Long Wavelength Array

The Long Wavelength Array (LWA)

The Murchison Widefield Array (MWA)

Student Seminar 2018 Spring

MURCHISON WIDEFIELD ARRAY

Presented by FuHeng Liang 梁赋珩
Advisor: Professor Zhou, Jianfeng

OUTLINE

- Low-frequency radio astronomy
- Similarities in LWA & MWA
- LWA Science
- MWA Science
- Future

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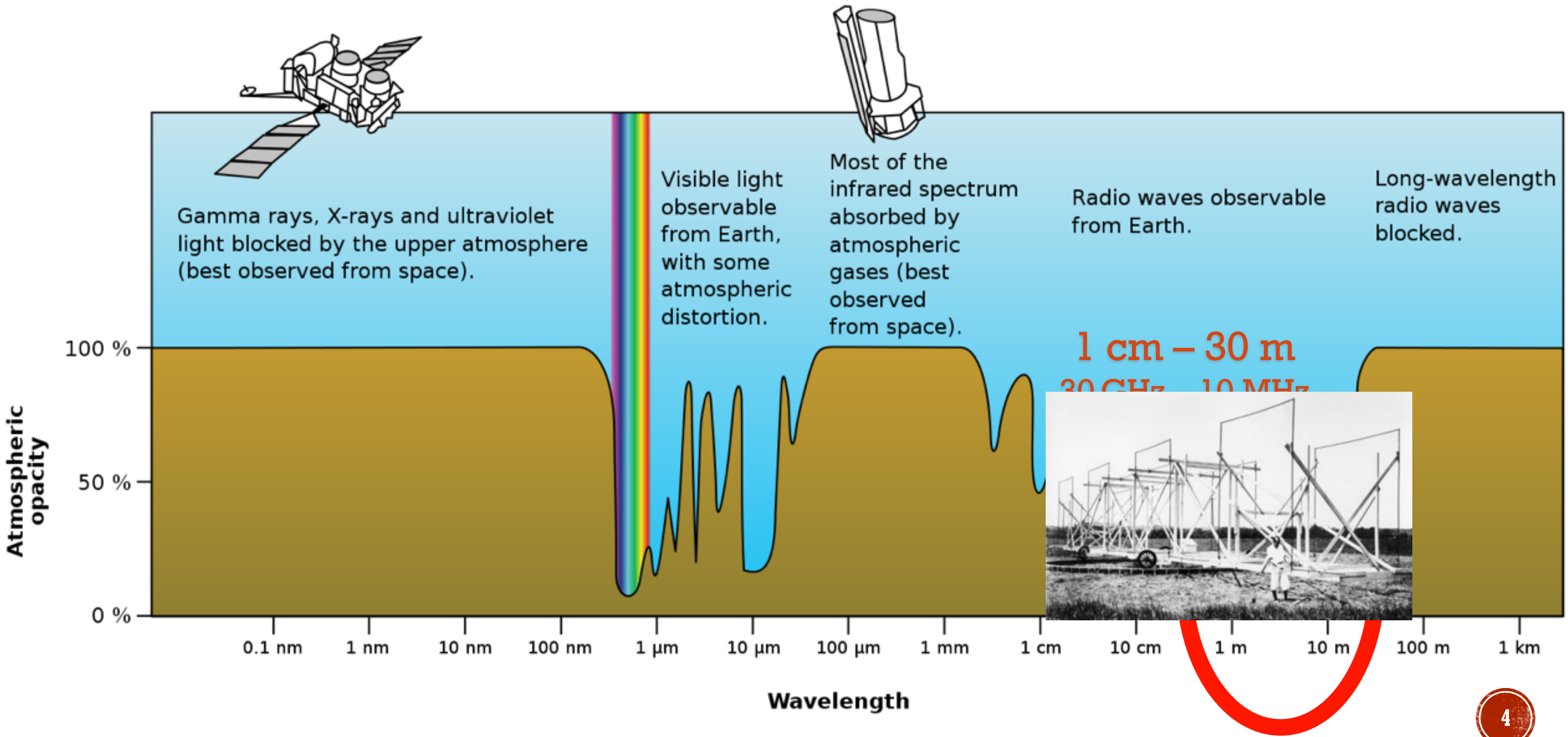
RADIO WINDOW



