BIGCAT Overview

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CABB

- Installed 2009
- 2x 2 GHz (dual pol) continuum bandwidth
  - 1 MHz default spectral resolution
  - Tunable independently across an 8 GHz IF
- Zoombands for spectral line astronomy
  - 16x 1 MHz with 2048 points (0.49 kHz)
  - 16x 64 MHz with 2048 points (31.25 kHz)
- 2x 64 MHz VLBI tied array bandwidth

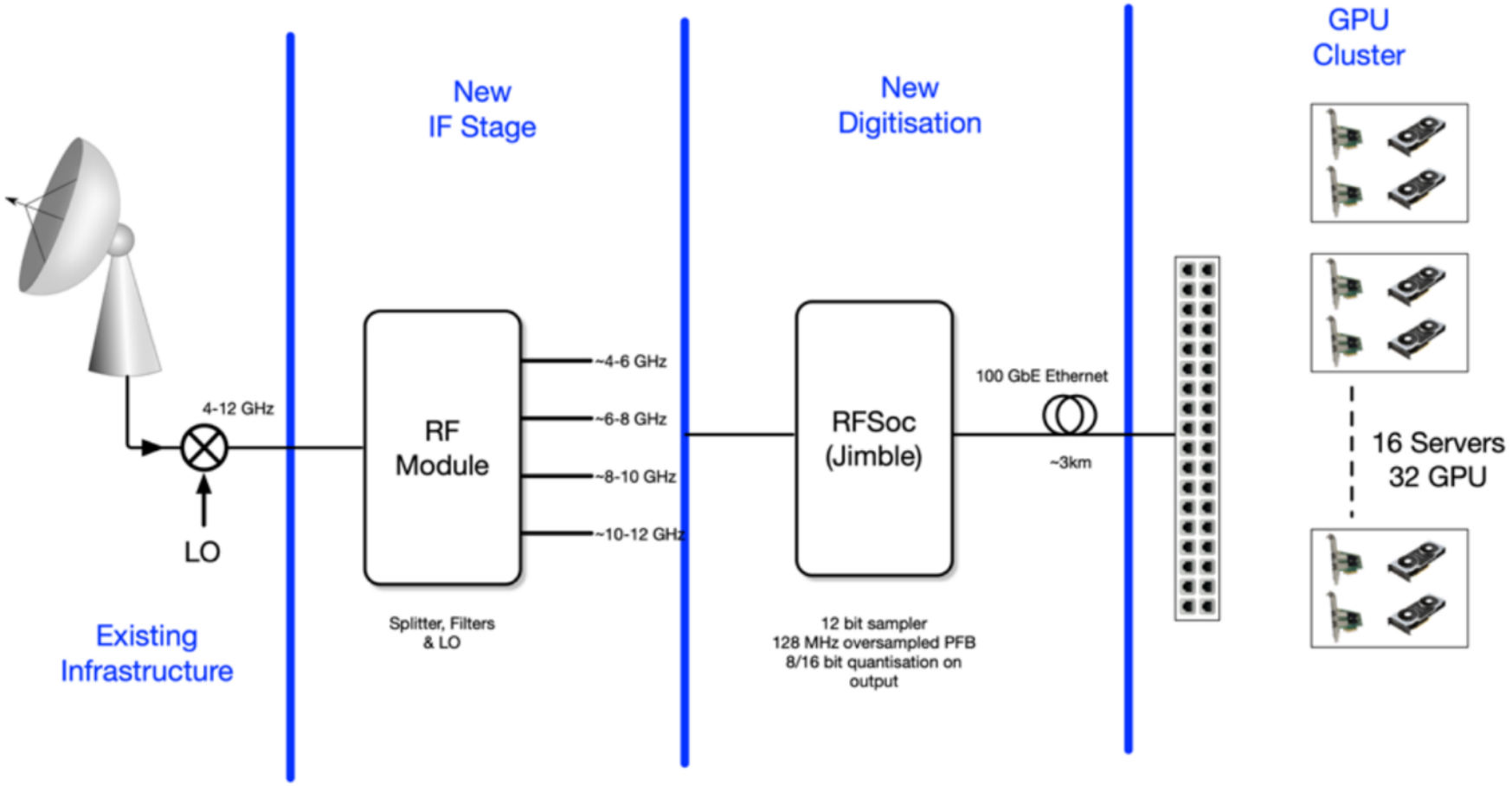
ATCA-BIGCAT upgrade

- BIGCAT: Broadband Integrated Gpu Correlator for ATca
  - Replacement of CABB digitisers and correlator with a hybrid FPGA+GPU backend
- LIEF funded, lead by WSU (PI Ray Norris)
- Key aspects of BIGCAT:
  - Double instantaneous bandwidth to ~8 GHz
  - Flexible spectral resolution
  - Improved reliability
