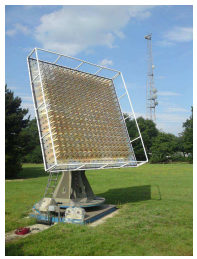
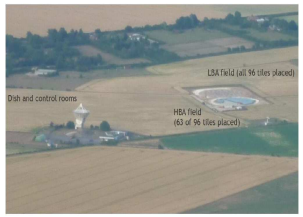
Real-time processing in the SKA

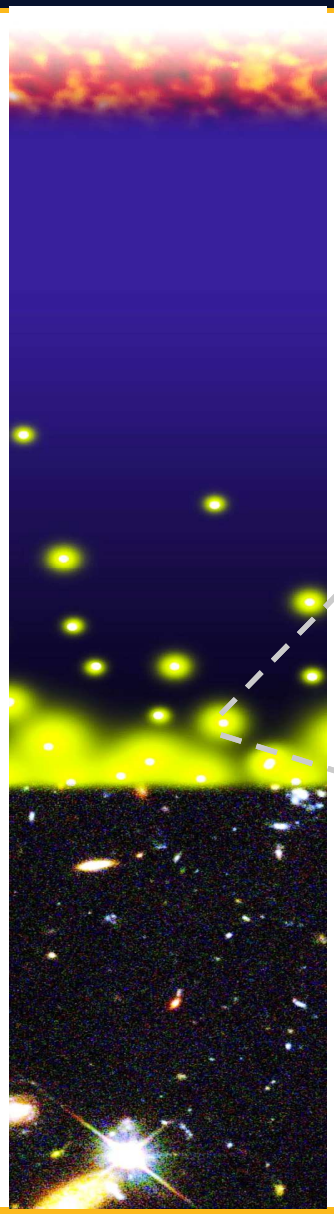
Kristian Zarb Adami

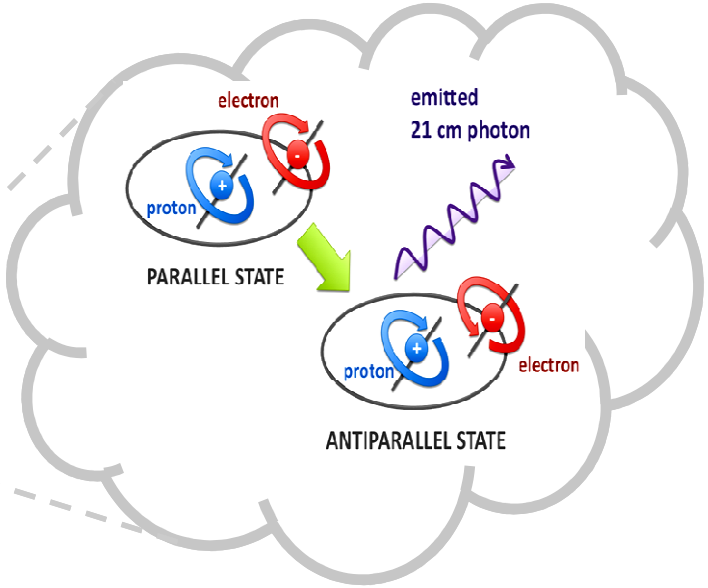
Instruments:

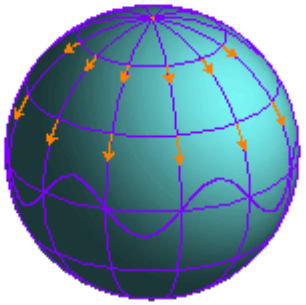




Hydrogen Emission Mechanisms







$$\frac{n_1}{n_0} \propto \exp(-E_{21cm}/k_b T_S)$$

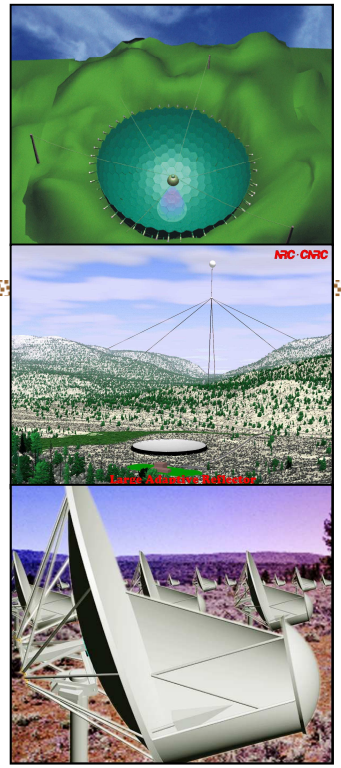
Boltzmann distribution

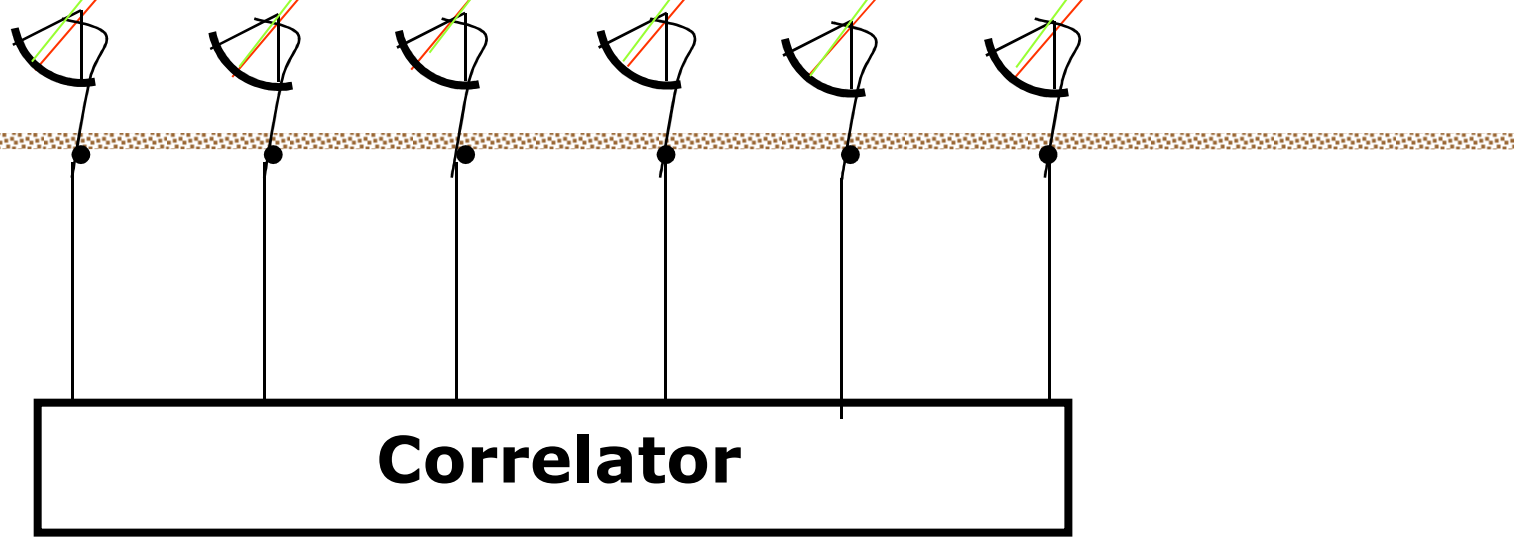
The need for Real Time Processing

- Network Infrastructure
  - 1.12 Pbyte/s of photons collected in 1.12M receiver chains
  - Correlator Raw Data rate ≈ 10 TB/s
  - Total Internet Traffic ≈ 8 TB/s in 2010
- Signal Processing System
  - 10^{19} Op/s for the Spectral decomposition
  - EXASCALE System 10^{18} Operations for Correlation and Imaging
- Power
  - Power Consumption of <100MW
  - Budget of < 1.5B$

