



Full wwPDB EM Validation Report ⓘ

Mar 24, 2026 – 05:38 AM UTC

PDB ID : 8FA1 / pdb_00008fa1
EMDB ID : EMD-28947
Title : Cryo-EM structure of the SARS-CoV-2 HR1HR2 fusion core complex with N969K mutation
Authors : Yang, K.; Brunger, A.T.
Deposited on : 2022-11-25
Resolution : 2.51 Å(reported)

This is a Full wwPDB EM 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/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:

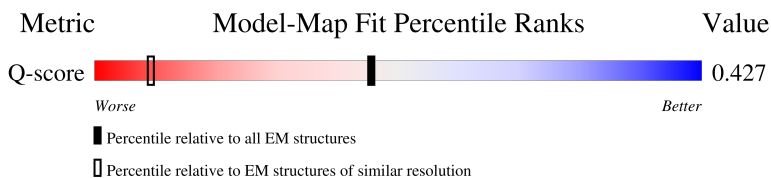
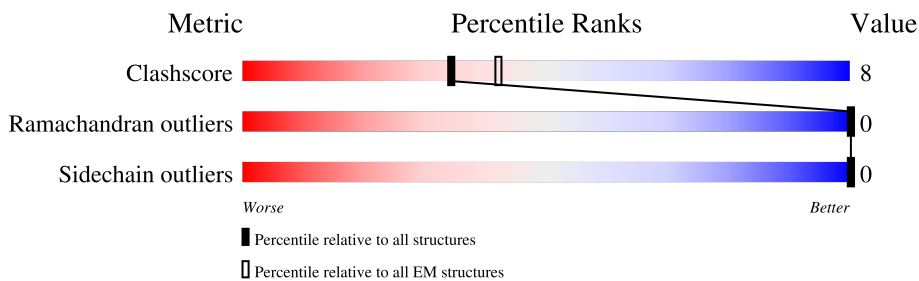
EMDB validation analysis : 0.0.1.dev132
MolProbity : 4-5-2 with Phenix2.0
Percentile statistics : 20250101.v01 (using entries in the PDB archive January 1st 2025)
EM percentile statistics : 202505.v01 (Using data in the EMDB archive up until May 2025)
MapQ : 1.9.13
Ideal geometry (proteins) : Engh & Huber (2001)
Ideal geometry (DNA, RNA) : Parkinson et al. (1996)
Validation Pipeline (wwPDB-VP) : 2.49

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 2.51 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.



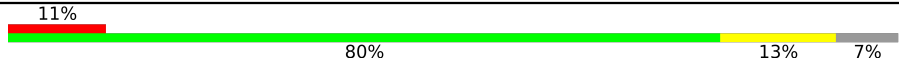

Metric	Whole archive (#Entries)	EM structures (#Entries)	Similar EM resolution (#Entries, resolution range(Å))
Clashscore	229148	23984	-
Ramachandran outliers	224038	23583	-
Sidechain outliers	223484	23102	-
Q-score	-	25397	7159 (2.01 - 3.01)

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 $\leq 5\%$. 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	257	
1	B	257	
1	C	257	
2	D	45	

Continued on next page...

Continued from previous page...

Mol	Chain	Length	Quality of chain
2	E	45	 11% 80% 13% 7%
2	F	45	 11% 82% 11% 7%

2 Entry composition

There are 2 unique types of molecules in this entry. The entry contains 2553 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 Ferritin, Dps family protein and Spike protein S2' chimera.

Mol	Chain	Residues	Atoms				AltConf	Trace
			Total	C	N	O		
1	A	71	532	329	94	109	0	0
1	B	71	532	329	94	109	0	0
1	C	71	532	329	94	109	0	0

There are 36 discrepancies between the modelled and reference sequences:

Chain	Residue	Modelled	Actual	Comment	Reference
A	732	MET	-	initiating methionine	UNP B2J981
A	733	SER	-	expression tag	UNP B2J981
A	734	HIS	-	expression tag	UNP B2J981
A	735	HIS	-	expression tag	UNP B2J981
A	736	HIS	-	expression tag	UNP B2J981
A	737	HIS	-	expression tag	UNP B2J981
A	738	HIS	-	expression tag	UNP B2J981
A	739	HIS	-	expression tag	UNP B2J981
A	740	GLY	-	expression tag	UNP B2J981
A	741	SER	THR	conflict	UNP B2J981
A	916	ALA	-	linker	UNP B2J981
A	969	LYS	ASN	engineered mutation	UNP A0A8B6RK57
B	732	MET	-	initiating methionine	UNP B2J981
B	733	SER	-	expression tag	UNP B2J981
B	734	HIS	-	expression tag	UNP B2J981
B	735	HIS	-	expression tag	UNP B2J981
B	736	HIS	-	expression tag	UNP B2J981
B	737	HIS	-	expression tag	UNP B2J981
B	738	HIS	-	expression tag	UNP B2J981
B	739	HIS	-	expression tag	UNP B2J981
B	740	GLY	-	expression tag	UNP B2J981
B	741	SER	THR	conflict	UNP B2J981
B	916	ALA	-	linker	UNP B2J981
B	969	LYS	ASN	engineered mutation	UNP A0A8B6RK57

Continued on next page...

Continued from previous page...

Chain	Residue	Modelled	Actual	Comment	Reference
C	732	MET	-	initiating methionine	UNP B2J981
C	733	SER	-	expression tag	UNP B2J981
C	734	HIS	-	expression tag	UNP B2J981
C	735	HIS	-	expression tag	UNP B2J981
C	736	HIS	-	expression tag	UNP B2J981
C	737	HIS	-	expression tag	UNP B2J981
C	738	HIS	-	expression tag	UNP B2J981
C	739	HIS	-	expression tag	UNP B2J981
C	740	GLY	-	expression tag	UNP B2J981
C	741	SER	THR	conflict	UNP B2J981
C	916	ALA	-	linker	UNP B2J981
C	969	LYS	ASN	engineered mutation	UNP A0A8B6RKS7

- Molecule 2 is a protein called Spike protein S2' HR2.

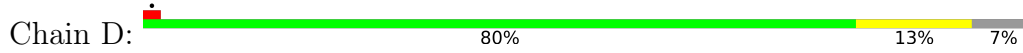
Mol	Chain	Residues	Atoms				AltConf	Trace
2	D	42	Total	C	N	O	0	0
			319	195	55	69		
2	E	42	Total	C	N	O	0	0
			319	195	55	69		
2	F	42	Total	C	N	O	0	0
			319	195	55	69		

GLU GLY
GLY SER
GLU PHE
GLU TYR
SER
LEU
HIS
GLU
PHE
PHE
ASN
GLU
ILE
ILE
GLY
TYR
VAL
GLN
VAL
GLN
ASP
HIS
ILE
HIS
GLN
GLU
ILE
GLY
LEU
GLY
ARG
LEU
ASP
GLY
LEU
GLY
THR
ARG
TYR
VAL
LEU
VAL
PRO
VAL
VAL
ALA
THR
PHE
SER
LYS
LEU
ALA
GLU
THR
ALA
THR
CYS
HIS
PHE
GLU
GLN
SER
SER
SER
GLY
VAL
TYR
SER
SER
LEU

