



Full wwPDB X-ray Structure Validation Report ⓘ

Mar 5, 2026 – 06:26 AM UTC

PDB ID : 9LUF / pdb_00009luf
Title : Crystal structure of SARS-Cov-2 main protease S144A mutant in complex with Bofutrelvir
Authors : Zhou, X.L.; Li, J.
Deposited on : 2025-02-08
Resolution : 1.99 Å(reported)

This is a Full wwPDB X-ray Structure Validation Report for a publicly released PDB entry.

We welcome your comments at validation@mail.wwpdb.org

A user guide is available at

<https://www.wwpdb.org/validation/2017/XrayValidationReportHelp>

with specific help available everywhere you see the ⓘ symbol.

The types of validation reports are described at

<http://www.wwpdb.org/validation/2017/FAQs#types>.

The following versions of software and data (see [references ⓘ](#)) were used in the production of this report:

MolProbity	:	4-5-2 with Phenix2.0
Mogul	:	2022.3.0, CSD as543be (2022)
Xtriage (Phenix)	:	2.0
EDS	:	3.0
Buster-report	:	wwPDB partial adaption of 1.1.7 (2018)
Percentile statistics	:	20250101.v01 (using entries in the PDB archive January 1st 2025)
CCP4	:	9.0.010 (Gargrove)
Density-Fitness	:	1.0.12
Ideal geometry (proteins)	:	Engh & Huber (2001)
Ideal geometry (DNA, RNA)	:	Parkinson et al. (1996)
Validation Pipeline (wwPDB-VP)	:	2.49

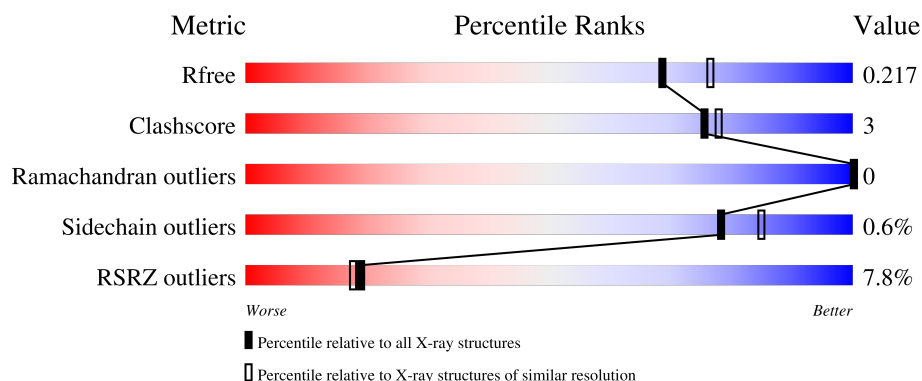
1 Overall quality at a glance

The following experimental techniques were used to determine the structure:

X-RAY DIFFRACTION

The reported resolution of this entry is 1.99 Å.

Percentile scores (ranging between 0-100) for global validation metrics of the entry are shown in the following graphic. The table shows the number of entries on which the scores are based.



Metric	Whole archive (#Entries)	Similar resolution (#Entries, resolution range(Å))
R_{free}	180053	10052 (2.00-2.00)
Clashscore	190562	11152 (2.00-2.00)
Ramachandran outliers	187476	11031 (2.00-2.00)
Sidechain outliers	187428	11029 (2.00-2.00)
RSRZ outliers	180081	10067 (2.00-2.00)

The table below summarises the geometric issues observed across the polymeric chains and their fit to the electron density. The red, orange, yellow and green segments of the lower bar indicate the fraction of residues that contain outliers for ≥ 3 , 2, 1 and 0 types of geometric quality criteria respectively. A grey segment represents the fraction of residues that are not modelled. The numeric value for each fraction is indicated below the corresponding segment, with a dot representing fractions $\leq 5\%$. The upper red bar (where present) indicates the fraction of residues that have poor fit to the electron density. The numeric value is given above the bar.

Mol	Chain	Length	Quality of chain
1	A	302	<div> <div>8%</div> <div>95%</div> <div>5%</div> </div>
1	B	302	<div> <div>8%</div> <div>91%</div> <div>8%</div> </div>

2 Entry composition [i](#)

There are 3 unique types of molecules in this entry. The entry contains 4974 atoms, of which 0 are hydrogens and 0 are deuteriums.

In the tables below, the ZeroOcc column contains the number of atoms modelled with zero occupancy, the AltConf column contains the number of residues with at least one atom in alternate conformation and the Trace column contains the number of residues modelled with at most 2 atoms.

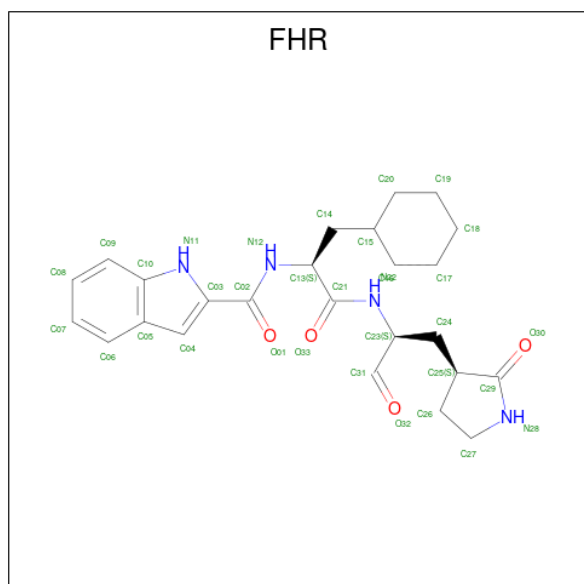
- Molecule 1 is a protein called ORF1a polyprotein.

