (dd, *J* = 9.6, 7.3 Hz, 1H), 2.26 (s, 3H), 1.88 (ddq, *J* = 7.5, 6.0, 1.6 Hz, 1H), 1.83 (dd, *J* = 9.5, 6.0 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 146.4, 142.7, 136.6, 128.8 (2C), 128.0 (2C), 125.4 (q, *J* = 274.6 Hz), 112.2, 110.6, 29.5 (q, *J* = 34.6 Hz), 26.9 (q, *J* = 2.0 Hz), 21.15, 14.0 (q, *J* = 2.3 Hz). ^{19}F NMR (282 MHz, $CDCl_3$) δ –69.4. IR (ATR): ṽ = 1333, 1291, 1223, 1140, 1059, 1014, 840, 809, 740 cm^{-1}. HRMS (EI) for $[M]^+$: calcd: 266.09130, found: 266.09153.



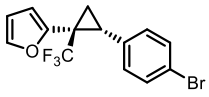
HPLC traces of **3b** (left) and corresponding the racemate (right).

2-((1*S*,2*R*)-2-(4-Methoxyphenyl)-1-(trifluoromethyl)cyclopropyl)furan (3c). Prepared according to the general procedure with 0.45 mmol of 4-methoxystyrene. Purified by preparative TLC (pentane:EtOAc, 90:10) as a pale yellow oil (20.1 mg, 80%, 91% *ee*). [The *ee* was determined by HPLC analysis: 150 mm YMC Cellulose SJ-3, Ø 4.6 mm, acetonitrile/Water = 50:50 v = 1.0 mL/min, λ = 220 nm, t(minor) = 9.46 min, t(major) = 10.38 min]. $[\alpha]_D^{20}$ = –63.7 (c = 1.0, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.22 (dd, *J* = 1.9, 0.8 Hz, 1H), 6.93 – 6.83 (m, 2H), 6.74 – 6.66 (m, 2H), 6.18 (dd, *J* = 3.3, 1.9 Hz, 1H), 6.10 (dd, *J* = 3.3, 0.8 Hz, 1H), 3.74 (s, 3H), 2.81 (dd, *J* = 9.5, 7.4 Hz, 1H), 1.89 – 1.77 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 158.7, 146.4, 142.7, 129.2, 127.2, 125.3 (q, *J* = 273.8 Hz), 113.6, 112.1, 110.6, 55.3, 29.4 (q, *J* = 34.6 Hz), 26.6 (q, *J* = 2.1 Hz), 14.0 (q, *J* = 2.3 Hz). ^{19}F NMR (282 MHz, $CDCl_3$) δ –69.3. IR (ATR): ṽ = 1517, 1333, 1287, 1249, 1223, 1178, 1134, 1058, 1034, 1014, 848, 807, 740 cm^{-1}; HRMS (EI) for $[M]^+$: calcd: 282.08622, found: 282.08657.

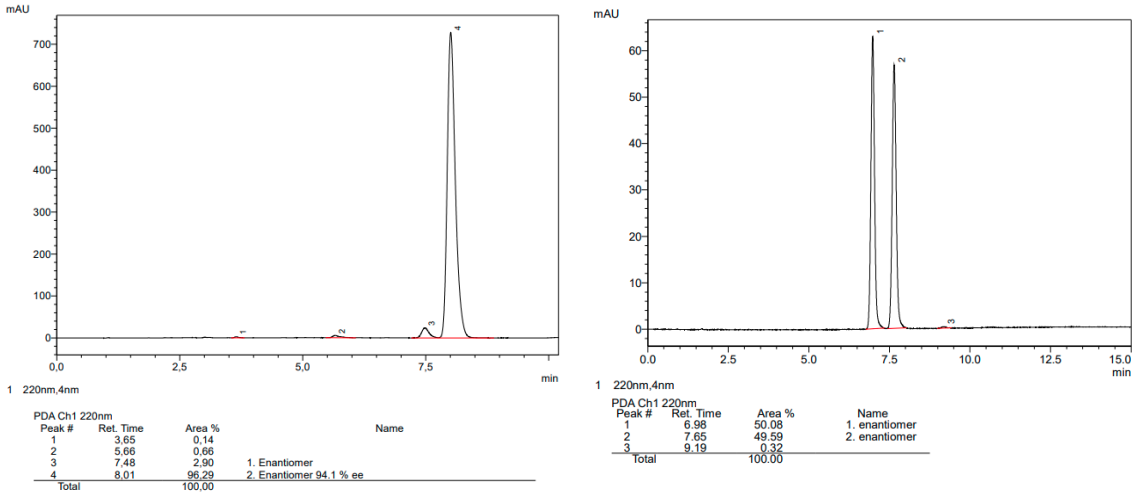


HPLC traces of **3c** (left) and the corresponding racemate (right).

2-((1*S*,2*R*)-2-(4-Bromophenyl)-1-(trifluoromethyl)cyclopropyl)furan (3d). Prepared according to

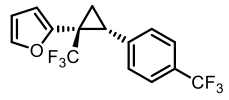


the general procedure with 0.9 mmol of 4-bromostyrene. Purification by flash chromatography (pentane:EtOAc, 75:1) afforded the title compound as a pale yellow oil (22 mg, 73%, 94% *ee*) which contained a small amount of an unknown impurity. An analytically pure sample was obtained via preparatory HPLC. [The *ee* was determined by HPLC analysis: 150 mm Chiralpak OJ-3R, Ø 4.6 mm i.D.; acetonitrile/water = 60:40, v = 1.0 mL/min, λ = 220 nm, t(minor) = 6.98 min, t(major) = 7.65 min]. $[\alpha]_D^{20}$ = –42.5 (c =1.4, $CHCl_3$). ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.30 – 7.27 (m, 2H), 7.22 (dd, *J* = 1.8, 0.8 Hz, 1H), 6.85 – 6.81 (m, 2H), 6.19 (dd, *J* = 3.3, 1.8 Hz, 1H), 6.13 (dd, *J* = 3.3, 0.8 Hz, 1H), 2.80 (dd, *J* = 9.3, 7.4 Hz, 1H), 1.87 (ddq, *J* = 7.4, 6.2, 1.4 Hz, 1H), 1.86 (dd, *J* = 9.4, 6.2 Hz, 1H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 125.10 (q, *J* = 274.2 Hz), 29.74 (q, *J* = 34.8 Hz), 26.62 (q, *J* = 2.2 Hz), 14.14 (q, *J* = 2.3 Hz). ^{19}F NMR (565 MHz, $CDCl_3$) δ –69.5 (d, *J* = 1.4 Hz). IR (ATR): ṽ =1493, 1381, 1333, 1294, 1224, 1213, 1152, 1115, 1076, 1056, 1012, 843, 813, 742 cm^{-1}. HRMS (EI) for $[M]^+$: calcd: 329.98618, found: 329.98622.

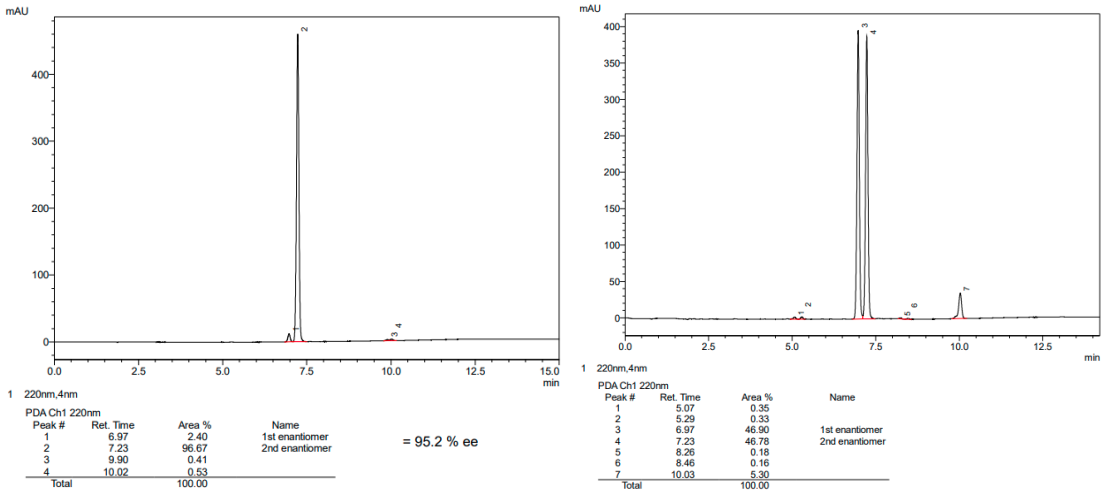


HPLC traces of **3d** (left) and the corresponding racemate (right).

2-((1*S*,2*R*)-1-(Trifluoromethyl)-2-(4-(trifluoromethyl)phenyl)cyclopropyl)furan (3e). Prepared

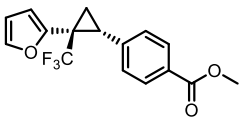


according to the general procedure with 0.9 mmol of 4-(trifluoromethyl)styrene. Purification by flash chromatography (pentane:EtOAc, 75:1) afforded the title compound as a colorless oil (18 mg, 62%, 95% *ee*). [The *ee* was determined by HPLC analysis: 150 mm Chiralpak OJ-3R, Ø 4.6 mm i.D., acetonitrile/water gradient: 50 % to 70 % in 10 min, v = 1.0 mL/min, λ = 220 nm, t(minor) = 6.97 min, t(major) = 7.23 min]. $[\alpha]_D^{20}$ = –48.5 (c = 0.4, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 (d, *J* = 7.9 Hz, 2H), 7.21 (dd, *J* = 1.9, 0.8 Hz, 1H), 7.06 (d, *J* = 7.2 Hz, 2H), 6.19 (dd, *J* = 3.3, 1.9 Hz, 1H), 6.15 (dd, *J* = 3.3, 0.8 Hz, 1H), 2.89 (dd, *J* = 9.4, 7.3 Hz, 1H), 2.00 – 1.86 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 145.6, 143.1, 139.5, 129.3 (q, *J* = 32.6 Hz) 128.4 (2C), 125.0 (q, *J* = 3.6 Hz, 2C), 124.6 (q, *J* = 274.2 Hz), 124.3 (q, *J* = 271.8 Hz), 112.6, 110.7, 30.1 (q, *J* = 35.1 Hz), 26.8 (q, *J* = 2.1 Hz), 14.4 (q, *J* = 2.3 Hz). ^{19}F NMR (282 MHz, $CDCl_3$) δ –62.5, –69.6. IR (ATR): ṽ = 1324, 1289, 1219, 116, 1070, 1058, 1017, 851, 742 cm^{-1}. HRMS (EI) for $[M]^+$: calcd: 320.06304, found: 320.06360.

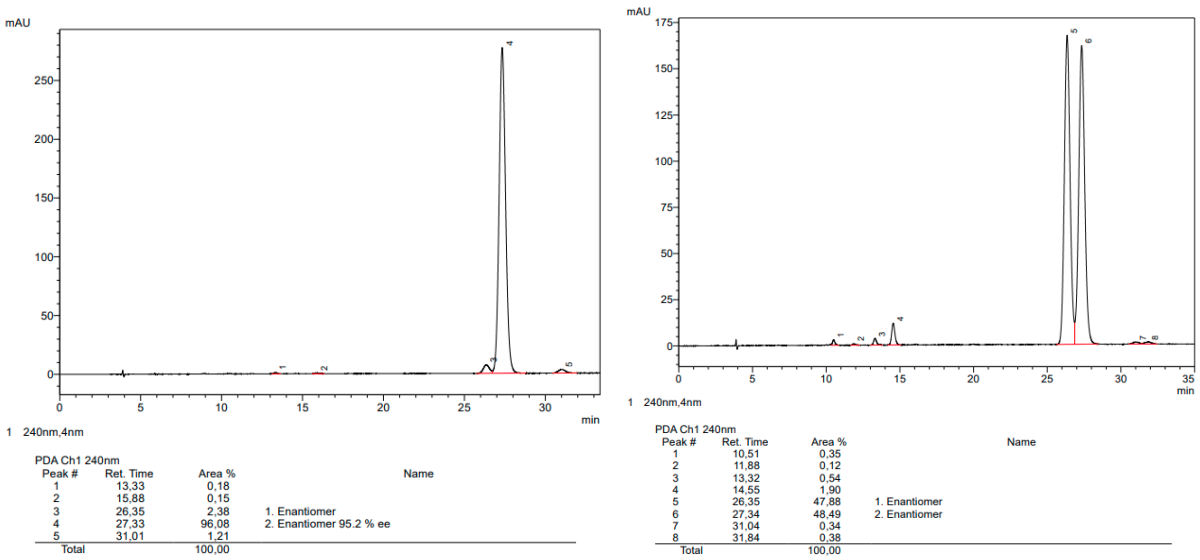


HPLC traces of **3e** (left) and the corresponding racemate (right).

Methyl 4-((1*R*,2*S*)-2-(furan-2-yl)-2-(trifluoromethyl)cyclopropyl)benzoate (3f). Prepared according

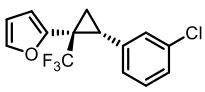


to the general procedure with 0.9 mmol of the alkene. Purification by flash chromatography (pentane:EtOAc, 40:1 to 30:1) afforded the title compound as a pale yellow oil (19.6 mg, 70%, 95% *ee*). [The *ee* was determined by HPLC analysis: 150 mm Chiralcel IB-N3, Ø 4.6 mm i.D., acetonitrile/water = 50:50, v = 1.0 mL / min, λ = 240 nm, t(minor) = 26.35 min, t(major) = 27.33 min]. $[\alpha]_D^{20}$ = –72.3 (c = 0.2, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.87 – 7.79 (m, 2H), 7.19 (dd, *J* = 1.8, 0.8 Hz, 1H), 7.06 – 6.97 (m, 2H), 6.16 (dd, *J* = 3.3, 1.8 Hz, 1H), 6.12 (dd, *J* = 3.3, 0.8 Hz, 1H), 3.87 (s, 3H), 2.89 (dd, *J* = 9.4, 7.3 Hz, 1H), 1.97 (ddq, *J* = 7.6, 6.2, 1.6 Hz, 1H), 1.90 (dd, *J* = 9.4, 6.2 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 167.0, 145.7, 143.0, 140.7, 129.4 (2C), 128.9, 128.1 (2C), 125.1 (q, *J* = 274.2 Hz), 112.47, 110.67, 52.18, 30.16 (q, *J* = 35.1 Hz), 27.04 (q, *J* = 2.3 Hz), 14.34 (q, *J* = 2.3 Hz). ^{19}F NMR (282 MHz, $CDCl_3$) δ –69.6. IR (ATR): ṽ = 1718, 1332, 1277, 1217, 1183, 1139, 1111, 1058, 1016, 743, 716 cm^{-1}. HRMS (EI) for $[M]^+$: calcd: 310.08113, found: 310.08133.

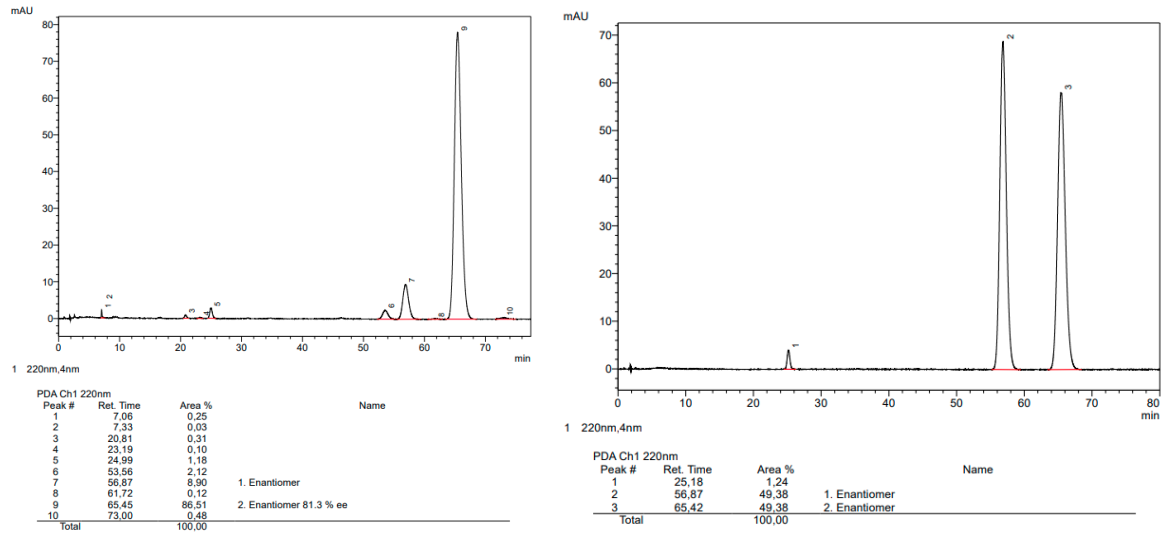


HPLC traces of **3f** (left) and the corresponding racemate (right).

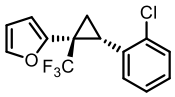
2-((1*S*,2*R*)-2-(3-Chlorophenyl)-1-(trifluoromethyl)cyclopropyl)furan (3g). Prepared according to

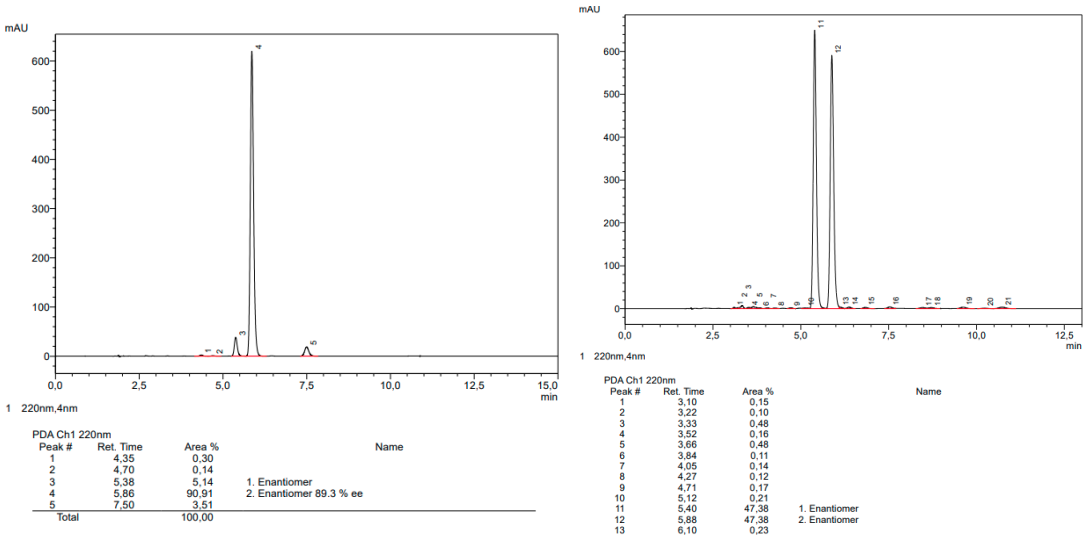


the general procedure with 0.9 mmol of the alkene. Purification by flash chromatography (pentane:EtOAc, 75:1) afforded the title compound as a yellow oil (18.4 mg, 71%, 81% *ee*). [The *ee* was determined by HPLC analysis: 150 mm Chiralpak OJ-3R, Ø 4.6 mm i.D., acetonitrile/water = 40:60 v = 1.0 mL / min, λ = 220 nm, t(minor) = 56.87 min, t(major) = 65.45 min]. $[\alpha]_D^{20}$ = –45.4 (c =0.9, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.22 (dd, *J* = 1.8, 0.8 Hz, 1H), 7.16 – 7.04 (m, 2H), 6.96 (t, *J* = 1.9 Hz, 1H), 6.88 – 6.81 (m, 1H), 6.20 (dd, *J* = 3.3, 1.9 Hz, 1H), 6.15 (dd, *J* = 3.4, 0.8 Hz, 1H), 2.82 (dd, *J* = 9.4, 7.3 Hz, 1H), 1.95 – 1.82 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 145.7, 143.0, 137.4, 134.0, 129.3, 128.4, 127.3, 126.3, 125.0 (q, *J* = 273.8 Hz), 112.4, 110.7, 29.9 (q, *J* = 35.5 Hz), 26.7 (q, *J* = 2.3 Hz), 14.1 (q, *J* = 2.3 Hz).^{19}F NMR (282 MHz, $CDCl_3$) δ –69.5. IR (ATR): ṽ = 1391, 1332, 1300, 1223, 1152, 1082, 1062, 1015, 814, 784, 742, 690 cm^{-1}. HRMS (EI) for $[M]^+$: calcd: 286.03668, found: 286.03656.

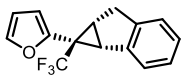


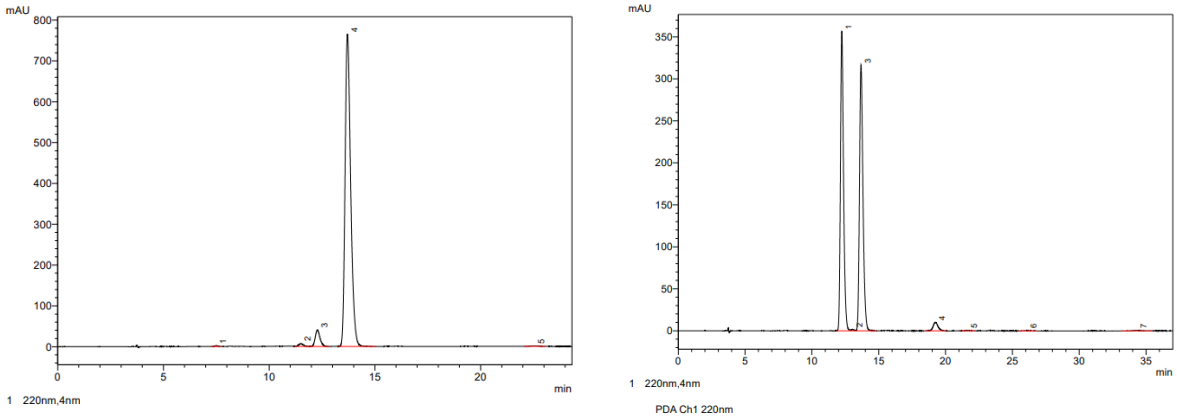
HPLC traces of **3g** (left) and the corresponding racemate (right).

2-((1*S*,2*S*)-2-(2-Chlorophenyl)-1-(trifluoromethyl)cyclopropyl)furan (3h).  Prepared according to the general procedure with 0.9 mmol of the alkene. Purification by flash chromatography (pentane:EtOAc, 75:1) afforded the title compound as a pale yellow oil (20 mg, 77%, 89% *ee*). [The *ee* was determined by HPLC analysis: 150 mm Chiralpak OJ-3R, Ø 4.6 mm i.D., acetonitrile/water = 60:40 v = 1.0 mL / min, λ = 220 nm, t(minor) = 5.38 min, t(major) = 5.86 min]. $[\alpha]_D^{20}$ = –118.5 (c = 0.8, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.33 (dd, *J* = 7.9, 1.3 Hz, 1H), 7.14 (dd, *J* = 0.9, 0.8 Hz, 2H), 7.10 (td, *J* = 7.7, 6.1 Hz, 1H), 7.03 (td, *J* = 7.5, 1.3 Hz, 1H), 6.18 (d, *J* = 3.1 Hz, 1H), 6.11 (dd, *J* = 3.3, 1.9 Hz, 1H), 3.06 (dd, *J* = 9.4, 7.4 Hz, 1H), 2.04 (ddd, *J* = 7.5, 6.1, 1.4 Hz, 1H), 1.86 (dd, *J* = 9.4, 6.2 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 145.8, 142.5, 136.2, 133.2, 129.3, 128.5, 128.4, 126.4, 125.2 (q, *J* = 274.4 Hz), 111.6, 110.7, 29.5 (q, *J* = 35.1 Hz), 26.1 (q, *J* = 2.2 Hz), 12.8 (q, *J* = 2.1 Hz). ^{19}F NMR (282 MHz, $CDCl_3$) δ –69.4. IR (ATR): ṽ = 1390, 1333, 1298, 1212, 1149, 1063, 1053, 1014, 754, 740 cm^{-1}. HRMS (EI) for $[M]^+$: calcd: 286.03668, found: 286.03672.



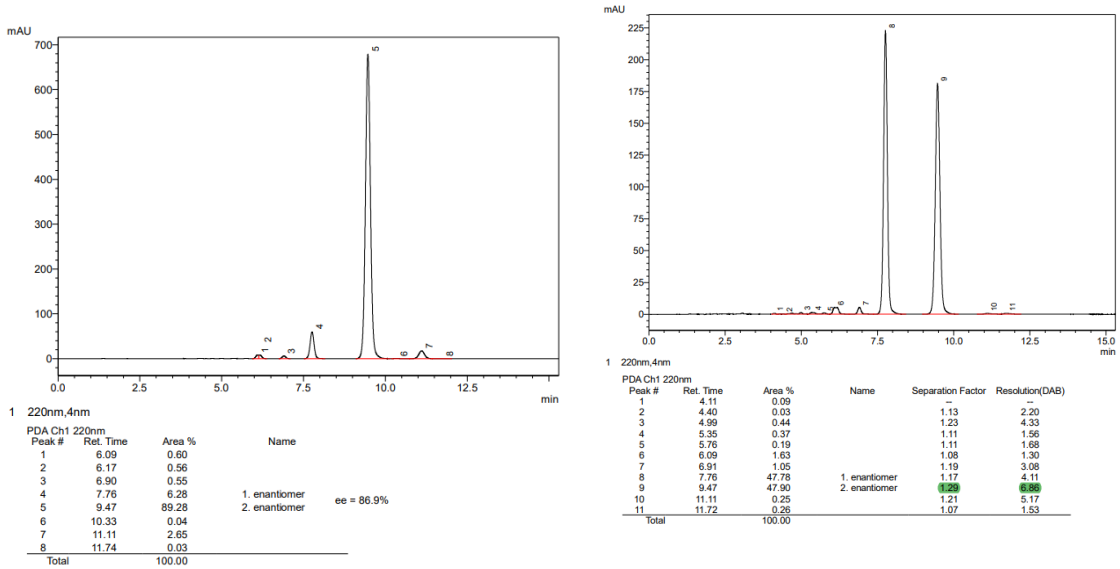
HPLC traces of **3h** (left) and the corresponding racemate (right).

2-((1*S*,1a*R*,6a*R*)-1-(Trifluoromethyl)-1,1a,6,6a-tetrahydrocyclopropa[a]inden-1-yl)furan (3i).  Prepared according to the general procedure using 0.9 mmol of indene. Purification by flash chromatography (pentane:EtOAc, 50:1) afforded the title compound as a pale yellow oil (17.5 mg, 73%, 91% *ee*). [The *ee* was determined by HPLC analysis: 150 mm Chiralcel OJ-3R, , Ø 4.6 mm i.D.; acetonitrile/water = 60:40, v = 0.5 mL/min, λ = 220 nm, t(minor) = 12.28 min, t(major) = 13.70 min]. $[\alpha]_D^{20}$ = –24.0 (c = 0.9, $CHCl_3$). ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.39 (d, *J* = 7.5 Hz, 1H), 7.16 (dd, *J* = 1.9, 0.8 Hz, 1H), 7.11 (tq, *J* = 7.4, 0.9 Hz, 1H), 7.02 (td, *J* = 7.5, 1.2 Hz, 1H), 6.88 (d, *J* = 6.8 Hz, 1H), 6.05 (dd, *J* = 3.3, 1.8 Hz, 1H), 5.86 (dd, *J* = 3.3, 0.8 Hz, 1H), 3.30 (dd, *J* = 6.9, 1.3 Hz, 1H), 3.22 (ddq, *J* = 17.6, 6.9, 1.3 Hz, 1H), 2.96 (d, *J* = 17.6 Hz, 1H), 2.66 (td, *J* = 6.9, 0.8 Hz, 1H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 144.8 (q, *J* = 1.0 Hz), 143.1, 142.9, 139.9, 126.9, 126.5, 125.1 (q, *J* = 274.9 Hz), 125.0, 124.3, 113.3, 110.0, 34.4 (q, *J* = 2.4 Hz), 33.0, 31.3 (q, *J* = 33.5 Hz), 26.2 (q, *J* = 2.2 Hz). ^{19}F NMR (565 MHz, $CDCl_3$) δ –68.6. IR (ATR): ṽ = 1330, 1278, 1265, 1224, 1136, 1026, 1011, 760, 739, 725, 598, 457 cm^{-1}. HRMS (EI) for $[M]^+$: calcd: 264.07565, found: 264.07612.



HPLC traces of **3i** (left) and the corresponding racemate (right).

2-((1*S*,2*R*)-2-(Naphthalen-2-yl)-1-(trifluoromethyl)cyclopropyl)furan (3j). Prepared according to the general procedure with 0.45 mmol of alkene. Purification by flash chromatography (pentane:EtOAc, 75:1) afforded the title compound as a pale yellow oil (22.8 mg 83%, 87% *ee*). [The *ee* was determined by HPLC analysis: 150 mm YMC Cellulose SJ-3, Ø 4.6 mm i.D., acetonitrile/water = 60:40 v = 1.0 mL/min, λ = 220 nm, t(minor) = 7.76 min, t(major) = 9.47 min]. $[\alpha]_D^{20}$ = –33.3 (c = 1.0, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.78 – 7.67 (m, 2H), 7.65 (d, *J* = 8.5 Hz, 1H), 7.49 – 7.37 (m, 3H), 7.17 (dd, *J* = 1.7, 0.9 Hz, 1H), 7.10 (dd, *J* = 8.5, 1.8 Hz, 1H), 6.11 (qd, *J* = 3.3, 1.3 Hz, 2H), 3.03 (dd, *J* = 9.5, 7.3 Hz, 1H), 2.06 (ddq, *J* = 7.6, 6.0, 1.6 Hz, 1H), 1.94 (dd, *J* = 9.5, 6.1 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 146.5, 143.1, 133.5, 133.2, 132.9, 128.0 (d, *J* = 5.1 Hz), 127.3, 126.6, 126.5, 126.2, 125.6 (q, *J* = 273.9 Hz), 112.6, 110.9, 77.7, 30.1 (q, *J* = 34.3 Hz) 27.7 (q, *J* = 2.1 Hz), 14.5 (q, *J* = 2.2 Hz). ^{19}F NMR (282 MHz, $CDCl_3$) δ –69.3. IR (ATR): $\tilde{\nu}$ = 1346, 1332, 1293, 1224, 1185, 1137, 1063, 1014, 859, 813, 742, 476 cm^{-1}; HRMS (ESI^+) for $[M+Na]^+$: calcd: 325.08107, found: 325.08074.



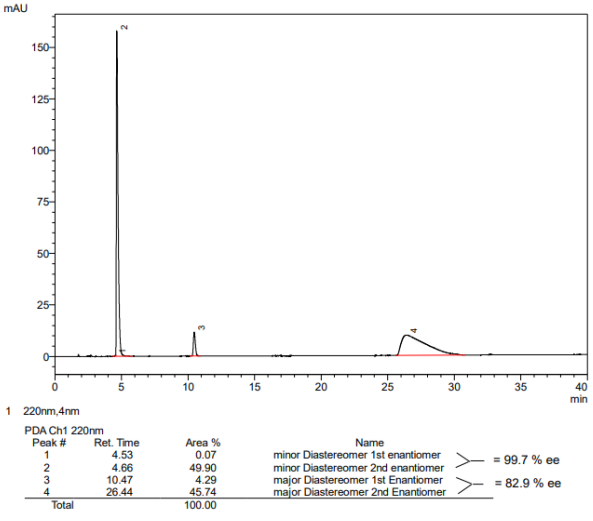
HPLC traces of **3j** (left) and the corresponding racemate (right).

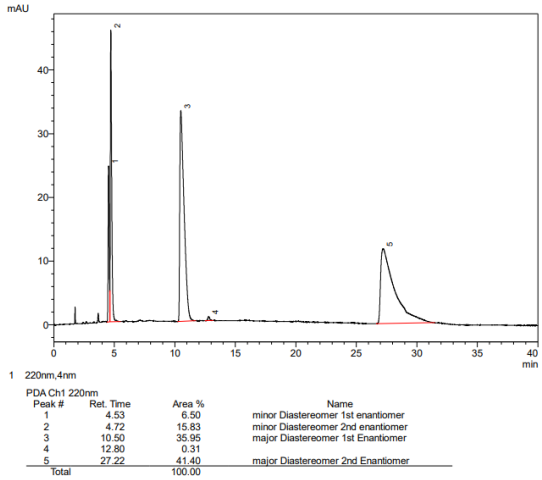
2-((1S,2R)-2-methyl-2-phenyl-1-(trifluoromethyl)cyclopropyl)furan (3k). Prepared according to the general procedure with 0.9 mmol of the alkene. Purification by flash column chromatography (pentane/EtOAc, 75:1 to 50:1) afforded a diastereomeric mixture of the title compound as a pale yellow oil (19.6 mg, 81 %, dr = 1:1.6; major diastereomer: 83 % *ee*; minor diastereomer: >99 % *ee*). [The *ee*'s were determined by HPLC analysis: 150 mm Chiralcel OD-3, Ø 4.6 mm i.D., *n*-heptan= 100 %, v = 1.0 mL/min, λ = 220 nm, $t_{minor\ dia}$(minor) = 4.53 min, $t_{major\ dia}$ (major) = 4.66 min; $t_{major\ dia}$(minor) = 10.47 min, $t_{major\ dia}$ (major) = 26.44 min]. $[\alpha]_D^{20}$ = –45.8 (c = 1.0), $CHCl_3$). IR (ATR): $\tilde{\nu}$ = 1339, 1274, 1214, 1134, 1113, 1096, 1084, 1071, 1043, 1028, 1011, 927, 766, 736, 698 cm^{-1}. HRMS (EI) for $[M]^+$: calcd: 266.09130, found: 266.09140.

major + minor

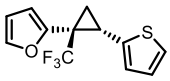
NMR characterization of the major diastereoisomer: ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.18 – 7.12 (m, 4H), 7.10 – 7.08 (m, 1H), 7.07 (m, 1H), 6.02 (dd, *J* = 3.3, 1.8 Hz, 1H), 5.92 (dd, *J* = 3.3, 0.8 Hz, 1H), 2.10 (dq, *J* = 6.0, 1.9 Hz, 1H), 1.73 (d, *J* = 6.0 Hz, 1H), 1.69 (q, *J* = 1.3 Hz, 3H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 148.70 (q, *J* = 1.8 Hz), 142.13 (q, *J* = 0.9 Hz), 141.98, 128.35, 127.99, 126.65, 126.00 (q, *J* = 275.2 Hz), 110.17, 109.71 (q, *J* = 0.9 Hz), 34.57, 32.73 (q, *J* = 33.8 Hz), 22.22 (q, *J* = 2.7 Hz), 20.70 (q, *J* = 2.3 Hz). ^{19}F NMR (565 MHz, $CDCl_3$) δ -60.25.

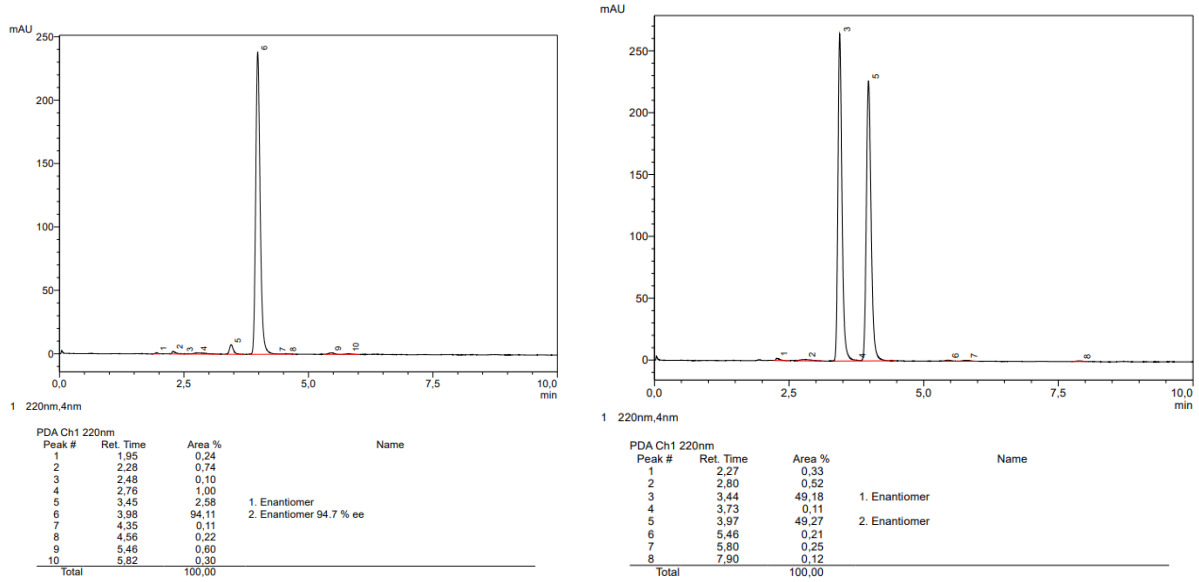
NMR characterization of the minor diastereoisomer: ^{1}H NMR (600 MHz, $CDCl_3$) δ 7.47 – 7.43 (m, 1H), 7.41 (d, *J* = 7.4 Hz, 2H), 7.34 (t, *J* = 7.4 Hz, 2H), 7.26 (tt, *J* = 7.4, 1.1 Hz, 1H), 6.48 (d, *J* = 3.2 Hz, 1H), 6.43 (dd, *J* = 3.2, 1.9 Hz, 1H), 2.02 (d, *J* = 5.7 Hz, 1H), 1.59 (dq, *J* = 5.7, 1.7 Hz, 1H), 1.17 (s, 3H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 149.07 (q, *J* = 1.5 Hz), 142.74, 141.15 (q, *J* = 0.8 Hz), 128.75, 128.47, 127.11, 125.29 (q, *J* = 275.2 Hz), 111.29 (q, *J* = 0.7 Hz), 110.76, 34.08, 32.33 (q, *J* = 33.2 Hz), 25.77 (q, *J* = 0.8 Hz), 20.53 (q, *J* = 2.2 Hz). ^{19}F NMR (565 MHz, $CDCl_3$) δ -63.24.



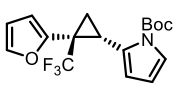


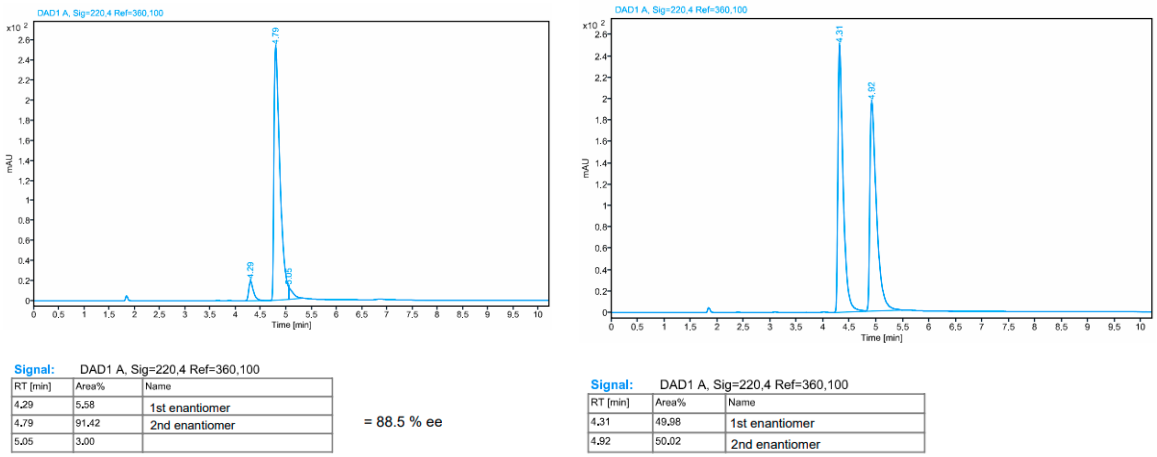
HPLC traces of **3k** (left) and the corresponding racemate (right).

2-((1*S*,2*S*)-2-(Thiophen-2-yl)-1-(trifluoromethyl)cyclopropyl)furan (3l). 
Prepared according to the general procedure with 0.45 mmol of the alkene. Purification by flash chromatography (pentane:EtOAc, 75:1) afforded the title compound as a pale yellow oil (17.6 mg 75%, 95% *ee*). [The *ee* was determined by HPLC analysis: 150 mm Chiralpak OJ-3R, Ø 4.6 mm i.D., *n*-heptane/2-propanol = 98:2, v = 1.0 mL/min, λ = 220 nm, t(minor) = 3.45 min, t(major) = 3.98 min]. $[\alpha]_D^{20}$ = –51.7(c = 0.7, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.28 (dd, *J* = 1.8, 0.9 Hz, 1H), 7.05 (dd, *J* = 5.1, 1.2 Hz, 1H), 6.81 (dd, *J* = 5.1, 3.5 Hz, 1H), 6.65 (dt, *J* = 3.6, 1.1 Hz, 1H), 6.25 (qd, *J* = 3.3, 1.3 Hz, 2H), 3.00 (dd, *J* = 9.5, 7.0 Hz, 1H), 1.95 (dd, *J* = 9.6, 6.0 Hz, 1H), 1.85 (tdd, *J* = 6.1, 3.2, 1.6 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 145.9, 143.0, 139.0, 126.7, 125.8, 125.0 (q, *J* = 274.6 Hz), 124.5, 112.5, 110.7,30.2 (q, *J* = 34.7 Hz), 22.5 (q, *J* = 2.5 Hz), 16.4 (q, *J* = 2.2 Hz). ^{19}F NMR (282 MHz, $CDCl_3$) δ –69.4. IR (ATR): ṽ = 1344, 1295, 1224, 1150, 1063, 1014, 742, 698 cm^{-1}. HRMS (EI) for $[M]^+$: calcd: 258.03258, found: 258.03207.



HPLC traces of **3l** (left) and the corresponding racemate (right)

***tert*-Butyl 2-((1*S*,2*S*)-2-(furan-2-yl)-2-(trifluoromethyl)cyclopropyl)-1*H*-pyrrole-1-carboxylate (3m).** 
Prepared according to the general procedure with 0.9 mmol of the alkene. Purification by preparative TLC (*n*-hexane:EtOAc, 20:1) afforded the title compound as a pale yellow oil (22.1 mg, 71%, 89% *ee*). [The *ee* was determined by HPLC analysis: 150 mm Chiralpak IB-N3, Ø 4.6 mm i.D., *n*-heptane/2-propanol = 99.99:0.01, v = 1.0 mL/min, λ = 220 nm, t(minor) = 4.29 min, t(major) = 4.79 min]. $[\alpha]_D^{20}$ = –180.8 (c =1.3, $CHCl_3$). ^{1}H NMR (400 MHz, CD_2Cl_2) δ 7.22 (dd, *J* = 1.9, 0.9 Hz, 1H), 7.11 (ddd, *J* = 3.3, 1.8, 0.6 Hz, 1H), 6.20 (dd, *J* = 3.3, 1.9 Hz, 1H), 6.12 (dd, *J* = 3.3, 0.8 Hz, 1H), 5.88 (t, *J* = 3.4 Hz, 1H), 5.72 (ddd, *J* = 3.2, 1.8, 1.1 Hz, 1H), 3.30 (dd, *J* = 9.0, 7.6 Hz, 1H), 1.85 – 1.74 (m, 2H), 1.64 (s, 9H). ^{13}C NMR (101 MHz, CD_2Cl_2) δ 149.6, 147.3, 143.0, 130.0, 125.6 (q, *J* = 274.3 Hz), 122.4, 112.8, 111.8, 110.7, 109.7, 84.3, 29.4 (q, *J* = 34.1 Hz), 28.1 (3C), 22.3 (q, *J* = 2.5 Hz), 14.1z (q, *J* = 2.1 Hz). ^{19}F NMR (282 MHz, $CDCl_3$) δ –69.0. IR (ATR): ṽ = 1744, 1417, 1371, 1327, 1307, 1288, 1126, 1102, 1059, 1013, 729, 717 cm^{-1}. HRMS (EI) for $[M]^+$: calcd: 341.12333, found: 341.12314.



Signal: DAD1 A, Sig=220,4 Ref=360,100

RT [min]	Area%	Name
4.29	5.58	1st enantiomer
4.79	91.42	2nd enantiomer
5.05	3.00	

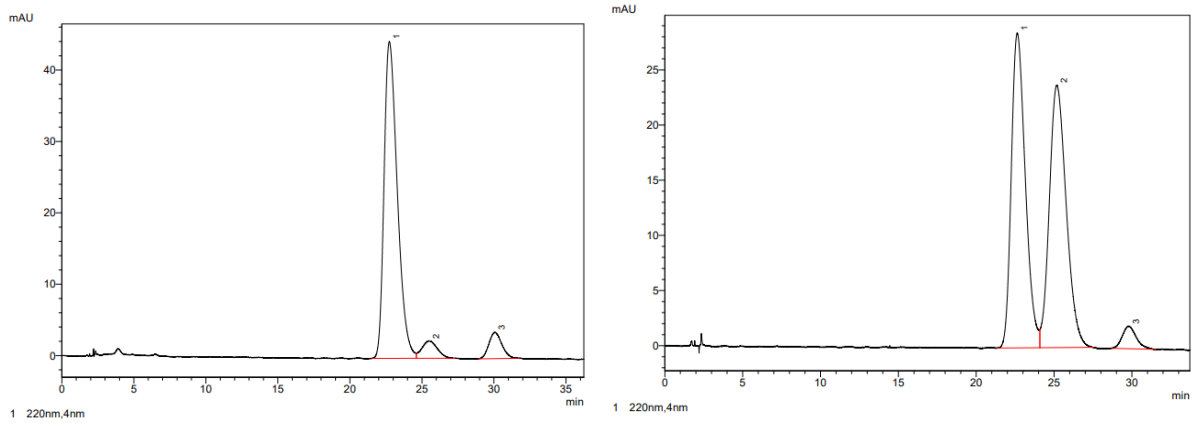
= 88.5 % ee

Signal: DAD1 A, Sig=220,4 Ref=360,100

RT [min]	Area%	Name
4.31	49.98	1st enantiomer
4.92	50.02	2nd enantiomer

HPLC traces of **3m** (left) and the corresponding racemate (right).

