International Centre for Radio Astronomy Research

Intensity Mapping with a Phased Array Feed

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THE UNIVERSITY OF WESTERN AUSTRALIA

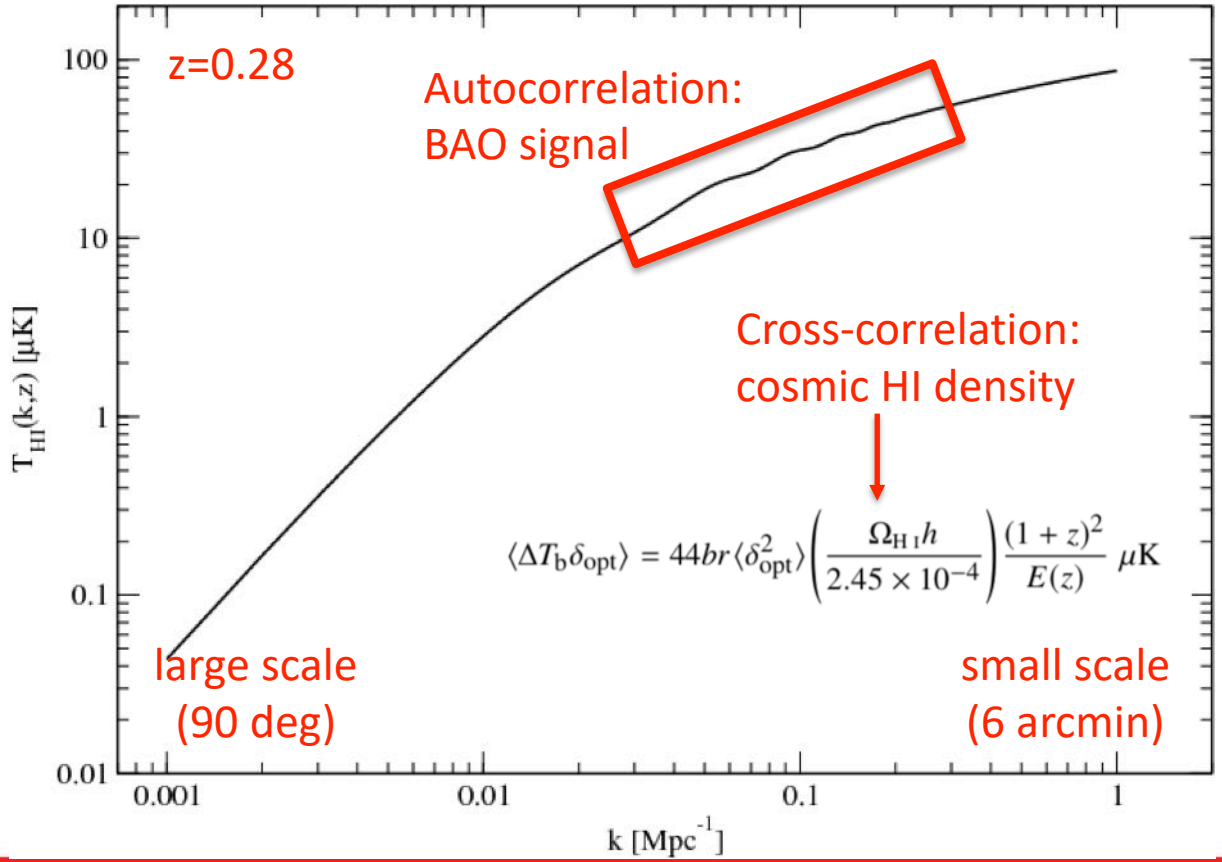
Government of Western Australia
Department of the Premier and Cabinet
Office of Science

MPIPAF installed at Parkes telescope

Li, Staveley-Smith and Rhee (2020)

10 Feb 2016

21cm power spectrum



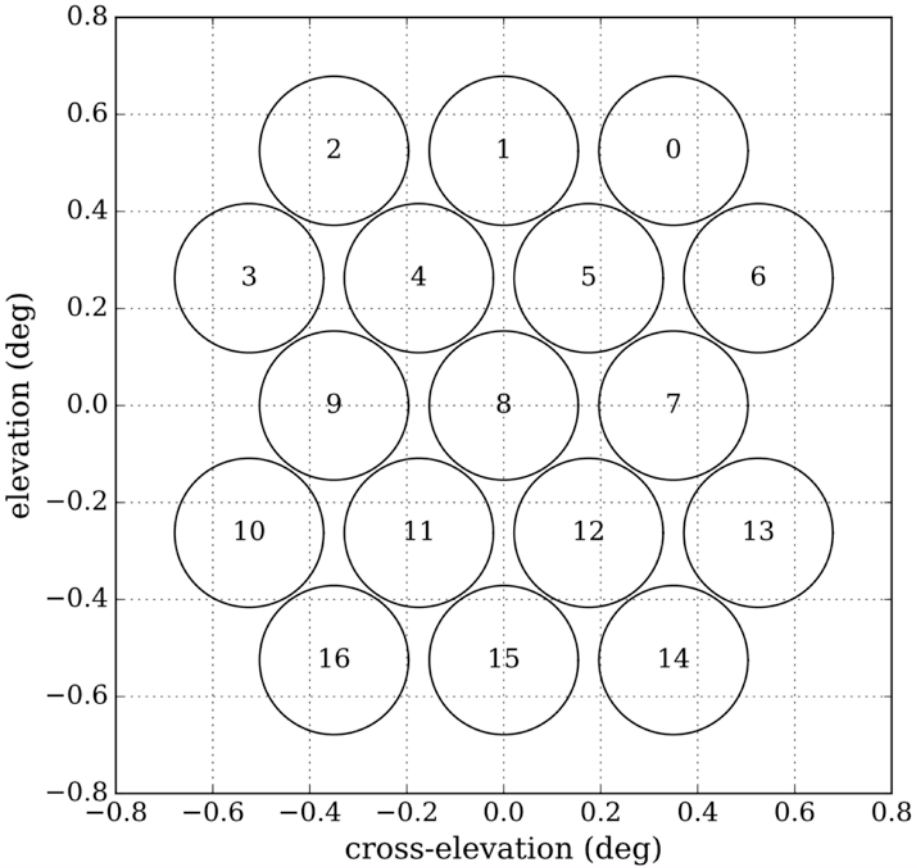
Max signal 0.1 mK

Battye et al. (2013)

