



# Enabling LWA Science with Bifrost

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LWA Users Meeting  
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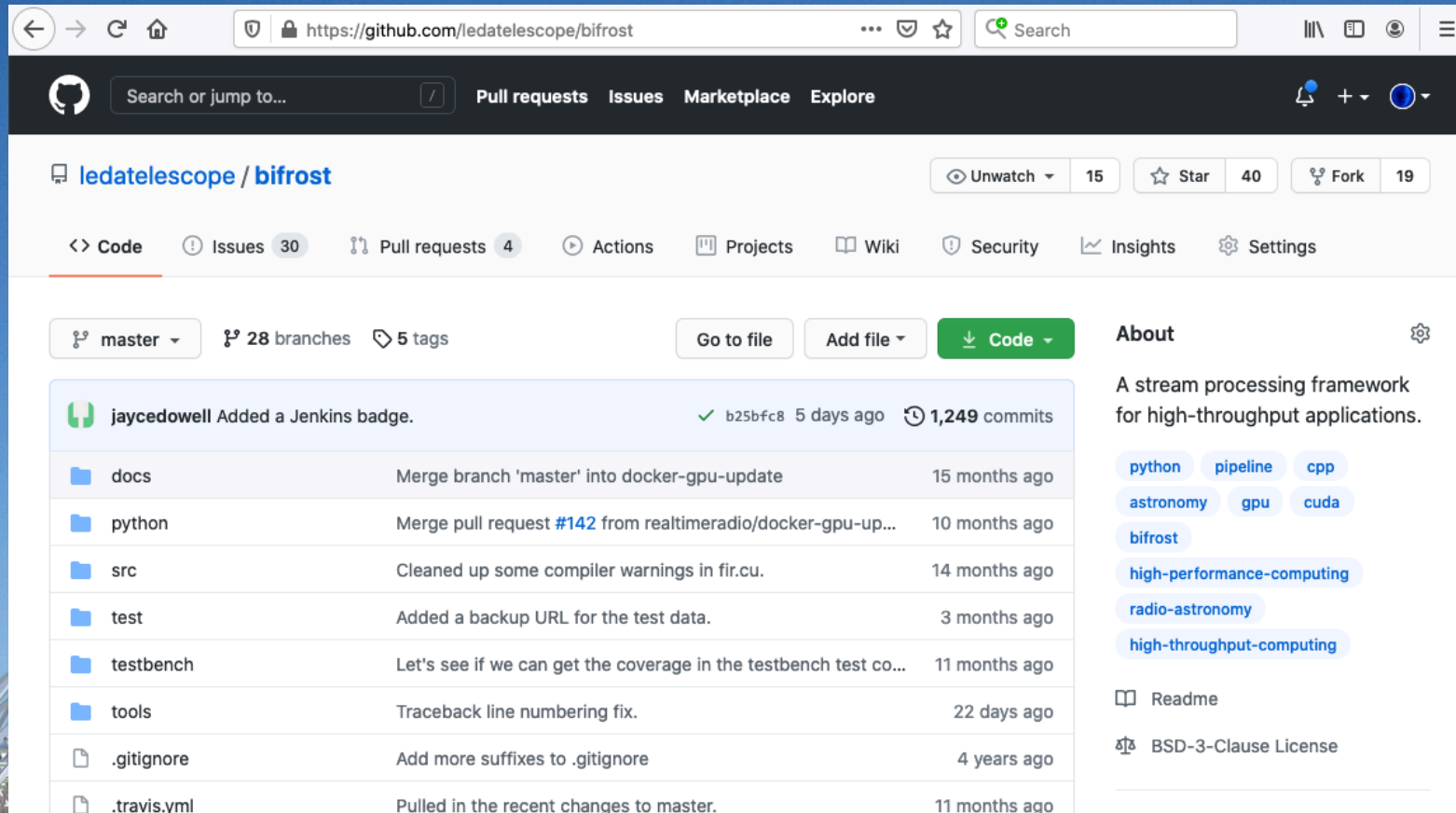
# What is Bifrost

- C++/Python framework for building CPU and GPU-based pipelines
  - Used for building hybrid FPGA/GPU systems or stand-alone pipelines
  - GPU support through the CUDA API
  - Cranmer et al. (2017, JAI, 1750007)



# What is Bifrost

<https://github.com/ledatelescope/bifrost>  
Or search for “leda telescope bifrost”