2-((1*S*,2*S*)-2-(*tert*-Butoxy)-1-(trifluoromethyl)cyclopropyl)furan (3n). Prepared according to the general procedure with 0.9 mmol of the alkene. Purification by flash chromatography (pentane:EtOAc, 75:1) afforded the title compound as a colorless oil (20 mg, 89%, 17:1 *dr*, 88% *ee* (major diastereomer)). [The *ee* was determined by HPLC analysis: 150 mm Chiralpak IG-3, Ø 4.6 mm i.D., methanol/water = 55:45, v = 1.0 mL/min, λ = 220 nm, t(minor) = 22.74 min, t(major) = 25.49 min]. $[\alpha]_D^{20}$ = –62.7 (c = 0.4, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40 (t, *J* = 1.3 Hz, 1H), 6.37 (d, *J* = 1.4 Hz, 2H), 3.78 (dd, *J* = 7.7, 5.0 Hz, 1H), 1.64 (ddq, *J* = 6.3, 5.0, 1.4 Hz, 1H), 1.55 (dd, *J* = 7.7, 6.9 Hz, 1H), 1.15 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 146.5, 142.3, 125.1 (q, *J* = 272.7 Hz), 110.7, 75.9, 54.1 (q, *J* = 2.8 Hz), 27.8 (3C), 27.8 (signal overlap quadruplet), 15.5 (q, *J* = 2.3 Hz).^{19}F NMR (282 MHz, $CDCl_3$) δ –62.5 (minor diastereomer), –67.6. (major diastereomer). IR (ATR): $\tilde{\nu}$ = 1719, 1578, 1468, 1383, 1366, 1291, 1271, 1191, 1183, 1083, 755, 746 cm^{-1}. HRMS (EI) for $[M]^+$: calcd: 248.10187, found: 248.10184.



PDA Ch1 220nm

Peak #	Ret. Time	Area %	Name
1	22.74	87.31	major diastereomer, 1st enantiomer
2	25.49	5.61	major diastereomer, 2nd enantiomer
3	30.05	7.08	minor diastereomer, 1st&2nd enantiomer
Total		100.00	

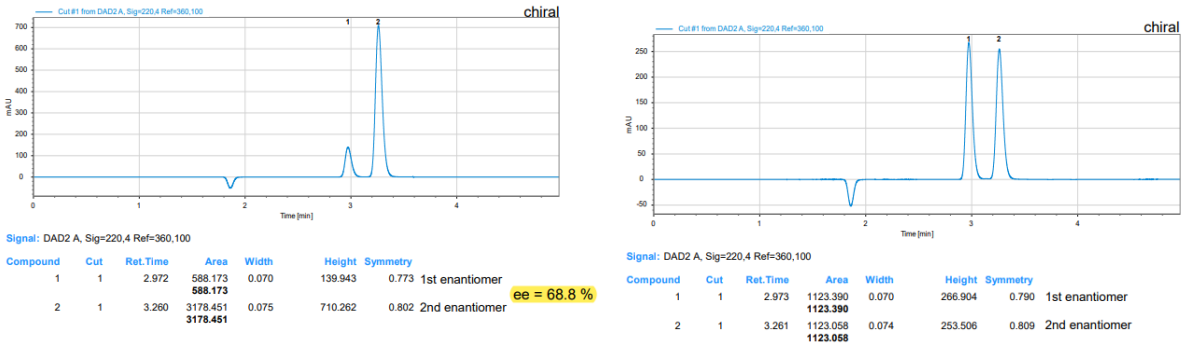
ee ~ 88.0 %

PDA Ch1 220nm

Peak #	Ret. Time	Area %	Name
1	22.63	48.17	major diastereomer, 1st. enantiomer
2	25.18	48.43	major diastereomer, 2nd enantiomer
3	29.80	3.40	minor diastereomer, 1st&2nd enantiomer
Total		100.00	

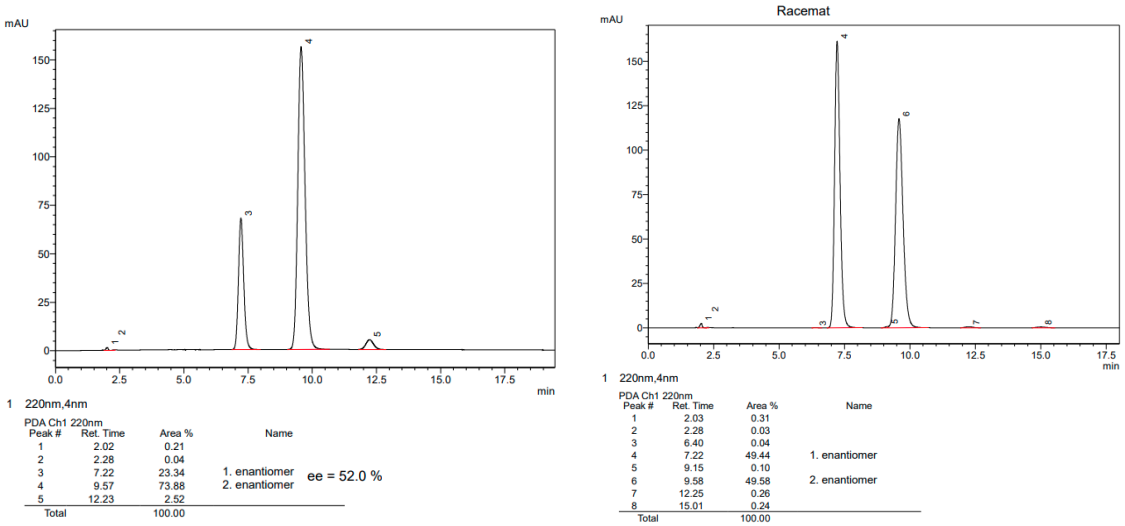
HPLC traces of **3n** (major diastereomer, left) and the corresponding racemate (right).

2-((1*S*,2*S*)-2-Butoxy-1-(trifluoromethyl)cyclopropyl)furan (3o). Prepared according to the general procedure with 0.9 mmol of the alkene. Purification by flash chromatography (pentane:EtOAc, 75:1) afforded the title compound as a pale yellow oil (19.8 mg, 88%, 15:1 *dr*, 69% *ee*). [The *ee* was determined by HPLC analysis: 150 mm Chiralpak IB N-3, Ø 4.6 mm i.D., 100 % *n*-heptane, v = 1.0 mL/min, λ = 220 nm, t(minor) = 2.97 min, t(major) = 3.26 min]. $[\alpha]_D^{20}$ = –42.5 (c = 0.2, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40 (dd, *J* = 1.9, 0.9 Hz, 1H), 6.42 (dd, *J* = 3.3, 0.8 Hz, 1H), 6.38 (dd, *J* = 3.3, 1.8 Hz, 1H), 3.73 (dd, *J* = 7.4, 4.7 Hz, 1H), 3.56 – 3.43 (m, 2H), 1.71 (ddq, *J* = 7.6, 4.6, 1.5 Hz, 1H), 1.55 (t, *J* = 7.2 Hz, 1H), 1.45 – 1.30 (m, 2H), 1.24 – 1.07 (m, 2H), 0.81 (t, *J* = 7.4 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 146.1, 142.7, 124.9 (q, *J* = 272.8 Hz), 111.5, 110.8, 71.2, 59.6 (q, *J* = 2.6 Hz), 31.5, 29.0 – 26.7 (m), 19.2, 15.6 (q, *J* = 2.3 Hz), 13.9. ^{19}F NMR (282 MHz, $CDCl_3$) δ –62.5 (minor diastereomer), –67.9 (major diasteromer). IR (ATR): $\tilde{\nu}$ = 1361, 1337, 1299, 1225, 1136, 1087, 1011, 738 cm^{-1}. HRMS (EI) for $[M]^+$: calcd: 248.10187, found: 248.10174.



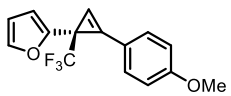
HPLC traces of **3o** (major diastereomer, left) and the corresponding racemate (right).

2-((1*S*,2*S*)-2-(Furan-2-yl)-2-(trifluoromethyl)cyclopropyl)benzofuran (3p). Prepared according to the general procedure with 0.9 mmol of the alkene. Purification by flash column chromatography (pentane:EtOAc, 75:1) afforded the title compound as a pale yellow oil (23.4 mg, 88 %, 52 % *ee*). [The *ee* was determined by HPLC analysis: 150 mm Chiralpak IJ-3, Ø 4.6 mm i.D., methanol/water = 85:15, v = 1.0 mL/min, λ = 220 nm, t(minor) = 7.22 min, t(major) = 9.57 min]. $[\alpha]_D^{20}$ = –31.5 (c = 1.5, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 (ddd, *J* = 7.4, 1.5, 0.7 Hz, 1H), 7.37 – 7.29 (m, 1H), 7.27 – 7.24 (m, 1H), 7.23 – 7.10 (m, 2H), 6.29 – 6.23 (m, 2H), 6.19 (dd, *J* = 3.3, 1.9 Hz, 1H), 2.96 (dd, *J* = 9.6, 7.0 Hz, 1H), 2.06 – 1.91 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 154.9, 153.0, 145.8, 143.1, 128.4, 126.2 (q, *J* = 274.4 Hz), 124.0, 122.8, 120.7, 112.2, 110.9, 110.8, 104.1, 29.5 (q, *J* = 35.1 Hz), 20.8 (q, *J* = 2.5 Hz), 14.2 (q, *J* = 2.2 Hz). ^{19}F NMR (282 MHz, $CDCl_3$) δ –69.8. IR (ATR): $\tilde{\nu}$ = 1454, 1334, 1289, 1139, 1108, 1061, 1013, 804, 738, 723, 426 cm^{-1}. HRMS (EI) for $[M]^+$: calcd: 292.07057, found: 292.07075.

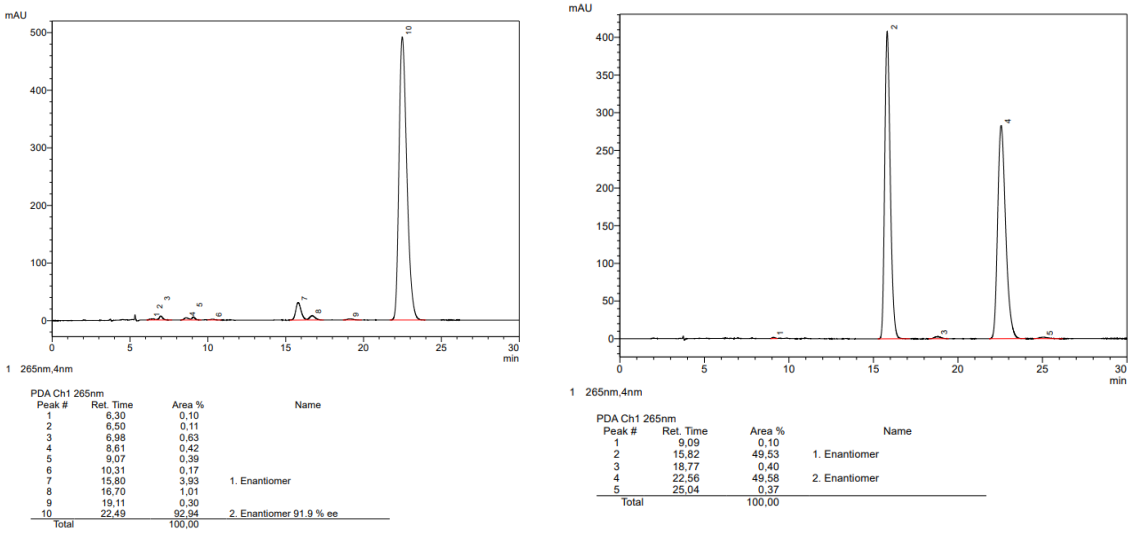


HPLC traces of **3p** (left) and the corresponding racemate (right).

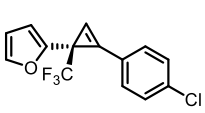
(*S*)-2-(2-(4-Methoxyphenyl)-1-(trifluoromethyl)cycloprop-2-en-1-yl)furan (9a)

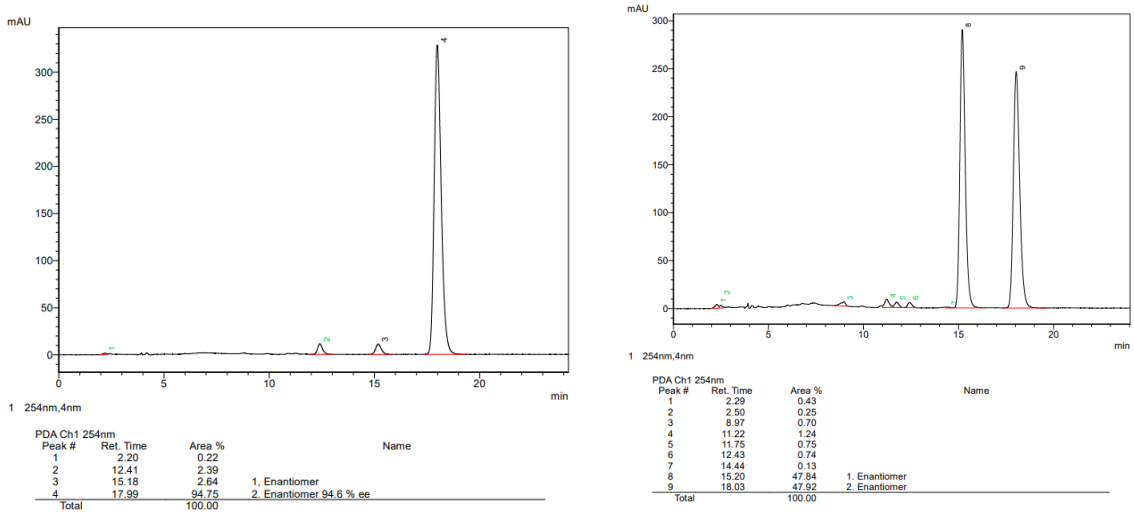


Prepared according to the general procedure with 0.9 mmol of the alkyne. Purification by flash chromatography (hexane:EtOAc, 50:1 to 40:1) afforded the title compound as a fluorescent yellow oil (22.7 mg, 90%, 92% *ee*). [The *ee* was determined by HPLC analysis: 150 mm Chiralpak OJ-3R, Ø 4.6 mm i.D., acetonitrile/water = 60:40, v = 0.5 mL/min, λ = 220 nm, t(minor) = 15.80 min, t(major) = 22.49 min]. $[\alpha]_D^{20}$ = –198.8 (c = 1.4, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.64 – 7.54 (m, 2H), 7.28 (dd, *J* = 1.8, 0.9 Hz, 1H), 7.01 – 6.93 (m, 2H), 6.89 (q, *J* = 1.5 Hz, 1H), 6.39 – 6.30 (m, 2H), 3.85 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 161.6, 152.0, 141.6, 131.9 (2C), 125.9 (q, *J* = 276.0 Hz), 117.3, 114.7 (2C), 110.7, 107.5, 94.0 (q, *J* = 2.5 Hz), 55.6, 27.3 (q, *J*= 37.2Hz). ^{19}F NMR (282 MHz, $CDCl_3$) δ –66.6. IR (ATR): ṽ = 1605, 1505, 1302, 1251, 1171, 1149, 1129, 1030, 953, 834, 731cm^{-1}. HRMS (ESI+) for $[M+H]^+$: calcd: 281.07839, found: 281.07848.

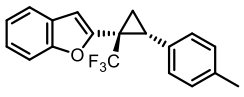


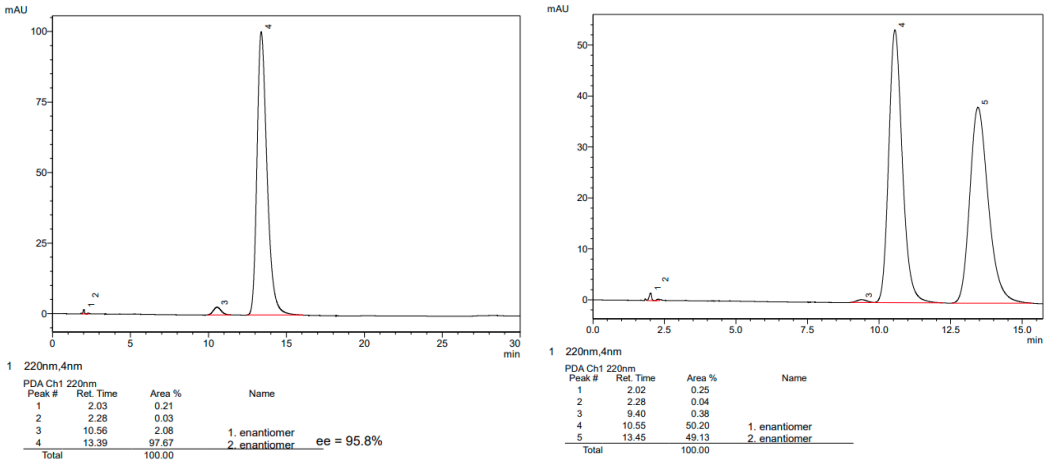
HPLC traces of **9a** (left) and the corresponding racemate (right).

(*S*)-2-(2-(4-Chlorophenyl)-1-(trifluoromethyl)cycloprop-2-en-1-yl)furan (9b).  Prepared according to the general procedure with 0.9 mmol of the alkyne. Purification by flash chromatography (hexane:EtOAc, 50:1) afforded the title compound as a fluorescent yellow oil (20.7 mg, 80%, 95% *ee*). [The *ee* was determined by HPLC analysis: 150 mm Chiralpak OJ-3R, Ø 4.6 mm i.D.; methanol/water = 85:15, v = 0.5 mL/min, λ = 220 nm, t(minor) = 15.18 min, t(major) = 17.99 min]. $[\alpha]_D^{20}$ = –226.4 (c = 1.3, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.58 (d, *J* = 57.2 Hz, 2H), 7.43 (d, *J* = 53.2 Hz, 2H), 7.28 (dd, *J* = 1.8, 0.8 Hz, 1H), 7.09 (q, *J* = 1.4 Hz, 1H), 6.38 (dt, *J* = 3.3, 0.9 Hz, 1H), 6.35 (dd, *J* = 3.3, 1.8 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 151.5, 142.1, 137.2, 131.7, 129.8, 125.9 (q, *J* = 276.2 Hz), 123.6, 114.9 (d, *J* = 2.0 Hz), 111.2, 108.1, 98.1 (q, *J* = 2.4 Hz), 27.9 (q, *J* = 38.1 Hz). ^{19}F NMR (282 MHz, $CDCl_3$) δ –66.6. IR (ATR): ṽ = 1486, 1308, 1175, 1131, 1094, 1014, 953, 869, 831, 767, 725, 686, 452 cm^{-1}. HRMS (EI) for $[M]^+$: calcd: 284.02103, found: 284.02124.



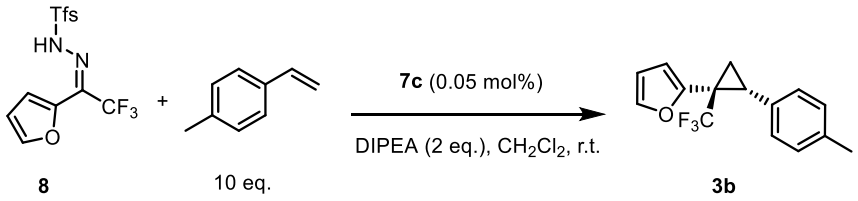
HPLC traces of **9b** (left) and the corresponding racemate (right).

2-((1*S*,2*R*)-2-(*p*-Tolyl)-1-(trifluoromethyl)cyclopropyl)benzofuran (11).  Prepared according to the general procedure using the benzofuran triftosylhydrazone **10** (0.0917 mmol, 40 mg) and 0.9 mmol of the alkene. Purification by flash chromatography (pentane:EtOAc, 75:1 to 50:1) afforded the title compound as a yellow oil that solidified after prolonged standing at rt. (27.8 mg, 96 %, 96 % *ee*). [The *ee* was determined by HPLC analysis: 150 mm Chiralpak IJ-3, Ø 4.6 mm i.D., methanol/water = 85:15, v = 1.0 mL / min, λ = 220 nm, t(minor) = 10.56 min, t(major) = 13.39 min]. $[\alpha]_D^{20}$ = –112.0 (c =1.6, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40 (ddq, *J* = 20.2, 8.3, 0.8 Hz, 1H), 7.23 (ddd, *J* = 8.3, 7.2, 1.4 Hz, 1H), 7.14 (td, *J* = 7.5, 1.1 Hz, 2H), 6.99 – 6.88 (m, 4H), 6.51 (d, *J* = 1.0 Hz, 1H), 2.96 (dd, *J* = 9.6, 7.5 Hz, 1H), 2.21 (s, 3H), 2.07 (ddq, *J* = 7.6, 6.1, 1.6 Hz, 1H), 1.94 (dd, *J* = 9.6, 6.1 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 154.8, 149.2, 136.8, 131.6, 129.0 (2C), 128.1 (2C), 128.1, 125.3 (q, *J* = 272.7 Hz), 124.4, 122.7, 121.1, 111.3, 108.9, 30.1 (q, *J* = 34.5 Hz), 27.5 (q, *J* = 2.0 Hz), 21.1, 14.1 (q, *J* = 2.2 Hz). ^{19}F NMR (282 MHz, $CDCl_3$) δ –68.8. IR (ATR): ṽ = 1453, 1384, 1319, 1282, 1257, 1235, 1209, 1132, 1095, 1053, 850, 816, 780, 750, 741, 730, 707 cm^{-1}. HRMS (EI) for $[M]^+$: calcd: 316.10695, found: 316.10710.



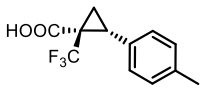
HPLC traces of **11** (left) and the corresponding racemate (right).

Gram-Scale Cyclopropanation with Reduced Catalyst Loading

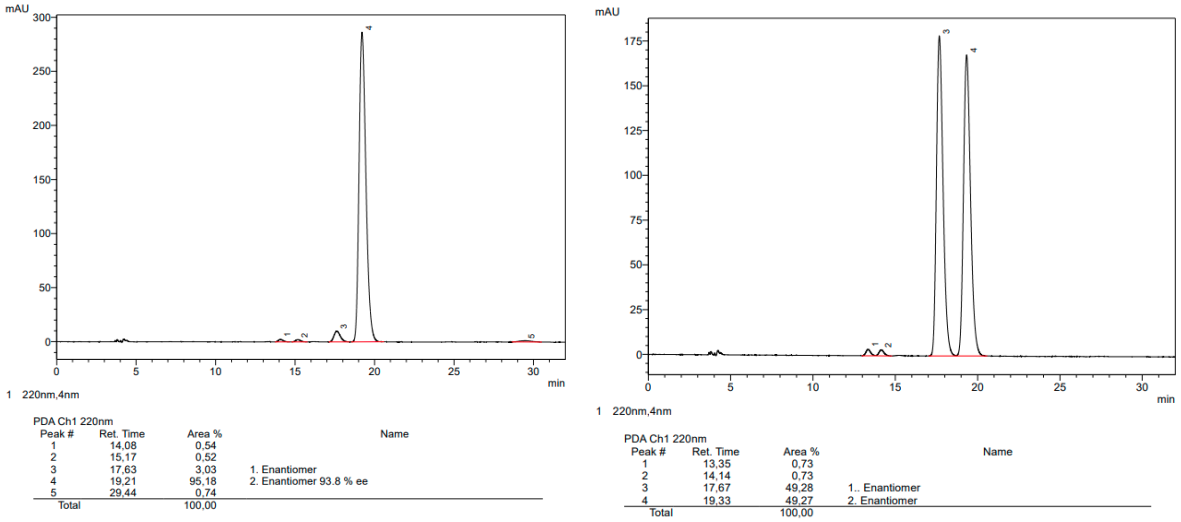


A flame dried three-neck flask equipped with a magnetic stirring bar was charged with the [BiRh] paddlewheel complex **7c** (9.2 mg, 0.05 mol %), triftosylhydrazone **8** (1.93 g, 5.0 mmol), *p*-methylstyrene (6.6 mL, 50 mmol) and CH_2Cl_2 (50 mL). A solution of diisopropylethyl amine (1.74 mL, 10 mmol) in CH_2Cl_2 (150 mL) was added dropwise to the mixture over a period of 1 h. Once the addition was complete, stirring was continued for 16 h. The mixture was concentrated and the residue purified by flash chromatography (pentane/EtOAc, 75:1 to 50:1) to afford product **3b** as a pale yellow oil (1.08 g, 81%, 94% *ee*). See above for the analytical and spectroscopic data.

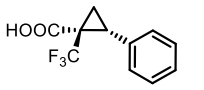
Derivatization



(1*S*,2*R*)-2-(*p*-Tolyl)-1-(trifluoromethyl)cyclopropane-1-carboxylic acid (4b). $NaIO_4$ (602 mg, 2.82 mmol) was added to a solution of cyclopropane **3b** (150 mg, 0.56 mmol) in heptane/EtOAc/H_2O (1:1:2, 12 mL). The mixture was stirred for 5 min before $RuCl_3$ (3 mg, 2.5 mol %) was added. After stirring for 18 h at 25 °C a second portion of $NaIO_4$ (3 eq) was added to the mixture and stirring continued for an additional 4 h. Water (10 mL) was introduced followed by EtOAc (10 mL). The layers were separated, the aqueous phase was extracted with EtOAc (3 × 20 mL), and the organic layers were combined, dried over $MgSO_4$ and concentrated under reduced pressure. The residue was purified by flash chromatography (pentane: EtOAc, 10:1 + 1 % formic acid) to afford the title compound as a white crystalline solid (90 mg, 65%, 94% *ee*).). [The *ee* was determined by HPLC analysis: 150 mm Chiralpak OJ-3R, Ø 4.6 mm i.D., methanol/TFA (0.1 %) in water = 70:30, v = 0.5 mL/min, λ = 220 nm, t(minor) = 17.6 min, t(major) = 19.2 min]. $[\alpha]_D^{20}$ = 0.6 (c = 1.2, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.09 (s, 4H), 2.98 (t, *J* = 9.1 Hz, 1H), 2.33 (s, 3H), 2.08 (ddq, *J* = 9.2, 5.6, 1.8 Hz, 1H), 1.80 (dd, *J* = 9.8, 5.7 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 170.7, 137.6, 129.9, 129.2, 129.0, 124.2 (q, *J* = 273 Hz), 34.1 (q, *J* = 33.9 Hz), 30.4, 21.3, 16.1. ^{19}F NMR (282 MHz, $CDCl_3$) δ –66.9. IR (ATR): ṽ = 1708, 1433, 1387, 1321, 1234, 1147, 1129, 1084, 823 cm^{-1}. HRMS (EI) for $[M]^+$: calcd: 244.07057, found: 244.07060.

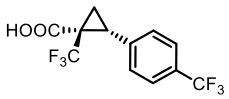


HPLC traces of acid **4b** (left) and the corresponding racemate (right).



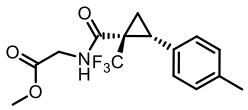
(1*S*,2*R*)-2-Phenyl-1-(trifluoromethyl)cyclopropane-1-carboxylic acid (4a). Prepared analogously from 2-furyl cyclopropane **3a** (100 mg, 0.40 mmol). The residue was purified by flash chromatography (pentane/EtOAc, 10:1 + 1 % formic acid) to afford the title compound as a colorless solid (72 mg, 79%). $[\alpha]_D^{20}$ = –12.4 (c = 0.75, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.33 – 7.24 (m, 3H), 7.23 – 7.15 (m, 2H), 3.01 (t, *J* = 9.1 Hz, 1H), 2.10 (ddq, *J* = 9.3, 5.6, 1.8 Hz, 1H), 1.81 (dd, *J* = 9.7, 5.7 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 170.4, 133.1, 129.2 (2C), 128.5 (2C), 127.8 124.2 (q, *J* = 274.0 Hz), 34.1 (q, *J* = 33.9 Hz), 30.5 (q, *J* = 2.0 Hz), 16.0 (q, *J* = 2.0 Hz). ^{19}F NMR (282 MHz, $CDCl_3$) δ –67.0. IR (ATR): ṽ = 1710, 1433, 1393, 1322, 1233, 1147, 1128, 1086, 783, 728, 697, 684 cm^{-1}. HRMS (EI) for $[M]^+$: calcd: 230.05492, found: 230.05496.

(1*S*,2*R*)-1-(Trifluoromethyl)-2-(4-(trifluoromethyl)phenyl)cyclopropane-1-carboxylic acid (4e).

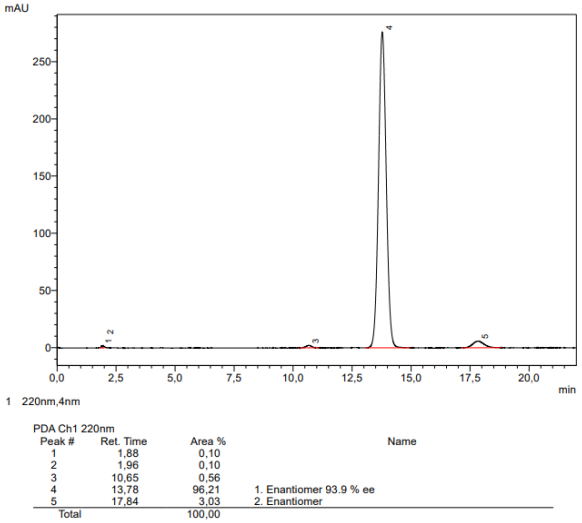


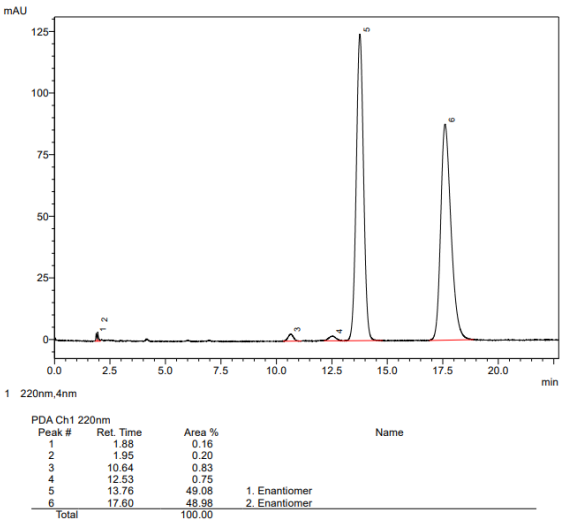
Prepared analogously from 2-furyl cyclopropane **3e** (51 mg, 0.16 mmol). The residue was purified by flash chromatography (pentane/EtOAc, 9:1 + 1 % formic acid) to afford the title compound as a colorless oil (34.3 mg, 72%). $[\alpha]_D^{20}$ = –4.2 (c = 0.74, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$) 7.54 (d, *J* = 8.1 Hz, 2H), 7.31 (d, *J* = 8.0 Hz, 2H), 3.04 (t, *J* = 9.1 Hz, 1H), 2.12 (dddd, *J* = 7.6, 6.1, 3.6, 1.7 Hz, 1H), 1.88 (dd, *J* = 9.7, 5.9 Hz, 1H) ^{13}C NMR (101 MHz, $CDCl_3$) δ 170.7, 137.2, 130.2 (q, *J* = 33.0 Hz), 129.7 (2C), 125.4 (2C, q, *J* = 3.8 Hz), 124.2 (q, *J* = 274.1 Hz), 124.0 (q, *J* = 272.5 Hz), 34.2 (q, *J* = 34.3 Hz), 30.1 (d, *J* = 2.0 Hz), 16.1 (d, *J* = 2.1 Hz). ^{19}F NMR (282 MHz, $CDCl_3$) δ –62.7, –67.2. IR (ATR): ṽ = 1712, 1434, 1392, 1323, 1233, 1152, 1124, 1113, 1065, 1020, 846 cm^{-1}. HRMS (EI) for $[M]^+$: calcd: 298.04230, found: 298.04246.

Methyl ((1*S*,2*R*)-2-(*p*-tolyl)-1-(trifluoromethyl)cyclopropane-1-carbonyl)glycinate (12). A flame



dried Schlenk flask was charged with acid **4b** (40 mg, 0.164 mmol) and DMF (1 mL). The solution was cooled to 0 °C before HATU (62.3 mg, 0.164 mmol), di-isopropylethylamine (0.11 mL, 0.655 mmol) and glycine methyl ester hydrochloride (30.8 mg, 0.246 mmol) were successively added. The mixture was stirred at room temperature for 16 h before it was diluted with water and the aqueous phase extracted with EtOAc (3x 15 mL). The organic layer was washed with sat. aq. $NaHCO_3$ and brine, dried over $MgSO_4$, and concentrated under reduced pressure. The residue was purified by flash chromatography (pentane/*tert*-butyl methyl ether, 60:40) to afford the title compound as transparent oil that solidified upon standing to give an off-white solid (37.4 mg, 72%, 94% *ee*). [The *ee* was determined by HPLC analysis: 150 mm Chiralpak IC-3, Ø 4.6 mm i.D. *n*-heptane/2-propanol = 95:5, v = 1.0 mL/min, λ = 220 nm, t(minor) = 17.84 min, t(major) = 13.78 min]. $[\alpha]_D^{20}$ = 39.3 (c = 1.5, $CHCl_3$). M.p. = 86-87 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.08 (s, 4H), 6.40 (s, 1H), 3.90 (dd, *J* = 18.4, 5.0 Hz, 1H), 3.73 (dd, *J* = 18.5, 4.7 Hz, 1H), 3.70 (s, 3H), 2.81 (t, *J* = 9.1 Hz, 1H), 2.21 (s, 3H), 2.19 (ddq, *J* = 7.8, 5.8, 1.8 Hz, 1H), 1.67 (dd, *J* = 9.7, 5.9 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 169.7, 162.8, 137.3, 130.5, 129.2, 128.5, 125.3 (q, *J* = 274.0 Hz), 52.5, 41.9, 36.2 (q, *J* = 32.9 Hz), 28.0 (q, *J* = 2.1 Hz), 21.2, 13.5 (d, *J* = 2.5 Hz). ^{19}F NMR (282 MHz, $CDCl_3$) δ –65.5. IR (ATR): ṽ = 1746, 1688, 1521, 1439, 1376, 1323, 1305, 1208, 1182, 1132, 1087, 828 cm^{-1}. HRMS (EI) for $[M]^+$: calcd: 315.10768, found: 315.10750.

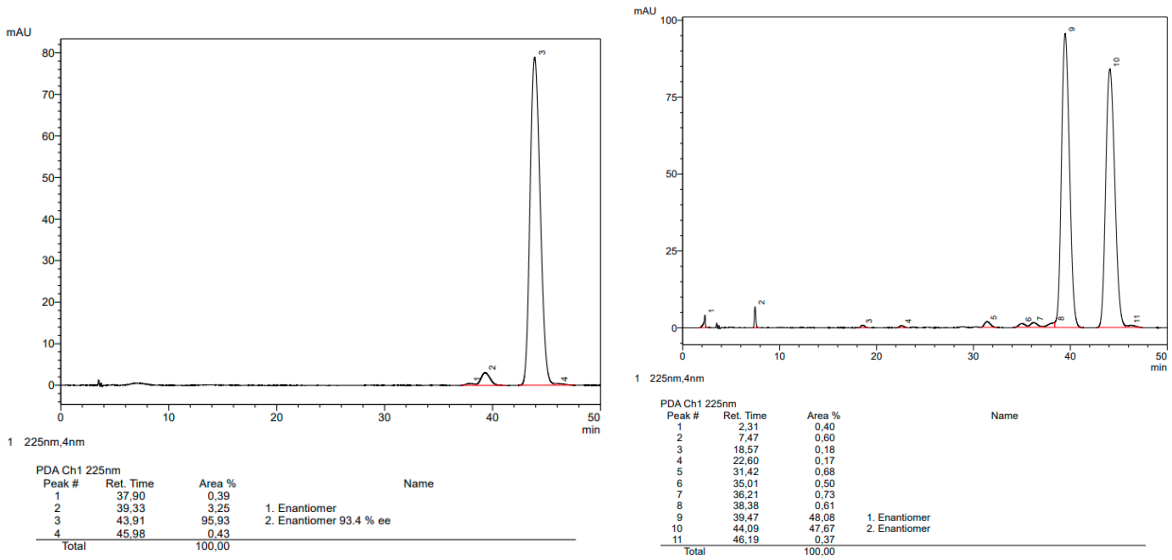




HPLC traces of **12** (left) and the corresponding racemate (right).

***tert*-Butyl ((1*R*,2*R*)-2-(*p*-tolyl)-1-(trifluoromethyl)cyclopropyl)carbamate (5b).** A flame dried two-neck round bottom flask was charged with acid **4b** (35 mg, 0.14 mmol)) and toluene (1.5 mL). Triethylamine (30 µL, 0.22 mmol) was added to the mixture, followed by dropwise addition of diphenylphosphoryl azide (37 µL, 0.17 mmol). The mixture was stirred at 90 °C (bath temperature) for 30 min. Dry *tert*-BuOH (0.3 mL) was slowly added and stirring was continued for 18 h at 90°C. The reaction mixture was diluted with EtOAc and water. The organic phase was washed with water (2 x 20 mL) and brine (20 mL), dried over $MgSO_4$ and concentrated under reduced pressure. The residue was purified by flash chromatography (pentane/*tert*-butyl methyl ether, 16:1) to afford the title compound as an off-white solid (39.7 mg, 89%, 93% *ee*). [The *ee* was determined by HPLC analysis: 150 mm Chiralpak OJ-3R, Ø 4.6 mm i.D., acetonitrile/water = 40:60, v = 0.5 mL/min, λ = 225nm, t(minor) = 43.91 min, t(major) = 45.98 min]. $[\alpha]_D^{20}$ = –109.9 (c = 1.4, $CHCl_3$).

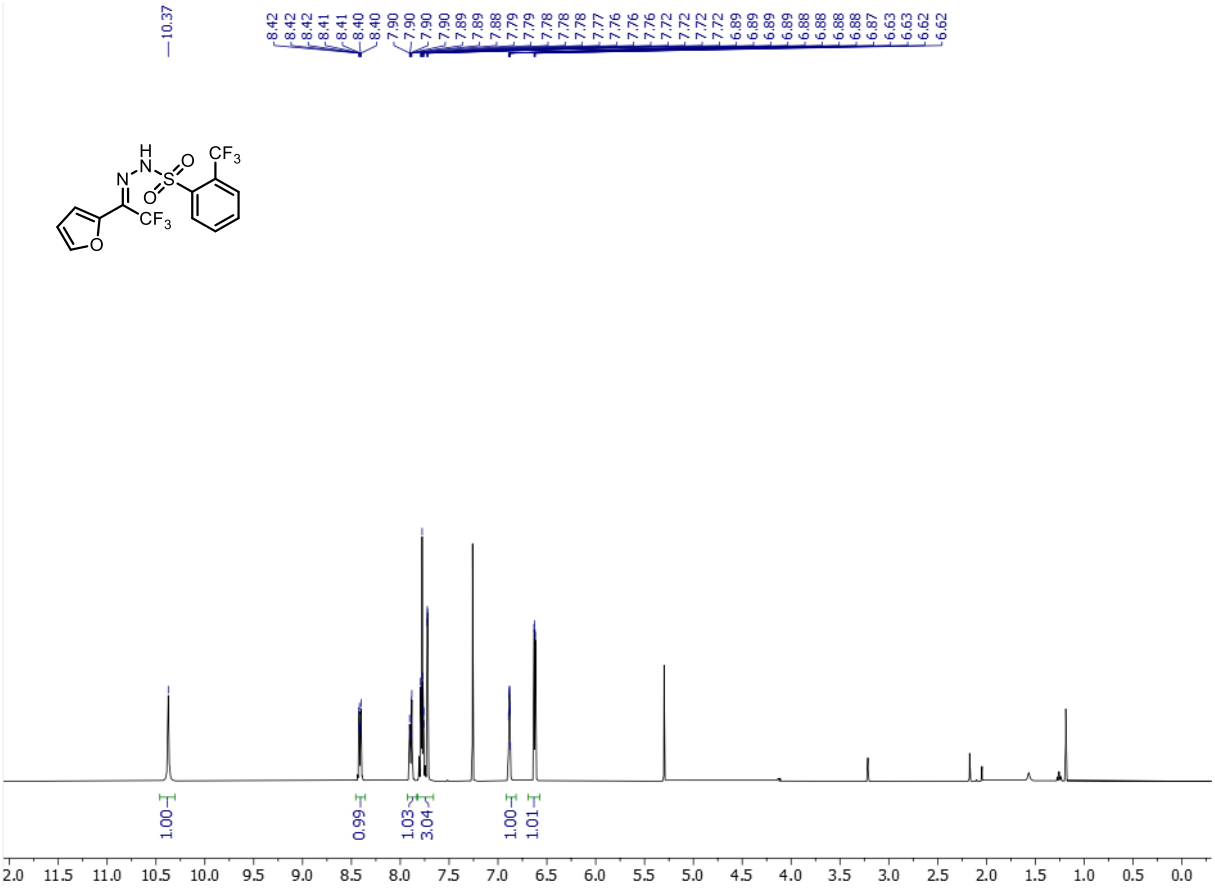
The NMR spectra were recorded at 80 °C to minimize signal broadening caused by the rotamers of the Boc group. ^{1}H NMR (600 MHz, CD_3CN) δ 7.19 – 7.14 (m, 2H), 7.12 – 7.07 (m, 2H), 5.18 (s, 1H), 2.72 (dd, *J* = 10.0, 8.1 Hz, 1H), 2.34 (s, 3H), 1.77 (ddd, *J* = 10.0, 7.0, 0.7 Hz, 1H), 1.73 (t, *J* = 7.8 Hz, 1H), 1.32 (s, 9H). ^{13}C NMR (151 MHz, CD_3CN) δ 156.2, 138.3, 132.5, 130.2, 129.9, 126.8 (q, *J* = 275.5 Hz), 80.9, 40.2 (q, *J* = 37.0 Hz), 28.7, 27.7, 21.3, 16.8. ^{19}F NMR (565 MHz, CD_3CN) δ –74.2. IR (ATR): $\tilde{\nu}$ = 1708, 1495, 1392, 1367, 1299, 1245, 1136, 1091, 1067, 1047, 827 cm^{-1}. HRMS (ESI+) for $[M+Na]^+$: calcd: 338.13383, found: 338.13419.



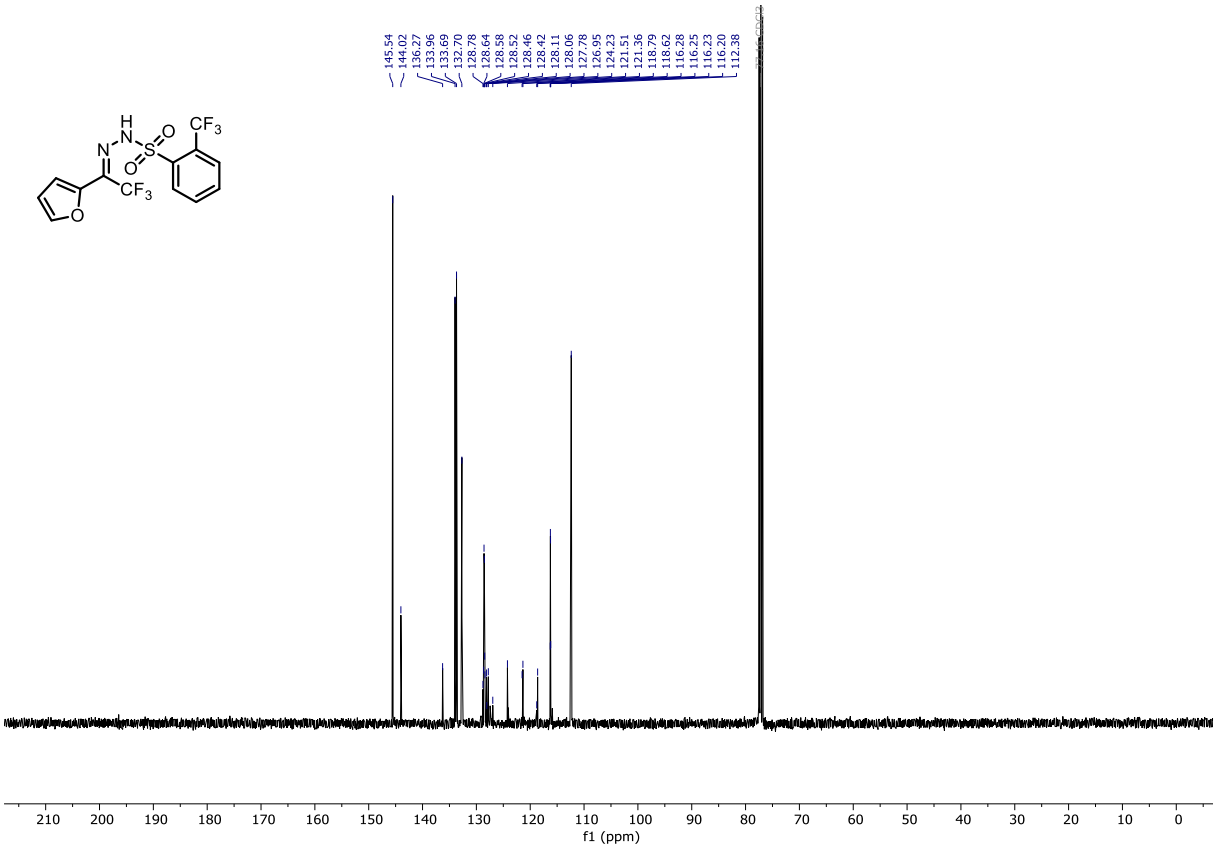
HPLC traces of **5b** (left) and the corresponding racemate (right).