ARG
GLN
MET
VAL
GLU
ASN
ASP
LEU
ALA
GLU
GLN
ALA
ILE
ILE
GLY
TYR
VAL
ILE
ARG
ARG
GLN
ALA
HIS
ILE
HIS
GLN
ALA
GLU
GLU
SER
LEU
GLY
ARG
LEU
ASP
GLY
THR
ARG
TYR
VAL
LEU
VAL
TYR
PRO
VAL
VAL
ALA
THR
PHE
SER
LYS
LEU
ALA
GLU
THR
ALA
THR
CYS
HIS
PHE
GLU
GLN
SER
SER
SER
LEU

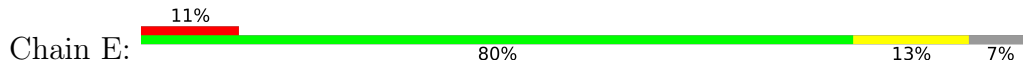
THR
LEU
GLY
PHE
ALA
TYR
E918
Q935
L938
L948
N960
V963
K964
Q965
L966
A972
V976
L977
N978
L981
S982
R983
L984
D985
E988

• Molecule 2: Spike protein S2' HR2



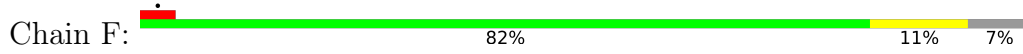
LYS
ASN
H1159
D1163
I1169
V1177
N1178
I1179
L1186
A1190
L1200
GLN

• Molecule 2: Spike protein S2' HR2



LYS
ASN
H1159
I1160
D1163
G1167
D1168
I1169
S1170
G1171
V1177
N1178
I1179
L1186
A1190
D1199
L1200
GLN

• Molecule 2: Spike protein S2' HR2



LYS
ASN
H1159
D1163
V1177
N1178
I1179
L1186
A1190
D1199
L1200
GLN

4 Experimental information

Property	Value	Source
EM reconstruction method	SINGLE PARTICLE	Depositor
Imposed symmetry	POINT, Not provided	
Number of particles used	883152	Depositor
Resolution determination method	FSC 0.143 CUT-OFF	Depositor
CTF correction method	NONE	Depositor
Microscope	FEI TITAN KRIOS	Depositor
Voltage (kV)	300	Depositor
Electron dose ($e^-/\text{\AA}^2$)	55	Depositor
Minimum defocus (nm)	300	Depositor
Maximum defocus (nm)	2000	Depositor
Magnification	Not provided	
Image detector	GATAN K3 (6k x 4k)	Depositor
Maximum map value	1.664	Depositor
Minimum map value	-0.002	Depositor
Average map value	0.001	Depositor
Map value standard deviation	0.020	Depositor
Recommended contour level	0.05	Depositor
Map size (\AA)	205.824, 205.824, 205.824	wwPDB
Map dimensions	256, 256, 256	wwPDB
Map angles ($^\circ$)	90.0, 90.0, 90.0	wwPDB
Pixel spacing (\AA)	0.804, 0.804, 0.804	Depositor

5 Model quality [i](#)

5.1 Standard geometry [i](#)

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	0.28	0/533	0.36	0/717
1	B	0.29	0/533	0.36	0/717
1	C	0.28	0/533	0.36	0/717
2	D	0.21	0/320	0.23	0/434
2	E	0.21	0/320	0.23	0/434
2	F	0.21	0/320	0.23	0/434
All	All	0.26	0/2559	0.31	0/3453

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	532	0	552	15	0
1	B	532	0	552	16	0
1	C	532	0	552	12	0
2	D	319	0	317	7	0
2	E	319	0	317	7	0
2	F	319	0	317	6	0
All	All	2553	0	2607	42	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 8.

All (42) 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:C:978:ASN:ND2	2:F:1163:ASP:OD1	2.29	0.66
1:B:978:ASN:ND2	2:E:1163:ASP:OD1	2.33	0.60
1:A:948:LEU:HD23	2:F:1177:VAL:HG21	1.84	0.59
1:C:948:LEU:HD23	2:E:1177:VAL:HG21	1.84	0.58
1:B:948:LEU:HD23	2:D:1177:VAL:HG21	1.84	0.58
1:A:978:ASN:ND2	2:D:1163:ASP:OD1	2.39	0.56
1:A:966:LEU:HD11	1:C:966:LEU:HD11	1.92	0.51
1:A:966:LEU:HD11	1:B:966:LEU:HD11	1.92	0.51
1:C:938:LEU:HD22	2:F:1186:LEU:HD22	1.93	0.51
2:D:1177:VAL:HG13	2:D:1179:ILE:HG23	1.93	0.50
1:A:938:LEU:HD22	2:D:1186:LEU:HD22	1.93	0.50
1:B:966:LEU:HD11	1:C:966:LEU:HD11	1.92	0.50
1:B:938:LEU:HD22	2:E:1186:LEU:HD22	1.93	0.50
2:E:1177:VAL:HG13	2:E:1179:ILE:HG23	1.93	0.49
1:B:977:LEU:O	1:B:981:LEU:HG	2.13	0.49
2:F:1177:VAL:HG13	2:F:1179:ILE:HG23	1.94	0.49
1:C:977:LEU:O	1:C:981:LEU:HG	2.13	0.49
1:A:977:LEU:O	1:A:981:LEU:HG	2.13	0.48
1:B:984:LEU:HB3	1:C:983:ARG:NH2	2.29	0.48
1:C:935:GLN:NE2	2:F:1190:ALA:O	2.42	0.48
1:A:984:LEU:HB3	1:B:983:ARG:NH2	2.29	0.47
1:B:965:GLN:NE2	2:D:1169:ILE:HA	2.30	0.47
1:A:935:GLN:NE2	2:D:1190:ALA:O	2.43	0.47
1:A:972:ALA:O	1:A:976:VAL:HG12	2.15	0.47
1:A:983:ARG:NH2	1:C:984:LEU:HB3	2.29	0.47
1:B:972:ALA:O	1:B:976:VAL:HG12	2.15	0.47
1:C:972:ALA:O	1:C:976:VAL:HG12	2.15	0.47
1:B:966:LEU:HD23	1:B:966:LEU:HA	1.81	0.44
1:A:984:LEU:HD23	1:A:984:LEU:HA	1.77	0.44
1:B:935:GLN:NE2	2:E:1190:ALA:O	2.43	0.44
1:A:964:LYS:HE3	1:A:964:LYS:HB2	1.65	0.43
1:B:964:LYS:HE3	1:B:964:LYS:HB2	1.64	0.43
1:A:960:ASN:O	1:A:963:VAL:HG12	2.19	0.42
1:A:966:LEU:HD23	1:A:966:LEU:HA	1.81	0.42
2:E:1186:LEU:HD23	2:E:1186:LEU:HA	1.91	0.42
1:B:960:ASN:O	1:B:963:VAL:HG12	2.19	0.42
1:B:984:LEU:HD23	1:B:984:LEU:HA	1.77	0.41
1:C:965:GLN:NE2	2:E:1169:ILE:HA	2.35	0.41
1:A:977:LEU:HD23	1:A:977:LEU:HA	1.86	0.41
1:C:960:ASN:O	1:C:963:VAL:HG12	2.19	0.40

Continued on next page...

