Full wwPDB X-ray Structure Validation Report ⓘ

May 5, 2025 – 04:50 PM EDT

PDB ID	:	9BQF / pdb_00009bqf
Title	:	Structure of the SARS-CoV-2 main protease in complex with inhibitor 78
Authors	:	Blankenship, L.R.; Liu, W.R.
Deposited on	:	2024-05-09
Resolution	:	1.70 Å(reported)

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

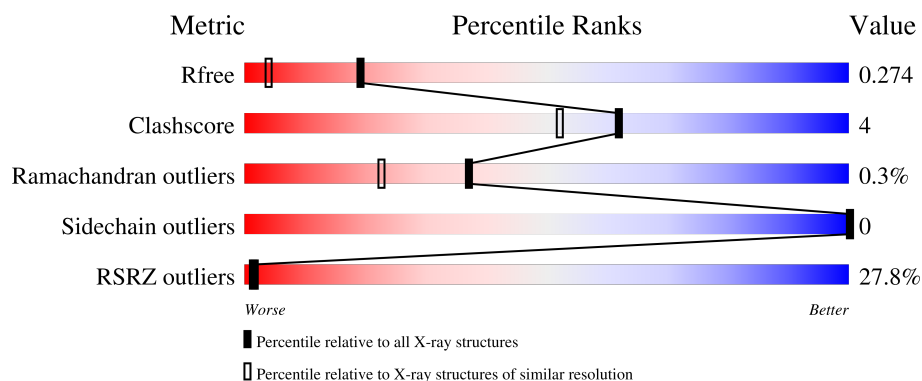|		
MolProbity	:	4-5-2 with Phenix2.0rc1
Mogul	:	2022.3.0, CSD as543be (2022)
Xtriage (Phenix)	:	2.0rc1
EDS	:	3.0
buster-report	:	1.1.7 (2018)
Percentile statistics	:	20231227.v01 (using entries in the PDB archive December 27th 2023)
CCP4	:	9.0.006 (Gargrove)
Density-Fitness	:	1.0.12
Ideal geometry (proteins)	:	Engh & Huber (2001)
Ideal geometry (DNA, RNA)	:	Parkinson et al. (1996)
Validation Pipeline (wwPDB-VP)	:	2.43.1

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 1.70 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	Percentile Ranks	Value
Rfree		0.274
Clashscore		4
Ramachandran outliers		0.3%
Sidechain outliers		0
RSRZ outliers		27.8%

Worse *Better*

▮ Percentile relative to all X-ray structures

▯ Percentile relative to X-ray structures of similar resolution

Metric	Whole archive (#Entries)	Similar resolution (#Entries, resolution range(Å))
R_{free}	164625	5161 (1.70-1.70)
Clashscore	180529	5671 (1.70-1.70)
Ramachandran outliers	177936	5594 (1.70-1.70)
Sidechain outliers	177891	5594 (1.70-1.70)
RSRZ outliers	164620	5159 (1.70-1.70)

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 <=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	306	28% / 91% / 9%

2 Entry composition ⓘ

There are 2 unique types of molecules in this entry. The entry contains 2406 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 3C-like proteinase nsp5.

Mol	Chain	Residues	Atoms					ZeroOcc	AltConf	Trace
			Total	C	N	O	S			
1	A	306	2363	1497	402	442	22	0	0	0

- Molecule 2 is N-[(BENZYLOXY)CARBONYL]-O-(TERT-BUTYL)-L-THREONYL-3-CYCLOHEXYL-N-[(1S)-2-HYDROXY-1-{[(3S)-2-OXOPYRROLIDIN-3-YL]METHYL}ETHYL]-L-ALANINAMIDE (CCD ID: NOL) (formula: $C_{32}H_{50}N_4O_7$) (labeled as "Ligand of Interest" by depositor).

