wwPDB EM Validation Summary Report

Nov 9, 2026 – 03:21 PM EST

PDB ID	:	36BF / pdb_000036bf
EMDB ID	:	EMD-77352
Title	:	CryoEM structure of the nitrogenase a-Val70Ala MoFe-protein under proton turnover
Authors	:	Warmack, R.A.
Deposited on	:	2026-05-28
Resolution	:	1.96 Å(reported)

This is a wwPDB EM Validation Summary 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/EMValidationReportHelp
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:

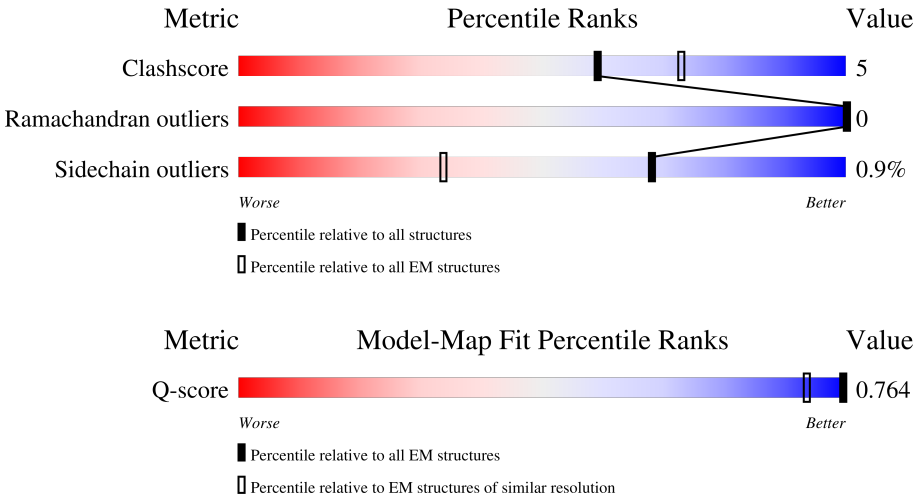
EMDB validation analysis	:	0.0.1.dev133
Mogul	:	2022.3.0, CSD as543be (2022)
MolProbity	:	4-5-2 with Phenix2.2
Buster-report	:	wwPDB partial adaption of 1.1.7 (2018)
Percentile statistics	:	20250101.v01 (using entries in the PDB archive January 1st 2025)
EM percentile statistics	:	202505.v01 (Using data in the EMDB archive up until May 2025)
MapQ	:	1.9.13
Ideal geometry (proteins)	:	Engh & Huber (2001)
Ideal geometry (DNA, RNA)	:	Parkinson et al. (1996)
Validation Pipeline (wwPDB-VP)	:	2.51

1 Overall quality at a glance (i)

The following experimental techniques were used to determine the structure:
ELECTRON MICROSCOPY

The reported resolution of this entry is 1.96 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)	EM structures (#Entries)	Similar EM resolution (#Entries, resolution range(Å))
Clashscore	229148	23984	-
Ramachandran outliers	224038	23583	-
Sidechain outliers	223484	23102	-
Q-score	-	25397	1340 (1.46 - 2.46)

The table below summarises the geometric issues observed across the polymeric chains and their fit to the map. The red, orange, yellow and green segments of the 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 EM map (all-atom inclusion < 40%). The numeric value is given above the bar.

Mol	Chain	Length	Quality of chain
1	A	492	80% 14% 5%
1	C	492	82% 12% 5%
2	B	523	90% 9%
2	D	523	90% 10%

2 Entry composition (i)

There are 9 unique types of molecules in this entry. The entry contains 17309 atoms, of which 0 are hydrogens and 0 are deuteriums.

In the tables below, 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 Nitrogenase molybdenum-iron protein alpha chain.

Mol	Chain	Residues	Atoms					AltConf	Trace
1	A	467	Total	C	N	O	S	1	0
			3719	2365	634	695	25		
1	C	467	Total	C	N	O	S	1	0
			3719	2365	634	695	25		

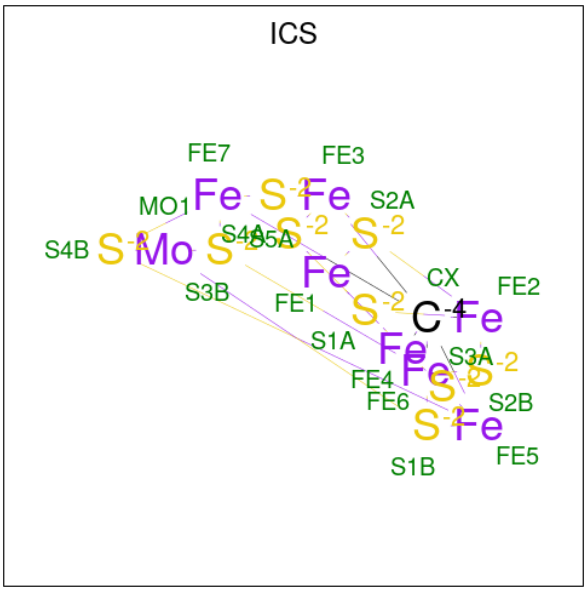
There are 4 discrepancies between the modelled and reference sequences:

Chain	Residue	Modelled	Actual	Comment	Reference
A	70	ALA	VAL	engineered mutation	UNP P07328
A	247	GLN	LEU	conflict	UNP P07328
C	70	ALA	VAL	engineered mutation	UNP P07328
C	247	GLN	LEU	conflict	UNP P07328

- Molecule 2 is a protein called Nitrogenase molybdenum-iron protein beta chain.

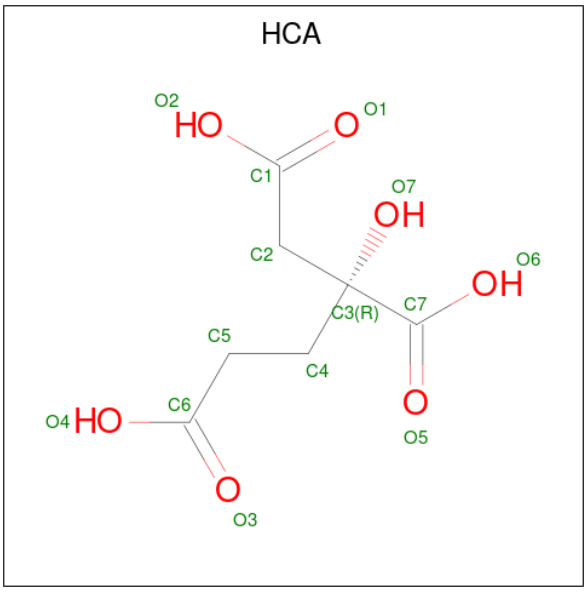
Mol	Chain	Residues	Atoms					AltConf	Trace
2	B	522	Total	C	N	O	S	0	0
			4174	2666	705	775	28		
2	D	522	Total	C	N	O	S	0	0
			4174	2666	705	775	28		

- Molecule 3 is iron-sulfur-molybdenum cluster with interstitial carbon (CCD ID: ICS) (formula: CFe_7MoS_9) (labeled as "Ligand of Interest" by depositor).



Mol	Chain	Residues	Atoms					AltConf
3	A	1	Total	C	Fe	Mo	S	0
			18	1	7	1	9	
3	C	1	Total	C	Fe	Mo	S	0
			18	1	7	1	9	

- Molecule 4 is 3-HYDROXY-3-CARBOXY-ADIPIC ACID (CCD ID: HCA) (formula: $C_7H_{10}O_7$).



Mol	Chain	Residues	Atoms			AltConf
4	A	1	Total	C	O	0
			14	7	7	

Continued on next page...

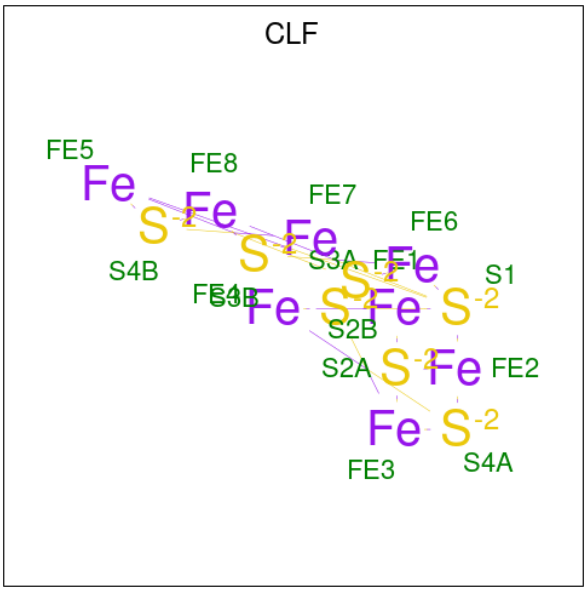
Continued from previous page...

Mol	Chain	Residues	Atoms	AltConf
4	C	1	Total C O 14 7 7	0

- Molecule 5 is UNKNOWN LIGAND (CCD ID: UNX) (formula: X) (labeled as "Ligand of Interest" by depositor).

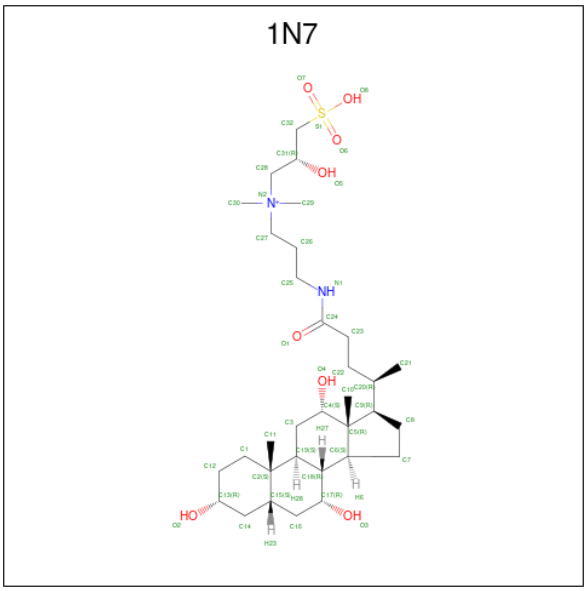
Mol	Chain	Residues	Atoms	AltConf
5	A	1	Total X 1 1	0
5	C	1	Total X 1 1	0

- Molecule 6 is FE(8)-S(7) CLUSTER (CCD ID: CLF) (formula: Fe_8S_7).



