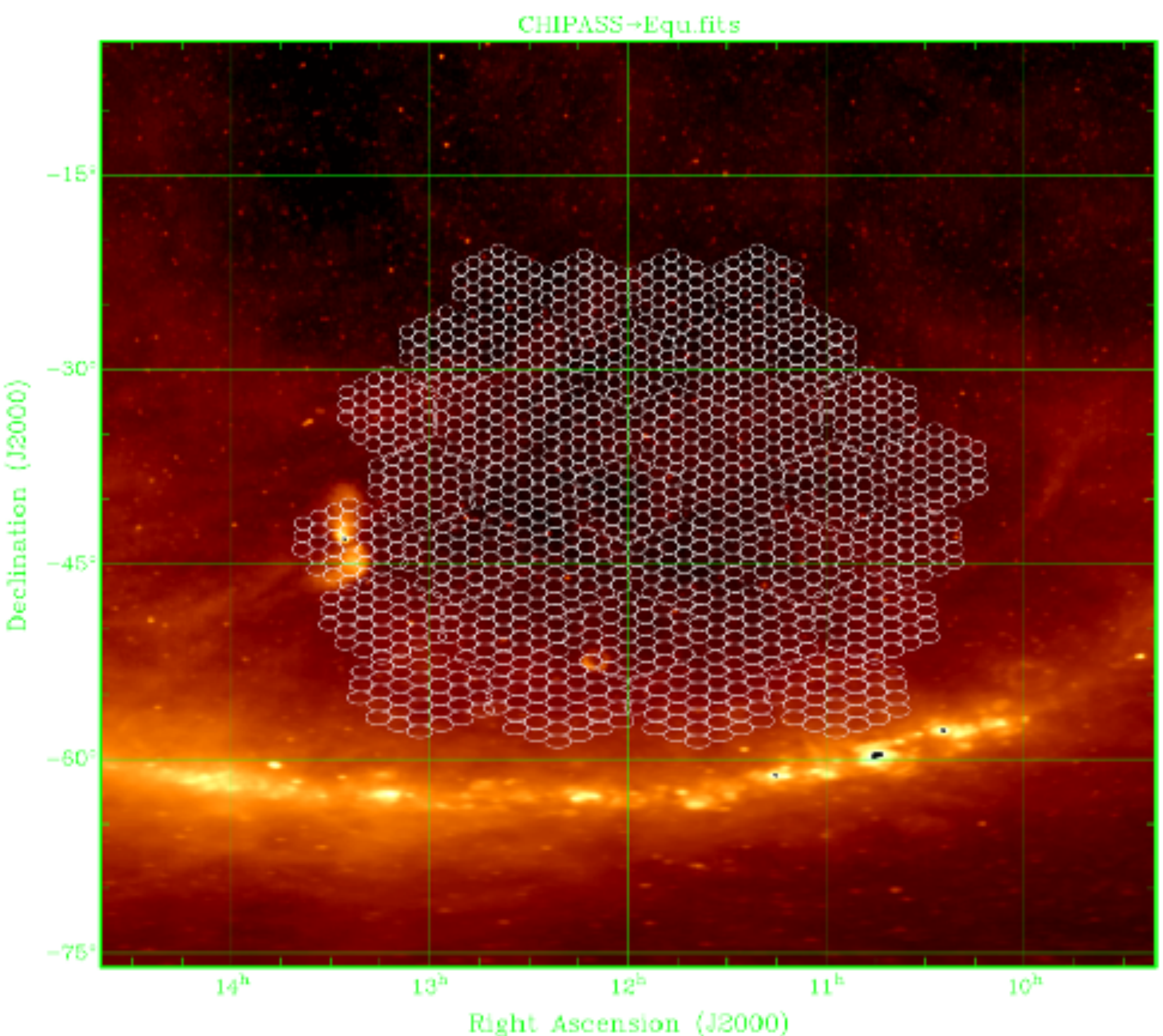
ASKAP instrumentation and future directions

Keith Bannister - Principal Research Engineer
CSIRO Astronomy and Space Science



Thanks!

- Andrew Brown (ATNF)
- John Tuthill (ATNF)
- Mike Pilawa (ATNF)
- Aidan Hotan (ATNF)
- Maxim Voronkov (ATNF)
- Mieke Bouwhuis (ATNF/Nikhef)
- Ron Ekers (ATNF)
- Ryan Shannon (ATNF/Curtin/Swinburne)
- Stefan Oslowski (Swinburne)
- Wael Farah (Swinburne)
- J-P Macquart (Curtin)
- Clancy James (Curtin)
- CAASTRO for the new machine

Overview

- Current capabilities and observations
- Planned capabilities and observations

Basic page *Register of astronomical bets* has been updated.