Challenges

- Signal-to-noise ratio, dynamic range
- Chromaticity
- Foregrounds
- Radio Frequency Interference (RFI)

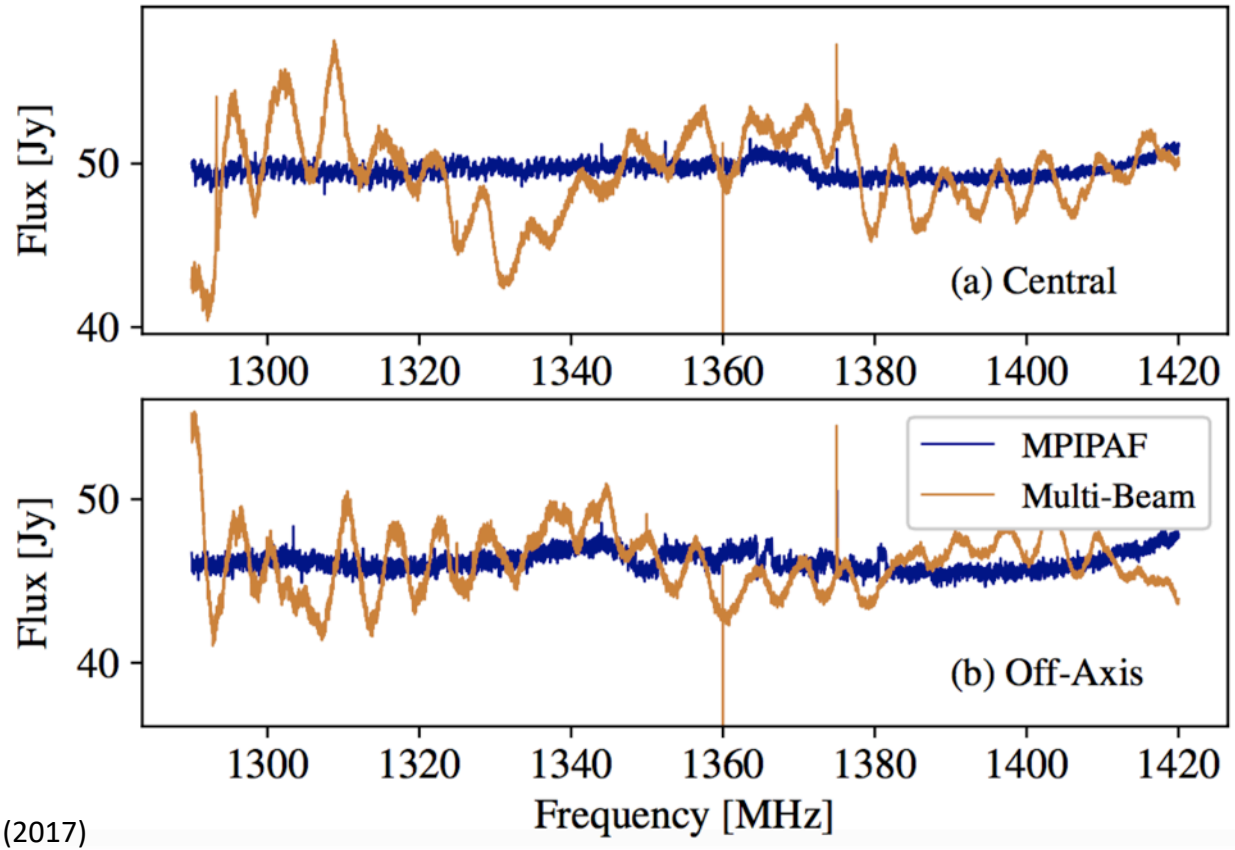
Multiple beams



1.4 GHz
36 independent beams at 1.4 GHz
(equivalent to 7K single-beam)

0.8 GHz
16 independent beams at 0.8 GHz
(equivalent to 14K single-beam)

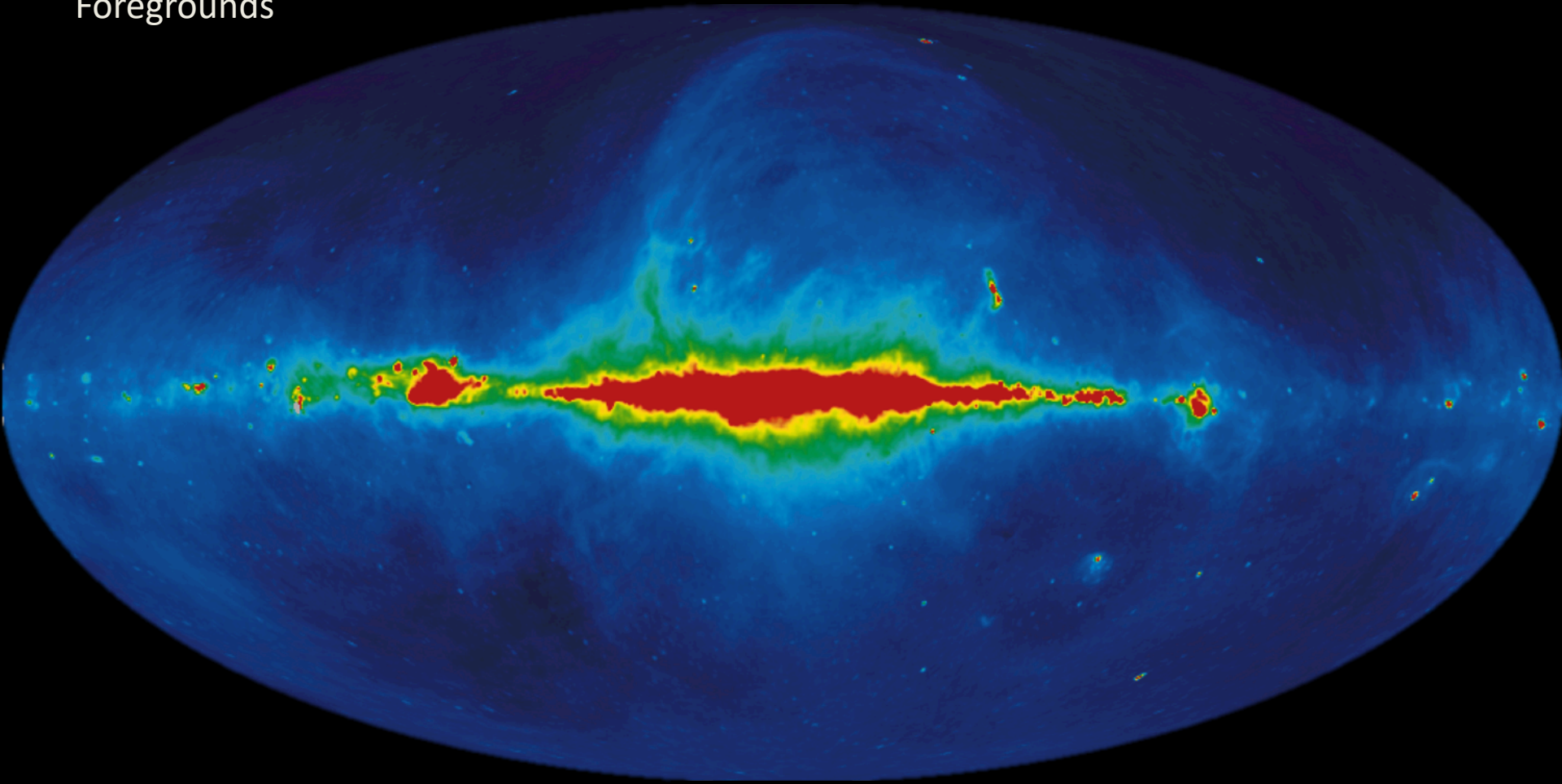
Standing waves: MB v PAF



Fundamental standing wave F-P mode same as BAO scale at z=0.8 for a 15-m dish

