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FM in CASP9

Lisa N. Kinch, **ShuoYong Shi**,
Qian Cong, Hua Cheng, Yuxing Liao,
Wenlin Li, Dustin Schaeffer & Nick V. Grishin

Howard Hughes Medical Institute and Biochemistry Department,
University of Texas Southwestern Medical Center,
Dallas, Texas, USA

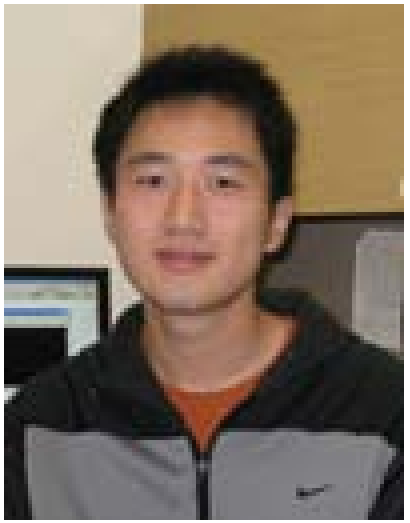
Lisa N. Kinch
research scientist

ShuoYong Shi
postdoc

Qian Cong
graduate student

Hua Cheng
postdoc

Wenlin Li
graduate student



Yuxing Liao
graduate student

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Our group

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Qian Cong
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Hua Cheng
Wenlin Li
Yuxing Liao
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Jing Tong
Raquel Bromberg
Chalam Chitturi
Sasha Safronova
Bong-Hyun Kim
Jeremy Semeiks

PREDICTORS for submitting models

CASP organizers

John Moult, CASP **president**, UM, USA
Krzysztof Fidelis, UC Davis, USA
Andriy Kryshtafovych, UC Davis, USA
Anna Tramontano, U of Rome, Italy

CASP9 assessors:

Torsten Schwede, UBasel, Switzerland
Ken Dill, UCSF, USA
Justin MacCallum, UCSF, USA

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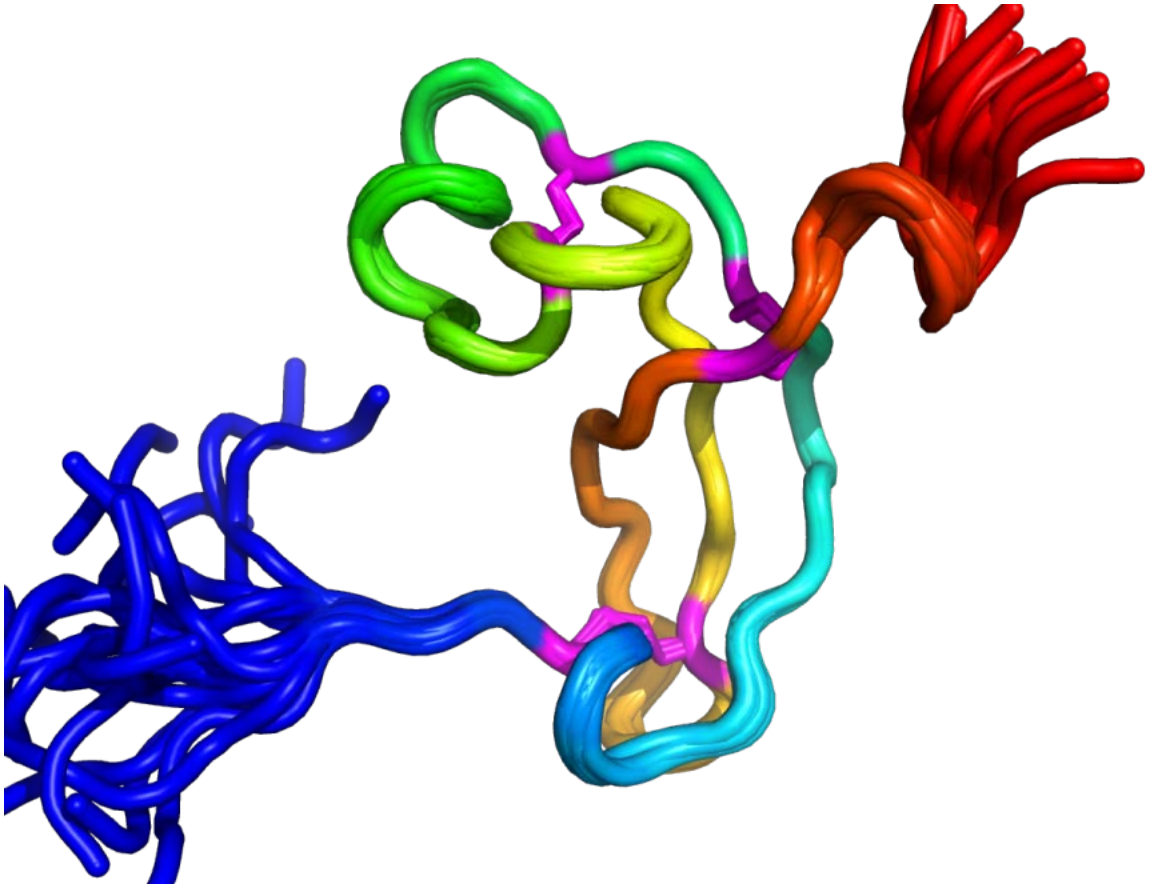

T0531

Talk plan

- Introduction: FM winner in CASP9!
- Manual Assessment
- New Scoring Function
- Meta-scoring in Assessment
- The bloody Ranking
- Problems and successes

Talk plan

- Introduction: FM winner in CASP9!
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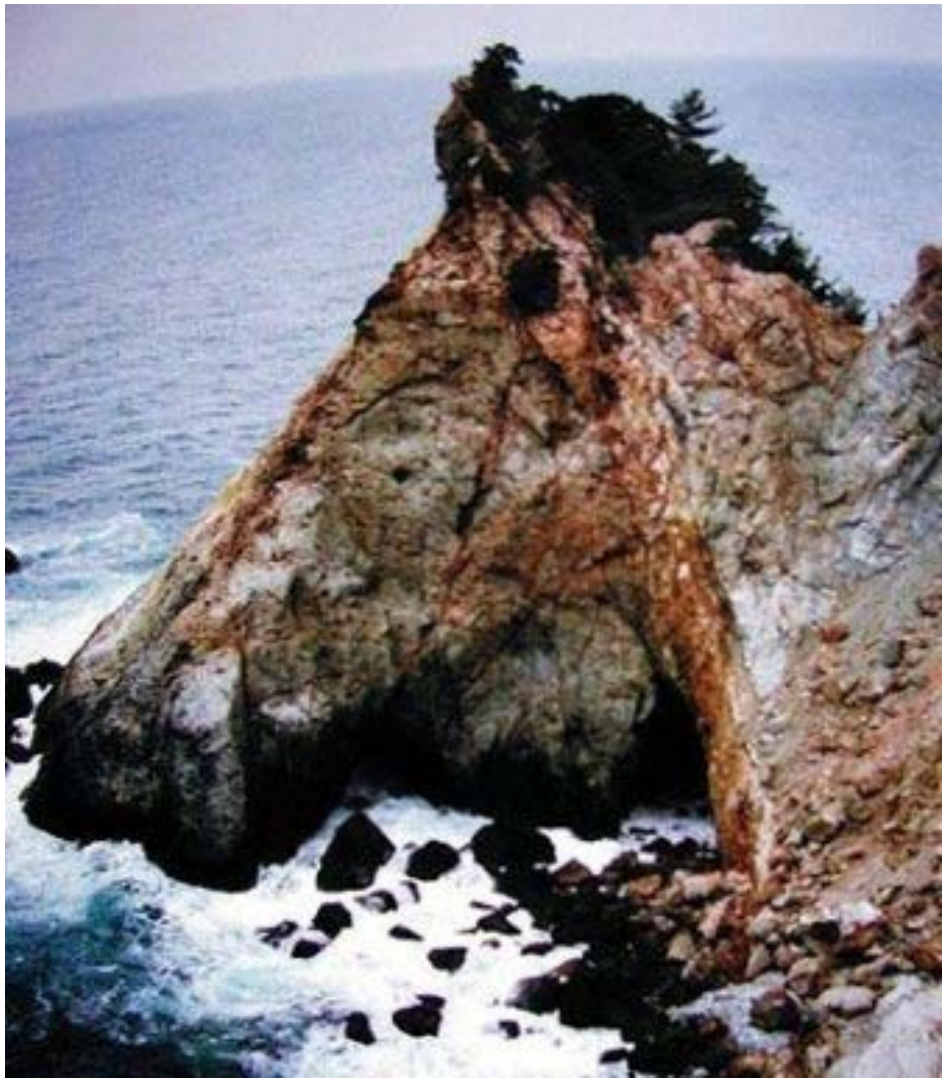
Free up your Minds

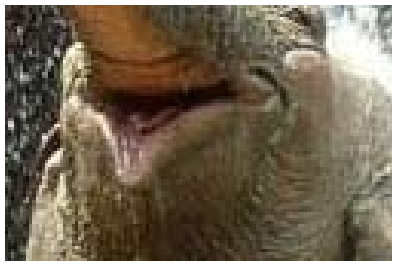
Free up your Minds



Free up your Minds

Torsten’s glass

TBM ant



FM elephant

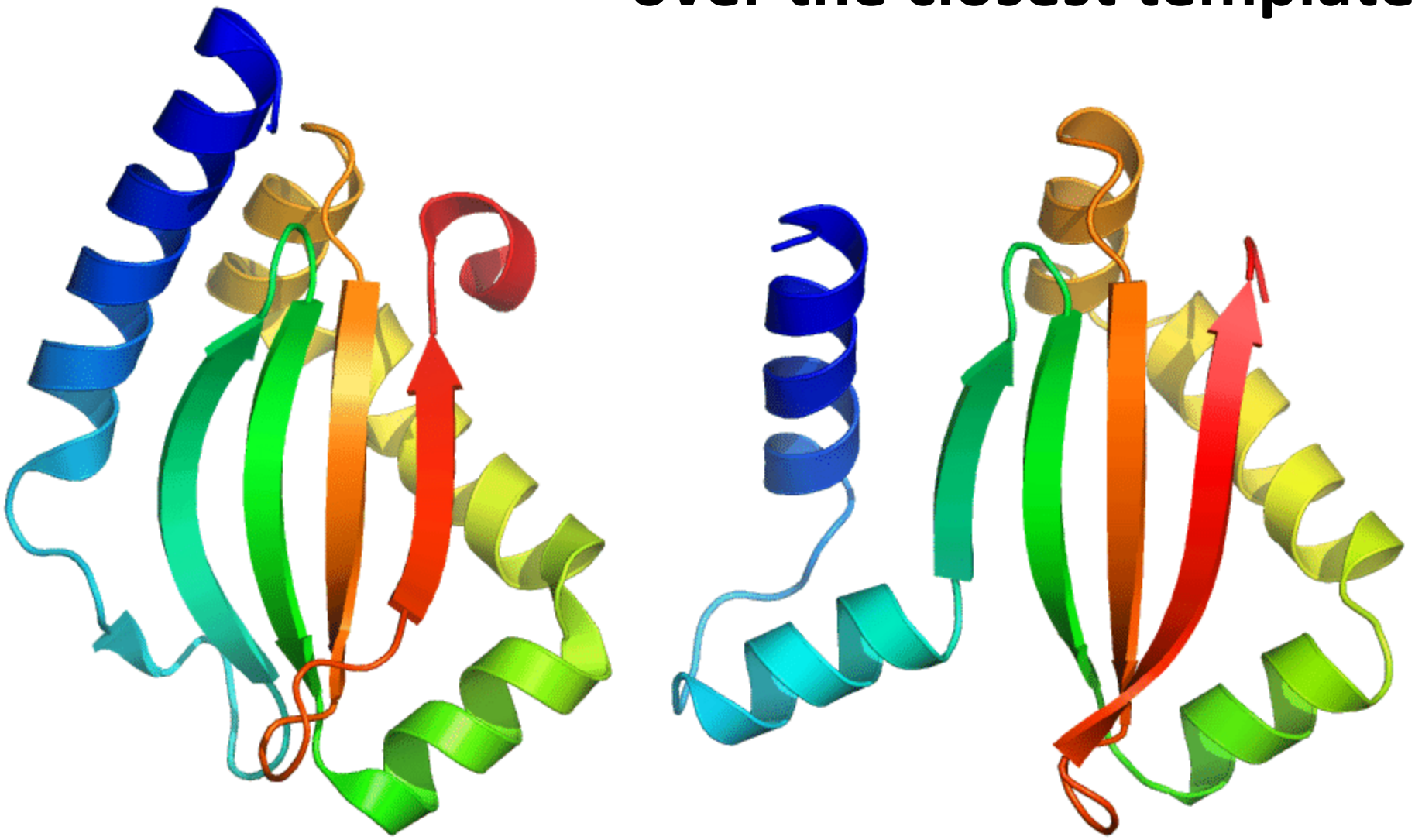
CASP9 winner: **Model 4**

for target **581** from server 321

But it was HARD to figure that out !!!

Why do we think it is the winner?

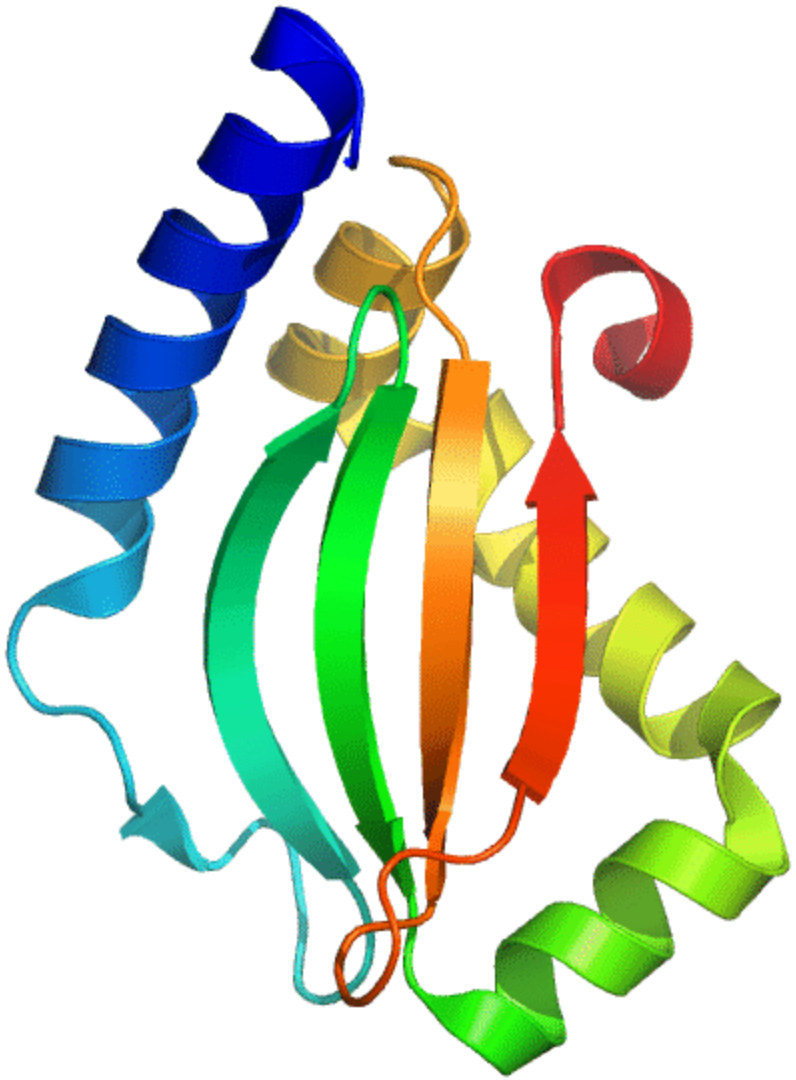
Reason #1: the largest “improvement” over the closest template



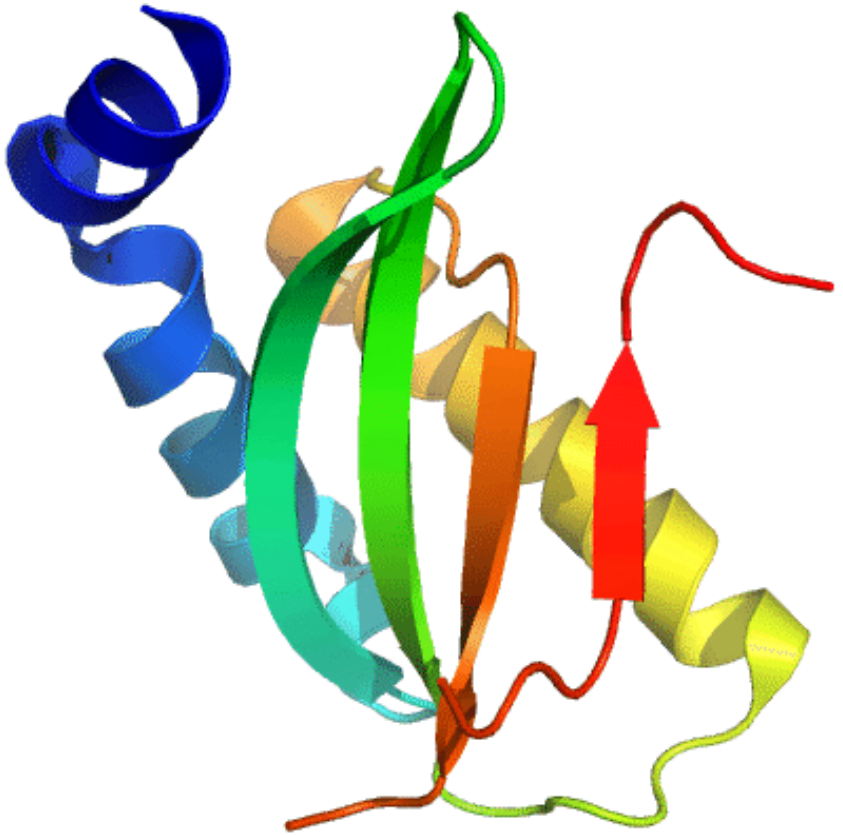
structure

model

Reason #1: the largest “improvement” over the closest template

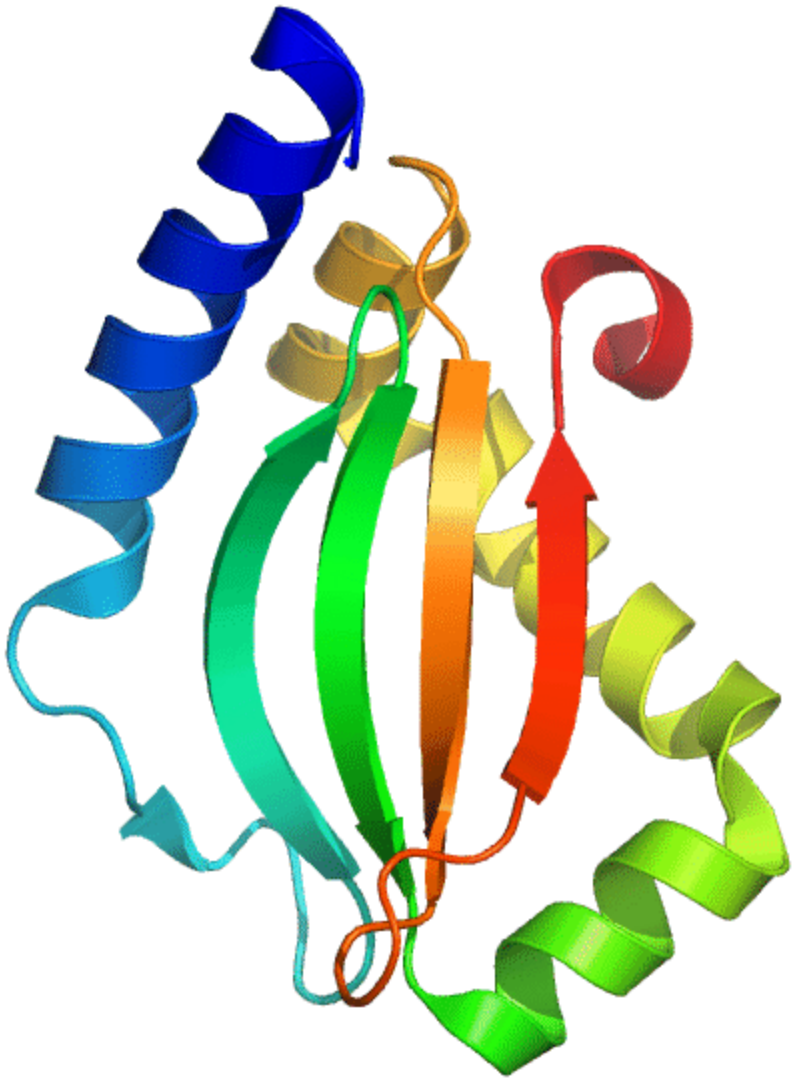


structure

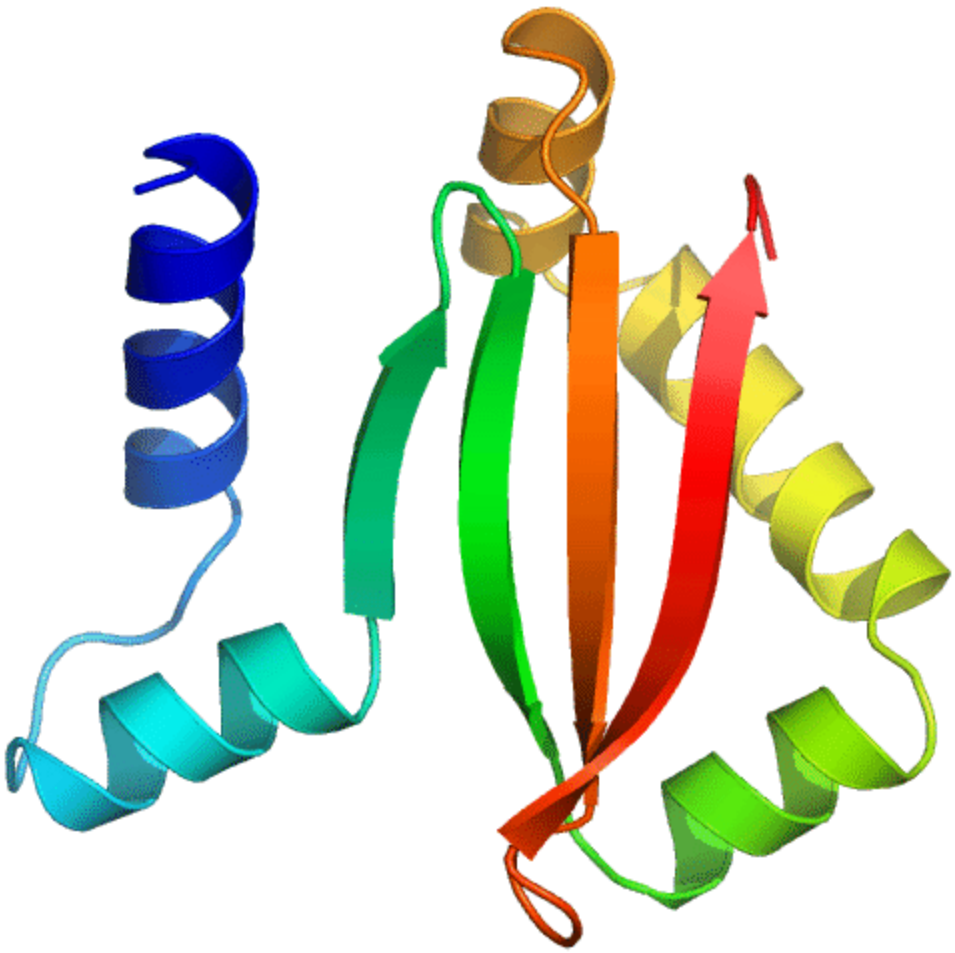


fatty acyl-adenylate ligase
C-terminal domain : 3lnv

Reason #1: the largest “improvement” over the closest template



structure



“improve” GDT by **44%**
compared to the best template

Reason #2: nobody else got it right

- although … it wasn't the best-scoring model;

- all "humans" who got 581 right (apparently) selected and modified this particular model;

- running ROSETTA locally gives this model

Reason #3: secondary structure prediction was VERY wrong

```
Conf: 9168998999982001110000000289999998622047882002767752483000 89
Pred: CHHHHHHHHHHHHCCHHHHHHHHHHHHHHHHHHHHHHHHCCCCCCCCCCHHHHHCCCCCCHH

AA:   MSRFMALALCFVLPTAAHAASLKDFELSKMLEKVAKESSVGTPRAINEDILDQGYTVEGN


Conf: 988888765768999641989999974014431322898850455578986110068861
Pred: HHHHHHHHHHHHHHHHHCCHHHHHHHHHHHHCCCCHHHHHHCCCEEEEEEEEECCCCCH

  AA: QLINHLSVRASHAERMRSNPDSVRSQLGDSVCSNTGYRQLLARGAILTYSFTEYKTNQPV


Conf: 465410100014687 9
Pred: HHHHHCCCCCCCCCCCC

  AA: ATERFDAGSCRIQGKK
```

Reason #3: secondary structure prediction was VERY wrong

```
Conf: 9168998999982001110000000289999998622047882002767752483000 89
Pred: CHHHHHHHHHHHHCCHHHHHHHHHHHHHHHHHHHHHHHCCCCCCCCCCHHHHHCCCCCCHH
DSSP: ..................CCHHHHHHHHHHHHHHHHHTTCSEESSSSEEEEEEEEETT
AA:   MSRFMALALCFVLPTAAHAASLKDFELSKMLEKVAKESSVGTPRAINEDILDQGYTVEGN

Conf: 9888887657689964198999997401443132289885045557898610068861
Pred: HHHHHHHHHHHHHHHHHCCHHHHHHHHHHHHHCCCCHHHHHHCCCEEEEEEEEECCCCCH
DSSP: EEEEEEEECHHHHHHHHHCHHHHHHHHHHHHHHTCHHHHHHHTTTCEEEEEEEETTTCCEE
  AA: QLINHLSVRASHAERMRSNPDSVRSQLGDSVCSNTGYRQLLARGAILTYSFTEYKTNQPV

Conf: 465410100014687 9
Pred: HHHHHCCCCCCCCCCC
DSSP: EEEEECHHHHC.....
  AA: ATERFDAGSCRIQGKK
```

```
Conf: 9168998999982001110000000289999998622047882002767752483000 89
Pred: CHHHHHHHHHHHHCCHHHHHHHHHHHHHHHHHHHHHHHCCCCCCCCCCHHHHHCCCCCCHH
DSSP: ....................CCHHHHHHHHHHHHHHHHHTTCSEESSSSEEEEEEEEETT
AA:   MSRFMALALCFVLPTAAHAASLKDFELSKMLEKVAKESSVGTPRAINEDILDQGYTVEGN

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  AA: QLINHLSVRASHAERMRSNPDSVRSQLGDSVCSNTGYRQLLARGAILTYSFTEYKTNQPV

Conf: 465410100014687 9
Pred: HHHHHCCCCCCCCCCC
DSSP: EEEEECHHHHC.....
  AA: ATERFDAGSCRIQGKK
```
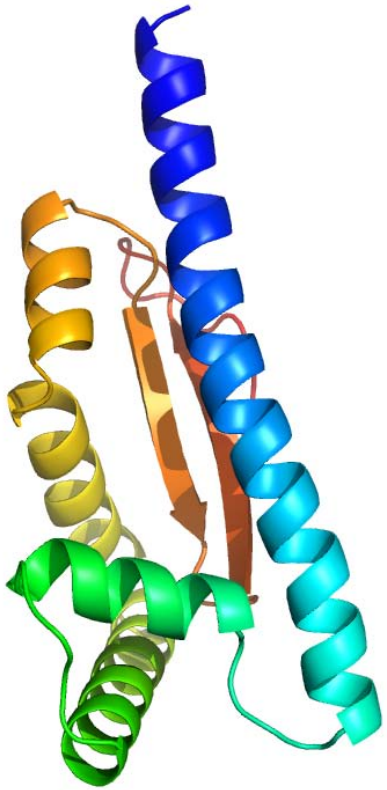
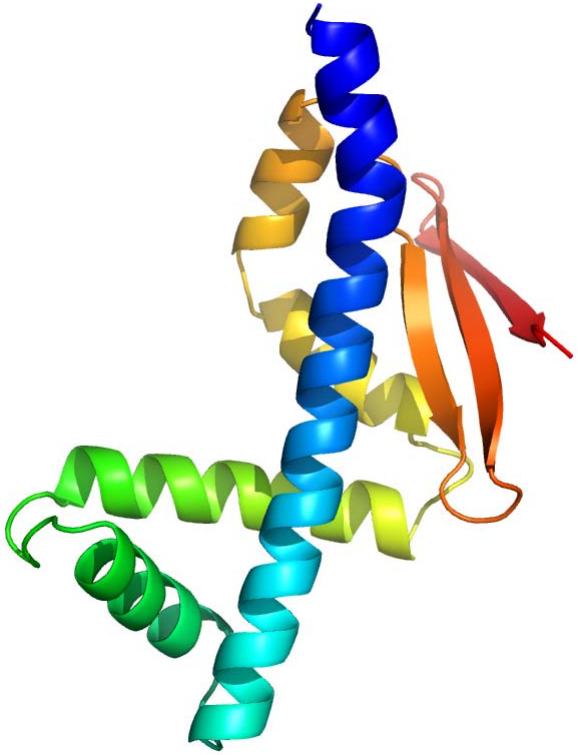
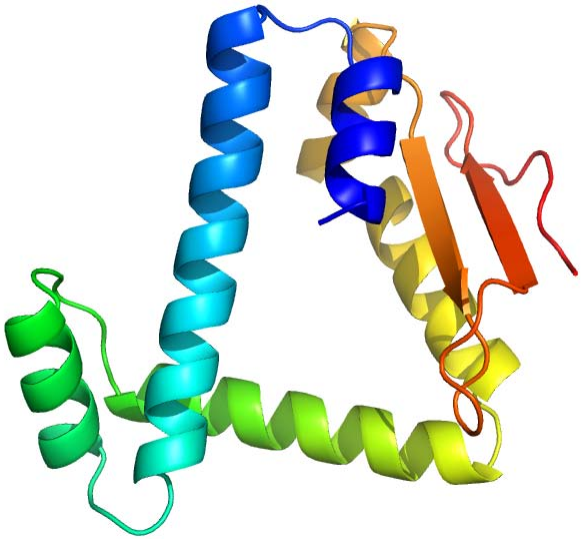
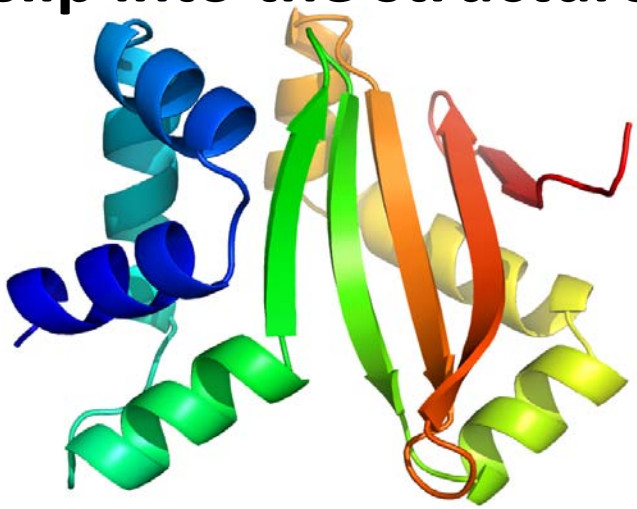
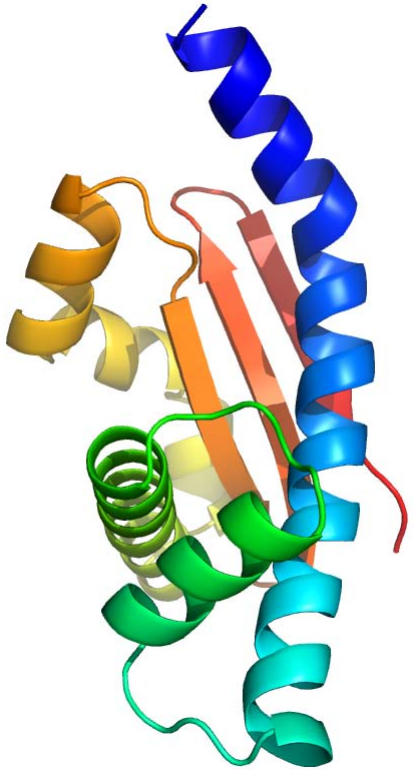

Strand cannot come by itself: must have a partner

Beta strand always slip into the structure

But it was HARD to figure that out !!!

FM targets in CASP9

FM Human/Server Targets (26 domains)

T0529d1, T0531, T0534d1, T0534d2, T0537, T0544d1, T0544d2, T0547d3, T0547d4, T0550d1, T0550d2, T0553d1, T0553d2, T0561, T0571d1, T0571d2, T0578, T0581, T0604d1, T0604d3, T0608d1, T0616, T0618, T0621, T0624, T0629d2

FM Server only Targets (30 domains)

Four more in addition to the FM Human/Server Targets
T0555d1, T0555d2, T0637, T0639

FM assessment in CASP9

at the end of the day, FM assessment

was (for the first time?) **entirely automated**

while still being **quite good**

Talk plan

- Introduction: FM winner in CASP9!
- Manual Assessment
- New Scoring Function
- Meta-scoring in Assessment
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Manual Assessment

Lisa Kinch

Manual Assessment of CASP9 Free Modeling Targets…

like finding a “needle in a haystack”

Manual Assessment of CASP9 Free Modeling Targets…

The Targets: *All FM domains*

T0529d1
T0531
T0534d1
T0534d2
T0537
T0544d1
T0544d2
T0547d3
T0547d4
T0550d1
T0550d2
T0553d1
T0553d2
T0561
T0571d1
T0571d2
T0578
T0581
T0604d1
T0604d3
T0608d1
T0616
T0618
T0621
T0624
T0629d2

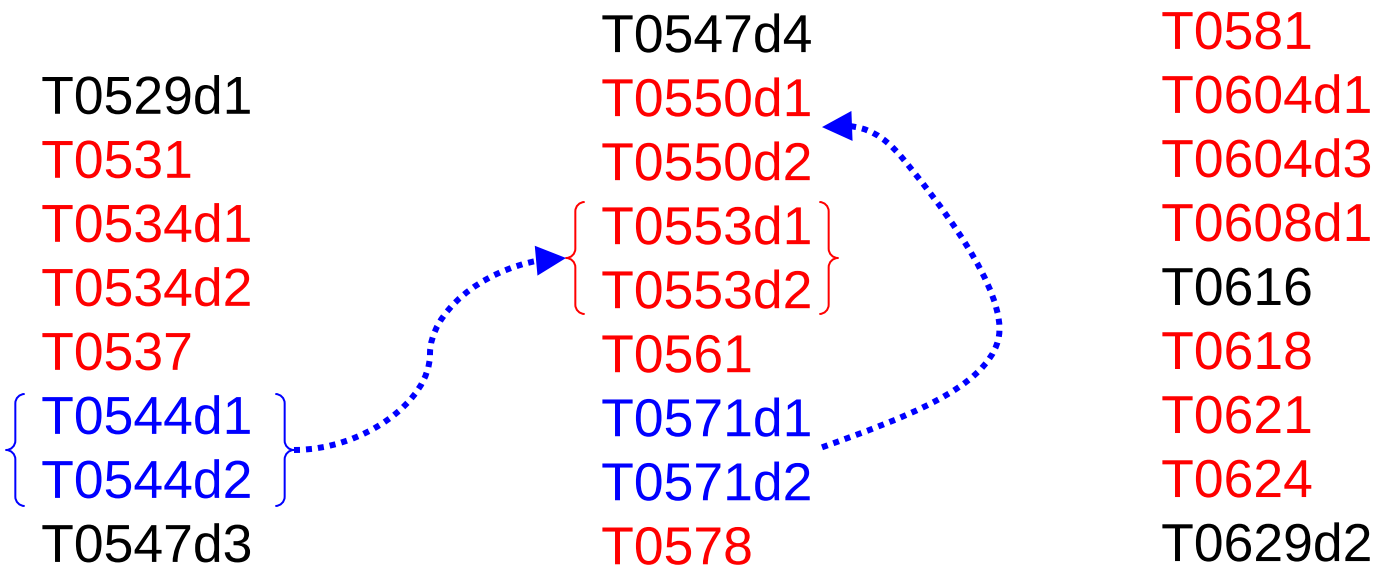
Manual Assessment of CASP9 Free Modeling Targets…

The Targets: *Manually scored FM domains*

T0529d1
T0531
T0534d1
T0534d2
T0537
T0544d1
T0544d2
T0547d3
T0547d4
T0550d1
T0550d2
T0553d1
T0553d2
T0561
T0571d1
T0571d2
T0578
T0581
T0604d1
T0604d3
T0608d1
T0616
T0618
T0621
T0624
T0629d2

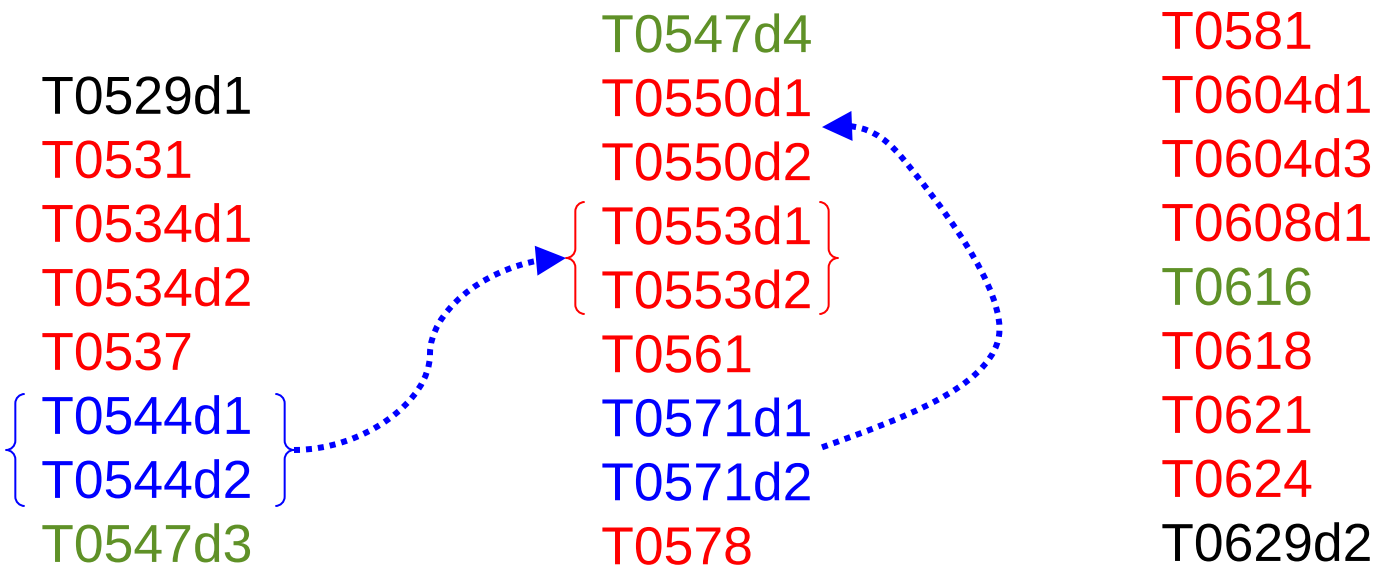
Manual Assessment of CASP9 Free Modeling Targets…

The Targets: *FM domains with redundant folds*



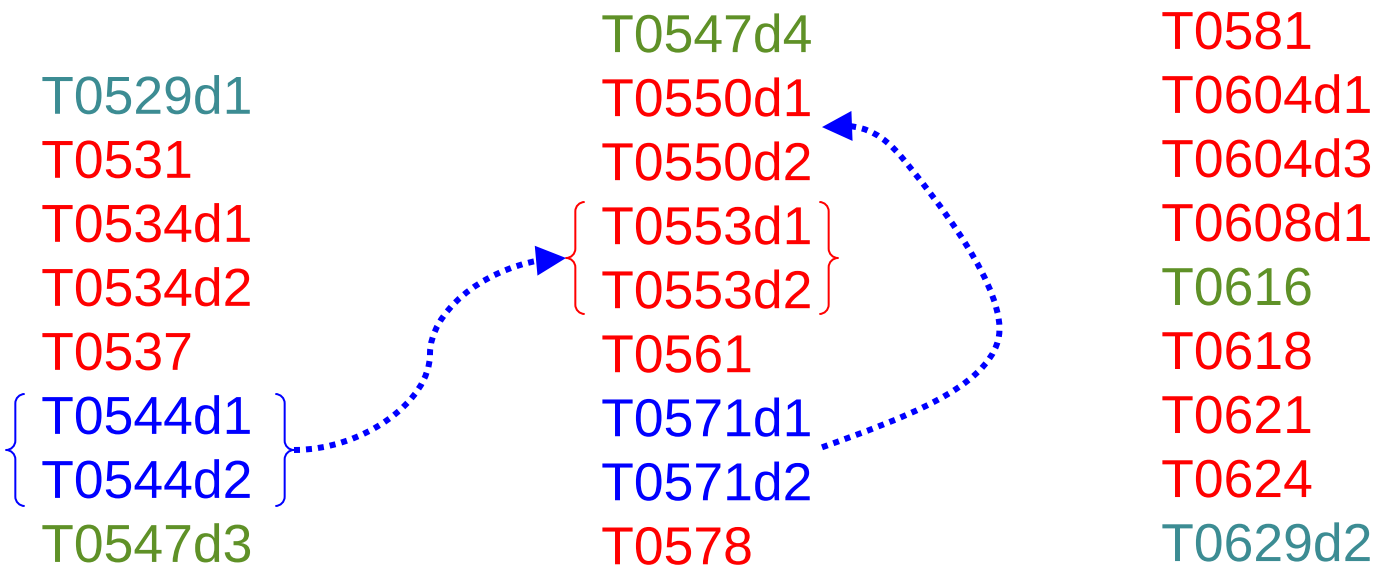
Manual Assessment of CASP9 Free Modeling Targets…

The Targets: *short segments (helical)*



Manual Assessment of CASP9 Free Modeling Targets…

The Targets: *FM domains with "bad" predictions*



Manual Assessment of CASP9 Free Modeling Targets…

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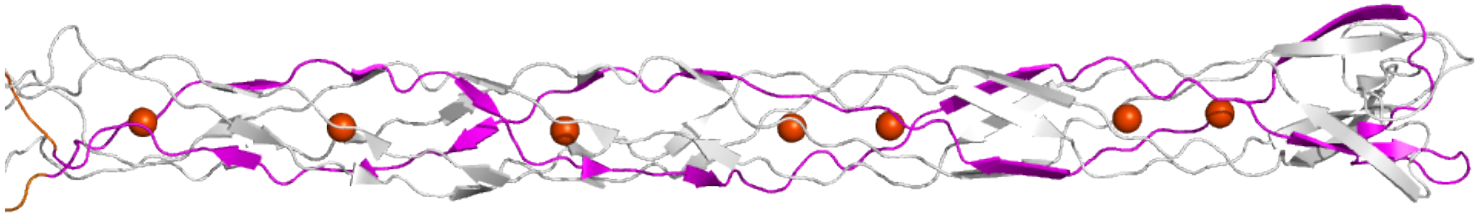
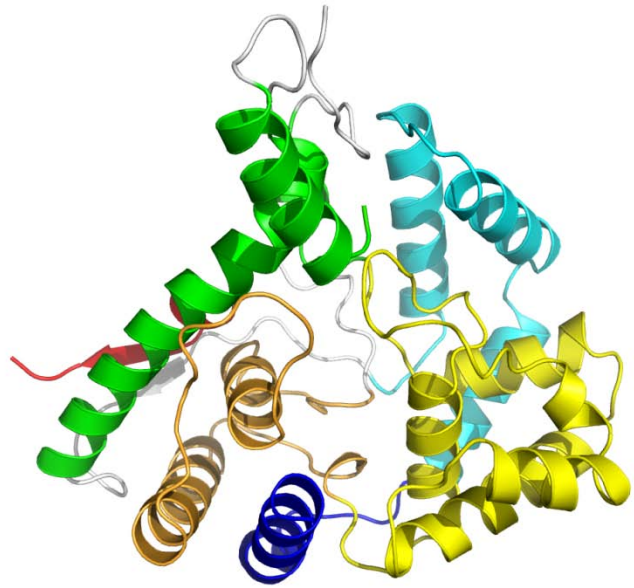




Target 629d2

Not Globular

Stabilized by trimer

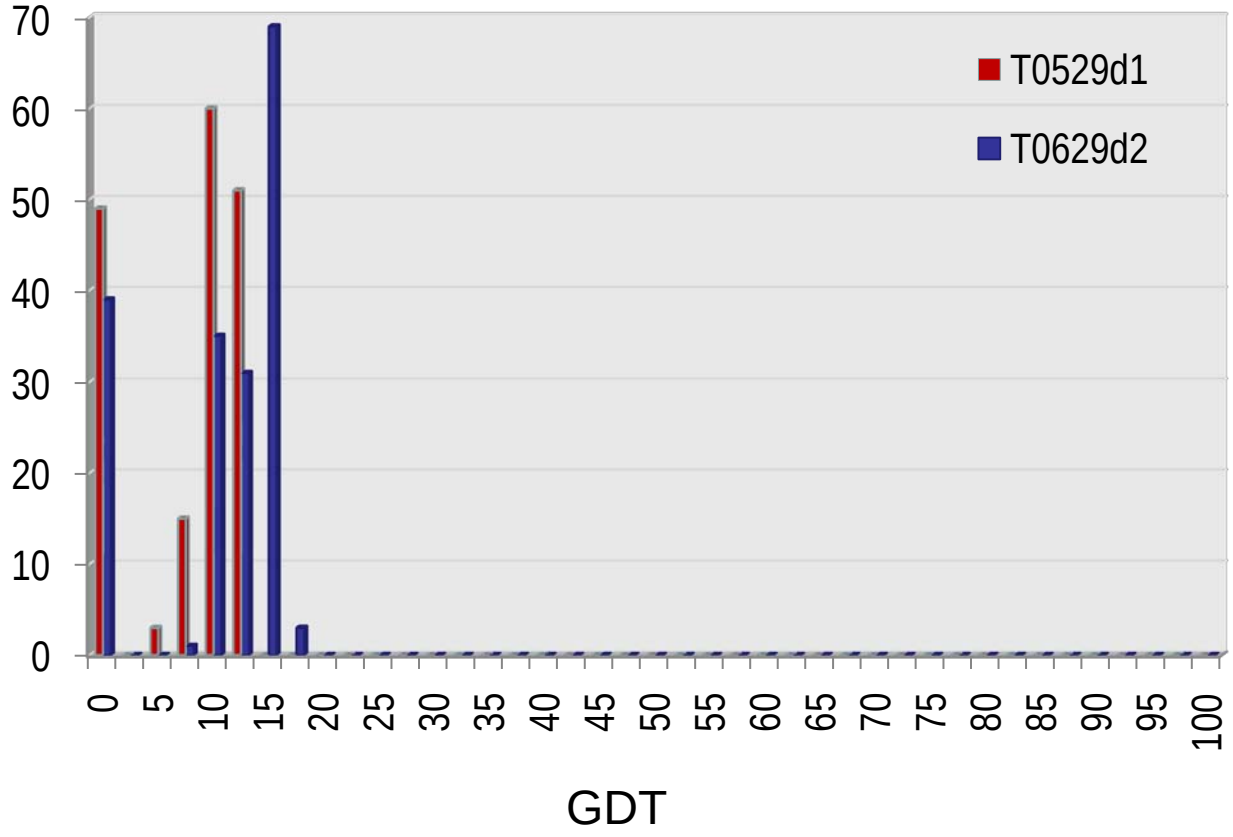
Target 529d1

Large

High contact order

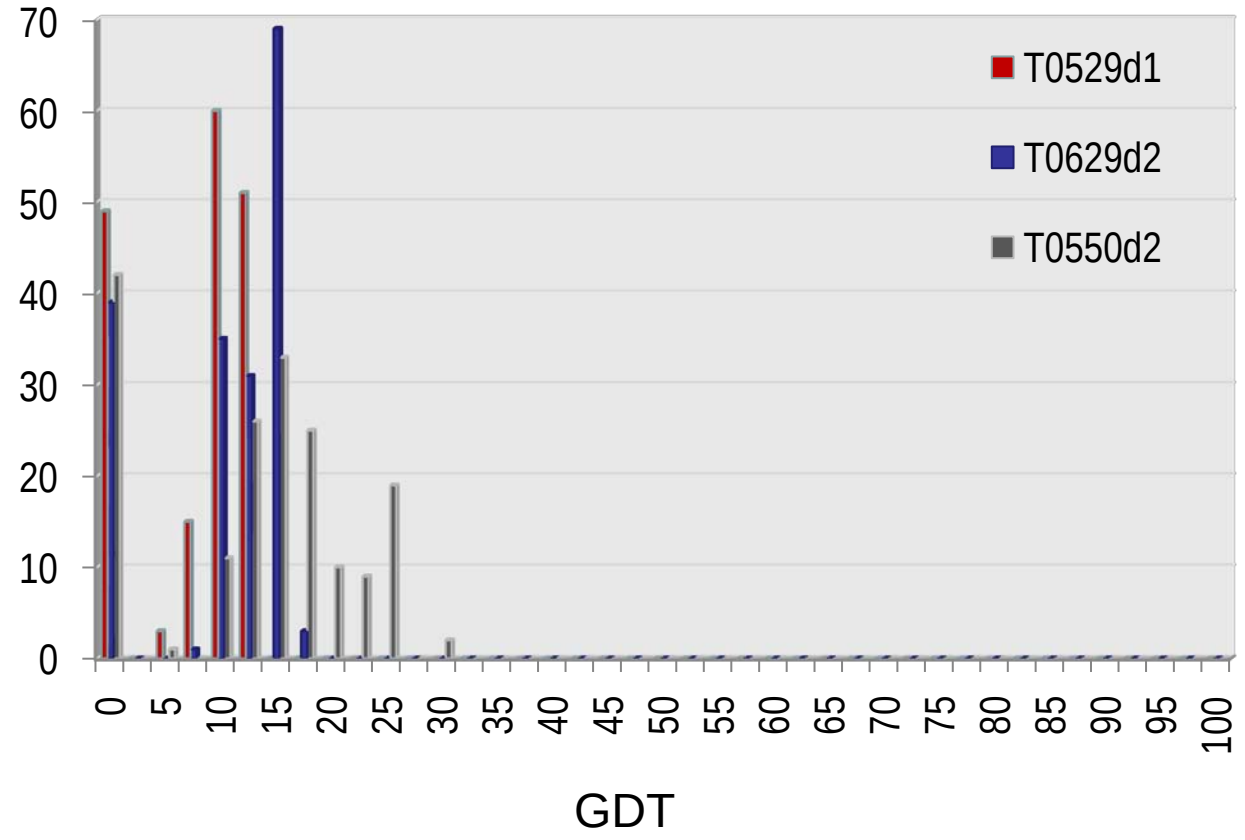
Manual Assessment of CASP9 Free Modeling Targets…

The Targets: *FM domains with "bad" predictions*



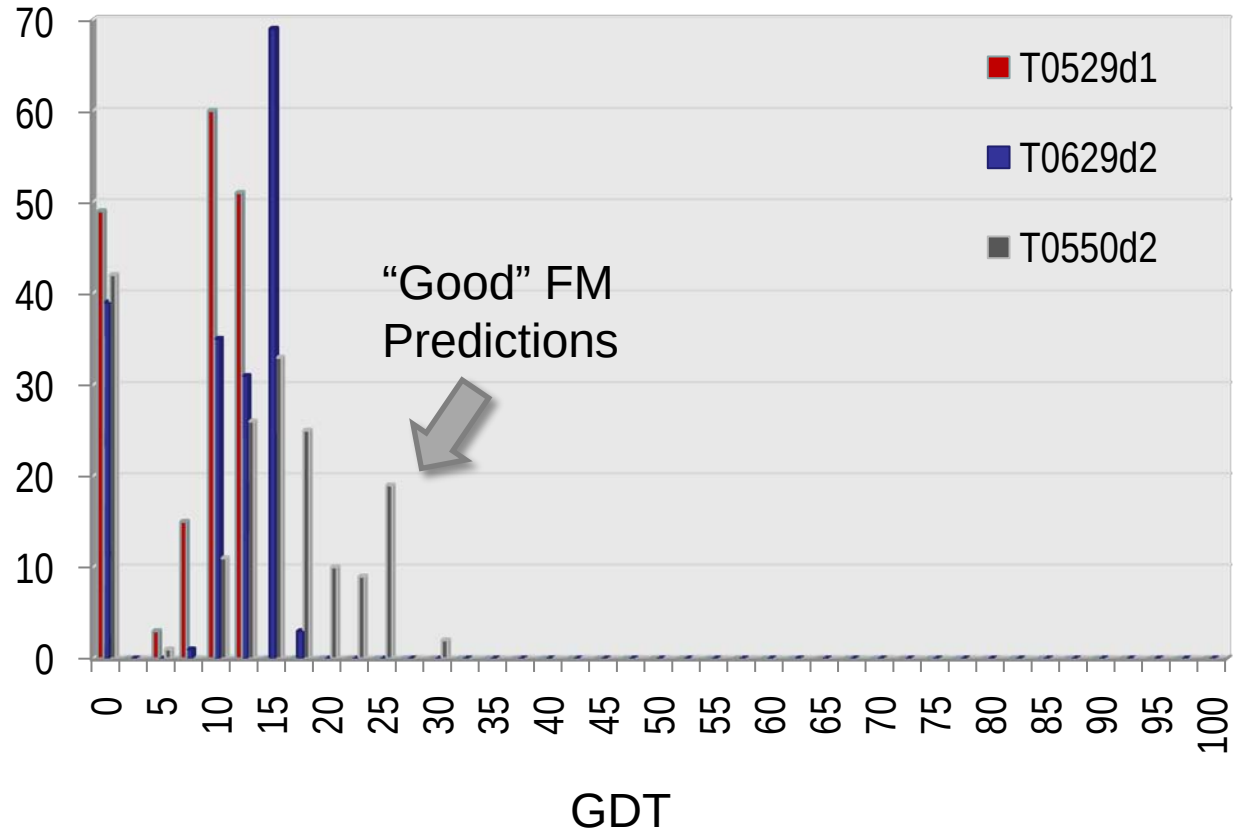
Manual Assessment of CASP9 Free Modeling Targets…

The Targets: *FM domains with "bad" predictions*



Manual Assessment of CASP9 Free Modeling Targets…

The Targets: *FM domains with "bad" predictions*



Manual Assessment of CASP9 Free Modeling Targets…

The Targets: *Manually scored FM domains (15)*

T0531
T0534d1
T0534d2
T0537

T0550d1
T0550d2
T0553d1d2
T0561

T0578

T0581
T0604d1

T0608d1
T0618
T0621
T0624

Manual Assessment of CASP9 Free Modeling Targets…

The Targets: *Manually scored FM domains (15)*

T0531
T0534d1
T0534d2
T0537

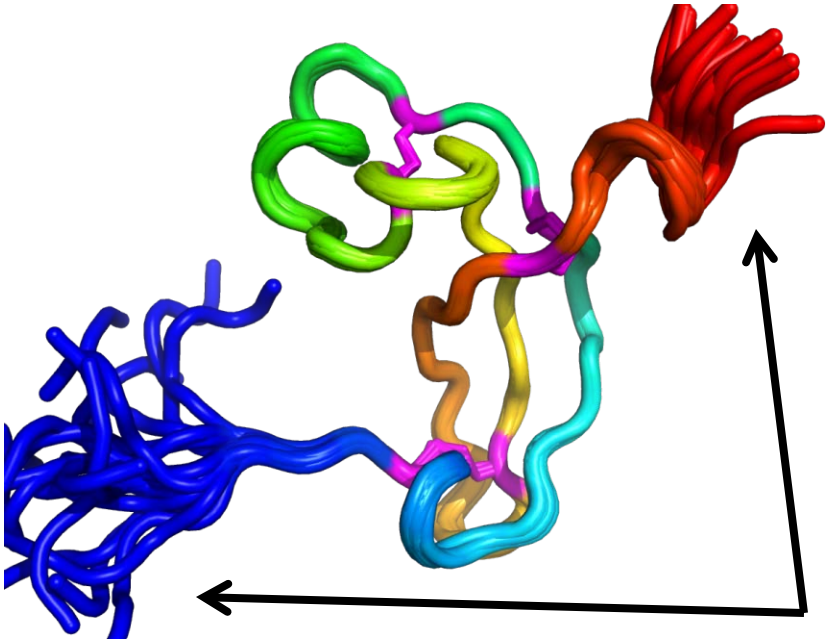
T0550d1
T0550d2
T0553d1d2
T0561

T0578

T0581
T0604d1

T0608d1
T0618
T0621
T0624

Free Modeling Target 531 Example Scoring

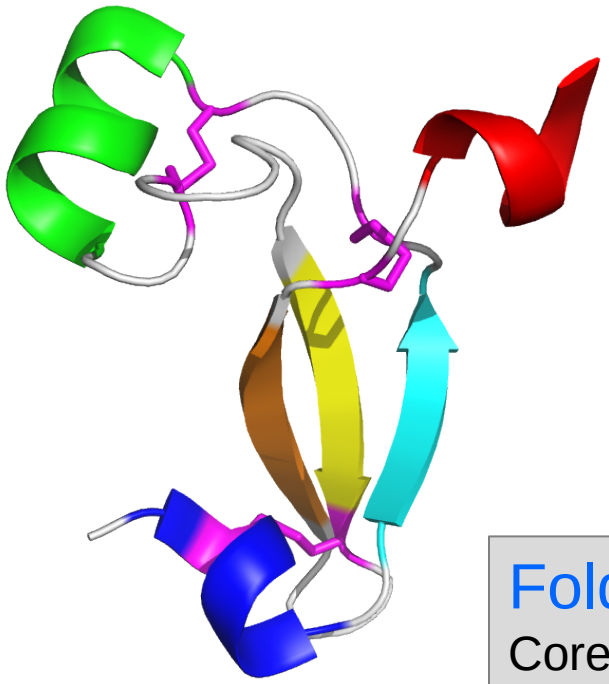


NMR Structure

Ignore 4 N-terminal residues and 1 C-terminal residue

Free Modeling Target 531 Example Scoring

What are the important components of the structure?

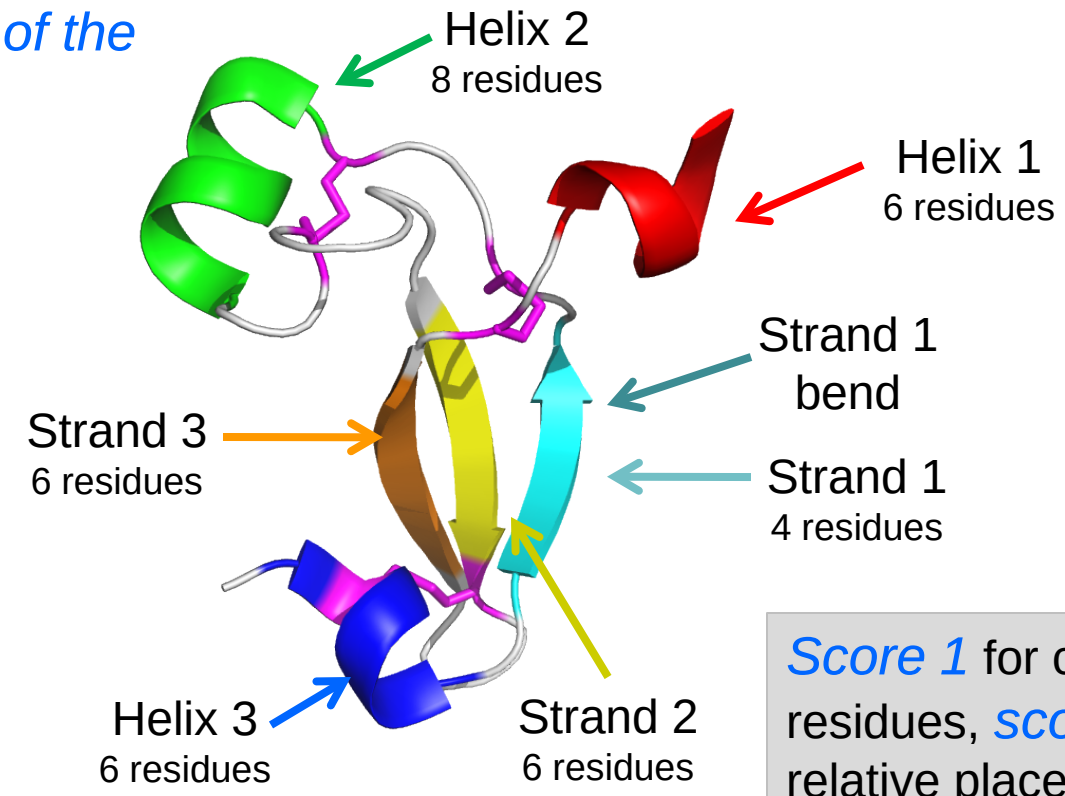


Fold Topology is Key

Core β-strand meander (**S1**,**S2**,**S3**); β-sheet is flanked by short helical extensions (**H1**,**H3**) and a helical insertion (**H2**)

Free Modeling Target 531 Example Scoring

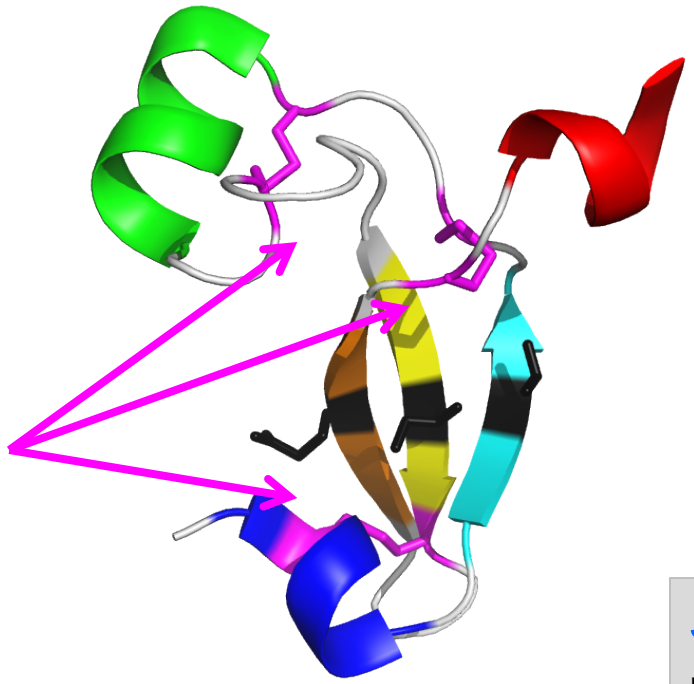
What are the important components of the structure?



Score 1 for correct SSE residues, *score 1* for relative placement and *+1* for contacts, *score 1* for strand1 bend

Free Modeling Target 531 Example Scoring

What are the important components of the structure?