NMR Spectra

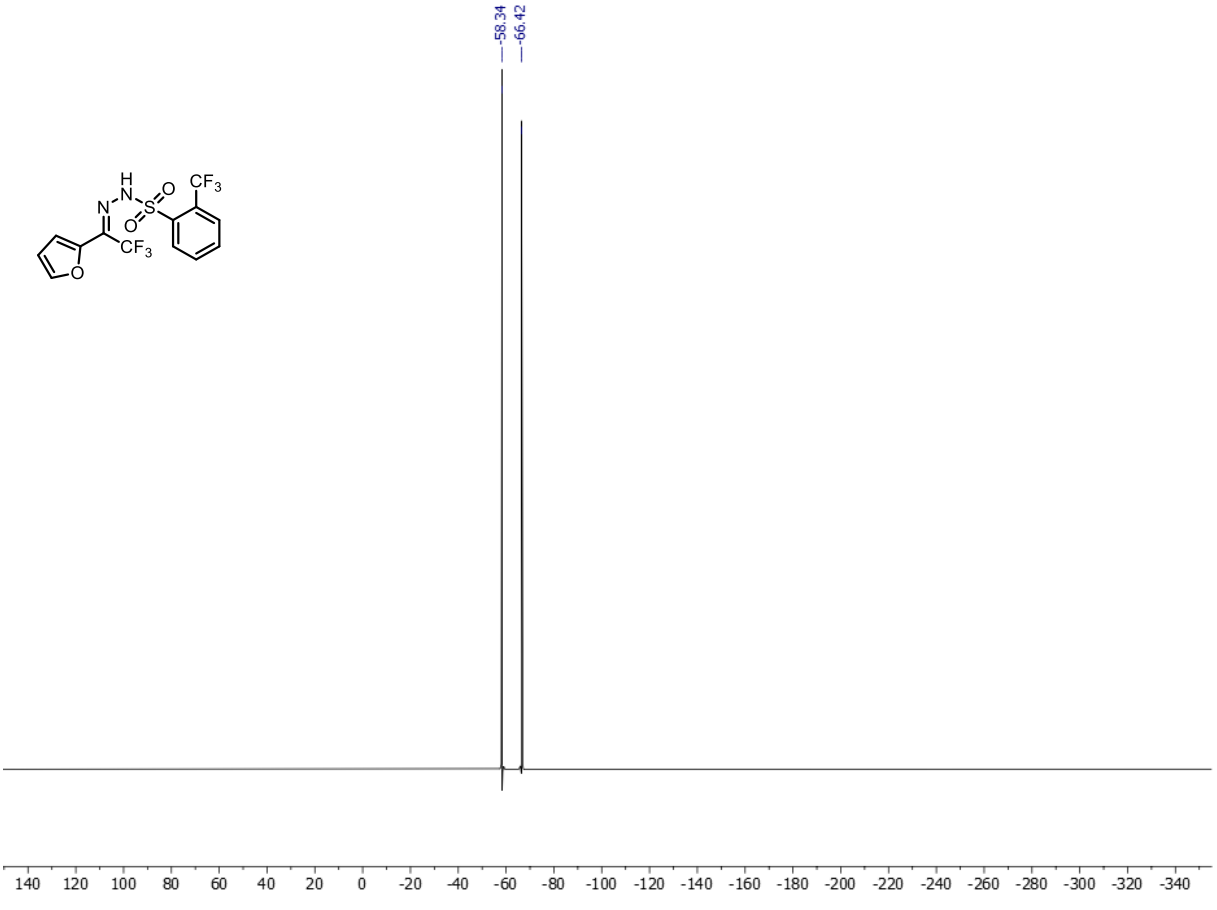
8: ^{1}H-NMR (400 MHz, $CDCl_3$):



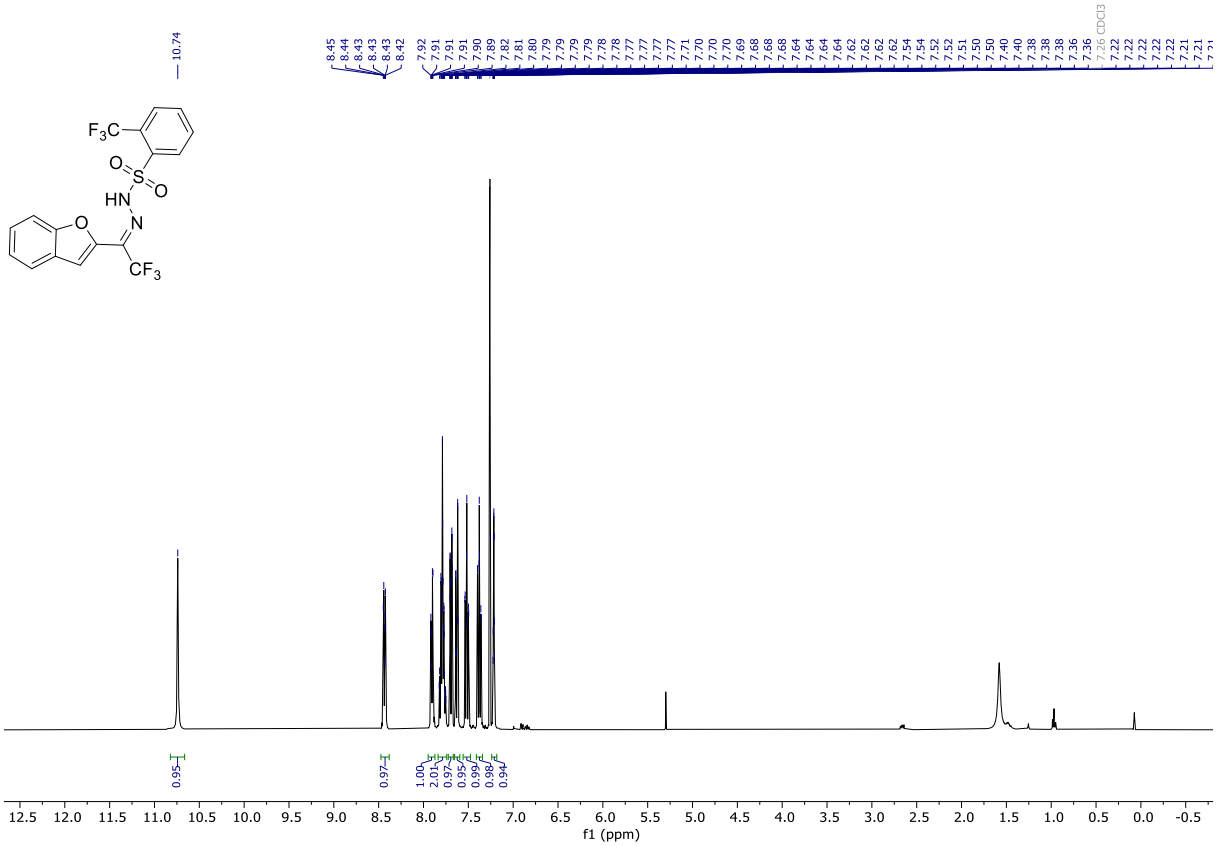
8 : ^{13}C-NMR (101 MHz, $CDCl_3$):



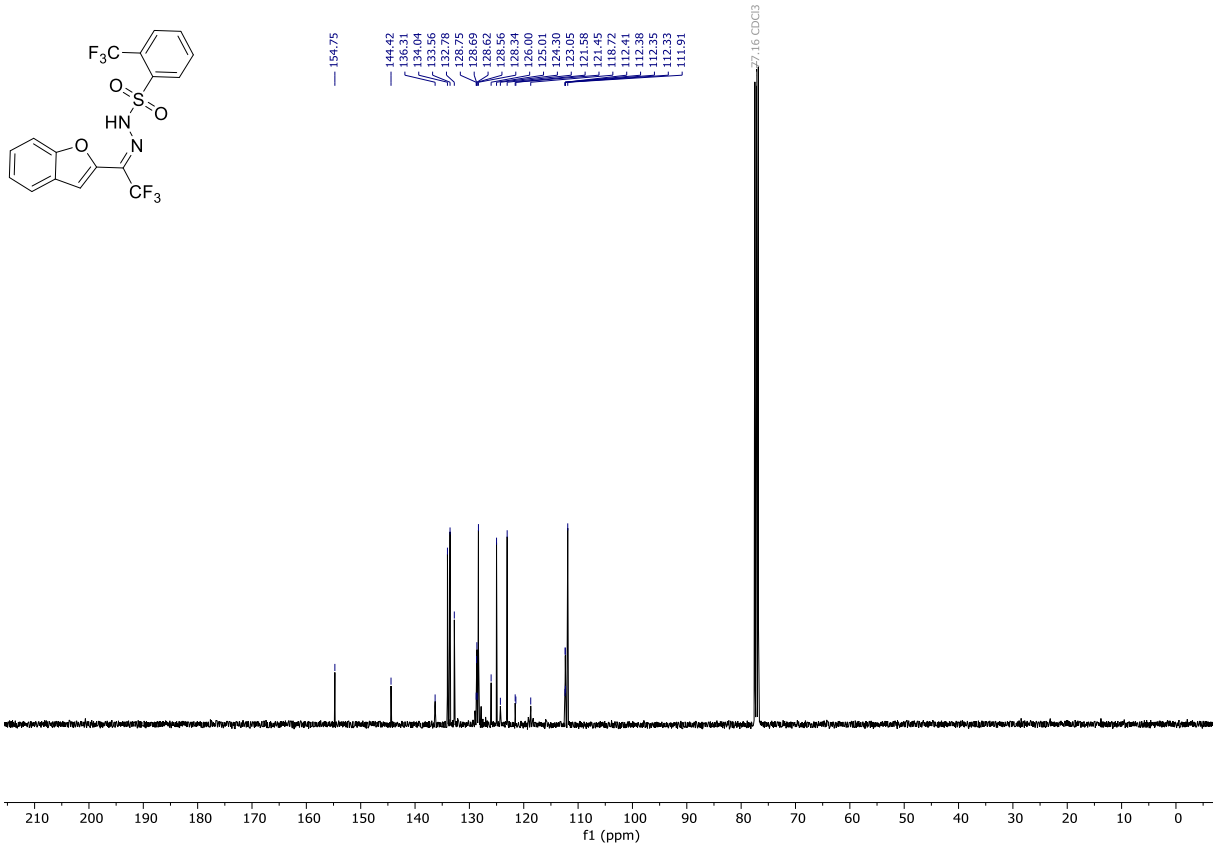
8 : ^{19}F NMR (282 MHz, $CDCl_3$):



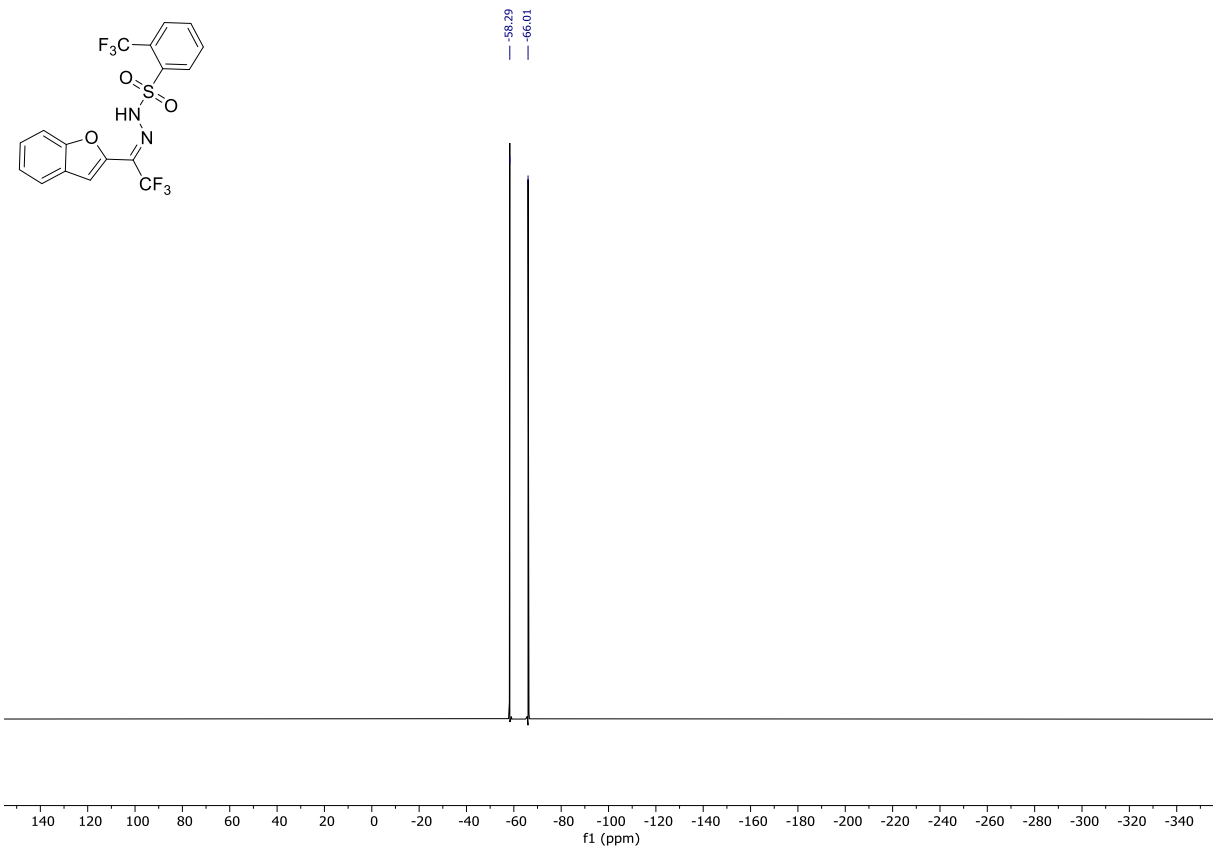
10: ^{1}H-NMR (400 MHz, $CDCl_3$):



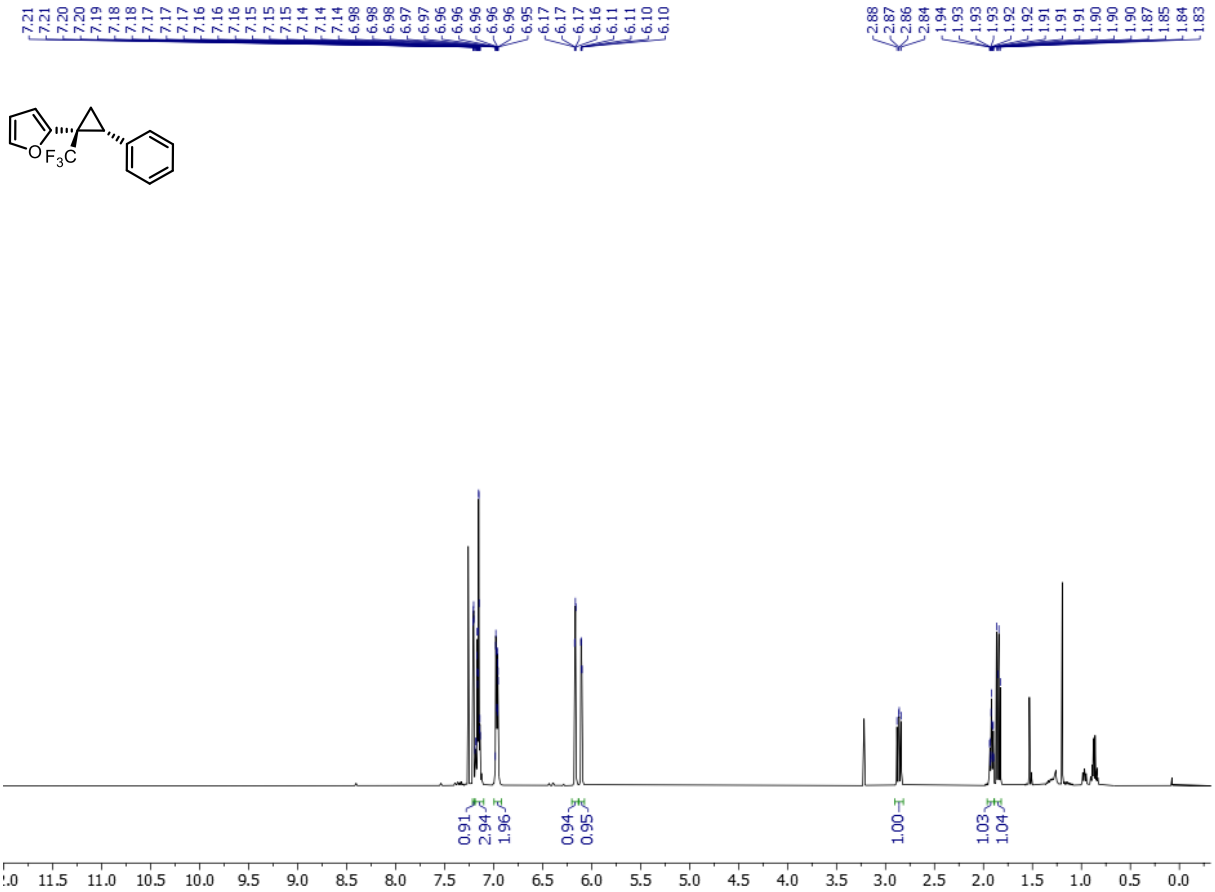
10: ^{13}C NMR (101 MHz, $CDCl_3$):



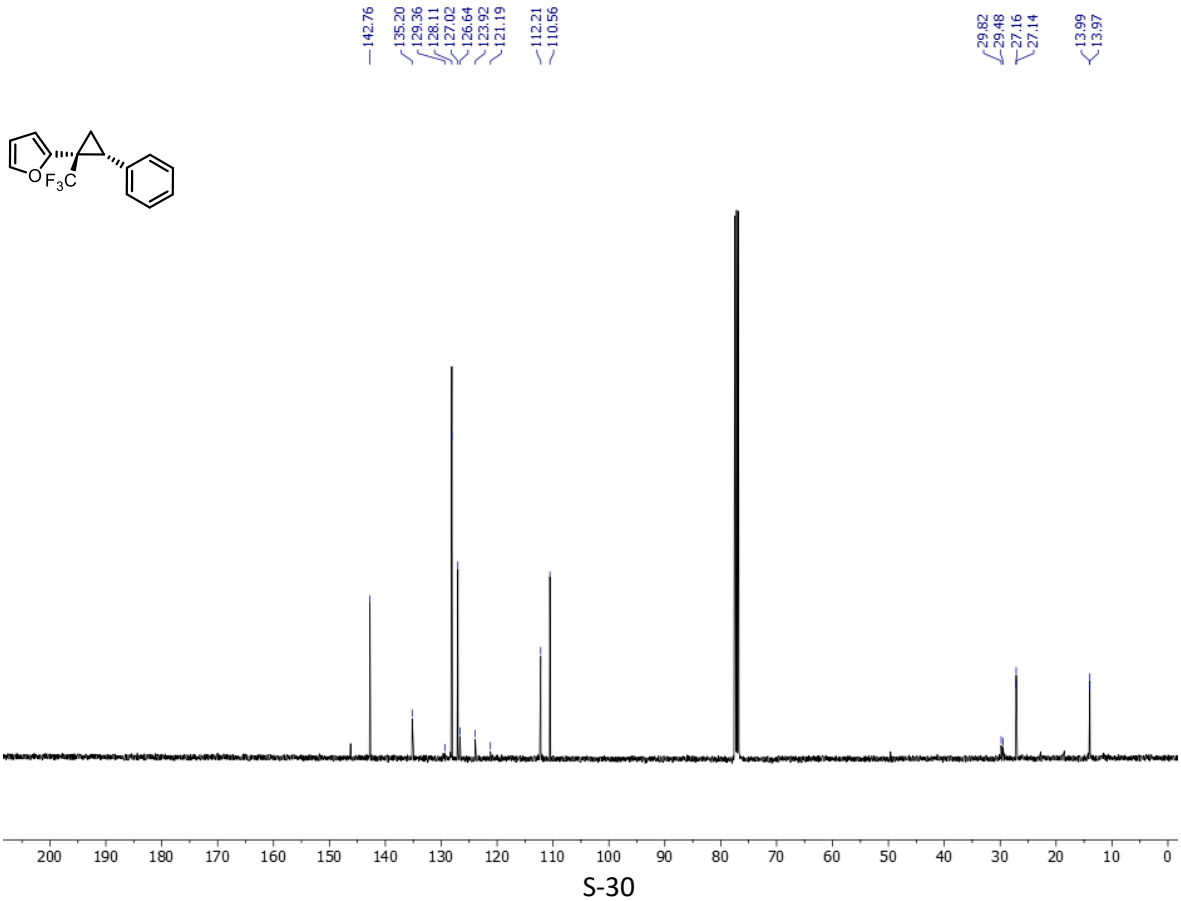
10: ^{19}F NMR (282 MHz, $CDCl_3$):



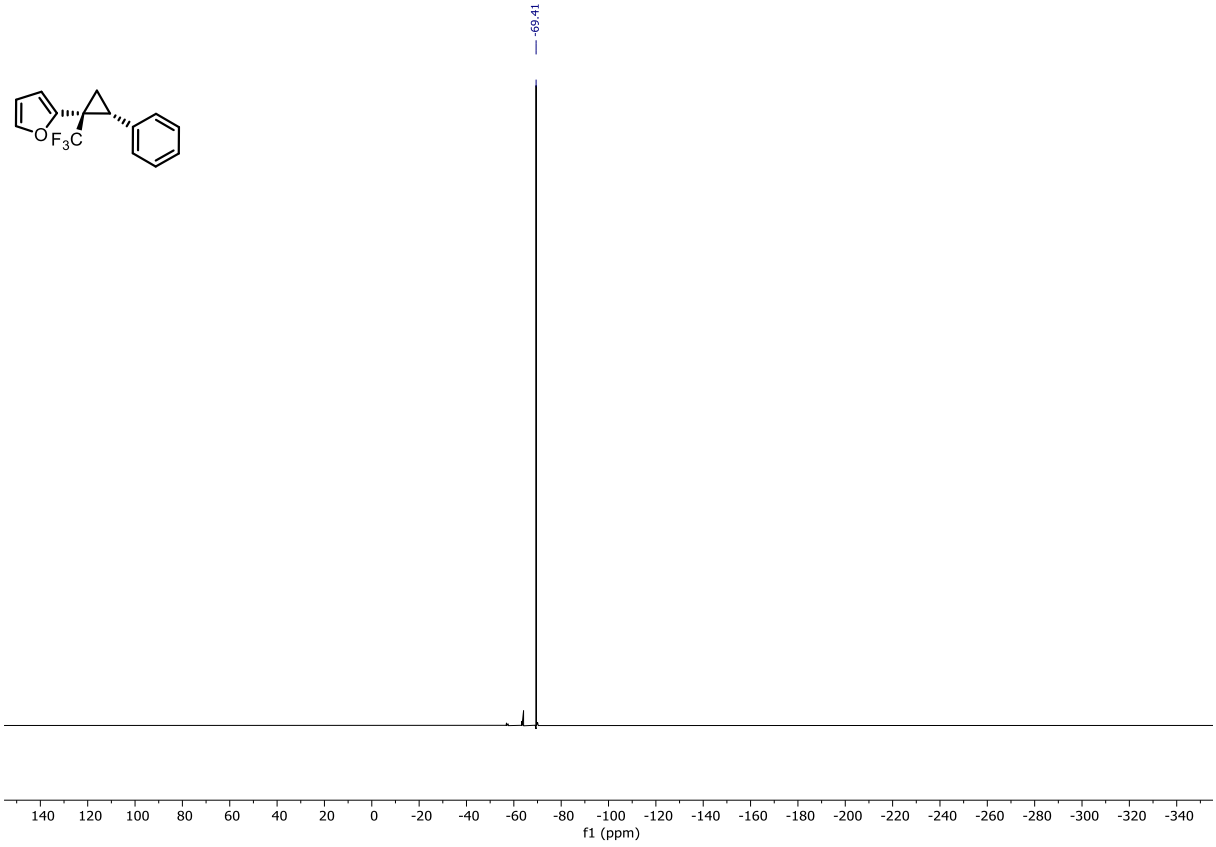
3a: ^{1}H-NMR (400 MHz, $CDCl_3$):



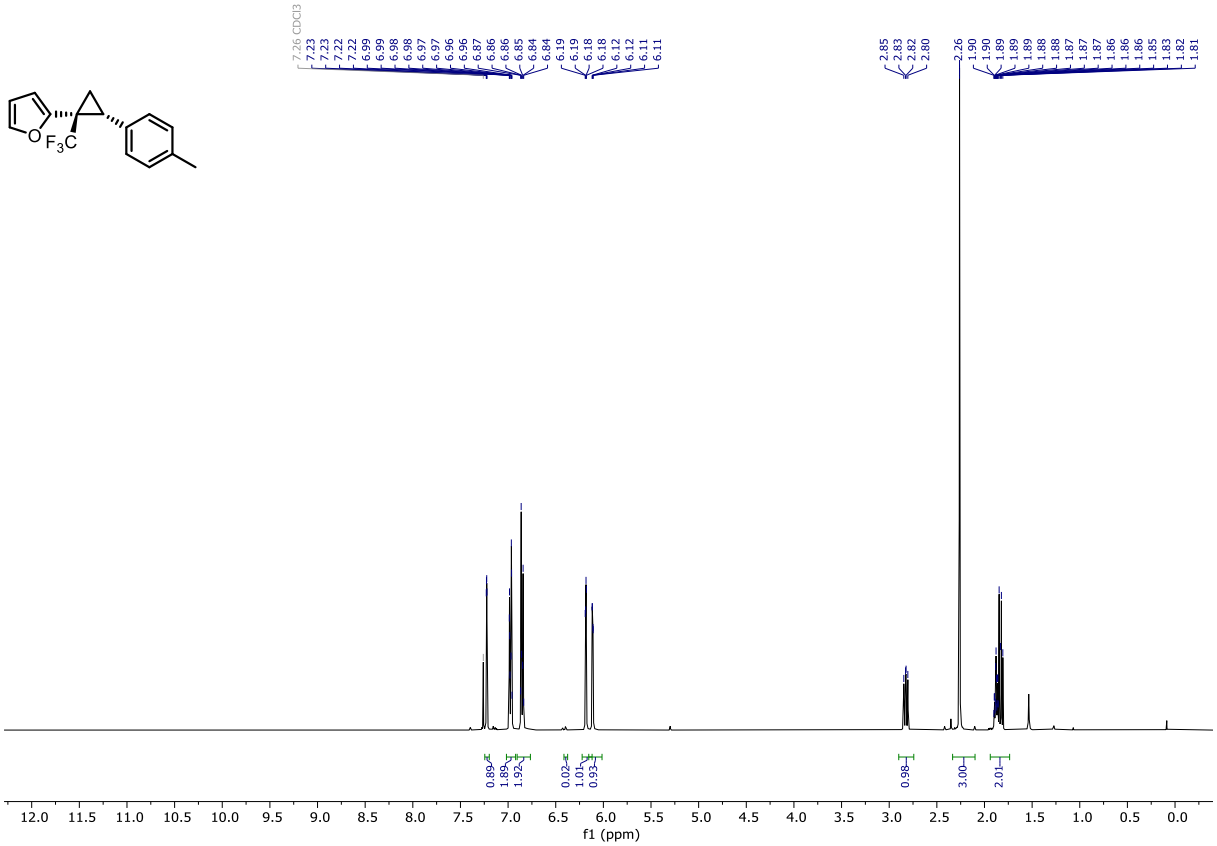
3a: ^{13}C NMR (101 MHz, $CDCl_3$):



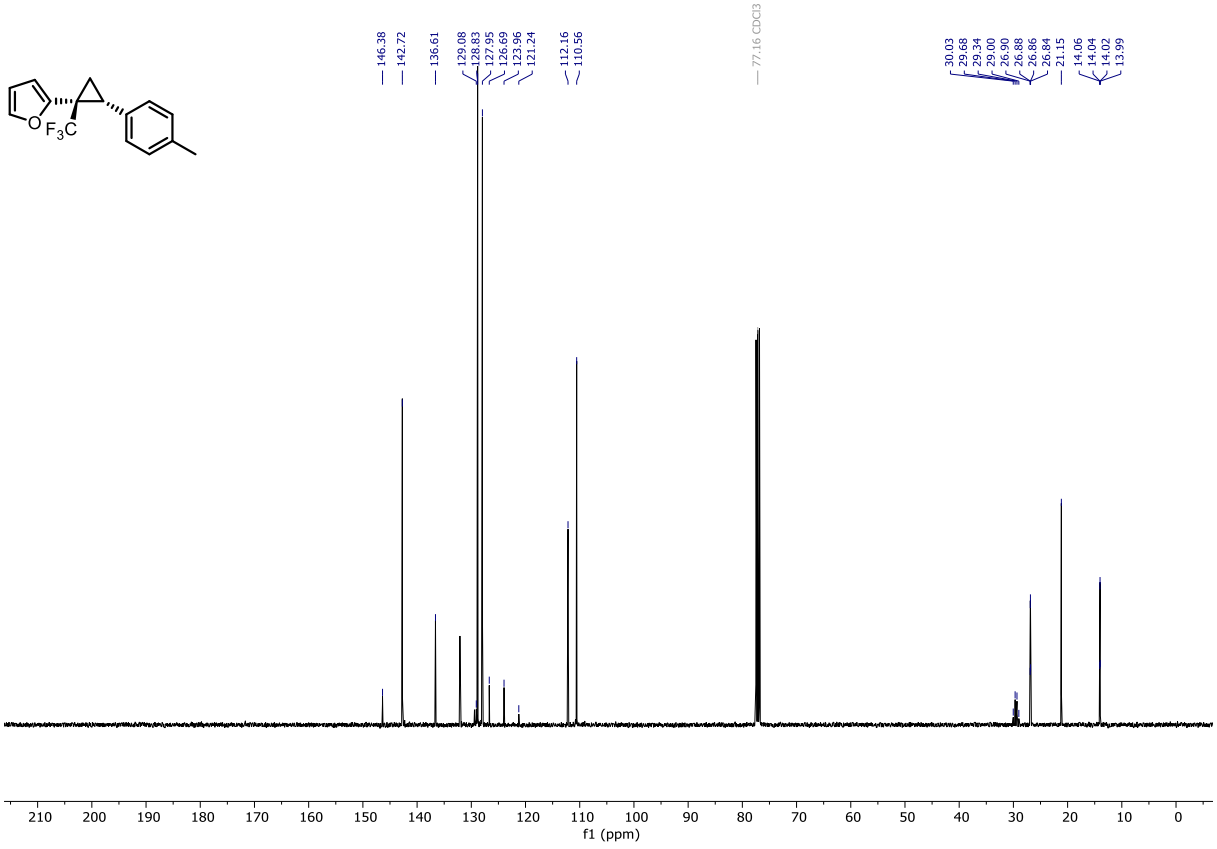
3a: ^{19}F NMR (282 MHz, $CDCl_3$):



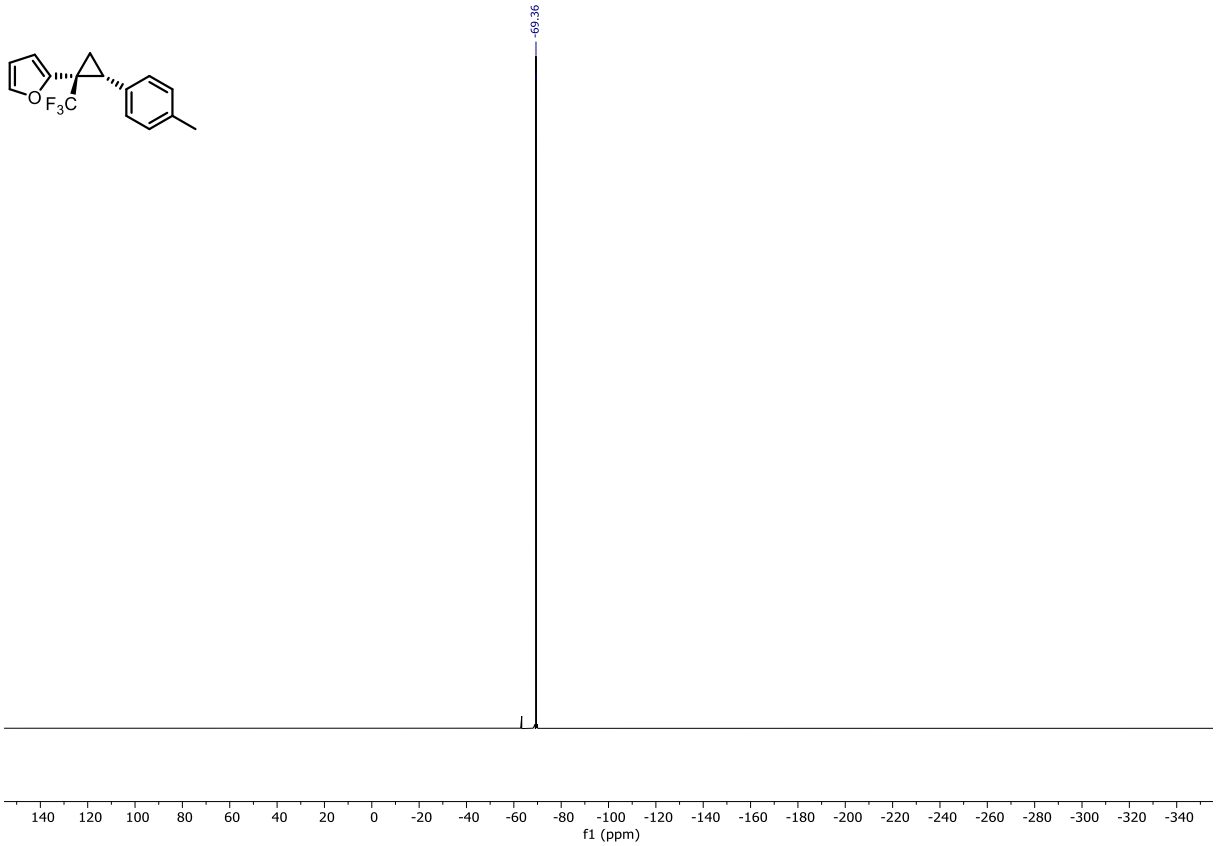
3b: ^{1}H-NMR (400 MHz, $CDCl_3$):



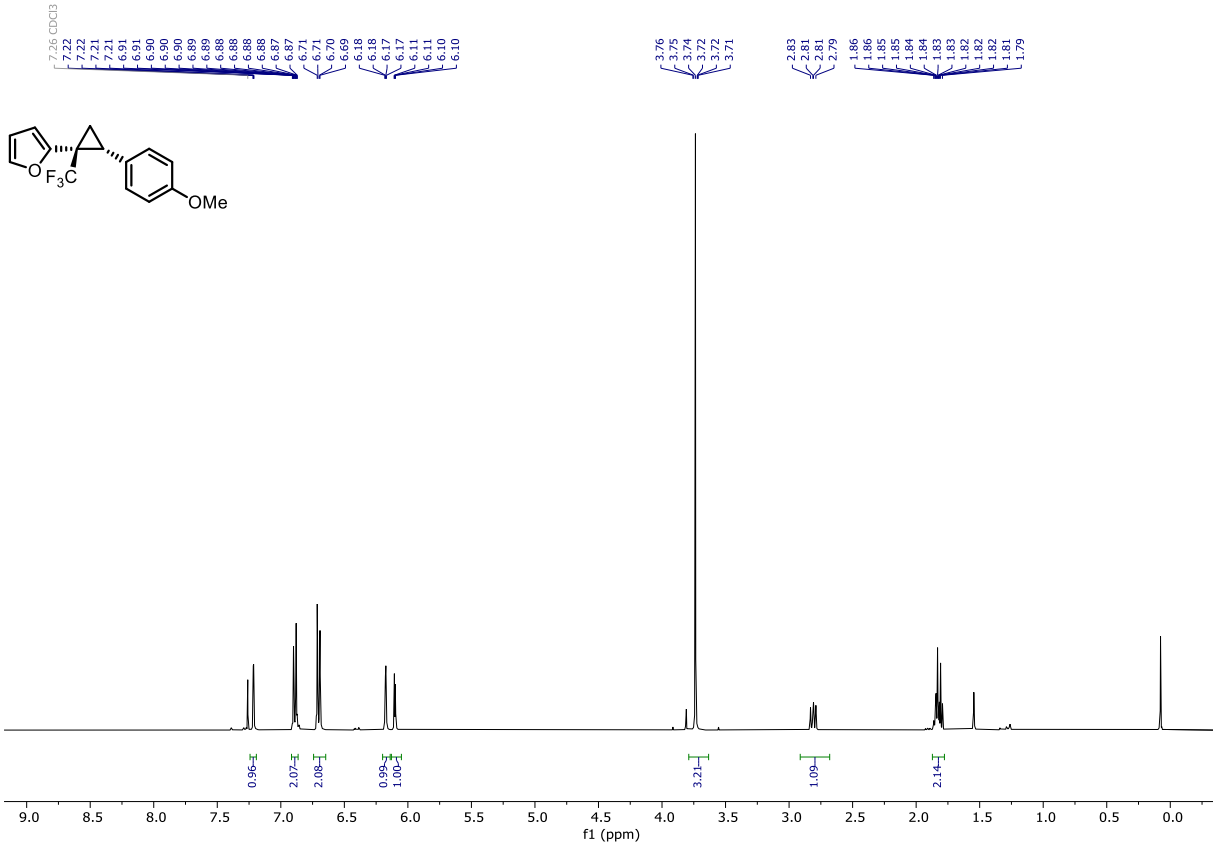
3b: ^{13}C NMR (101 MHz, $CDCl_3$):



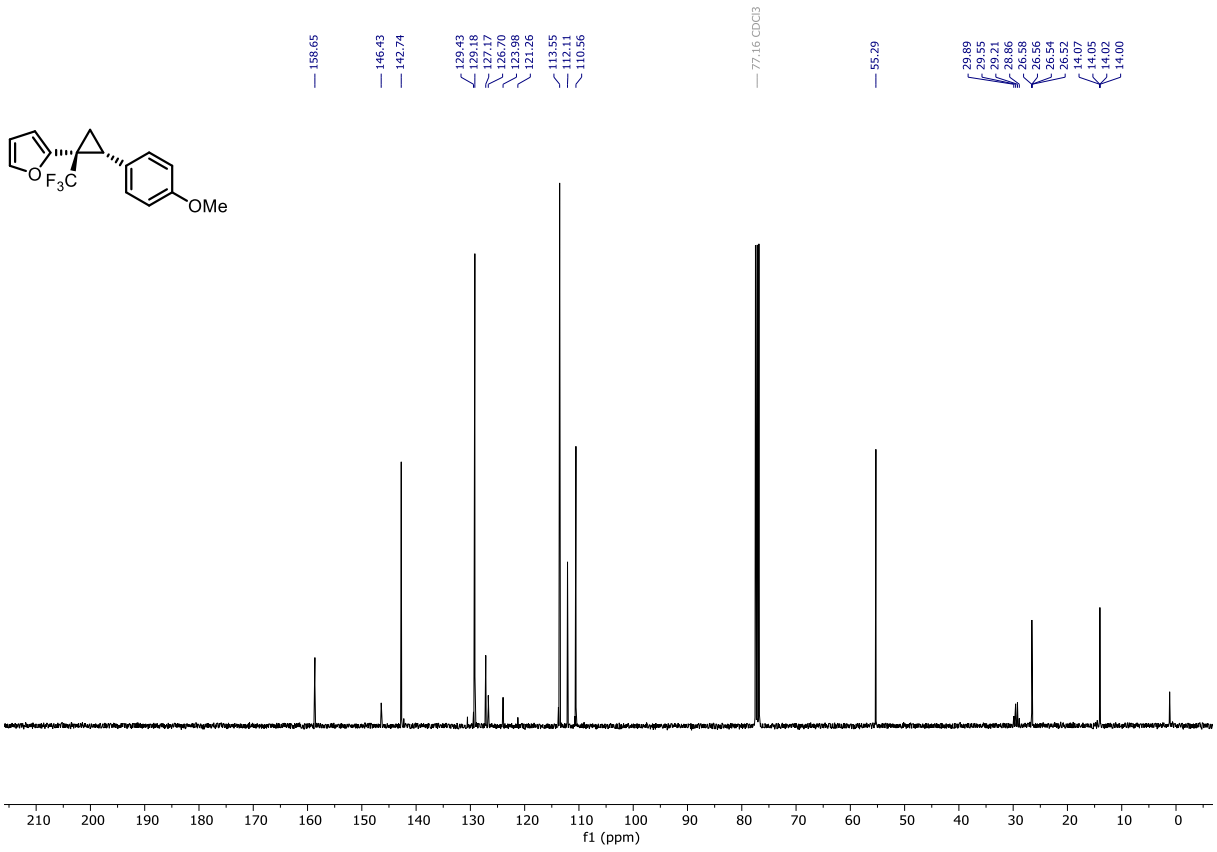
3b: ^{19}F NMR (282 MHz, $CDCl_3$):



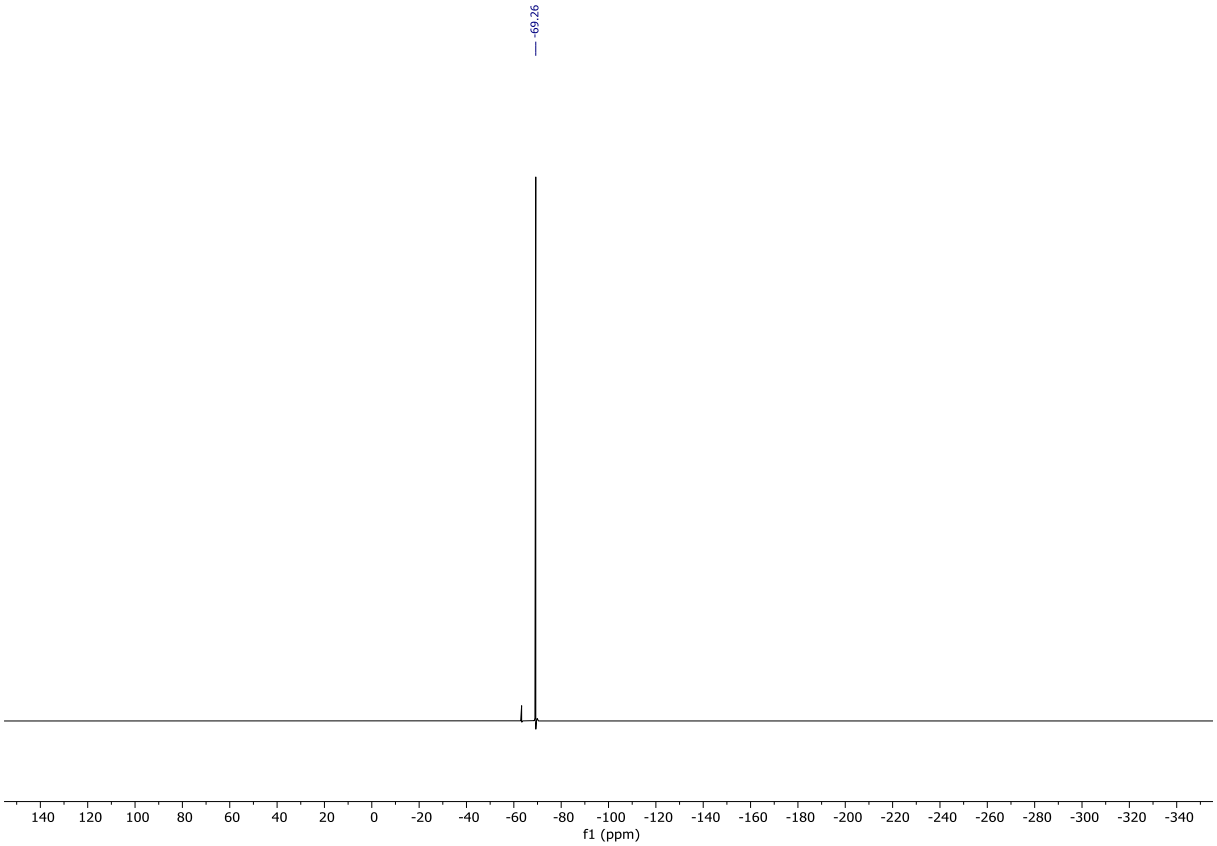
3c: ^{1}H-NMR (400 MHz, $CDCl_3$):



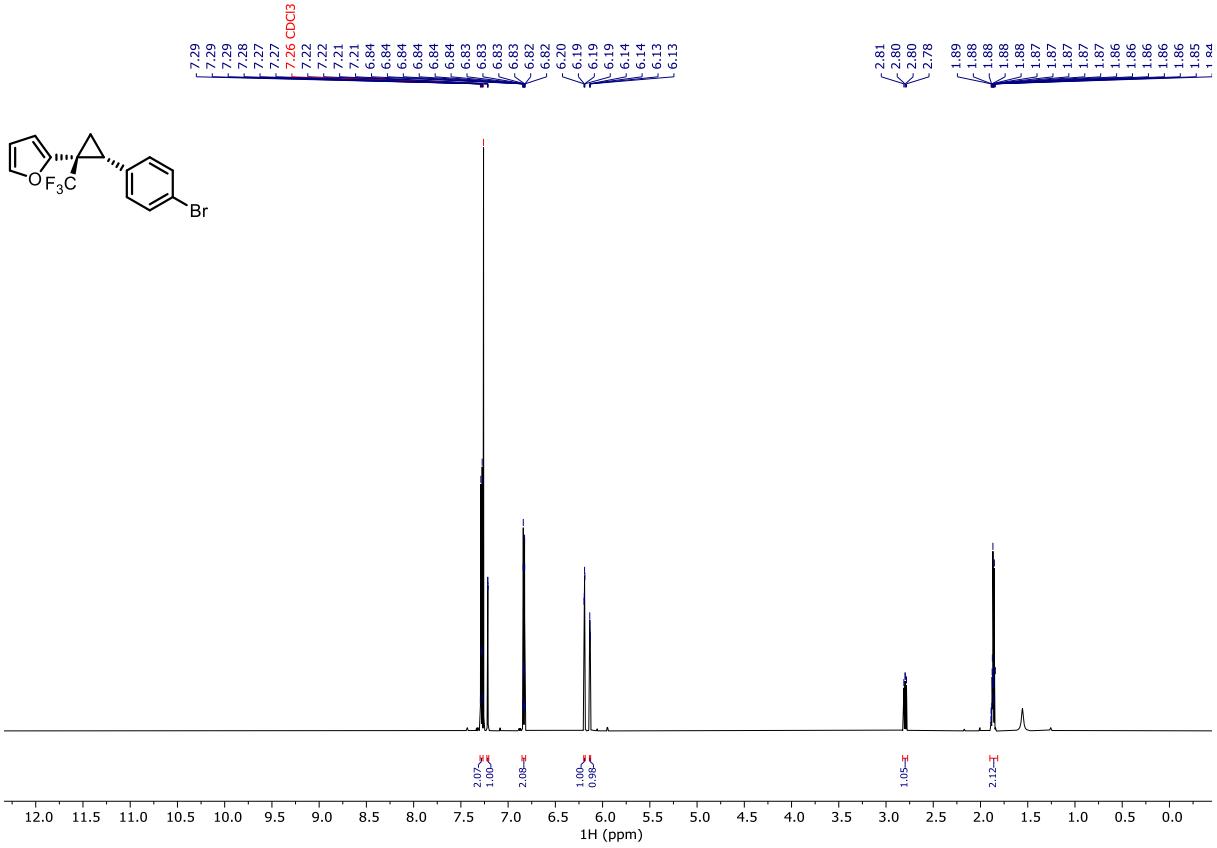
3c: ^{13}C NMR (101 MHz, $CDCl_3$):



