ASKAP’s phased array feeds

for radio astronomy

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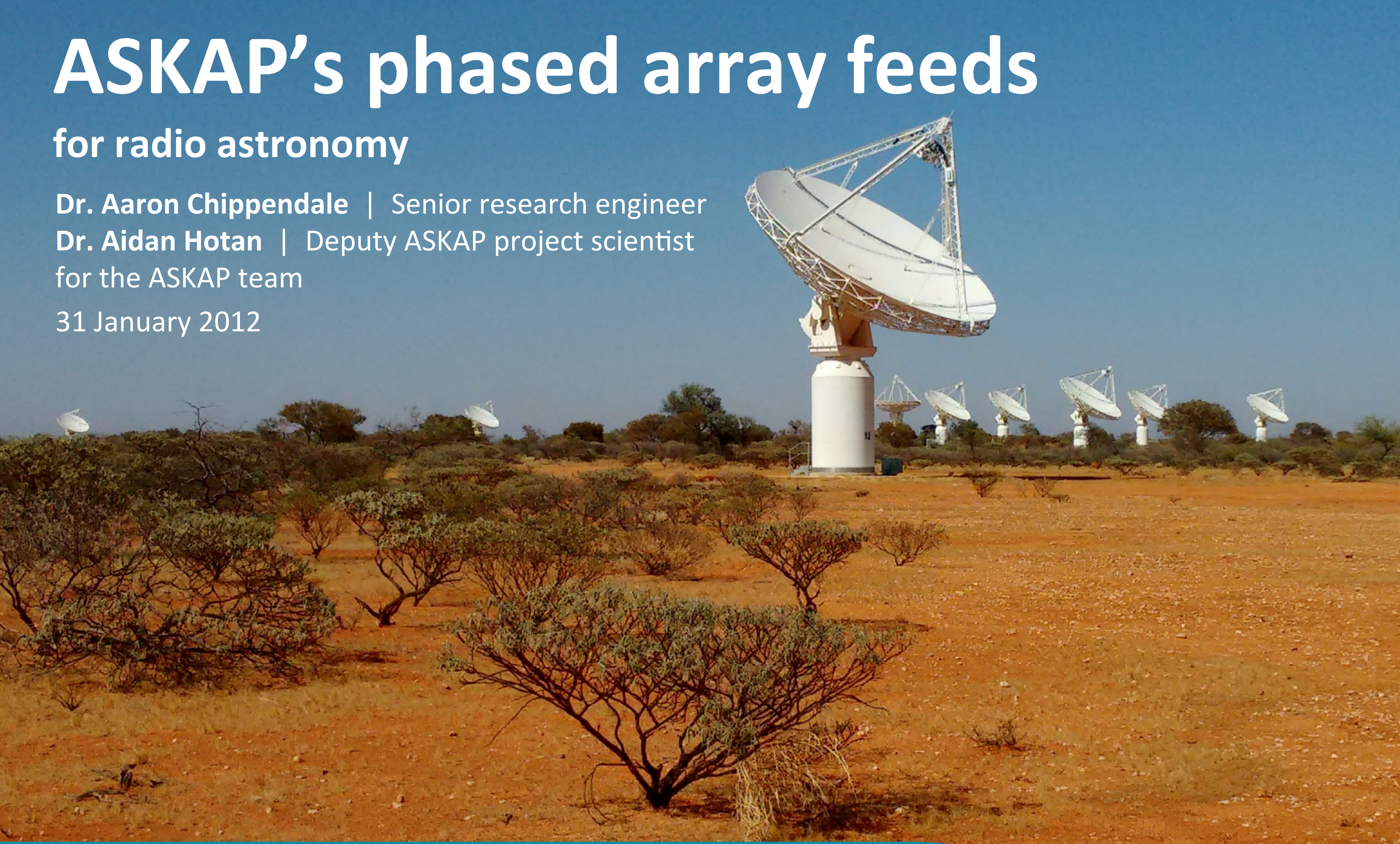
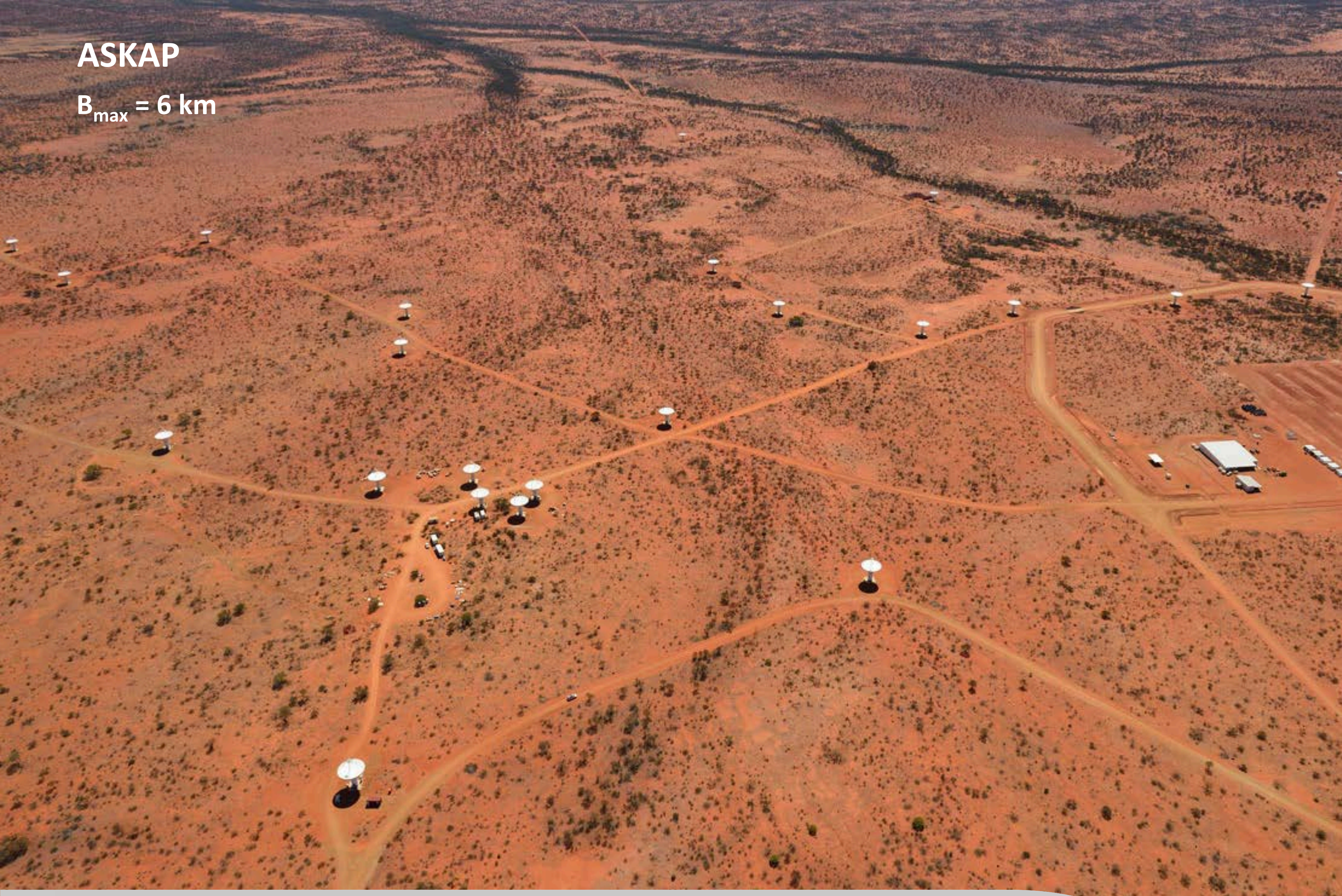
for the ASKAP team

31 January 2012





ASKAP

B_{max} = 6 km

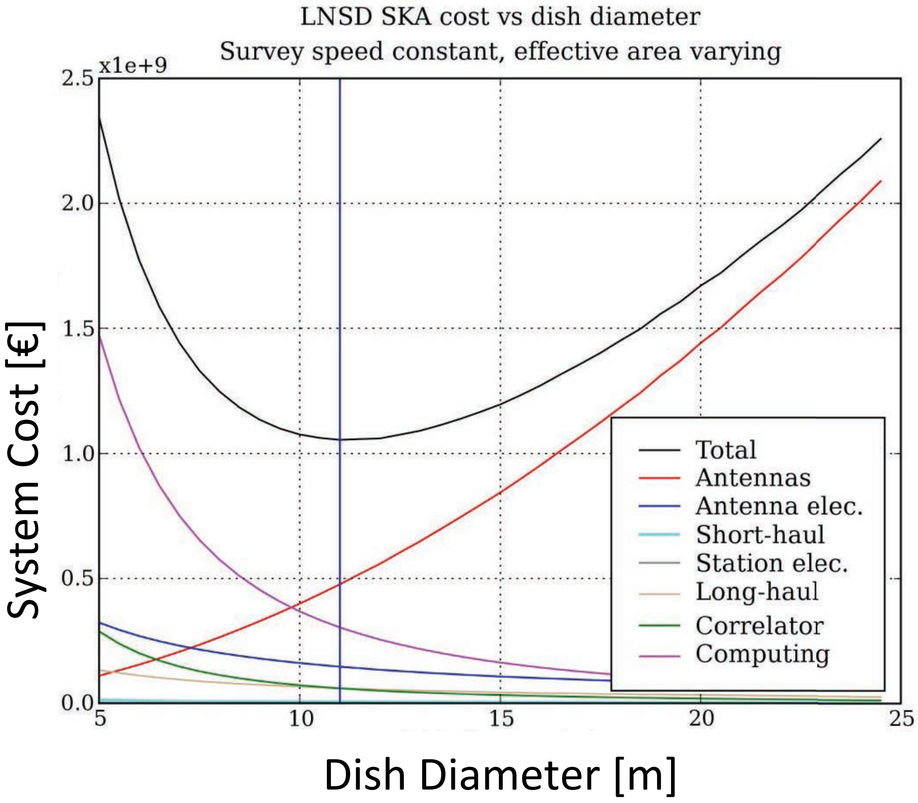
Australian SKA Pathfinder | 36 antennas | 0.7 – 1.8 GHz | 30 deg^2 FOV

Overview

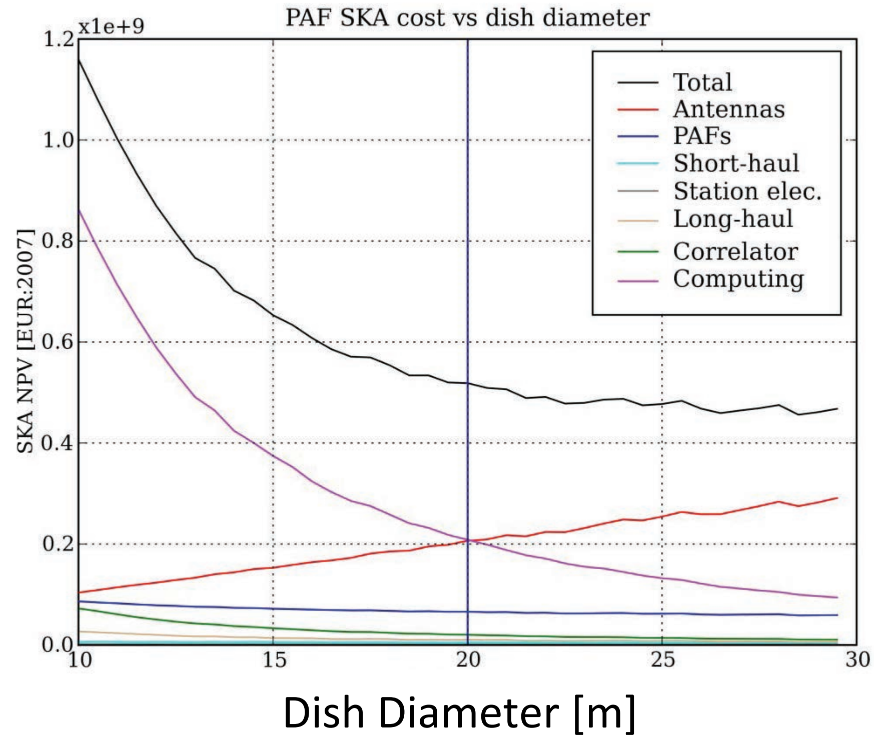
- How well do PAFs do astronomy?
- How do we scale PAFs to SKA?