Disulfide Pairs

Score 1 for each disulfide pair, *score 0.5* for non-bonded pairs within a short distance of each other

Free Modeling Target 531 Example Scoring

Manual inspection of ***661 Predictions***

Scoring System												
H1res	H1int	S1res	S1int	Hres	H2int	S2res	S2int	S3res	H3res	H3int	Cys	Max
(2)	*(2)*	*(2)*	*(3)*	*(2)*	*(2)*	*(2)*	*(2)*	*(2)*	*(2)*	*(2)*	*(3)*	*(26)*

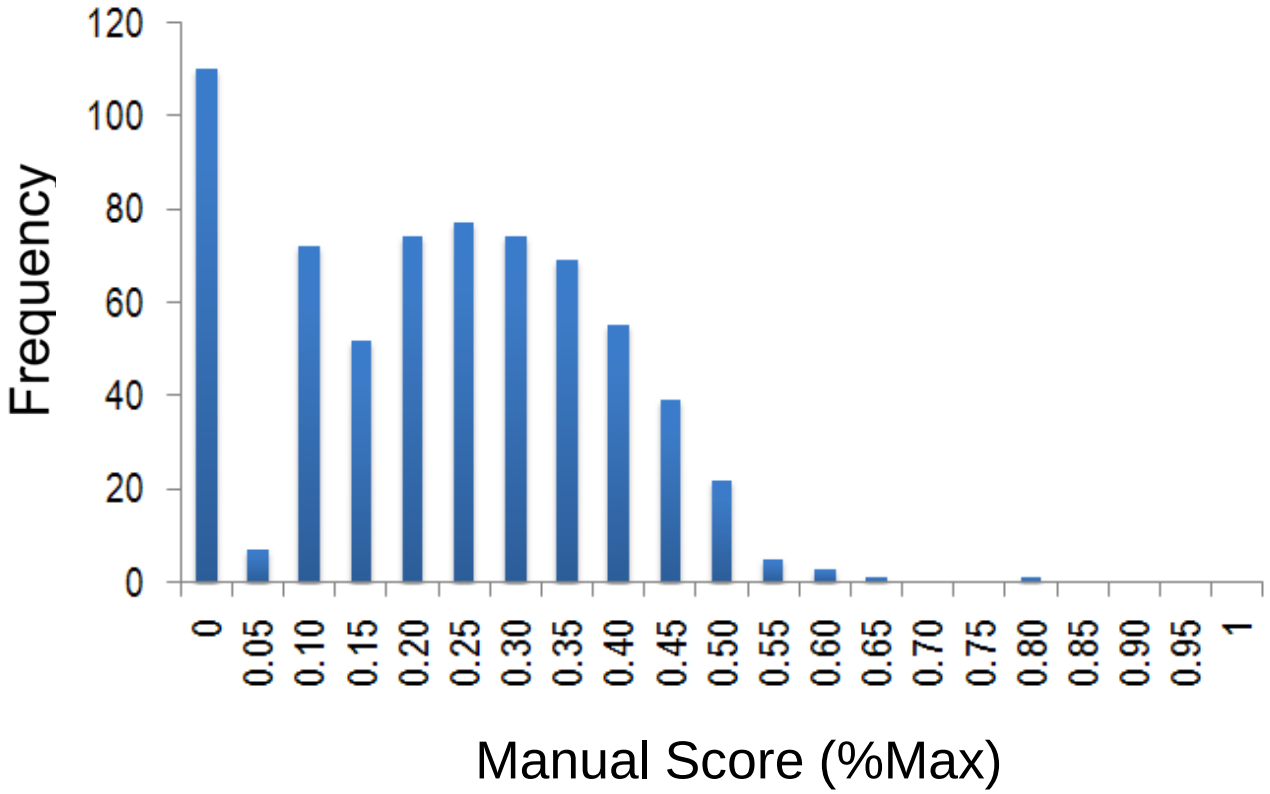
T0531AL285_1

…

T0531TS490_5

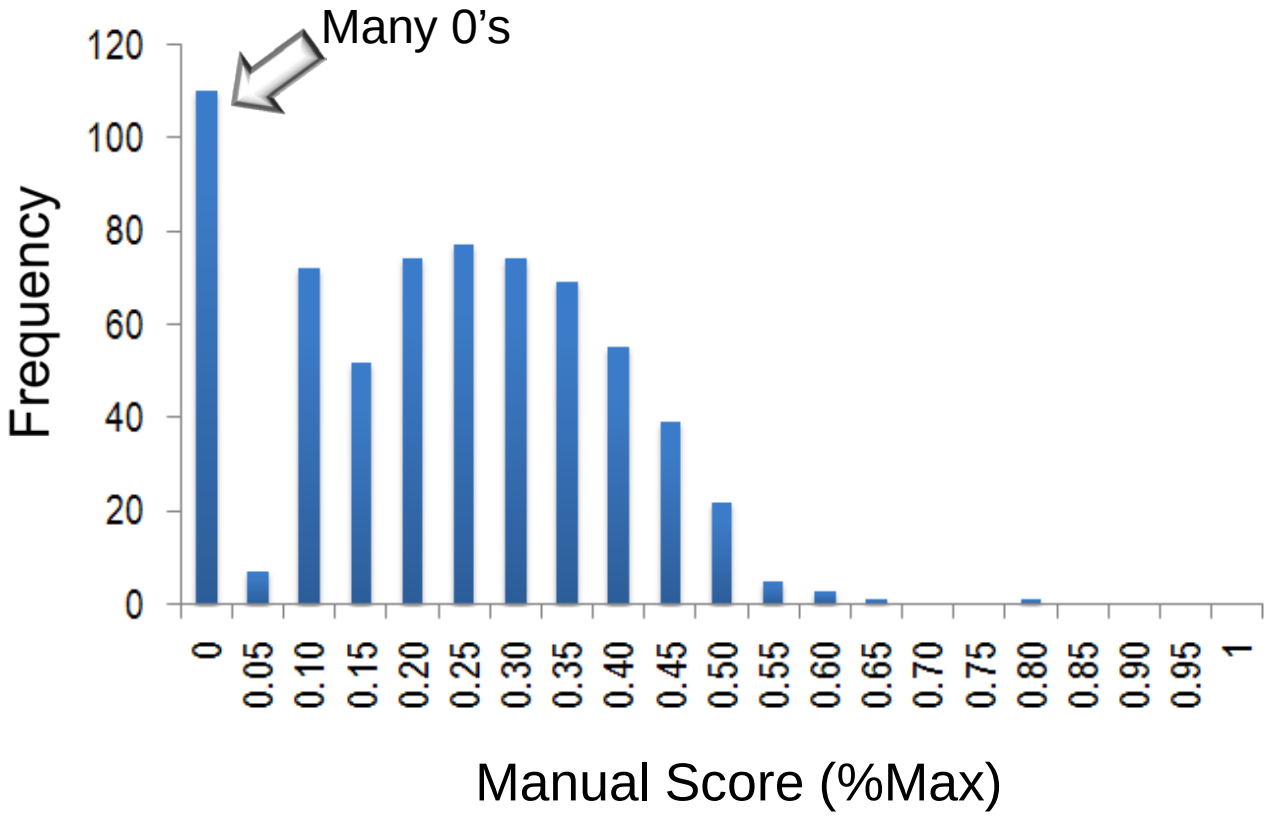
Free Modeling Target 531 Example Scoring

Manual Score Distribution of ***661 Predictions***



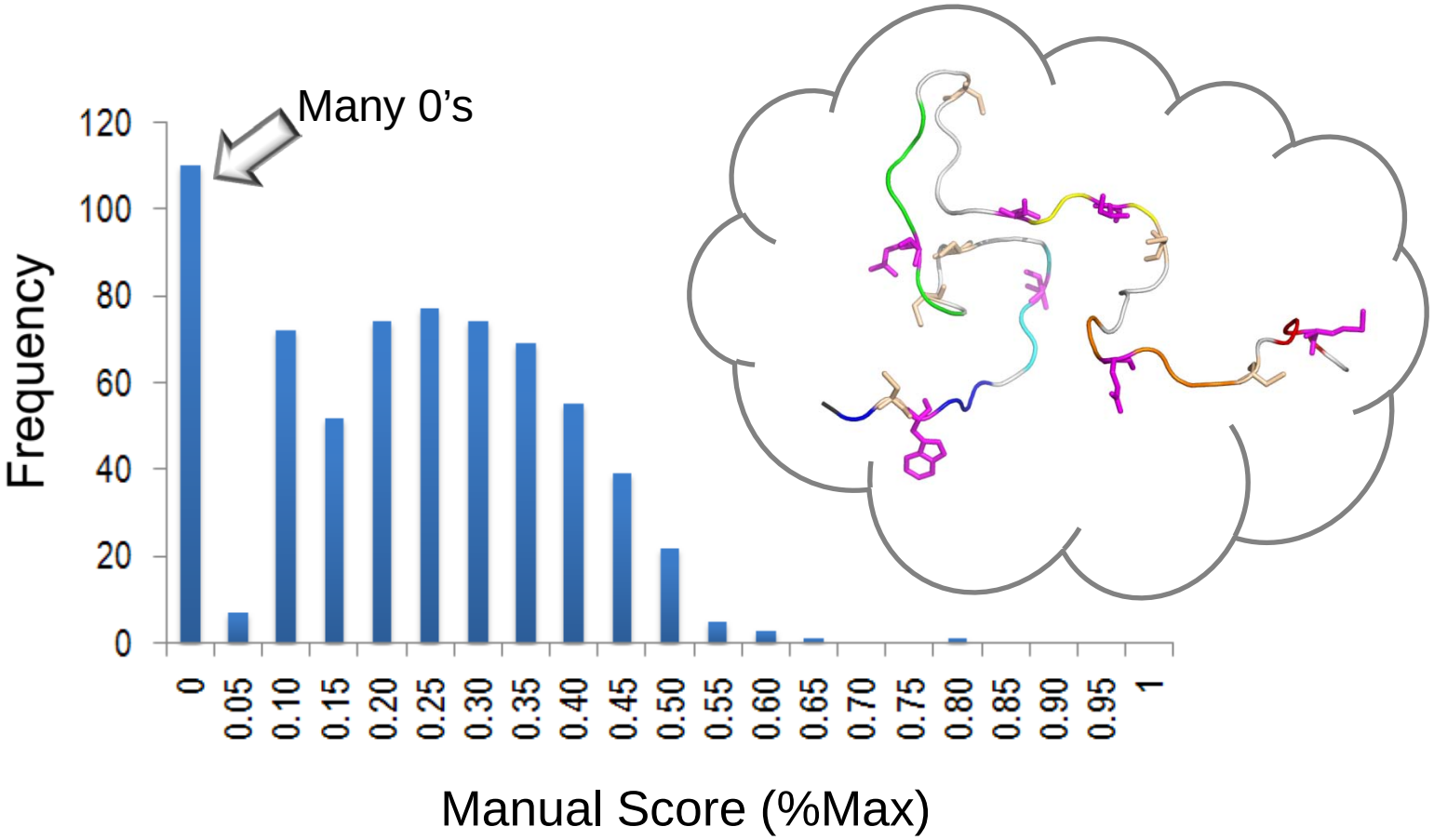
Free Modeling Target 531 Example Scoring

Manual Score Distribution of ***661 Predictions***



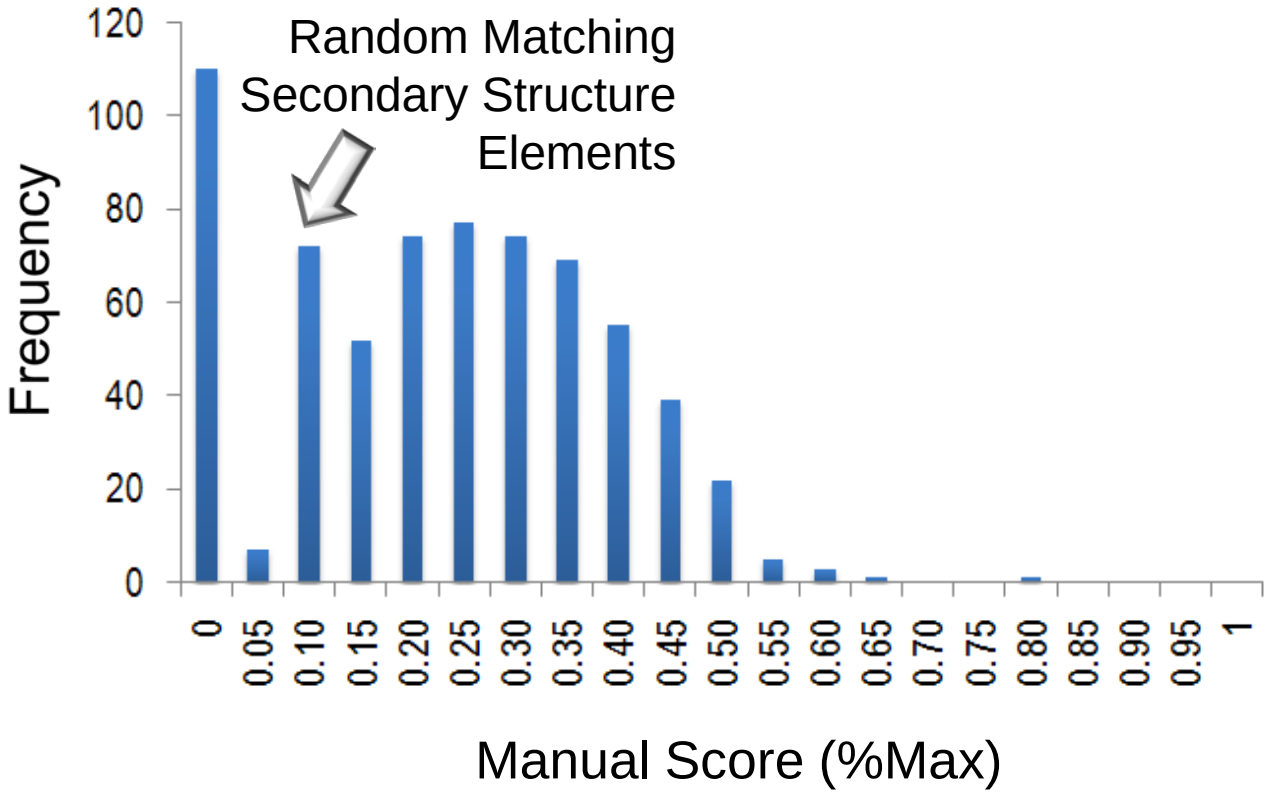
Free Modeling Target 531 Example Scoring

Manual Score Distribution of ***661 Predictions***



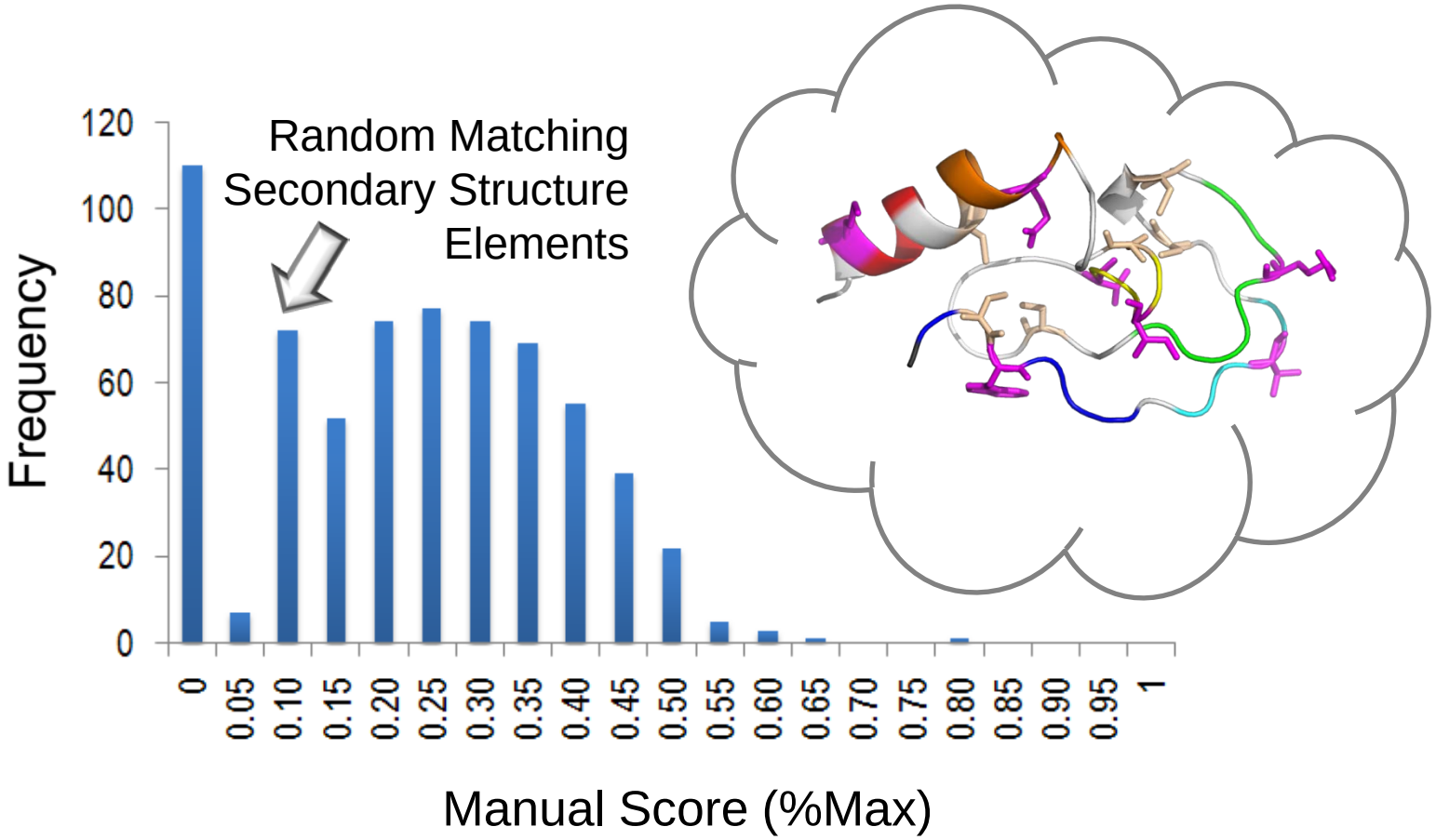
Free Modeling Target 531 Example Scoring

Manual Score Distribution of ***661 Predictions***



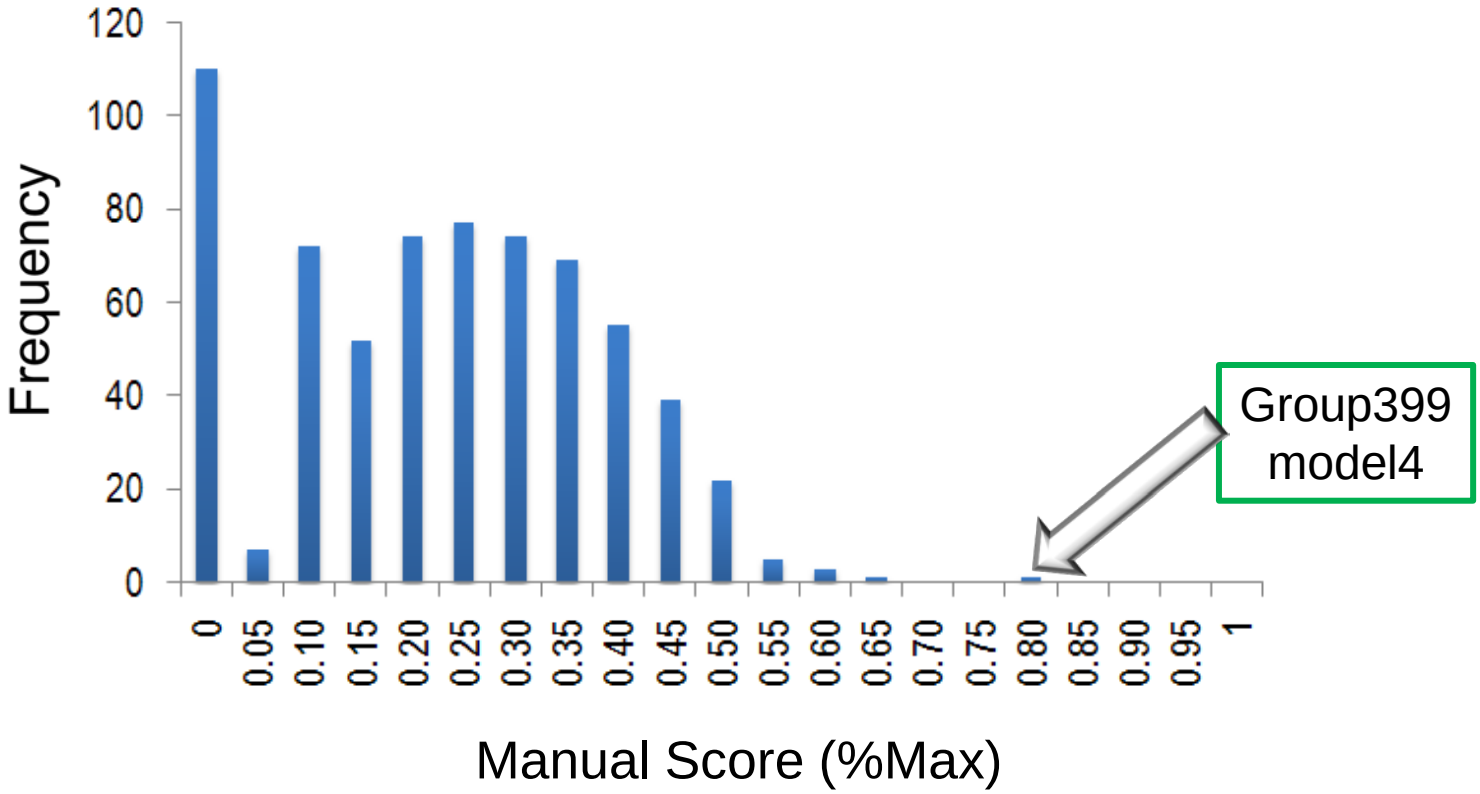
Free Modeling Target 531 Example Scoring

Manual Score Distribution of ***661 Predictions***



Free Modeling Target 531 Example Scoring

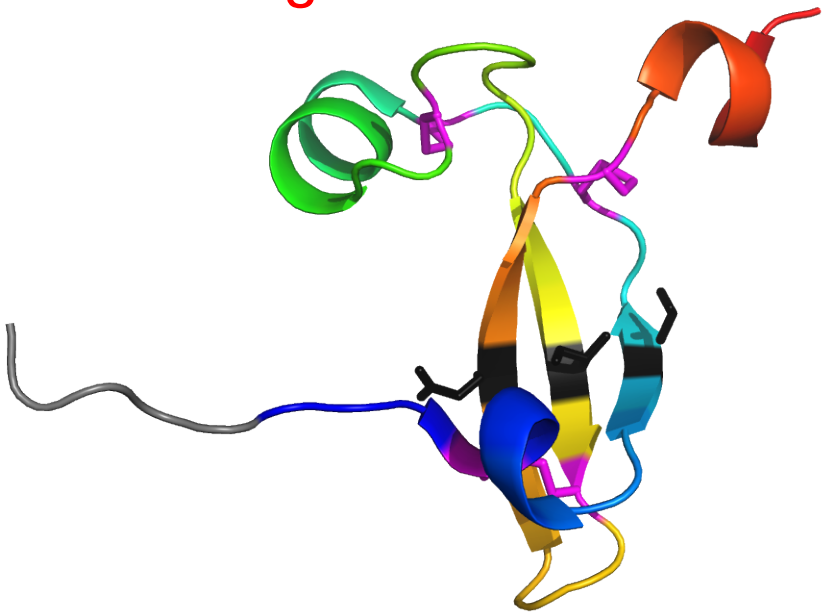
Manual Score Distribution of ***661 Predictions***

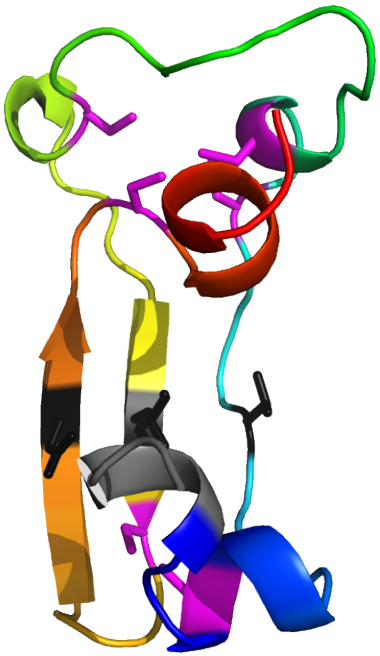


Free Modeling Target 531 Example Scoring

Top Scoring Predictions

Target





Correct
β-meander
Rank1

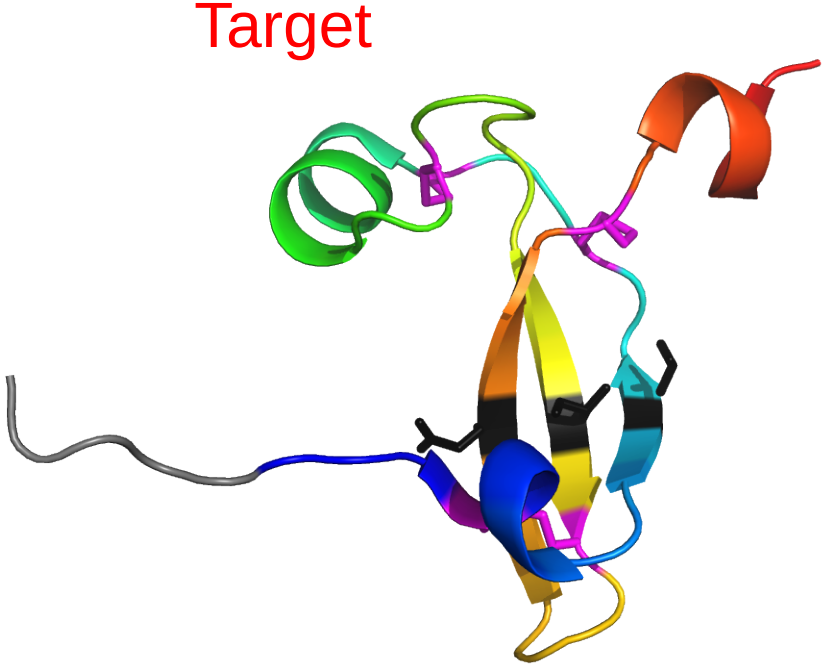
Group399
model4

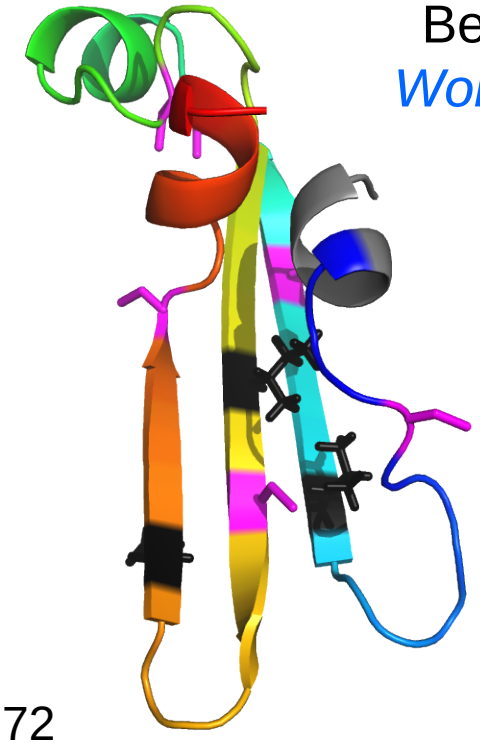
GDT: 38.71

Free Modeling Target 531 Example Scoring

Top Scoring Predictions

Target





Elongated meander

Better sse residues

Worse sse placement

Rank2

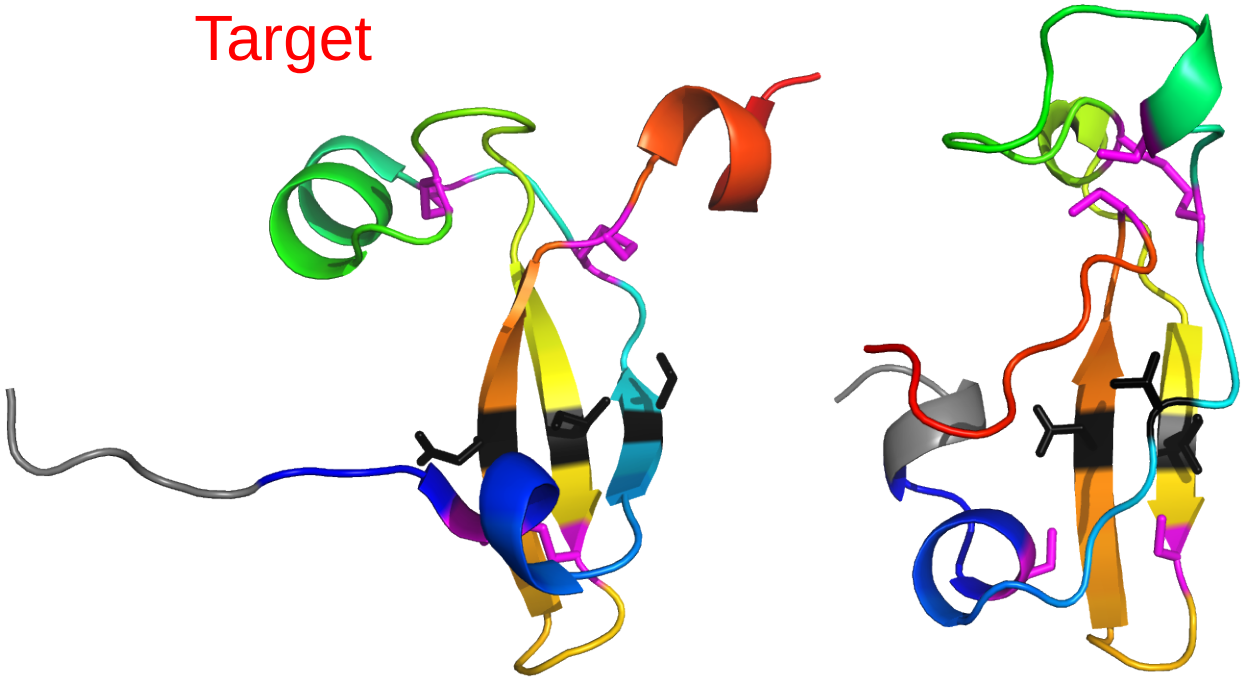
Group055
model1

GDT: 40.72

Free Modeling Target 531 Example Scoring

Top Scoring Predictions

Target



Not "Protein-like"
No shifts
compacted
Rank5

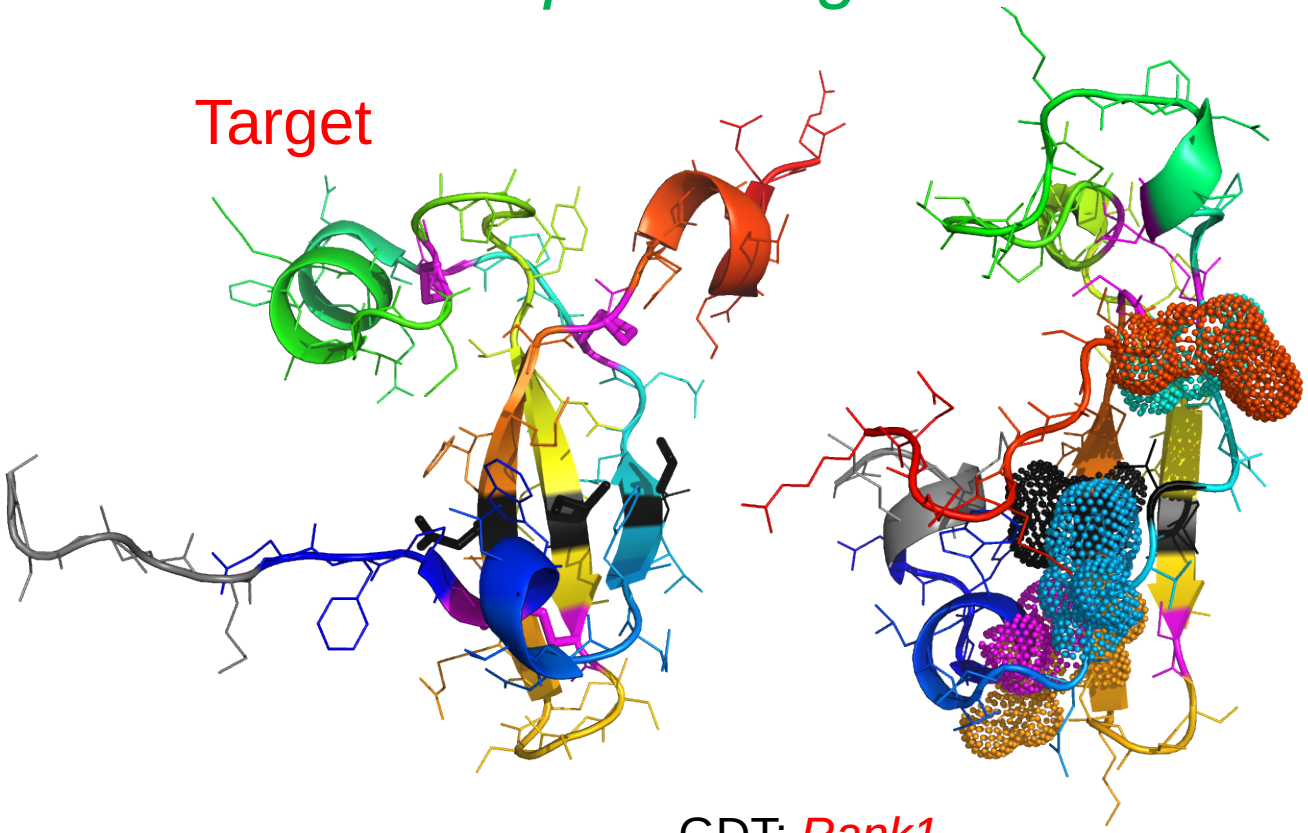
Group399
model5

GDT: 42.74

Free Modeling Target 531 Example Scoring

Top Scoring Predictions

Target

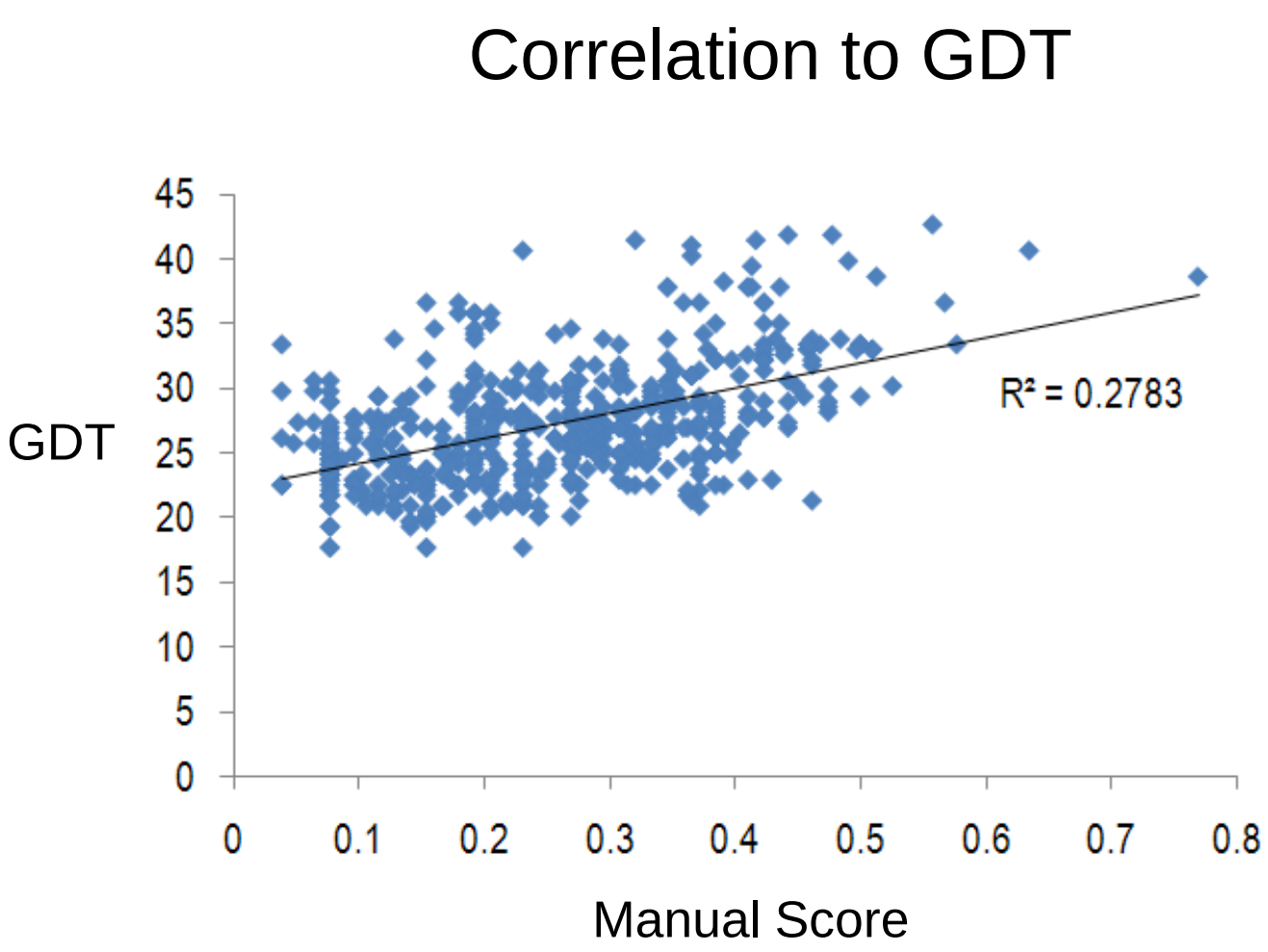


Not "Protein-like"
No shifts
compacted
Rank5

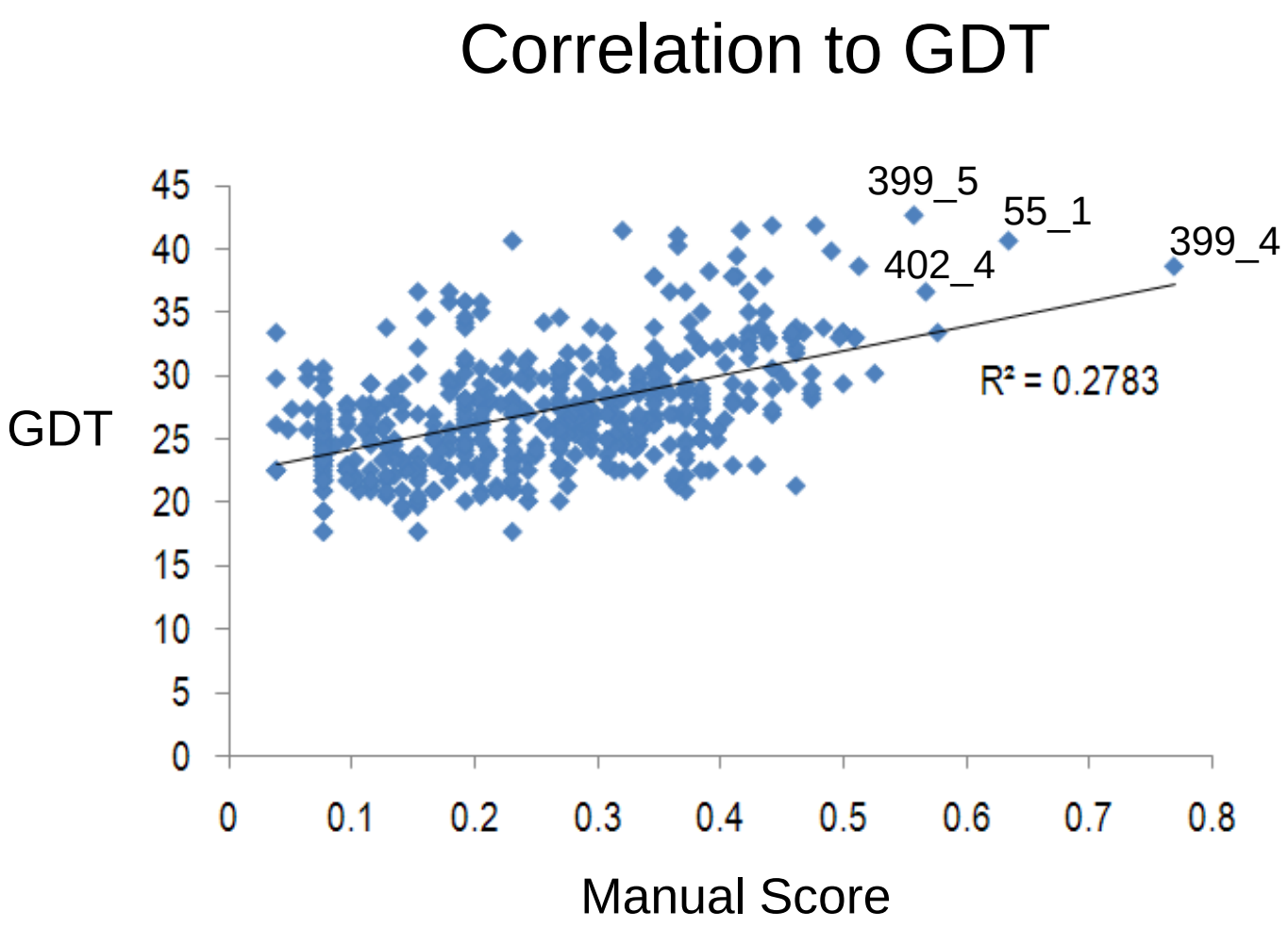
Group399
model5

GDT: *Rank1*

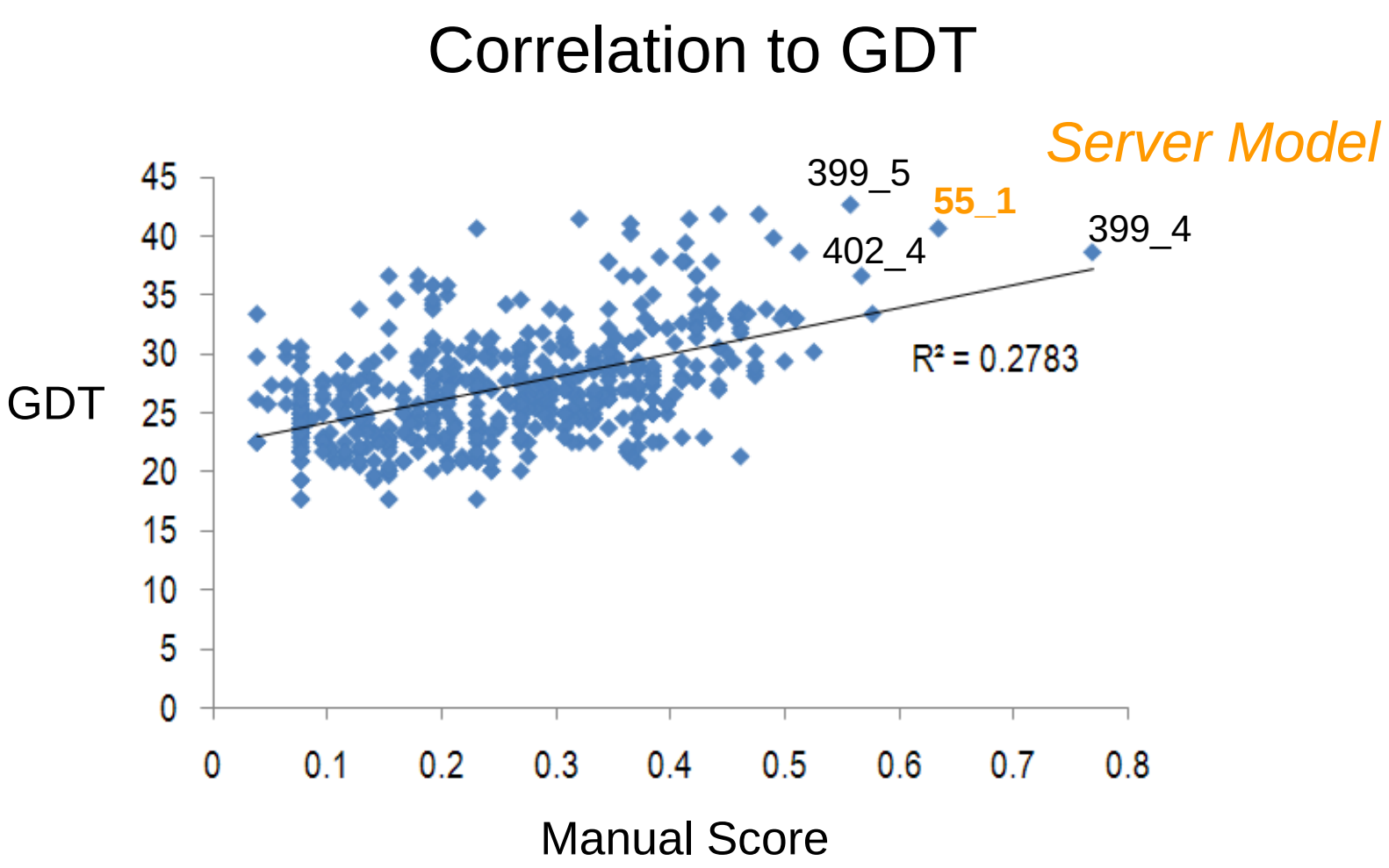
Free Modeling Target 531 Example Scoring



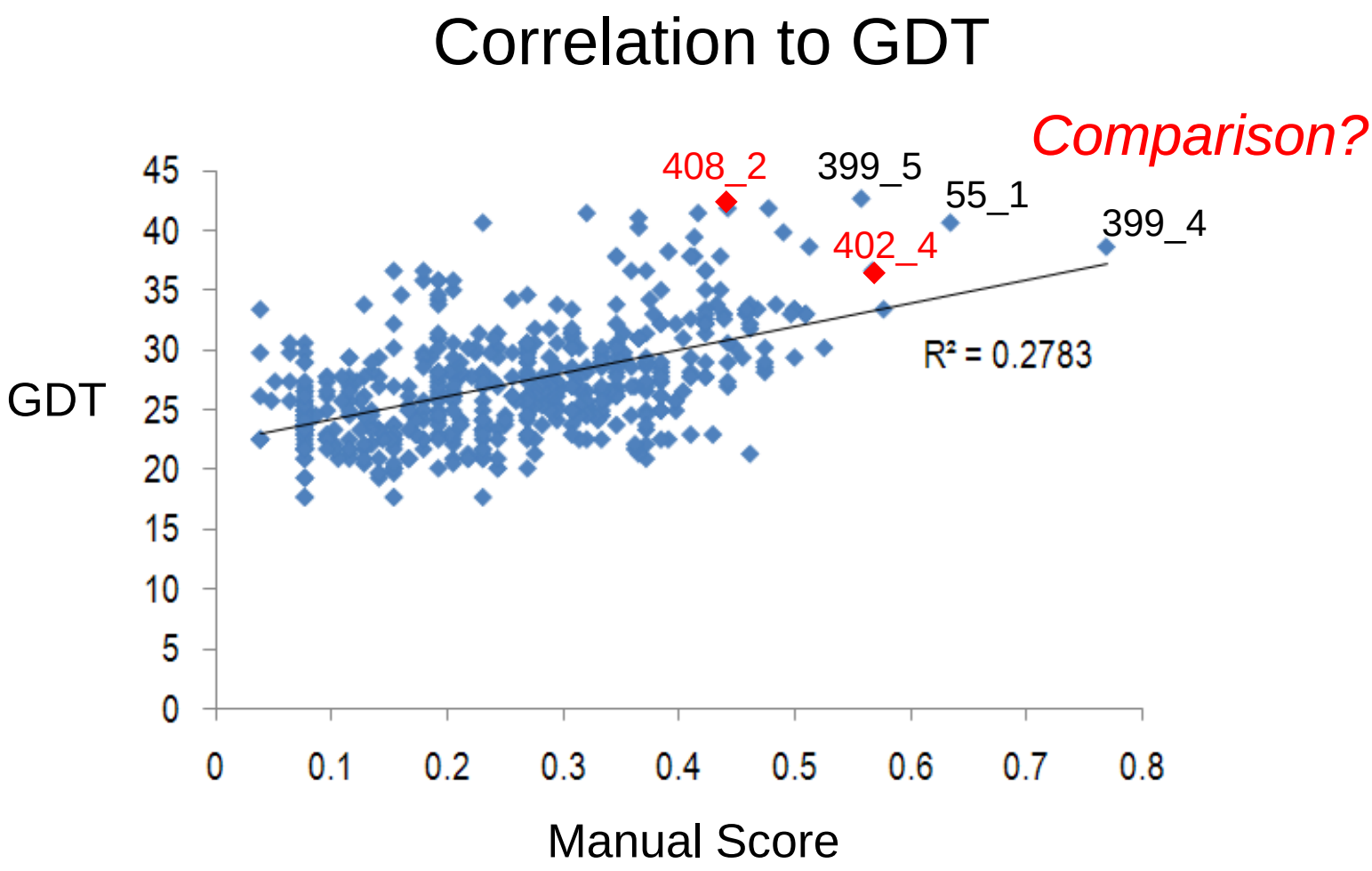
Free Modeling Target 531 Example Scoring



Free Modeling Target 531 Example Scoring



Free Modeling Target 531 Example Scoring

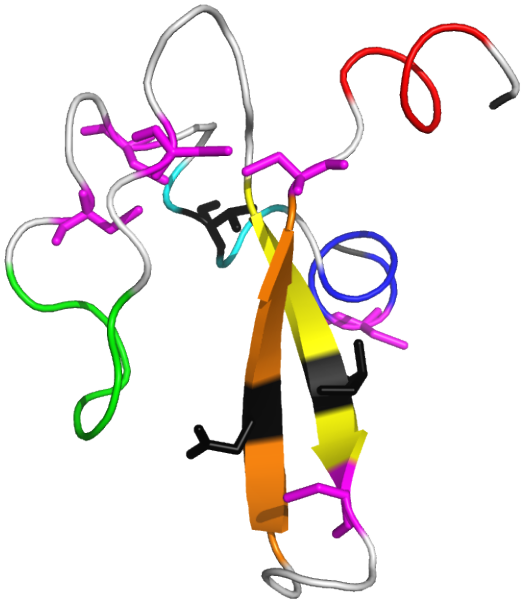


Free Modeling Target 531 Example Scoring

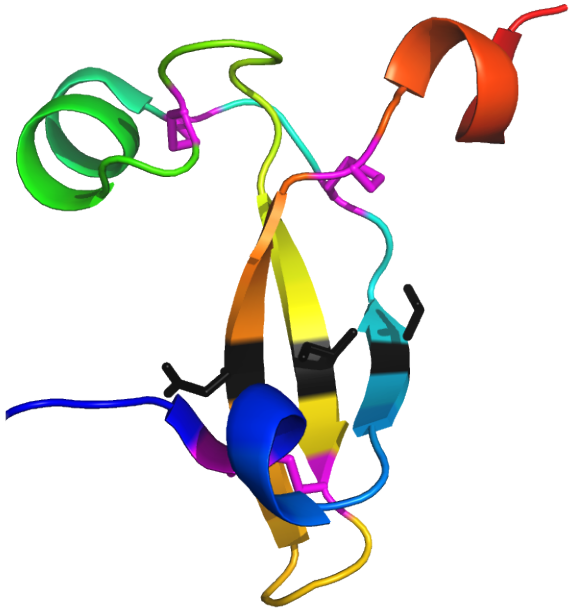
GDT Score
favors good local β-hairpin structure,
but bad H1 position, missing S1

tradeoff

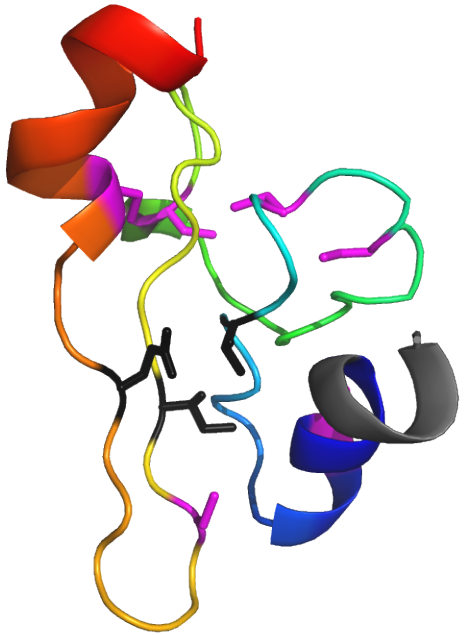
Manual Score
favors good global SSE position,
but bad local backbone (SSE's)



Group408 model 2



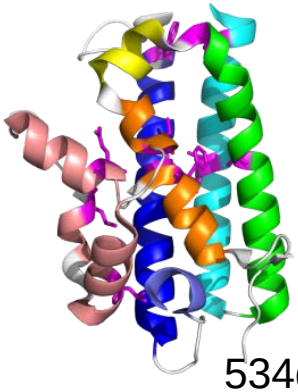
Target



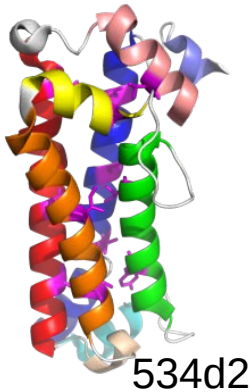
Group402 model 4

Manual Assessment Criteria

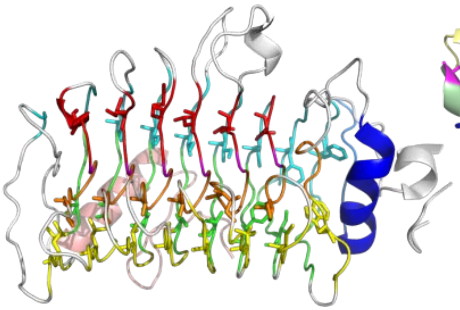
531



534d1



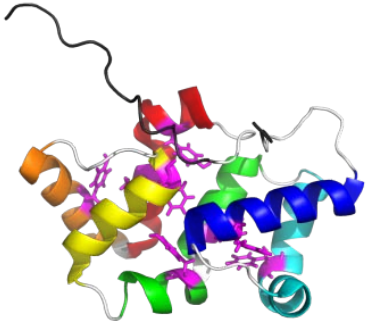
534d2



537

550d1

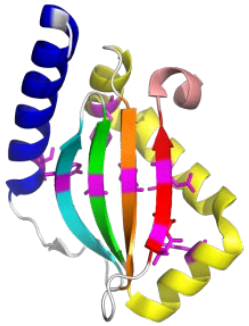
550d2



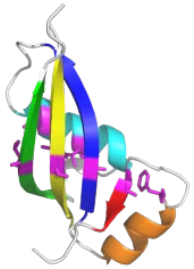
553d1d2

561

578

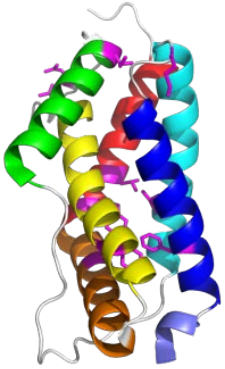


581

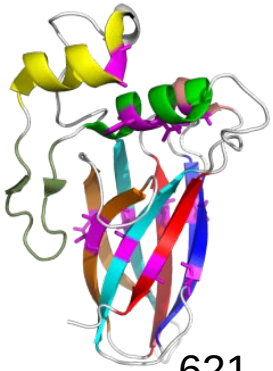


604d1

608d1



618



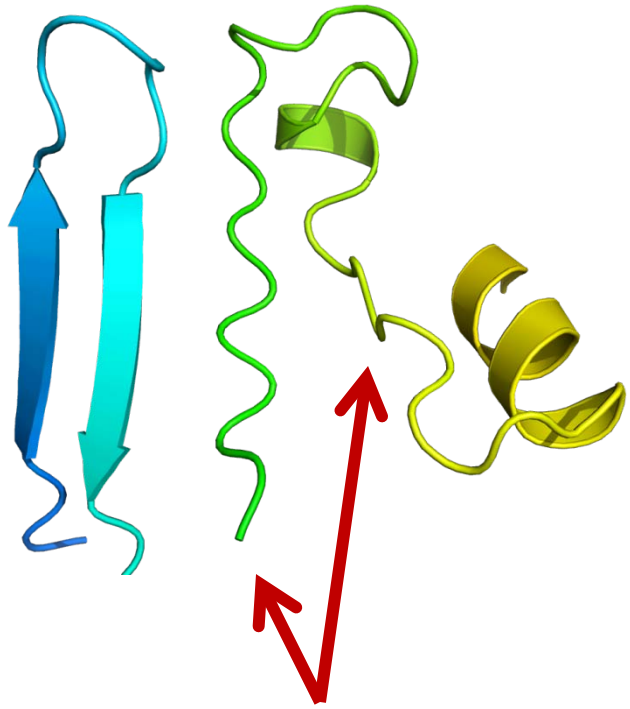
621

624

Manual Assessment Criteria

Interesting FM Model Problems

Target 578: 37_5

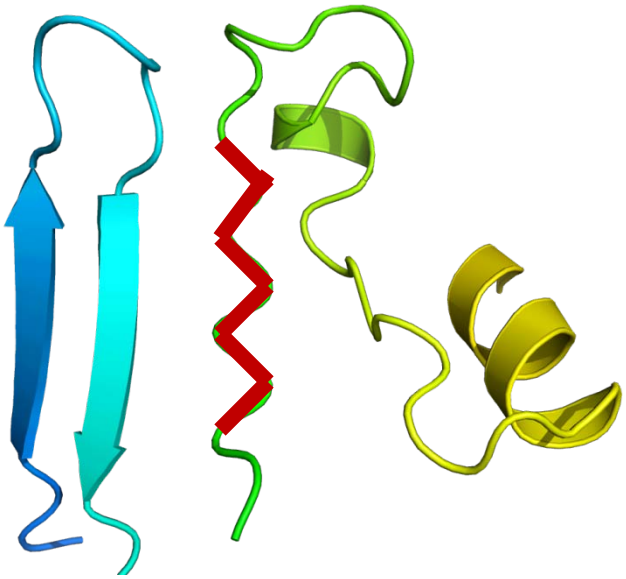


Poor quality secondary structures

Manual Assessment Criteria

Interesting FM Model Problems

Target 578: 37_5



Poor quality secondary structures

"Strand" Problems:

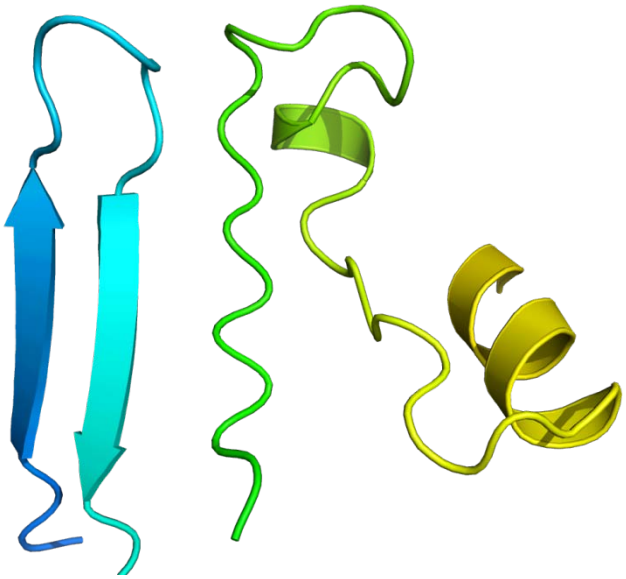
Incorrect backbone torsion angles:

- No hydrogen-bonds with neighboring strand
- Compressed side chain distances limit contacts
- Shorter loops limit secondary structure angles

Manual Assessment Criteria

Interesting FM Model Problems

Target 578: 37_5



Problem Source?

From the abstract book methods description:
- “picked server models”
- “refined and rebuilt” models
- “model quality evaluation”

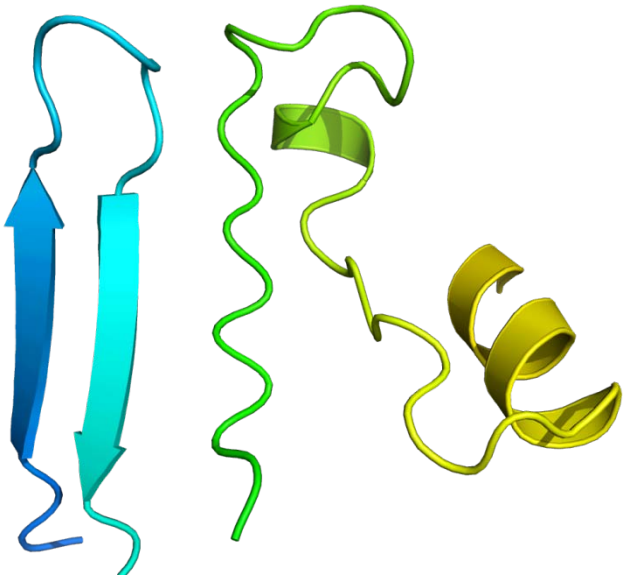
From submitted pdb:
“PARENT N/A”

Poor quality secondary structures

Manual Assessment Criteria

Interesting FM Model Problems

Target 578: 37_5



Poor quality secondary structures

The Answer?

From the abstract book methods description:

- "picked server models"
- "refined and rebuilt" models
- "model quality evaluation"

From submitted pdb:

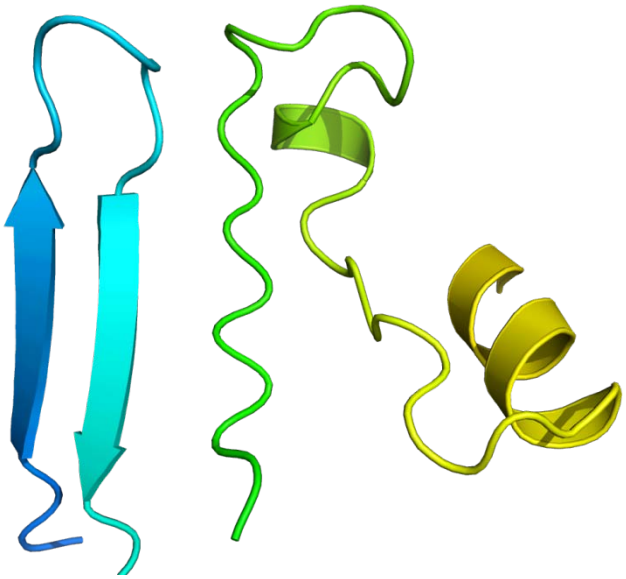
"PARENT N/A"

Should state "ServerX_1"!

Manual Assessment Criteria

Interesting FM Model Problems

Target 578: 37_5



What happened to?