Electronic Lens

Small D, large N

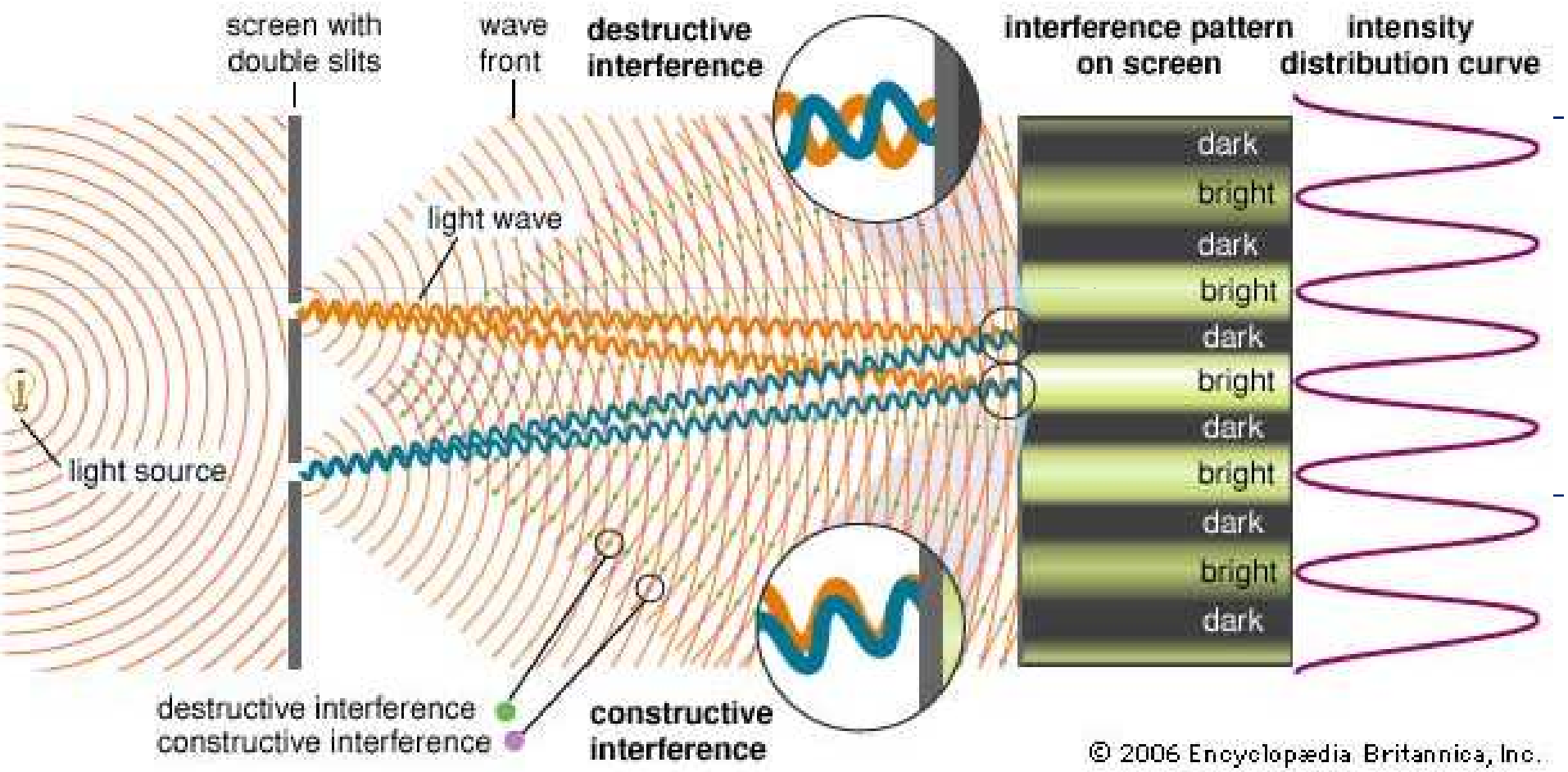




$\Delta\Theta = \lambda/D$

$I(\theta)$

Back to GCSE Physics

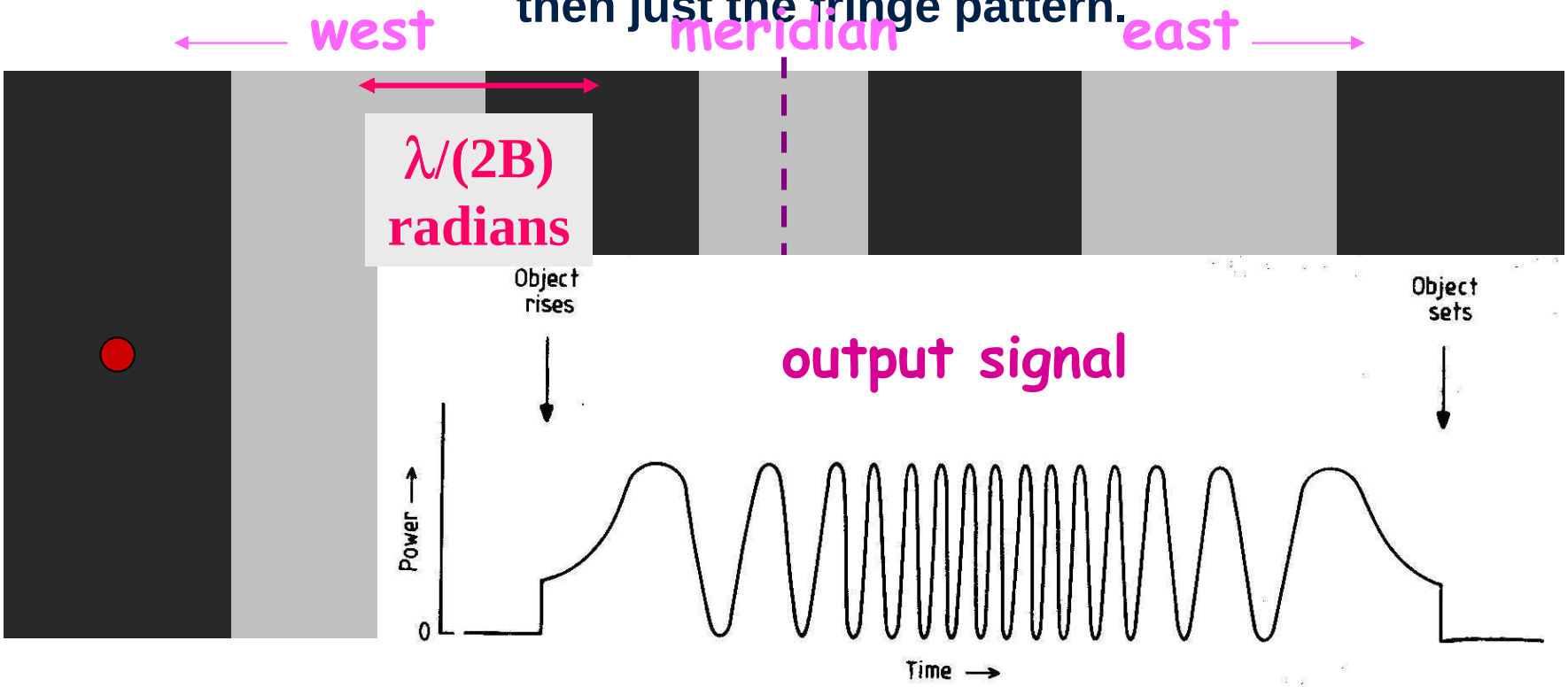


Basic Concepts

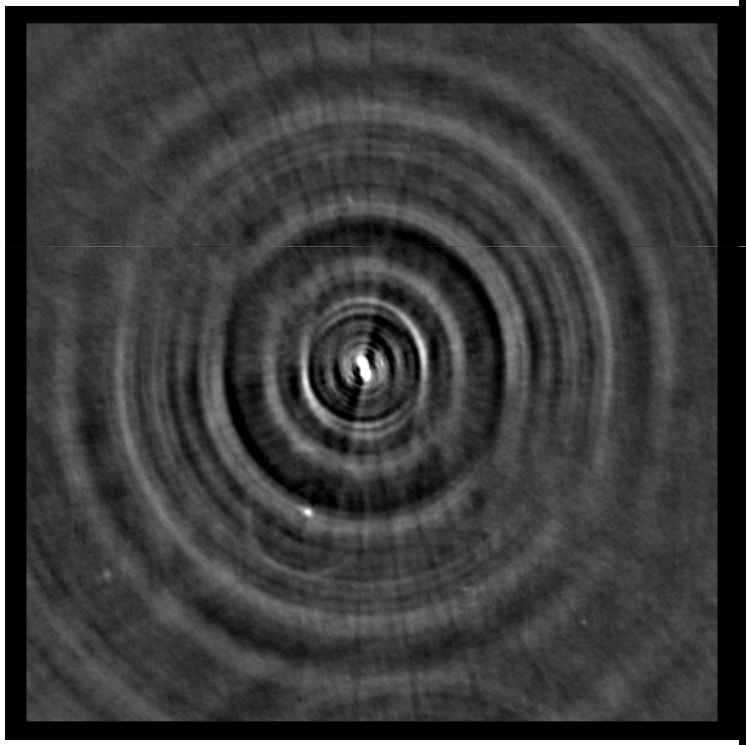
By analogy to the double slit experiment, regions which would cause constructive and destructive interference can be considered "stripes" in the sky. As the source moves through it, it produces oscillating output signal.

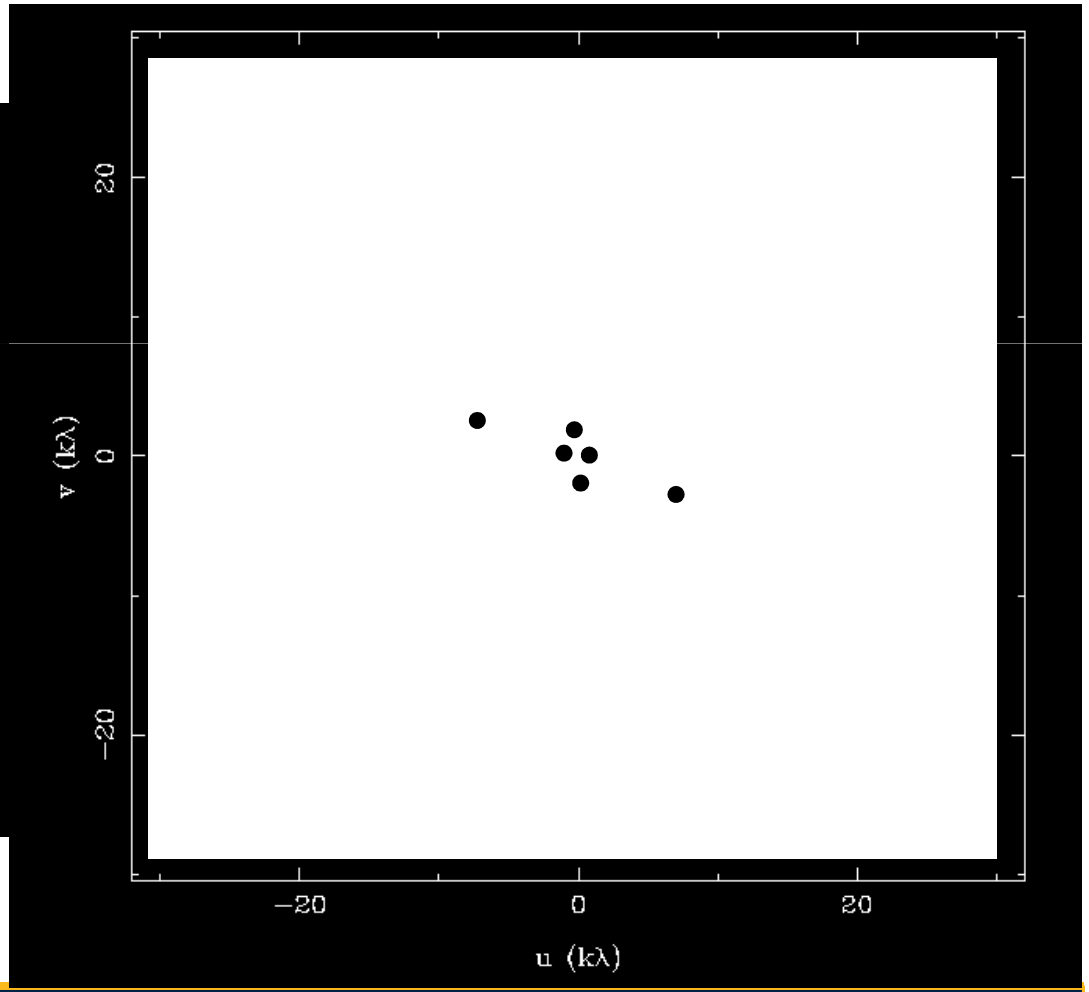
The **angular resolution** is now given by the **fringe half-spacing $\lambda/2B$ (in radian)**.

If the source is very small compared to the fringe half-spacing $\lambda/(2S)$, we say it is unresolved. The output signal is then just the fringe pattern.