Cost effective wide surveys
(cost trades with fixed survey speed)

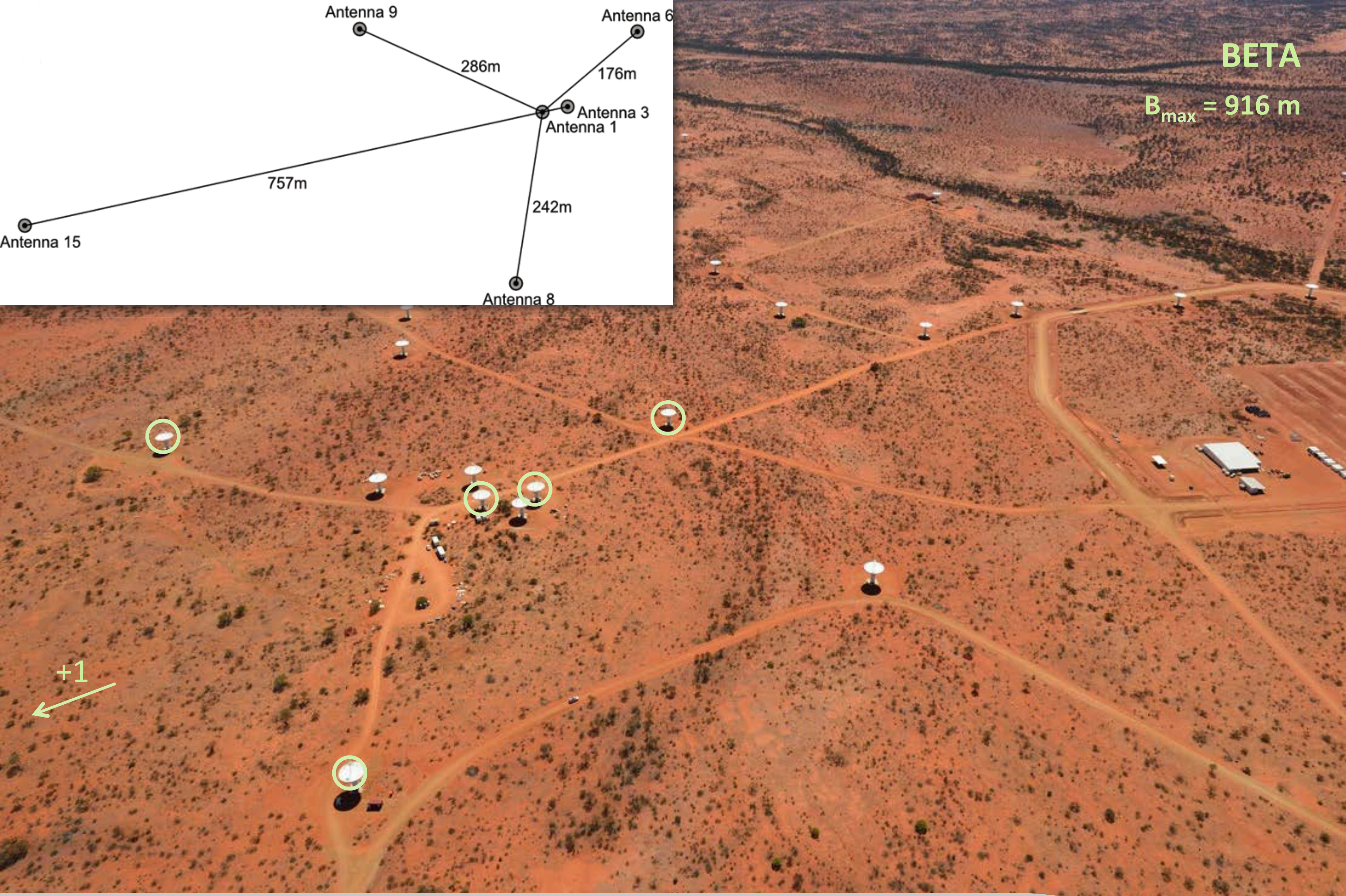
Single pixel feeds



Phased array feeds



(Chippendale et al., SKA Memo 92, 2007)



Boolardy Engineering Test Array| 6 of 36 antennas | 9 of 36 beams

Wide fields fast!

- 150 deg^2
- 12 hours per observation
- noise 1σ < 1 mJy
- 2,000 sources > 5σ
- 3 × 12 hr observations in RGB

This demonstration with:

- Just 6 of 36 antennas
- Just 9 of 36 beams

Credit: Keith Bannister (observations), Ian Heywood (calibration & Imaging), ACES/ASKAP team.

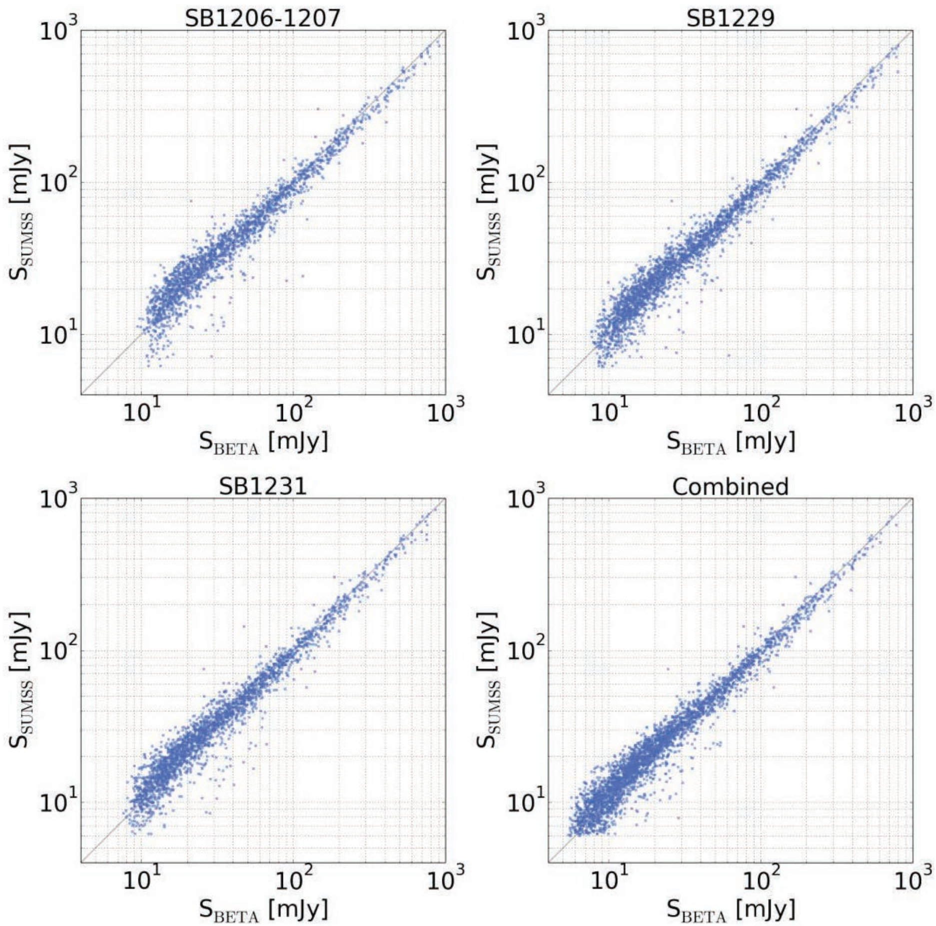
(Heywood et al., MNRAS, submitted)

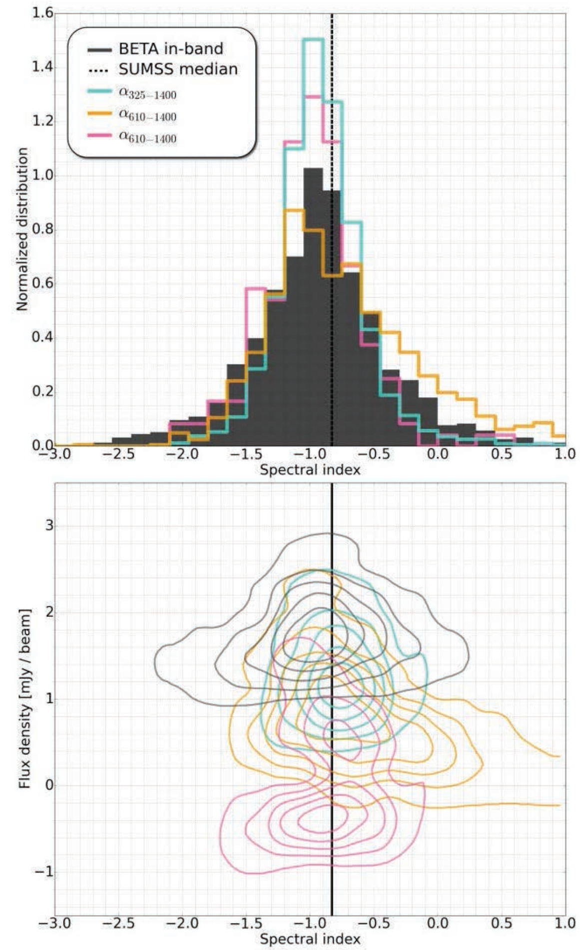
Demonstrating stability:
pseudo Stokes V pixel intensity histograms

- Noise integrates down with integration time and bandwidth
- Effective noise level (blue) is ~3 times thermal noise (pink)
- Effective noise is higher due to incomplete deconvolution as (u,v) plane coverage is limited with the 6 BETA antennas.
- Stable noise

(Heywood et al., MNRAS, submitted)

Demonstrating fidelity: *flux and spectral index*





(Heywood et al., MNRAS, submitted)

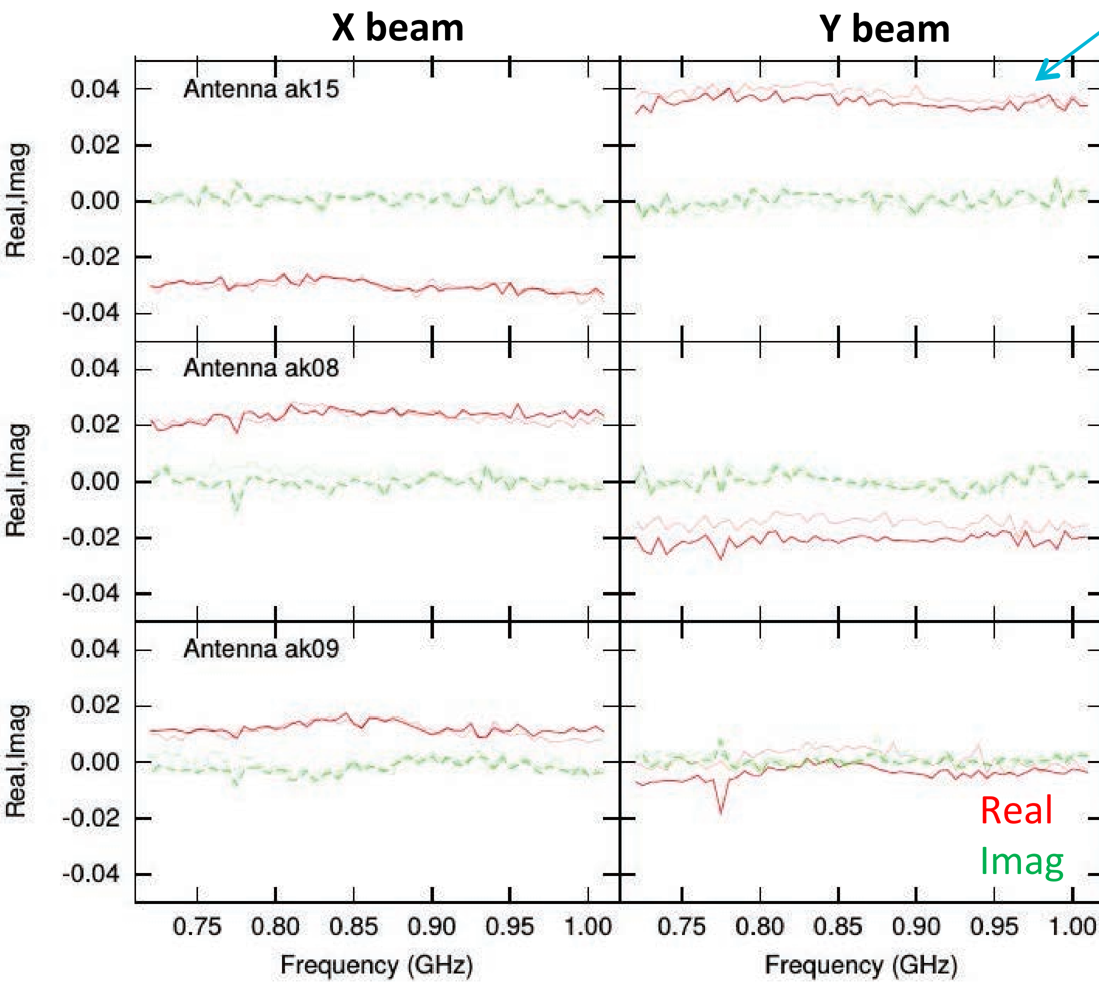
Good flux and spectral index fidelity.