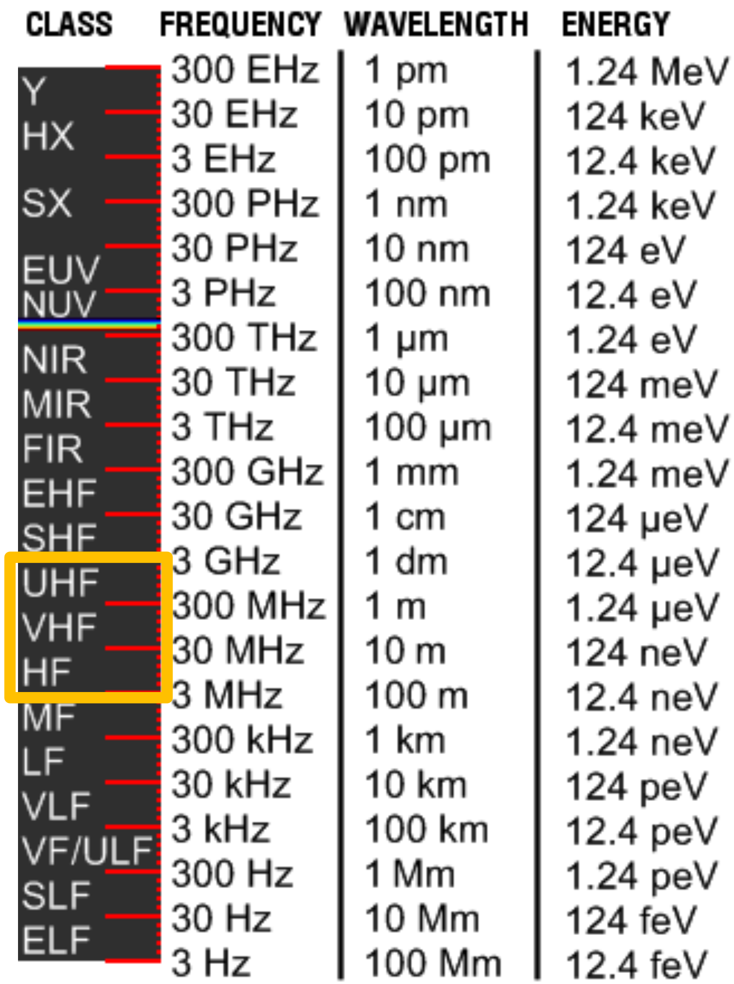
LOW-FREQUENCY RADIO WINDOW

Radio astronomy in engineering definition:

- HF (3 MHz – 30 MHz)
- VHF (30 MHz – 300 MHz)
- UHF (300 MHz – 3 GHz)

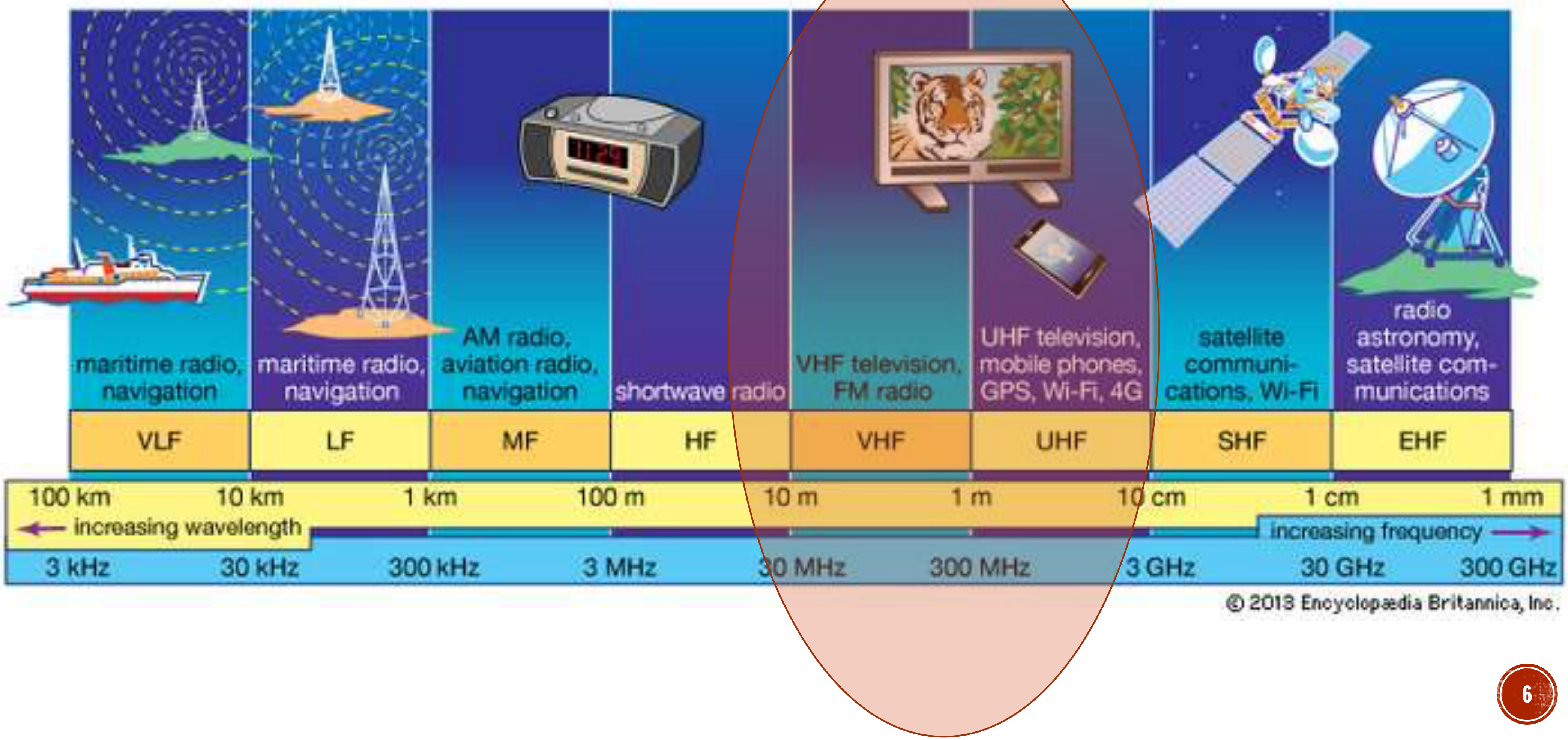
Low frequency:

