Bridges-2 Webinar

Utilizing Bridges-2 for State-of-the-Art Open Source Large Language Models

Mei-Yu Wang

Pittsburgh Supercomputing Center

May 24, 2024

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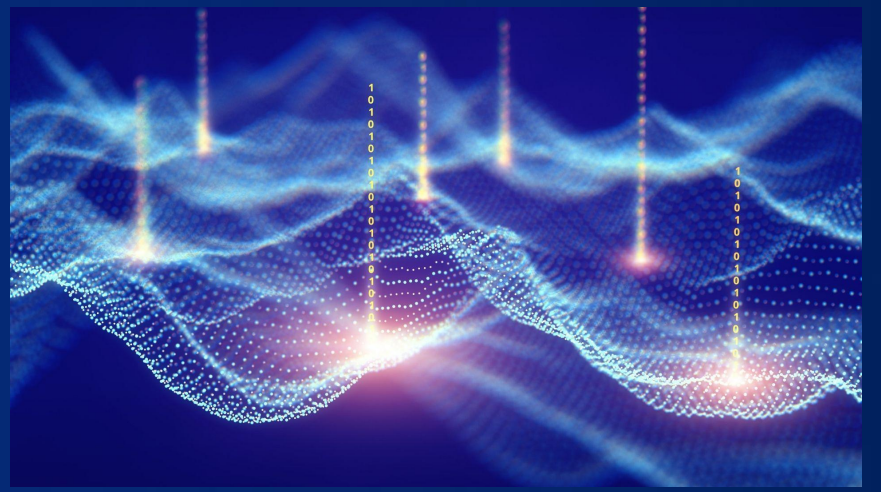


Welcome!
BRIDGES-2
Bridges-2
PITTSBURGH SUPERCOMPUTING CENTER
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Bridges-2 Overview
Hewlett Packard Enterprise is delivering Bridges-2

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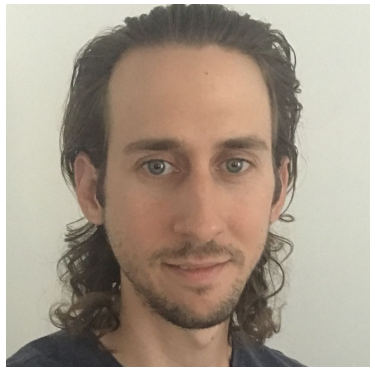

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Bridges-2 Webinars

- A forum for the Bridges-2 community to learn and share ideas and achievements: Bridges-2 Webinar series | PSC
- Topics and speakers of interest to work that is being done, or that may be done in future.
- Please suggest future speakers (including from your own team) and/or topics (including your own)!

Just email: sergiu@psc.edu

Introducing today's presenter: Dr. Mei-Yu Wang

Mei-Yu Wang acquired her Ph.D. in astrophysics from the University of Pittsburgh. Her doctoral research focused on developing novel probes for studying dark matter. She did postdoctoral research in studying dark matter and the Milky Way at the Texas A&M University and Carnegie Mellon University befores she joined the HPC AI and Big Data Group group at PSC in 2022. Her primary roles now include addressing support requests and developing tests and benchmarking for the Neocortex system and the Open Compass project.

Q&A Logistics

- **We abide by https://support.access-ci.org/code-of-conduct**
- All of us except Mei-Yu will be muted during his presentation.
- Please type your questions into the Zoom chat.
- We may be able to address some questions in the chat while Mei-Yu is presenting.
- When Mei-Yu finishes her presentation, she will answer questions live during the final ~10 minutes of this webinar.
- For any remaining or follow-up questions, Mei-Yu may engage after the webinar: *mwang7@psc.edu*

Outline

- **Two examples of popular open LLMs: Llama & Gemma**
  - Llama (Meta)
  - Gemma (Google)
- **Examples of techniques for fine-tuning models with limited resources**
  - Parameter-efficient fine-tuning (PEFT)
  - Quantization
  - Fully Sharded Data Parallel
- **Brief Overview of the Bridges-2 GPU partition**
  - Type of GPU nodes/partitions
  - Batch job/interactive mode/OnDemand
  - How to set up the environment
- **Demo : performing model finetuning/inference with Llama-2 7B and Llama-3 8B (optionally Gemma 7B) using LoRA.**
- **Conclusion**

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Llama

- **Llama (Large Language Model Meta AI)** is a family of autoregressive large language models released by Meta AI starting in February 2023.

Name	Release Date	Number of Parameters	Context Length	Corpus size	Commercial viability
LLaMA-2	July 18, 2023	• 7B/7B-chat • 13B/13B-chat • 70B/70B-chat	2049	2T	Yes
LLaMA-3	April 18, 2024	• 8B/8B-Instruct • 70B/70B-Instruct	8912	15T	Yes

- **Other variants**
  - **Code Llama:** a collection of code-specialized versions of Llama 2 in three flavors (base model, Python specialist, and instruct tuned).
  - **Llama Guard**: a 7B Llama 2 safeguard model for classifying LLM inputs and responses.