Mol	Chain	Residues	Atoms				ZeroOcc	AltConf
			Total	C	N	O		
2	A	1	43	32	4	7	0	0
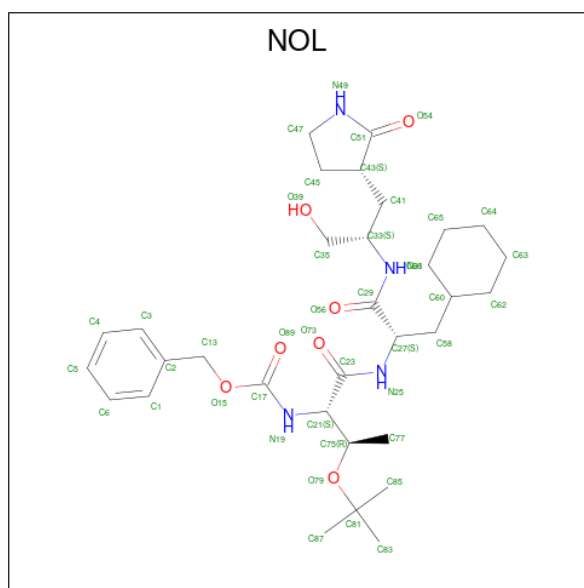
3 Residue-property plots ⓘ

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: 3C-like proteinase nsp5
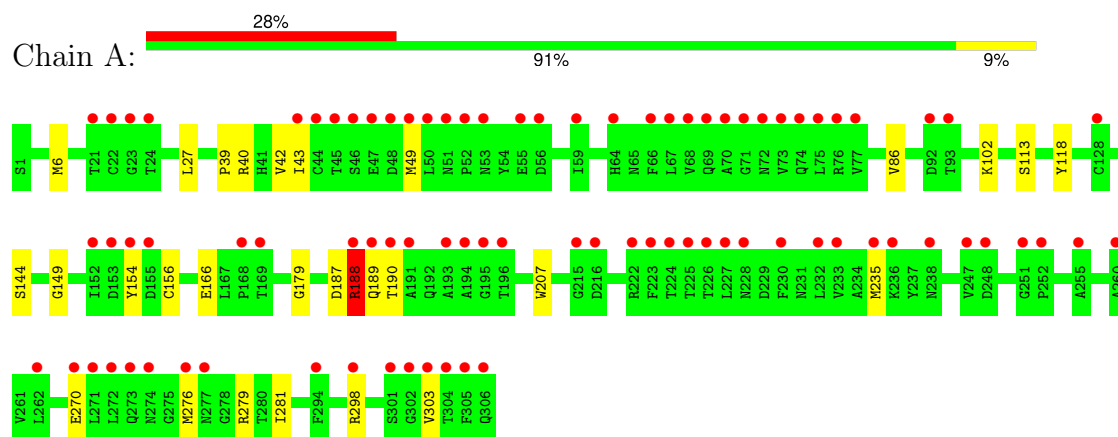
4 Data and refinement statistics (i)

Property	Value	Source
Space group	I 1 2 1	Depositor
Cell constants a, b, c, α, β, γ	54.30Å 81.04Å 86.40Å 90.00° 97.09° 90.00°	Depositor
Resolution (Å)	48.39 – 1.70 48.39 – 1.70	Depositor EDS
% Data completeness (in resolution range)	98.8 (48.39-1.70) 98.8 (48.39-1.70)	Depositor EDS
R_{merge}	(Not available)	Depositor
R_{sym}	(Not available)	Depositor
$< I/\sigma(I) >$ [1]	1.14 (at 1.70Å)	Xtriage
Refinement program	PHENIX 1.20.1_4487, PHENIX 1.20.1_4487	Depositor
R, R_{free}	0.255 , 0.273 0.255 , 0.274	Depositor DCC
R_{free} test set	2026 reflections (4.97%)	wwPDB-VP
Wilson B-factor (Å^2)	20.6	Xtriage
Anisotropy	0.449	Xtriage
Bulk solvent k_{sol}(e/Å^3), B_{sol}(Å^2)	0.38 , 31.9	EDS
L-test for twinning[2]	$< |L| > = 0.49, < L^2 > = 0.32$	Xtriage
Estimated twinning fraction	No twinning to report.	Xtriage
F_o,F_c correlation	0.92	EDS
Total number of atoms	2406	wwPDB-VP
Average B, all atoms (Å^2)	30.0	wwPDB-VP

Xtriage's analysis on translational NCS is as follows: *The largest off-origin peak in the Patterson function is 6.40% of the height of the origin peak. No significant pseudotranslation is detected.*

---

[1]Intensities estimated from amplitudes.

[2]Theoretical values of $< |L| >$, $< L^2 >$ for acentric reflections are 0.5, 0.333 respectively for untwinned datasets, and 0.375, 0.2 for perfectly twinned datasets.