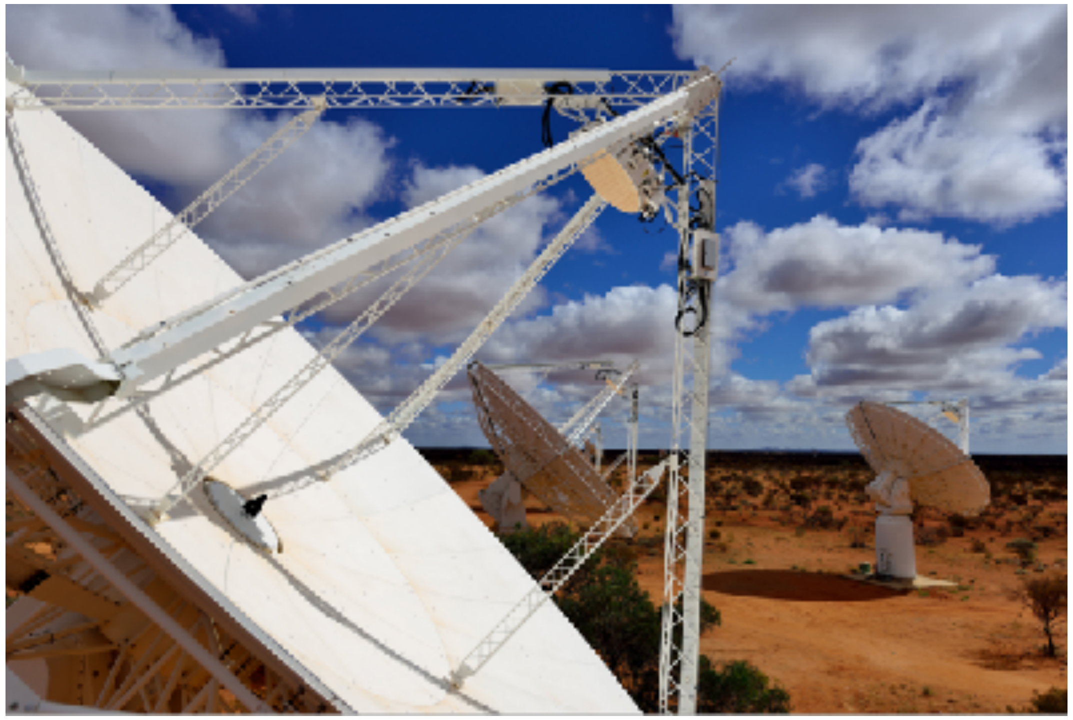
View | Edit

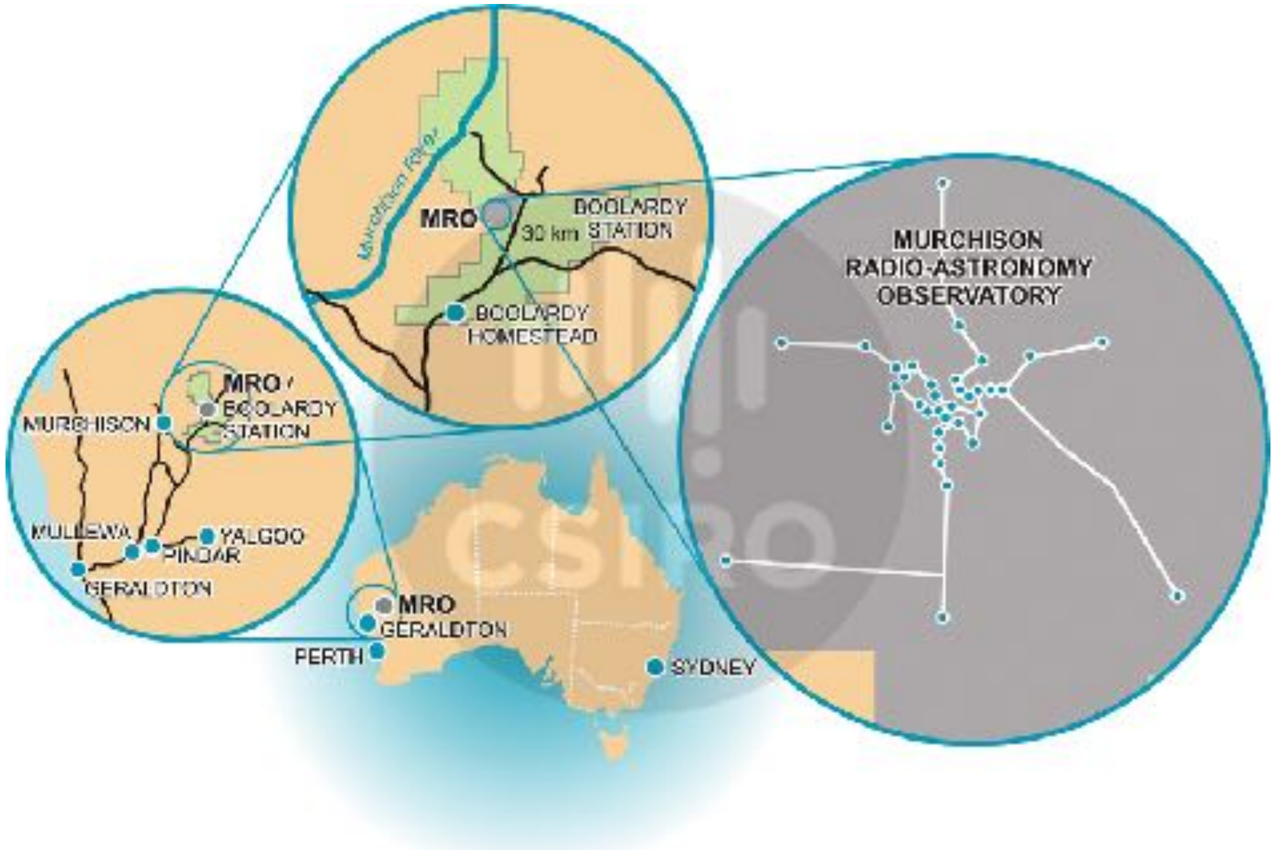
Register of astronomical bets

Bet	For	Against	Made when & where	Wager	Status
Variance imaging will detect a previously unknown pulsars	Ron Ekers	Simon Johnston		Bottle of wine	
FRBs are real	Paul Groot	Shri Kulkarni		$1000 USD	Wone. Paid by Shri at B&E 2016
ASKAP 12-antenna Fly's-eye rate will be 4/day	Keith Bannister	Jean-Pierre Macquart	Early 2017	J-P: Bottle of fine red wine KB: Bottle of fine home brew	Lost. KB not yet paid.
Black Holes exist	Kip Thorne	Steven Hawking	1974	Magazine subscriptions	Not yet settled

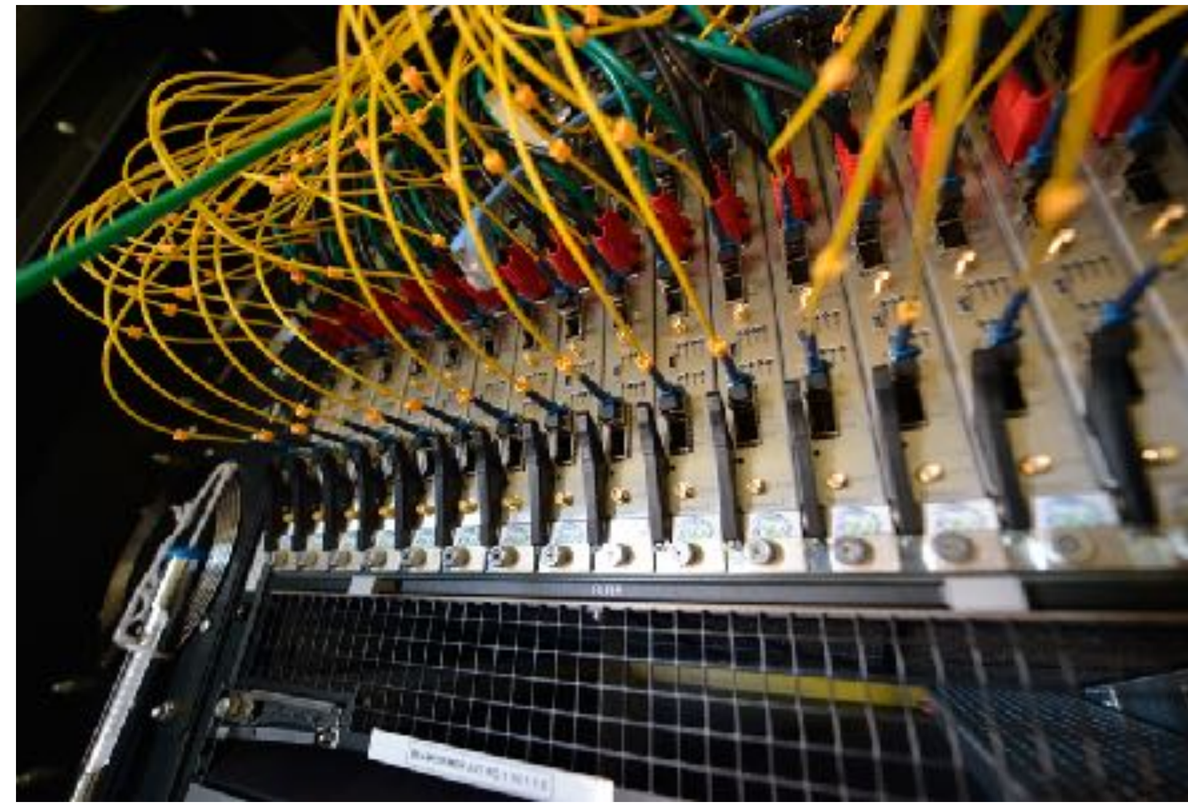
ASKAP will be…

- 36 antennas
- 36 beams = ~ 30 deg^2 per antenna
- Tuning: 0.7-1.8 GHz
- 336 x 1 MHz channels
- Autocorrelations with ~1ms time resolution
- 10” synthesised beam at 1.4 GHz





ASKAP is… (Feb 2018)



- “Main Array” - 16 antennas with all equipment, connected to the correlator
- “Commissioning array” - 8 antennas, used for single-dish work only (e.g. CRAFT).
- Total: 36 PAFs on antennas, 24 backends.
- All other parameters as per design

ASKAP Early Science
WALLABY M83 field continuum map

Daytime observations taken on 31 Dec 2016
10 antennas, 36 beams, 192 MHz bandwidth,
1344.5 MHz central frequency