Llama 3 Performance

Meta Llama 3 Instruct model performance

	Meta Llama 3 8B	Gemma 7B - It Measured	Mistral 7B Instruct Measured
MMLU 5-shot	**68.4**	53.3	58.4
GPQA 0-shot	**34.2**	21.4	26.3
HumanEval 0-shot	**62.2**	30.5	36.6
GSM-8K 8-shot, CoT	**79.6**	30.6	39.9
MATH 4-shot, CoT	**30.0**	12.2	11.0

	Meta Llama 3 70B	Gemini Pro 1.5 Published	Claude 3 Sonnet Published
MMLU 5-shot	**82.0**	81.9	79.0
GPQA 0-shot	39.5	**41.5** CoT	38.5 CoT
HumanEval 0-shot	**81.7**	71.9	73.0
GSM-8K 8-shot, CoT	**93.0**	91.7 11-shot	92.3 0-shot
MATH 4-shot, CoT	50.4	**58.5** Minerva prompt	40.5

See https://github.com/meta-llama/llama3/blob/main/MODEL_CARD.md#benchmarks for benchmark results.

Source: https://llama.meta.com/llama3

Resources for getting started with Llama

- **Website**
  - https://llama.meta.com/
- **Ways to download the model:**
  - Meta: https://llama.meta.com/llama-downloads
  - Hugging face: https://huggingface.co/meta-llama
  - Kaggle: https://www.kaggle.com/models/metaresearch/llama-3, https://www.kaggle.com/models/metaresearch/llama-2
- **Github**
  - Meta-llama/llama-recipes
    - https://github.com/meta-llama/llama-recipes
    - examples to get started using Llama for fine-tuning, inference…etc.
  - Meta-llama/llama
    - https://github.com/meta-llama/llama
    - Provide a script for downloading the model weights and a minimal example to load models and run inference.
  - Torchtune
    - https://github.com/pytorch/torchtune

Gemma

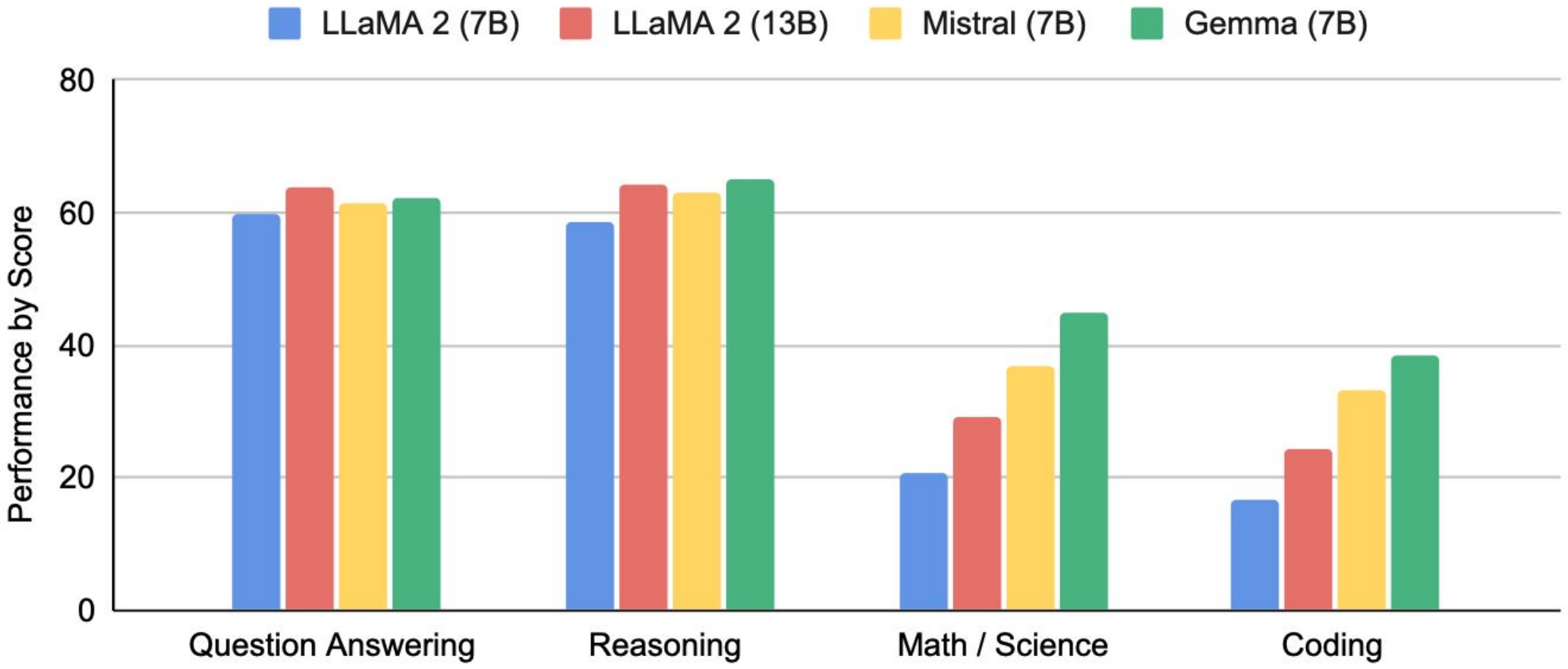
- Gemma is a family of lightweight, state-of-the-art open models built from the same research and technology used to create the Gemini models, developed by Google DeepMind and other teams across Google.