Mol	Chain	Residues	Atoms					ZeroOcc	AltConf	Trace
1	A	302	Total	C	N	O	S	0	0	0
			2338	1480	399	437	22			
1	B	299	Total	C	N	O	S	0	0	0
			2320	1469	396	433	22			

There are 2 discrepancies between the modelled and reference sequences:

Chain	Residue	Modelled	Actual	Comment	Reference
A	144	ALA	SER	engineered mutation	UNP A0A8B1JNT2
B	144	ALA	SER	engineered mutation	UNP A0A8B1JNT2

- Molecule 2 is {N}-[(2 {S})-3-cyclohexyl-1-oxidanylidene-1-[(2 {S})-1-oxidanylidene-3-[(3 {S})-2-oxidanylidene-pyrrolidin-3-yl]propan-2-yl]amino]propan-2-yl]-1 {H}-indole-2-carboxamide (CCD ID: FHR) (formula: C₂₅H₃₂N₄O₄) (labeled as "Ligand of Interest" by depositor).



Mol	Chain	Residues	Atoms				ZeroOcc	AltConf
2	A	1	Total 33	C 25	N 4	O 4	0	0
2	B	1	Total 33	C 25	N 4	O 4	0	0

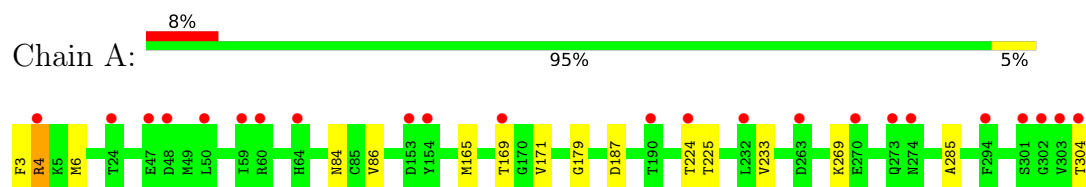
- Molecule 3 is water.

Mol	Chain	Residues	Atoms		ZeroOcc	AltConf
3	A	103	Total 103	O 103	0	0
3	B	147	Total 147	O 147	0	0

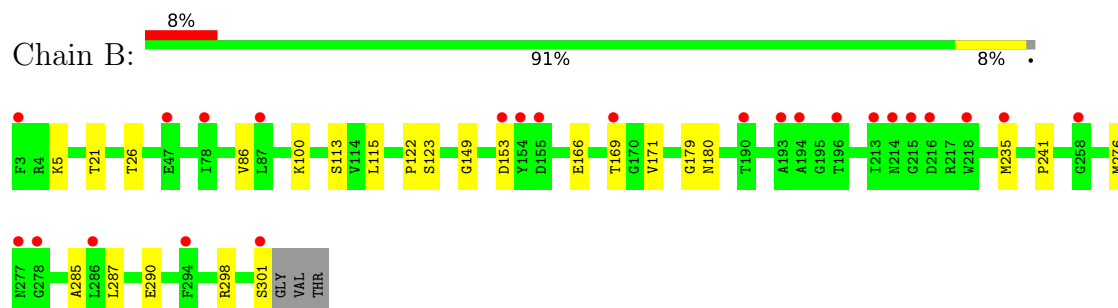
3 Residue-property plots [i](#)

These plots are drawn for all protein, RNA, DNA and oligosaccharide chains in the entry. The first graphic for a chain summarises the proportions of the various outlier classes displayed in the second graphic. The second graphic shows the sequence view annotated by issues in geometry and electron density. Residues are color-coded according to the number of geometric quality criteria for which they contain at least one outlier: green = 0, yellow = 1, orange = 2 and red = 3 or more. A red dot above a residue indicates a poor fit to the electron density ($RSRZ > 2$). Stretches of 2 or more consecutive residues without any outlier are shown as a green connector. Residues present in the sample, but not in the model, are shown in grey.

- Molecule 1: ORF1a polypeptide



- Molecule 1: ORF1a polypeptide



4 Data and refinement statistics

Property	Value	Source
Space group	P 21 21 21	Depositor
Cell constants a, b, c, α , β , γ	68.08Å 101.12Å 104.31Å 90.00° 90.00° 90.00°	Depositor
Resolution (Å)	40.59 – 1.99 40.59 – 1.99	Depositor EDS
% Data completeness (in resolution range)	100.0 (40.59-1.99) 100.0 (40.59-1.99)	Depositor EDS
R_{merge}	0.14	Depositor
R_{sym}	(Not available)	Depositor
$\langle I/\sigma(I) \rangle$ ¹	1.95 (at 2.00Å)	Xtriage
Refinement program	PHENIX 1.12_2829	Depositor
R, R_{free}	0.199 , 0.230 (Not available) , 0.217	Depositor DCC
R_{free} test set	2404 reflections (4.80%)	wwPDB-VP
Wilson B-factor (Å ²)	28.8	Xtriage
Anisotropy	0.355	Xtriage
Bulk solvent k_{sol} (e/Å ³), B_{sol} (Å ²)	0.35 , 31.0	EDS
L-test for twinning ²	$\langle L \rangle = 0.50$, $\langle L^2 \rangle = 0.33$	Xtriage
Estimated twinning fraction	0.007 for -h,l,k	Xtriage
F_o, F_c correlation	0.95	EDS
Total number of atoms	4974	wwPDB-VP
Average B, all atoms (Å ²)	33.0	wwPDB-VP

Xtriage's analysis on translational NCS is as follows: *The largest off-origin peak in the Patterson function is 3.90% of the height of the origin peak. No significant pseudotranslation is detected.*

¹Intensities estimated from amplitudes.

