

HIGH PERFORMANCE RESEARCH COMPUTING

Introduction to AlphaFold for 3D Protein Structure Prediction on Grace



High Performance
Research Computing
DIVISION OF RESEARCH

Fall 2022

AlphaFold for 3D Protein Structure Prediction on Grace

- Resources and Limitations
- Database Files
- Running AlphaFold
 - Google Colab
 - ChimeraX + Google Colab
 - Grace GPU or non-GPU nodes
- Visualization of Results
 - job resource usage
 - view predictions in ChimeraX
 - plotting pLDDT values
- Alternative Workflows

<https://hprc.tamu.edu/wiki/SW:AlphaFold>

Resource Limitations

- AlphaFold
 - currently AlphaFold can only utilize one GPU
 - about 90% of processing is done on CPU when using DeepMind's workflow
- AlphaFold on HPRC Grace
 - sometimes GPU not detected on certain nodes
- AlphaFold in Google Colab (web browser or ChimeraX app)
 - no guarantee of available resources in Colab
 - runs as a Jupyter notebook on Google Colab cloud servers
 - 12GB RAM max
 - a notebook can run for up to 12 hours per day
 - 24 hours per day with Colab Pro (\$9.99/month)
 - not suitable for large predictions

AlphaFold Databases on Grace

/scratch/data/bio/alphafold/2.2.0

```
bfd
├── [1.4T] bfd_metaclust_clu_complete_id30_c90_final_seq.sorted_opt_a3m.ffdata
├── [1.7G] bfd_metaclust_clu_complete_id30_c90_final_seq.sorted_opt_a3m.ffindex
├── [ 16G] bfd_metaclust_clu_complete_id30_c90_final_seq.sorted_opt_cs219.ffdata
├── [1.6G] bfd_metaclust_clu_complete_id30_c90_final_seq.sorted_opt_cs219.ffindex
├── [304G] bfd_metaclust_clu_complete_id30_c90_final_seq.sorted_opt_hhm.ffdata
├── [124M] bfd_metaclust_clu_complete_id30_c90_final_seq.sorted_opt_hhm.ffindex
mgnify
├── [ 64G] mgy_clusters_2018_12.fa
mgnify_2019_05
├── [271G] mgy_proteins.fa
params
├── [ 18K] LICENSE
├── [356M] params_model_1_multimer_v2.npz
├── [356M] params_model_1.npz
├── [356M] params_model_1_ptm.npz
├── [356M] params_model_2_multimer_v2.npz
├── [356M] params_model_2.npz
├── [356M] params_model_2_ptm.npz
├── [356M] params_model_3_multimer_v2.npz
├── [354M] params_model_3.npz
├── [355M] params_model_3_ptm.npz
├── [356M] params_model_4_multimer_v2.npz
├── [354M] params_model_4.npz
├── [355M] params_model_4_ptm.npz
├── [356M] params_model_5_multimer_v2.npz
├── [354M] params_model_5.npz
├── [355M] params_model_5_ptm.npz
pdb70
├── [ 410] md5sum
├── [ 53G] pdb70_a3m.ffdata
├── [2.0M] pdb70_a3m.ffindex
├── [6.6M] pdb70_clu.tsv
├── [ 21M] pdb70_cs219.ffdata
├── [1.5M] pdb70_cs219.ffindex
├── [3.2G] pdb70_hhm.ffdata
├── [1.8M] pdb70_hhm.ffindex
├── [ 19M] pdb_filter.dat
pdb_mmcif
├── [9.4M] mmcif_files
├── [141K] obsolete.dat
pdb_seqres
├── [218M] pdb_seqres.txt
small_bfd
├── [ 17G] bfd-first_non_consensus_sequences
uniclust30
├── [ 87G] uniclust30_2018_08
├── [206G] uniclust30_2021_03
uniprot
├── [104G] uniprot.fasta
uniref90
├── [ 62G] uniref90.fasta
```

total size: 2.6TB
number of files: 183,000+

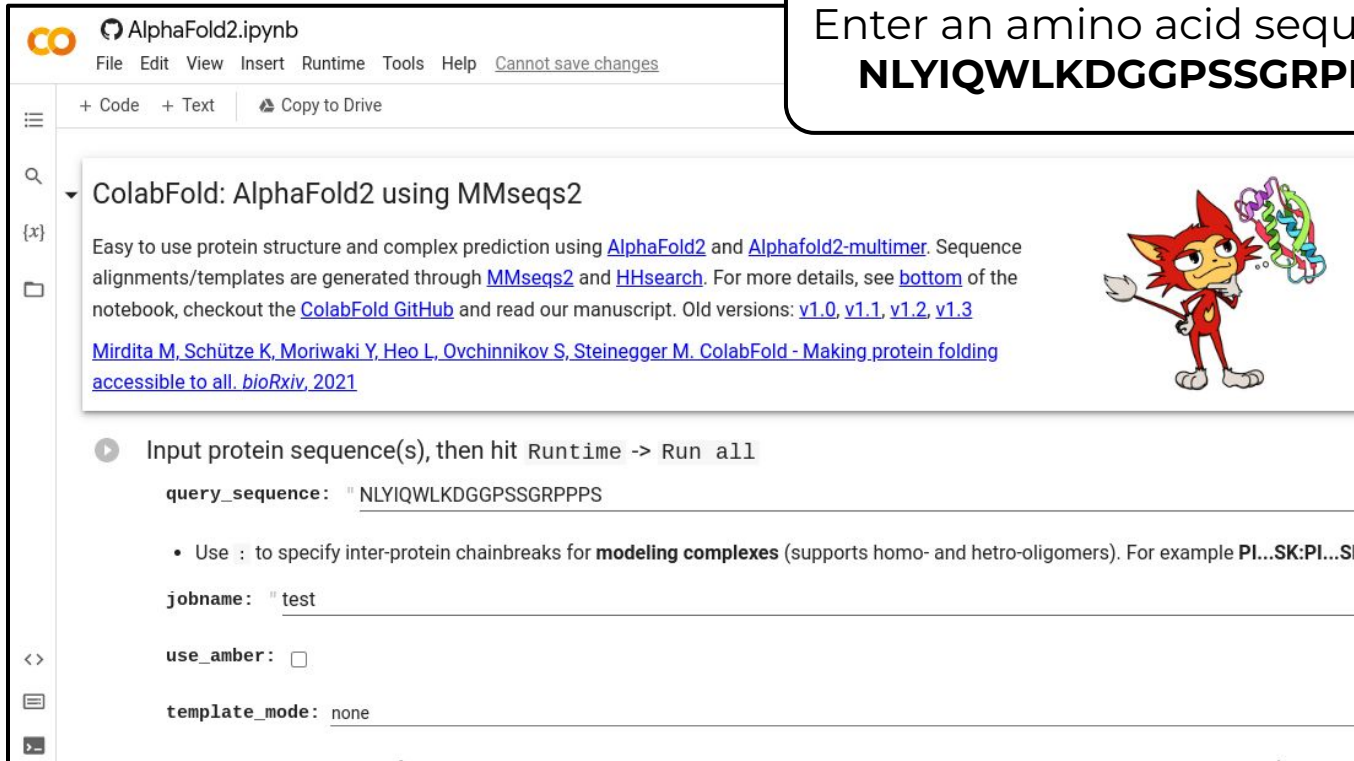
Resources for Running AlphaFold

- Run as a Jupyter [Notebook](#) on Google Colab in web browser
- Run as a Jupyter Notebook on Google Colab in ChimeraX
 - ChimeraX Interactive App on HPRC Grace Portal
 - <https://portal-grace.hprc.tamu.edu>
- Run as a Slurm job script on Grace