From the abstract book methods description:

- "picked server models"
- "refined and rebuilt" models
- "model quality evaluation"

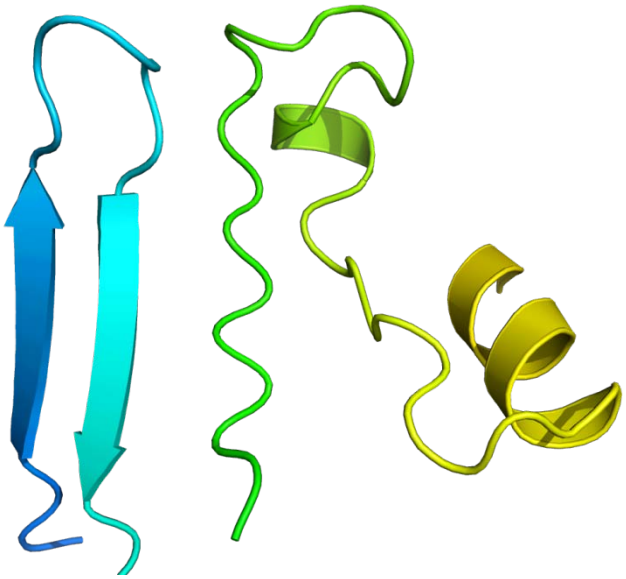
From submitted pdb:
"PARENT N/A"

Poor quality secondary structures

Manual Assessment Criteria

Interesting FM Model Problems

Target 578: serverX



The quest continues…

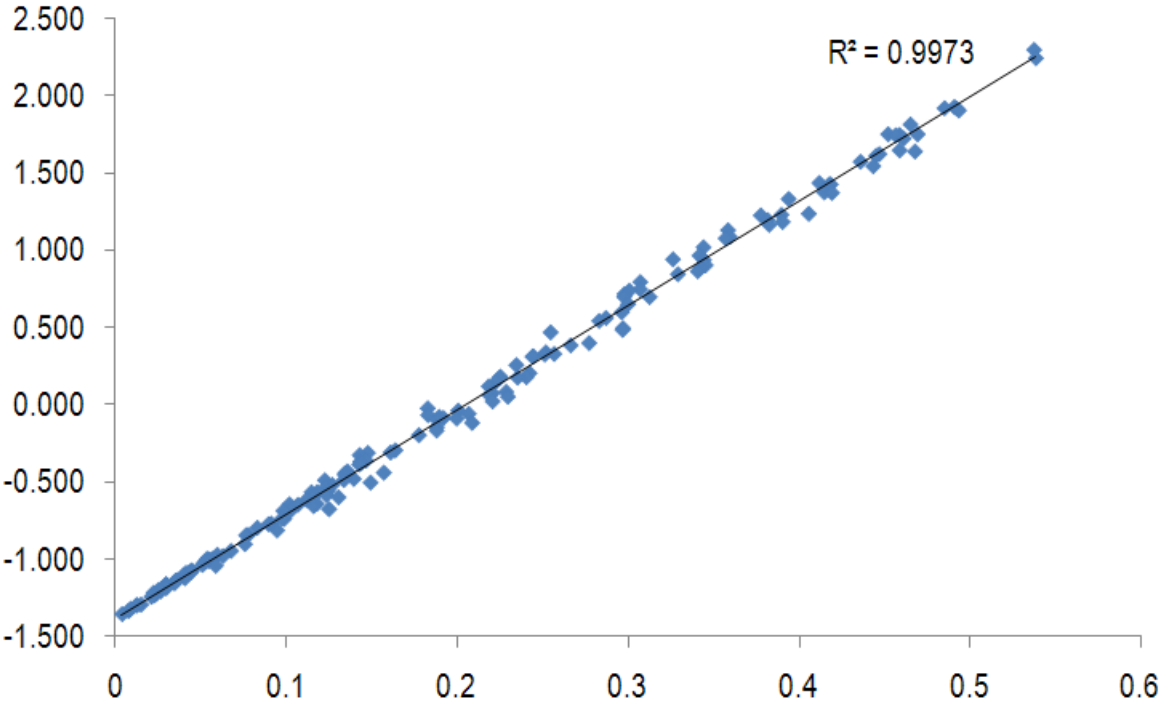
From the abstract book methods description:
"*ab initio*… fragment assembly"

- Knowledge-base potentials
- Backbone moves
- Build and refine full chain
- Model quality assessment

Poor quality secondary structures

Manual Assessment: Group Scores

Strategy: combine *best* model score for each target to rank groups



Manual Assessment: Group Scores

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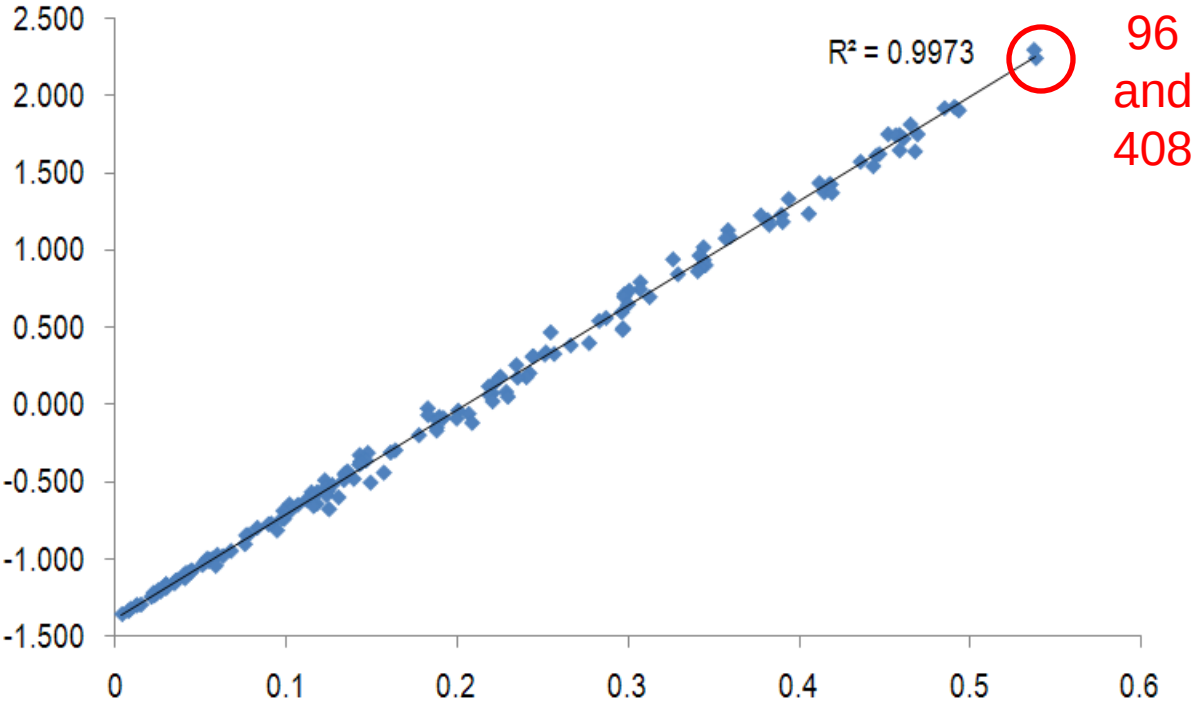

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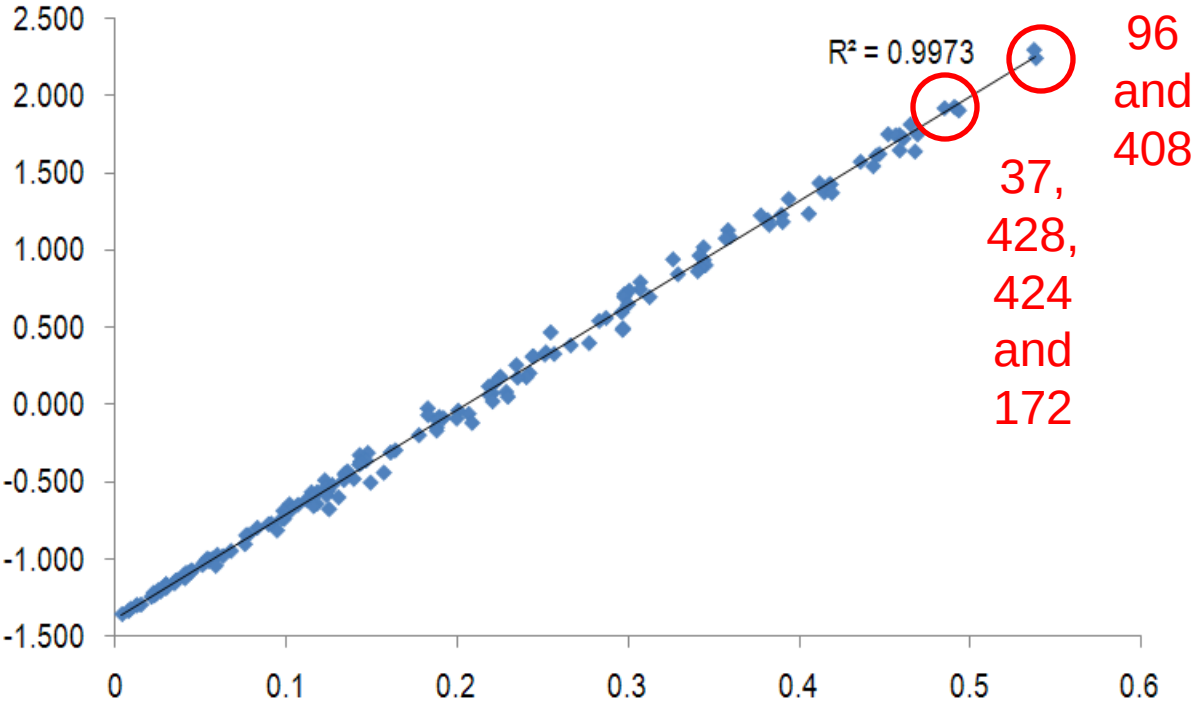


“If Edison had a needle to find in a haystack, he would proceed at once with the diligence of the bee to examine straw after straw until he found the object of his search... I was a sorry witness of such doings, knowing that a little theory and calculation would have saved him ninety per cent of his labor.”

Nikola Tesla, *New York Times*, Oct. 19, 1931

Development of automatic score to “predict” manual assessment for CASP FM targets

Qian Cong

Development of automatic score to “predict” manual assessment for CASP FM targets

Tesla: curiosity driven

Me: laziness driven

Qian Cong

Development of automatic score to "predict" manual assessment for CASP FM targets

36 targets
(whole chain + domain)
around 18000 models

Tesla: curiosity driven

Me: laziness driven

Qian Cong

Inspiration from expert's manual analysis

Expert: global features + local features

Local feature:

secondary structure assignment of each residue

Global feature:

global positions of each Secondary Structure Elements (SSEs)

packing and interactions between SSEs

Inspiration from expert's manual analysis

Expert: global features + local features

Local feature:

secondary structure assignment of each residue

Global feature:

global positions of each Secondary Structure Elements (SSEs)

packing and interactions between SSEs

Develop a score to "mimic" expert inspection:
check each secondary structure element,
and inspect their packing and interactions.

Overview of features get considered

Measurements on single secondary structure element or residue

The global position of each SSE
The length of each SSE
The residue DSSP assignment

Measurements on secondary structure pairs or residue pairs

The angle between SSE pair
The interactions between SSE pair
The residue contact score (used for CASP8)

Overview of features get considered

Measurements on single secondary structure element or residue

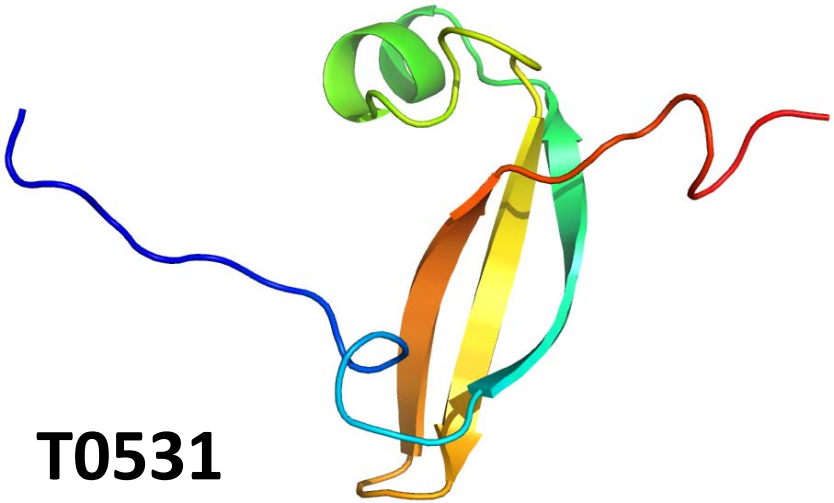
The global position of each SSE
The length of each SSE
The residue DSSP assignment

Measurements on secondary structure pairs or residue pairs

The angle between SSE pair
The interactions between SSE pair
The residue contact score (used for CASP8)

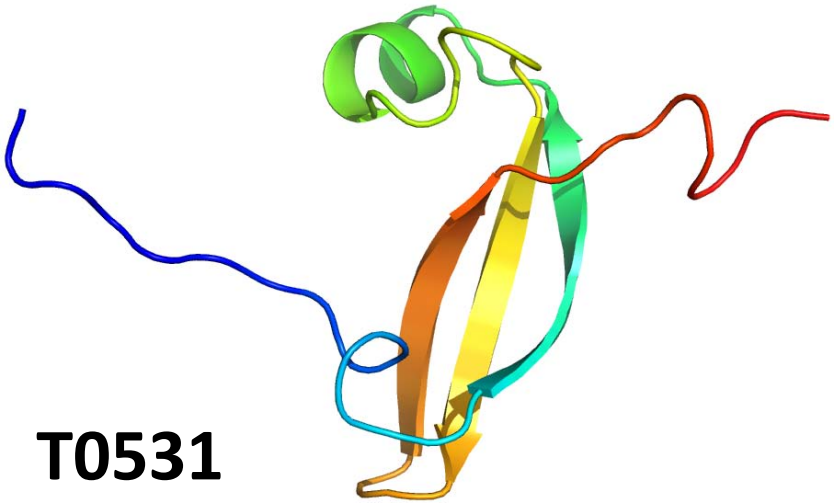
Local features as modulator

Step 1.1: Get SSE definition and vector set for target



T0531

Step 1.1: Get SSE definition and vector set for target



Type	Start		End		Length
HELIX	SER	26	PRO	32	7
SHEET	GLU	14	CYS	19	6
SHEET	GLU	19	CYS	24	6
SHEET	GLU	39	CYS	43	5
SHEET	GLY	43	SER	48	6
SHEET	SER	49	CYS	57	9

PALSSE

I.Majumdar et al. (**2005**) *BMC Bioinformatics*

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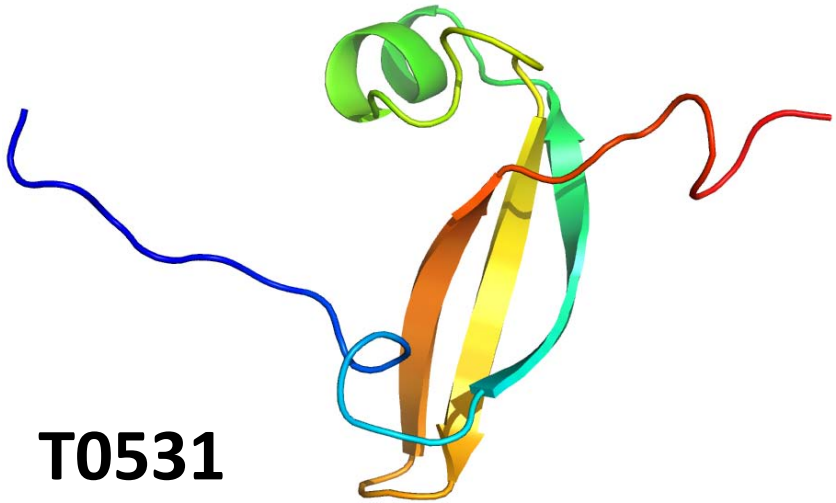
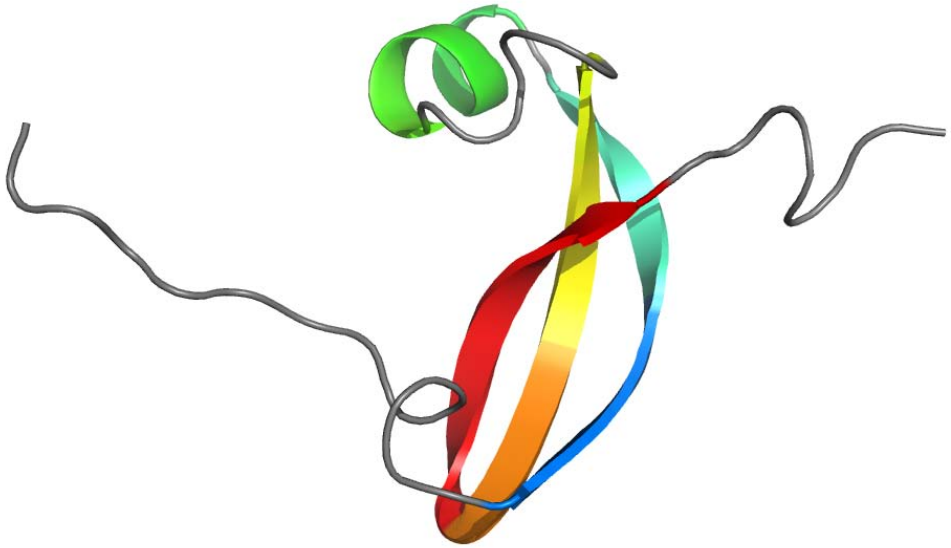


T0531



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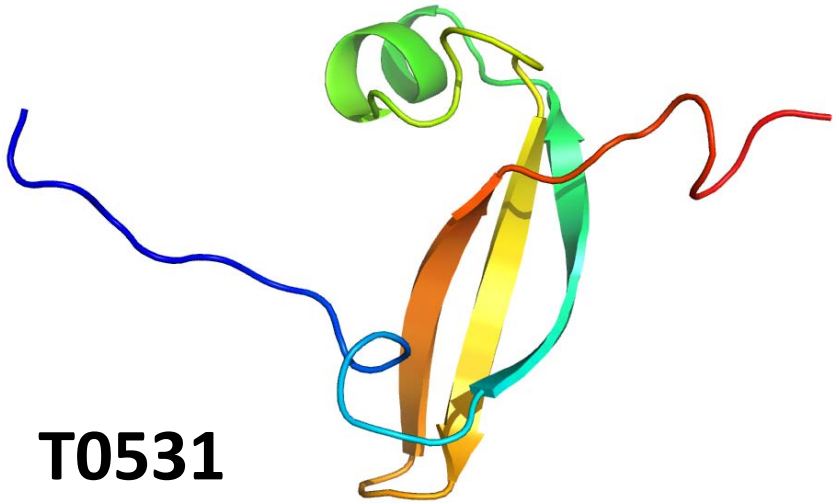

T0531

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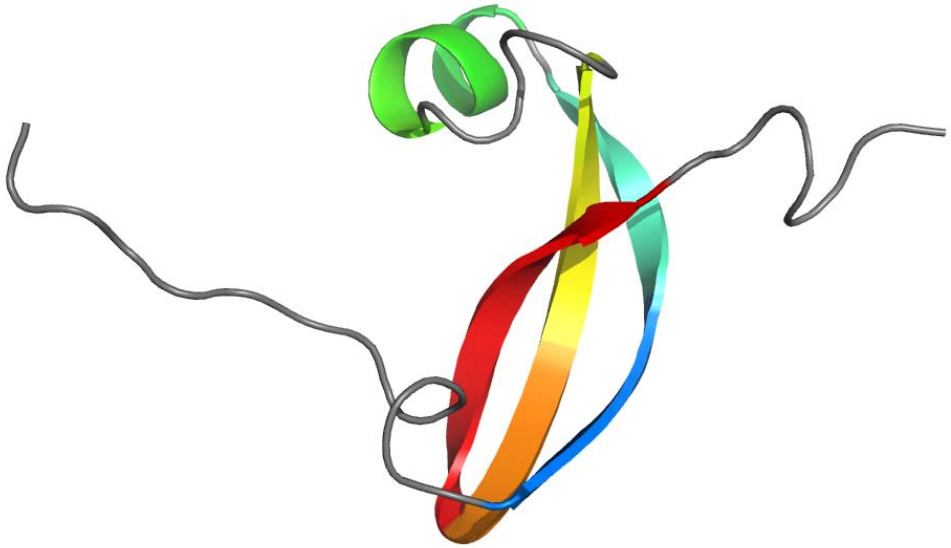
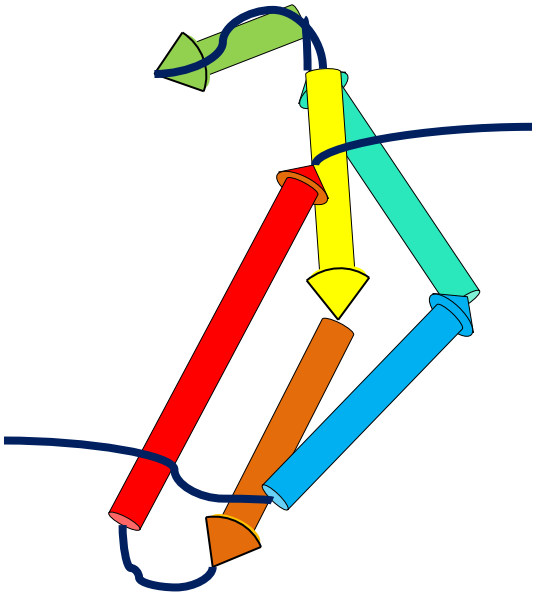
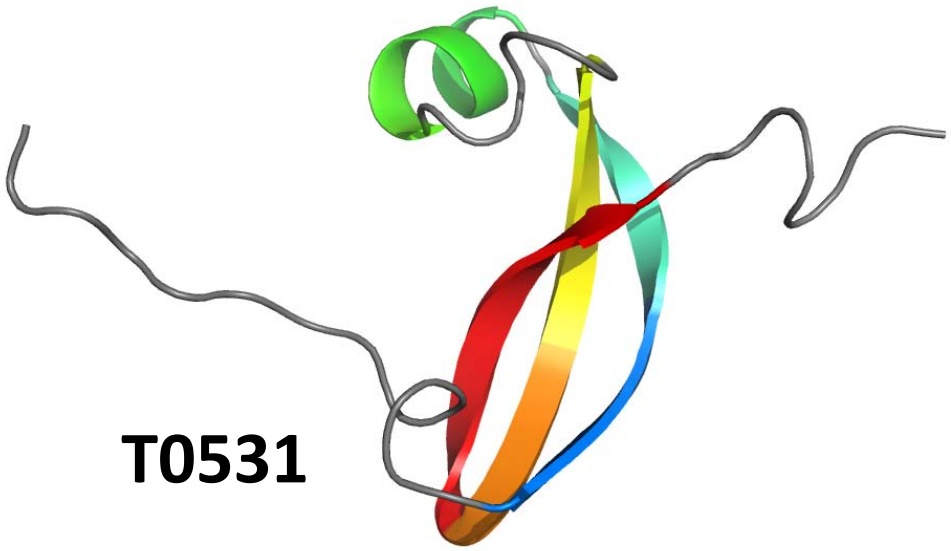




PALSSE

I.Majumdar et al. (**2005**) *BMC Bioinformatics*

Step 1.2: Get the interacting residue pairs

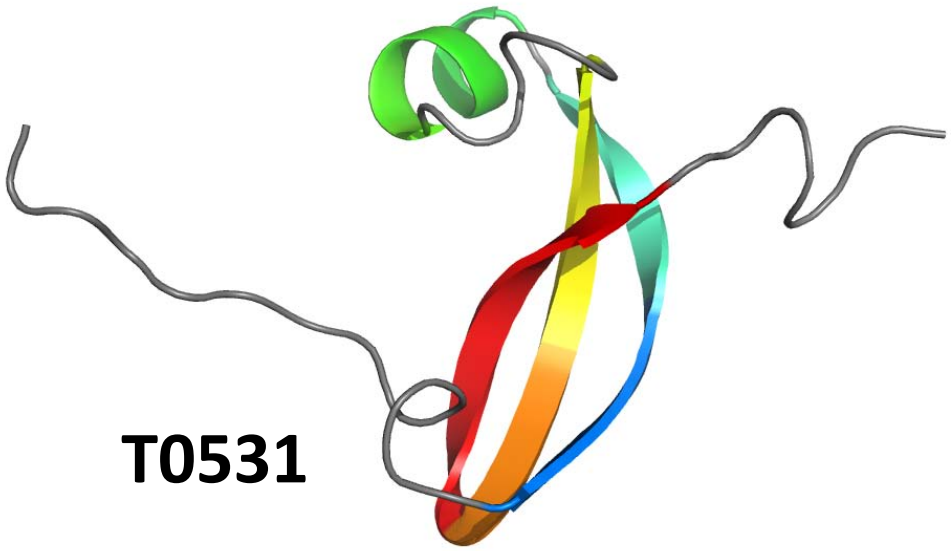


Interactions criteria:

1. The shortest distance of central part of two SSEs

2. Below 8.5 Å

Step 1.2: Get the interacting residue pairs



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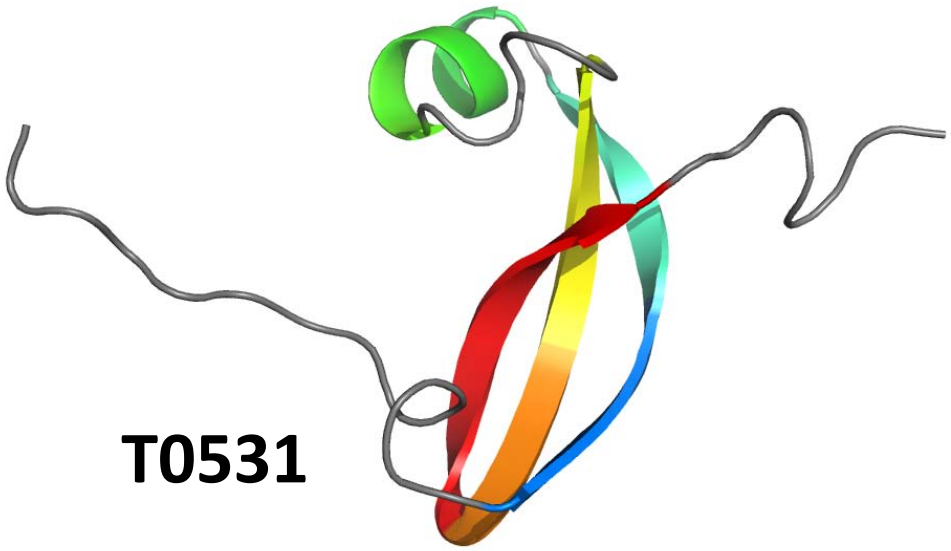
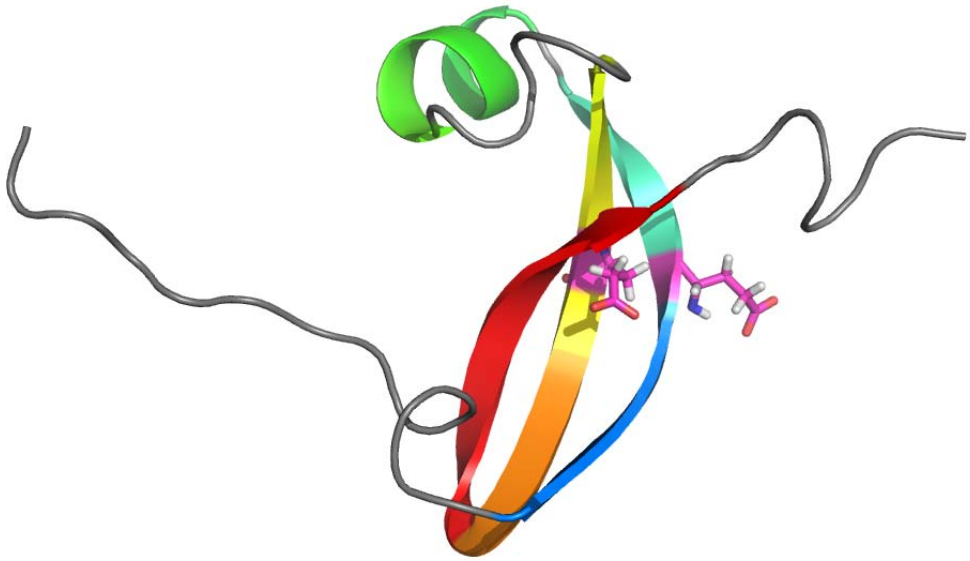
15, 46	15, 52	17, 42	20, 44
21, 42	21, 55	23, 29	32, 41
32, 54	42, 52	45, 55	

Step 1.2: Get the interacting residue pairs





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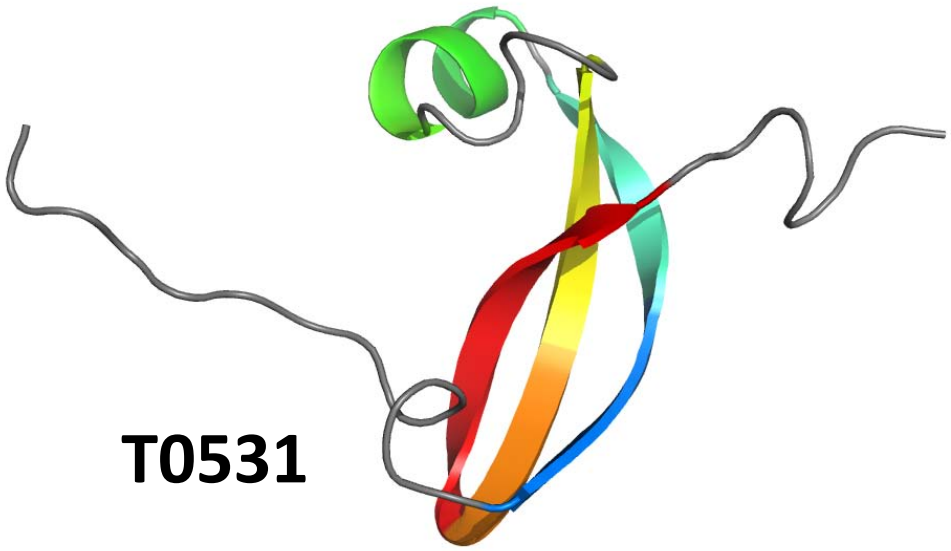
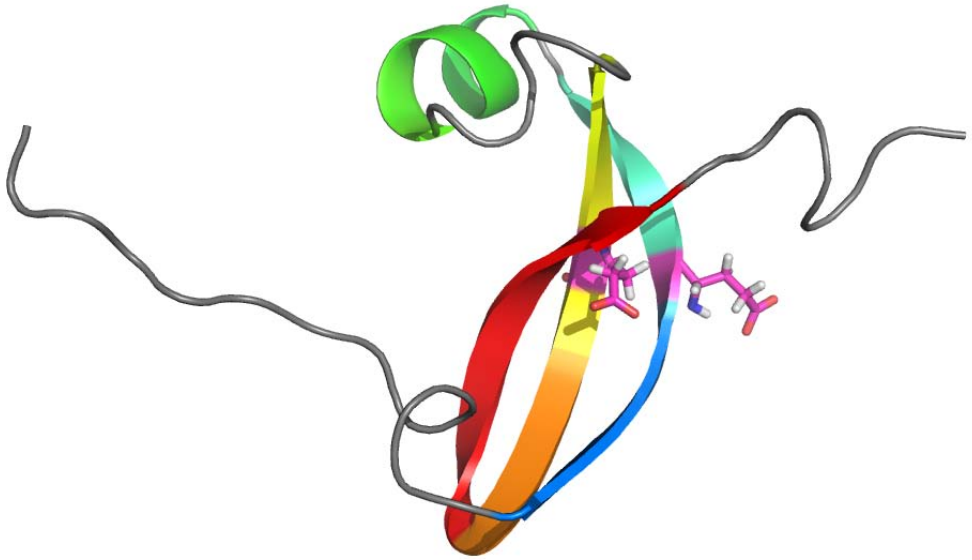


T0531



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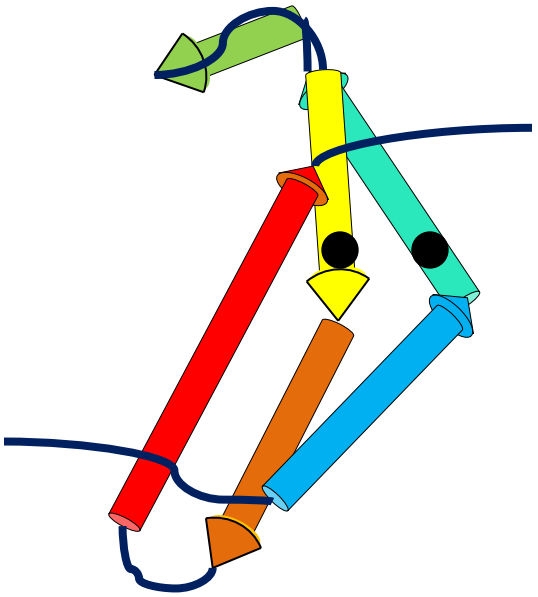

Step 2: Simplify models into vectors and key points

The SSE definition and interacting residue pair definition are propagated to models, and thus models are simplified as a set of vectors and point pairs too.

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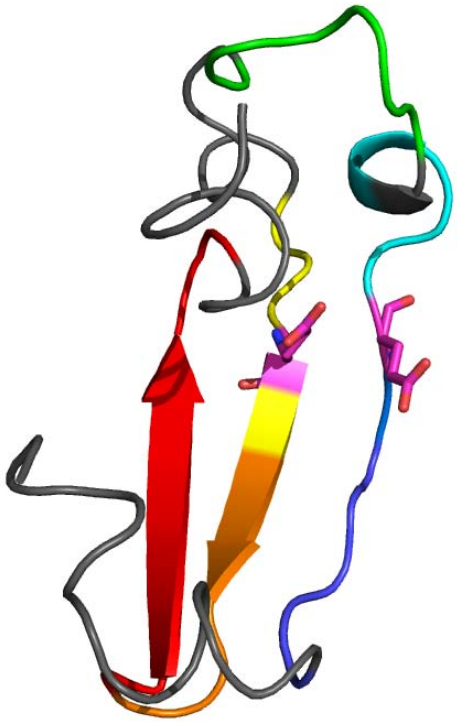
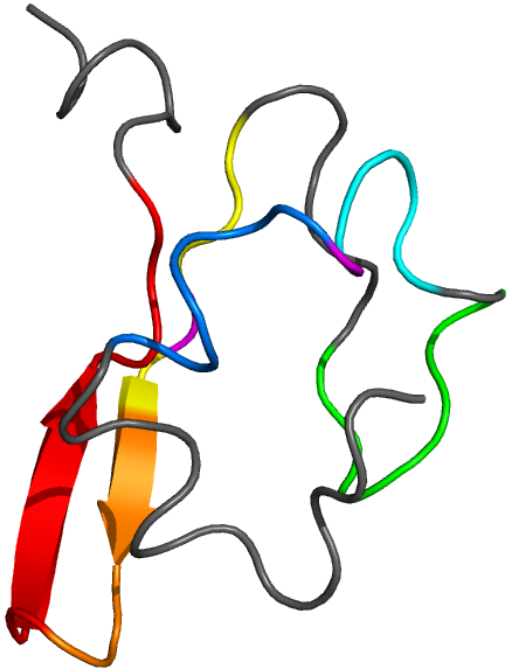
TS399_4



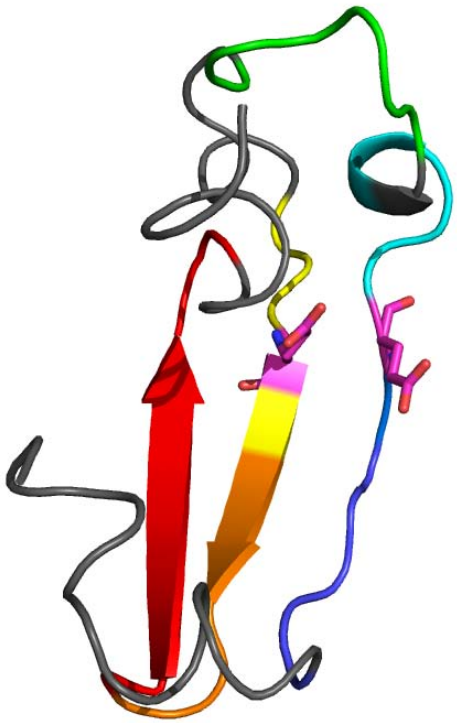


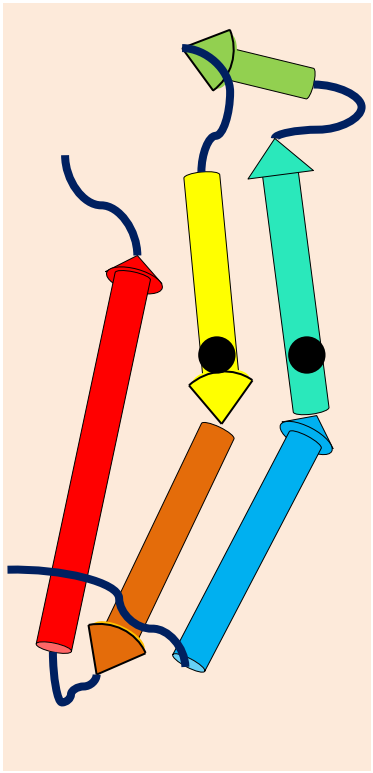
TS490_2

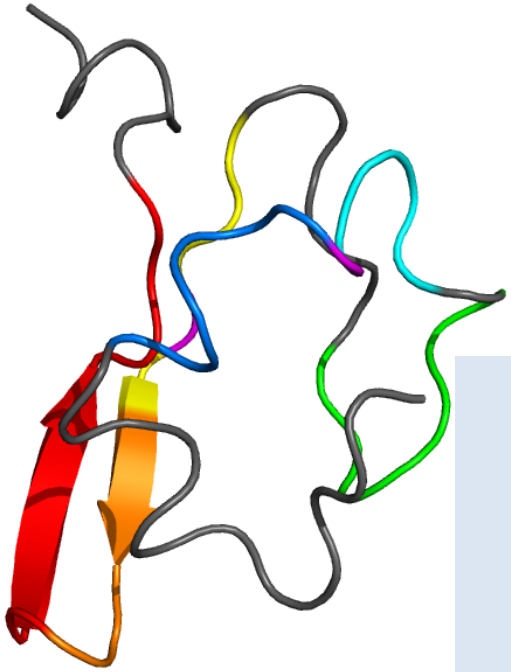
Step 2: Simplify models into vectors and key points

The SSE definition and interacting residue pair definition are propagated to models, and thus models are simplified as a set of vectors and point pairs too.

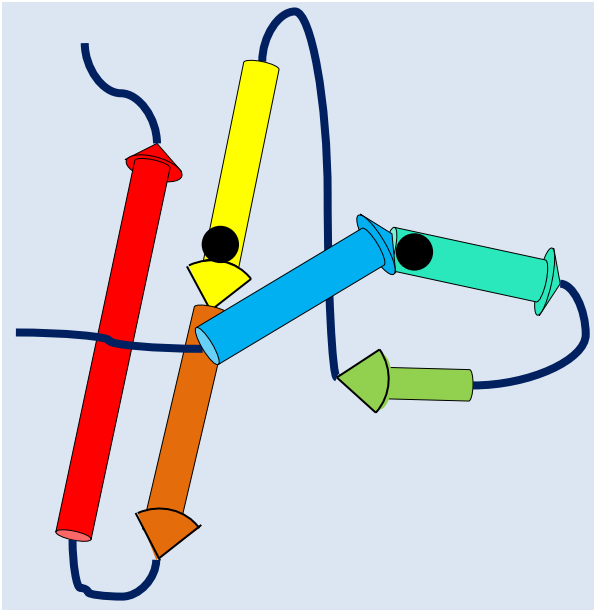
TS399_4



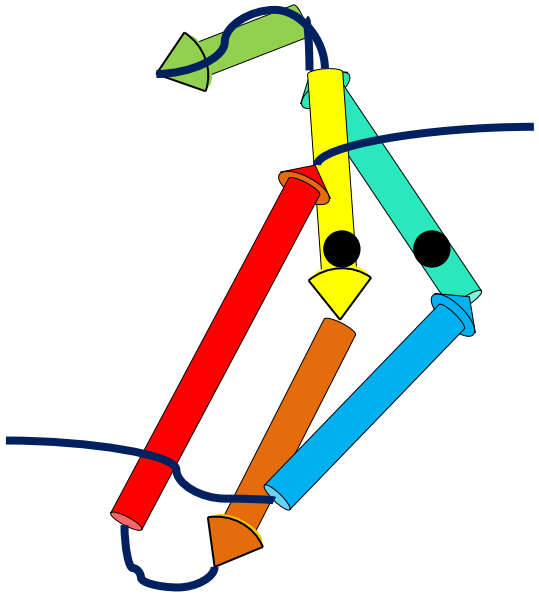




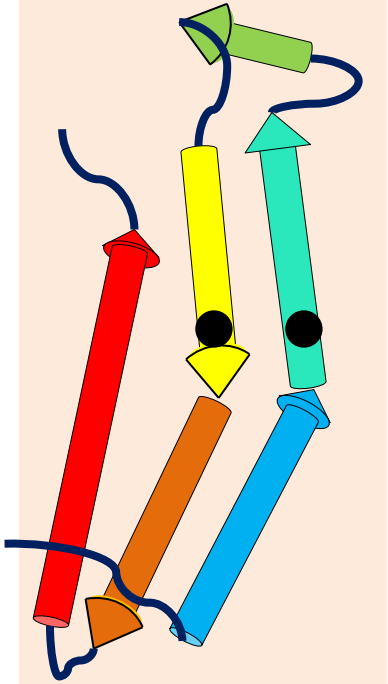
TS490_2



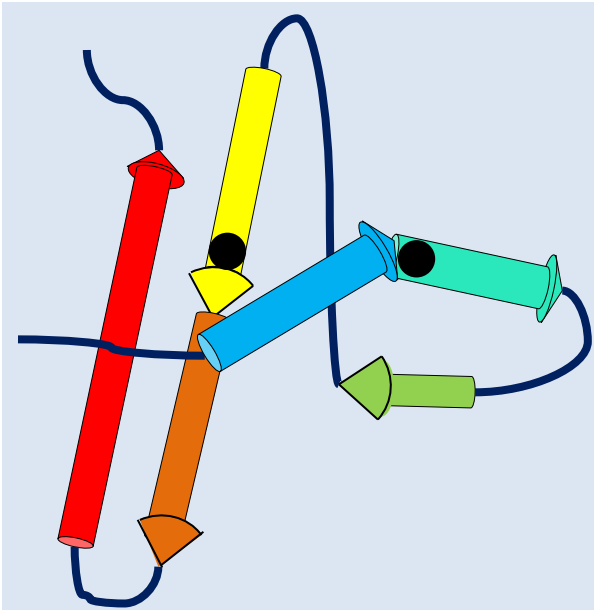
What should we look at?



Target



A good model



A “bad” model

Step 3.1: compare the global position of SSE vectors

Definition of global position: the distance between the geometry center of SSE and the center of the whole protein

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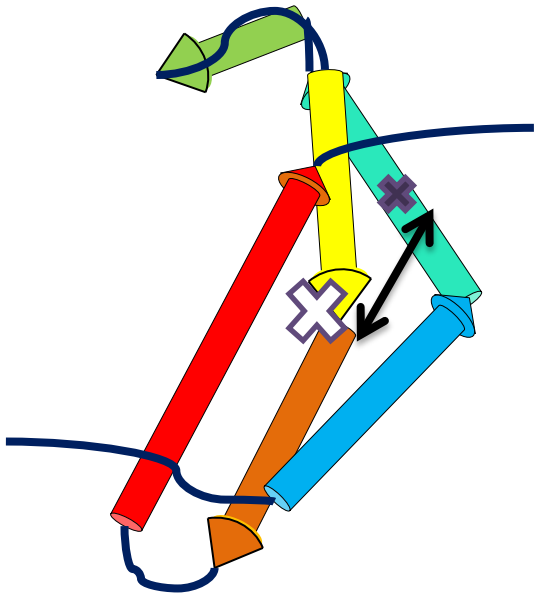
Definition of global position: the distance between the geometry center of SSE and the center of the whole protein



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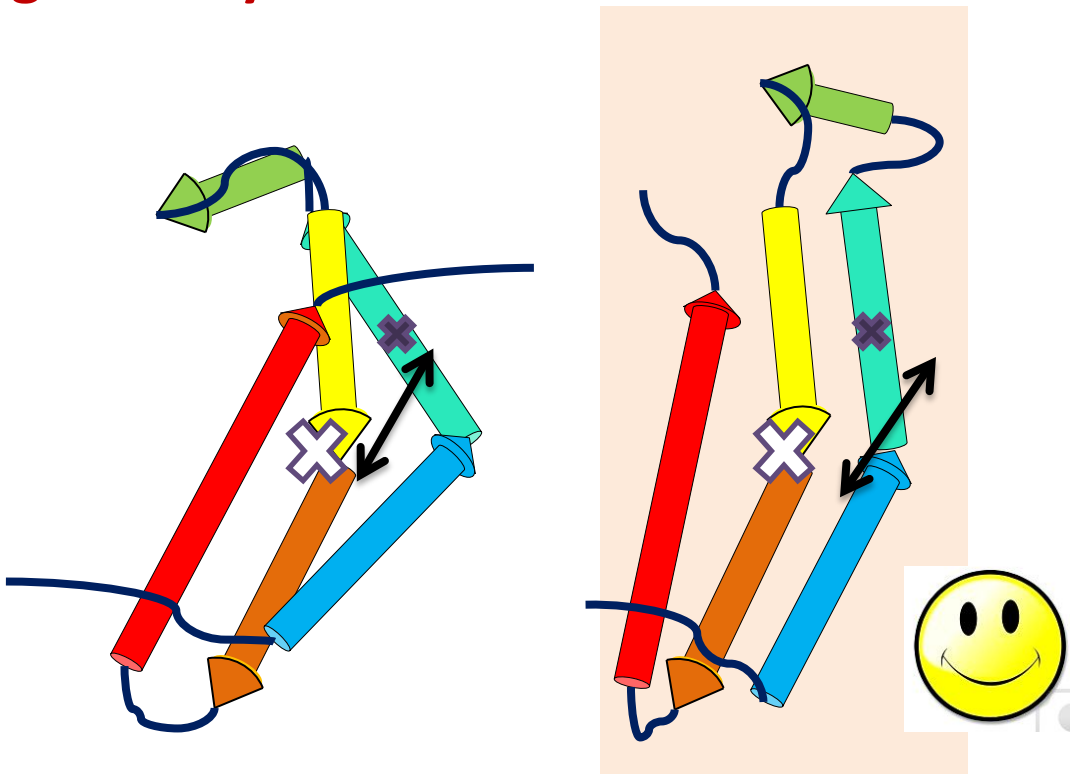

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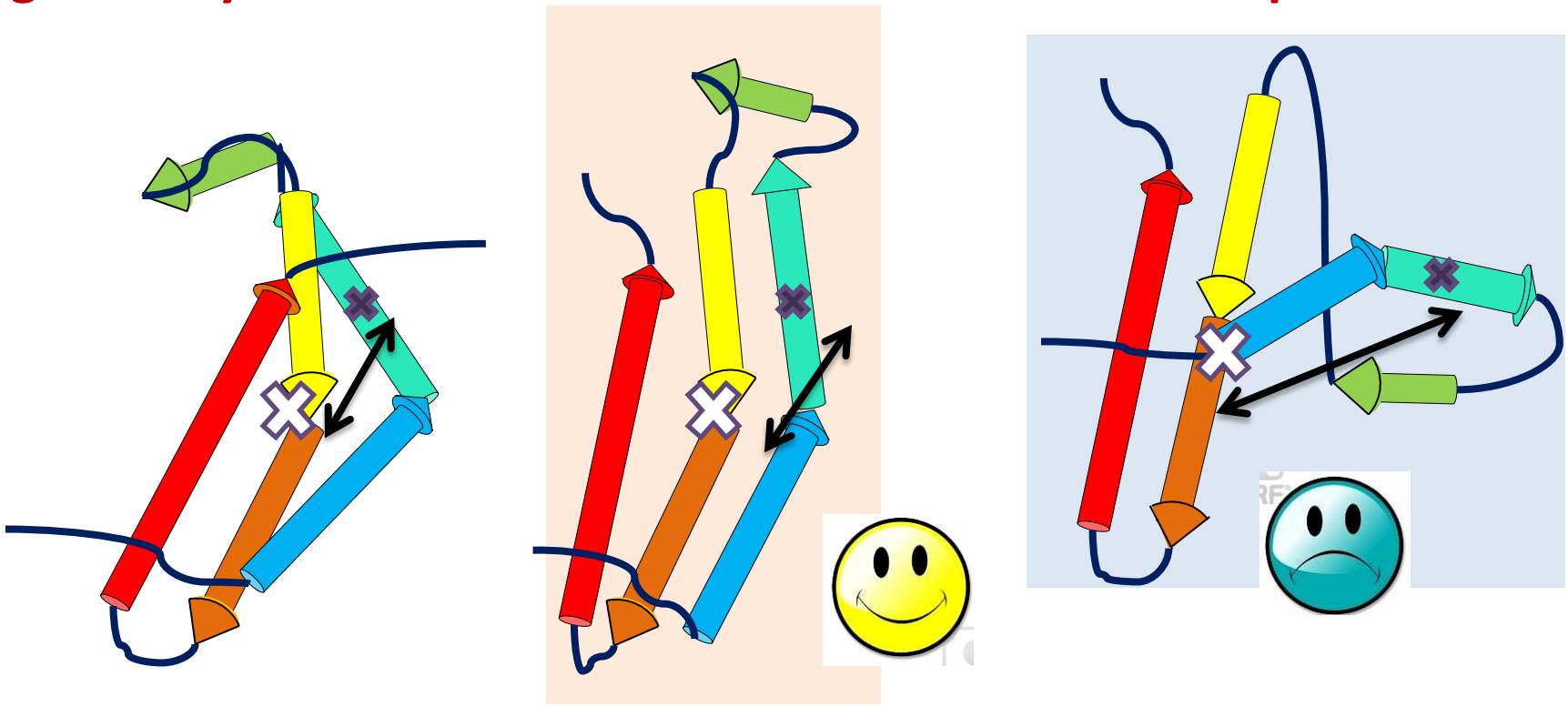

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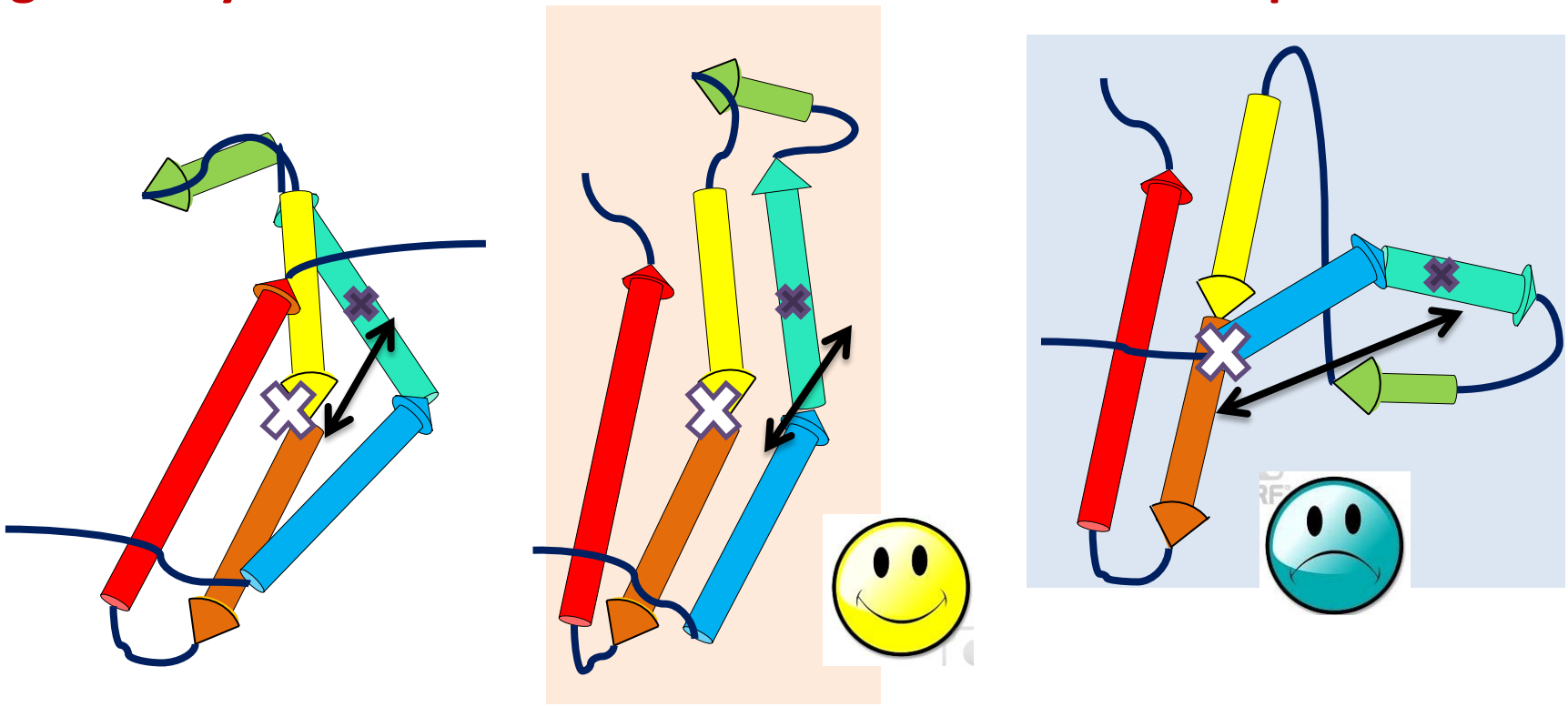
Definition of global position: the distance between the geometry center of SSE and the center of the whole protein



$$s_{Position}(i) = \frac{1}{1 + \left(\frac{P_i(M) - P_i(R)}{0.5 \times P_i(R)}\right)^2}$$

$$S_{Position} = \frac{\sum_i w_i * s_{Position}(i)}{\sum_i w_i}$$

Step 3.2: compare the length of SSE vectors

Assumption: wrong SS prediction and improper break of SSE will result in difference from target in vector length

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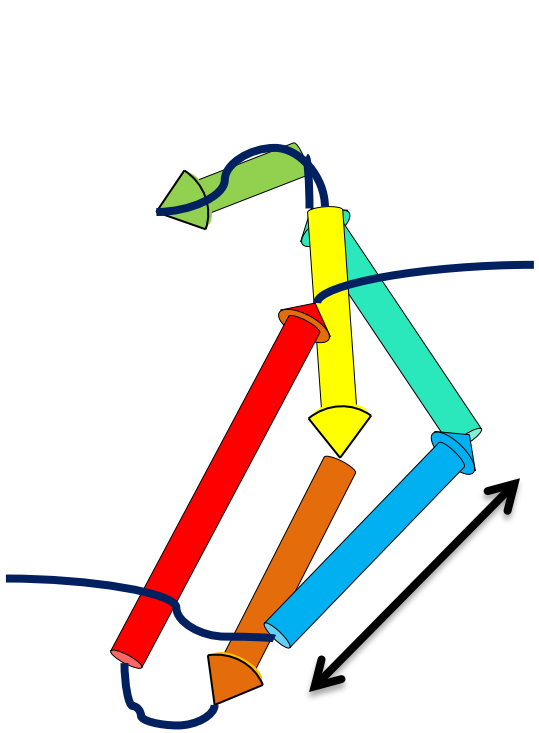
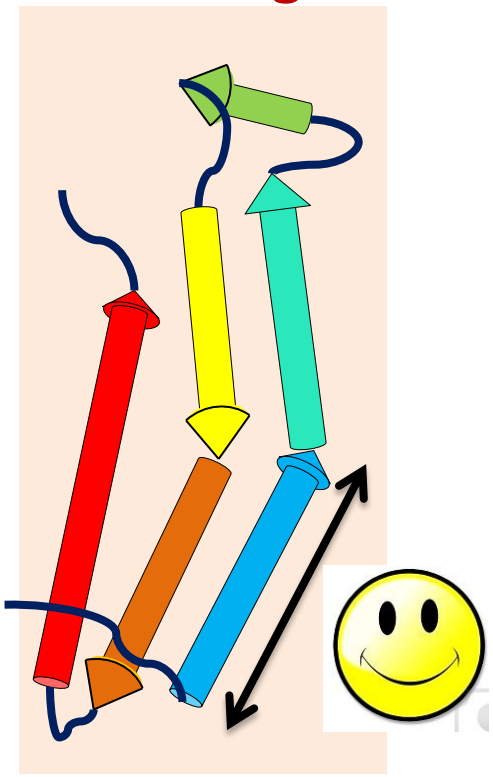
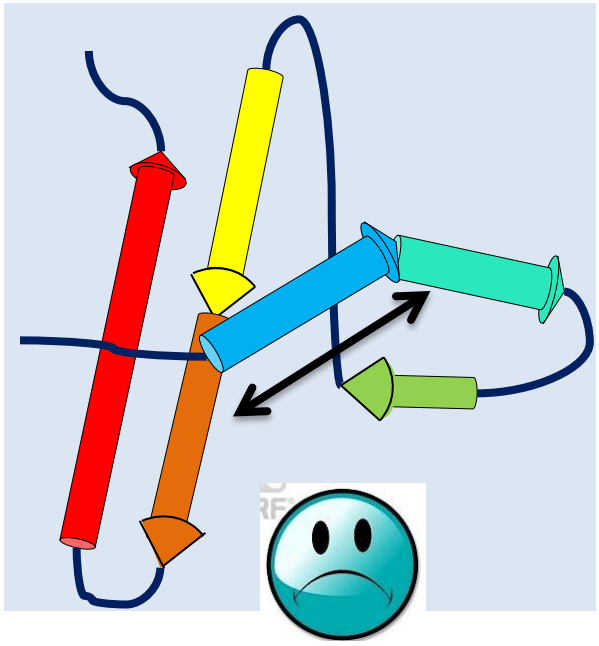
Assumption: wrong SS prediction and improper break of SSE will result in difference from target in vector length







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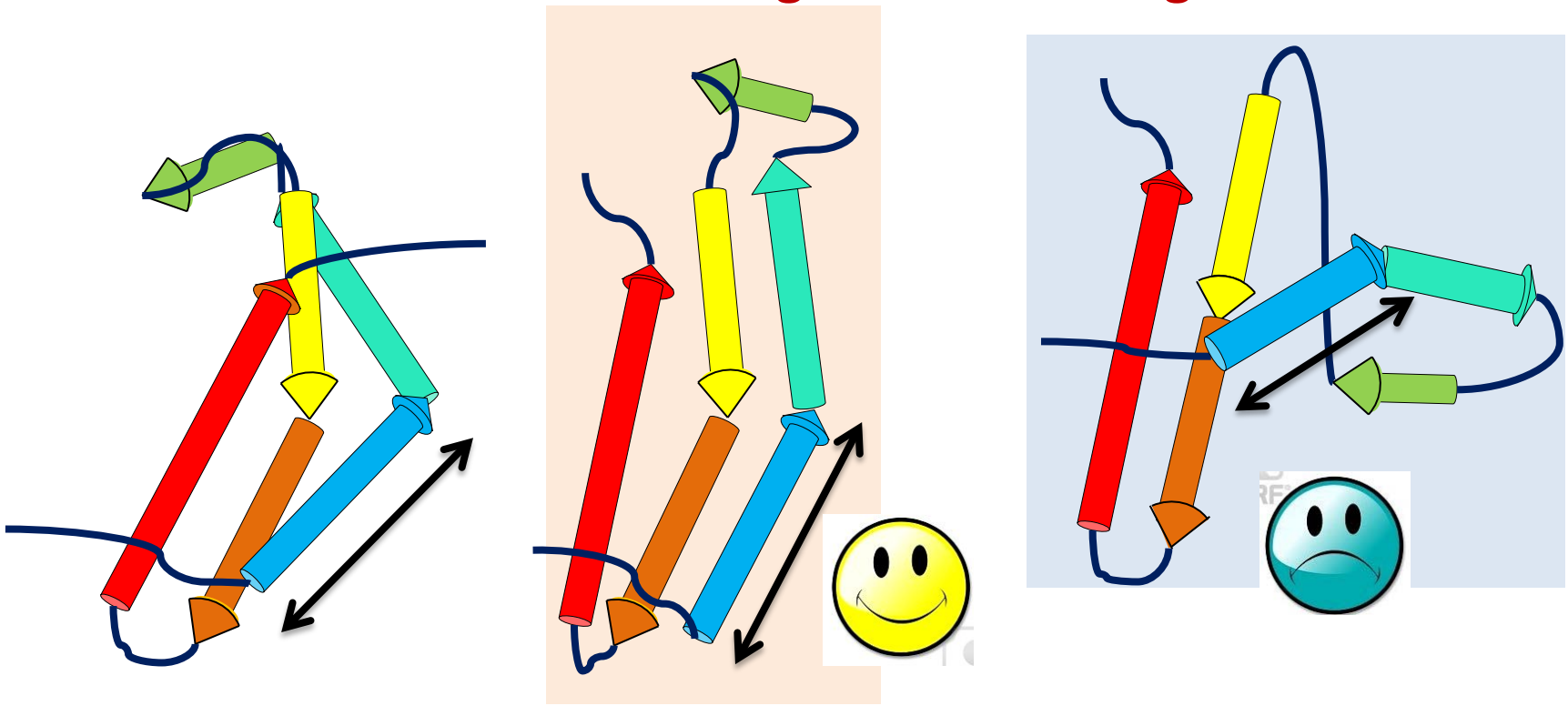
Assumption: wrong SS prediction and improper break of SSE will result in difference from target in vector length

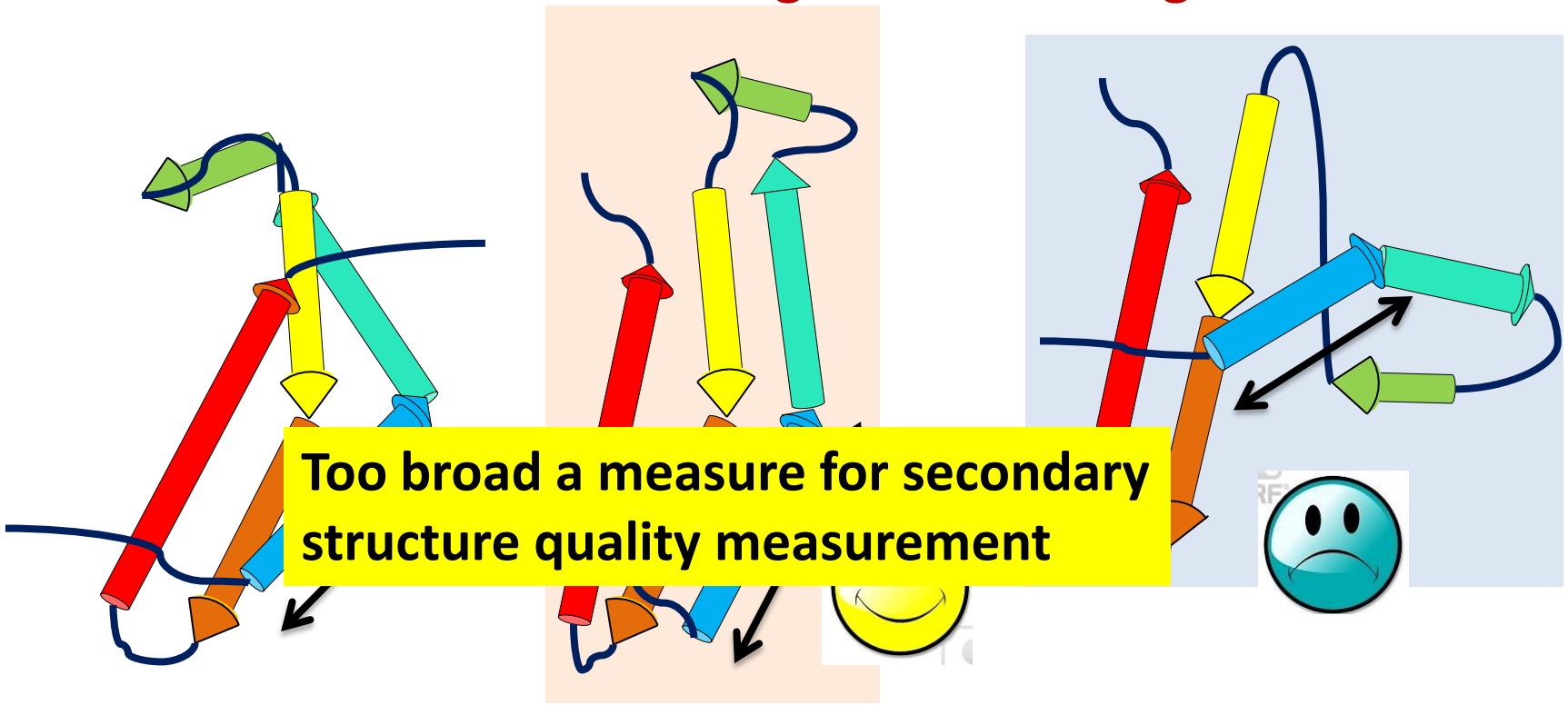


$$s_{Length}(i) = \frac{1}{1 + \left(\frac{L_i(M) - L_i(R)}{L_i(R) \times 0.25}\right)^2}$$

$$S_{Length} = \frac{\sum_i w_i * s_{Length}(i)}{\sum_i w_i}$$

Step 3.2: compare the length of SSE vectors

Assumption: wrong SS prediction and improper break of SSE will result in difference from target in vector length