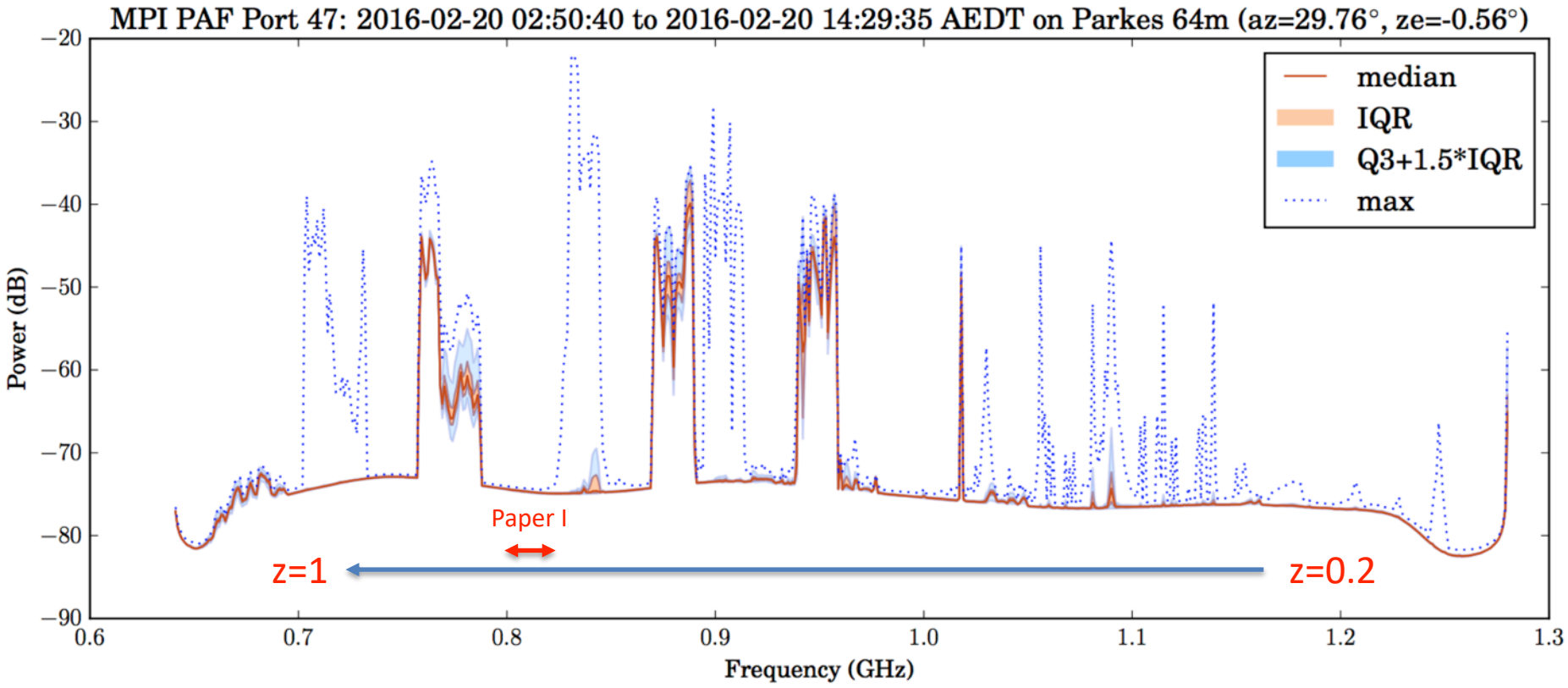
Reynolds et al. (2017)

Foregrounds

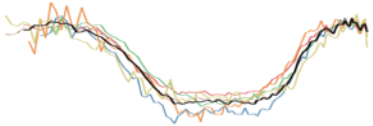


1420 MHz

MPIPAF@Parkes: Band 1



S/N, dynamic range requirement



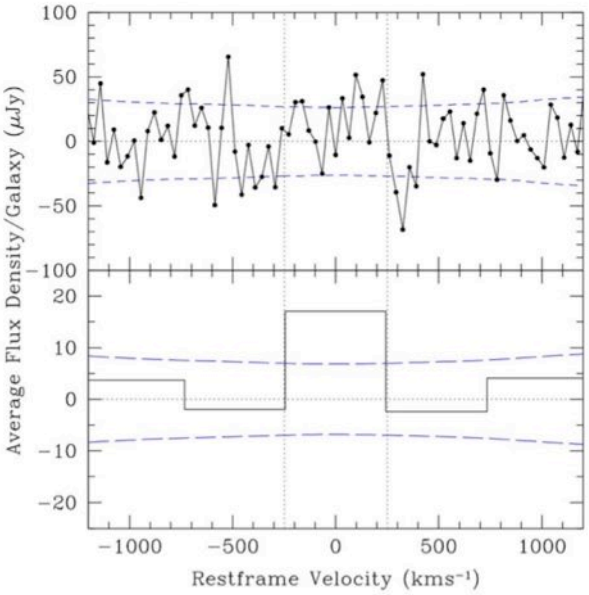
	EOR/EDGES (cosmic dawn)	IM (z=0.8)
Signal	0.5 K	0.1 mK
Noise (receiver + foreground)	1800 K	100 K
RFI	0.05 K	5×10^{6} K
Signal-to-noise	2×10^{-3}	10^{-6}
Spectral dynamic range (RFI/signal)	3600	5×10^{10}