Google DeepMind

Name	Release Date	Number of Parameters	Context Length	Corpus size	Commercial viability
Gemma	February 21, 2024	• 2B/2B-it (v1.0, v1.1) • 7B/7B-it (v1.0, v1.1)	8192	6T	Yes

- Other variants:
  - **CodeGemma**: a collection of code-specialized versions of Gemma.
  - **PaliGemma**: an open vision-language model built with open components such as the SigLIP vision model and the Gemma language model.
  - **RecurrentGemma**: an open model based on Griffin, a hybrid model that mixes gated linear recurrences with local sliding window attention.

Gemma Performance



Source: Gemma technical report
https://storage.googleapis.com/deepmind-media/gemma/gemma-report.pdf

Resources for getting started with Gemma

- **Website:** https://ai.google.dev/gemma
- **Ways to download the model:**
  - Kaggle: https://www.kaggle.com/models/google/gemma
  - Hugging Face: https://huggingface.co/google
- **Technical report**: https://storage.googleapis.com/deepmind-media/gemma/gemma-report.pdf
- **Github:**
  - google-deepmind/gemma:
    - https://github.com/google-deepmind/gemma
    - examples to get started using Gemma for fine-tuning, inference...etc.
  - For tutorials, reference implementations in various ML frameworks:
    - https://github.com/google/generative-ai-docs/tree/main/site/en/gemma/docs
  - Torchtune
    - https://github.com/pytorch/torchtune

Examples of scientific applications with Llama

- **Fine Tuned with domain specific knowledge:**
  - **Medical specific LLMs:** finetuned with medical paper (arXiv:2304.14454), medical conversational model (arXiv:2304.08247) , clinical data: (arxiv:2307.03042), Medical application: (arxiv:2402.12749)
  - **Biochemistry:** (arxiv:2306.08018**)**
  - **Finance:** FinLlama (arxiv:2403.12285)
- **Retrieval Augmented Generation (RAG)**
  - **Medical:** Disease prediction system (arxiv:2402.00746), PMC-LLaMA (arxiv:2304.14454)

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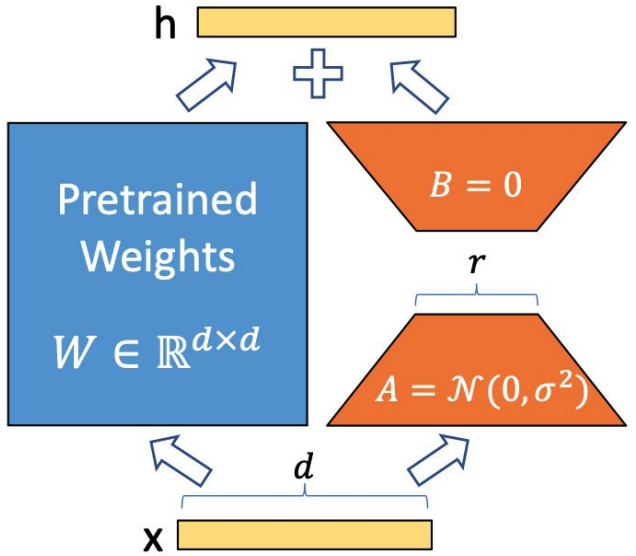
Parameter-efficient fine-tuning (PEFT)

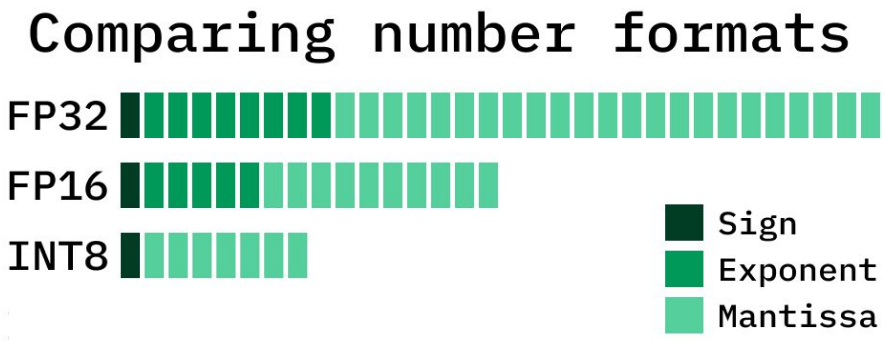
- In traditional fine-tuning, all model parameters are updated to tailor the outputs to the specific task. It is also possible to freeze some layers and leave the rests trainable.
- In contrast, when fine-tuning with PEFT (Parameter-Efficient Fine-Tuning), the base model weights remain frozen, and only the adapter modules are trained. Consequently, the number of trainable parameters could be drastically reduced to less than 1%.
- Examples:
  - **LoRA**
  - **P-tuning**
  - **Prefix tuning**