<https://hprc.tamu.edu/wiki/SW:AlphaFold>

ColabFold AlphaFold2 Jupyter Notebook

Enter an amino acid sequence
NLYIQWLKDGGPSSGRPPPS




AlphaFold2.ipynb
File Edit View Insert Runtime Tools Help [Cannot save changes](#)

+ Code + Text Copy to Drive

ColabFold: AlphaFold2 using MMseqs2

Easy to use protein structure and complex prediction using [AlphaFold2](#) and [Alphafold2-multimer](#). Sequence alignments/templates are generated through [MMseqs2](#) and [HHsearch](#). For more details, see [bottom](#) of the notebook, checkout the [ColabFold GitHub](#) and read our manuscript. Old versions: [v1.0](#), [v1.1](#), [v1.2](#), [v1.3](#)

[Mirdita M, Schütze K, Moriwaki Y, Heo L, Ovchinnikov S, Steinegger M. ColabFold - Making protein folding accessible to all. bioRxiv, 2021](#)



▶ Input protein sequence(s), then hit Runtime -> Run all

```
query_sequence: " NLYIQWLKDGGPSSGRPPPS
```

- Use : to specify inter-protein chainbreaks for **modeling complexes** (supports homo- and hetro-oligomers). For example **PI...SK:PI...SK**

```
jobname: " test
```

```
use_amber: 
```

```
template_mode: none
```

ChimeraX

- Can be used to visualize protein structures
- Can be launched using the Grace portal
 - portal-grace.hprc.tamu.edu
- Can be used to run AlphaFold using the daily build version (2022.02.22+)
 - uses Google Colab with limited resources

ChimeraX

This app will launch a [UCSF ChimeraX GUI](#) on [Grace](#)

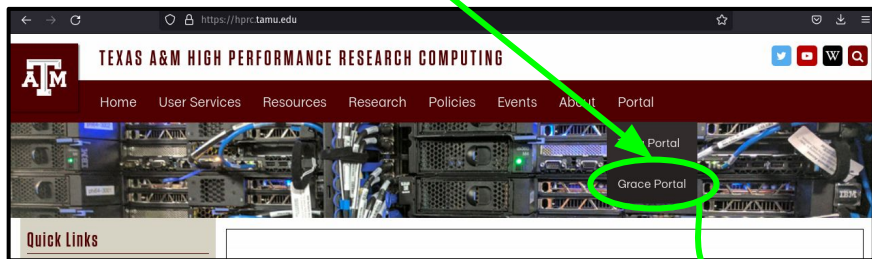
[UCSF ChimeraX](#) is a program for the interactive visualization and analysis of molecular structures and related data, including density maps, trajectories, and sequence alignments.

chimeraX version

ChimeraX/2022.02.22



- Launch a ChimeraX job on the Grace portal portal-grace.hprc.tamu.edu
 - select Node Type: ANY
 - AlphaFold runs on Google Colab GPUs so we can use a non-GPU for running ChimeraX
- ChimeraX will be used later for the following
 - run AlphaFold in Google Colab
 - visualize results from an AlphaFold job on Grace



 A screenshot of the TAMU HPRC OnDemand (Grace) web interface. The top navigation bar includes 'TAMU HPRC OnDemand (Grace)', 'Files', 'Jobs', 'Clusters', 'Interactive Apps', and 'Dashboard'. The main content area is titled 'ChimeraX' and shows configuration options for an interactive session. On the left, a sidebar lists various interactive apps, with 'ChimeraX' selected and highlighted in blue. The main configuration panel includes:

- ChimeraX**: This app will launch a UCSF ChimeraX GUI on Grace. Description: UCSF ChimeraX is a program for the interactive visualization and analysis of molecular structures and related data, including density maps, trajectories, and sequence alignments.
- chimerax version**: ChimeraX/2022.02.22
- Number of hours**: 4
- Number of cores**: 1. Note: Specify number of cores [1-48] allocated on a node from the Grace cluster.
- Total memory (GB)**: 7. Note: Requested total memory (7 - 360GB)
- Node type**: ANY. Note: ANY - select any node to reduce wait time.

 A green circle highlights the 'Node type' dropdown menu, which is currently set to 'ANY'. A green arrow from the 'Grace Portal' link in the previous image points to the 'ChimeraX' option in the sidebar.

Running AlphaFold on Grace

- Can be run as a job script requesting one GPU
- shared databases are available: 2.6TB total size

benchmark	monomer_ptm 98 aa	multimer 98 & 73 aa
A100	1 hour 26 minutes	4 hours 49 minutes
RTX 6000	2 hours 39 minutes	4 hours 44 minutes
T4	2 hours 35 minutes	4 hours 45 minutes
CPU only	2 hours 50 minutes	6 hours 11 minutes

- Can be run in ChimeraX from the Grace portal
 - using the ChimeraX AlphaFold option
 - all processing done on Google cloud servers
 - monomer_ptm (98 aa) on GPU = 1 hour 14 minutes

Finding AlphaFold template job scripts using GCATemplates on Grace

- Genomic Computational Analysis Templates have example input data so you can run the script for demo purposes

```
mkdir $SCRATCH/af2demo
```

```
cd $SCRATCH/af2demo
```

```
gcatemplates
```