Mol	Chain	Residues	Atoms	AltConf
6	B	1	Total Fe S 15 8 7	0
6	D	1	Total Fe S 15 8 7	0

- Molecule 7 is CHAPSO (CCD ID: 1N7) (formula: $C_{32}H_{59}N_2O_8S$).



Mol	Chain	Residues	Atoms					AltConf
7	B	1	Total	C	N	O	S	0
			43	32	2	8	1	
7	D	1	Total	C	N	O	S	0
			43	32	2	8	1	

- Molecule 8 is CALCIUM ION (CCD ID: CA) (formula: Ca).

Mol	Chain	Residues	Atoms		AltConf
8	B	1	Total	Ca	0
			1	1	
8	D	1	Total	Ca	0
			1	1	

- Molecule 9 is water.

Mol	Chain	Residues	Atoms		AltConf
9	A	247	Total	O	0
			247	247	
9	B	422	Total	O	0
			422	422	
9	C	252	Total	O	0
			252	252	
9	D	418	Total	O	0
			418	418	

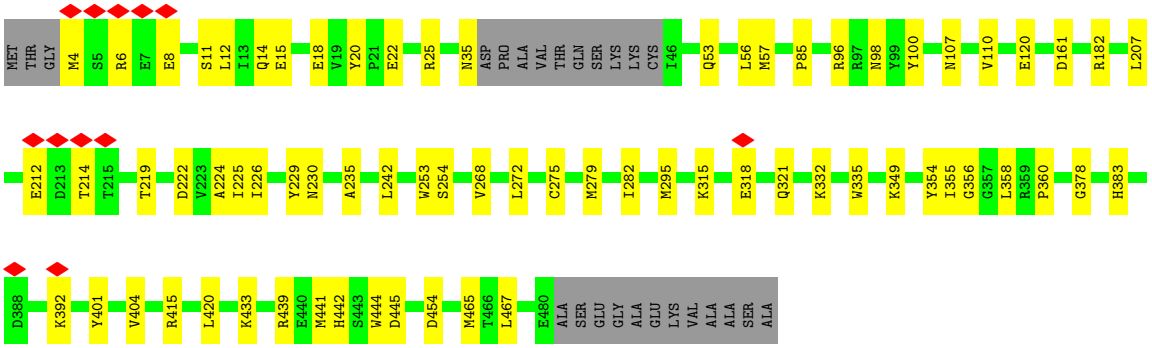
3 Residue-property plots (i)

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 atom inclusion in map 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 diamond above a residue indicates a poor fit to the EM map for this residue (all-atom inclusion < 40%). 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: Nitrogenase molybdenum-iron protein alpha chain

Chain A:

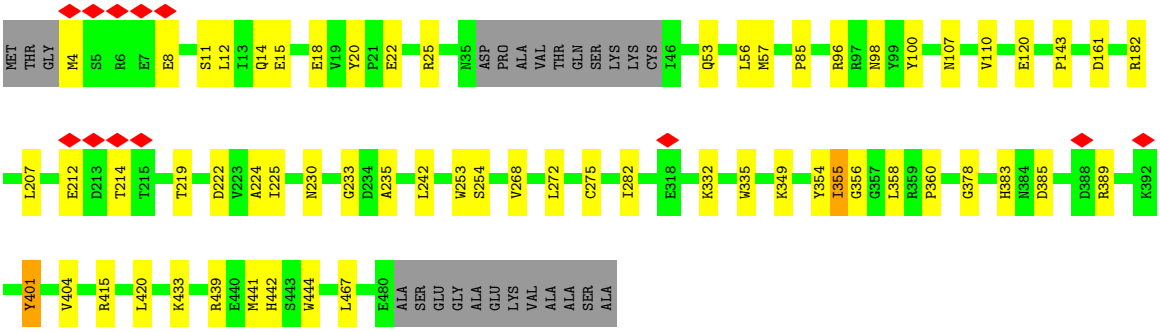




• Molecule 1: Nitrogenase molybdenum-iron protein alpha chain

Chain C:

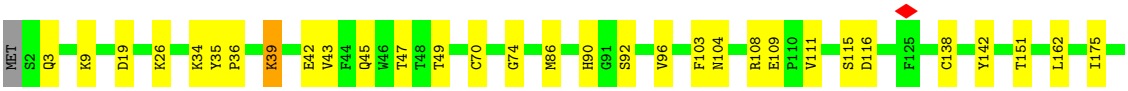


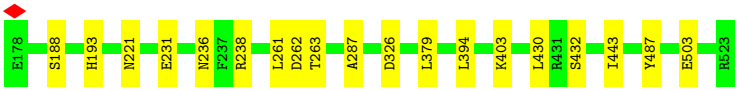


• Molecule 2: Nitrogenase molybdenum-iron protein beta chain

Chain B:

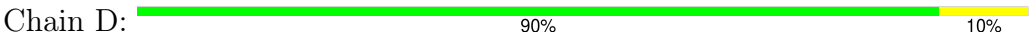


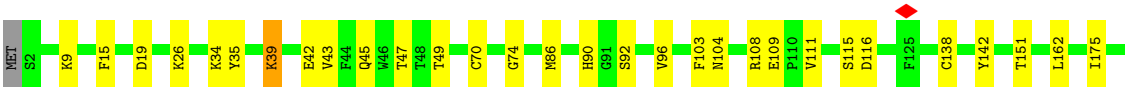


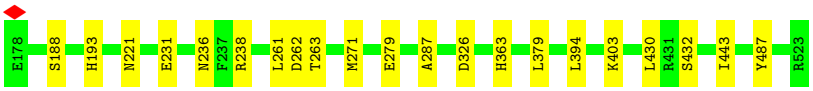


• Molecule 2: Nitrogenase molybdenum-iron protein beta chain

Chain D:







4 Experimental information (i)

Property	Value	Source
EM reconstruction method	SINGLE PARTICLE	Depositor
Imposed symmetry	POINT, Not provided	
Number of particles used	105550	Depositor
Resolution determination method	FSC 0.143 CUT-OFF	Depositor
CTF correction method	PHASE FLIPPING AND AMPLITUDE CORRECTION	Depositor
Microscope	TFS KRIOS	Depositor
Voltage (kV)	300	Depositor
Electron dose ($e^-/Å^2$)	60	Depositor
Minimum defocus (nm)	500	Depositor
Maximum defocus (nm)	2500	Depositor
Magnification	Not provided	
Image detector	GATAN K3 (6k x 4k)	Depositor
Maximum map value	3.245	Depositor
Minimum map value	-1.370	Depositor
Average map value	0.000	Depositor
Map value standard deviation	0.035	Depositor
Recommended contour level	0.25	Depositor
Map size (Å)	374.4, 374.4, 374.4	wwPDB
Map dimensions	576, 576, 576	wwPDB
Map angles (°)	90.0, 90.0, 90.0	wwPDB
Pixel spacing (Å)	0.65, 0.65, 0.65	Depositor

5 Model quality

5.1 Standard geometry

Bond lengths and bond angles in the following residue types are not validated in this section: HCA, ICS, UNX, 1N7, CLF, CA

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	0.13	0/3808	0.33	0/5132
1	C	0.13	0/3808	0.33	0/5132
2	B	0.13	0/4280	0.31	0/5786
2	D	0.13	0/4280	0.31	0/5786
All	All	0.13	0/16176	0.32	0/21836

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

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	3719	0	3650	44	0
1	C	3719	0	3650	39	0
2	B	4174	0	4088	32	0
2	D	4174	0	4088	35	0
3	A	18	0	0	1	0
3	C	18	0	0	1	0
4	A	14	0	6	2	0
4	C	14	0	6	2	0
5	A	1	0	0	0	0

Continued on next page...

Continued from previous page...

Mol	Chain	Non-H	H(model)	H(added)	Clashes	Symm-Clashes
5	C	1	0	0	0	0
6	B	15	0	0	1	0
6	D	15	0	0	1	0
7	B	43	0	59	4	0
7	D	43	0	59	8	0
8	B	1	0	0	0	0
8	D	1	0	0	0	0
9	A	247	0	0	2	0
9	B	422	0	0	5	0
9	C	252	0	0	3	0
9	D	418	0	0	4	0
All	All	17309	0	15606	145	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 5.

The worst 5 of 145 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:11:SER:O	1:A:15:GLU:HG3	1.93	0.69
2:B:503:GLU:OE1	9:B:701:HOH:O	2.11	0.68
1:C:11:SER:O	1:C:15:GLU:HG3	1.95	0.67
1:A:20:TYR:O	1:A:25:ARG:NH1	2.30	0.65
1:C:20:TYR:O	1:C:25:ARG:NH1	2.31	0.63

There are no symmetry-related clashes.

5.3 Torsion angles (i)

5.3.1 Protein backbone (i)

In the following table, the Percentiles column shows the percent Ramachandran outliers of the chain as a percentile score with respect to all PDB entries followed by that with respect to all EM entries.

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	464/492 (94%)	451 (97%)	13 (3%)	0	100	100

Continued on next page...

Continued from previous page...

