

Signature

The Parkes Radio Telescope as an SKA science and technology pathfinder

NZ SKA FORUM (S4SKA) 2018

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CSIRO ASTRONOMY AND SPACE SCIENCE
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Overview

The CSIRO Parkes Radio Telescope, the 'Dish'

Square Kilometre Array **technology** with the Dish

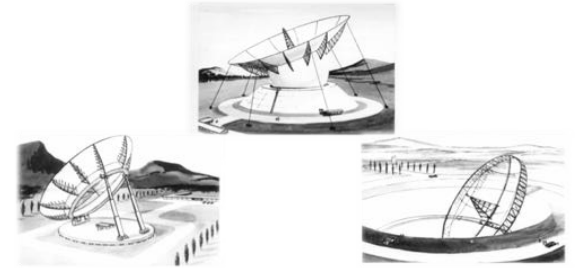
Square Kilometre Array **science** with the Dish

Square Kilometre Array **education** with the Dish

Parkes Radio Telescope, 'The Dish'

Brief History

- 64 m radio telescope, ~380 km west of Sydney, ~20 km north from town of Parkes, owned and operated by CSIRO
- Three years to design and two years to build - officially opened on 31 October 1961
 - Operating for more than 55 years
- Continual upgrades & evolution have been key (new surfaces, new focus cabin, new receivers e.g. multibeam, backend systems)
- Multitude of scientific discoveries
- Other activities - space craft tracking ('The Dish')



Parkes Radio Telescope, 'The Dish'

Current capabilities

- 700 MHz to ~25GHz across 8 receivers
 - Including 13-beam 21cm 'multibeam' system
- Spectral and temporal back end capabilities
 - For single-beam time domain (events < 1s) and spectrometry ("DFB4")
 - For single-beam time domain and new limited piggyback spectrometry ("CASPSR")
 - For multi-beam (13 beams) time domain and spectrometry ("HIPSR/BPSR")
 - Real-time Fast Radio Burst detection
 - For Very Long Baseline Interferometry, VLBI ("DAS" & "Mk-V")
 - Fledgling GPU based backend 'medusa'



SKA Technology with the Dish

Phased Array Feed Development

- Crucial to enabling high survey speeds for large-area/all-sky science
- Consortium working on PAF designs, part of Advanced Instrumentation Programme -> Observatory Development Programme
- Various designs/technologies being explored
- Australian SKA Pathfinder Phased Array Feeds
 - Initial 'BETA' used CSIRO 1st generation, "MKI", PAFs
 - Antennas now outfitted with 2nd generation, "MKII" PAFs

The teams from Canada (NRC), the Netherlands (ASTRON) and Australia (CSIRO) with their respective Phased Array Feed designs