  - More flexibility:
    - Many more options wrt. frequency resolution and integration times
    - Ability to change quickly between different observing modes
  - More adaptable to automated observing (e.g. rapid ToO follow-up)
  - Retain standard CABB features (e.g. mosaicing)

BIGCAT

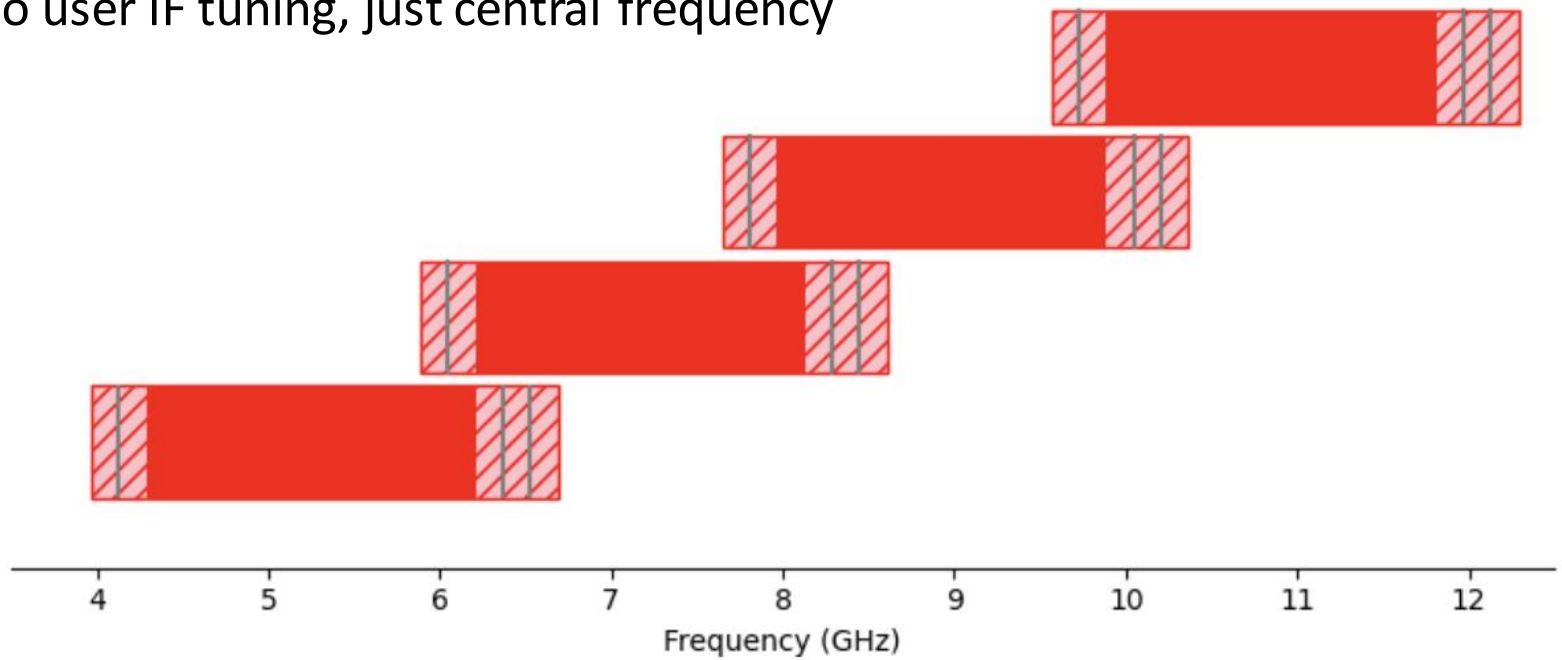
- Replace last stage of analogue IF
  - Retain existing 8 GHz IF stage
- All new digital system
- Hybrid FPGA/GPU solution
  - Xilinx RFSoC bases digitizer and coarse filterbank
  - Stream data over standard 100 Gbps Ethernet from antenna
  - Limited configurations
- “Astronomical” processing done on GPU
  - Fine channelisation
  - Geometric correction (”fringe rotation”)
  - Cross correlation
  - RFI removal (eventually)