Continued from previous page...

Atom-1	Atom-2	Interatomic distance (Å)	Clash overlap (Å)
1:B:951:VAL:HG11	2:D:1177:VAL:HG23	2.04	0.40
2:F:1186:LEU:HD23	2:F:1186:LEU:HA	1.91	0.40

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	69/257 (27%)	69 (100%)	0	0	100	100
1	B	69/257 (27%)	69 (100%)	0	0	100	100
1	C	69/257 (27%)	69 (100%)	0	0	100	100
2	D	40/45 (89%)	35 (88%)	5 (12%)	0	100	100
2	E	40/45 (89%)	35 (88%)	5 (12%)	0	100	100
2	F	40/45 (89%)	35 (88%)	5 (12%)	0	100	100
All	All	327/906 (36%)	312 (95%)	15 (5%)	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	61/220 (28%)	61 (100%)	0	100	100

Continued on next page...

Continued from previous page...

Mol	Chain	Analysed	Rotameric	Outliers	Percentiles	
1	B	61/220 (28%)	61 (100%)	0	100	100
1	C	61/220 (28%)	61 (100%)	0	100	100
2	D	38/41 (93%)	38 (100%)	0	100	100
2	E	38/41 (93%)	38 (100%)	0	100	100
2	F	38/41 (93%)	38 (100%)	0	100	100
All	All	297/783 (38%)	297 (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 (3) such sidechains are listed below:

Mol	Chain	Res	Type
2	D	1159	HIS
2	E	1159	HIS
2	F	1159	HIS

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](#)

There are no ligands in this entry.

5.7 Other polymers [i](#)

There are no such residues in this entry.

5.8 Polymer linkage issues

There are no chain breaks in this entry.

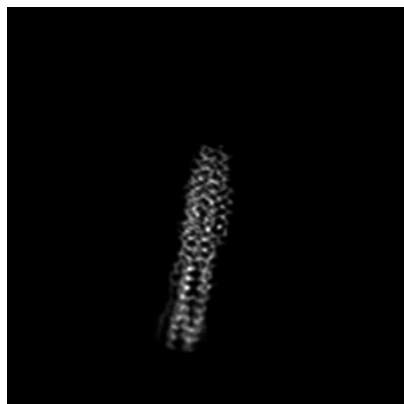
6 Map visualisation [i](#)

This section contains visualisations of the EMDB entry EMD-28947. These allow visual inspection of the internal detail of the map and identification of artifacts.

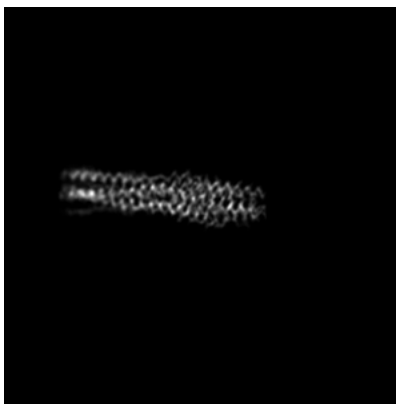
Images derived from a raw map, generated by summing the deposited half-maps, are presented below the corresponding image components of the primary map to allow further visual inspection and comparison with those of the primary map.

