

Validation: data analysis

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phenix-online.org



lbl.gov

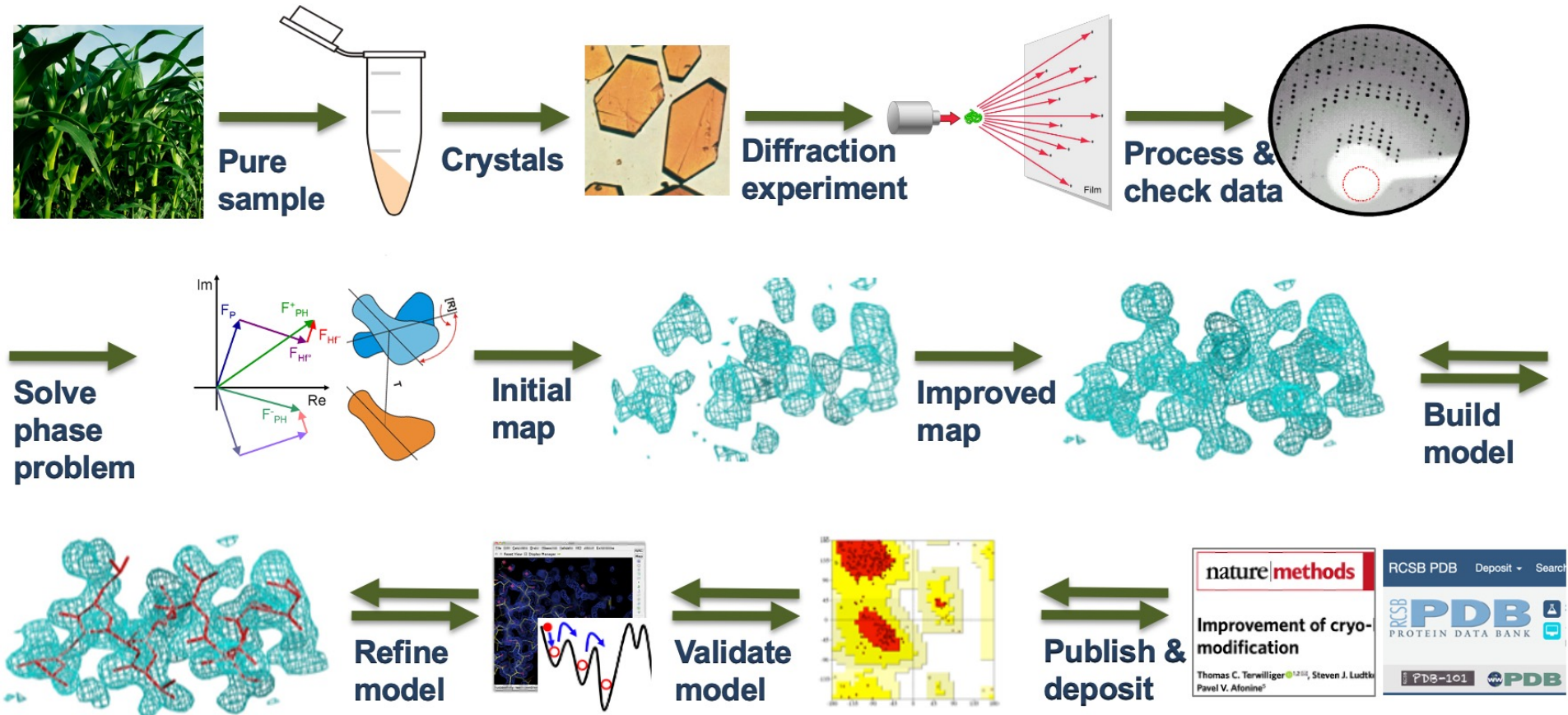


qrefine.com

Hosted by the Oklahoma COBRE in Structural Biology

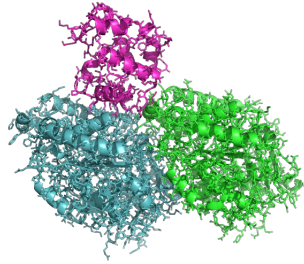
March 18th 2024

Solving structure by crystallography

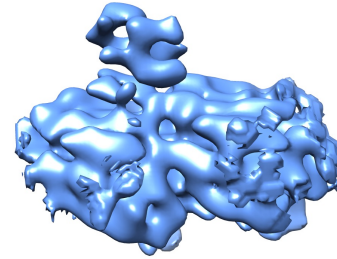


Validation

Model

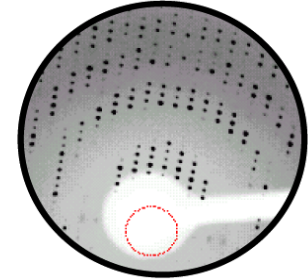


Data



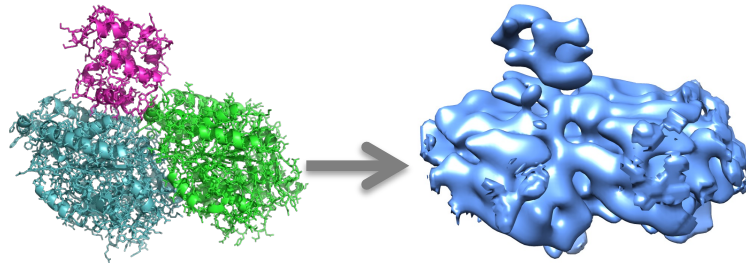
Cryo-EM

or



Diffraction

Model to data fit

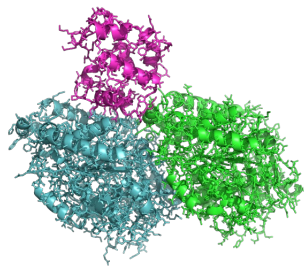


Validation = checking model, data and model-to-data fit are all make sense and obey to prior expectations