ATCA-BIGCAT signal chain



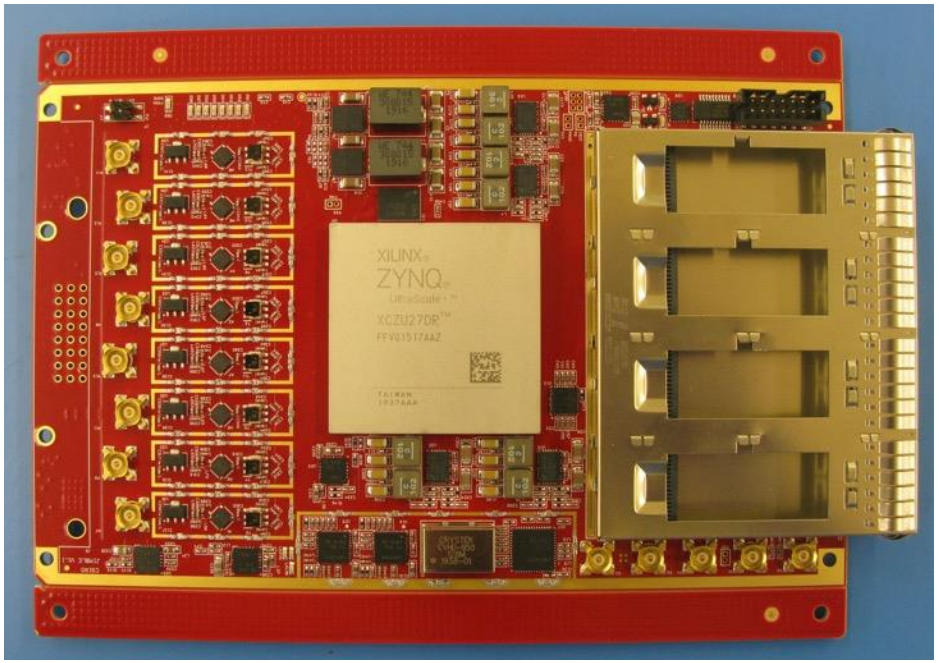
BIGCAT Frequency Bands

- 4 x 1.92 GHz IFs stitched together to form a contiguous 7.68 GHz bandwidth
- Limited tunability in 160 MHz steps
- Single ”8 GHz” IF chunk for higher frequencies
- No user IF tuning, just central frequency



BIGCAT Digitisers

- 2 GHz IFs sampled using Xilinx RFSoC ADC
  - 8 samplers and FPGA fabric on single chip
- Built into CASS “Jimble board”
  - 4x 2 GHz per board
  - 2x 100 GbE output
- Jimble common to CryoPAF project
  - Plan to upgrade for Parkes UWB systems using same firmware as BIGCAT