²Theoretical values of $\langle |L| \rangle$, $\langle L^2 \rangle$ for acentric reflections are 0.5, 0.333 respectively for untwinned datasets, and 0.375, 0.2 for perfectly twinned datasets.

5 Model quality [i](#)

5.1 Standard geometry [i](#)

Bond lengths and bond angles in the following residue types are not validated in this section: FHR

The Z score for a bond length (or angle) is the number of standard deviations the observed value is removed from the expected value. A bond length (or angle) with $|Z| > 5$ is considered an outlier worth inspection. RMSZ is the root-mean-square of all Z scores of the bond lengths (or angles).

Mol	Chain	Bond lengths		Bond angles	
		RMSZ	$\# Z > 5$	RMSZ	$\# Z > 5$
1	A	0.32	0/2390	0.52	0/3250
1	B	0.33	0/2372	0.56	0/3225
All	All	0.33	0/4762	0.54	0/6475

There are no bond length outliers.

There are no bond angle outliers.

There are no chirality outliers.

There are no planarity outliers.

5.2 Too-close contacts [i](#)

In the following table, the Non-H and H(model) columns list the number of non-hydrogen atoms and hydrogen atoms in the chain respectively. The H(added) column lists the number of hydrogen atoms added and optimized by MolProbity. The Clashes column lists the number of clashes within the asymmetric unit, whereas Symm-Clashes lists symmetry-related clashes.

Mol	Chain	Non-H	H(model)	H(added)	Clashes	Symm-Clashes
1	A	2338	0	2285	13	0
1	B	2320	0	2266	17	0
2	A	33	0	0	0	0
2	B	33	0	0	1	0
3	A	103	0	0	4	2
3	B	147	0	0	2	2
All	All	4974	0	4551	28	2

The all-atom clashscore is defined as the number of clashes found per 1000 atoms (including hydrogen atoms). The all-atom clashscore for this structure is 3.

All (28) close contacts within the same asymmetric unit are listed below, sorted by their clash

magnitude.

Atom-1	Atom-2	Interatomic distance (Å)	Clash overlap (Å)
1:A:4:ARG:NH1	3:A:501:HOH:O	1.70	1.22
1:B:235:MET:CE	1:B:241:PRO:HG3	1.88	1.02
1:B:235:MET:HE2	1:B:241:PRO:HG3	1.54	0.87
1:B:235:MET:HE1	1:B:241:PRO:HG3	1.59	0.85
1:B:153:ASP:OD2	3:B:501:HOH:O	1.97	0.81
1:A:3:PHE:N	3:A:502:HOH:O	2.17	0.78
1:B:169:THR:HG23	1:B:171:VAL:HG22	1.90	0.54
1:A:165:MET:HE1	1:A:187:ASP:HA	1.91	0.53
1:A:224:THR:HG22	1:A:225:THR:N	2.25	0.52
1:B:180:ASN:OD1	3:B:502:HOH:O	2.19	0.51
1:B:21:THR:HG23	1:B:26:THR:HG22	1.92	0.51
1:A:224:THR:HG22	1:A:225:THR:H	1.75	0.50
1:A:285:ALA:HB3	1:B:285:ALA:HB3	1.95	0.48
1:B:100:LYS:HE2	1:B:100:LYS:H	1.80	0.46
1:B:276:MET:HE2	1:B:287:LEU:HD23	1.99	0.45
1:A:169:THR:HG23	1:A:171:VAL:HG22	1.99	0.45
1:A:86:VAL:HG13	1:A:179:GLY:HA2	1.98	0.44
1:A:169:THR:HG21	3:A:598:HOH:O	2.17	0.44
1:B:115:LEU:HD11	1:B:122:PRO:HB3	1.99	0.44
1:B:5:LYS:HE2	1:B:290:GLU:HB2	1.99	0.43
1:A:84:ASN:C	3:A:540:HOH:O	2.62	0.43
1:A:233:VAL:HG21	1:A:269:LYS:HE2	2.01	0.43
1:B:113:SER:O	1:B:149:GLY:HA2	2.20	0.42
1:A:6:MET:HE3	1:A:6:MET:HB2	1.65	0.42
1:B:166:GLU:O	2:B:401:FHR:C04	2.68	0.42
1:B:235:MET:HE2	1:B:241:PRO:CG	2.38	0.41
1:B:86:VAL:HG13	1:B:179:GLY:HA2	2.03	0.41
1:A:304:THR:HG22	1:B:123:SER:HB3	2.03	0.40

All (2) symmetry-related close contacts are listed below. The label for Atom-2 includes the symmetry operator and encoded unit-cell translations to be applied.