Low-z Parkes 21-cm stacking

GMRT

121 Subaru galaxies @ z=0.24

Lah+ (2007)



neutral hydrogen gas measurement

using 121 redshifts

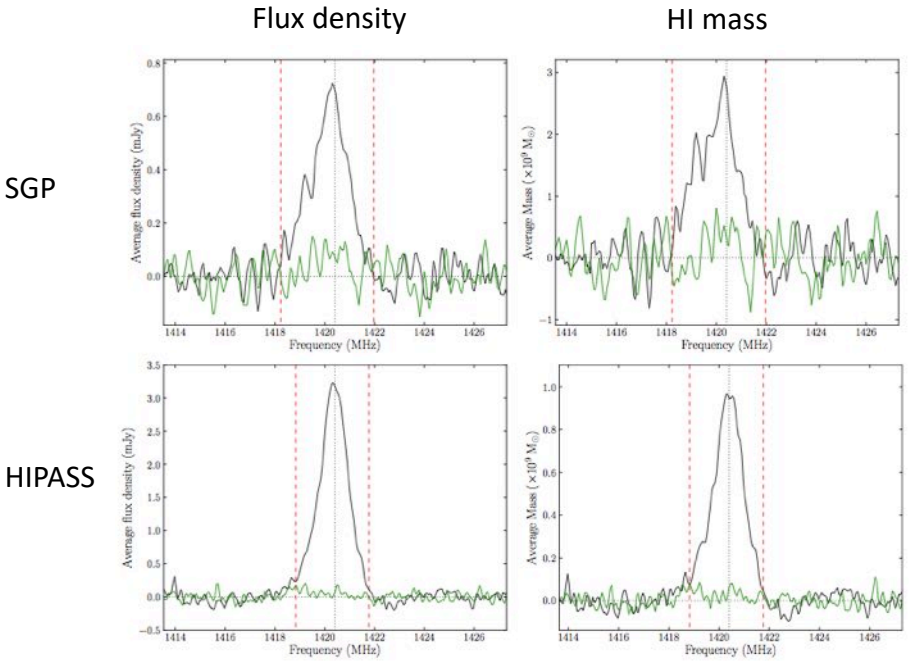
$M_{HI} = (2.26 \pm 0.90) \times 10^9 M_\odot$

0.36 ± 0.14 M*

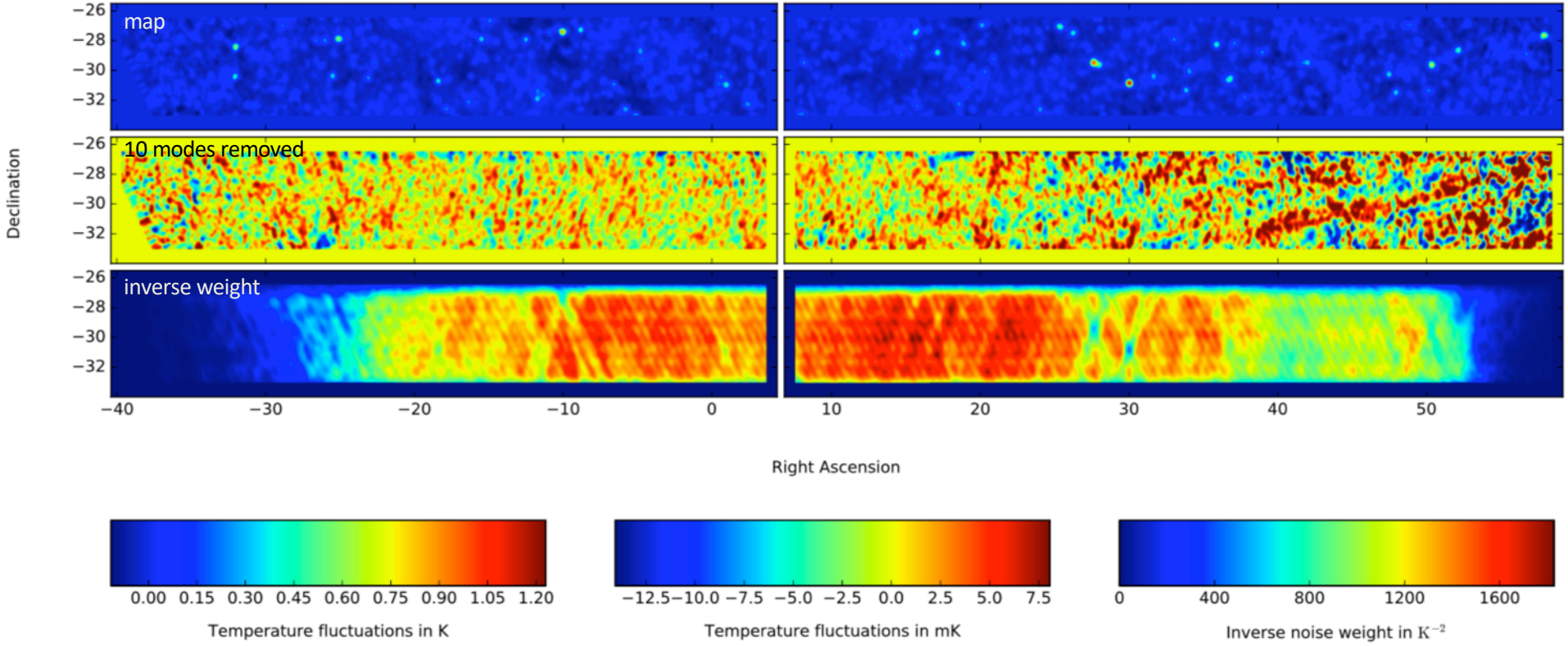
Parkes

SGP/2dFGRS: 3,277 galaxies; HIPASS/6dFGS 15,093 galaxies

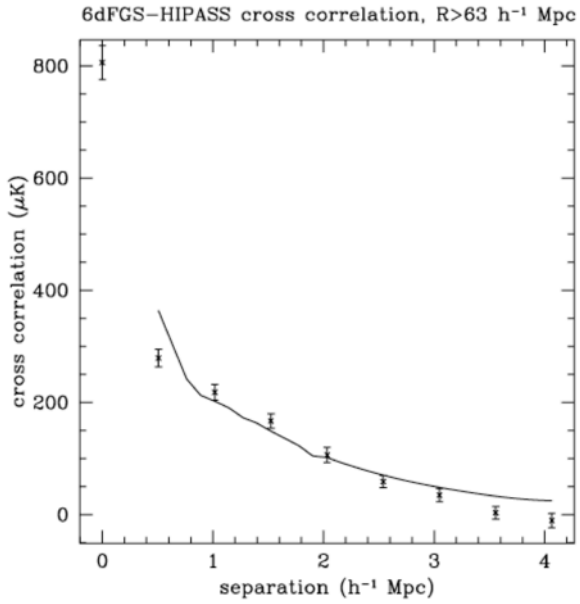
Delhaize+ (2013)