Validation tools: *Crystallography vs Cryo-EM*

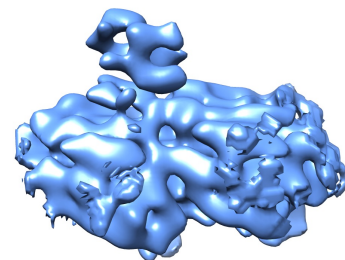
Exact same

Model



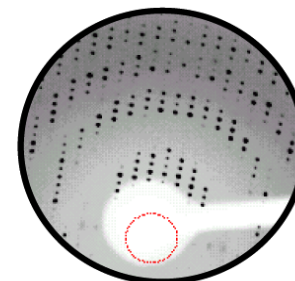
Different

Data



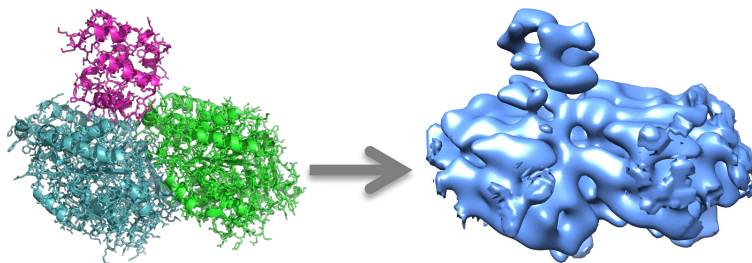
Cryo-EM

or



Diffraction

Model to data fit



Similar

Validation tools in Phenix

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Actions Job history

Projects

Show group: All groups Manage...

Select Delete New project Settings

ID	Last modified	# of jobs	R-free
✓ ChrisF	Apr 13 2020 09:42...	28	0.1944
real-space-refin...	Apr 03 2020 07:42...	2	---
zzz1	Mar 21 2020 09:10...	1	---
chris	Mar 12 2020 12:27...	11	0.1890
dan	Mar 11 2020 05:44...	1	---
3j63	Mar 11 2020 02:28...	1	---
jason	Mar 11 2020 11:36...	1	---
rt6	Mar 11 2020 10:31...	1	0.2459
mate	Mar 10 2020 01:36...	1	---
emily	Mar 09 2020 03:52...	3	---
—	Mar 05 2020 08:25...	3	0.1923
alex	Feb 27 2020 11:33...	6	---
rt20201	Feb 18 2020 12:50...	4	0.2213
1f8t	Feb 03 2020 09:00...	1	0.1977
real-space-refin...	Jan 30 2020 02:38...	2	---
real-space-refin...	Jan 29 2020 10:56...	1	---
ion_channel_den...	Jan 27 2020 07:36...	3	---
10101	Jan 27 2020 12:38...	2	---
demos	Jan 27 2020 10:57...	3	---
ion_channel_den...	Jan 27 2020 10:03...	2	---
malcolm	Jan 22 2020 10:22...	14	0.1748
real-space-refin...	Jan 16 2020 04:28...	3	---
3NIR	Dec 05 2019 10:2...	1	---
leighton	Sep 02 2019 05:1...	2	---
5pti	Aug 27 2019 03:4...	3	---

Favorites

Data analysis

- Xtrriage**
Analysis of data quality and crystal defects
- Merging statistics**
Calculates a variety of statistics for unmerged intensities, including I/sigma, R-merge, R-meas, and CC1/2.
- Mtrriage**
Analyze quality of maps in CCP4 format

Experimental phasing

Molecular replacement

Model building

Refinement

Cryo-EM

Validation

- Comprehensive validation (X-ray/Neutron)**
Model quality assessment, including real-space correlation and geometry inspection using MolProbity tools
- Comprehensive validation (cryo-EM)**
Model quality assessment, including real-space correlation, for cryo-EM structures

Structure comparison

Identify differences between multiple structures of the same protein, using multiple criteria

Calculate CC*

Comparison of unmerged data quality with refined model, as described in Karplus & Diederichs (2012)

EMRinger

Model validation for de novo electron microscopy structures

Ligands

Current directory: /Users/pafonine/Desktop/all/people/ChrisF Browse...

PHENIX version dev-svn-000 Project: ChrisF

Xtrriage: all about your diffraction data

- Matthews coefficient probabilities
- Completeness by resolution
- Wilson plot sanity
- Detection of translational NCS (tNCS)
- Analysis of systematic absences and combination of tNCS with current space group
- Anomalous signal from measurability analysis
- Symmetry and twinning analyses
- Alternative point-group symmetry (can be detected on the basis of an R-value analyses)

Xtrriage

Xtrriage (Project: porin-twin)