Hu et al., (2021) "LoRA: Low-Rank Adaptation of Large Language Models" https://arxiv.org/abs/2106.09685

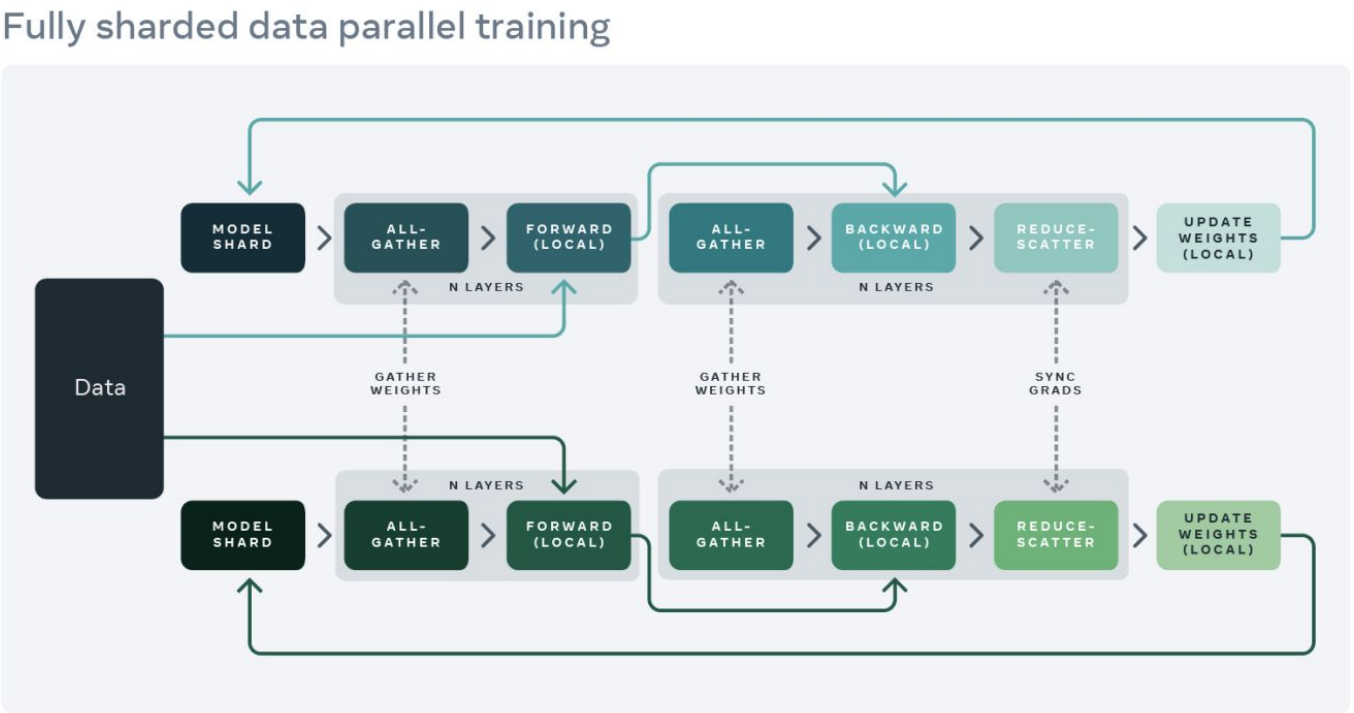
Quantization

- Quantization involves representing model weights and activations, typically 32-bit floating numbers, with lower precision data such as 8-bit int or 4-bit int.
- The benefits of quantization include smaller model sizes, faster fine-tuning, and faster inference—particularly beneficial in resource-constrained environments.
- However, the tradeoff is a reduction in model quality due to the loss of precision.
- Example library:
  - BitsAndBytes
  - Quanto
  - TorchAO



Fully Sharded Data Parallel (FSDP)

- Unlike traditional data-parallel, which maintains a per-GPU copy of a model's parameters, gradients and optimizer states, FSDP shards all of these states across data-parallel workers and can optionally offload the sharded model parameters to CPUs.
- It is available in PyTorch and is Integrated with Hugging Face Accelerate
- Paper: https://arxiv.org/pdf/2304.11277



source: https://engineering.fb.com/2021/07/15/open-source/fsdp/

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Bridges-2 GPU and GPU-shared partitions

