International Centre for Radio Astronomy Research

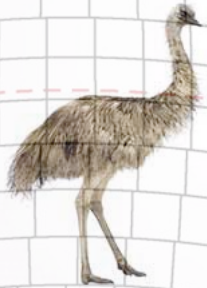
An MWA/ASKAP/ eROSITA study of the Magellanic Clouds

Lister Staveley-Smith (ICRAR/UWA/CAASTRO)

New southern radio surveys

GLEAM

Galactic and Extragalactic All-sky MWA survey
http://www.mwatelescope.org/science/gleam-survey



EMU
(Ray Norris talk)

GASKAP

Galactic ASKAP survey
https://sites.google.com/site/gaskapproject/home

ASKAP-FLASH
First Large Absorption Survey in HI

FLASH
Vanessa Moss talk

WALLABY

Widefield ASKAP L-band Legacy All-sky Blind Survey
https://wallaby-survey.org

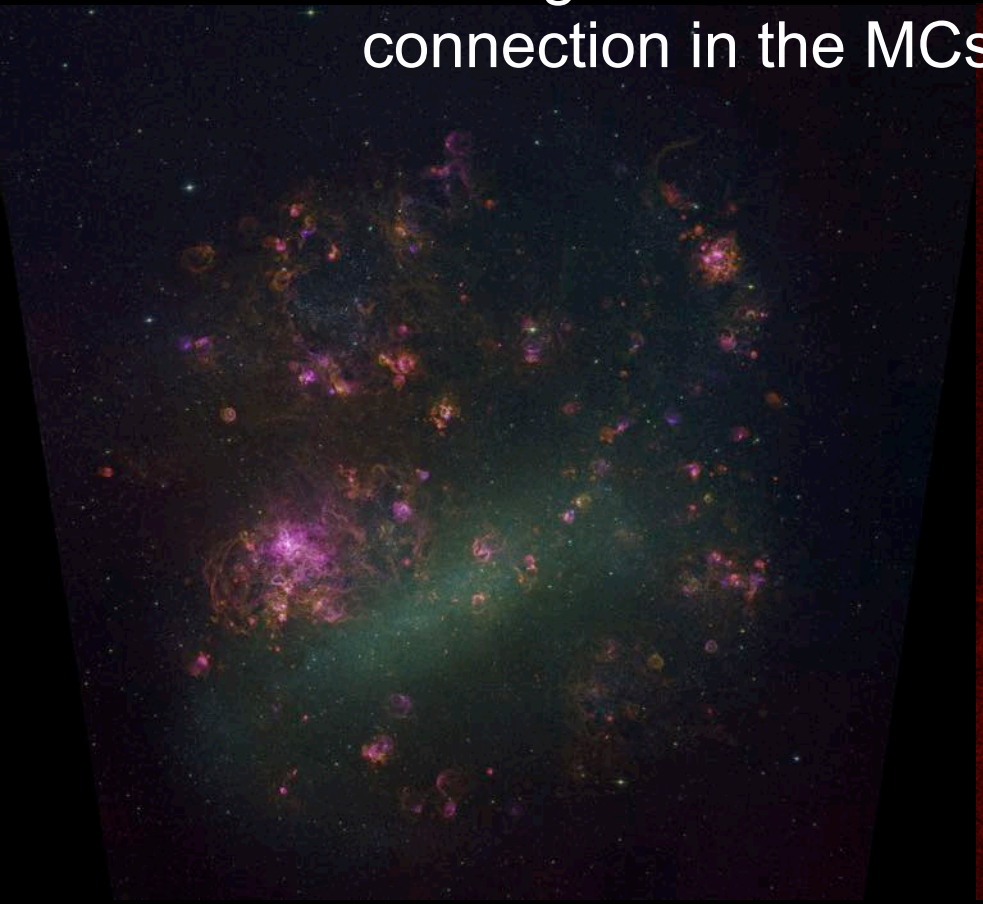
CAASTRO
ARC CENTRE OF EXCELLENCE FOR ALL-SKY ASTROPHYSICS

Astronomy Australia Ltd.

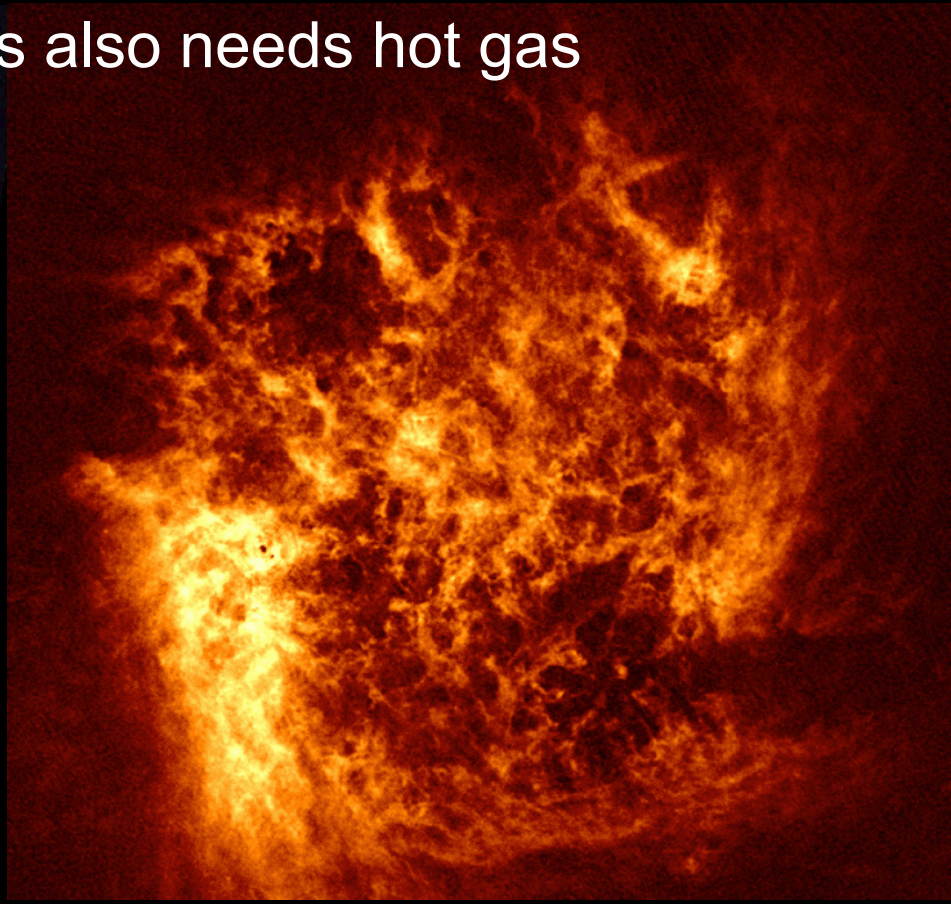
AU/eROSITA_DE MoU partners


NASA Swift

Understanding mechanical feedback and the stellar-ISM connection in the MCs also needs hot gas

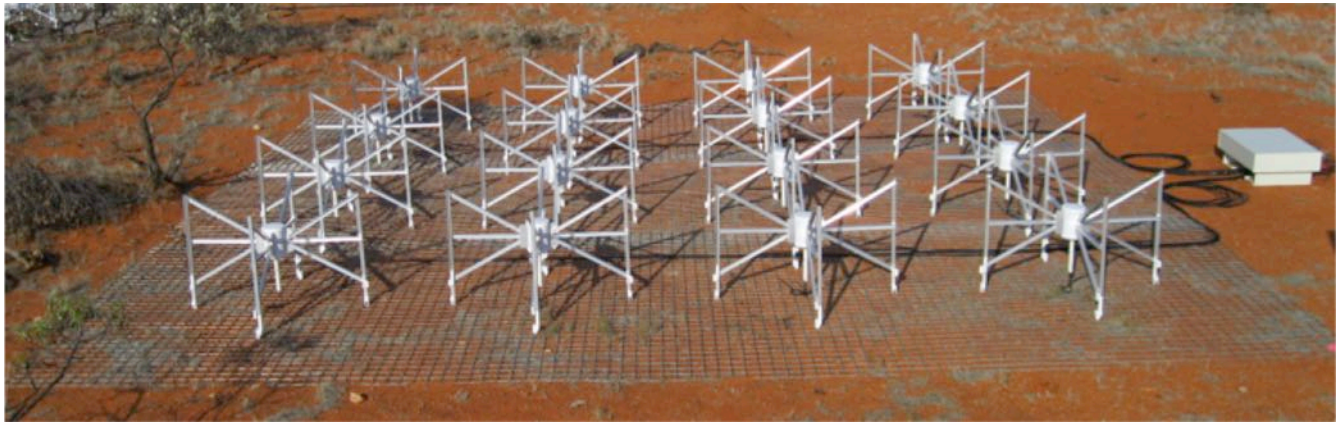


Stars and emission-line gas (Smith) - CTIO



HI (Kim et al. 2003) - ATCA/PKS

Murchison Widefield Array



Gurlgamarnu

ICRAR

GOVERNMENT OF WESTERN AUSTRALIA

Australian Government

SWINBURNE UNIVERSITY OF TECHNOLOGY

THE AUSTRALIAN NATIONAL UNIVERSITY

UNIVERSITY OF TORONTO

WESTERN SYDNEY UNIVERSITY

CSIRO

THE UNIVERSITY OF WESTERN AUSTRALIA

TOHOKU UNIVERSITY

熊本大学 Kumamoto University

MWA MURCHISON WIDEFIELD ARRAY

UWM

KAGOSHIMA UNIVERSITY

THE UNIVERSITY OF SYDNEY

THE UNIVERSITY OF MELBOURNE

NAOJ

Curtin University

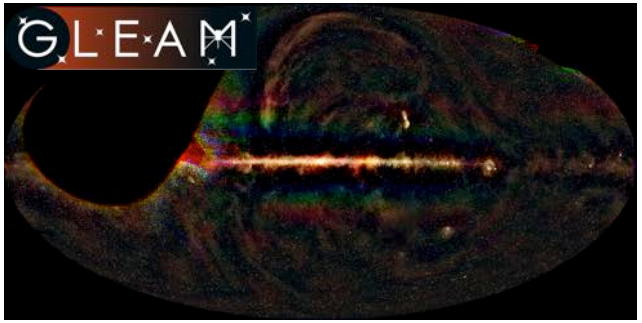
TE WHARE WĀNANGA O TE ŪPOKO O TE IKA A MĀUI VICTORIA UNIVERSITY OF WELLINGTON

東京大学 THE UNIVERSITY OF TOKYO

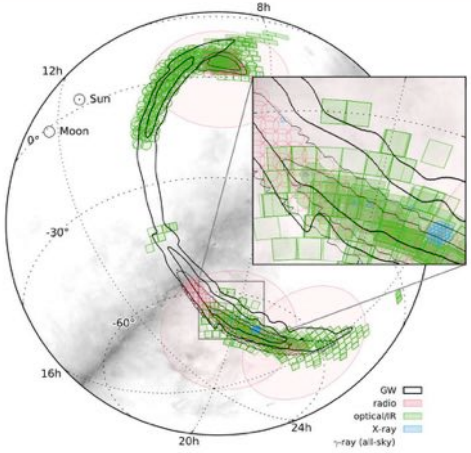
MWA Key science

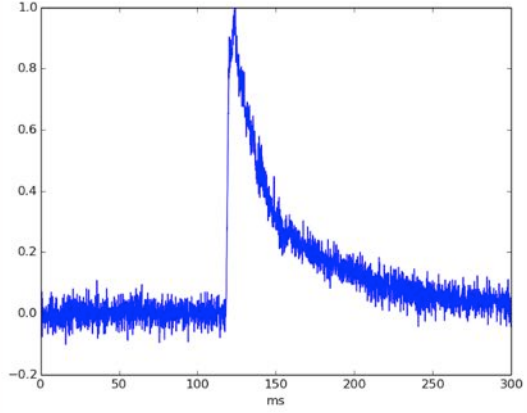
Bowman et al., 2013.