6.1 Orthogonal projections [i](#)

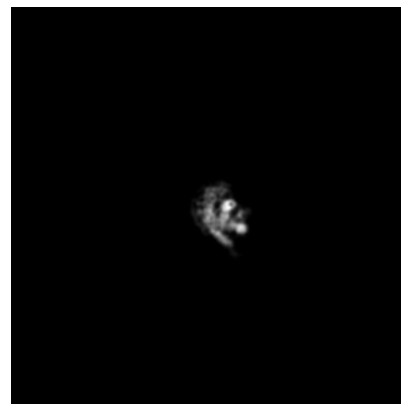
6.1.1 Primary map



X

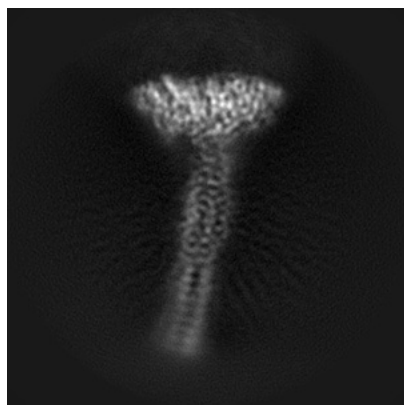


Y

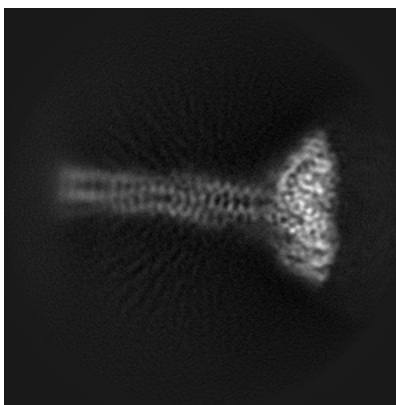


Z

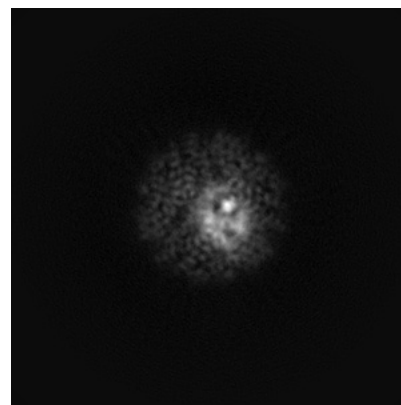
6.1.2 Raw map



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: 128

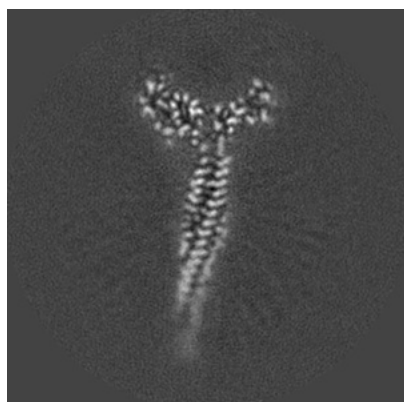


Y Index: 128

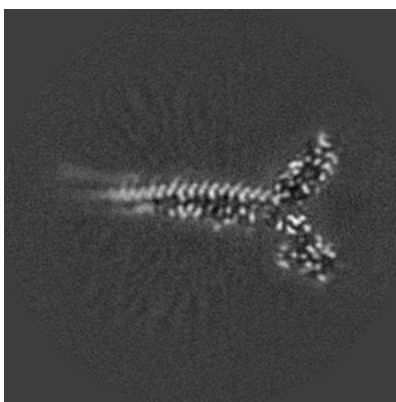


Z Index: 128

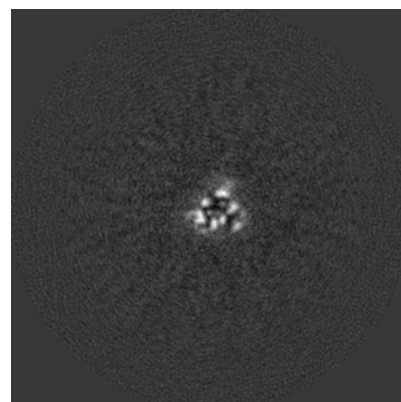
6.2.2 Raw map



X Index: 128



Y Index: 128

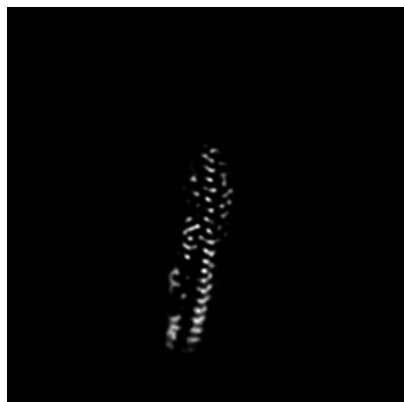


Z Index: 128

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

6.3 Largest variance slices [i](#)

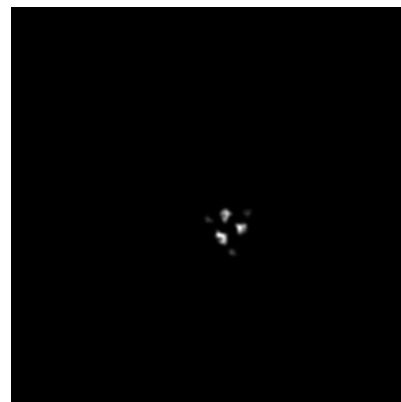
6.3.1 Primary map



X Index: 137

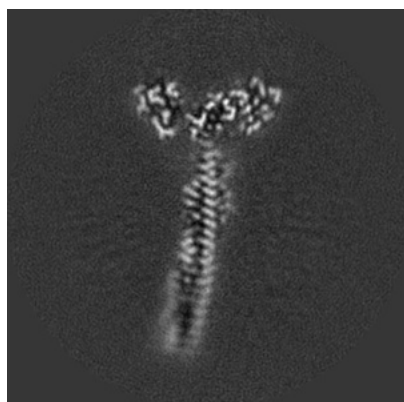


Y Index: 115

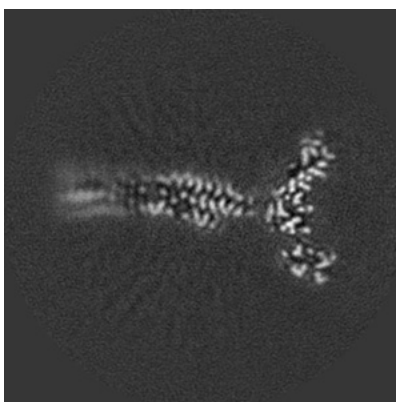


Z Index: 56

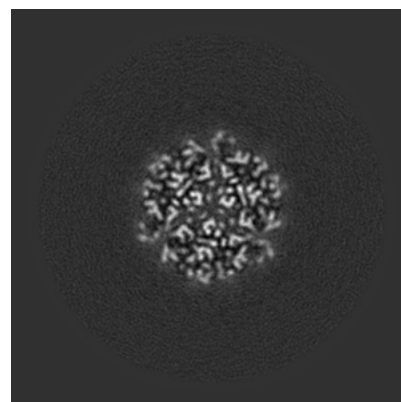
6.3.2 Raw map



X Index: 139



Y Index: 120

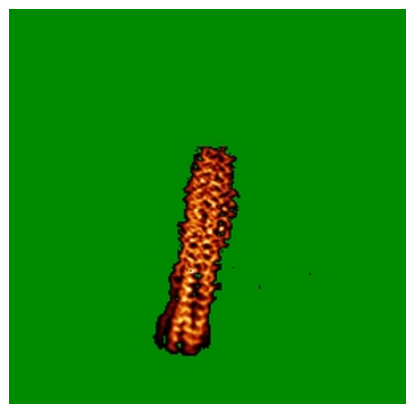


Z Index: 195

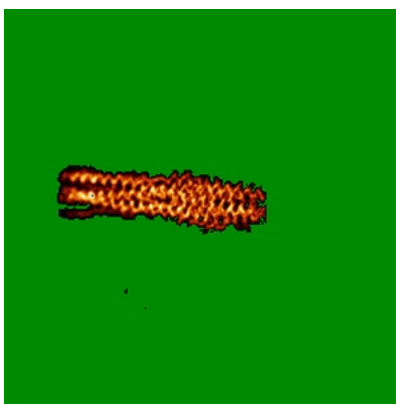
The images above show the largest variance slices of the map in three orthogonal directions.

6.4 Orthogonal standard-deviation projections (False-color) [i](#)

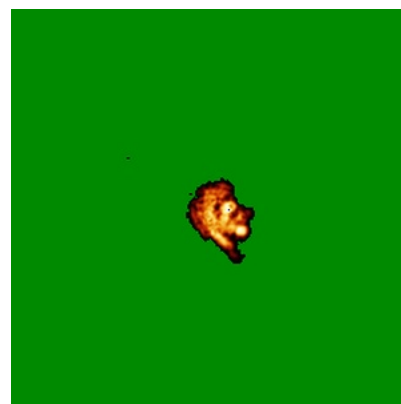
6.4.1 Primary map



X



Y

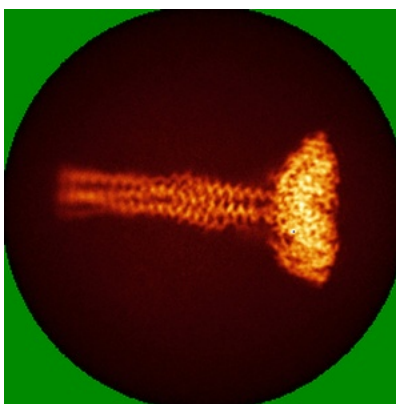


Z

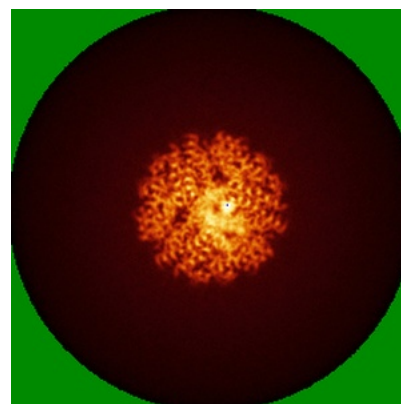
6.4.2 Raw map



X



Y

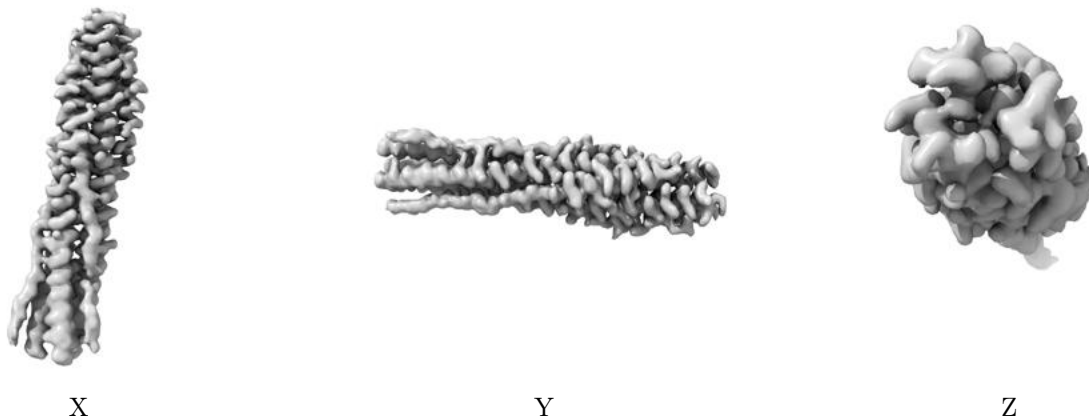


Z

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.