5 Model quality ⓘ

5.1 Standard geometry ⓘ

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

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	0.49	2/2416 (0.1%)	1.16	14/3284 (0.4%)

Chiral center outliers are detected by calculating the chiral volume of a chiral center and verifying if the center is modelled as a planar moiety or with the opposite hand. A planarity outlier is detected by checking planarity of atoms in a peptide group, atoms in a mainchain group or atoms of a sidechain that are expected to be planar.

Mol	Chain	#Chirality outliers	#Planarity outliers
1	A	0	1

All (2) bond length outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(Å)	Ideal(Å)
1	A	188	ARG	CD-NE	-7.25	1.36	1.46
1	A	188	ARG	NE-CZ	-6.26	1.26	1.33

All (14) bond angle outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(^{o})	Ideal(^{o})
1	A	188	ARG	CD-NE-CZ	28.86	164.80	124.40
1	A	188	ARG	NE-CZ-NH1	-27.47	94.03	121.50
1	A	188	ARG	N-CA-C	-17.41	81.65	108.99
1	A	187	ASP	CA-C-N	-12.82	99.17	121.85
1	A	187	ASP	C-N-CA	-12.82	99.17	121.85
1	A	270	GLU	CB-CG-CD	10.25	130.03	112.60
1	A	188	ARG	CB-CG-CD	9.94	134.16	111.30
1	A	188	ARG	CB-CA-C	-9.27	90.19	109.94
1	A	188	ARG	NE-CZ-NH2	8.69	127.02	119.20
1	A	188	ARG	N-CA-CB	8.28	126.91	111.52
1	A	270	GLU	CG-CD-OE1	5.97	132.13	118.40

Continued on next page...

Continued from previous page...

Mol	Chain	Res	Type	Atoms	Z	Observed(^{o})	Ideal(^{o})
1	A	188	ARG	CA-CB-CG	-5.48	103.14	114.10
1	A	270	GLU	CG-CD-OE2	-5.43	105.92	118.40
1	A	270	GLU	N-CA-C	5.40	117.17	111.28

There are no chirality outliers.

All (1) planarity outliers are listed below:

Mol	Chain	Res	Type	Group
1	A	188	ARG	Sidechain

5.2 Too-close contacts ⓘ

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	2363	0	2309	19	0
2	A	43	0	49	2	0
All	All	2406	0	2358	19	0

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 4.

All (19) 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:49:MET:HE3	2:A:401:NOL:H662	1.67	0.76
1:A:188:ARG:NH1	1:A:190:THR:HG21	2.01	0.75
1:A:188:ARG:HH12	1:A:190:THR:HG21	1.57	0.68
1:A:40:ARG:O	1:A:43:ILE:HG12	2.01	0.61
1:A:276:MET:HE2	1:A:279:ARG:O	2.03	0.59
1:A:86:VAL:HG13	1:A:179:GLY:HA2	1.89	0.54
1:A:49:MET:HE2	1:A:189:GLN:CD	2.37	0.49
1:A:27:LEU:HD13	1:A:39:PRO:HD2	1.94	0.48
1:A:6:MET:HE3	1:A:6:MET:HB2	1.78	0.47
1:A:118:TYR:CE1	1:A:144:SER:HB3	2.50	0.46
1:A:49:MET:HB3	1:A:189:GLN:HG3	2.00	0.44

Continued on next page...

Continued from previous page...

Atom-1	Atom-2	Interatomic distance (Å)	Clash overlap (Å)
1:A:49:MET:HE2	1:A:189:GLN:OE1	2.18	0.43
1:A:166:GLU:O	2:A:401:NOL:H832	2.18	0.43
1:A:298:ARG:HG3	1:A:303:VAL:HB	2.01	0.42
1:A:113:SER:O	1:A:149:GLY:HA2	2.19	0.42
1:A:102:LYS:HG3	1:A:156:CYS:SG	2.60	0.41
1:A:235:MET:HE3	1:A:235:MET:HB2	1.89	0.41
1:A:27:LEU:HD21	1:A:42:VAL:HB	2.03	0.41
1:A:207:TRP:CH2	1:A:281:ILE:HB	2.55	0.41

There are no symmetry-related clashes.

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	304/306 (99%)	296 (97%)	7 (2%)	1 (0%)	37	23

All (1) Ramachandran outliers are listed below:

Mol	Chain	Res	Type
1	A	154	TYR

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	262/263 (100%)	262 (100%)	0	100 100

There are no protein residues with a non-rotameric sidechain to report.