The Epoch of Reionisation

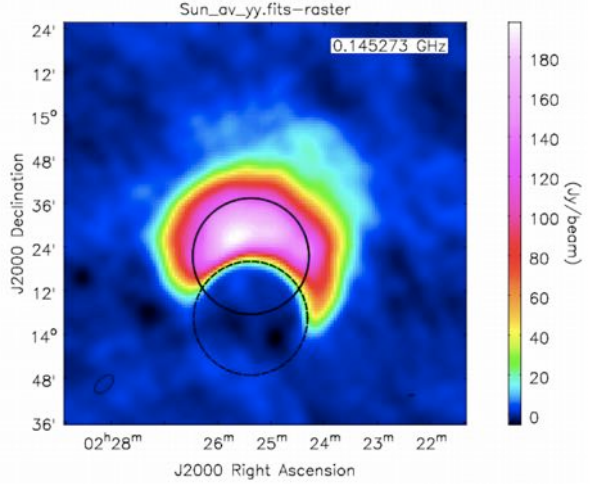


Galactic & extragalactic astrophysics





Transient & variable universe

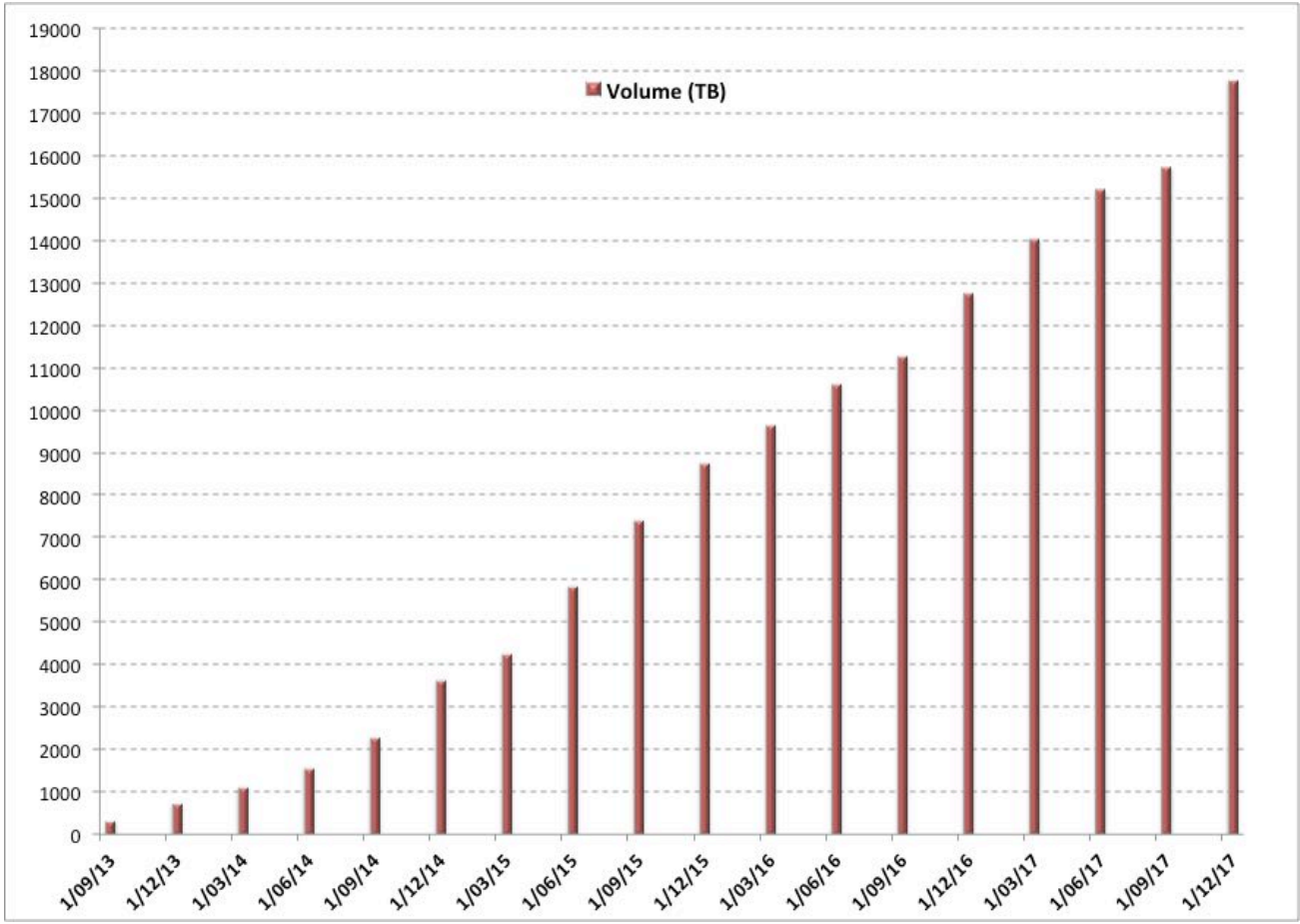


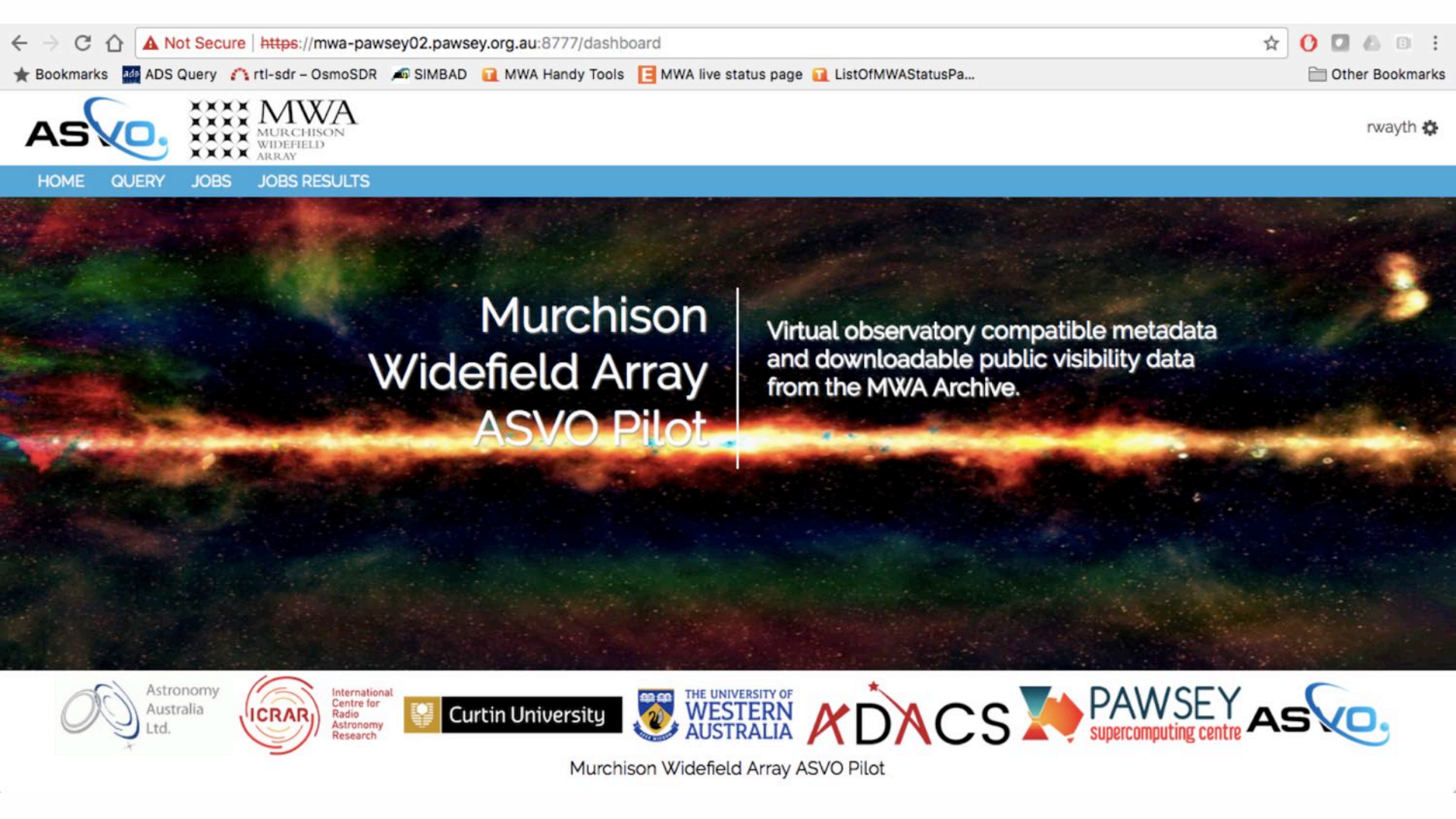
Solar & heliospheric science

Hurley-Walker et al. (2017)

Observing & archive

- 100+ publications
- 80+ TAC-approved projects since 2013-B
- ~9+ PB of data **publicly available** (end 2017)
- Current archive: ~18 PB including ephemeral data

