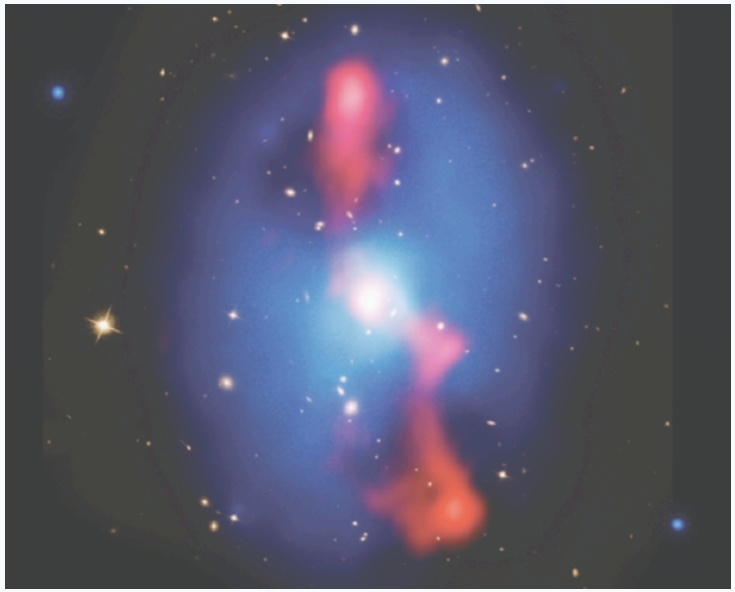
MIGHTEE: The plan going forward

Matt Jarvis & Russ Taylor

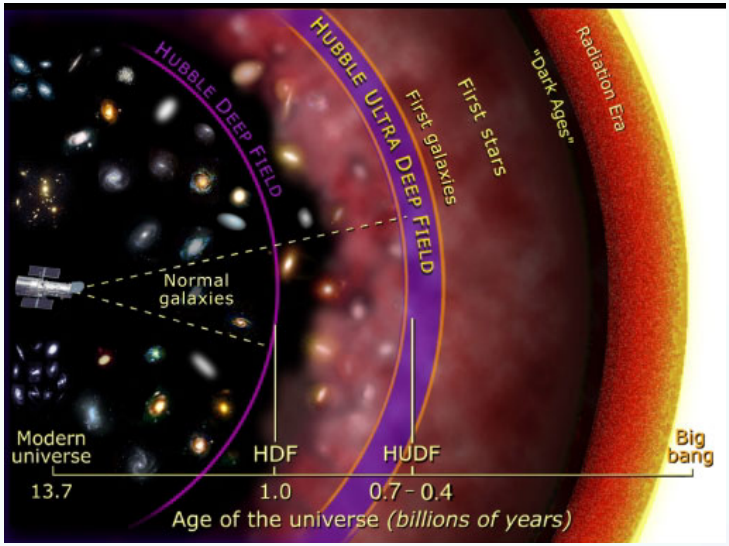
MeerKAT is arriving quickly…

Galaxy Formation and Evolution

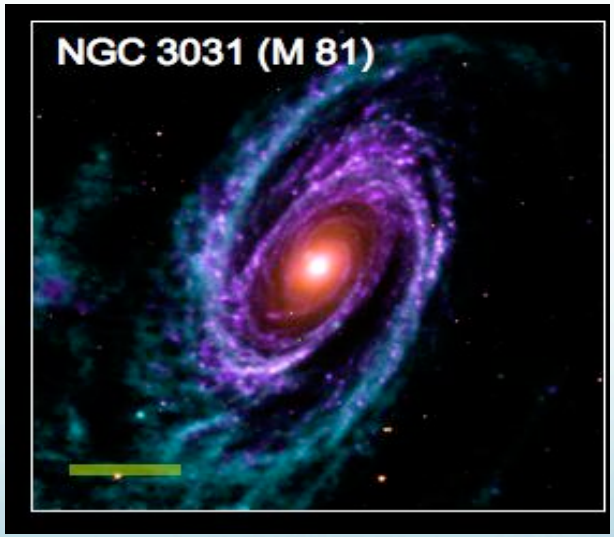
How does accretion onto black holes affect the evolution of galaxies?



How and when were the first galaxies formed?

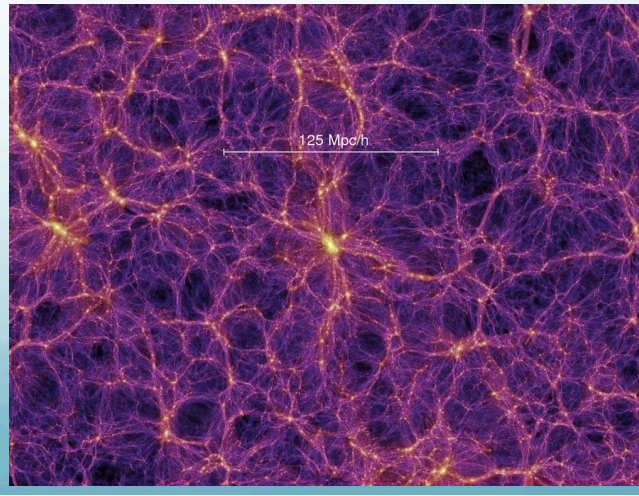


What is the environmental influence?



How do we go from gas to stars in galaxies?

How do Baryons trace and affect the Dark Matter distribution?



Who is MIGHTEE?