- Type **s** for search then enter **alphafold** to search for the alphafold 2.2.0 template script and select the **reduced_dbs** script
- Review the script and submit the job script which takes about 30 minutes to complete

```
sbatch run_alphafold_2.2.0_reduced_dbs_monomer_ptm_grace.sh
```

```
BIOINFORMATICS GCATemplates (grace)

CATEGORY
1. FASTA files
2. FASTQ files (QC, trim, SRA)
3. Genome assembly
4. Metagenomics
5. PacBio tools
6. Phylogenetics
7. Population genetics
8. Protein tools
9. RNA-seq
10. SNPs & indels
11. Sequence alignments
12. Simulate data

s search
q quit

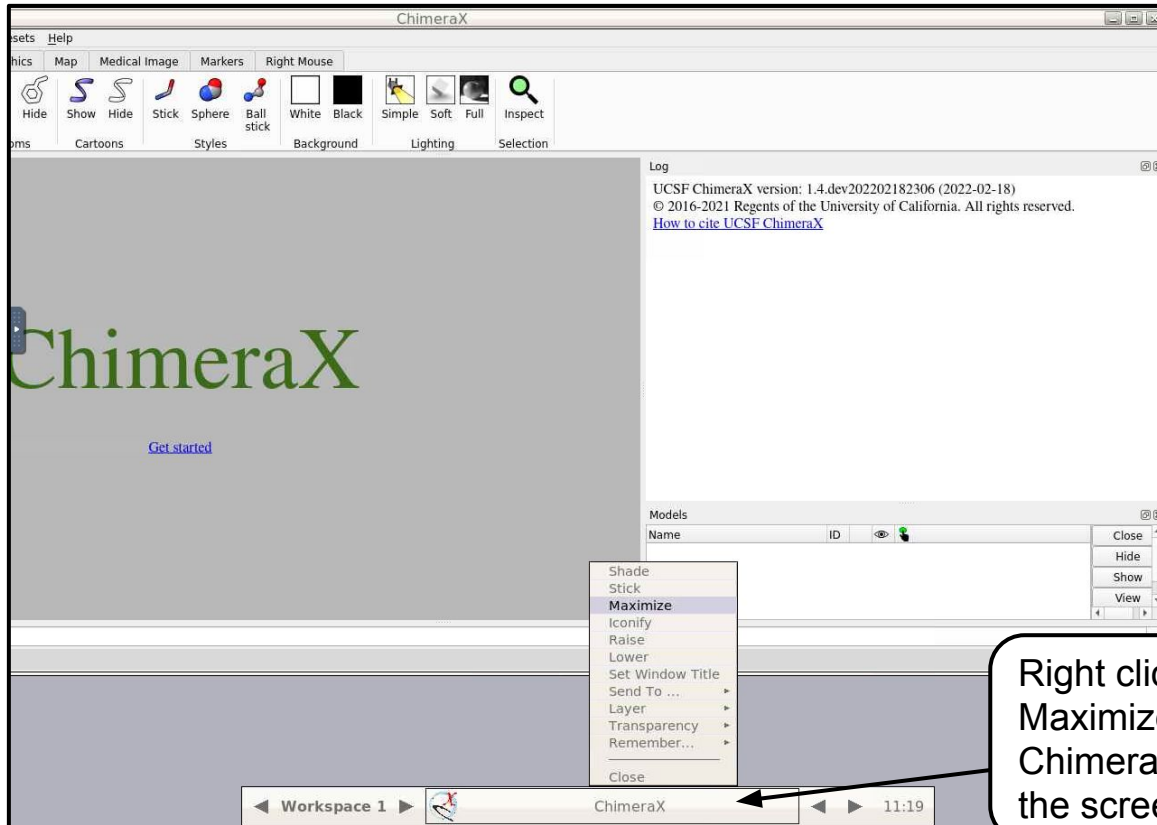
Select:s
```

Monitoring AlphaFold GPUs Found

- Check to make sure that AlphaFold can detect GPUs
 - wait a few minutes after the job starts
 - search for the text "No GPU/TPU found, falling back to CPU."
 - `grep CPU stderr*`
- If the job did not detect GPUs
 - find the compute node name in the NodeList column
 - `sacct -j jobID`
 - cancel the job
 - `scancel jobID`
 - add a line in your job script to ignore the compute node
 - `#SBATCH --exclude=g016`
 - submit your updated job script
 - send an email to the HPRC helpdesk with the node name
 - `help@hprc.tamu.edu`

AlphaFold with ChimeraX + Google Colab

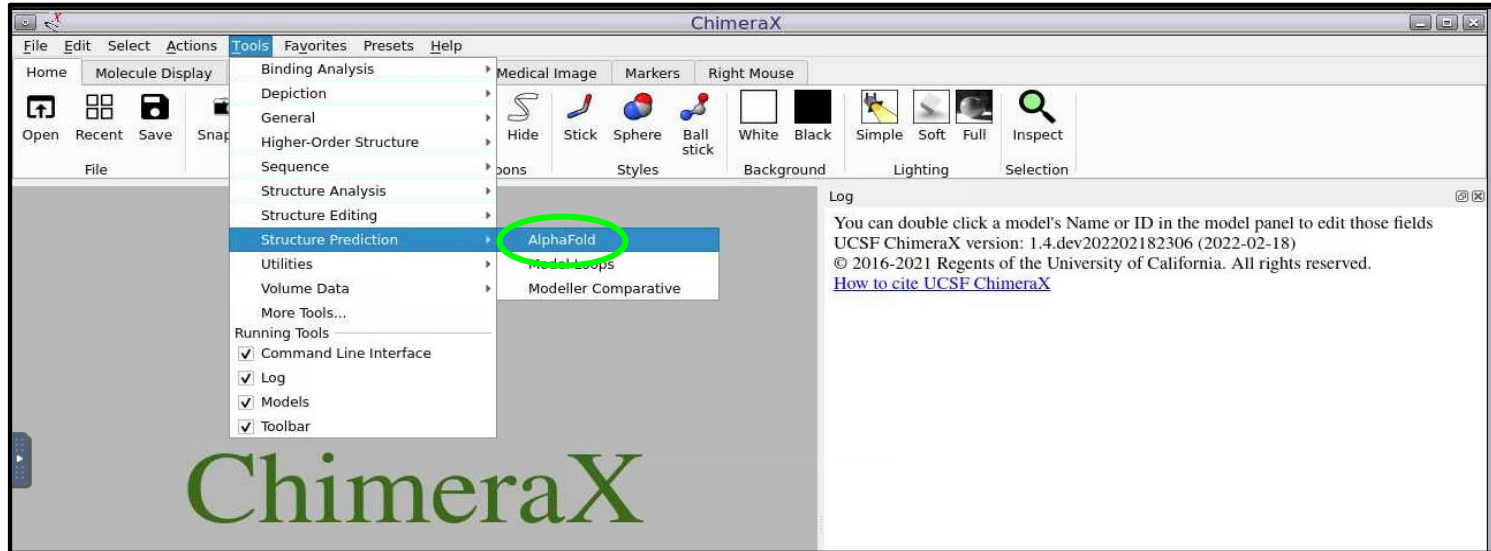
Maximize ChimeraX Window



Right click and select Maximize if the ChimeraX window is off the screen

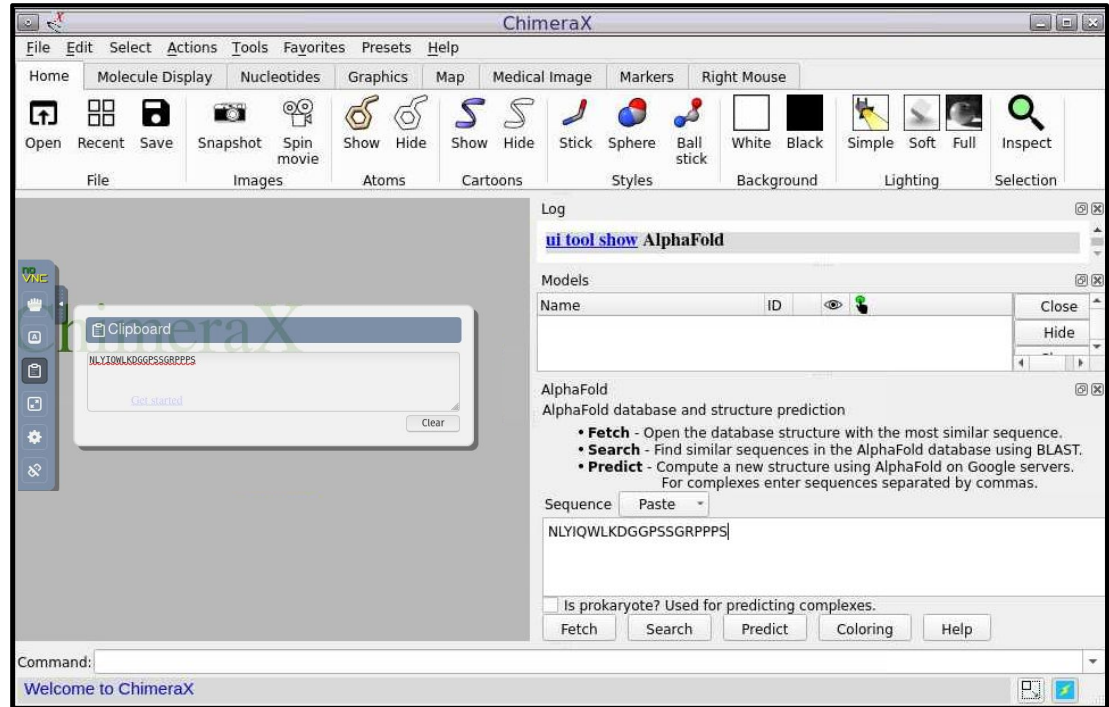
AlphaFold with ChimeraX

- Launch ChimeraX using the HPRC Grace portal
- Select the AlphaFold Structure Prediction option