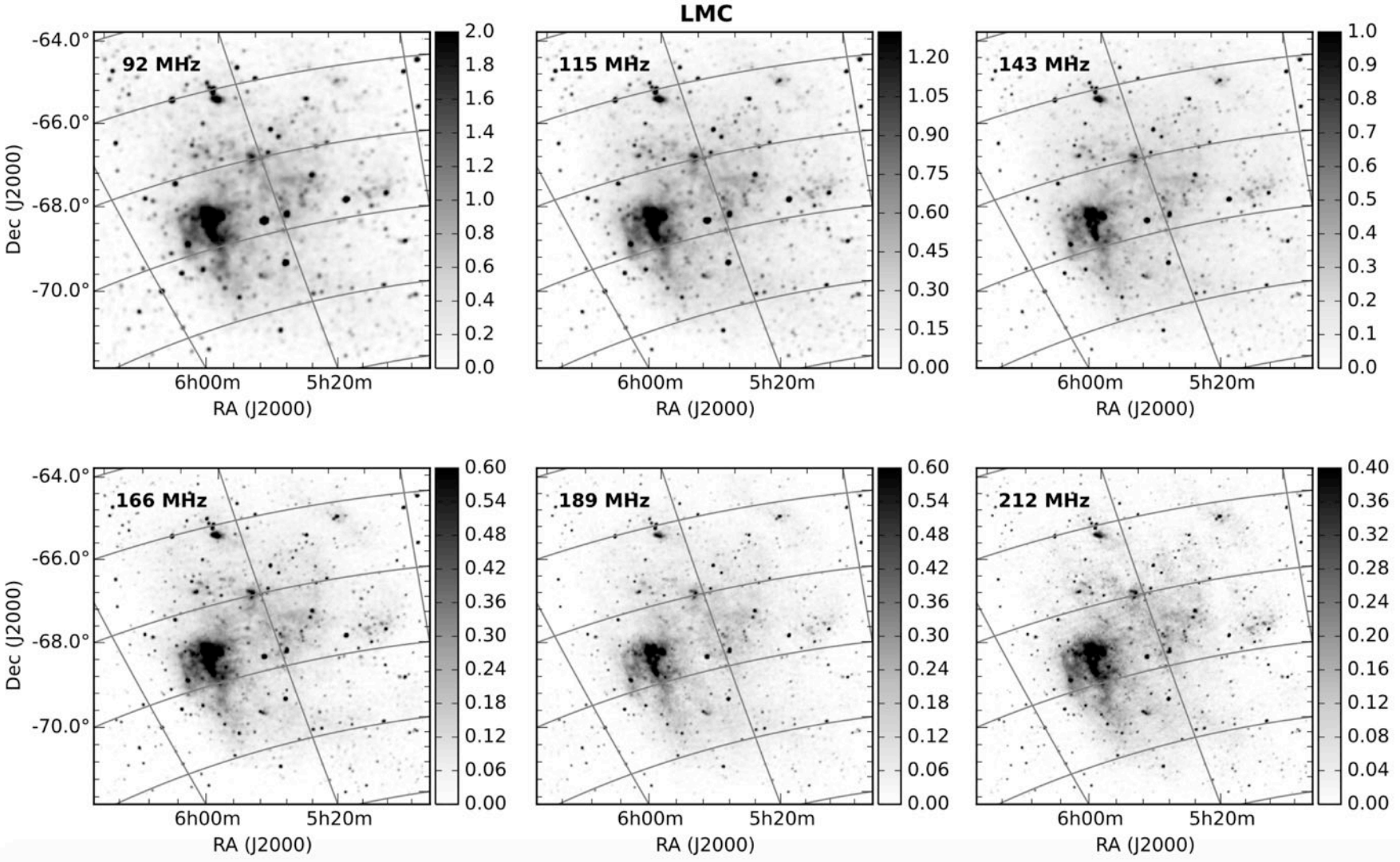


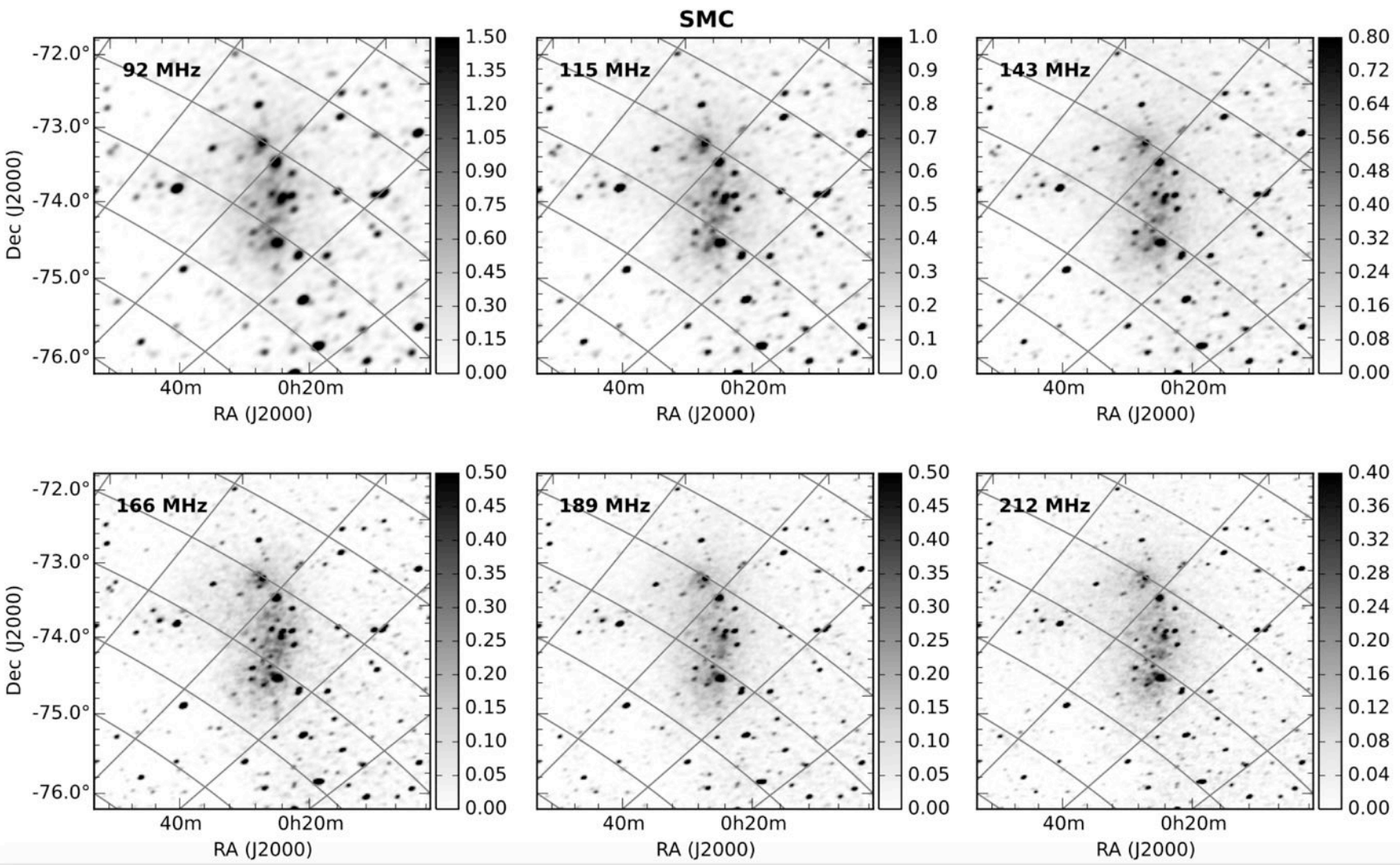

Not Secure | https://mwa-pawsey02.pawsey.org.au:8777/dashboard
Bookmarks
ADS Query
rtl-sdr – OsmoSDR
SIMBAD
MWA Handy Tools
MWA live status page
ListOfMWAStatusPa...
Other Bookmarks
ASVO
MWA
MURCHISON WIDEFIELD ARRAY
rwayth
HOME
QUERY
JOBS
JOBS RESULTS
Murchison Widefield Array ASVO Pilot
Virtual observatory compatible metadata and downloadable public visibility data from the MWA Archive.
Astronomy Australia Ltd.
ICRAR
International Centre for Radio Astronomy Research
Curtin University
THE UNIVERSITY OF WESTERN AUSTRALIA
ADACS
PAWSEY supercomputing centre
ASVO
Murchison Widefield Array ASVO Pilot

Phase 1 LMC/SMC reductions

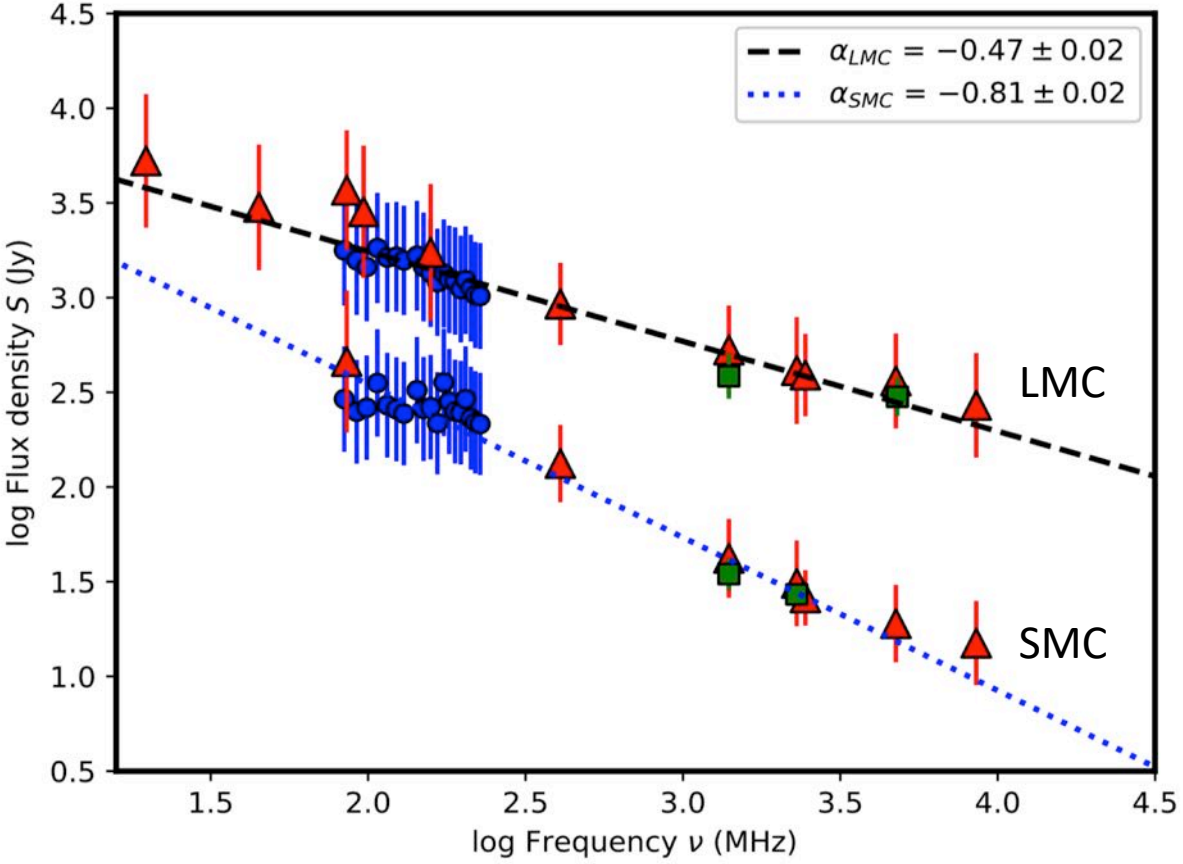
Bi-Qing For + GLEAM team (2018):

- GLEAM year 1 drift scans (Wayth et al. 2015)
- Frequencies: 72 – 231 MHz (5 bands)
- Integration: 40 – 80 min per pixel
- Weighting: robust = 0 (*cf.* robust = –1 for EG cat; Hurley-Walker et al. 2017)
  - Increases brightness sensitivity
  - Decreases resolution (3.3 arcmin v 2.9 arcmin at 200 MHz)
- Flux density accuracy: 9% – 13%


LMC
92 MHz
115 MHz
143 MHz
166 MHz
189 MHz
212 MHz
Dec (J2000)
RA (J2000)
-64.0°
-66.0°
-68.0°
-70.0°
6h00m
5h20m
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1.20
1.05
0.90
0.75
0.60
0.45
0.30
0.15
0.00
0.60
0.54
0.48
0.42
0.36
0.30
0.24
0.18
0.12
0.06
0.00
0.40
0.36
0.32
0.28
0.24
0.20
0.16
0.12
0.08
0.04
0.00

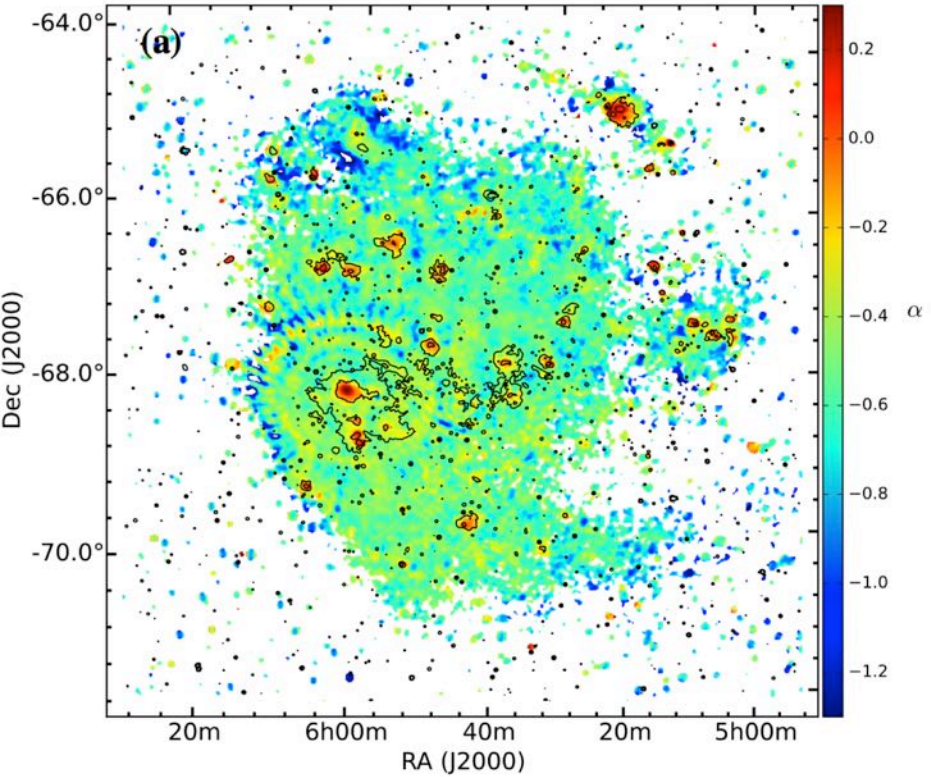

SMC
92 MHz
115 MHz
143 MHz
166 MHz
189 MHz
212 MHz
Dec (J2000)
RA (J2000)
-72.0°
-73.0°
-74.0°
-75.0°
-76.0°
40m
0h20m
1.50
1.35
1.20
1.05
0.90
0.75
0.60
0.45
0.30
0.15
0.00
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.80
0.72
0.64
0.56
0.48
0.40
0.32
0.24
0.16
0.08
0.00
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.40
0.36
0.32
0.28
0.24
0.20
0.16
0.12
0.08
0.04
0.00