Filipe Abdalla* (UCL, UK), Jose Afonso (Lisbon, Portugal), Vinod Arumugam (ATC, Edinburgh), **David Bacon* (Portsmouth, UK)**, **Manda Banerji (Cambridge, UK)**, **Bruce Bassett (UCT, SA)**, **Richard Battye (Manchester, UK)**, Werner Becker (MPE, Germany), Girish Beeharry* (Univ. Mauritius, Mauritius), **Philip Best* (Edinburgh, UK)**, **Rob Beswick* (Manchester, UK)**, Michael Bietenholz (HartRAO/York, SA/Canada), **Dave Bonfield (Hertfordshire, UK)**, Malcolm Bremer (Bristol, UK), Michael Brown (Monash, Australia), Michael Brown (Cambridge, UK), Shea Brown (CSIRO, Australia), Ian Browne (Manchester, UK), **Marcus Brüggen* (Jacobs University, Germany)**, Scott Chapman (Cambridge, UK), Chris Clarkson (UCT, SA), Marcel Clemens (INAF, It), Pieter Conradie (NASSP, SA), Chris Conselice (Nottingham, UK), John Conway (Chalmers, Sweden), Kristen Coppin (Durham, UK), Garret Cotter (Oxford, UK), Steve Crawford (SAAO, SA), **Catherine Cress (UWC, SA)**, Simon Cross (MeerKAT, SA), Erwin De Blok (UCT, SA), Okkie De Jager (NWU, SA), Roger Deane* (Oxford, UK), James Dunlop (Edinburgh, UK) , Loretta Dunne (Nottingham, UK), Ed Elson (UCT, SA), Andreas Faltenbacher (UWC, SA), Ilana Feain (CSIRO, Australia), Chiara Ferrari* (OCA, France), Luigina Feretti (INAF, It), Tony Foley (MeerKAT, SA) Bradley Frank (UCT, SA), Bryan Gaensler (Sydney, Australia), Mike Garret (ASTRON, NL), Jim Geach (Durham, UK), Gabriele Giovannini* (INAF, It), Eduardo Gonzalez-Solares (IoA, Cambridge), Dave Green (Cambrdige, UK), **Martin Hardcastle* (Hertfordshire, UK)**, George Heald (ASTRON, NL), Nalini Heeralall Issur (Univ. Mauritius, Mauritius), **Ian Heywood (Oxford,UK)**, Matt Hilton (UKZN, SA), Renee Hlozek* (Oxford, UK), Benne Holwerda (UCT, SA), Andrew Hopkins* (AAO, Australia), Cathy Horellou* (Chalmers, Sweden), Jasper Horrel (MeerKAT, SA), Minh Huynh (IPAC, USA), **Hans-Rainer Klöckner (Oxford, UK)**, Roger Ianjamasimanana (UCT, SA), Eduardo Ibar (ATC, UK), Rob Ivison (ATC, UK), Neal Jackson* (JB, UK), Justin Jonas (MeerKAT, SA), Louise Ker (Edinburgh, UK), Alexei Kniazev (SALT, SA), Anton Koekemoer (STSci, USA), Renée Kraan-Korteweg (UCT, SA), Jean-Claude Kubwimana (UCT, SAAO), Koen Kuijken (Leiden, NL), Mark Lacy* (ALMA, USA), **Nicola Loaring (SAAO, SA)**, Ilani Loubser (NWU, SA), Stuart Lumsden* (Leeds, UK), Roy Maartens* (Portsmouth, UK), Gordon Macleod (DST, SA), Steve Maddox (Nottingham, UK), Bryony Martin (NASSP, SA), Ross McLure (Edinburgh, UK), Richard McMahon* (Cambridge, UK), Pieter Meintjies (UFS, SA), Hugo Messias (Lisbon, Portugal), George Miley* (Leiden, NL), Kavilan Moodley (KwaZulu Natal, SA), Rafaella Morganti (ASTRON, NL), Eric Murphy (Caltech, USA), **Ray Norris* (CSIRO, Australia)**, **Nadeem Oozeer (HartRAO, SA)**, Se Heon Oh (UCT, SA), Patrice Okouma (UCT, SA), **Seb Oliver (Sussex, UK)**, Darragh O'Donoghue (SAAO, SA), Bob Osano (UCT, SA), Viral Parekh (UCT, SA), Prina Patel (Portsmouth, UK), Chris Pearson (RAL, UK), Nikki Pekeur (UNW, SA), Mirjana Povic (IAC/UKZN,Spain/SA), **Isabella Prandoni* (INAF, It)**, Alvise Raccanelli (Portsmouth, UK), Dinesh Radhakhrishna (Univ. Mauritius, Mauritius), **Steve Rawlings (Oxford, UK)**, Somak Raychaudhury* (Birmingham, UK), Marco Regis (UCT, SA), Laura Richter (MeerKAT, SA), Dimitra Rigopoulou (Oxford, UK), Encarni Romero Colmenero (SALT, SA), **Huub Röttgering (Leiden, NL)**, Lawrence Rudnick* (UMN, USA), Mario Santos (UTL, Portugal), **Anna Scaife (Dublin, Ireland)**, Anja Schröder (MeerKAT, SA), Ramotholo Sefako (SAAO, SA), Stephen Serjeant* (OU, UK), Nick Seymour (MSSL, UK), Muzikayise Sikhonde (NASSP, SA), **Chris Simpson (LJMU, UK)**, Bruce Slee (CSIRO, Australia), **Ian Smail (Durham, UK)**, Anthony Smith (Sussex, UK), Mathew Smith (UCT, SA), **Ian Stewart (UCT, SA)**, Jeroen Stil (Calgary, Canada), Kim Sung (Sejong, Korea), Yabebal Tadessa (SISSA, It), Russ Taylor* (Calgary, Canada), Petri Vaisanen (SALT, SAAO), Melvin Varughese (UCT, SA), Mattia Vaccarri (Padova, It), **Nic Walton (Cambridge, UK)**, Aprajita Verma (Oxford, UK), Amanda Weldman (UCT, SA), Glenn White (OU, UK), Eric Wilcots (Wisconsin, USA), **Richard Wilman (Swinburne, Australia)**, Hartmut Winkler (UJ, SA), **Patrick Woudt (UCT, SA)**