Atom-1	Atom-2	Interatomic distance (Å)	Clash overlap (Å)
3:A:593:HOH:O	3:B:631:HOH:O[2_454]	2.14	0.06
3:A:515:HOH:O	3:B:618:HOH:O[2_454]	2.17	0.03

5.3 Torsion angles

5.3.1 Protein backbone

In the following table, the Percentiles column shows the percent Ramachandran outliers of the chain as a percentile score with respect to all X-ray entries followed by that with respect to entries of similar resolution.

The Analysed column shows the number of residues for which the backbone conformation was analysed, and the total number of residues.

Mol	Chain	Analysed	Favoured	Allowed	Outliers	Percentiles	
1	A	300/302 (99%)	295 (98%)	5 (2%)	0	100	100
1	B	297/302 (98%)	291 (98%)	6 (2%)	0	100	100
All	All	597/604 (99%)	586 (98%)	11 (2%)	0	100	100

There are no Ramachandran outliers to report.

5.3.2 Protein sidechains

In the following table, the Percentiles column shows the percent sidechain outliers of the chain as a percentile score with respect to all X-ray entries followed by that with respect to entries of similar resolution.

The Analysed column shows the number of residues for which the sidechain conformation was analysed, and the total number of residues.

Mol	Chain	Analysed	Rotameric	Outliers	Percentiles	
1	A	259/259 (100%)	258 (100%)	1 (0%)	84	89
1	B	257/259 (99%)	255 (99%)	2 (1%)	73	80
All	All	516/518 (100%)	513 (99%)	3 (1%)	78	85

All (3) residues with a non-rotameric sidechain are listed below:

Mol	Chain	Res	Type
1	A	4	ARG
1	B	298	ARG
1	B	301	SER

Sometimes sidechains can be flipped to improve hydrogen bonding and reduce clashes. All (6) such sidechains are listed below:

Mol	Chain	Res	Type
1	A	119	ASN
1	A	180	ASN
1	B	107	GLN
1	B	119	ASN
1	B	180	ASN
1	B	214	ASN

5.3.3 RNA [i](#)

There are no RNA molecules in this entry.

5.4 Non-standard residues in protein, DNA, RNA chains [i](#)

There are no non-standard protein/DNA/RNA residues in this entry.

5.5 Carbohydrates [i](#)

There are no oligosaccharides in this entry.

5.6 Ligand geometry [i](#)

2 ligands are modelled in this entry.

In the following table, the Counts columns list the number of bonds (or angles) for which Mogul statistics could be retrieved, the number of bonds (or angles) that are observed in the model and the number of bonds (or angles) that are defined in the Chemical Component Dictionary. The Link column lists molecule types, if any, to which the group is linked. The Z score for a bond length (or angle) is the number of standard deviations the observed value is removed from the expected value. A bond length (or angle) with $|Z| > 2$ is considered an outlier worth inspection. RMSZ is the root-mean-square of all Z scores of the bond lengths (or angles).

Mol	Type	Chain	Res	Link	Bond lengths			Bond angles		
					Counts	RMSZ	$\# Z > 2$	Counts	RMSZ	$\# Z > 2$
2	FHR	B	401	1	35,36,36	6.18	17 (48%)	44,49,49	1.30	6 (13%)
2	FHR	A	401	1	35,36,36	6.24	17 (48%)	44,49,49	1.50	8 (18%)

In the following table, the Chirals column lists the number of chiral outliers, the number of chiral centers analysed, the number of these observed in the model and the number defined in the Chemical Component Dictionary. Similar counts are reported in the Torsion and Rings columns. '-' means no outliers of that kind were identified.

Mol	Type	Chain	Res	Link	Chirals	Torsions	Rings
2	FHR	B	401	1	-	0/25/44/44	0/4/4/4
2	FHR	A	401	1	-	0/25/44/44	0/4/4/4

All (34) bond length outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(Å)	Ideal(Å)
2	A	401	FHR	C29-N28	24.93	1.60	1.33
2	B	401	FHR	C29-N28	24.80	1.59	1.33
2	B	401	FHR	C26-C27	11.86	1.70	1.53
2	A	401	FHR	C26-C27	11.67	1.70	1.53
2	A	401	FHR	C09-C10	11.38	1.58	1.39
2	B	401	FHR	C09-C10	11.05	1.57	1.39
2	A	401	FHR	C06-C05	10.00	1.58	1.41
2	B	401	FHR	C06-C05	9.69	1.57	1.41
2	A	401	FHR	C26-C25	-8.40	1.30	1.54
2	B	401	FHR	C26-C25	-8.22	1.31	1.54
2	A	401	FHR	C08-C09	7.55	1.51	1.38
2	A	401	FHR	C07-C06	7.28	1.51	1.38
2	B	401	FHR	C07-C06	7.15	1.51	1.38
2	B	401	FHR	C08-C09	7.12	1.51	1.38
2	A	401	FHR	C27-N28	-6.89	1.31	1.46
2	B	401	FHR	C27-N28	-6.67	1.31	1.46
2	B	401	FHR	C02-N12	5.92	1.46	1.34
2	A	401	FHR	C02-N12	5.80	1.46	1.34
2	A	401	FHR	C21-N22	5.70	1.46	1.34
2	B	401	FHR	C21-N22	5.51	1.45	1.34
2	A	401	FHR	C08-C07	4.80	1.48	1.38
2	B	401	FHR	C08-C07	4.71	1.48	1.38
2	B	401	FHR	C24-C25	3.59	1.61	1.53
2	B	401	FHR	O33-C21	-3.48	1.16	1.23
2	A	401	FHR	C24-C25	3.47	1.61	1.53
2	A	401	FHR	O33-C21	-3.25	1.17	1.23
2	B	401	FHR	C25-C29	3.19	1.60	1.52
2	A	401	FHR	C25-C29	2.97	1.59	1.52
2	A	401	FHR	C03-C02	2.91	1.55	1.48
2	B	401	FHR	C03-C02	2.59	1.54	1.48
2	B	401	FHR	C05-C04	-2.34	1.36	1.44
2	B	401	FHR	O30-C29	-2.17	1.19	1.23
2	A	401	FHR	O30-C29	-2.02	1.19	1.23
2	A	401	FHR	C05-C04	-2.01	1.37	1.44