CSIRO Australian SKA Pathfinder, ASKAP

SKA Technology with the Dish

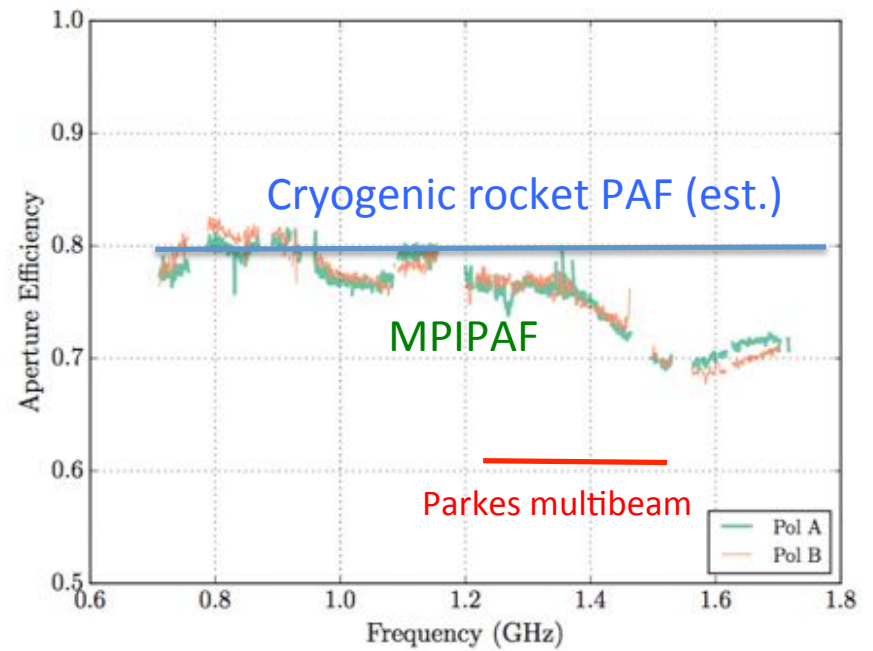
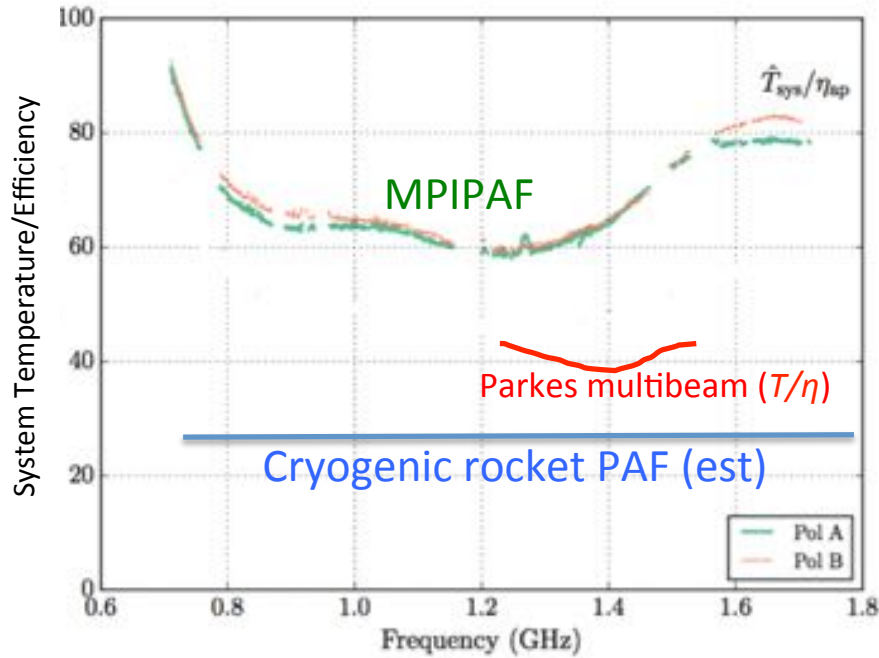
Phased Array Feed Development

- Max Planck Institute (MPIfR) Phased Array Feed - Re-purposed ASKAP feed (“MKII”), commissioned on Parkes in 2016
 - Timed 3 Pulsars simultaneously
 - Spectral line observations - very flat and stable bandpass
 - Now commissioning on Effelsberg
- 12-m antenna monitoring Vela pulsar (“MKI” PAF)
- ‘Rocket’ Phased Array Feed (third generation)
 - Prototype (uncooled) on dish testing (plus aperture tests) May 2016 - very encouraging for purpose built version
 - 700MHz – 2GHz, 3 x MB field of view, sub-20K Tsys
 - LIEF proposal in preparation for funding for 2019 construction