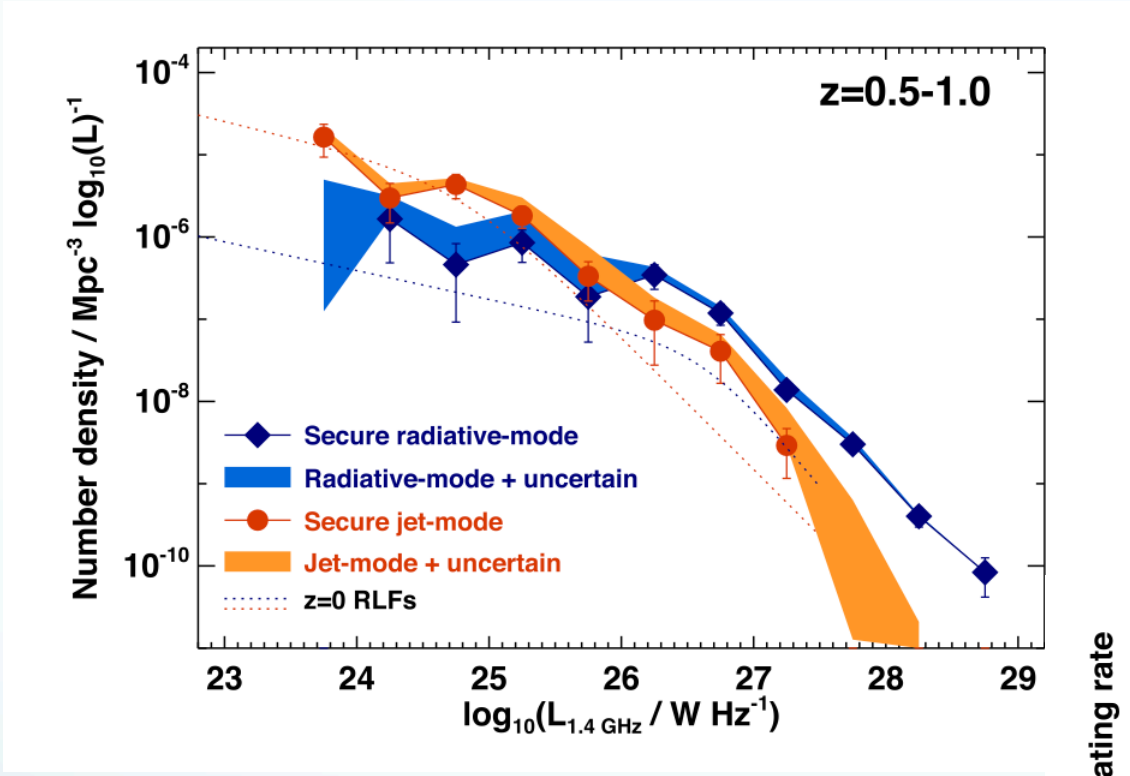
What was MIGHTEE?

Three tiers originally proposed:

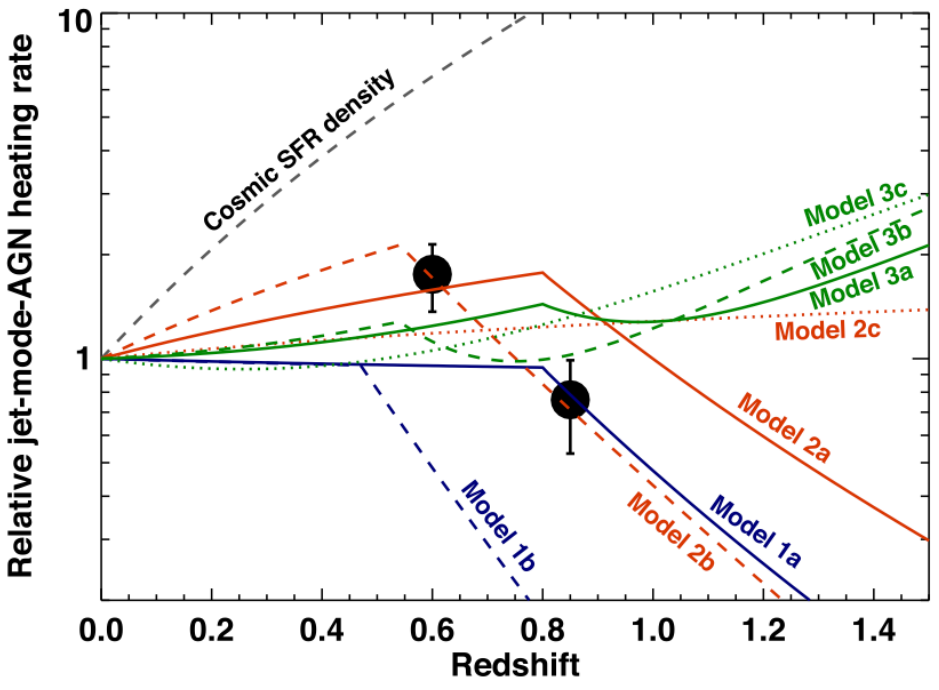
- Wide ~1000sq.deg to 5uJy rms ✗
  - Mario Santos – IM proposal
- Deep ~35sq.deg to 1uJy rms ✓
  - ❑ LSST Deep drilling Fields
- Ultra-deep ~1sq.deg to 0.1uJy rms ✓
  - ❑ Confused