Global spectra

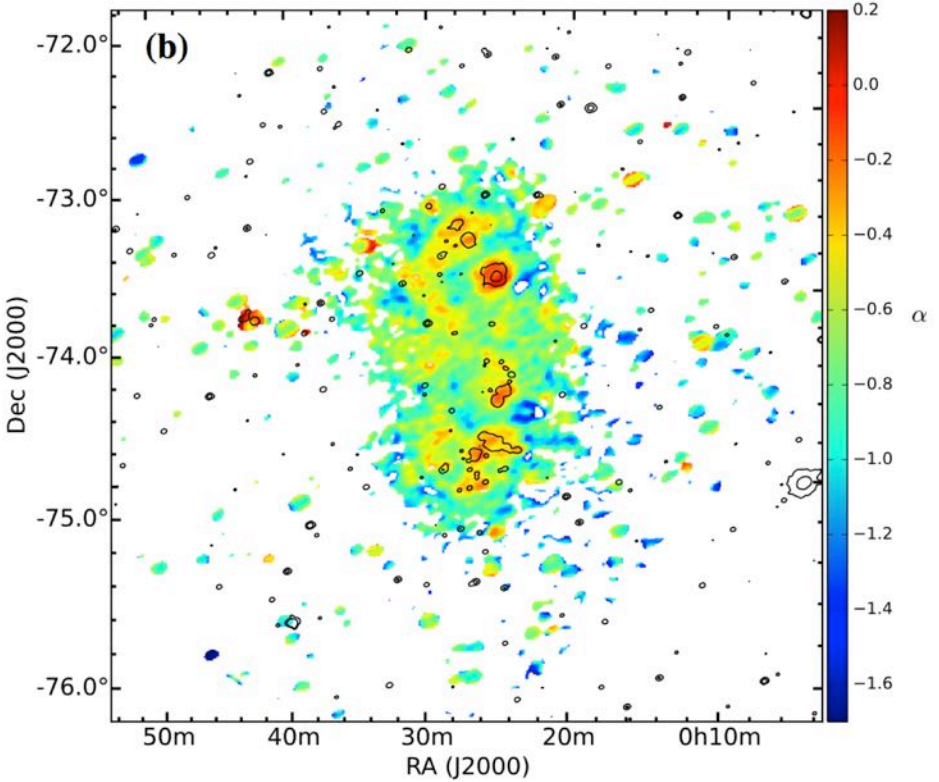


GLEAM-ATCA spectral index images

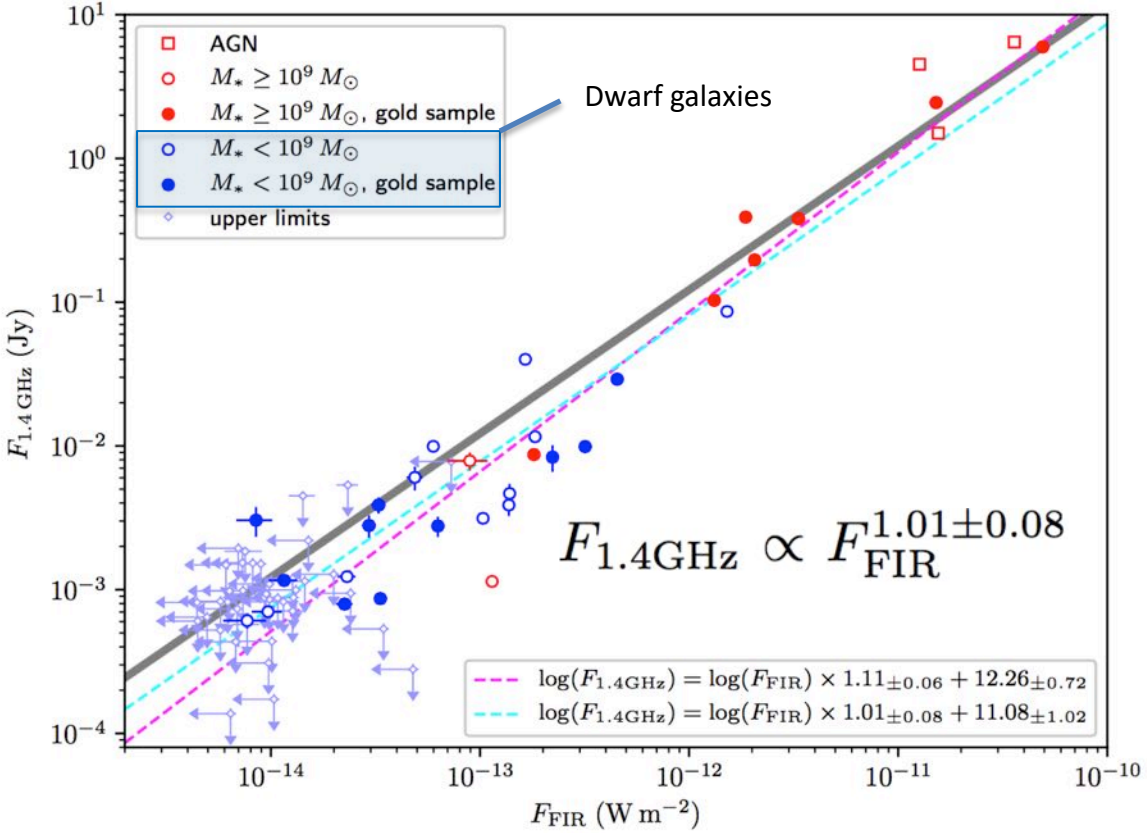
LMC



SMC



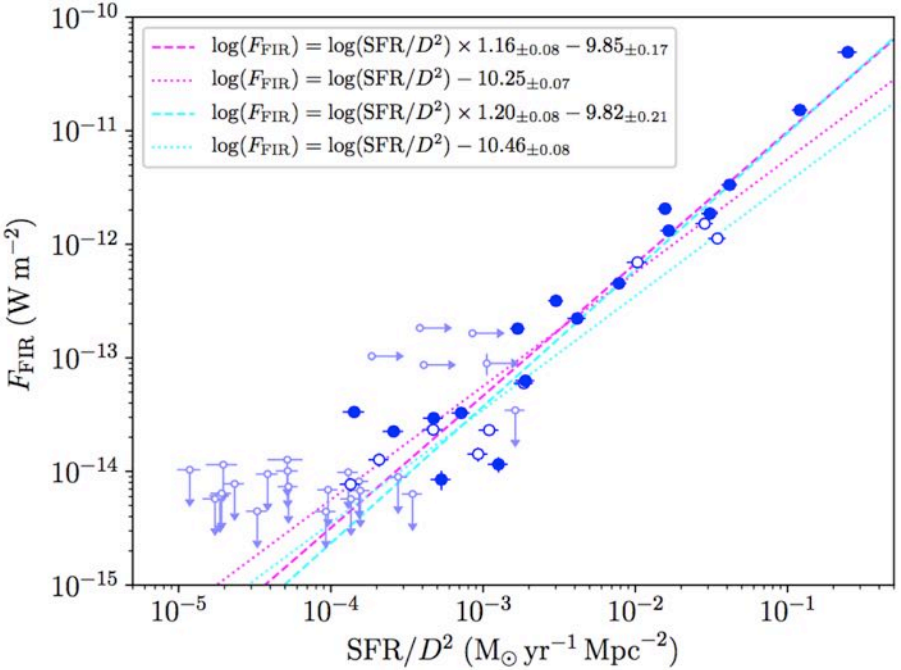
Radio-FIR correlation (non-AGN)



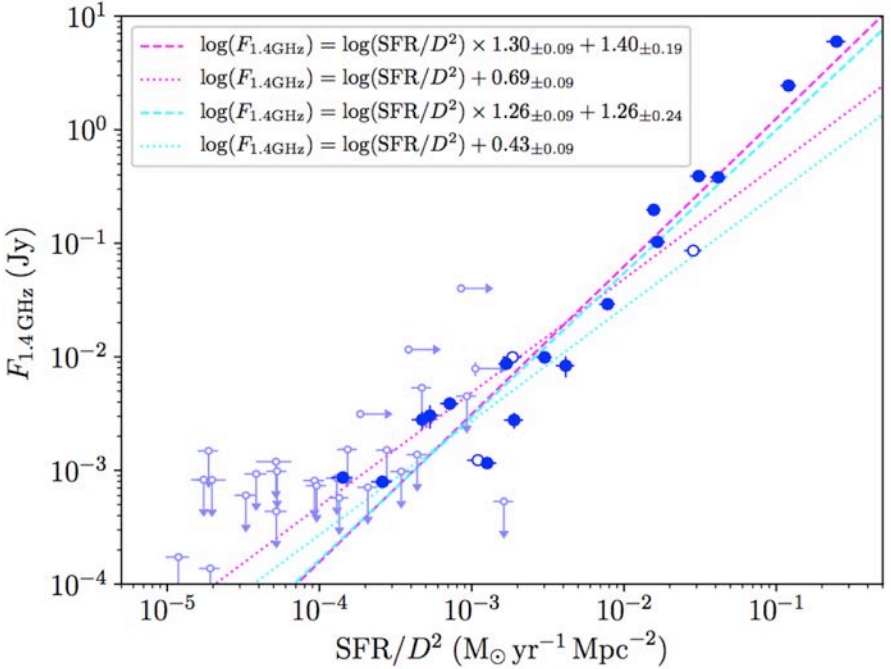
Local Volume galaxies:
Shao et al (2018)

Radio and FIR: non-linear with SFR

$$L_{\rm FIR} \propto {\rm SFR}^{1.20\pm0.08}$$



$$L_{\rm 1.4GHz} \propto {\rm SFR}^{1.26\pm0.09}$$



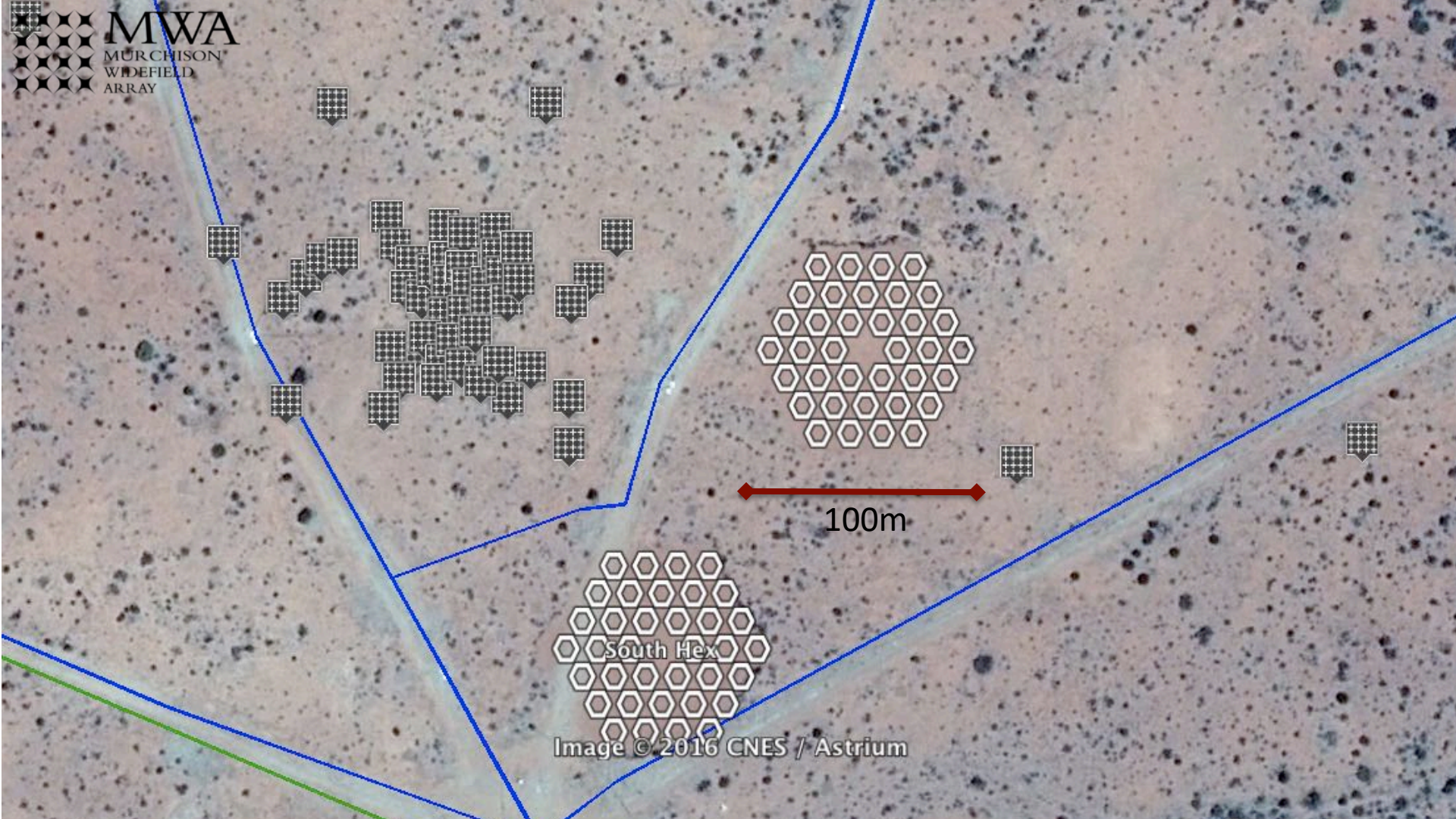
Results (For et al. 2018)