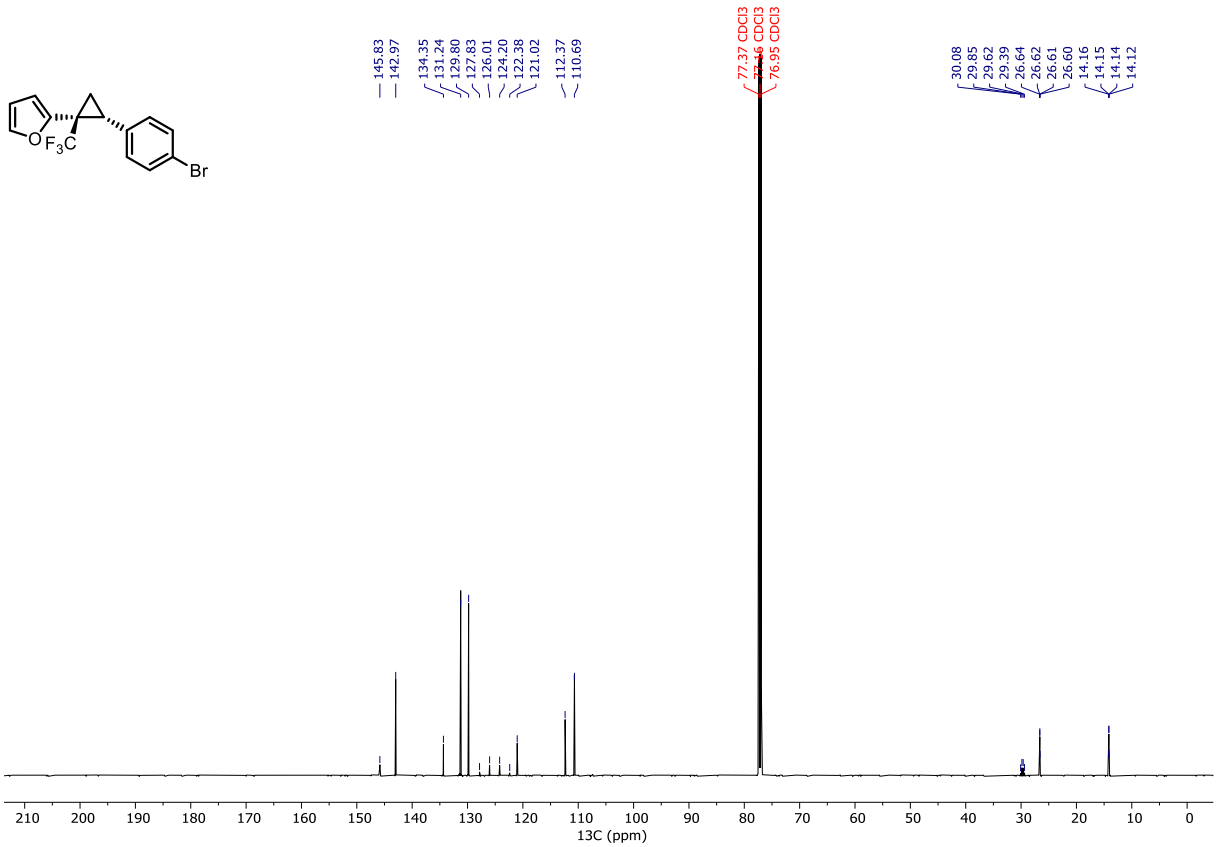
3c: ^{19}F NMR (282 MHz, $CDCl_3$):



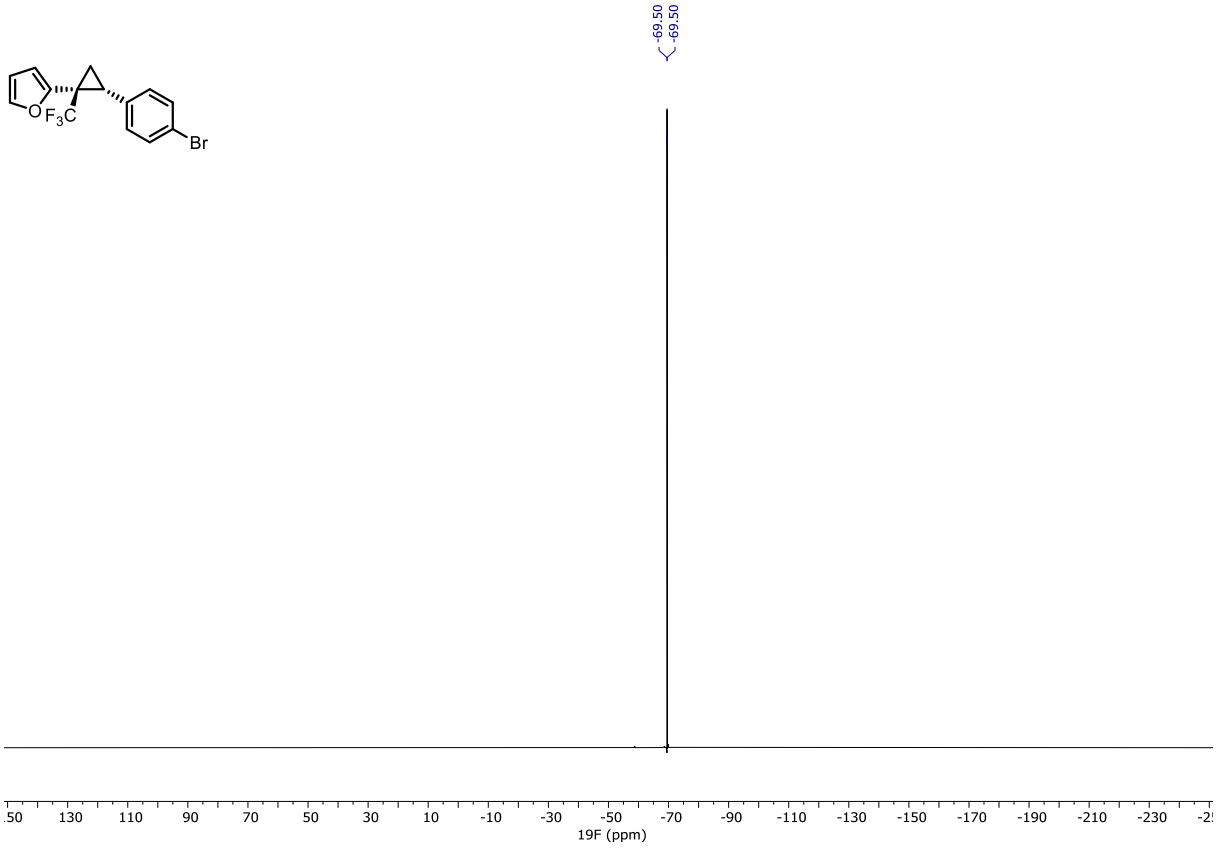
3d: ^{1}H-NMR (600 MHz, $CDCl_3$):



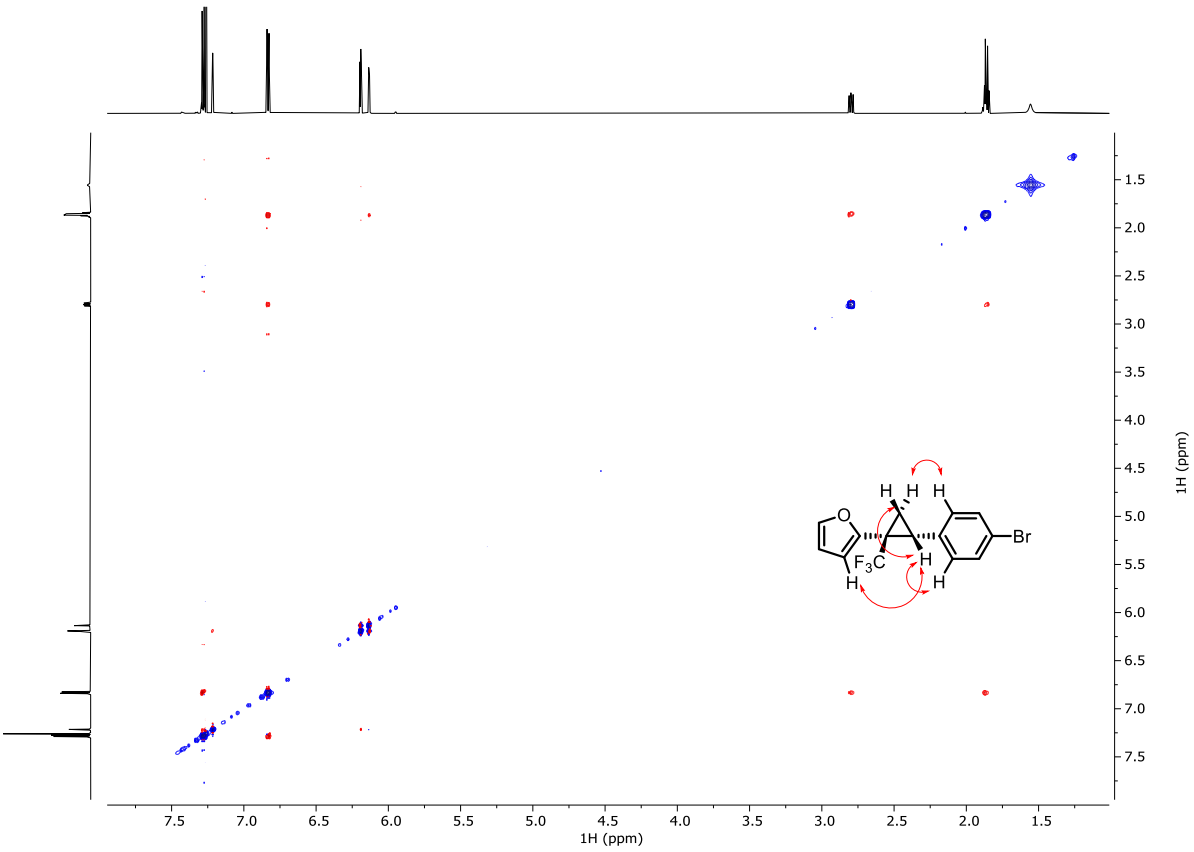
3d: ^{13}C NMR (151 MHz, $CDCl_3$):



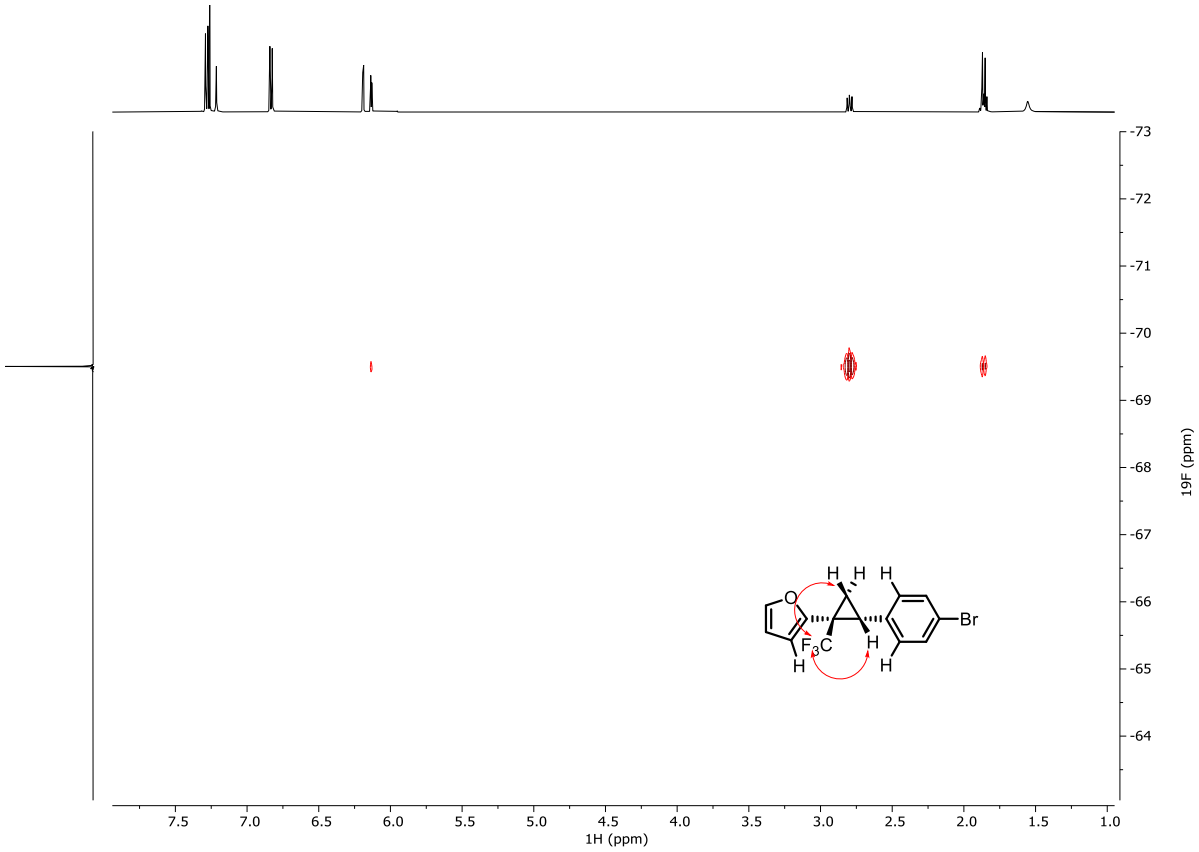
3d: ^{19}F NMR (565 MHz, $CDCl_3$):



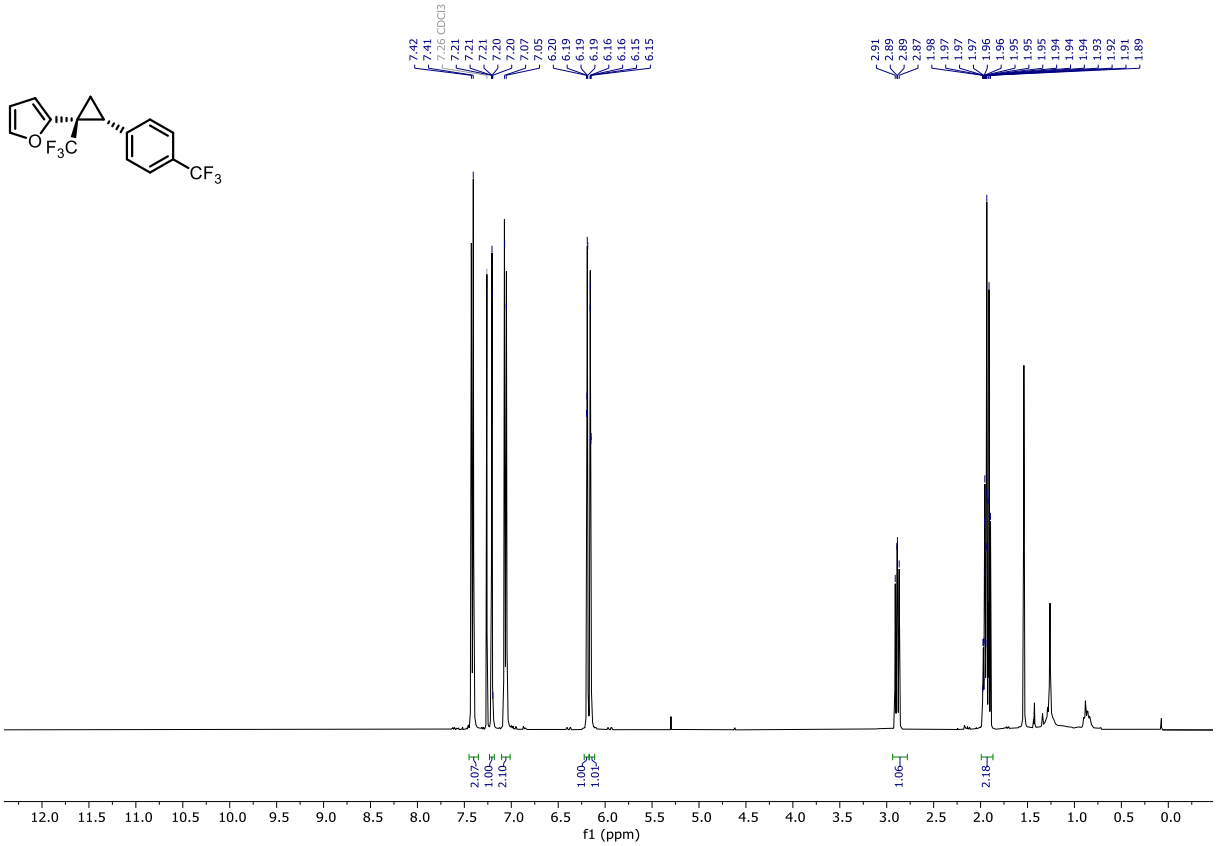
3d: ^{1}H-^{1}H NOESY ($CDCl_3$):



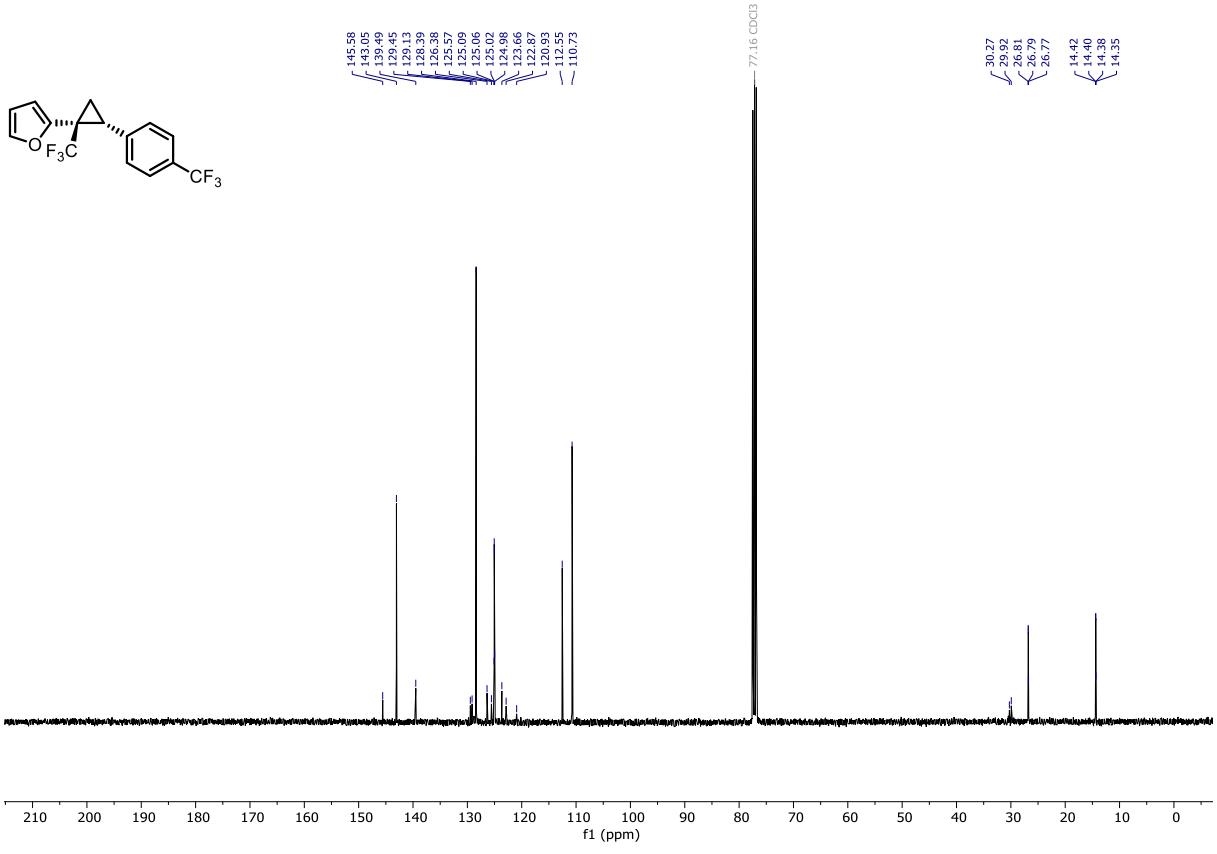
3d: ^{1}H-^{19}F HOESY ($CDCl_3$):



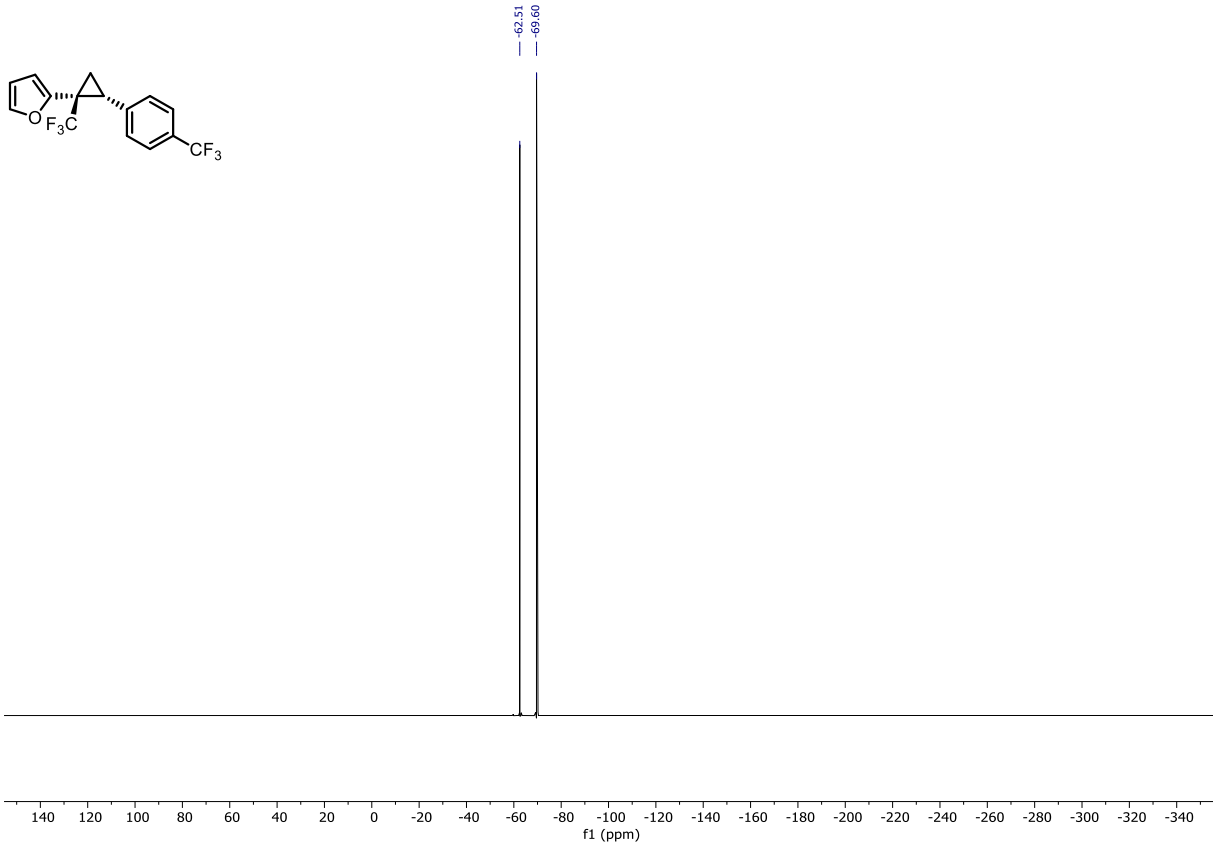
3e: ^{1}H-NMR (400 MHz, $CDCl_3$):



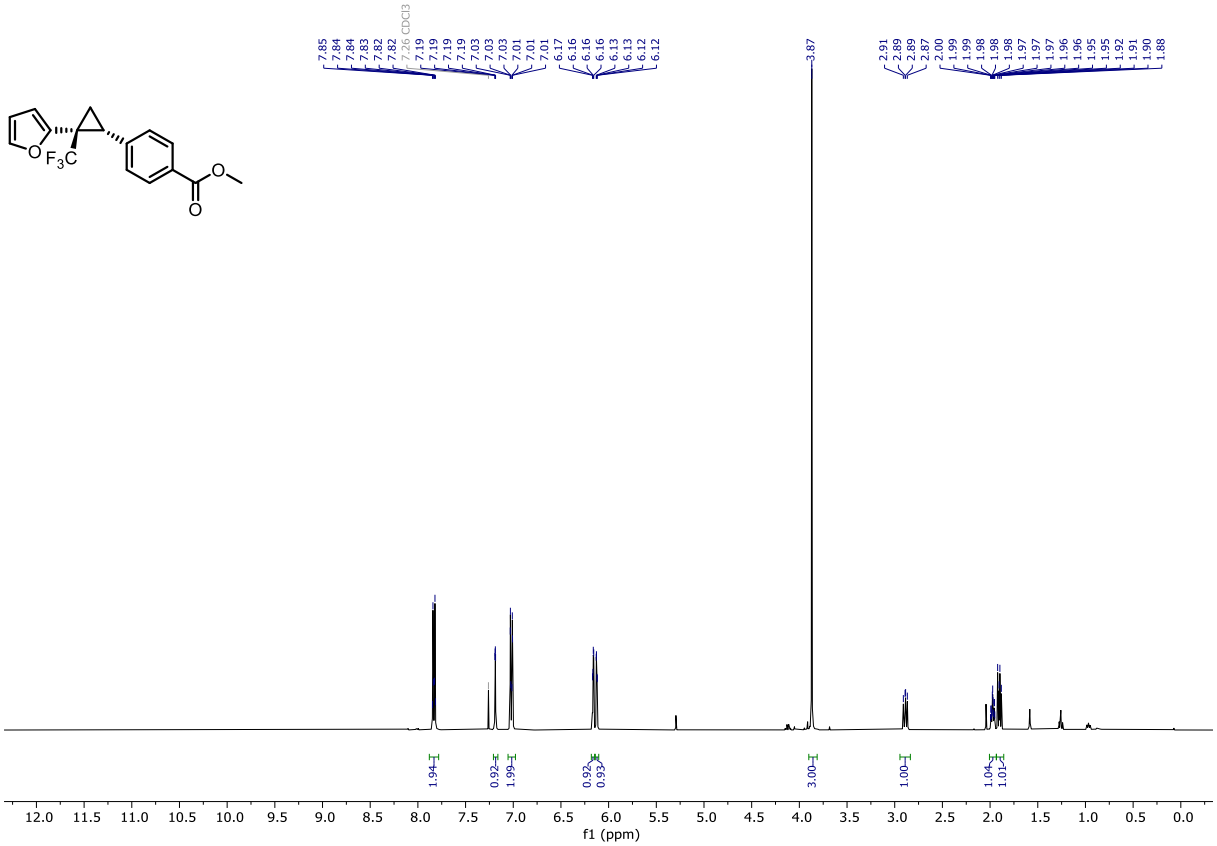
3e: ^{13}C NMR (101 MHz, $CDCl_3$):



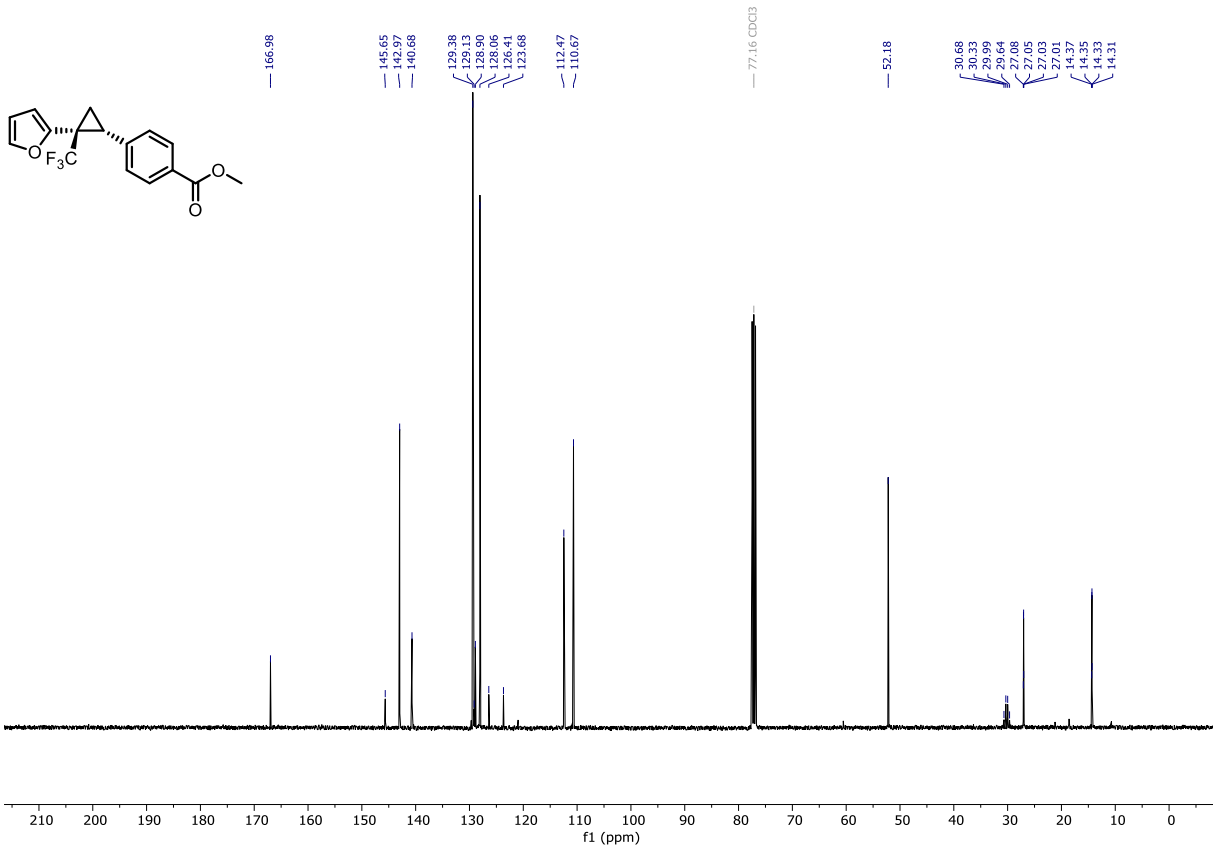
3e: ^{19}F NMR (282 MHz, $CDCl_3$):



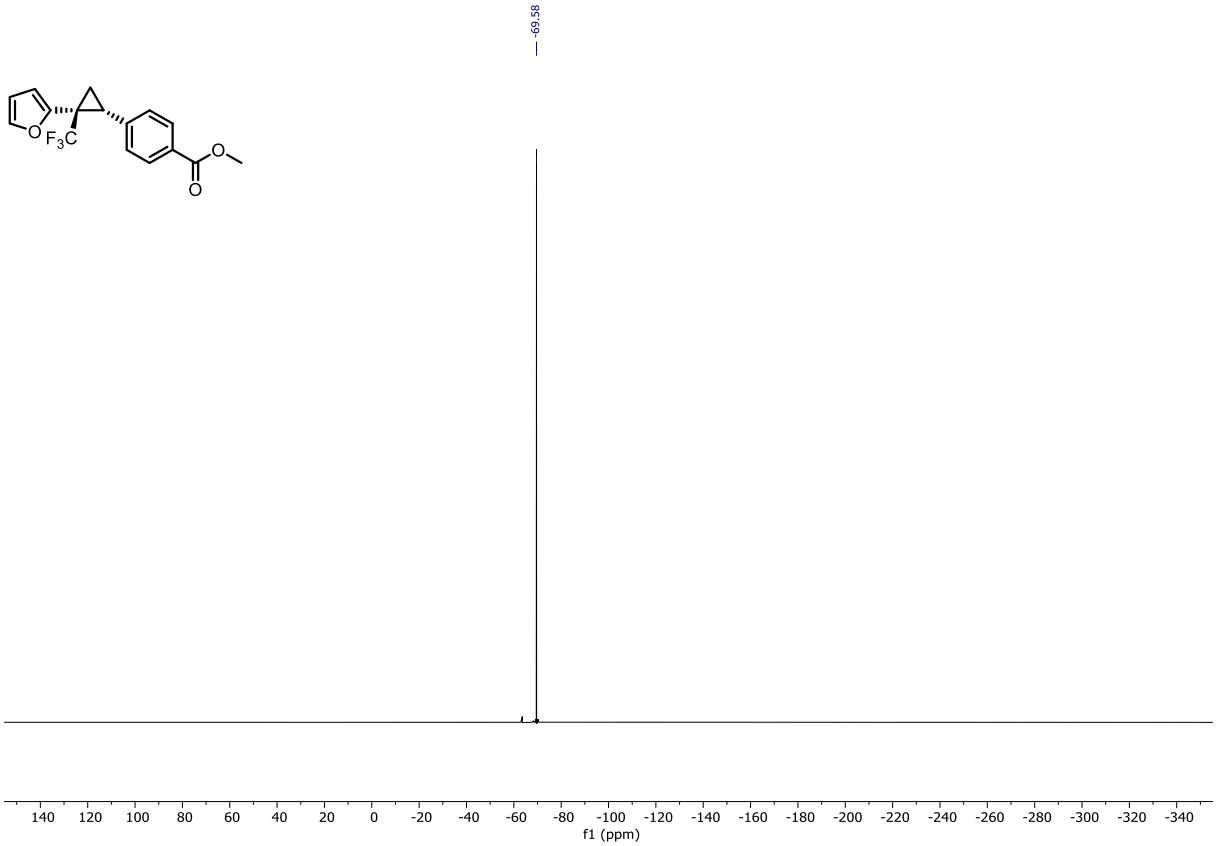
3f: ^{1}H-NMR (400 MHz, $CDCl_3$):



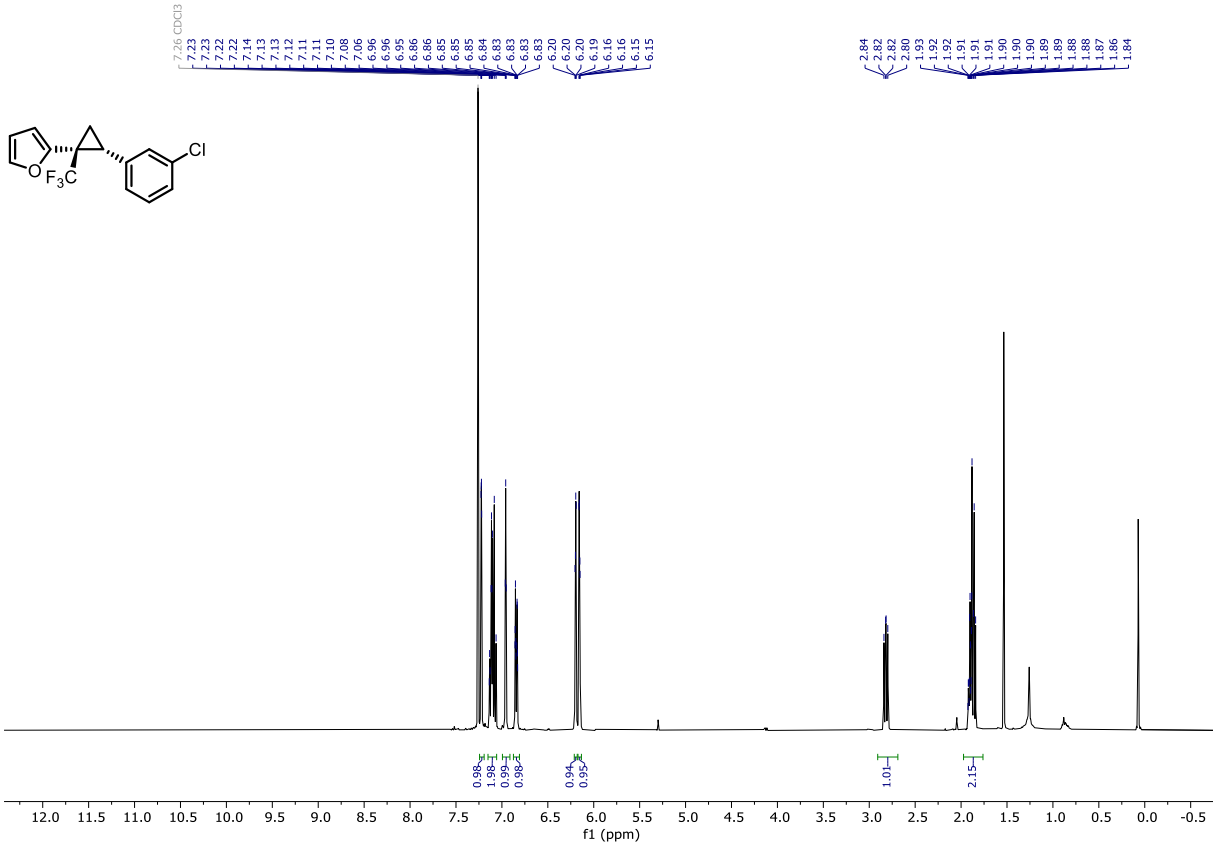
3f: ^{13}C NMR (101 MHz, $CDCl_3$):



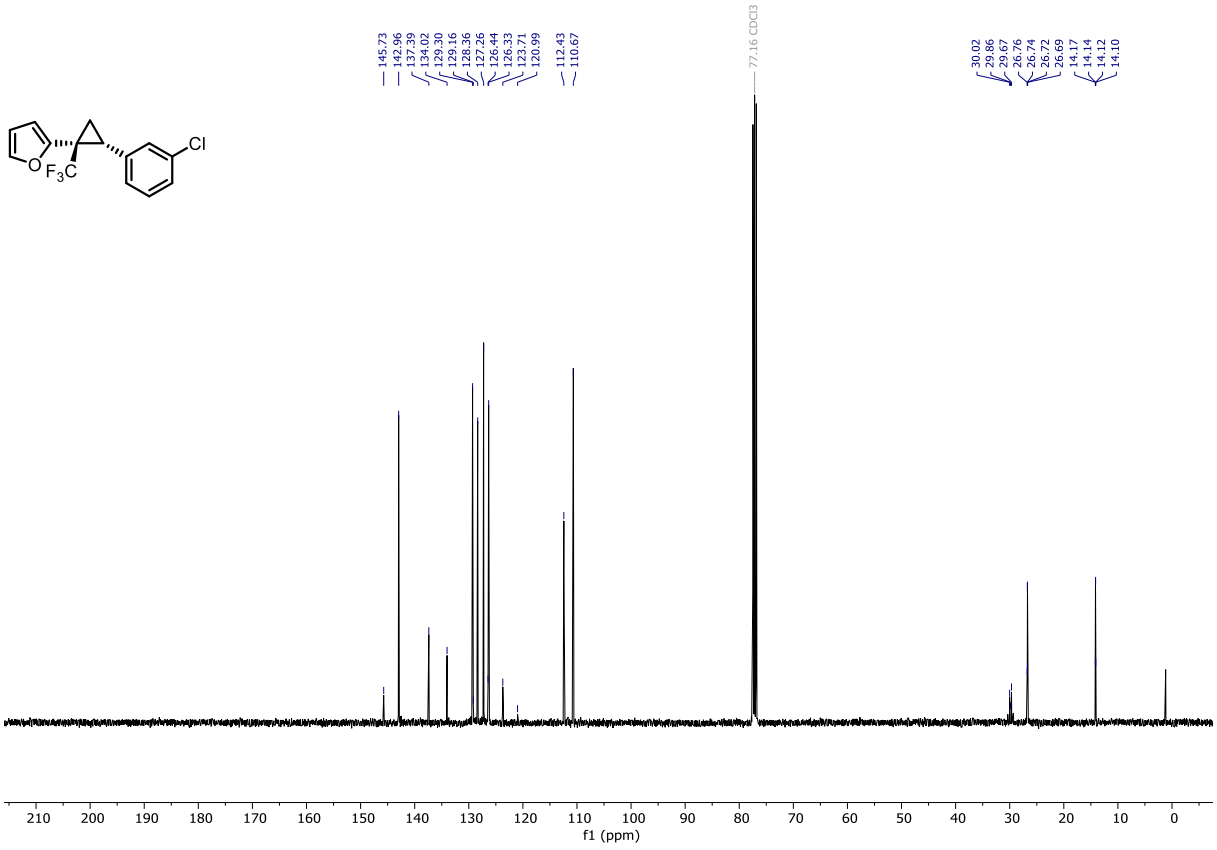
3f: ^{19}F NMR (282 MHz, $CDCl_3$):



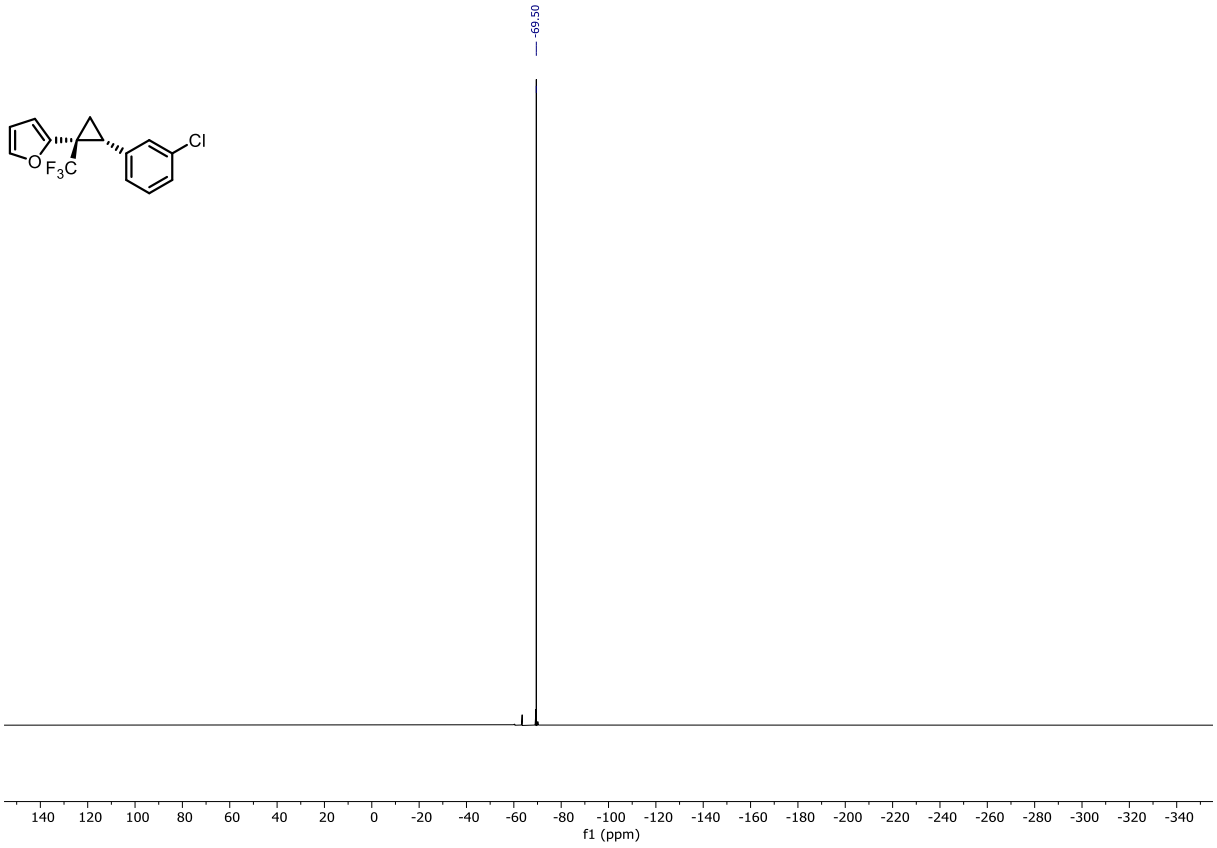
3g: ^{1}H-NMR (400 MHz, $CDCl_3$):