All (14) bond angle outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(°)	Ideal(°)
2	A	401	FHR	C13-N12-C02	-3.64	115.87	122.00
2	A	401	FHR	C15-C14-C13	-3.58	109.71	114.52
2	B	401	FHR	C27-N28-C29	-3.39	106.61	113.79
2	A	401	FHR	C27-N28-C29	-3.15	107.11	113.79
2	B	401	FHR	O32-C31-C23	-2.79	117.59	124.77
2	A	401	FHR	C26-C25-C29	2.79	106.70	102.87
2	B	401	FHR	C13-N12-C02	-2.27	118.17	122.00
2	B	401	FHR	C26-C25-C29	2.14	105.80	102.87
2	A	401	FHR	C02-C03-N11	2.11	126.77	120.04
2	B	401	FHR	C10-N11-C03	-2.07	106.79	109.01
2	A	401	FHR	C03-C02-N12	2.05	119.59	116.86
2	B	401	FHR	C02-C03-N11	2.04	126.55	120.04
2	A	401	FHR	O01-C02-N12	-2.04	119.50	123.09
2	A	401	FHR	C24-C23-C31	-2.03	107.87	110.99

There are no chirality outliers.

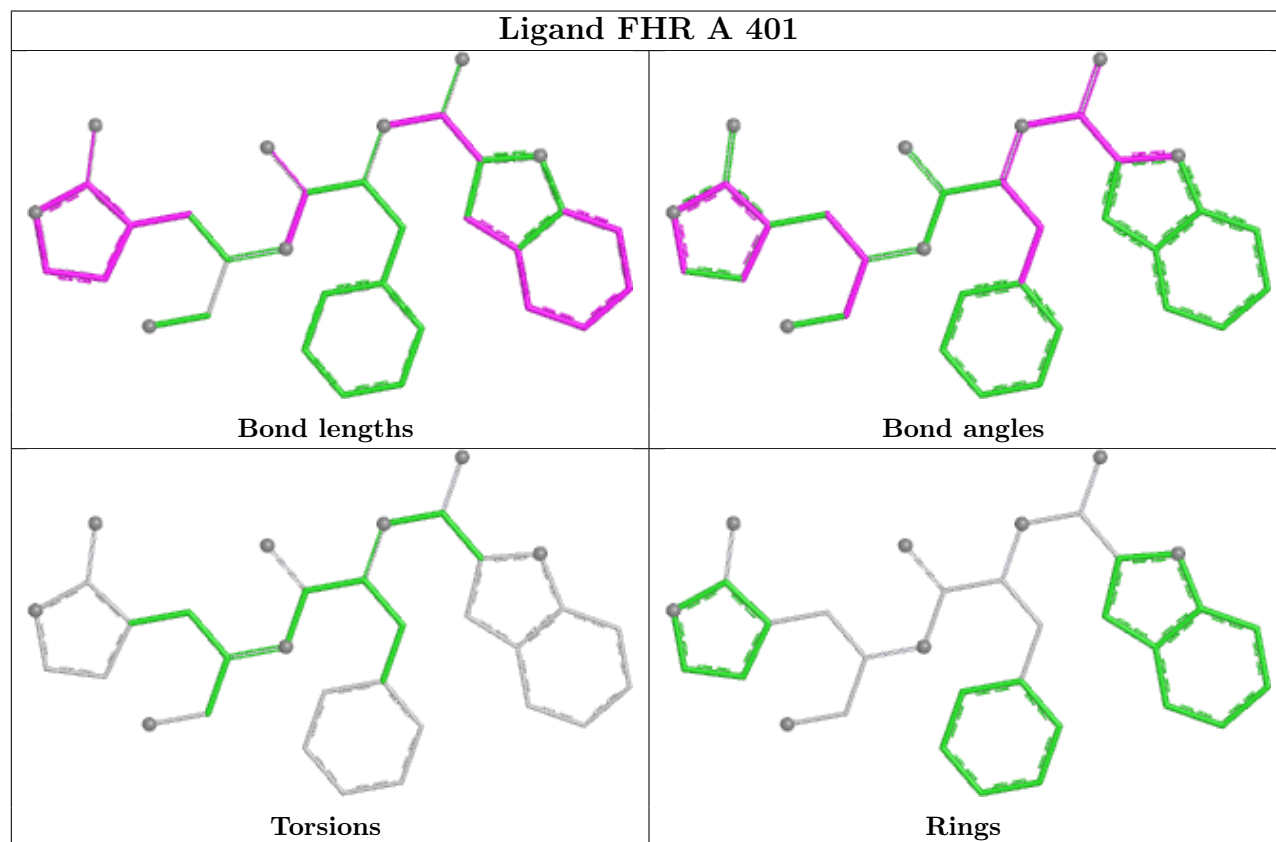
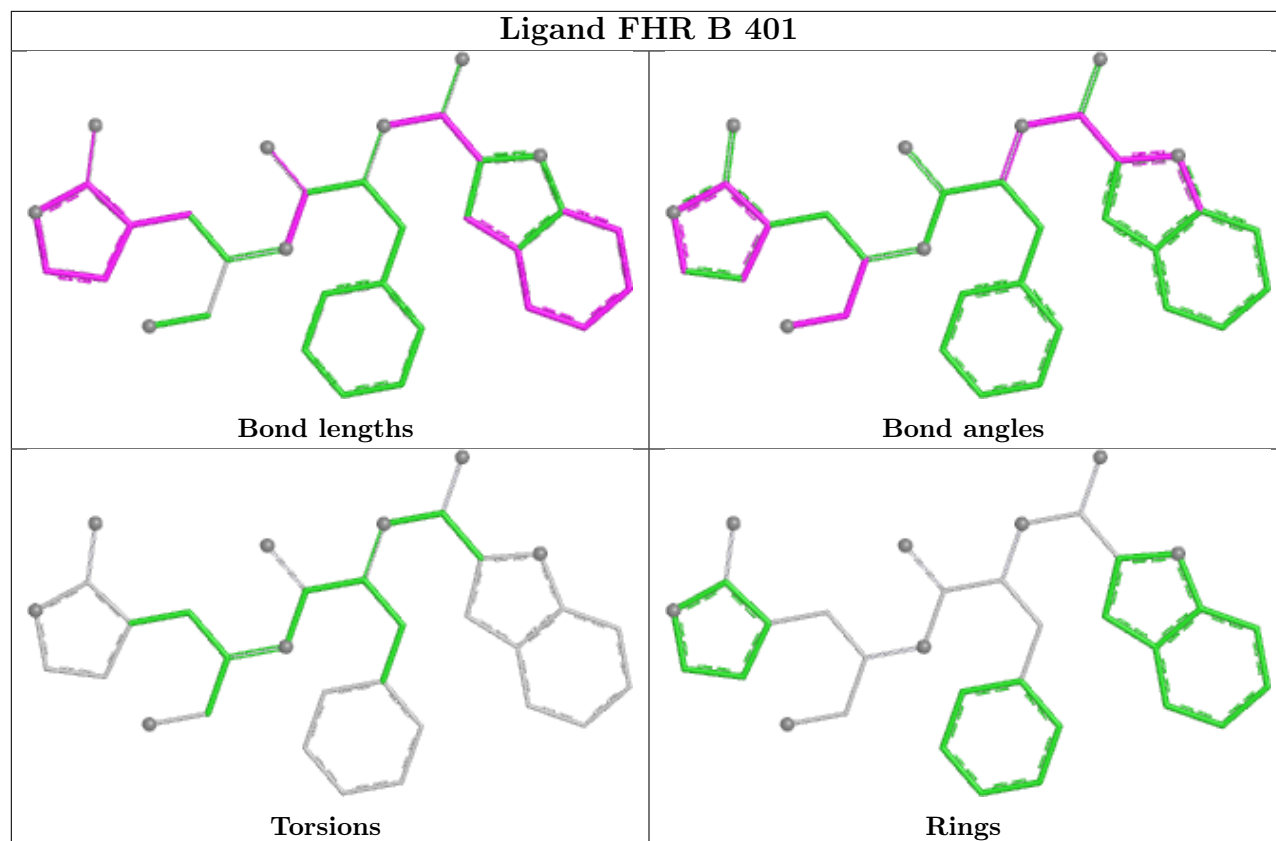
There are no torsion outliers.

There are no ring outliers.

1 monomer is involved in 1 short contact:

Mol	Chain	Res	Type	Clashes	Symm-Clashes
2	B	401	FHR	1	0

The following is a two-dimensional graphical depiction of Mogul quality analysis of bond lengths, bond angles, torsion angles, and ring geometry for all instances of the Ligand of Interest. In addition, ligands with molecular weight > 250 and outliers as shown on the validation Tables will also be included. For torsion angles, if less than 5% of the Mogul distribution of torsion angles is within 10 degrees of the torsion angle in question, then that torsion angle is considered an outlier. Any bond that is central to one or more torsion angles identified as an outlier by Mogul will be highlighted in the graph. For rings, the root-mean-square deviation (RMSD) between the ring in question and similar rings identified by Mogul is calculated over all ring torsion angles. If the average RMSD is greater than 60 degrees and the minimal RMSD between the ring in question and any Mogul-identified rings is also greater than 60 degrees, then that ring is considered an outlier. The outliers are highlighted in purple. The color gray indicates Mogul did not find sufficient equivalents in the CSD to analyse the geometry.



5.7 Other polymers [i](#)

There are no such residues in this entry.