- Magellanic Cloud radio emission dominated by non-thermal emission at low frequencies:
  - LMC: $\alpha = -0.47 \pm 0.02$
  - SMC: $\alpha = -0.81 \pm 0.02$
  - No spectral turnover
  - Strong correlation with gas and dust morphology
- Brown et al. 150 MHz GMRT calibration:
  - LMC global star-formation rate: 0.08 – 0.16 $M_\odot$ yr^{-1}
  - SMC global star-formation rate: 0.02 – 0.04 $M_\odot$ yr^{-1}

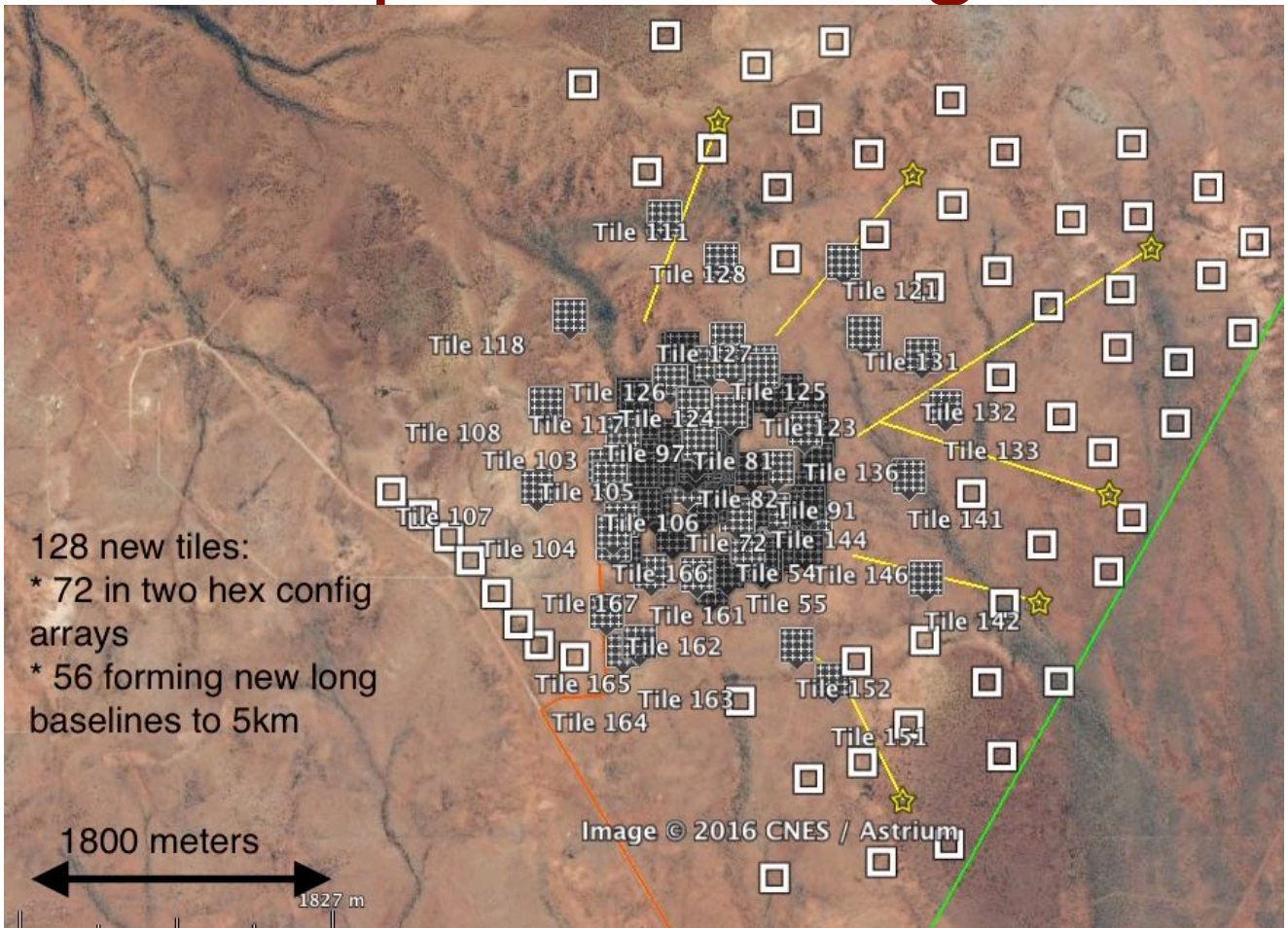
MWA
MURCHISON
WIDEFIELD
ARRAY

Past, present, future

- Phase 1: 2013-2016
  - 128 antennas, 2.5 km max baseline
- Phase 2: 2017+
  - Expanded with additional 128 antennas
  - 72 closely spaced in 2x hexagonal grids approx 100m size
  - 56 new long baseline antennas to double max baseline to 5km


MWA
MURCHISON
WIDEFIELD
ARRAY
100m
South Hex
Image © 2016 CNES / Astrium

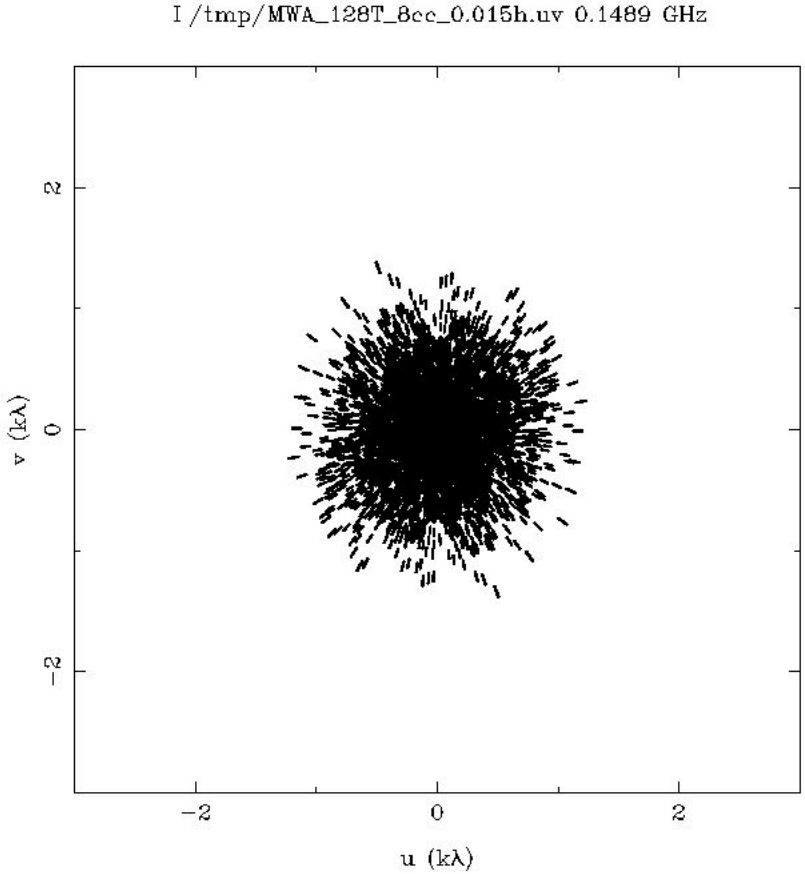
MWA phase II – long baselines

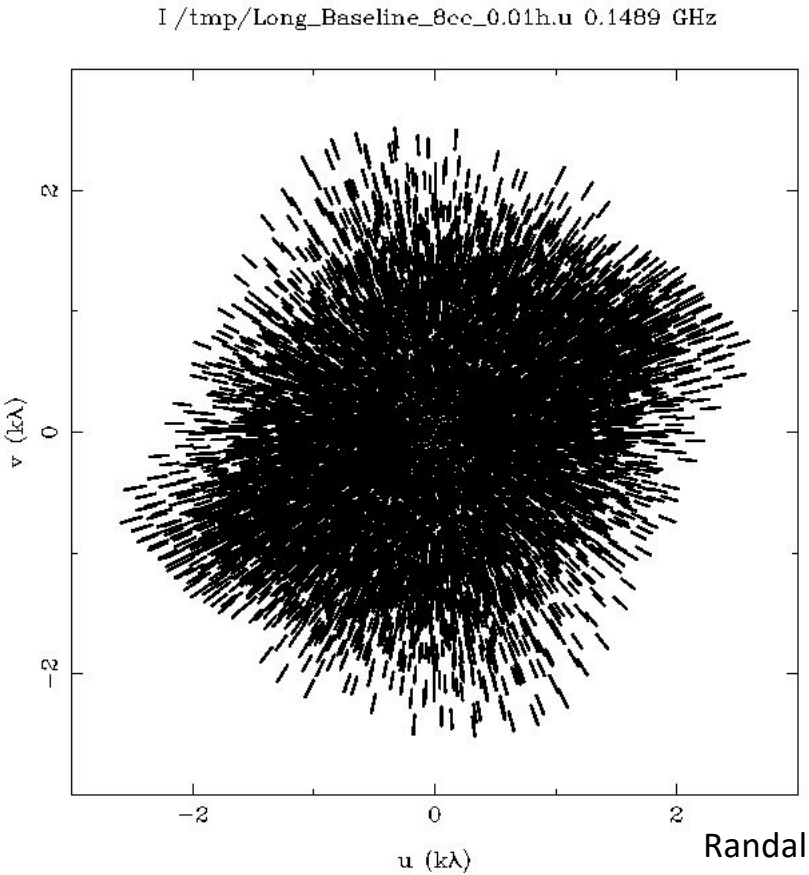


MWA
MURCHISON
WIDEFIELD
ARRAY

Phase 1 vs Phase 2 extended

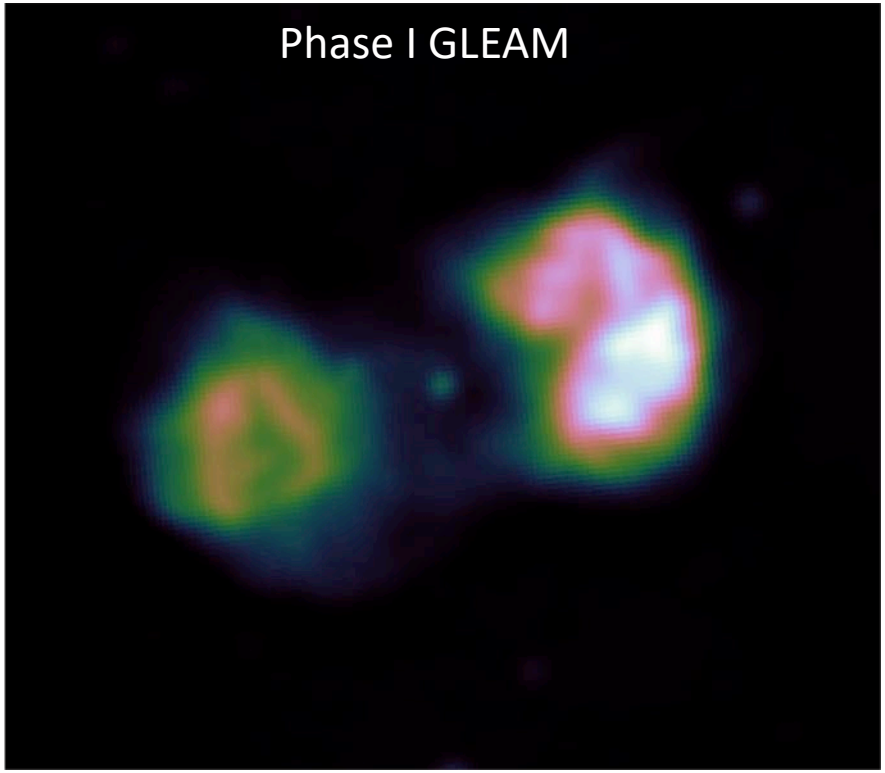
10 MHz MFS u,v coverage @ 150 MHz.