- **See Bridges-2 user guide for details:**

  https://www.psc.edu/resources/bridges-2/user-guide/#gpu-partitions

- **Partition:**
  - The **GPU-shared** partition
    The GPU-shared partition is for jobs that will use **part of one GPU node** (up to **4** GPUs, maximum runtime: **48 hours**).
  - The **GPU** partition
    The GPU partition is for jobs that will use **one or more entire GPU nodes** (up to **64** GPUs, maximum runtime: **48 hours**)

- **GPU type:**

Node Type	Total # of nodes	# GPUs per node	Memory per GPU	RAM per node
V100-32	**24 Tesla V100-32GB SXM2**	**8**	**32 GB**	**512 GB**
	1 DGX-2	16	32 GB	1.5 TB
V100-16	8 V100-16GB	8	16 GB	192 GB

How to run jobs on Bridges-2

- **See Bridges-2 user guide for details:**
  https://www.psc.edu/resources/bridges-2/user-guide/#running-jobs

  - **Batch Mode** (https://www.psc.edu/resources/bridges-2/user-guide/#batch-jobs)

    Using slurm scripts to submit jobs to the queue so that they will run as soon as resources are available.

  - **Interactive Sessions** (https://www.psc.edu/resources/bridges-2/user-guide/#interactive-sessions)

    Where you type commands and receive output back to your screen as the commands complete. Best for debugging and short test jobs (maximum requested time is up to **8 hours**).

  - **OnDemand** (https://www.psc.edu/resources/bridges-2/user-guide/#ondemand)

    A web browser interface that allows you to run interactively, or create, edit and submit batch jobs and also provides a graphical interface to tools like RStudio, Jupyter notebooks, and IJulia

How to set up the environments for AI/ML applications

- **See Bridges-2 user guide for details:**
  - **PSC Pre-Built AI module** (https://www.psc.edu/resources/bridges-2/user-guide/#ai-environments)
    Pre-built AI environment (Anaconda-based) including several popular AI/ML/BD packages.
  - **NVIDIA NGC containers** (https://www.psc.edu/resources/software/singularity/)
    Containers developed by NVIDIA that are performance-optimized and ready to deploy for AI/ML applications on GPU-powered systems.
  - **Create your own Conda environment/custom AI environment**
    https://www.psc.edu/resources/bridges-2/user-guide/#using-a-conda-module-environment
    https://www.psc.edu/resources/bridges-2/user-guide/#ai-environments
  - **Create your own Singularity container**
    (https://www.psc.edu/resources/bridges-2/user-guide/#using-singularity-containers)

Ways to run deep learning jobs

Interactive Sessions

- **Commands to start interactive sessions:**
  - For GPU-shared partition:

    `interact --partition GPU-shared --gres=gpu:type:n -t time`

    - example: `interact -p GPU-shared --gres=gpu:v100:2 -t 2:00:00`
  - For GPU partition:

    `interact --partition GPU --gres=gpu:type:n –N x -t time`

    - example: `interact -p GPU --gres=gpu:v100-32:8 -N 1 -t 1:00:00`

- **Rules:**
  - **`--partition`**: `GPU-shared` or `GPU`
  - **`--gres=gpu:type:n`**
    - **`type`:** `v100-32` or `v100-16`. Use `v100` if node type is not specified.
    - **`n`: number of GPUs per node**. For `GPU` partition, `n` must be either 8 or 16 for DGX-2. For `GPU-shared` partition, `n` should be less than 4.
  - **`-t`:** requested walltime, in the format HH:MM:SS
  - **`-N/--nodes`:** number of nodes
- See https://www.psc.edu/resources/bridges-2/user-guide/#gpu-partitions for more details

Batch mode

Example slurm script (NGC container)

```
#!/bin/bash
#SBATCH -p GPU-shared
#SBATCH -t 2:00:00
#SBATCH --gpus=v100:4
#SBATCH --account=xxxxxxx     # Please change it to your allocation ID

#type 'man sbatch' for more information and options
#this job will ask for 4 V100 GPUs for 2 hours (node type not specified)

#echo commands to stdout
set -x

# move to working directory
cd /ocean/projects/groupname/username/path-to-directory

#run the program which is already in your project space
singularity exec --nv /ocean/containers/ngc/pytorch/pytorch_latest.sif python3 pytorch_test.py
```

Rules:

Similar to interactive sessions, but use **`--gpus=type:n`** instead to specify **total number of GPUs** for `n` and node types.