5.8 Polymer linkage issues [i](#)

There are no chain breaks in this entry.

6 Fit of model and data

6.1 Protein, DNA and RNA chains

In the following table, the column labelled ‘#RSRZ > 2’ contains the number (and percentage) of RSRZ outliers, followed by percent RSRZ outliers for the chain as percentile scores relative to all X-ray entries and entries of similar resolution. The OWAB column contains the minimum, median, 95th percentile and maximum values of the occupancy-weighted average B-factor per residue. The column labelled ‘Q < 0.9’ lists the number of (and percentage) of residues with an average occupancy less than 0.9.

Mol	Chain	Analysed	<RSRZ>	#RSRZ > 2		OWAB(Å ²)	Q < 0.9
1	A	302/302 (100%)	0.53	23 (7%)	20 18	21, 34, 52, 68	0
1	B	299/302 (99%)	0.33	24 (8%)	18 17	20, 29, 50, 66	0
All	All	601/604 (99%)	0.43	47 (7%)	19 18	20, 31, 51, 68	0

All (47) RSRZ outliers are listed below:

Mol	Chain	Res	Type	RSRZ
1	B	154	TYR	6.0
1	A	302	GLY	5.2
1	A	303	VAL	4.8
1	B	153	ASP	4.6
1	A	301	SER	3.7
1	A	294	PHE	3.7
1	A	169	THR	3.7
1	B	294	PHE	3.5
1	A	50	LEU	3.5
1	A	154	TYR	3.5
1	B	155	ASP	3.4
1	A	24	THR	3.3
1	A	304	THR	3.3
1	B	216	ASP	3.2
1	B	193	ALA	3.1
1	B	190	THR	3.0
1	A	153	ASP	3.0
1	B	278	GLY	3.0
1	B	196	THR	2.9
1	B	235	MET	2.9
1	B	218	TRP	2.8
1	B	78	ILE	2.7
1	B	277	ASN	2.7
1	B	215	GLY	2.6

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Mol	Chain	Res	Type	RSRZ
1	B	301	SER	2.6
1	B	194	ALA	2.6
1	A	190	THR	2.6
1	A	64	HIS	2.5
1	B	3	PHE	2.5
1	A	232	LEU	2.5
1	A	59	ILE	2.5
1	A	60	ARG	2.4
1	B	214	ASN	2.4
1	A	263	ASP	2.3
1	A	4	ARG	2.3
1	A	273	GLN	2.3
1	B	286	LEU	2.3
1	A	47	GLU	2.3
1	B	47	GLU	2.2
1	B	213	ILE	2.2
1	B	87	LEU	2.1
1	A	270	GLU	2.1
1	A	224	THR	2.1
1	A	274	ASN	2.1
1	A	48	ASP	2.1
1	B	169	THR	2.0
1	B	258	GLY	2.0

6.2 Non-standard residues in protein, DNA, RNA chains [i](#)

There are no non-standard protein/DNA/RNA residues in this entry.

6.3 Carbohydrates [i](#)

There are no oligosaccharides in this entry.

6.4 Ligands [i](#)

In the following table, the Atoms column lists the number of modelled atoms in the group and the number defined in the chemical component dictionary. The B-factors column lists the minimum, median, 95th percentile and maximum values of B factors of atoms in the group. The column labelled 'Q< 0.9' lists the number of atoms with occupancy less than 0.9.