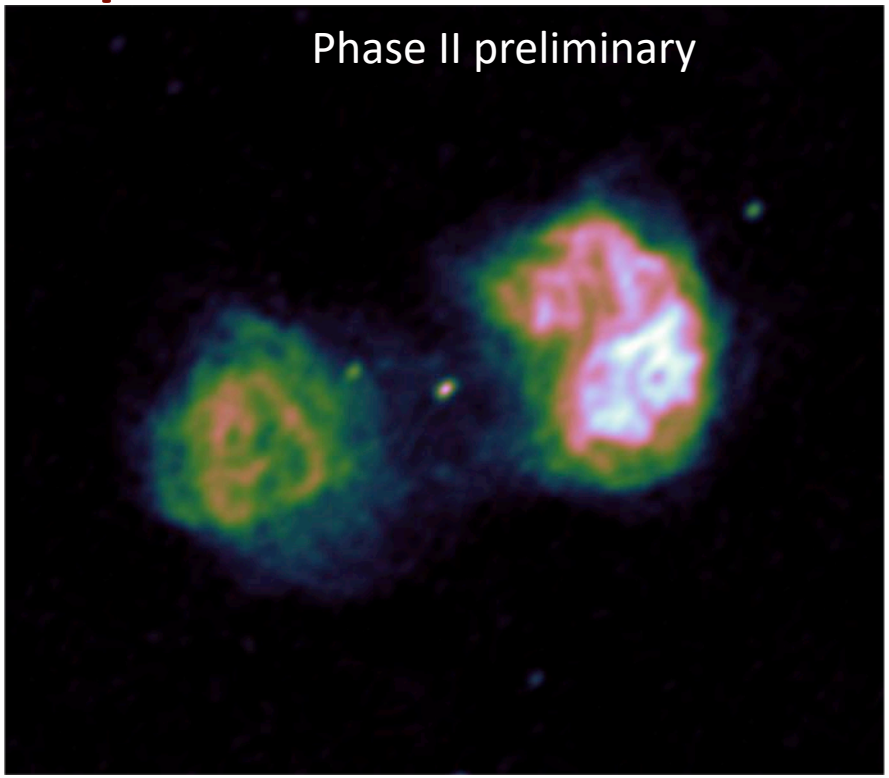




Randall Wayth

Phase II build expansion: complete





Ben McKinley

eRASS and MWA/ASKAP etc

Approved eROSITA-CAASTRO Science Project

Supernova remnants, superbubbles, and the global structure of the interstellar medium in the Magellanic Clouds:

- DE: **Sasaki**, Haberl, Kerp
- AU: Staveley-Smith, Filipovic, Koribalski
- Other: Kavanagh, Points

Investigate the relation of cold gas, hot gas and cosmic rays in MCs to investigate evolution of star-formation regions, superbubbles and SNRs and their impact on the evolution of the MCs.

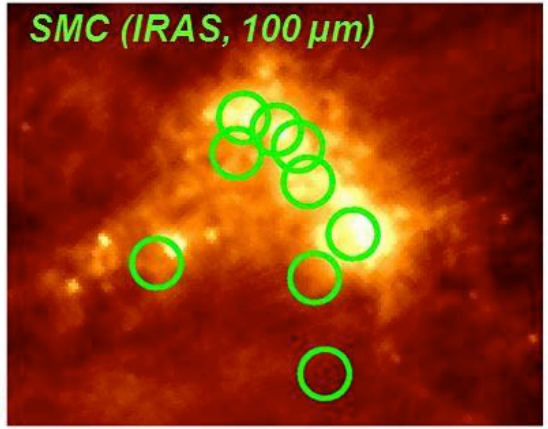
Magellanic Clouds

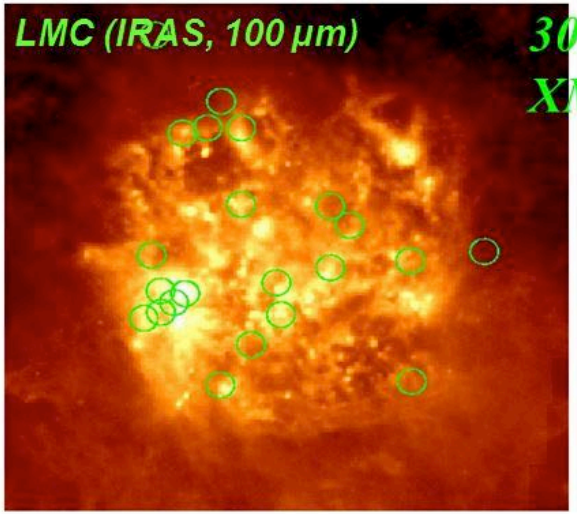
. High SFR/M_* $N_{HMXB} > N_{LMXB}$

. D=50-60 kpc

Sensitivity(XMM) $L_{Xmin} \sim 10^{33}$ erg/s

. Low metallicity

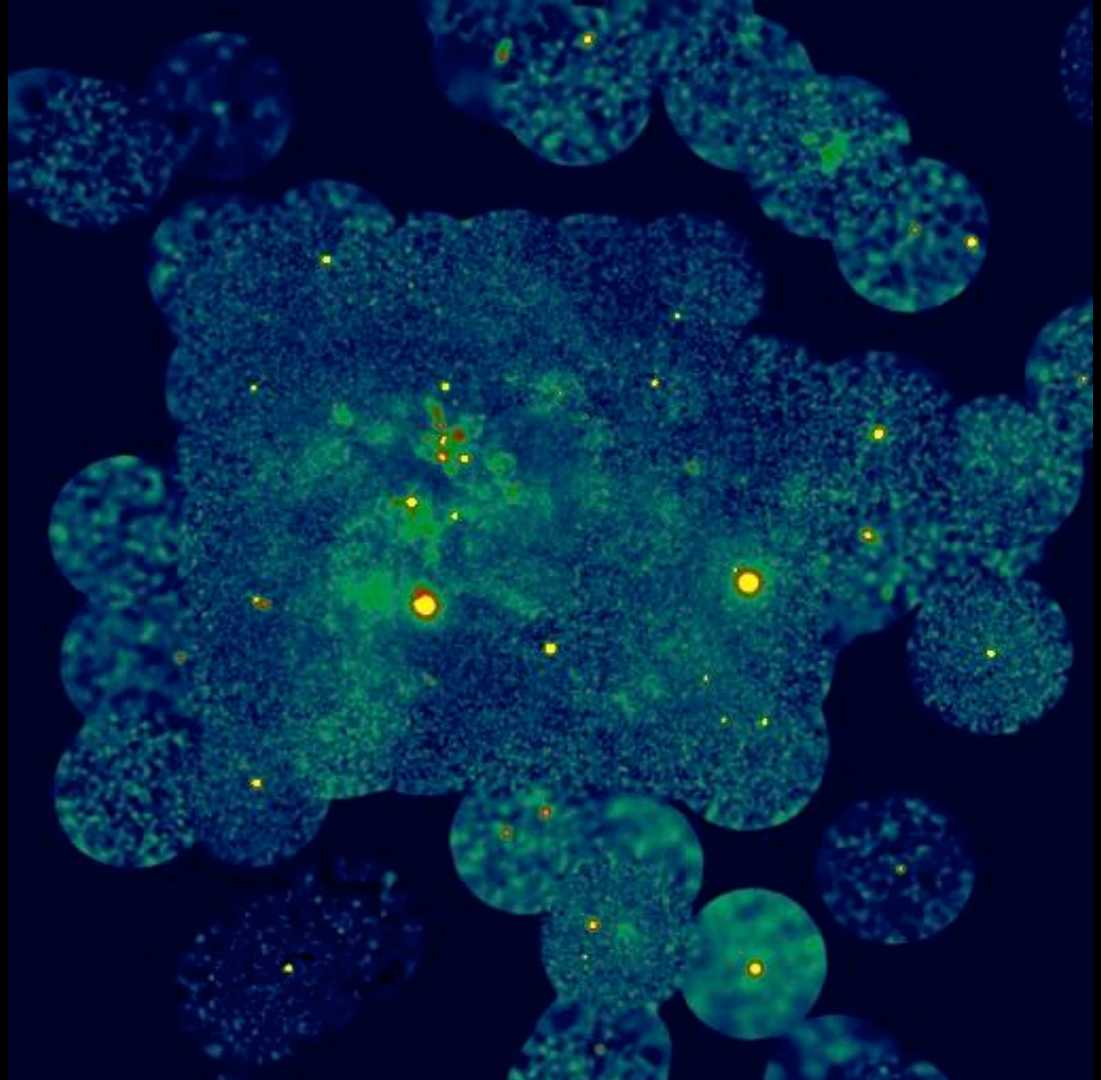




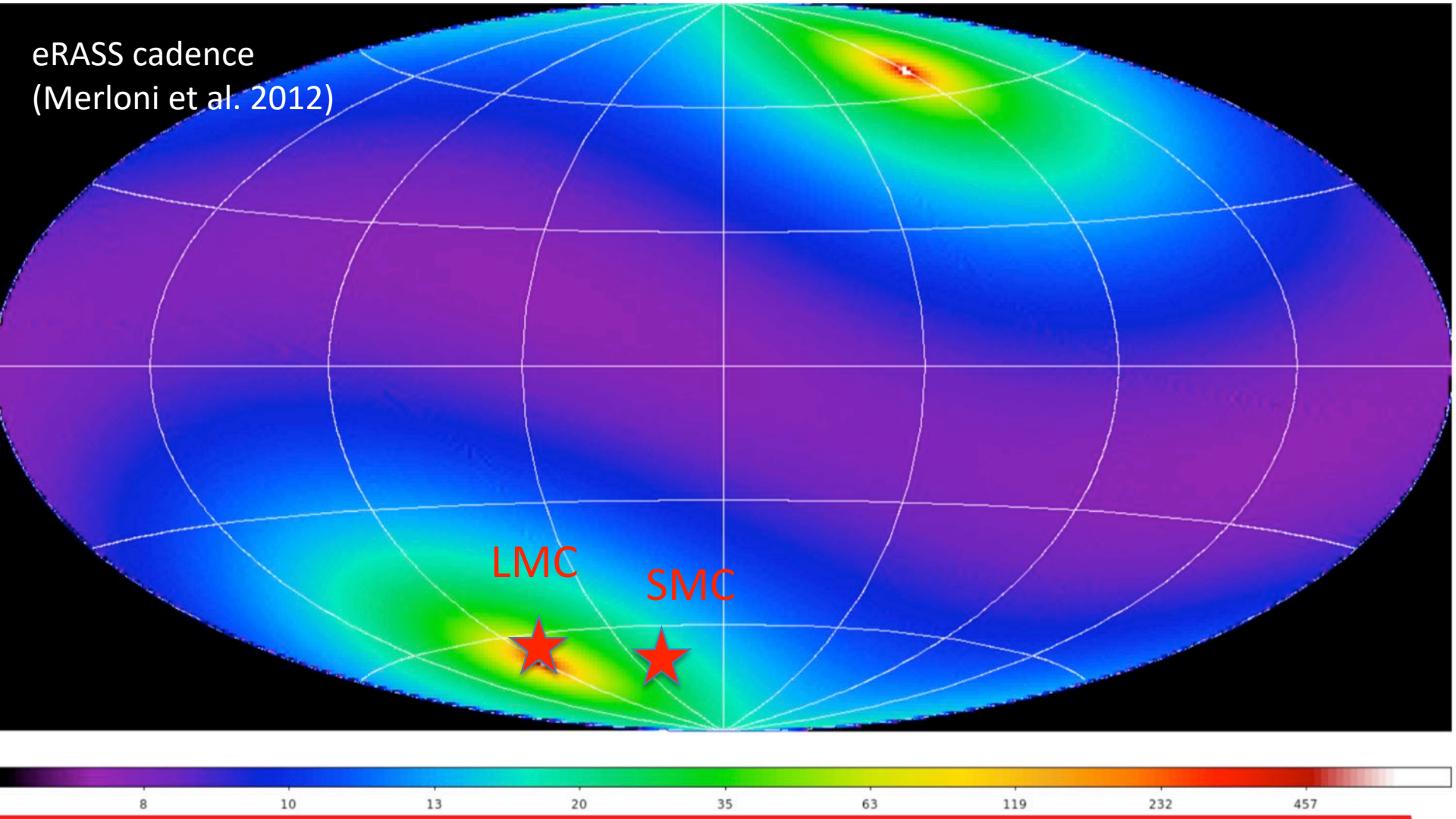
30 pointings

XMM-Newton

Shtykovskiy & Gilfanov (2005)