Mol	Chain	Analysed	Favoured	Allowed	Outliers	Percentiles	
1	C	464/492 (94%)	454 (98%)	10 (2%)	0	100	100
2	B	520/523 (99%)	511 (98%)	9 (2%)	0	100	100
2	D	520/523 (99%)	512 (98%)	8 (2%)	0	100	100
All	All	1968/2030 (97%)	1928 (98%)	40 (2%)	0	100	100

There are no Ramachandran outliers to report.

5.3.2 Protein sidechains (i)

In the following table, the Percentiles column shows the percent sidechain outliers of the chain as a percentile score with respect to all PDB entries followed by that with respect to all EM entries.

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	398/414 (96%)	395 (99%)	3 (1%)	73	74
1	C	398/414 (96%)	394 (99%)	4 (1%)	68	67
2	B	454/455 (100%)	450 (99%)	4 (1%)	70	70
2	D	454/455 (100%)	450 (99%)	4 (1%)	70	70
All	All	1704/1738 (98%)	1689 (99%)	15 (1%)	68	70

5 of 15 residues with a non-rotameric sidechain are listed below:

Mol	Chain	Res	Type
1	C	98	ASN
2	D	175	ILE
1	C	214	THR
2	D	432	SER
2	D	39	LYS

Sometimes sidechains can be flipped to improve hydrogen bonding and reduce clashes. 5 of 14 such sidechains are listed below:

Mol	Chain	Res	Type
1	C	35	ASN
1	C	53	GLN
2	D	518	ASN

Continued on next page...

Continued from previous page...

Mol	Chain	Res	Type
2	D	53	GLN
2	D	163	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)

Of 12 ligands modelled in this entry, 2 are unknown and 2 are monoatomic - leaving 8 for Mogul analysis.

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	$\#\|Z\| > 2$
3	ICS	A	501	1,4	6,30,30	1.49	1 (16%)	-		
3	ICS	C	501	1,4	6,30,30	1.48	1 (16%)	-		
7	1N7	D	603	-	44,46,46	0.53	1 (2%)	69,72,72	0.79	2 (2%)
4	HCA	C	502	3	13,13,13	1.02	0	15,18,18	1.56	2 (13%)
4	HCA	A	502	3	13,13,13	1.01	0	15,18,18	1.56	2 (13%)
7	1N7	B	602	-	44,46,46	0.54	1 (2%)	69,72,72	0.80	1 (1%)
6	CLF	D	602	1,2	0,24,24	-	-	-		
6	CLF	B	601	1,2	0,24,24	-	-	-		

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
7	1N7	D	603	-	-	24/27/92/92	0/4/4/4
4	HCA	C	502	3	-	6/17/17/17	-
7	1N7	B	602	-	-	13/27/92/92	0/4/4/4
4	HCA	A	502	3	-	6/17/17/17	-
6	CLF	D	602	1,2	-	-	0/12/10/10
6	CLF	B	601	1,2	-	-	0/12/10/10

All (4) bond length outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(Å)	Ideal(Å)
3	A	501	ICS	S2B-FE6	-2.83	2.18	2.24
3	C	501	ICS	S2B-FE6	-2.80	2.18	2.24
7	B	602	1N7	O8-S1	2.17	1.55	1.47
7	D	603	1N7	O8-S1	2.10	1.55	1.47

The worst 5 of 7 bond angle outliers are listed below:

Mol	Chain	Res	Type	Atoms	Z	Observed(^{o})	Ideal(^{o})
4	C	502	HCA	O6-C7-C3	3.82	120.47	113.14
4	A	502	HCA	O6-C7-C3	3.81	120.44	113.14
7	D	603	1N7	C28-C31-C32	2.84	114.46	108.44
7	B	602	1N7	C28-C31-C32	2.57	113.88	108.44
4	A	502	HCA	O4-C6-C5	2.18	120.89	114.00

There are no chirality outliers.

5 of 49 torsion outliers are listed below:

Mol	Chain	Res	Type	Atoms
4	A	502	HCA	C2-C3-C4-C5
4	A	502	HCA	O7-C3-C4-C5
4	C	502	HCA	C2-C3-C4-C5
4	C	502	HCA	O7-C3-C4-C5
7	B	602	1N7	C31-C28-N2-C27

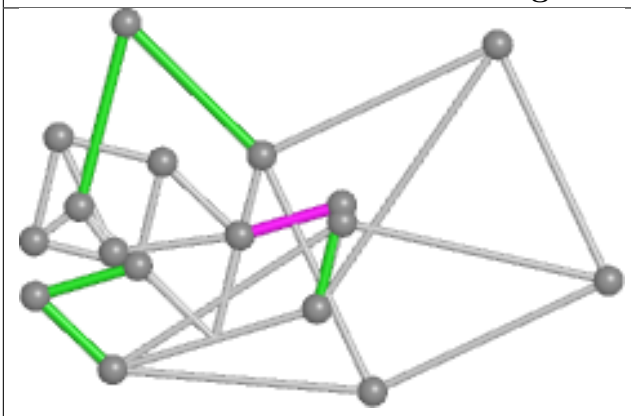
There are no ring outliers.

8 monomers are involved in 20 short contacts:

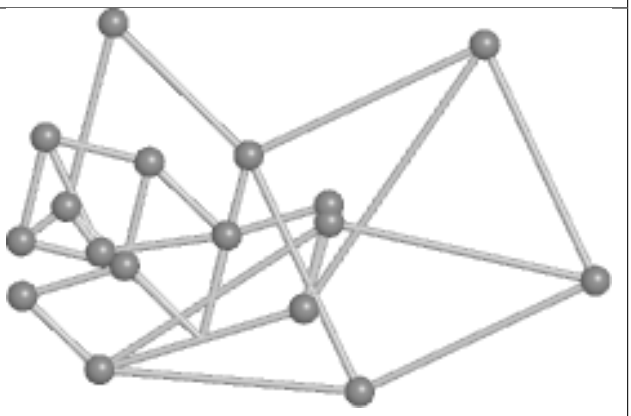
Mol	Chain	Res	Type	Clashes	Symm-Clashes
3	A	501	ICS	1	0
3	C	501	ICS	1	0
7	D	603	1N7	8	0
4	C	502	HCA	2	0
4	A	502	HCA	2	0
7	B	602	1N7	4	0
6	D	602	CLF	1	0
6	B	601	CLF	1	0

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 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.