Preferences Help Run Abort View log Save graph Ask for help

Configure **Xtrriage_1**

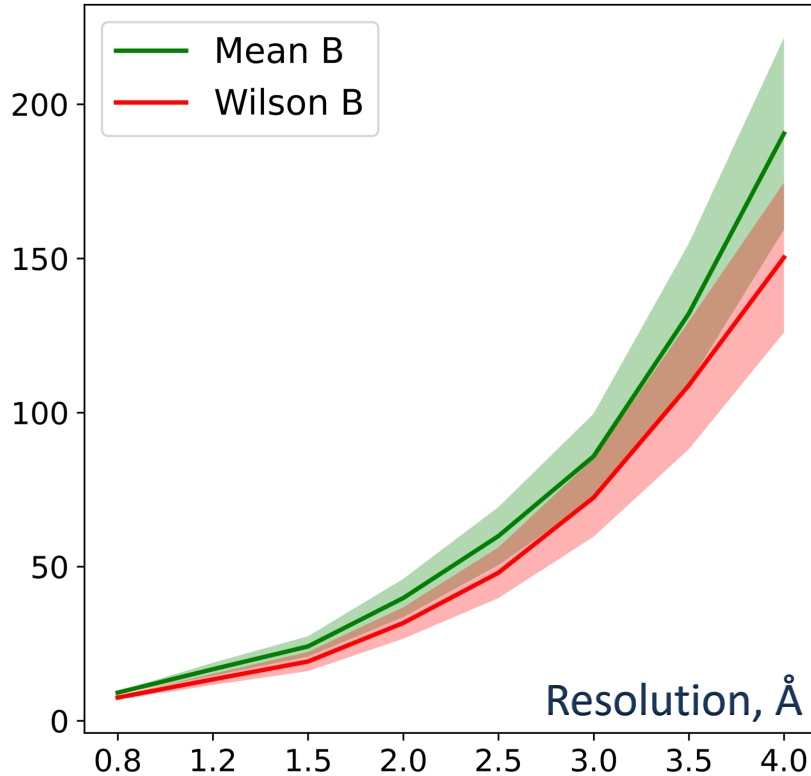
Run status **Results**

Xtrriage summary

- Intensity statistics suggest twinning (intensities are significantly different from expected for normal data) and one or more twin operators show a significant twin fraction.
- Translational NCS does not appear to be present.
- Ice rings do not appear to be present.
- The fraction of outliers in the data is less than 0.1%.
- The data are not significantly anisotropic.
- The resolution cutoff appears to be similar in all directions.
- The overall completeness in low-resolution shells is at least 90%.
- Overall completeness is above 90%.

Wilson B

Whole PDB (quality filtered)

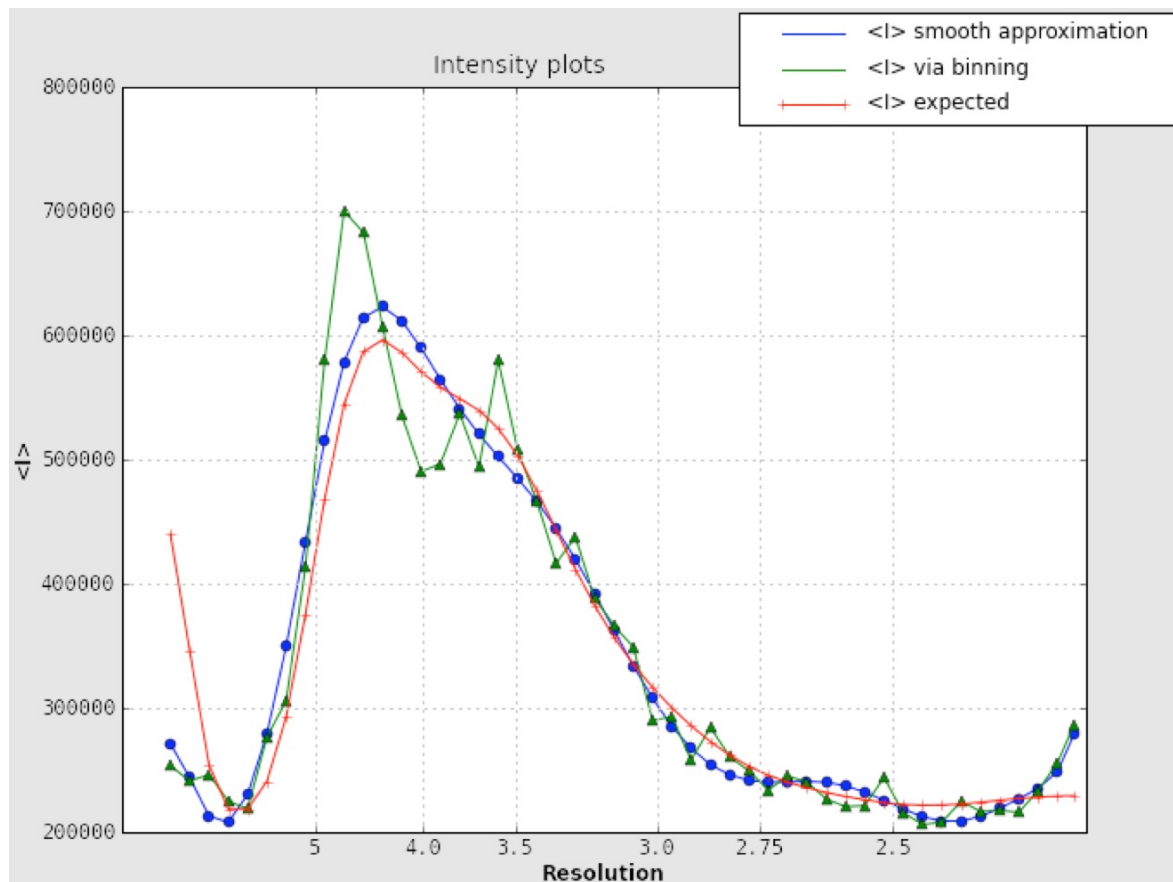


Wilson statistics assumes atoms of the same kind are randomly distributed in the unit cell and have the same isotropic B-factors