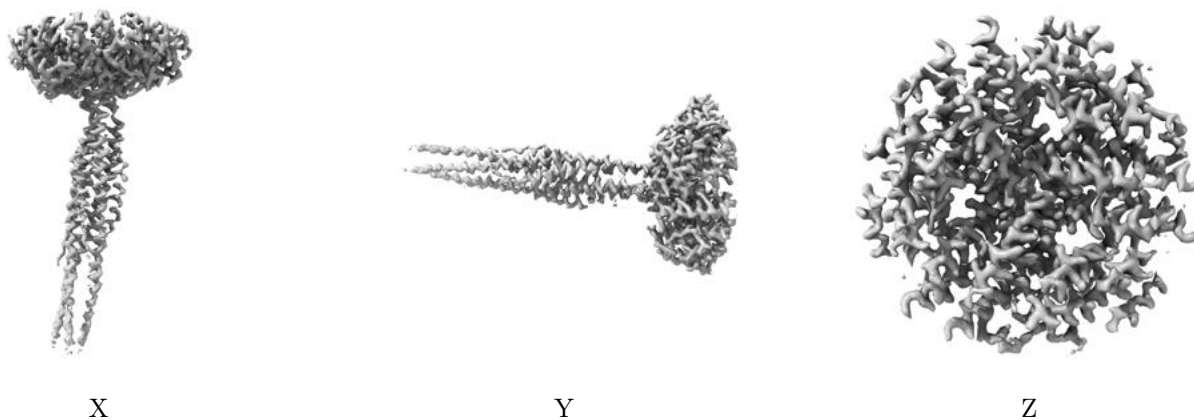
6.5 Orthogonal surface views [i](#)

6.5.1 Primary map



The images above show the 3D surface view of the map at the recommended contour level 0.05. 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



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.

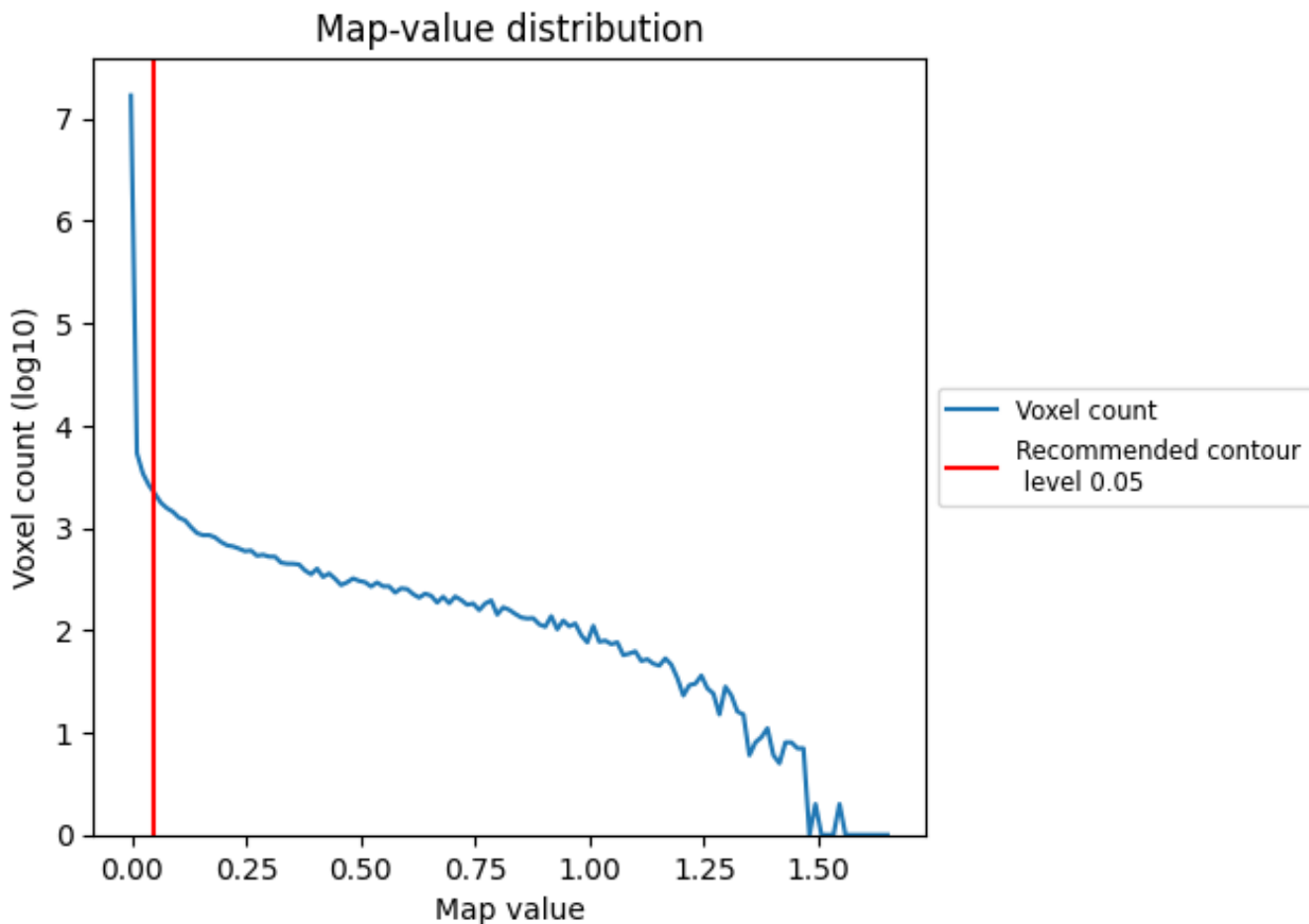
6.6 Mask visualisation [i](#)