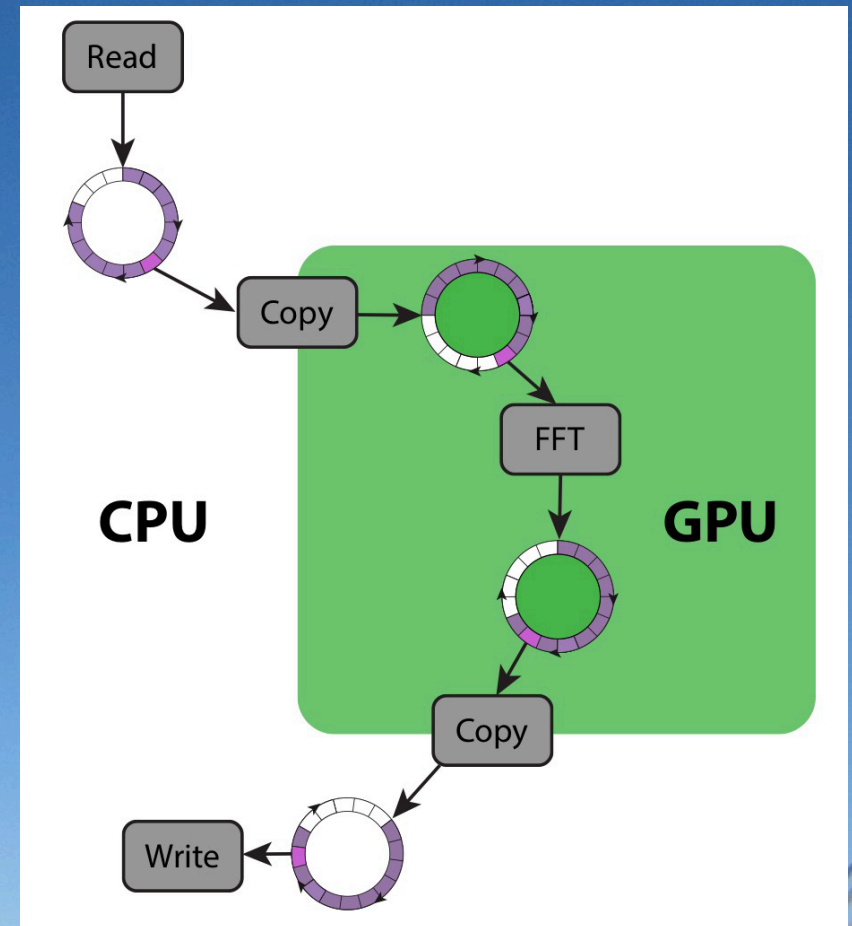
The screenshot shows the GitHub repository page for `ledatelescope/bifrost`. The browser address bar displays `https://github.com/ledatelescope/bifrost`. The repository name is `ledatelescope / bifrost`, with 15 Unwatch, 40 Star, and 19 Fork actions. The repository has 30 Issues, 4 Pull requests, and 1,249 commits. The main content area shows a list of recent commits and files. The commit history includes:

File	Commit Message	Time
docs	Merge branch 'master' into docker-gpu-update	15 months ago
python	Merge pull request #142 from realtimeradio/docker-gpu-up...	10 months ago
src	Cleaned up some compiler warnings in fir.cu.	14 months ago
test	Added a backup URL for the test data.	3 months ago
testbench	Let's see if we can get the coverage in the testbench test co...	11 months ago
tools	Traceback line numbering fix.	22 days ago
.gitignore	Add more suffixes to .gitignore	4 years ago
.travis.yml	Pulled in the recent changes to master.	11 months ago

The right sidebar contains the **About** section, which describes Bifrost as a stream processing framework for high-throughput applications. It lists tags such as `python`, `pipeline`, `cpp`, `astronomy`, `gpu`, `cuda`, `bifrost`, `high-performance-computing`, `radio-astronomy`, and `high-throughput-computing`. Below the tags, there are links for `Readme` and `BSD-3-Clause License`.

# Bifrost Concepts

- Blocks
  - “Atomic unit” of processing
  - Independent thread
- Ring Buffers (Rings)
  - Emulates wrap-around in memory
  - Assigned to a specific “space”
- Pipelines
  - Combination of the above



# Bifrost Design

- Python frontend wraps fast C++/CUDA backend
- Backend:
  - “Ring buffer” used for inter—block communication
  - Common type definitions and “BFarray” generic data structure
  - Several common modules implemented
    - FFT, matrix-matrix multiplication, FIR filters



# Bifrost Design

- Python frontend wraps fast C++/CUDA backend
- Frontend:
  - Blocks and Pipelines are Python object abstractions for the backend
  - ctypes wraps all C calls
  - ndarray object for memory management (span of ring buffer)
    - Compatibility with many numpy functions, matplotlib, etc.