- Mean B and Wilson B are usually similar
- Wilson B is dominated by strongly diffracting (lower B) atoms that contribute more to high-res reflections
 - Wilson B represents the lower end of the range of B-factors
 - Discrepancy between Wilson B and mean B is not important

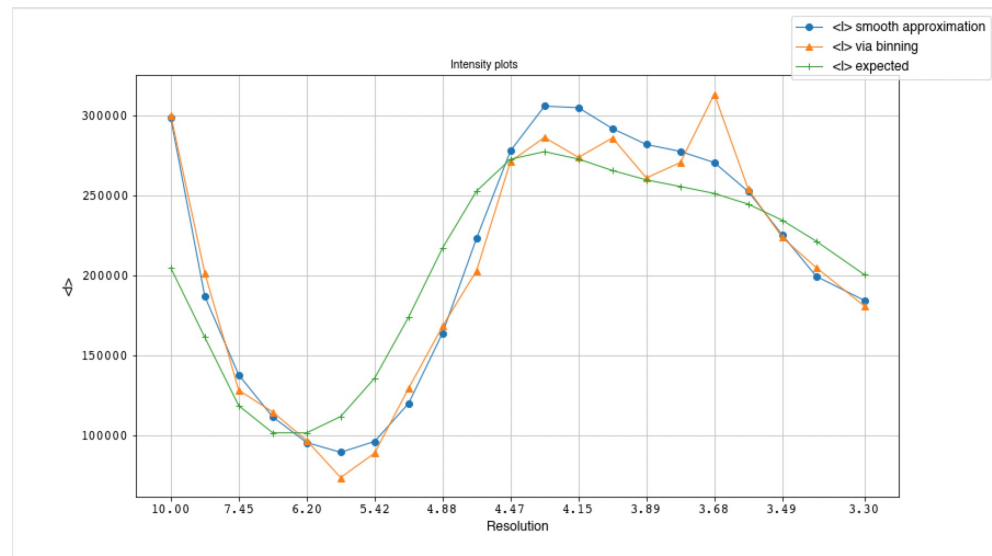
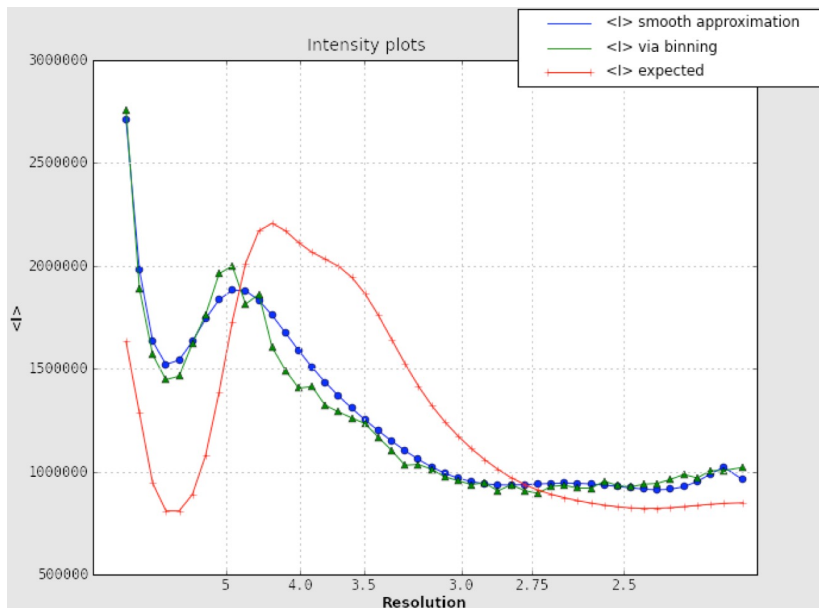
Wilson plot (mean intensity vs resolution)

- The Wilson plot looks at mean intensity of diffraction by resolution, a curve which has a predictable shape



Wilson plot (mean intensity vs resolution)