But spectral index vs. flux density trend may indicate bias due to simplistic beam model

Demonstrating fidelity and stability: *polarisation*

(Sault, ACES Memo 2, 2014)

[*http://www.atnf.csiro.au/projects/askap/ACES-memos*](http://www.atnf.csiro.au/projects/askap/ACES-memos)

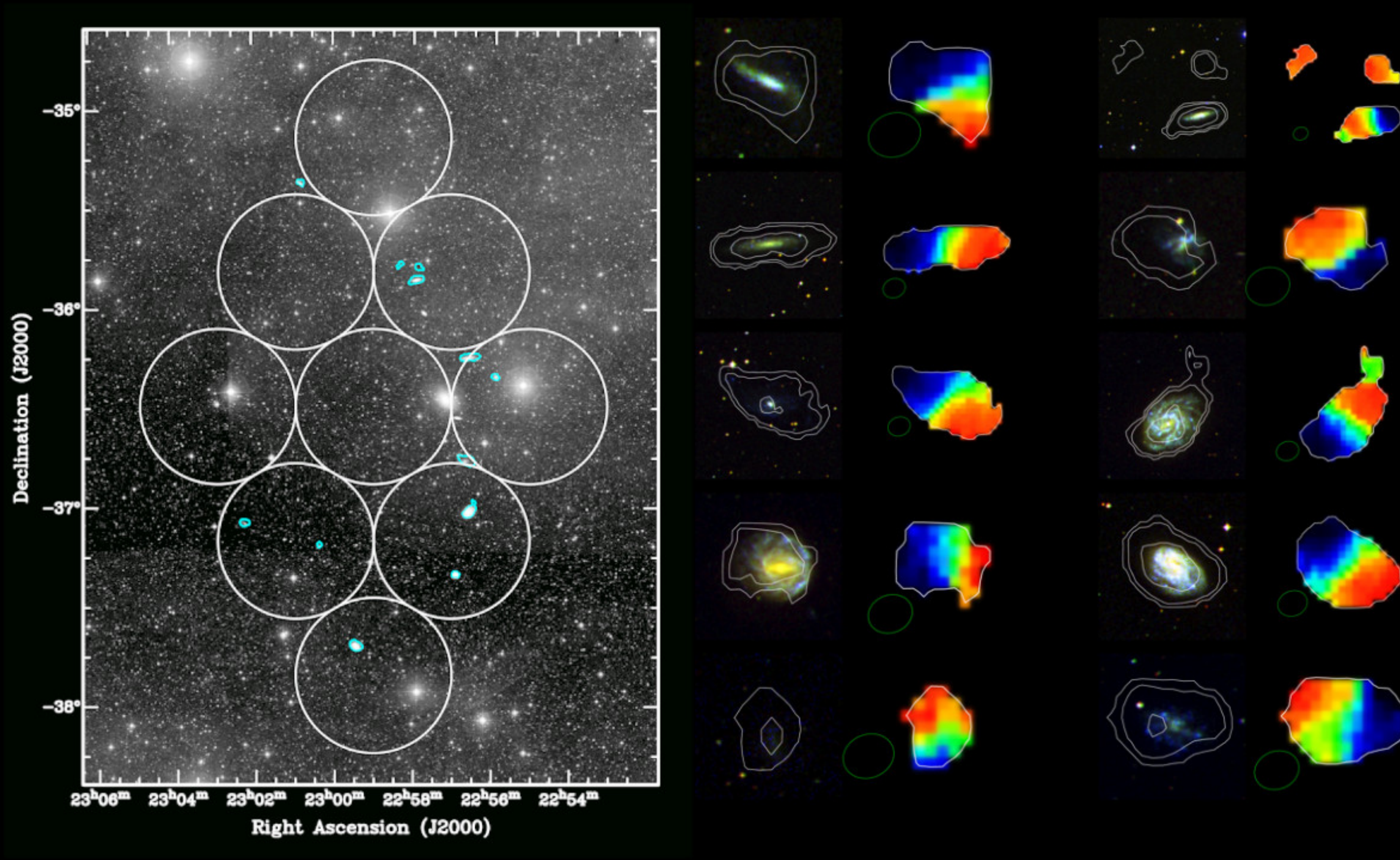


Largest error not leakage but roll axis misalignment

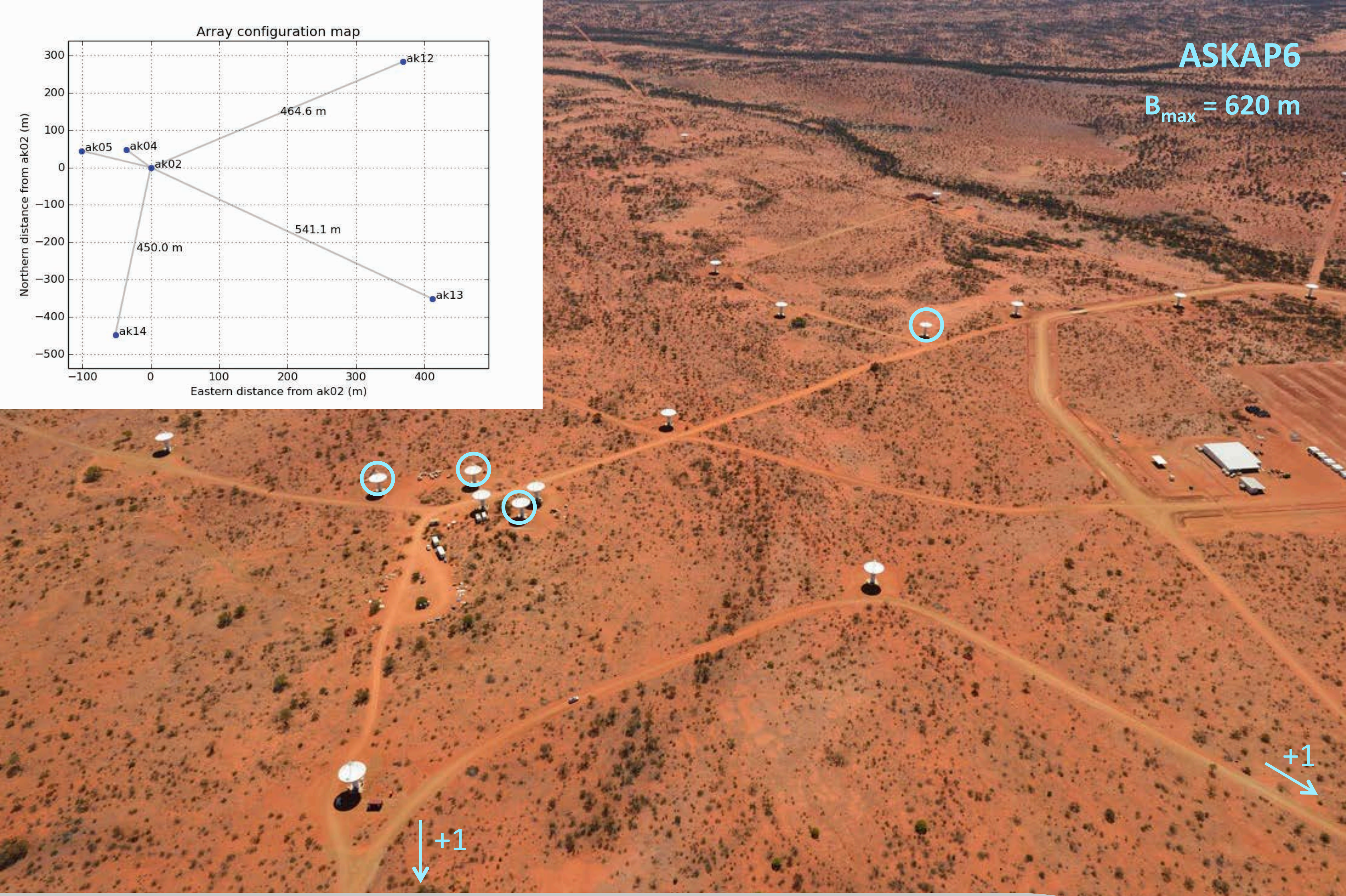
- Measured on 1934-638 (unpolarised)
- Boresight beam
- 2 epochs overlayed
  - 3 July 2014
  - +6 weeks
- Good results
  - low leakage
  - smooth with freq.
  - stable over 6 weeks

Great start. Will do better with pattern constrained beams using all X and Y inputs for both X and Y beams

HI in galaxy group IC 1459 *(Serra et al., MNRAS 2015)*



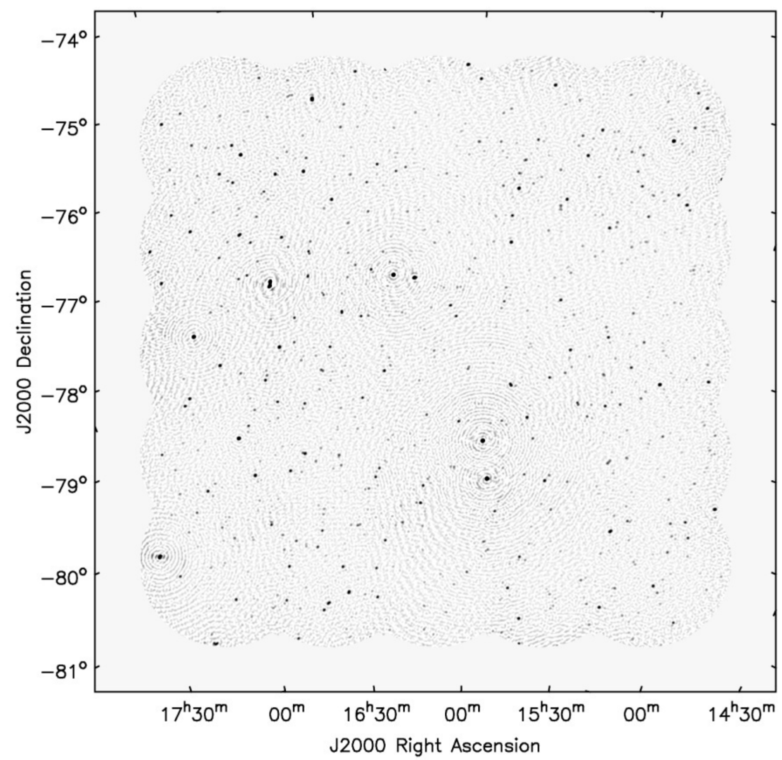
10 hr | 1.4 GHz | 6 deg^2 FOV | 8 km.s^{-1} res. | Slide Design: Ian Heywood