Too broad a measure for secondary structure quality measurement

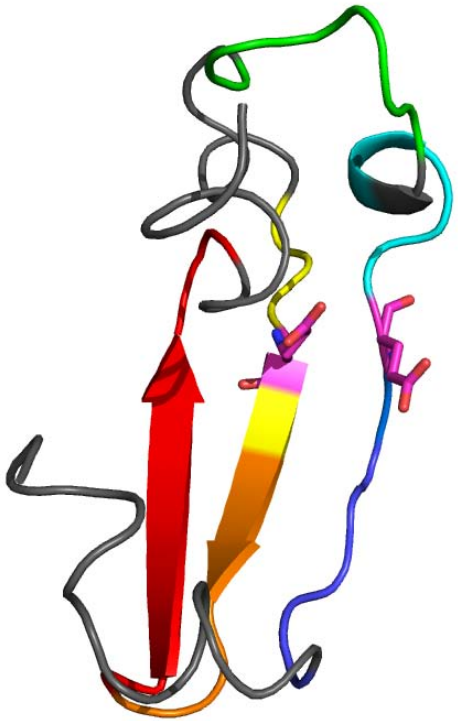
$$s_{Length}(i) = \frac{1}{1 + \left(\frac{L_i(M) - L_i(R)}{L_i(R) \times 0.25}\right)^2}$$

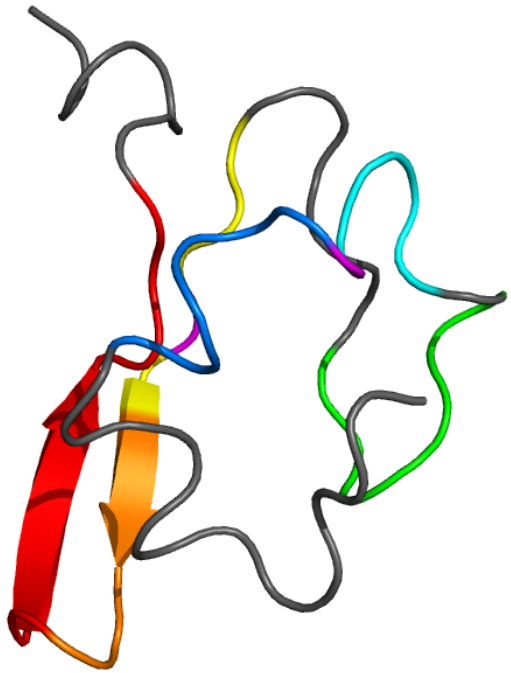
$$S_{Length} = \frac{\sum_i w_i * s_{Length}(i)}{\sum_i w_i}$$

Step 3.3: compare DSSP assignment

Percent agreement of DSSP assignment reflects the detailed quality of secondary structures

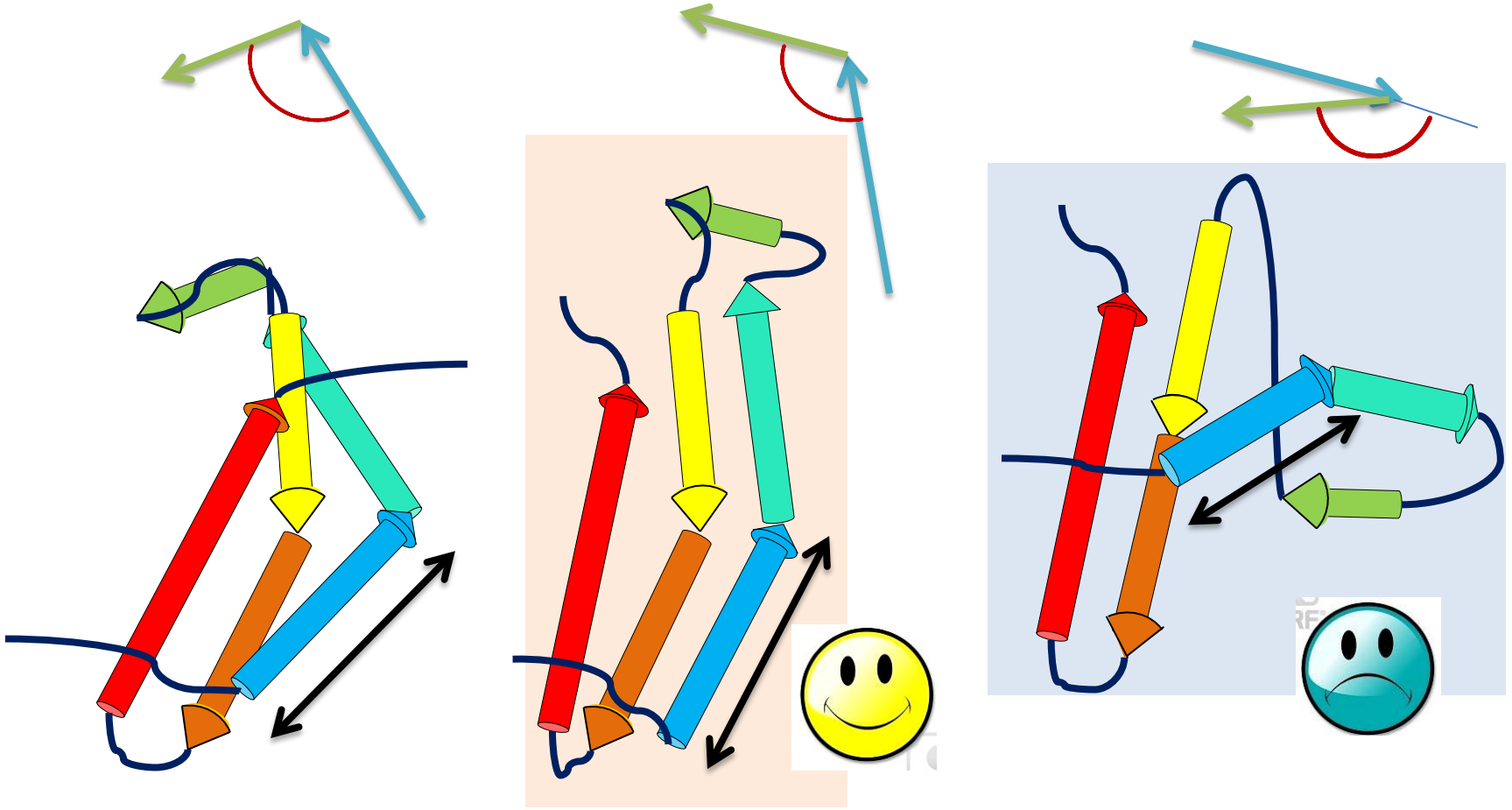
```
Target:CCCCCCCCSTTTSCEEEEEEEEECCHHHHHHCGGGTTTCEEEEEEETTTTEEEEEECCHHHHSCC
Model1:CCHHHHSHHHHTTCEECCCCCSGGGCSSCSSCCCCGGGTCCEEEEETTTTEEEEESSCHHHHTCC
Model2:CCCCSSSTTSSTTHHHHTTSCSSCSSCCSSCCCCCCSSCCCCEEEETTTTEEEECCCSCHHHHHC
```





$$S_{DSSP} = \frac{Correct}{Total}$$

Step 3.4: compare the angle between SSE vector pairs

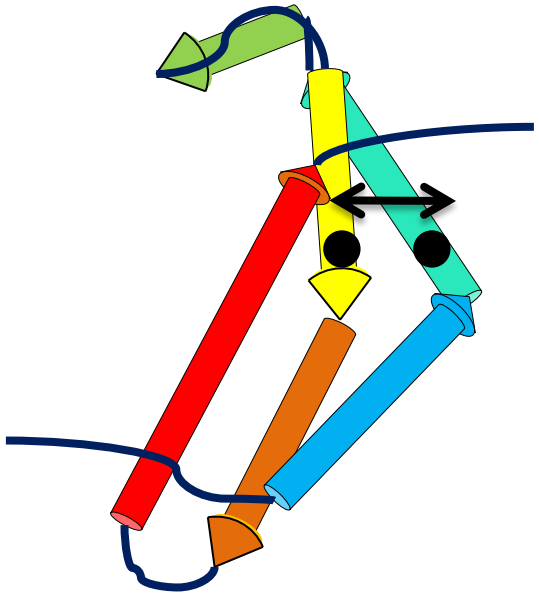


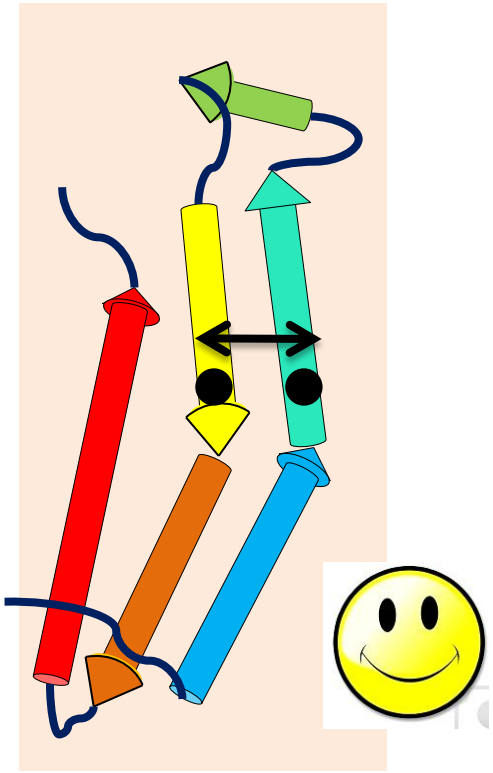
$$s_{Angle}(i,j) = \frac{1}{1 + \left(\frac{\theta_{i,j}(M) - \theta_{i,j}(R)}{0.7}\right)^2}$$

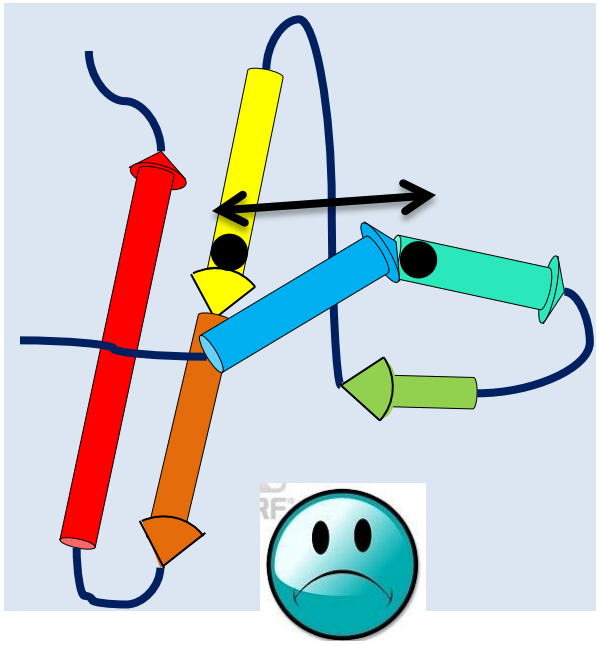
$$S_{Angle} = \frac{\sum_{i,j} w_{i,j} * s_{Angle}(i,j)}{\sum_{i,j} w_{i,j}}$$

Step 3.5: compare the interactions between SSE pairs

Motivation: some key interactions defined the general packing of elements, they should be emphasized more







$$s_{\text{Interaction}}(i) = \frac{1}{1+\left(\frac{L_i(M)-L_i(R)}{L_i(R)\times 0.25}\right)^2}$$

$$S_{Interaction} = \frac{\sum_i w_i * s_{Length}(i)}{\sum_i w_i}$$

Step 3.6: compare all C-alpha contact score

C-alpha contact score is added as a modulator for key SSE interaction score

Define all alpha contact at a cut off of 8.44 Å, similar program is proved to be good measurement by CASP8 assessors

$$s_{\mathrm{Contact}}(\mathrm{i}) = 2^{-\left(\frac{D_i(M)-D_i(R)}{0.2}\right)^2}$$

$$S_{Contact} = \frac{\sum_i s_{Length}(i)}{N}$$

Shuoyong Shi, Jimin Pei, Ruslan I. Sadreyev, Lisa N. Kinch, Indraneel Majumdar, Jing Tong, Hua Cheng, Bong-Hyun Kim, Nick V. Grishin. **Analysis of CASP8 targets, predictions and assessment methods**. *Database: The Journal of Biological Database and Curation (2009)*.

Let’s sum up all the scores

$$S_{Position} + S_{Length} + S_{Dssp} + S_{Angle} + S_{Interaction} + S_{Contact}$$

Let's sum up all the scores

$$S_{Position} + S_{Length} + S_{Dssp} + S_{Angle} + S_{Interaction} + S_{Contact}$$

superimposition independent

global and local comparison

manual analysis simulating score

SIGLACMASS ?

Let's sum up all the scores

$$S_{Position} + S_{Length} + S_{Dssp} + S_{Angle} + S_{Interaction} + S_{Contact}$$

superimposition independent

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SIGLACMASS ?

Qian Cong score = QCS

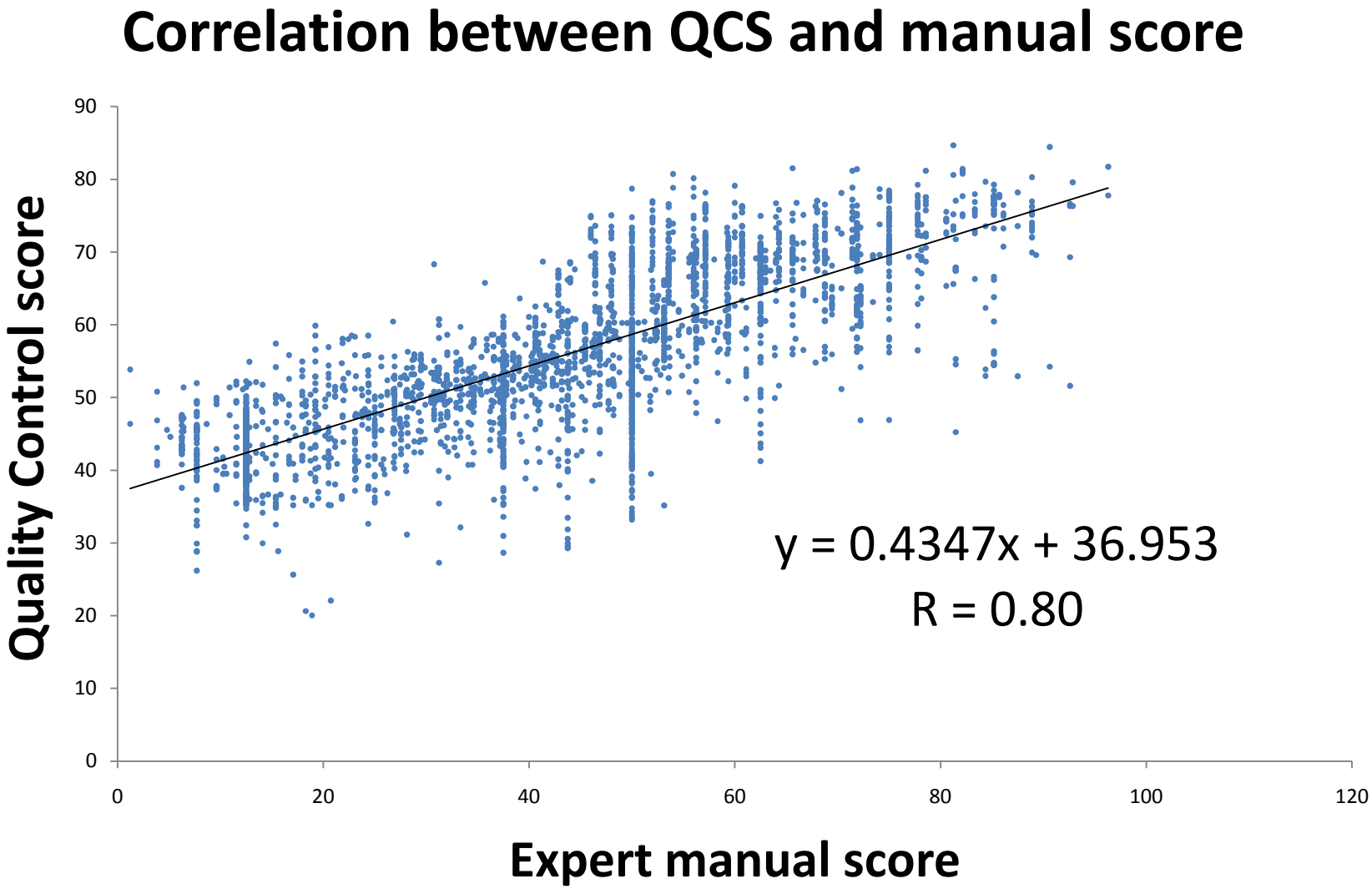
Let's sum up all the scores

$$S_{Position} + S_{Length} + S_{Dssp} + S_{Angle} + S_{Interaction} + S_{Contact}$$

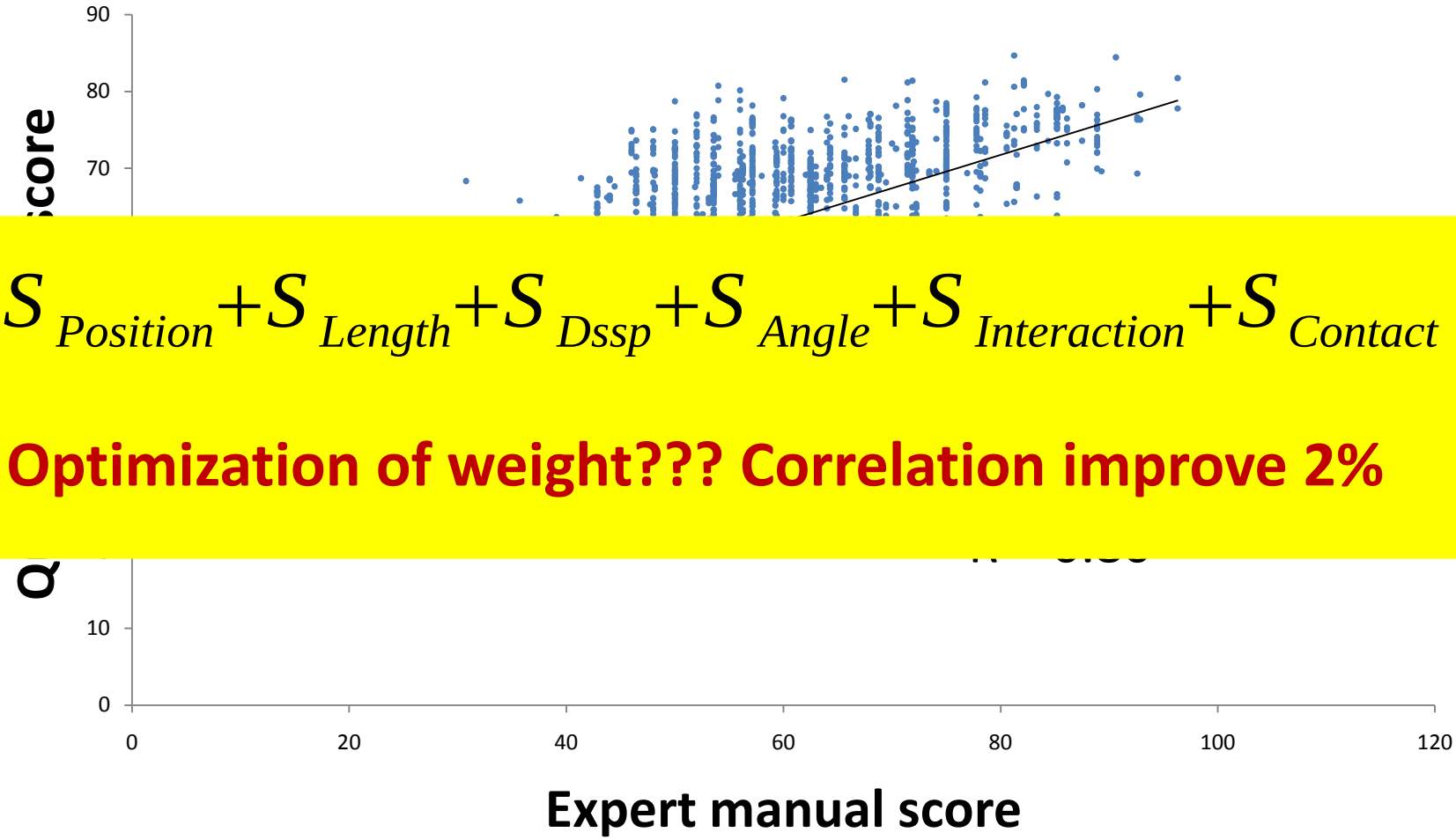
superimposition independent
global and local comparison
manual analysis simulating score
SIGLACMASS ?

Qian Cong score = QCS = Quality Control score

Global view: Correlations



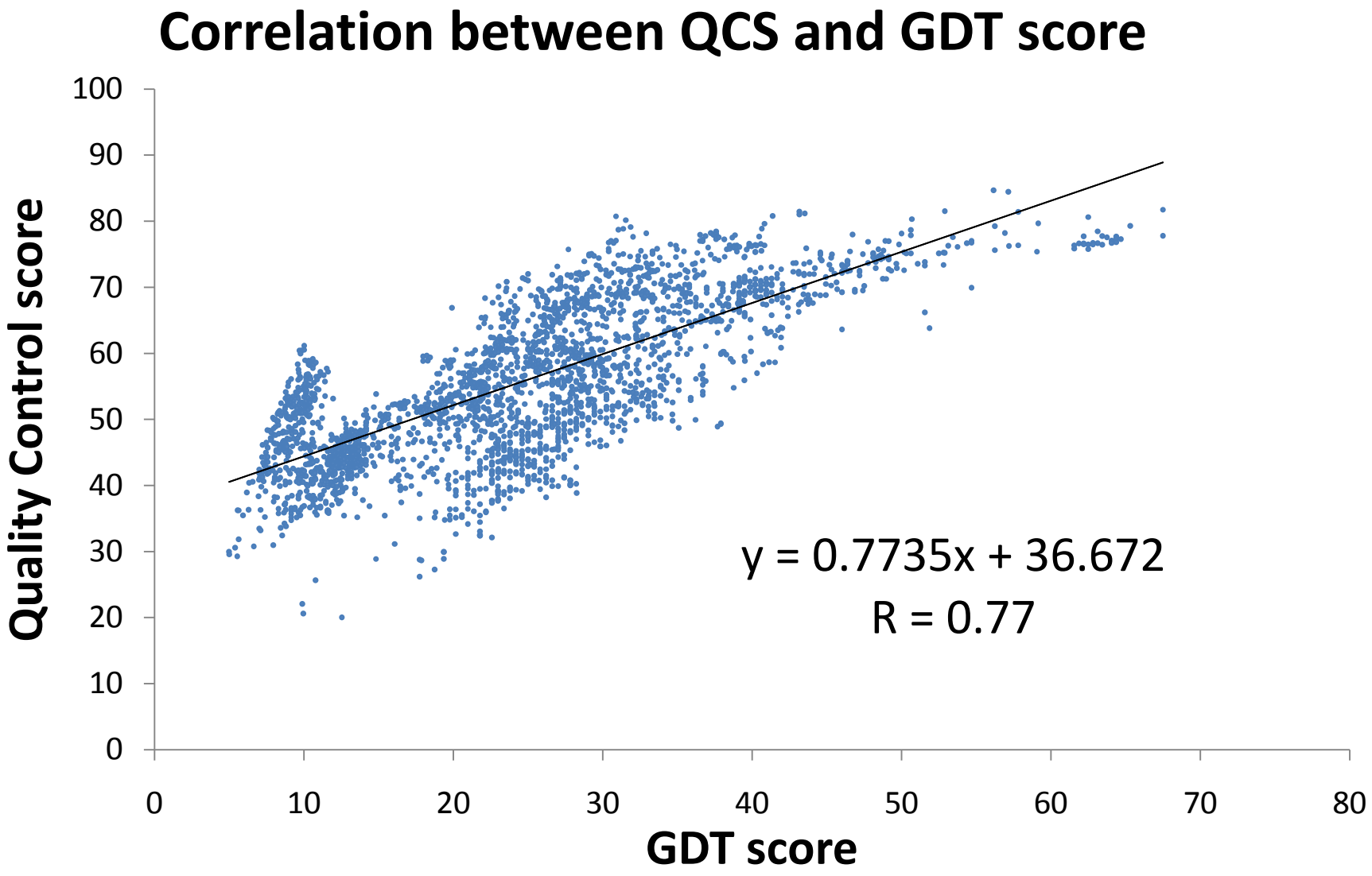
Global view: Correlations



$$S_{Position} + S_{Length} + S_{Dssp} + S_{Angle} + S_{Interaction} + S_{Contact}$$

Optimization of weight??? Correlation improve 2%

Global view: Correlations



Go to individual: Top picks

Most cases, the top models selected by GDT generally agree with top models selected by QCS and manual assessment

Go to individual: Top picks

Most cases, the top models selected by GDT generally agree with top models selected by QCS and manual assessment

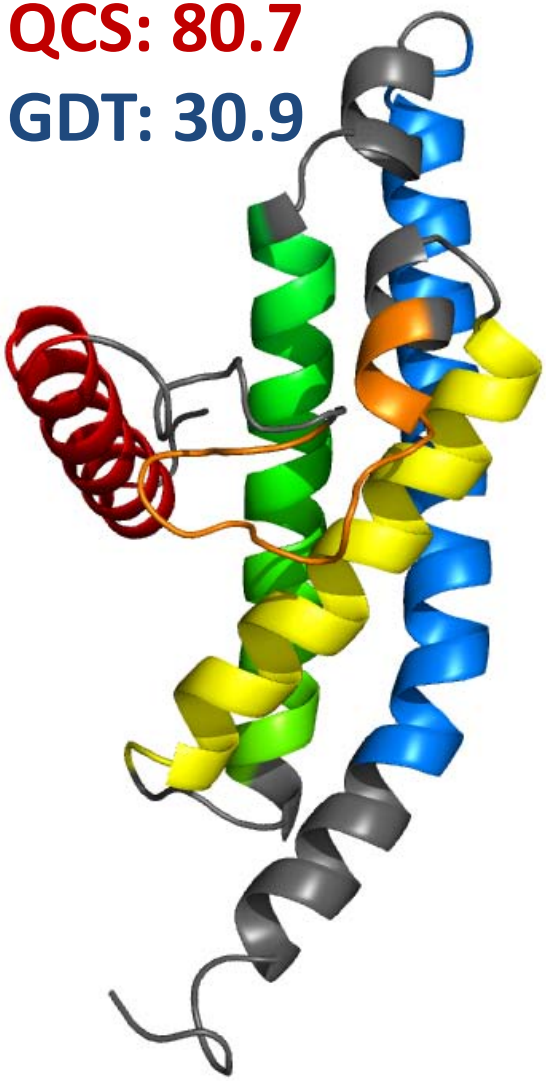
But there are cases where QCS reveals features we like …

Example where QCS reveals better model

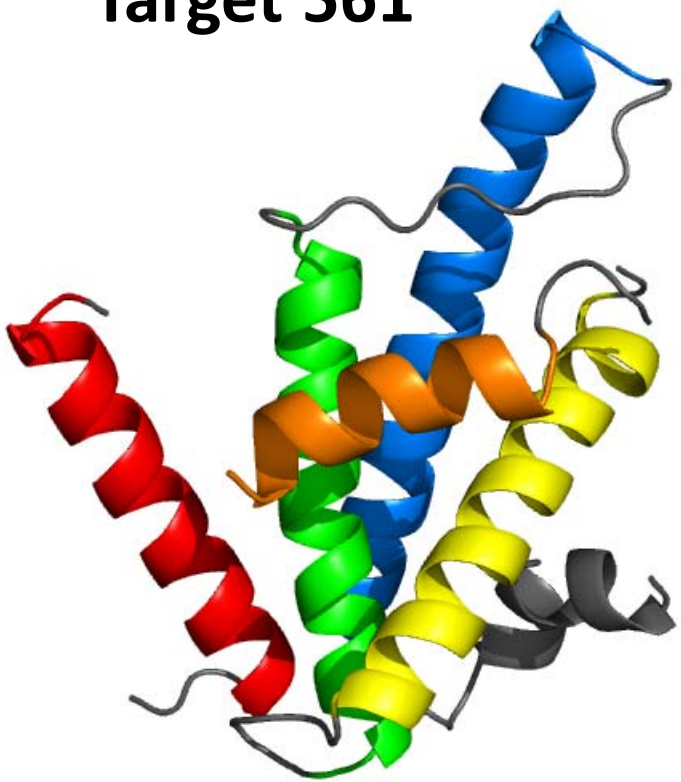
TS382_5

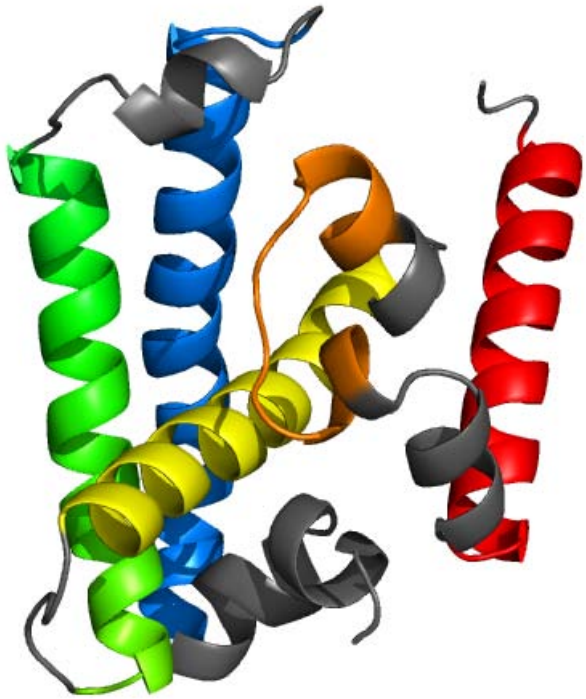
QCS: 80.7

GDT: 30.9



Target 561



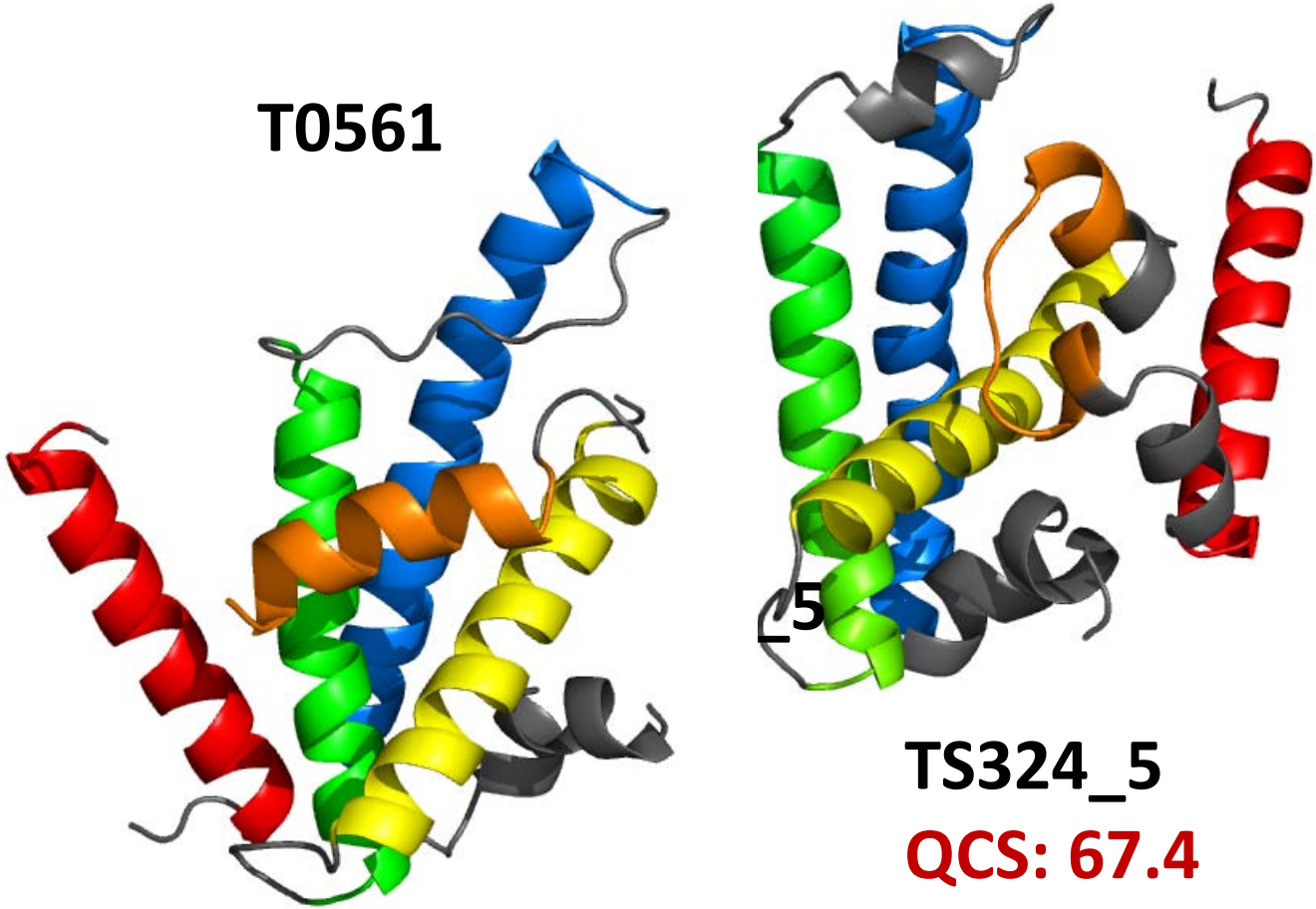


TS324_5

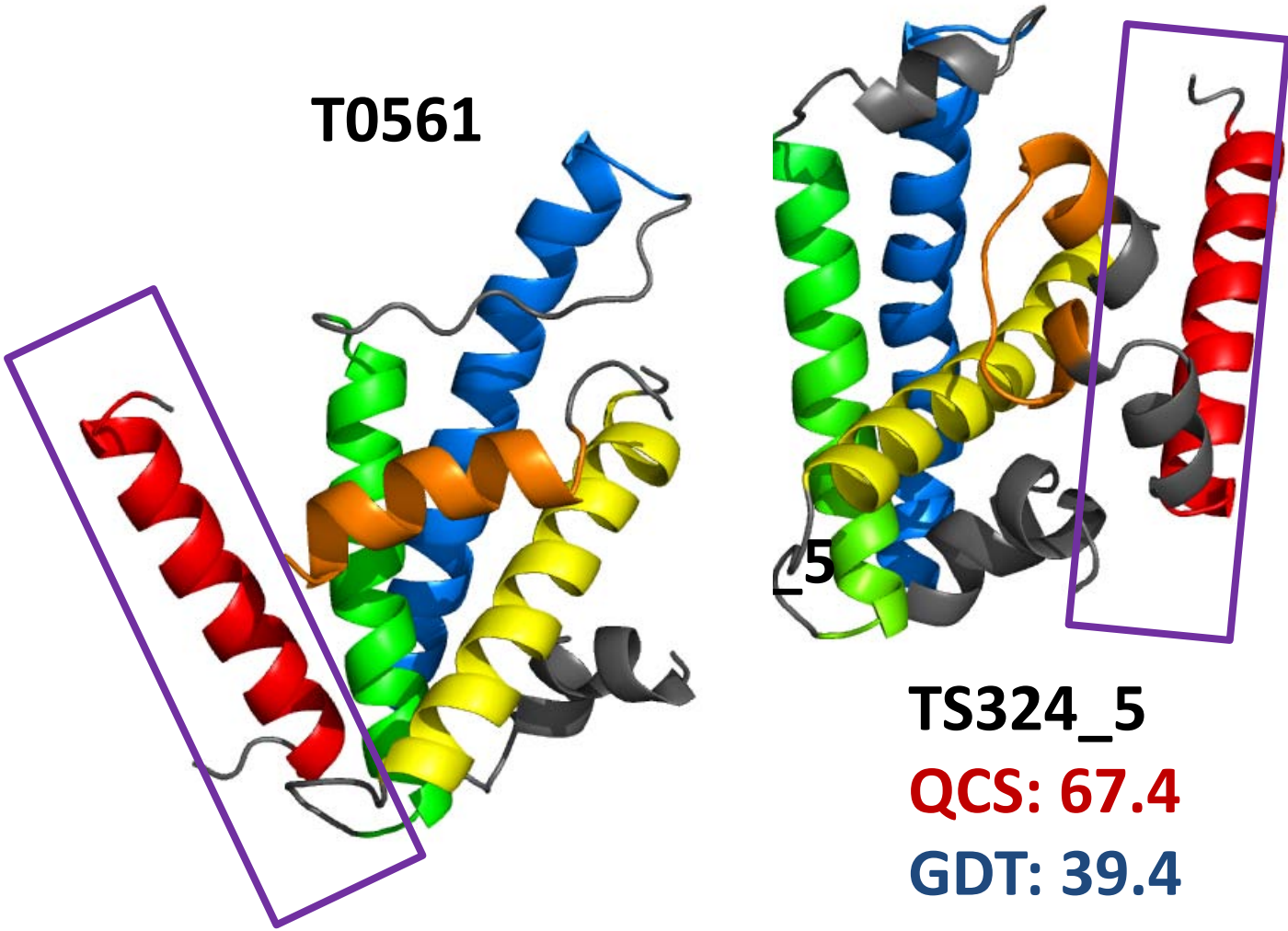
QCS: 67.4

GDT: 39.4

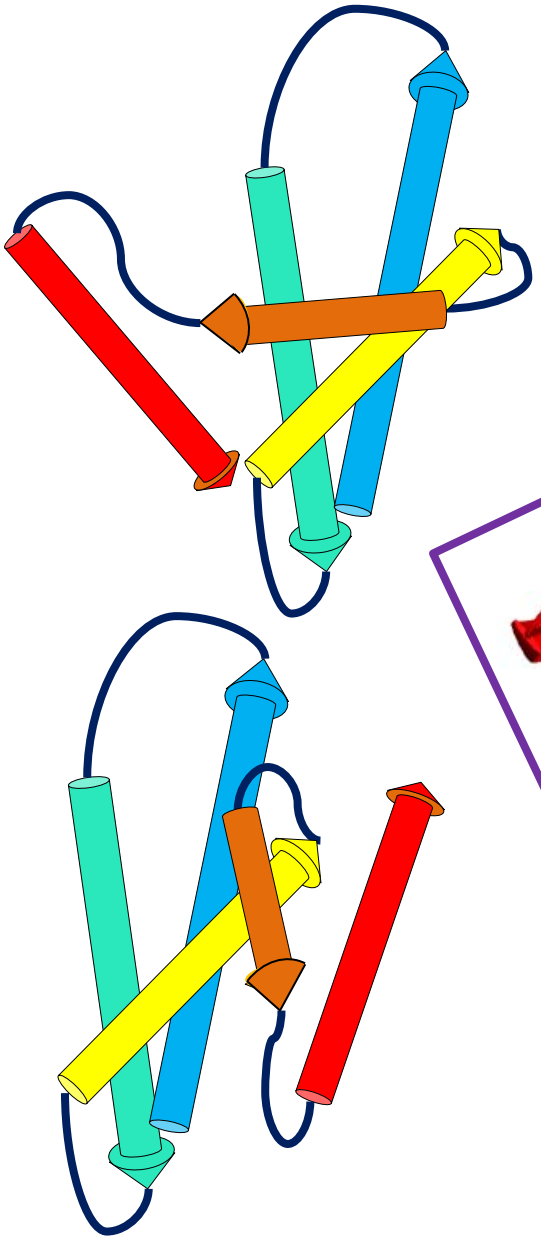
QCS reveals good global topology

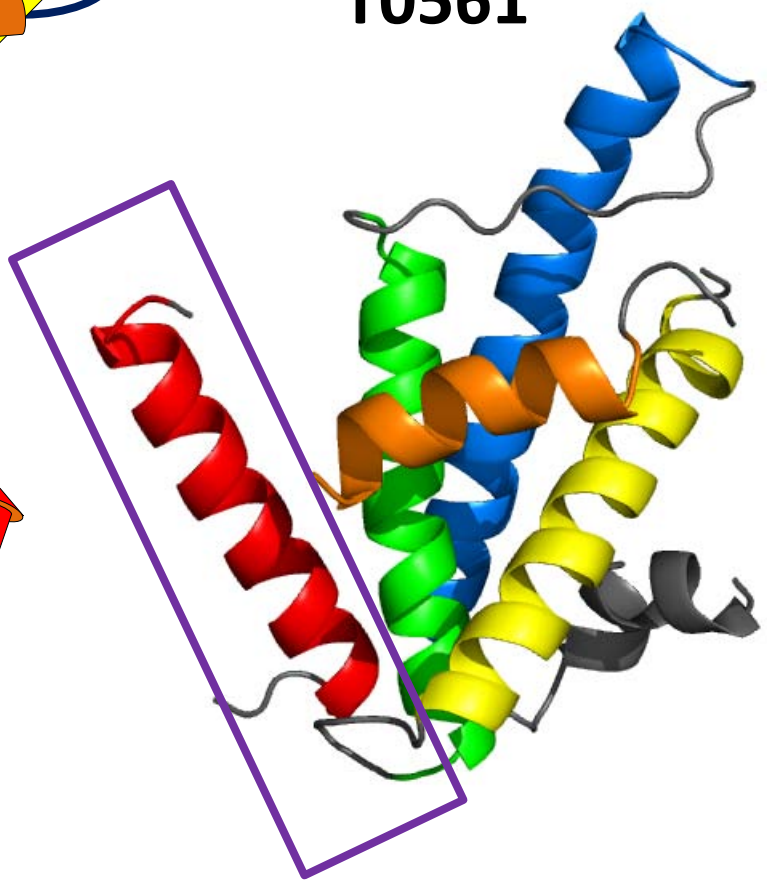


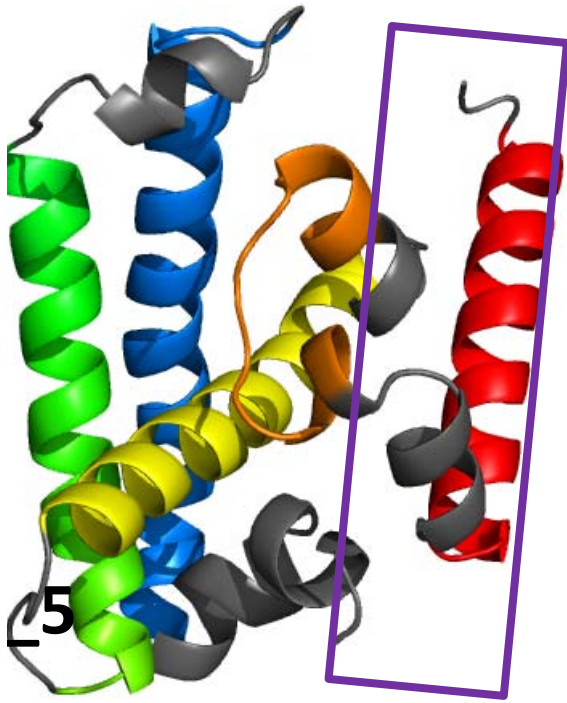
QCS reveals good global topology



QCS reveals good global topology







TS324_5

QCS: 67.4

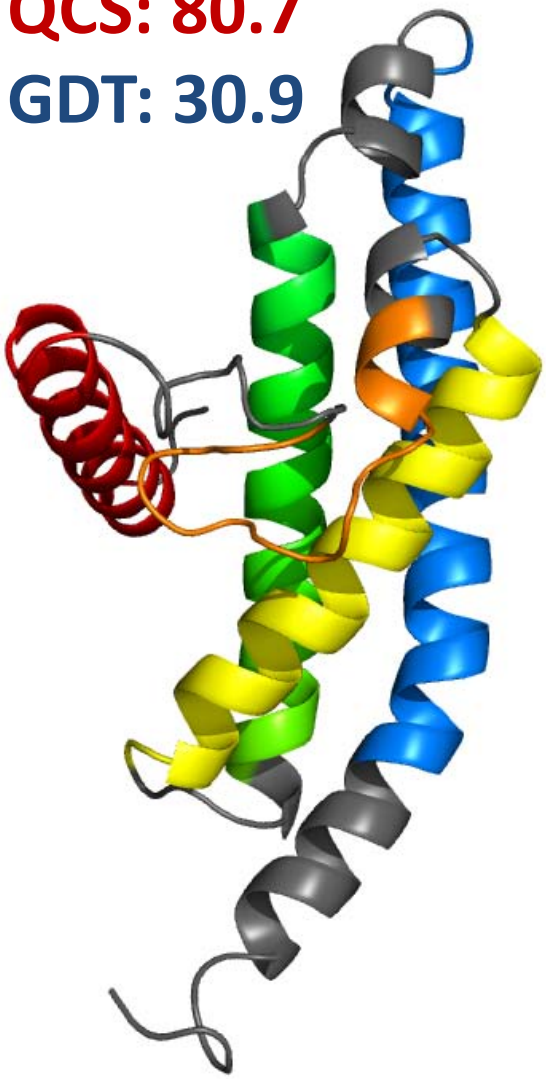
GDT: 39.4

QCS reveals good global topology

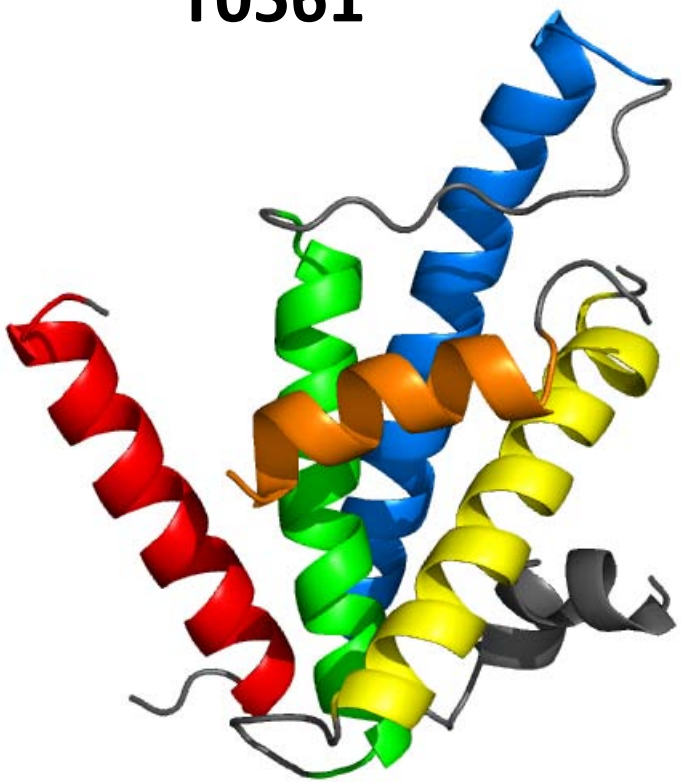
TS382_5

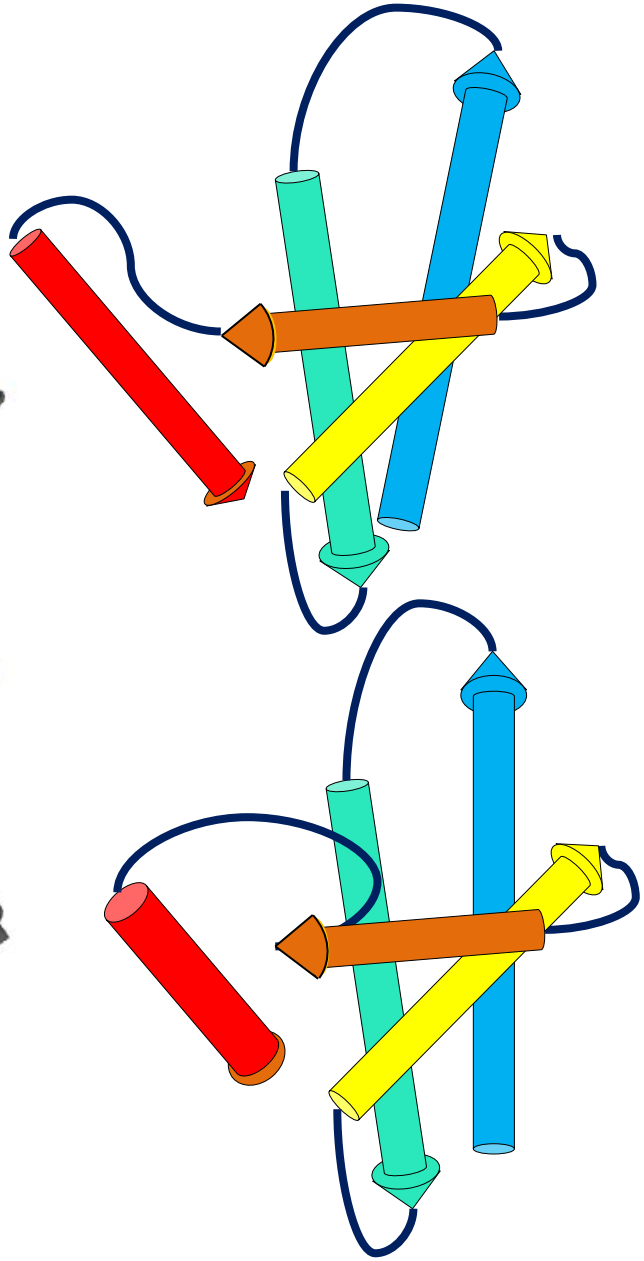
QCS: 80.7

GDT: 30.9

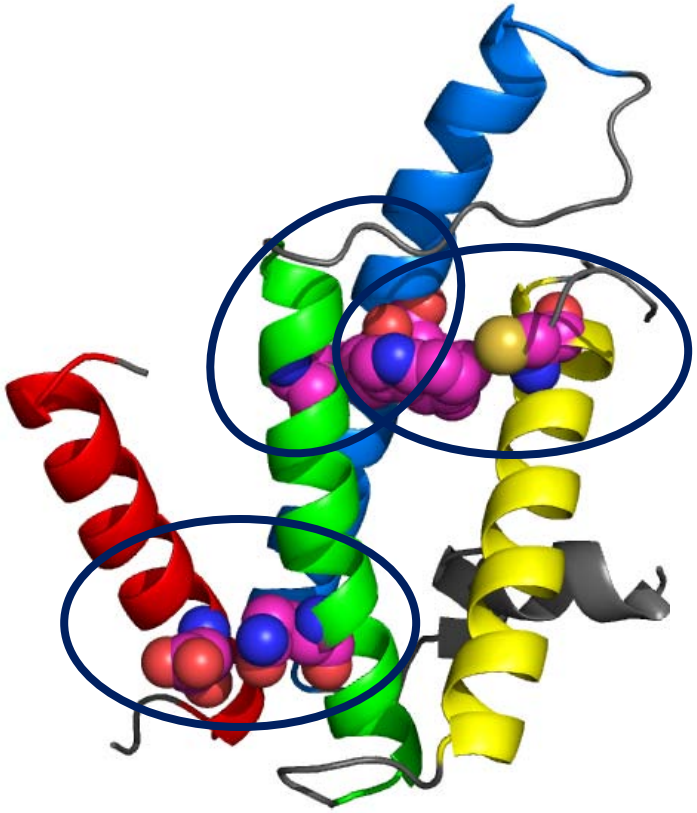


T0561

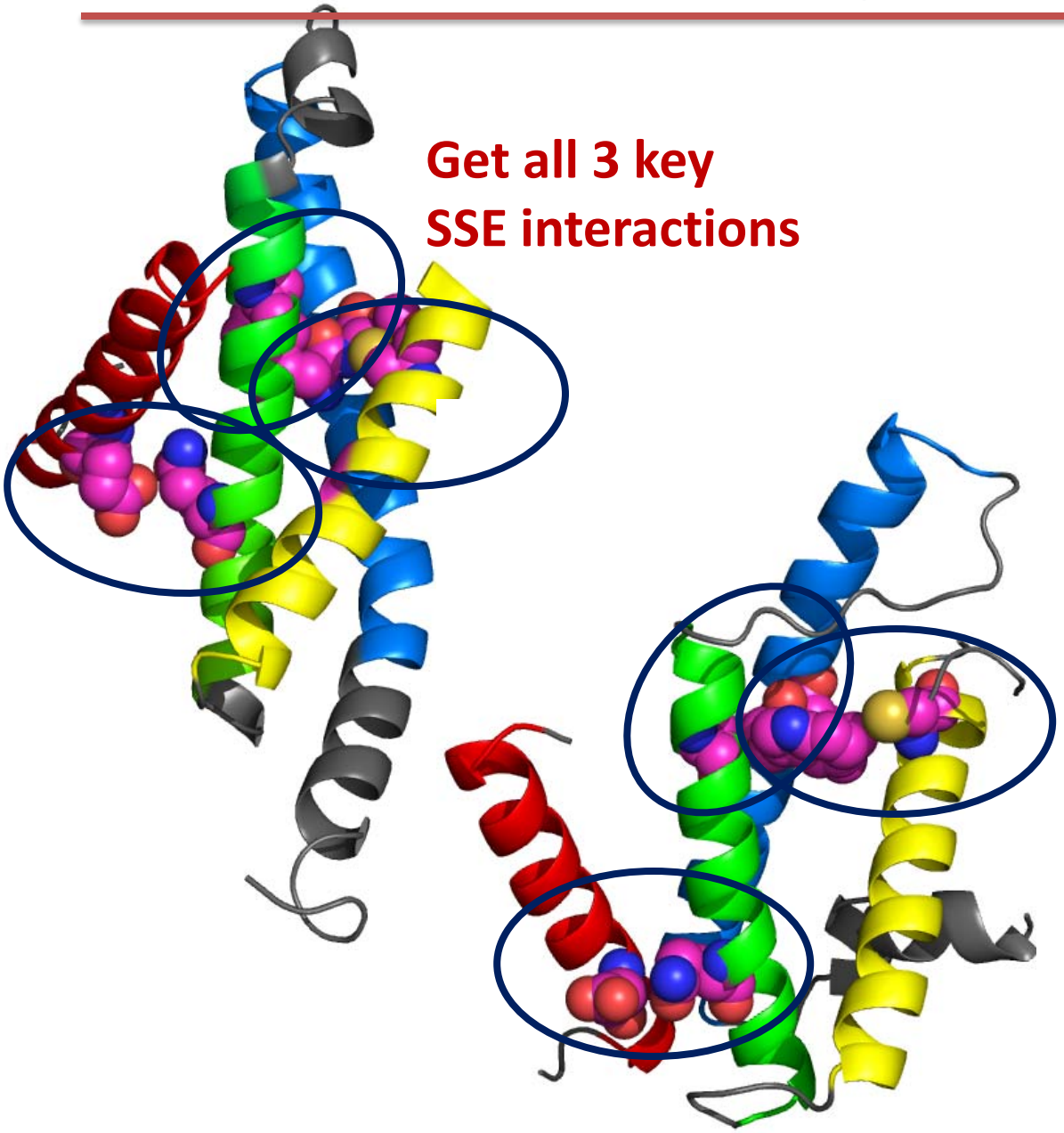




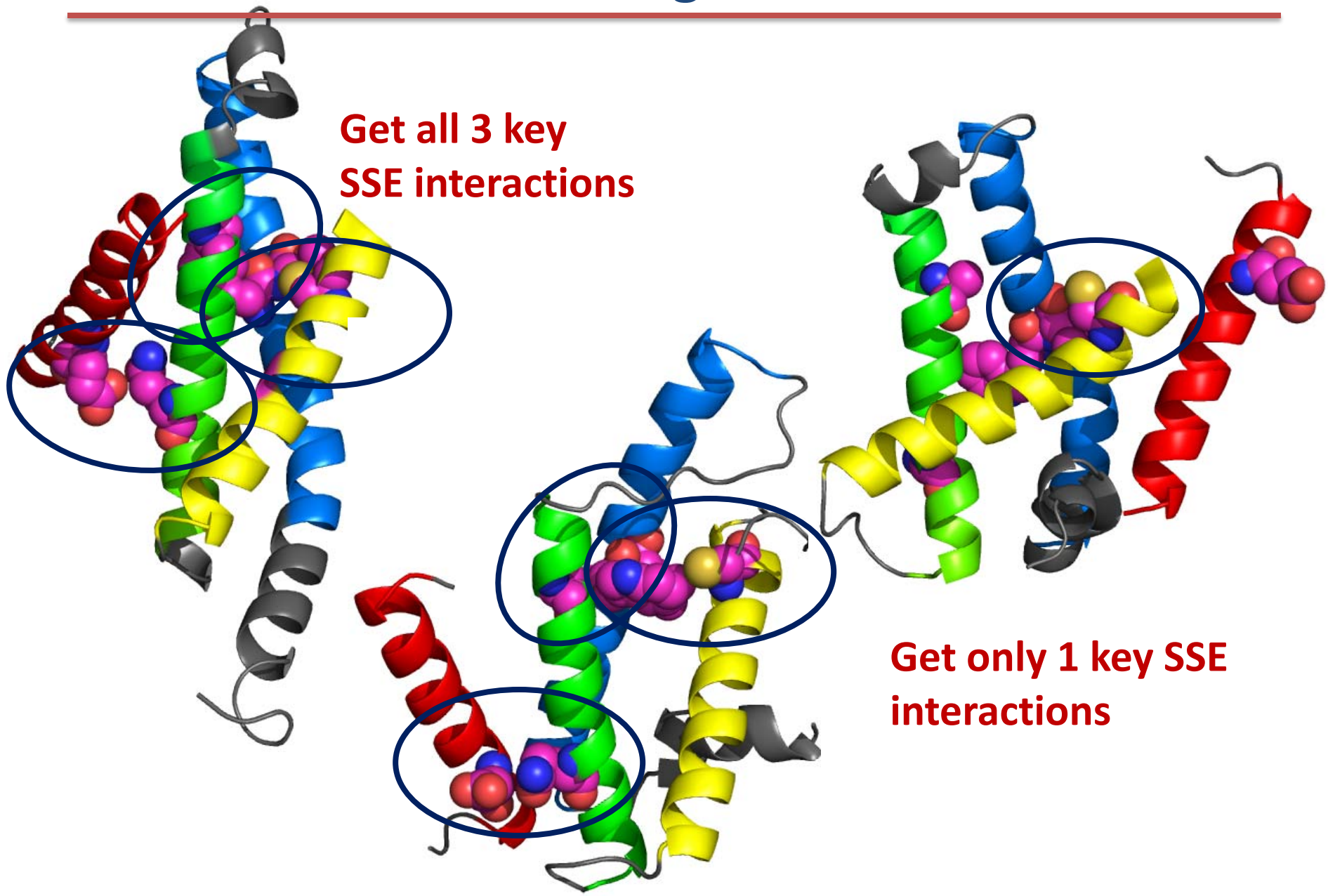
QCS reveals model with good interactions



QCS reveals model with good interactions



QCS reveals model with good interactions



Being lazy cannot be a final solution

To assess CASP we need a lot of diligent, efficient, smart and careful analysis on a large scale

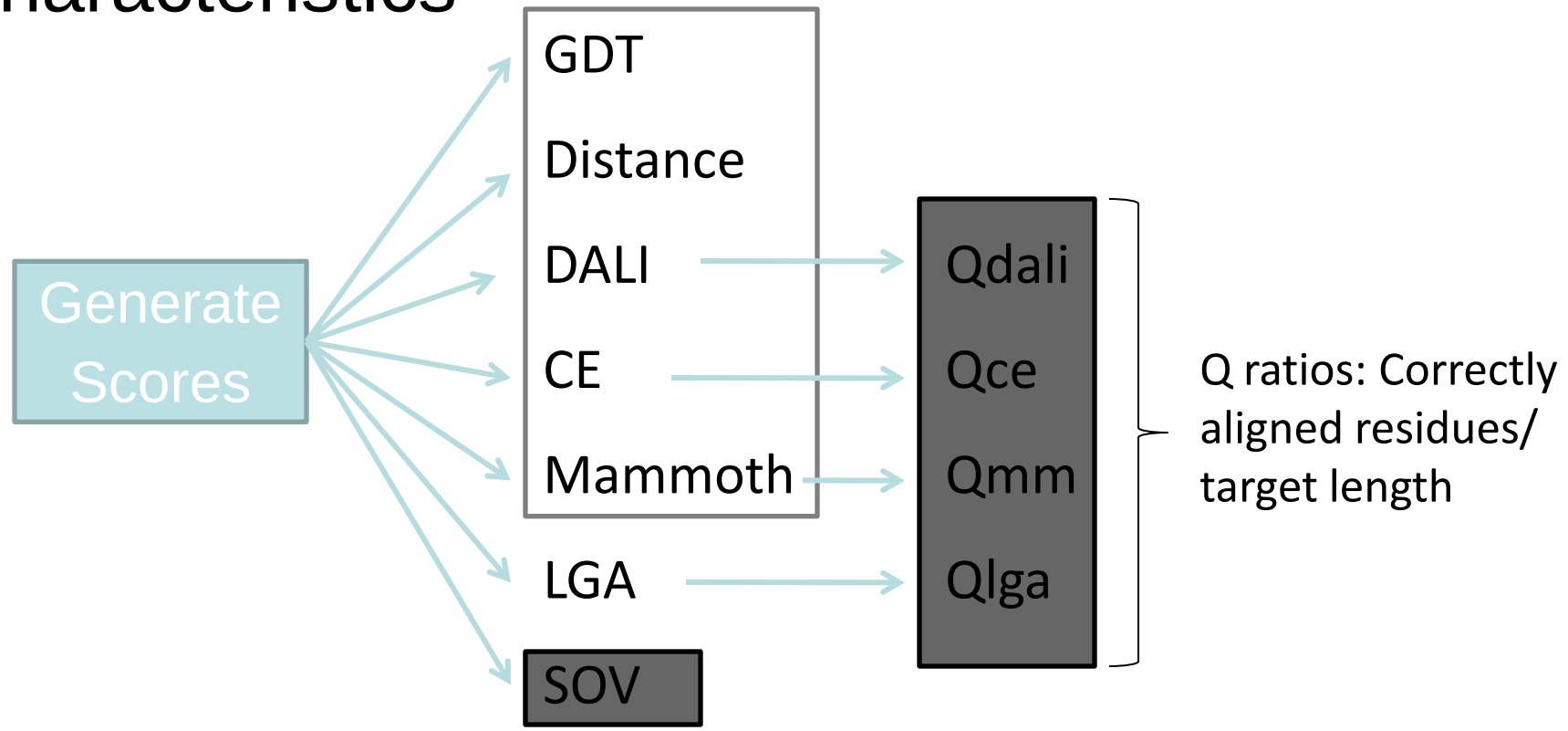
Talk plan

- Introduction: FM winner in CASP9!
- Manual Assessment
- New Scoring Function
- Meta-scoring in Assessment
- The bloody Ranking
- Problems and successes