# Bifrost Advantages

- Metadata describes the units of ring buffer dimensions; used in algorithms (e.g., dedispersion)
- Multi-sequence ring buffers, useful for different observations
  - The metadata will propagate down the pipeline

81/53



# Bifrost Advantages

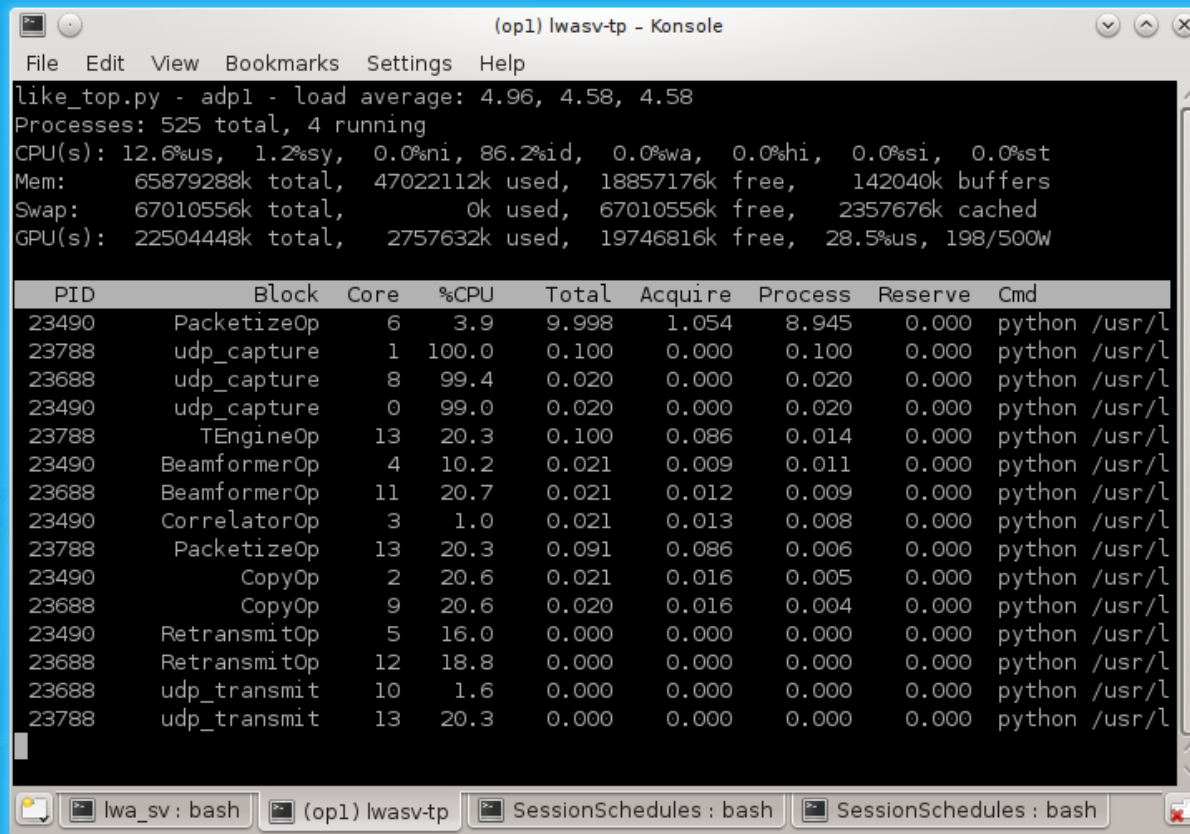
- Time-tagged sequences in ring buffers
  - Can dump section of data to disk based on time range, observation name
    - Useful for detections of transient phenomena
- Many astronomy and general processing blocks already built