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

7 Map analysis [i](#)

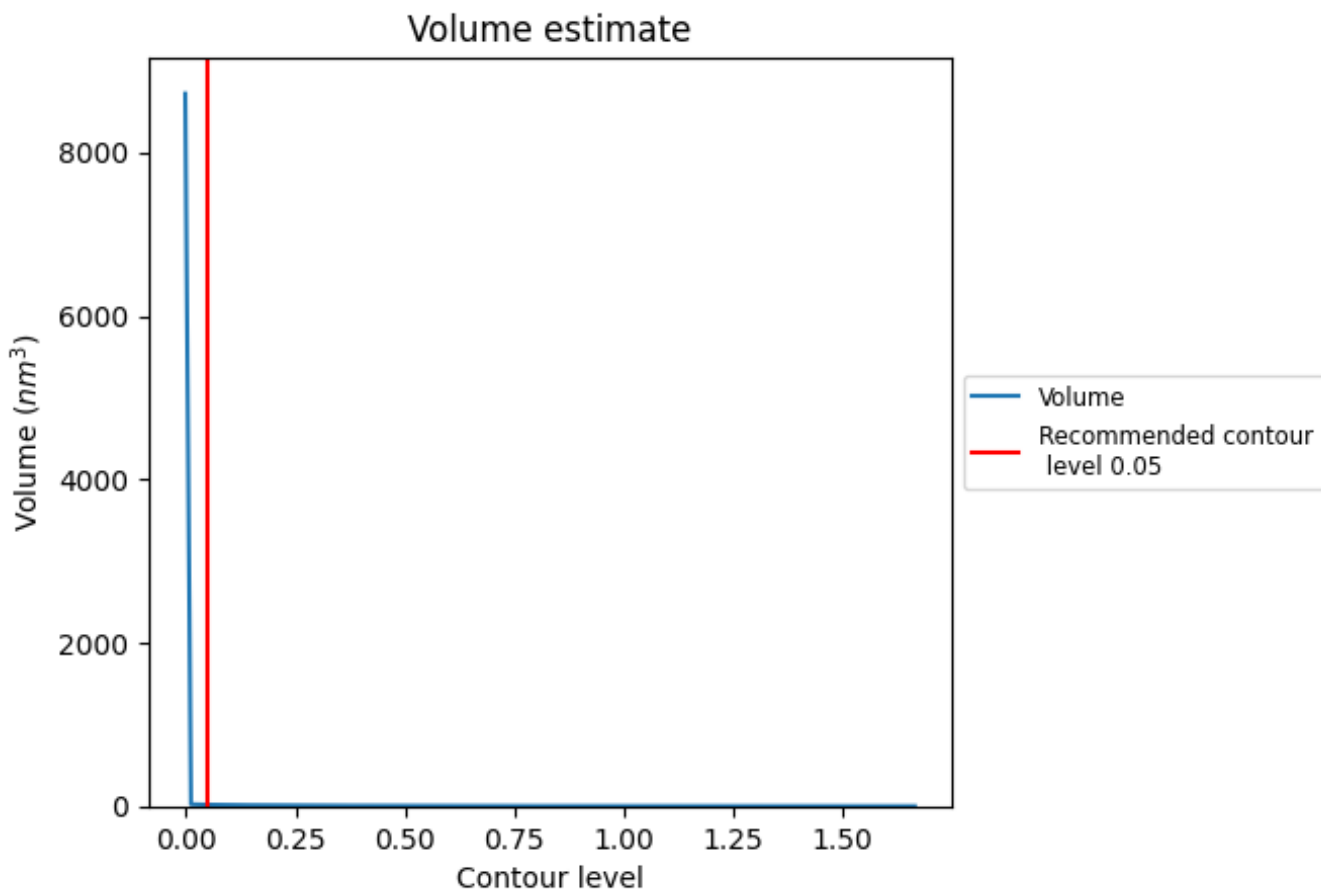
This section contains the results of statistical analysis of the map.

7.1 Map-value distribution [i](#)



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.

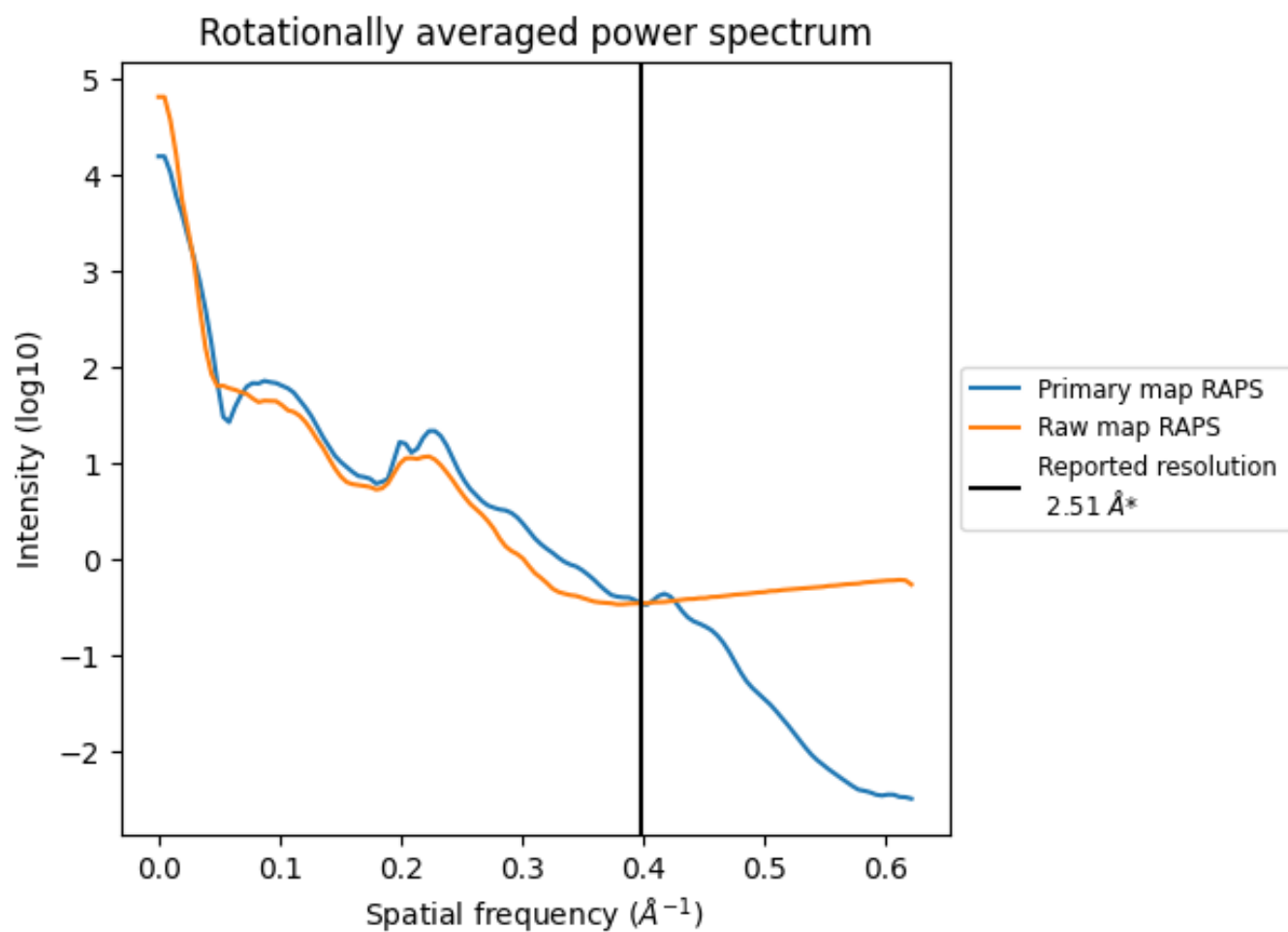
7.2 Volume estimate [i](#)



The volume at the recommended contour level is 17 nm^3 ; this corresponds to an approximate mass of 16 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