Meta-scoring in Assessment

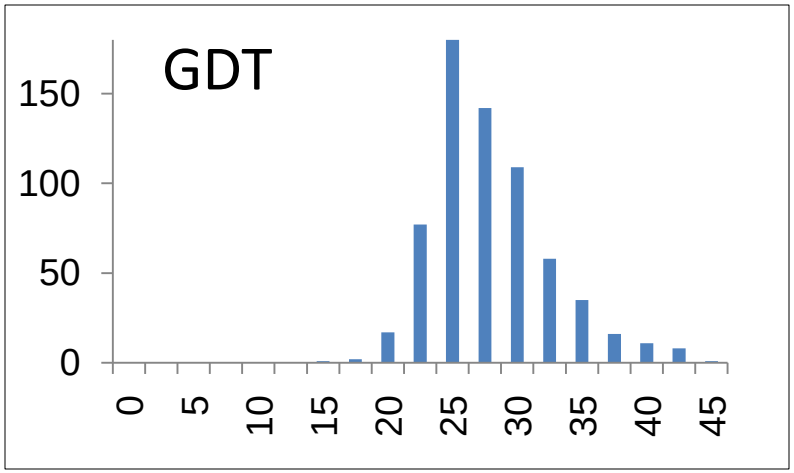
ShuoYong Shi

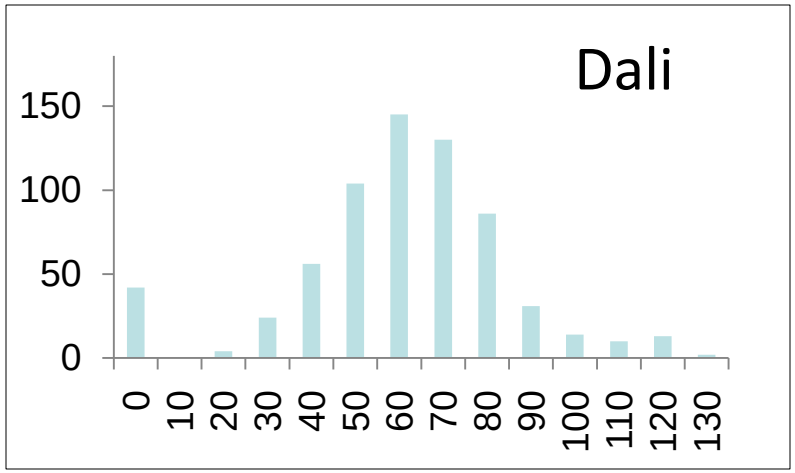
*Scores used in CASP5 Assessment**: Ten scores encompass ***structure*** and ***sequence*** characteristics

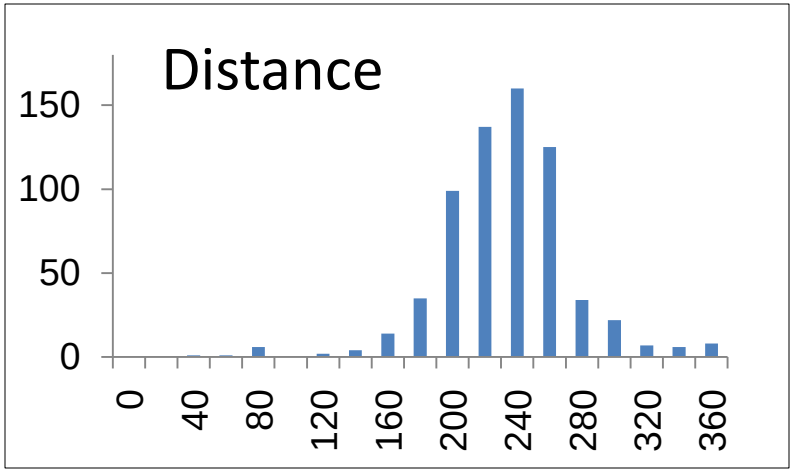


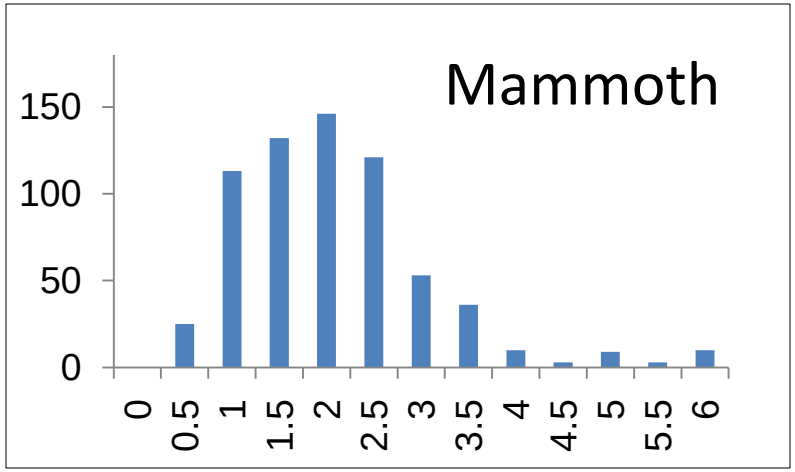
*Kinch LN, et al. *Proteins*. 2003; 53 Suppl 6:395-409

Structure Score Distributions: Target 531

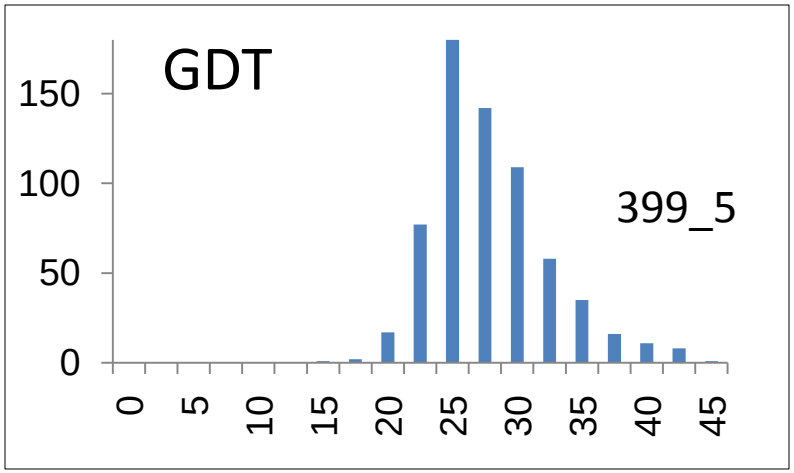


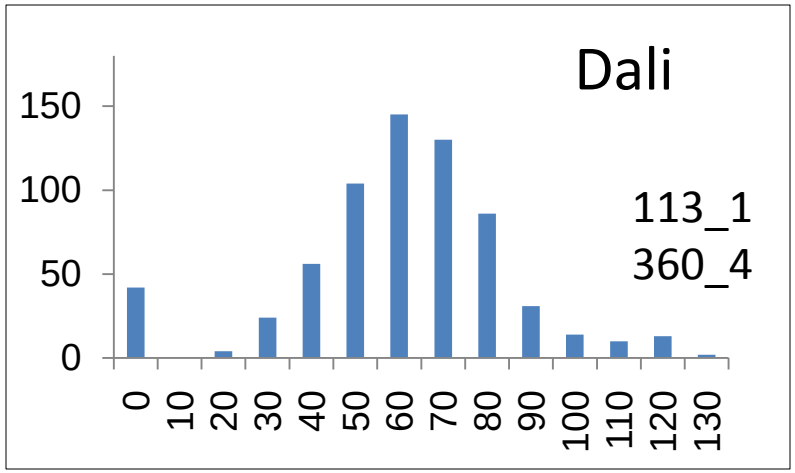


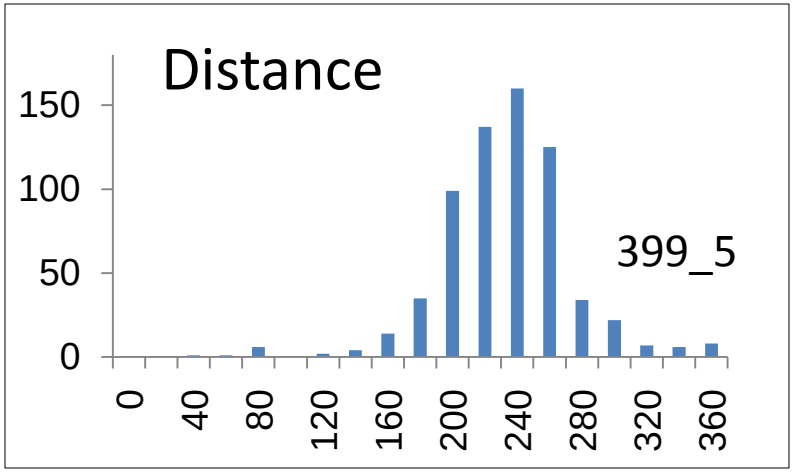


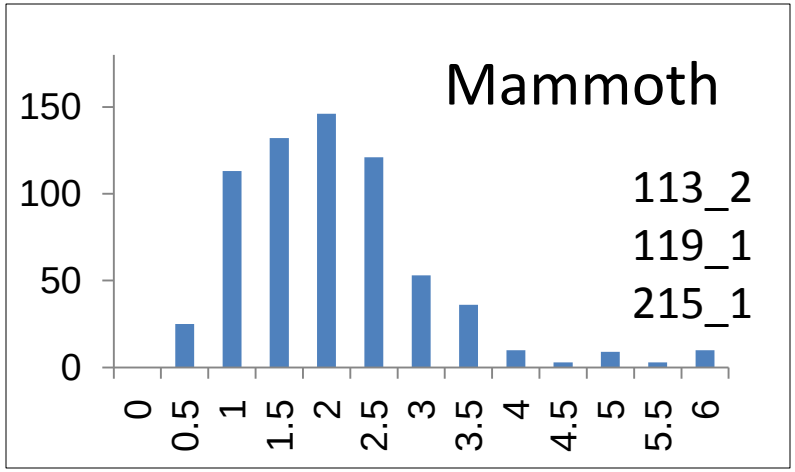


Structure Score Distributions: Target 531

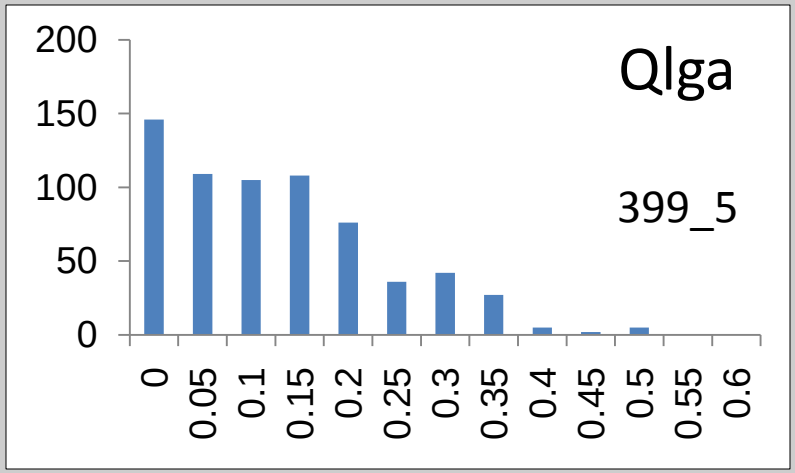


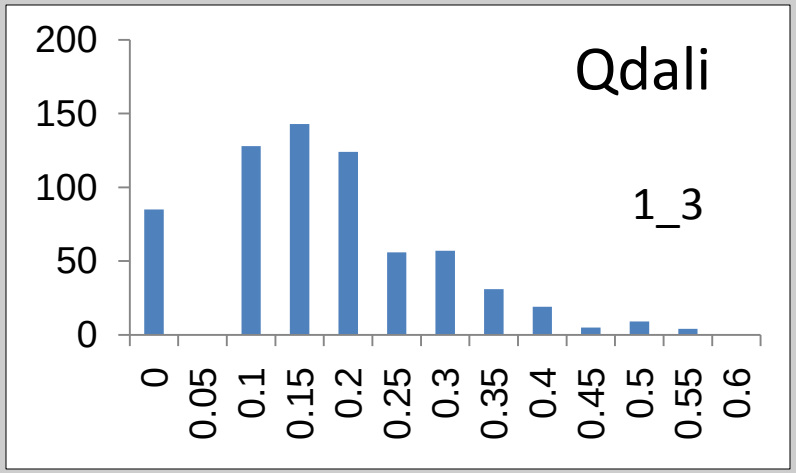


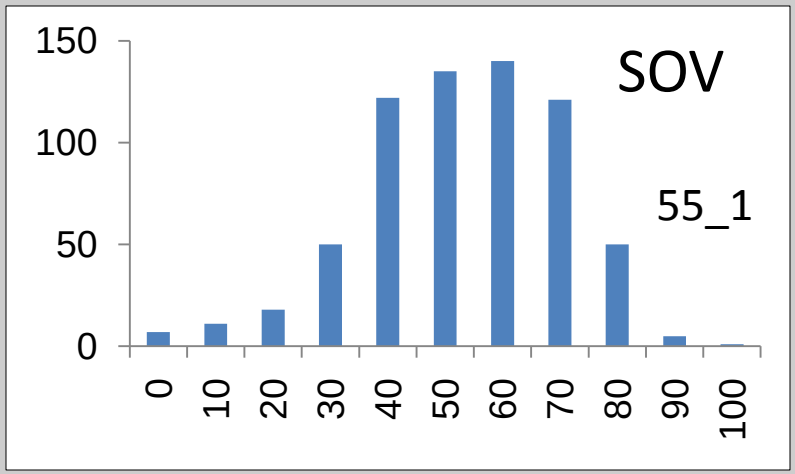


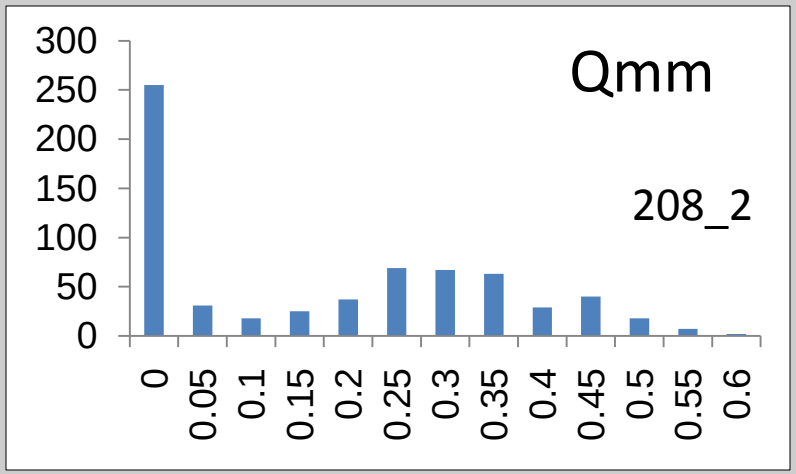


Sequence Score Distributions: Target 531

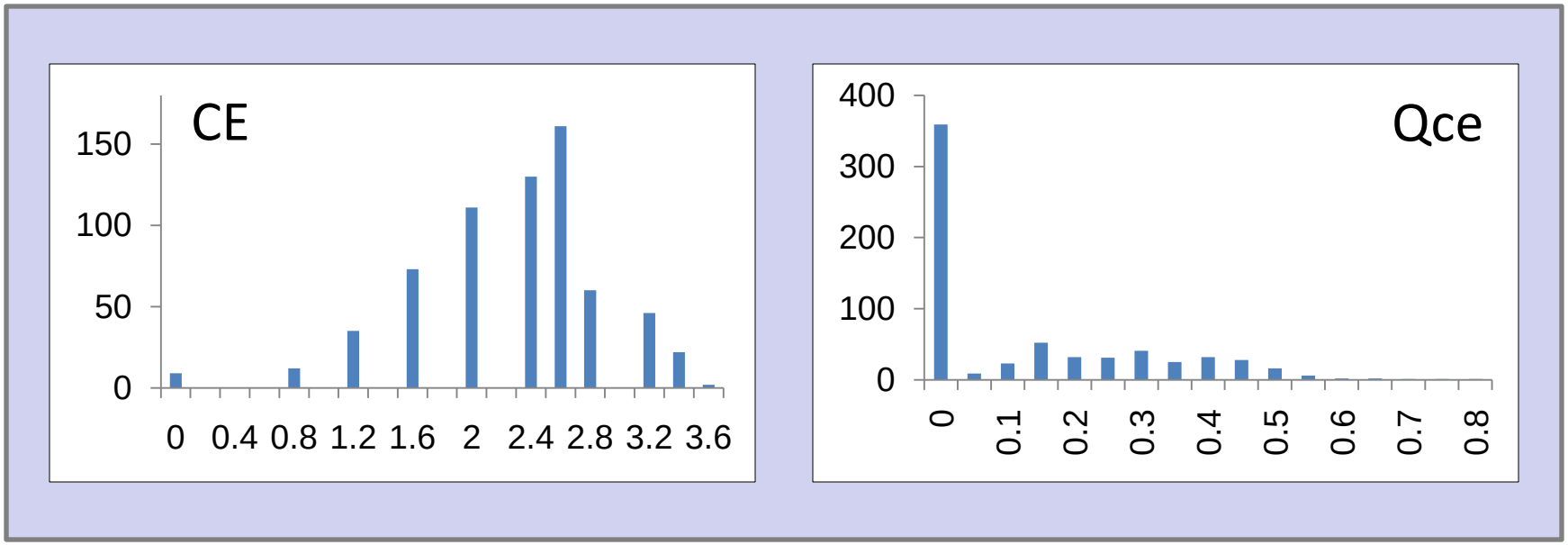




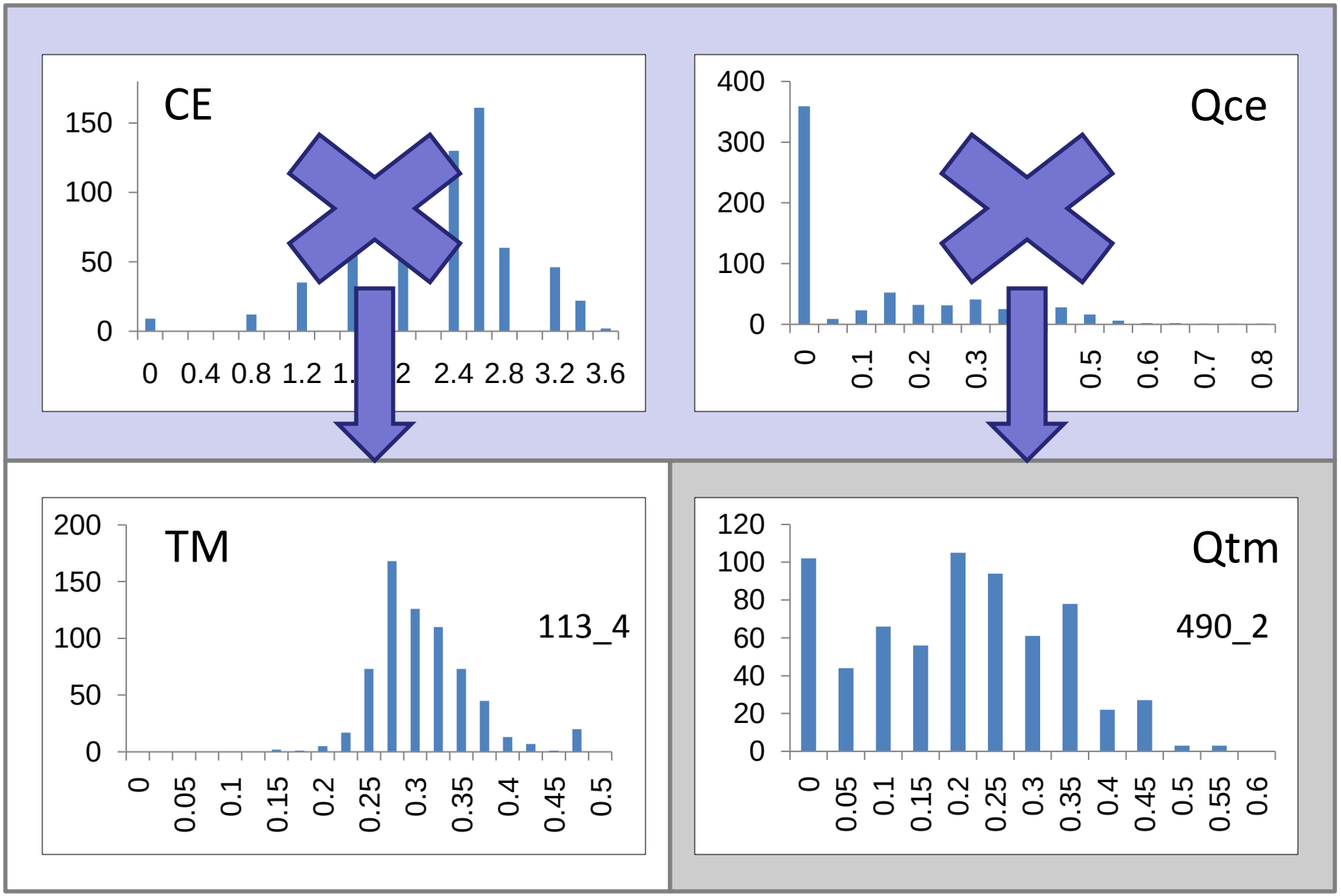




Bad Score Distributions: Target 531



Replace Score Distributions: Target 531



Combine Ten Scores: TenS

Strategy to combine scores:

1) Transform raw scores to Z-scores

   • Throw out zeros, calculate Z-score

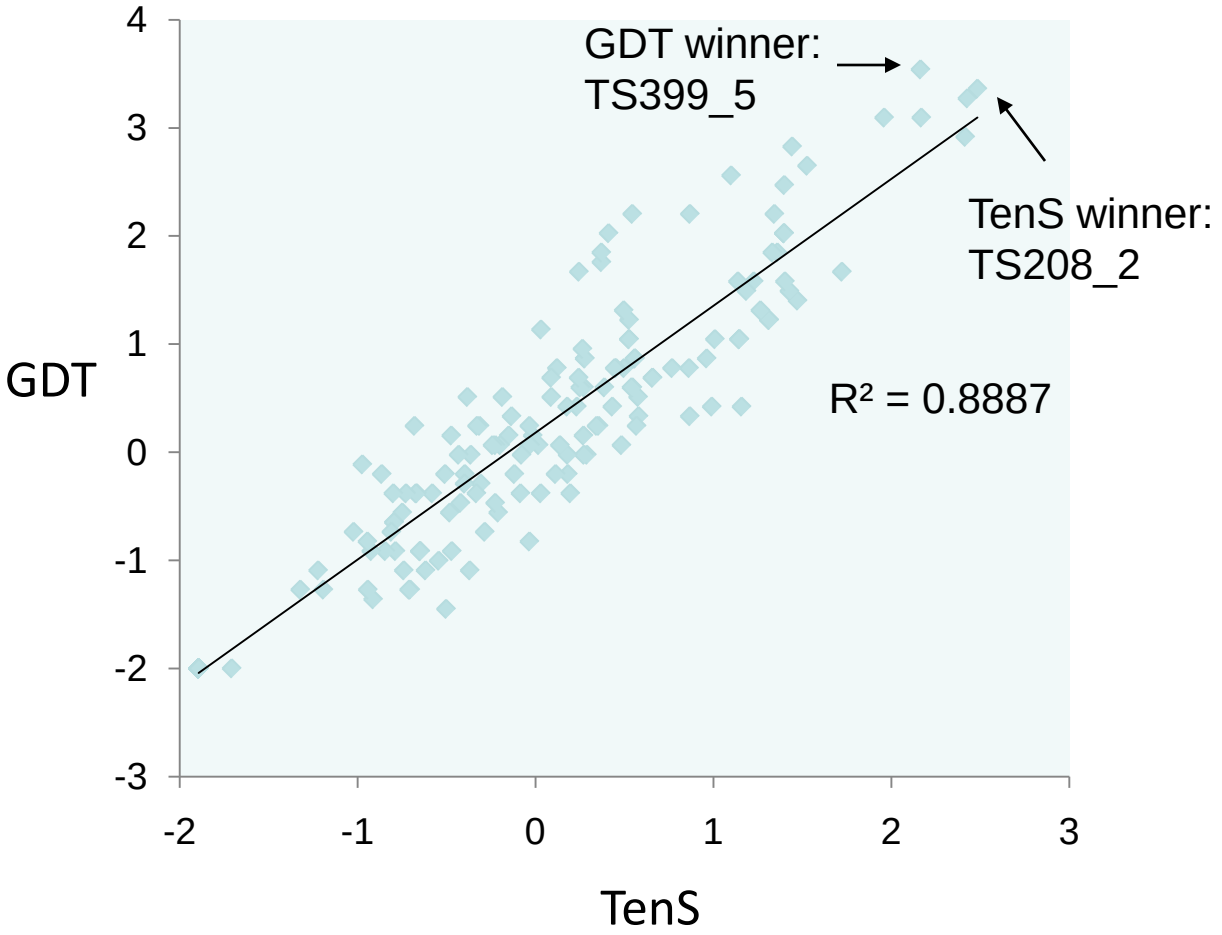
   • Throw out raw score with Z-score<-2, recalculate mean and stdev

   • Recalculate Z-score on entire population, and assign Z-score <-2 to -2.

2) Sum of Z-scores using equal weight (TenS)

Combine Scores (TenS): Target 531

Rank	Model	TenS
1	TS208_2	2.4843
2	TS490_1	2.4279
3	TS001_2	2.4159
4	TS055_1	2.169
5	TS399_5	2.1644
6	TS088_5	1.9601
7	TS365_5	1.7227
8	TS457_4	1.5268
9	TS113_2	1.4734
10	TS160_1	1.4429
11	TS119_1	1.4276
12	TS037_4	1.4023
13	TS215_5	1.3986
14	TS447_1	1.397
15	TS142_3	1.397



Combine Main Scores: TenS, QCS, GDT, and CS

Score	Used in	Components	Raw Form
TenS	new	10 (GDT)	Z score
QCS	*new*	6 (CS)	% Max
GDT	CASP*		% Max
CS	CASP8		% Max

Strategy to combine scores:

1) Transform raw scores to Z-scores

2) Sum of Z-scores for each target (ComS)

Additional Score: Comparison to top server Model

Motivation: Top performing groups use similar strategies that rank server models with various scoring functions and refine top picks

Who did better than servers?

Score Strategy: Ratio of best group model scores to top server model for each of the main scores

Additional Score: Comparison to top server Model

Server Ratio Score Combinations:

1)Ratio scores below 1 are ignored

2)Average Scores(4) for each target

3)Sum score averages

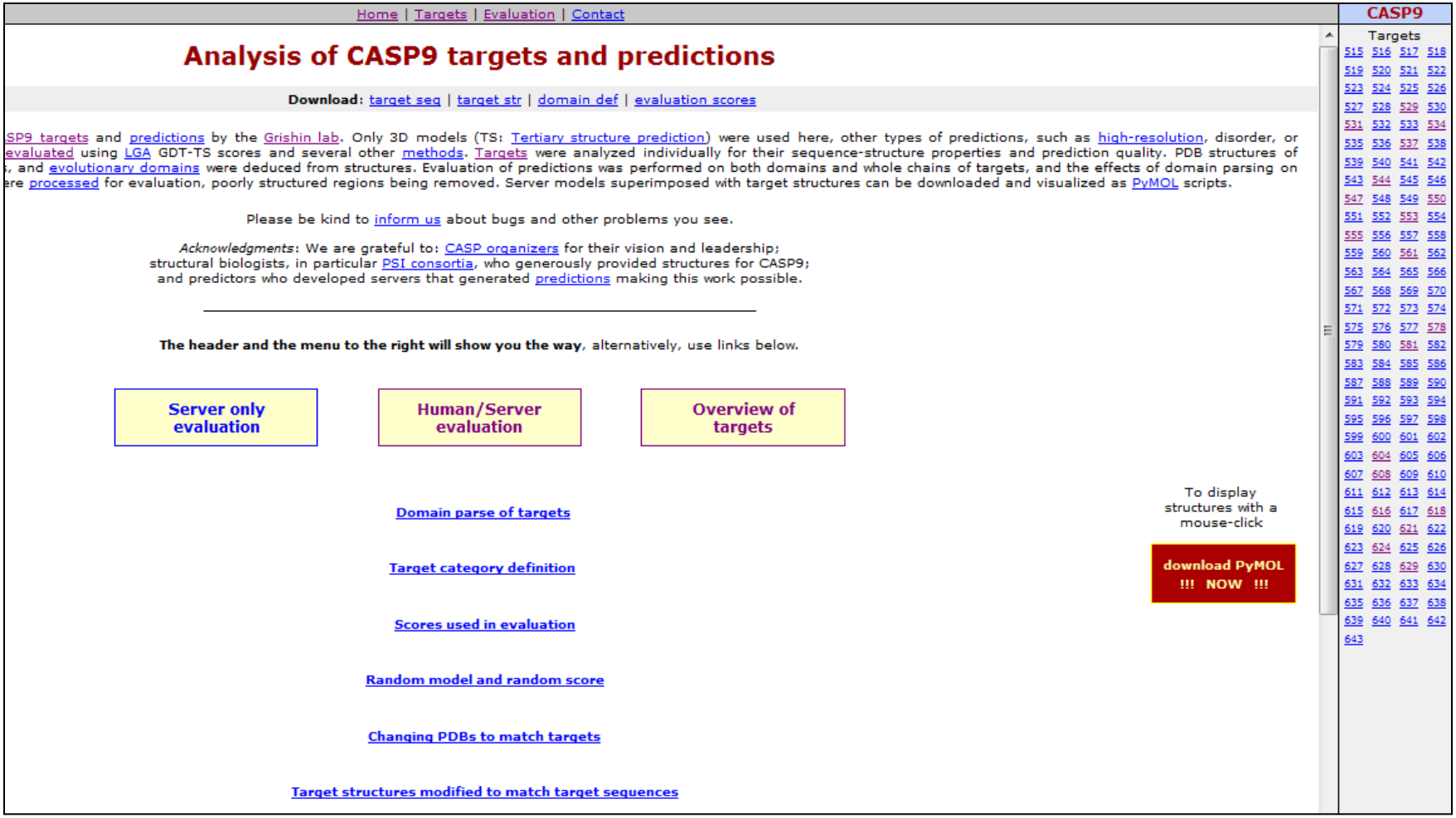
The Sum of average ratios (which are rarely much larger than 1) indicates the number of times each group *outperformed servers*

Additional Score: Comparison to top server Model (Target 531 Example)

Top Servers

Group	Sum	TenS	QCS	GDT	CS
TS399	1.04	0	1.03	1.019	1.06
TS110	1.01	0	1.01	0	0
TS055	1	0	1	0	1
TS001	1	0	0	1	0
TS208	1	1	0	1	0
…	0	0	0	0	0

Report Scores: A Web Site and Many, Many, Many Sortable Tables



http://prodata.swmed.edu/CASP9/evaluation/CASP9Home.htm

Report Scores: Many, Many, Many Sortable Tables and a Web Site

CombS	TenS	QCS	GDT	CS
SUM				
2612.9743	23.1500	1715.0651	875.0310	14.0121
3008.0026	54.5453	1856.2351	1132.0380	15.6904
1902.7535	6.2601	1297.3440	624.2310	10.3620
1800.2115	5.9530	1215.6216	595.3050	9.6558
2689.4090	27.4929	1733.2877	939.2690	14.5279
2073.7197	12.5606	1388.2484	690.0940	11.4027
2614.7950	29.8639	1686.7942	908.7700	14.1273
194.3294	1.4429	123.4052	70.3130	0.8431
2476.0043	18.2959	1626.0470	835.7910	13.3794
2453.1764	23.4261	1583.9750	844.1890	13.3232

Report Scores: Many, Many, Many Sortable Tables and a Web Site

CombS	TenS	QCS
SUM		
2612.9743	23.1500	1715.0651
3008.0026	54.5453	1856.2351
1902.7535	6.2601	1297.3440
1800.2115	5.9530	1215.6216
2689.4090	27.4929	1733.2877
2073.7197	12.5606	1388.2484
2614.7950	29.8639	1686.7942
194.3294	1.4429	123.4052
2476.0043	18.2959	1626.0470
2453.1764	23.4261	1583.9750

CombS	TenS	QCS	GDT	CS
MEAN				
100.4990	0.8904	65.9640	33.6550	0.5389
100.2668	1.8182	61.8745	37.7346	0.5230
63.4251	0.2087	43.2448	20.8077	0.3454
60.0070	0.1984	40.5207	19.8435	0.3219
92.7382	0.9480	59.7685	32.3886	0.5010
69.1240	0.4187	46.2749	23.0031	0.3801
90.1653	1.0298	58.1653	31.3369	0.4871
0.0000	0.0000	0.0000	0.0000	0.0000
82.5335	0.6099	54.2016	27.8597	0.4460
94.3529	0.9010	60.9221	32.4688	0.5124
835.7910	13.3794			
844.1890	13.3232			

Report Scores: Many, Many, Many Sortable Tables and a Web Site

CombS	TenS	QCS
SUM		
2612.9743	23.1500	1715.0651
3008.0026	54.5453	1856.2351
1902.7535	6.2601	1297.3440
1800.2115	5.9530	1215.6216
2689.4090	27.4929	1733.2877
2073.7197	12.5606	1388.2484
2614.7950	29.8639	1686.7942
194.3294	1.4429	123.4052
2476.0043	18.2959	1626.0470
2453.1764	23.4261	1583.9750

CombS	TenS	QCS	GDT	CS
MEAN				
100.4990	0.8904	65.9640	33.65	
100.2668	1.8182	61.8745	37.73	
63.4251	0.2087	43.2448	20.80	
60.0070	0.1984	40.5207	19.84	
92.7382	0.9480	59.7685	32.38	
69.1240	0.4187	46.2749	23.00	
90.1653	1.0298	58.1653	31.33	
0.0000	0.0000	0.0000	0.00	
82.5335	0.6099	54.2016	27.85	
94.3529	0.9010	60.9221	32.46	
835.7910	13.3794			
844.1890	13.3232			

CombS	TenS	QCS	GDT	CS
64.1369				
71.0358				
56.4329				
51.0264				
70.2034				
52.4065				
71.1074				
0.0000				
60.3086				
64.2086				

CombS	TenS	QCS	GDT	CS
2612.9743	23.			
3008.0026	54.			
1902.7535	6.			
1800.2115	5.			
2689.4090	27.			
2073.7197	12.			
2614.7950	29.			
194.3294	1.			
2476.0043	18.			
2453.1764	23.			

CombS	TenS	QCS	GDT	CS
MEAN				
100.4990	0.8904	65.9640	33.6550	0.5389
100.2668	1.8182	61.8745	37.7346	0.5230
63.4251	0.2087	43.2448	20.8077	0.3454
60.0070	0.1984	40.5207	19.8435	0.3219
92.7382	0.9480	59.7685	32.3886	0.5010
69.1240	0.4187	46.2749	23.0031	0.3801
90.1653	1.0298	58.1653	31.3369	0.4871
0.0000	0.0000	0.0000	0.0000	0.0000
82.5335	0.6099	54.2016	27.8597	0.4460
94.3529	0.9010	60.9221	32.4688	0.5124

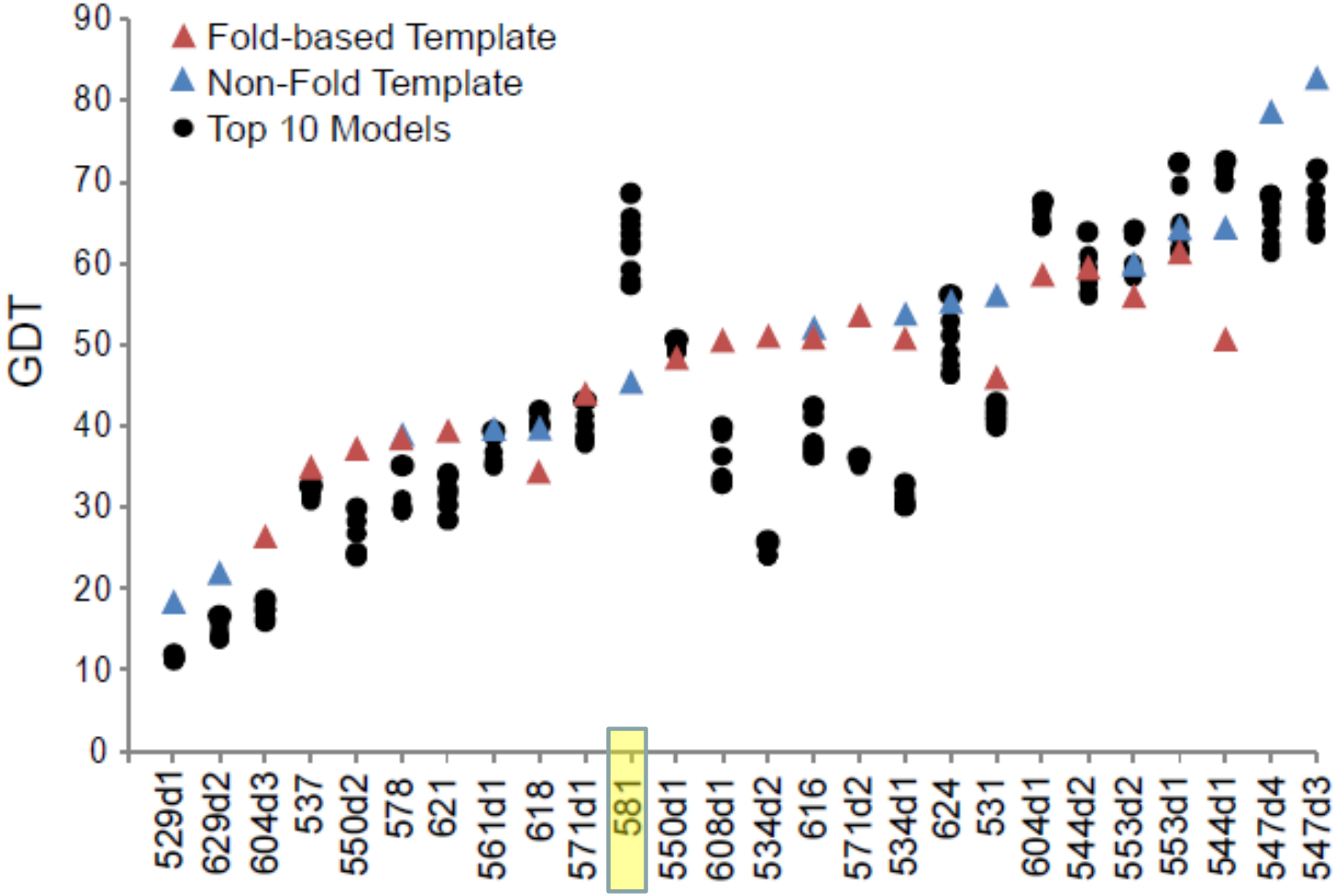
Talk plan

- Introduction: FM winner in CASP9!
- Manual Assessment
- New Scoring Function
- Meta-scoring in Assessment
- The bloody Ranking
- Problems and successes

The bloody Ranking and statistical significance

Nick Grishin

Comparison to Top GDT Templates



Server Ranking with Bootstrap Significance

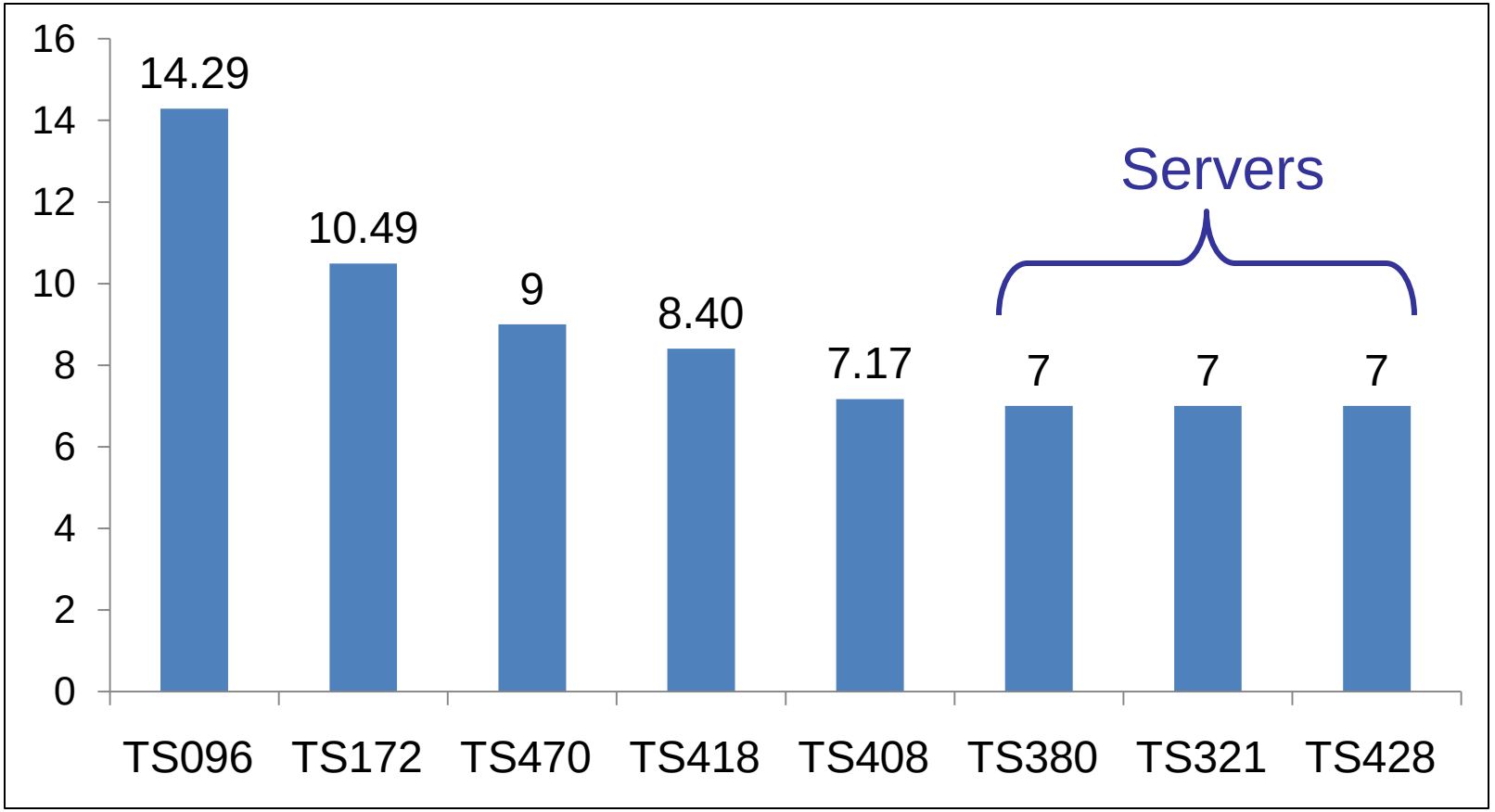
Groupname	TS380	TS428	TS321	TS002	TS457	TS253	TS080	TS119	TS215	TS077	TS286	TS063	TS276	TS236	TS291	TS055	TS481	TS174	TS166	TS355
TS380	-	0.762	0.656	0.997	1.000	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
TS428	30	-	0.600	0.994	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
TS321	30	30	-	0.936	0.971	0.975	0.978	0.995	1.000	0.992	0.993	0.999	0.994	1.000	1.000	1.000	1.000	1.000	0.999	1.000
TS002	30	30	30	-	0.652	0.689	0.971	0.964	0.958	0.881	0.909	0.919	0.914	0.934	0.960	0.970	0.992	0.994	0.994	0.999
TS457	30	30	30	30	-	0.471	0.603	0.756	0.754	0.808	0.826	0.868	0.850	0.881	0.944	0.975	0.973	0.975	0.998	0.999
TS253	30	30	30	30	30	-	0.635	0.743	0.782	0.839	0.832	0.875	0.851	0.928	0.965	0.946	0.991	0.974	0.998	1.000
TS080	30	30	30	30	30	30	-	0.615	0.653	0.697	0.716	0.715	0.762	0.782	0.831	0.895	0.932	0.955	0.985	0.966
TS119	30	30	30	30	30	30	30	-	0.671	0.638	0.701	0.685	0.684	0.739	0.826	0.867	0.920	0.942	0.976	0.989
TS215	30	30	30	30	30	30	30	30	-	0.636	0.615	0.647	0.655	0.715	0.778	0.860	0.919	0.942	0.971	0.987
TS077	30	30	30	30	30	30	30	30	30	-	0.582	0.533	0.851	0.589	0.650	0.805	0.819	0.967	0.958	0.896
TS286	30	30	30	30	30	30	30	30	30	30	-	0.487	0.728	0.565	0.631	0.781	0.813	0.956	0.969	0.900
TS063	30	30	30	30	30	30	30	30	30	30	30	-	0.507	0.557	0.678	0.771	0.906	0.884	0.955	0.904
TS276	30	30	30	30	30	30	30	30	30	30	30	30	-	0.538	0.608	0.761	0.829	0.950	0.946	0.885
TS236	30	30	30	30	30	30	30	30	30	30	30	30	30	-	0.613	0.748	0.872	0.866	0.966	0.928
TS291	30	30	30	30	30	30	30	30	30	30	30	30	30	30	-	0.688	0.790	0.790	0.936	0.884
TS055	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	-	0.607	0.612	0.708	0.848
TS481	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	-	0.514	0.627	0.615
TS174	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	-	0.640	0.543
TS166	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	-	0.472
TS355	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	-

Server Ranking with Bootstrap Significance

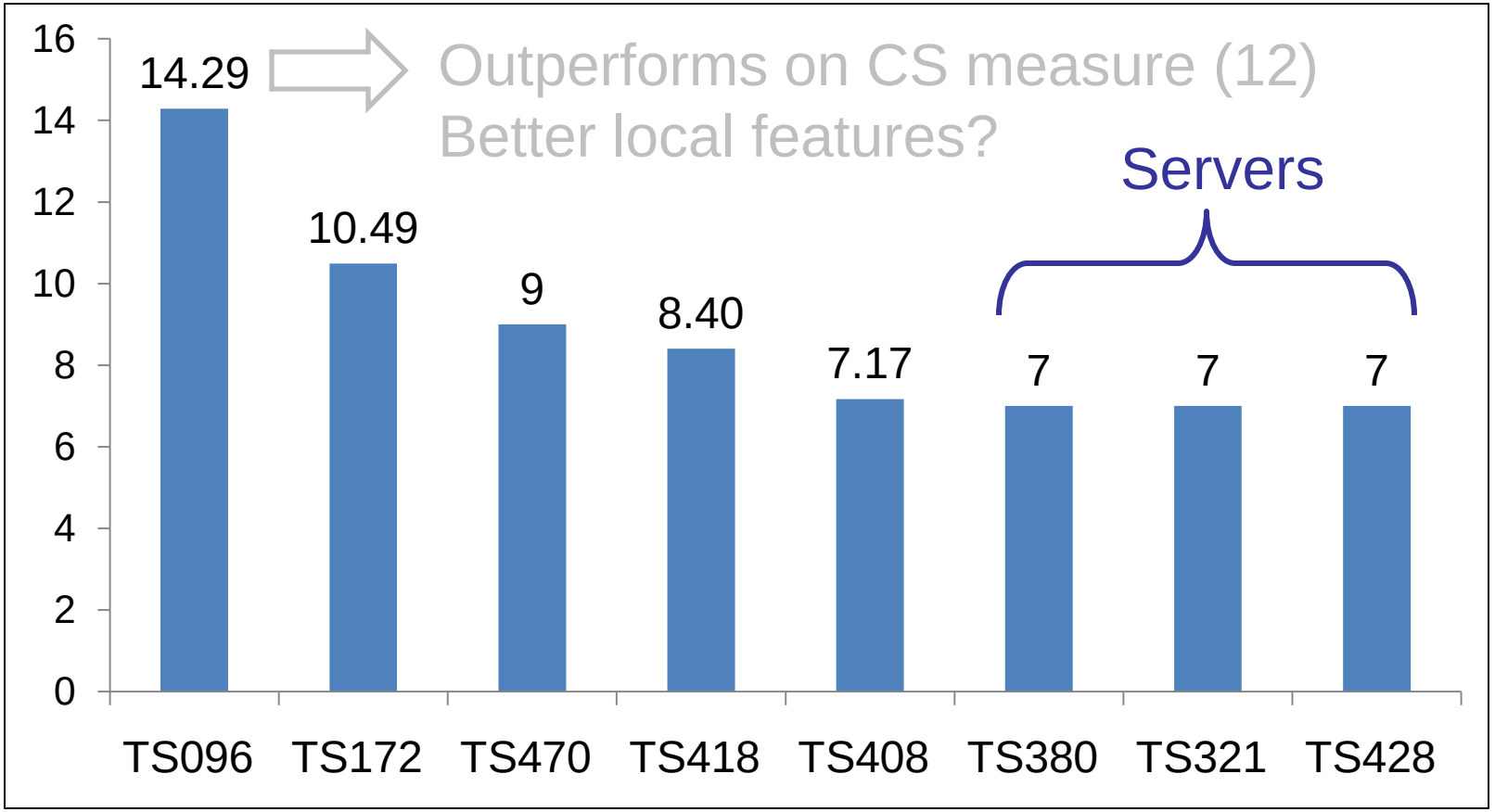
Quark, Zhang-Server (Yang Zhang);
Baker-Rosettaserver

Groupname	TS380	TS428	TS321	TS002	TS457	TS253	TS080	TS119	TS215	TS077	TS286	TS063	TS276	TS236	TS291	TS055	TS481	TS174	TS166	TS355
TS380	-	0.762	0.656	0.997	1.000	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
TS428	30	-	0.600	0.994	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
TS321	30	30	-	0.936	0.971	0.975	0.978	0.995	1.000	0.992	0.993	0.999	0.994	1.000	1.000	1.000	1.000	1.000	0.999	1.000
TS002	30	30	30	-	0.652	0.689	0.971	0.964	0.958	0.881	0.909	0.919	0.914	0.934	0.960	0.970	0.992	0.994	0.994	0.999
TS457	30	30	30	30	-	0.471	0.603	0.756	0.754	0.808	0.826	0.868	0.850	0.881	0.944	0.975	0.973	0.975	0.998	0.999
TS253	30	30	30	30	30	-	0.635	0.743	0.782	0.839	0.832	0.875	0.851	0.928	0.965	0.946	0.991	0.974	0.998	1.000
TS080	30	30	30	30	30	30	-	0.615	0.653	0.697	0.716	0.715	0.762	0.782	0.831	0.895	0.932	0.955	0.985	0.966
TS119	30	30	30	30	30	30	30	-	0.671	0.638	0.701	0.685	0.684	0.739	0.826	0.867	0.920	0.942	0.976	0.989
TS215	30	30	30	30	30	30	30	30	-	0.636	0.615	0.647	0.655	0.715	0.778	0.860	0.919	0.942	0.971	0.987
TS077	30	30	30	30	30	30	30	30	30	-	0.582	0.533	0.851	0.589	0.650	0.805	0.819	0.967	0.958	0.896
TS286	30	30	30	30	30	30	30	30	30	30	-	0.487	0.728	0.565	0.631	0.781	0.813	0.956	0.969	0.900
TS063	30	30	30	30	30	30	30	30	30	30	30	-	0.507	0.557	0.678	0.771	0.906	0.884	0.955	0.904
TS276	30	30	30	30	30	30	30	30	30	30	30	30	-	0.538	0.608	0.761	0.829	0.950	0.946	0.885
TS236	30	30	30	30	30	30	30	30	30	30	30	30	30	-	0.613	0.748	0.872	0.866	0.966	0.928
TS291	30	30	30	30	30	30	30	30	30	30	30	30	30	30	-	0.688	0.790	0.790	0.936	0.884
TS055	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	-	0.607	0.612	0.708	0.848
TS481	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	-	0.514	0.627	0.615
TS174	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	-	0.640	0.543
TS166	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	-	0.472
TS355	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	-

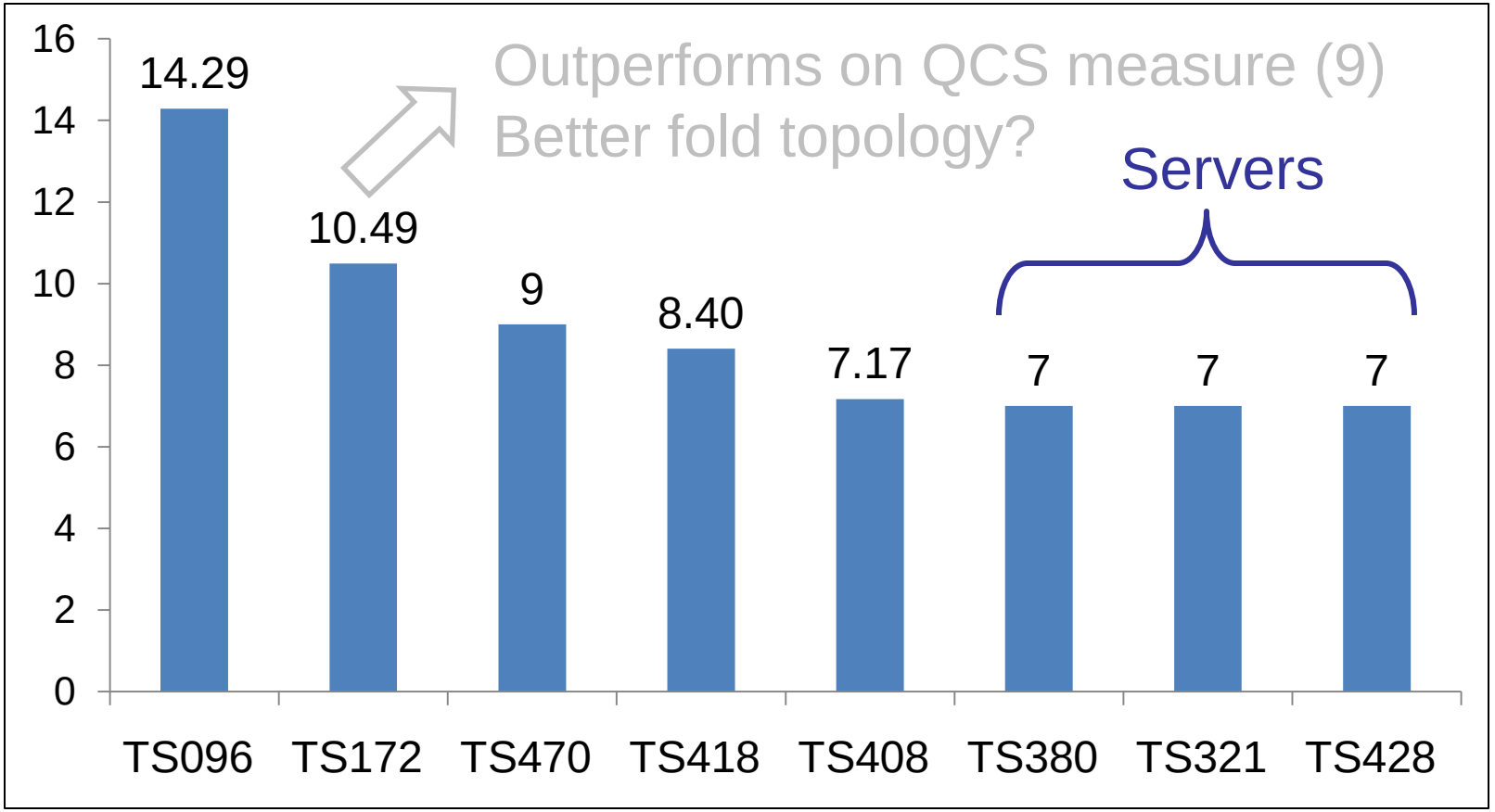
Comparison to Top Server Models:
Combined Scores,
only no-worse than the best server predictions scored



Comparison to Top Server Models:
Combined Scores,
only no-worse than the best server predictions scored



Comparison to Top Server Models:
Combined Scores,
only no-worse than the best server predictions scored



Comparison to Server

Targets where ***Servers*** Performed relatively better than experts

547d3	621	537	531	624	544d1	581	629d2
75	80	418	399	172	402	170	192
	2	96	110	316	170	424	242
	476	102	55	119	119	408	88
		103	1	276	2	**321**	63
			208	286	**321**		291
				77	457		18
					215		304

Note: CASP8 Top-performing server (Zhang) is absent

Comparison to Server

Targets where SOME (<10) *experts* outperformed (or correctly picked) ***server models***

571d1	618	604d3	616	608d1	550d1	561	529d1	534d2	544d2	550d2
299	386	316	297	172	400	324	402	172	418	104
96	470	42	45	316	429	382	418	316	96	386
429	300	96	153	42	147	295	408	42	386	96
324	407	400	83	114	88	490	424	299	172	408
16	94	142	110	147	113	470	295	16	37	470
165	**428**	291	419	299	470	407	60	96	170	60
129	**380**	302	**321**	96	407	94	37	399	490	407
		166	119	75	276	55	63	110	470	300
			80	174	286	**428**	174	63	**380**	35
				236	127	**380**	**321**	174		**380**
							481	457		481
								47		**428**

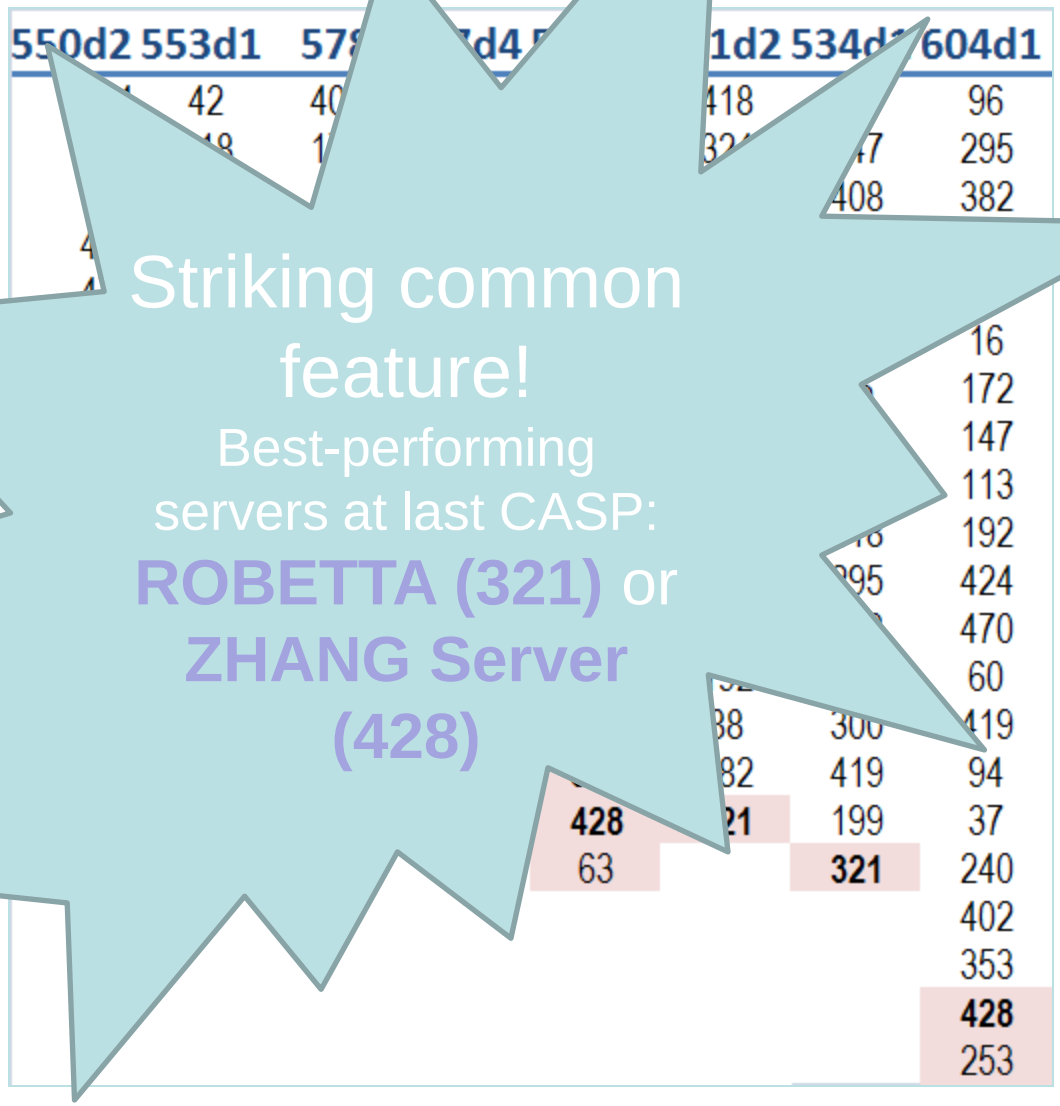
Comparison to Server

Targets where MANY (10+) *experts* outperformed (or correctly picked) ***server models***

550d2	553d1	578	547d4	553d2	571d2	534d1	604d1
104	42	408	242	399	418	297	96
386	418	172	172	418	324	147	295
96	172	96	423	423	295	408	382
408	16	365	42	96	96	16	408
470	96	386	84	172	61	42	429
60	490	418	297	386	408	316	16
407	470	37	399	16	386	96	172
300	300	113	96	297	424	172	147
35	94	94	316	490	429	395	113
380	419	407	147	300	300	418	192
481	**380**	**380**	61	419	470	295	424
428	**428**	**428**	240	94	60	423	470
	350	2	2	470	192	37	60
		80	457	60	88	300	419
			321	**380**	382	419	94
				428	**321**	199	37
				63		**321**	240
							402
							353
							428
							253