ASKAP6: First 6 ASKAP Antennas with Mk II PAFs | 36 beams

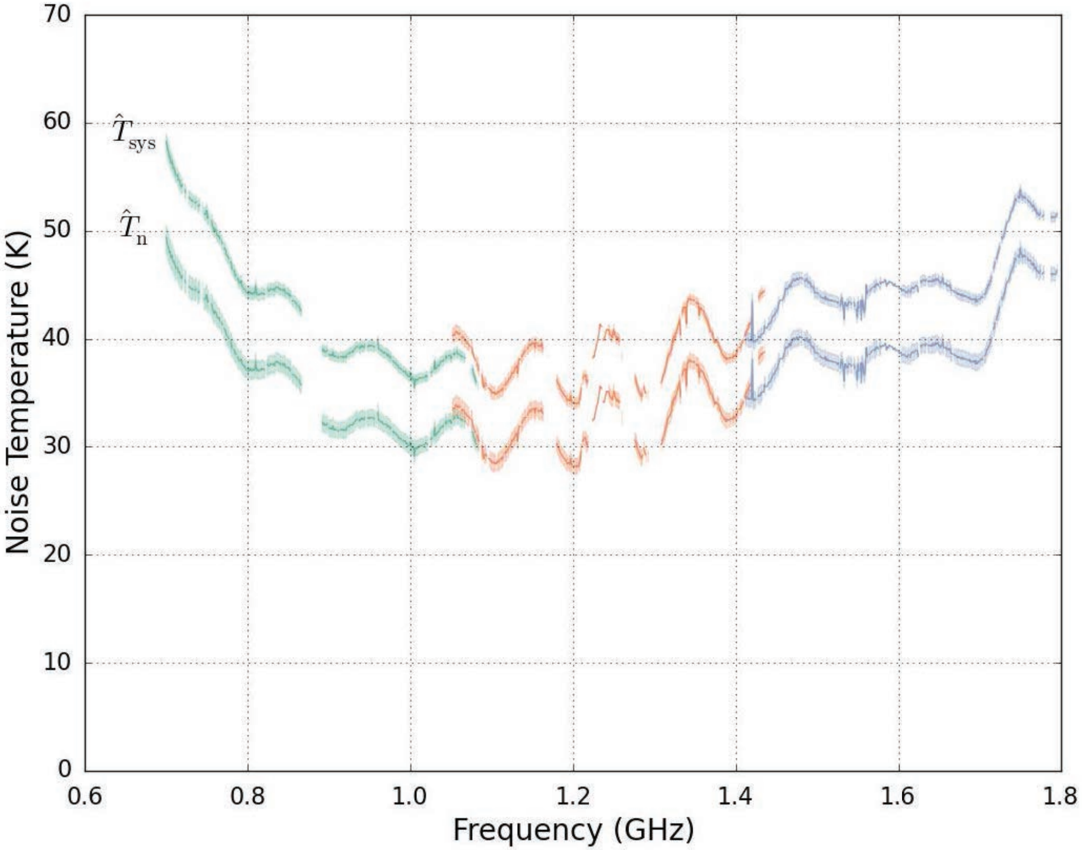
First 25 PAF-beam synthesis image

- Five Mk II PAFs on ASKAP antennas
- 12 hr synthesis on Apus field
- 30 deg^2 field of view
- Calibrated and imaged on the ASKAP real-time computer at the Pawsey Supercomputing Centre in Perth
- 48 MHz bandwidth commissioning mode



The first ever 25 beam image produced in radio astronomy, using five ASKAP antennas installed with Mk II PAFs at the MRO. This image is approximately 30 square degrees - the complete ASKAP field-of-view. Credit: CSIRO ACES team.

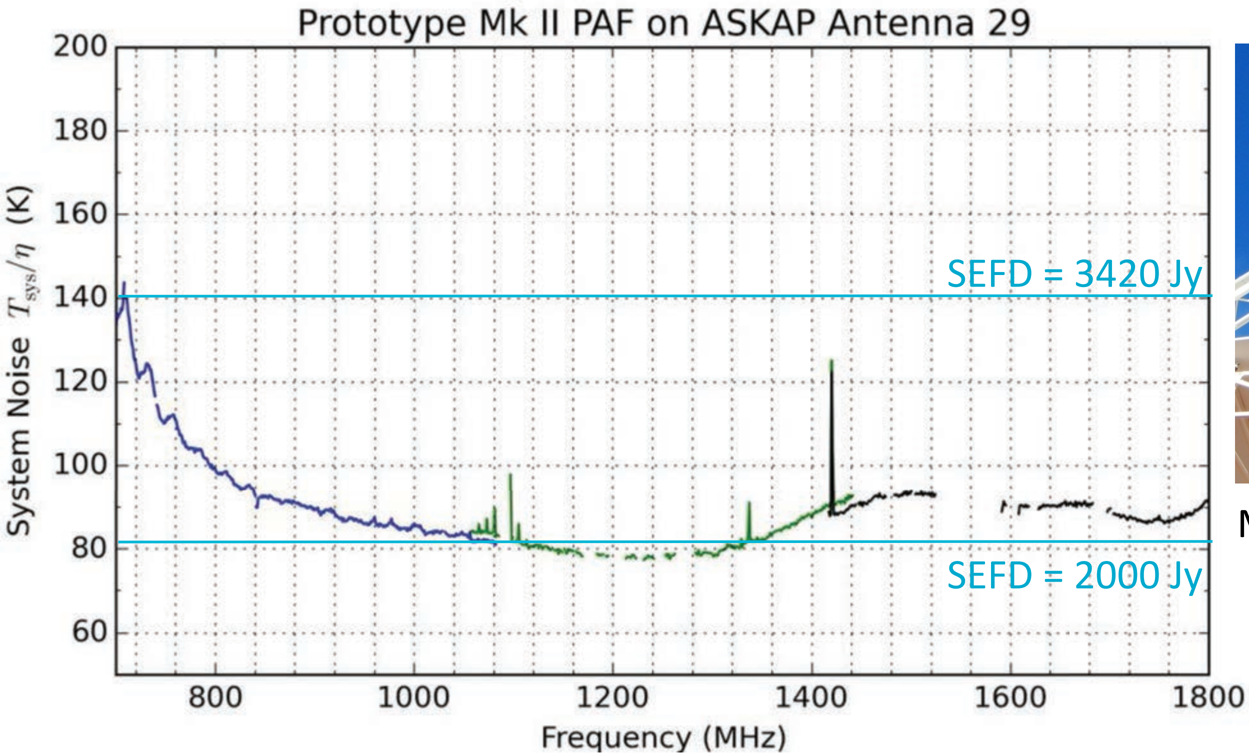
Mk II: Aperture array noise temperatures

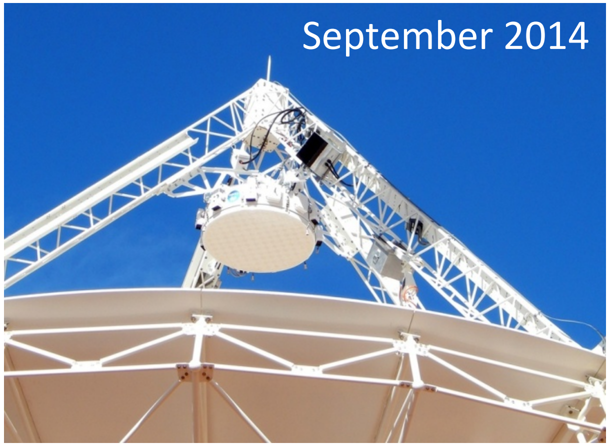


Measurement on Mk II prototype

Chippendale et al., ISAP 2015
Chippendale et al., PASA 2014

Mk II: On-dish system noise temperature





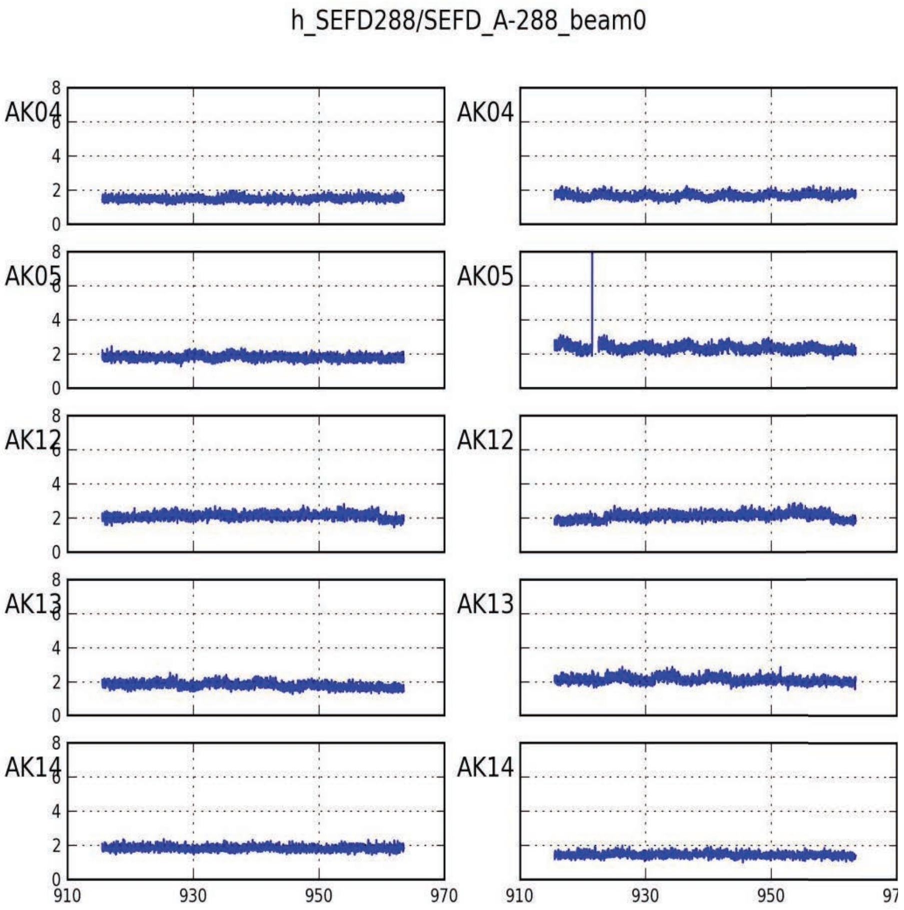
Measurement on Mk II prototype

Beamformed T_{sys}/η < 95 K from 835 MHz to 1,800 MHz

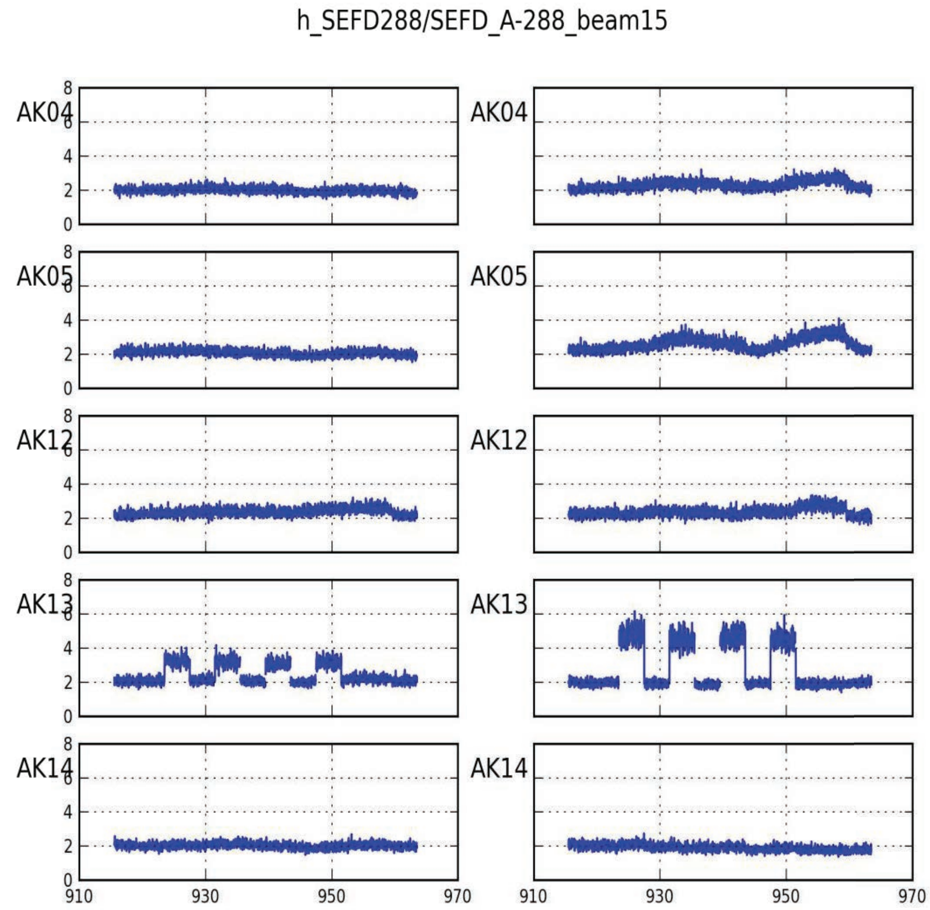
Chippendale et al., ICEAA 2015

Mk. II SEFD: Preliminary Measurements of 5 PAFs

Beam 0 (boresight)