- Typically ν < 400 MHz

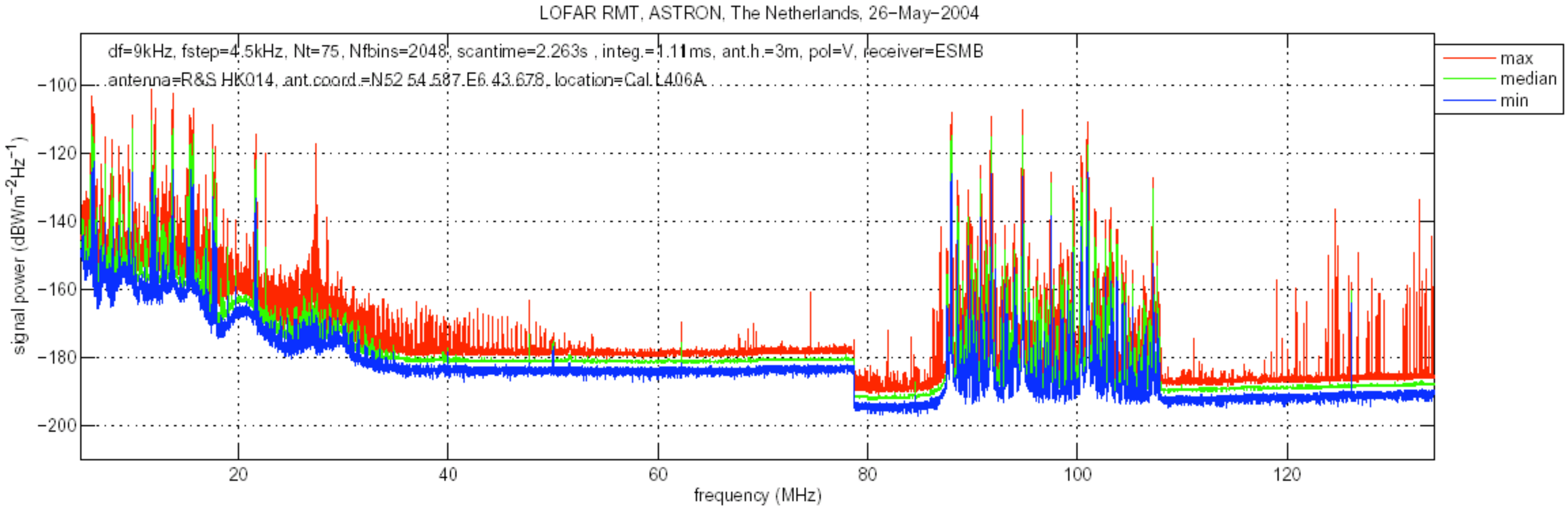


(From International Telecommunications Union & IEEE)