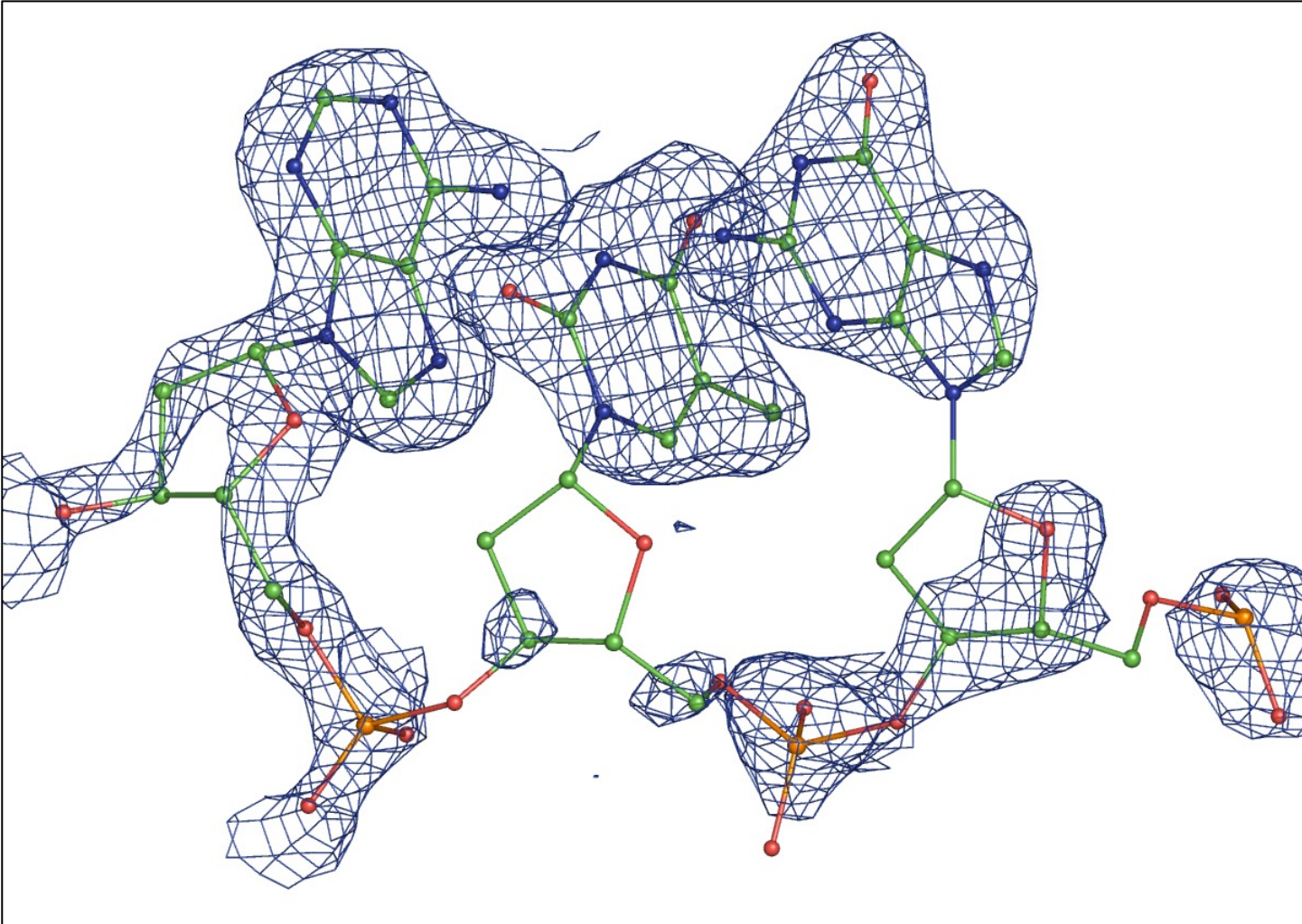
- Main reasons for deviations from expected distribution
 - Bad data (e.g., ice rings or poor data processing)
 - Macromolecule that doesn't look like the average protein
 - Looking at only a part of the plot (e.g., low-resolution data)



Data completeness

- PDB code: 1NH2, resolution 1.9Å, showing E6-E8

2mFo-DFc , 1σ



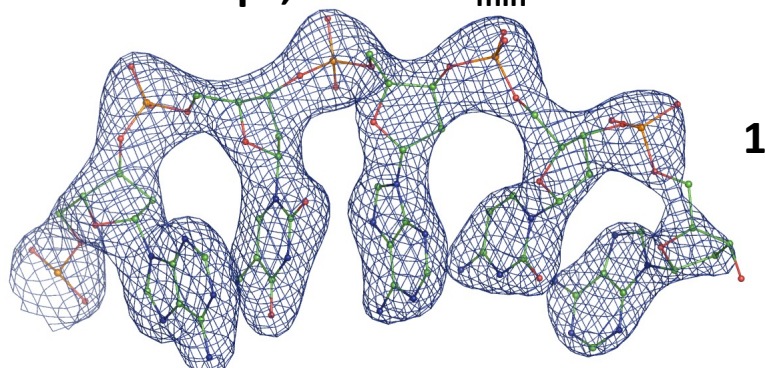
Data completeness

Completeness by resolution:

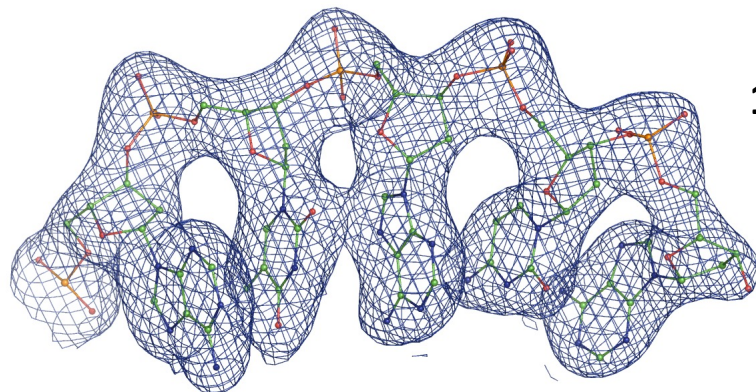
19.9274	-	3.2441	0.78
3.2441	-	2.5767	0.99
2.5767	-	2.2515	1.00
2.2515	-	2.0459	1.00
2.0459	-	1.8993	0.99