# Bifrost Advantages

- Built-in logging and performance benchmarking



(op1) lwasv-tp - Konsole

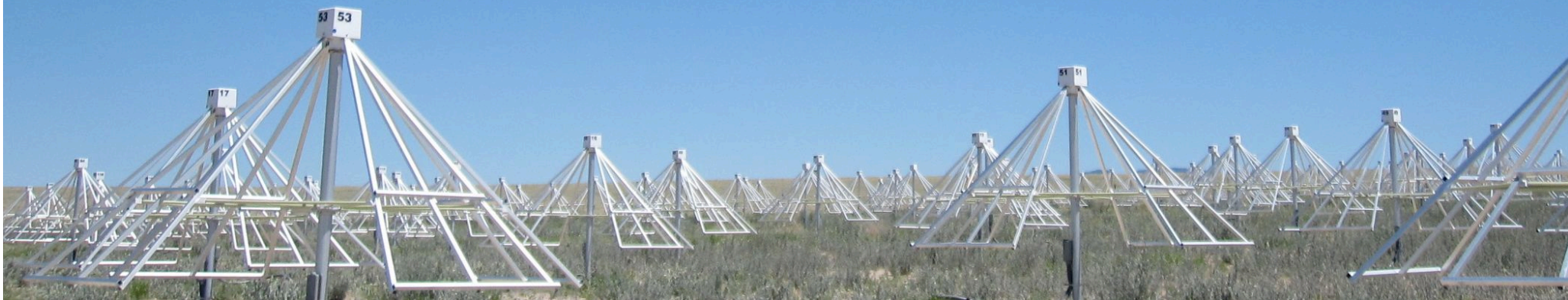
File Edit View Bookmarks Settings Help

like\_top.py - adp1 - load average: 4.96, 4.58, 4.58  
Processes: 525 total, 4 running  
CPU(s): 12.6%us, 1.2%sy, 0.0%ni, 86.2%id, 0.0%wa, 0.0%hi, 0.0%si, 0.0%st  
Mem: 65879288k total, 47022112k used, 18857176k free, 142040k buffers  
Swap: 67010556k total, 0k used, 67010556k free, 2357676k cached  
GPU(s): 22504448k total, 2757632k used, 19746816k free, 28.5%us, 198/500W

PID	Block	Core	%CPU	Total	Acquire	Process	Reserve	Cmd
23490	PacketizeOp	6	3.9	9.998	1.054	8.945	0.000	python /usr/l
23788	udp_capture	1	100.0	0.100	0.000	0.100	0.000	python /usr/l
23688	udp_capture	8	99.4	0.020	0.000	0.020	0.000	python /usr/l
23490	udp_capture	0	99.0	0.020	0.000	0.020	0.000	python /usr/l
23788	TEngineOp	13	20.3	0.100	0.086	0.014	0.000	python /usr/l
23490	BeamformerOp	4	10.2	0.021	0.009	0.011	0.000	python /usr/l
23688	BeamformerOp	11	20.7	0.021	0.012	0.009	0.000	python /usr/l
23490	CorrelatorOp	3	1.0	0.021	0.013	0.008	0.000	python /usr/l
23788	PacketizeOp	13	20.3	0.091	0.086	0.006	0.000	python /usr/l
23490	CopyOp	2	20.6	0.021	0.016	0.005	0.000	python /usr/l
23688	CopyOp	9	20.6	0.020	0.016	0.004	0.000	python /usr/l
23490	RetransmitOp	5	16.0	0.000	0.000	0.000	0.000	python /usr/l
23688	RetransmitOp	12	18.8	0.000	0.000	0.000	0.000	python /usr/l
23688	udp_transmit	10	1.6	0.000	0.000	0.000	0.000	python /usr/l
23788	udp_transmit	13	20.3	0.000	0.000	0.000	0.000	python /usr/l

lwa\_sv : bash (op1) lwasv-tp SessionSchedules : bash SessionSchedules : bash

# How LWA is Using Bifrost



# LWA-SV



- ADP used for the backend
  - hybrid FPGA/GPU architecture
- Four data products:
  - TBF – 4+4-bit complex spectra, two tunings, up to a few seconds
  - TBN – same as LWA1
  - DRX – same as LWA1
  - COR – correlator visibility output



# LWA-SV



- Up to 19.6 MHz per tuning
  - TBF and wide band correlator running at 19.8 MHz
- Two Beams
  - Not fully independent; tunings are tied together
- Orville Wideband Imager
  - Provides LWA-TV 2



# OVRO-LWA

- 352 dipoles
- Next generation LWA hardware
- See Marin's talk



# LWA-NA



- Prototype LWA mini station for the swarm
  - 64 dipoles
- Builds off OVRO-LWA hardware/software



# Progress and Plans

- Current development focused on packet capture
  - New packet capture framework to make it easier to add new formats – both input and output
  - Support for InfiniBand Verbs
- Also want to add an interface for plugins and improve usability

# Progress and Plans

- Work funded through NSF Cyberinfrastructure for Sustained Scientific Innovation grant
- Will support development as well as help for users wanting to get started with Bifrost
  - Initially focused on radio astronomy but interested in applications from other domains
  - Includes funding for a postdoc





# For More Information

- Bifrost
  - <https://github.com/ledatelescope/bifrost>
  - <https://ledatelescope.github.io/bifrost/>
  - [https://github.com/ledatelescope/bifrost\\_tutorial](https://github.com/ledatelescope/bifrost_tutorial)
  - <https://arxiv.org/abs/1708.00720>