Synthesis imaging





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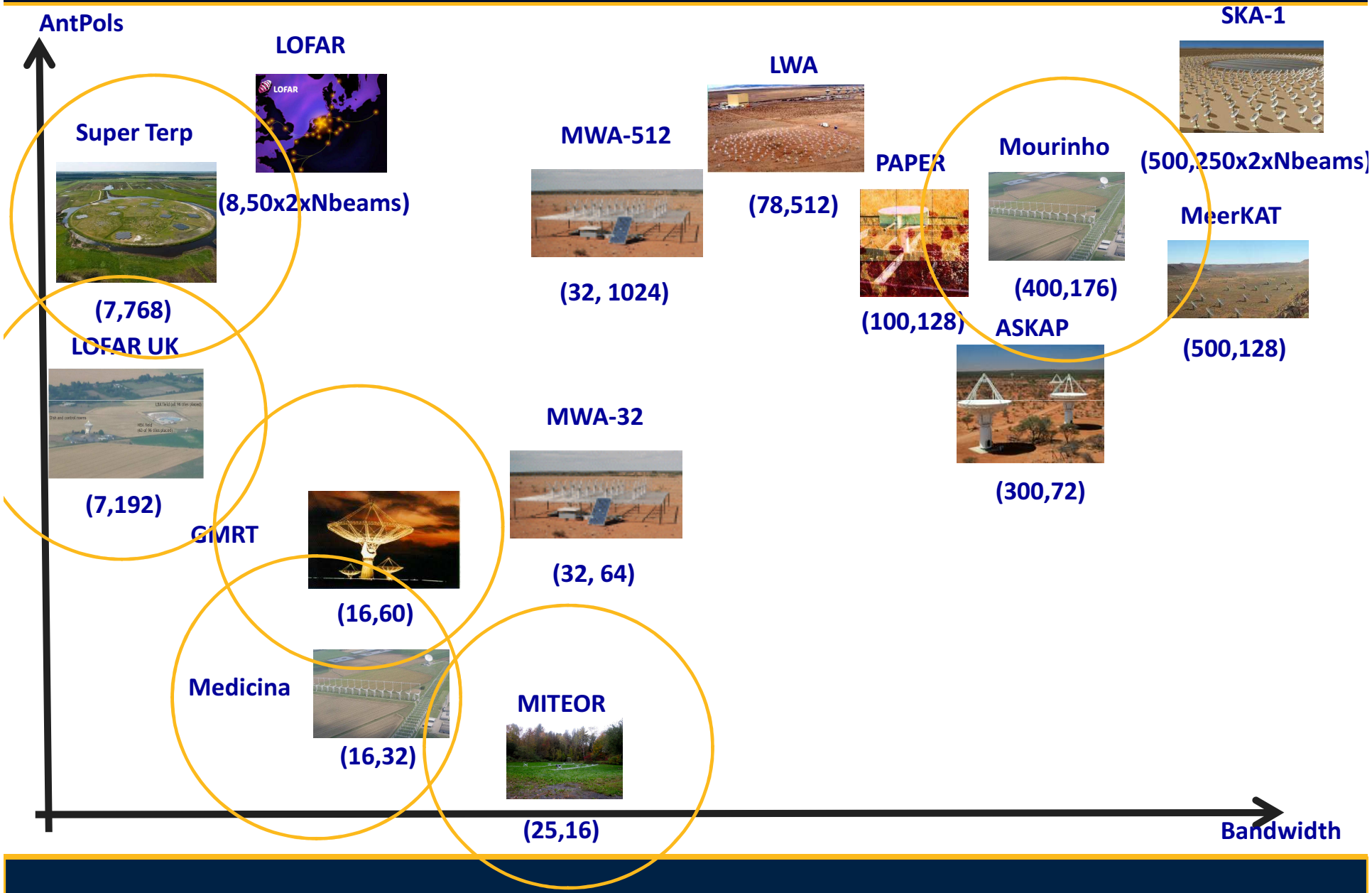
Roadmap to the SKA



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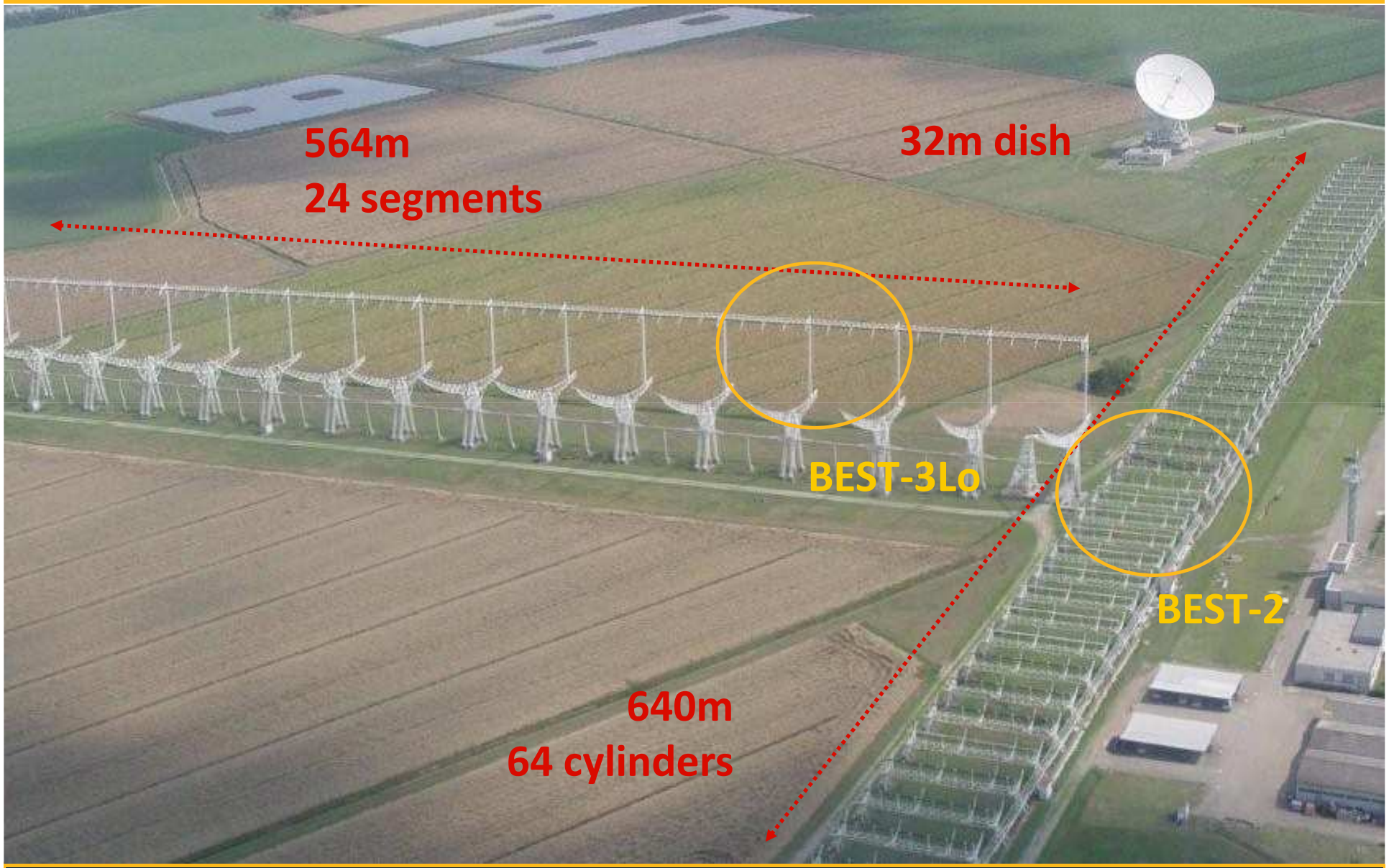
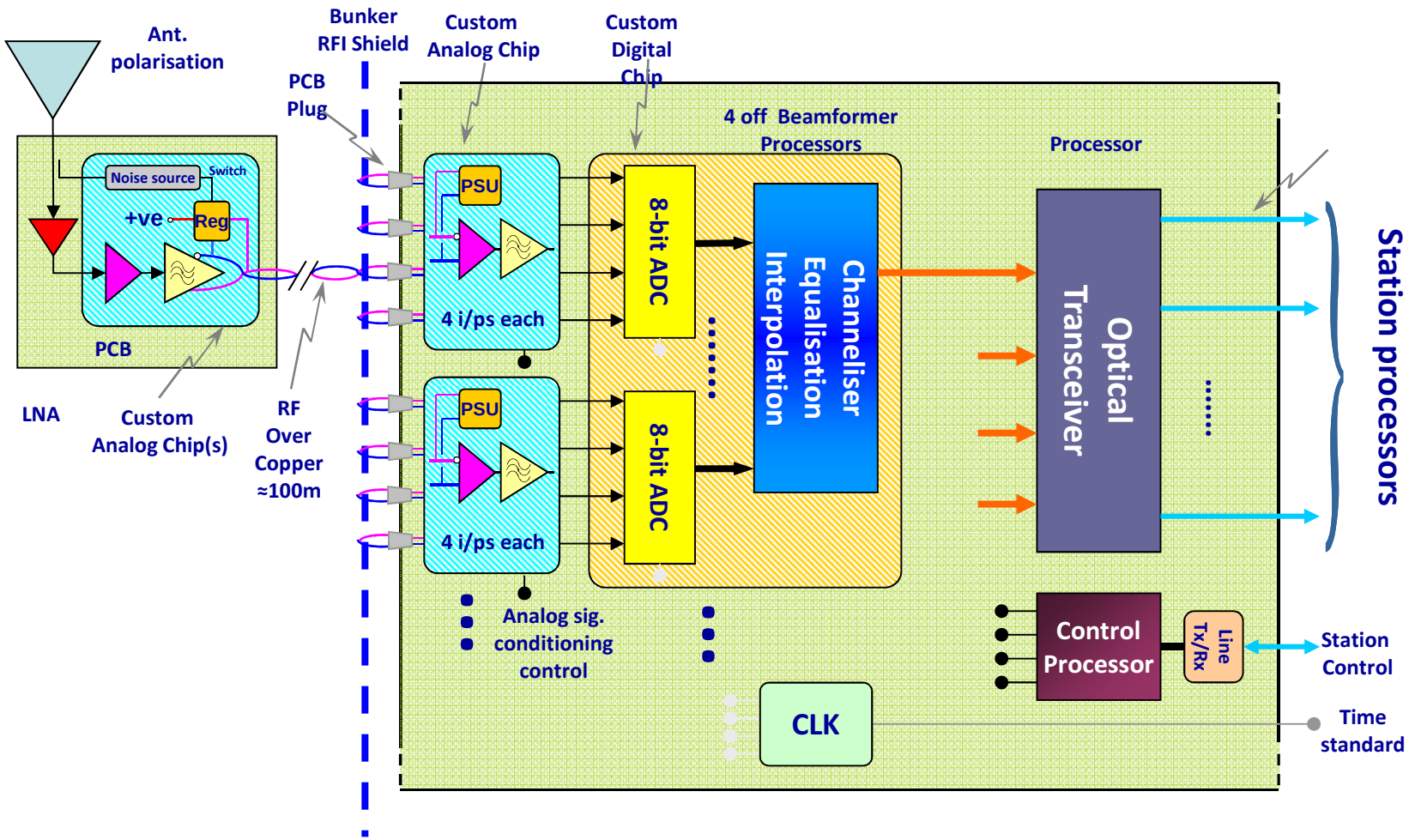
Medicina Radio Telescopes