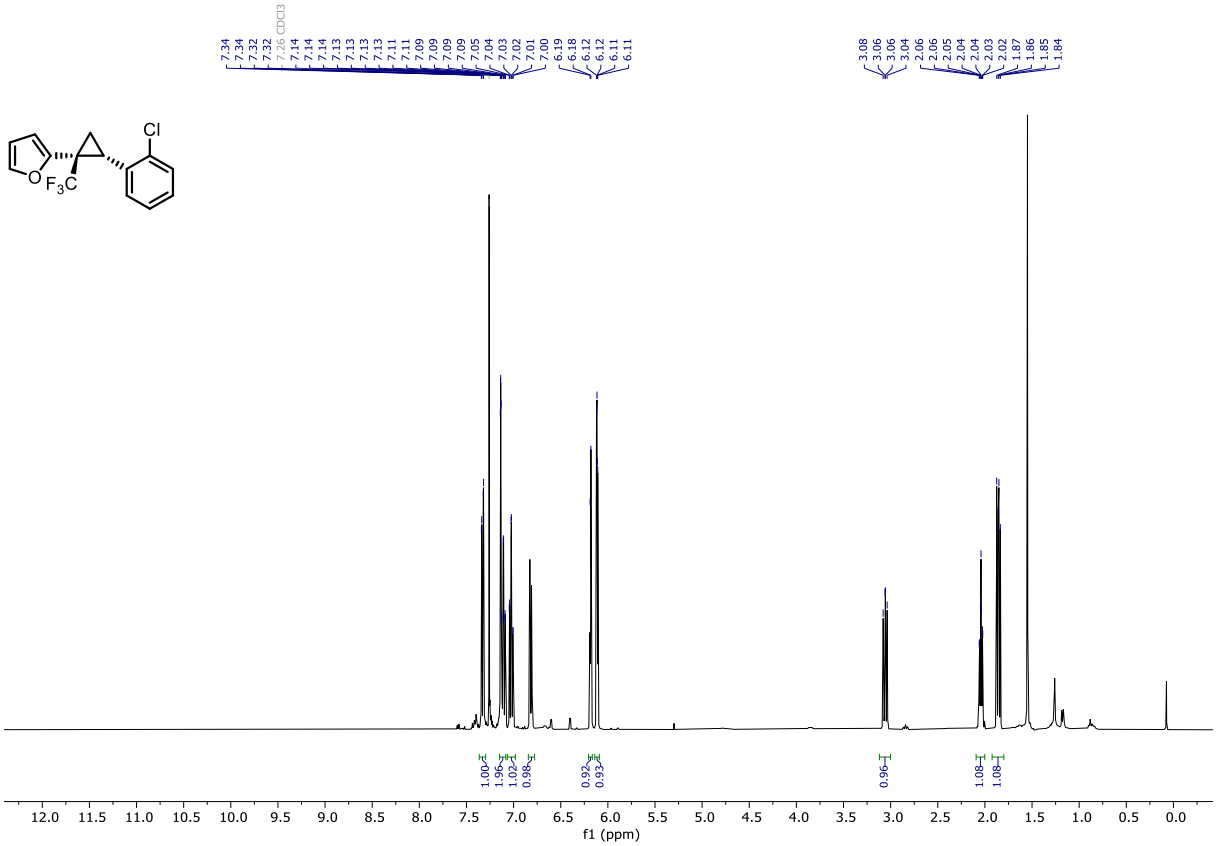
3g: ^{13}C NMR (101 MHz, $CDCl_3$):



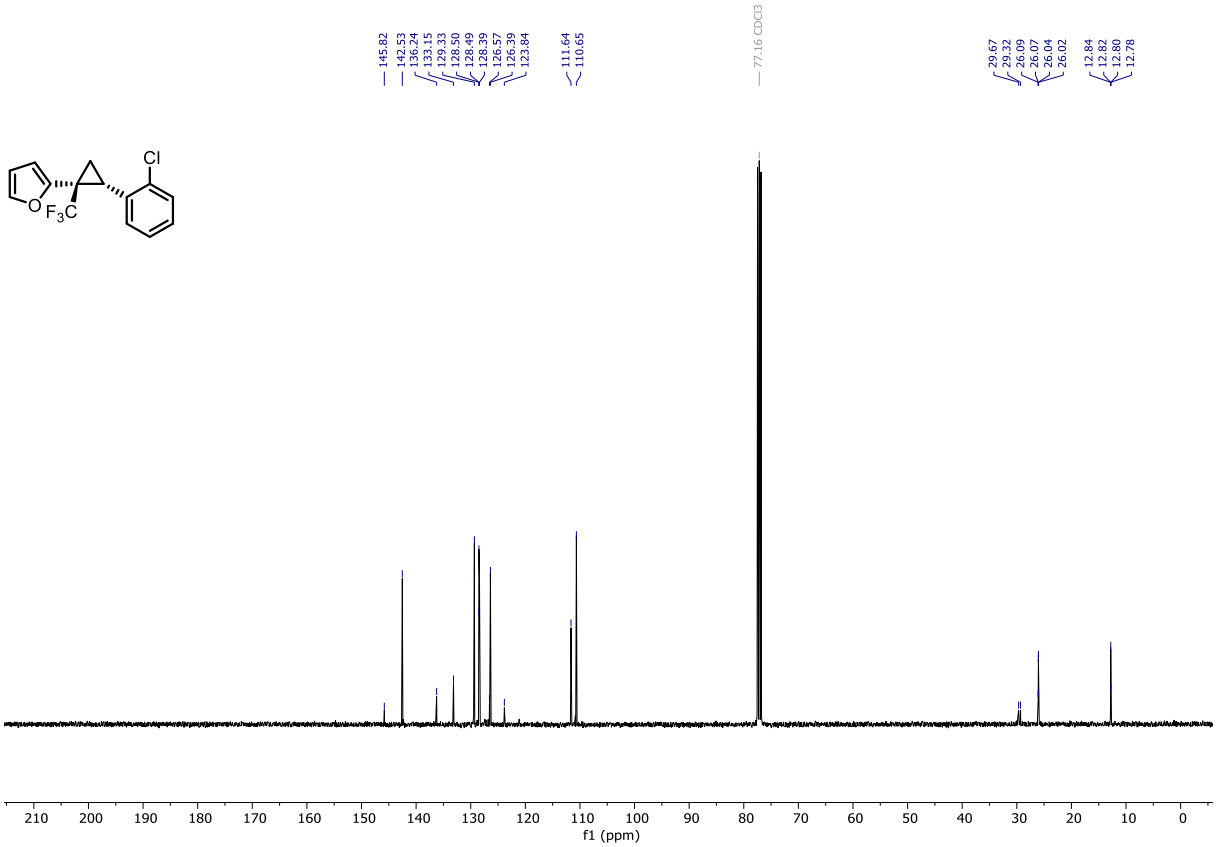
3g: ^{19}F NMR (282 MHz, $CDCl_3$):



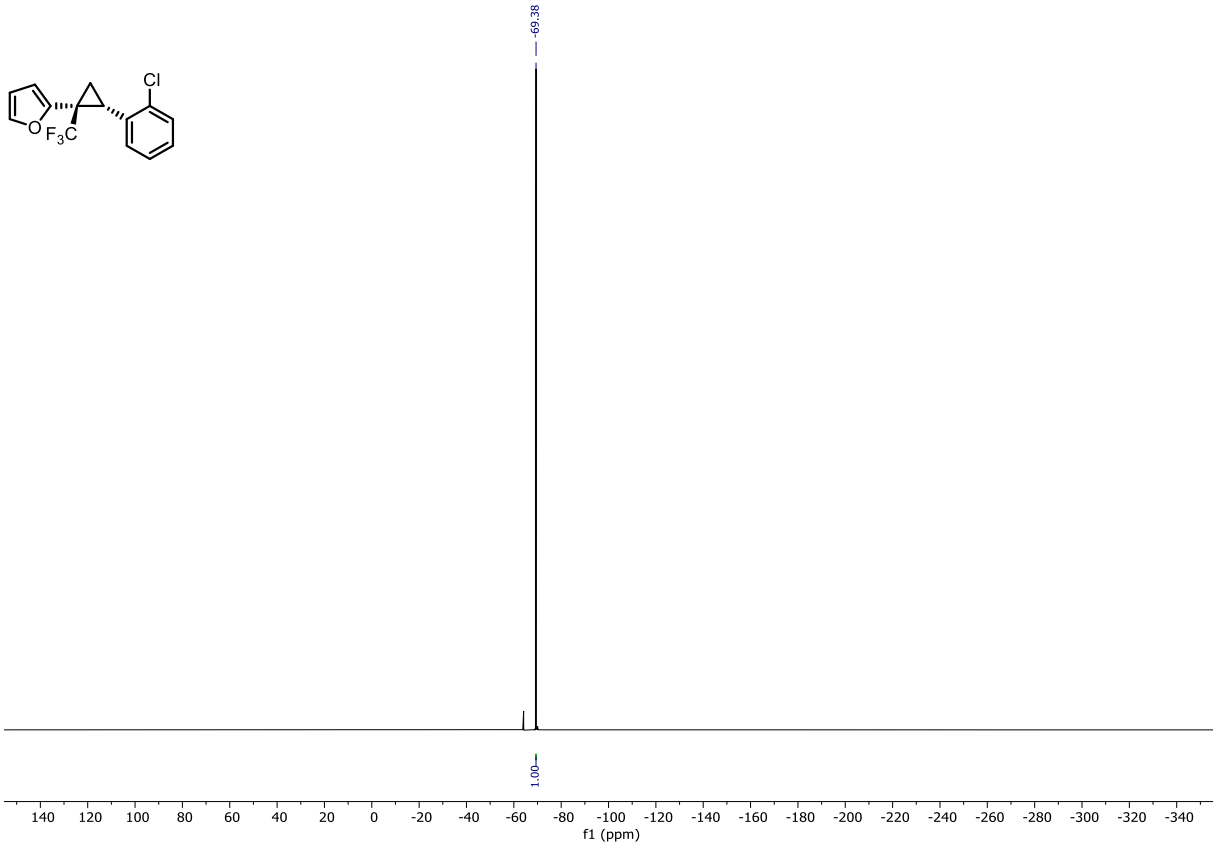
3h: ^{1}H-NMR (400 MHz, $CDCl_3$):



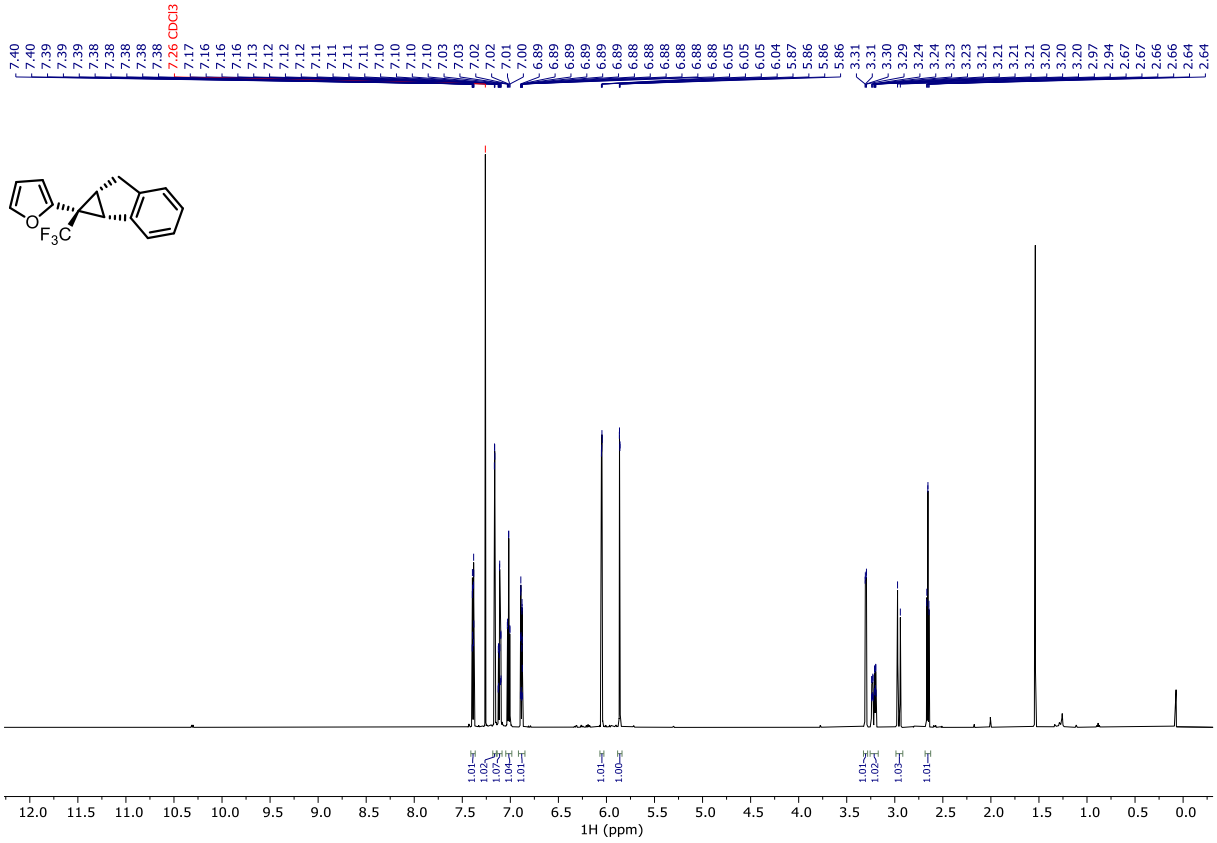
3h: ^{13}C NMR (101 MHz, $CDCl_3$):



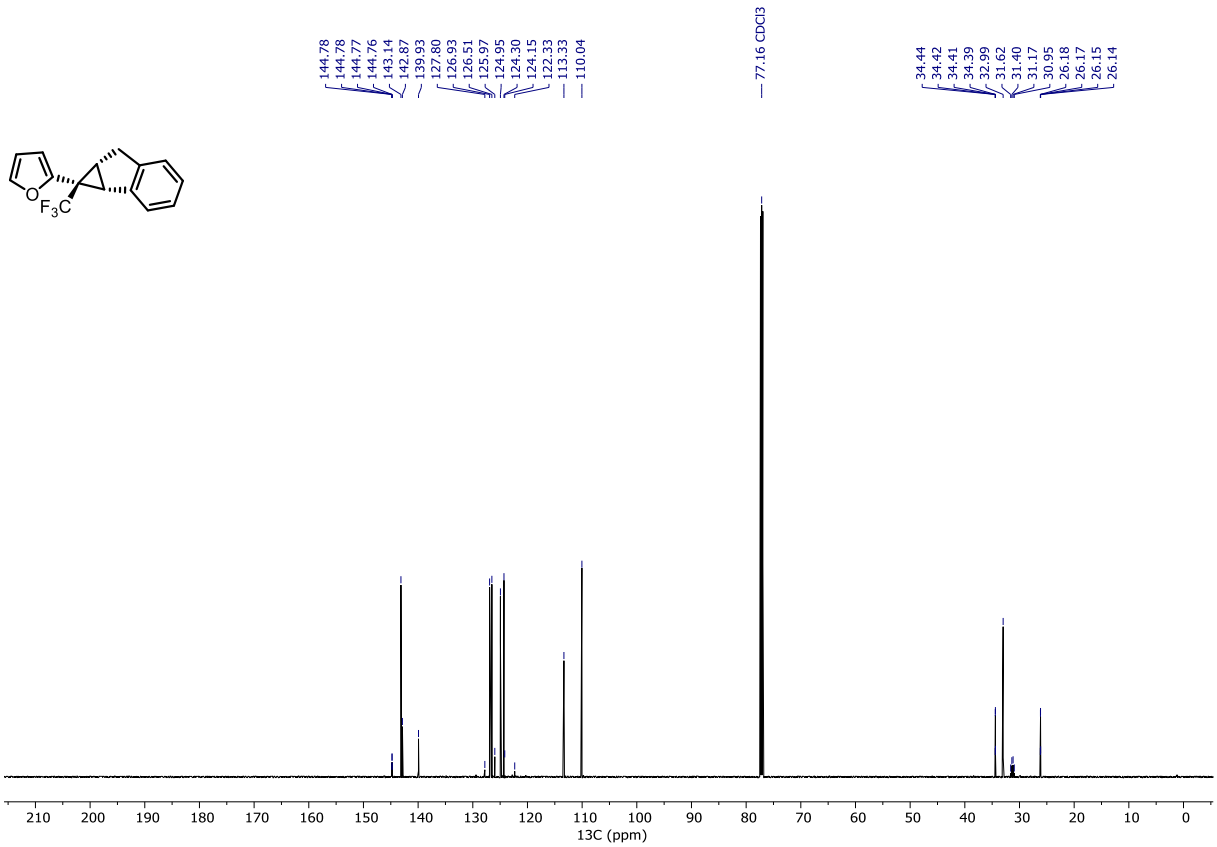
3h: ^{19}F NMR (282 MHz, $CDCl_3$):



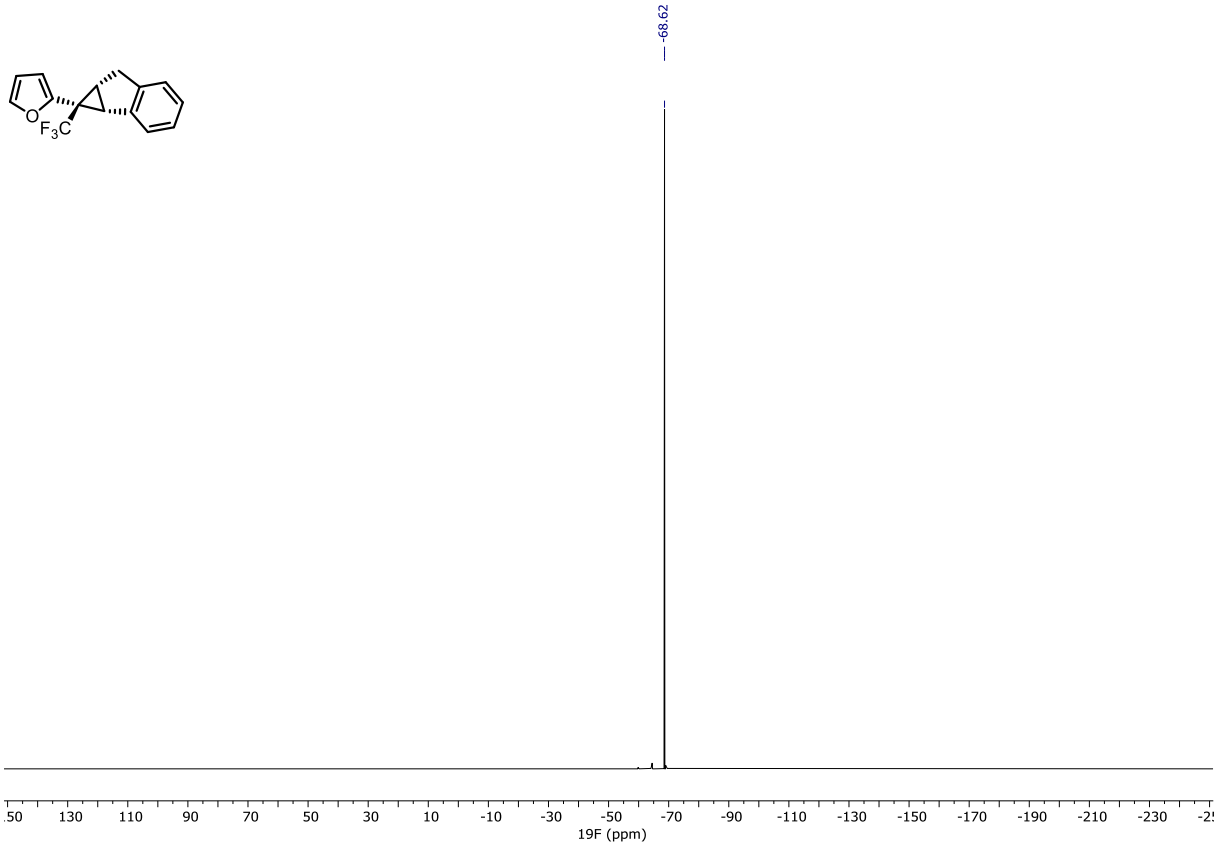
3i: ^{1}H-NMR (600 MHz, $CDCl_3$):



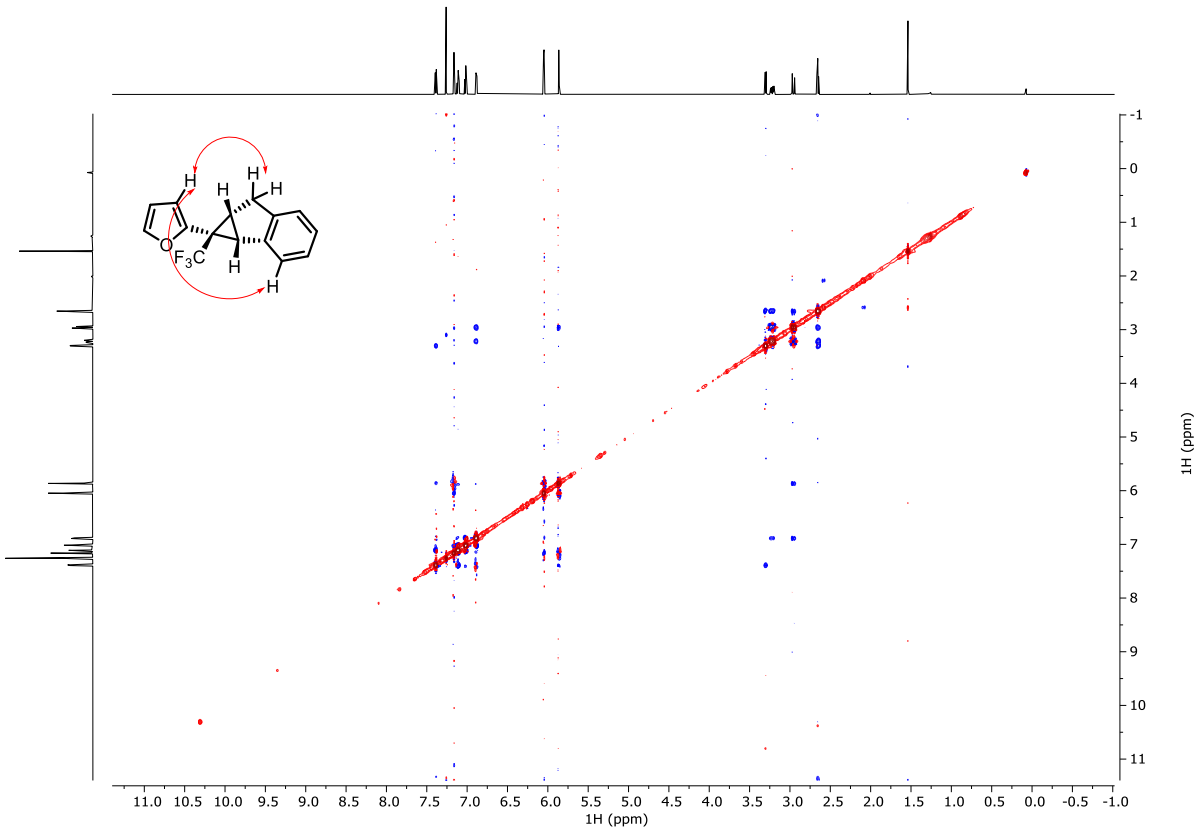
3i: ^{13}C NMR (151 MHz, $CDCl_3$):



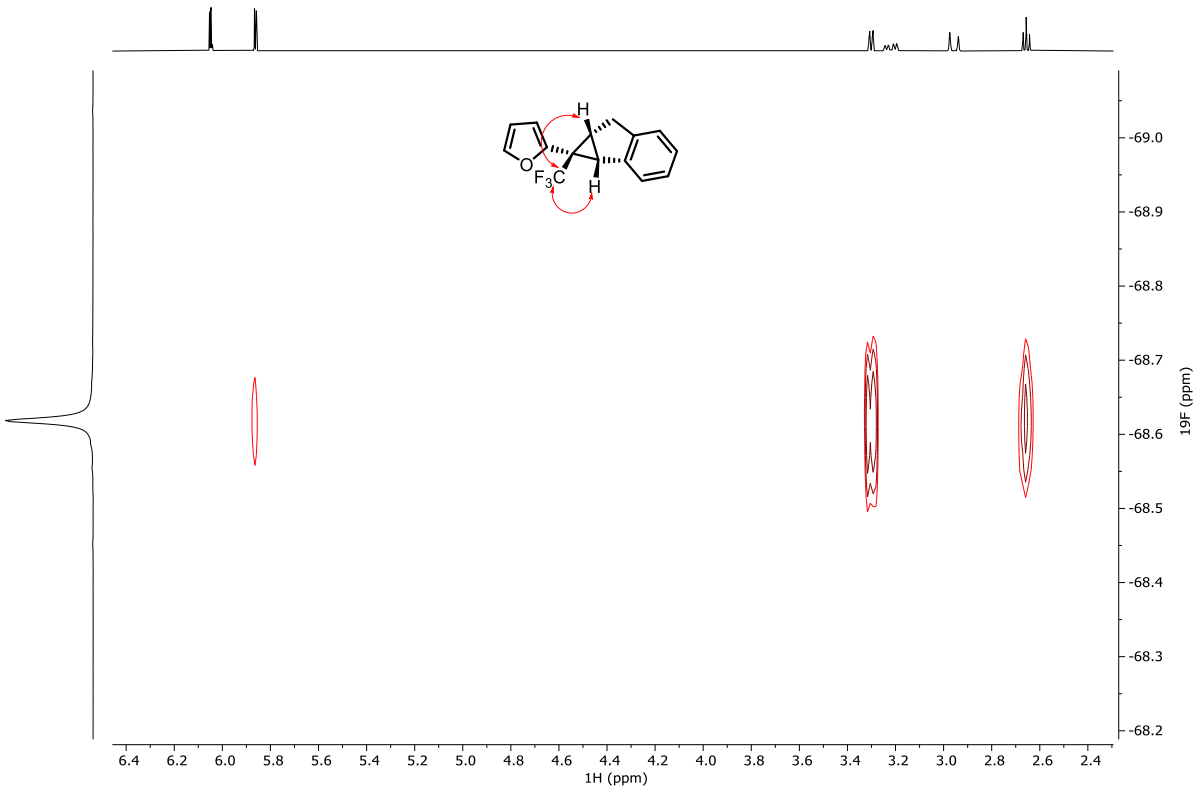
3i: ^{19}F NMR (565 MHz, $CDCl_3$):



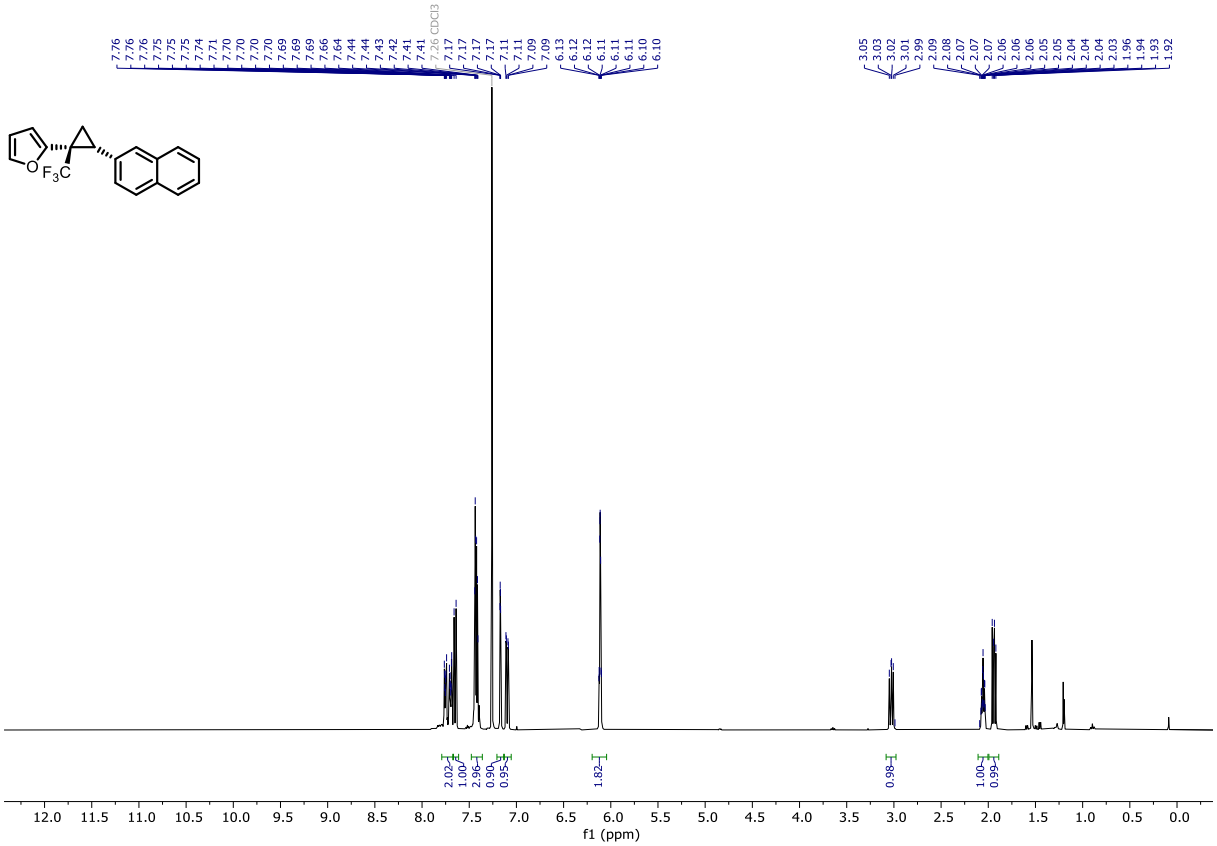
3i: ^{1}H-^{1}H NOESY ($CDCl_3$):



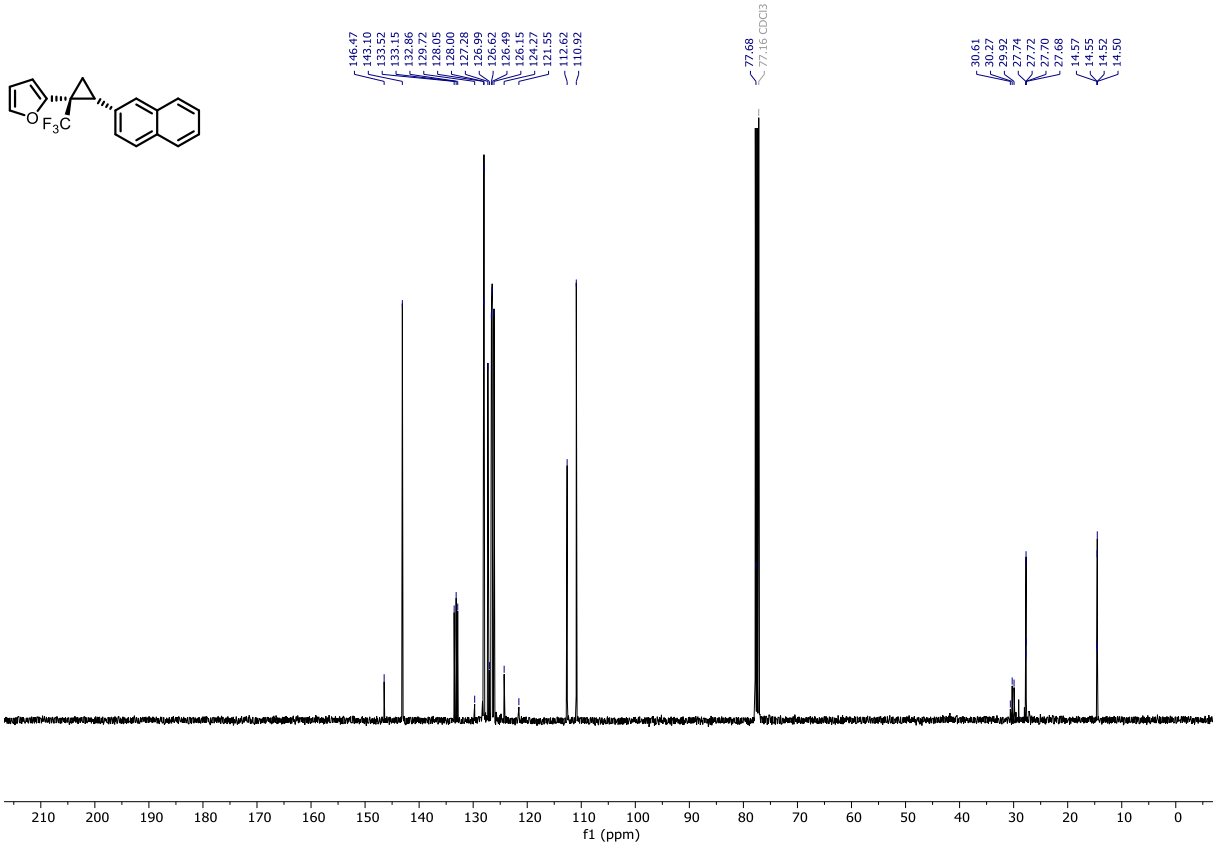
3i: ^{1}H-^{19}F NOESY ($CDCl_3$):



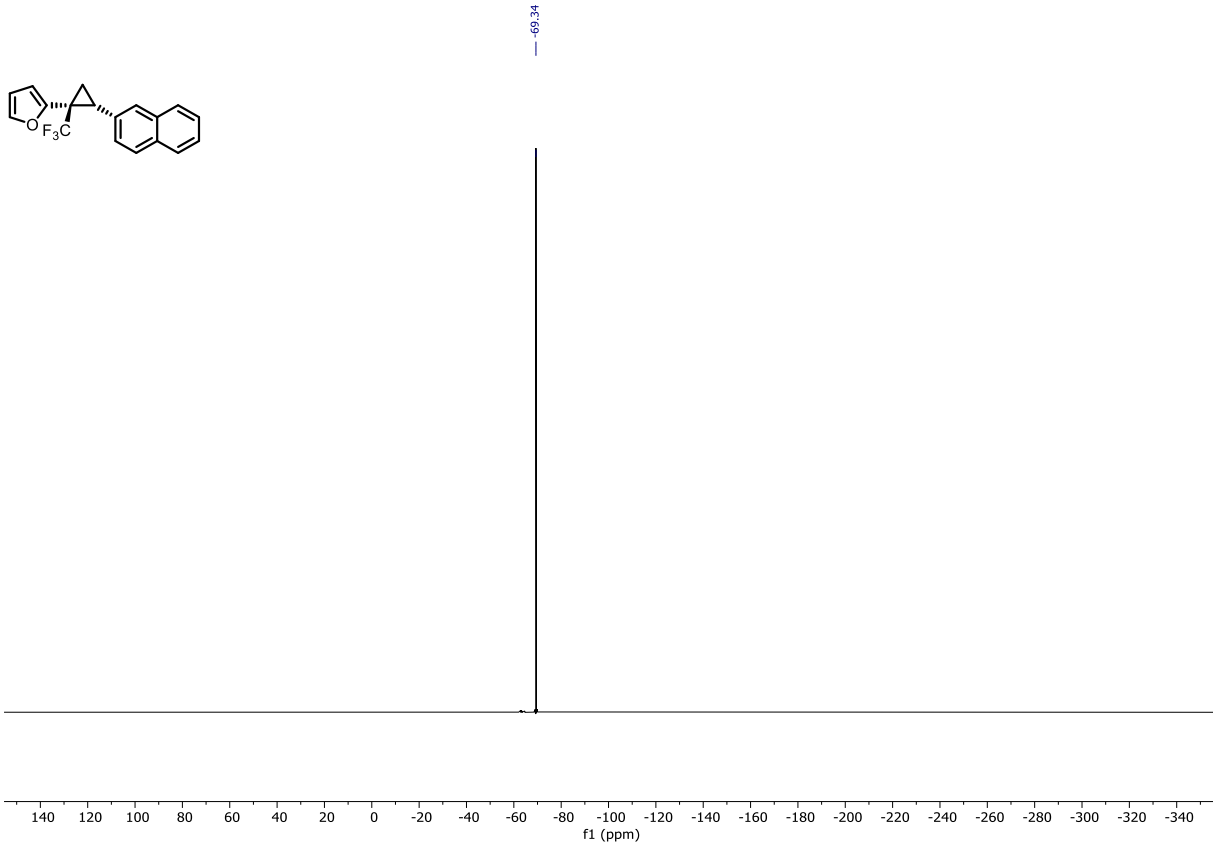
3j: ^{1}H-NMR (400 MHz, $CDCl_3$):



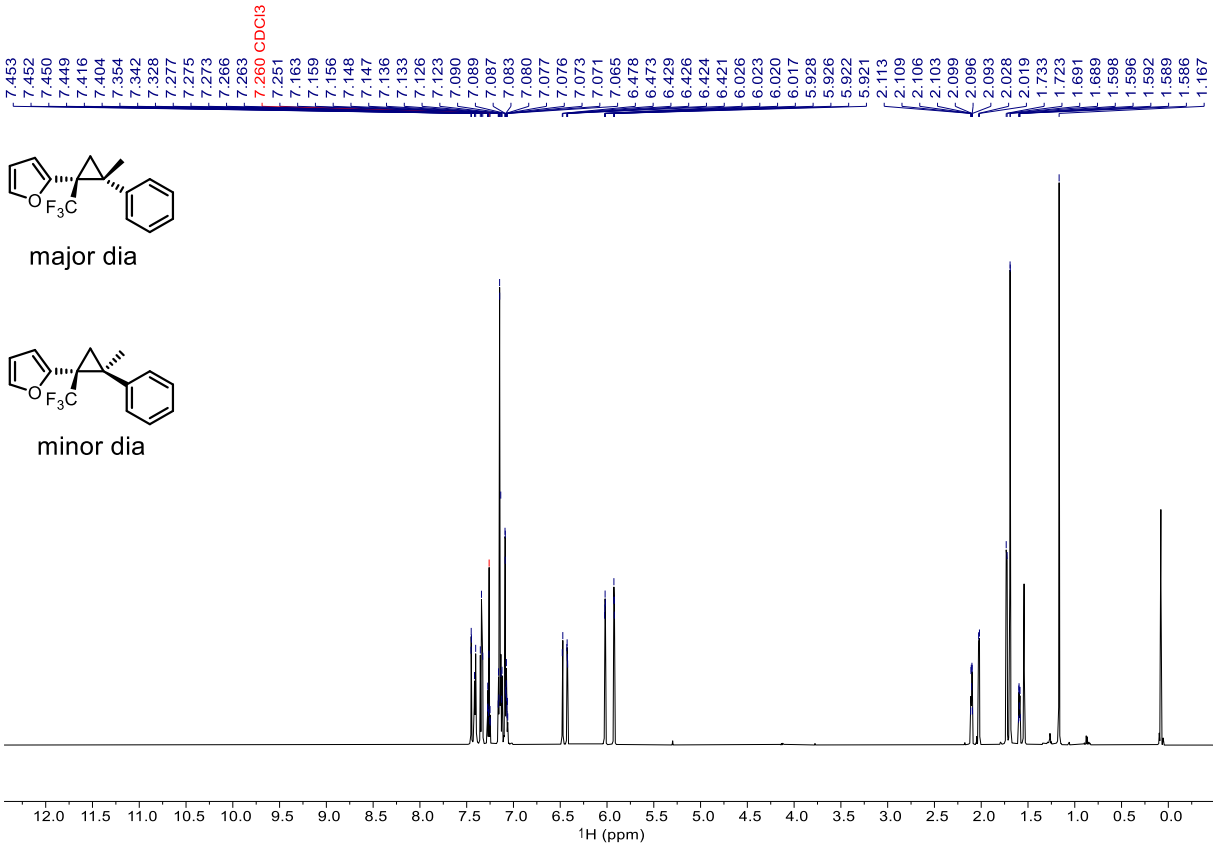
3j: ^{13}C NMR (101 MHz, $CDCl_3$):



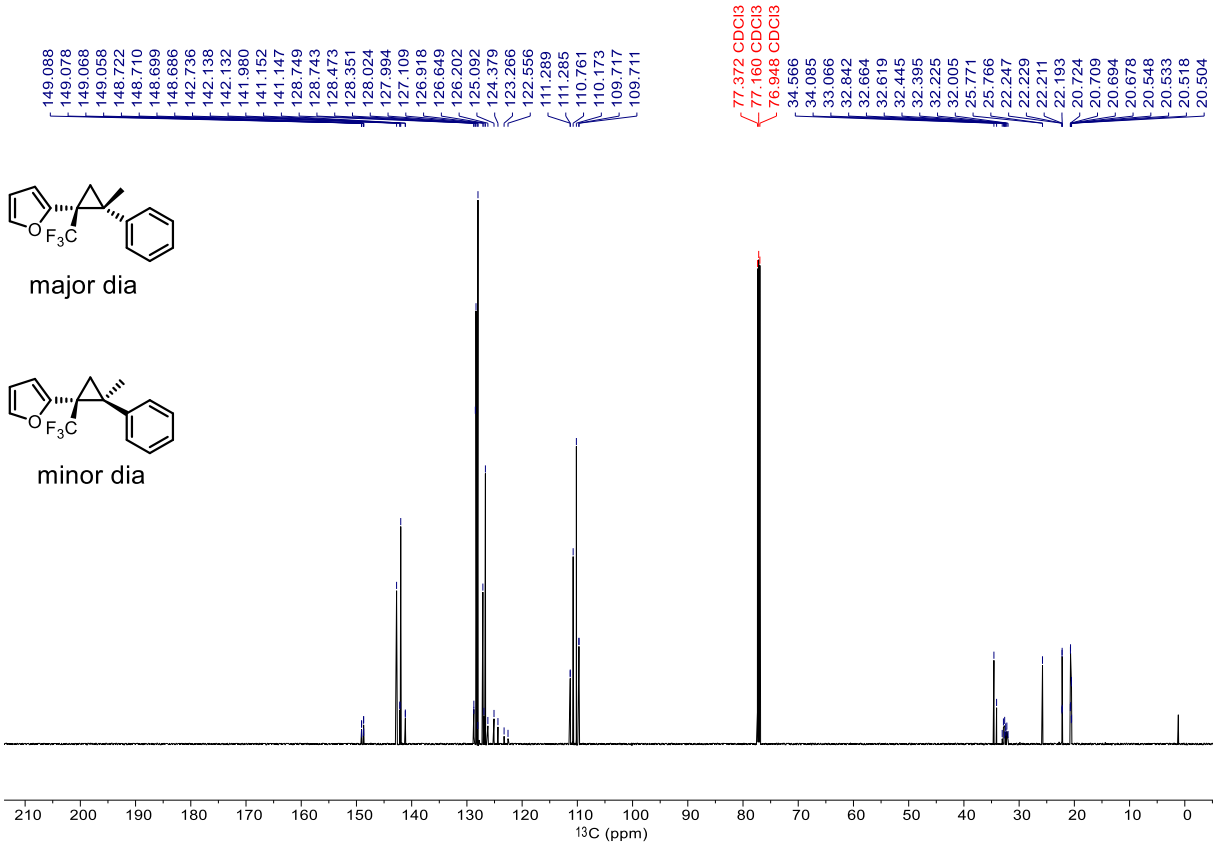
3j: ^{19}F NMR (282 MHz, $CDCl_3$):



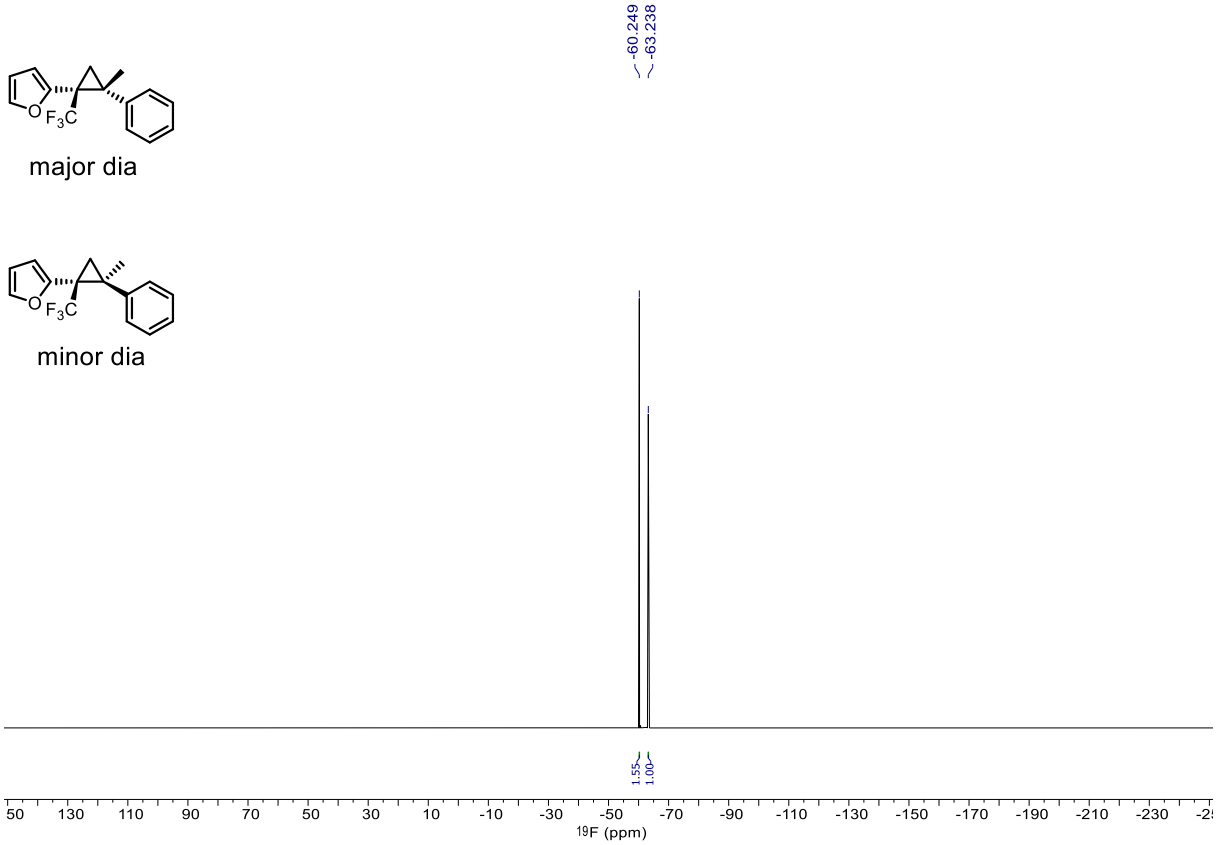
3k: ^{1}H-NMR (600 MHz, $CDCl_3$):