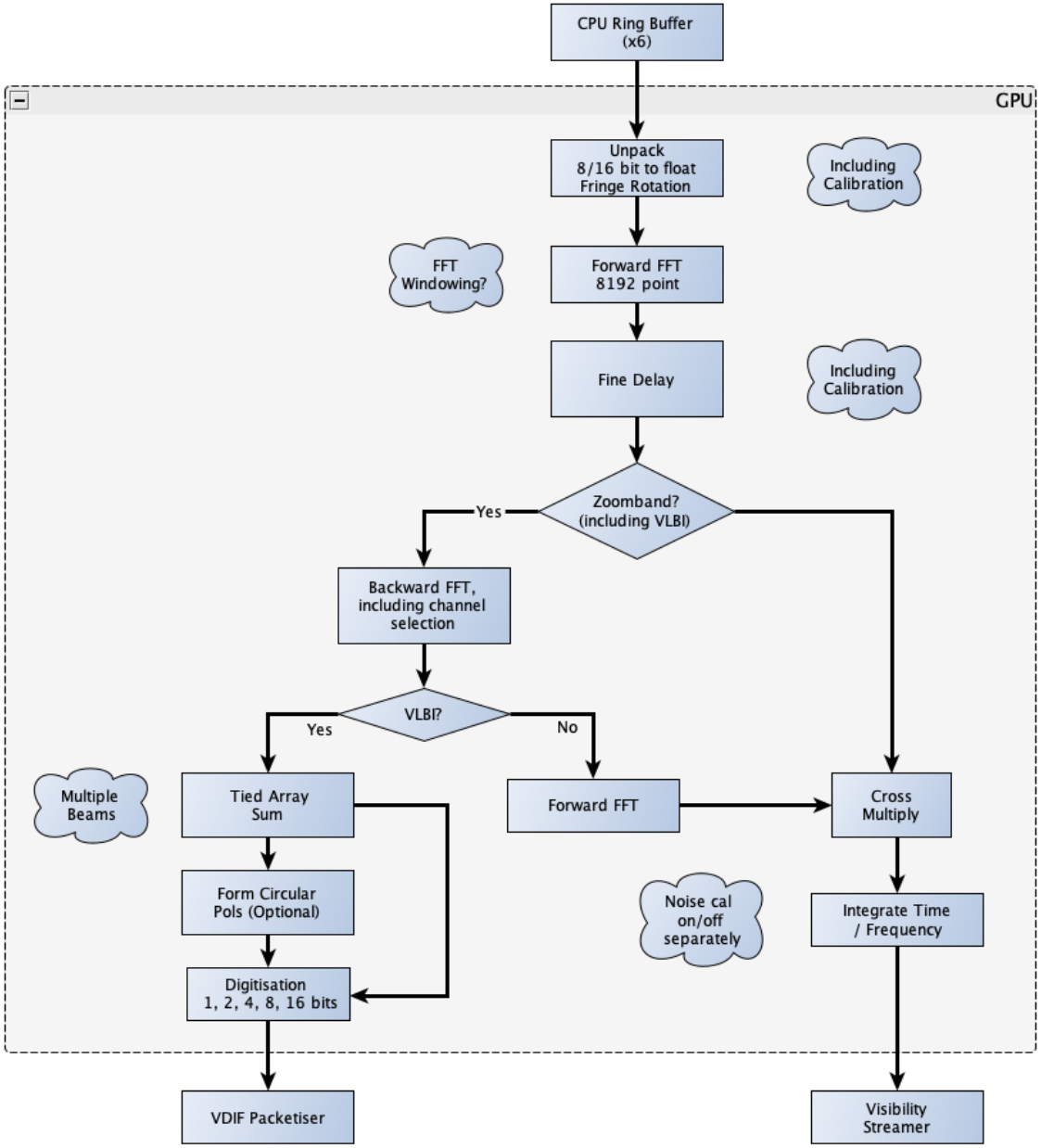


Jimble Specs

- 12 bit sampling (4096 MS/sec)
- 128 MHz oversampled polyphase filterbank
  - 32/27 oversampling ratio (151.7 MHz effective bandwidth/channel)
- 2x 100 Gbps Ethernet output (CODIF)
- 8 or 16 bit quantisation (complex, 8+8/16+16)
  - 8 bit required to get 8 GHz bandwidth
  - 16 bit 1-3 GHz, 8 bit for higher frequencies)