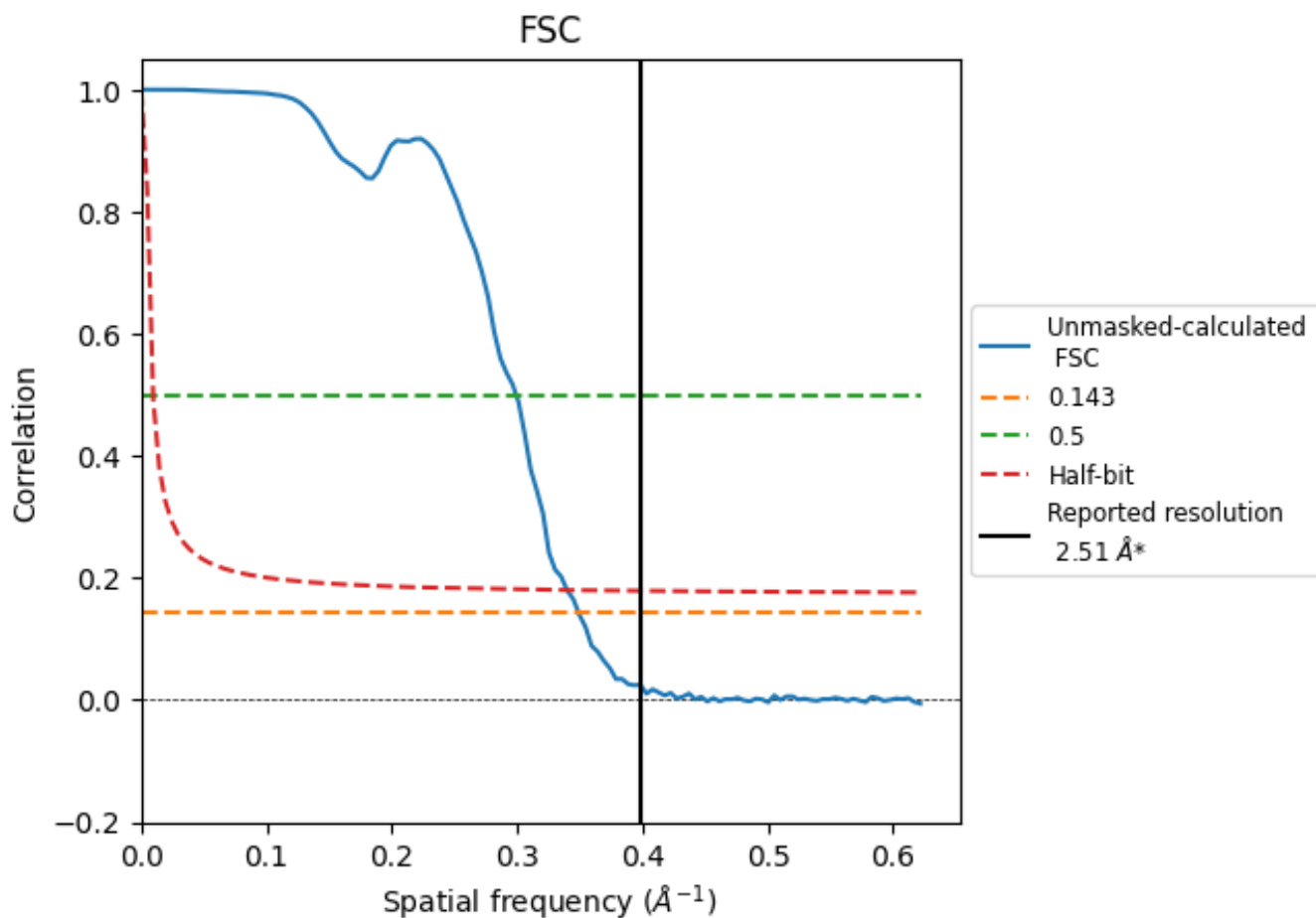


*Reported resolution corresponds to spatial frequency of 0.398 \AA^{-1}

8 Fourier-Shell correlation [i](#)

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 [i](#)



*Reported resolution corresponds to spatial frequency of 0.398 Å⁻¹

8.2 Resolution estimates [i](#)

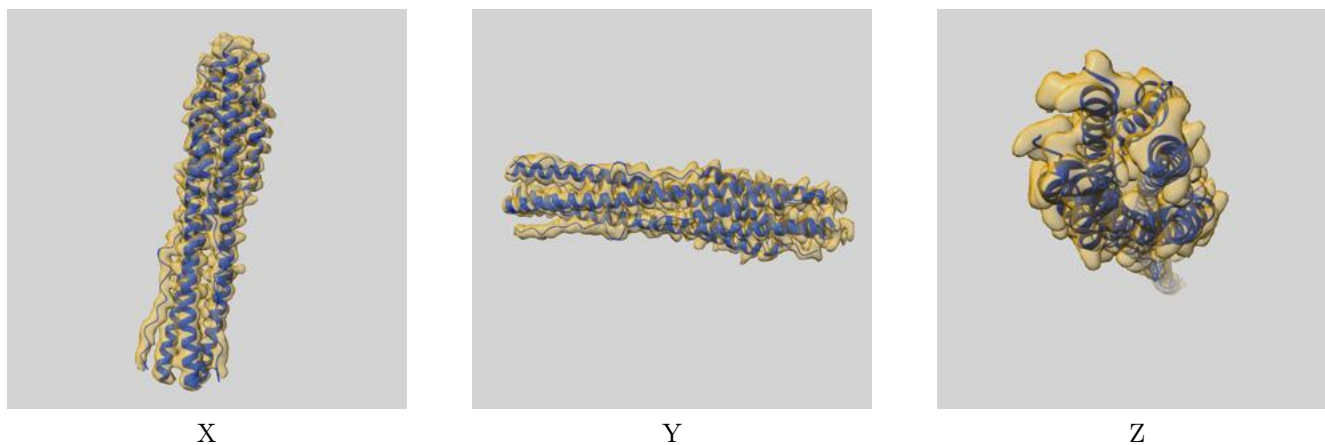
Resolution estimate (Å)	Estimation criterion (FSC cut-off)		
	0.143	0.5	Half-bit
Reported by author	2.51	-	-
Author-provided FSC curve	-	-	-
Unmasked-calculated*	2.86	3.34	2.94

*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 2.86 differs from the reported value 2.51 by more than 10 %

9 Map-model fit [i](#)

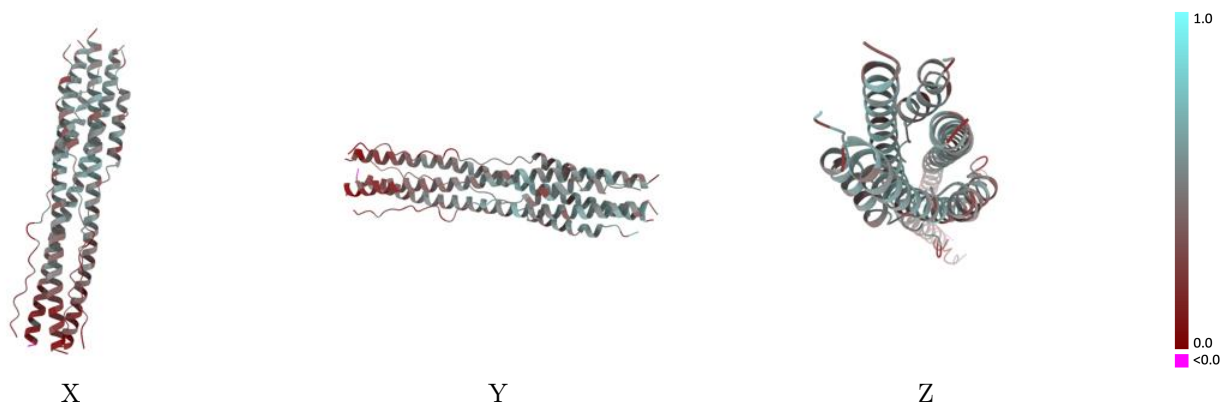
This section contains information regarding the fit between EMDB map EMD-28947 and PDB model 8FA1. Per-residue inclusion information can be found in section 3 on page 6.