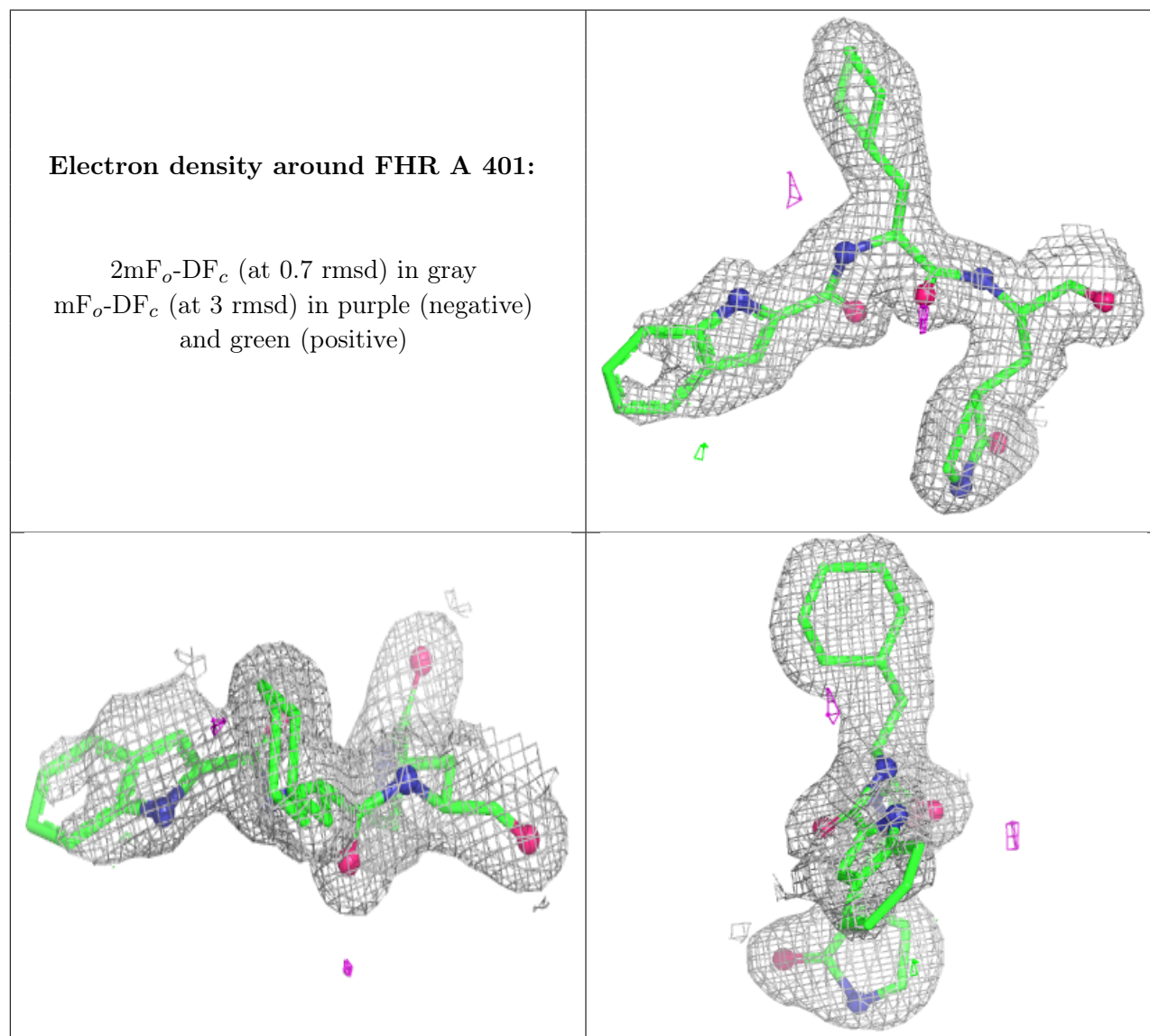
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Mol	Type	Chain	Res	Atoms	RSCC	RSR	B-factors(\AA^2)	Q<0.9
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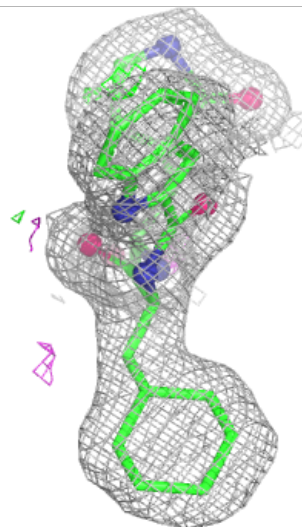
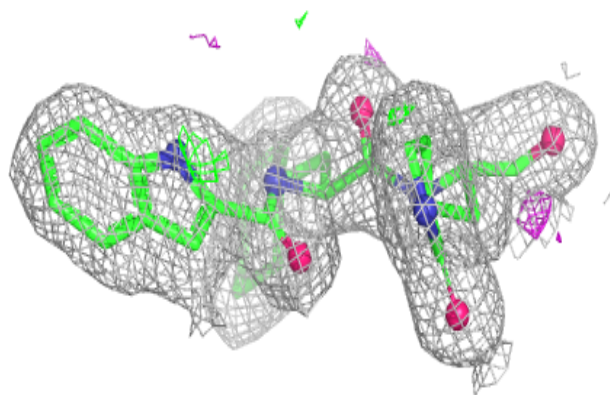
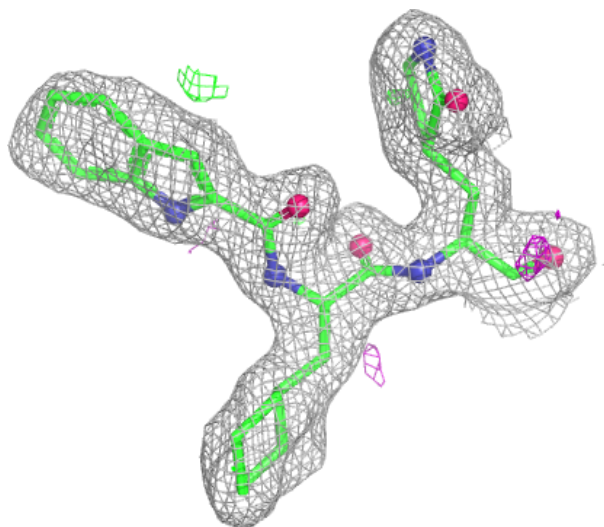
Mol	Type	Chain	Res	Atoms	RSCC	RSR	B-factors(\AA^2)	Q<0.9
2	FHR	A	401	33/33	0.94	0.10	26,30,43,45	0
2	FHR	B	401	33/33	0.95	0.08	22,26,37,39	0

The following is a graphical depiction of the model fit to experimental electron density of all instances of the Ligand of Interest. In addition, ligands with molecular weight > 250 and outliers as shown on the geometry validation Tables will also be included. Each fit is shown from different orientation to approximate a three-dimensional view.



Electron density around FHR B 401:

$2mF_o-DF_c$ (at 0.7 rmsd) in gray
 mF_o-DF_c (at 3 rmsd) in purple (negative)
and green (positive)



6.5 Other polymers ⓘ

There are no such residues in this entry.