AlphaFold with ChimeraX

- Enter an amino acid sequence
NLYIQWLKDGGPSSGRPPPS
 - or paste in Clipboard first then paste in Sequence field
- Click Predict
- A Google Colab page will start and prompt you for your Google login
- Login to your Google account to begin processing
- Prediction completes in about 1 hour
- Not ideal for large prediction jobs



AlphaFold Grace Job Scripts

Example AlphaFold Job Script

- **multimer**
 - dbs in **red** required for multimer
- AlphaFold can only use one GPU so reserve half the CPU and memory resources so another job can use the other GPU
 - Grace compute nodes have 360GB of available memory and 48 cores

```
#!/bin/bash
#SBATCH --job-name=alphafold           # job name
#SBATCH --time=2-00:00:00             # max job run time dd-hh:mm:ss
#SBATCH --ntasks-per-node=1          # tasks (commands) per compute node
#SBATCH --cpus-per-task=24           # CPUs (threads) per command
#SBATCH --mem=180G                   # total memory per node
#SBATCH --gres=gpu:a100:1            # request 1 A100 GPU
#SBATCH --output=stdout.%x.%j        # save stdout to file
#SBATCH --error=stderr.%x.%j         # save stderr to file

module purge

export SINGULARITYENV_TF_FORCE_UNIFIED_MEMORY=1
export SINGULARITYENV_XLA_PYTHON_CLIENT_MEM_FRACTION=4.0

DOWNLOAD_DIR=/scratch/data/bio/alphafold/2.2.0

# run gpustats in the background (&) to monitor gpu usage in order to create a graph later
gpustats &

singularity exec --nv /sw/hprc/sw/containers/alphafold/alphafold_2.2.0.sif \
python /app/alphafold/run_alphafold.py \
--use_gpu_relax \
--data_dir=$DOWNLOAD_DIR \
--uniref90_database_path=$DOWNLOAD_DIR/uniref90/uniref90.fasta \
--mgnify_database_path=$DOWNLOAD_DIR/mgnify/mgy_clusters_2018_12.fa \
--uniclust30_database_path=$DOWNLOAD_DIR/uniclust30/uniclust30_2021_03/UniRef30_2021_03 \
--bfd_database_path=$DOWNLOAD_DIR/bfd/bfd_metaclust_clu_complete_id30_c90_final_seq.sorted_opt \
--model_preset=multimer \
--pdb_seqres_database_path=$DOWNLOAD_DIR/pdb_seqres/pdb_seqres.txt \
--uniprot_database_path=$DOWNLOAD_DIR/uniprot/uniprot.fasta \
--template_mmcif_dir=$DOWNLOAD_DIR/pdb_mmcif/mmcif_files \
--obsolete_pdbs_path=$DOWNLOAD_DIR/pdb_mmcif/obsolete.dat \
--max_template_date=2022-1-1 \
--db_preset=full_dbs \
--output_dir=out_alphafold \
--fasta_paths=$DOWNLOAD_DIR/example_data/T1083_T1084_multimer.fasta

# run gpustats to create a graph of gpu usage for this job
gpustats
```

Example AlphaFold Job Script

- **monomer**
 - dbs in **red** required for monomer
- **monomer_ptm**
 - will produce pTM scores that can be graphed using AlphaPickle
- AlphaFold can only use one GPU so reserve half the CPU and memory resources so another job can use the other GPU

```
#!/bin/bash
#SBATCH --job-name=alphafold           # job name
#SBATCH --time=2-00:00:00             # max job run time dd-hh:mm:ss
#SBATCH --ntasks-per-node=1          # tasks (commands) per compute node
#SBATCH --cpus-per-task=24            # CPUs (threads) per command
#SBATCH --mem=180G                    # total memory per node
#SBATCH --gres=gpu:a100:1             # request 1 A100 GPU
#SBATCH --output=stdout.%x.%j        # save stdout to file
#SBATCH --error=stderr.%x.%j         # save stderr to file

module purge

export SINGULARITYENV_TF_FORCE_UNIFIED_MEMORY=1
export SINGULARITYENV_XLA_PYTHON_CLIENT_MEM_FRACTION=4.0

DOWNLOAD_DIR=/scratch/data/bio/alphafold/2.2.0

# run gpustats in the background (&) to monitor gpu usage in order to create a graph later
gpustats &

singularity exec --nv /sw/hprc/sw/containers/alphafold/alphafold_2.2.0.sif \
python /app/alphafold/run_alphafold.py \
--use_gpu_relax \
--data_dir=$DOWNLOAD_DIR \
--uniref90_database_path=$DOWNLOAD_DIR/uniref90/uniref90.fasta \
--mgnify_database_path=$DOWNLOAD_DIR/mgnify/mgy_clusters_2018_12.fa \
--uniclust30_database_path=$DOWNLOAD_DIR/uniclust30/uniclust30_2021_03/UniRef30_2021_03 \
--bfd_database_path=$DOWNLOAD_DIR/bfd/bfd_metaclust_clu_complete_id30_c90_final_seq.sorted_opt \
--model_preset=monomer \
--pdb70_database_path=$DOWNLOAD_DIR/pdb70/pdb70 \
--template_mmcif_dir=$DOWNLOAD_DIR/pdb_mmcif/mmcif_files \
--obsolete_pdbs_path=$DOWNLOAD_DIR/pdb_mmcif/obsolete.dat \
--max_template_date=2022-1-1 \
--db_preset=full_dbs \
--output_dir=out_alphafold \
--fasta_paths=$DOWNLOAD_DIR/example_data/T1083.fasta

# run gpustats to create a graph of gpu usage for this job
gpustats
```