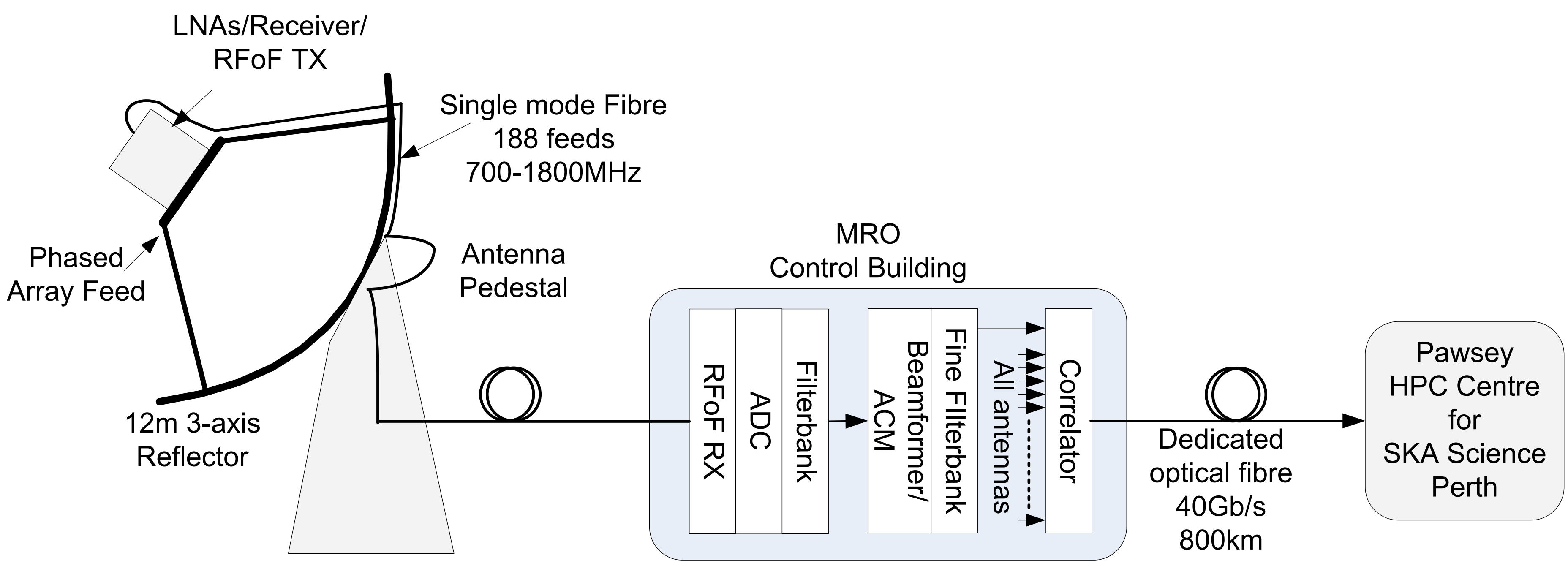


Beam 15 (3.9 deg from boresight)



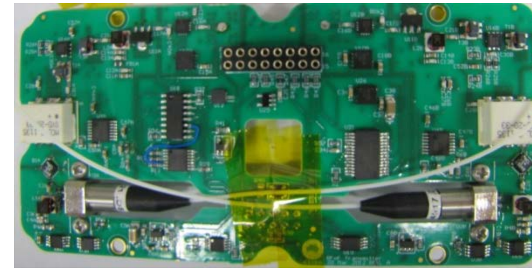
(McConnell, Unpublished, 2015)

ASKAP system architecture

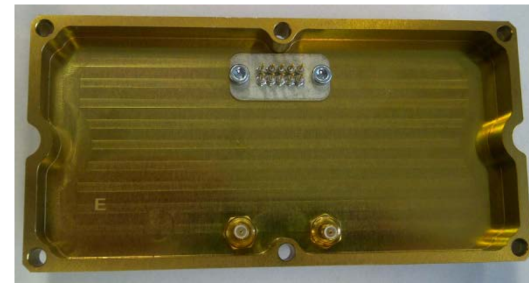


RF module (domino)

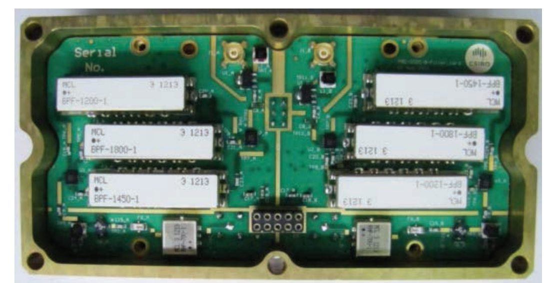
RFoF Tx



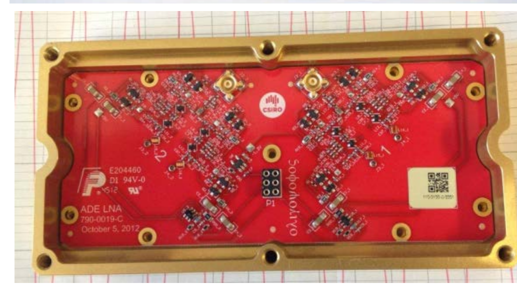
connector

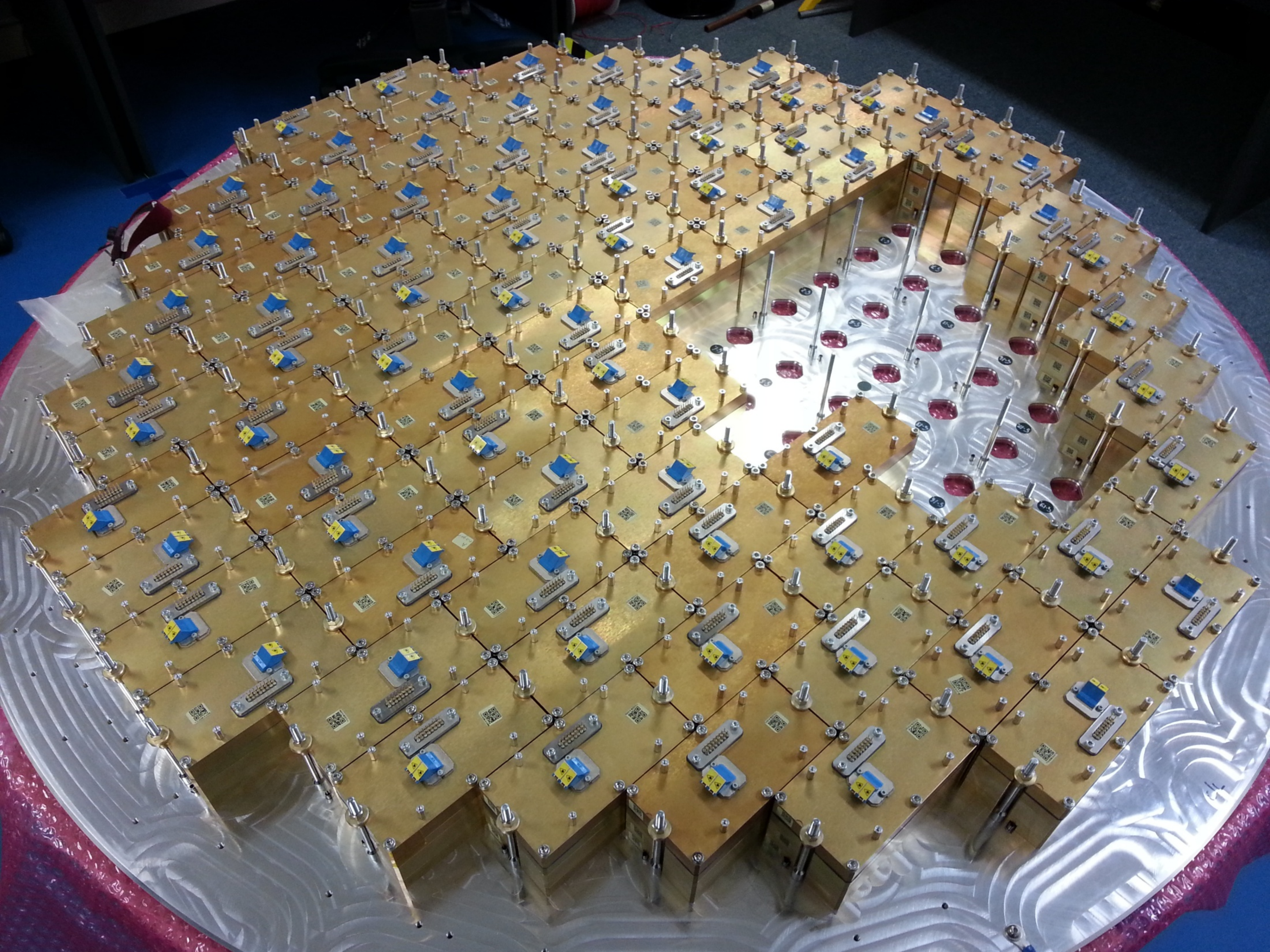


filter (3 × 600 MHz BPF)