Overall completeness in d_{\min} -inf: 0.95

Fcalc maps, full set d_{\min} -inf

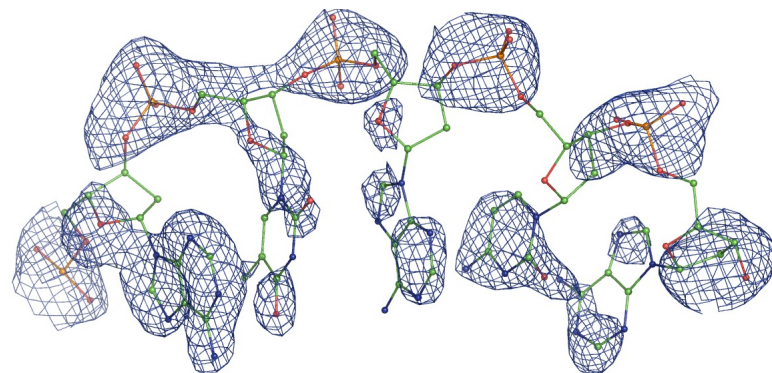
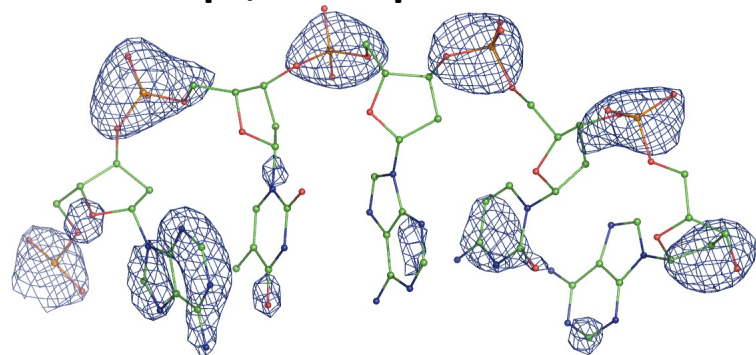


1.5 σ map cutoff



1 σ map cutoff

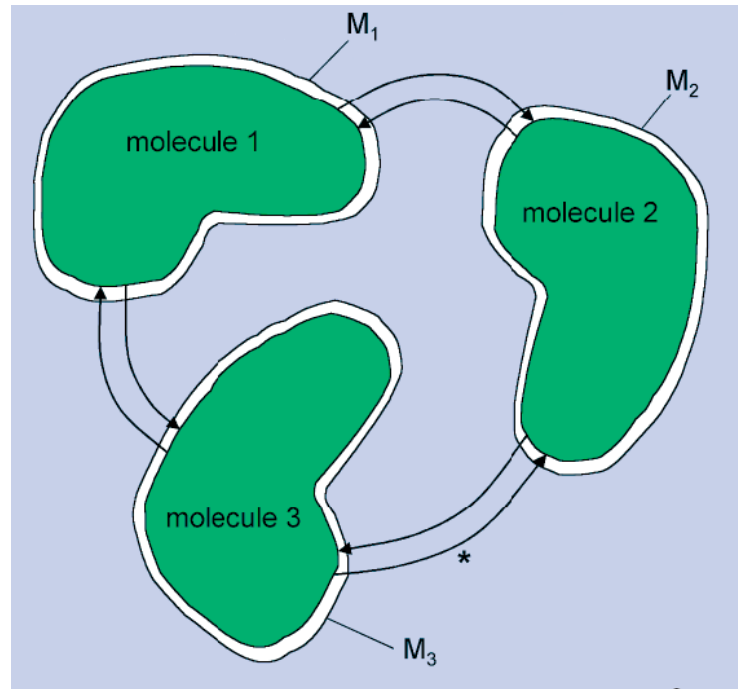
Fcalc maps, incomplete set



Systematic data incompleteness can distort maps

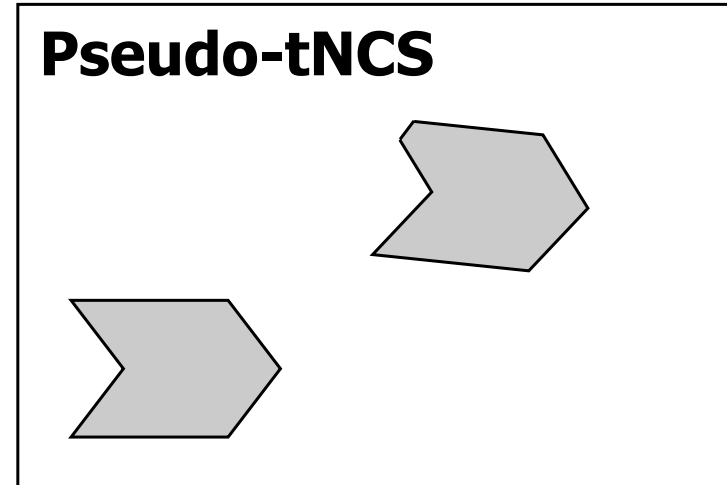
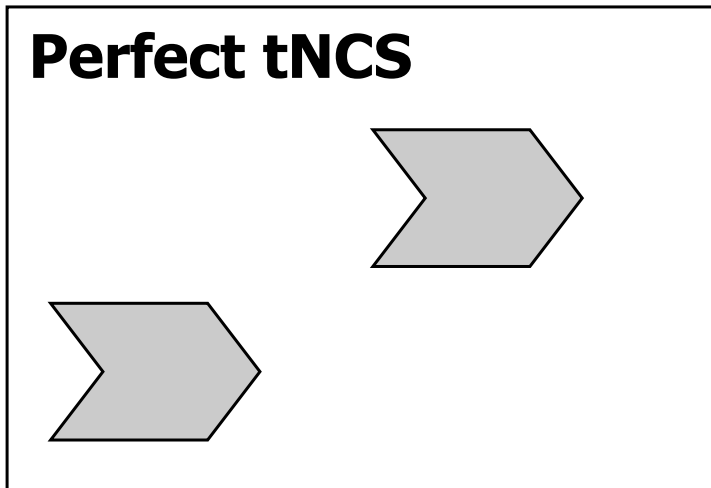
Non-crystallographic symmetry NCS

- Two or more molecules in the ASU related by rotation-translation
- NCS is found in about 1/3 to 1/2 of crystal structures
- Usually helps solving/refining models at medium-to-low resolution
- A special case of NCS, translational NCS (tNCS) leads to complications



Translational NCS (tNCS)

- tNCS arises when the ASU contains components that are oriented in (nearly) the same way and can be superimposed by a translation that does not correspond to any symmetry operation in the space group.