Example AlphaFold Job Script

- **monomer + reduced_dbs**
- dbs in **red** required for monomer + reduced_dbs
- small_bfd_database is a subset of BFD and is generated by taking the first non-consensus sequence from every cluster in BFD
- AlphaFold can only use one GPU so reserve half the CPU and memory resources so another job can use the other GPU

```
#!/bin/bash
#SBATCH --job-name=alphafold           # job name
#SBATCH --time=2-00:00:00             # max job run time dd-hh:mm:ss
#SBATCH --ntasks-per-node=1          # tasks (commands) per compute node
#SBATCH --cpus-per-task=24           # CPUs (threads) per command
#SBATCH --mem=180G                   # total memory per node
#SBATCH --gres=gpu:a100:1            # request 1 A100 GPU
#SBATCH --output=stdout.%x.%j        # save stdout to file
#SBATCH --error=stderr.%x.%j         # save stderr to file

module purge

export SINGULARITYENV_TF_FORCE_UNIFIED_MEMORY=1
export SINGULARITYENV_XLA_PYTHON_CLIENT_MEM_FRACTION=4.0

DOWNLOAD_DIR=/scratch/data/bio/alphafold/2.2.0

# run gpustats in the background (&) to monitor gpu usage in order to create a graph later
gpustats &

singularity exec --nv /sw/hprc/sw/containers/alphafold/alphafold_2.2.0.sif \
python /app/alphafold/run_alphafold.py \
--use_gpu_relax \
--data_dir=$DOWNLOAD_DIR \
--uniref90_database_path=$DOWNLOAD_DIR/uniref90/uniref90.fasta \
--mgnify_database_path=$DOWNLOAD_DIR/mgnify/mgy_clusters_2018_12.fa \
--small_bfd_database_path=$DOWNLOAD_DIR/small_bfd/bfd-first_non_consensus_sequences.fasta \
--model_preset=monomer \
--pdb70_database_path=$DOWNLOAD_DIR/pdb70/pdb70 \
--template_mmcif_dir=$DOWNLOAD_DIR/pdb_mmcif/mmcif_files \
--obsolete_pdbs_path=$DOWNLOAD_DIR/pdb_mmcif/obsolete.dat \
--max_template_date=2022-1-1 \
--db_preset=reduced_dbs \
--output_dir=out_alphafold \
--fasta_paths=$DOWNLOAD_DIR/example_data/T1083.fasta

# run gpustats to create a graph of gpu usage for this job
gpustats
```

Unified Memory

```
#!/bin/bash
#SBATCH --job-name=alphafold           # job name
#SBATCH --time=2-00:00:00              # max job run time dd-hh:mm:ss
#SBATCH --ntasks-per-node=1           # tasks (commands) per compute node
#SBATCH --cpus-per-task=24            # CPUs (threads) per command
#SBATCH --mem=180G                    # total memory per node
#SBATCH --gres=gpu:a100:1             # request 1 A100 GPU
#SBATCH --output=stdout.%x.%j         # save stdout to file
#SBATCH --error=stderr.%x.%j         # save stderr to file

export SINGULARITYENV_TF_FORCE_UNIFIED_MEMORY=1
export SINGULARITYENV_XLA_PYTHON_CLIENT_MEM_FRACTION=4.0
```

- unified memory can be used to request more than just the total GPU memory for the JAX step in AlphaFold
 - A100 GPU has 40GB memory
 - GPU total memory (40) * XLA_PYTHON_CLIENT_MEM_FRACTION (4.0)
 - XLA_PYTHON_CLIENT_MEM_FRACTION default = 0.9
- this example script has 160 GB of unified memory
 - 40 GB from A100 GPU + 120 GB DDR from motherboard

AlphaFold Results Visualization

Review GPU and CPU usage for a Job

The **jobstats** command monitors GPU and CPU resource usage and create graphs

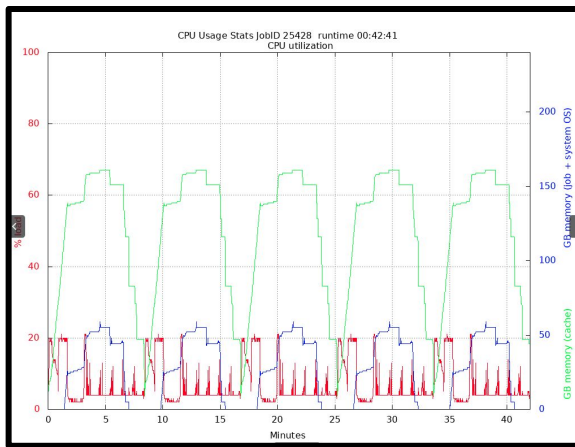
```
#!/bin/bash
#SBATCH --job-name=my_gpu_job
#SBATCH --time=1-00:00:00
#SBATCH --ntasks-per-node=1
#SBATCH --cpus-per-task=24
#SBATCH --mem=180G
#SBATCH --gres=gpu:a100:1
#SBATCH --output=stdout.%x.%j
#SBATCH --error=stderr.%x.%j

module purge

# run gpustats in the background (&)
# to monitor gpu usage
jobstats &

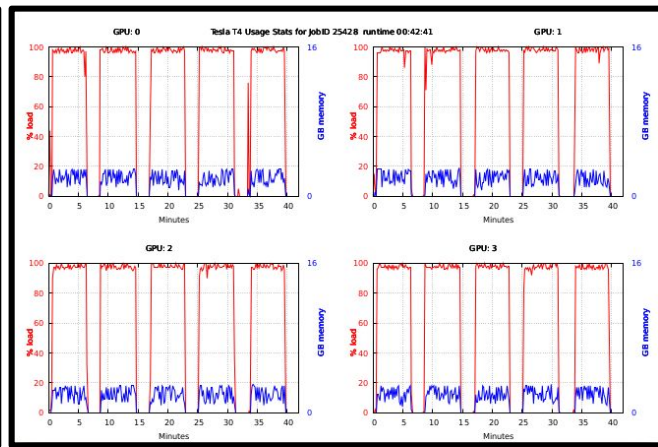
my_alphafold_command

# run gpustats to create a graph
# of GPU and CPU usage for this job
jobstats
```



eog stats_cpu.25428.png

only works for jobs using just
one compute node



evince stats_gpu.25428.pdf

.pdf file created when more than 4
GPUs used in a job

When the job is complete, login with ssh -X option and view graphs of GPU and CPU usage stats using **eog** for .png files and **evince** for .pdf files

Review CPU usage for a Job

The **seff** command displays CPU resource usage

```
seff 3411850
```

```
Job ID: 3411850
Cluster: grace
User/Group: netid/netid
State: COMPLETED (exit code 0)
Nodes: 1
Cores per node: 24
CPU Utilized: 06:24:58
CPU Efficiency: 2.70% of 9-21:48:24 core-walltime
Job Wall-clock time: 09:54:31
Memory Utilized: 54.59 GB
Memory Efficiency: 30.33% of 180.00 GB
```

usage stats are not accurate until the job is complete

Visualize Results with ChimeraX

AlphaFold Run

alphafold21_predict_colab.ipynb

File Edit View Insert Runtime Tools Help Cannot save changes

+ Code + Text Copy to Drive Reconnect Editing

```
31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71
Merging chunk sequence alignments for mgnify
```

Runtime disconnected

Your runtime has been disconnected due to inactivity or reaching its maximum duration. [Learn more](#)

If you are interested in longer runtimes with more lenient timeouts, you may want to check out [Colab Pro](#).