High-frequency (X-band) observations also proposed but not discussed here

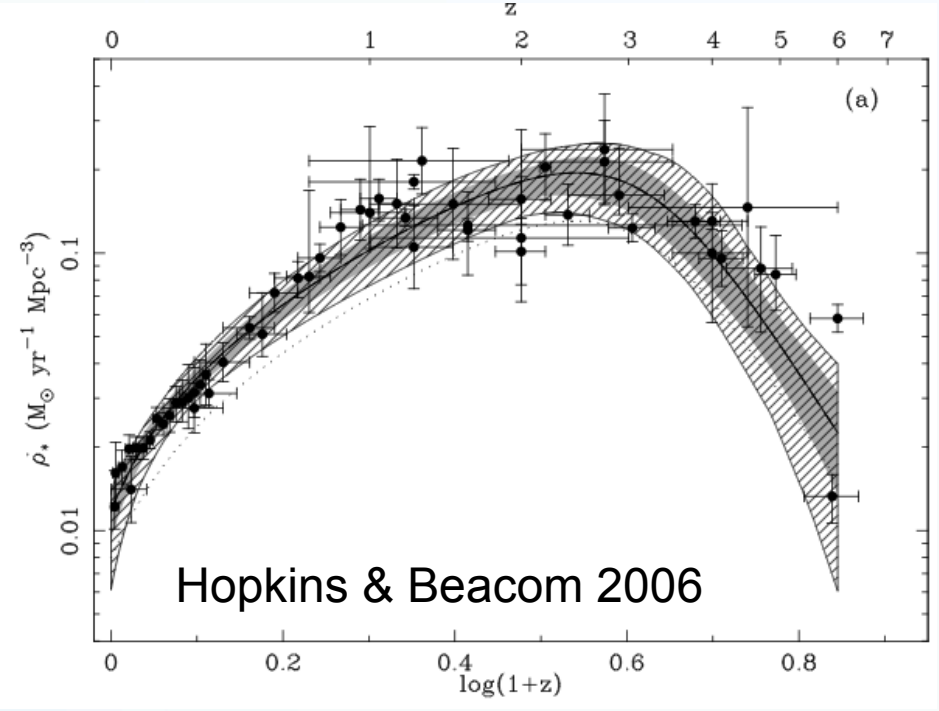
AGN: Feedback



Best et al. 2014
See also Smolcic et al. 2009, 2015



Evolution of the star-formation rate density

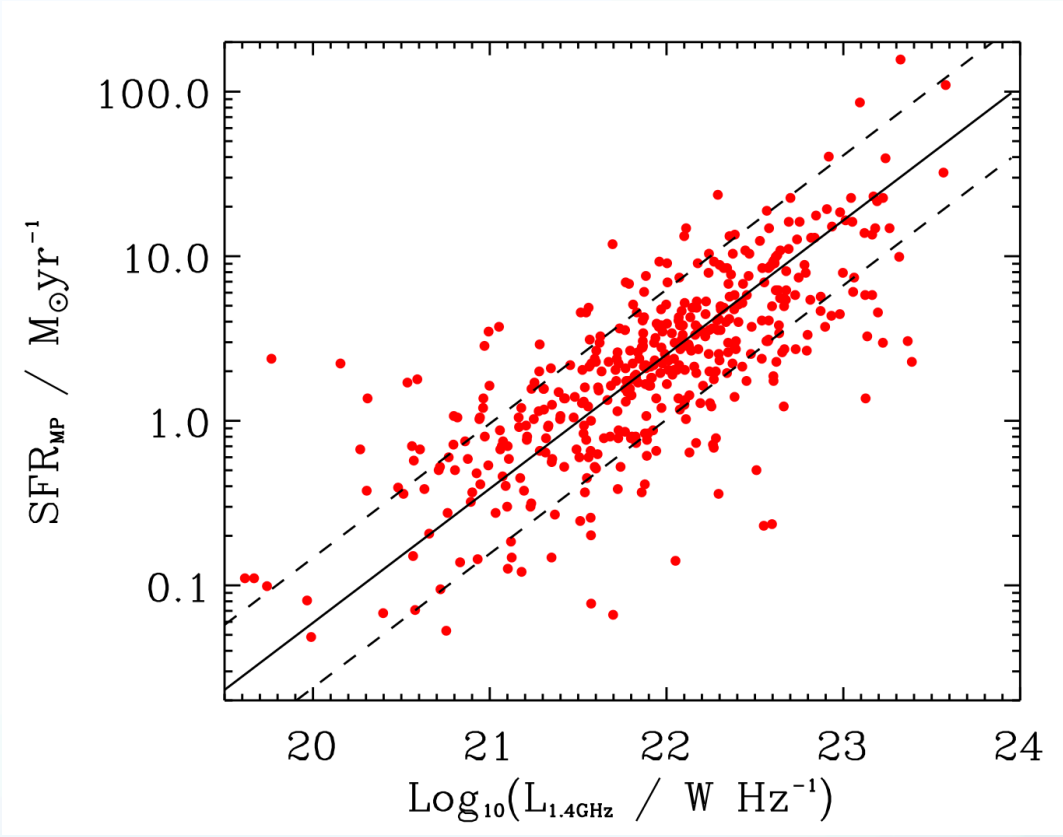


UV/Optical – dust extinction

Far-IR – poor resolution means confusion

Radio – unaffected by dust, high-resolution

*AGN contamination in all at varying degrees



SFR – radio correlation from H-ATLAS (Jarvis et al. in prep.)

What is MIGHTEE?

How do we observe galaxies at radio wavelengths?

- **Spectral Line**
  - Atomic gas (HI) ✓
  - Cold molecular gas (e.g. CO, CII)
  - Masers (OH) ✓
- **Polarisation**
  - Magnetic fields in galaxies ✓
  - Rotation measure synthesis for probing line of sight ✓
- **Continuum**
  - Synchrotron emission at <5GHz ✓
  - Free-Free emission at >10GHz

Radio continuum survey machines and their strengths…

	FoV (~1.4GHz)	Rms/beam/hr	N/deg/hr	N/FoV/hr
JVLA	~0.5 sq.deg	~18uJy	~900	~450
LOFAR	~10 sq.deg	~50uJy*	~300	~3000
BETA	~9 sq.deg	~1mJy	~30	~270
ASKAP	~30sq.deg	~50uJy	~300	~9000
MeerKAT-16	~1.5sq.deg	~14uJy	~1200	~1800
MeerKAT-32	~1.5sq.deg	~10uJy	~1800	~2700
MeerKAT-64	~1.5sq.deg	~7uJy	~2800	~4200
SKA-Mid	~1 sq.deg	~4uJy	~5000	~5000

*Scaled to 1.4GHz using spectral index of -0.8

- Most efficient way to get as many sources as you can per unit time is to go wide and shallow – EMU's territory (Ray's talk tomorrow)
- So survey design depends on the science you want to do (obviously!)
- MeerKAT most efficient at going deep!