Sometimes sidechains can be flipped to improve hydrogen bonding and reduce clashes. All (4) such sidechains are listed below:

Mol	Chain	Res	Type
1	A	69	GLN
1	A	80	HIS
1	A	180	ASN
1	A	244	GLN

5.3.3 RNA ⓘ

There are no RNA molecules in this entry.

5.4 Non-standard residues in protein, DNA, RNA chains ⓘ

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

5.5 Carbohydrates ⓘ

There are no oligosaccharides in this entry.

5.6 Ligand geometry ⓘ

1 ligand is 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	NOL	A	401	1	45,45,45	0.97	1 (2%)	57,61,61	1.16	4 (7%)

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	NOL	A	401	1	-	0/44/62/62	0/3/3/3

All (1) bond length outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(Å)	Ideal(Å)
2	A	401	NOL	O15-C17	5.46	1.46	1.35

All (4) bond angle outliers are listed below:

| Mol	Chain	Res	Type	Atoms	Z	Observed(°)	Ideal(°)
2	A	401	NOL	O15-C17-N19	3.69	118.35	110.45
2	A	401	NOL	O54-C51-C43	-3.24	122.47	126.21
2	A	401	NOL	O15-C17-O89	-2.64	119.19	124.26
2	A	401	NOL	C13-O15-C17	2.20	120.89	115.93

There are no chirality outliers.

There are no torsion outliers.

There are no ring outliers.

1 monomer is involved in 2 short contacts:

Mol	Chain	Res	Type	Clashes	Symm-Clashes
2	A	401	NOL	2	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 then 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.