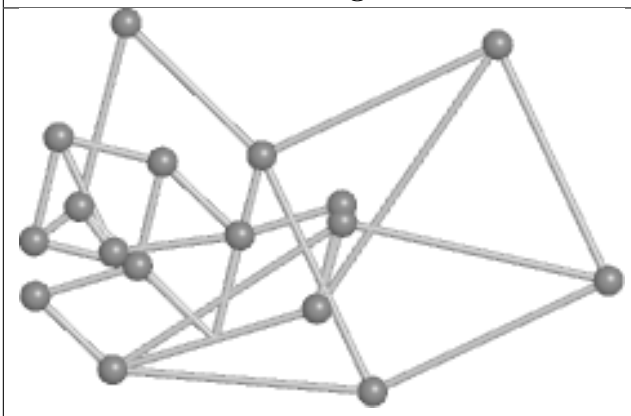
Ligand ICS A 501



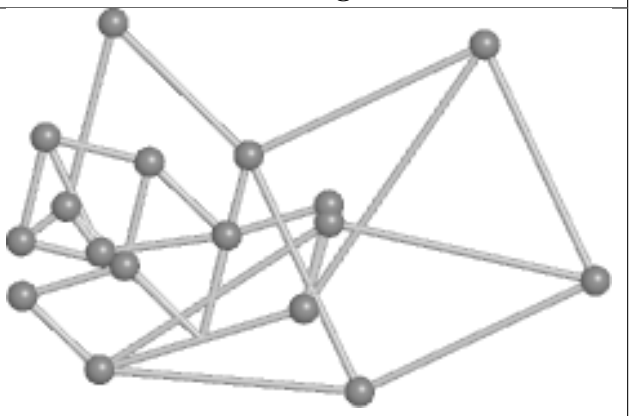
Bond lengths



Bond angles

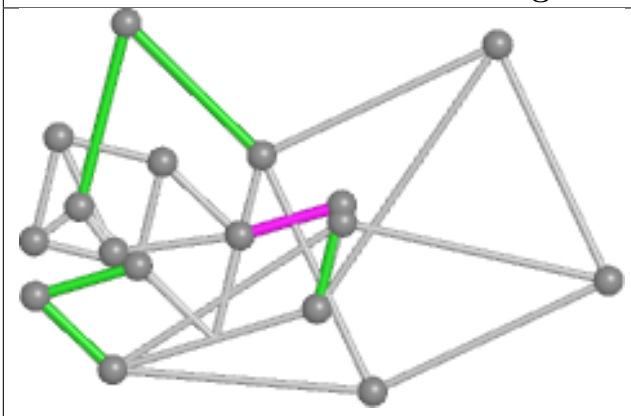


Torsions

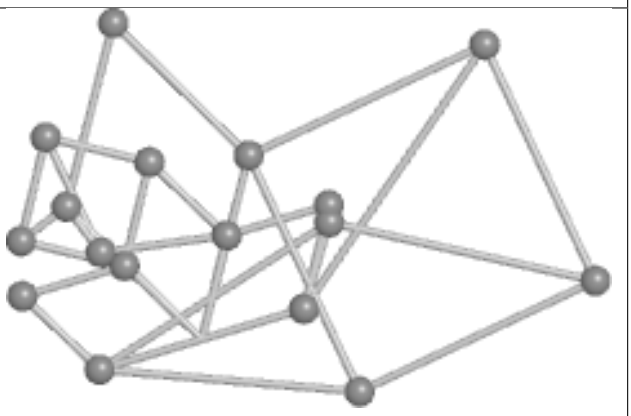


Rings

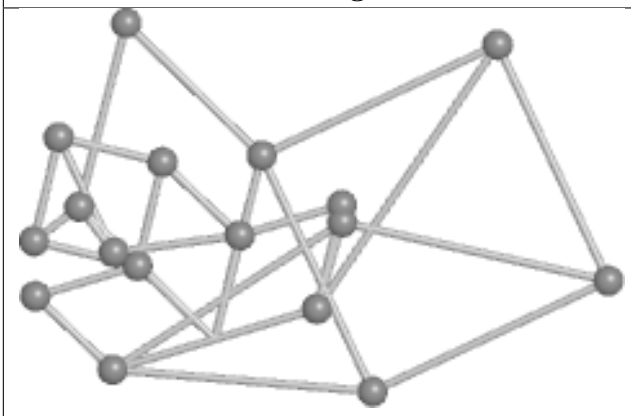
Ligand ICS C 501



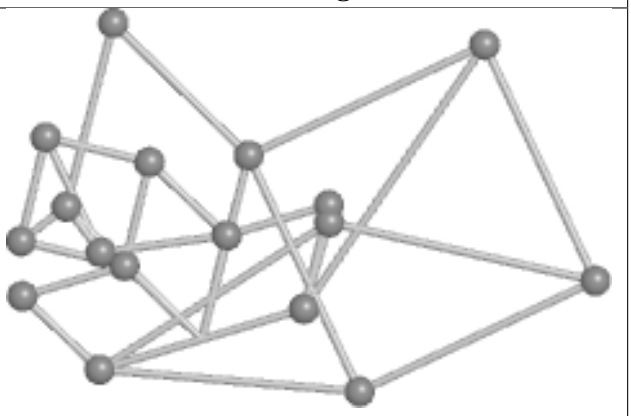
Bond lengths



Bond angles

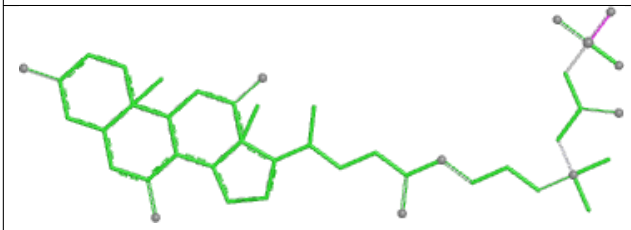


Torsions

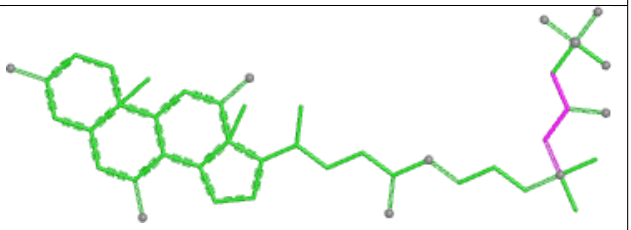


Rings

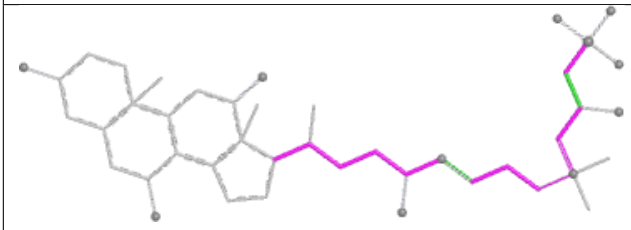
Ligand 1N7 D 603



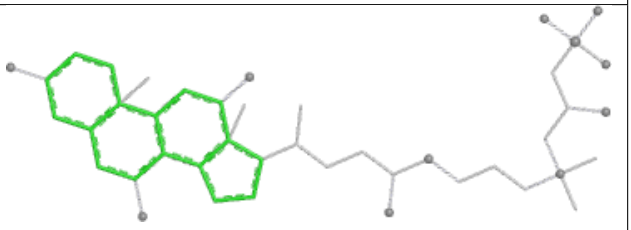
Bond lengths



Bond angles

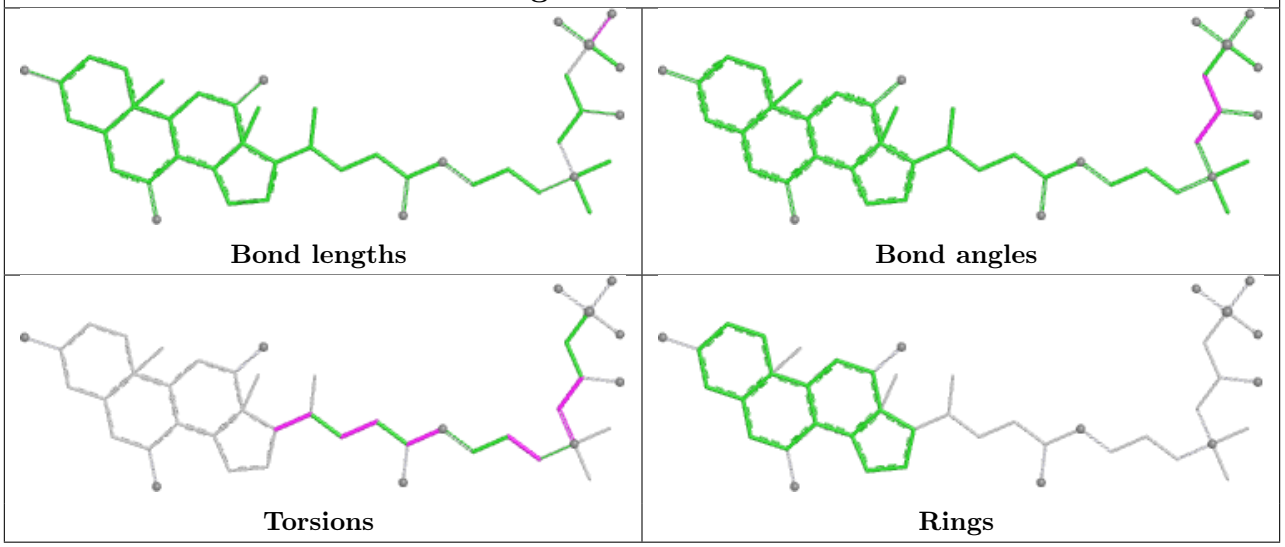


Torsions



Rings

Ligand 1N7 B 602



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.

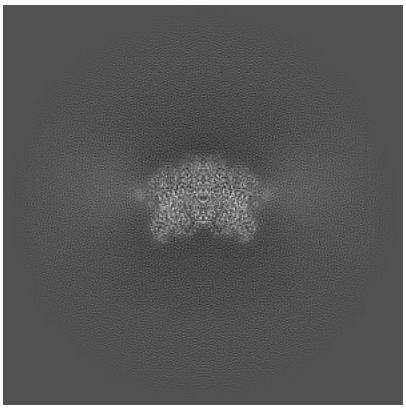
6 Map visualisation

This section contains visualisations of the EMDB entry EMD-77352. These allow visual inspection of the internal detail of the map and identification of artifacts.

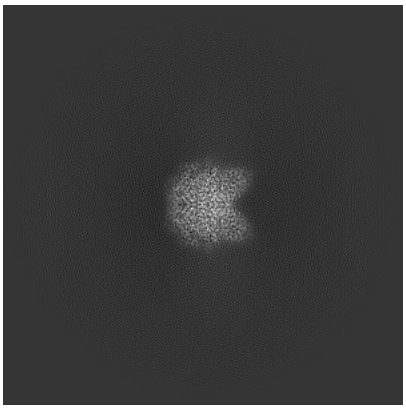
Images derived from a raw map, generated by summing the deposited half-maps, are presented below the corresponding image components of the primary map to allow further visual inspection and comparison with those of the primary map.