9.1 Map-model overlay [i](#)



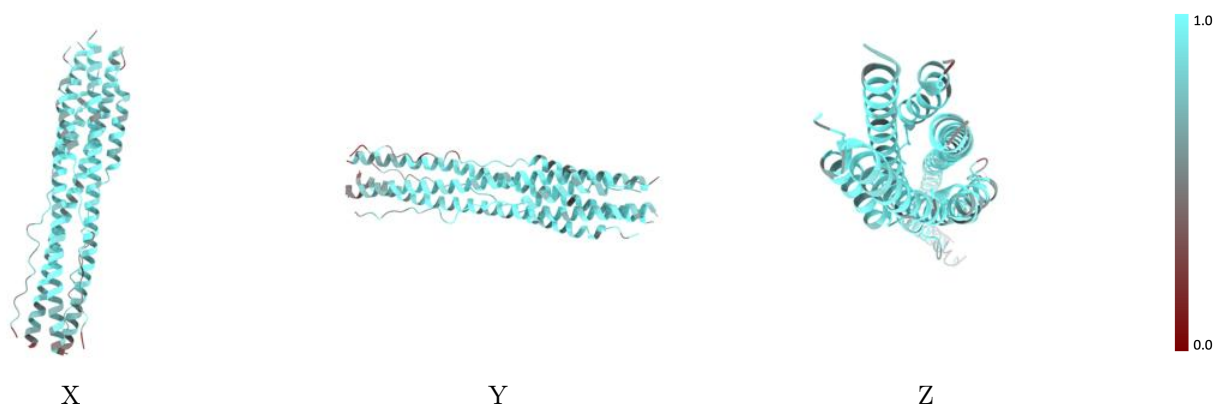
The images above show the 3D surface view of the map at the recommended contour level 0.05 at 50% transparency in yellow overlaid with a ribbon representation of the model coloured in blue. These images allow for the visual assessment of the quality of fit between the atomic model and the map.

9.2 Q-score mapped to coordinate model [\(i\)](#)



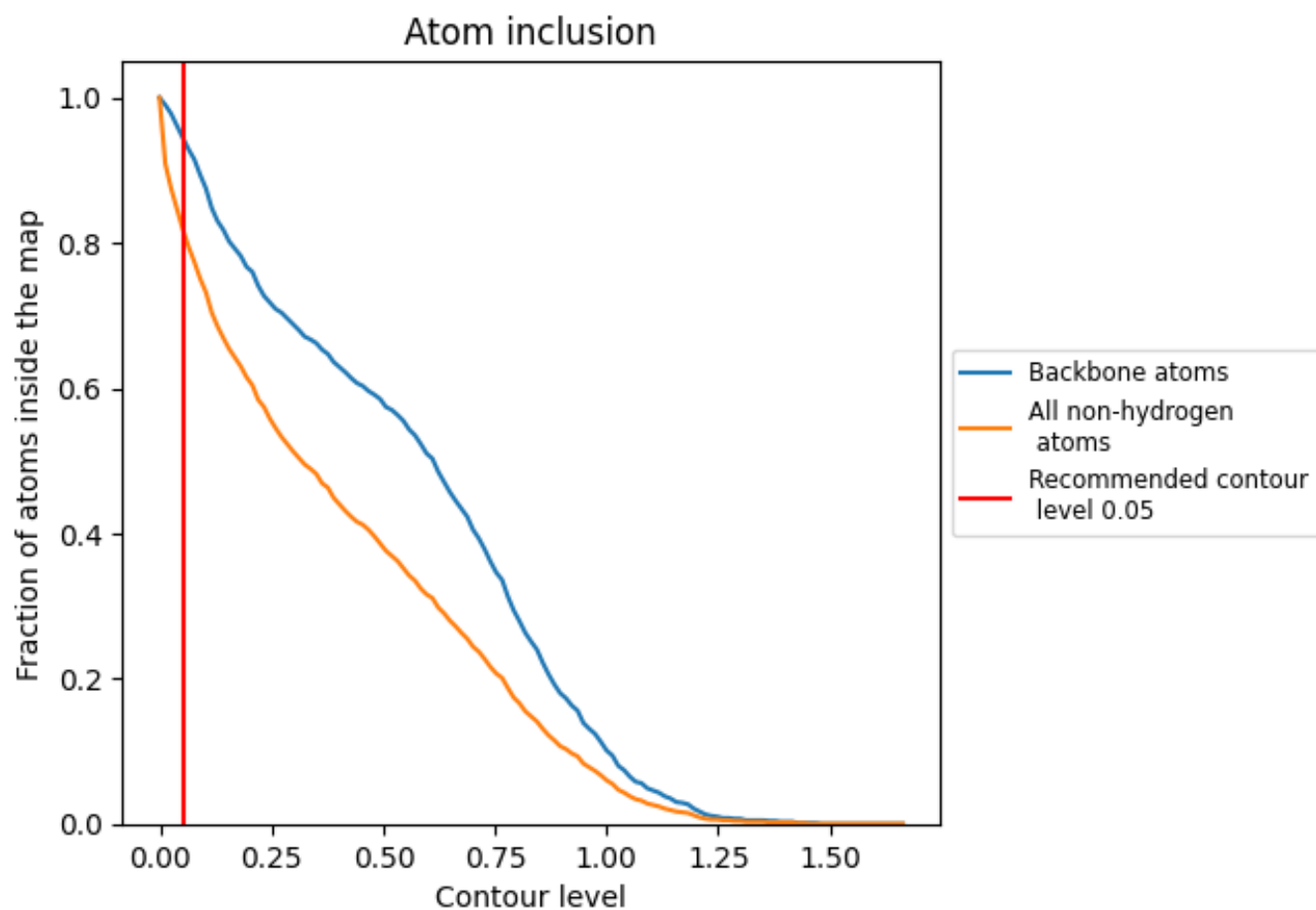
The images above show the model with each residue coloured according to its Q-score. This shows their resolvability in the map with higher Q-score values reflecting better resolvability. Please note: Q-score is calculating the resolvability of atoms, and thus high values are only expected at resolutions 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 [\(i\)](#)



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 (0.05).















9.4 Atom inclusion [i](#)



At the recommended contour level, 94% of all backbone atoms, 82% of all non-hydrogen atoms, are inside the map.

9.5 Map-model fit summary [i](#)

The table lists the average atom inclusion at the recommended contour level (0.05) and Q-score for the entire model and for each chain.

Chain	Atom inclusion	Q-score
All	 0.8190	 0.4270
A	 0.8510	 0.4470
B	 0.8590	 0.4420
C	 0.8380	 0.4240
D	 0.7980	 0.4360
E	 0.7190	 0.3770
F	 0.7890	 0.4150