SKA Technology with the Dish

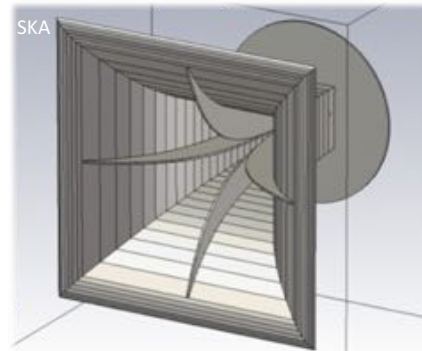
Phased Array Feed Development



SKA Technology with the Dish

Wide-bandwidth feeds

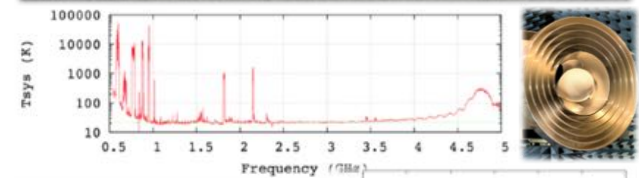
- Enables affordable frequency agility and increased science return
- SKA consortium dedicated to this activity ('WBSPF'), part of Advanced Instrumentation Programme / Observatory Development
- Typical receivers have an 'octave' bandwidth ratio of $\sim 1:1.85$, e.g. H-OH receiver is 1.2 to 1.8 GHz
- 'Wide-bandwidth' pushes technology to ratios of 1:3, 1:5, 1:10....
- Reduces need for multiple receivers and provides more frequency coverage simultaneously



SKA Technology with the Dish

Wide-bandwidth feeds

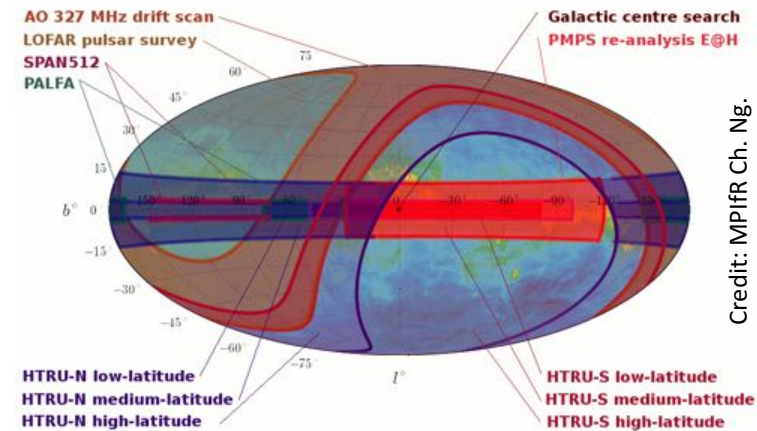
- Ultra-Wideband Low Frequency Single Pixel Feed
 - Quadridge structure with dielectric spear
 - 0.7—4.0 GHz, $T_{\text{sys}} \sim 22\text{K}$, SEFD $\sim 35\text{ Jy}$
 - Partly funded through Australian Research Council LIEF grant
 - First light August 2017 with prototype build
 - Scheduled for full commissioning in coming months
- Ultra-Wideband Mid/High Frequency Single Pixel Feed(s) in planning - one or two feeds to cover 4 GHz up to 25 GHz – VLBI and radar tracking benefits
- Wideband feeds share ‘pan’: focus cabin with 1 PAF + single pixel coverage 0.7 -> $\sim 25\text{ GHz}$



SKA Science with the Dish

Pulsars and Transients

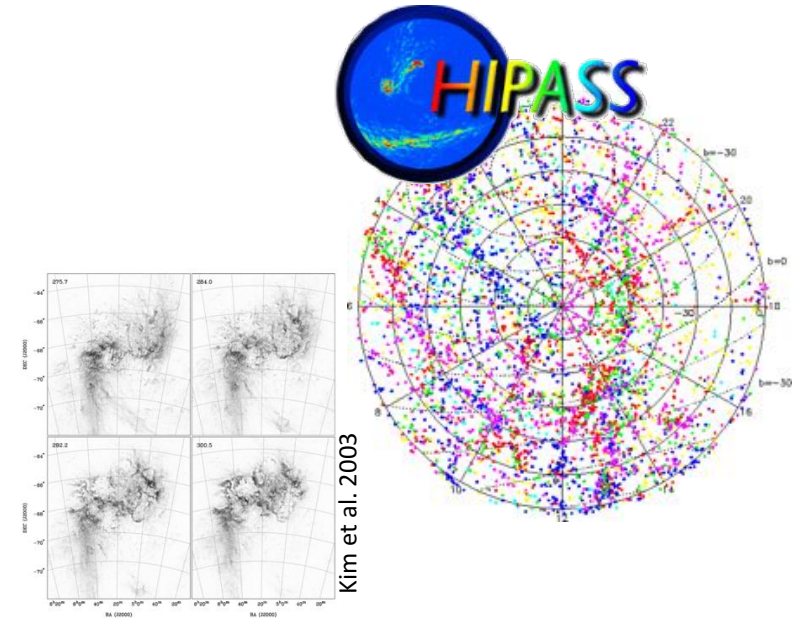
- Pulsar Searching
 - Detection machine >1500, ~1/2 of all
 - Cryo-PAF – larger field of view + localisation
 - New collaboration with FAST
- Parkes Timing
 - Parkes Pulsar Timing Array (PPTA): decade of high precision measurements
 - Ultra-Wideband – increased sensitivity / improved Time-Of-Arrivals
 - New collaboration with FAST
- Transients - Fast Radio Bursts (FRBs)
 - First FRB discovered with Parkes (Lorimer et al. 2007)
 - >=21 of >=26 to date discovered with Parkes
 - Major search campaigns, e.g. SUPERB real-time detection project and now commensal studies
 - Cryo-PAF – larger field of view + localisation