RADIO FREQUENCY IN ENGINEERING



RADIO FREQUENCY INTERFERENCE (RFI)



(M. Bentum & A.-J. Boonstra, 2011)

LOW-FREQUENCY SIGNAL

- Synchrotron Continuum

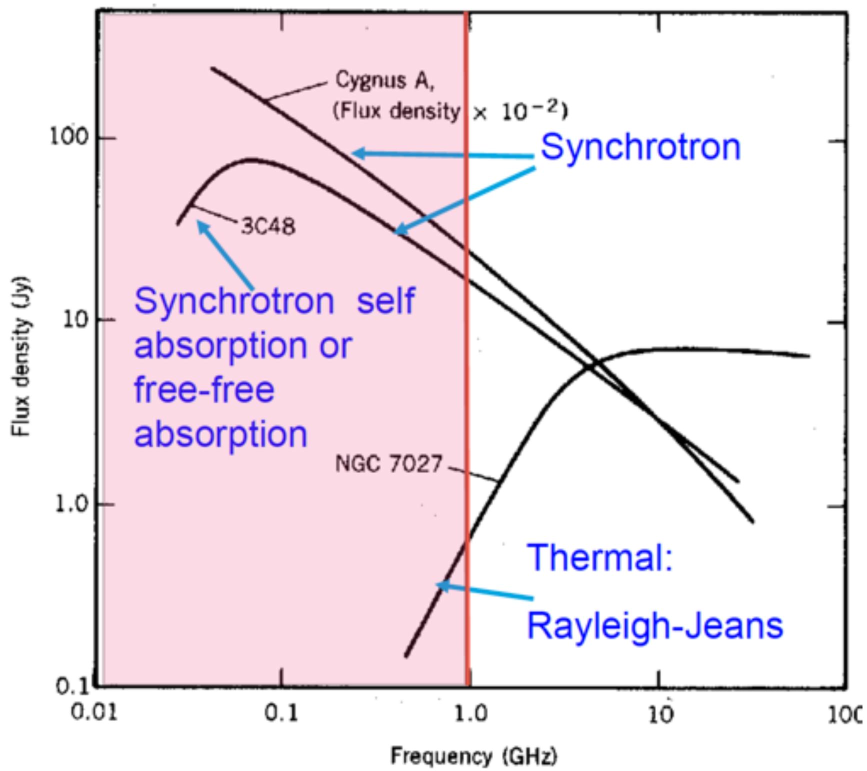
Best observed at ν < 1 GHz

- Redshifted Line

ν = 1420/(1+z) MHz (21 cm)

ν = 1665(7)/(1+z) MHz (OH (Mega) Maser)

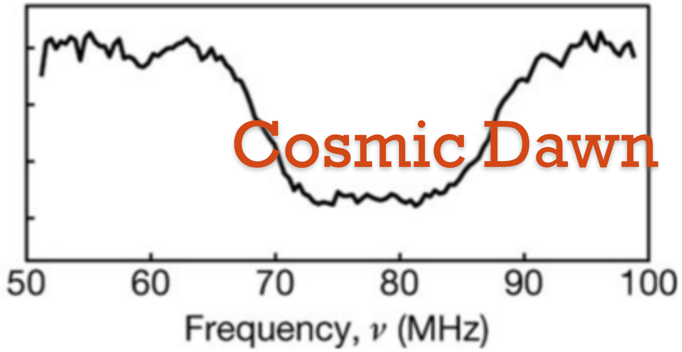
- Radio Recombination Lines



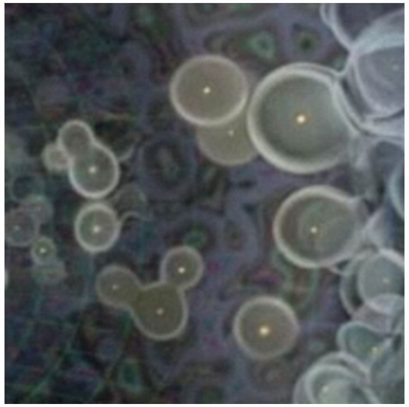
(Thompson, Moran, & Swenson)