Front-End System



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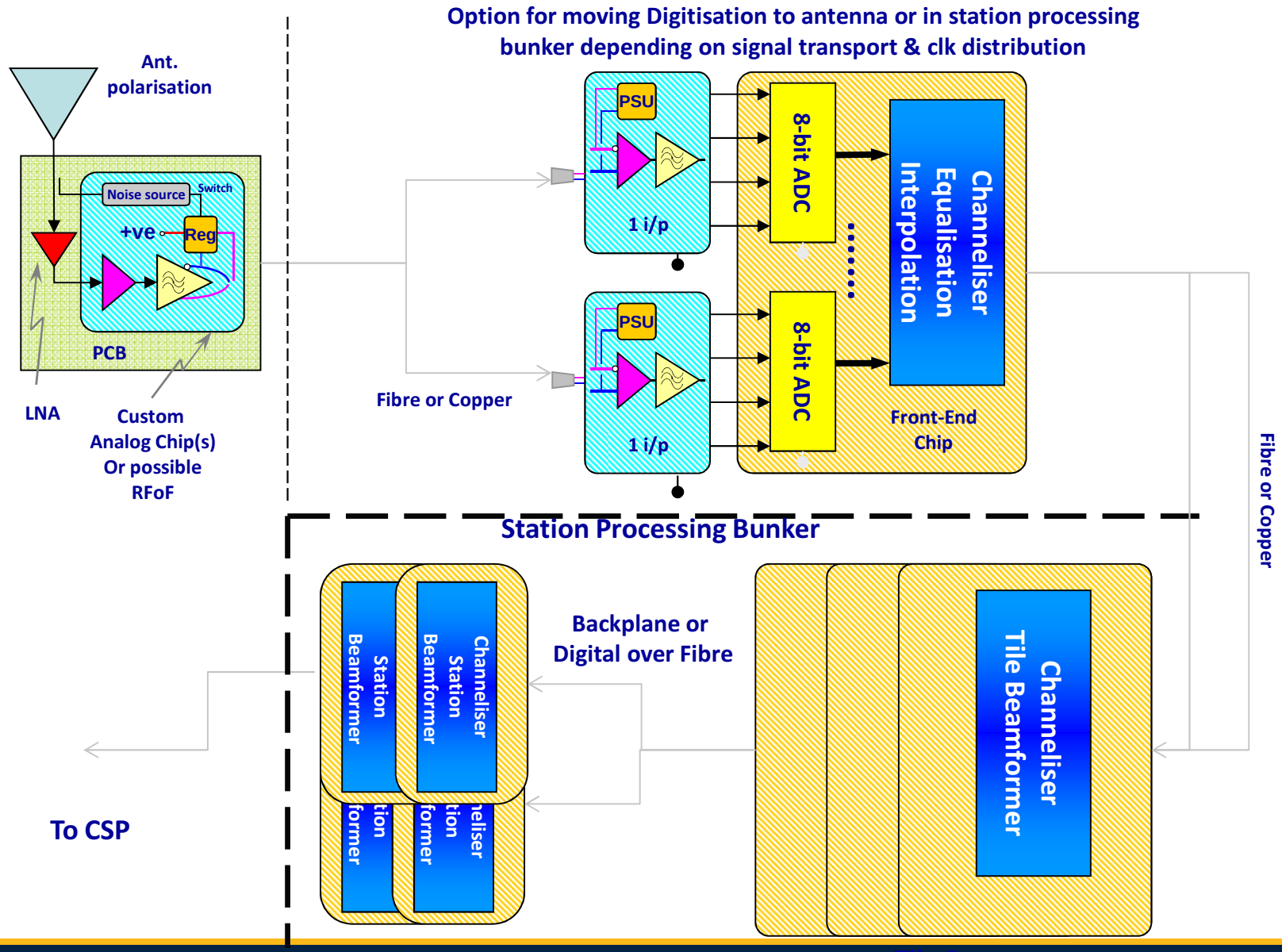
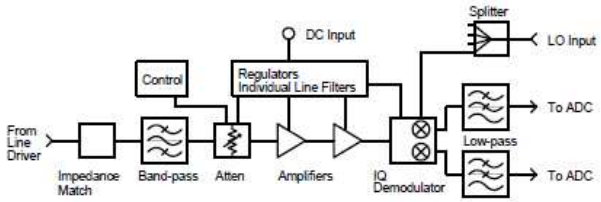
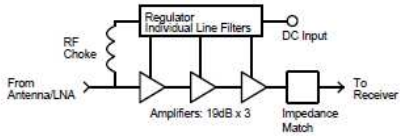
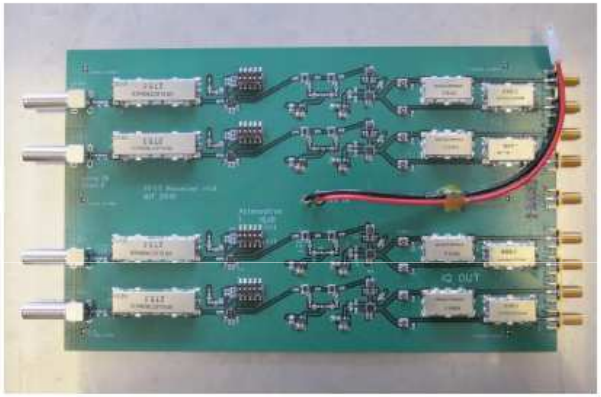
System Diagram