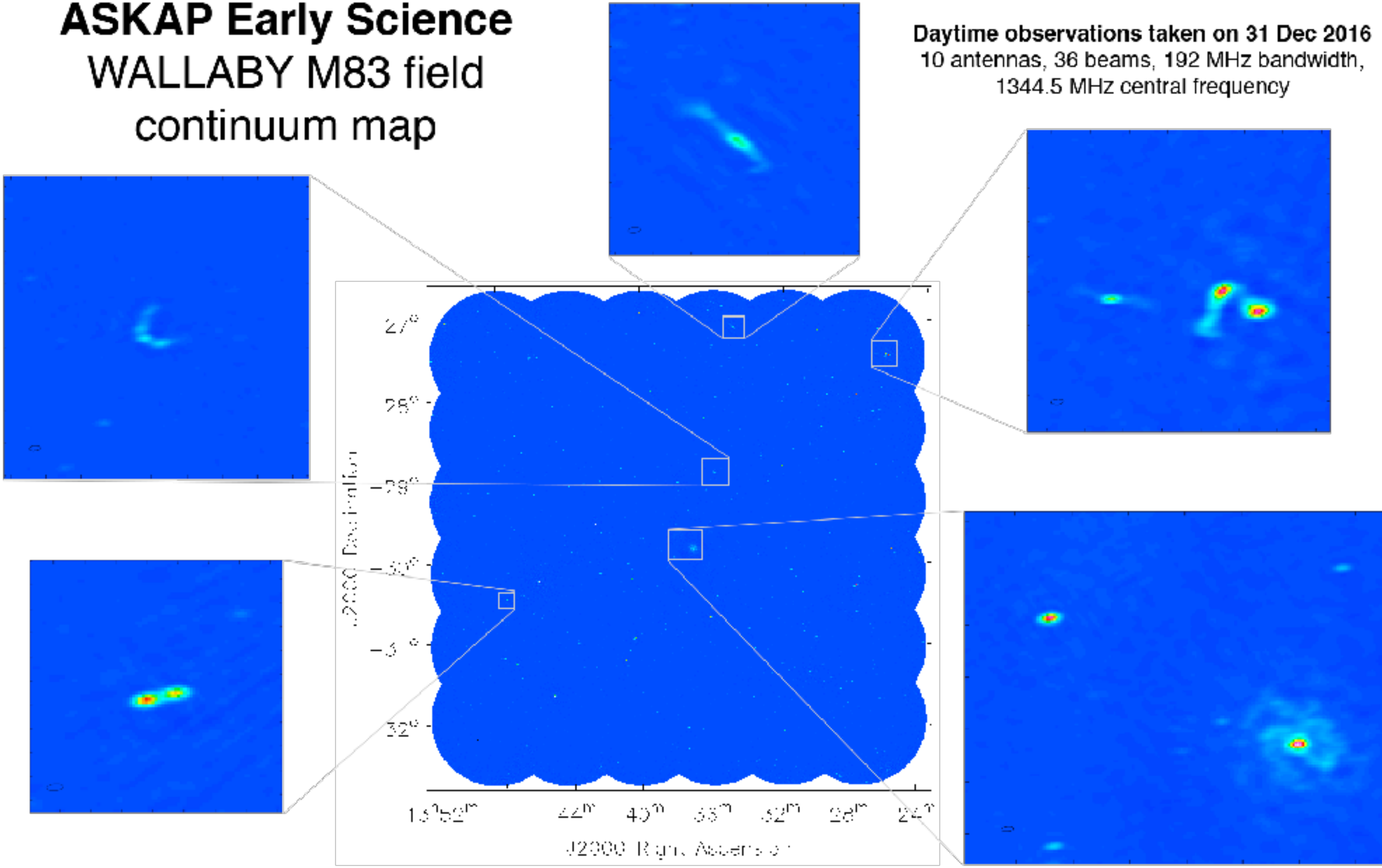
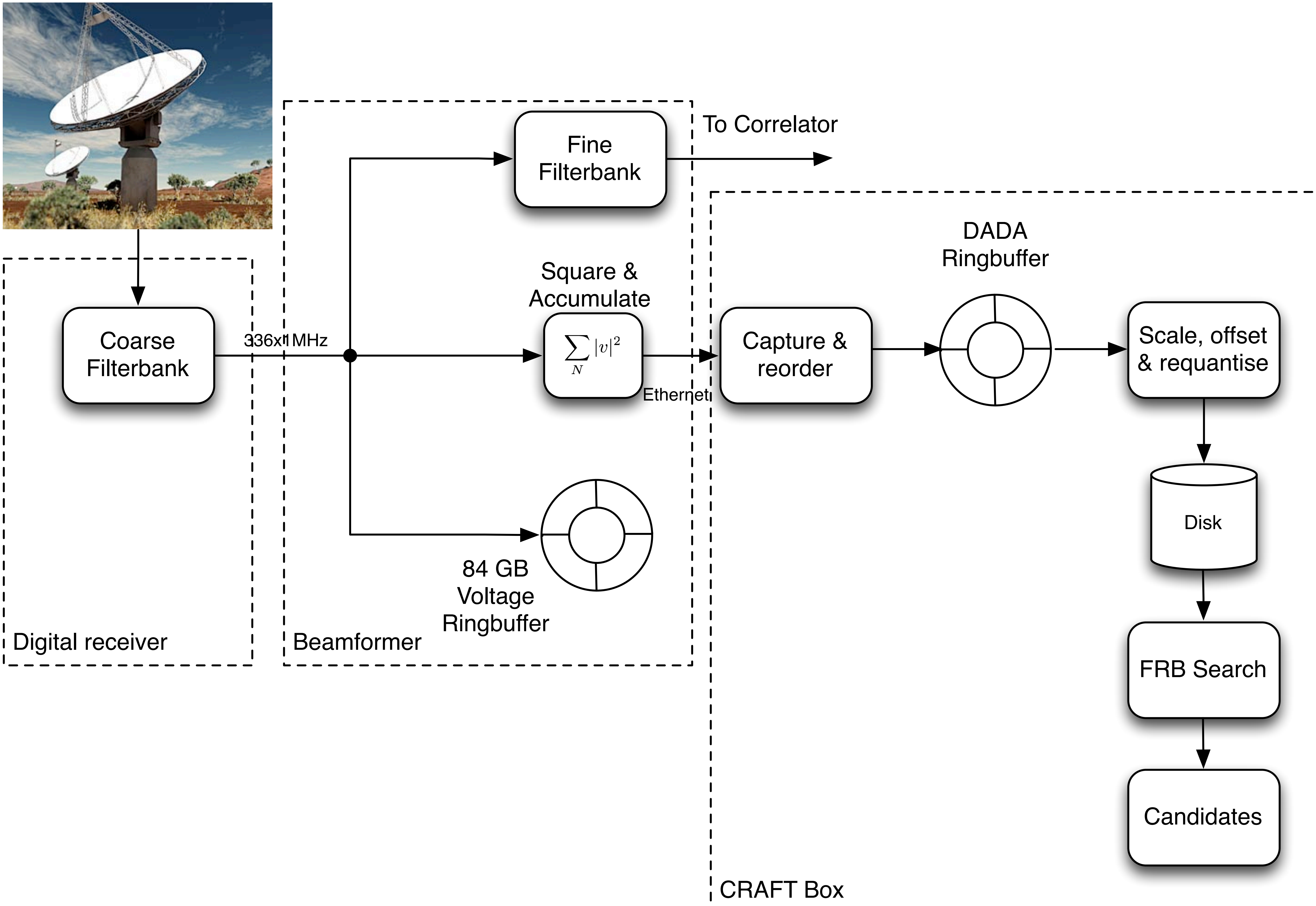


Image: Karen Lee-Waddell RMS: 500 uJy

Capabilities - Feb 2018

Spectra capture to disk	12 antennas/336 MHz/1ms/36 beams polsum/8bits
Transfer to Pawsey disk	100 MB/sec ~ real time for 12 antennas
Offline processing on Galaxy (64 x K20X)	36 beams @ 7x real time / GPU
On-site processing hardware	Titan (2x GTX 1070) - 24 antennas real-time Tethys (2 x P100) - 12 antennas real-time
Check CRAFT is commensal	No (!) - work ongoing.
Astronomer-friendly monitoring	OK - Grafana
Astronomer-friendly control	No: GNU screen/bash/Python
Rapid response to GCN triggers	Planned for March 2018
Voltage trigger & download	Firmware available Commissioning Feb-March 2018
Real-time FRB search	Planned for March 2018
Calibration & Imaging pipeline	Planned for April 2018
Real-time public VOEvents	Planned for ~ 2019