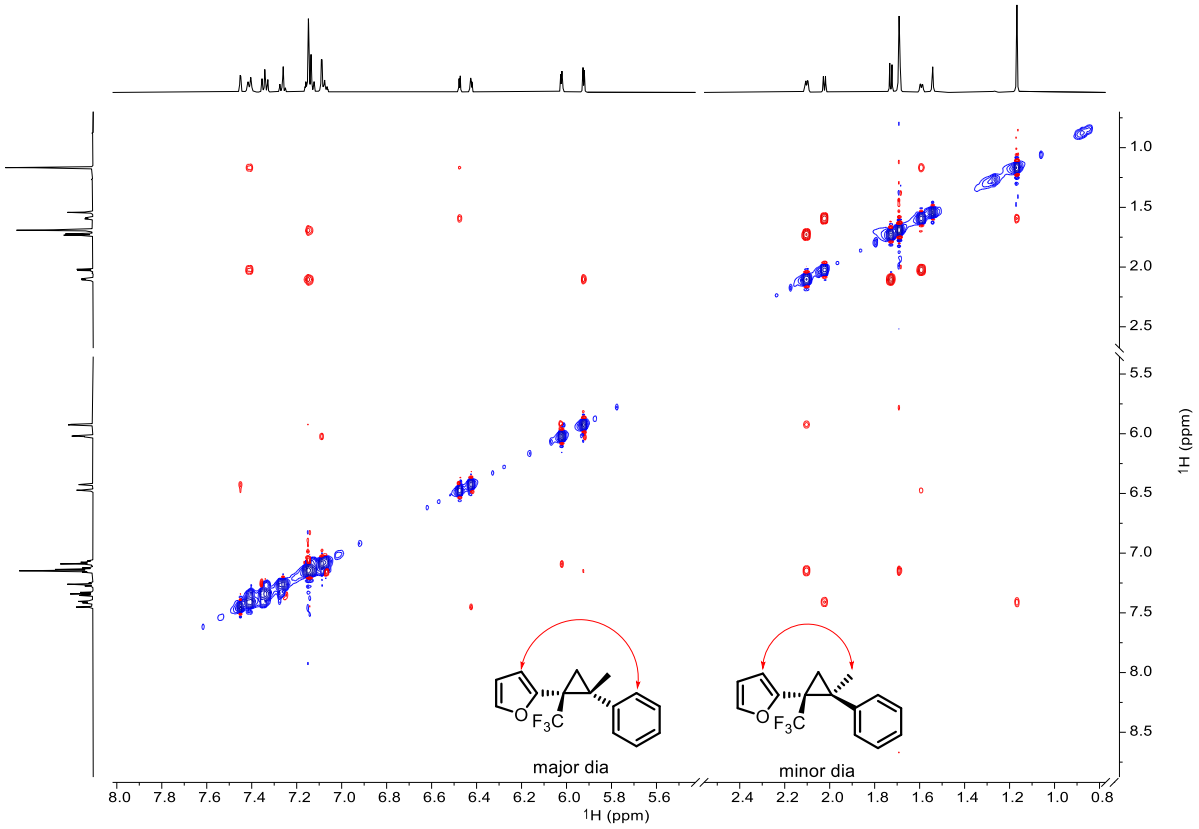
3k: ^{13}C NMR (151 MHz, $CDCl_3$):



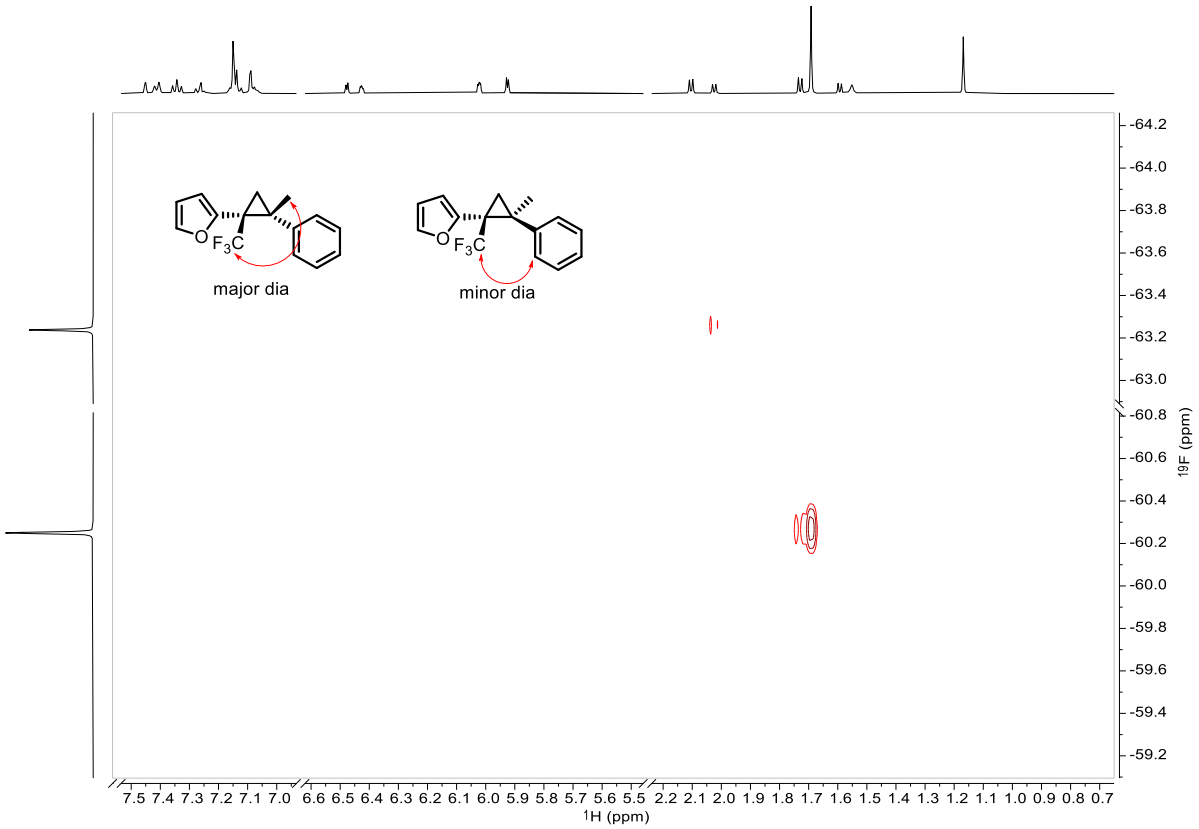
3k: ^{19}F NMR (282 MHz, $CDCl_3$):



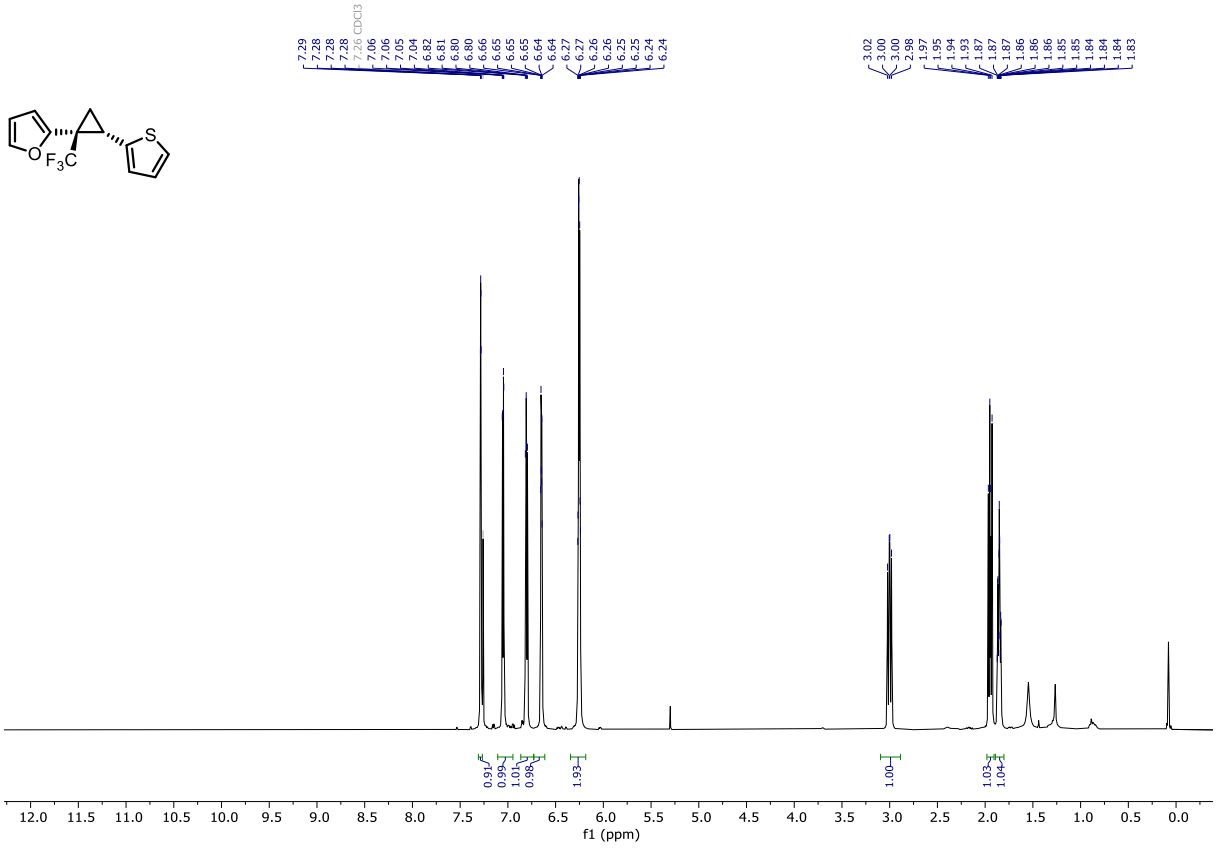
3k: ^{1}H-^{1}H NOESY ($CDCl_3$):



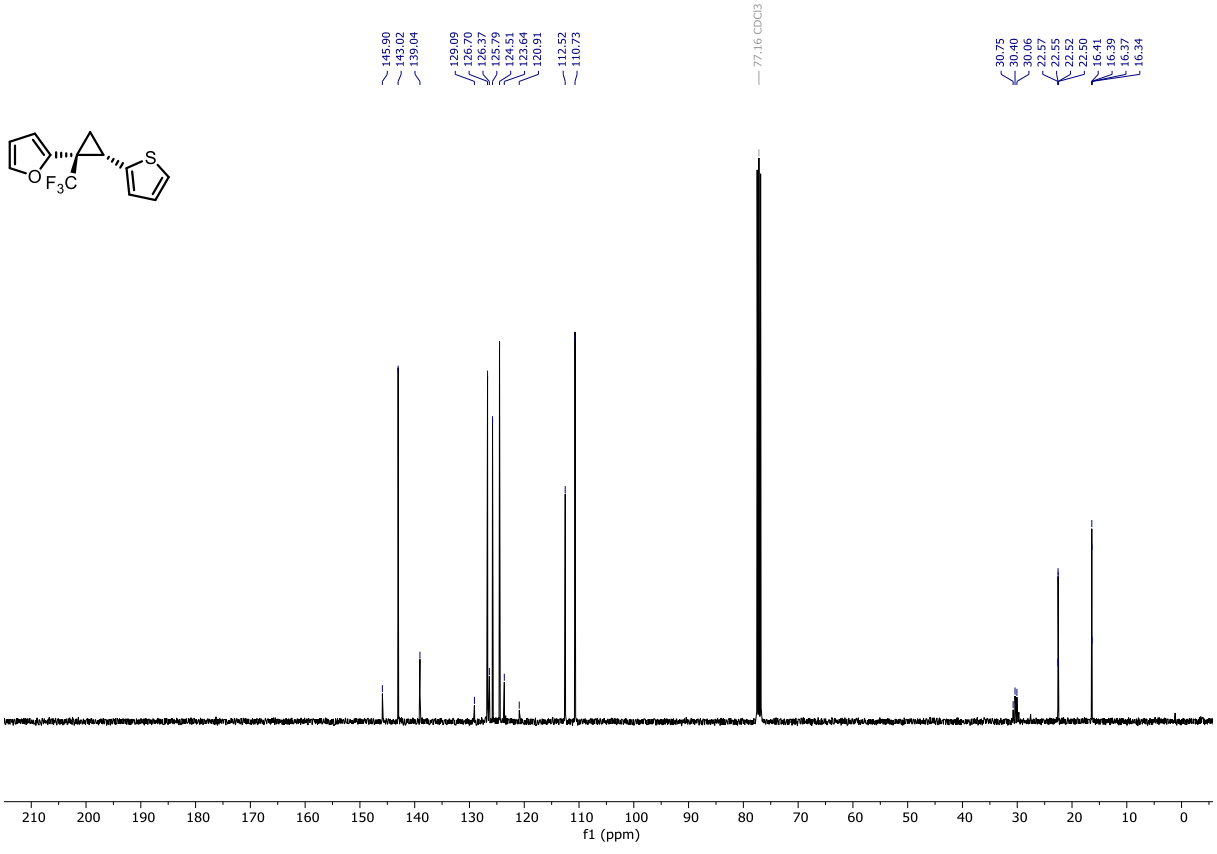
3k: ^{1}H-^{19}F HOESY ($CDCl_3$):



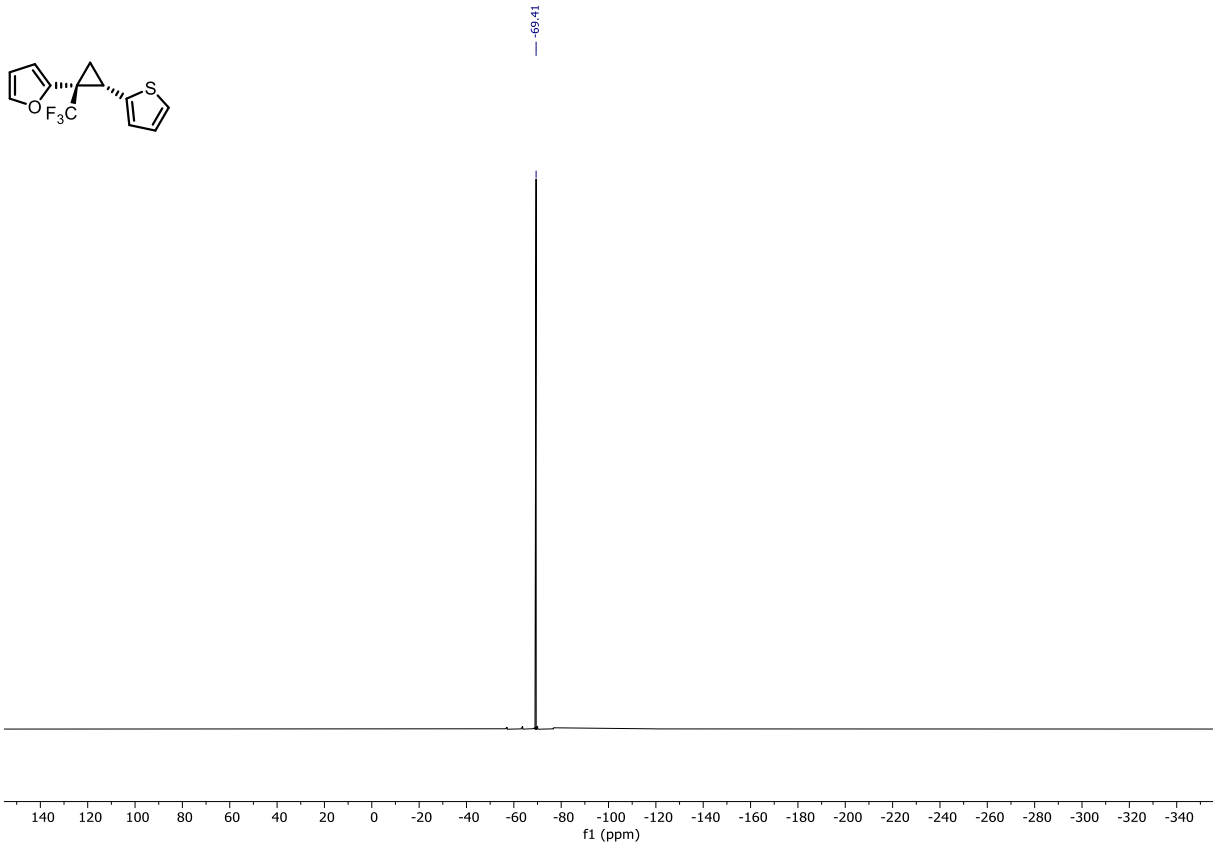
3l: ^{1}H-NMR (400 MHz, $CDCl_3$):



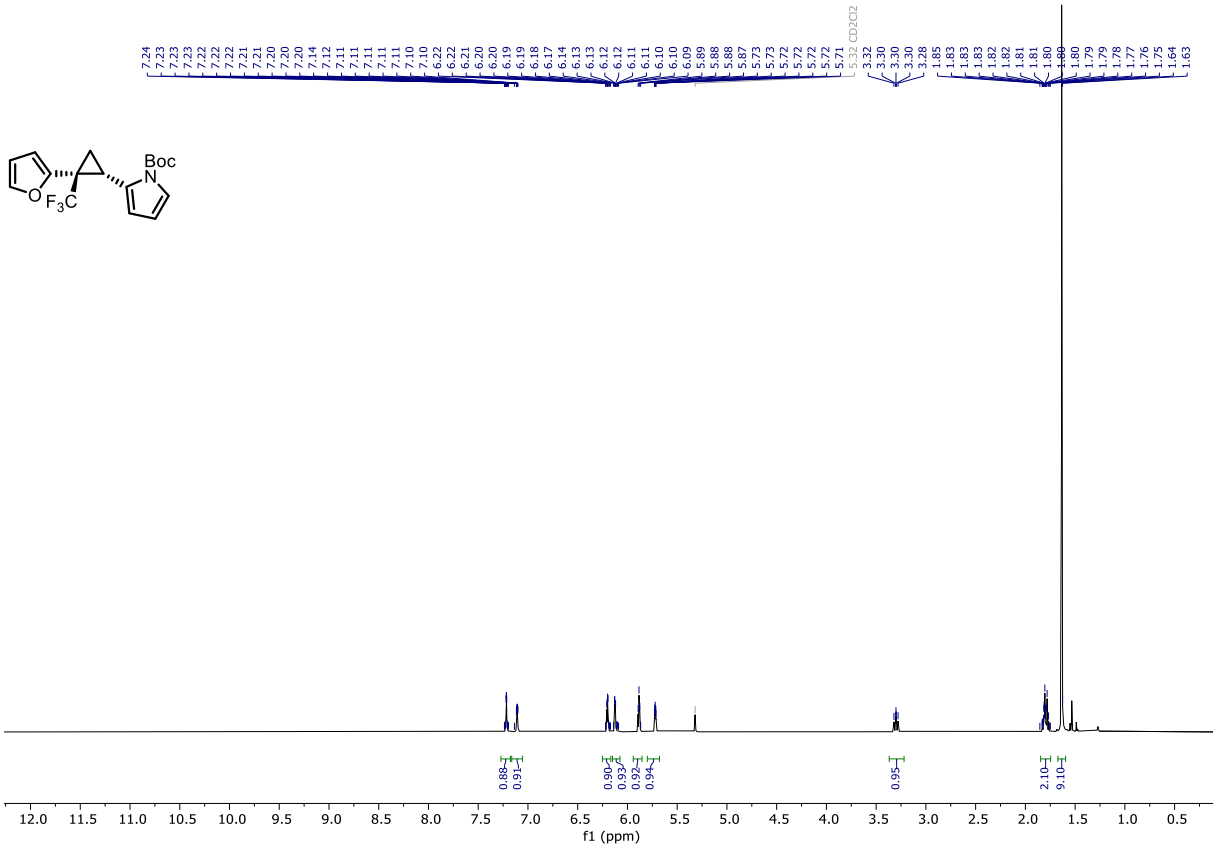
3l: ^{13}C NMR (101 MHz, $CDCl_3$):



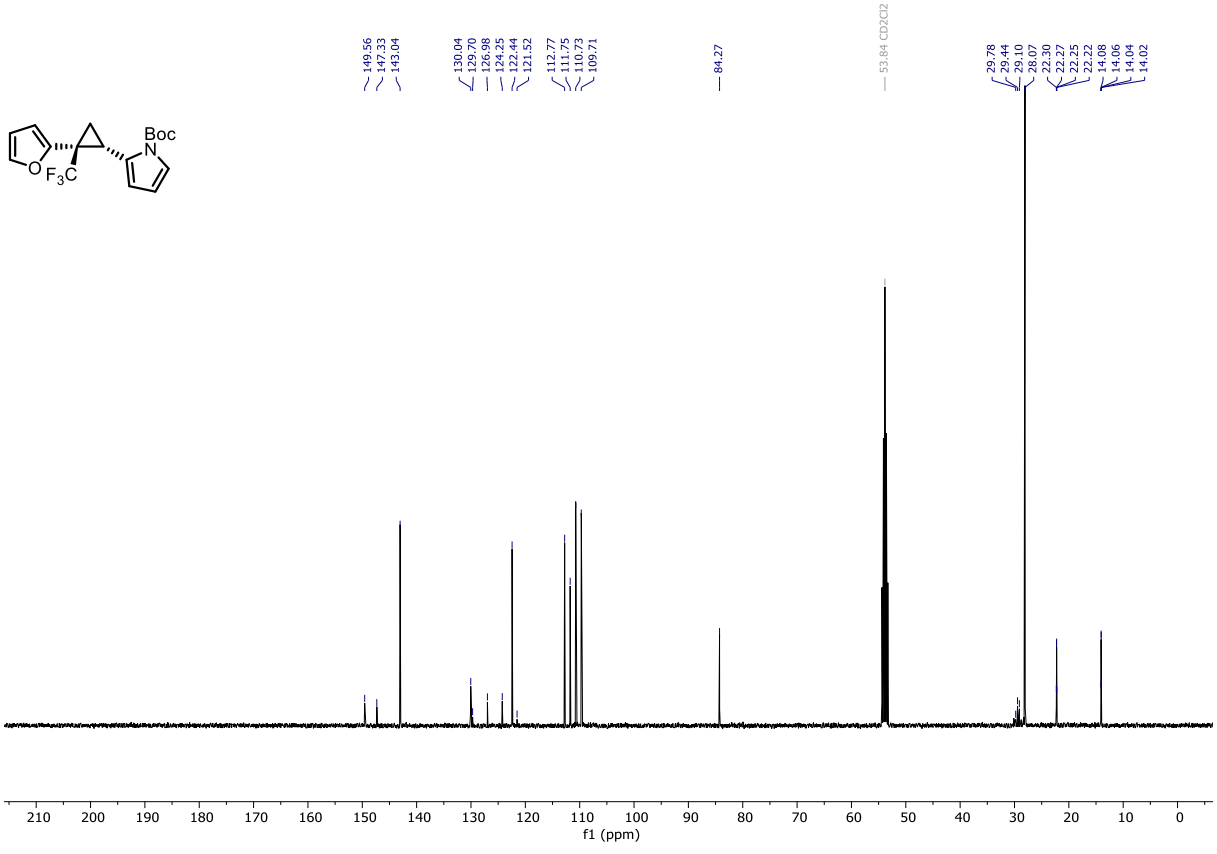
3l: ^{19}F NMR (282 MHz, $CDCl_3$):



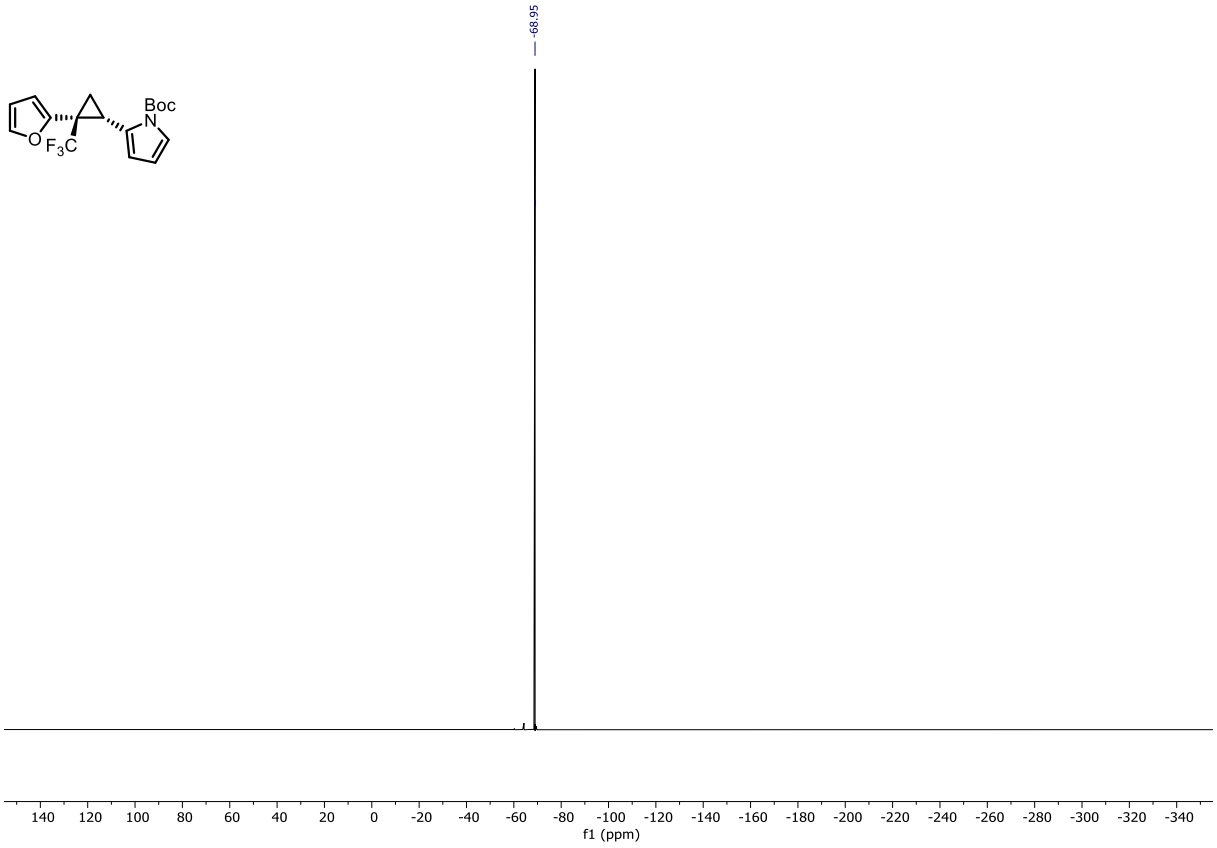
3m: ^{1}H-NMR (400 MHz, CD_2Cl_2):



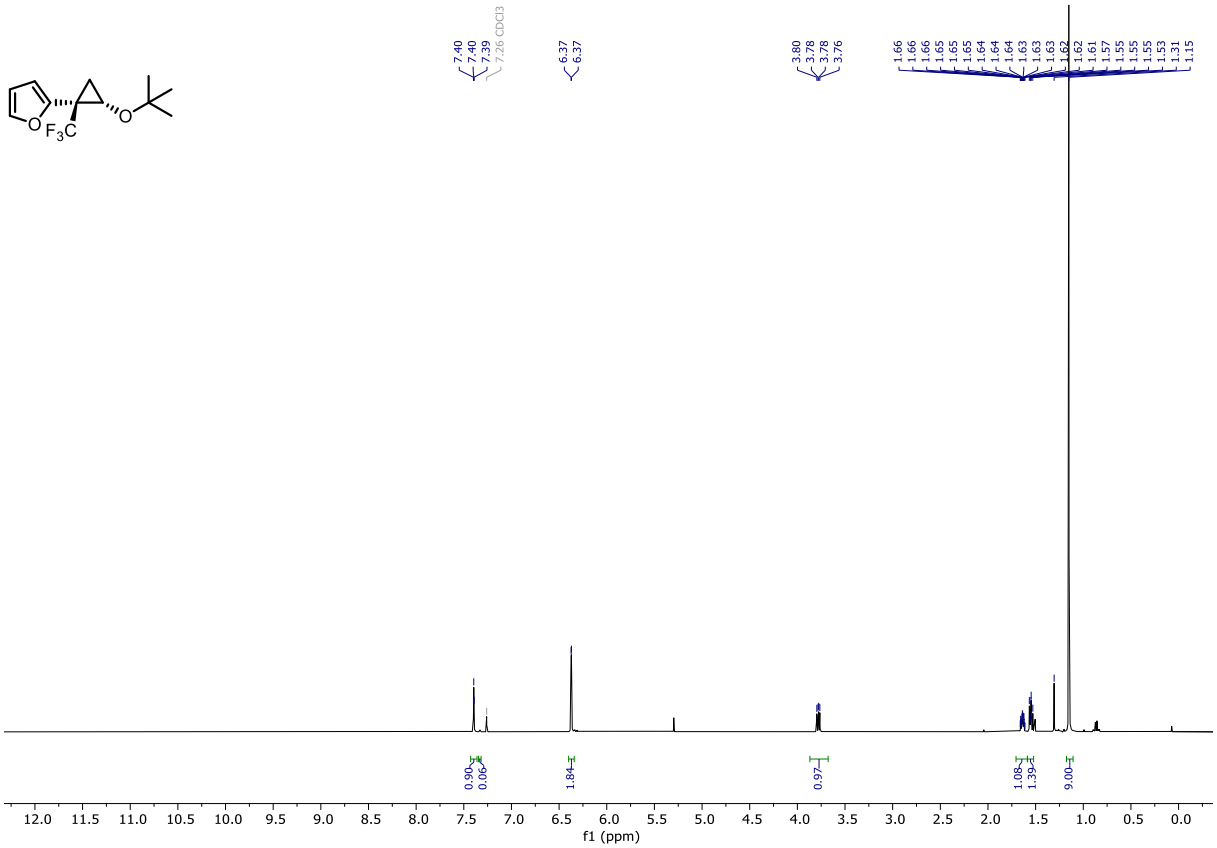
3m: ^{13}C NMR (101 MHz, CD_2Cl_2):



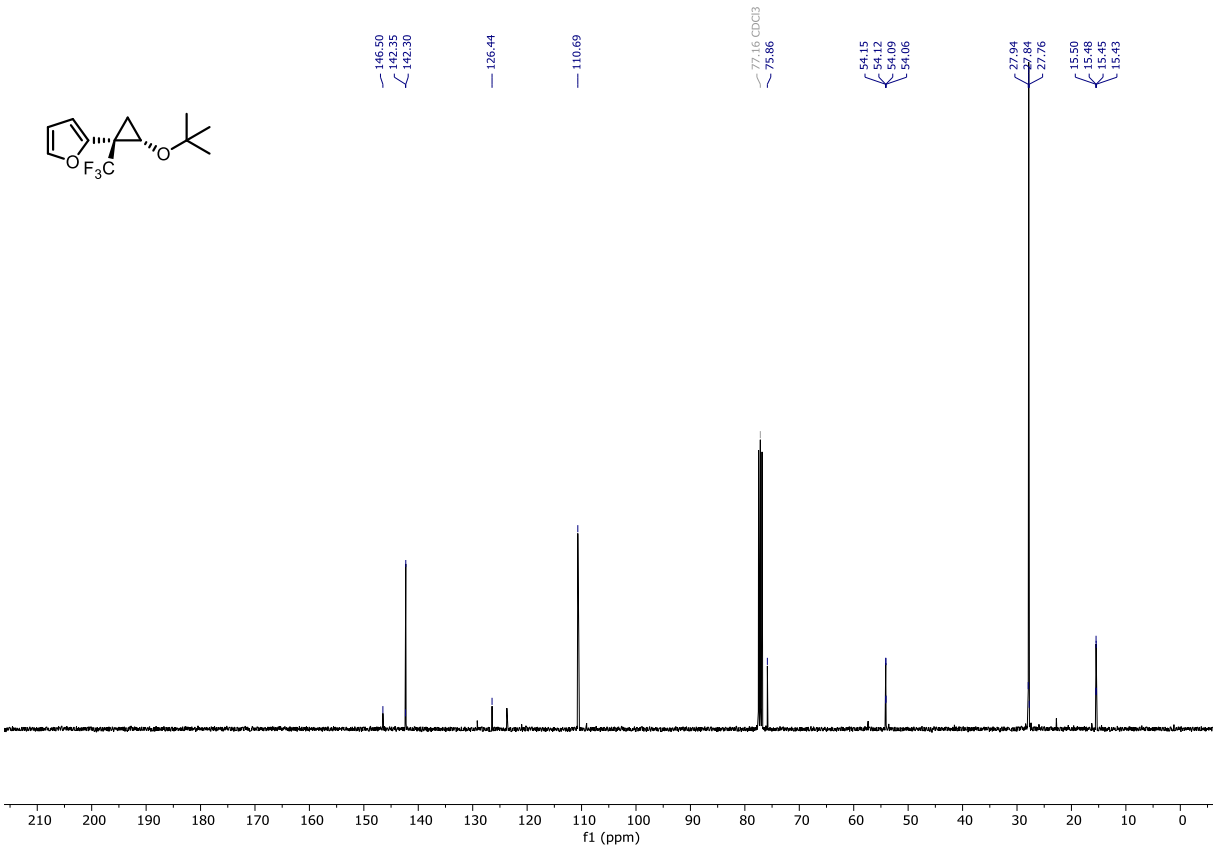
3m: ^{19}F NMR (282 MHz, $CDCl_3$):



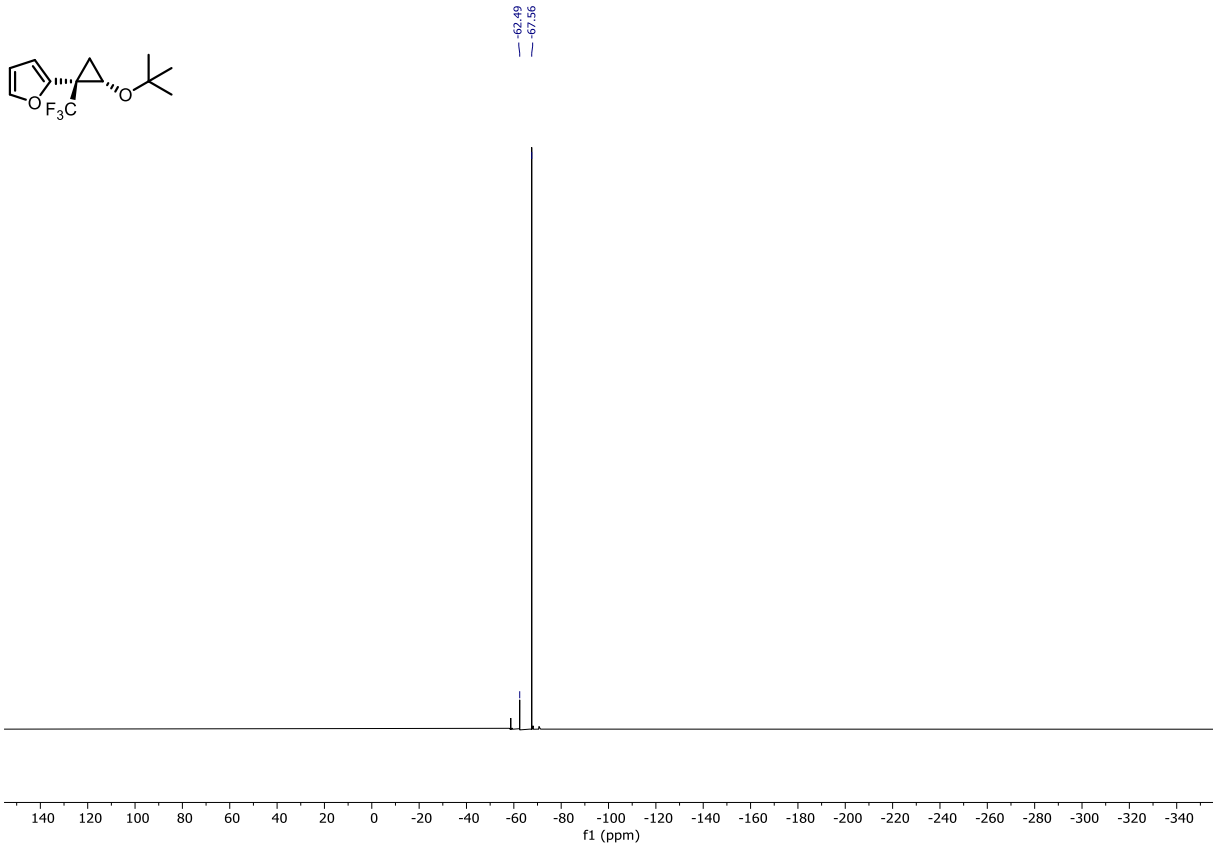
3n: ^{1}H-NMR (400 MHz, $CDCl_3$):



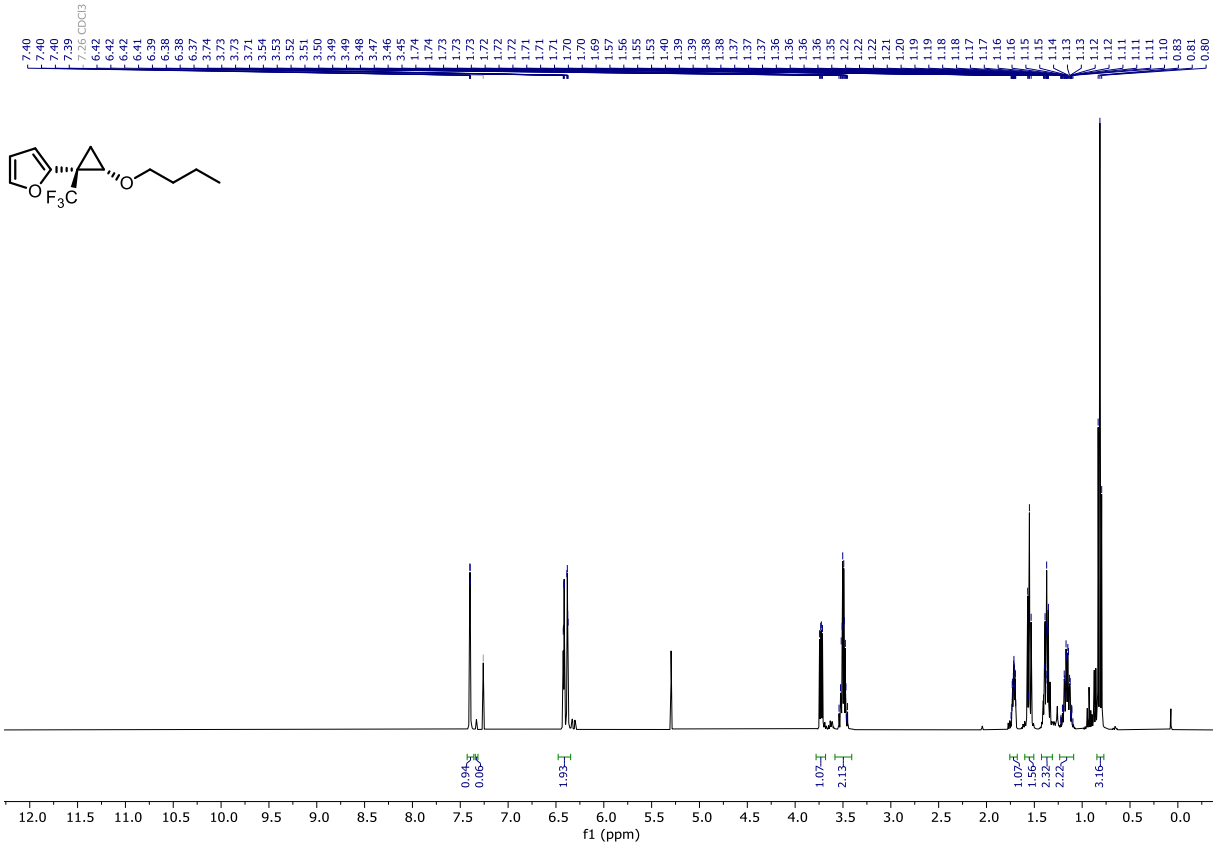
3n: ^{13}C NMR (101 MHz, $CDCl_3$):



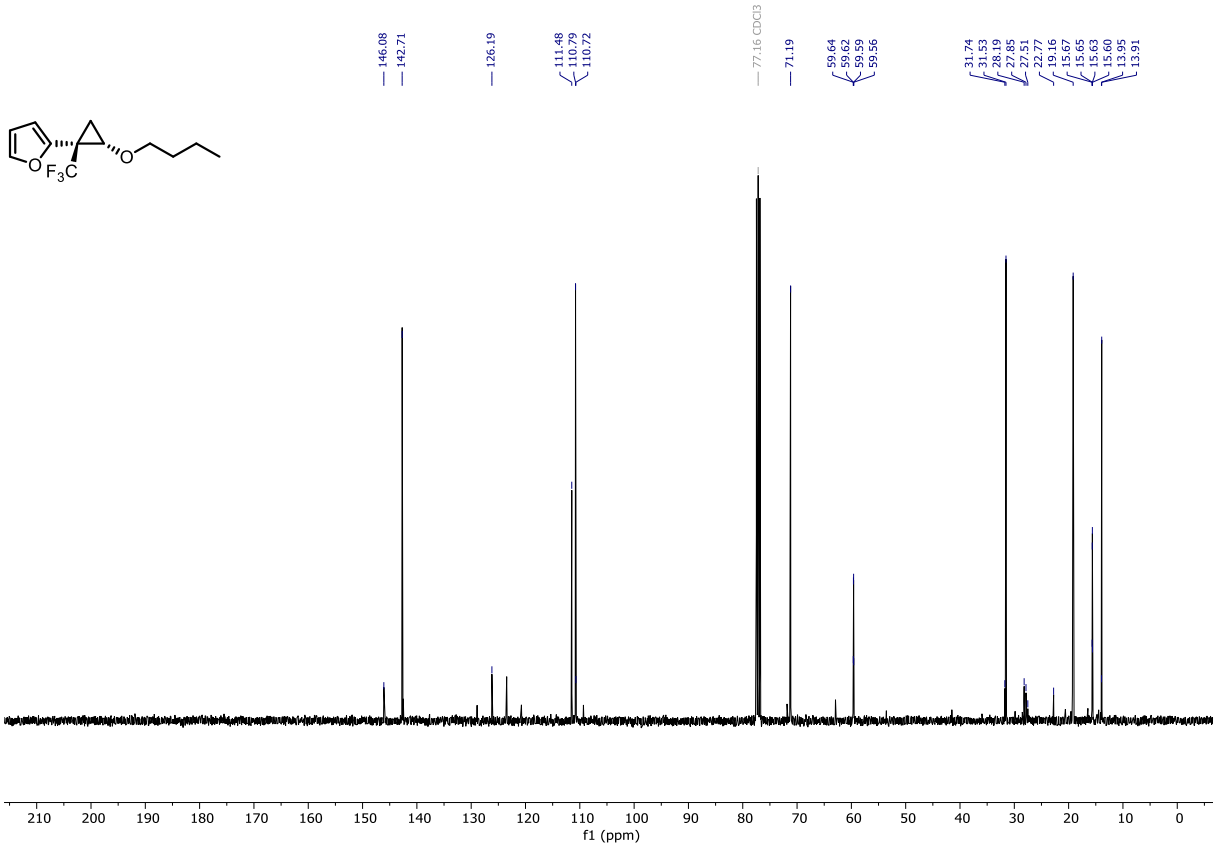
3n: ^{19}F NMR (282 MHz, $CDCl_3$):



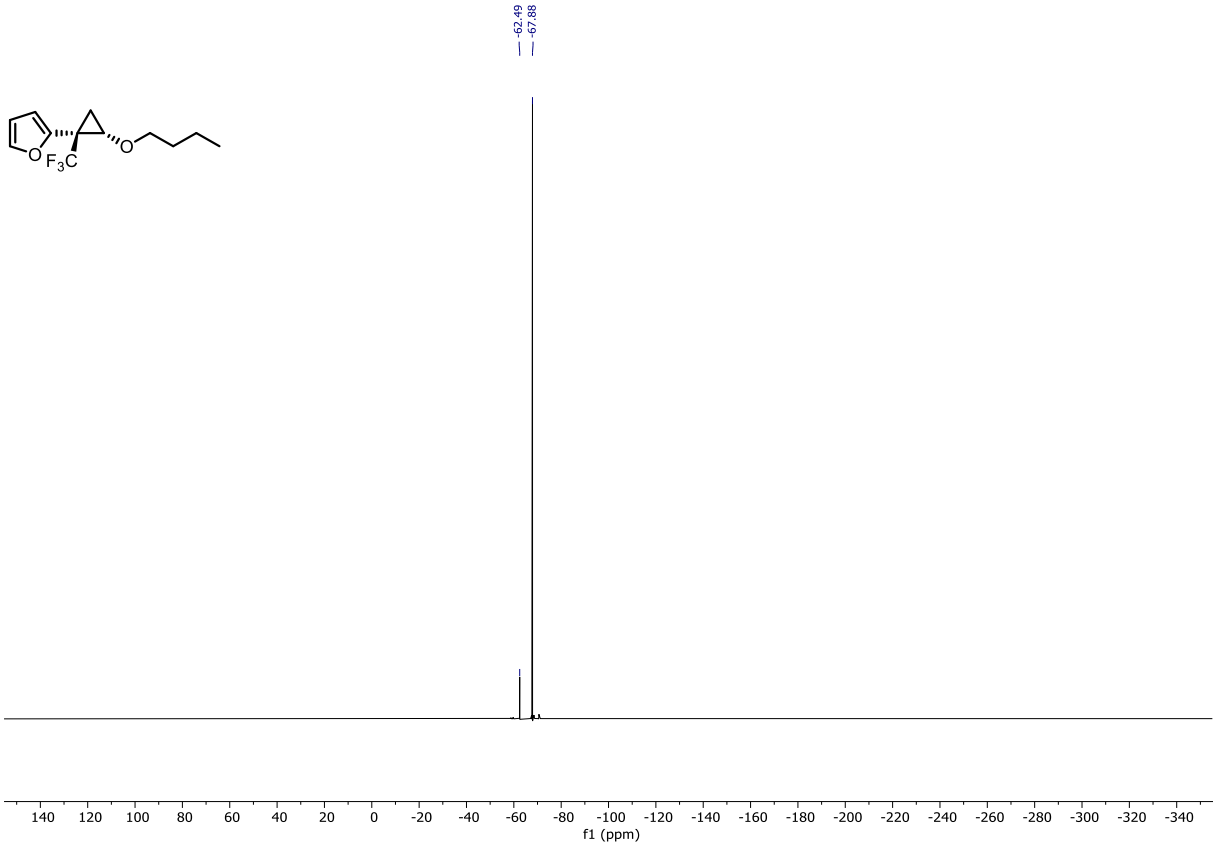
3o: ^{1}H-NMR (400 MHz, $CDCl_3$):