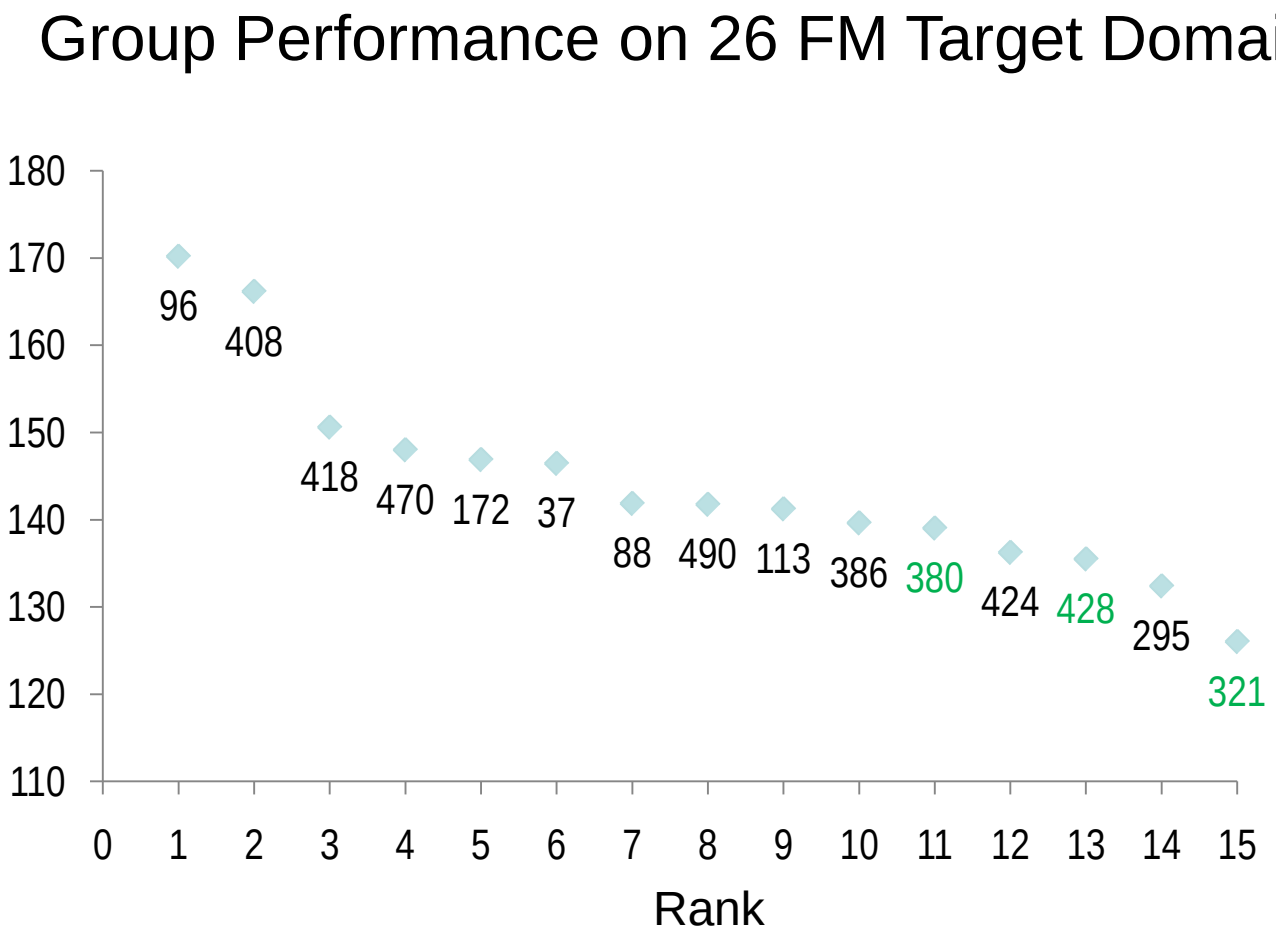
Comparison to Server

Targets where MANY (10+) *experts* outperformed (or correctly picked) ***server models***

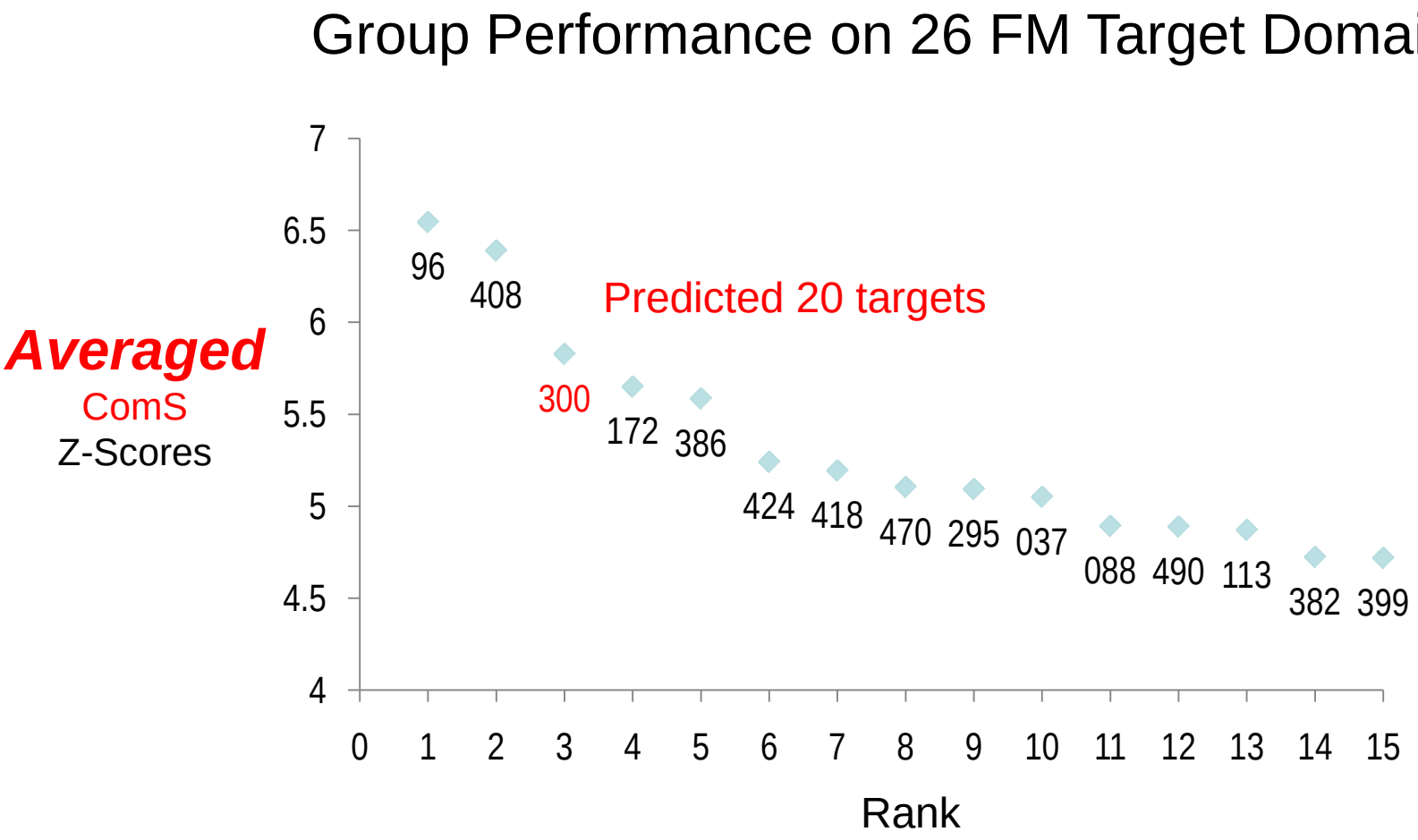


Combined Score (*ComS*) ranks on Best Models

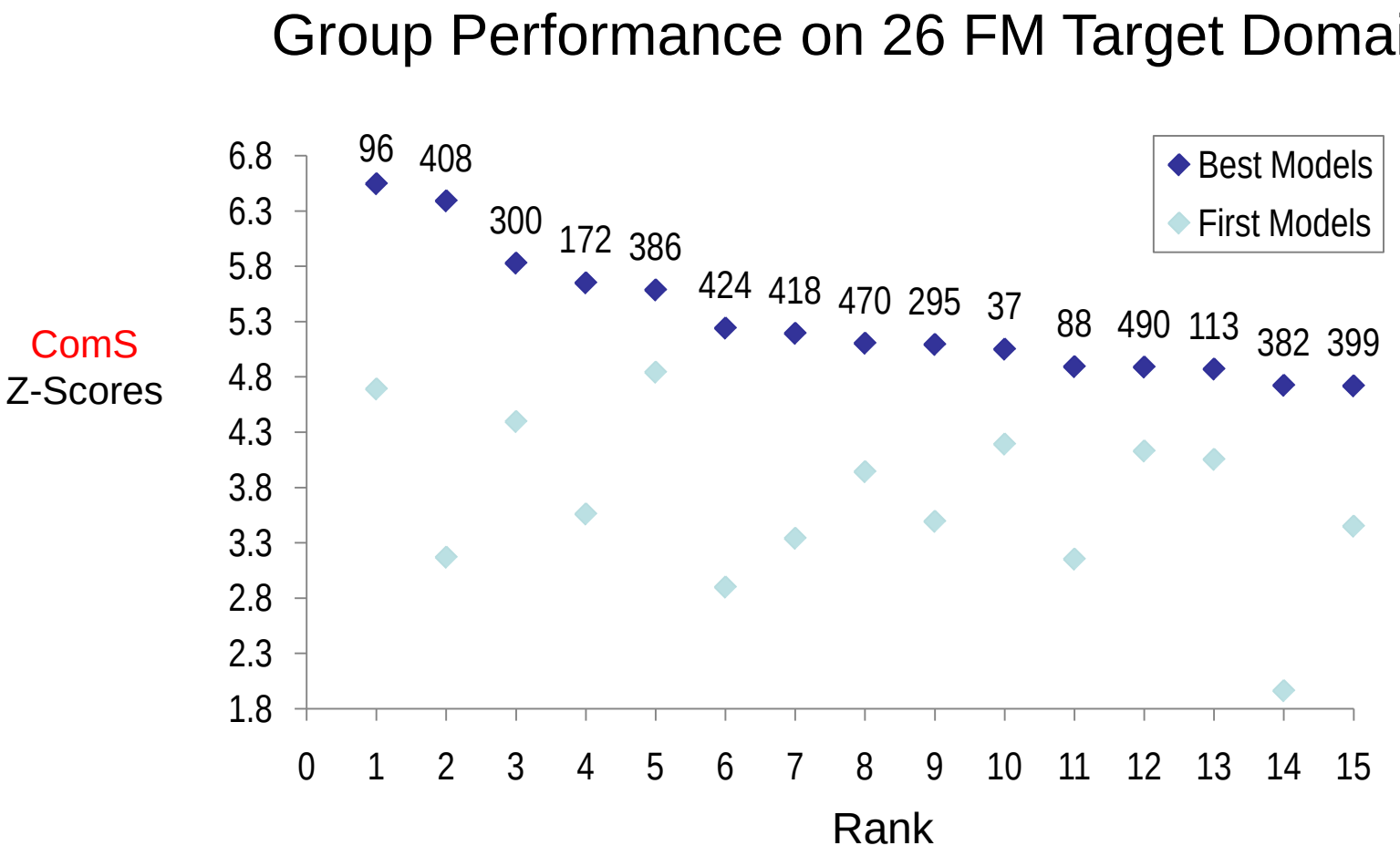
Summed
ComS
Z-Scores



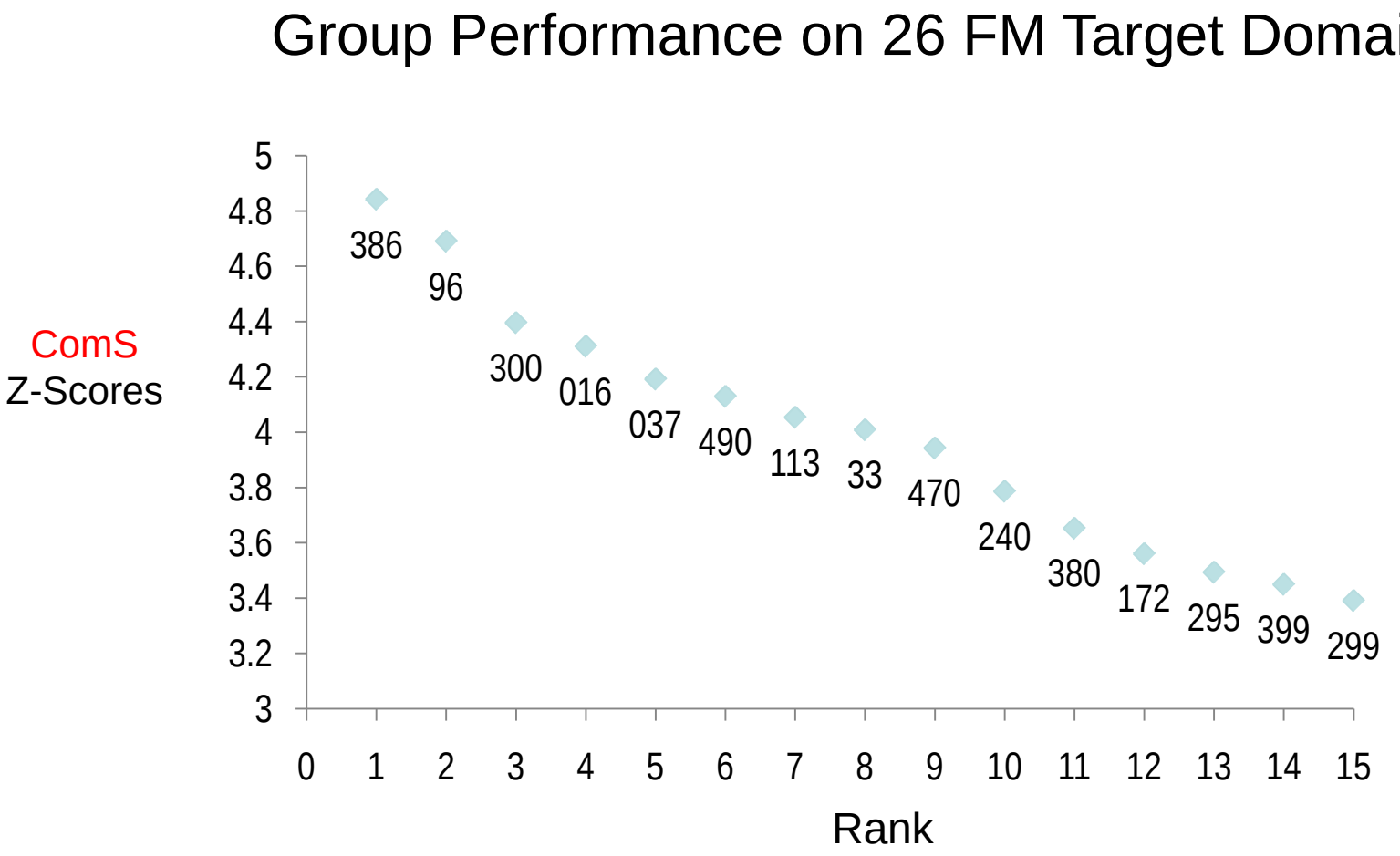
Combined Score (*ComS*) ranks on Best Models



FIRST model performance: same old story



FIRST model performance: same old story



Are Ranks Significant? Paired T-Test

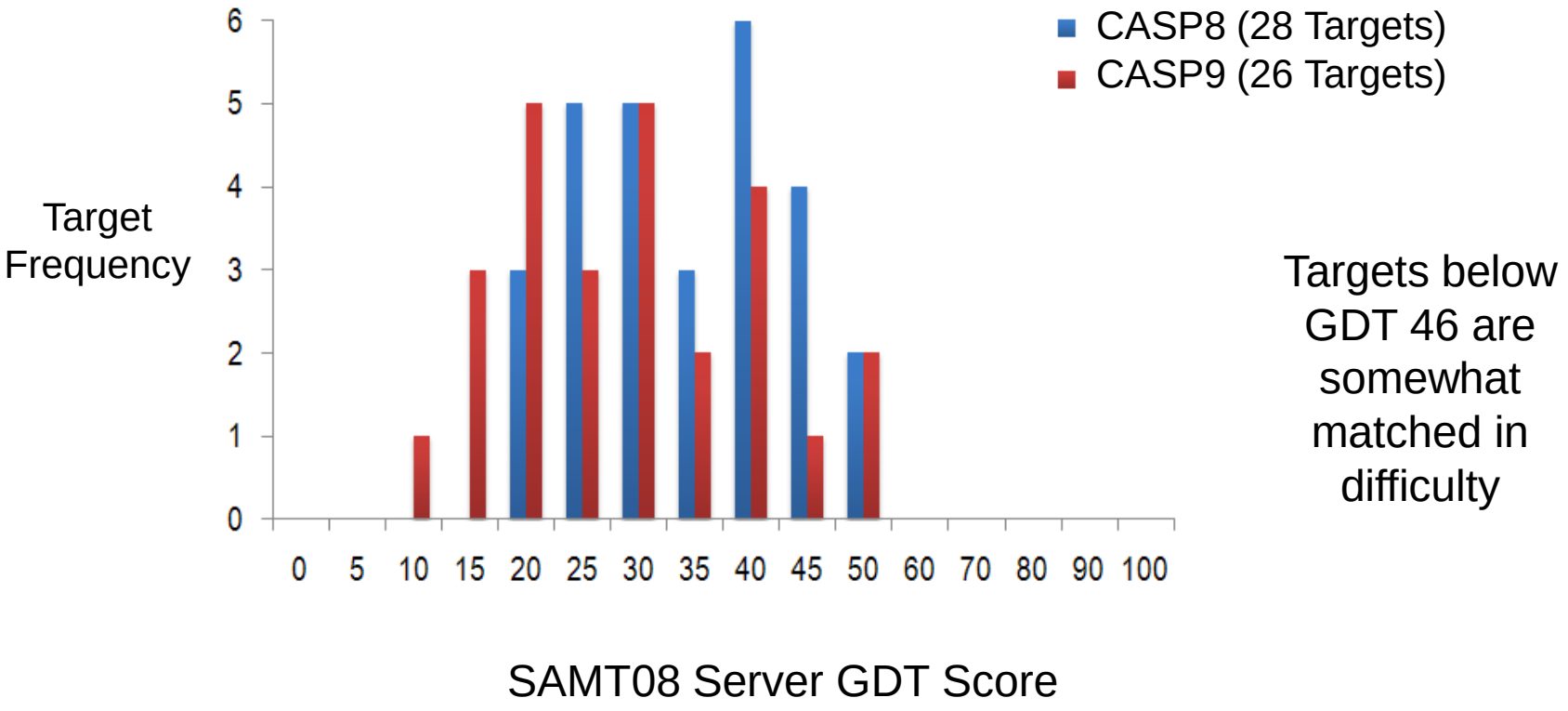
Group	96	408	418	470	172	37	88	490	113	386	380	424	428	295	321	382	399	94	60	407	16	110	114	395	147	402	300
96	-	0.59	0.93	0.99	0.89	0.99	0.98	0.98	0.99	0.99	1	0.95	1	1	0.97	1	1	1	1	1	1	1	1	1	1	1	0.95
408	26	-	0.79	0.84	0.88	0.9	0.89	0.9	0.91	0.8	0.93	1	0.96	0.98	1	1	0.98	0.98	0.97	0.99	1	0.99	1	1	0.99	1	0.54
418	26	26	-	0.58	0.57	0.62	0.72	0.71	0.71	0.68	0.82	0.75	0.87	0.91	0.87	0.97	0.96	0.96	0.91	0.97	0.99	0.98	0.99	0.99	0.98	0.99	0.6
470	26	26	26	-	0.52	0.57	0.68	0.67	0.76	0.85	0.9	0.72	0.91	0.87	0.83	0.99	0.93	0.98	0.97	1	0.98	0.97	0.99	1	0.98	0.99	0.55
172	26	26	26	26	-	0.51	0.59	0.62	0.61	0.61	0.67	0.72	0.75	0.77	0.83	0.89	0.89	0.9	0.72	0.92	0.97	0.93	0.96	0.96	0.95	0.97	0.65
37	26	26	26	26	26	-	0.64	0.64	0.78	0.57	0.8	0.71	0.89	0.83	0.84	0.98	0.94	0.98	0.95	0.99	1	0.97	1	1	0.99	1	0.64
88	26	26	26	26	26	26	-	0.5	0.52	0.55	0.57	0.61	0.66	0.7	0.77	0.9	0.88	0.88	0.78	0.94	0.91	0.95	0.98	0.97	0.97	0.95	0.75
490	26	26	26	26	26	26	26	-	0.51	0.62	0.58	0.62	0.69	0.7	0.77	0.88	0.93	0.97	0.77	0.94	0.96	0.98	0.95	0.95	0.95	0.98	0.9
113	26	26	26	26	26	26	26	26	-	0.55	0.59	0.59	0.7	0.7	0.75	0.95	0.86	0.97	0.9	0.98	0.97	0.95	0.98	0.99	0.95	0.98	0.63
386	25	25	25	25	25	25	25	25	25	-	0.65	0.94	0.78	0.87	0.98	0.99	0.89	0.95	0.93	0.99	0.97	0.95	0.99	0.99	0.96	0.98	0.52
380	26	26	26	26	26	26	26	26	26	25	-	0.55	0.78	0.68	0.71	0.9	0.85	0.94	0.79	0.98	0.96	0.93	0.97	0.98	0.92	0.98	0.76
424	26	26	26	26	26	26	26	26	26	25	26	-	0.52	0.59	0.81	0.8	0.76	0.75	0.69	0.81	0.85	0.83	0.9	0.91	0.89	0.91	1
428	26	26	26	26	26	26	26	26	26	25	26	26	-	0.59	0.66	0.84	0.79	0.89	0.63	0.93	0.95	0.9	0.95	0.97	0.9	0.97	0.76
295	26	26	26	26	26	26	26	26	26	25	26	26	26	-	0.64	0.83	0.7	0.74	0.58	0.81	0.87	0.79	0.91	0.98	0.87	0.92	0.93
321	26	26	26	26	26	26	26	26	26	25	26	26	26	26	-	0.58	0.56	0.6	0.58	0.67	0.69	0.7	0.74	0.75	0.71	0.76	1
382	26	26	26	26	26	26	26	26	26	25	26	26	26	26	26	-	0.5	0.58	0.52	0.68	0.68	0.67	0.78	0.82	0.73	0.77	0.99
399	26	26	26	26	26	26	26	26	26	25	26	26	26	26	26	26	-	0.57	0.71	0.64	0.67	0.67	0.7	0.74	0.73	0.77	1
94	26	26	26	26	26	26	26	26	26	25	26	26	26	26	26	26	26	-	0.76	0.61	0.6	0.61	0.64	0.65	0.65	0.69	0.92
60	23	23	23	23	23	23	23	23	23	22	23	23	23	23	23	23	23	23	-	0.83	0.82	0.74	0.93	0.94	0.94	0.91	0.94
407	26	26	26	26	26	26	26	26	26	25	26	26	26	26	26	26	26	26	23	-	0.5	0.52	0.57	0.59	0.58	0.59	0.95
16	26	26	26	26	26	26	26	26	26	25	26	26	26	26	26	26	26	26	23	26	-	0.51	0.58	0.6	0.59	0.65	0.98
110	26	26	26	26	26	26	26	26	26	25	26	26	26	26	26	26	26	26	23	26	26	-	0.55	0.56	0.57	0.58	0.95
114	26	26	26	26	26	26	26	26	26	25	26	26	26	26	26	26	26	26	23	26	26	26	-	0.53	0.55	0.54	0.99
395	26	26	26	26	26	26	26	26	26	25	26	26	26	26	26	26	26	26	23	26	26	26	26	-	0.52	0.52	1
147	26	26	26	26	26	26	26	26	26	25	26	26	26	26	26	26	26	26	23	26	26	26	26	26	-	0.5	0.94
402	26	26	26	26	26	26	26	26	26	25	26	26	26	26	26	26	26	26	23	26	26	26	26	26	26	-	1
300	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	16	19	19	19	19	19	19	19	-

Are Ranks Significant? Bootstrap

Groupname	TS096	TS408	TS418	TS470	TS172	TS037	TS088	TS490	TS113	TS386	TS380	TS424	TS428	TS295	TS321	TS382	TS399	TS094	TS060
TS096	-	0.623	0.941	0.993	0.904	0.998	0.982	0.987	0.994	0.998	1.000	0.945	1.000	1.000	0.966	1.000	0.998	1.000	1.000
TS408	26	-	0.792	0.875	0.873	0.931	0.909	0.930	0.947	0.798	0.976	0.998	0.991	0.995	1.000	0.999	0.990	0.995	0.990
TS418	26	26	-	0.587	0.568	0.626	0.733	0.744	0.716	0.691	0.837	0.778	0.884	0.920	0.881	0.981	0.954	0.972	0.927
TS470	26	26	26	-	0.528	0.533	0.672	0.683	0.767	0.864	0.911	0.730	0.904	0.880	0.855	0.993	0.937	0.992	0.973
TS172	26	26	26	26	-	0.503	0.570	0.636	0.583	0.396	0.662	0.719	0.754	0.786	0.872	0.904	0.888	0.915	0.698
TS037	26	26	26	26	26	-	0.612	0.645	0.802	0.587	0.812	0.727	0.897	0.849	0.845	0.983	0.943	0.989	0.961
TS088	26	26	26	26	26	26	-	0.506	0.522	0.496	0.591	0.633	0.658	0.705	0.794	0.906	0.879	0.879	0.767
TS490	26	26	26	26	26	26	26	-	0.530	0.361	0.573	0.652	0.674	0.689	0.775	0.889	0.945	0.985	0.794
TS113	26	26	26	26	26	26	26	26	-	0.432	0.594	0.598	0.712	0.681	0.773	0.959	0.882	0.981	0.921
TS386	25	25	25	25	25	25	25	25	25	-	0.640	0.954	0.778	0.887	0.984	0.991	0.884	0.964	0.948
TS380	26	26	26	26	26	26	26	26	26	25	-	0.583	0.770	0.697	0.731	0.909	0.866	0.958	0.818
TS424	26	26	26	26	26	26	26	26	26	25	26	-	0.486	0.569	0.815	0.793	0.768	0.767	0.699
TS428	26	26	26	26	26	26	26	26	26	25	26	26	-	0.561	0.687	0.850	0.803	0.914	0.635
TS295	26	26	26	26	26	26	26	26	26	25	26	26	26	-	0.660	0.843	0.706	0.753	0.561
TS321	26	26	26	26	26	26	26	26	26	25	26	26	26	26	-	0.551	0.552	0.574	0.563
TS382	26	26	26	26	26	26	26	26	26	25	26	26	26	26	26	-	0.541	0.541	0.520
TS399	26	26	26	26	26	26	26	26	26	25	26	26	26	26	26	26	-	0.581	0.259
TS094	26	26	26	26	26	26	26	26	26	25	26	26	26	26	26	26	26	-	0.222
TS060	23	23	23	23	23	23	23	23	23	22	23	23	23	23	23	23	23	23	-

Overall performance: Progress?

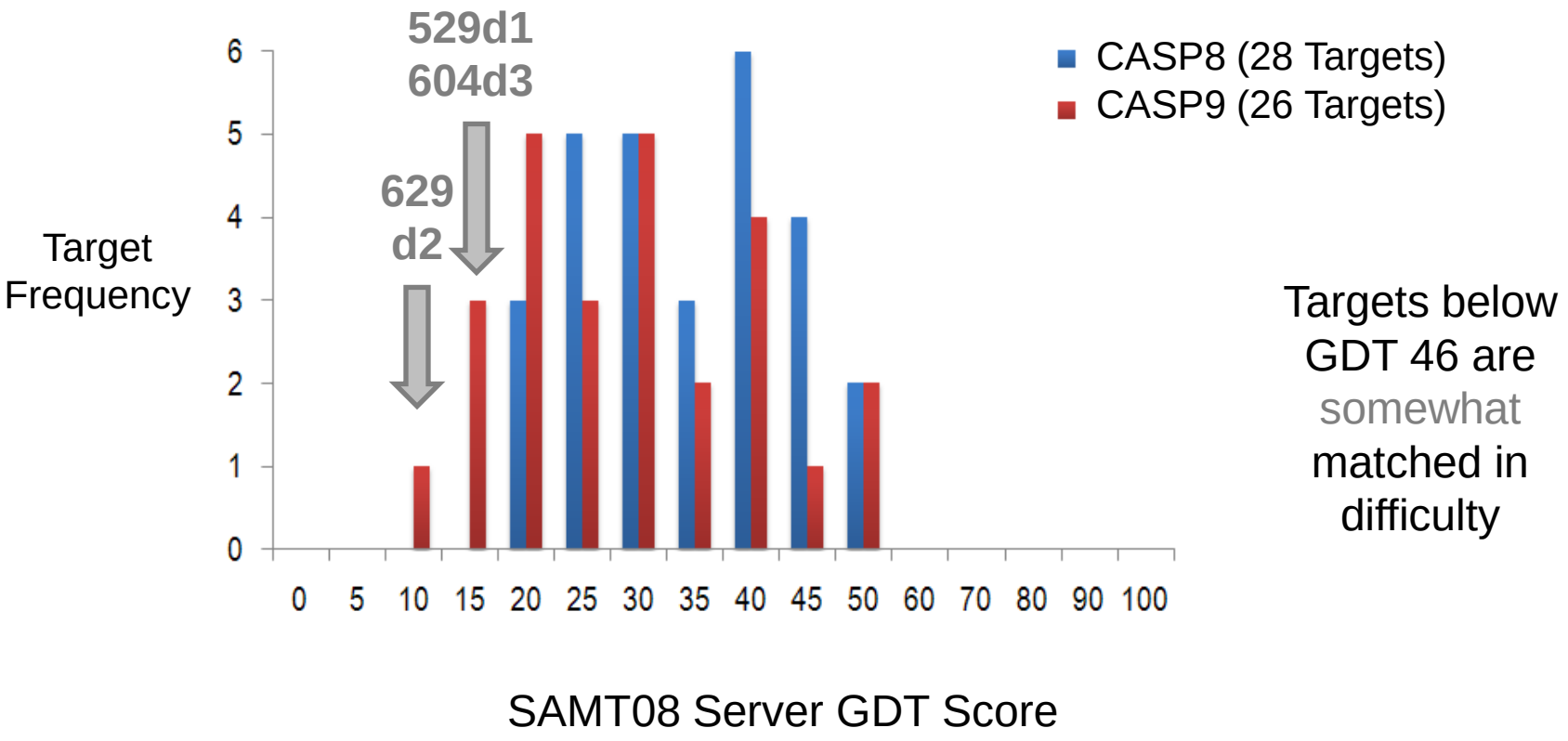
SAMT08 server did not change = good benchmark for Target Difficulty



Targets below GDT 46 are somewhat matched in difficulty

Overall performance: Progress?

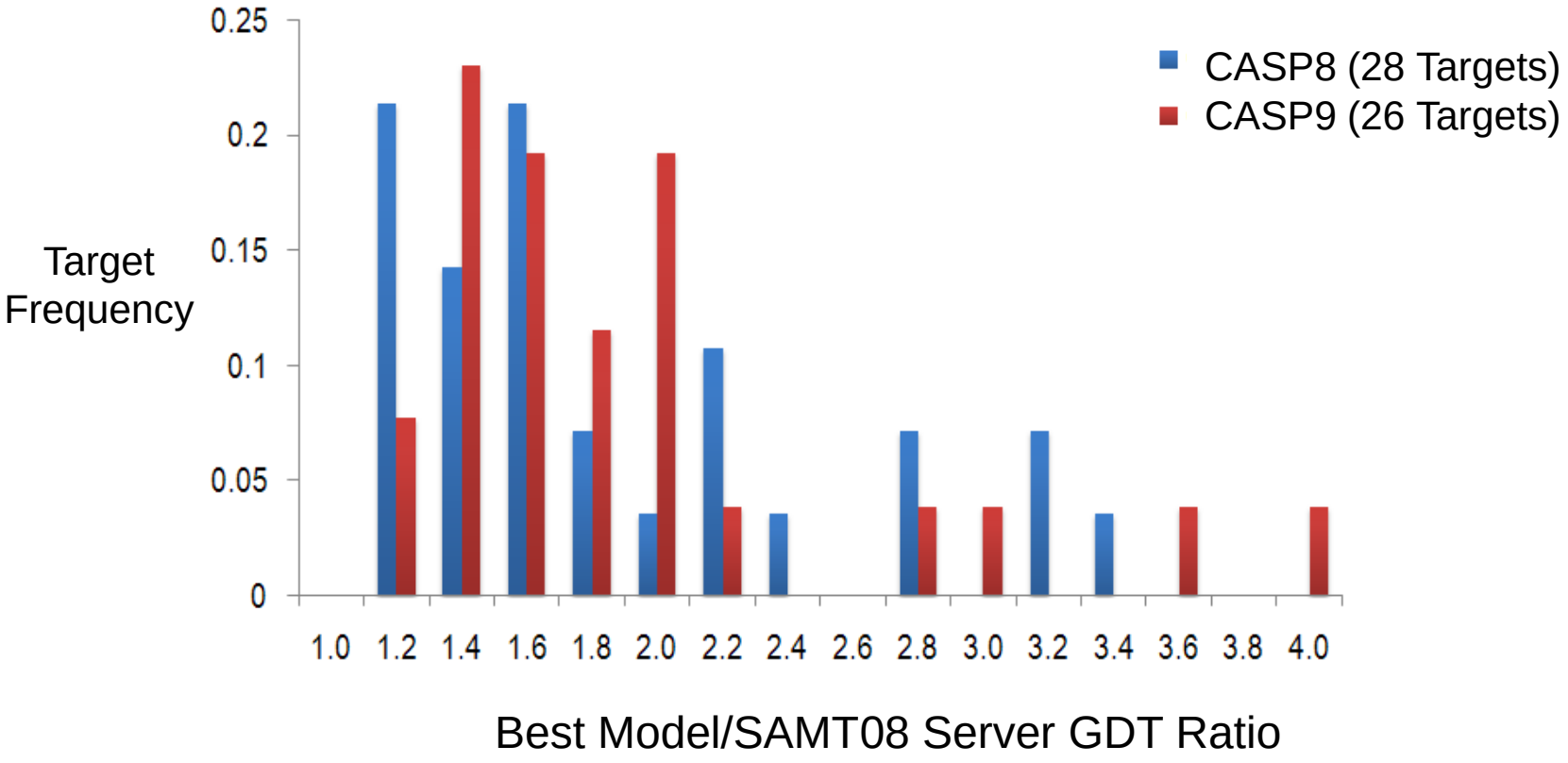
SAMT08 server did not change = good benchmark for Target Difficulty



Targets below GDT 46 are somewhat matched in difficulty

Overall performance: Progress?

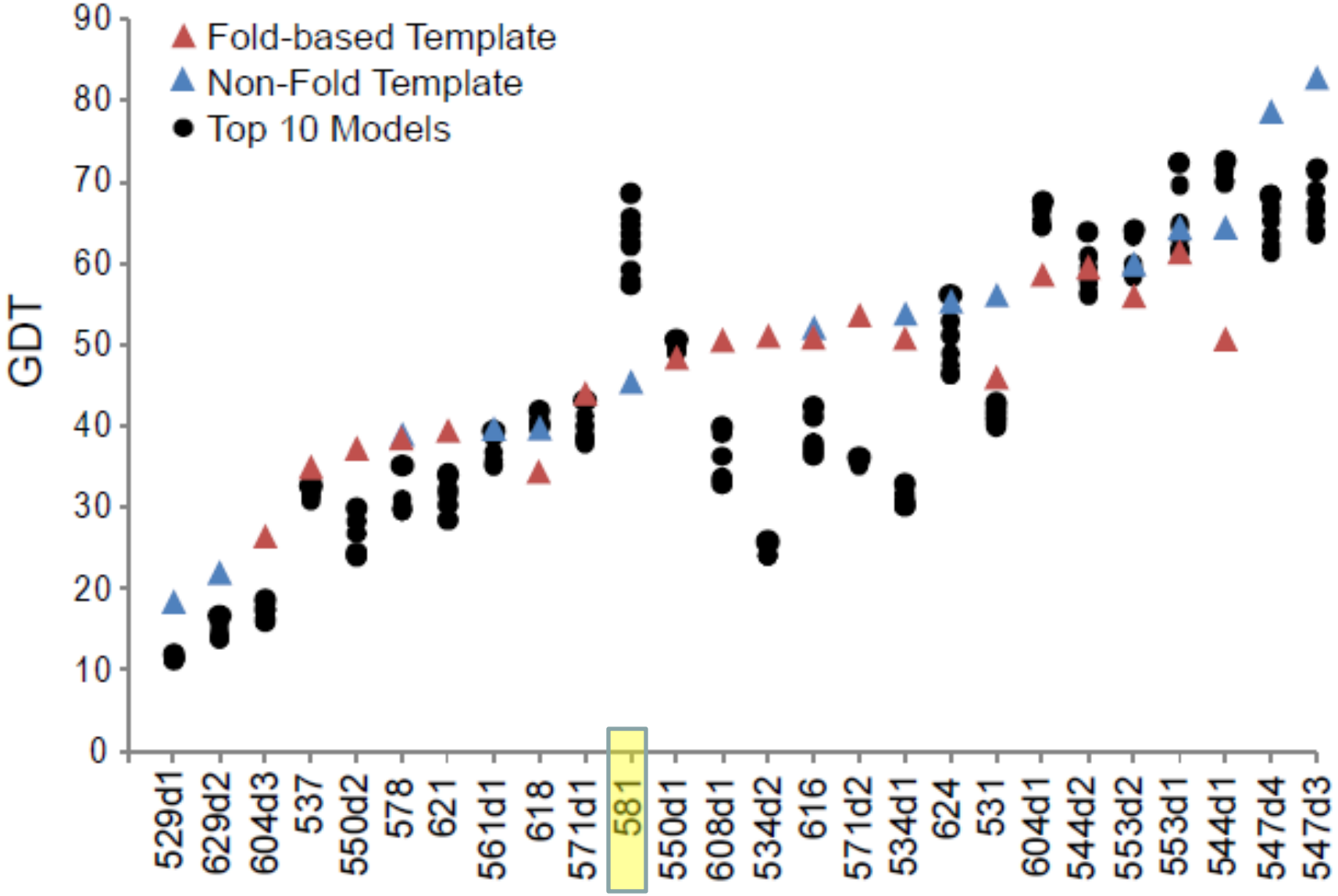
SAMT08 server did not change = good benchmark
Ratio indicates Performance



Talk plan

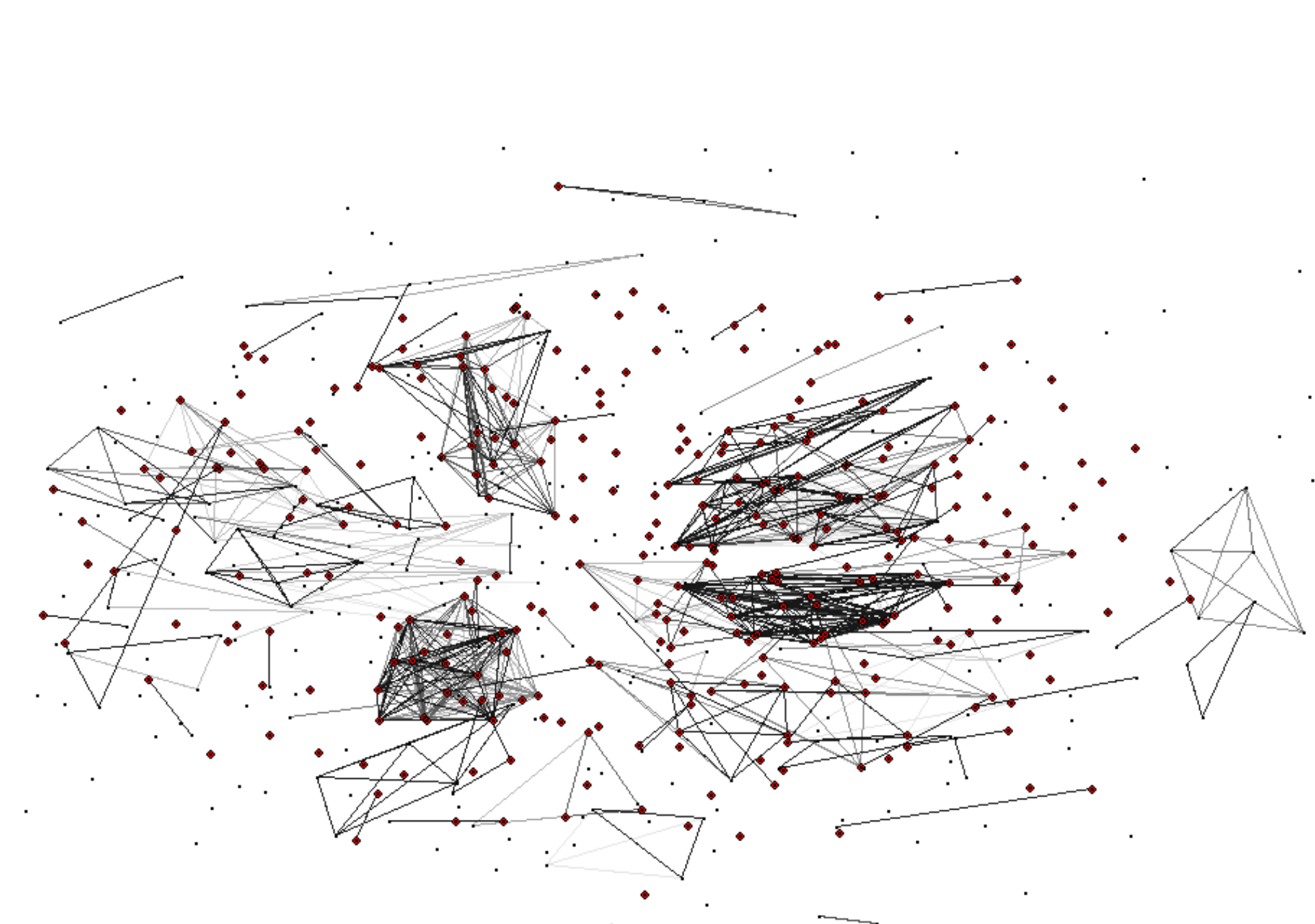
- Introduction: FM winner in CASP9!
- Manual Assessment
- New Scoring Function
- Meta-scoring in Assessment
- The bloody Ranking
- Problems and successes

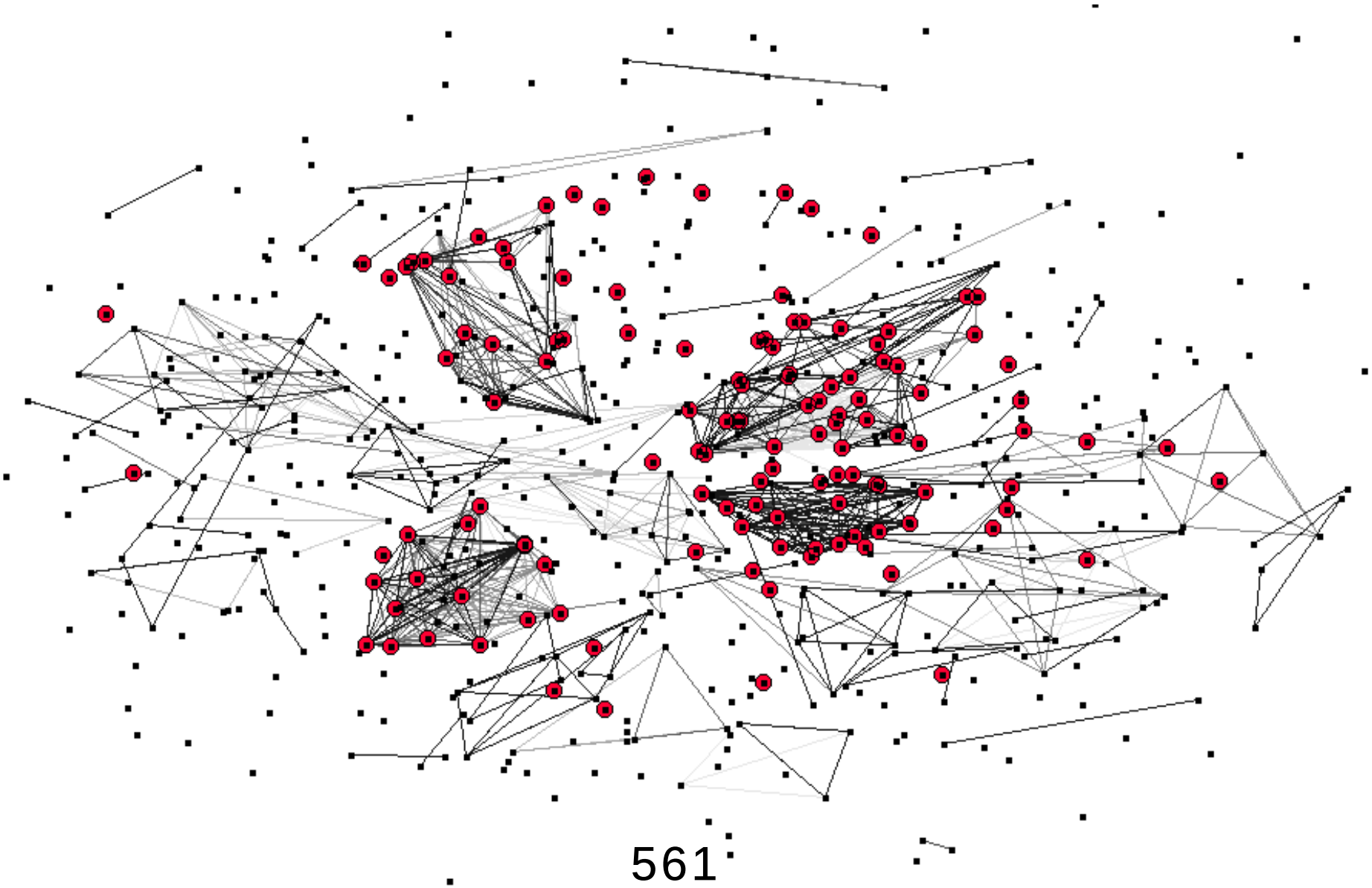
Comparison to Top GDT Templates

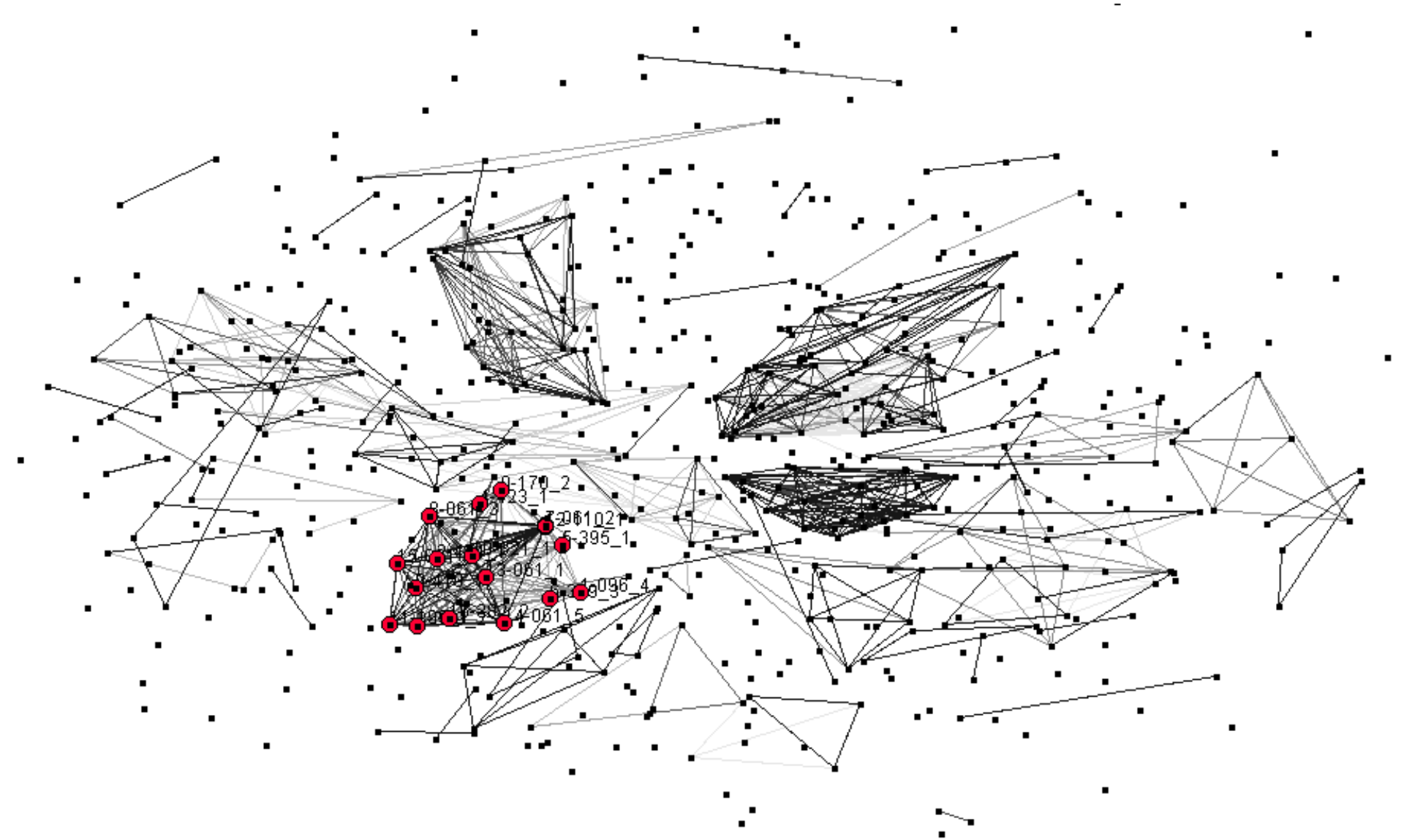


Another success story: T0604_1

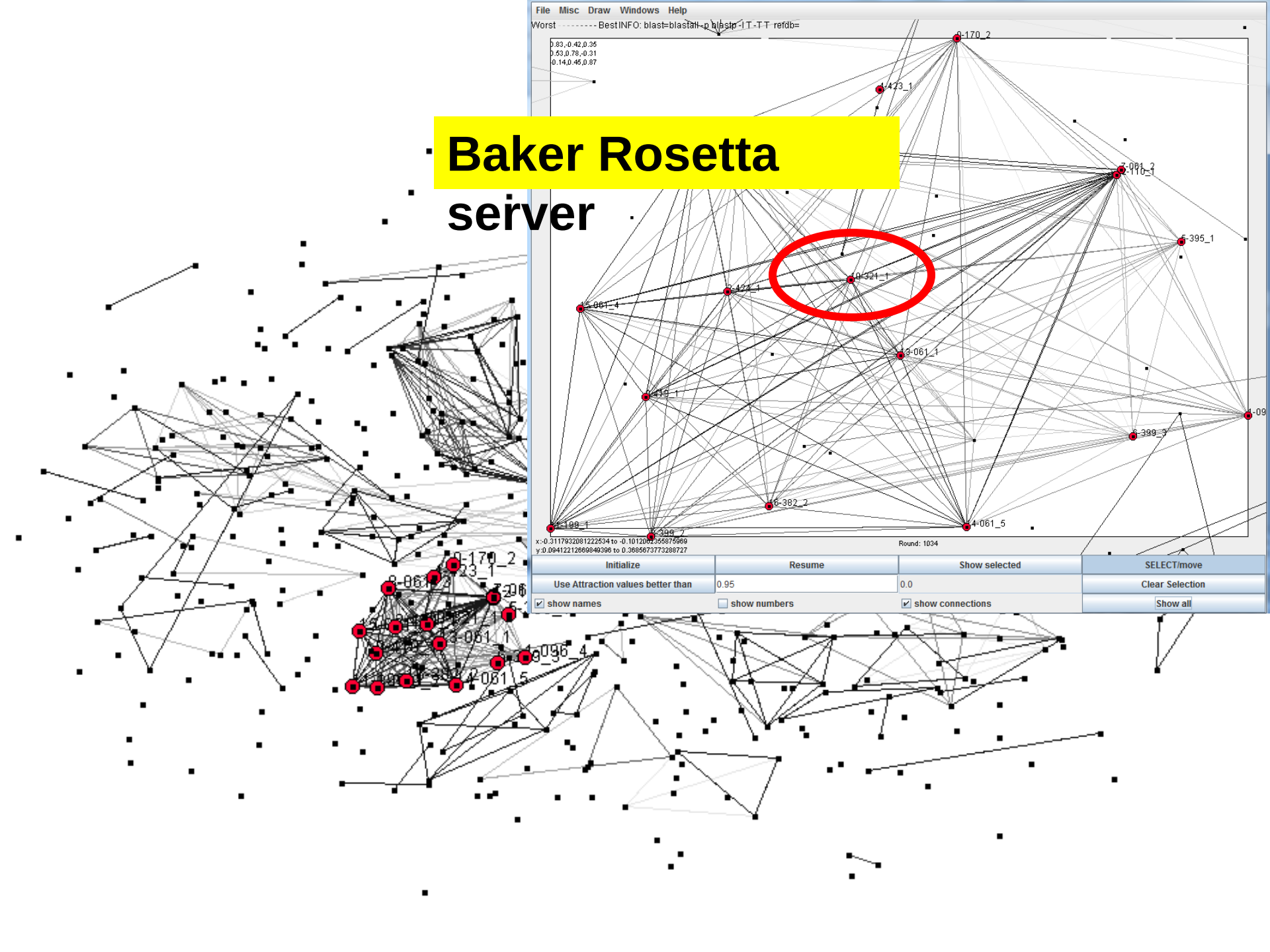
Winning model: group **96** model **1**

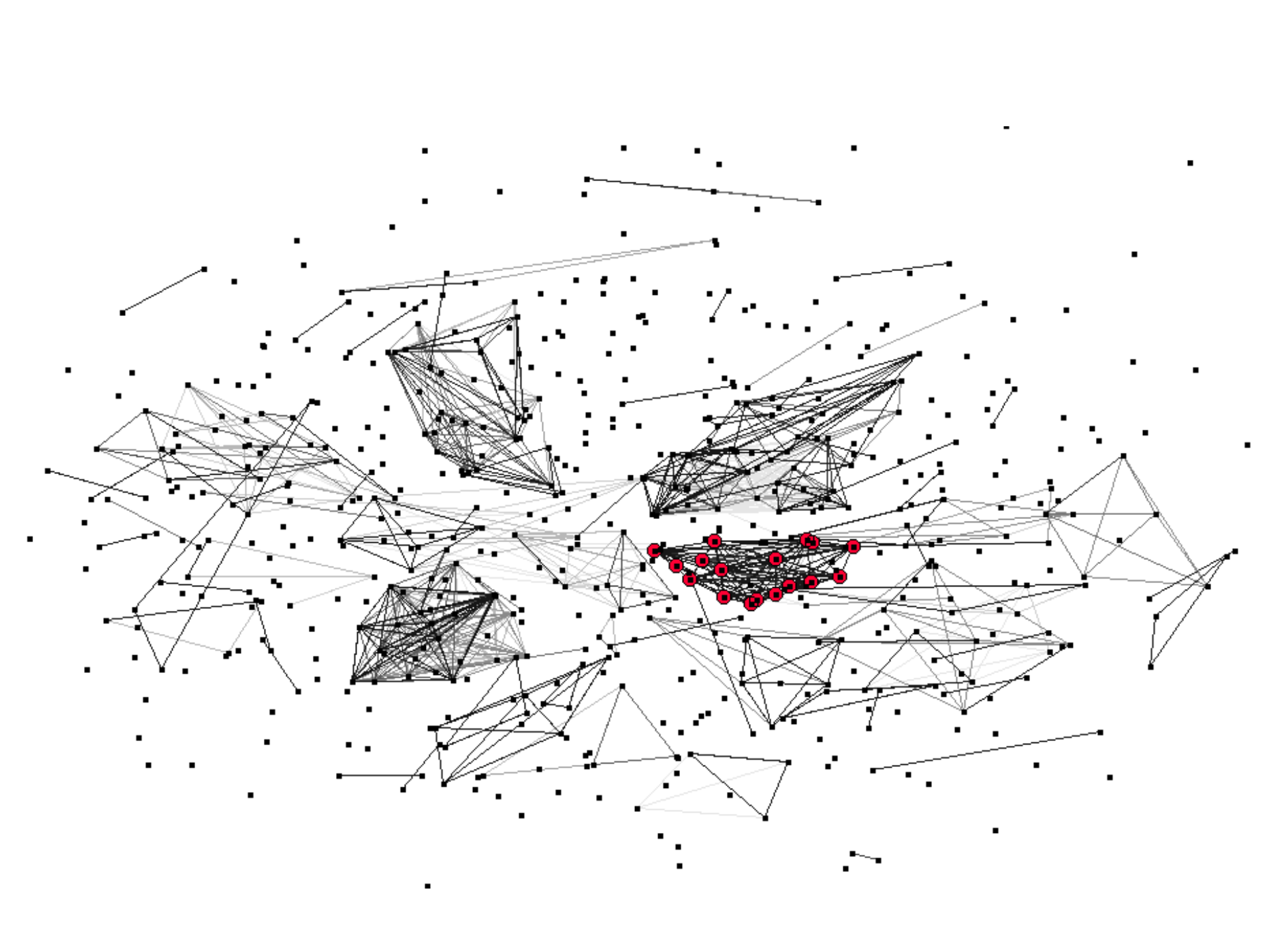


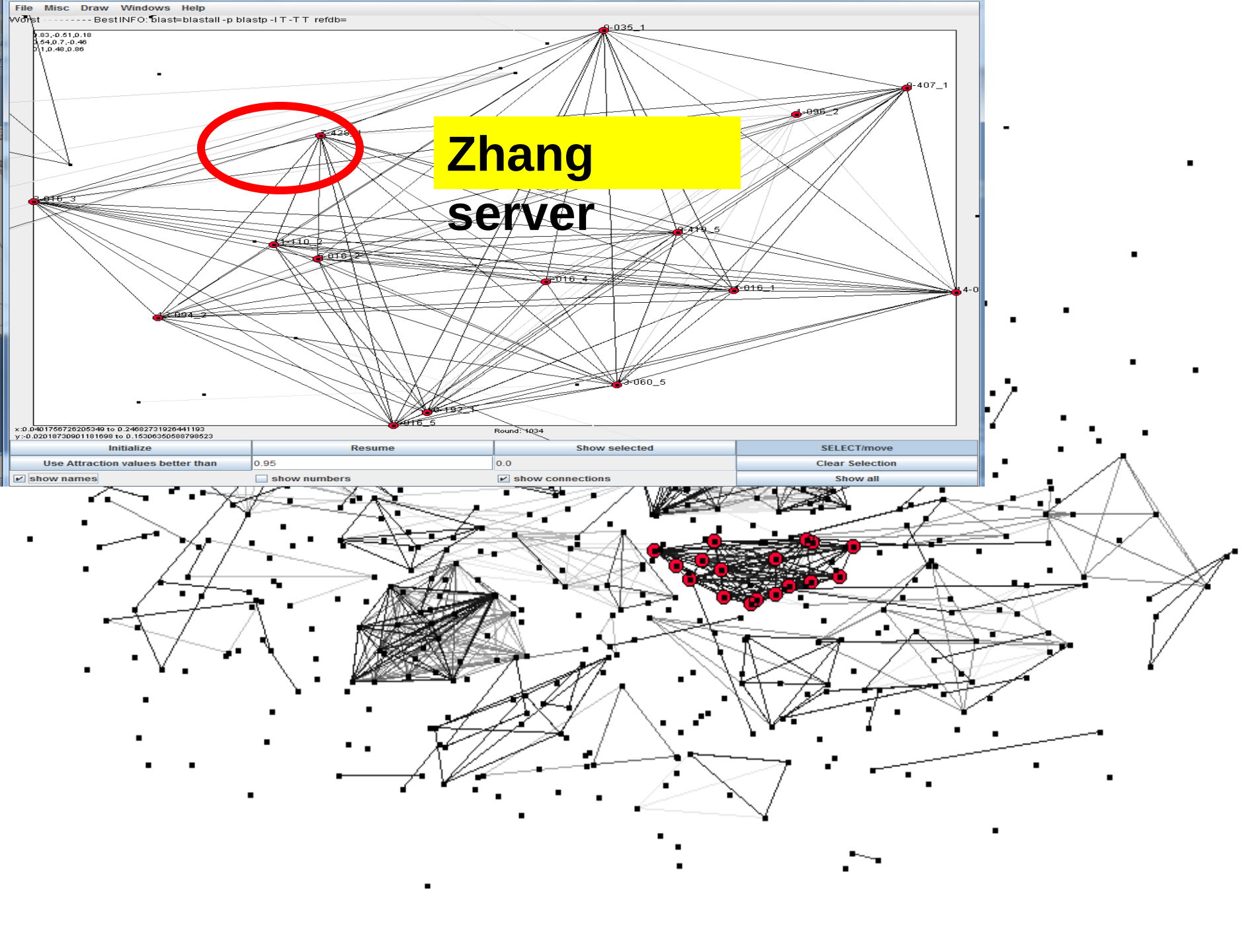




Baker Rosetta server






File Misc Draw Windows Help
Zhang
server
Initialize
Resume
Show selected
SELECT/move
Use Attraction values better than
0.95
0.0
Clear Selection
show names
show numbers
show connections
Show all

Sorry to people on our panel

Instead of emphasize on sharing experience for success
We will focus more on sharing lessons out of failures

And we are only interested in severe problems with top models, i.e., **promising** models (groups)
If you are always on the top, you will need to bear the most criticism.

A bad joke:

How could we have won this CASP FM category with minimal time and resources invested?

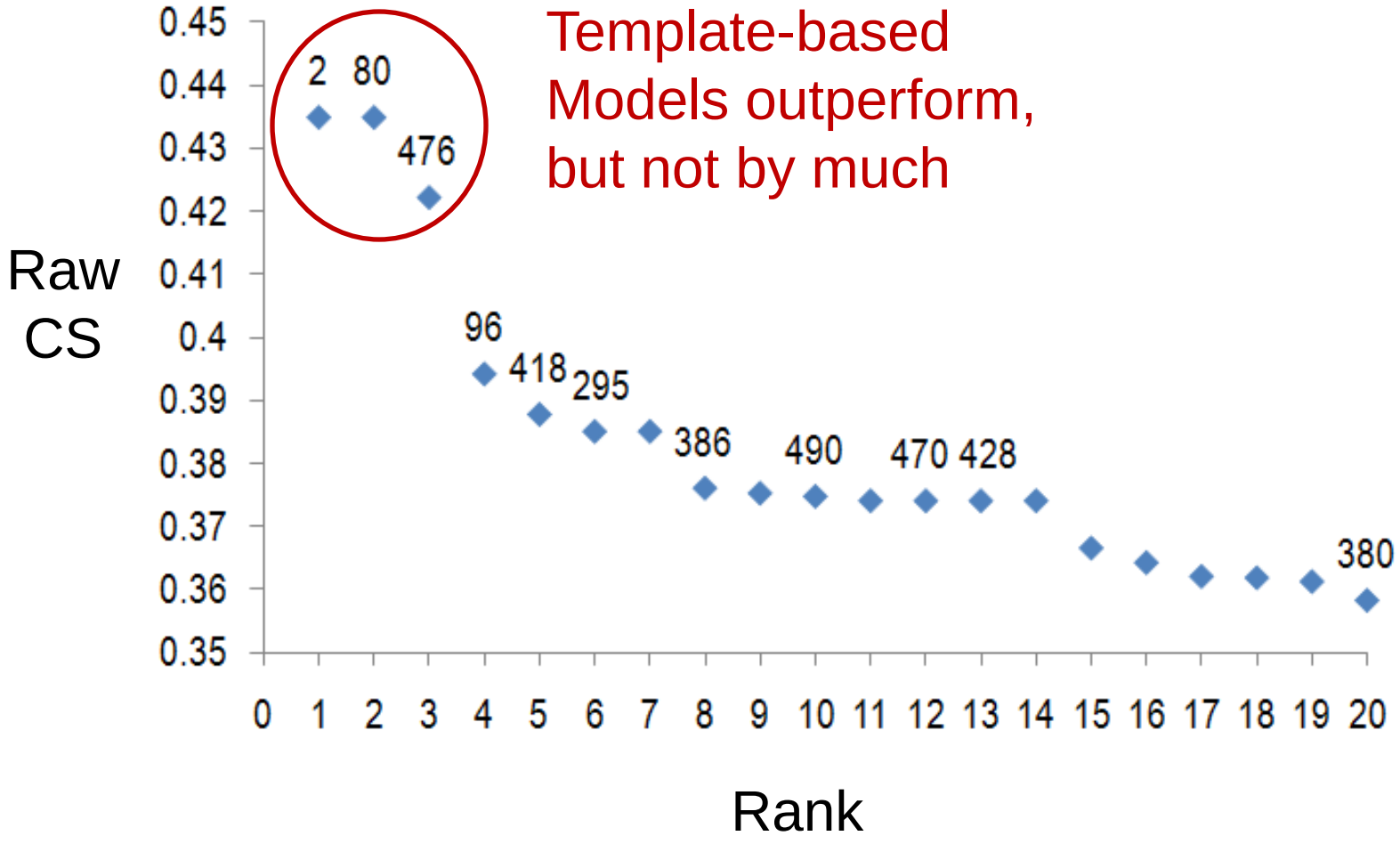
Run PSIPRED for each protein to get secondary structure components

If it is alpha protein made of long helices we use Robetta models
If it is alpha protein made of short helices we use Quark models
If it is alpha + beta protein we use Zhang-server models
If it is beta protein we use Quark models.