6.1 Orthogonal projections

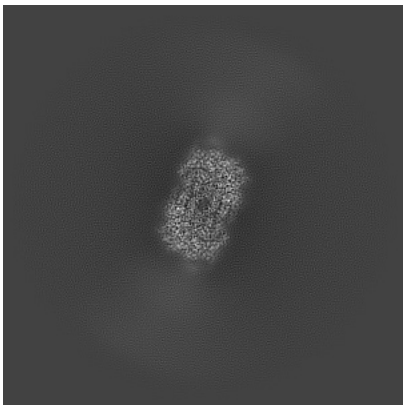
6.1.1 Primary map



X

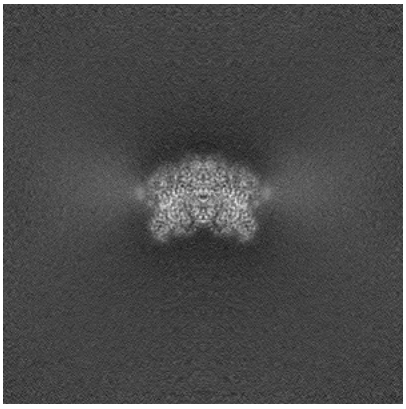


Y

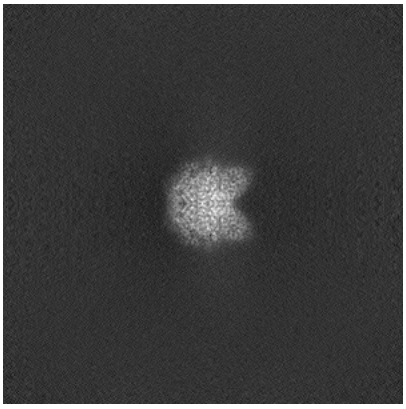


Z

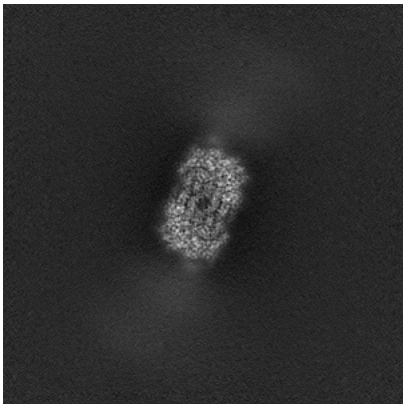
6.1.2 Raw map



X



Y

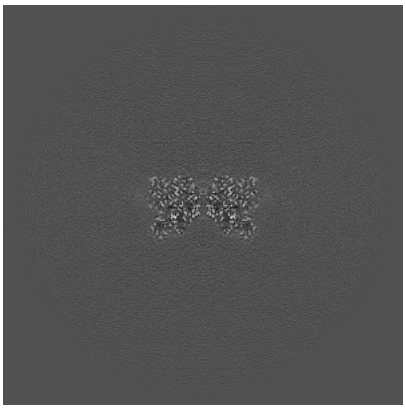


Z

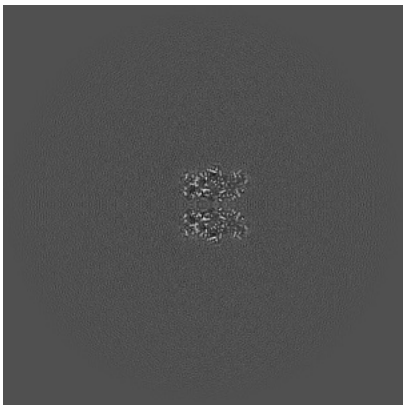
The images above show the map projected in three orthogonal directions.

6.2 Central slices (i)

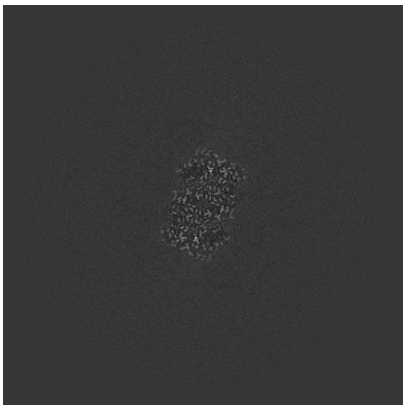
6.2.1 Primary map



X Index: 288

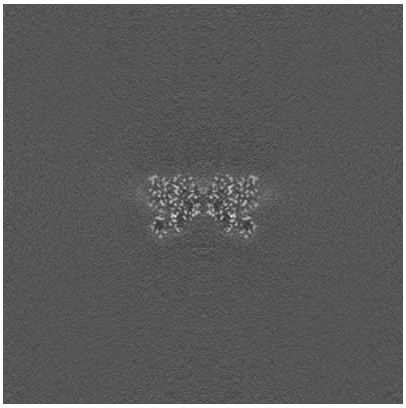


Y Index: 288

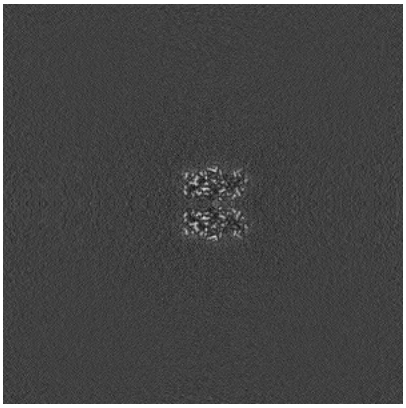


Z Index: 288

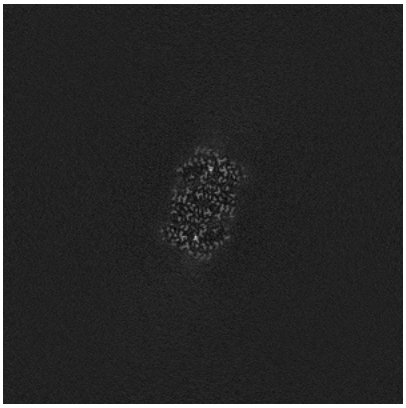
6.2.2 Raw map



X Index: 288



Y Index: 288

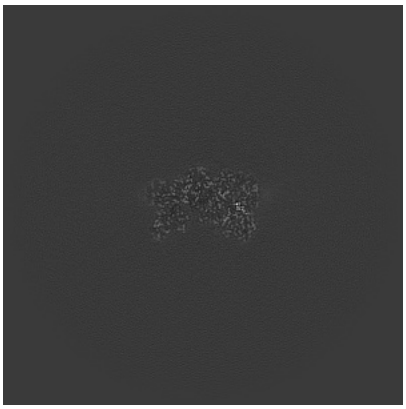


Z Index: 288

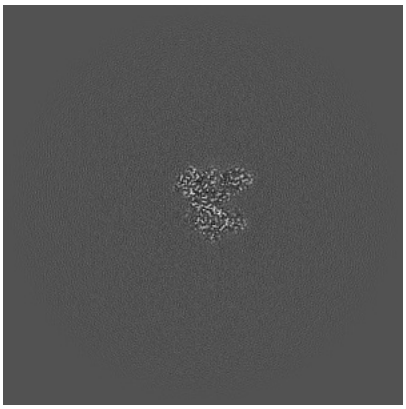
The images above show central slices of the map in three orthogonal directions.

6.3 Largest variance slices (i)

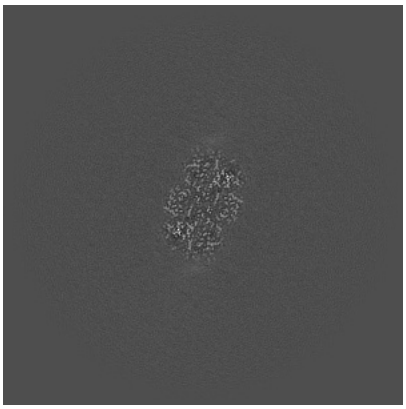
6.3.1 Primary map



X Index: 299

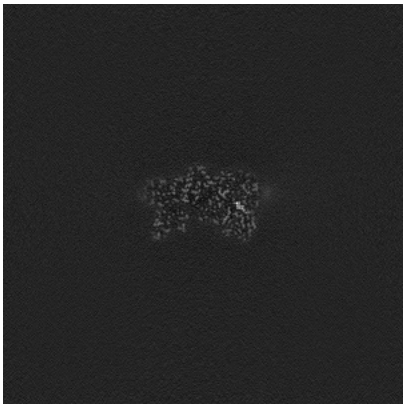


Y Index: 298

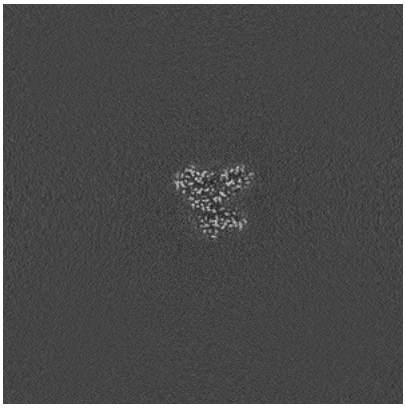


Z Index: 301

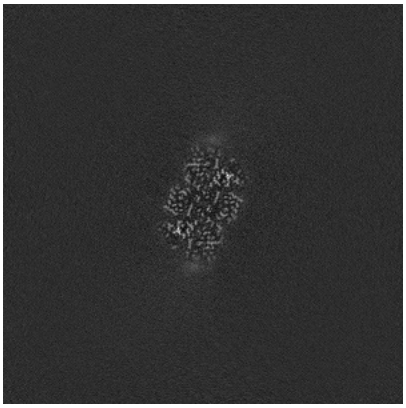
6.3.2 Raw map



X Index: 299



Y Index: 300

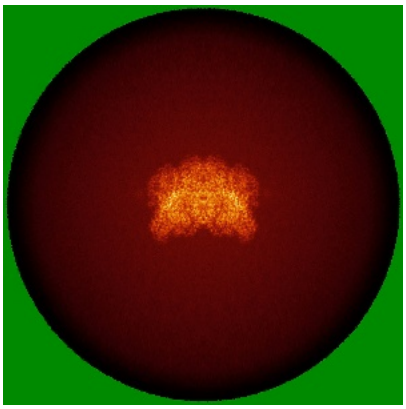


Z Index: 301

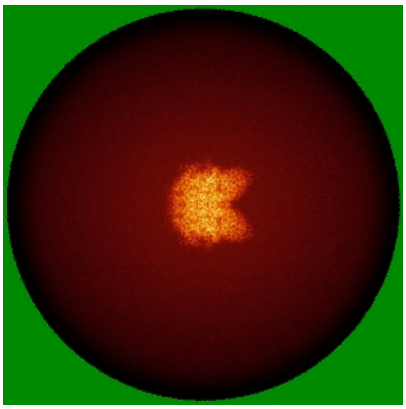
The images above show the largest variance slices of the map in three orthogonal directions.