CRAFT - now

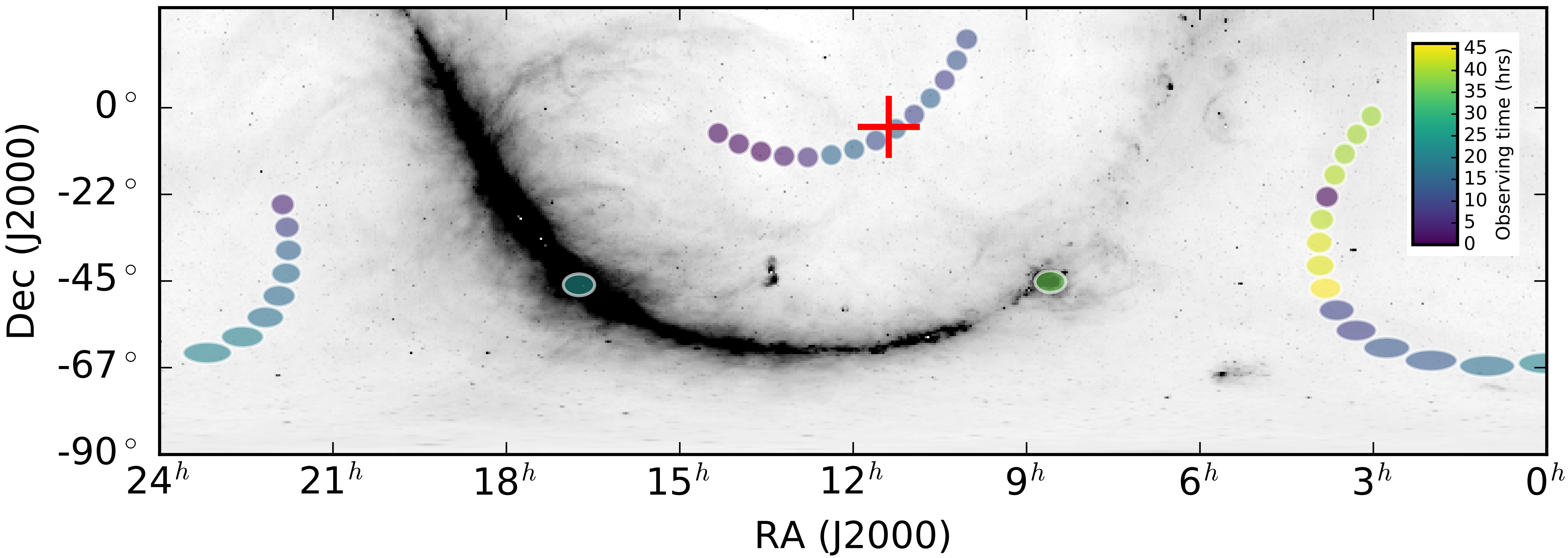


To Correlator
Fine Filterbank
Square & Accumulate
$\sum_N |v|^2$
Ethernet
DADA Ringbuffer
Coarse Filterbank
336x1MHz
Capture & reorder
Scale, offset & requantise
Disk
84 GB Voltage Ringbuffer
FRB Search
Candidates
Digital receiver
Beamformer
CRAFT Box

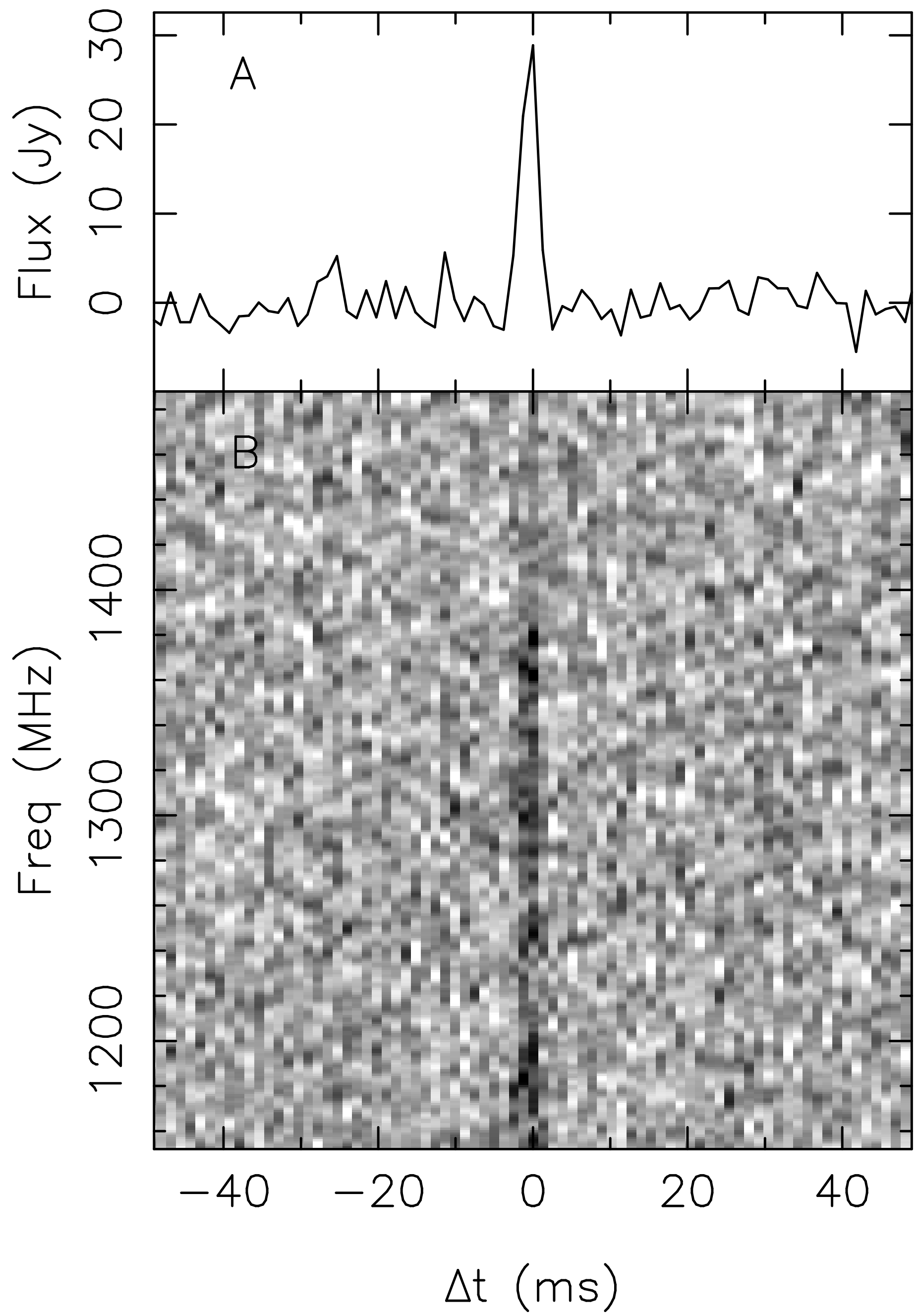
Software Suite

craft_udpdb	**UDP listener and reorder to DADA buffer** Configurable buffer size
craft_dbsplit	**Reads DADA buffer and writes to disk** Optional rescale to 8 bits Optional polsum Optional split by beam DADA or filterbank format
FREDDA	**FDMT-based dedispersion pipeline (Zackay & Ofek 2014)** 7x faster than real time on 36 beams (K20X, ndm=1024) Rescale to mean=0, std=S/N Channel flagging on N=1..4 moments DM0 flagging on max/min/mean/rms Single time/channel cell flagging on S/N Latency << max DM float32 arithmetic Boxcar sliding window N=1..32 TODO: incoherent & pol sum, better candidate selection, int8 arithmetic
Obsman	**Watches ASKAP and runs craft_udpdb and craft_dbsplit** Generates DADA headers for metadata
Python	General python plotting and data handling tools