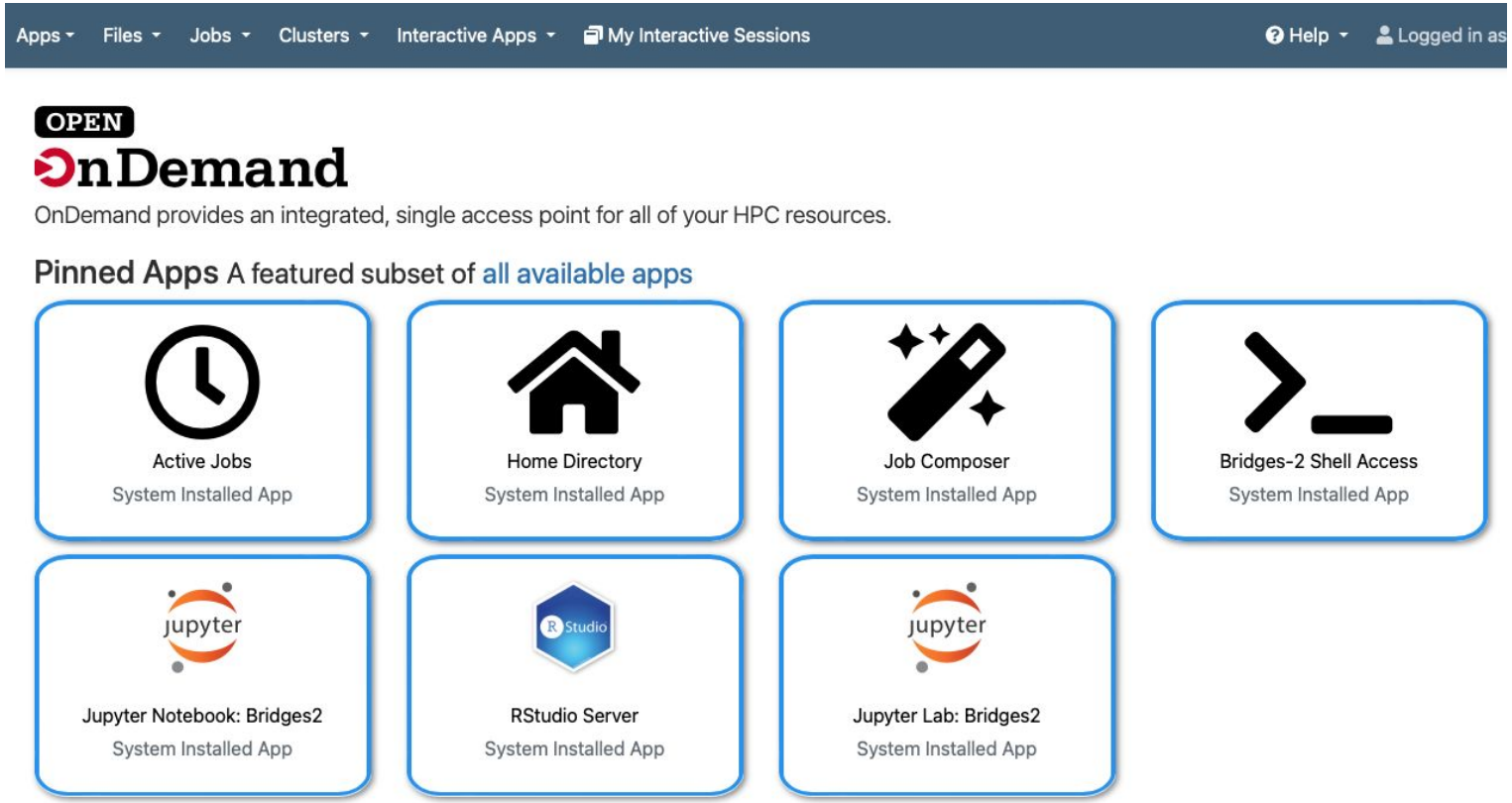
To submit slurm script, type `sbatch name_of_your_script`

See https://www.psc.edu/resources/bridges-2/user-guide/#batch-jobs about sbatch commands and options

See https://www.psc.edu/resources/bridges-2/user-guide/#gpu-partitions for more details about GPU batch jobs.