LMC: ROSAT-PSPC
Chu and Snowden (2001)


eRASS cadence
(Merloni et al. 2012)
LMC
SMC
8
10
13
20
35
63
119
232
457

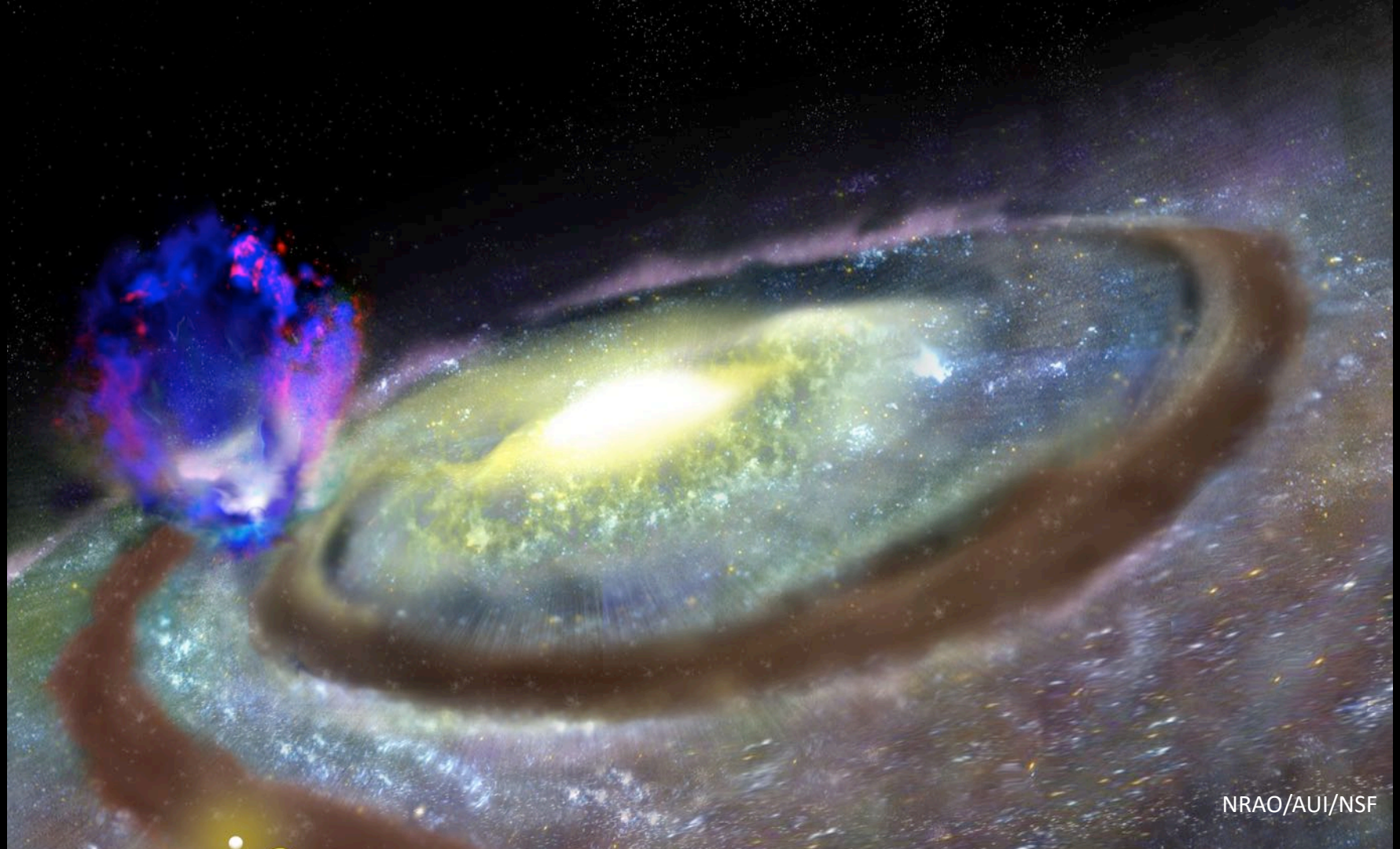
eRASS/radio science

Thermodynamics

- Gas pressure and energy density: hot gas, cool gas, CR, magnetic fields
- Momentum outflow
- Kinematics

Star formation

- Self-propagating star formation
- Supernova remnants
- Metallicity
- Galactic fountain



NRAO/AUI/NSF

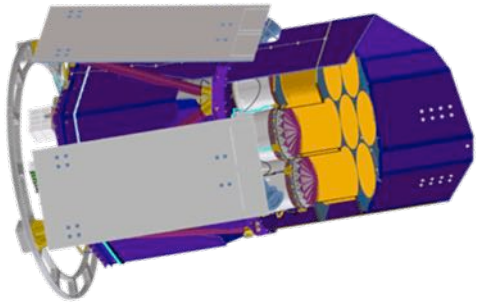
A hot Galactic halo?

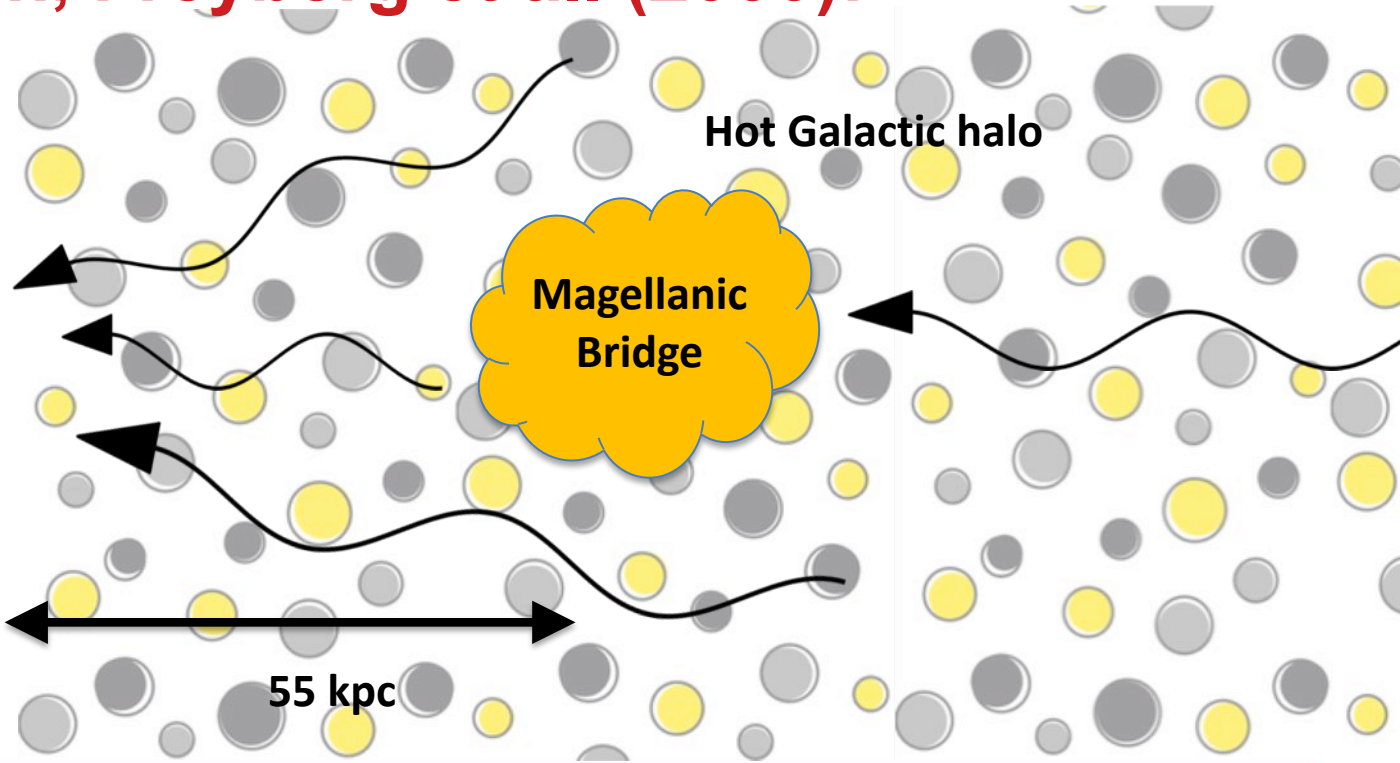
"The distribution, spacial extent, and mass of this warm-hot gas provide important constraints to models of galaxy formation and the accretion and feedback mechanisms" (Gupta et al. 2017)

Hot Milky Way halo	Gatuzz & Churazov (2017)	Gupta et al. (2017)
Column density	1.3×10^{19} cm^{-2}	2×10^{20} cm^{-2}
Mass	not constrained	$3 - 10\times10^{10}$ $M_{\odot}$
Size	not constrained	80 – 170 kpc

X-ray shadows

e.g. Snowden, Freyberg et al. (2000):

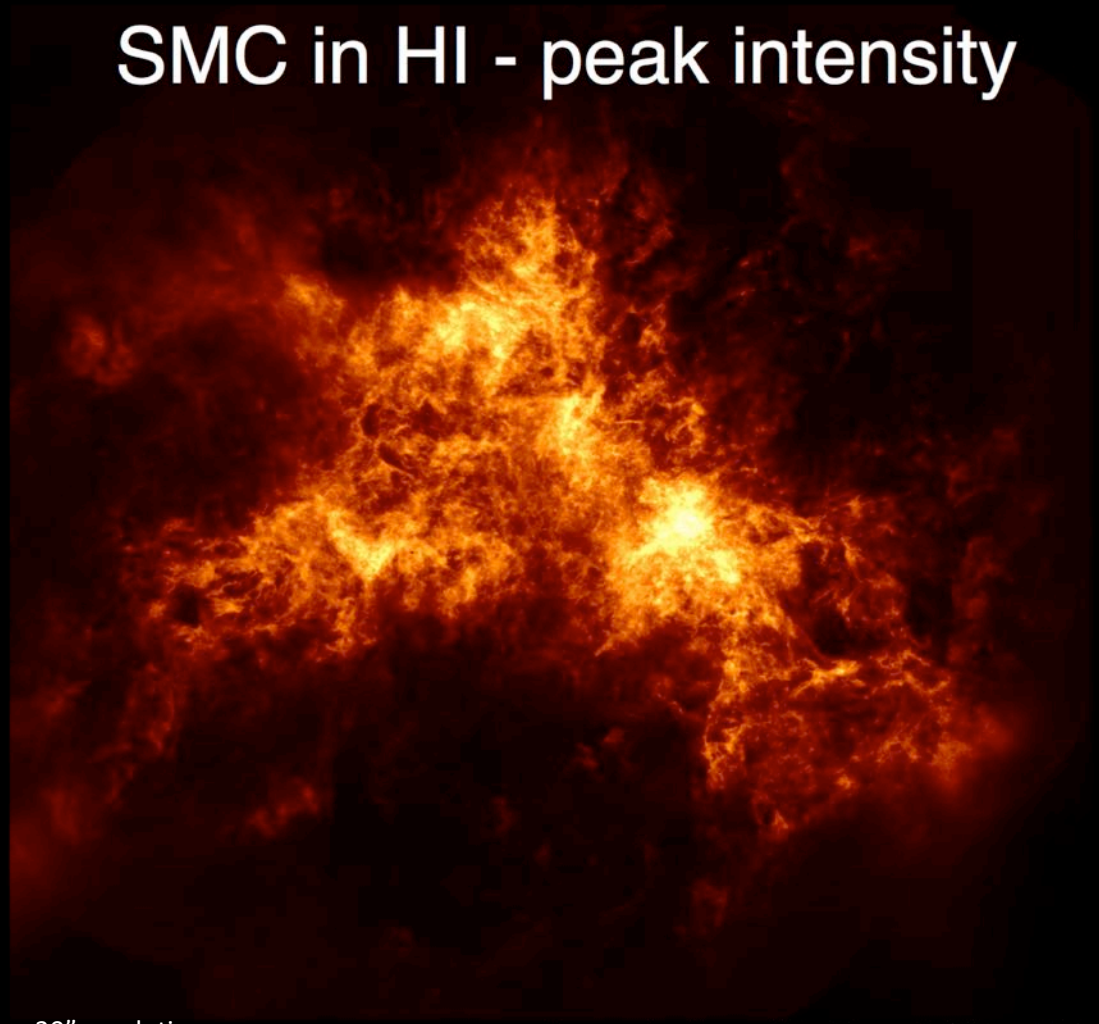




Forthcoming radio observations

- Initial MWA phase 2 observations (G0041) complete:
  - 127 hrs; Oct 7 – Nov 30, 2017
  - 1.5 arcmin resolution @ 200 MHz
- Galactic ASKAP project
  - SMC already observed in HI (McClure-Griffiths et al)
- ASKAP EMU project
  - Test LMC and SMC observations (Filipovic, Norris et al.)
- SKA-low potential:
  - 10 arcsec resolution at 200 MHz
  - Scan angle specification ± 45 deg makes LMC observations just possible at transit; SMC difficult