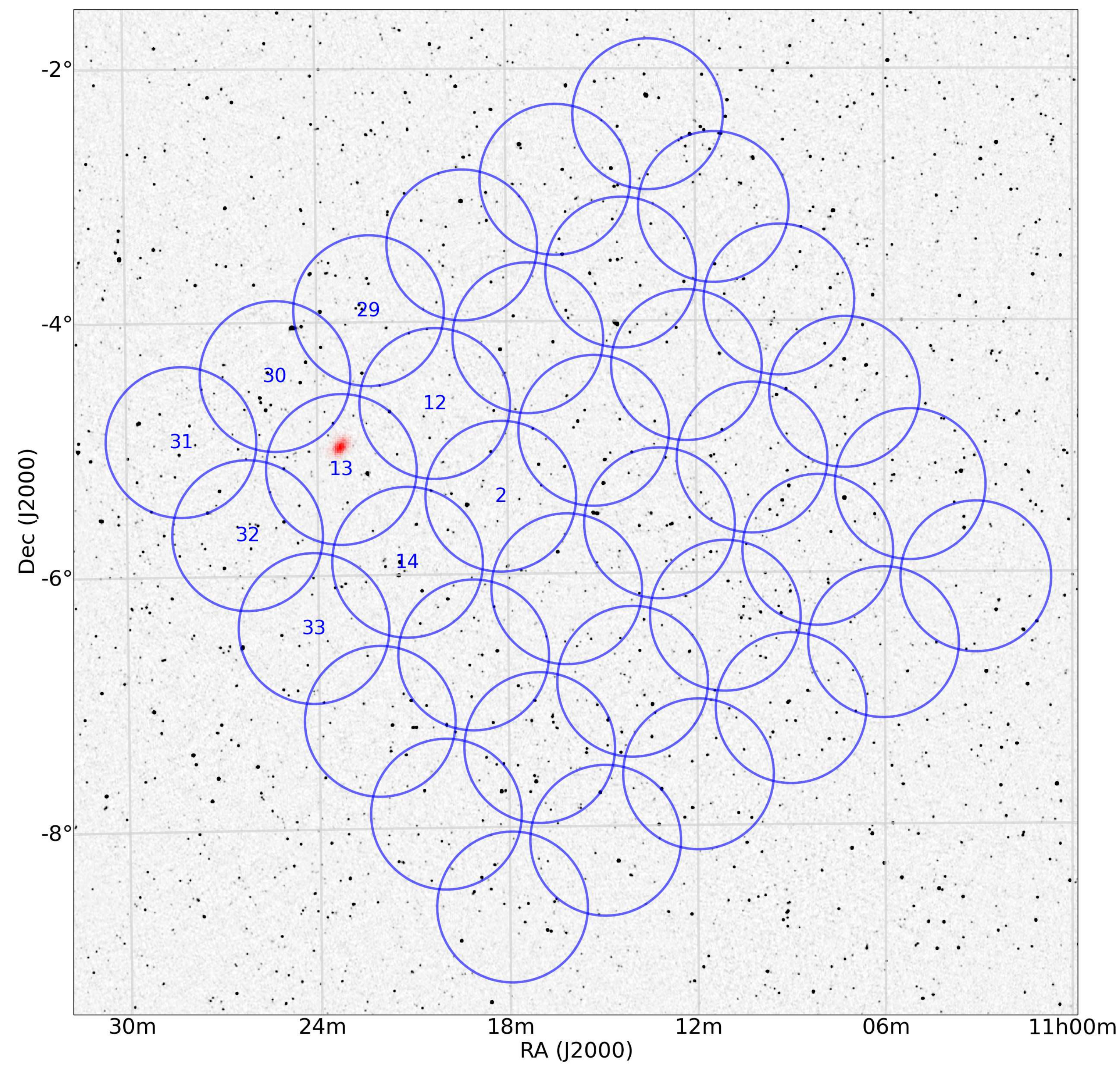
Fly's-eye observing



FRB170107



Spectral cutoff above 1.4 GHz
DM=610 pc/cm3
Fluence=58 Jy.ms

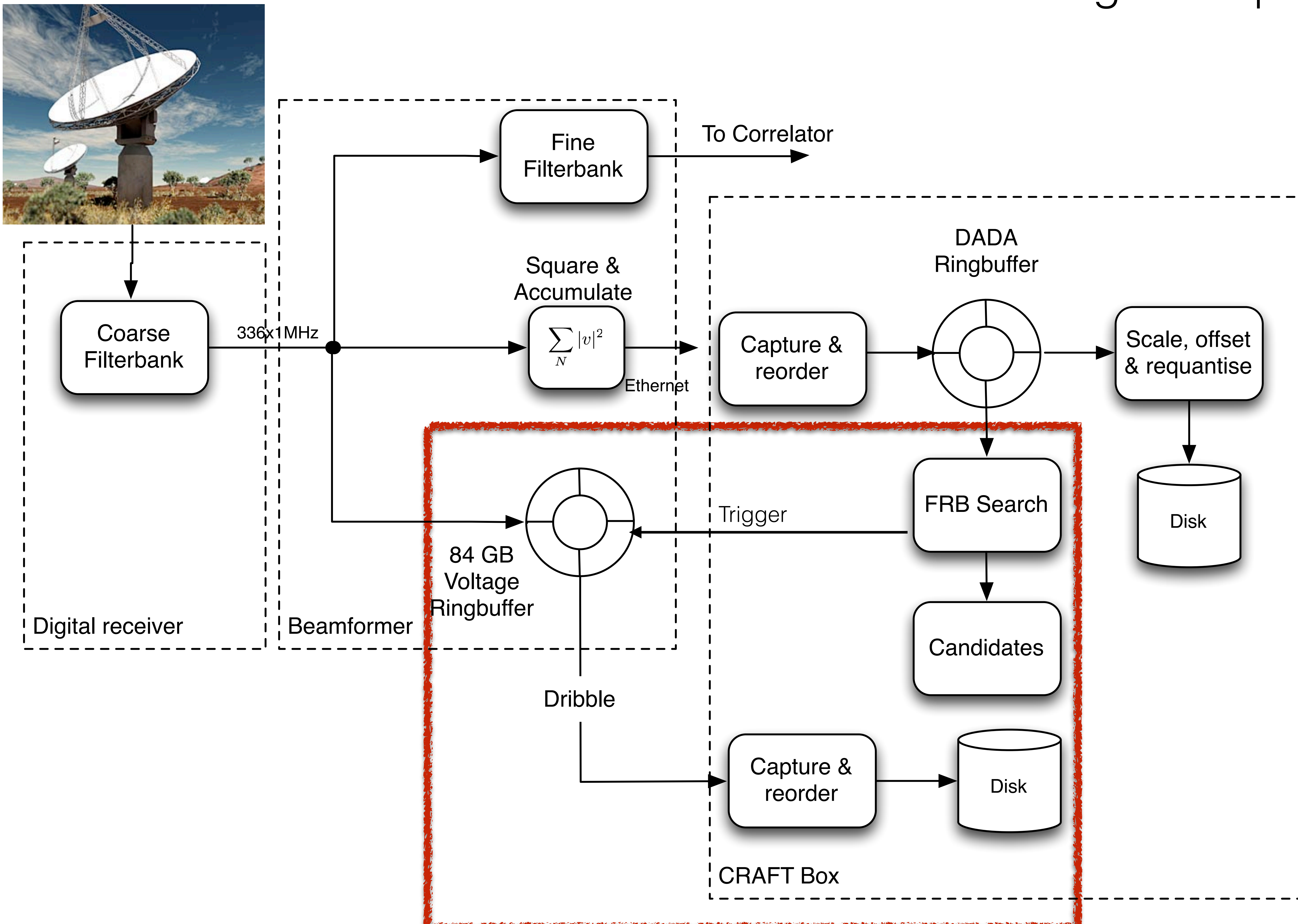


Localised to 8x8 arcmin
- thanks to fully-sampled focal plane!