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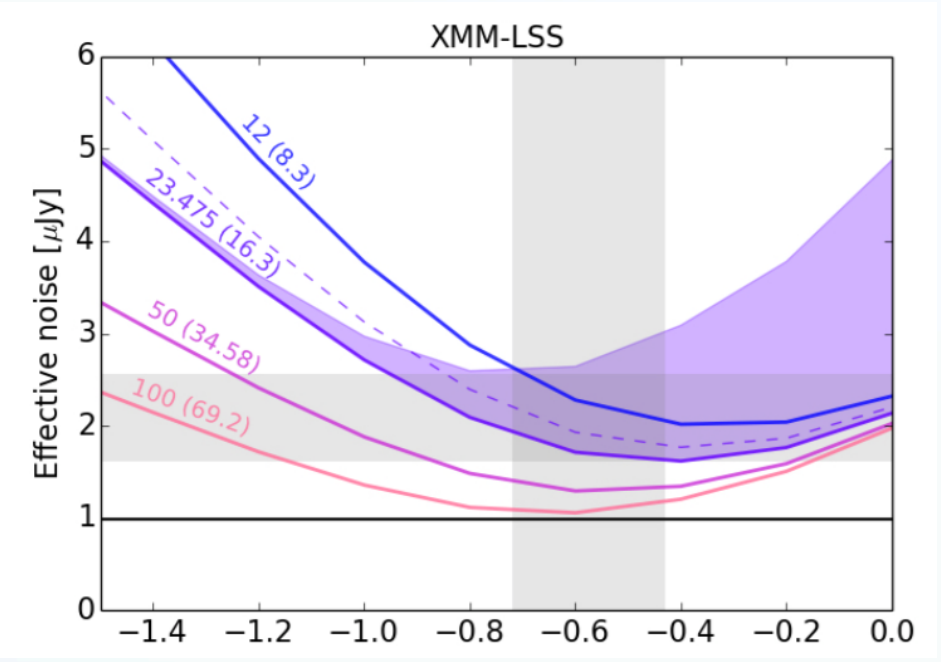
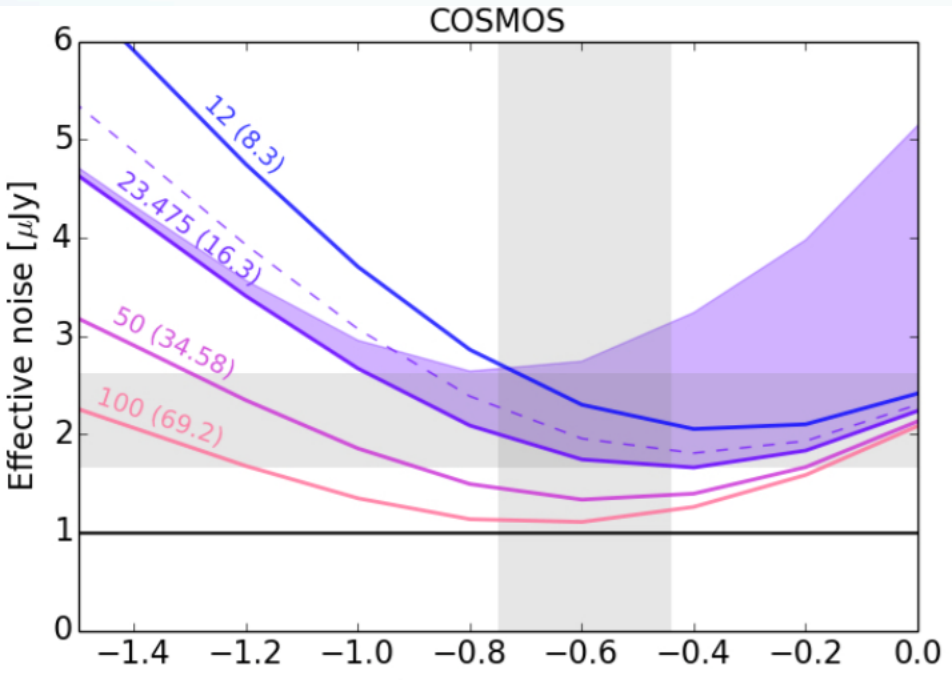