LNA



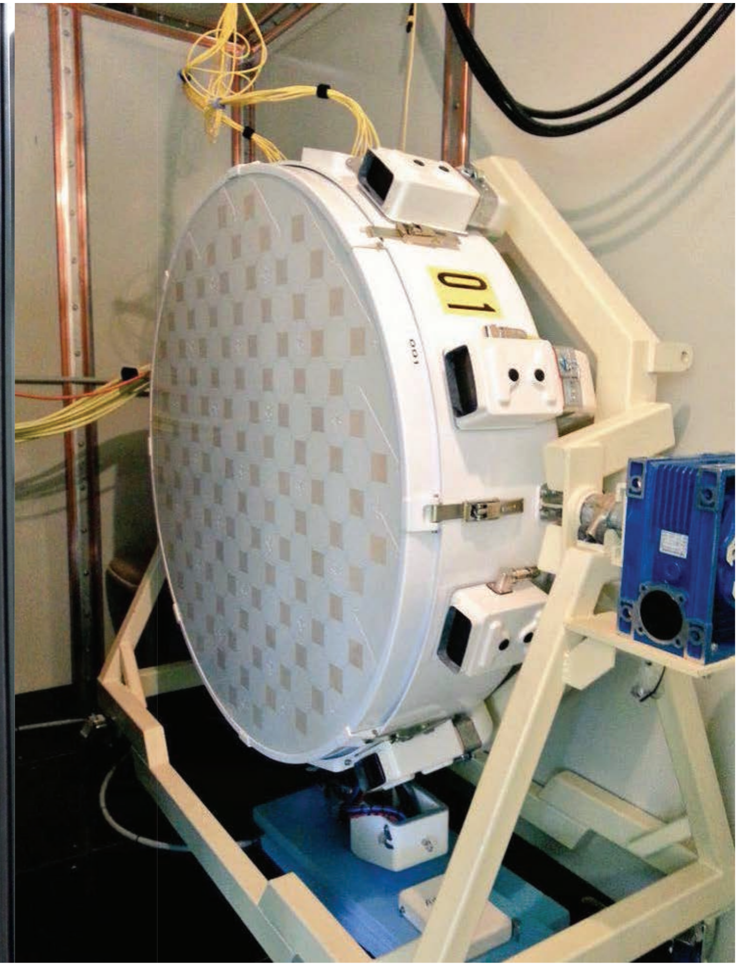


All fiber direct sampling system

Hampson et al., URSI GASS 2014

Brown et al., ICEAA 2014

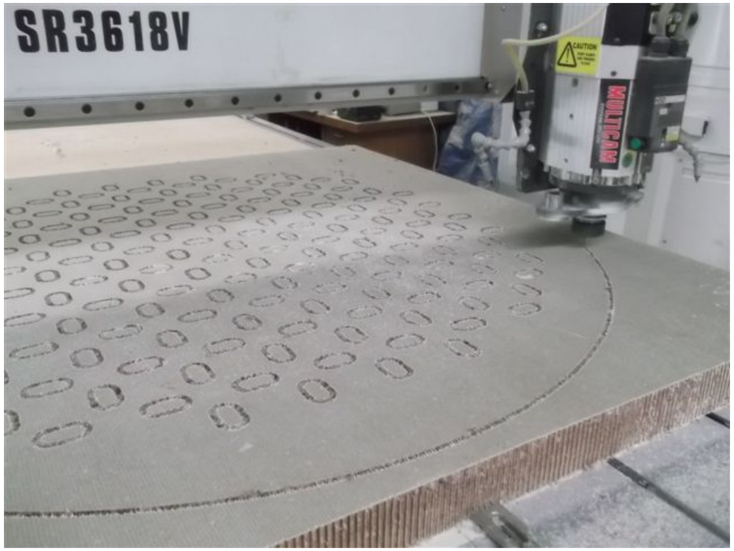
Hampson et al., ICEAA 2012

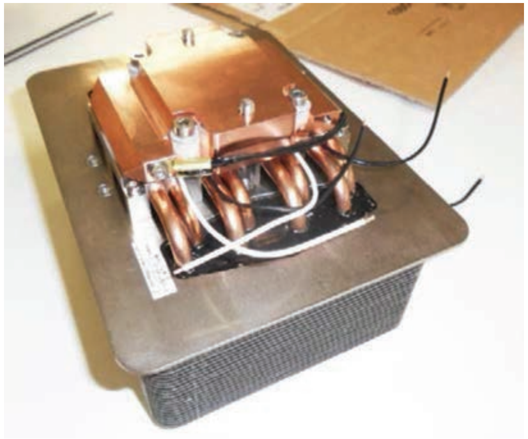


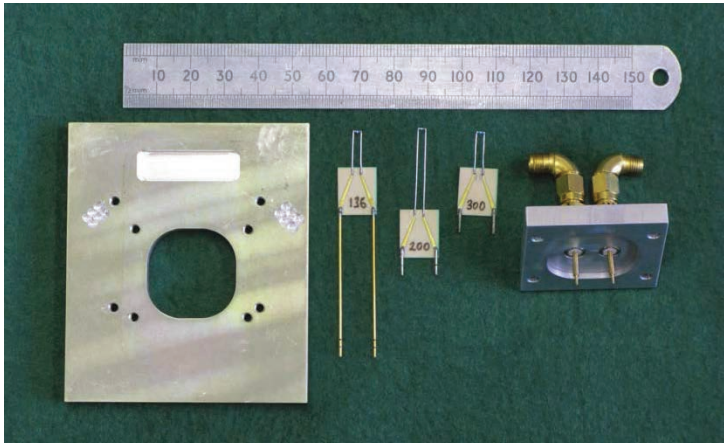
BW: 384 MHz 600 MHz 600 MHz

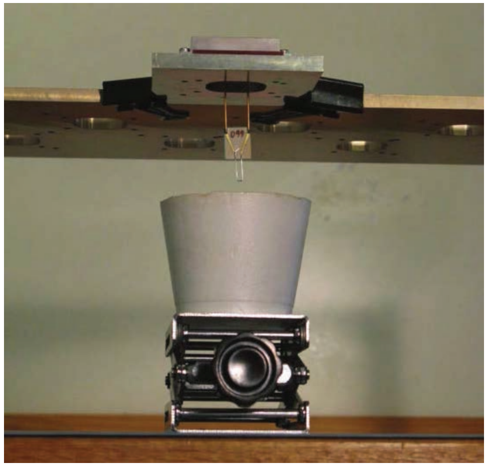
CSIRO

New materials, technology and techniques









PAF Production/Installation Status (as of 16/12/2015)

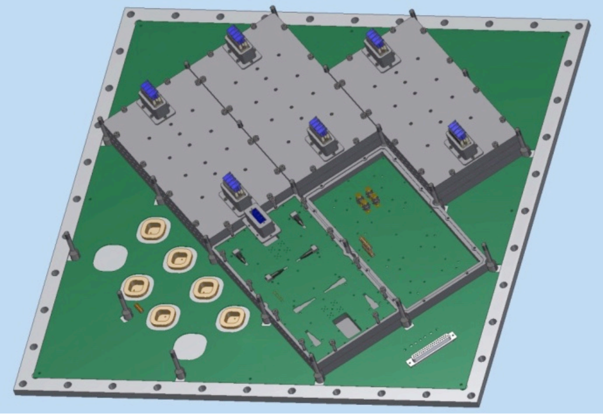
PAF #	FEEDER WIRES SOLDERED	THERMAL EDGES INSTALLED	DOMINOES & PCBS INSTALLED	DC CABLES TESTED	OPTICAL FIBRES TESTED	AIR LEAK TESTED	FUNCTIONAL TESTING	EMI TESTED	CRATED	Installed @ MRO
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓ AK04
2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓ AK05
3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓ AK02
4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓ AK13
5	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓ AK12
6	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓ AK14
7	✓	✓	✓	✓	✓	✓	✓	✓	✓	
8	✓	✓	✓	✓	✓	➡				
9	✓	✓	✓	✓	✓	✓	✓	✓	✓	
10	✓	✓	✓	✓	✓	✓	✓	✓		
11	✓	✓	✓	✓	✓	✓	➡			
12	✓	✓	✓	✓	✓	✓	↑			
13	✓									
14	✓	✓	✓	↑						
15	✓	✓								
16	✓	✓								
17	✓									
18	✓									

✓ COMPLETED / PASS ↑ PARTIAL COMPLETION ➡ RETEST REQUIRED

Provided by Adrian Rispler, ASKAP PM

Ongoing development

led by Alex Dunning



- 5x4 Mk III prototype nearing completion
  - evolved from SKA survey band 2 PAF work
  - 650 MHz to 1670 MHz
- May reduce T_{sys} significantly (>10 K) compared to Mk II ASKAP PAFs
  - Expectation from infinite array simulations including measured LNA data
- New element, LNA, and RFoF design (8 channels per module)
- New mechanical design
- Power and control and monitor integrated into groundplane
- Compatible with Mk II AKSAP digital backend optical input

To SKA and beyond...

We acknowledge the Wajarri Yamatji people as the traditional owners of the observatory site.

Thank you

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Register now: www.csiro.au/ASKAP2016

CSIRO

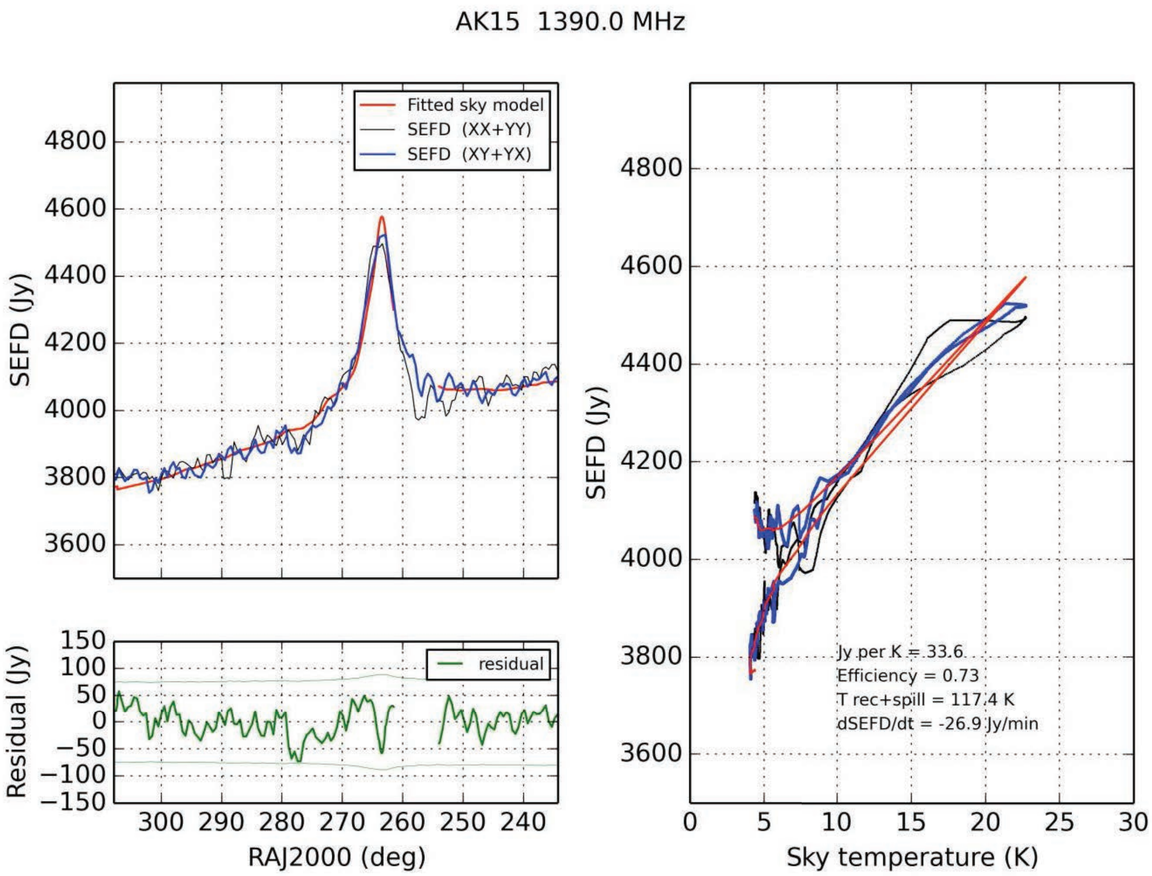
ICRAR International Centre for Radio Astronomy Research

CAASTRO ARC CENTRE OF EXCELLENCE FOR ALL-SKY ASTROPHYSICS

Astronomy Australia Ltd.

Measuring sensitivity: Mk I PAF at 1390 MHz

(McConnell et al., ACES Memo 5, 2015)
http://www.atnf.csiro.au/projects/askap/ACES-memos



$$\mathrm{SEFD} = \frac{2k}{\eta A}(T_{rec} + T_{spill} + T_{sky})$$

$$\mathrm{SEFD} = aT_{sky} + b$$

Invert for all baselines and decompose per antenna

$$T_{sys} = 111 \pm 7\ \mathrm{K}$$

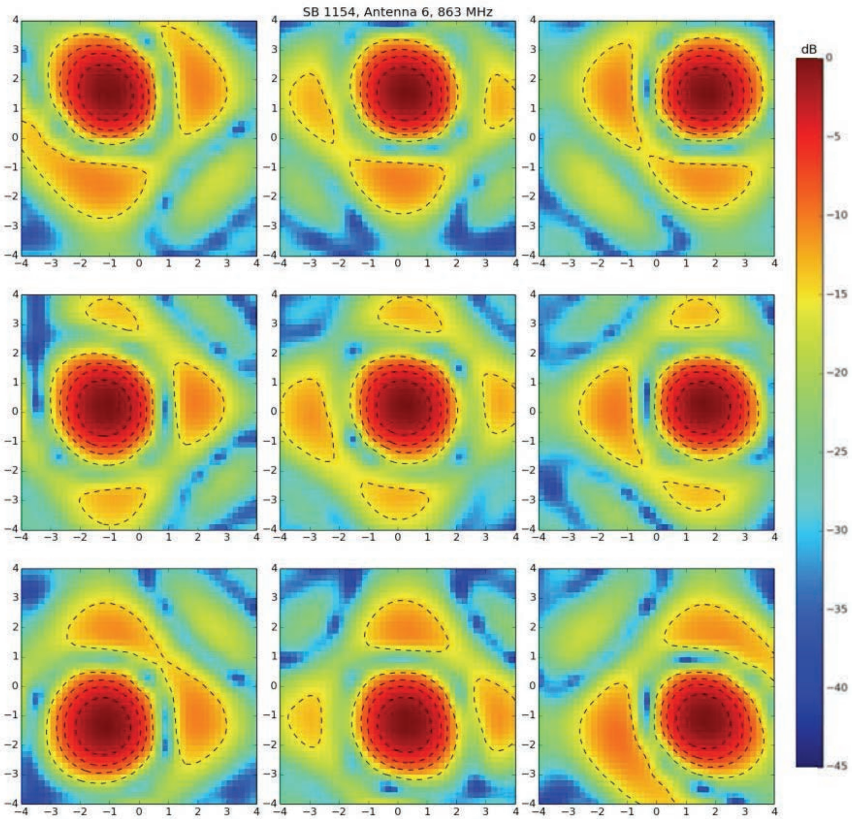
$$\eta = 70 \pm 4\ \%$$

Neglected loss variation with ambient temp.