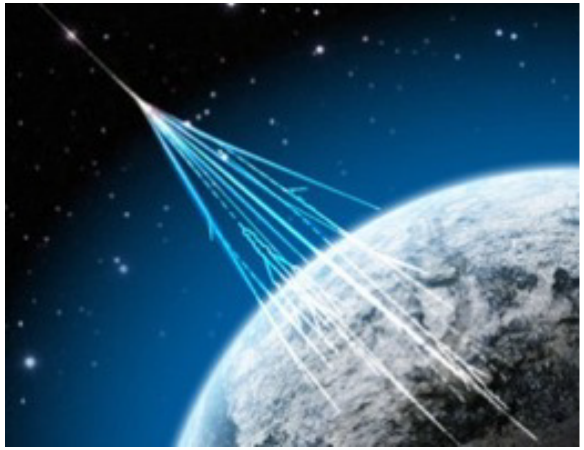
LOW-FREQUENCY SCIENCE

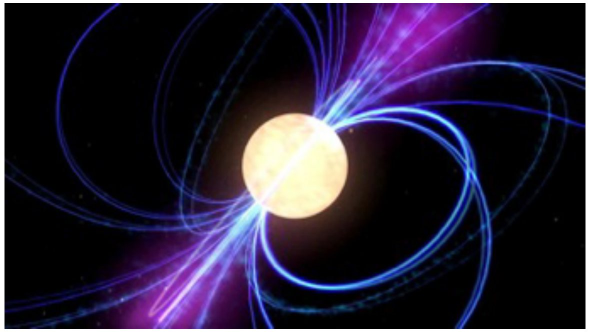
- Early universe
- Cosmic rays
- Transients



(Bowman et al. 2018)