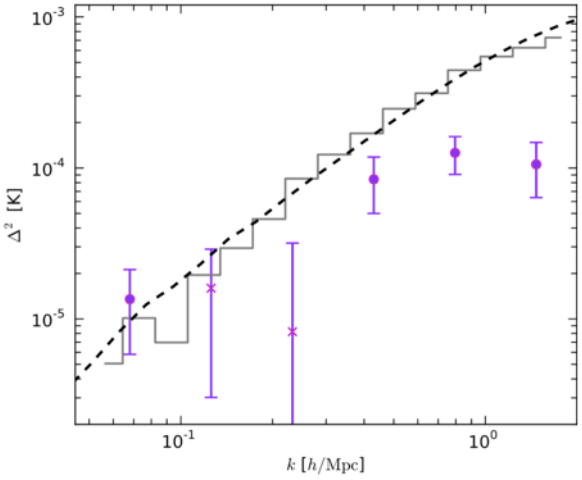
Parkes 2dFGRS IM (Anderson+ 2017)



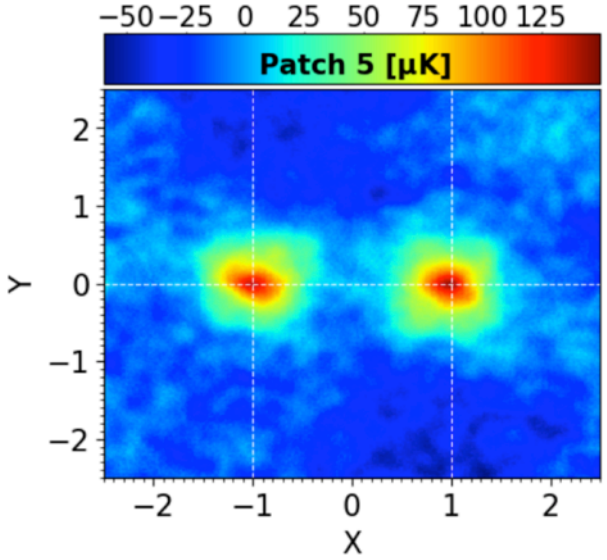
Low-z Parkes IM experiments



Pen+ (2009)



Anderson+ (2017)



Tramonte+ (2019)

MPIPAF installed at Parkes telescope

Li, Staveley-Smith and Rhee (2020)

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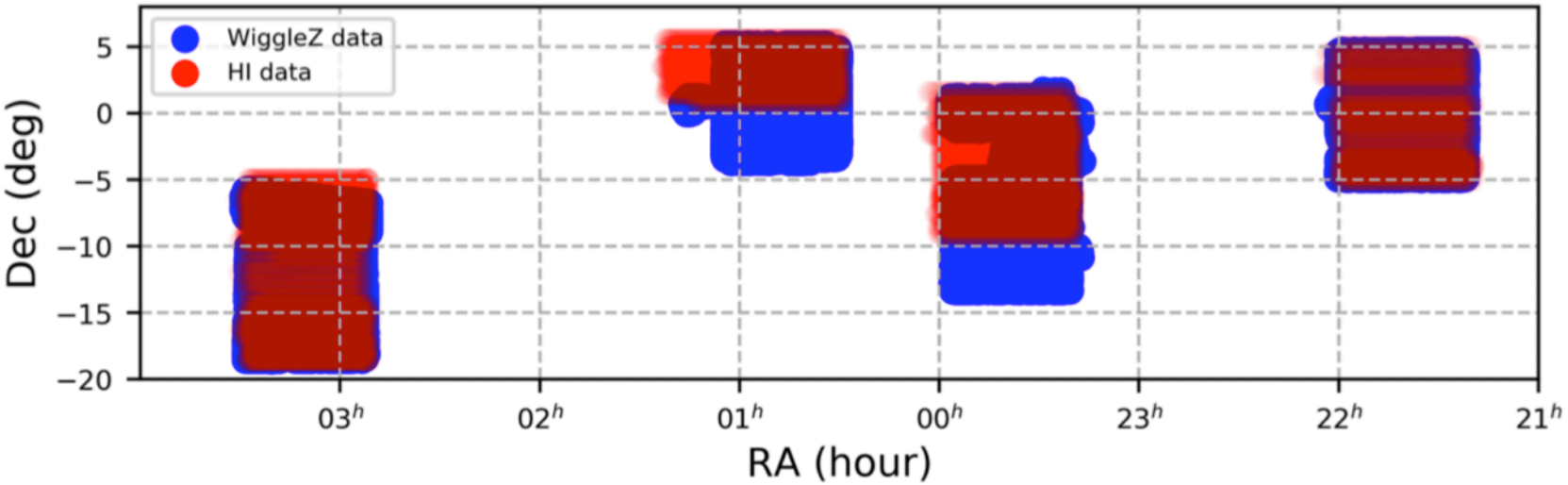
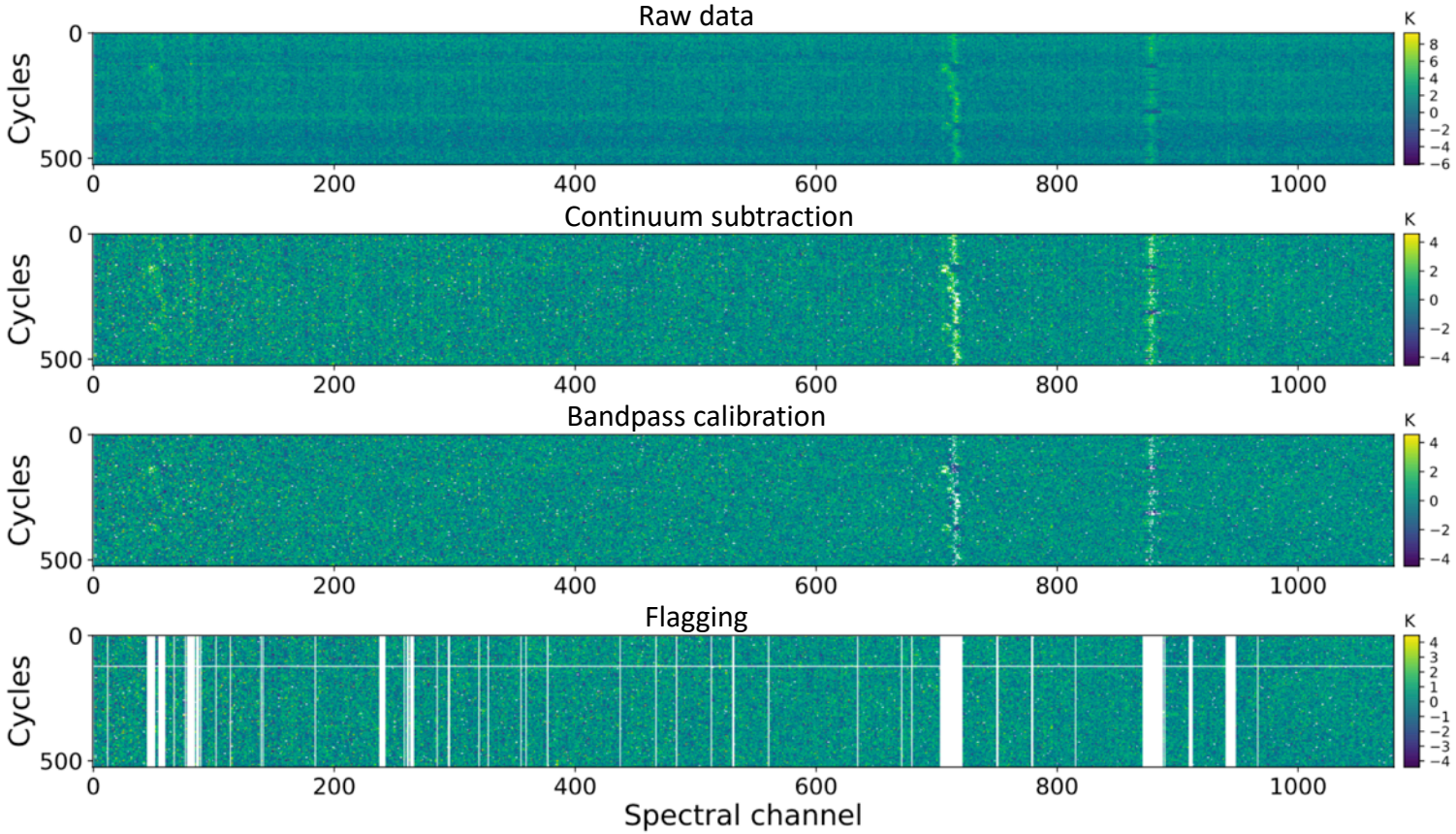
Parkes WiggleZ IM (Li+2020)