Evidence of temperature dependent gain and gain/calibration errors

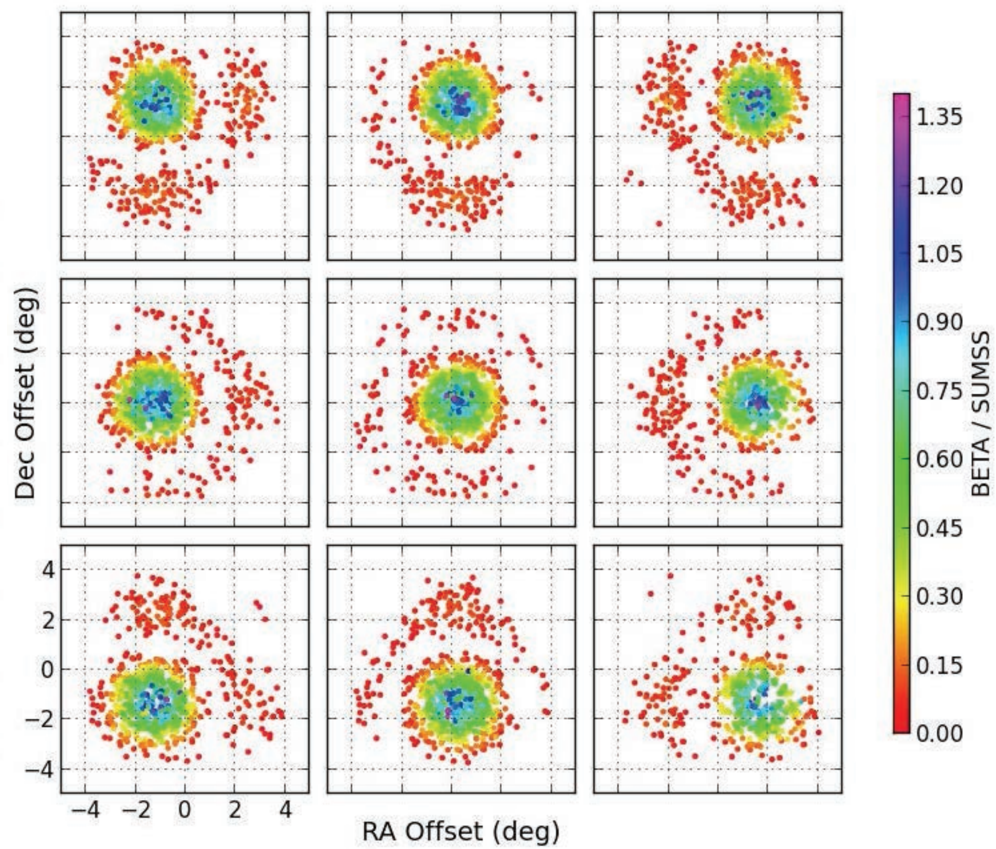
Measuring patterns: Mk I PAF at 863 MHz

Holography



(Hotan, unpublished 2014)

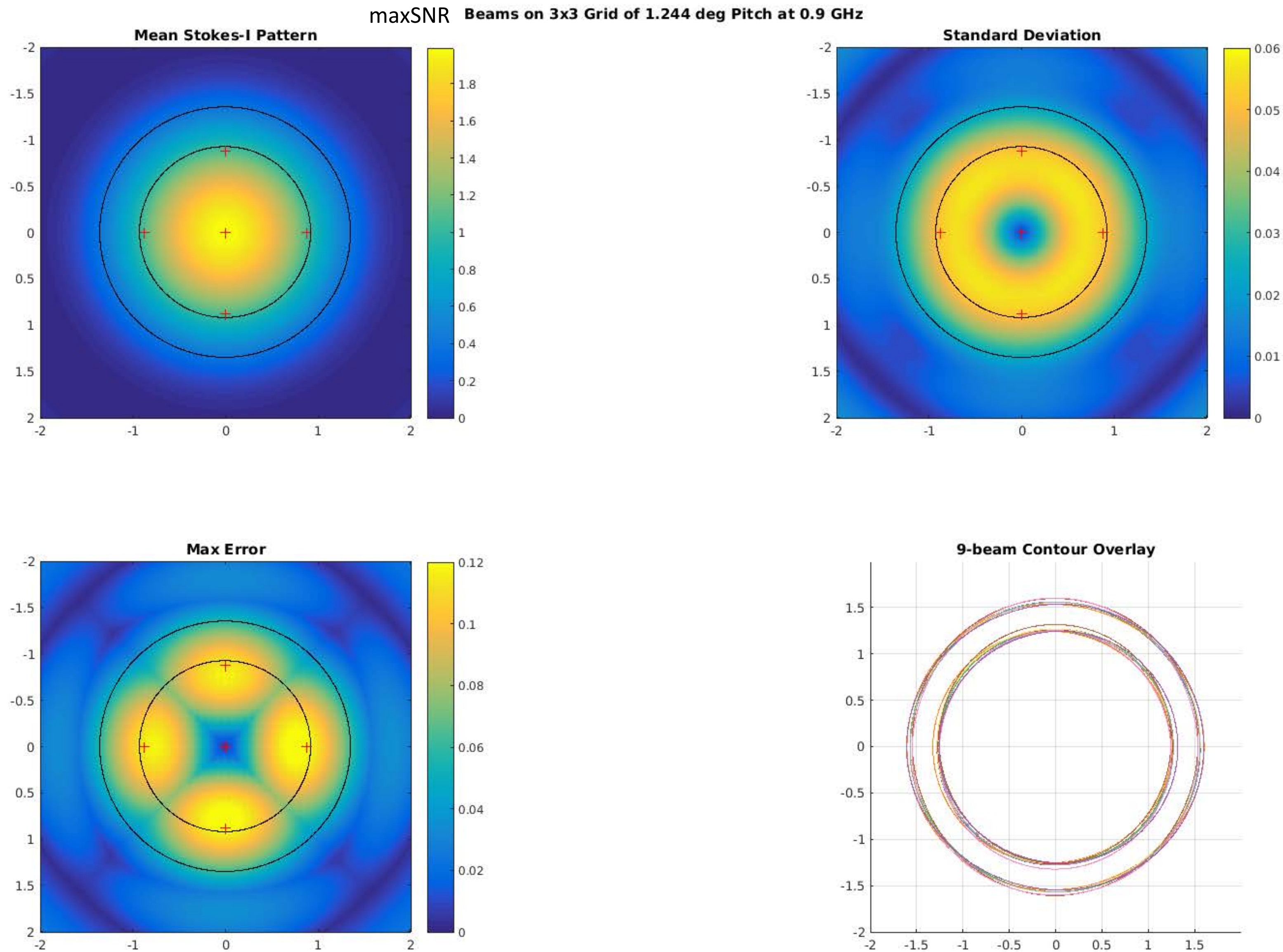
Comparing measured to known source fluxes



(Heywood, unpublished 2014)

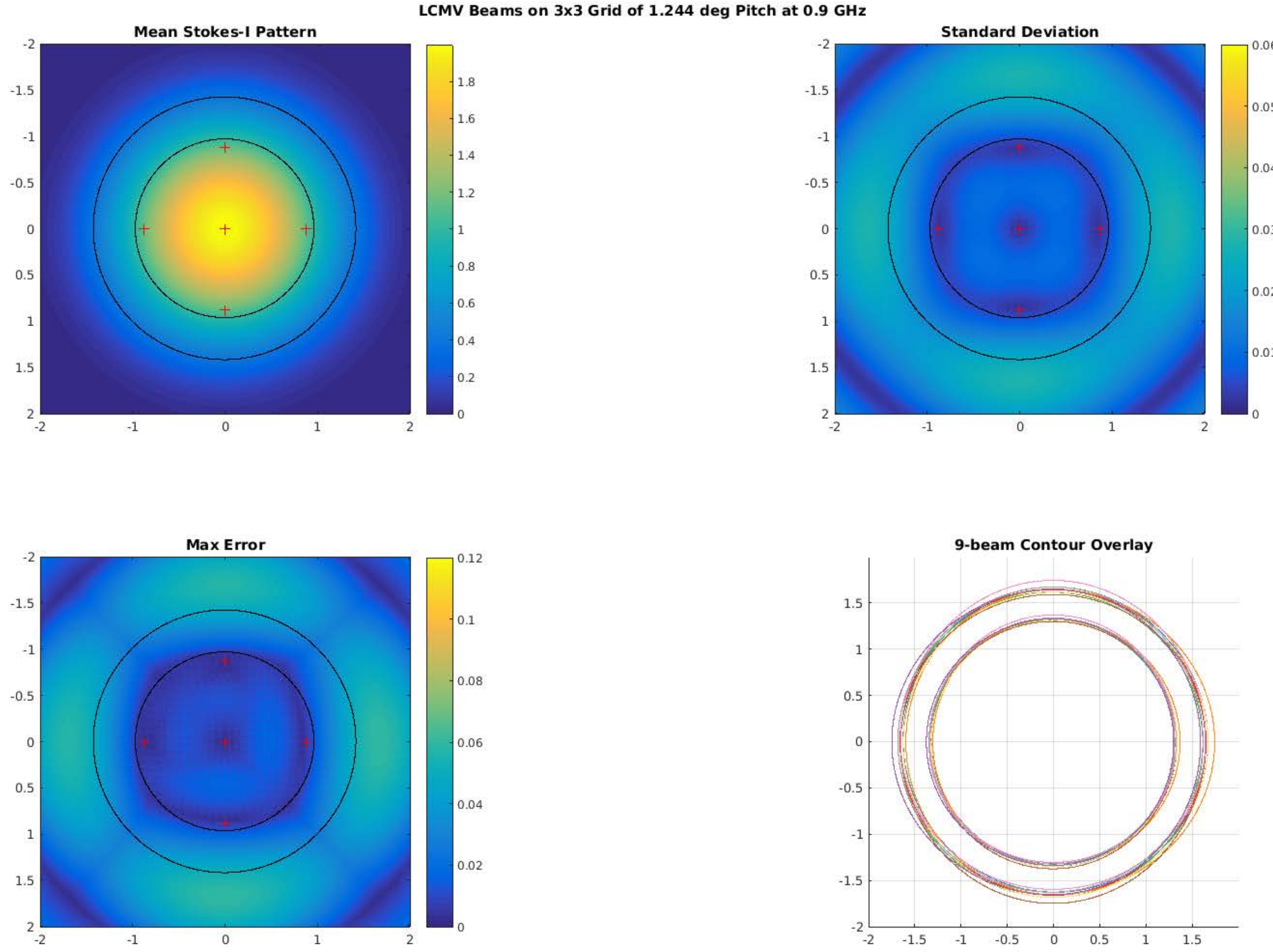
Variance over 3x3 maxSNR Beams (simulation)

(Chippendale, unpublished, 2015)

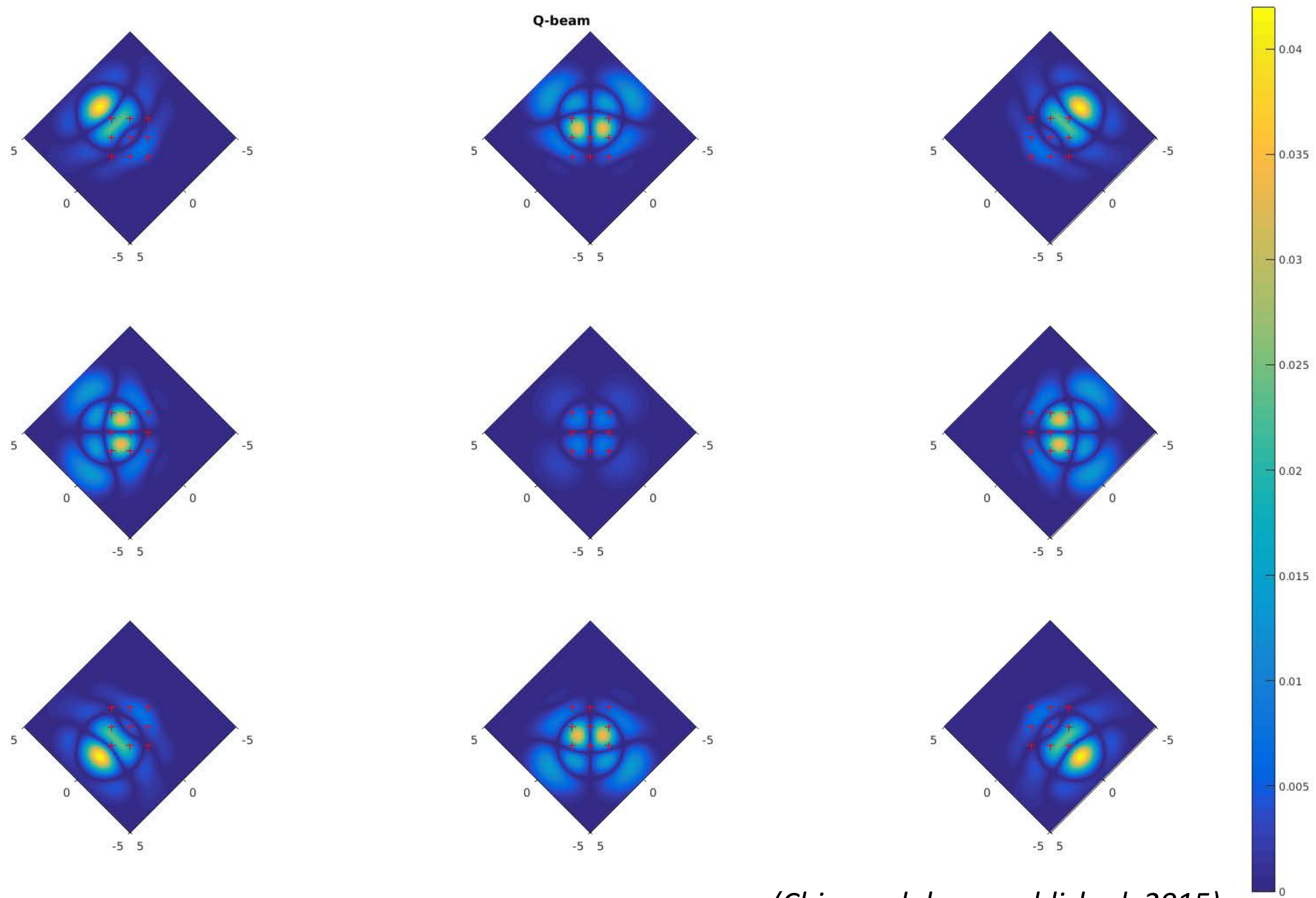


Reduced variance over 3x3 LCMV beams (simulation)