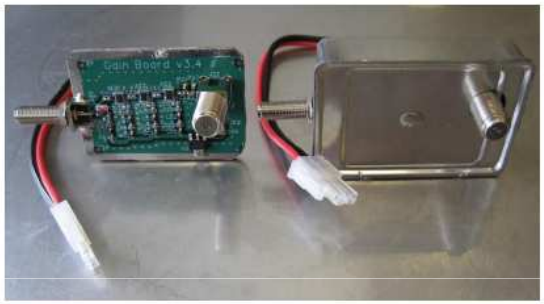


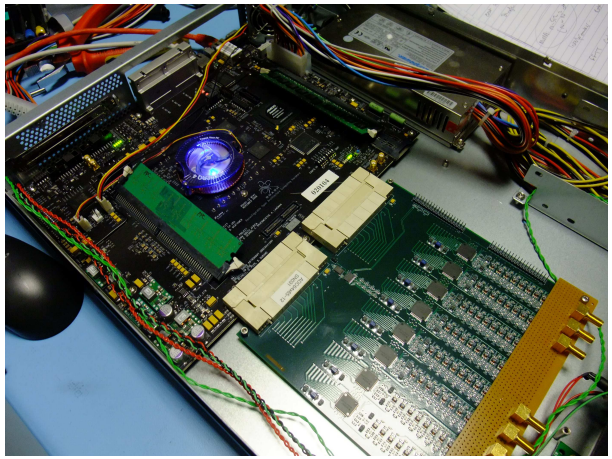
Integrated Electronics

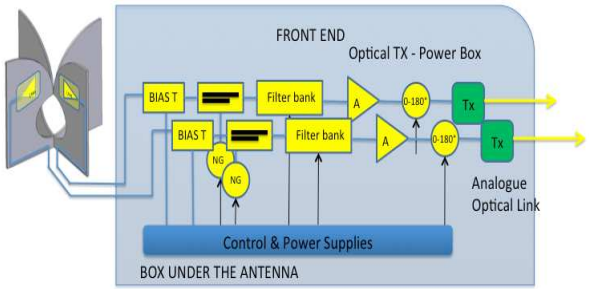


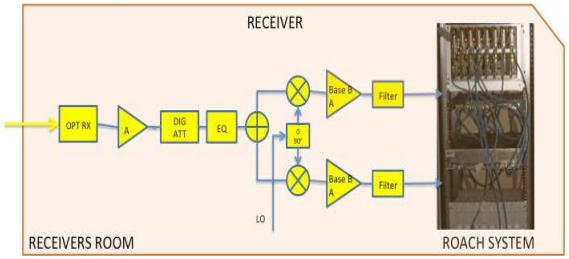






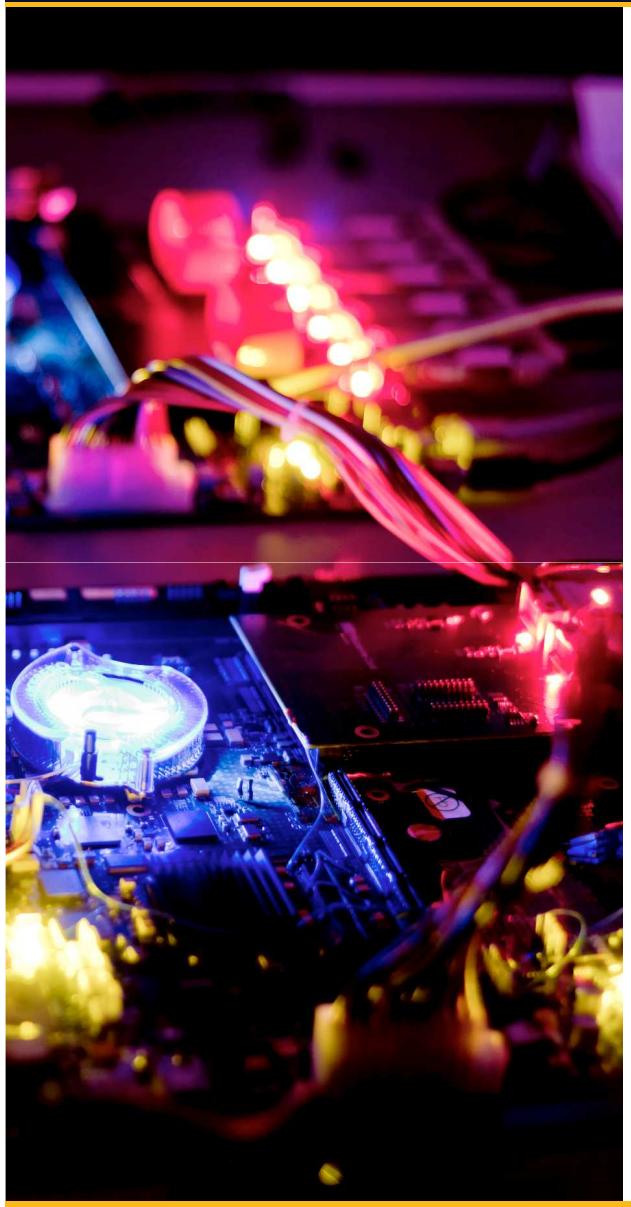




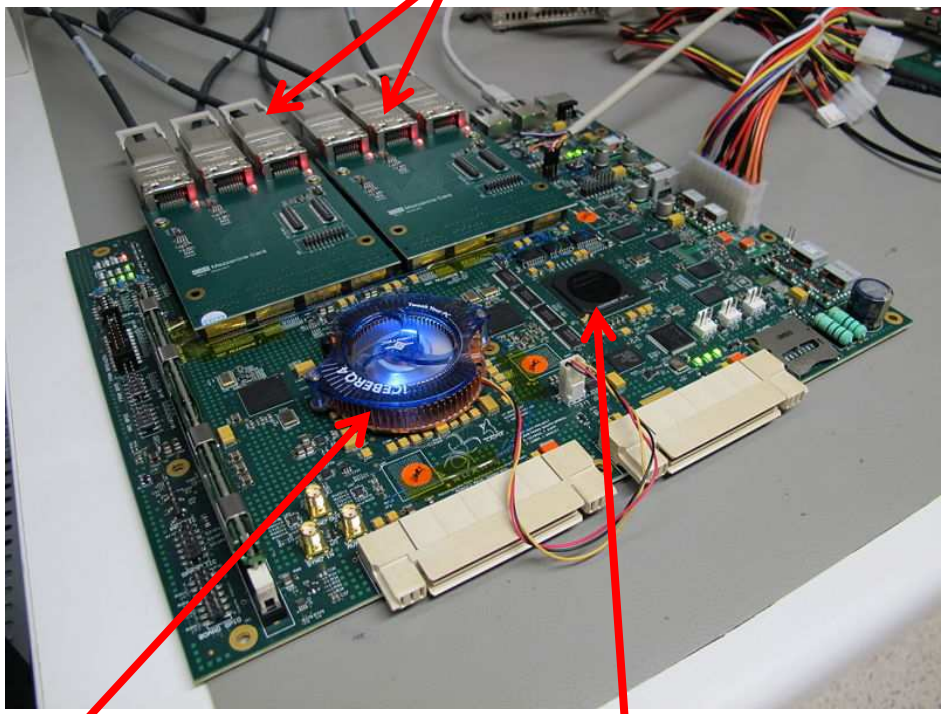


Credit: Eben Kunz and Burns Industries

ROACH 2



Up to 8 available 10GbE interfaces via CX4 or SFP+ mezzanine cards

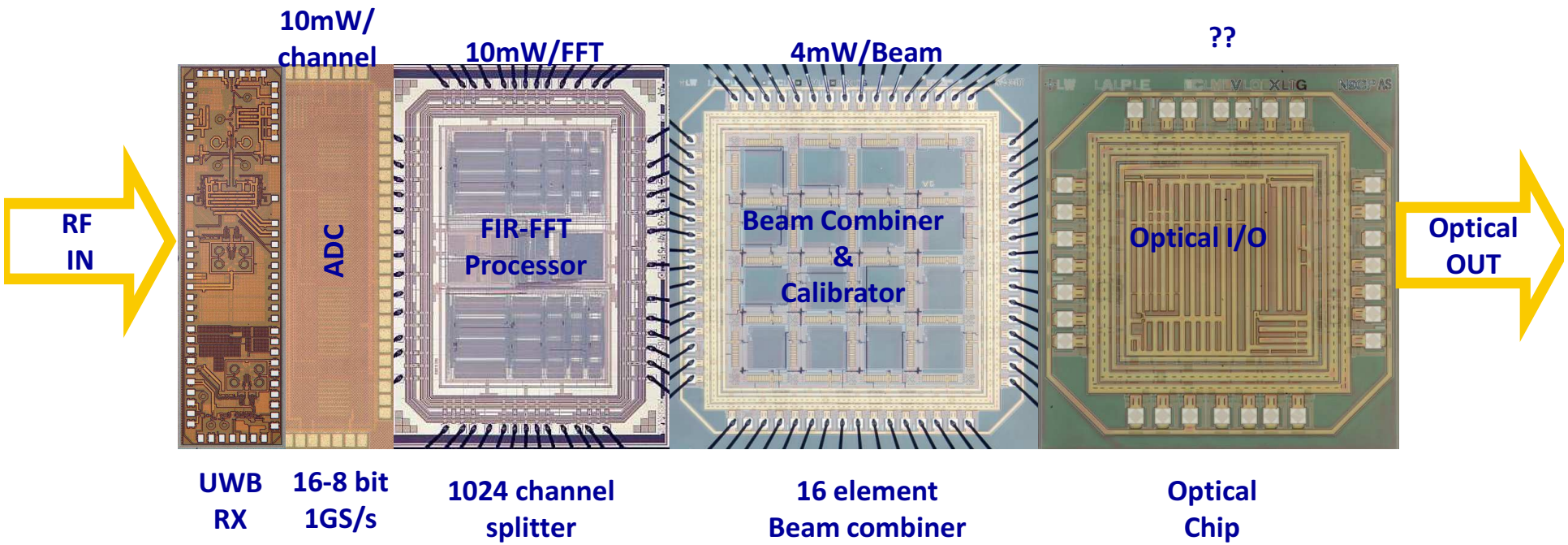


Virtex-6 SX475T FPGA

PowerPC 440EPx

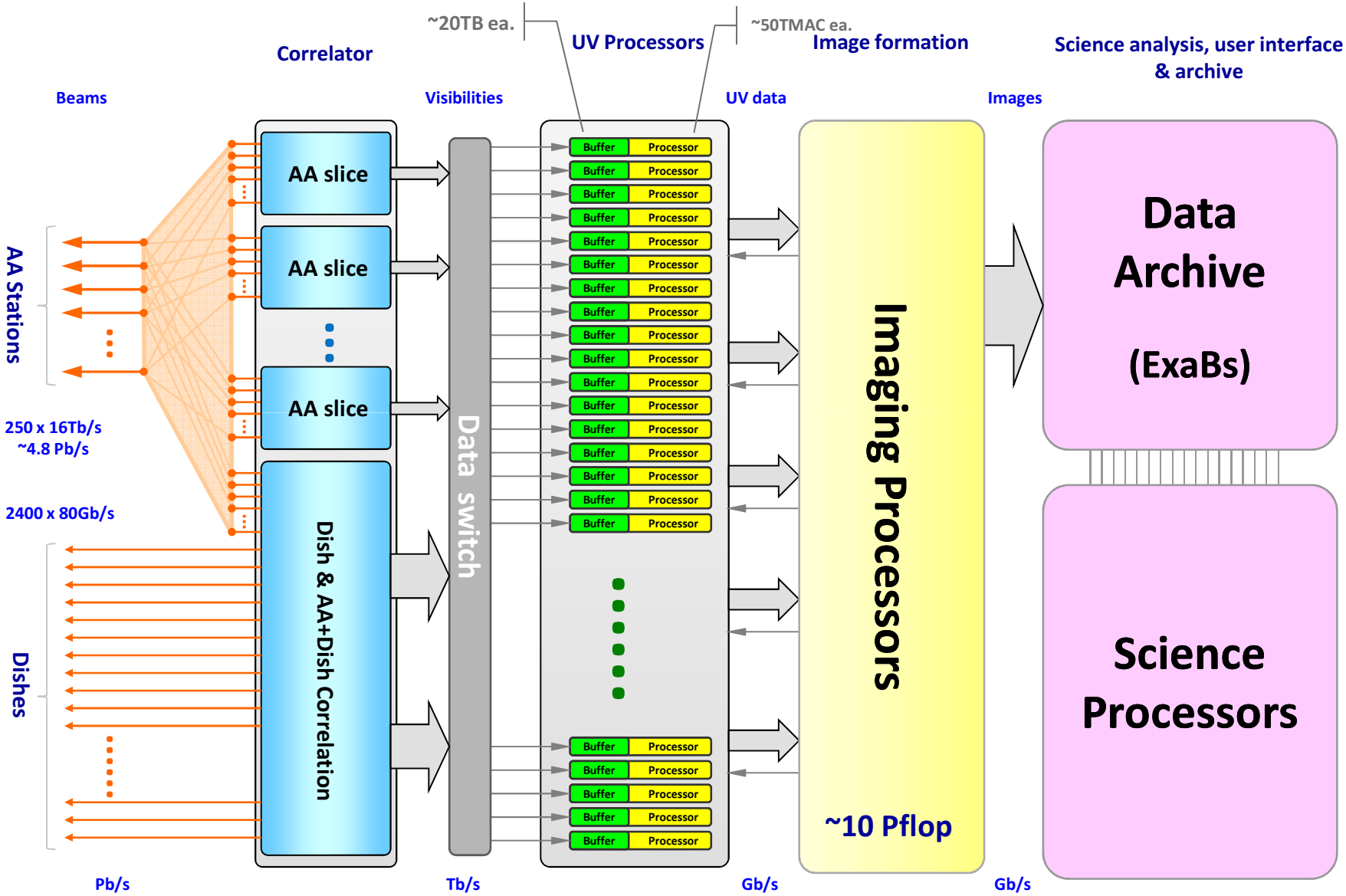
More integration…

- Multi-Chip Module (One Chip to Rule them all!)
- 4 x 4 antenna array (currently) – easily extended to 8x8
- Can also be used for Phased Array feeds for dishes



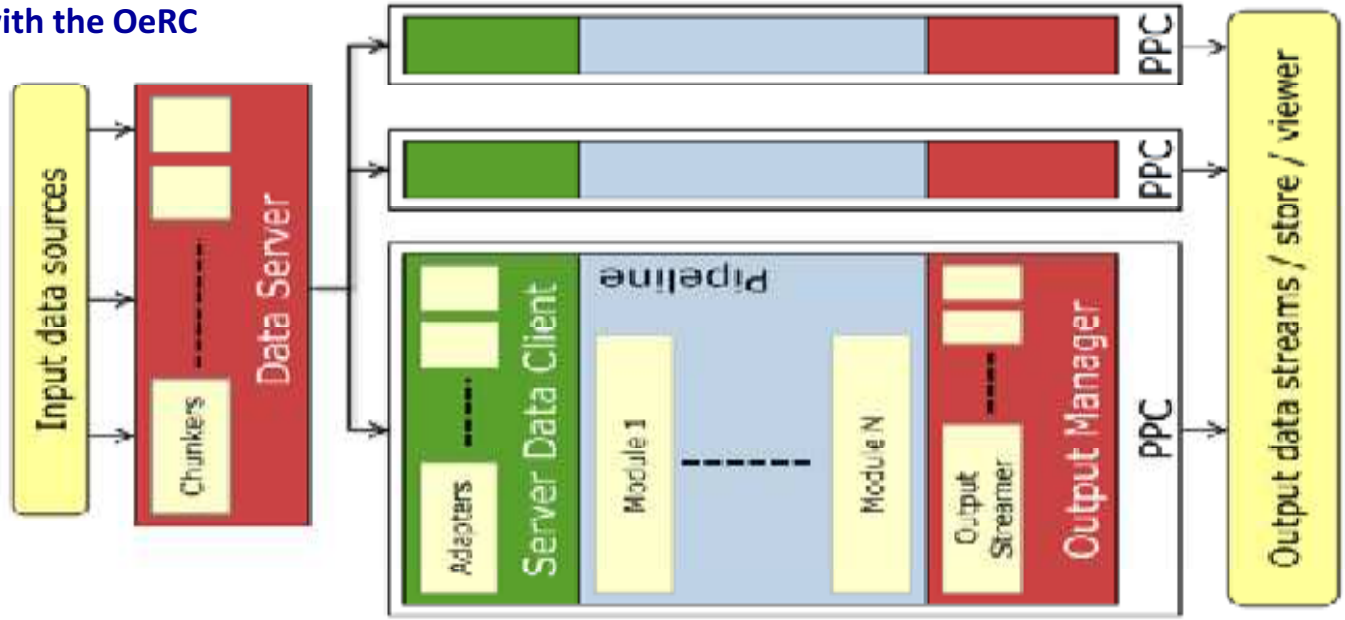
- Current Chip RFI protection shows -57dB/m (in air)