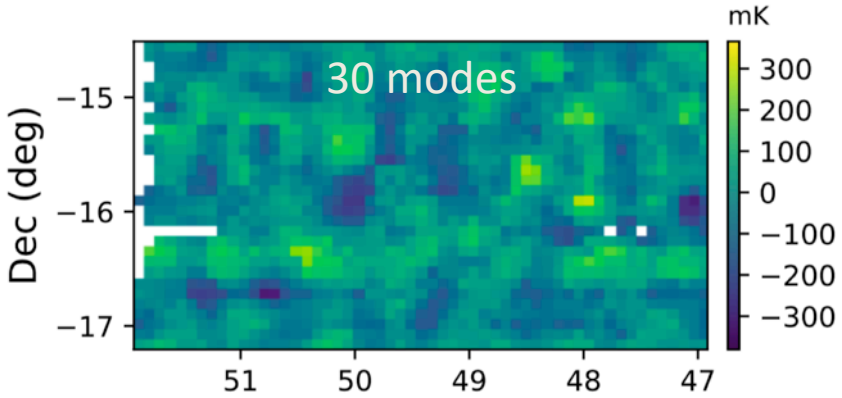
- 4 fields
- $0.2 < z < 1.0$
- 60 hrs
- 230 deg^2
- Drift scans