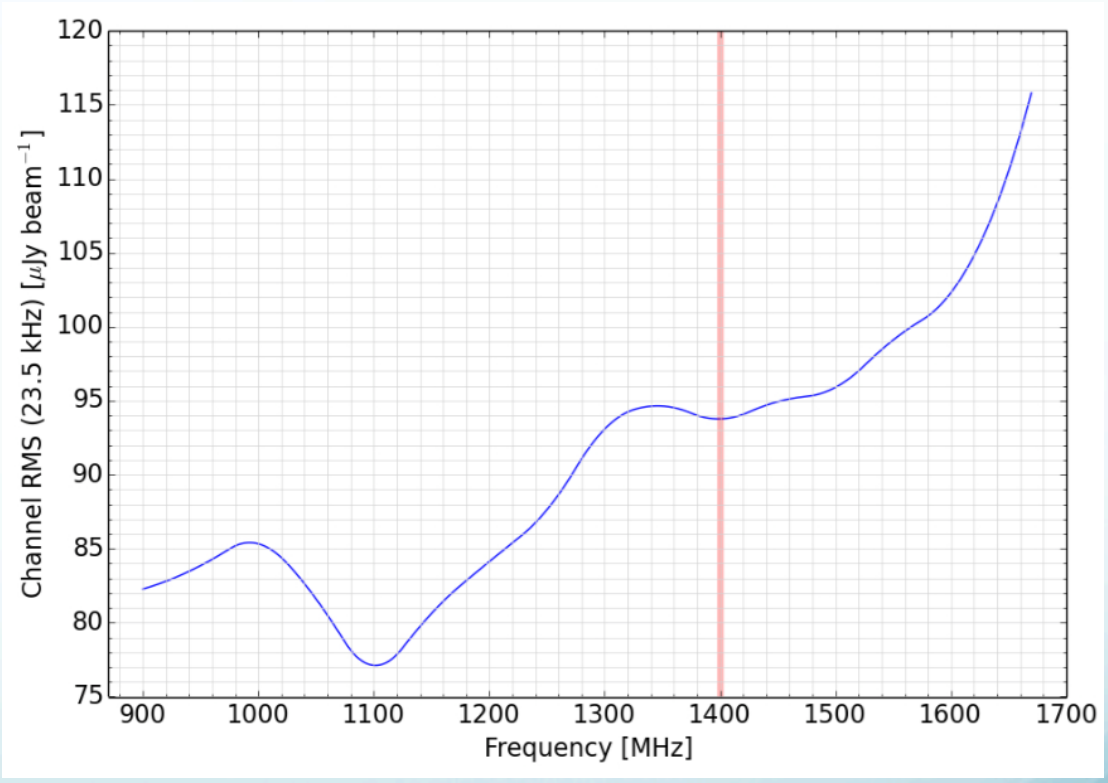
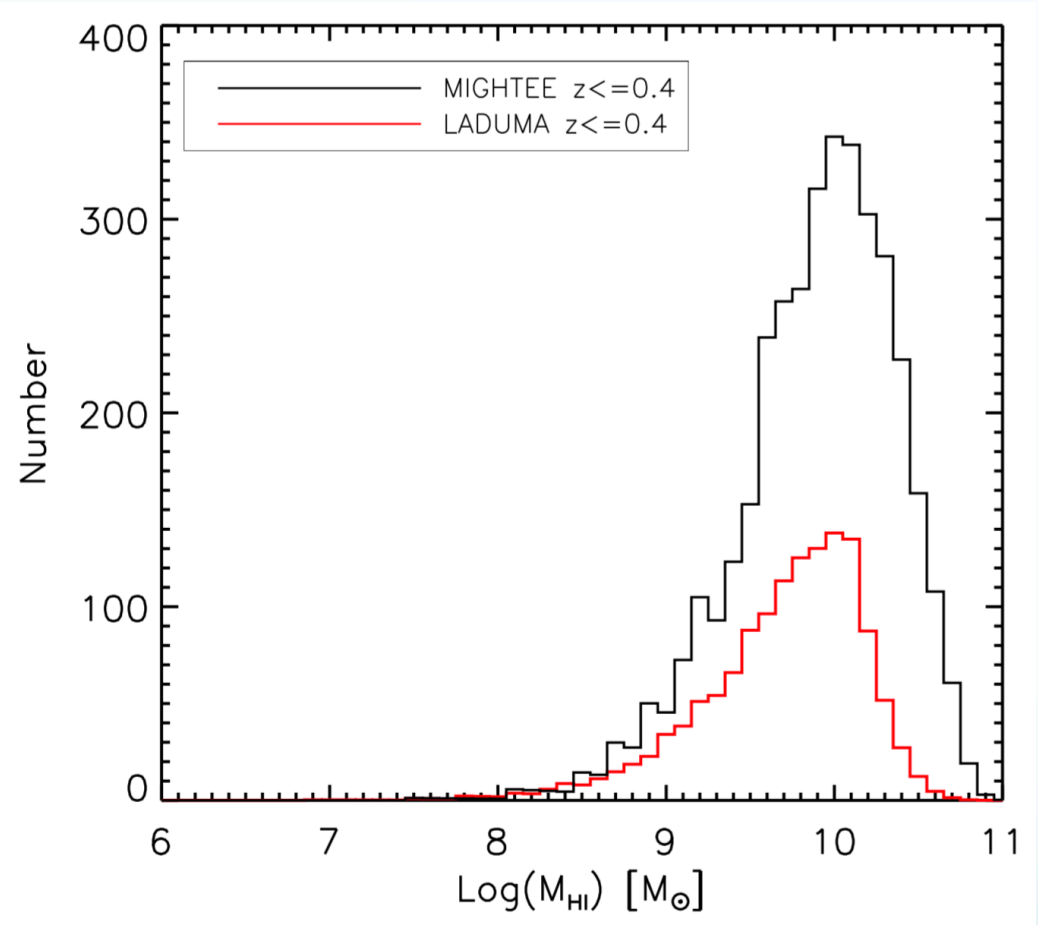
Sensitivity of MeerKAT