Central Processing Facility



PELICAN Software Pipeline

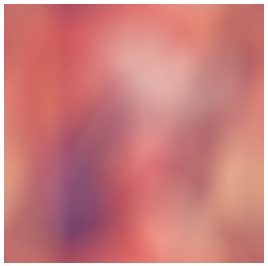
Developed with the OeRC



Correlation Matrix

$$G, \theta$$

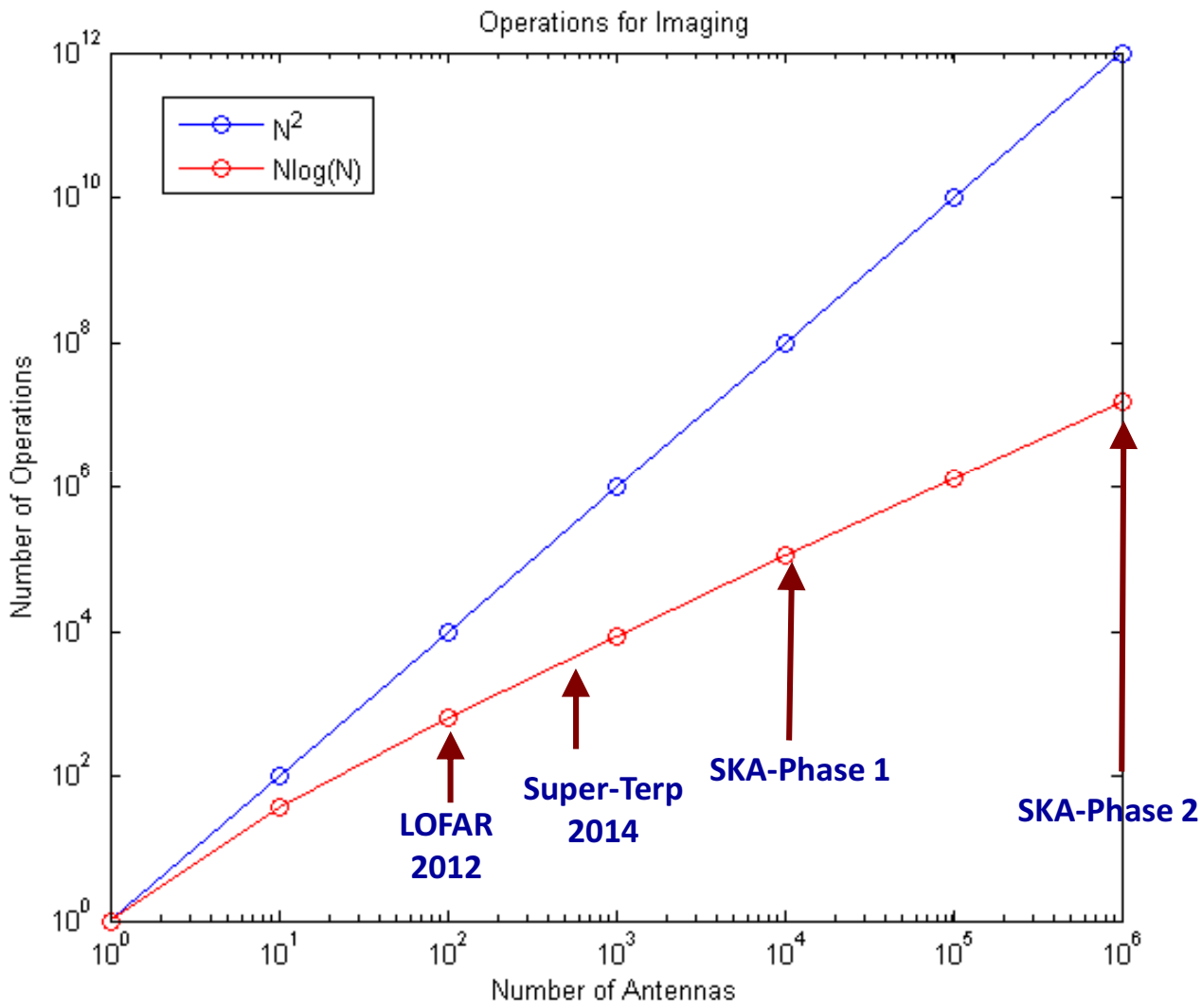
Calibration Co-efficients



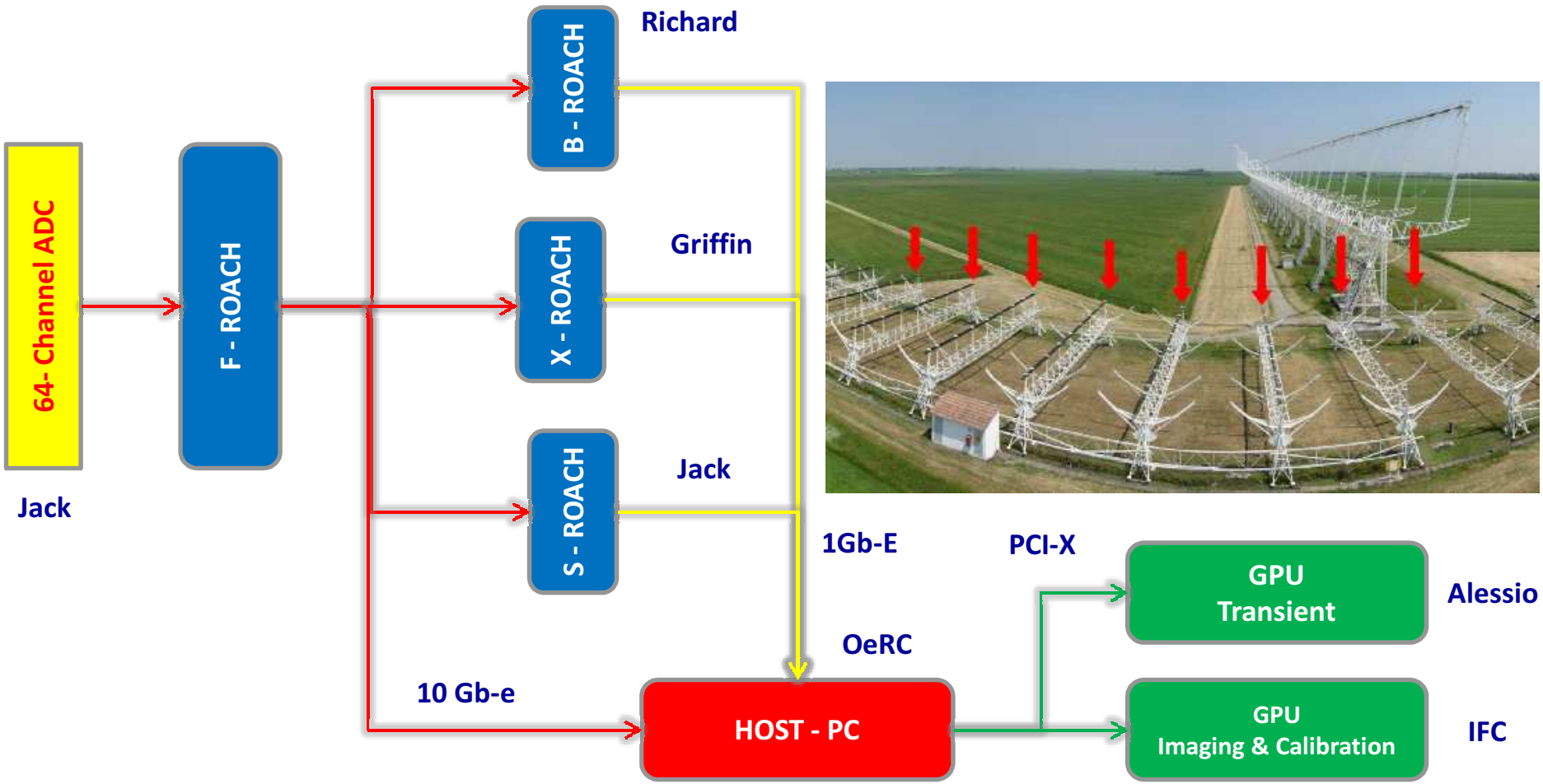
Imaging

Deconvolution

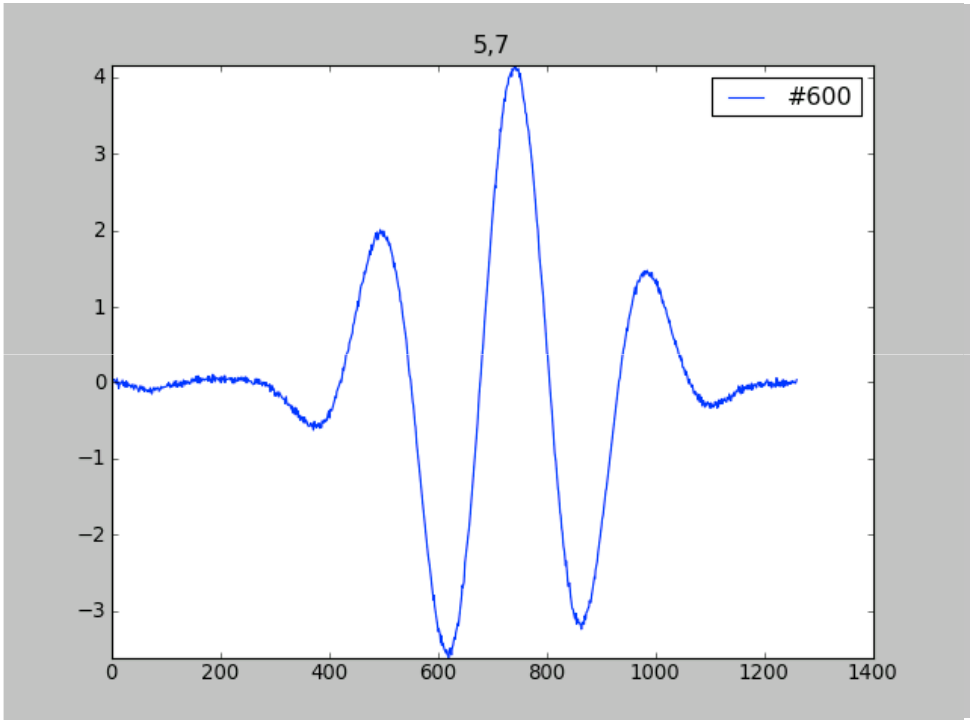
Nlog(N) vs. N^2 Correlation

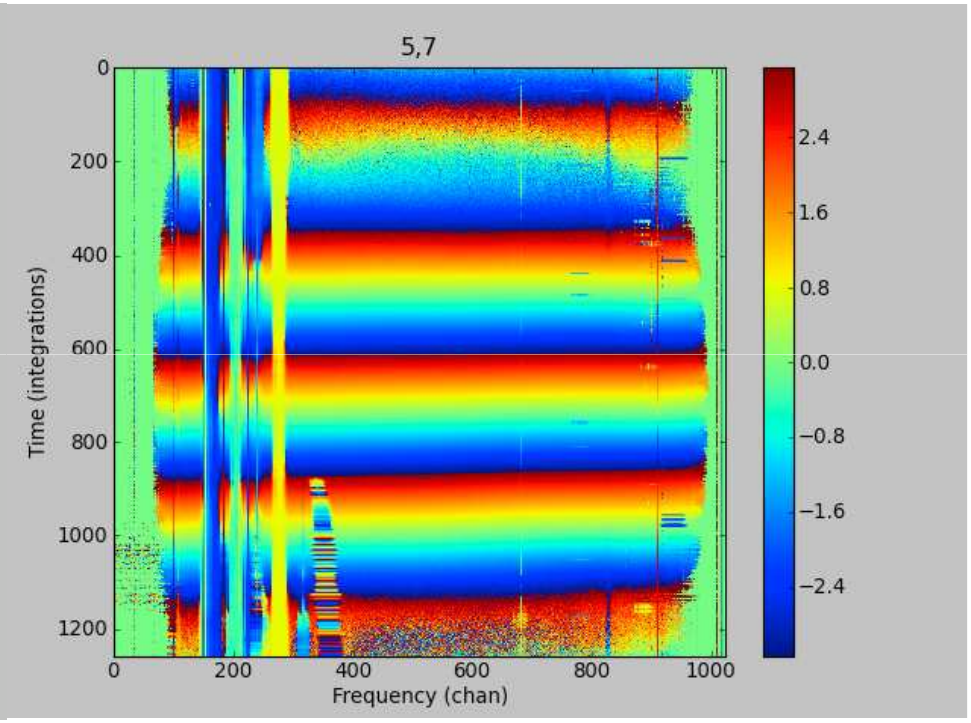


FFT radio-telescopes