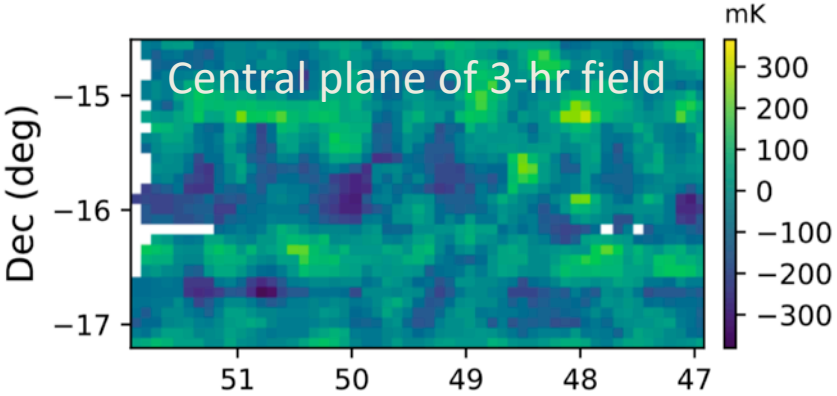
Pipeline data reduction

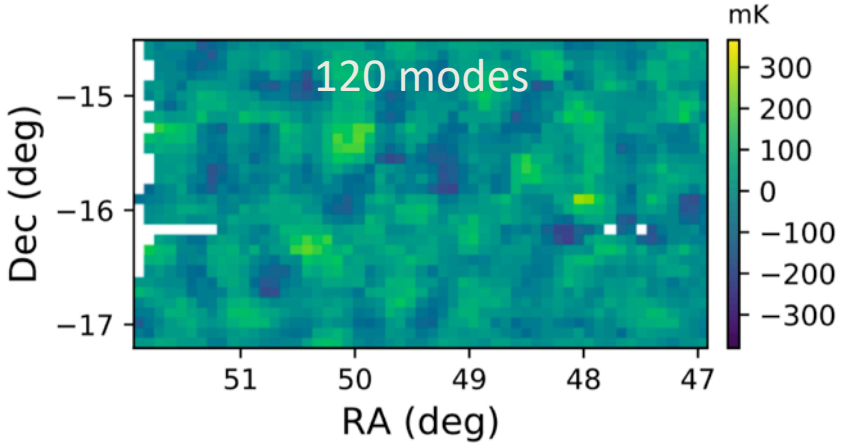


Residual foreground removal

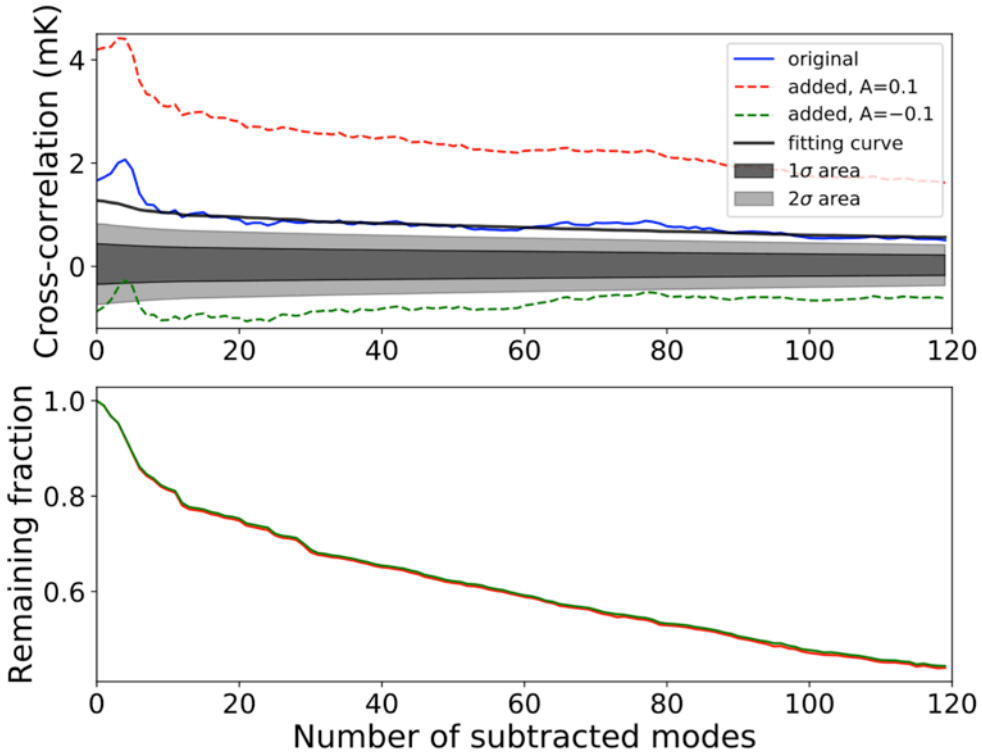
Singular value decomposition
(also trialled FastICA w. Woltz)







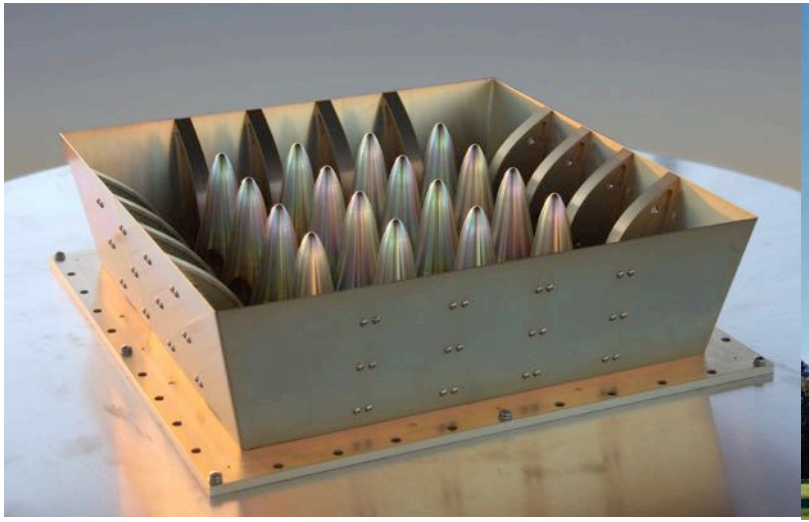
Parkes-WiggleZ cross-correlation



SVD removes foreground, but also signal

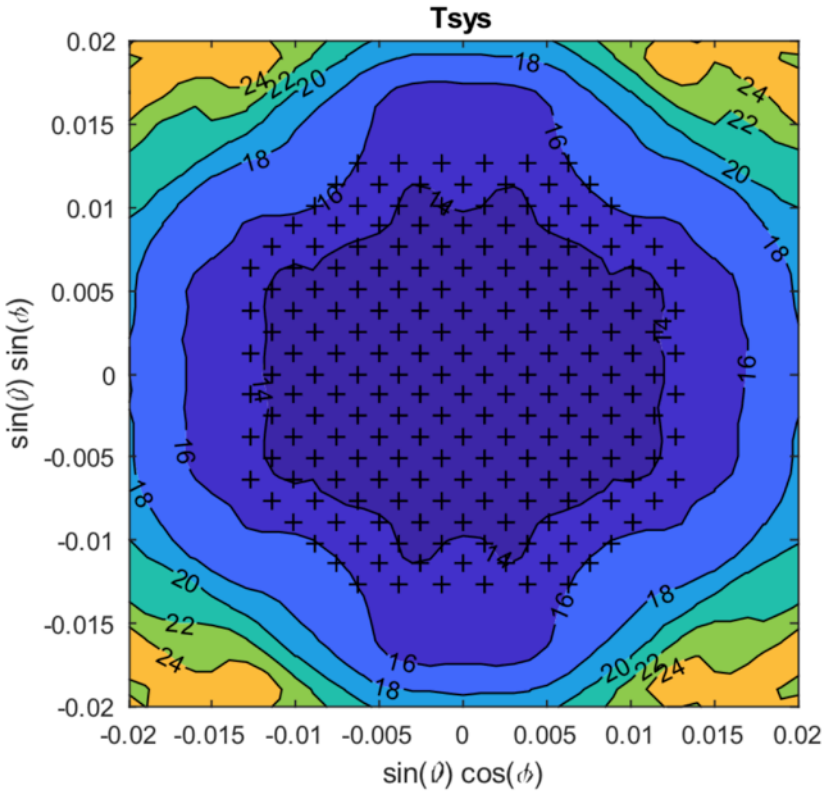
Li+ (2020)