Ligand NOL A 401

Bond lengths

Bond angles

Torsions

Rings
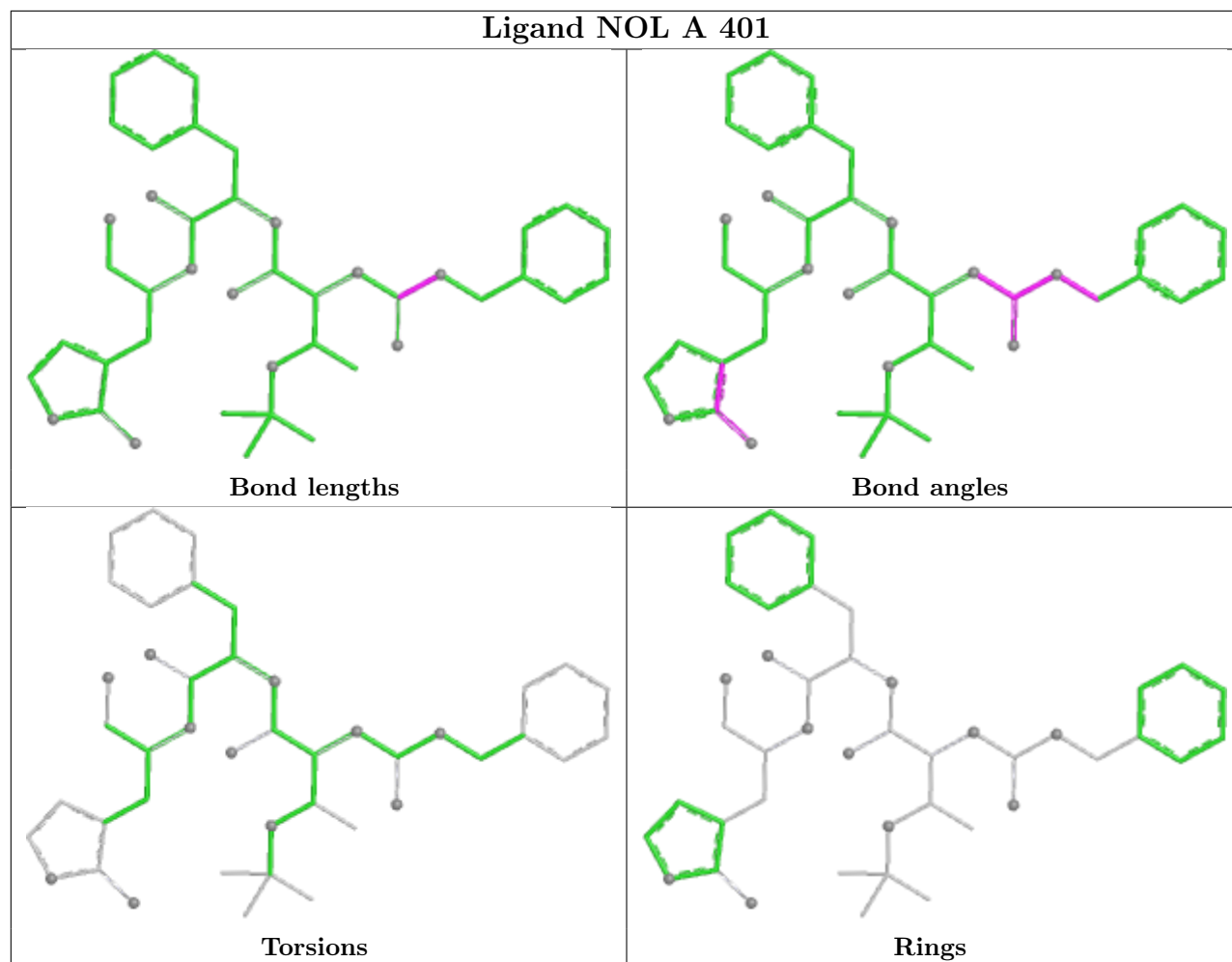
5.7 Other polymers ⓘ

There are no such residues in this entry.

5.8 Polymer linkage issues ⓘ

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(Å²)	Q<0.9
1	A	306/306 (100%)	1.37	85 (27%)	2	1	13, 27, 55, 100	0

All (85) RSRZ outliers are listed below:

Mol	Chain	Res	Type	RSRZ
1	A	154	TYR	8.9
1	A	50	LEU	8.8
1	A	305	PHE	7.9
1	A	46	SER	6.8
1	A	45	THR	6.6
1	A	73	VAL	6.4
1	A	303	VAL	6.1
1	A	72	ASN	6.1
1	A	306	GLN	6.1
1	A	49	MET	5.9
1	A	48	ASP	5.8
1	A	223	PHE	5.5
1	A	232	LEU	5.1
1	A	47	GLU	4.8
1	A	304	THR	4.7
1	A	44	CYS	4.6
1	A	74	GLN	4.5
1	A	194	ALA	4.3
1	A	222	ARG	4.2
1	A	71	GLY	4.2
1	A	294	PHE	4.0
1	A	277	ASN	4.0
1	A	169	THR	3.6
1	A	233	VAL	3.6
1	A	70	ALA	3.6
1	A	188	ARG	3.6
1	A	227	LEU	3.5

Continued on next page...

Continued from previous page...

Mol	Chain	Res	Type	RSRZ
1	A	51	ASN	3.5
1	A	56	ASP	3.5
1	A	189	GLN	3.5
1	A	235	MET	3.3
1	A	153	ASP	3.2
1	A	270	GLU	3.2
1	A	155	ASP	3.2
1	A	216	ASP	3.2
1	A	43	ILE	3.2
1	A	69	GLN	3.2
1	A	193	ALA	3.0
1	A	255	ALA	3.0
1	A	168	PRO	3.0
1	A	190	THR	3.0
1	A	64	HIS	3.0
1	A	226	THR	2.9
1	A	52	PRO	2.9
1	A	75	LEU	2.8
1	A	224	THR	2.8
1	A	67	LEU	2.8
1	A	23	GLY	2.8
1	A	301	SER	2.8
1	A	195	GLY	2.8
1	A	230	PHE	2.8
1	A	196	THR	2.7
1	A	276	MET	2.7
1	A	59	ILE	2.6
1	A	24	THR	2.6
1	A	215	GLY	2.6
1	A	22	CYS	2.6
1	A	53	ASN	2.6
1	A	55	GLU	2.6
1	A	77	VAL	2.5
1	A	236	LYS	2.5
1	A	93	THR	2.5
1	A	262	LEU	2.4
1	A	152	ILE	2.4
1	A	191	ALA	2.4
1	A	21	THR	2.3
1	A	298	ARG	2.3
1	A	68	VAL	2.3
1	A	66	PHE	2.3

Continued from previous page...