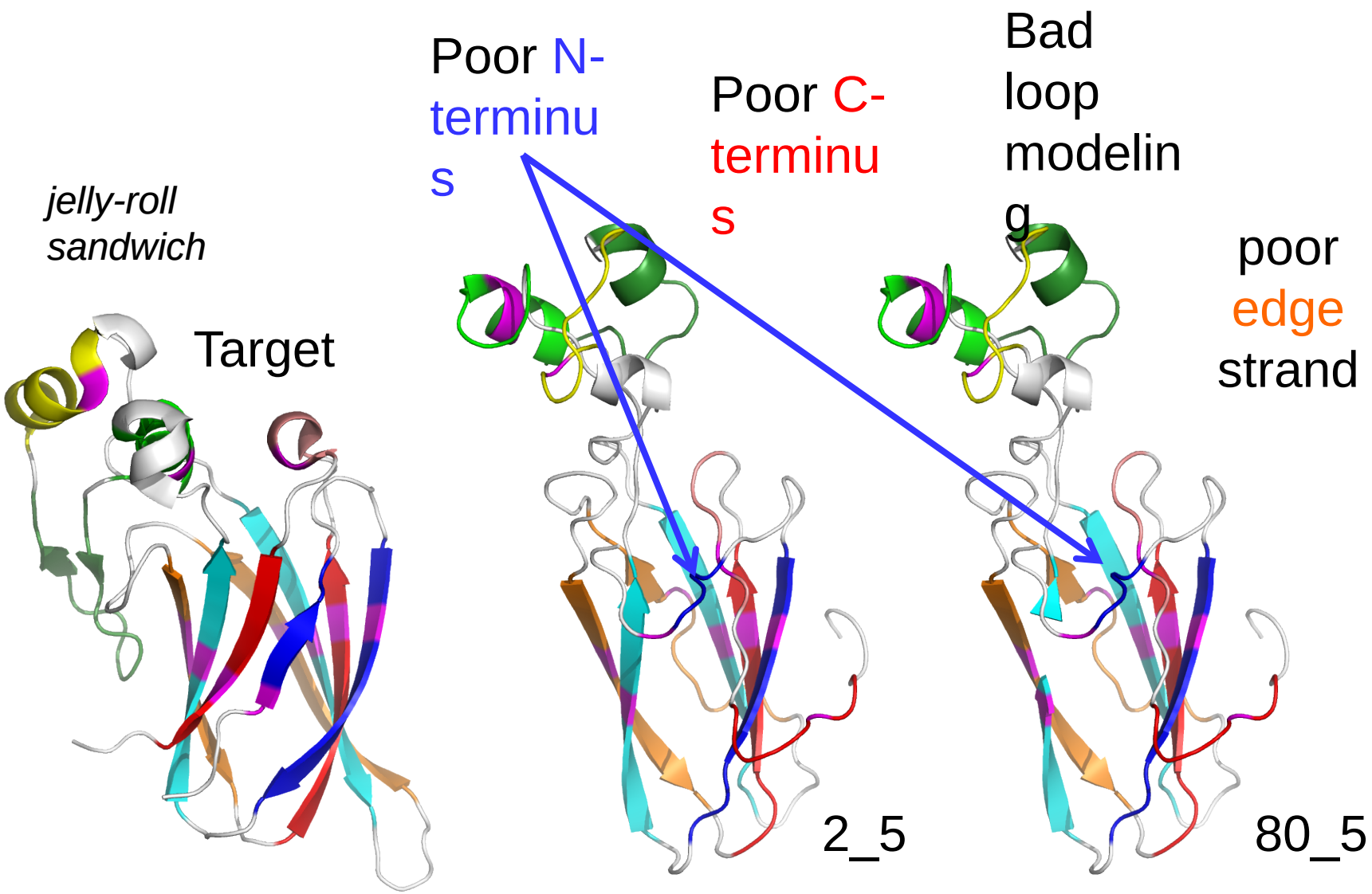
We would have be among the winners, rank No.7 for sum of zscores

FM Model Assessment: T0621 – FM and TBM boundaries are becoming blurred

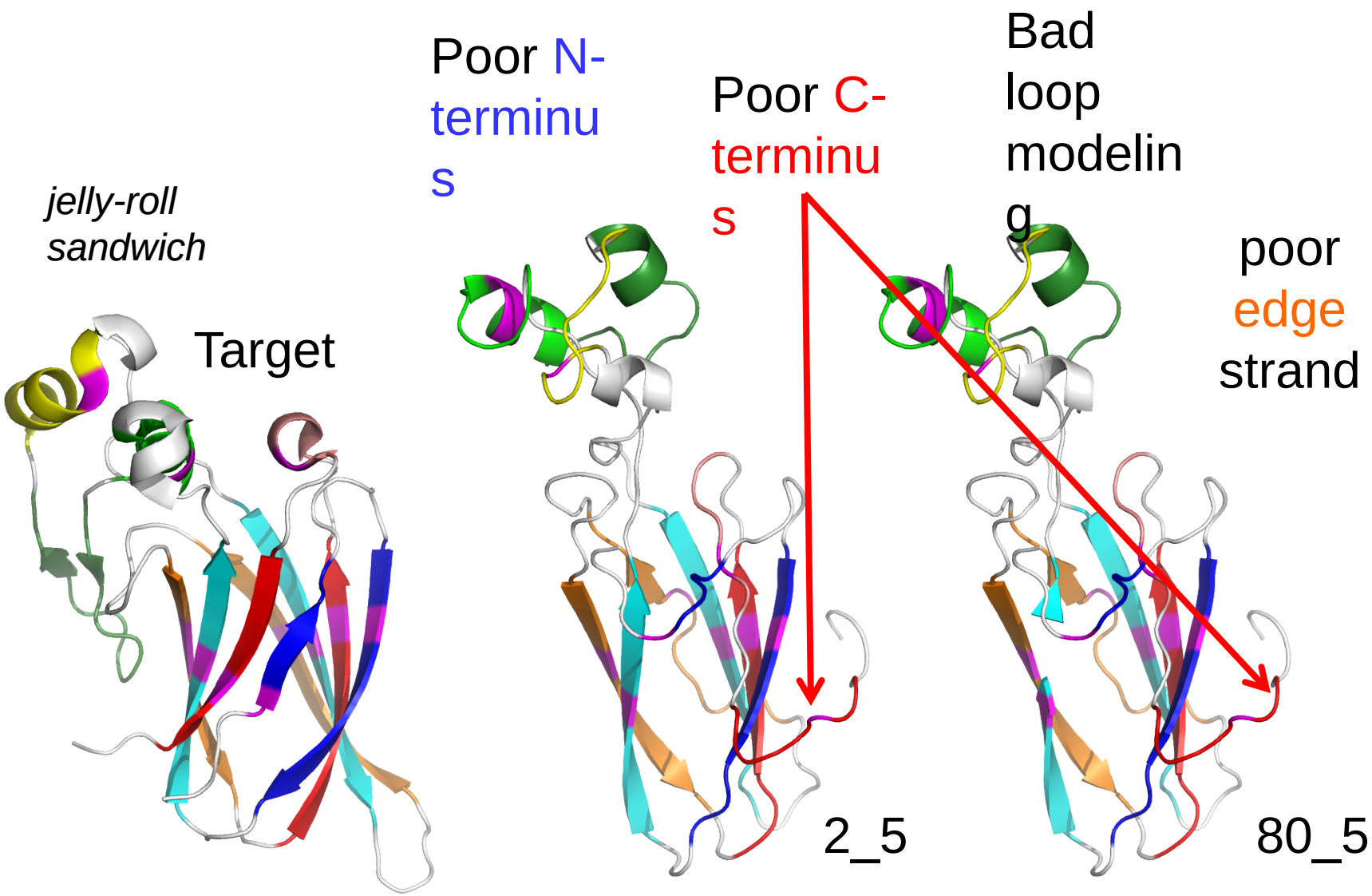
Target 621: Template-based *AND* FM Models



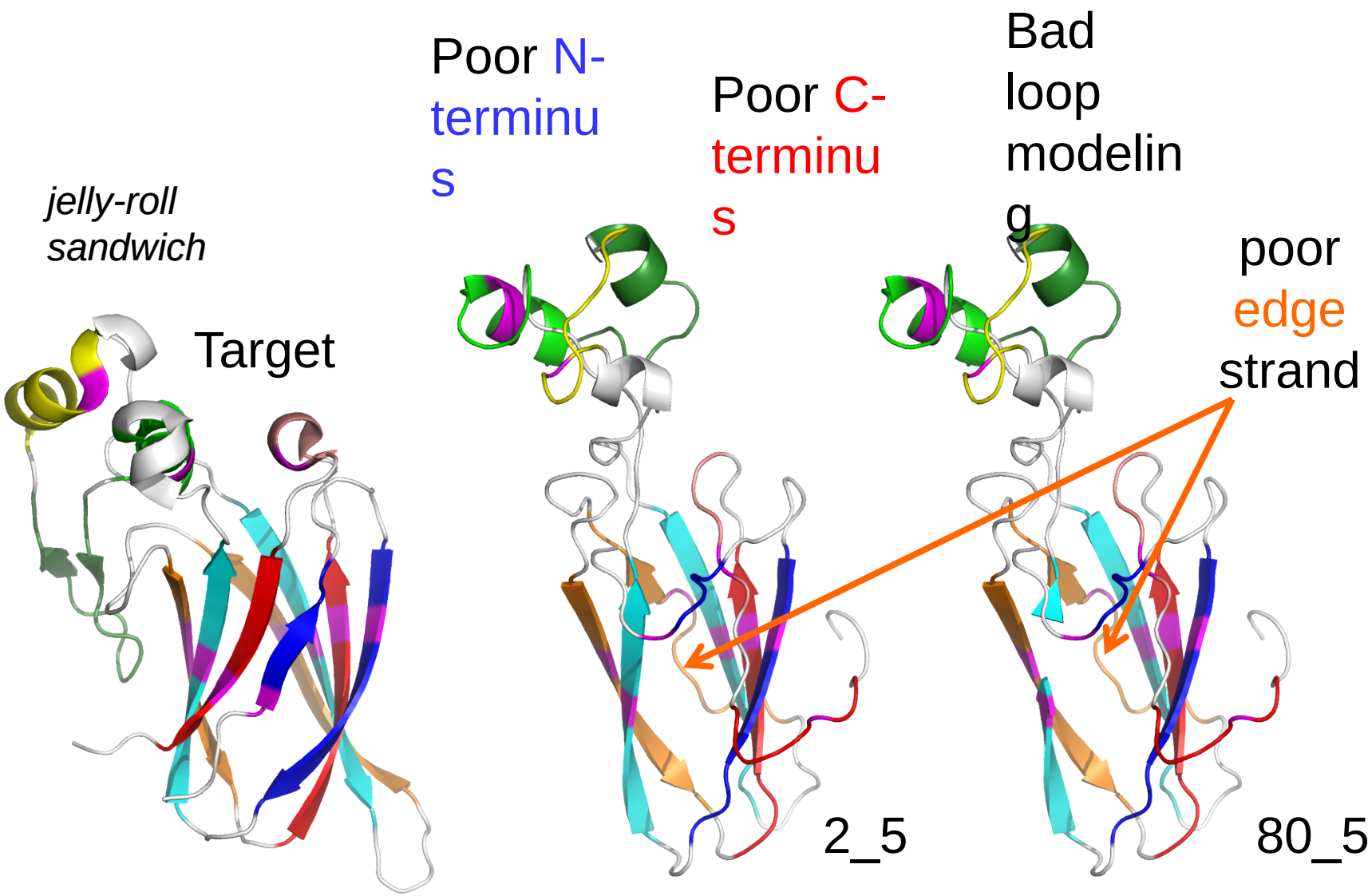
Target 621: Template-based *AND* FM Models



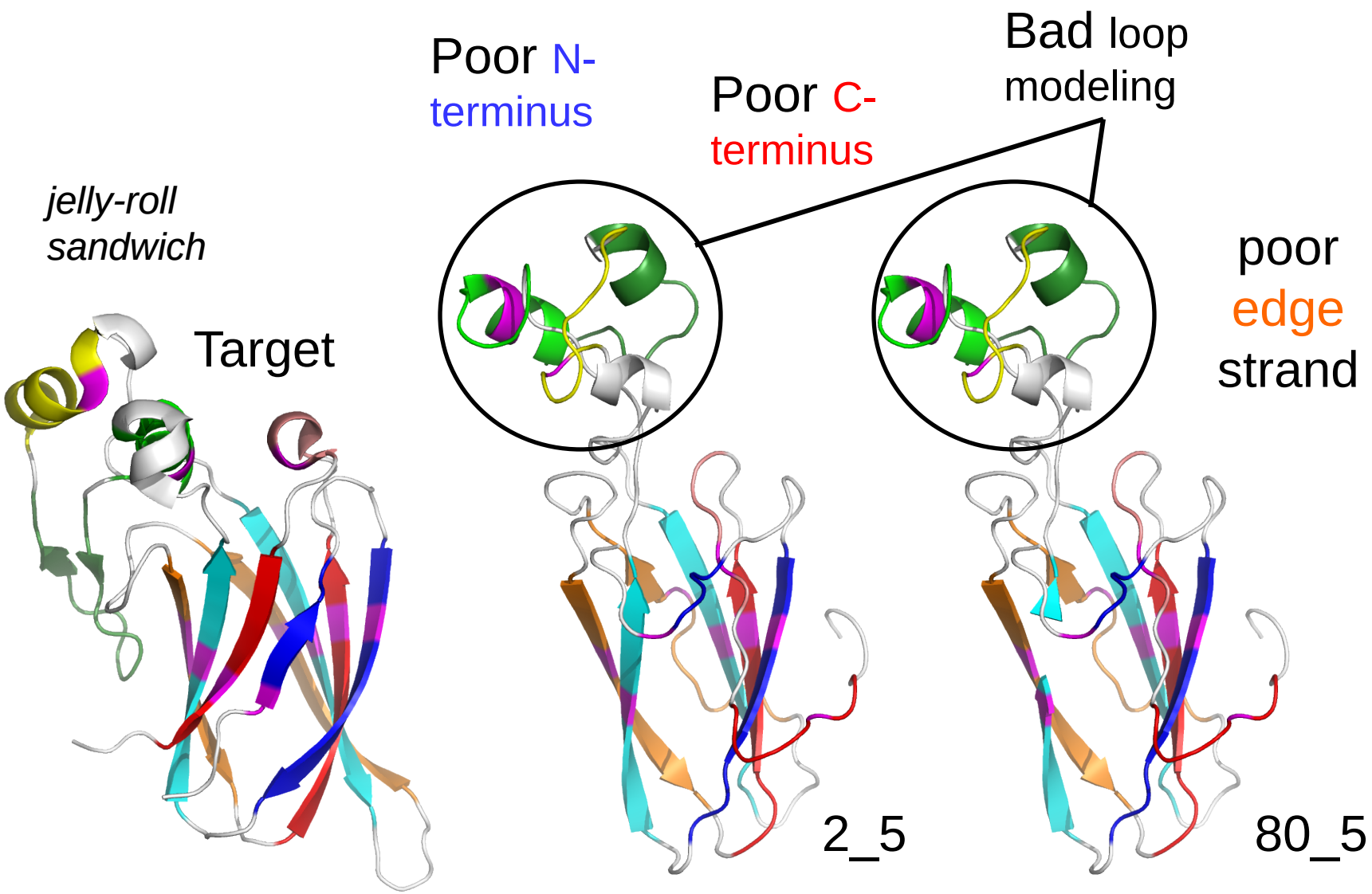
Target 621: Template-based *AND* FM Models



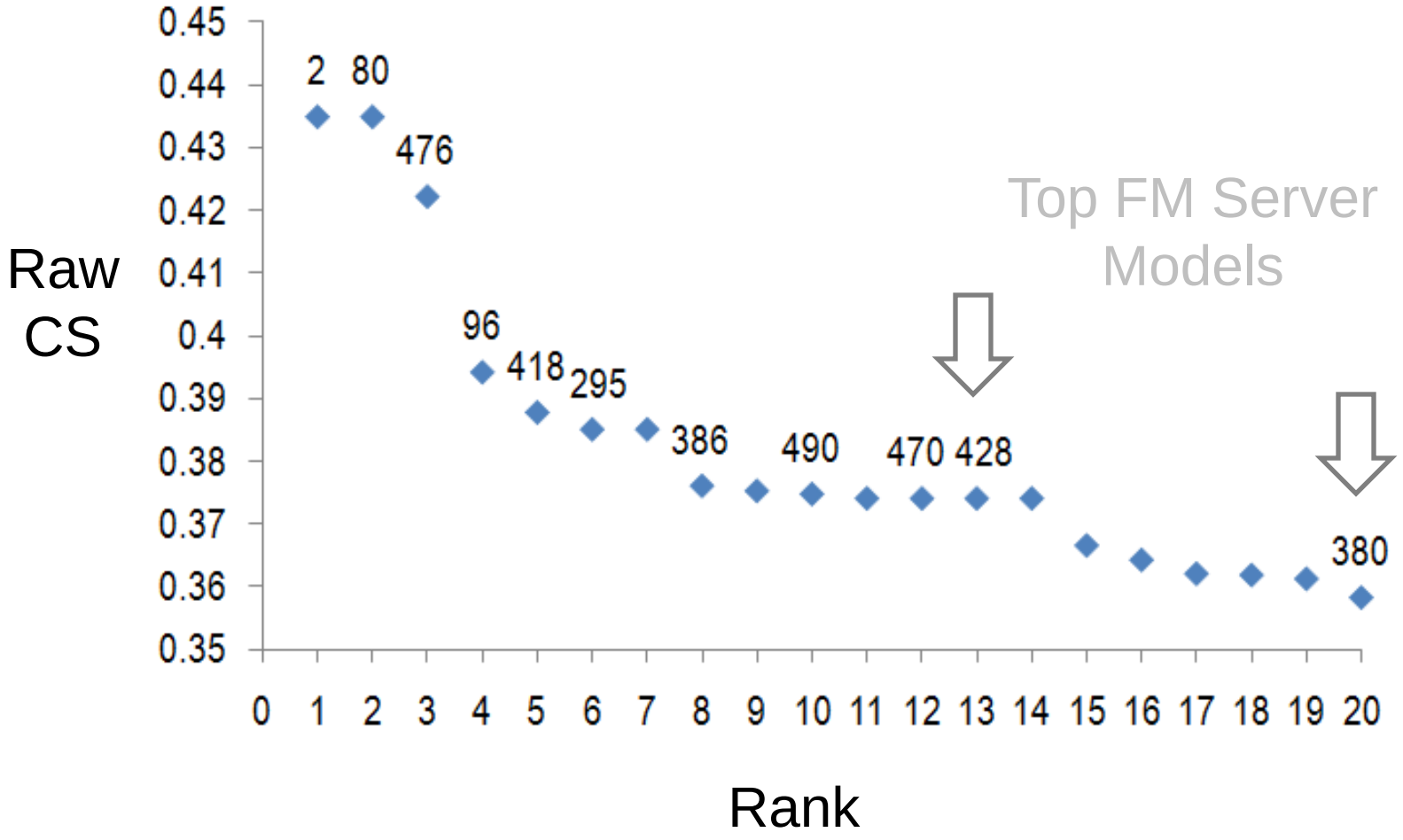
Target 621: Template-based *AND* FM Models



Target 621: Template-based *AND* FM Models



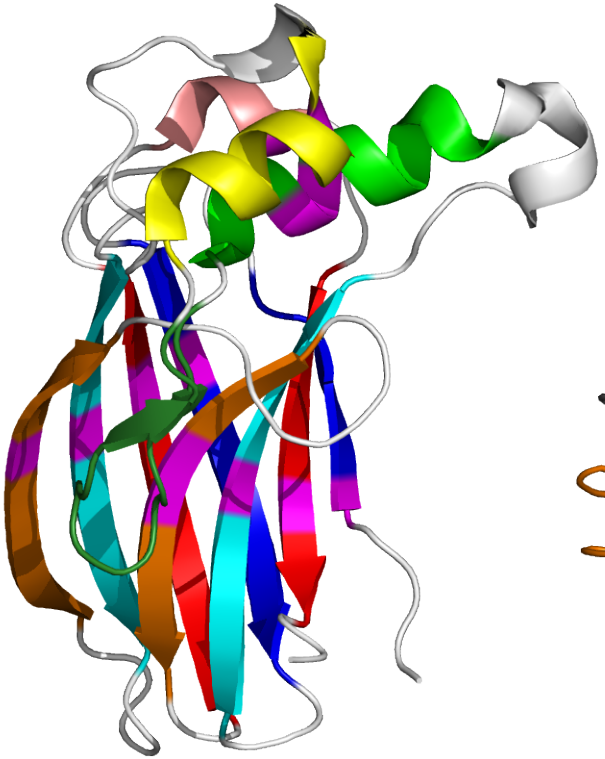
Target 621: Template-based *AND* FM Models



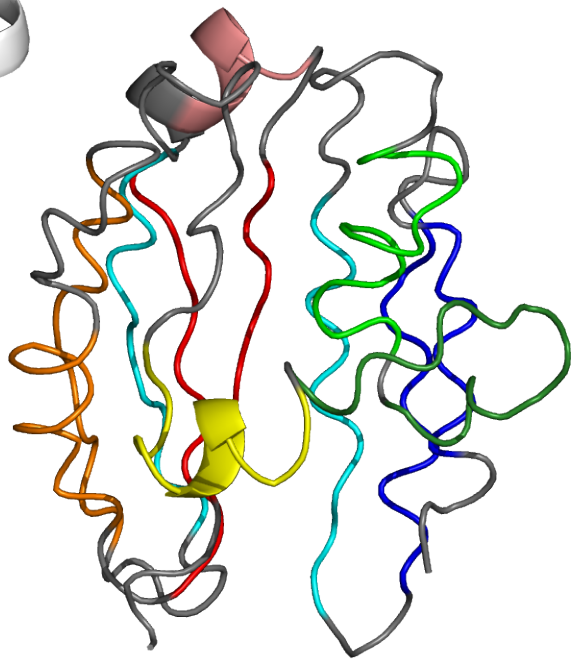
Target 621: Template-based *AND* FM Models

jelly-roll sandwich

Target

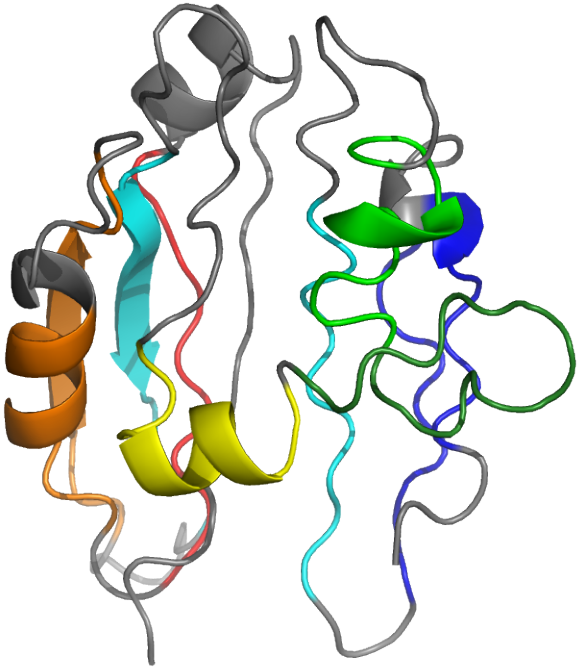


380_2
0.36



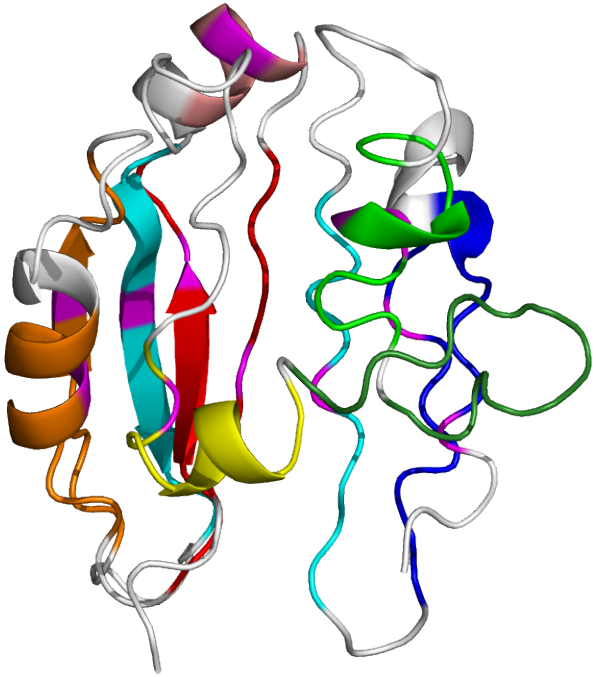
Sheet???

428_4
0.37

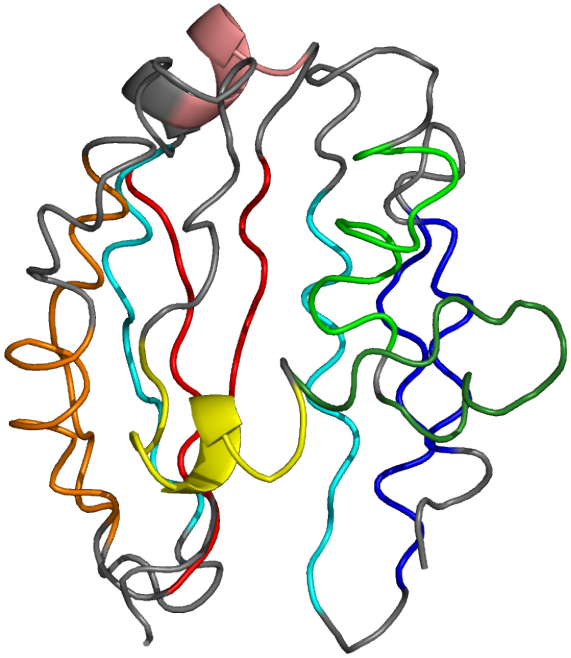


Target 621: Template-based *AND* FM Models

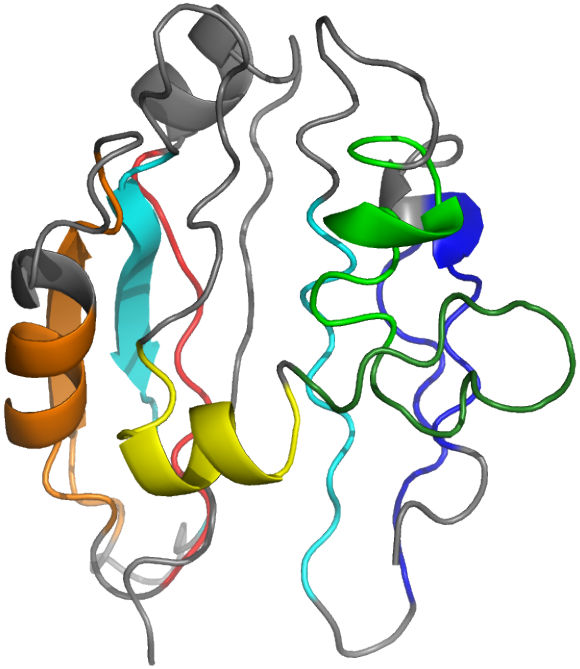
386_4
0.376



380_2
0.358



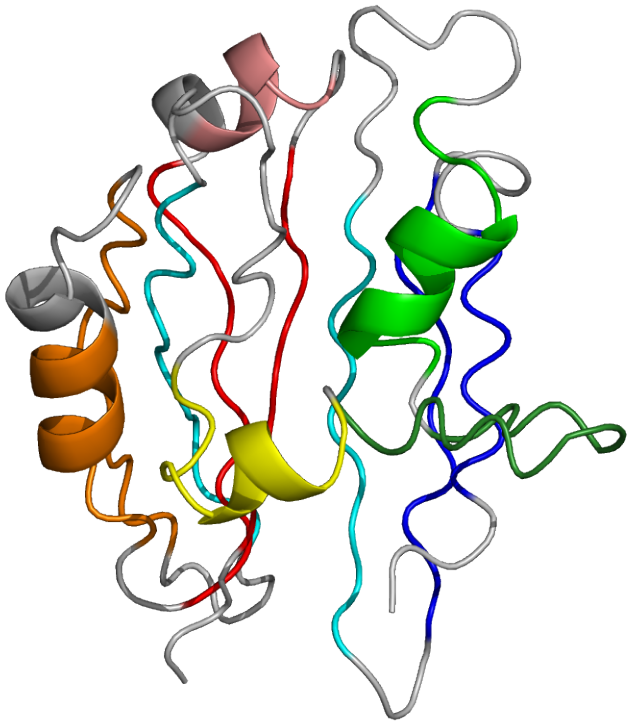
428_4
0.374



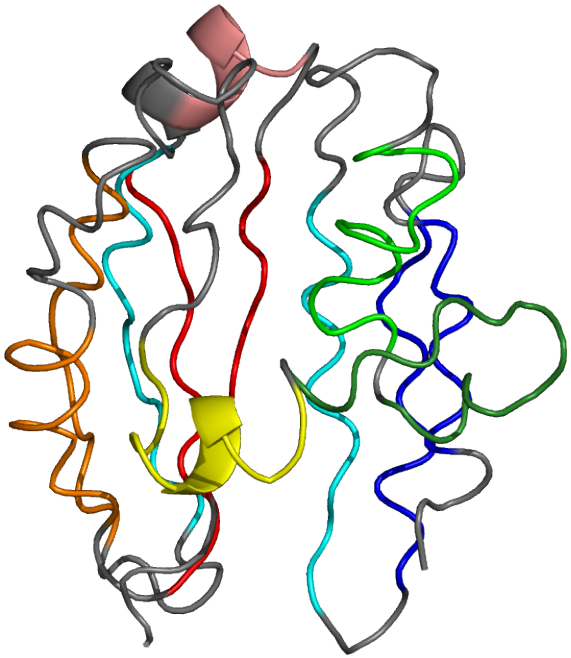
Target 621: Template-based *AND* FM Models

Why the increase in score???

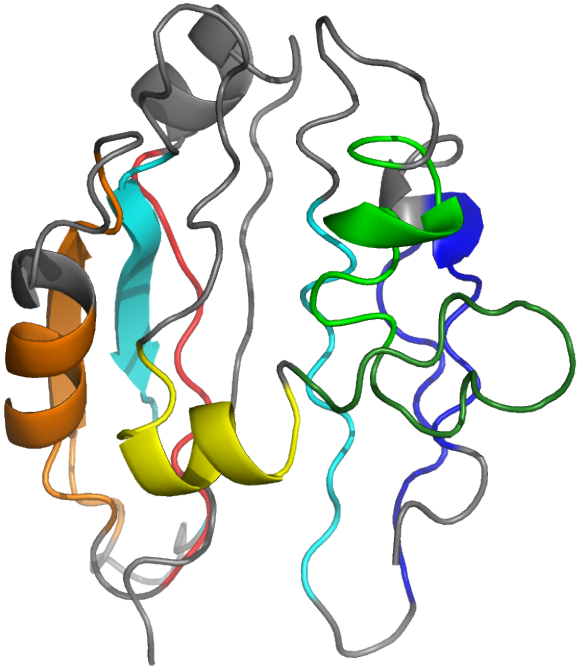
96_3
0.394



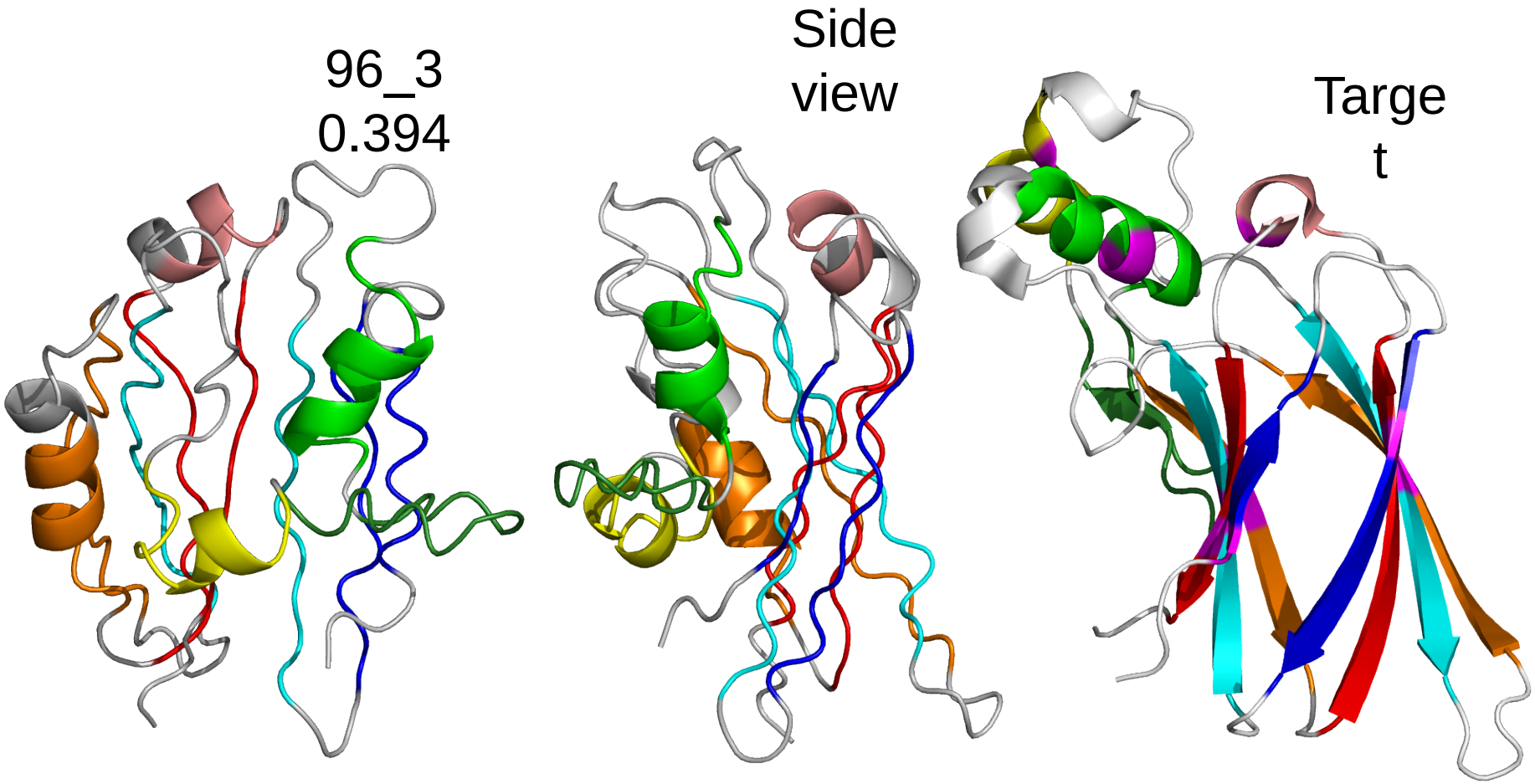
380_2
0.358



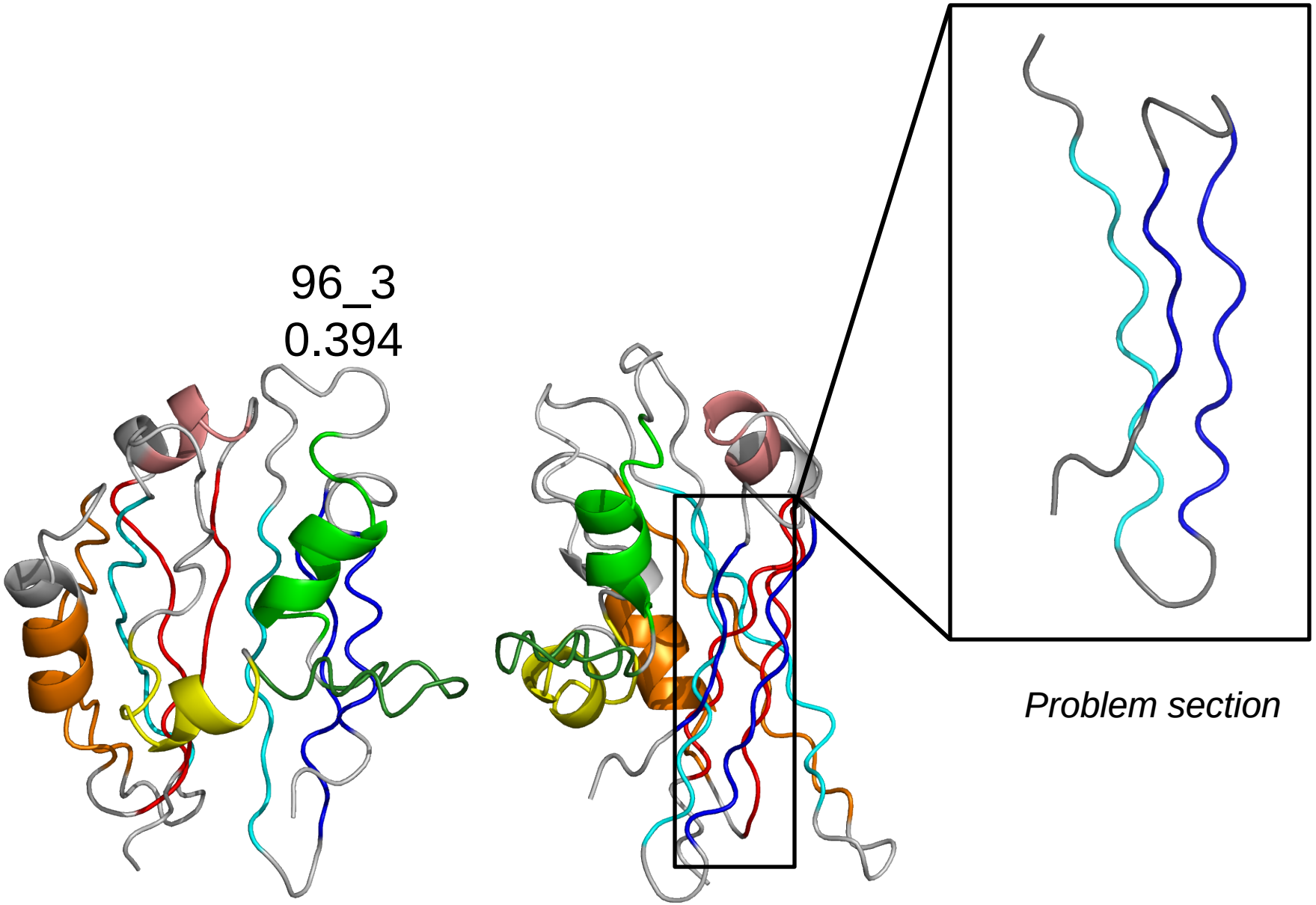
428_4
0.374



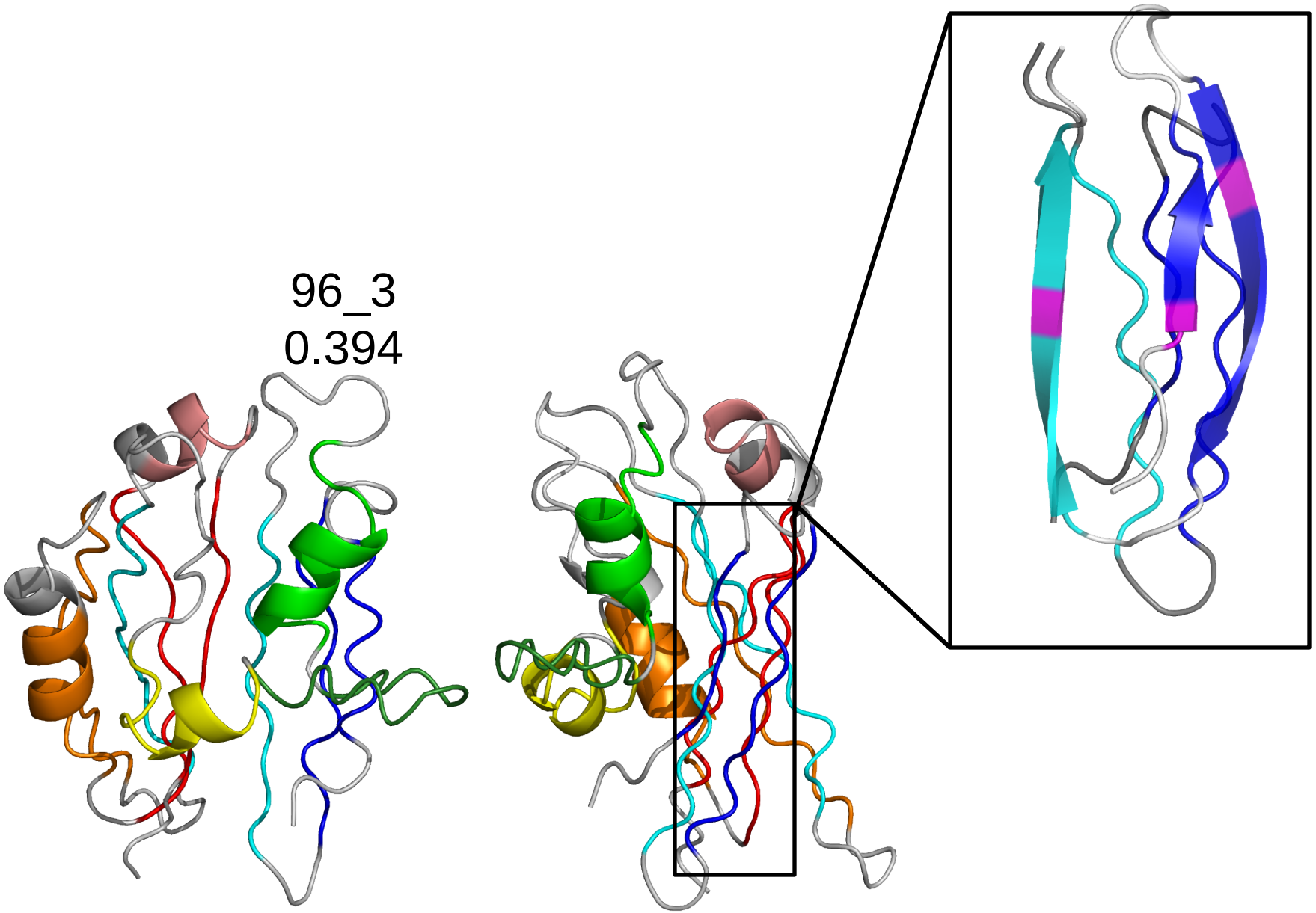
Target 621: Template-based *AND* FM Models



Target 621: Template-based *AND* FM Models



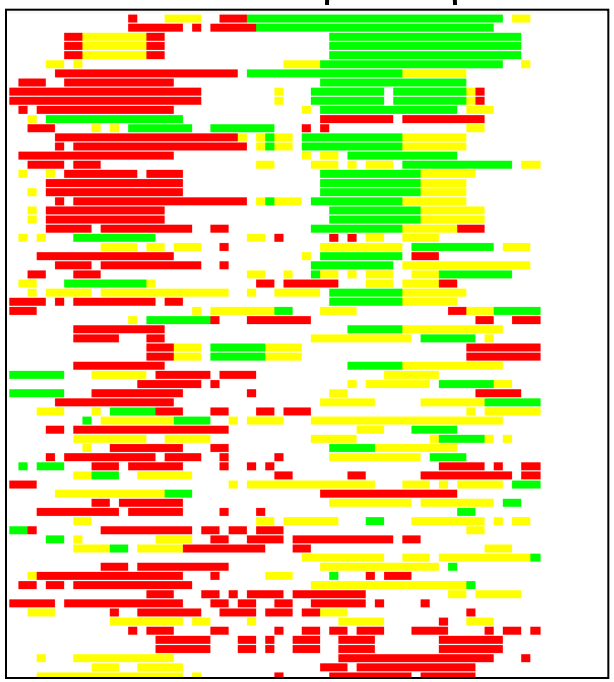
Target 621: Template-based *AND* FM Models



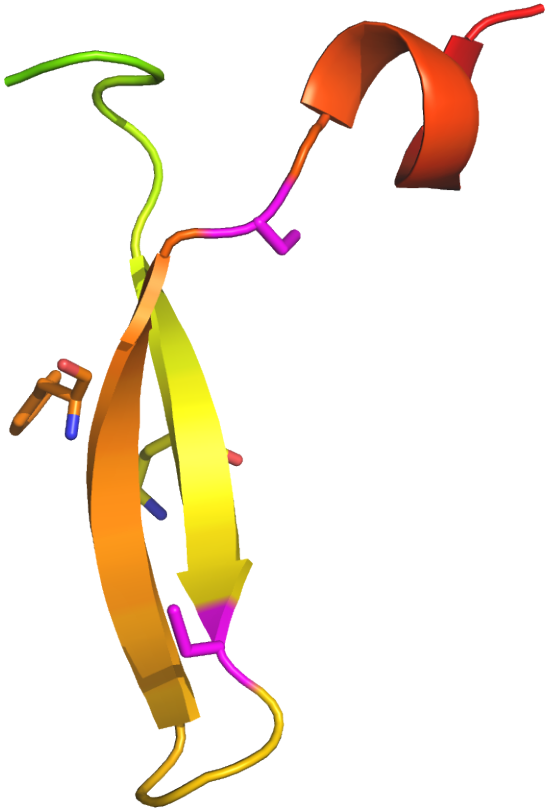
FM Model Assessment: Local Cores

Models Tend to Predict Common Local Cores

Local Core



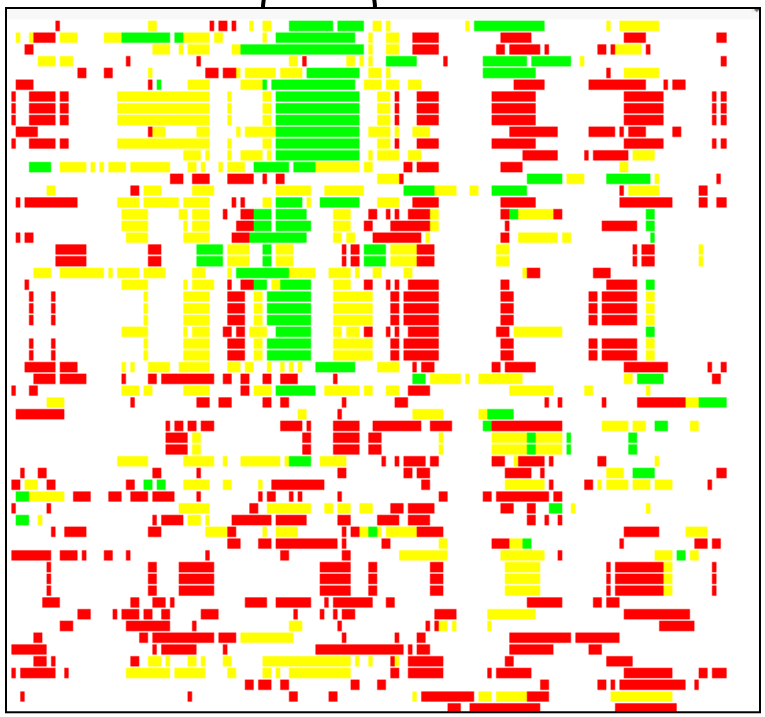
Position Specific Alignment (Prediction Center)



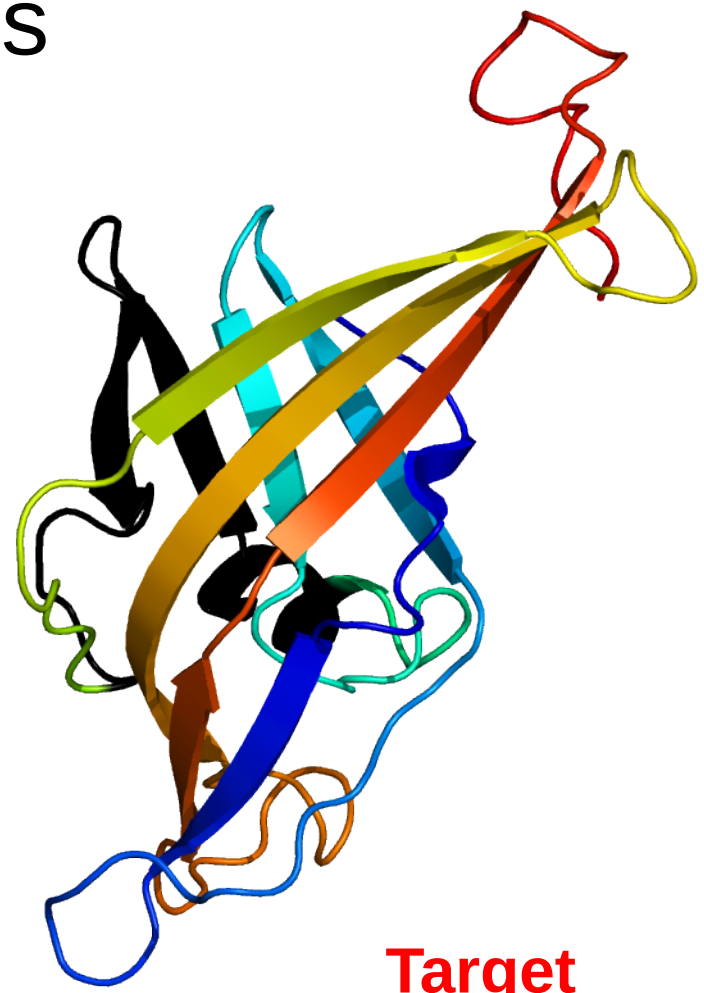
Target 531
Local Core

Models Tend to Predict Common Local Cores

Local Core



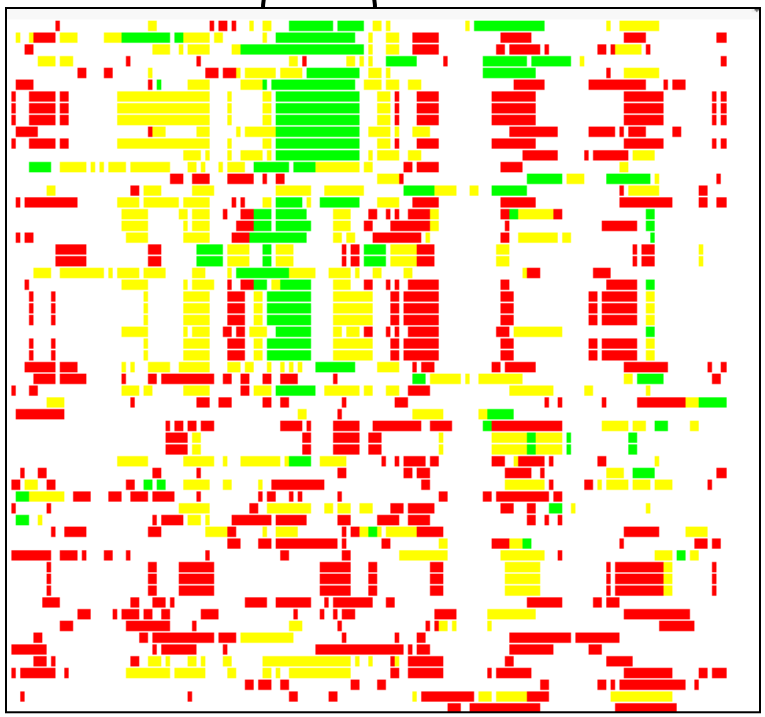
Position Specific Alignment (Prediction Center)



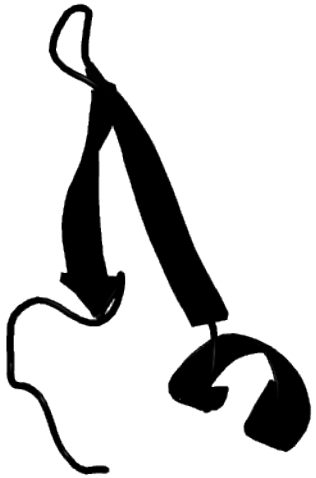
Target 550d2 Local Core

Models Tend to Predict Common Local Cores

Local Core



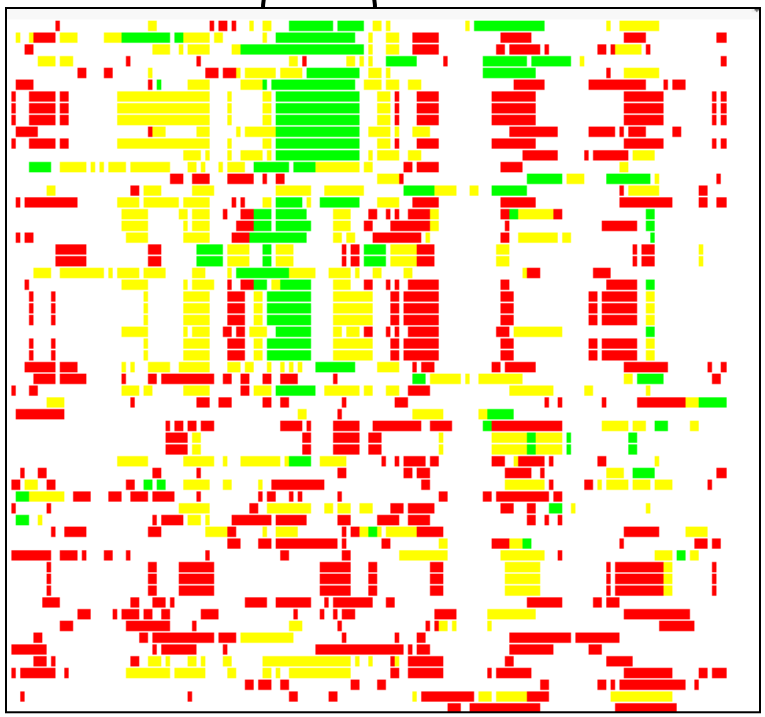
Position Specific Alignment (Prediction Center)



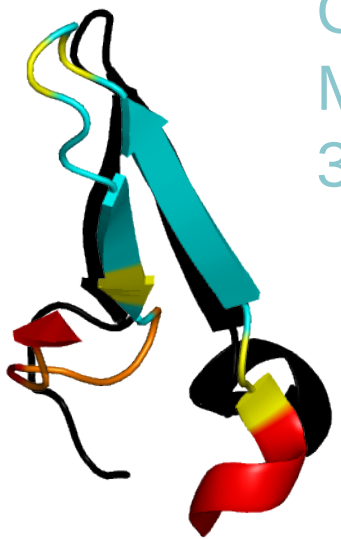
Target 550d2 Local Core

Models Tend to Predict Common Local Cores

Local Core



Position Specific Alignment (Prediction Center)

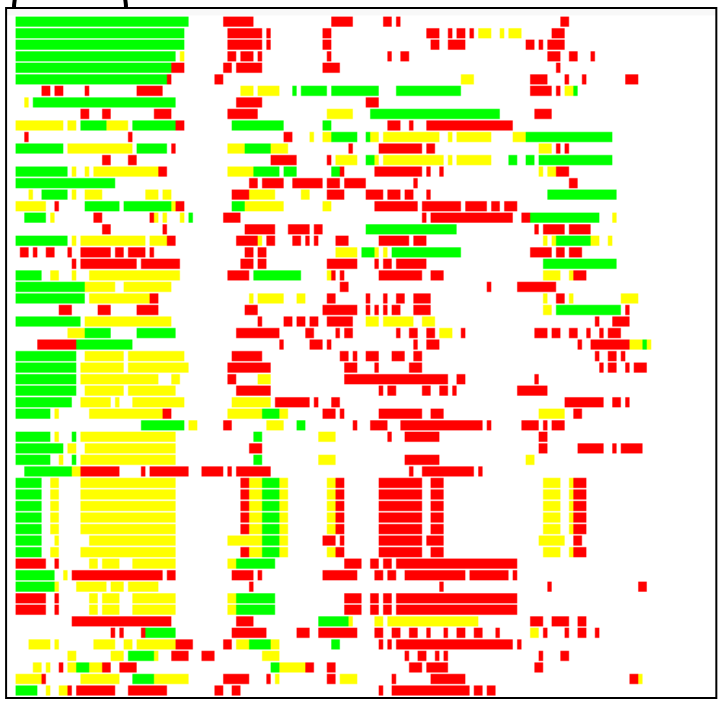


Group Model 386_1

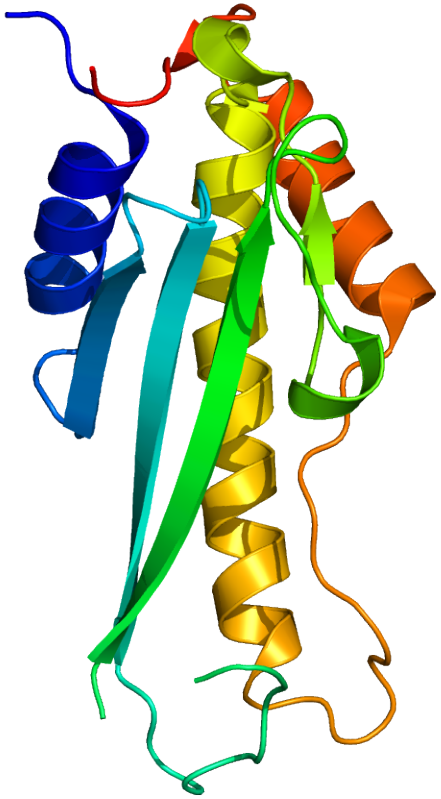
Target 550d2 Local Core

Models Tend to Predict Common Local Cores

Local Core



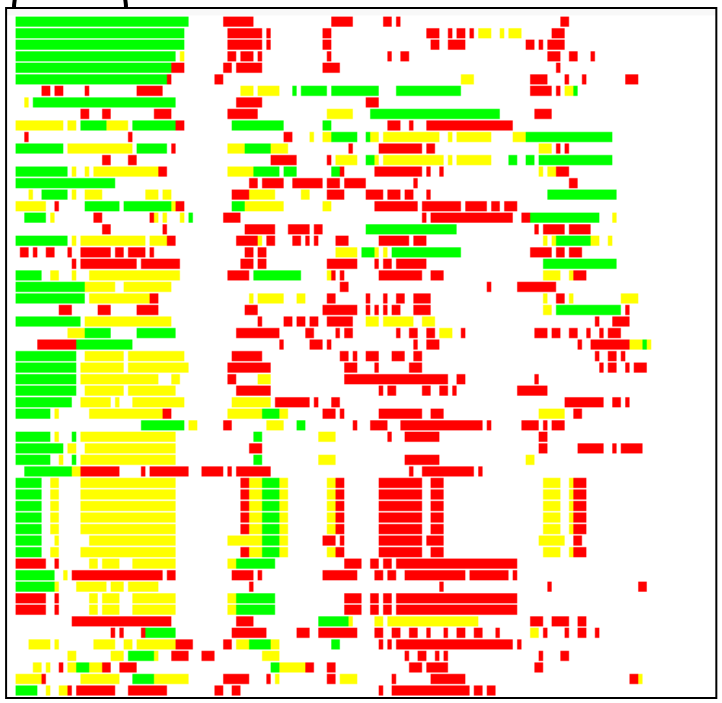
Position Specific Alignment (Prediction Center)



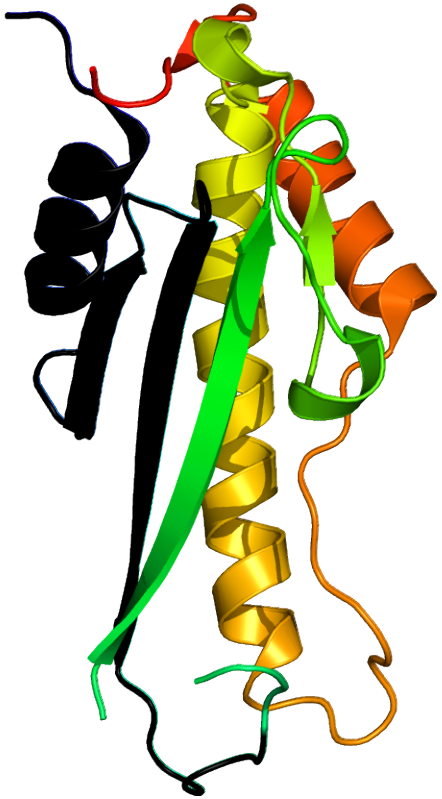
Target 578
Local Core

Models Tend to Predict Common Local Cores

Local Core

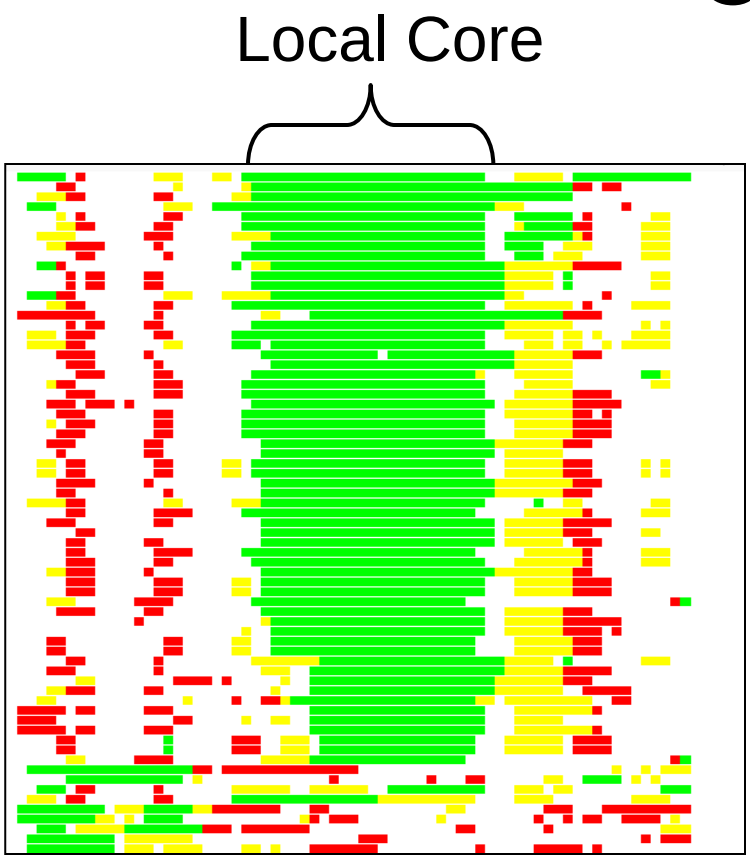


Position Specific Alignment (Prediction Center)

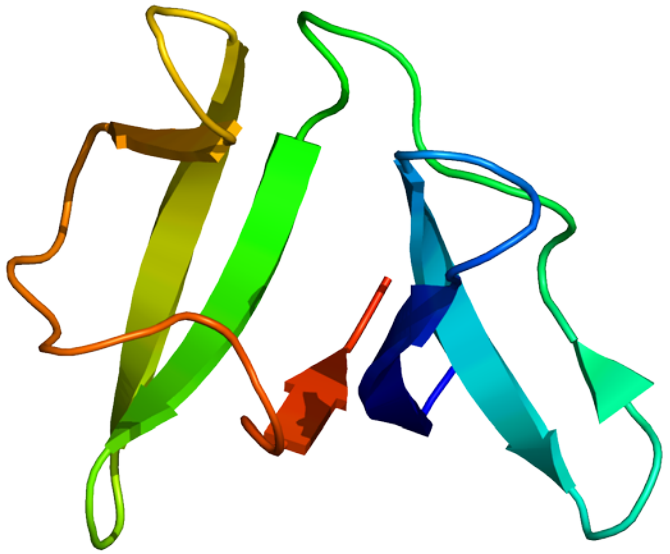


Target 578
Local Core

Models Tend to Predict Common Local Cores

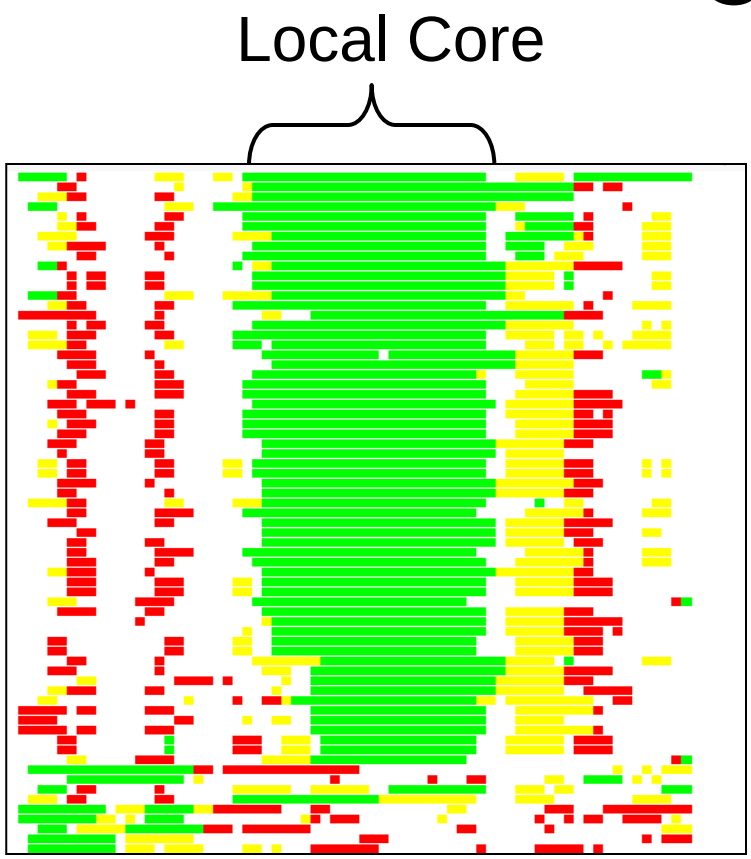


Position Specific Alignment (Prediction Center)

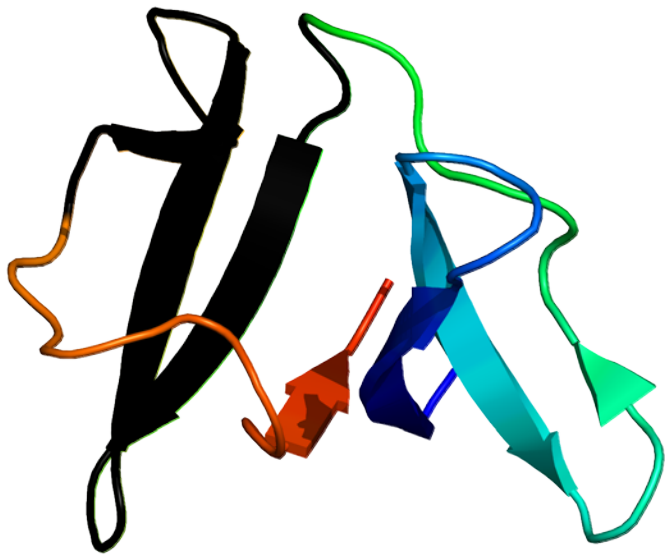


Target 624
Local Core

Models Tend to Predict Common Local Cores



Position Specific Alignment (Prediction Center)



Target 624
Local Core

FM Models Tend to Predict Common Local Cores

Potential reasons for common local cores:

Uninteresting byproduct of superimposing structures

Result of many manual groups picking and refining similar server models

Local cores are easy

Potential Uses for the community?:
Quality assessment: mimic predictions – use server models, enhance with refinements using different energy functions?
Identify and fix cores and use as a building block for the rest of the secondary structure elements/fragments?