- Used to complicate MR (Phaser now can deal with it!)
- Risk to bias OMIT map

Translational NCS (tNCS)

The screenshot shows the Xtrialog software interface for project 1j4r. The window title is "Xtrialog (Project: 1j4r)". The top toolbar contains icons for Preferences, Help, Run, Abort, View log, Save graph, and Help. Below the toolbar, there are tabs for "Configure" (with a sub-tab "Xtrialog_1") and "Run status" (with a sub-tab "Results"). The main content area is titled "Xtrialog summary" and contains a list of diagnostic results:

- Translational NCS is present at a level that may complicate refinement (one or more peaks greater than 20% of the origin)
- The intensity statistics look normal, indicating that the data are not twinned.
- Ice rings do not appear to be present.
- The fraction of outliers in the data is less than 0.1%.
- The data are not significantly anisotropic.
- The resolution cutoff appears to be similar in all directions.
- The overall completeness in low-resolution shells is at least 90%.
- The completeness is 98.98%.

Below the list, a note states: "Please inspect all individual results closely, as it is difficult to automatically detect all issues."

The status bar at the bottom left shows "Idle" and the bottom right shows "Project: 1j4r".

Translational NCS (tNCS) and twinning

Xtriage (Project: 1j4r)

Preferences Help Run Abort View log Save graph Help

Configure Xtriage_1

Run status Results

Diagnostic tests for twinning and pseudosymmetry

Using data between 10.00 to 2.21 Angstrom.

Patterson analyses

Largest Patterson peak with length larger than 15 Angstrom:

Frac. coord.	:	0.333	-0.333	-0.330
Distance to origin	:	41.406		
Height relative to origin	:	62.542 %		
p_value(height)	:			

1.109e-05

Explanation

The p-value, the probability that a peak of the specified height or larger is found in a Patterson function of a macromolecule that does not have any translational pseudo-symmetry, is equal to 1.109e-05. p_values smaller than 0.05 might indicate weak translational pseudo symmetry, or the self vector of a large anomalous scatterer such as Hg, whereas values smaller than 1e-3 are a very strong indication for the presence of translational

Translational pseudo-symmetry is very likely present in these data. Be aware that this will change the intensity statistics and may impact subsequent analyses, and in practice may lead to higher R-factors in refinement.

Wilson ratio and moments

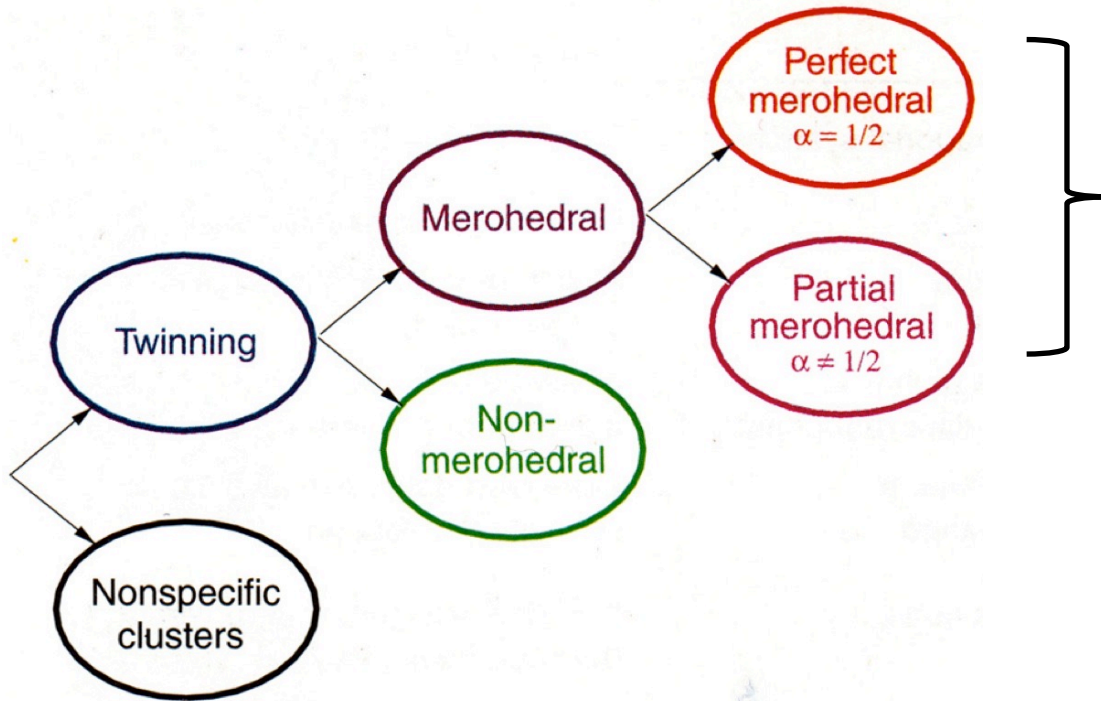
Acentric reflections:

$\langle I^2 \rangle / \langle I \rangle^2$:	2.430	(untwinned: 2.000; perfect
twin 1.500)			
$\langle F^2 \rangle / \langle F \rangle^2$:	0.750	(untwinned: 0.785; perfect
twin 0.885)			