GPU Backend

- GPU backend 16 servers, each with 2 GPU and 2x100 GbE
  - RTX 3080 current plan (High end gaming card)
  - 58 Gbps/GPU (without reference antenna)
- Each 128 MHz coarse frequency channel processed independently
  - Same frequencies from all telescopes (ATCA + reference) to single GPU
    - No GPU cross connect planned
    - 2 coarse channels/GPU (except LS)
- Plan to allow bespoke “user” processing on GPU


CPU Ring Buffer (x6)
GPU
Unpack 8/16 bit to float Fringe Rotation
Including Calibration
FFT Windowing?
Forward FFT 8192 point
Fine Delay
Including Calibration
Zoomband? (including VLBI)
Yes
Backward FFT, including channel selection
VLBI?
Yes
No
Multiple Beams
Tied Array Sum
Forward FFT
Cross Multiply
Form Circular Pols (Optional)
Noise cal on/off separately
Integrate Time / Frequency
Digitisation 1, 2, 4, 8, 16 bits
VDIF Packetiser
Visibility Streamer

BIGCAT Frequency Resolution

- Standard frequency resolution across full 8 GHz 18.5 kHz:
  - 8192 frequency points across every coarse channel
  - Average after integration to the spectral resolution required
  - Suitable for most thermal lines
- Flexible zoombands available with higher spectral resolution
  - E.g. 0.1 kHz easily achieved over limited bandwidth
- Number of zoombands limited by GPU compute and output data rate
  - Main limit total bandwidth of zooms, so trade #zooms for bandwidth
  - Zooms can have separate bandwidth and spectral resolution
- ***How to expose flexibility to user?***
- All observations will get low spectral resolution continuum data across the full bandwidth.

VLBI (Voltage Streaming)

- VLBI requires tied array voltage beam
  - Assume any other “voltage” users will use VLBI mechanism
- VLBI requirements talk tomorrow
  - Full bandwidth available
    - Recorded bandwidth configurable
  - Multiple steerable tied array beams
- 16 Gbps recording available initially
  - Higher rates possible with purchase of more VLBI recorders

Advanced Modes

- No planning yet for “advanced” modes
  - Pulsar binning
    - Coherent de-dispersion?
  - RFI mitigation
    - Flag tables
    - Adaptive filters
    - Clipping on high time and frequency resolution data
  - FRB mode?
    - Blind search marginal
    - Repeater follow up?
  - Space craft tracking and asteroid bistatic radar built in?
    - Or just supply raw voltage stream from tied array
    - Near field effects
  - Fast dump visibilities?

Control

- RF control will depend on “pre-canned” setups for IF
  - Standard mode will presumably be 7.6 GHz continuous frequency coverage
  - Option for modes with slightly wider frequency coverage but some ”gaps” between 2 GHz IFs
  - Tunable central frequency for mm receivers (15+ GHz)
  - Cannot observe frequencies > 8 GHz separated
- Setup entirely included in caobs schedule
  - No more “prog”
- Infinite setup possibilities – how to allow user customization but ensure tested setup
  - Zoombands particularly
- No plan to replace caobs

Feedback and questions:

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BIGCAT overview: https://www.atnf.csiro.au/people/Chris.Phillips/BIGCAT_Overview.pdf

Thank you

CSIRO Astronomy and Space Science
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