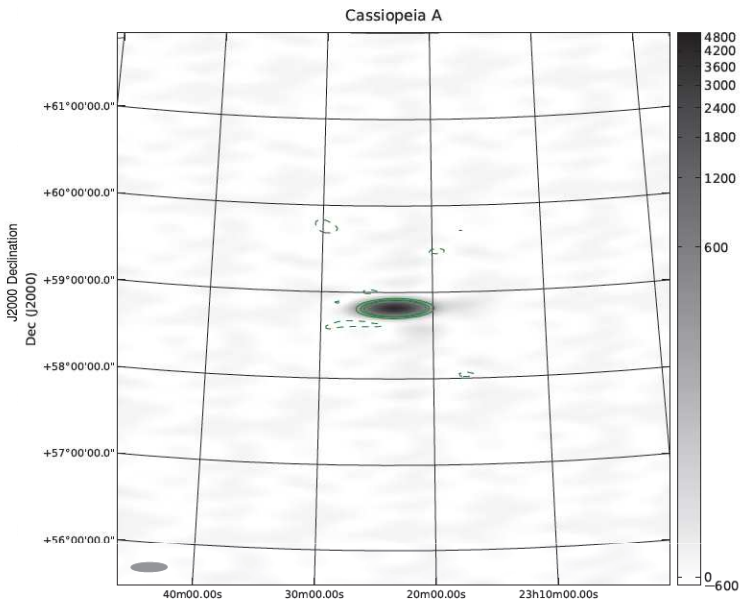


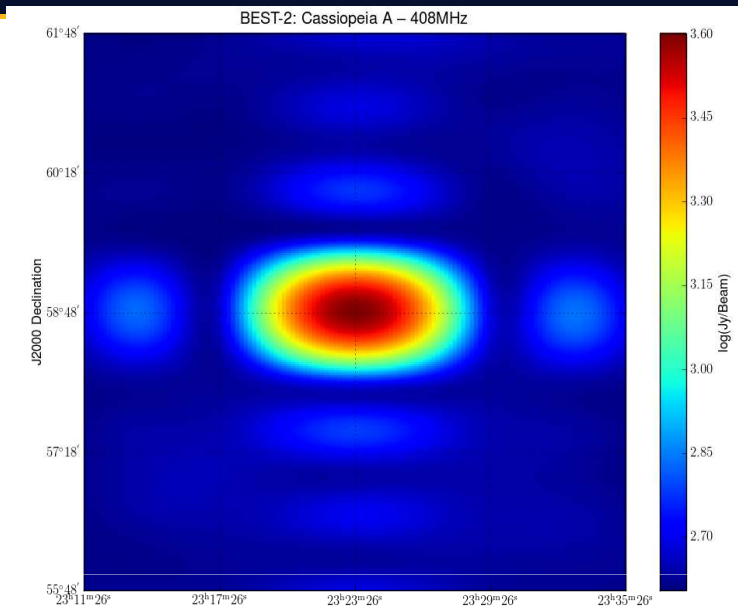
Medicina Fringes…

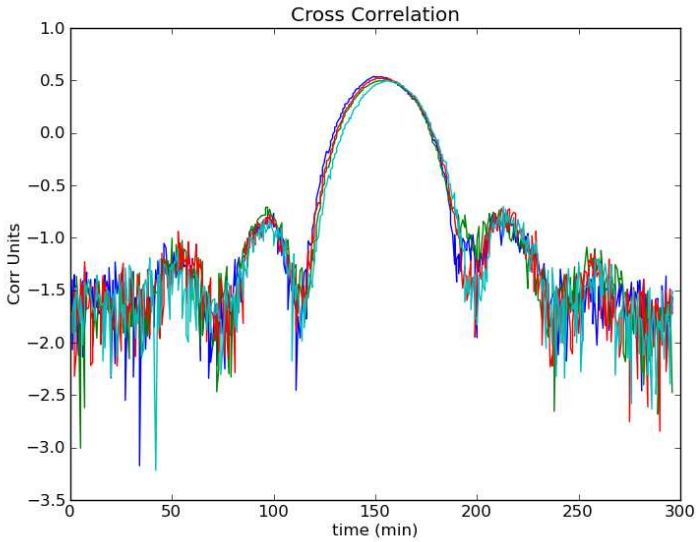


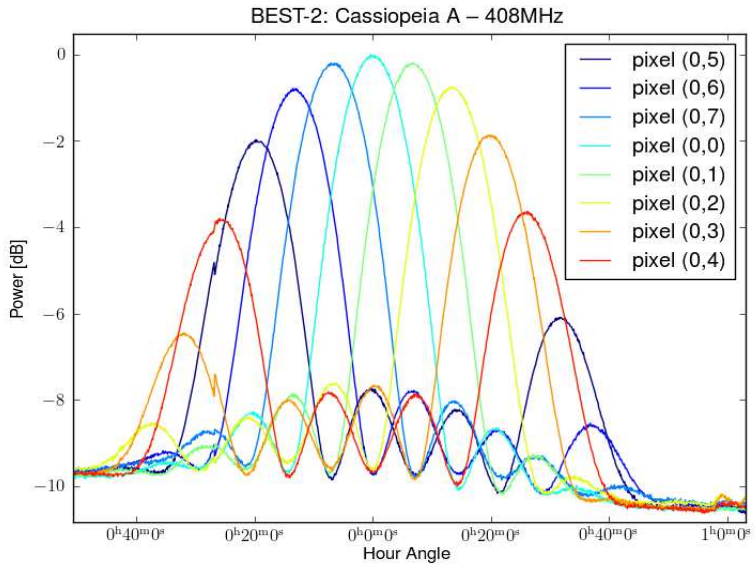


Spatial-FFT & FX Results



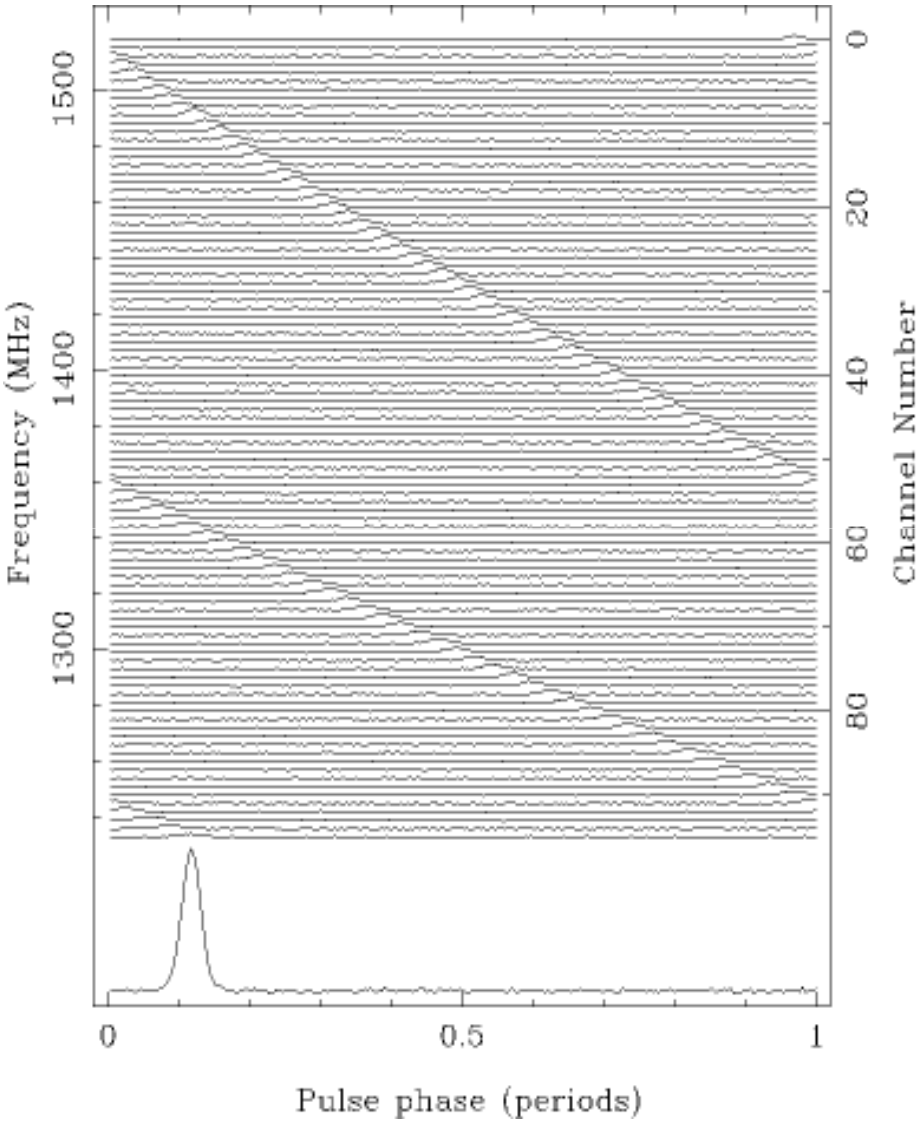


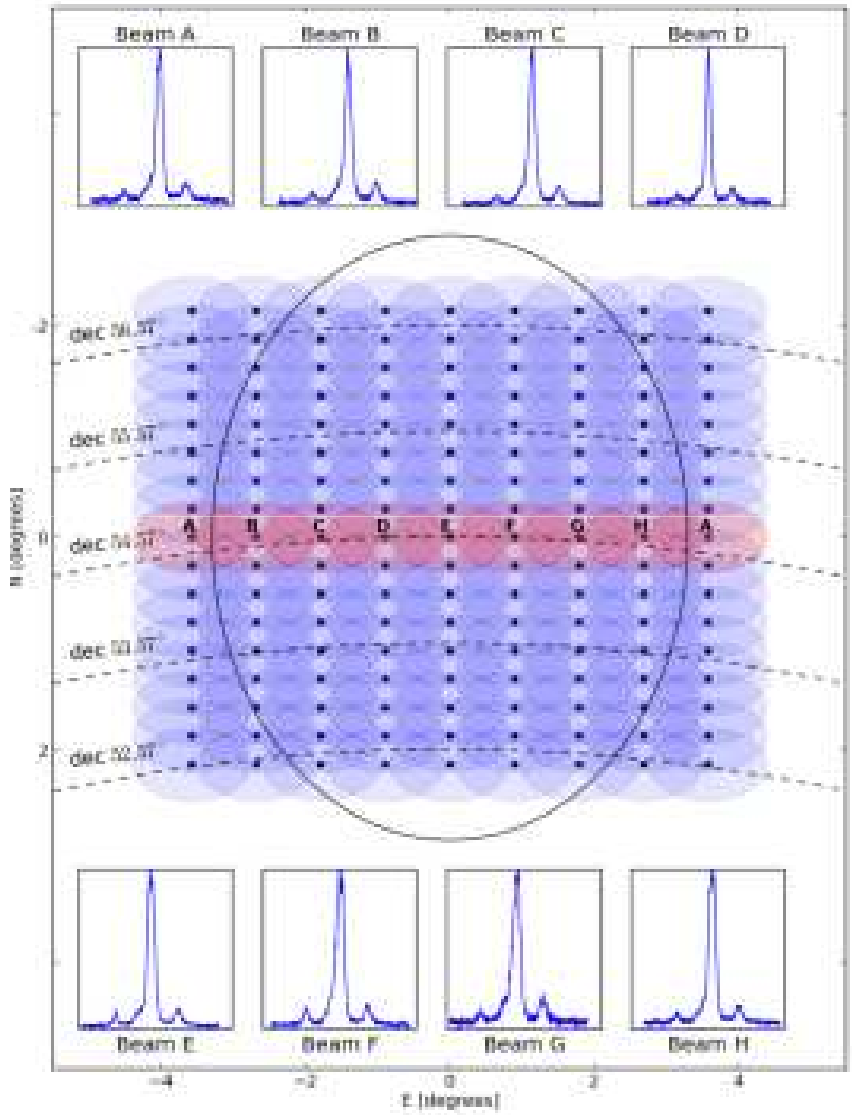




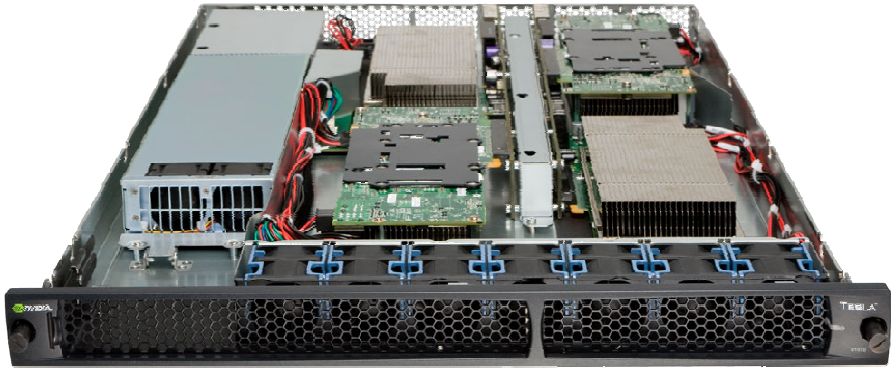
Real-Time Triggering on Transients

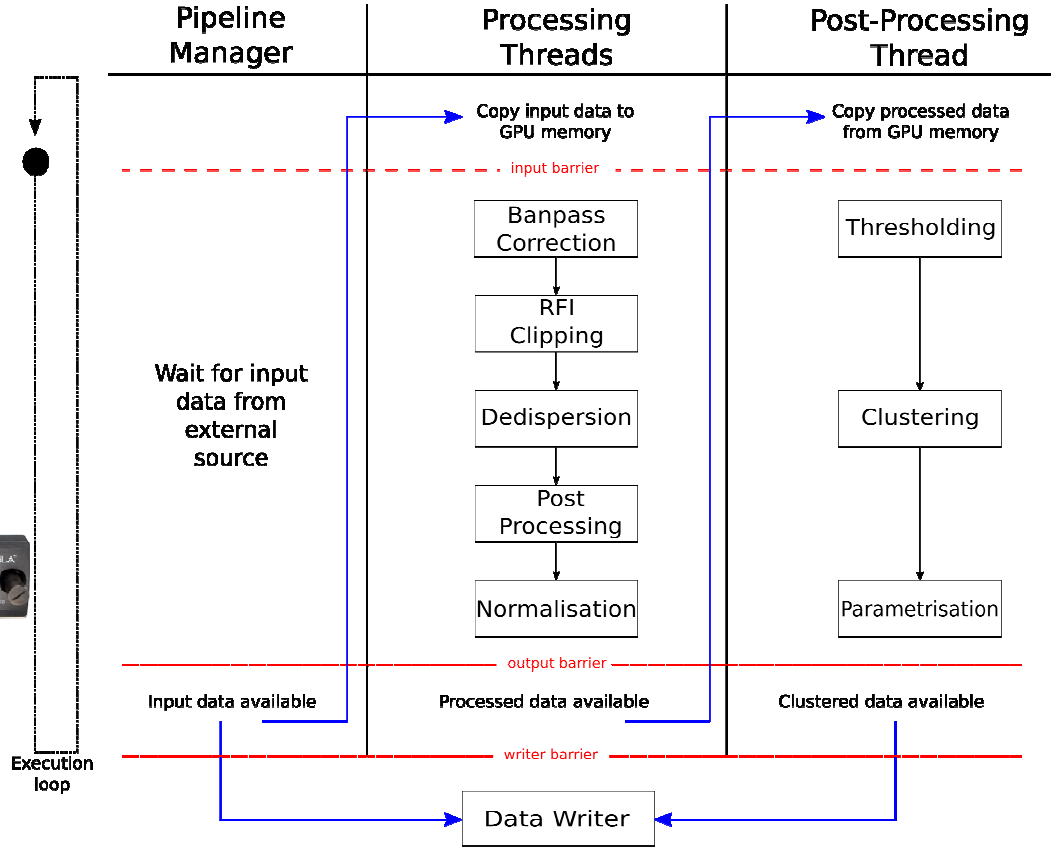