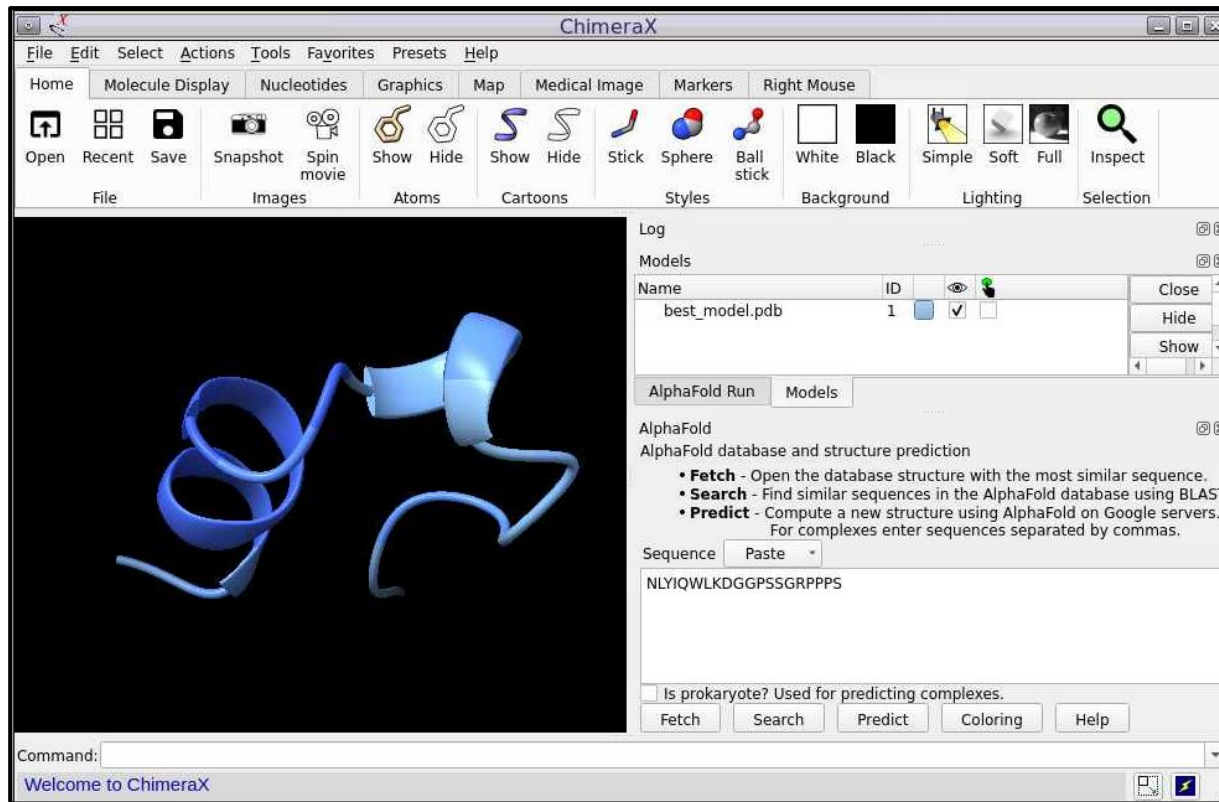
Close Reconnect

```
Computing structures using 5 AlphaFold parameter sets:
model_1_ptm model_2_ptm model_3_ptm model_4_ptm model_5_ptm
Energy minimizing best structure model_3_ptm with OpenMM and Amber forcefield
Structure prediction completed.
```

✓ 1h 4m 59s completed at 3:14 PM

Click the minimize button to return to ChimeraX or click Reconnect then minimize

Visualize AlphaFold Google Colab Results with ChimeraX



View PDB Structure if Available

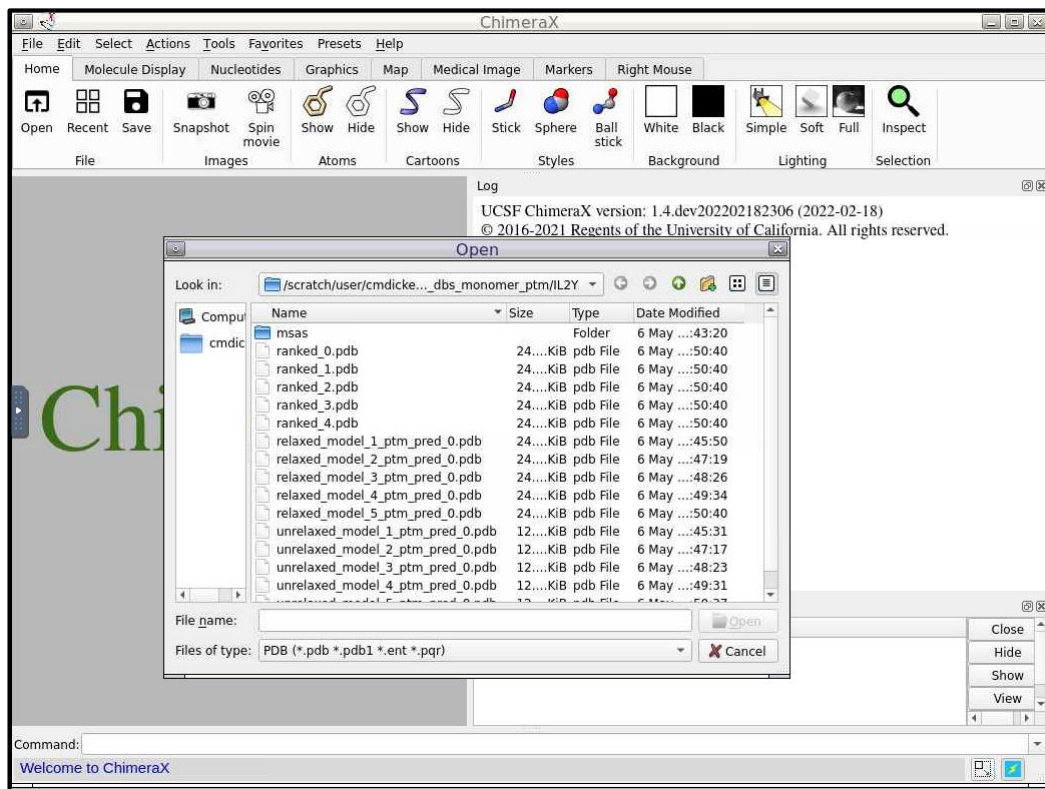
The screenshot shows the ChimeraX interface with a protein structure rendered in pink. The right-hand side features several panels: a Log panel with entries for 'close #2' and 'show #13 models'; a Models panel with a table listing 'best_model.pdb' (ID 1) and '1l2y group' (ID 3); an AlphaFold panel with instructions for Fetch, Search, and Predict, and a sequence input field containing 'NLYIQWLKDGPPSSGRPPPS'; and an AlphaFold Run panel showing a Jupyter Notebook execution for 'alphafold21_predict_colab.ipynb' which completed at 1:17 PM.