6.4 Orthogonal standard-deviation projections (False-color) (i)

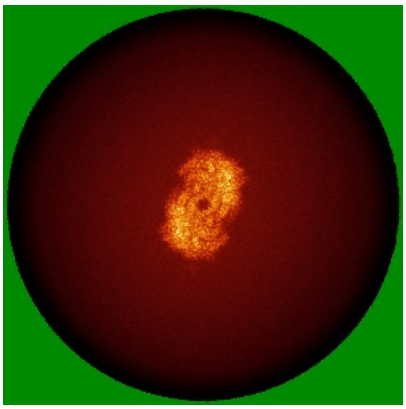
6.4.1 Primary map



X

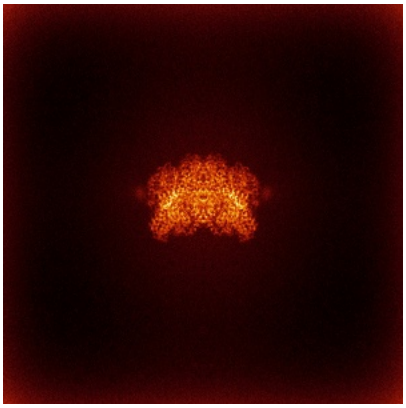


Y

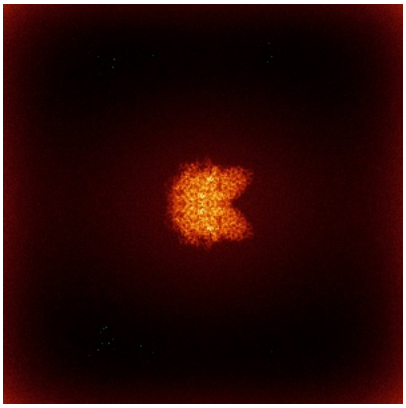


Z

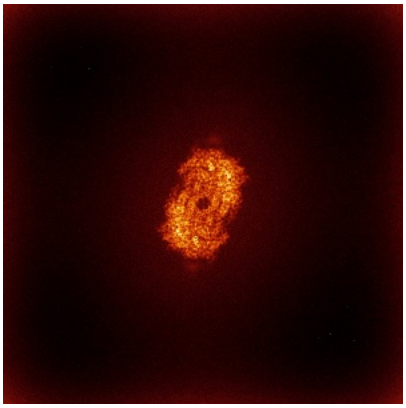
6.4.2 Raw map



X



Y



Z

The images above show the map standard deviation projections with false color in three orthogonal directions. Minimum values are shown in green, max in blue, and dark to light orange shades represent small to large values respectively.

6.5 Orthogonal surface views (i)

6.5.1 Primary map



X Y Z

The images above show the 3D surface view of the map at the recommended contour level 0.25. These images, in conjunction with the slice images, may facilitate assessment of whether an appropriate contour level has been provided.

6.5.2 Raw map



X Y Z

These images show the 3D surface of the raw map. The raw map's contour level was selected so that its surface encloses the same volume as the primary map does at its recommended contour level.

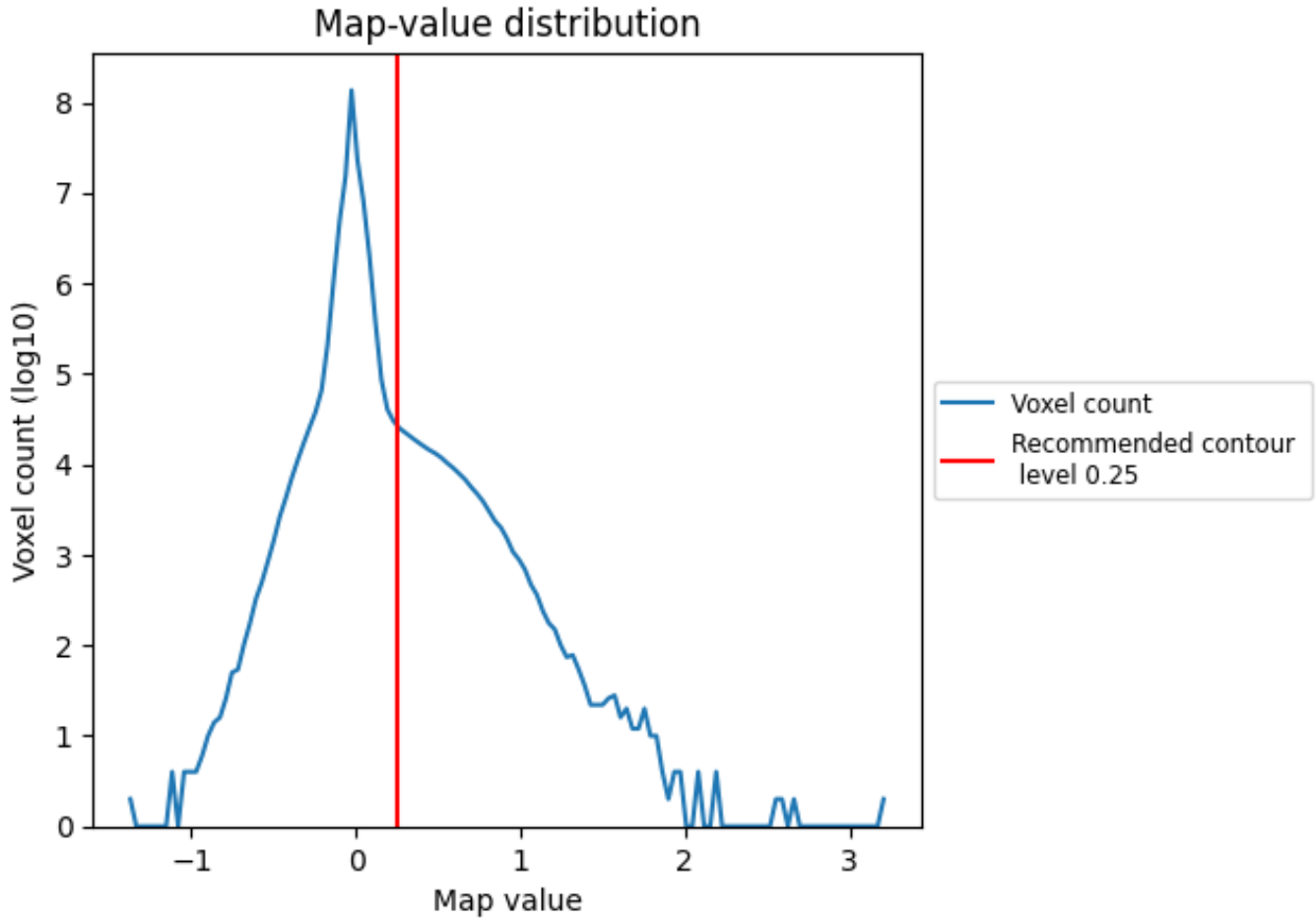
6.6 Mask visualisation (i)

This section was not generated. No masks/segmentation were deposited.

7 Map analysis

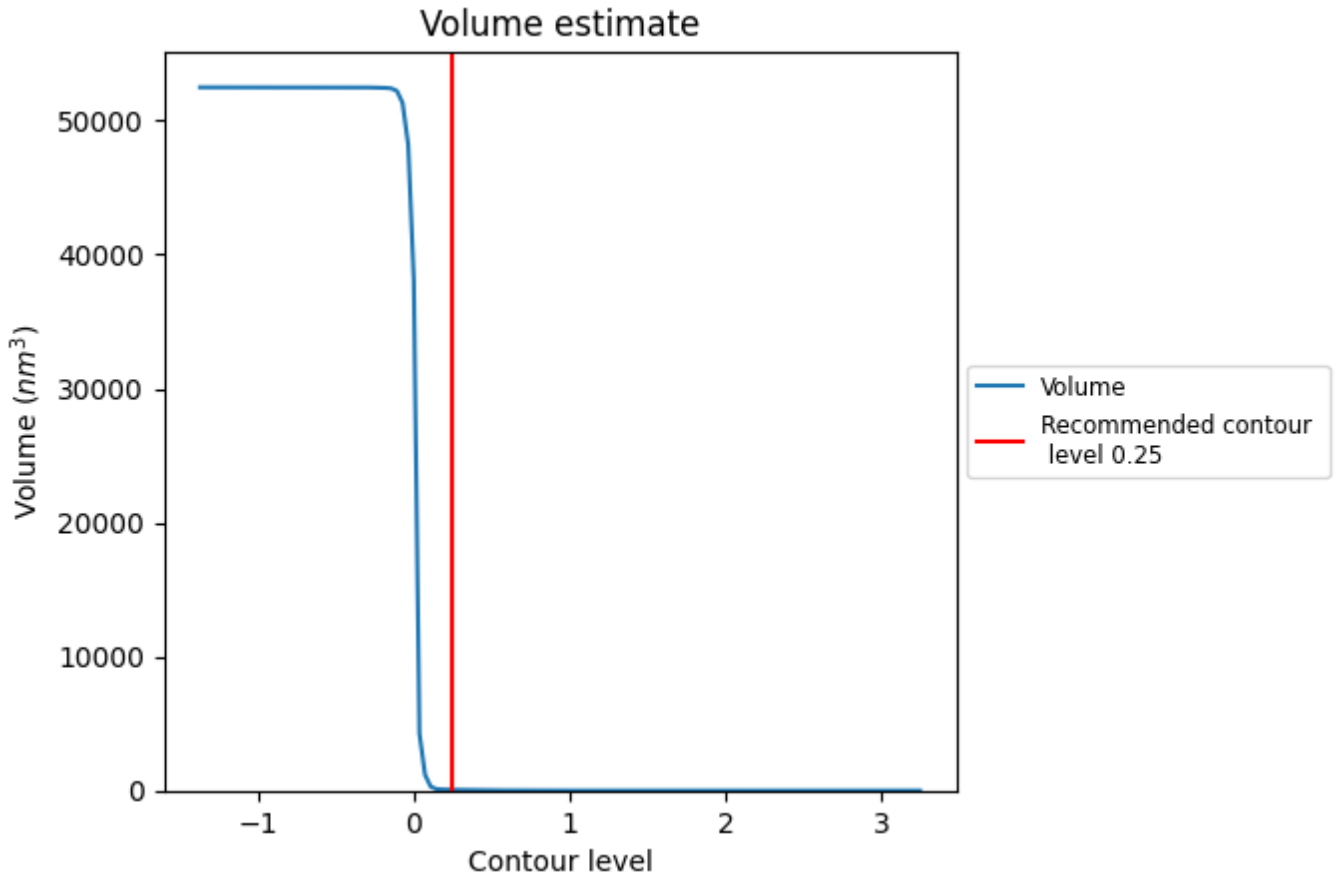
This section contains the results of statistical analysis of the map.