2018/2019 plans

2018	Development	Commissioning array	Main array
Q1	Real-time fly's-eye Voltage dump HW calibration pipeline Real-time incoherent sum GCN response	Virgo offline incoherent GP fly's-eye All-sky fly's-eye GCN response	
Q2	Quicklook pipeline	GP fly's-eye All-sky fly's-eye GCN response	Commensal 16 antennas
Q3	FREDDA S/N improvements DM Window Improvements	X	Commensal 24 antennas
Q4	Antenna-coherent proof-of concept	X	Commensal 36 antennas DM Window Improved S/N
Q1	VOEvent distribution	X	Commensal 36 antennas DM Window Improved S/N

Real-time detection and voltage dump



Transient Buffer

- Each beam former FPGA has 2 GB of memory for saving 8 MHz of bandwidth in a ring buffer
- Native resolution is 32 bits (16 bits complex)
- Configurable truncation & rounding down to 16, 8, 2 bits to increase buffer duration (no level setting)
- Configurable number of dual-pol beams: 36 or 1
- Full buffer download time: 96 s @ full rate = 7 Gbps/antenna = 84 Gbps/12 antennas
- Total Memory: 84 GB per antenna. 1.1 TB per 12 antennas
- Can choose a time range to download, aligned with BAT.
- Dispersion time: 1000 pc/cm^3 = 1.6s assuming band 2 = 1-1.3 GHz.

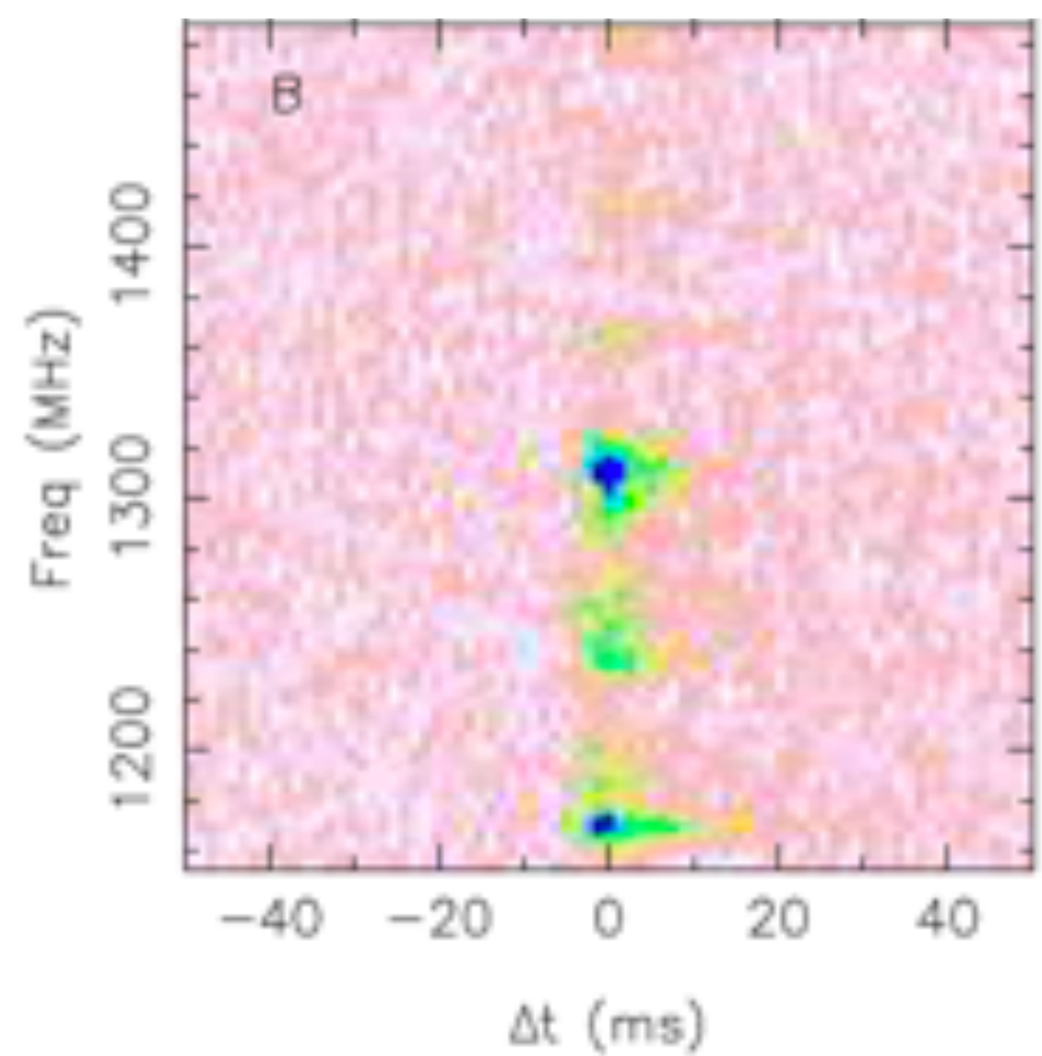
Example transient buffer modes

Nbits	Nbeams	Buffer Duration (s)	Download size * (GB)	Time to download ** (min)
32	36	0.9	84	7
16	36	1.8	84	7
8	36	3.6	84	7
2	36	14.2	84	7
32	1	32	3024	252
2	1	512	3024	252