SMC in HI - peak intensity



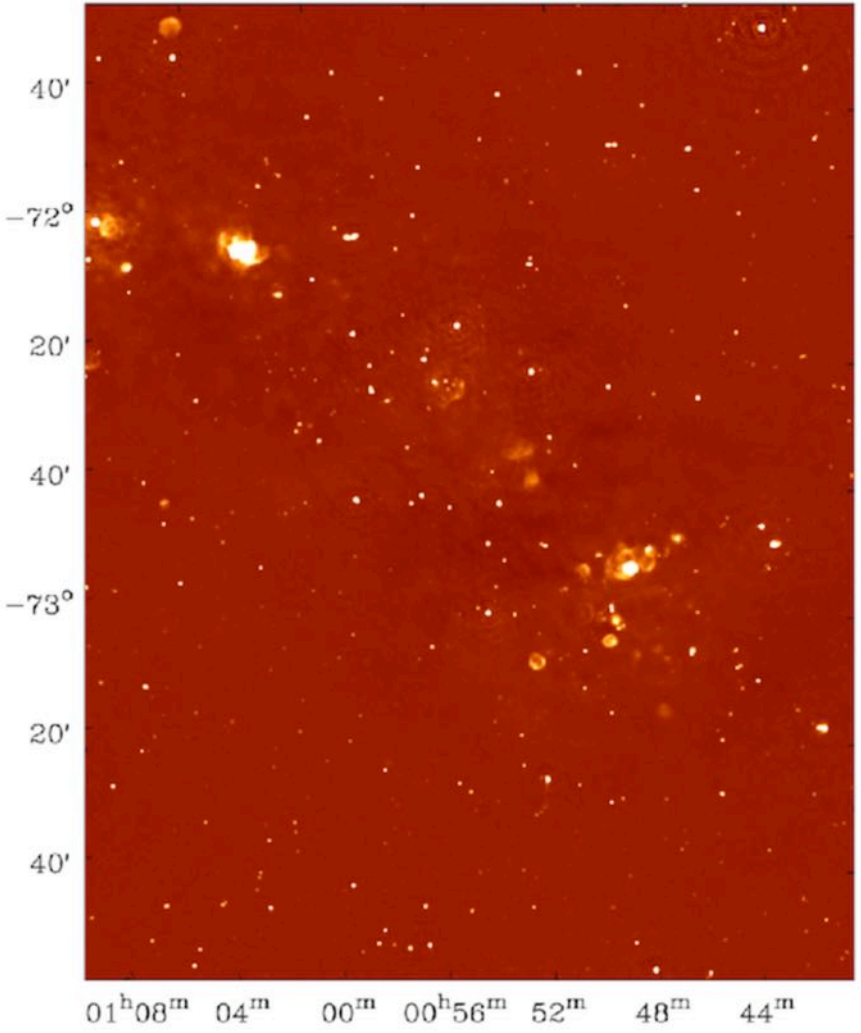
30” resolution

Image by Naomi McClure-Griffiths, Helga Denes

Forthcoming radio observations

- Initial MWA phase 2 observations (G0041) complete:
  - 127 hrs; Oct 7 – Nov 30, 2017
  - 1.5 arcmin resolution @ 200 MHz
- Galactic ASKAP project
  - SMC already observed in HI (McClure-Griffiths et al)
- ASKAP EMU project
  - Test LMC and SMC observations (Filipovic, Norris et al.)
- SKA-low potential:
  - 10 arcsec resolution at 200 MHz
  - Scan angle specification ± 45 deg makes LMC observations just possible at transit; SMC difficult

SMC at 1 GHz: ASKAP-12

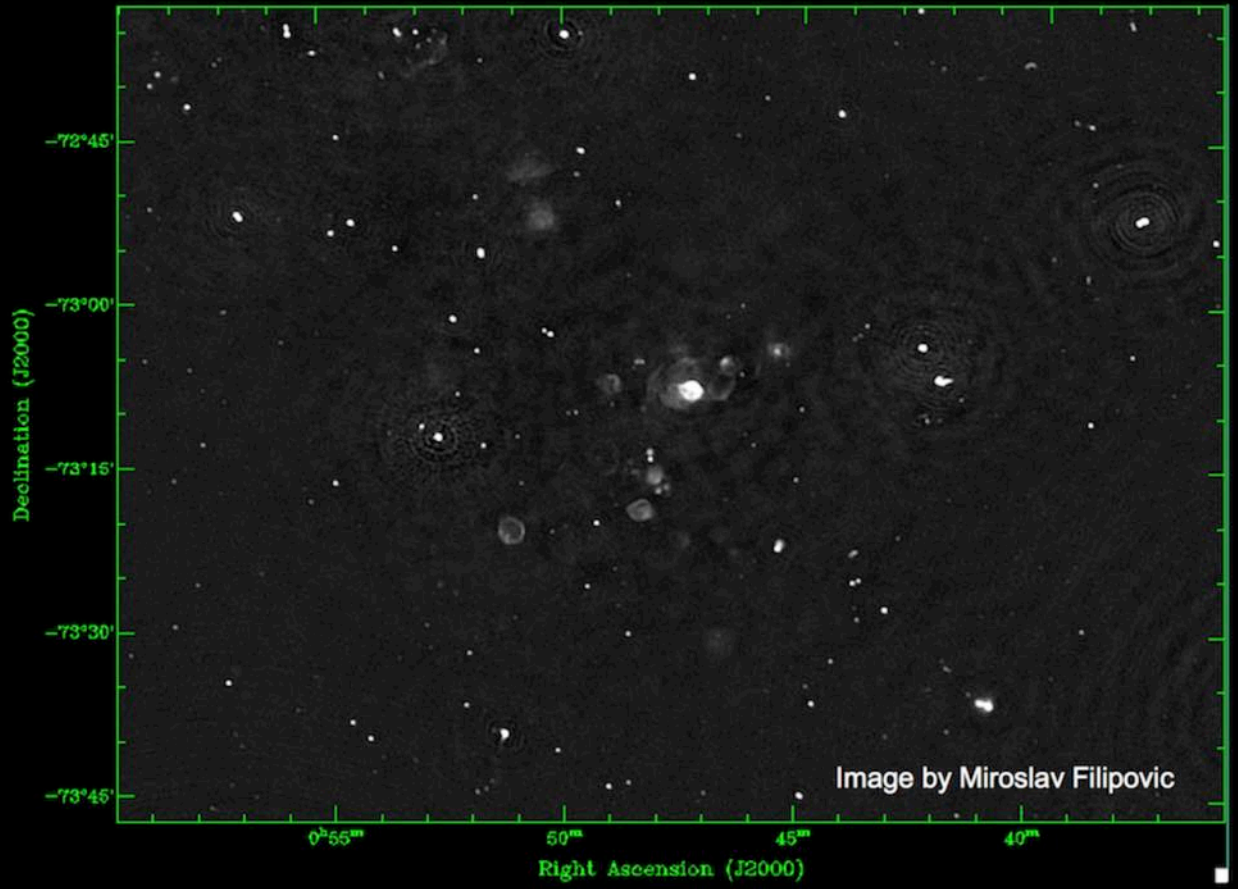


Obs duration was ~9 hours
Bandwidth 240MHz
Tsys/eff = 75K
Naturally weighted
Expect rms = 32uJy/bm.

Actual 50uJy/bm in the Stokes-V
60uJy/bm in the Stokes-I
Used robustness of -0.5

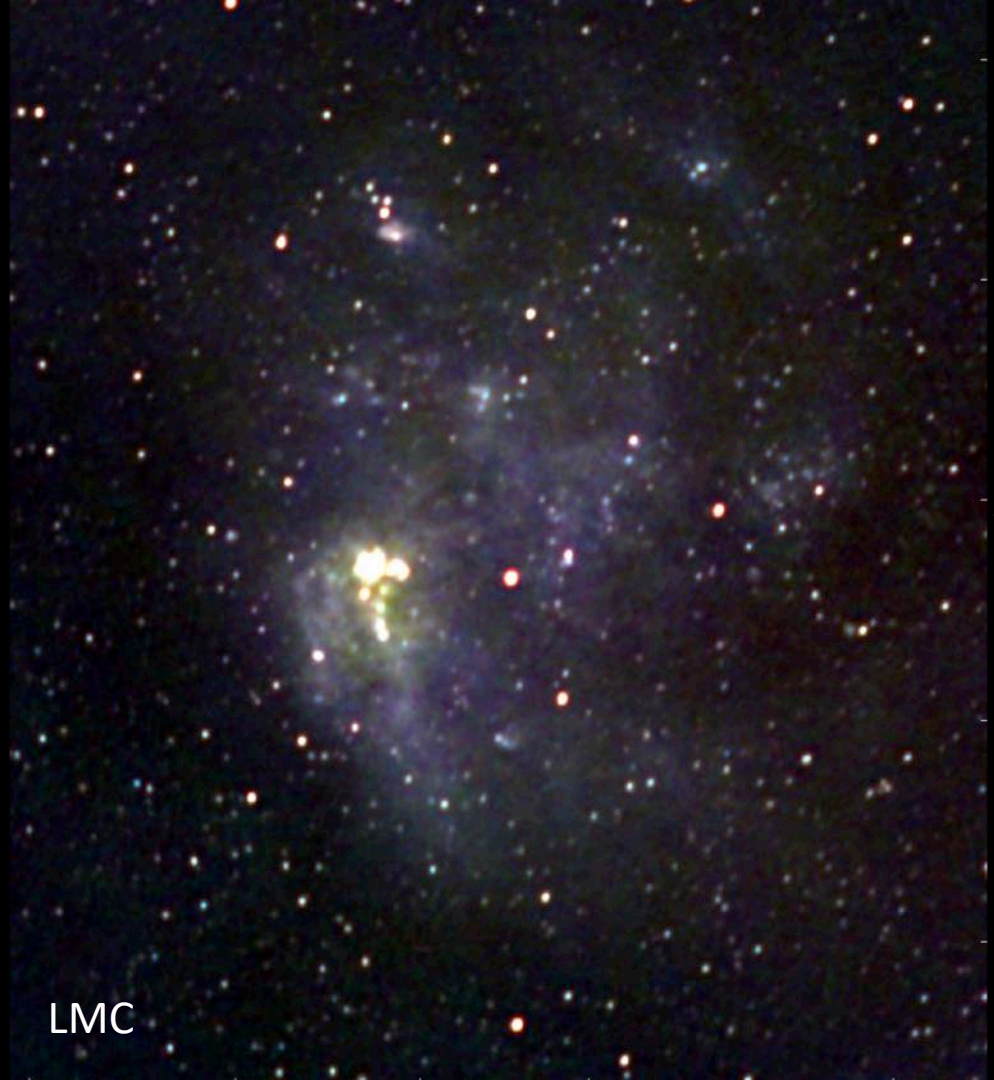
Image by Wasim Raja

Portion of the SMC (continuum)



Forthcoming radio observations

- Initial MWA phase 2 observations (G0041) complete:
  - 127 hrs; Oct 7 – Nov 30, 2017
  - 1.5 arcmin resolution @ 200 MHz
- Galactic ASKAP project
  - SMC already observed in HI (McClure-Griffiths et al)
- ASKAP EMU project
  - Test LMC and SMC observations (Filipovic, Norris et al.)
- SKA-low potential:
  - 10 arcsec resolution at 200 MHz
  - Scan angle specification ± 45 deg makes LMC observations just possible at transit; SMC difficult



123, 181, 227 MHz, three-colour images
(For et al.2017)