7.1 Map-value distribution



The map-value distribution is plotted in 128 intervals along the x-axis. The y-axis is logarithmic. A spike in this graph at zero usually indicates that the volume has been masked.

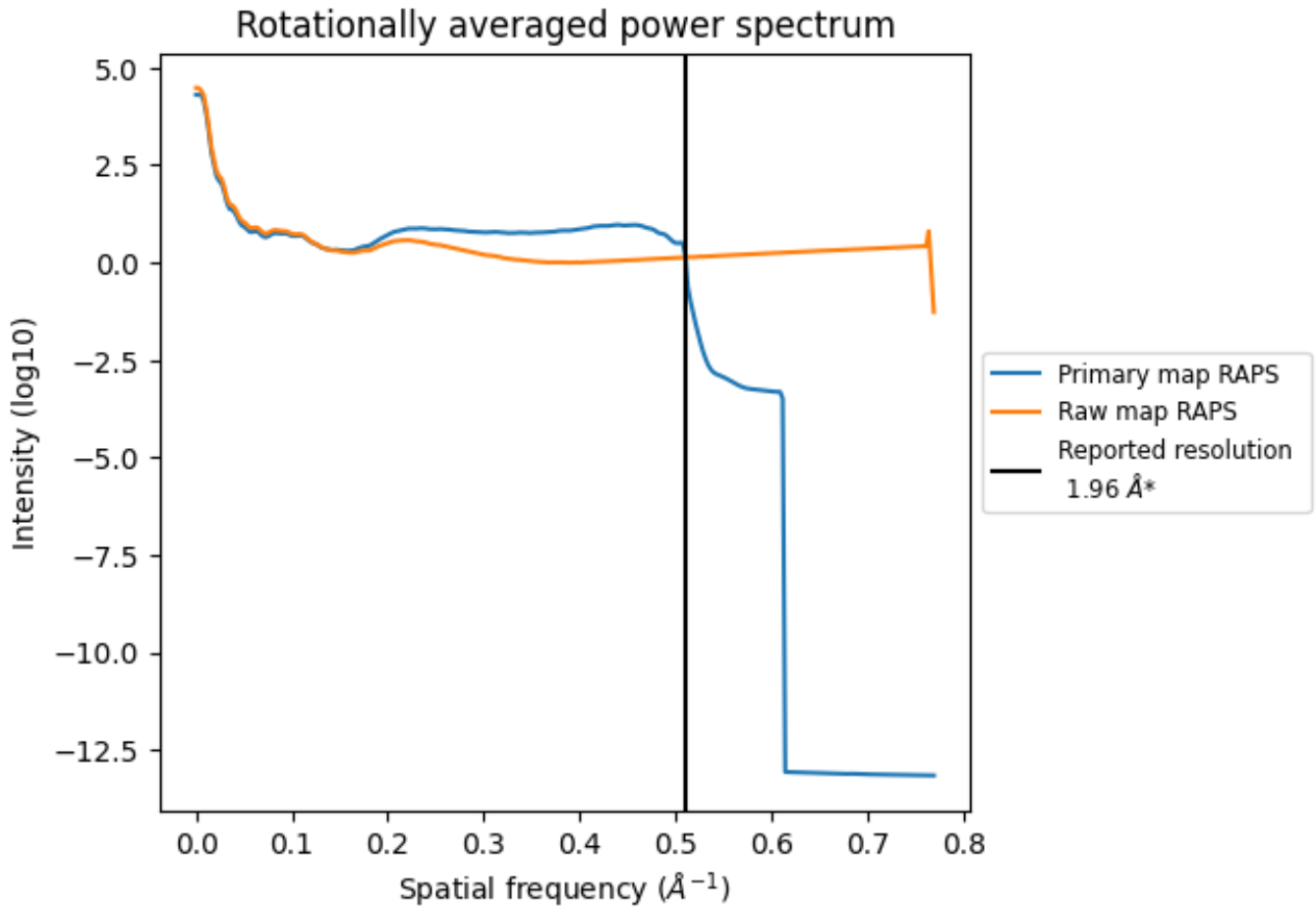
7.2 Volume estimate (i)



The volume at the recommended contour level is 59 nm^3; this corresponds to an approximate mass of 53 kDa.

The volume estimate graph shows how the enclosed volume varies with the contour level. The recommended contour level is shown as a vertical line and the intersection between the line and the curve gives the volume of the enclosed surface at the given level.

7.3 Rotationally averaged power spectrum (i)

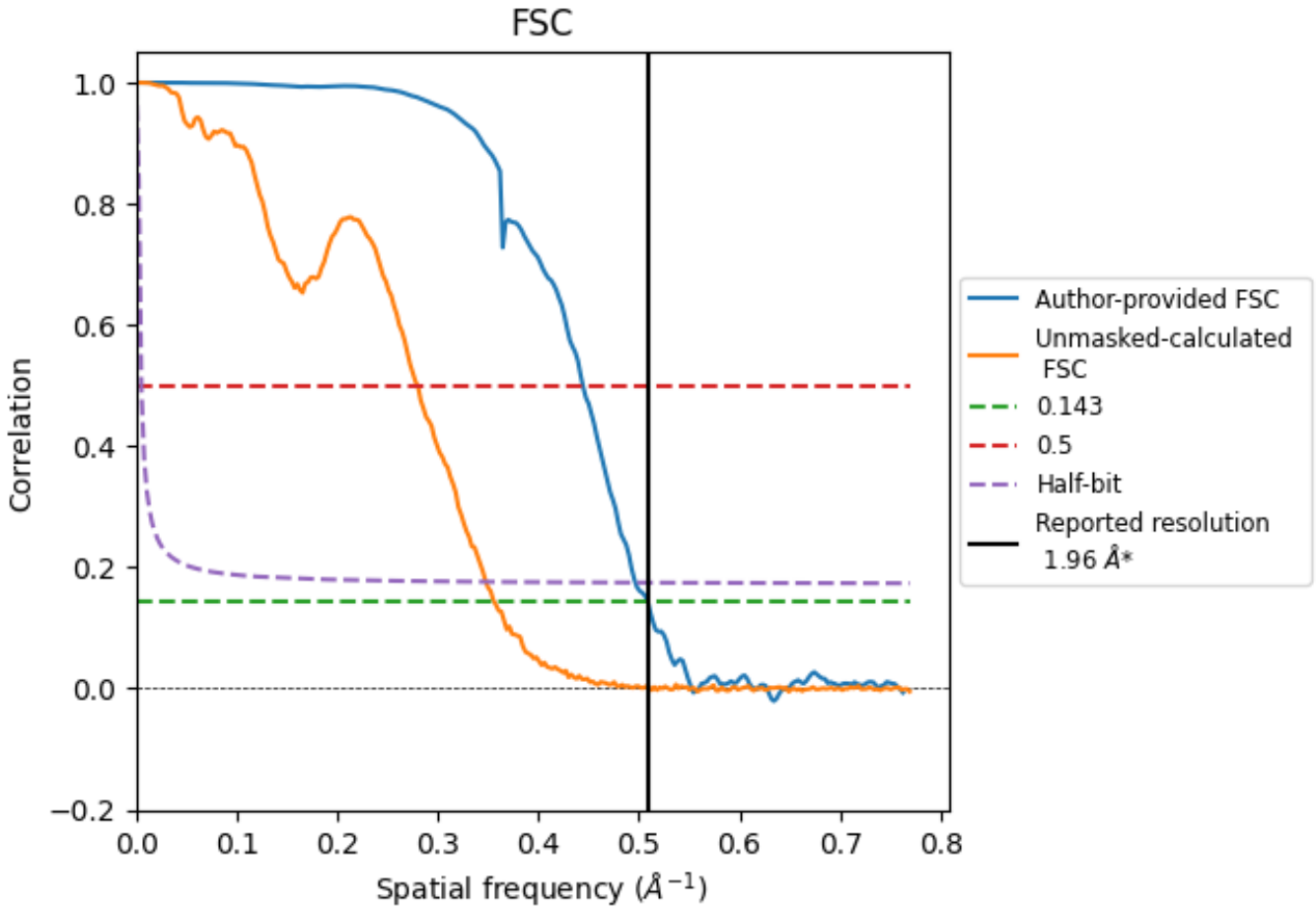


*Reported resolution corresponds to spatial frequency of 0.510 $Å^{-1}$

8 Fourier-Shell correlation

Fourier-Shell Correlation (FSC) is the most commonly used method to estimate the resolution of single-particle and subtomogram-averaged maps. The shape of the curve depends on the imposed symmetry, mask and whether or not the two 3D reconstructions used were processed from a common reference. The reported resolution is shown as a black line. A curve is displayed for the half-bit criterion in addition to lines showing the 0.143 gold standard cut-off and 0.5 cut-off.

8.1 FSC



*Reported resolution corresponds to spatial frequency of 0.510 Å^{-1}

8.2 Resolution estimates (i)

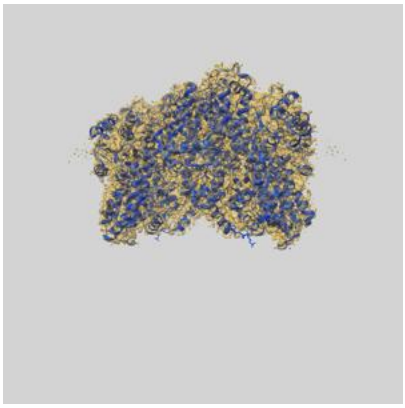
Resolution estimate (Å)	Estimation criterion (FSC cut-off)		
	0.143	0.5	Half-bit
Reported by author	1.96	-	-
Author-provided FSC curve	1.96	2.25	2.01
Unmasked-calculated*	2.81	3.57	2.87

*Resolution estimate based on FSC curve calculated by comparison of deposited half-maps. The value from deposited half-maps intersecting FSC 0.143 CUT-OFF 2.81 differs from the reported value 1.96 by more than 10 %

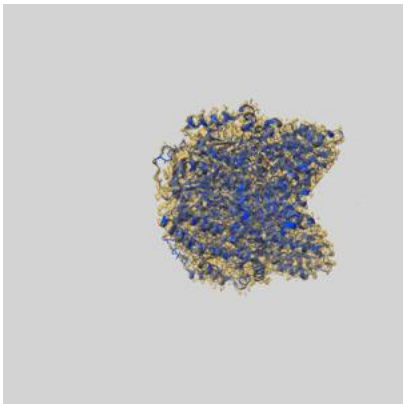
9 Map-model fit

This section contains information regarding the fit between EMDB map EMD-77352 and PDB model 36BF. Per-residue inclusion information can be found in section 3 on page 7.