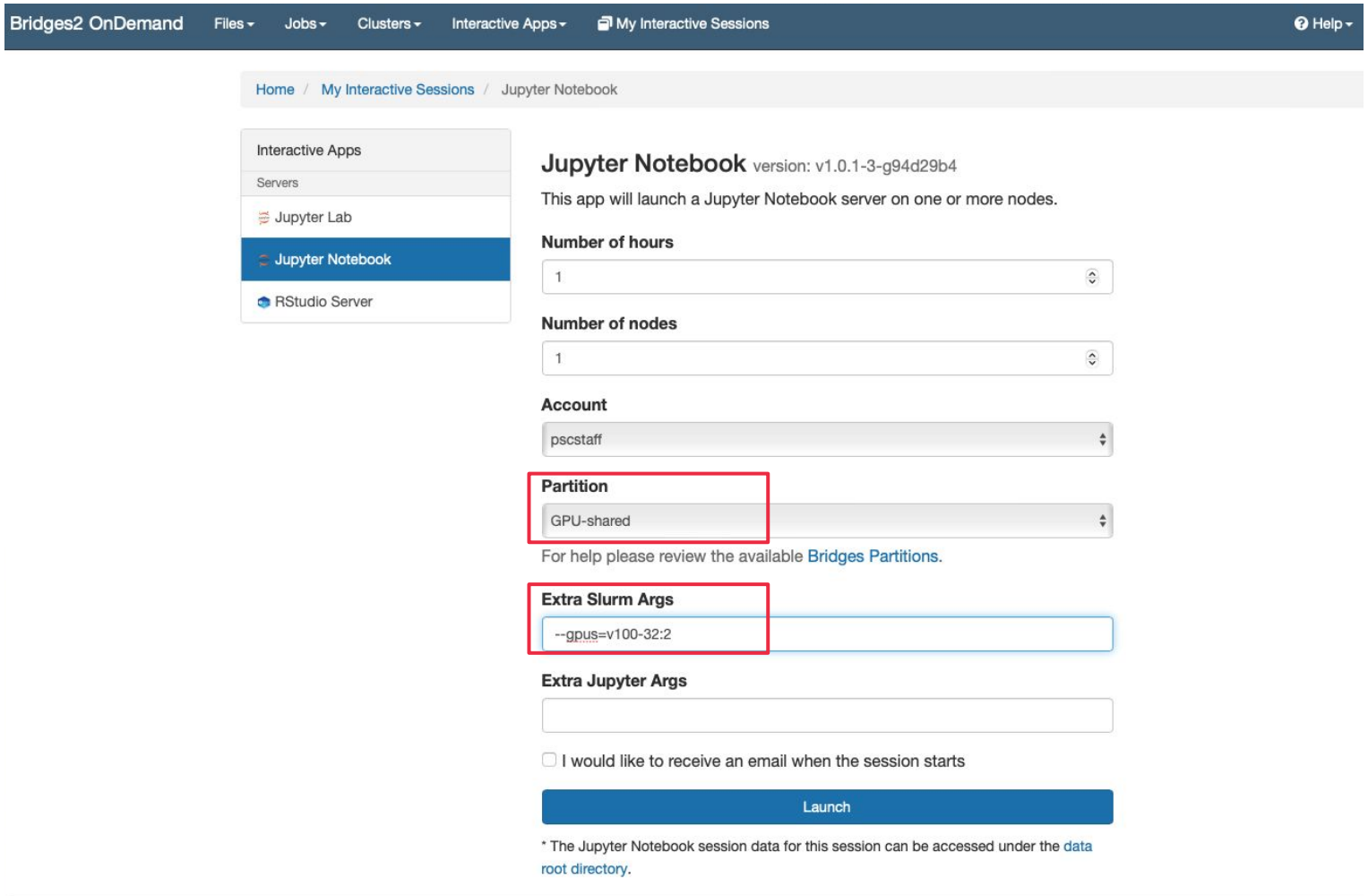
Using OnDemand to run Jupyter notebooks

- Open https://ondemand.bridges2.psc.edu via a web browser. Enter your PSC username and password.
- Once logged in, click on “Jupyter Notebook: Bridges2” or go to “Interactive Apps -> Jupyter Notebook”