Mol	Chain	Res	Type	RSRZ
1	A	272	LEU	2.3
1	A	274	ASN	2.2
1	A	92	ASP	2.2
1	A	128	CYS	2.2
1	A	251	GLY	2.2
1	A	248	ASP	2.2
1	A	302	GLY	2.2
1	A	260	ALA	2.1
1	A	271	LEU	2.1
1	A	273	GLN	2.1
1	A	228	ASN	2.1
1	A	225	THR	2.1
1	A	238	ASN	2.1
1	A	252	PRO	2.0
1	A	76	ARG	2.0
1	A	247	VAL	2.0

6.2 Non-standard residues in protein, DNA, RNA chains ⓘ

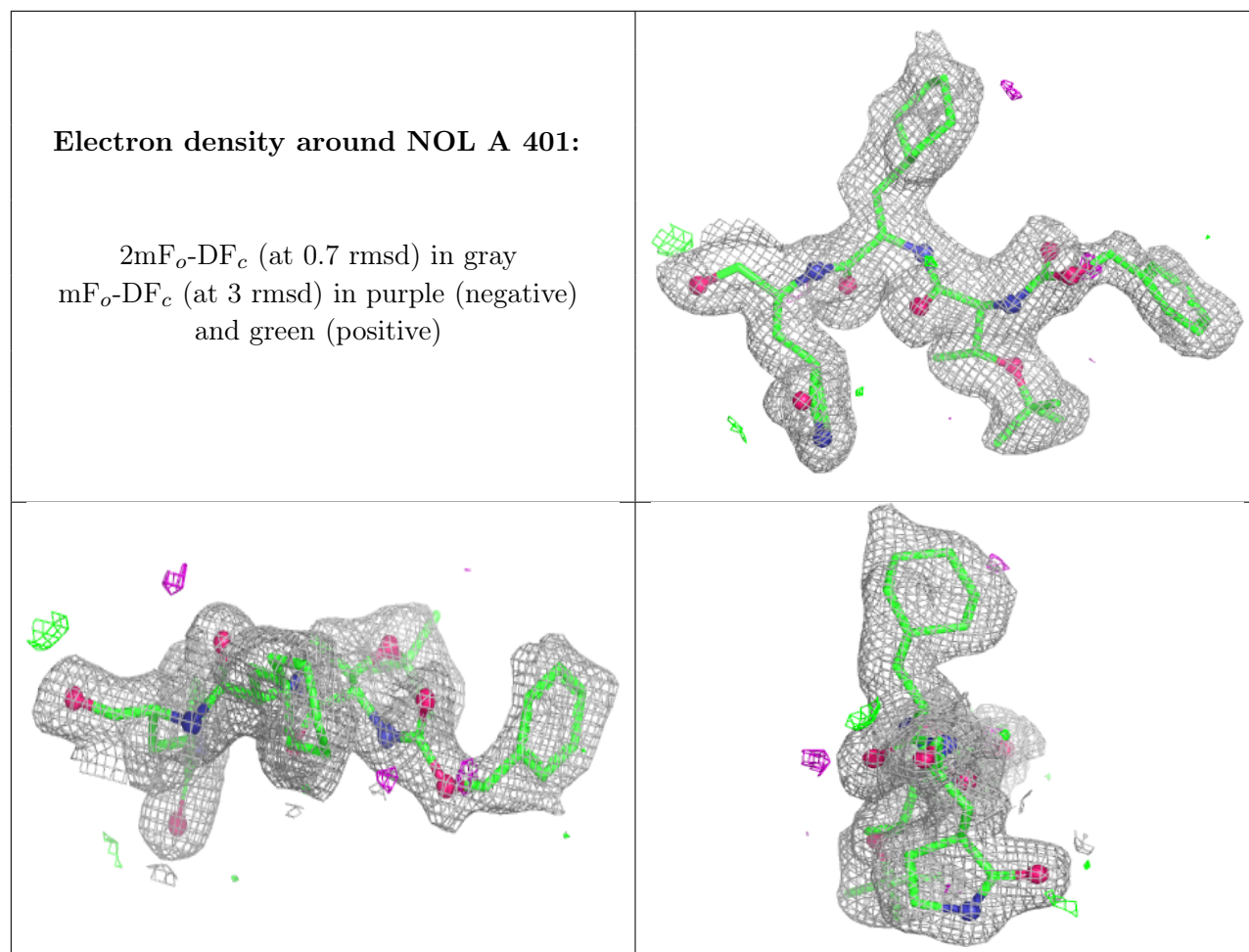There are no non-standard protein/DNA/RNA residues in this entry.

6.3 Carbohydrates ⓘ

There are no monosaccharides in this entry.

6.4 Ligands ⓘ

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.

Mol	Type	Chain	Res	Atoms	RSCC	RSR	B-factors(Å^2)	Q<0.9
2	NOL	A	401	43/43	0.90	0.13	21,31,43,46	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 NOL A 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.