Real-Time Processing



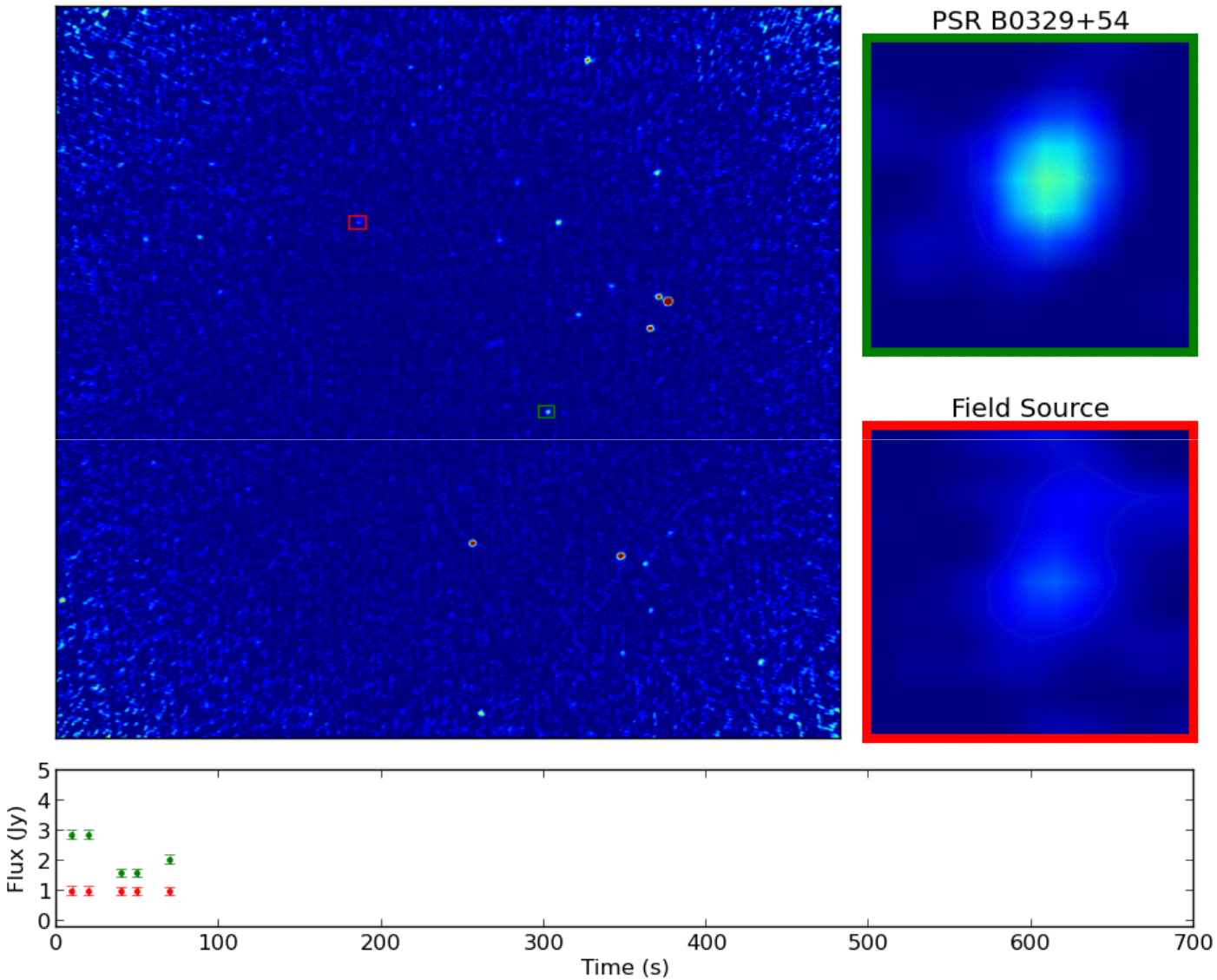


Real-time processing on GPU(s)





Watching a pulsar live…



Courtesy: Fender et al.

The **SKA ICT Challenge**

- > 10 Tb/s network + “Mount ExaFlop”
- ~30000 40 TMACs DSP engines
- ~10000 50-Tflop many-core processors
- >10 Pflop supercomputer
- Pb/s input to ExaByte archive
- ~100 MW power budget

Nobel Prizes in Astronomy
Instrument Scale v Date