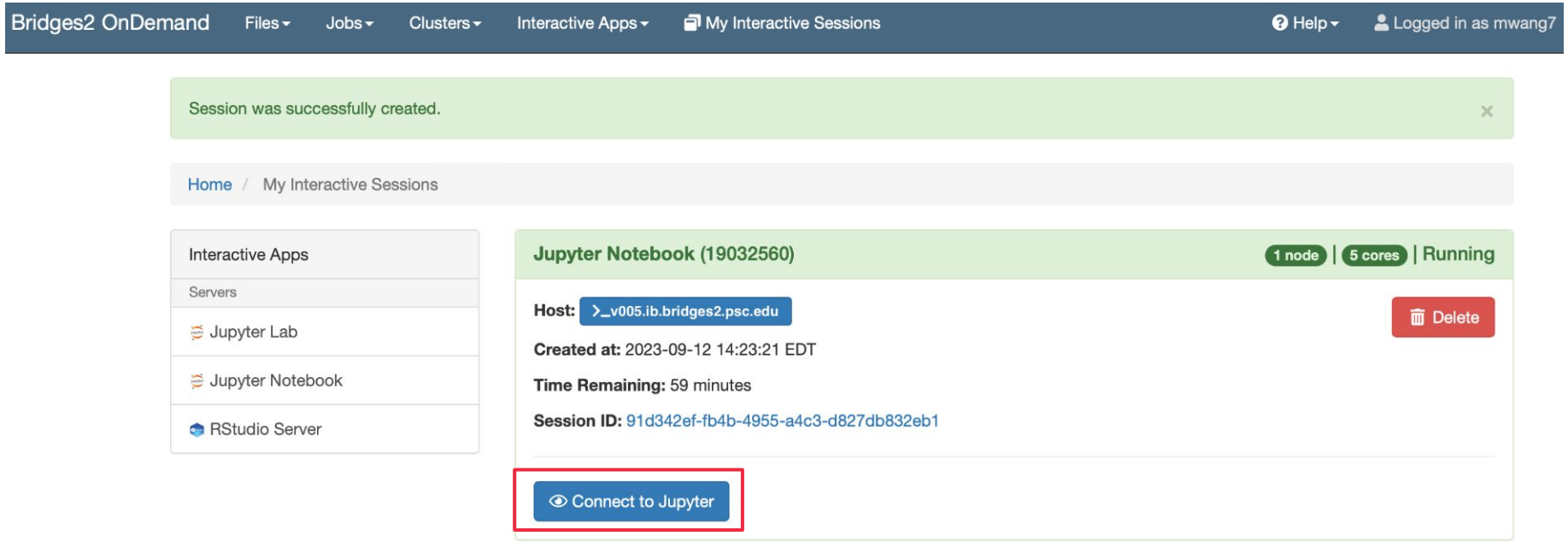
OnDemand

- Enter the information about your job, such as requested time, number of nodes, partition, and specify the number of GPUs using the “Extra Slurm Args” column (similar to typical batch job).
- Click “Launch” to submit the job



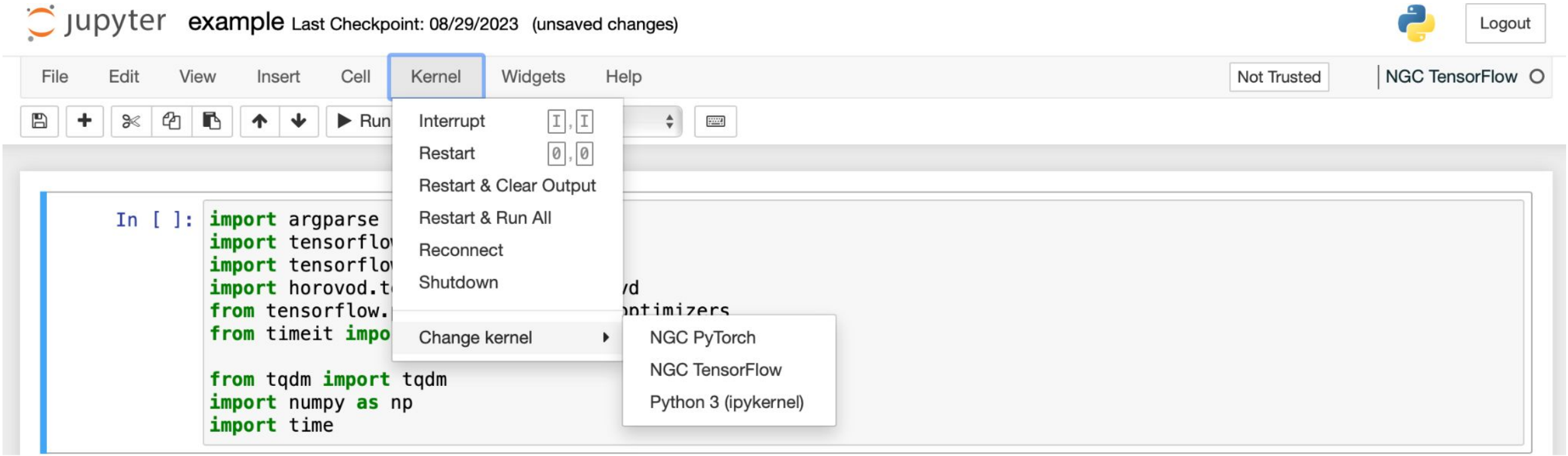
OnDemand

- Once the job starts, click the “Connect to Jupyter” to launch the Jupyter notebook interface



OnDemand

- You can use NGC containers for Pytorch and Tensorflow (latest) by selecting them from the "Kernel -> Change kernel -> NGC PyTorch/NGC TensorFlow"
- To use custom conda environment/containers, please check the Bridges-2 User Guide: https://www.psc.edu/resources/bridges-2/user-guide/#custom-env



Demo:

Performing model finetuning/inference for Llama 2-7B, Llama 3-8B and Gemma 7B with LoRA

See https://github.com/pscedu/bridges2-examples/tree/main/bridges2-llm-examples for detailed instructions and scripts/Jupyter notebooks

Summary

- The recent release of open LLMs such as Llama and Gemma provides a big step towards democratizing LLM usage.
- There are various techniques for fine-tuning LLMs with limited computational resources, such various Parameter-efficient fine-tuning (PEFT) techniques, quantization, and fully shared data parallel methods.
- For Bridges-2 GPU partition, it is best to utilized the V100 32GB GPUs to work with LLMs. Bridges-2 also provide various way to run jobs, such as batch/interactive mode and OnDemand web interface to easily set up and run Jupyter notebooks.
- We provide examples and instructions for doing model finetuning/inference with Llama/Gemma on Bridges-2: https://github.com/pscedu/bridges2-examples/tree/main/bridges2-llm-examples
- Please email **help@psc.edu** with any general questions regarding Bridges-2. You can also reach me by email **mwang7@psc.edu**.