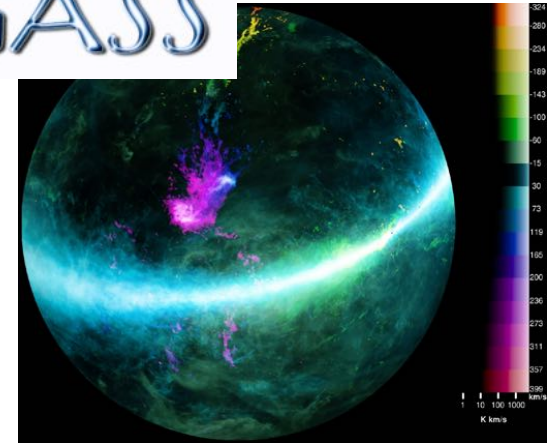
SKA Science with the Dish

Hydrogen over cosmic time

- HI Parkes All Sky Survey (HIPASS), Southern Galactic Plane Survey (SGPS), Galactic All Sky Survey (GASS)
- Parkes surveyed our Galaxy, Magellanic Clouds, 1000s of nearby galaxies, pushing further in redshift
- Observations made with MPIfR PAF
- Cryo-PAF HI - intended for galaxy gas content, cosmic web, intensity mapping



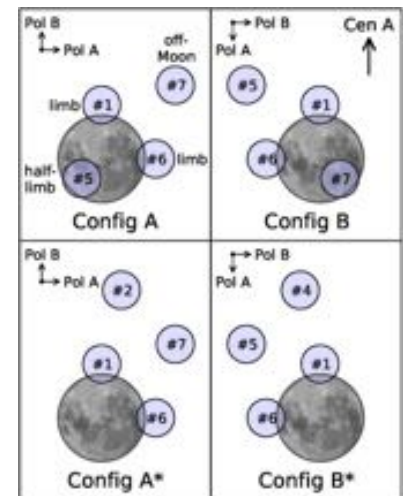
GASS



SKA Science with the Dish

high-energy particle detection

- Parkes' conducted most sensitive experiment to date to detect high-energy particles, via Cerenkov radio pulse, used the Parkes 21 cm multibeam receiver, which was able to see $\leq 1/3$ of the useful area of the moon (Bray et al. 2015)
- Other projects underway:
 - CROME (previously), EASIER@AUGER, SKA, LOFAR, AuScope
 - FAST with a PAF (VLA, WSRT previously)
- Seeking to know the nature & origin of ultra-high-energy particles (“one of the biggest mysteries of modern astrophysics”)
- Cryo-PAF - increased field of view: see the entirety of the moon.