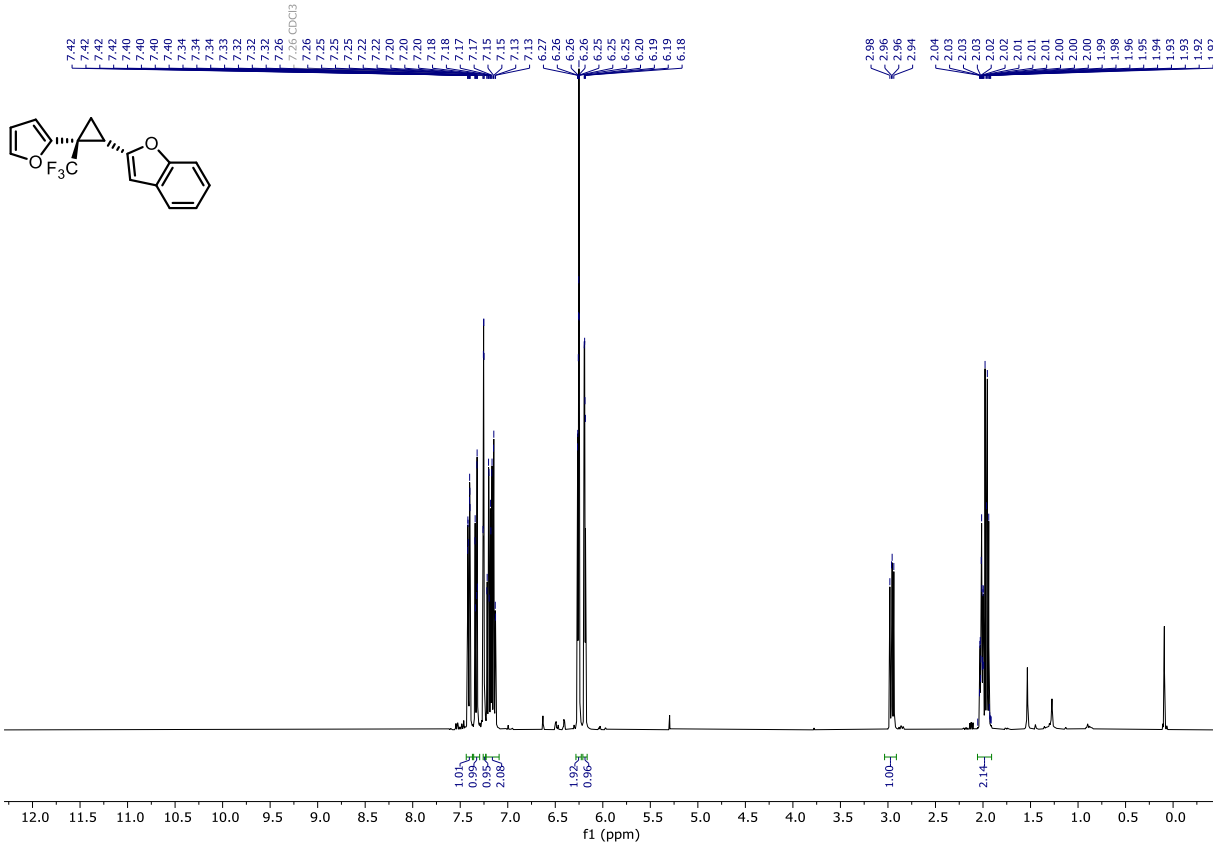
3o: ^{13}C NMR (101 MHz, $CDCl_3$):



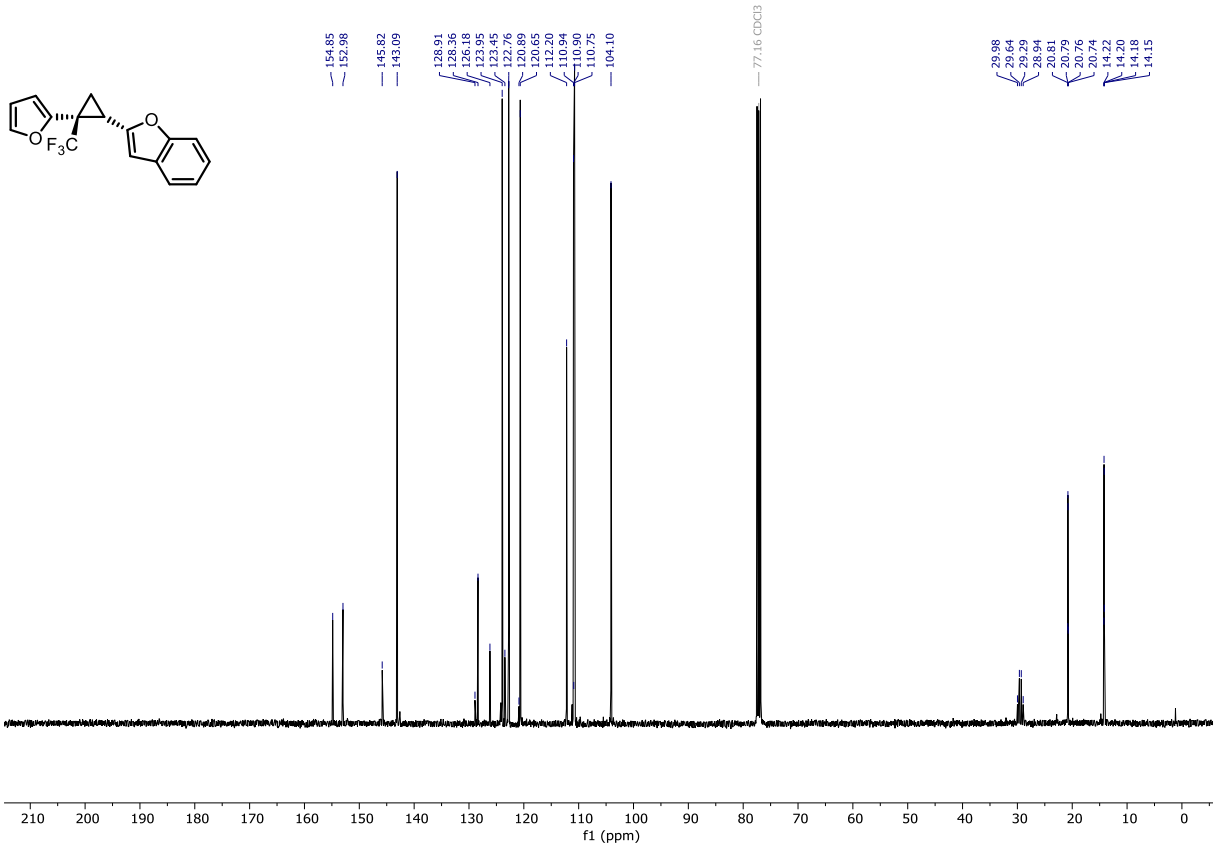
3o: ^{19}F NMR (282 MHz, $CDCl_3$):



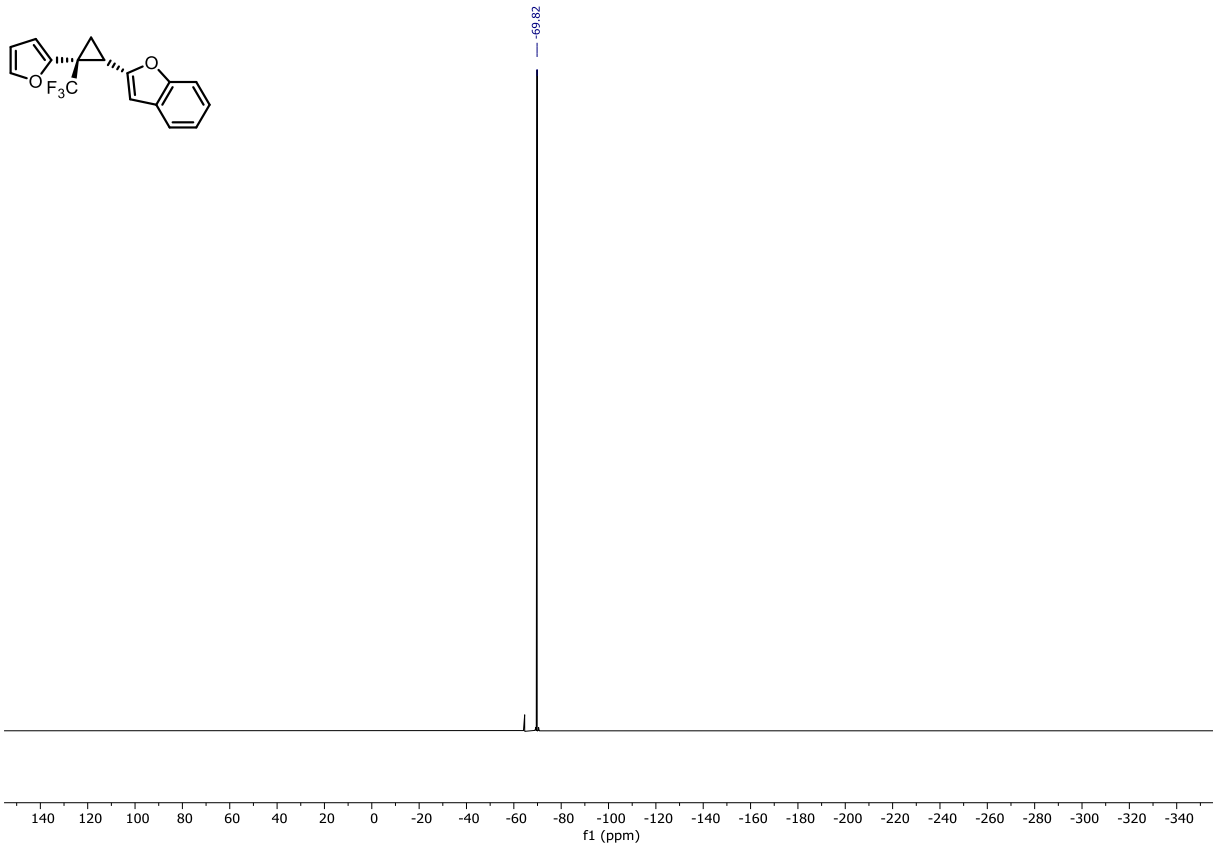
3p: ^{1}H-NMR (400 MHz, $CDCl_3$):



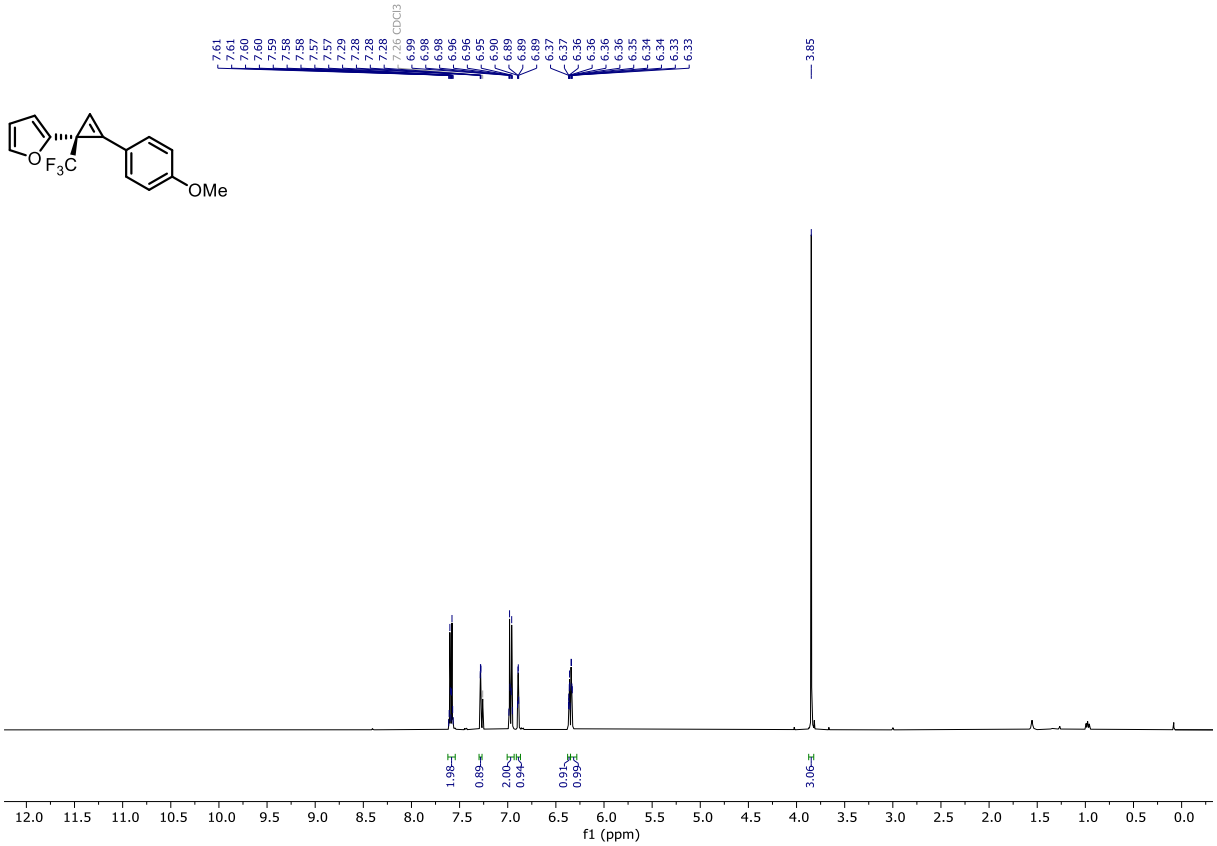
3p: ^{13}C NMR (101 MHz, $CDCl_3$):



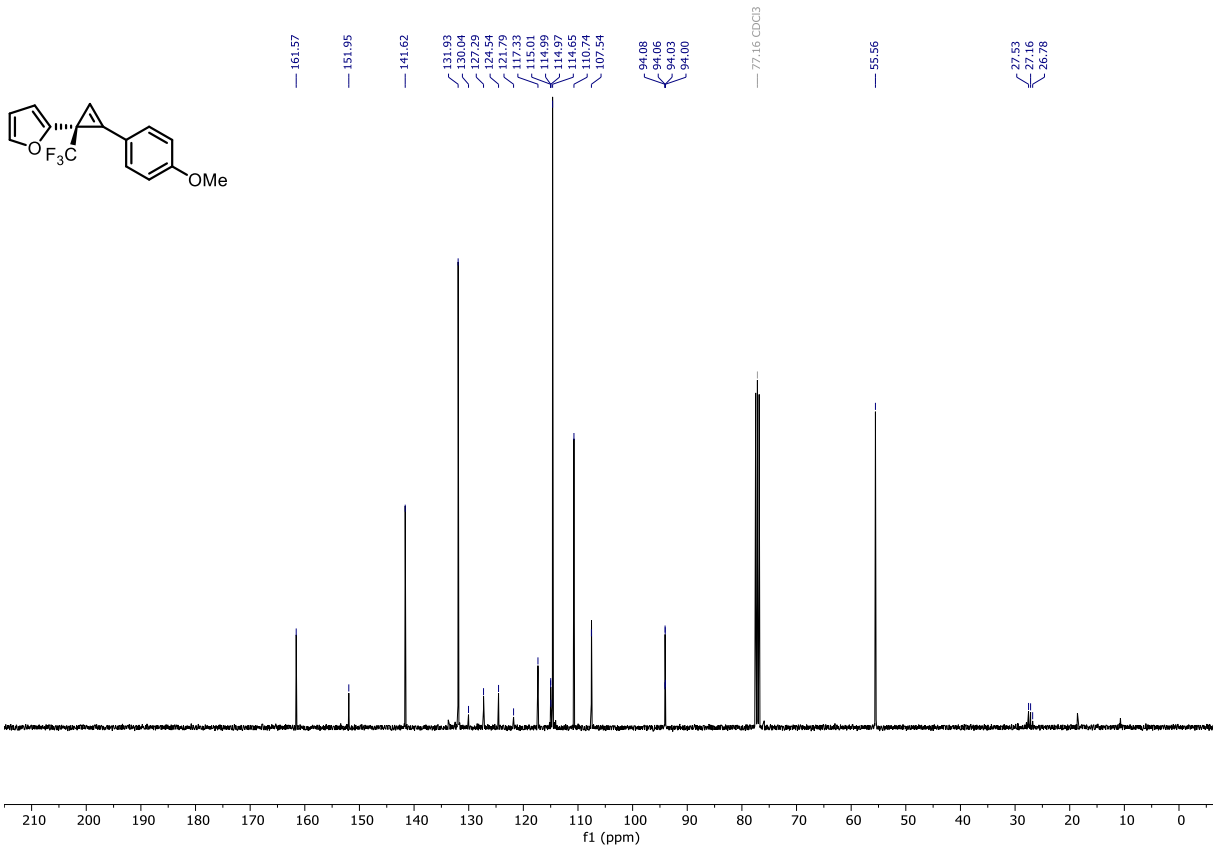
3p: ^{19}F NMR (282 MHz, $CDCl_3$):



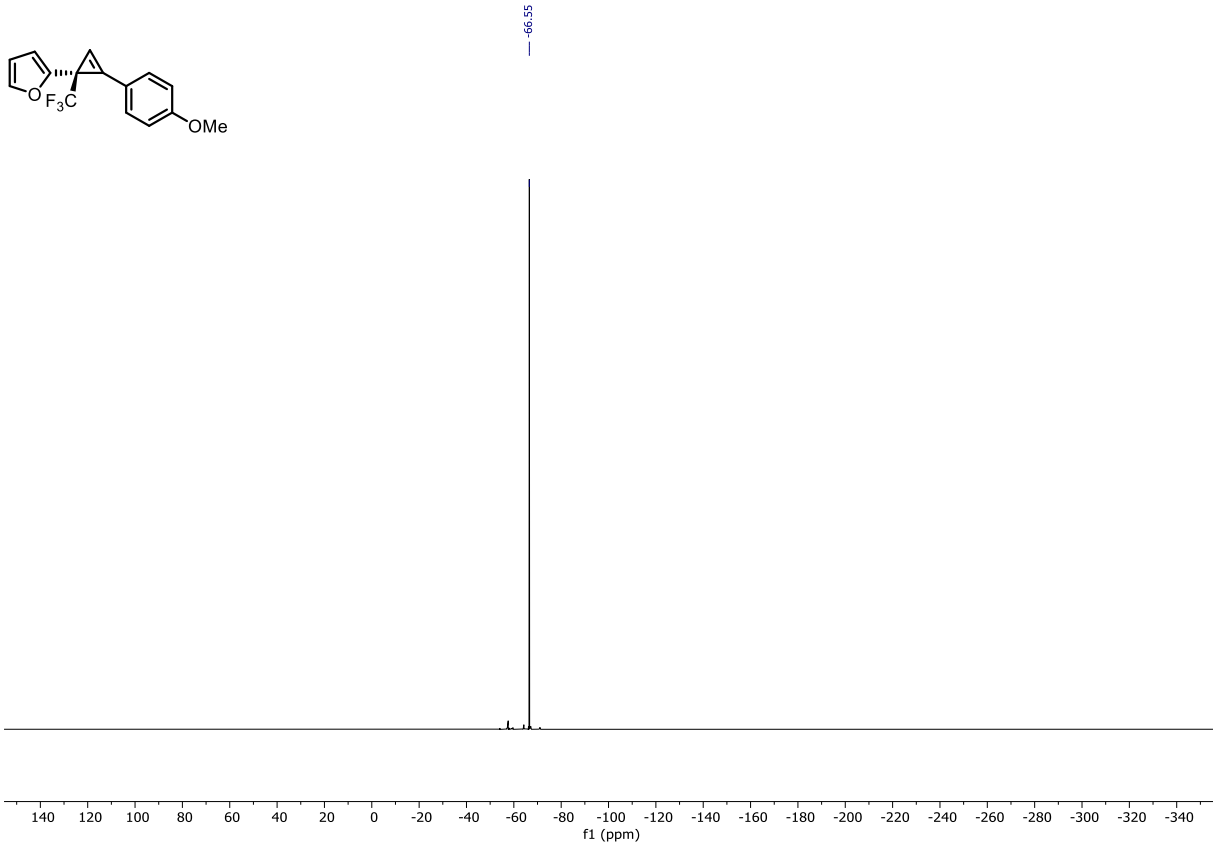
9a: ^{1}H-NMR (400 MHz, $CDCl_3$):



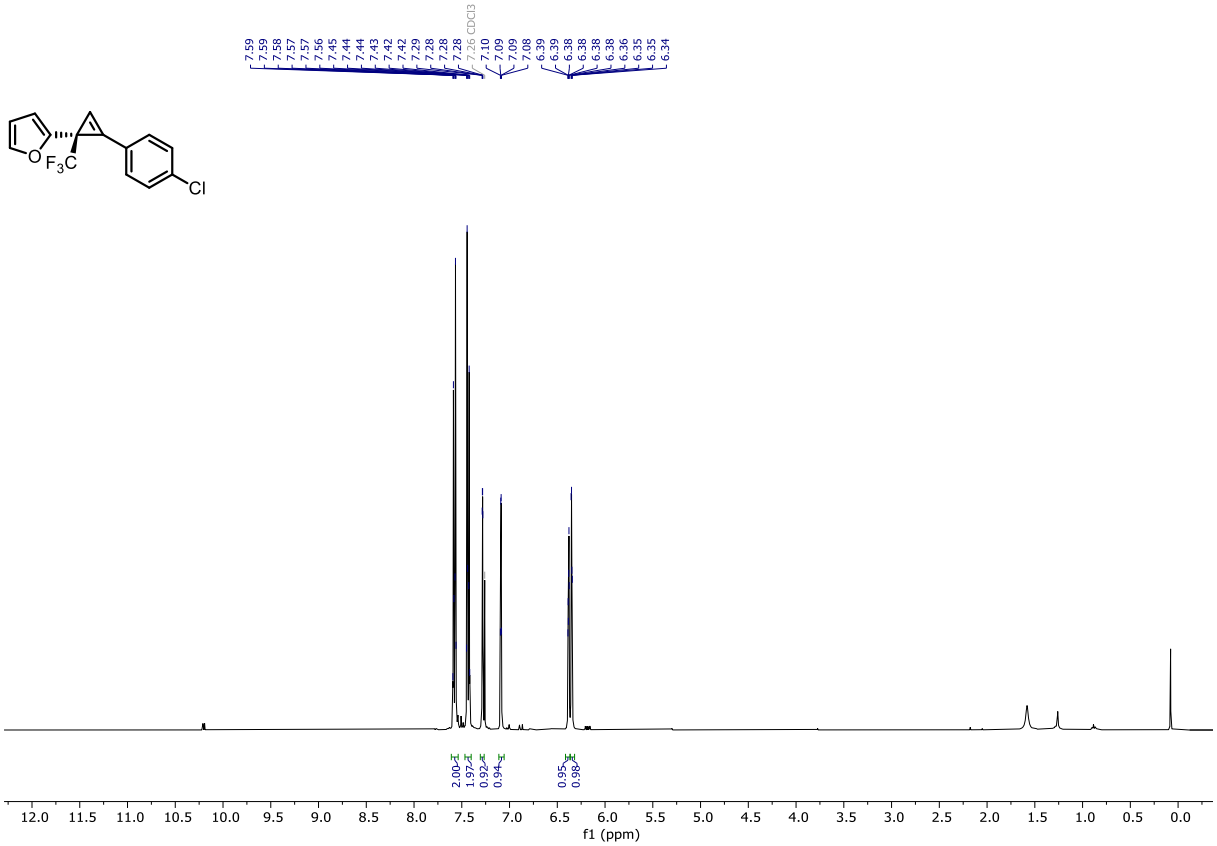
9a: ^{13}C NMR (101 MHz, $CDCl_3$):



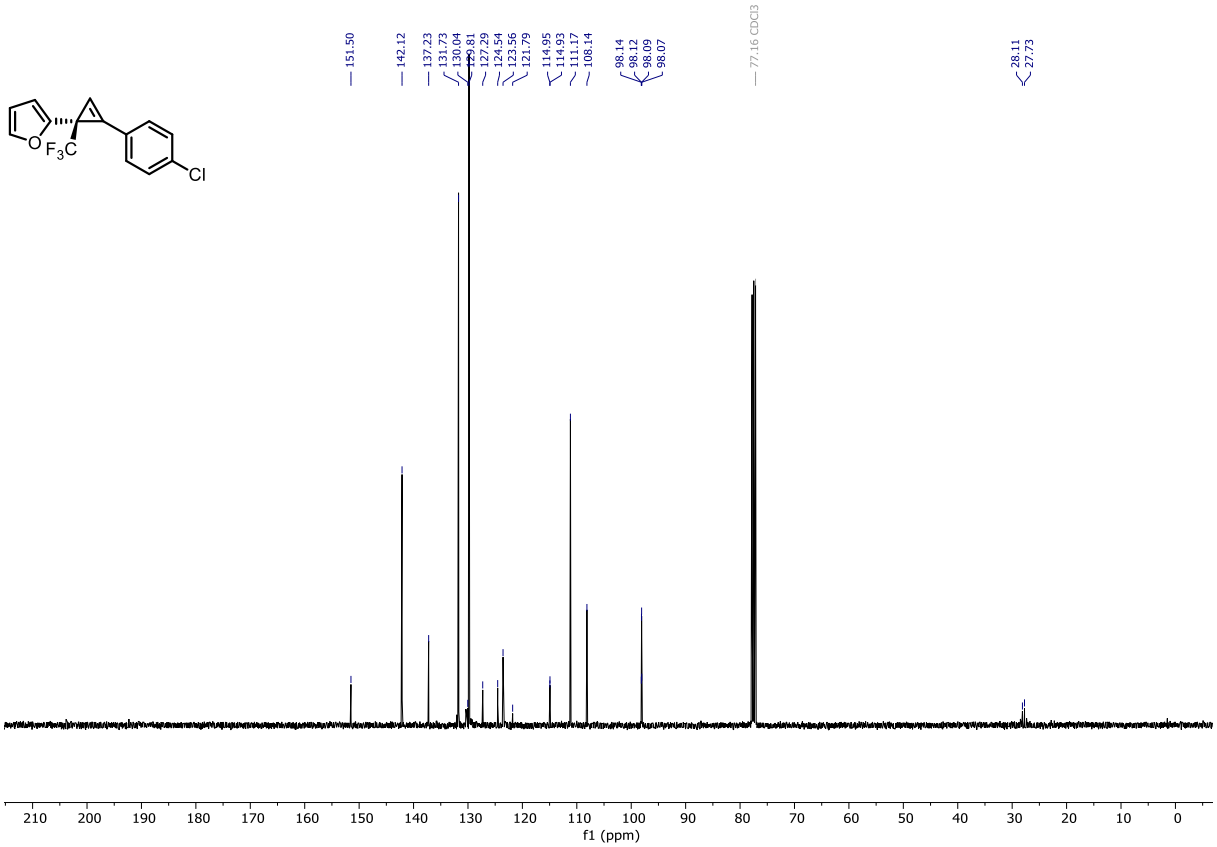
9a: ^{19}F NMR (282 MHz, $CDCl_3$):



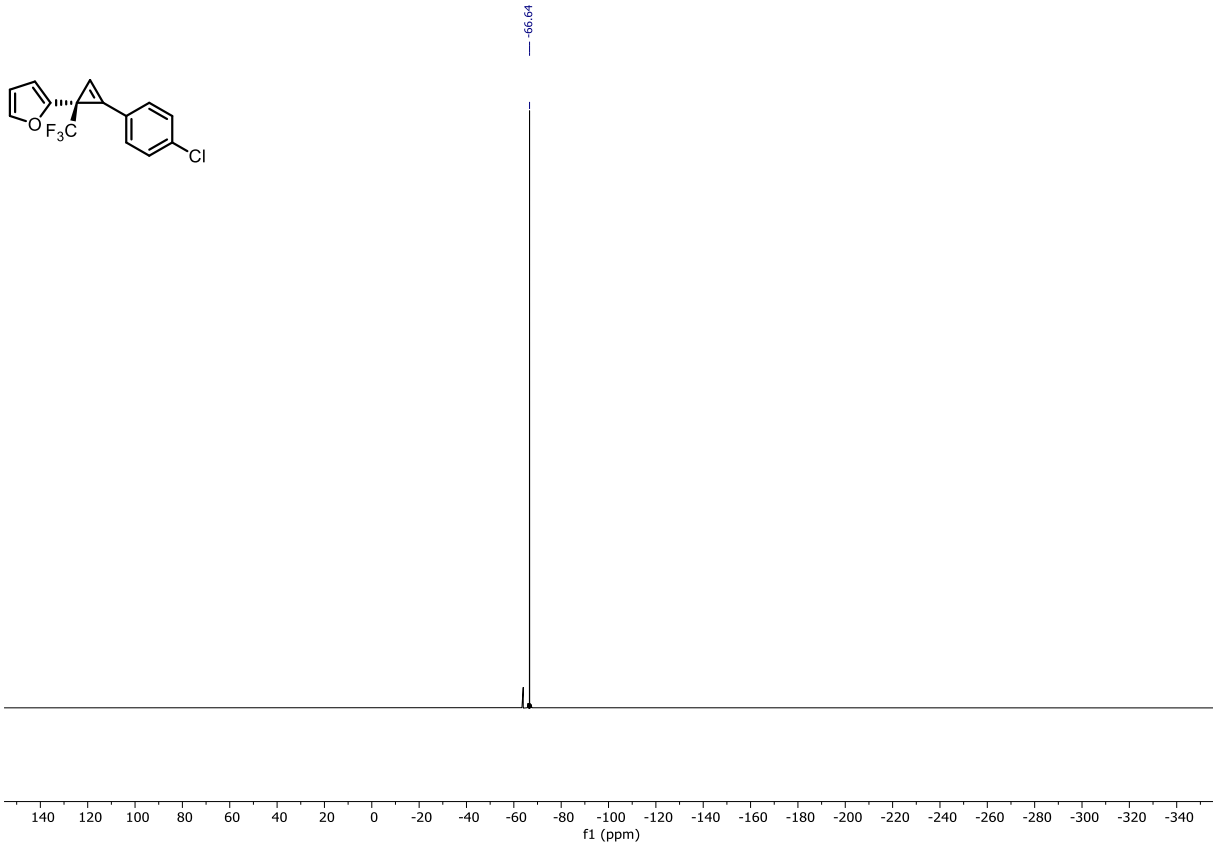
9b: ^{1}H-NMR (400 MHz, $CDCl_3$):



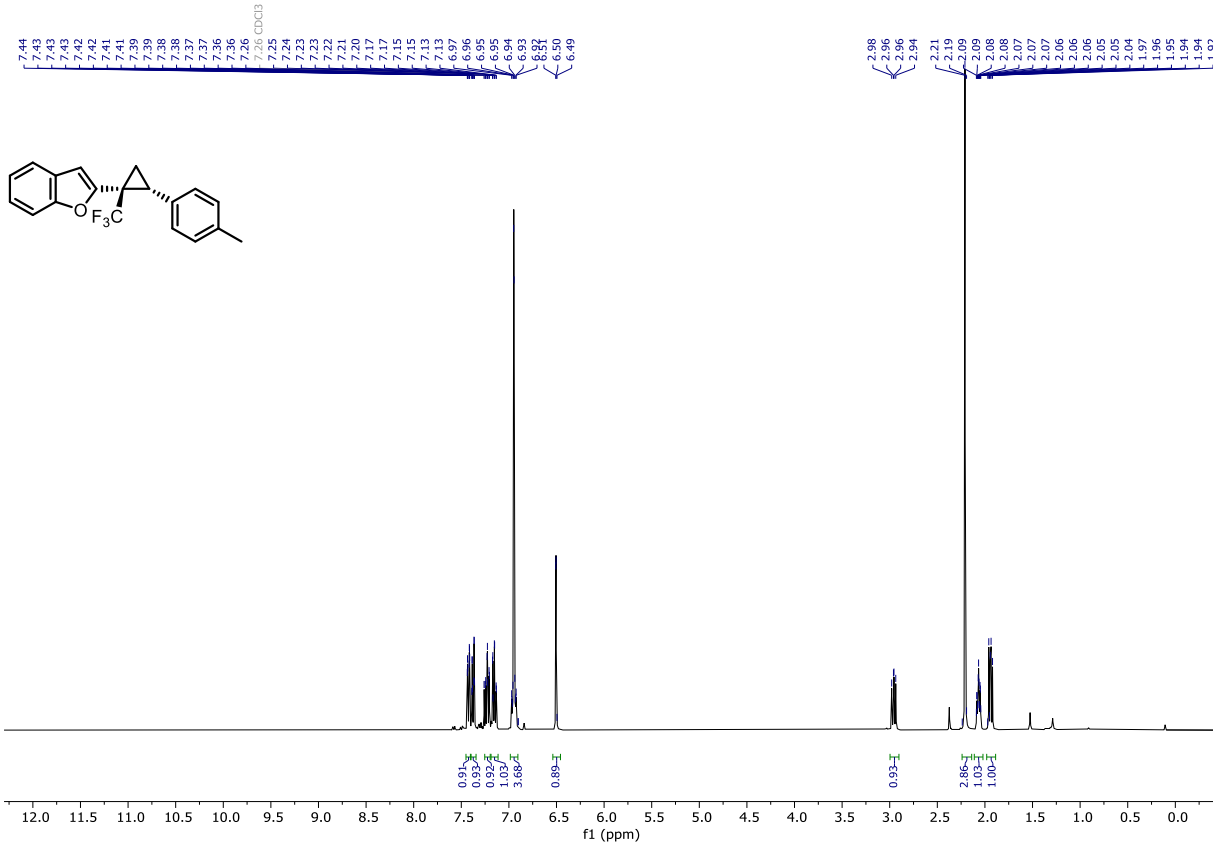
9b: ^{13}C NMR (101 MHz, $CDCl_3$):



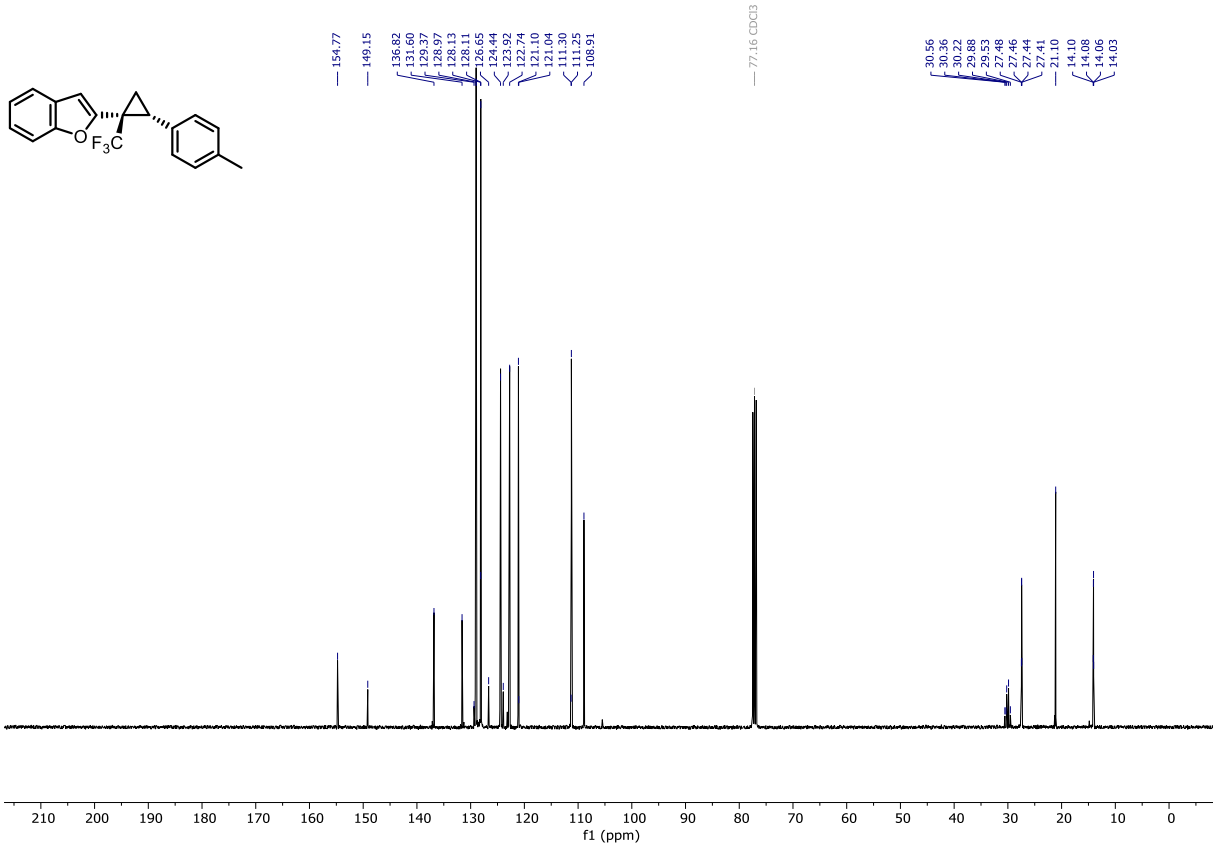
9b: ^{19}F NMR (282 MHz, $CDCl_3$):



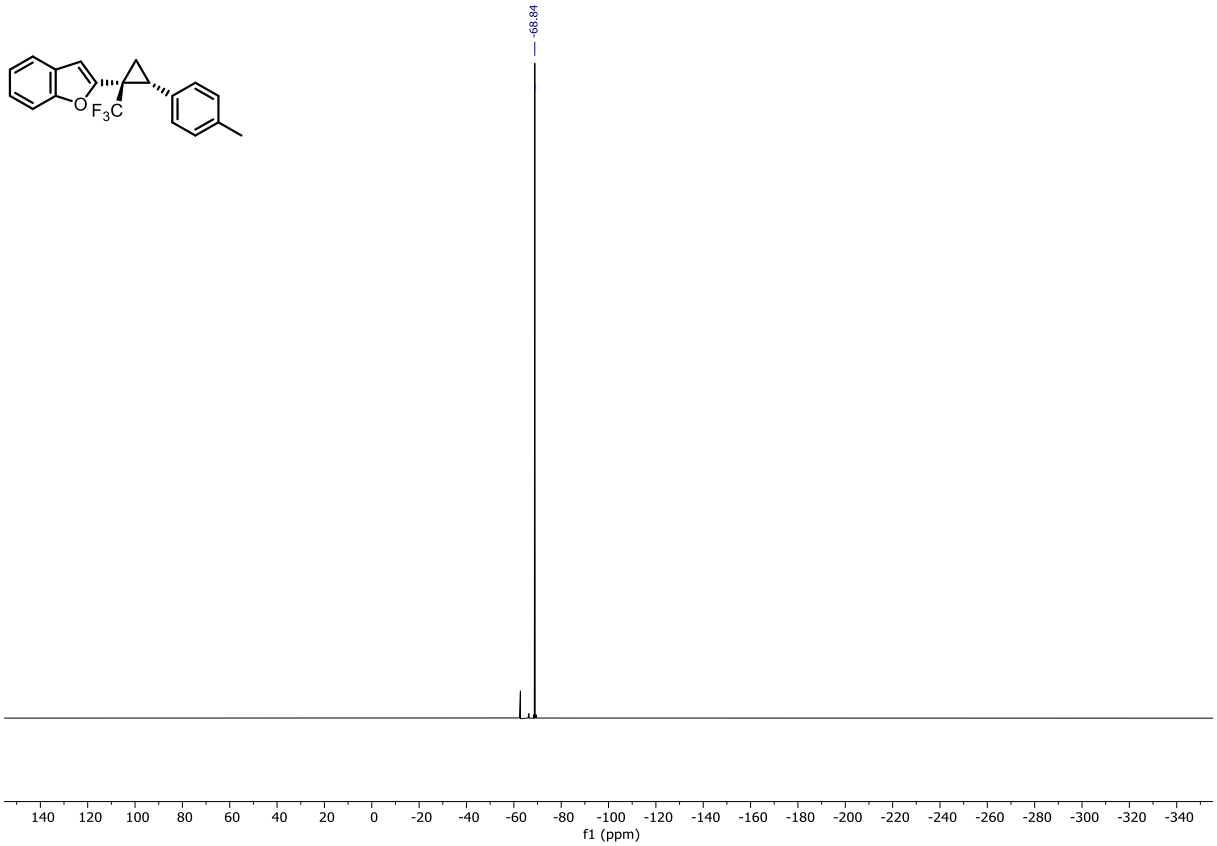
11: ^{1}H-NMR (400 MHz, $CDCl_3$):



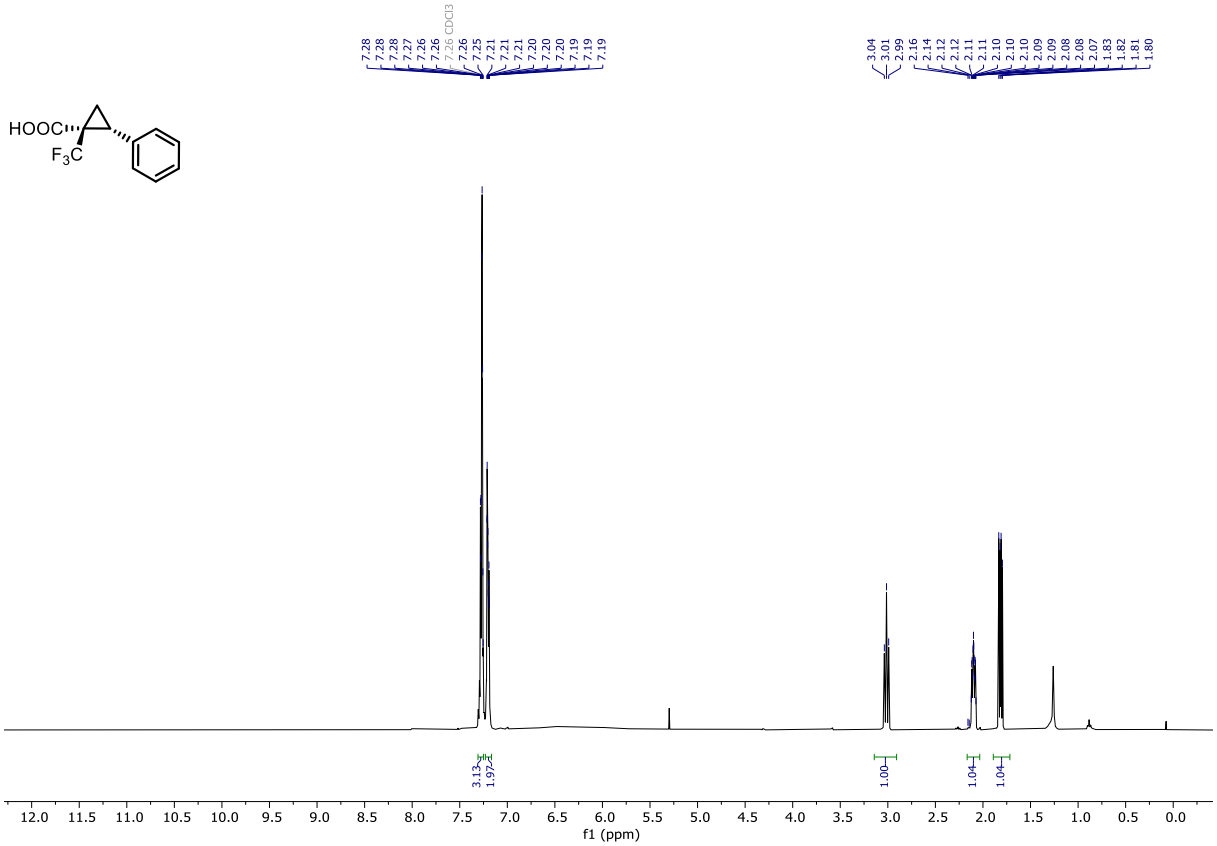
11: ^{13}C NMR (101 MHz, $CDCl_3$):



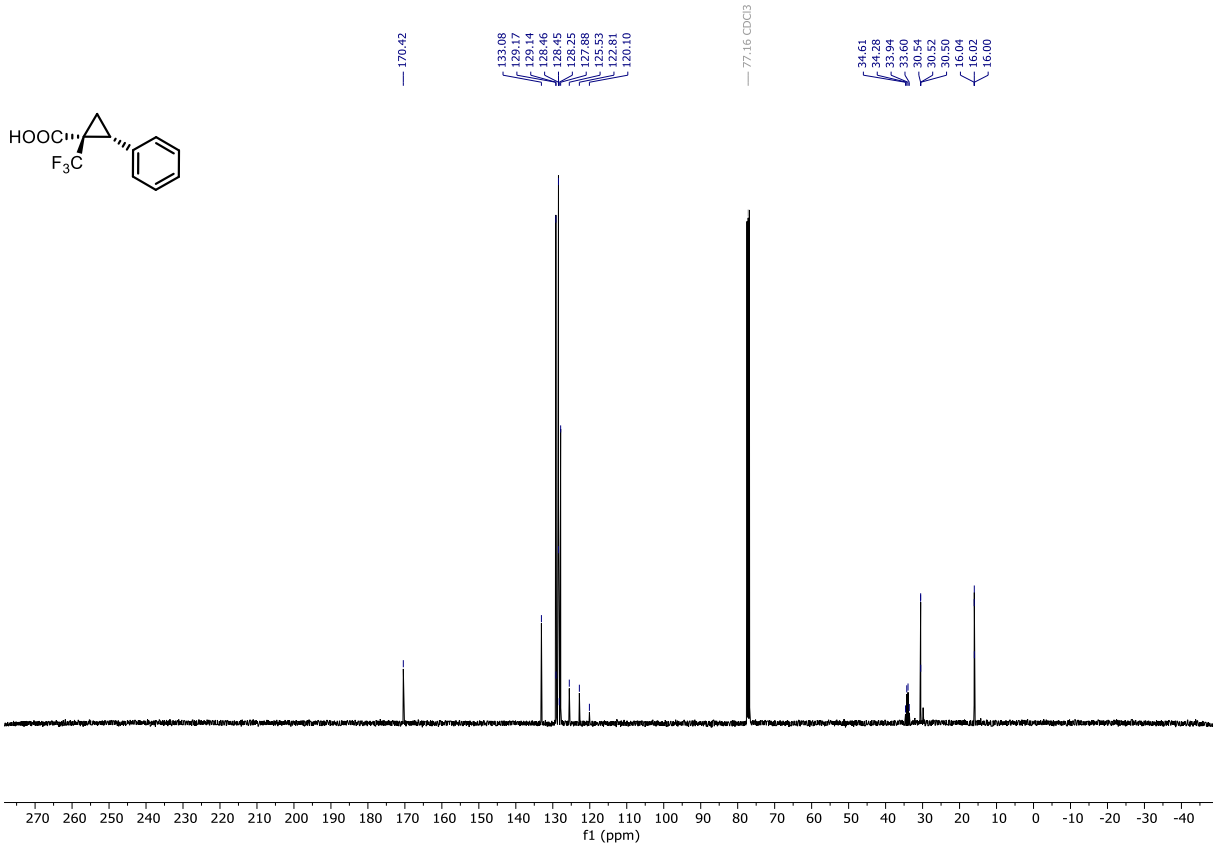
11: ^{19}F NMR (282 MHz, $CDCl_3$):