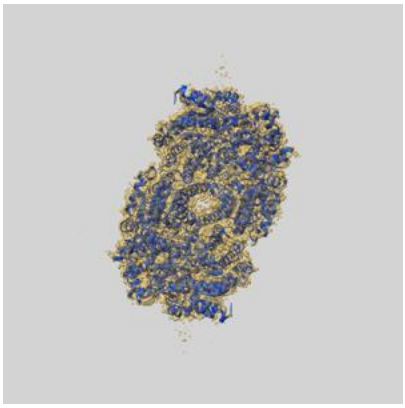
9.1 Map-model overlay



X



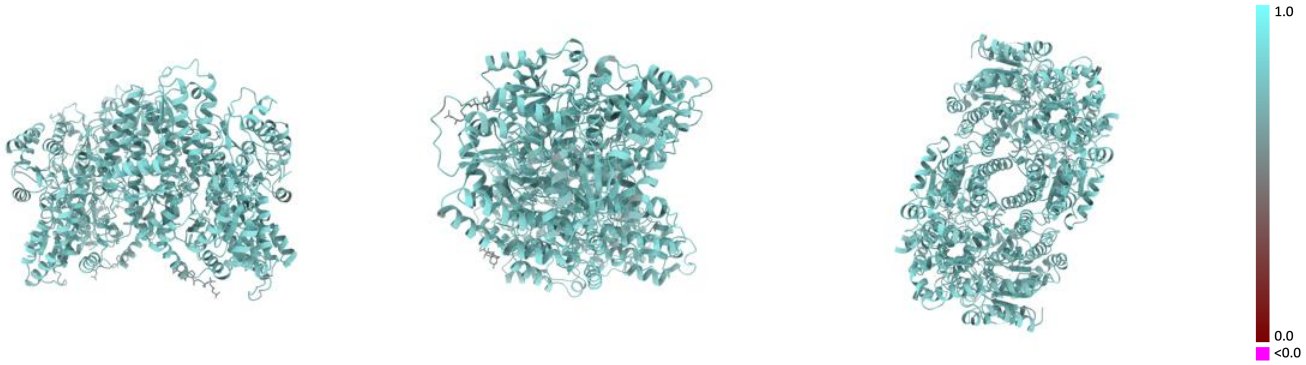
Y



Z

The images above show the 3D surface view of the map at the recommended contour level 0.25 at 50% transparency in yellow overlaid with a ribbon representation of the model coloured in blue. These images allow for the visual assessment of the quality of fit between the atomic model and the map.

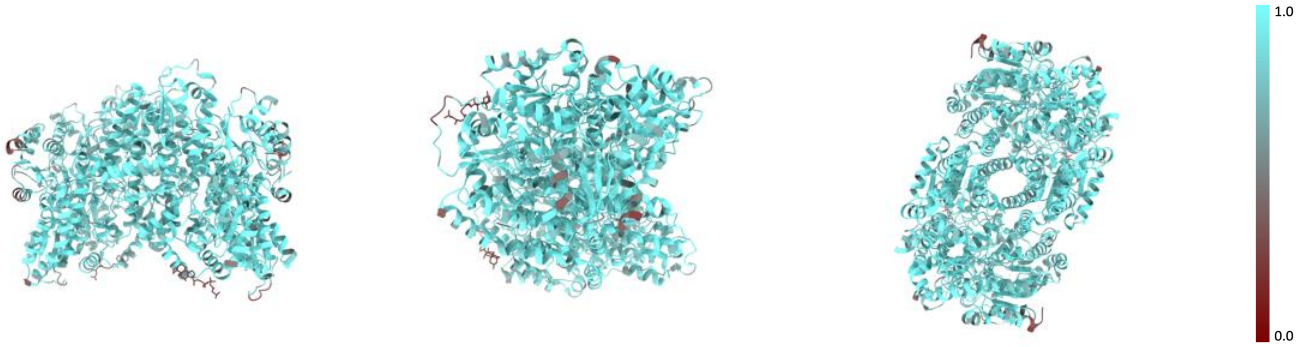
9.2 Q-score mapped to coordinate model (i)



X Y Z

The images above show the model with each residue coloured according its Q-score. This shows their resolvability in the map with higher Q-score values reflecting better resolvability. Please note: Q-score is calculating the resolvability of atoms, and thus high values are only expected at resolutions at which atoms can be resolved. Low Q-score values may therefore be expected for many entries.

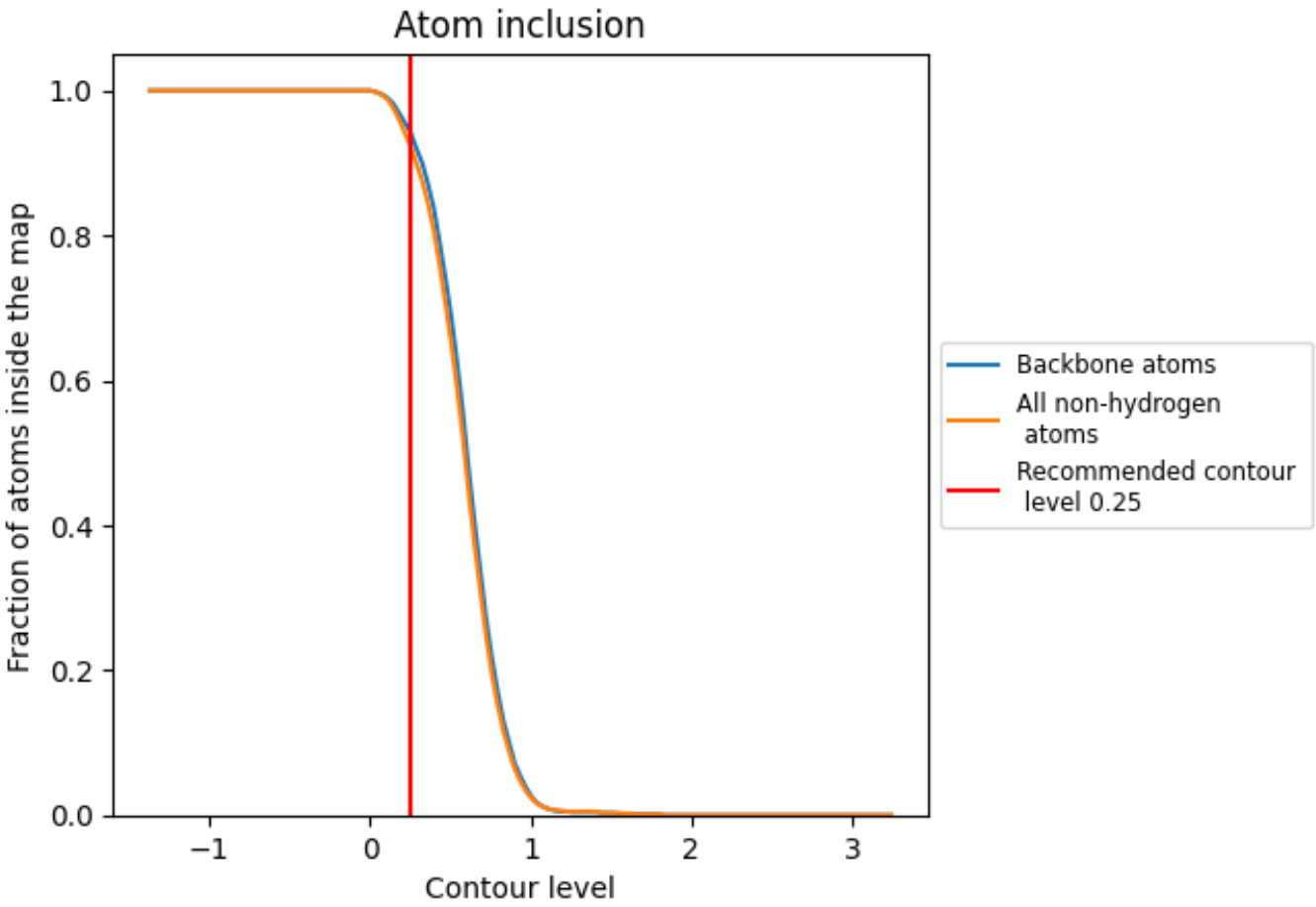
9.3 Atom inclusion mapped to coordinate model (i)



X Y Z

The images above show the model with each residue coloured according to its atom inclusion. This shows to what extent they are inside the map at the recommended contour level (0.25).

9.4 Atom inclusion (i)



At the recommended contour level, 94% of all backbone atoms, 92% of all non-hydrogen atoms, are inside the map.

9.5 Map-model fit summary

The table lists the average atom inclusion at the recommended contour level (0.25) and Q-score for the entire model and for each chain.



Chain	Atom inclusion	Q-score
All	0.9240	0.7640
A	0.9110	0.7560
B	0.9370	0.7700
C	0.9120	0.7560
D	0.9370	0.7710