* 1 dual-pol beam, full duration.
**Assumes 200 MB/sec disk write speed

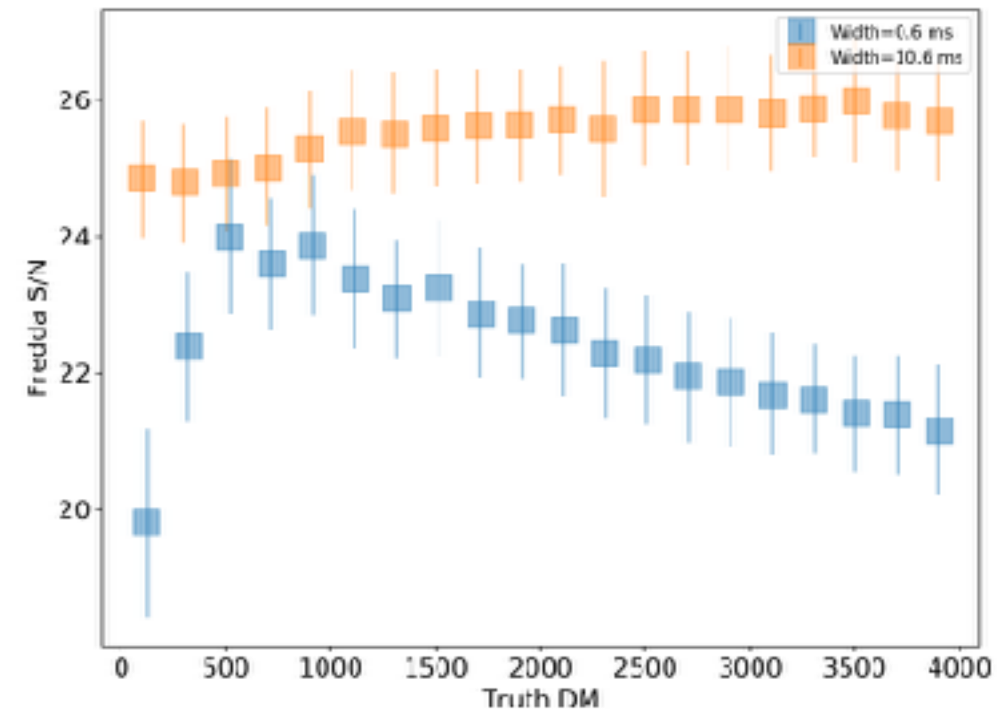
FREDDA S/N Improvements

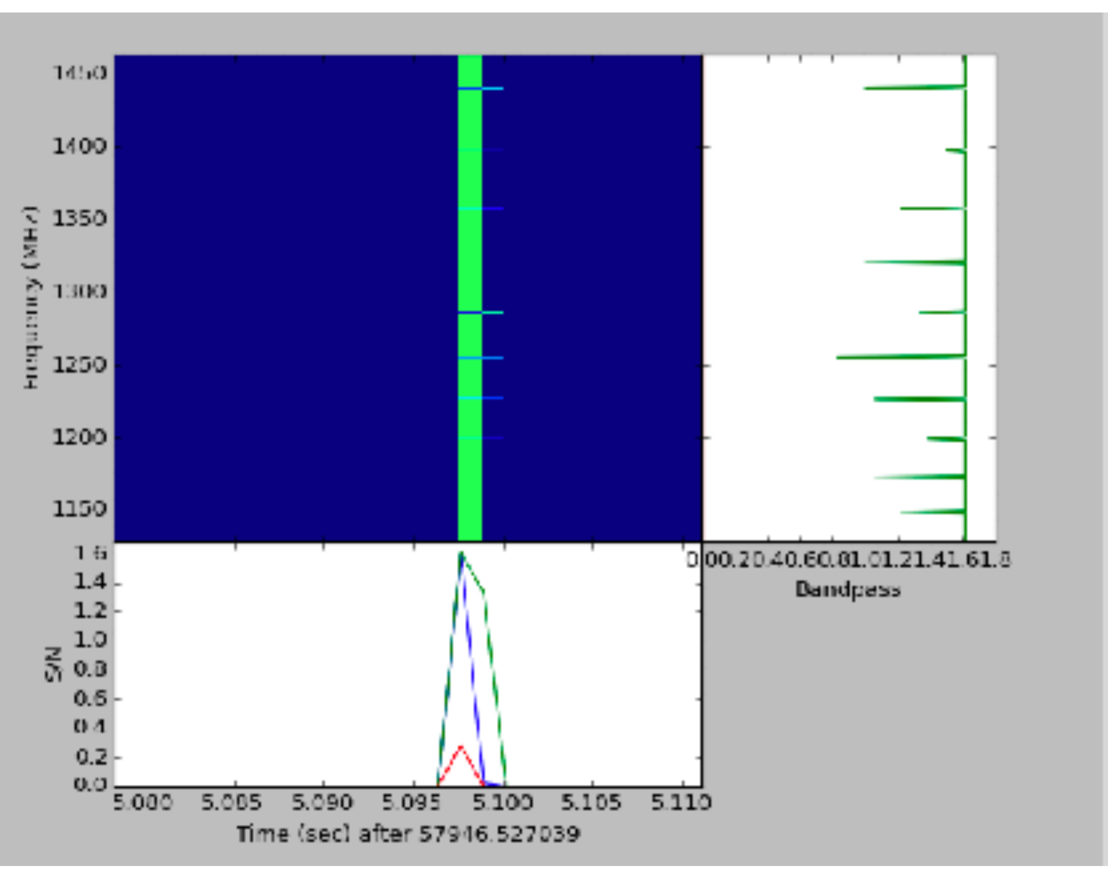
- Barak Zakay is working on a new algorithm to find speckly-FRBs.
- Run standard search at an S/N threshold = 5, then post-processing to find speckles
- Improves sensitivity by up to 2x

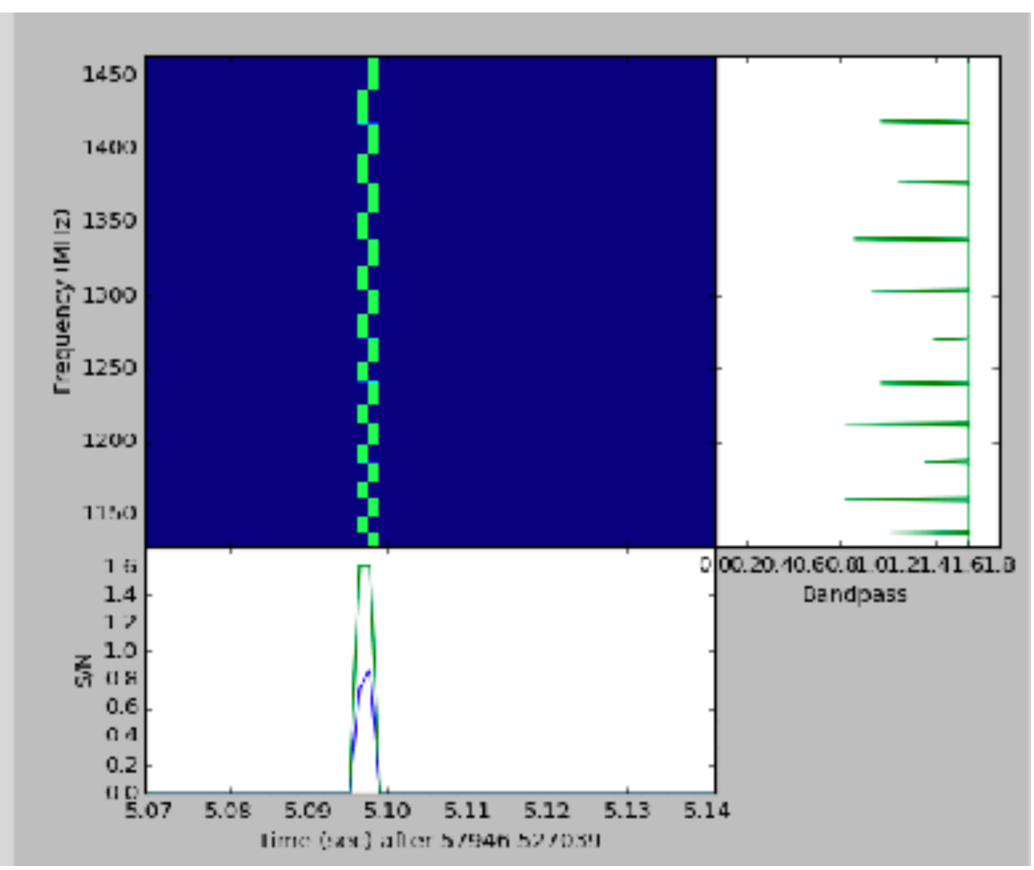


FREDDA S/N Improvements

- Half-sample offsets reduce sensitivity - but this can be recovered during dedispersion
- Search over offset improves S/N by sqrt(2) for DM < diagonal (300 pc/cm3)







Harry Qiu

Improving high DM performance with a DM window

- ASKAP Native resolutions: 1 MHz (coarse filterbank) and 18 kHz (fine filterbank)

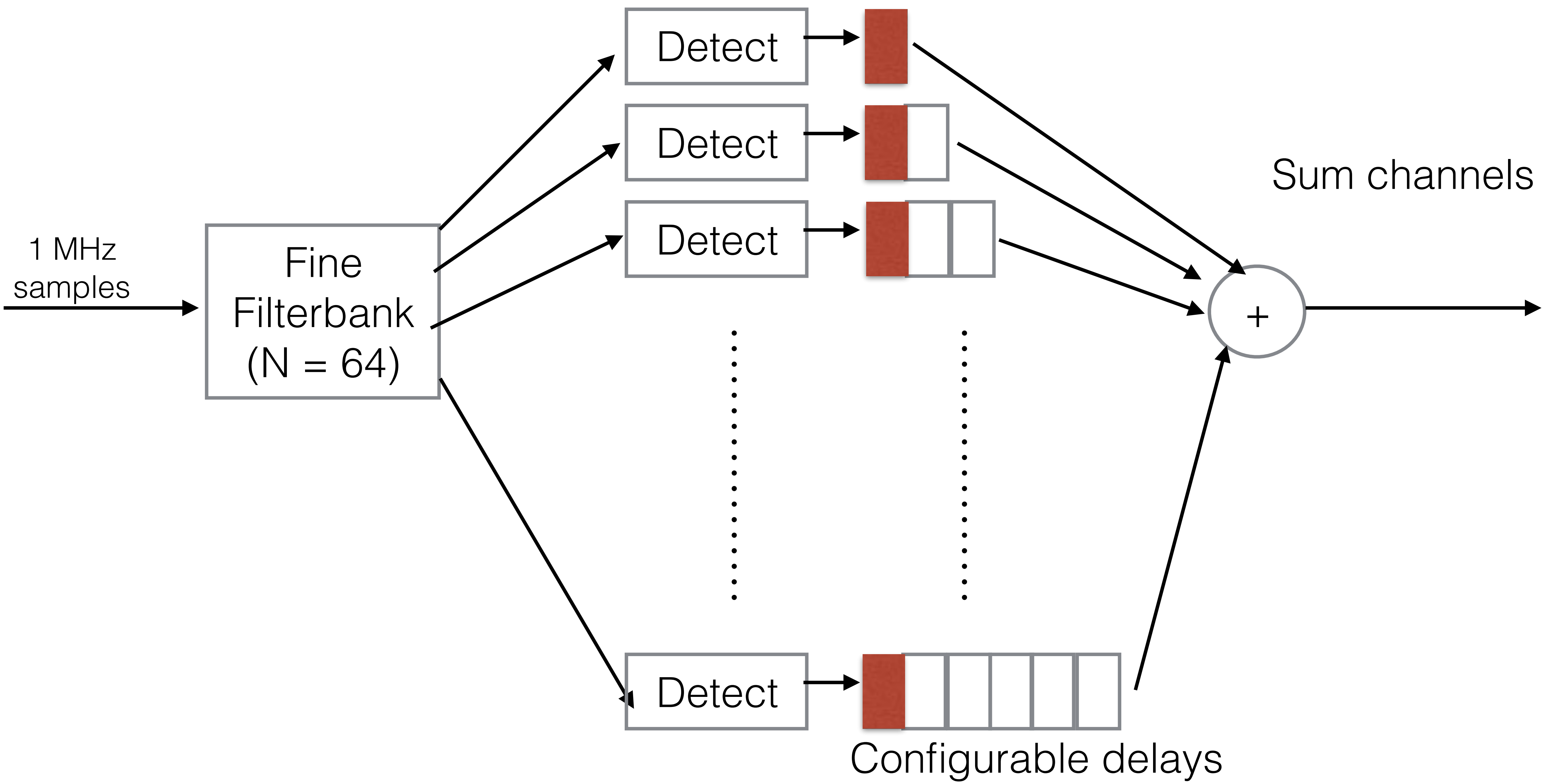
- 1 MHz reduces sensitivity to high DMs, but 18 kHz gives us a processing headache.