SKA (precursor) Science with the Dish

ASKAP with Parkes PAF VLBI complement

- EMU survey will detect about 70 million radio sources.
 - Separate Active Galactic Nuclei (AGN) vs star-forming galaxies, through single-baseline Very Long Baseline interferometer (e.g. Norris & Kesteven, 2012, Middelberg et al., 2013)
 - polarisation studies of the AGN, imaging of OH megamasers, and classification of pulsars and radio stars
- FLASH survey will detect HI absorption in ~ 1000 radio-loud AGN at $z = 0.5 - 1$ (Allison et al., 2015).
 - detect neutral gas outflows, associated with AGN feedback via < 1 -percent optical depth sensitivity (achieved with very good spectral baseline and real-time RFI mitigation)
 - localise position, measure size & kinematics of HI absorbers

SKA (precursor) Science with the Dish

ASKAP single dish & VLBI complement

- GASKAP survey will observe HI and OH in the Milky Way over an area of 13,000 sq. degs (Dickey et al., 2013).
 - Zero-spacing data to probe large spatial scales that ASKAP is insensitive to
 - ultra-high sensitivity OH survey of entire Southern sky, probing new physical environments
- SKA1-mid/Parkes baseline astrometry towards a sample of 100 OH-maser sources would allow the internal angular rotations of the Magellanic Clouds to be modelled (proper motion to 10 micro-arc seconds yr⁻¹ (~2 km/s) accuracy
- Astrometry of pulsars is often beneficial in providing direct measurements of their distances independent of single dish timing data.

SKA Science with the Dish

Search for Extra Terrestrial Intelligence: Breakthrough Listen

- 5-year programme, multi-year investment for telescope time
- Officially began observing October/November 2016
- Observing blocks each day, stepping in time (Local Sidereal Time) through the week
- Dedicated backend managed by University of California, Berkeley
 - Initial test system installed Feb/Mar 2016
 - Single beam system installed Sept & Dec 2016
 - Multibeam system installed June 2017
- Open access to data planned
- Targeted observations, Galactic plane survey, transient/Fast Radio Burst simultaneous searches



BREAKTHROUGH
LISTEN



SKA Education with the Dish

PULSE@Parkes and OPTIMUS

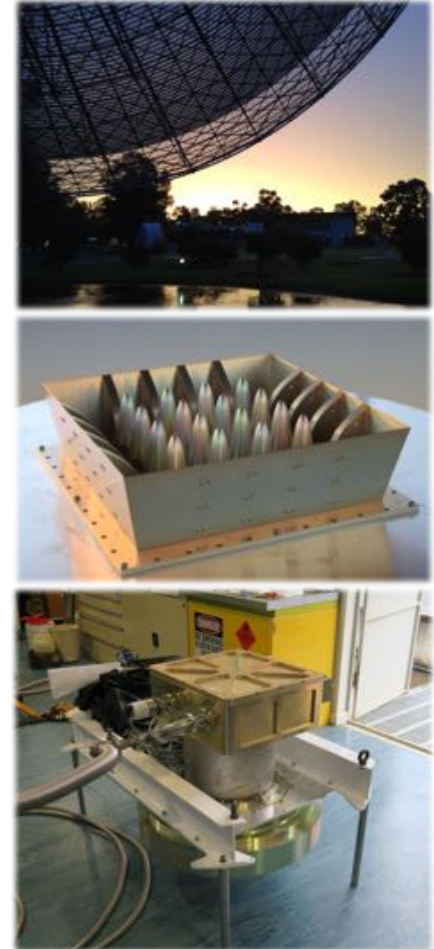
- PULSE@Parkes programme
 - Pulsar focused, secondary-level education programme with real-time access to, and control of, Parkes Telescope
 - ~1500 high school students (plus some higher levels) to date, ~130 schools, sessions across Australia, plus Canada, China, England, Japan, South Africa & Wales... would welcome New Zealand interest!
- **O**bserving with **P**arkes, **T**raining and **I**ntroduction, **M**odule for **U**niversity **S**cience, **OPTIMUS**, programme
 - Undergraduate/postgraduate extension
 - Part of CSIRO's 'ON **PRIME**' development scheme
 - Undergraduate level training package including Parkes telescope time
 - Extending/varying science to include other aspects



Summary



- Parkes formally recognised as SKA Pathfinder
- Wideband feed(s) imminently coming to Parkes
- Cryogenically cooled Phased Array Feed proposed for Parkes
- SKA oriented science underway & enabled by technology
- Training avenues for future SKA scientists
- Telescope time available, proposal & purchase







Thank you

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