We got 2 clean FM results:

1. Servers (380, 428, Zhang) and (321 Rosetta) are tied and statistically distinguished from the rest of the pack.

2. "Manual" groups who performed better were re-scoring server models and refining them - recycling of server models is a "winning" strategy for this FM casp.

FM Model Assessment: roundtable

Yang Zhang
Chen, Keasar
David Baker
Dong Xu
Hongyi Zhou (Jeff Skolnick)

Andrzej Kloczkowski
Jianlin Cheng
Arne Elofsson
Mayuko Takeda-Shitaka
Chopra Gaurav (Mike Levitt)

Free Modeling by Zhang_Server, Quark, Zhang_ab_initio, and Zhang

96, 418, 428

Zhang Lab
Center for Computational Medicine and Bioinformatics,
The University of Michigan

(12/07/2010)

What's new to I-TASSER Pipeline?

1. A new developed tool QUARK for *ab initio* protein folding

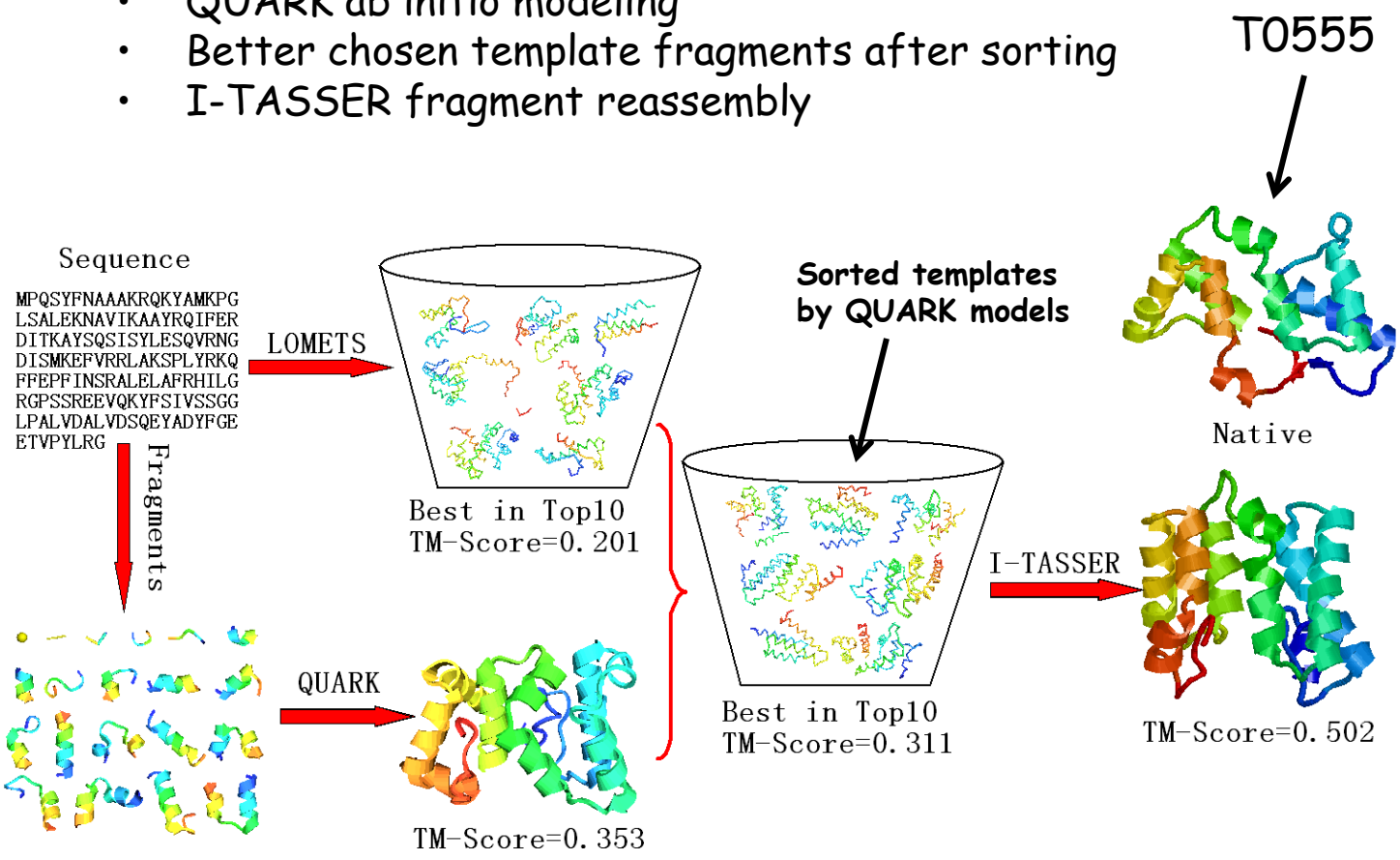
2. Sorting threading templates by QUARK models

3. *Ab initial* contact predictions by SVMSEQ incorporated to I-TASSER simulations

Sorting templates help pick up better fragments

Advantages in *ab initio* folding:

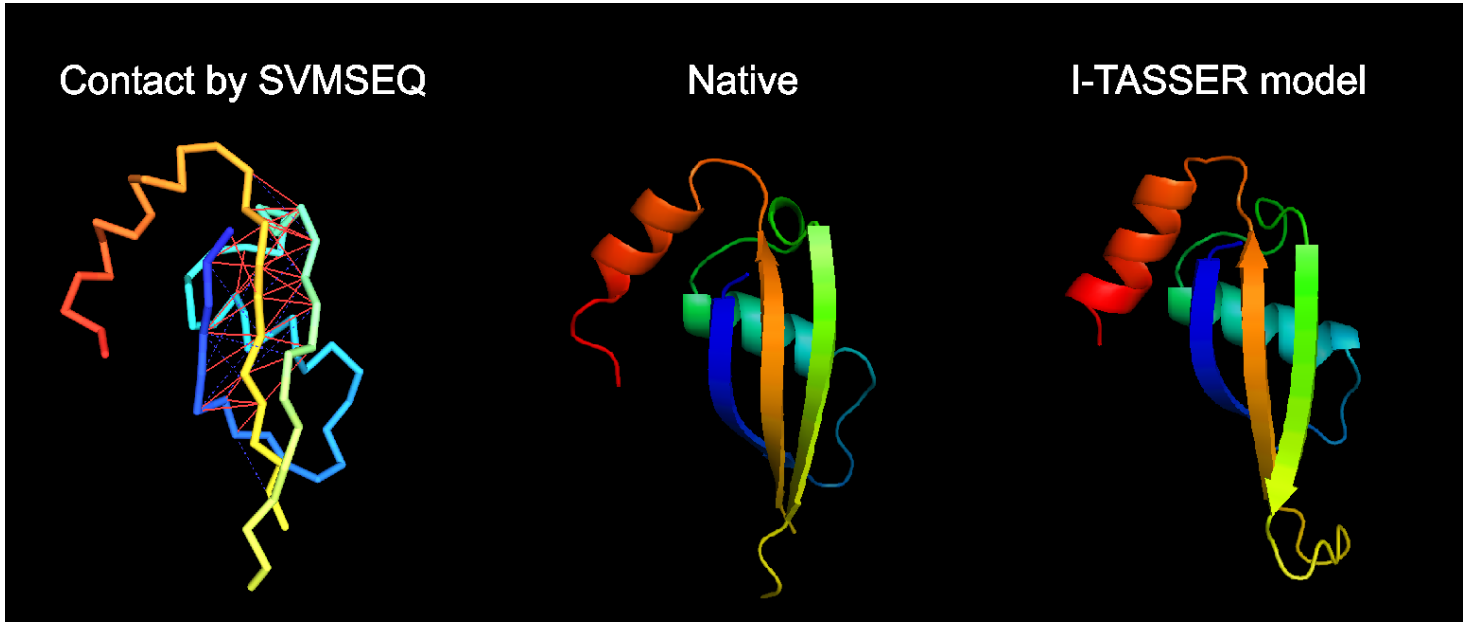
- QUARK ab initio modeling
- Better chosen template fragments after sorting
- I-TASSER fragment reassembly



SVMSEQ contact predictions help free modeling (Modeling of T0604_1 by Zhang-Server)

Nine sets of SVMSEQ contacts used in I-TASSER:

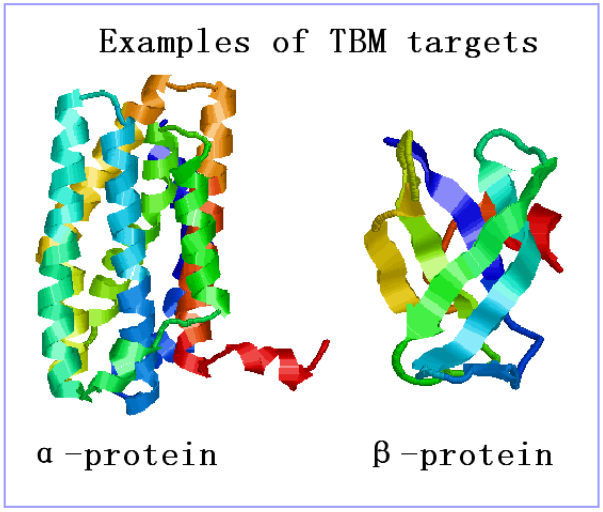
- *Cα-Cα* contacts at 6, 7, 8Å
- *Cβ-Cβ* contacts at 6, 7, 8Å
- Sidechain-Sidechain contacts at 6, 7, 8Å

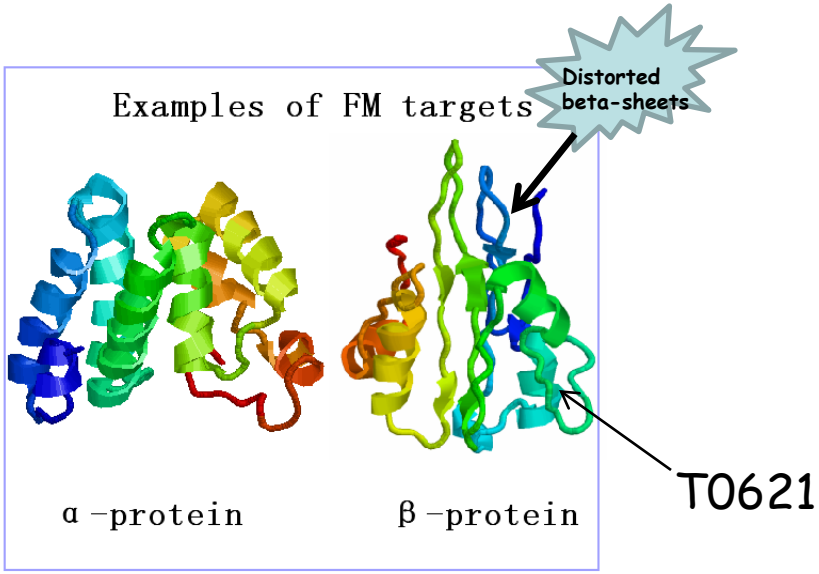


Target name	Target type	TM-score of best template	SVMSEQ contact accuracy (coverage)	TM-score of first model	RMSD of first model
T0604_1	FM	0.204	0.729 (0.6L)	0.691	2.66 Å

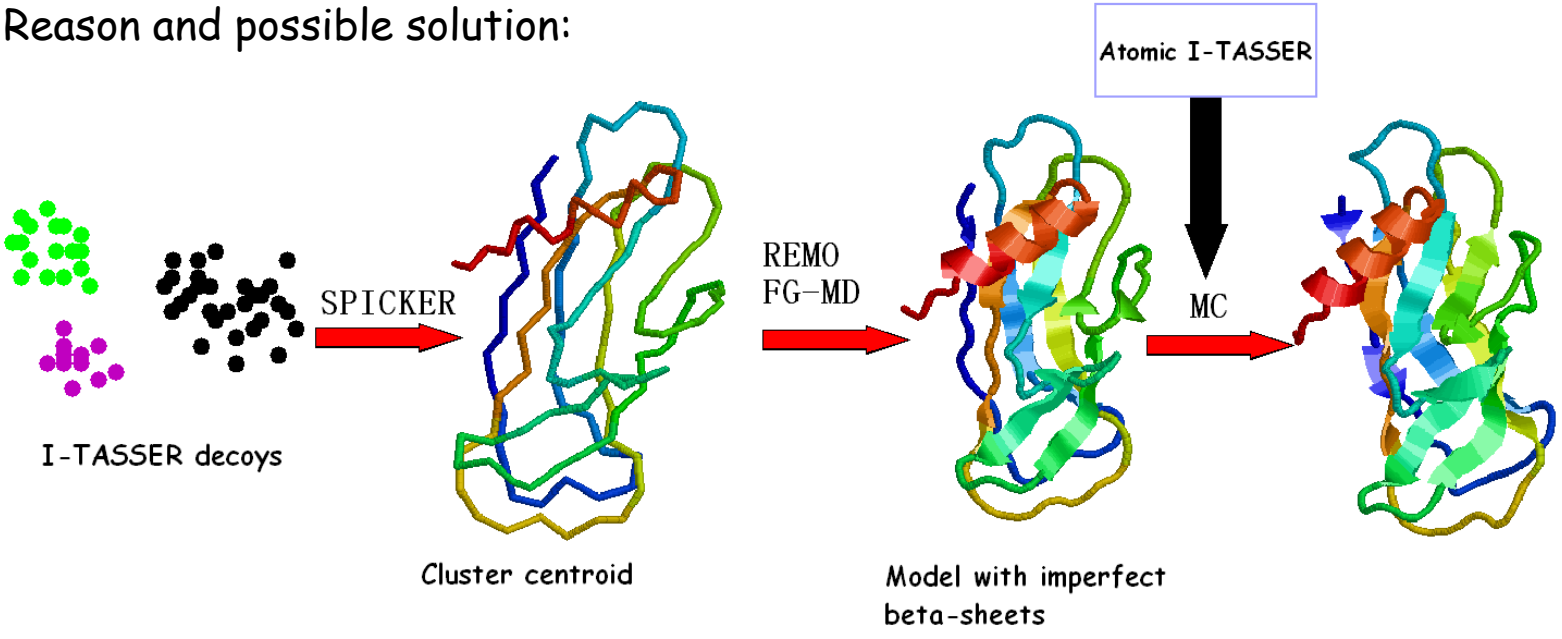
Issues in local geometry of hard β-proteins

- Current status of local geometry



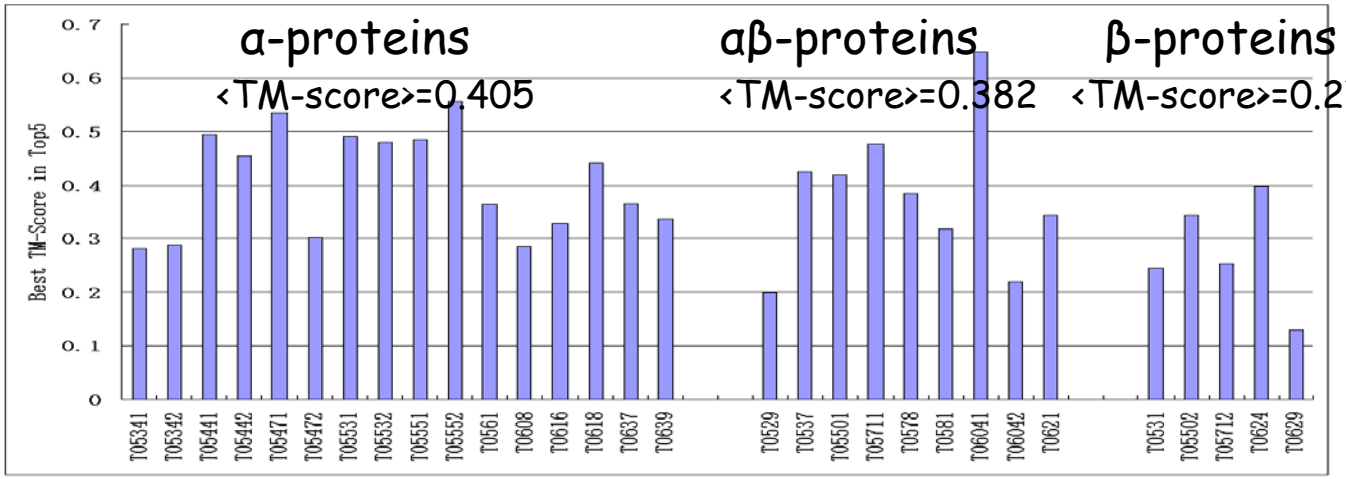


- Reason and possible solution:



Limit in folding β-proteins

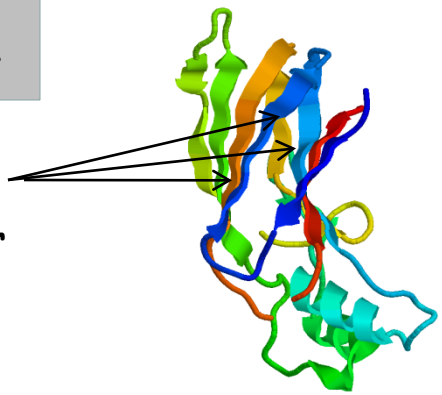
- TM-Score of Zhang-Server models for 30 FM domains:



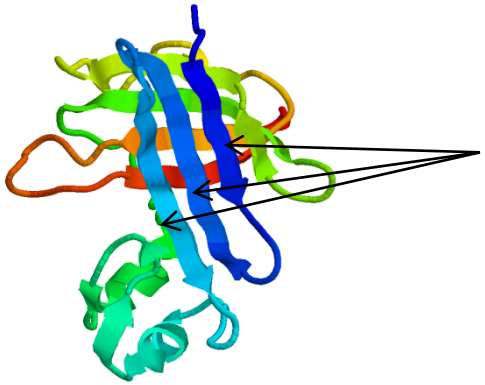
- Inability to generate beta-sheets of long-range contact order

Example fromT0621

Beta-sheets of long-range contact-order



Native



Model1 by Zhang-Ab-Initio

All beta-sheets have short-range hairpins

Summary

What went right?

- QUARK *ab initio* folding generate reasonable α-, αβ-topologies
- Sorting templates helps pick up good fragments for I-TASSER
- SVMSEQ contacts help FM folding

What to do next?

- Refining H-bond network for hard beta-structures (by atomic-ITASSER?)
- Enumerate all beta-scaffolds to fold beta-protein?

Any high-level design principle for use in protein structure prediction?

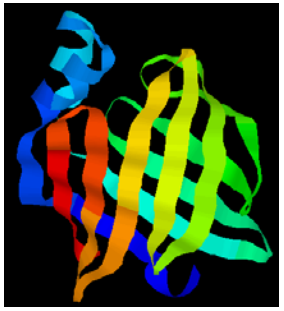
Predictions for FM so far mostly relied on physics (bottom-up):

- Force field
- Energy funnel (minimization)
- Fragments (units with stable energy)

Protein knows (top-down, driving by function and evolution):

- Beta strands come all the way to close a barrel
- Add disulphide bonds when needed
- …

Can we utilize such design principles (currently known or to be mined) for structure prediction?

Artifacts in models

- Model artifacts due to aiming for high GDT score
  - Helices are too long (over-predicting helices and sheets is a safe bet for uncertain boundaries from a gambling strategy point of view), as it has high penalty to lose such secondary structures while it is hard to predict loop structures correctly anyway.
  - Make the structures more compact (e.g. for long loops or tail regions): this is advantageous for GDT-score although it may not be good for RMSD.

- This shows that people optimize GDT (or CASP performance) by artifacts (most likely intentionally since it could be achieved by automatic training especially for those tools with many parameters).

- Is it a good thing to pursue?
  - Maybe: as many users like to see more protein-like models.
  - Maybe not: encourage fine-tuning instead of novel approaches.

Chunk-TASSER & pro-sp3-TASSER for FM modeling in CASP9

Group 457 & 253 from Skolnick Lab

Our servers performed well overall among servers, especially well for T0547_3 & T0547_4. These two are small helical domains. In general, according to our benchmark, chunk-TASSER performs better for helical protein than for beta protein. The reason is because that helical proteins usually have smaller contact orders than beta proteins. Besides these two targets, our method also performed well for T0544 (a pure helical bundles). We also have some very good models for T0555 which are failed to be selected for submission. The common problem in folding of simple topology helical protein (like these two 3 helix bundles) is how to distinguish native topology from mirror image.

Here is how we did for T0547:

Our SP3 alignment detected a large unaligned gap 356-450 (differs from real domain boundary of T0547_3: 343-421). We modeled 356-450 by chunk-TASSER and rest of the target by normal TASSER because it was decided as an easy target. In T0547_3 modeling, chunk-TASSER takes as input from ab initio folded structures by fragment assembly and selected by comparison to top threading templates and fragments. These comparisons utilized the weak evolution information from templates and fragments and were able to distinguish native-like from mirror images. We did not model T0547_4 separately and , surprisingly, it was among the best modeled structures by servers. We have no clue about that.

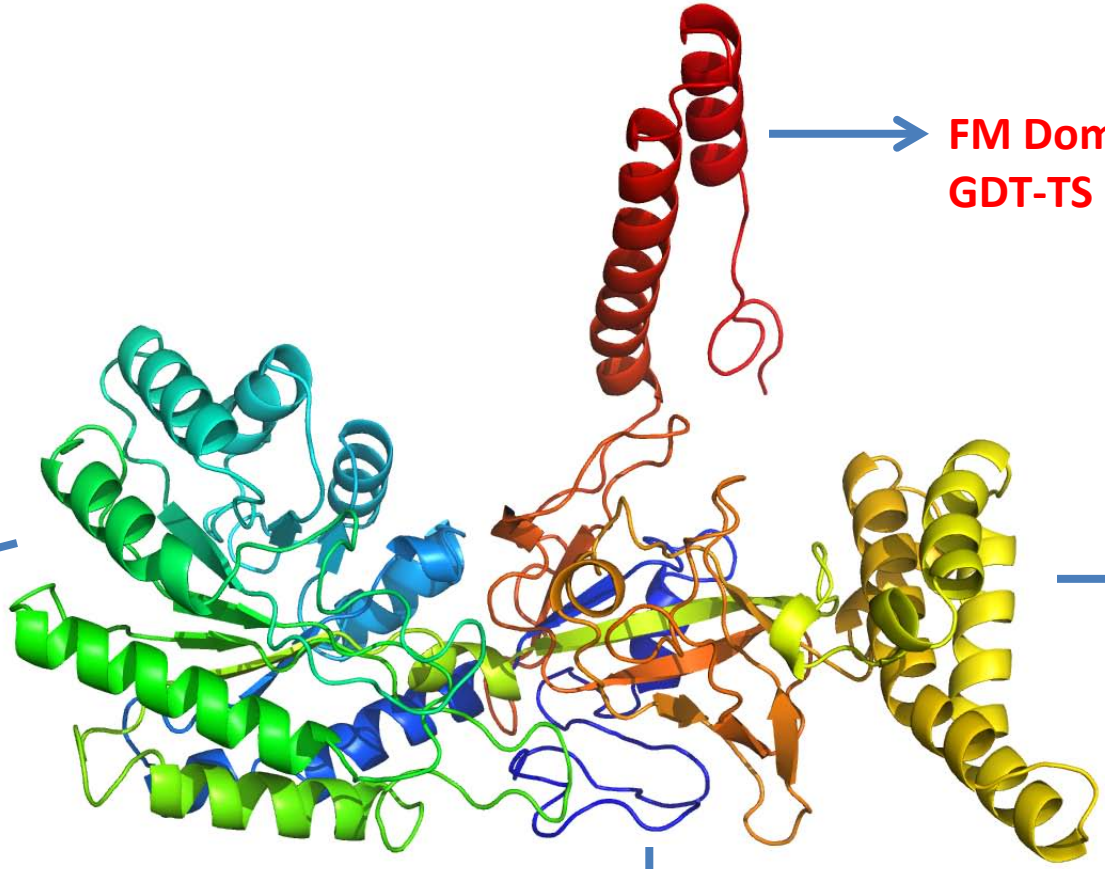
Among the failures of our methods, T0571_1 and T0571_2 are pronounced compared to some other servers. Our failure is purely due to inability to recognize the relative good templates like 1et9A that most of the top performed servers for this target had used. I think that servers did better for this target are merely due to better template identification. Nobody can fold it by ab initio method.

Here is the list of reason for other failures:

Target	Best template TMscore	Best of top 5 SP3 template	Chunk-TASSER TMscore	Reason for failure
T0624	2qyza 0.57	2bh0a 0.45	0.36	template identification & alignment
T0621	1j5qa 0.55	2j1kc 0.40	0.20	template identification & alignment
T0608_1	153l_ 0.59	2hsia 0.38	0.26	domain boundary, signal peptide ?, template identification & alignment
T0604_3	2uv8a 0.43	1kssa 0.33	0.20	alignment
T0604_1	3kg4a 0.61	1qo8a 0.39	0.46	template identification

Target	Best template TMscore	Best of top 5 SP3 template	Chunk-TASSER TMscore	Reason for failure
T0581	3kxwa 0.55	2f6la 0.36	0.26	template identification & alignment
T0571_2	1p4ta 0.66	2mdah 0.36	0.24	template identification & alignment
T0561	1f0la 0.51	1ui5a 0.35	0.34	template identification
T0553_1	3leta 0.66	1y1xa 0.53	0.39	domain parse , temp identification & alignment
T0553_2	1lxya 0.55	1hqva 0.54	0.36	domain parse, alignment
T0550_2	1uf6a 0.54	1nr0a 0.36	0.23	template identification & alignment
T0544_1	3hlza 0.58	1uhna 0.42	0.55	
T0544_2	1odba 0.59	1uhna 0.47	0.26	domain parse, template identification & alignment,
T0534_1	1h2rl 0.55	1st6a 0.43	0.27	domain parse, template identification & alignment
T0534_2	3caxa 0.67	1st6a 0.57	0.22	domain parse, alignment

T0547 – A MULTICOM-REFINE Prediction



FM Domain 4
GDT-TS = 0.61

TBM Domain 2
(Insertion)
GDT-TS = 0.74

FM Domain 3
(Insertion)
GDT-TS = 0.58

TBM Domain 1 – Three Discontinuous Fragments
GDT-TS = 0.76

Jianlin Jack Cheng, University of Missouri, Columbia

Region / Domain Decomposition and Classification from Alignments

Template: 1TWIA

```
-------MLGNDTVEIK-DGRFFI---DGYDA-IELAEK---------FGTPLYVMSEEQIKINYNRYI
EAFKRWEEETG--KEFIVAYAYKANANLAITRLLAKLGC----GADVVSGGELYIAKLSNVPSK----K
IVFNGNC-KTKEEIIMGIE---ANIRA-FNVDSISELILINETAKE-LGETANVAFRINPNVNPKTHPK
ISTGLKKNKFGLDVESGIAMKAIKMALE--MEYV-NVVGVHCHIGSQLTDISPFIEETRKVMDFVVELK
E-----E-GI-EIEDVNLGGGLGIPYYKDKQI----PTQKDLADAIINTMLKYKD--KVEMPNLILEPG
RSLVATAGYLLGKVHHIKETPVT-----------------------------------------------
-----------------------------------------KWVMIDAGMNDMMRP-AMYE
AY-HHIINCK----VKN----EKEVVSIAGGLCESSDVFGRDR-------ELD-KVEVGD---VLAIFD
VGAYGISMAN-NYNARGRPRMVLTS--KKG-V--FLIRERETYADLIAK--------------------
----------------------------*
```

Query: T0547

Domain 3

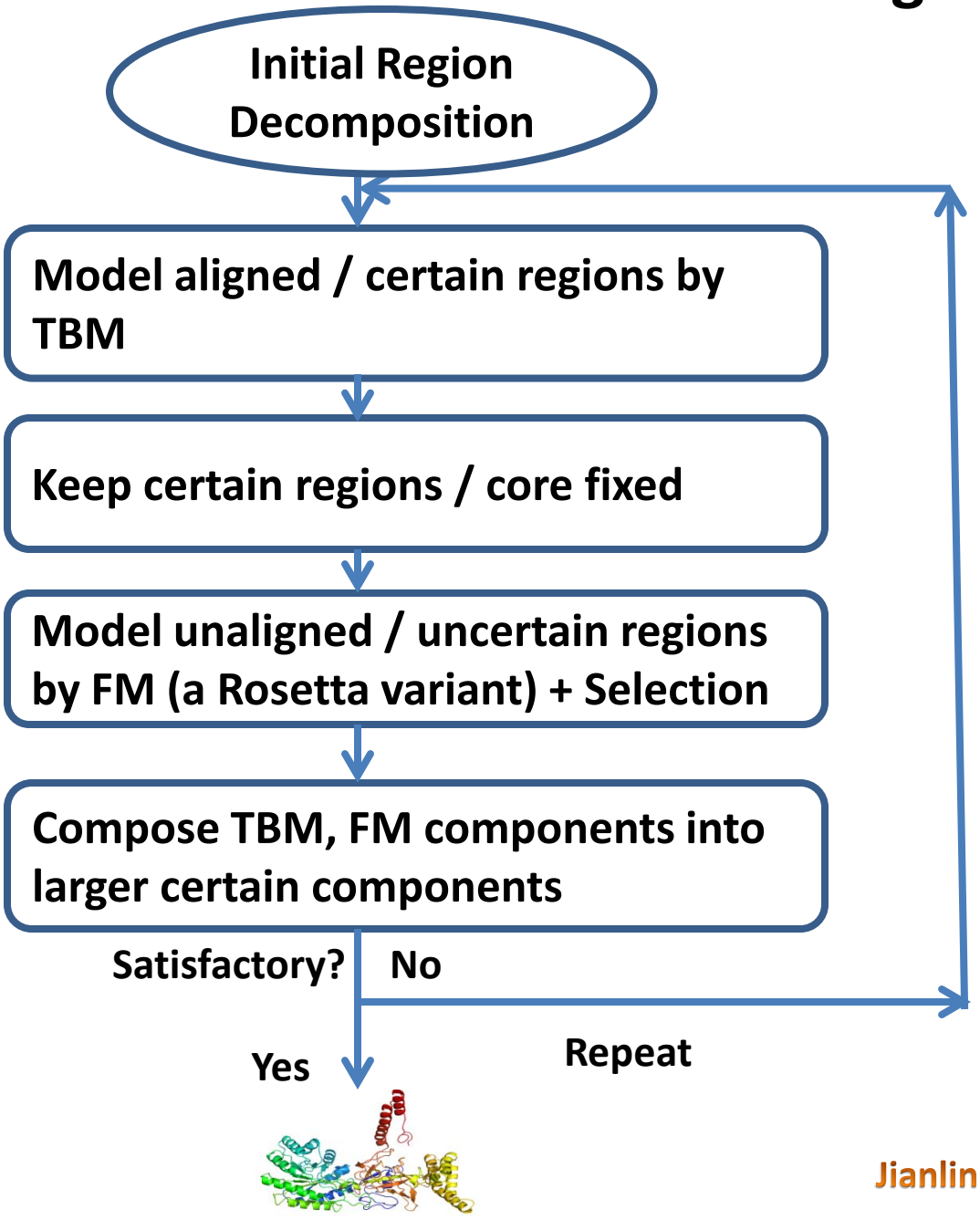
Domain 4

```
MMDYGIDIWGNENFIIK-NGKVCINYEKKPAI-IDIVKELR----DDGYKGPLLLRFPHLIQKQIENIY
GNFNKARKEFGYKGGFNAVYPLKVNQYPGFVKNLVKLGKDYNYGLEAGSKAELLLAMAYNNEGA----P
ITVNG-F-KDRELINIGFIAAEMGHNITLTIEGLNELEAIIDIAKERFKPKPNIGLRVRLHSAGVGI-W
AKSGGINSKFGLTSTE--LIEAVNLLKE--NKLLEQFTMIHFHLGSQITEIHPLKKALNEAGNIYTELR
K-----M-GAKNLKAINLGGGLAVEYSQFKNEKSRNYTLREYANDVVFILKNIAEQKKDLEPDIFIESG
RFVAANHAVLIAPVLELFSQEYAENKLILKKQNPKLID-ELYDLYKSI--KPSNALEYLHDSIDHLESI
LTLFDLGYVDLQDRSNAEILTHLITKKAILLLGDKQNPADLLAIQDEVQERYLVNFSLFQSMPDFWGLE
QN-FPIMPLD----RLD--EEPTRSASIWDITCDSDGEISYSKD---KPLFLH-DVDVEKENYFLGFFL
VGAYQEVLGM-KHNLFTHPTEAIISINEKG-YEVEGIIEAQSILDTLEDLDYDIHAIMDILNERISNSK
LVNDKQKKHILGELYLFLNDNGYLKSIGV*
```

Integration: 70% TMB + 30% FM

Jianlin Jack Cheng, University of Missouri, Columbia

Recursive Protein Modeling – Integrate TBM and FM

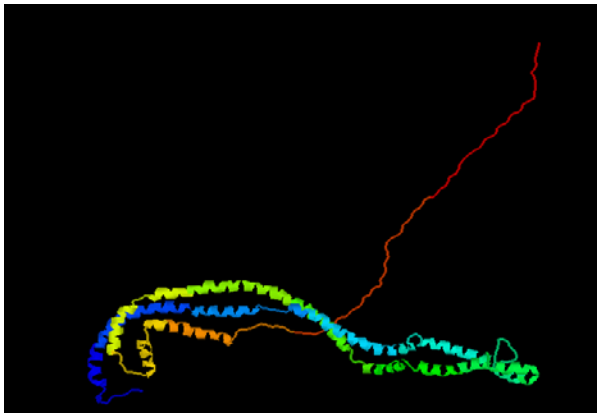


- Several Good Cases in CASP9
- Computational Mimic of Hierarchical Protein Folding Cascade
- Divide and Conquer
- Computationally Efficient

Jianlin Jack Cheng, University of Missouri, Columbia

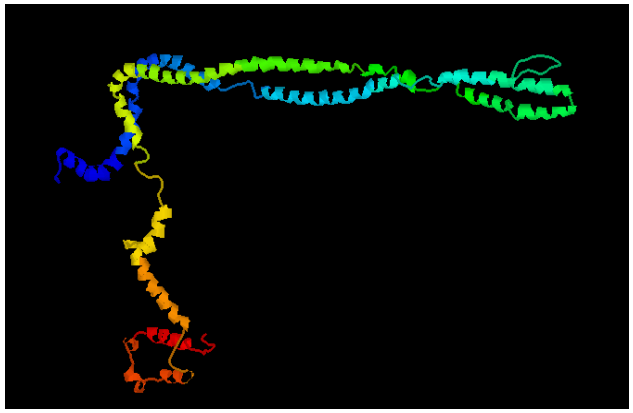
T0534 – An Unsuccessful Example

Step 1: TMB Modeling



Experimental Structure

Step 2: TMB + FM Modeling



Domain 1, GDT-TS = 0.15
Domain 2, GDT-TS = 0.16

Jianlin Jack Cheng, University of Missouri, Columbia

splicer in CASP9

single-model assessment server (non-consensus)

Non-linear combination of energy functions

- Physics-based energy

  hydrophobicity, hydrogen bonds, ….

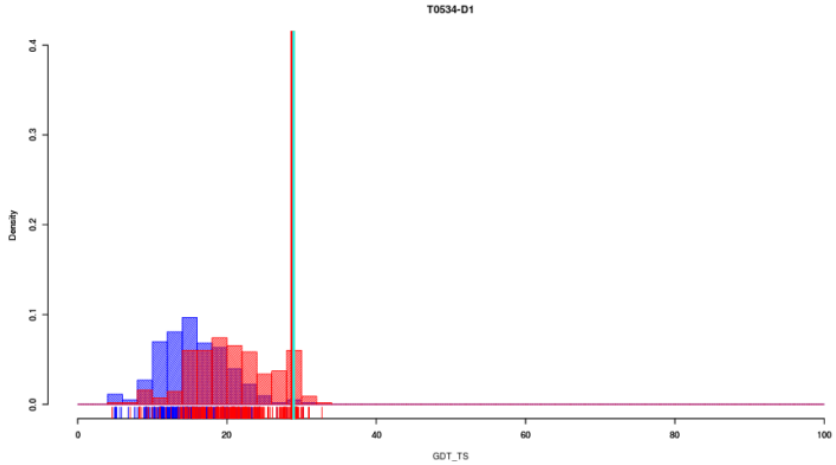
- Statistics-based energy

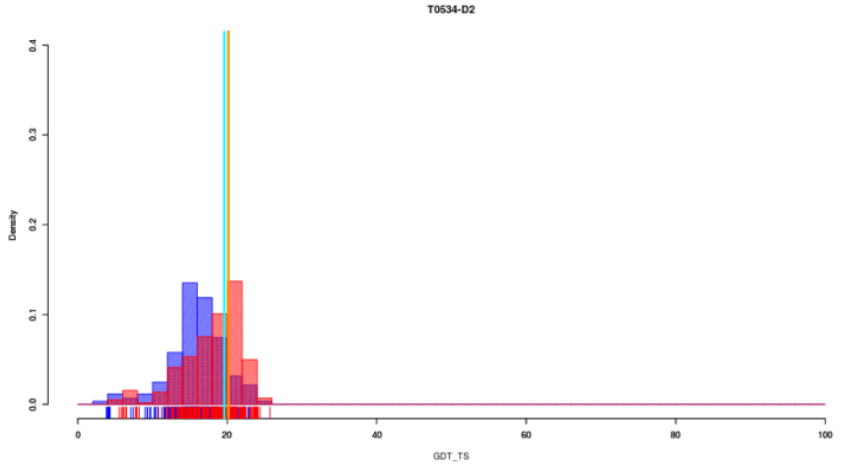
  secondary structure score (PSI-PRED)

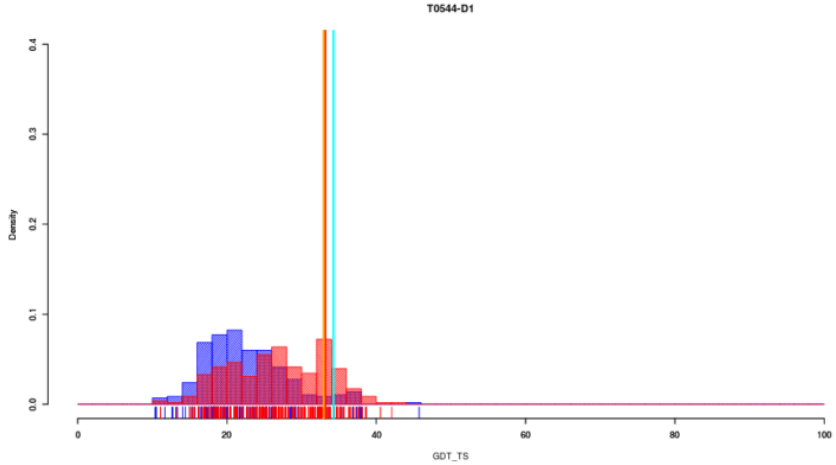
  model quality score (CIRCLE)

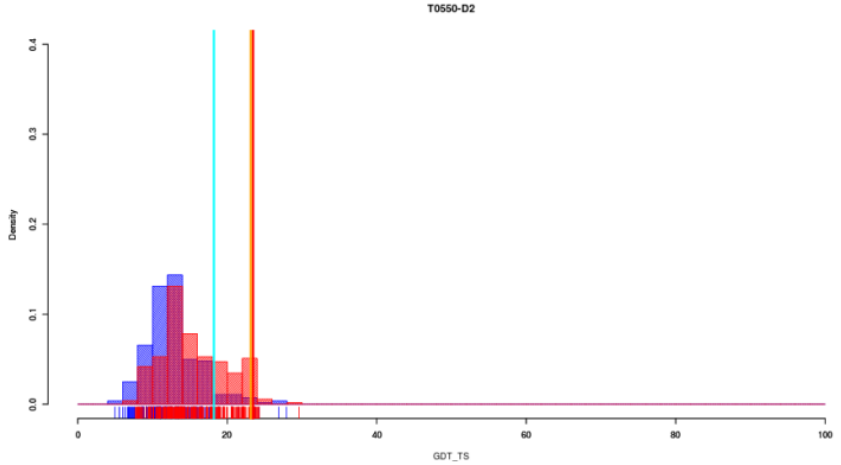
In all 3 methods (fams-ace3, fams-sec and splicer), server models are refined to be removed bad steric constants between atoms (FAMS).

GDT_TS of models of fams-ace3, fams-sec and splicer

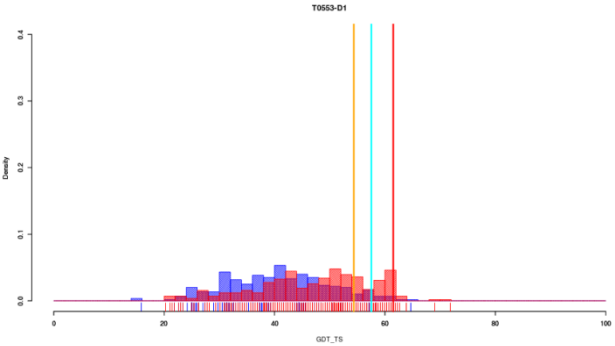


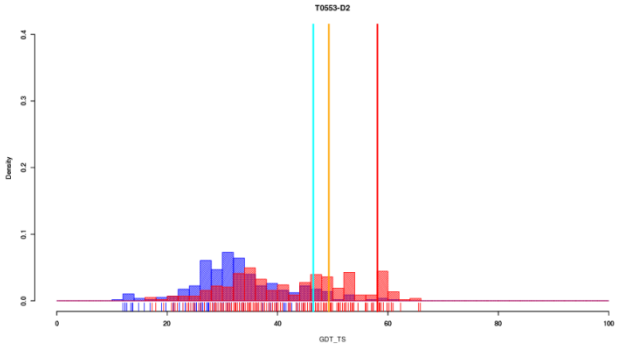






Orange: fams-ace3, red: fams-sec, cyan: splicer


T0553-D1
Density
GDT_TS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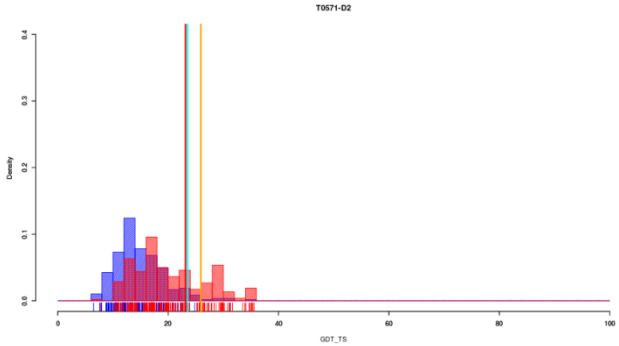
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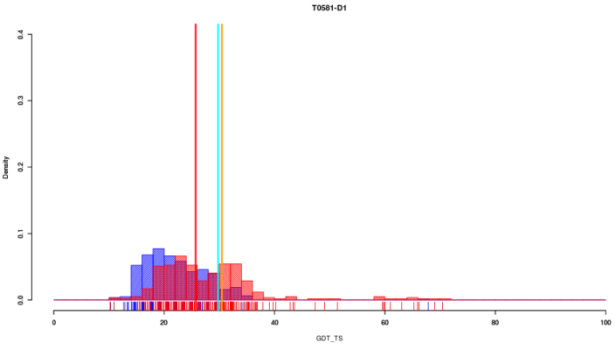
GDT_TS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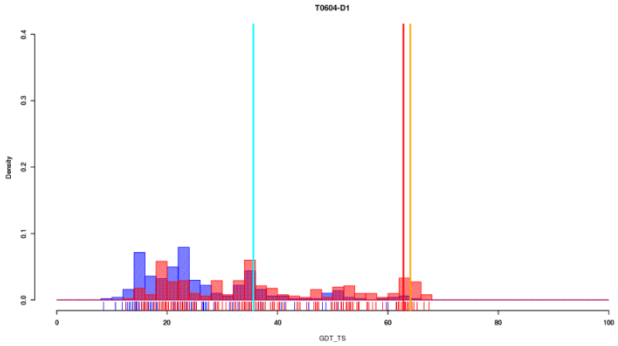
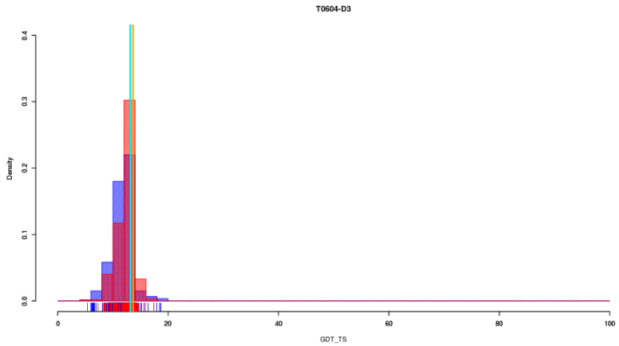
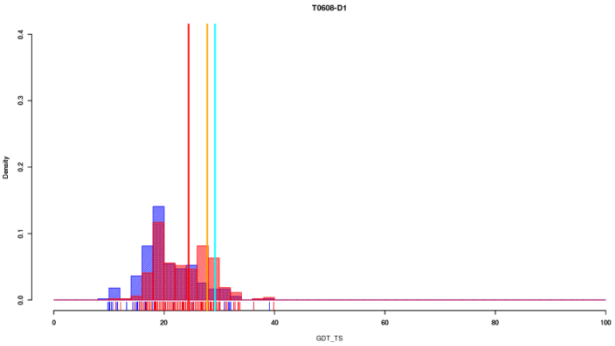
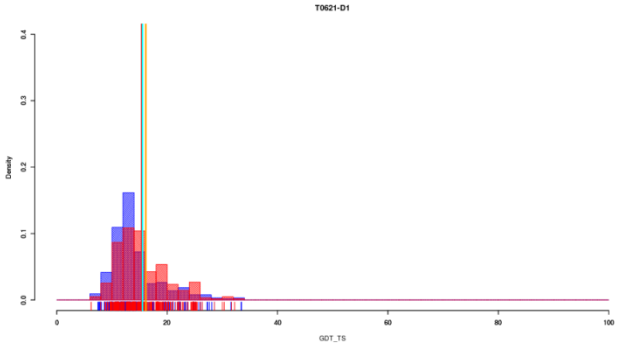
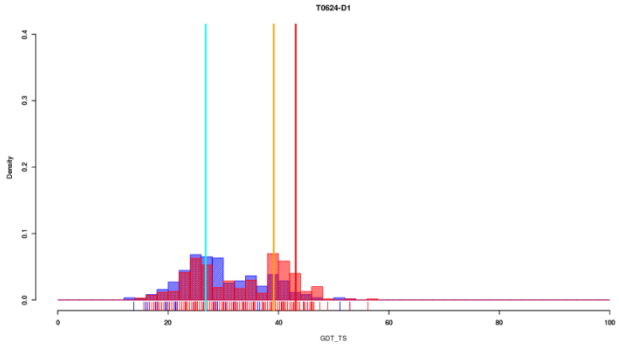
Density
GDT_TS


T0604-D1
Density
GDT_TS


T0604-D3
Density
GDT_TS


T0608-D1
Density
GDT_TS


T0621-D1
Density
GDT_TS


T0624-D1
Density
GDT_TS

Good point

- 3 meta-servers are in the top group in FM

mainly because they did not make serious failures.

Problems

- 3 meta-servers could not select the best model in each target.
  There is much room for improvement.

- As is often said, meta-servers do not work when servers don’t provide any good models.

Single MQAP do help in FM

#	Group Name	Z GDT_TS	SUM GDT_TS	Domains
1	***elofsson***	***27,134***	***729,50***	***23***
2	Mufold	26,460	713,16	22
3	Zhang	26,014	736,29	23
4	FAMSSEC	24,935	723,72	23
5	MULTICOM	24,771	705,19	23
6	fams-ace3	24,679	736,98	23
7	Seok-meta	23,882	734,66	23
8	QUARK	23,070	714,77	23
9	Chicken_George	22,624	696,37	23
10	Zhang_Ab_Initio	21,913	693,21	23
11	TMD3D	21,601	683,51	23
12	***ProQ2_QA***	***21,321***	***672,37***	***23***
13	RecombineIt	21,286	682,10	22
14	McGuffin	21,169	689,08	23
15	prmls	20,667	668,72	23
16	Zhang-Server	20,584	701,70	23
17	TASSER	20,194	687,83	23
18	United3D	20,168	669,94	23
19	LEEcon	20,139	681,30	22
20	KnowMIN	20,053	670,50	23
21	CNIO	19,616	625,39	20
22	keasar	19,401	682,70	23
23	Splicer	19,109	652,25	23
24	chunk-TASSER	18,625	697,77	23
25	BAKER	18,543	693,89	23
26	fams-multi	18,289	679,36	23
27	GeneSilico	18,031	672,68	23
28	***Pcons_QA***	***17,153***	***646,32***	***23***

0.8Pcons+0.2ProQ2

Single MQAP

Standard Consensus

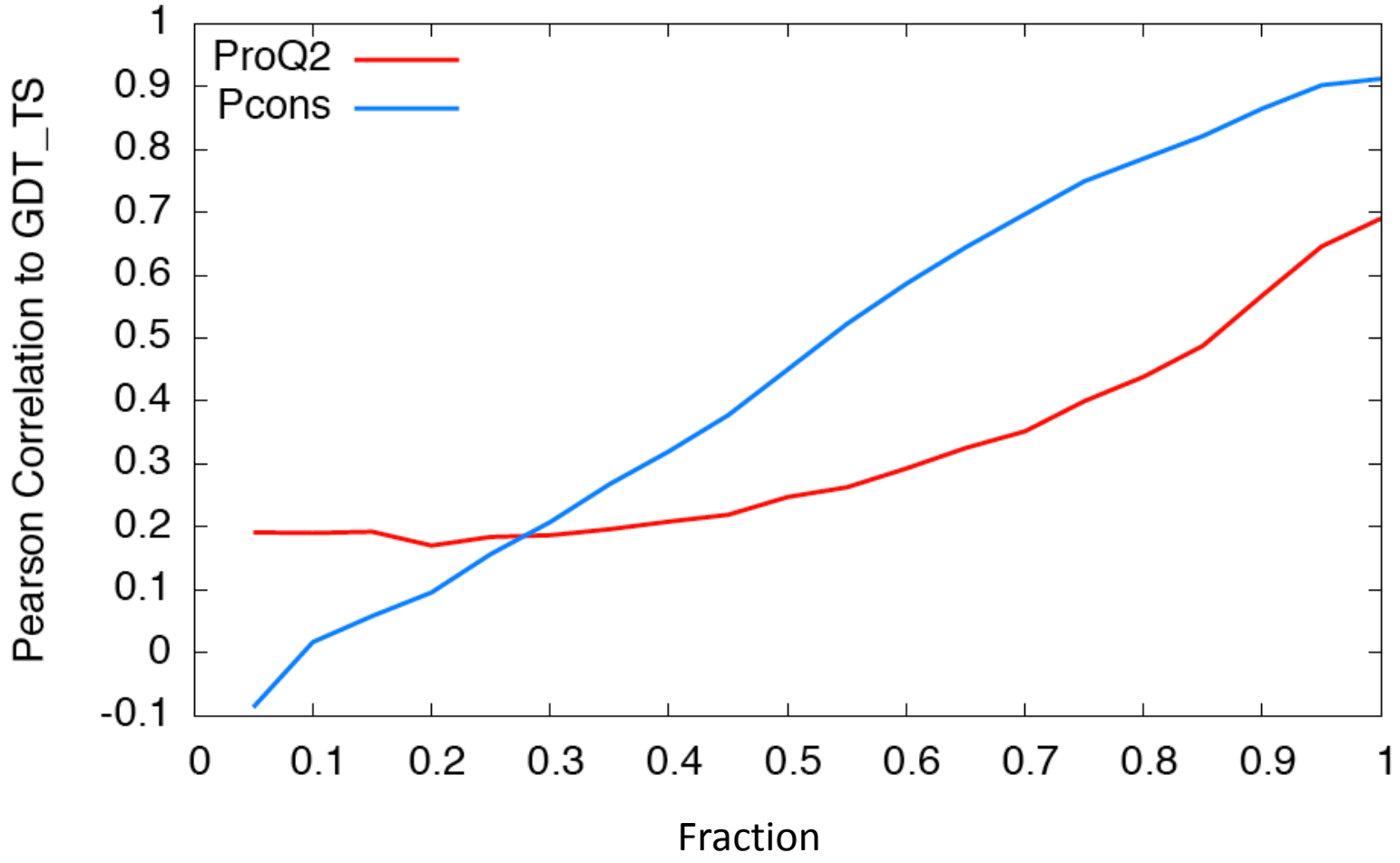
Single MQAP about the same performance as consensus for ALL targets

#	Group Name	Z GDT_TS	SUM GDT_TS	Domains
1	Zhang	77,550	4349,3	77
2	Mufold	77,306	4324,1	76
3	***elofsson***	**76,872**	**4331,5**	**78**
4	MULTICOM	73,535	4294,6	78
5	Seok-meta	72,329	4225,6	76
6	FAMSSEC	72,209	4251,9	78
7	United3D	71,306	4289,9	78
8	McGuffin	70,483	4310,3	78
9	RecombineIt	70,327	4243,8	76
10	fams-ace3	69,386	4246,5	78
11	Chicken_George	68,183	4187,6	77
12	prmls	66,937	4180,2	77
13	QUARK	66,919	4213,2	78
14	fams-multi	66,343	4204,8	78
15	LEEcon	65,346	4200,2	76
16	Zhang-Server	65,198	4229,9	78
17	Sternberg	63,319	4157,8	77
18	***ProQ2_QA***	**62,988**	**4086,9**	**78**
19	***Pcons_QA***	**62,628**	**4103,7**	**78**

Model Origin

Method	ProQ2	Pcons	Pcomb [elofsson]
QUARK	10 43,5 %	4 17,4 %	7 30,4 %
Zhang-Server	5 21,7 %	7 30,4 %	9 39,2 %
Other <=2	8 34,8 %	12 52,2 %	7 30,4 %
Total	23	23	23

There is no correlation of any energy function among the topmodels. Correlation of two MQAPs for the best X% predictions for each target drops significantly when all models are not included.



1. signal peptides, low comlexity and artificial tags need removal;

2. ugly models (=non-protein) - necessity? sloppiness? "cheating?"

3. wrong templates. there shouldn't really be any templates for a target, but templates are picked and used, but they, of course, are wrong. How to avoid the problem? Is it that general template picking should be improved, or this is a special problem to reject possibly bad templates in favor of ab initio algorithms?

4. domain parsing from sequence - predictors don't consider domains inserted into other domains, and generally, if several domains are without clear templates, domain parsing does not work.

5. Picking from server models - are they rotten cherries? Almost all successful groups threaded on server models as templates. this method didn't work where servers don't provide any good models.

6. structures with more local contacts are modeled better.

7. structures with more common topology (even when templates are not findable) are modeled better. why? some "memory" in potentials? fragments?

8. methods too generic? not looking at specifics? e.g. beta strands come all the way around almost closing the barrel, but predictors don't close it. can they guess that they should? "common sense" in computer programs is lacking.

9. helices are too long. N-terminus is usually on the mark, but C-terminus extended. this results in loops being too short and angles between helices too acute.

10. strands too short. ends of strands are more diffuse, without H-zipping. This results in distorted sheets.

11. packing of longer helices is usually well modeled (coiled-coil?) but angles formed by shorted helices are usually off. should shorter helices be docked better?

12. structure termini are packed worse. why? is it because they are intrinsically more flexible, or because errors in the rest of the model accumulate and do not allow accurate docking of the terminal elements.

13. for small proteins with disulphide bonds some attempt should be made to link the cysteines, this should result in better models.

General assessment of the (sad) situation:

"A part of this problem is that it has not been a lot of progress during the last few years and that the progress that appeared is to a large degree due to
tuning. This is not very exiting.

"I believe we are stuck in a very deep local minimum."

"the ideas that resulted in rapid progress some ten years ago have exhausted their potential."

"The present dead-lock situation in CASP comes from the fact that almost all participants apply the same methods, there are no innovators".

"In most cases we can either do modeling with psiblast or not at all".

Collaboration vs. competition:

"CASP hasn't particularly encouraged win-win collaboration and code/tool sharing".

"most researchers like to keep an edge in CASP predictions by not releasing their tools or releasing only web servers/outdated tools".

really good scientists are infinitely generous, they are so rich that they are not afraid of someone stealing from them - there is always more there where it came from.

"we could benefit from a set of public interfaces".

"The less impossible scenario is to have one open-source platform for the whole community, like SBML or Cytoscape, where developers in the field contribute to it without any reservation."

"get these top predictors to work as a group to solve these tough problems rather than perfecting one method of their own".

Do we need to understand folding to predict structures

"The powerful idea of fragment assembly (probably the strongest one in the last twenty years) has emerged from folding theory. We may need further theoretical input for the next breakthrough".

"Our understanding for protein folding as a scientific problem had little (or probably no) progress since the folding funnel hypothesis.

"A further improvement in protein structure prediction requires the solution of fundamental problems of protein folding".

"CASP conferences should give more exposure to researchers who try to address fundamental problems in protein folding, protein packing and protein dynamics".

How to "win" casp?

"the best servers just performed a grain better on each target".

inching towards success by avoiding failure. How wise is it?

is your rank higher because you make good predictions, or because you are better at avoiding failures?

General departures from current standards, odds and ends:

"a better approach might be the use of multibody potentials".

"I think we should not rely too much on the PDB for ab-initio".

algorithms vs. physics: would advanced computer science help?

"how to replace almost clueless random sampling of fragments with a more information-guided sampling".

Difficult structures- template or ab initio? Integration of TBM with FM, or separation?

"identify more informative features that can distinguish a good model".

"why Zhang is so good. Is he the best template picker, the best aligner, the master of pipelining, or all of them?"