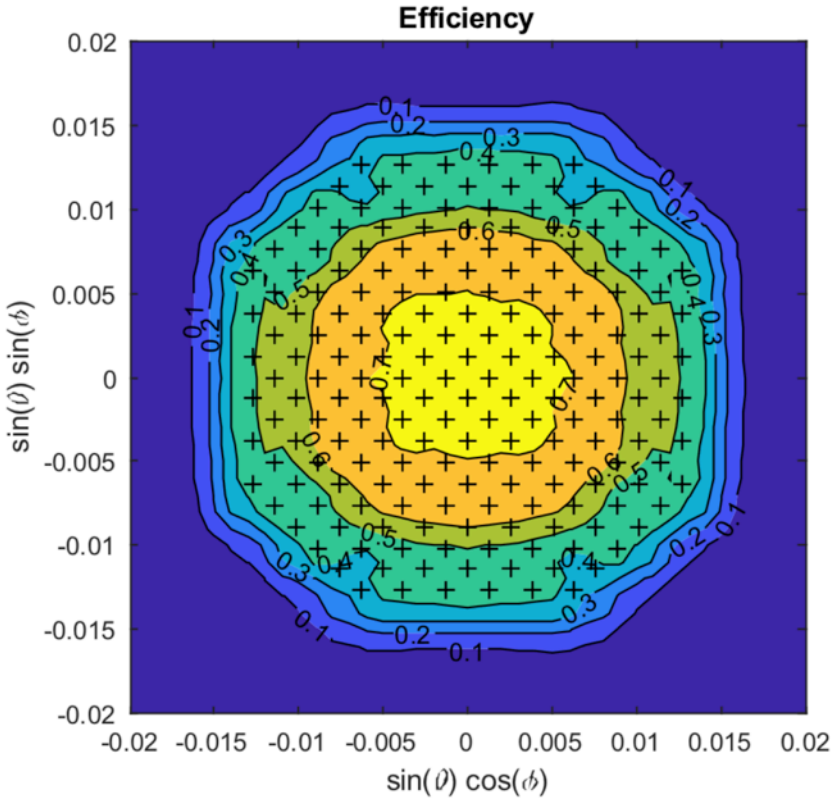
Cryogenic Phased Array Feed



Rocket design funded by ARC, UWA, CSIRO and partners for construction 2020-2022

Predicted T_{sys} and Efficiency

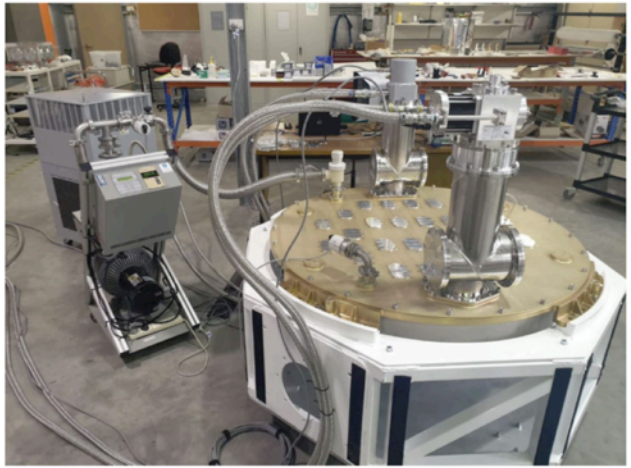


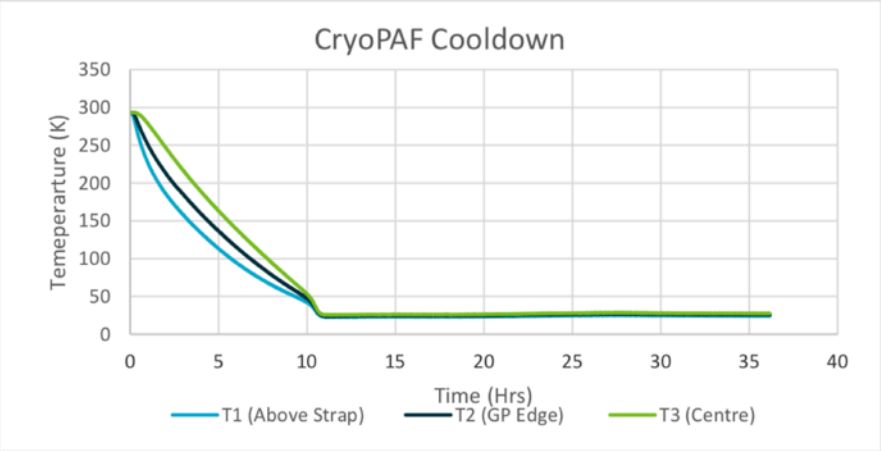


Mechanical/Cryogenics

- Structural/Thermal model built
  - CSIRO built MLI blankets installed
  - Vacuum loading equivalent of 10t through cryogenic Fiberglass struts and skirt
  - Rockets to be silver plated and installed
  - Target <35K, 28K achieved. Major risks retired

- Mass budget
  - 555kg + 13% margin (491kg nominal)





Cryo-PAF specifications

- System temperature: 14 K (4x better than ASKAP; 40% better than MB)
- Efficiency: 70% (same as ASKAP; 30% better than MB)
- Frequency range: 0.7 to 1.8 GHz (same as ASKAP; 4x better than MB)
- Instantaneous bandwidth: 0.9 GHz (3x ASKAP; 5x MB)
- Resolution: 20 kHz (same as ASKAP, MB)
- Beam forming interval: 20 kHz (TBD) (50x finer than ASKAP)
- Beams: 72 dual polarization (2x ASKAP; 6x MB)
- Output data rate: 76 PB/day into GPU cluster (1000x ASKAP)
- *Partial system in late-2021; full cryo-PAF in mid-2022*

Summary

- Intensity mapping powerful tool to study:
  - Astrophysics (cosmic gas density, galaxy clustering)
  - Cosmology (dark energy equation of state)
- Tentative detections at z=0.8 with MPIPAF@Parkes
  - Sensitivity a bit too low; systematics too high
- Cryo-PAF with 900 MHz bandwidth and 72 beams funded
- Challenges:
  - Calibration, foregrounds, RFI
- SKA pathfinders such as ASKAP (1296 beams), MeerKAT (64 beams) are in low-RFI zones