- Option: Make autocorrelations of fine channels (instead of coarse channels), then sum back to ~1 MHz channels at an intermediate DM.

- Improves the largest DM at the expense of low DMs, keeps data volume the same.

- (Thanks to Jason Hessels for kicking off this thinking, and Alex Dunning for the proposed design!)

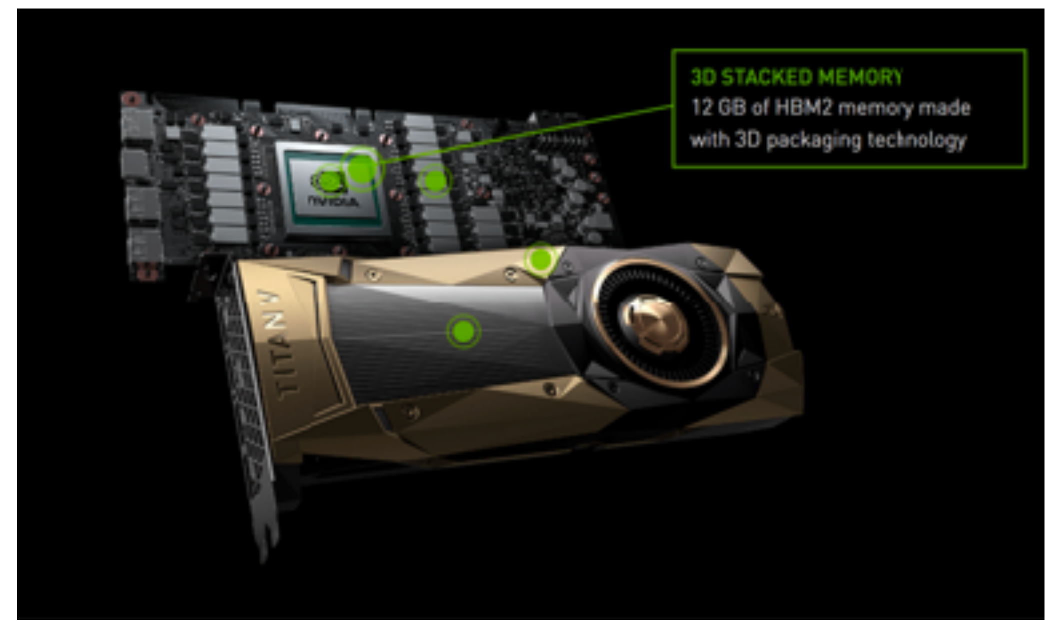
DM Window



Tune delays to the centre of the desired DM window

Antenna-coherent upgrade

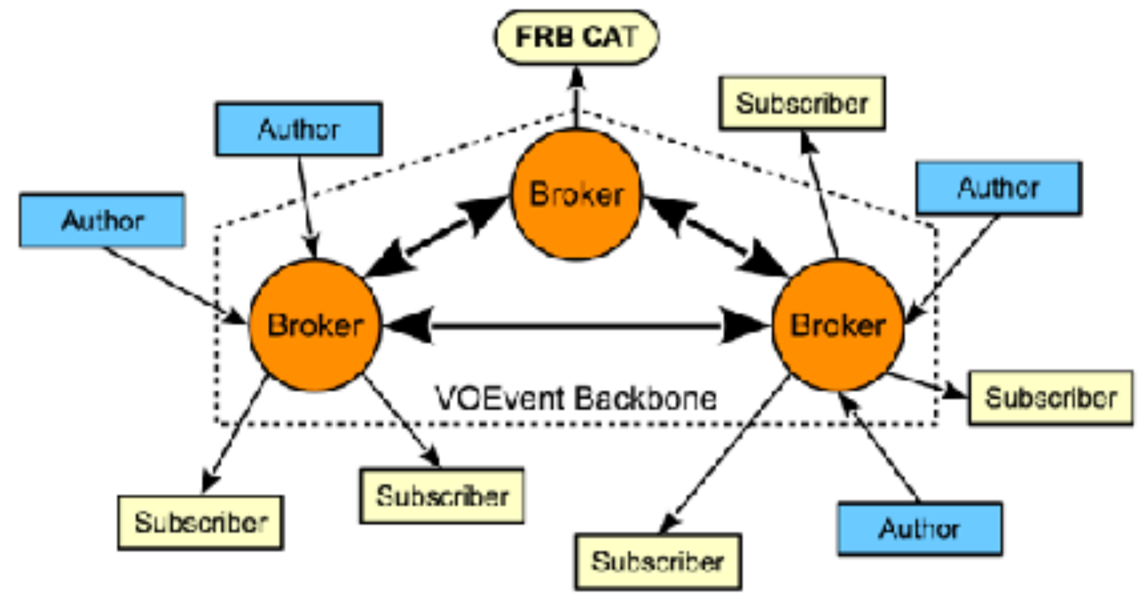
- Tied array beams for the full FoV is too difficult.
- Fast-dump visibilities (~1 ms) could be produced by the exisiting hardware (TBC)
- Dedispersion/imaging similar to RealFAST.
- Improves sensitivity by 6x = i.e. 10 sigma= 0.6 Jy.
- Currently unfunded. Aim to produce a proof-of-concept end 2018 & propose for funding in 2019.



NVIDIA Titan V: 130 TFlops (!)

Real-time VoEvents

- ASKAP data policy (when full science is runni is that all data products should be made available immediately, after an appropriate quality control period. I.e. no proprietary peric
- For CRAFT this (probably) means we should distribute alerts in real-time.
- We will do this using VOEvents (Petroff et al. arXiv:1710.08155).
- ASKAP will produce different messages with varying latencies, confidences and position uncertainties (similar to SWIFT/Fermi) as yet undefined.
- Plan to do this by the time ASKAP is doing full science - ~ 2019.



Conclusions

- ASKAP has detected 19 FRBs in fly's-eye mode.
- ASKAP FRB collaboration (CRAFT) has been quickly re-energised, with now more than 25 members representing 6 institutes from Australia and around the world
- ASKAP will have a relatively good product of detection rate and localisation.
- ASKAP will distribute real-time triggers and localisations to the world-wide community
- Detection rate & localisation will improve markedly over the next 12-18 months.