Name	ID	Visible	Selected	Close
best_model.pdb	1	<input type="checkbox"/>	<input type="checkbox"/>	
1l2y group	3	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	

AlphaFold Run
alphafold21_predict_colab.ipynb
1h 6m 47s completed at 1:17 PM

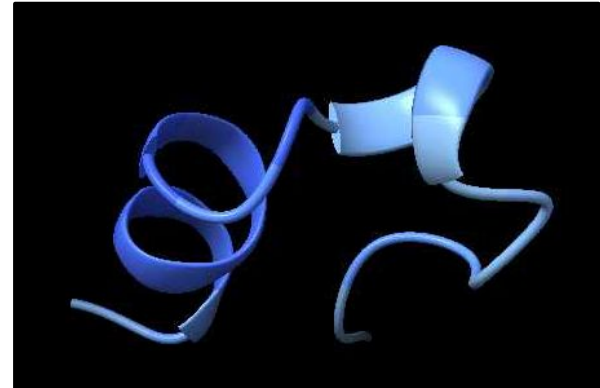
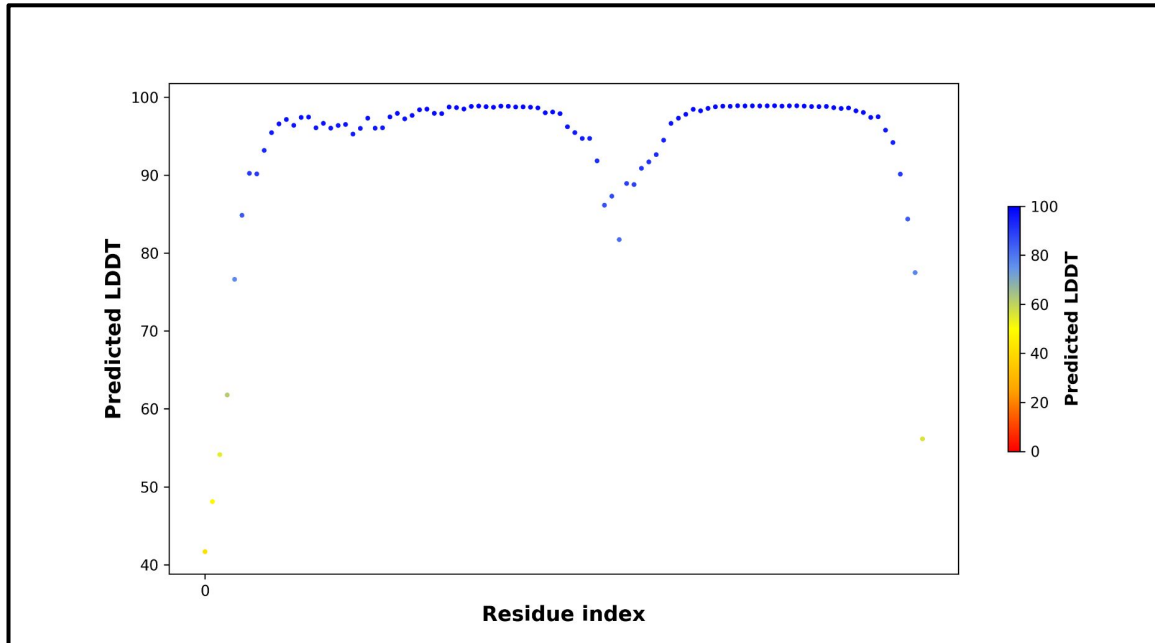
type *open* and the protein name *1L2Y*

Visualize AlphaFold Grace Results with ChimeraX



AlphaFold Confidence Metrics

Visualize AlphaFold .pkl Results

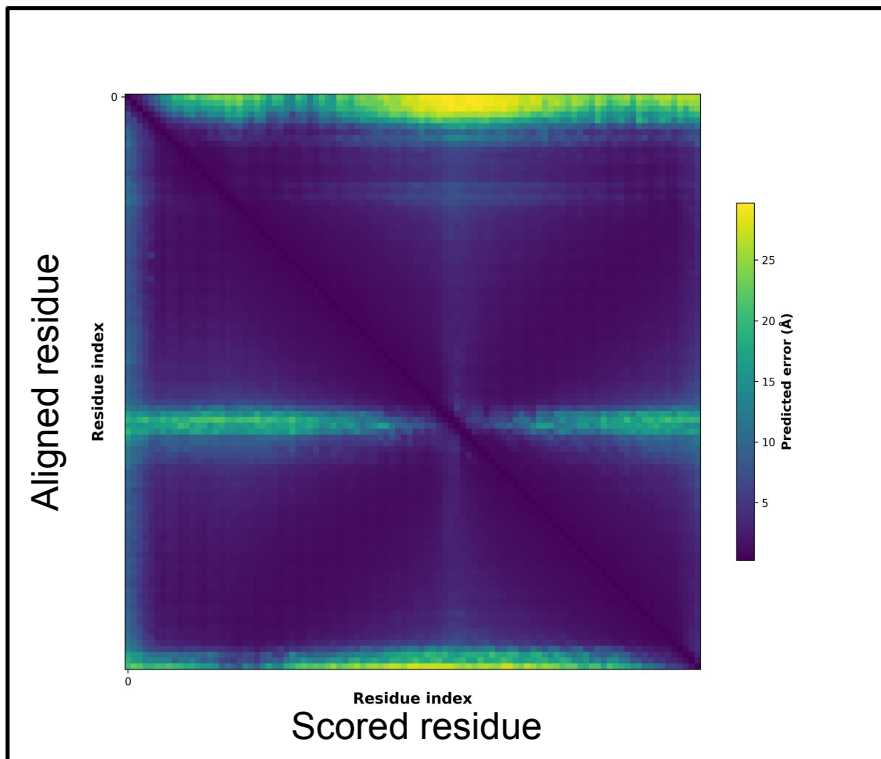


> 90 = Very high
70 - 90 = Confident
50 - 70 = Low
< 50 = Very low

```
eog output_dir/protein_dir/ranked_0_pLDDT.png
```

you may get different results compared to the image above when using reduced_dbs

Visualize AlphaFold PAE Results (monomer_ptm)

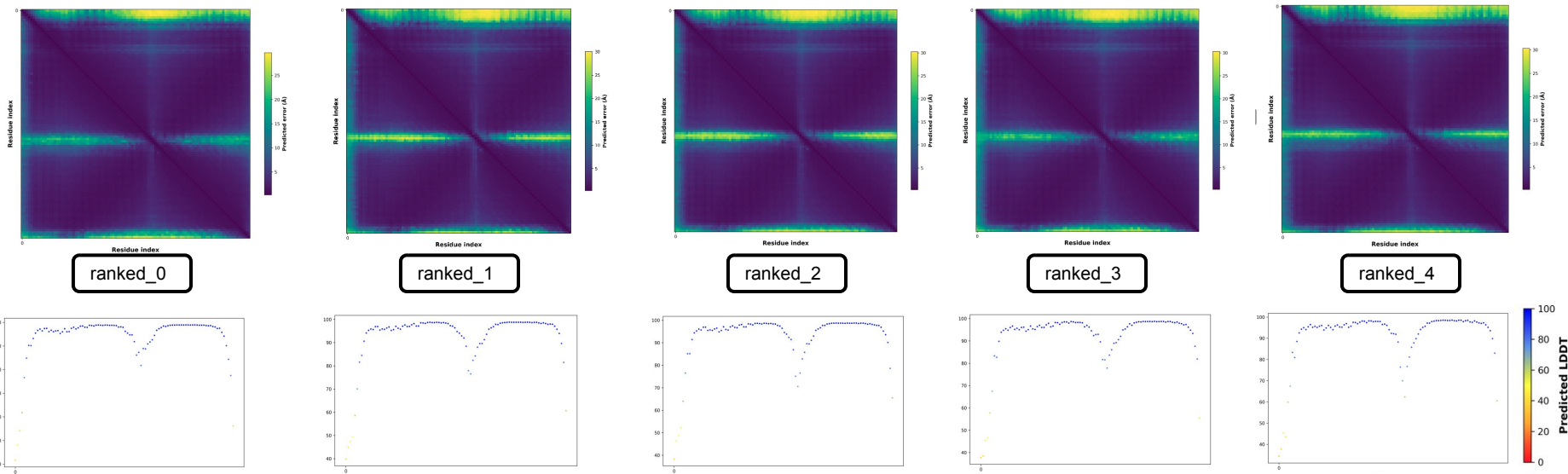


- Low Predicted Aligned Error (PAE) value has higher confidence of accuracy
- Must use monomer_ptm or multimer as model_preset to create PAE image
- The colour at position (x, y) indicates AlphaFold's expected position error at residue x , when the predicted and true structures are aligned on residue y .