(Chippendale, unpublished, 2015)

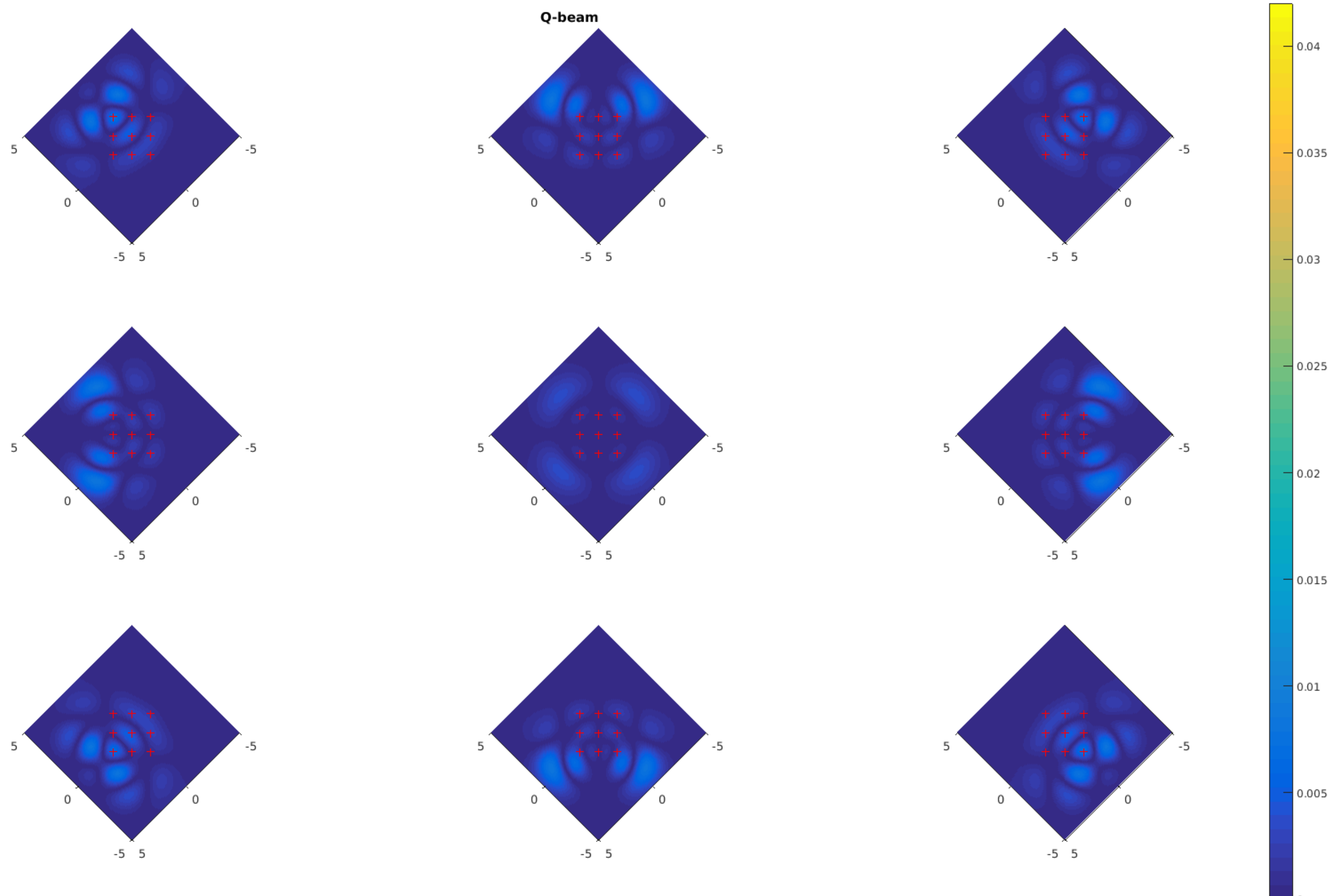


Can we reduce leakage of I into Q? (maxSNR)



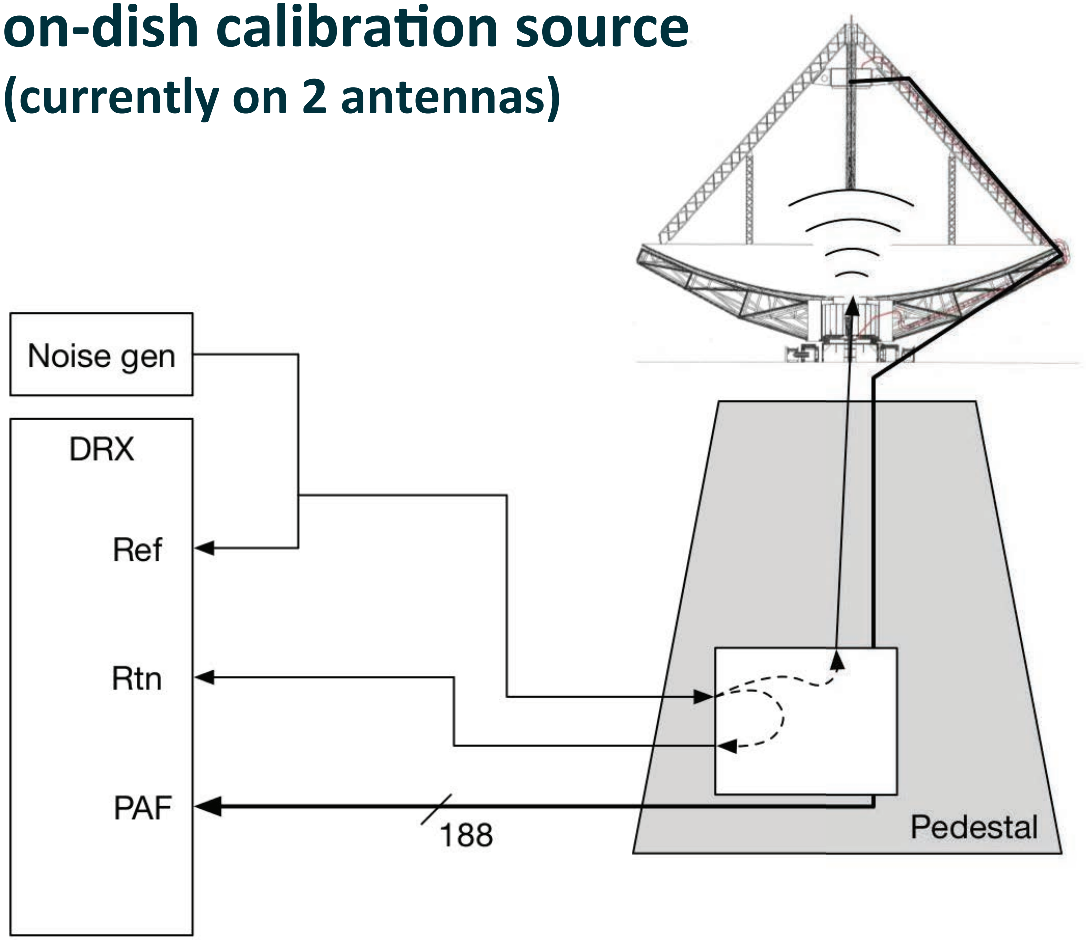
(Chippendale, unpublished, 2015)

Can we reduce leakage of I into Q? (LCMV) Yes



(Chippendale, unpublished, 2015)

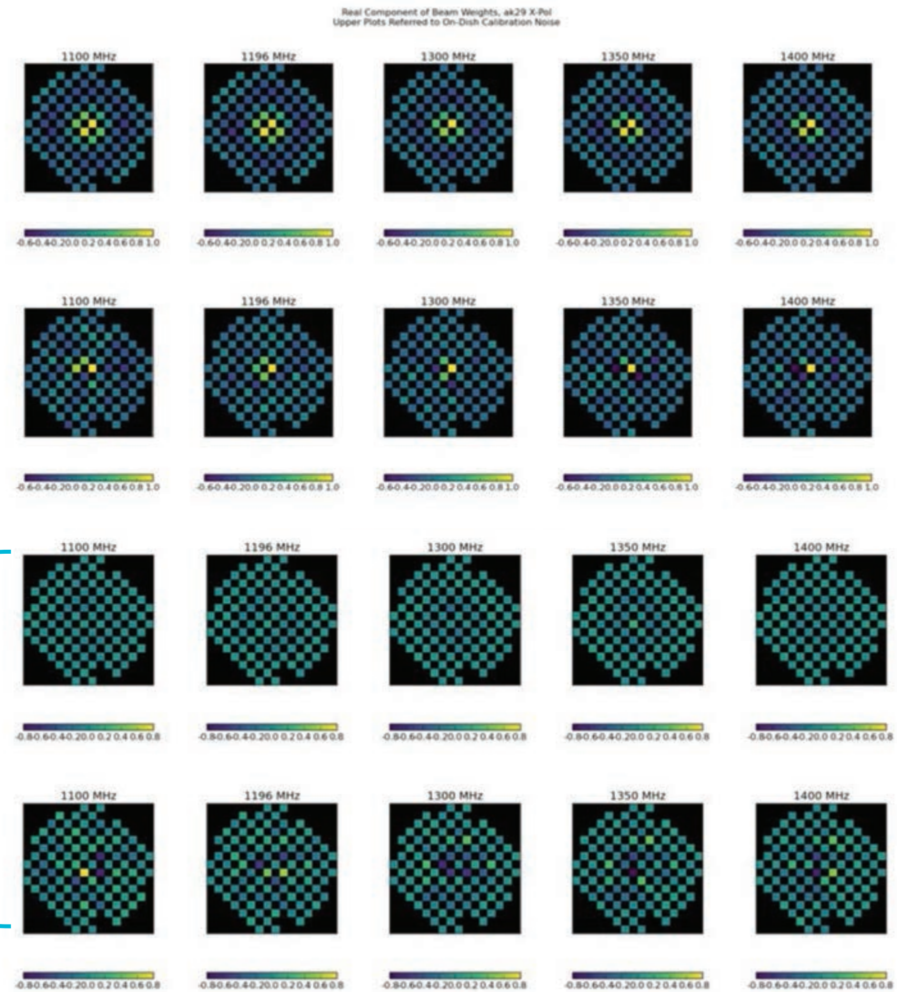
Improvements:
on-dish calibration source
(currently on 2 antennas)



Demonstrated relative port voltage-gain estimates with uncertainty as low as 0.1%

Improvements: on-dish calibration source

Measured weights for x-pol. boresight beam



Real: Calibrated, Raw

Imaginary: Calibrated, Raw

1100 MHz 1196 MHz 1300 MHz 1350 MHz 1400 MHz

Mk II PAF measurements

(Chippendale, unpublished, 2015)