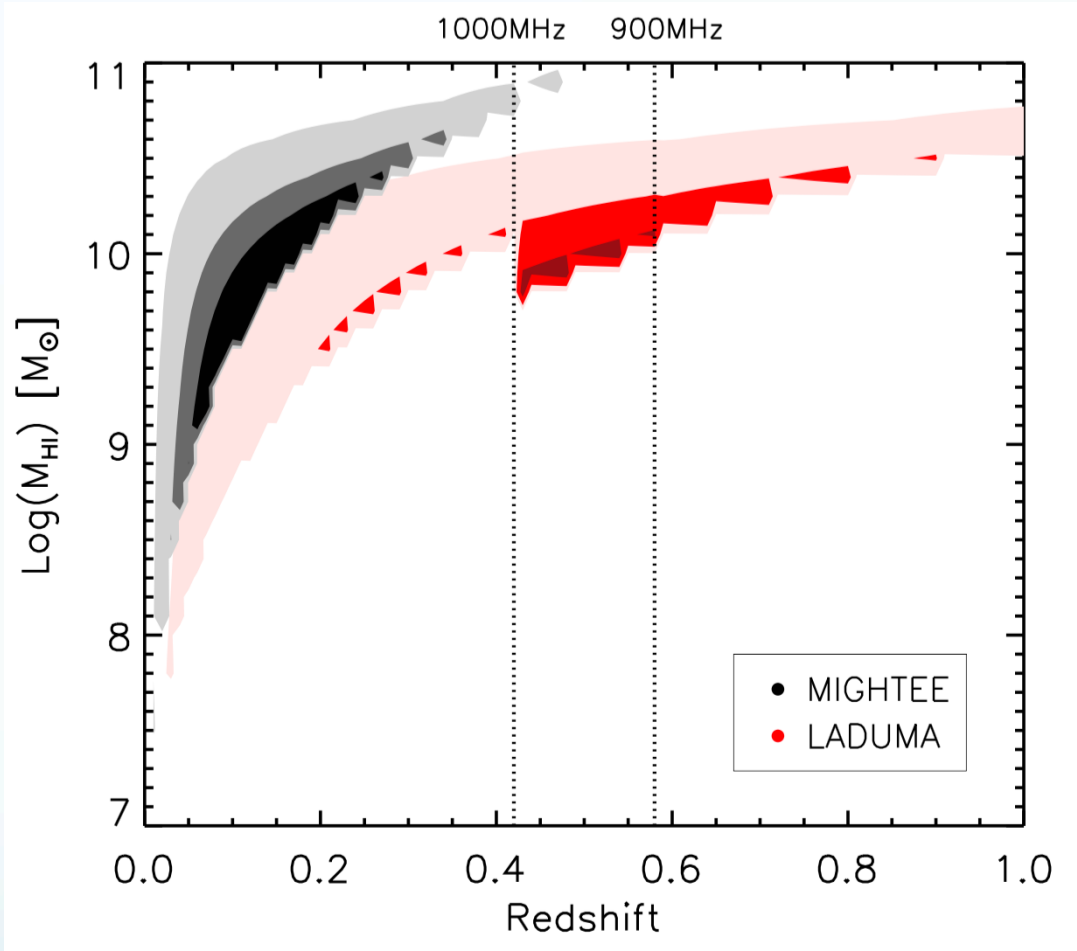






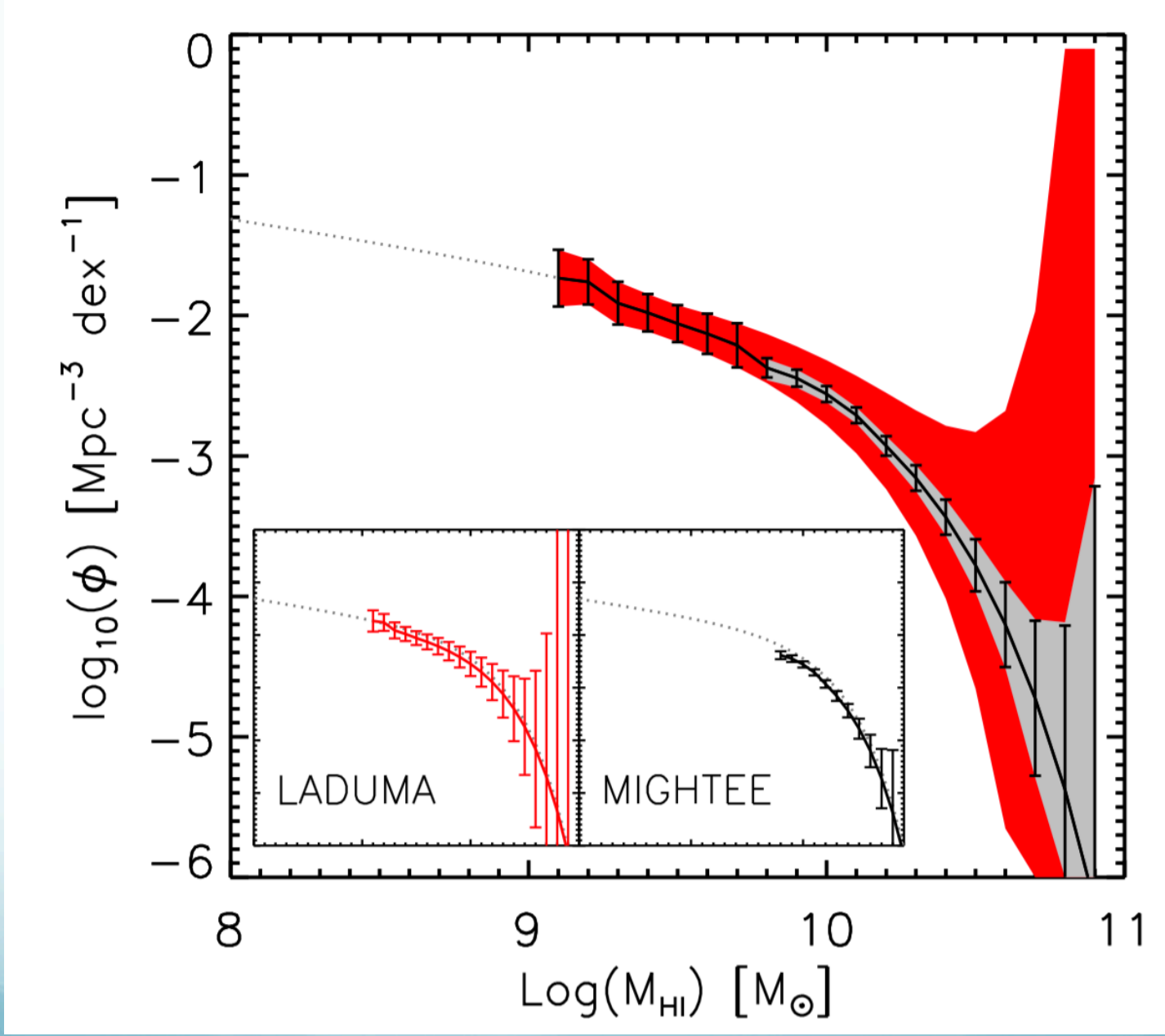
HI + continuum + polarisation in one survey!