`eog output_dir/protein_dir/ranked_0_PAE.png`

<https://alphafold.ebi.ac.uk>

Evaluating Models



see which model has the top rank based on pLDDT score

```
cat out_IL2Y_reduced_dbs_monomer_ptm/IL2Y/ranking_debug.json
```

```
"pLDDTs": {  
  "model_1_ptm_pred_0": 94.16585478746399,  
  "model_2_ptm_pred_0": 94.64120852328334,  
  "model_3_ptm_pred_0": 89.94980057627299,  
  "model_4_ptm_pred_0": 77.53515668415058,  
  "model_5_ptm_pred_0": 88.40610380463586  
},  
"order": [  
  "model_2_ptm_pred_0",  
  "model_1_ptm_pred_0",  
  "model_3_ptm_pred_0",  
  "model_5_ptm_pred_0",  
  "model_4_ptm_pred_0"  
]
```

ranked_0

AlphaFold Workflow Alternatives

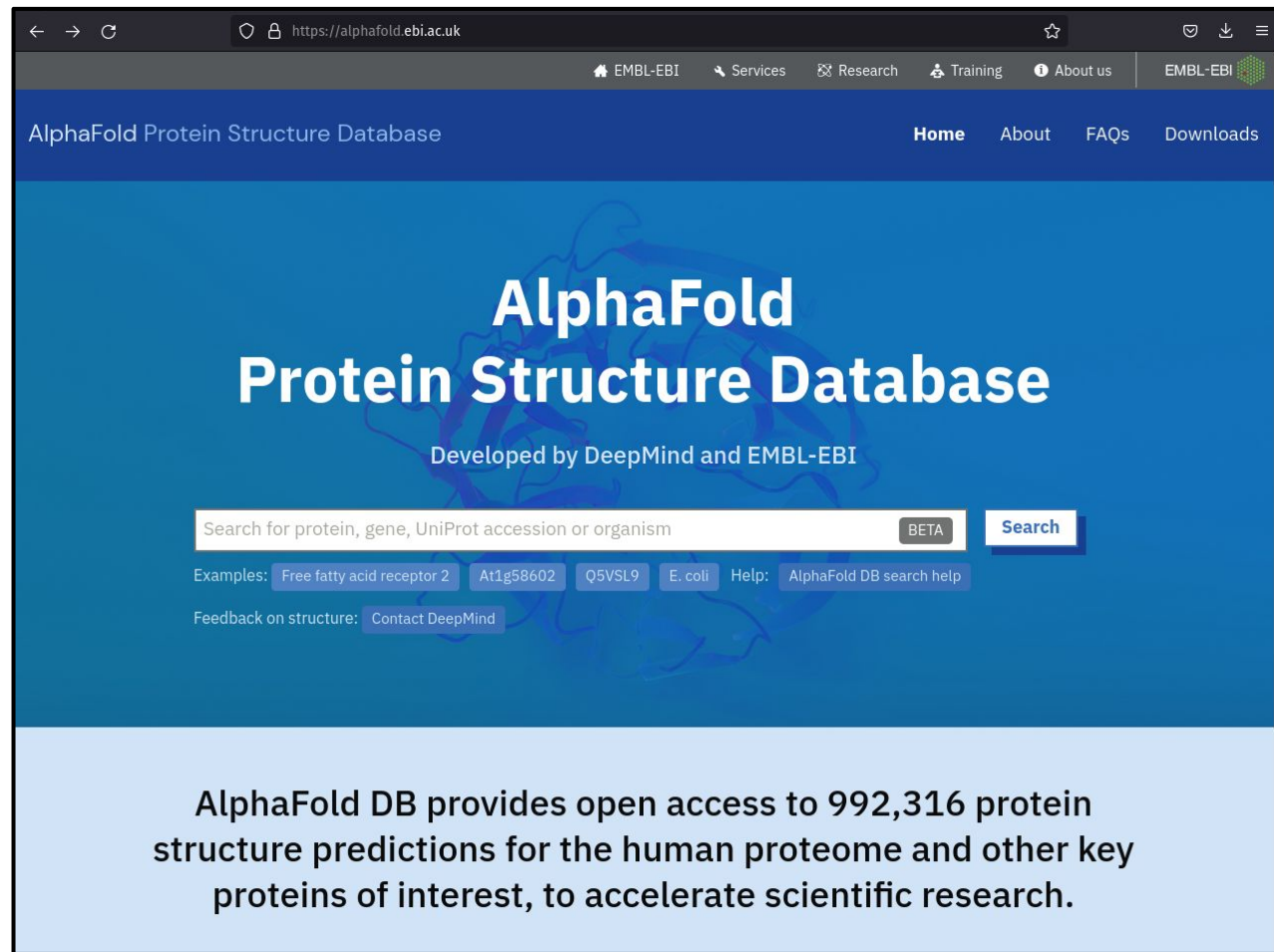
ParallelFold

- ParallelFold (ParaFold) breaks the AlphaFold workflow into two steps
 - processing of the three CPU steps in parallel
 - processing of the GPU step
- The parallel portion for CPU steps is not implemented yet resulting in similar or longer runtimes than the DeepMind approach
 - the first three CPU steps, jackhammer, jackhammer and HHblits are supposed to run as three separate processes in parallel but currently this parallelization step is not implemented yet
 - when the CPU processing is parallelized, it will require 21 cores
 - 8 cores for each of the two jackhammer steps
 - 5 cores for the HHblits step.
- These steps may be implemented in parallel in AlphaFold soon

<https://github.com/Zuricho/ParallelFold>

Databases and References

DeepMind and EMBL's European Bioinformatics Institute ([EMBL-EBI](https://www.ebi.ac.uk)) have partnered to create AlphaFold DB to make these predictions freely available to the scientific community.



← → ↻ 🔒 https://alphafold.ebi.ac.uk

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AlphaFold Protein Structure Database

Developed by DeepMind and EMBL-EBI

Search for protein, gene, UniProt accession or organism BETA Search

Examples: [Free fatty acid receptor 2](#) [At1g58602](#) [Q5VSL9](#) [E. coli](#) Help: [AlphaFold DB search help](#)

Feedback on structure: [Contact DeepMind](#)

AlphaFold DB provides open access to 992,316 protein structure predictions for the human proteome and other key proteins of interest, to accelerate scientific research.

References

Article | [Open Access](#) | [Published: 15 July 2021](#)

Highly accurate protein structure prediction with AlphaFold

[John Jumper](#) ✉, [Richard Evans](#), ... [Demis Hassabis](#) ✉ [+ Show authors](#)

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[Kathryn Tunyasuvunakool](#) ✉, [Jonas Adler](#), ... [Demis Hassabis](#) ✉ [+ Show authors](#)

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