Idle Project: 1j4r

Twinning

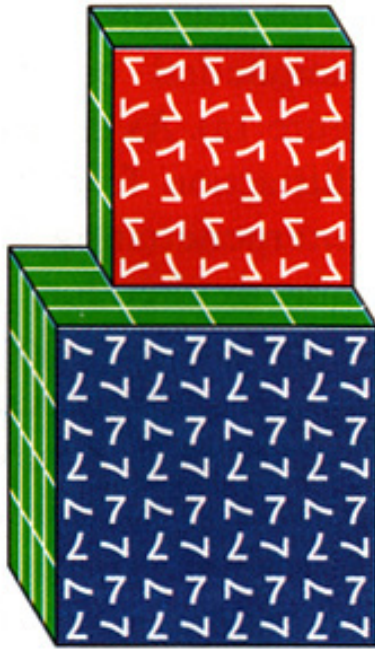
- Twinning is a crystal growth disorder



Typically only merohedral twinning is dealt with in a meaningful way in macromolecules

Twinning

- Merohedral twinning occurs when your crystal is composed of identical but rotated crystals combined together such that their lattices matching



- Observed intensity is a weighted sum of individual intensities:

$$I_{\text{OBS}}(\mathbf{h}) = \alpha_1 I(\mathbf{h}) + \dots + \alpha_N I(\mathbf{T}_N \mathbf{h})$$

$$\alpha_1 + \dots + \alpha_N = 1$$

Twinning

- Twinning parameterization
 - **Twin law** describes orientation of different species relative to each other (rotation matrix T that transforms hkl indices of one species into the other)
 - **Twin fraction (α)**: fractional contribution of each component
 - Estimated by Xtriage
 - Refined by phenix.refine

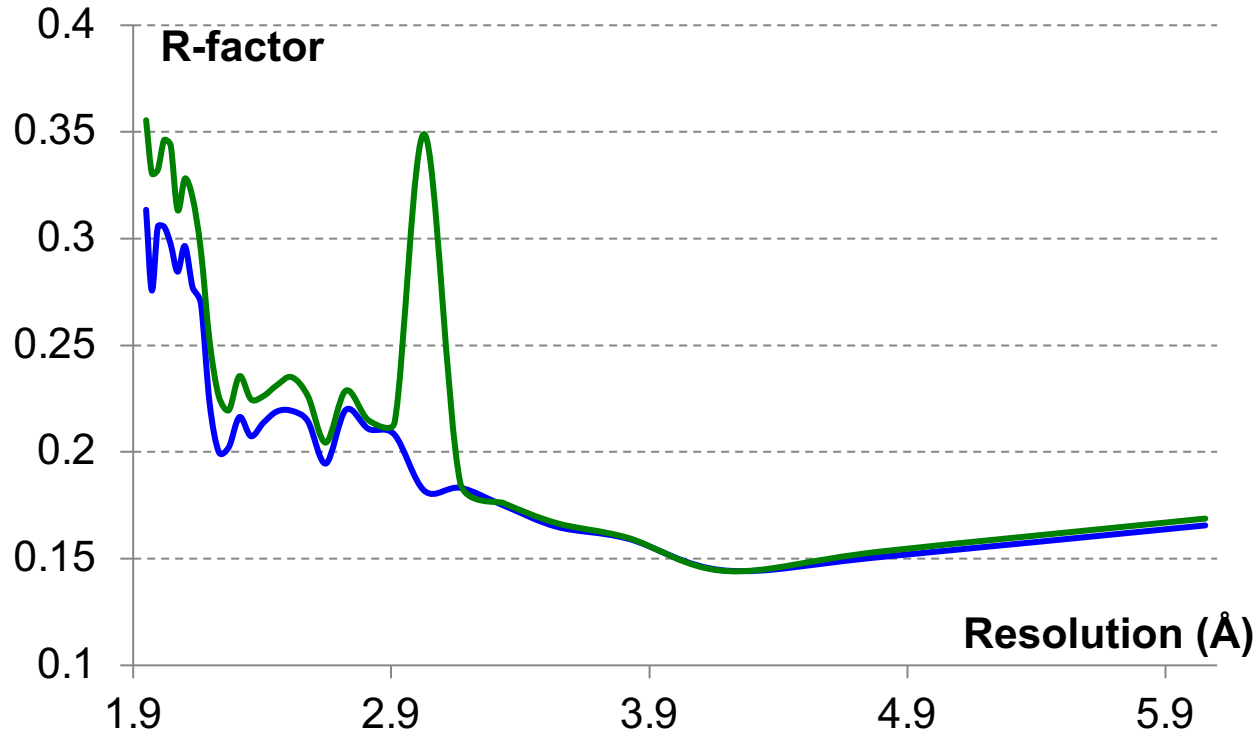
$$I_{\text{OBS}}(\mathbf{h}) = \alpha_1 I(\mathbf{h}) + \dots + \alpha_N I(\mathbf{T}_N \mathbf{h})$$

$$\alpha_1 + \dots + \alpha_N = 1$$

Twinning

- tNCS can mask effects of twinning
- If both are present, intensity distributions may look like normal
 - First check for tNCS and use different test for twinning (L-test)
- If crystal is twinned, you have lost information
- Maps going to have model bias that is worse than usual
- Experimental phasing may be difficult
- False symmetry may appear

Watch for outliers



- **R-factor in resolution bins helps to identify:**

- **Problem with bulk-solvent modeling**
- **Problems at high resolution**
- **Artifacts (green line):**

INDE 3 5 -42 IOBS= 99999.999 SIGIOBS= 0.000