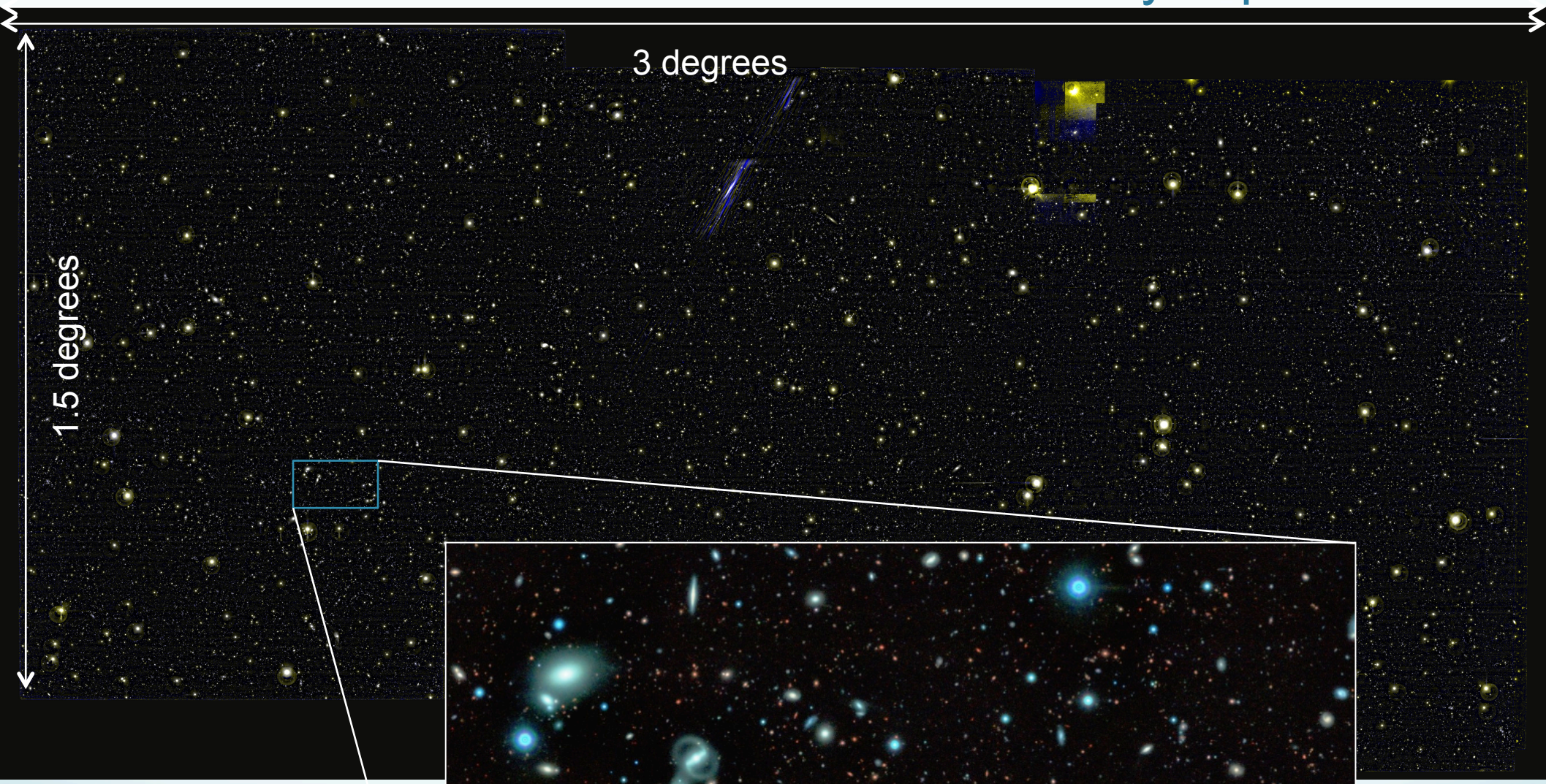
Maddox, Jarvis & Oosterloo, submitted

HI—continuum synergies



Maddox, Jarvis & Oosterloo, submitted

HELP! - A lot of the multi-λ data is already in place!



VIDEO Survey in XMMLSS
Jarvis et al. 2013

~1.2 Million galaxies

Work Packages

- MIGHTEE-Cont - Kim McAlpine (UWC) & Ian Heywood (CSIRO/ Rhodes)
- MIGHTEE-Pol - Russ Taylor (UCT/UWC) & Anna Scaife (Manchester)
- MIGHTEE-HI_em - Brad Frank (UCT) & Natasha Maddox (ASTRON)_
- MIGHTEE-HI_abs - James Allison (CSIRO) & Neeraj Gupta (IUCAA)
- MIGHTEE-VLBI – Roger Deane (Rhodes)

Work Packages being defined

Want to ensure SA leadership in the technical development and in the science – also want strong links with ASKAP-EMU…

- MIGHTEE-XID - Matt Jarvis (Oxford/UWC) & Mattia Vaccari (UWC)
- MIGHTEE-noise - Jon Zwart (UCT/UWC) & Mario Santos (UWC/SASKA)
- AGN-SF separation
- Simulations
- Full Polarisation Source Extraction
- RM Synthesis
- 3-D source finding for spectral lines (links with LADUMA)

Key Science

- The cosmic star-formation history
- Large-scale structure
- RM synthesis to trace extragalactic magnetic fields
- HI emission and the evolution of HI

- The evolution of accretion activity over cosmic time
- Galaxy Clusters
- The Polarised Sky
- Transients (link to ThunderKAT)

- HI absorption and the evolution of HI
- HI absorption and the fueling of AGN

- The link between gas and stars in galaxies over cosmic time

- High-z OH studies

MIGHTEE – what is happening….

- Using the new S-band receiver for MIGHTEE (adding to L-band)
    - Pros
        - Beat confusion level with a factor of ~2 higher resolution (3.5arcsec)
        - More bandwidth for spectral index
        - More bandwidth -> big gains in polarisation science
    - Cons
        - To reach the same depth over the same area in S-band for a typical source will require **10x** more time

➢ Go very deep over fraction of the L-band area

- Re-introduce wide tier and how wide?
    - Pros
        - Piggy back on intensity mapping (Day 1 talks)
        - Fits neatly between EMU and MIGHTEE-Tier 2 to give access to same comoving volume across all redshifts
    - Cons
        - None apart from asking for more time

- GMRT observations to complement MeerKAT observations
    - 500-900 MHz at same resolution as MeerKAT L-band

MIGHTEE – redefined survey…

- 20 sq.deg over VIDEO+UVISTA/LSST-deep drill fields – equivalent of 23hours per pixel (~1uJy with 7arcsec resolution)
- 3-5 sq.deg with S-band to matched depth with L-band for a alpha=-0.7 source
- Full spectral line for HI absorption and emission
- Full polarisation for RM synthesis and magnetised sky

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MIGHTEE

- MeerKAT is one of the key facilties that bring us close to SKA-like requirements
- It is happening in the very soon
- MIGHTEE will be one of the surveys that will be running in total intensity, full polarisation and spectral line at the same time (which is the plan for large surveys with SKA)
- Storage required for *visibilties* ~10 Peta Bytes
- Storage required for *reduced* image cubes ~700TB
- This is an ideal test-bed for SKA surveys plans

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- Updated science case to be submitted in mid-May
- MeerKAT Science meeting to present cases – end of May
- MIGHTEE to start with 32 dish array in late 2016
- If you want to contribute then please let me know