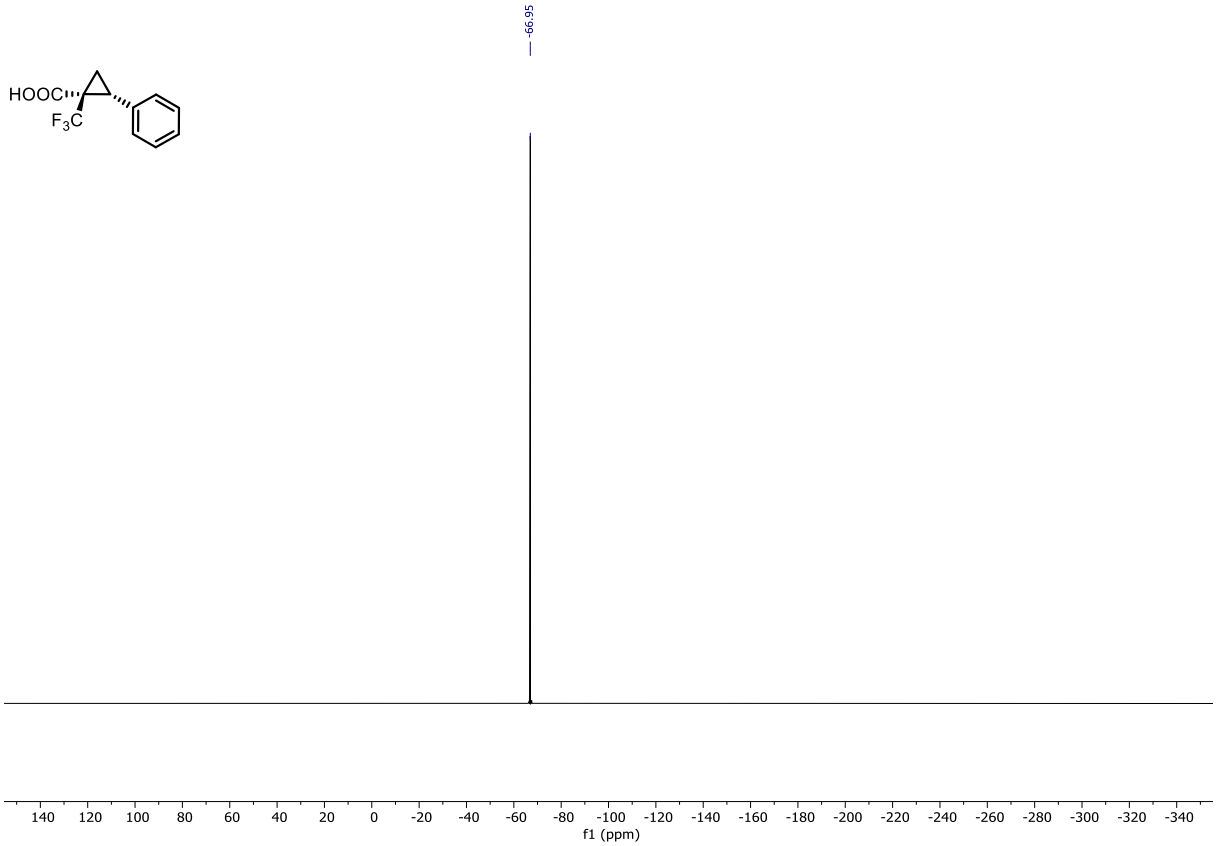
4a: ^{1}H-NMR (400 MHz, $CDCl_3$):



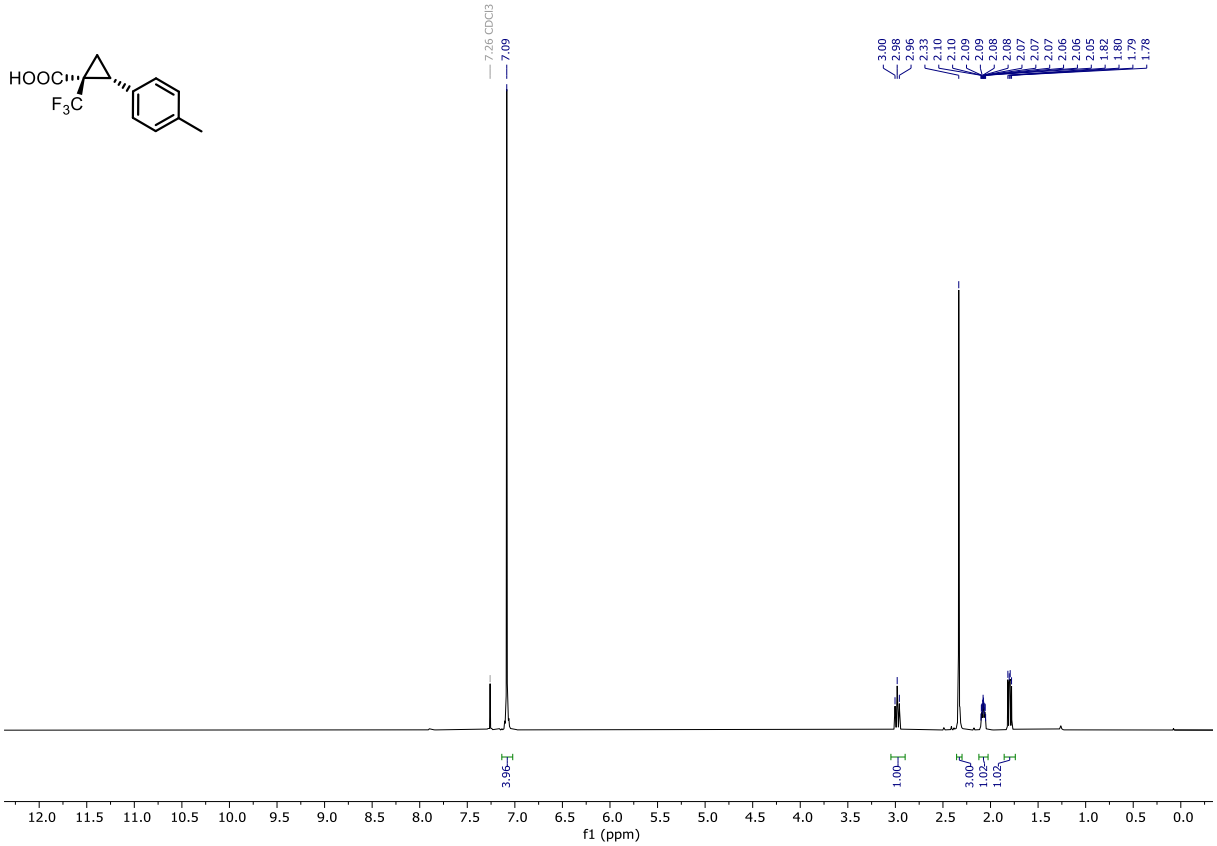
4a: ^{13}C NMR (101 MHz, $CDCl_3$):



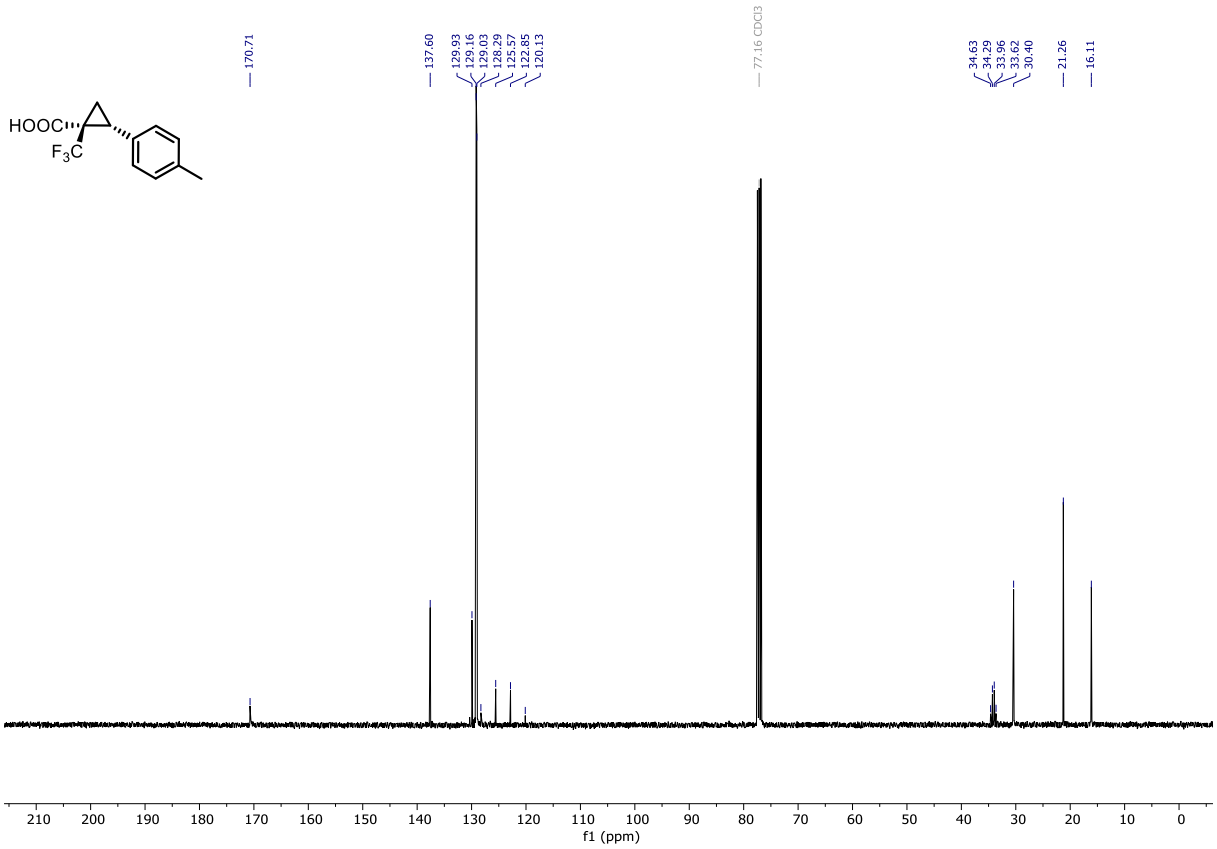
4a: ^{19}F NMR (282 MHz, $CDCl_3$):



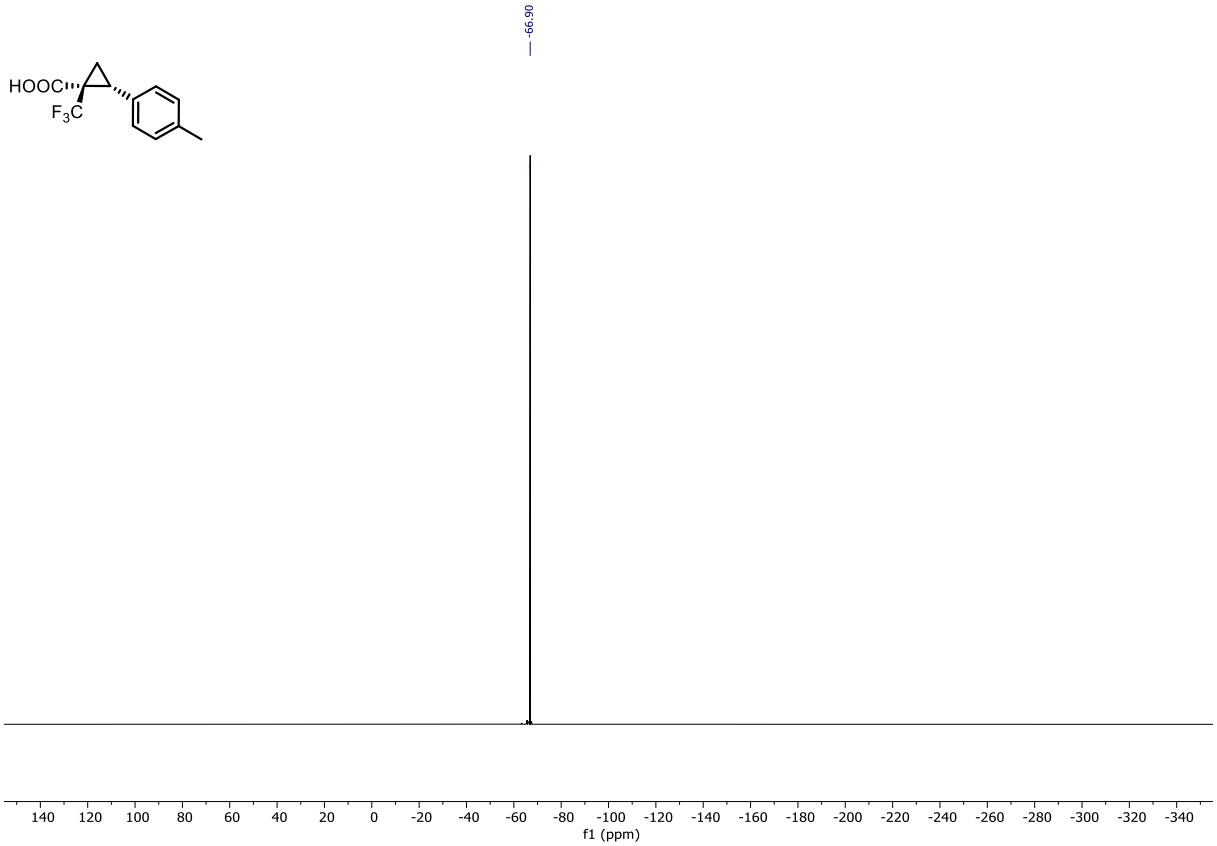
4b: ^{1}H-NMR (400 MHz, $CDCl_3$):



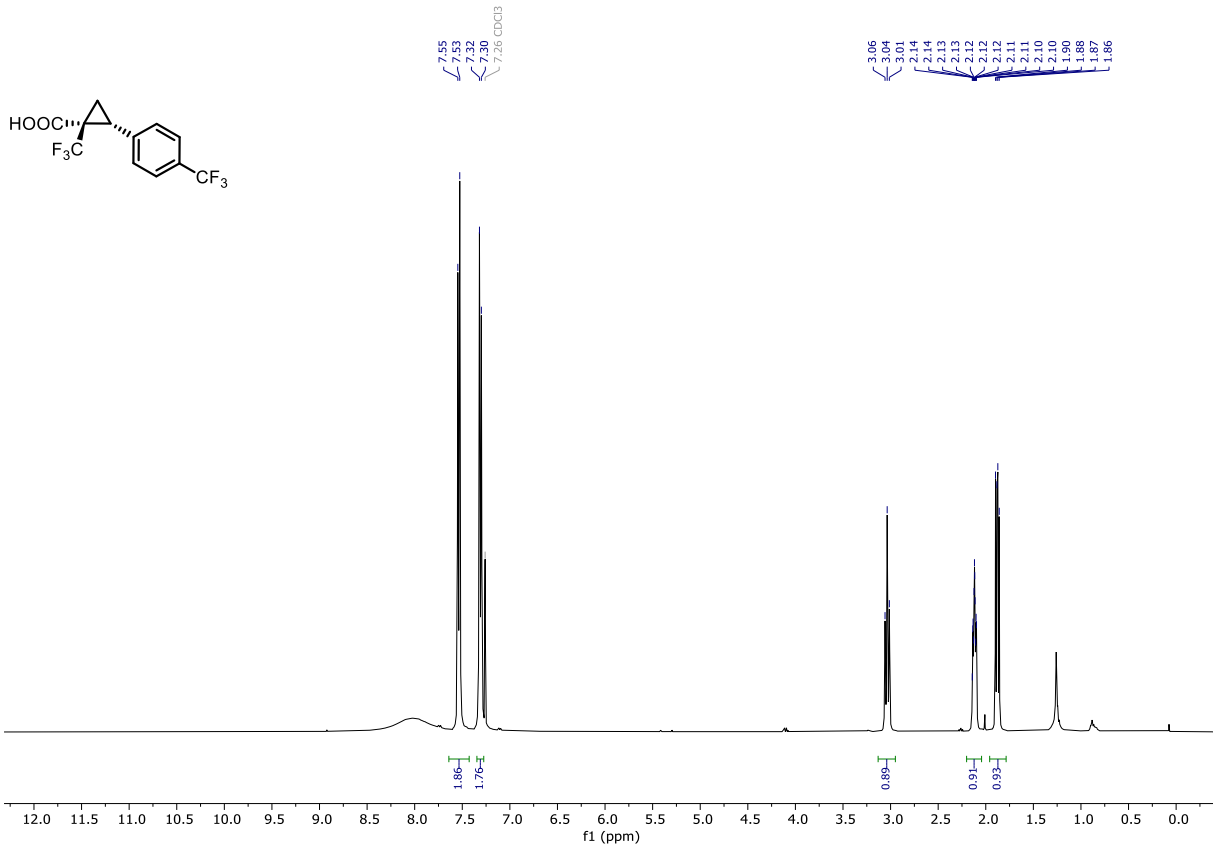
4b: ^{13}C NMR (101 MHz, $CDCl_3$):



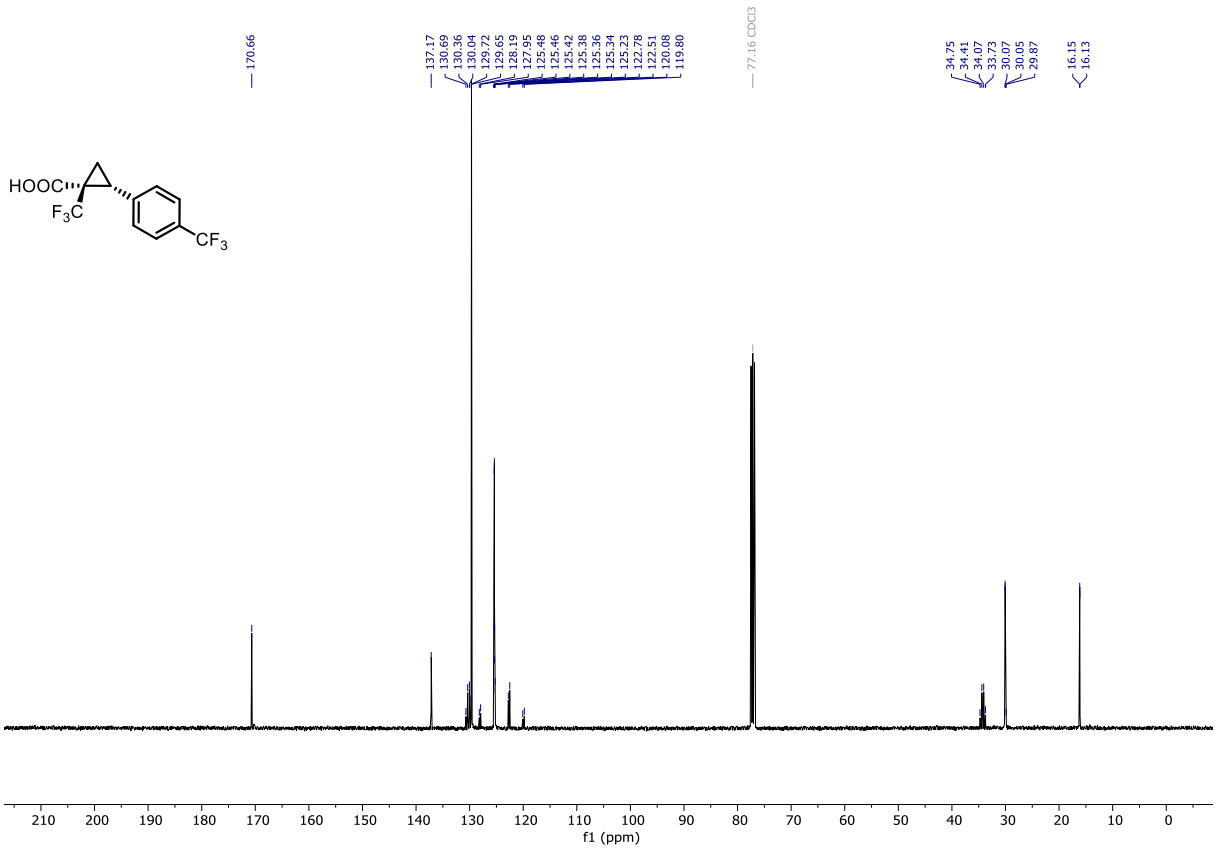
4b: ^{19}F NMR (282 MHz, $CDCl_3$):



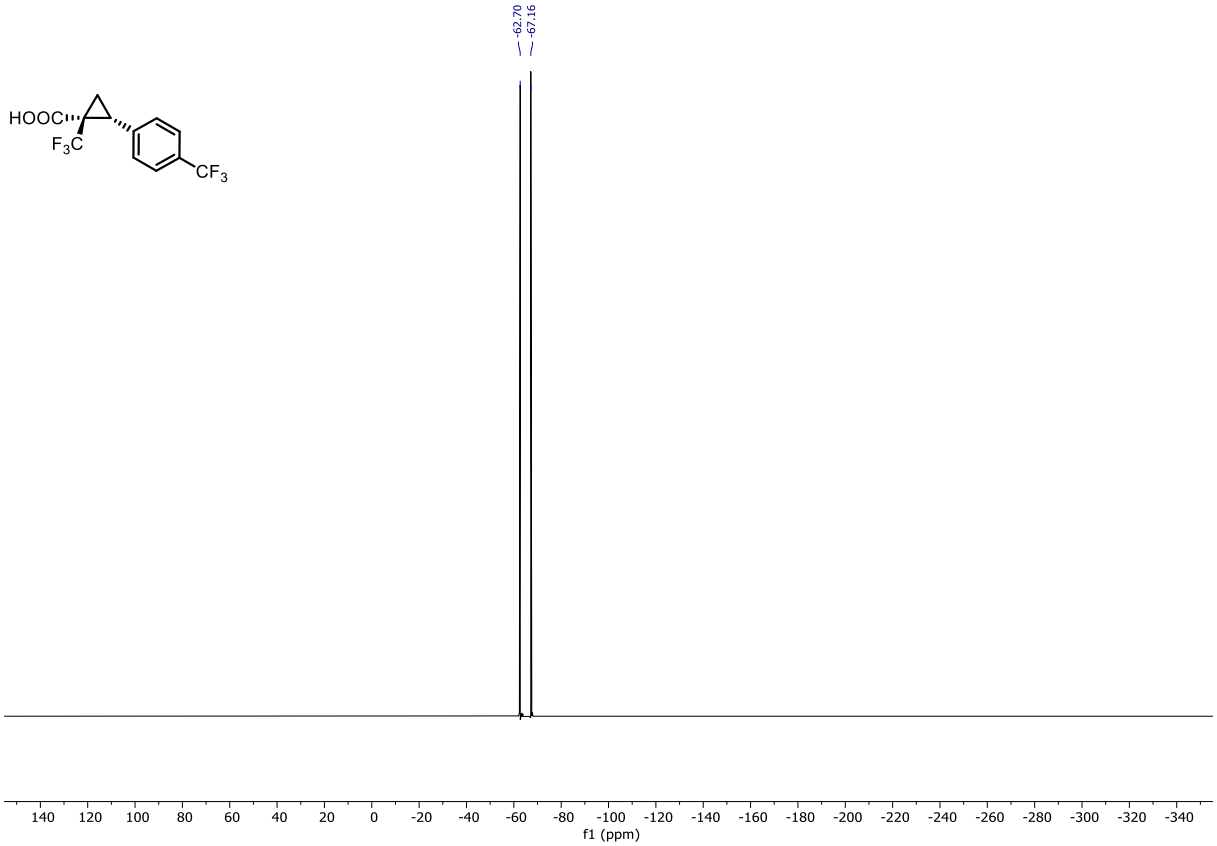
4e: ^{1}H-NMR (400 MHz, $CDCl_3$):



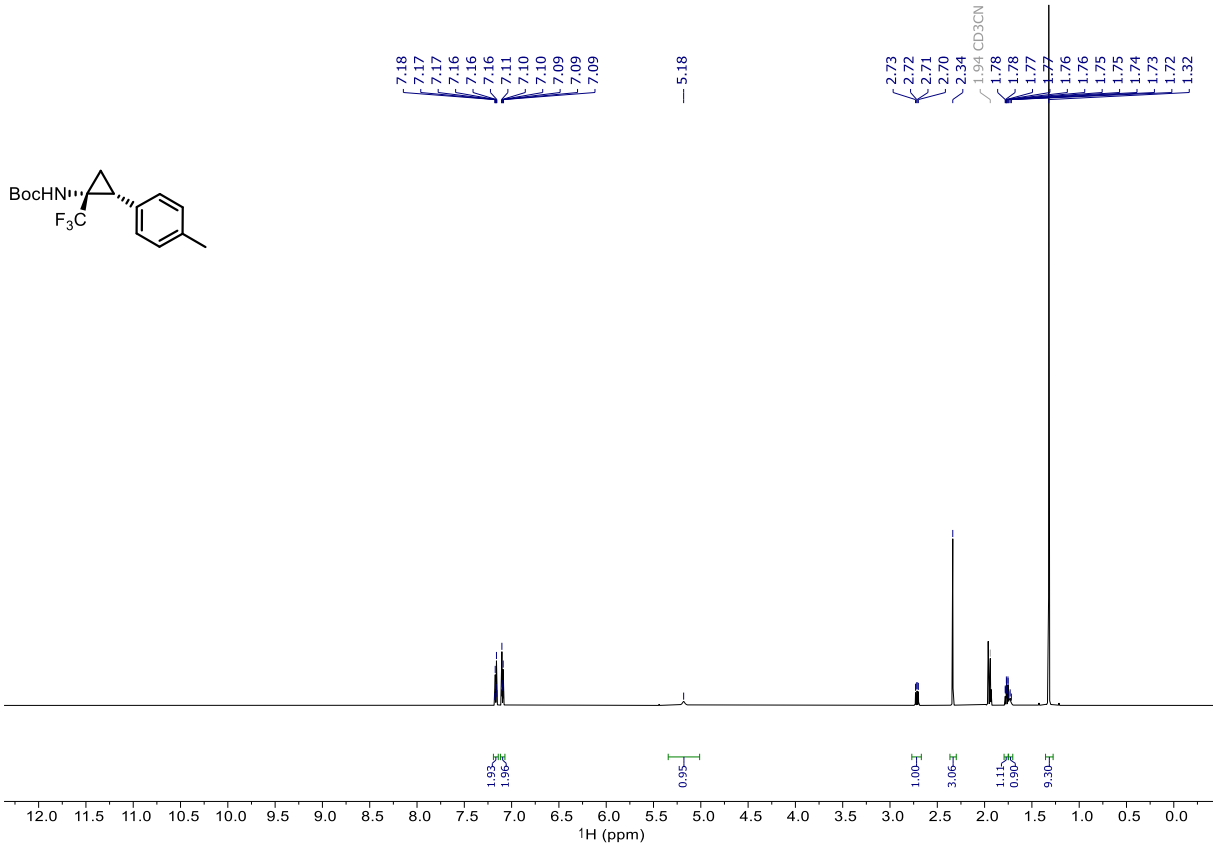
4e: ^{13}C NMR (101 MHz, $CDCl_3$):



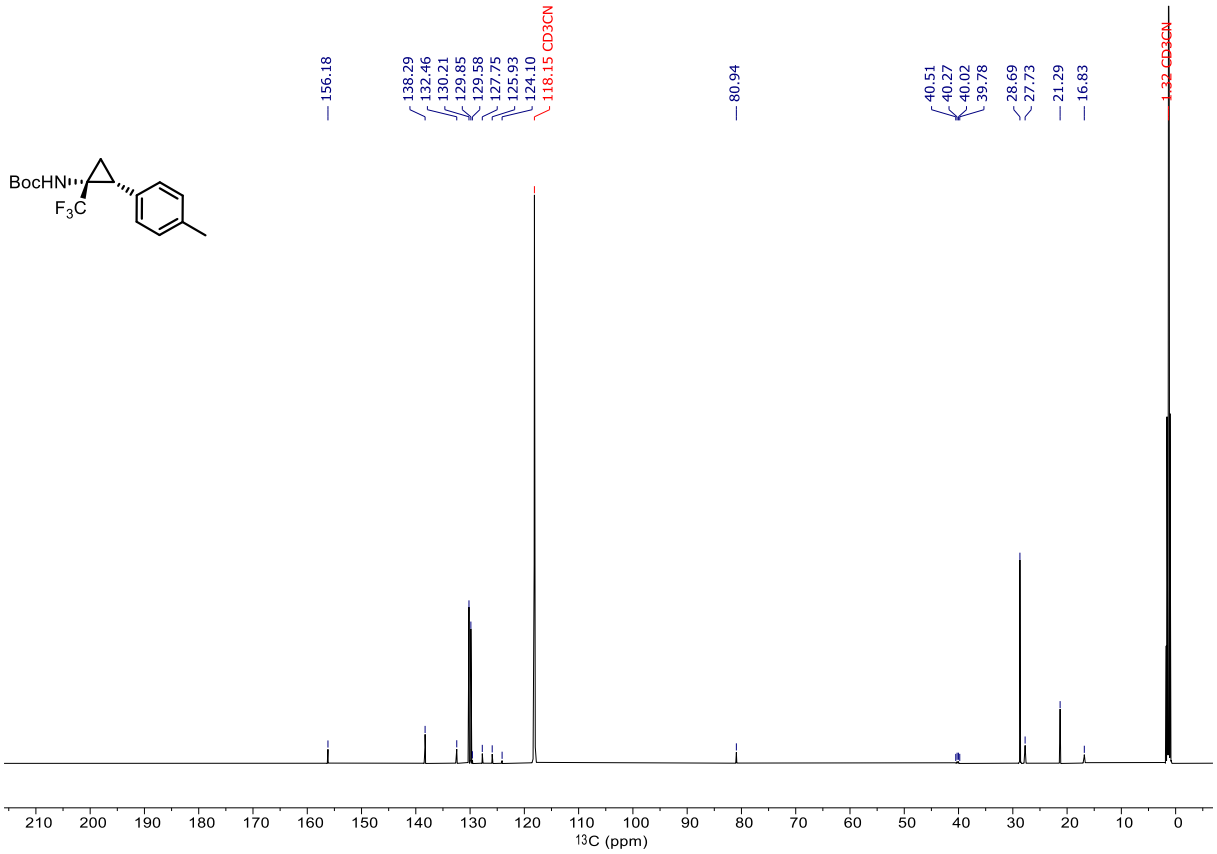
4e: ^{19}F NMR (282 MHz, $CDCl_3$):



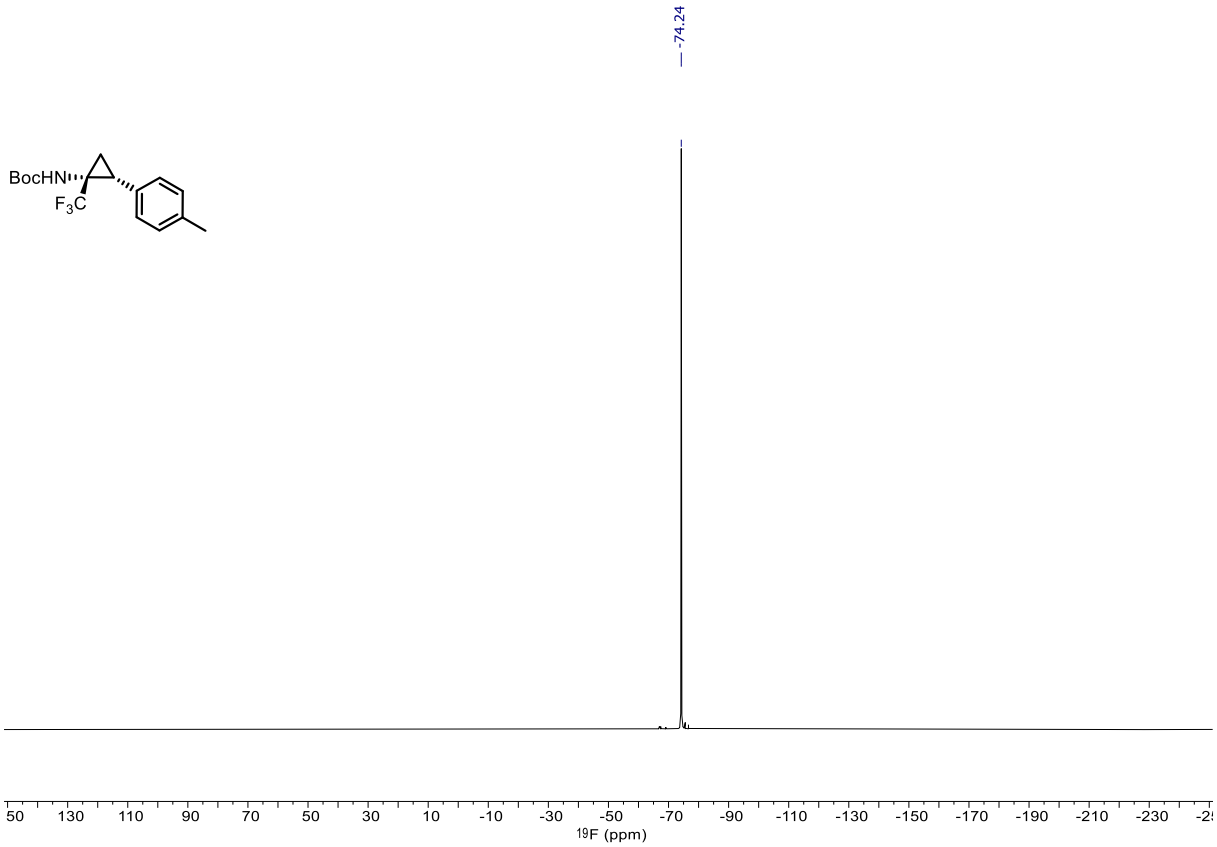
5b: ^{1}H-NMR (600 MHz, CD_3CN, measured at 80 °C):



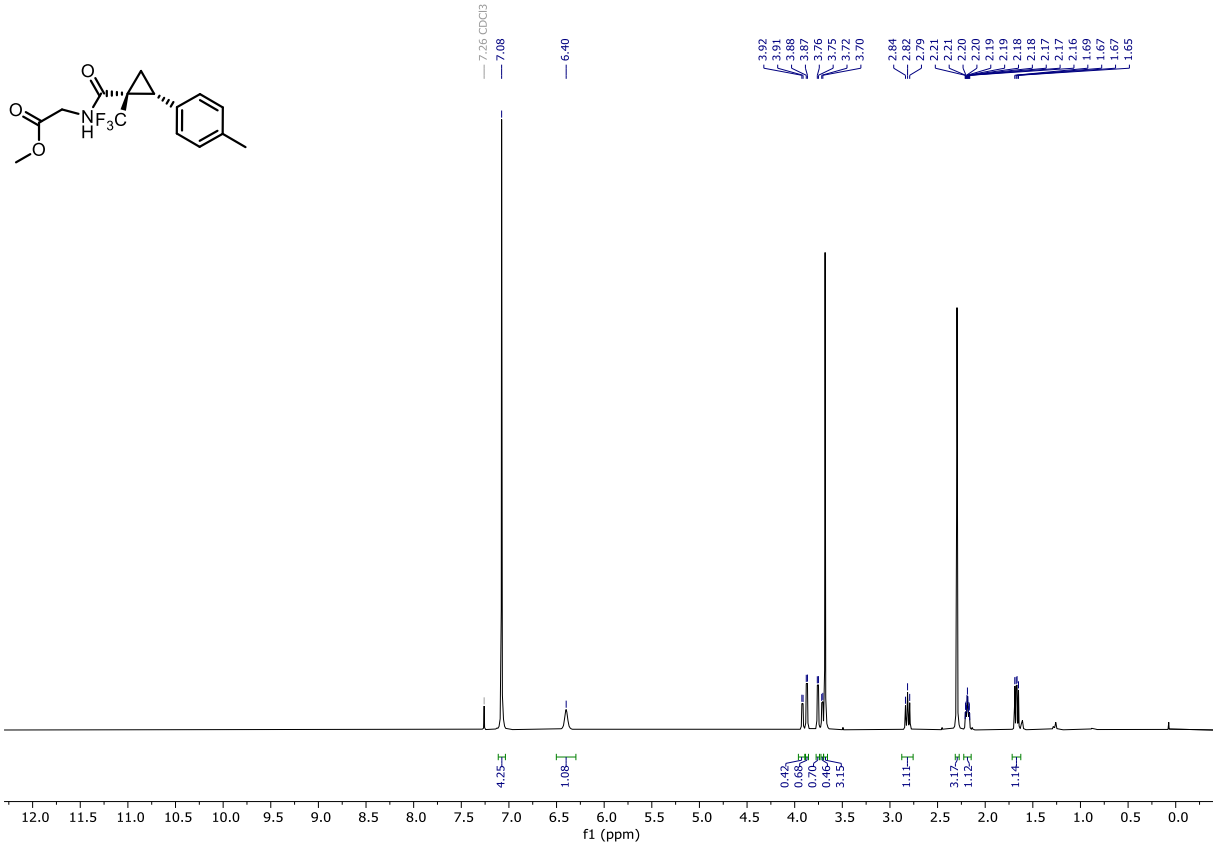
5b: ^{13}C NMR (151 MHz, CD_3CN):



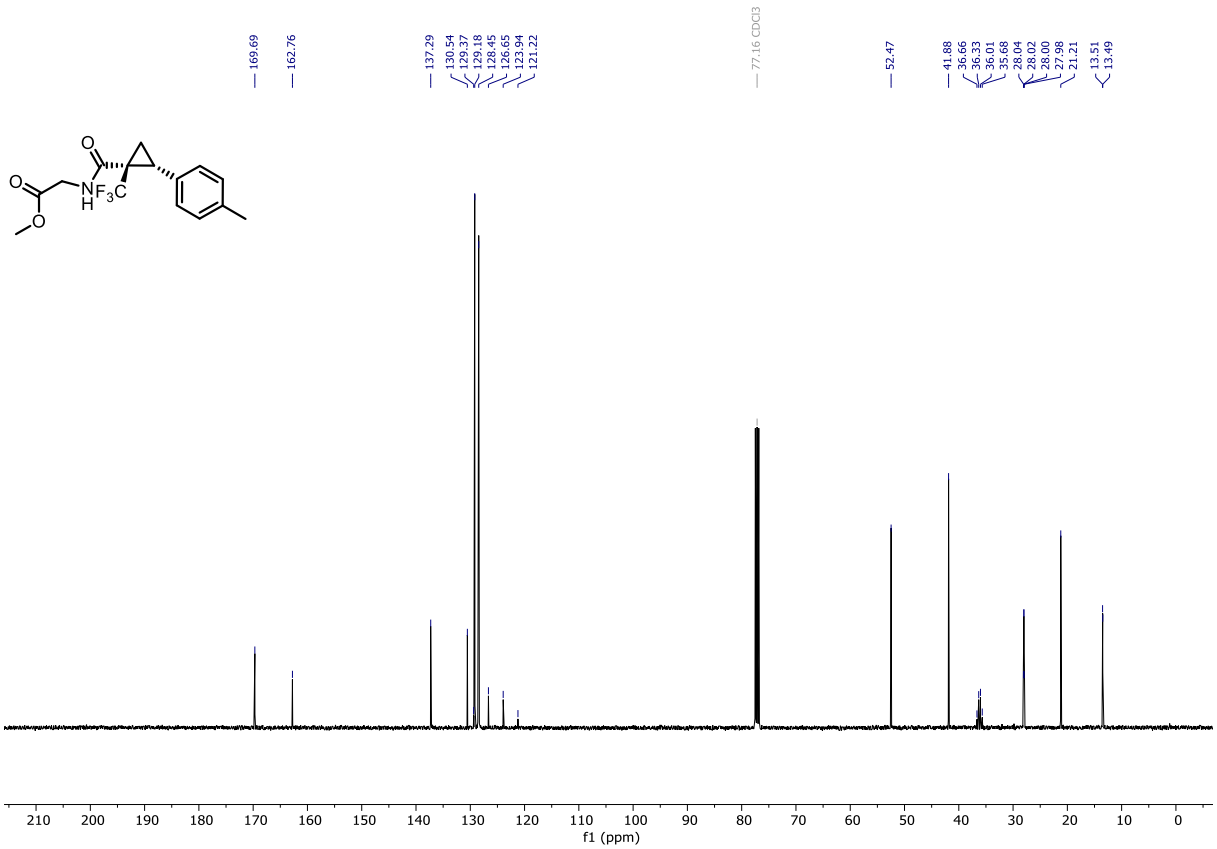
5b: ^{19}F NMR (565 MHz, $CDCl_3$):



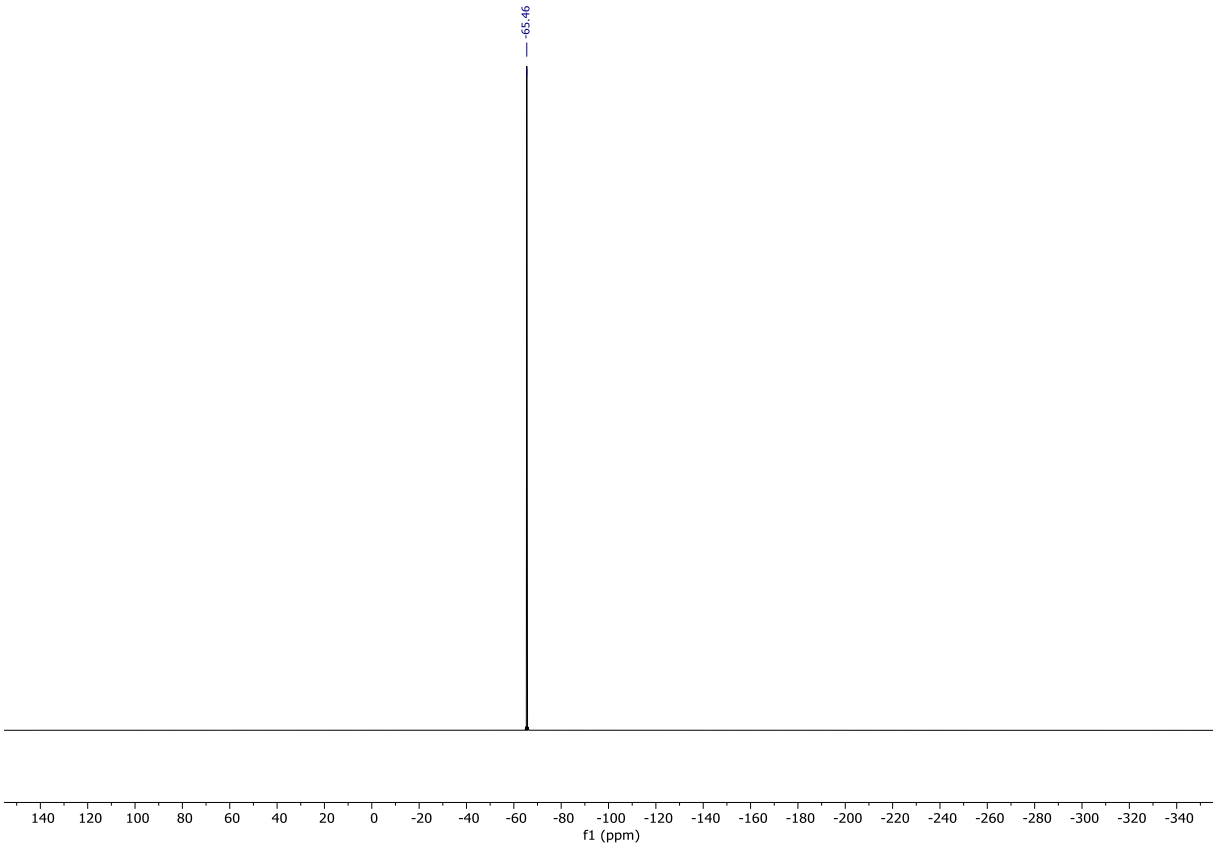
12: ^{1}H-NMR (400 MHz, $CDCl_3$):



12: ^{13}C NMR (101 MHz, $CDCl_3$):



12: ^{19}F NMR (282 MHz, $CDCl_3$):



References

1. Newberry, R. W.; Raines, R. T., The n→π* Interaction. *Acc. Chem. Res.* **2017,** *50* (8), 1838-1846.
2. Waser, J.; Gaspar, B.; Nambu, H.; Carreira, E. M., Hydrazines and Azides via the Metal-Catalyzed Hydrohydrazination and Hydroazidation of Olefins. *Journal of the American Chemical Society* **2006,** *128* (35), 11693-11712.
3. Ning, X.; Chen, Y.; Hu, F.; Xia, Y., Palladium-Catalyzed Carbene Coupling Reactions of Cyclobutanone N-Sulfonylhydrazones. *Organic Letters* **2021,** *23* (21), 8348-8352.
4. Singha, S.; Buchsteiner, M.; Bistoni, G.; Goddard, R.; Fürstner, A., A New Ligand Design Based on London Dispersion Empowers Chiral Bismuth–Rhodium Paddlewheel Catalysts. *J. Am. Chem. Soc.* **2021,** *143* (15), 5666-5673.
5. Buchsteiner, M.; Singha, S.; Decaens, J.; Fürstner, A., Chiral Bismuth-Rhodium Paddlewheel Complexes Empowered by London Dispersion: The C−H Functionalization Nexus. *Angew. Chem. Int. Ed.* **2022,** *61* (45), e202212546.
6. Kremlev, M. M.; Mushta, A. I.; Tyrra, W.; Naumann, D.; Fischer, H. T. M.; Yagupolskii, Y. L., Silver compounds in synthetic chemistry: Part 5: Selective syntheses of trifluoromethylketones, $RCOCF_3$, from trifluoromethylsilver, AgCF3, and corresponding acyl chlorides, RCOCl. *Journal of Fluorine Chemistry* **2007,** *128* (11), 1385-1389.
7. Trost, B. M.; Debien, L., Palladium-Catalyzed Trimethylenemethane Cycloaddition of Olefins Activated by the σ-Electron-Withdrawing Trifluoromethyl Group. *Journal of the American Chemical Society* **2015,** *137* (36), 11606-11609.