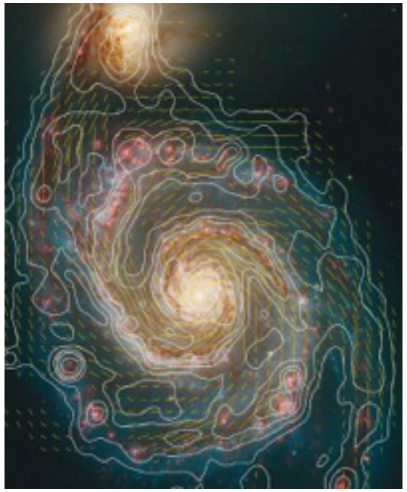


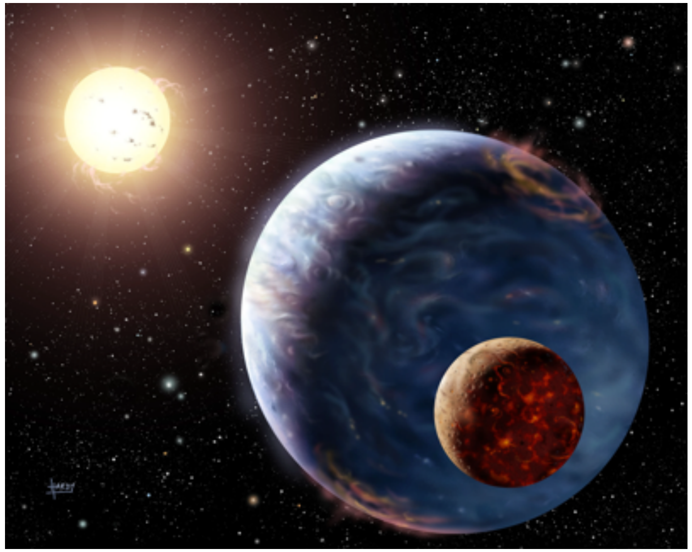


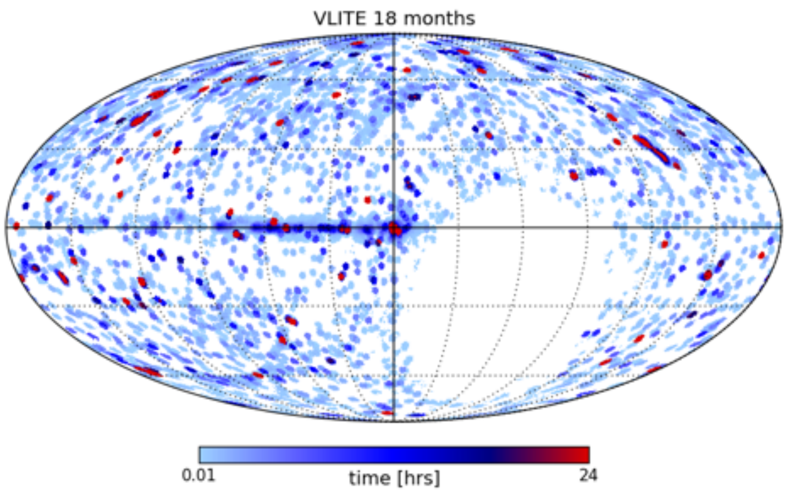


LOW-FREQUENCY SCIENCE

- Solar system
- Magnetic fields
- Population surveys
- Exoplanets







LOW-FREQUENCY FACILITIES

Instrument	Location	Telescope Type	Frequency Range (MHz)
DSL	Space (China-Europe)	Dipole array	0.1 - 50
LWA (LEDA, DAWN)	New Mexico, USA	Dipole array	10 - 88
LOFAR	The Netherlands	Dipole array	30 - 80, 120 - 240
DARE (future)	Space (USA)	Single dipole	40 - 120
SKA Low (future)	Western Australia	Dipole array	50 - 350
21CMA	Tianshan, China	Dipole array	50 - 200
JVLA	New Mexico, USA	Dish array	50 - 80, 74, 300 - 350, …
EDGES	Western Australia	Single dipole	50 - 200
MWA	Western Australia	Dipole array	80 - 300
HERA	South Africa	Dish array	100 - 200
PAPER	South Africa	Dipole array	110 - 180
GMRT	India	Dish array	150, 232, 325, …
WSRT	The Netherlands	Dish array	270 - 390, …

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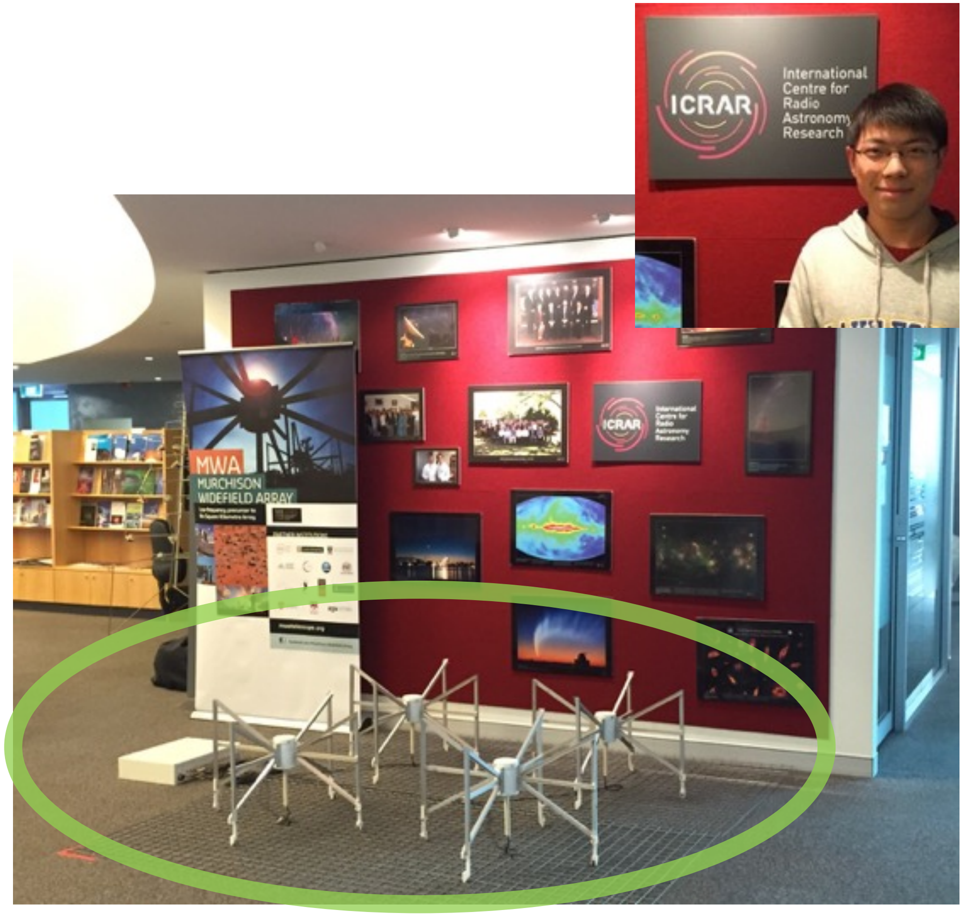
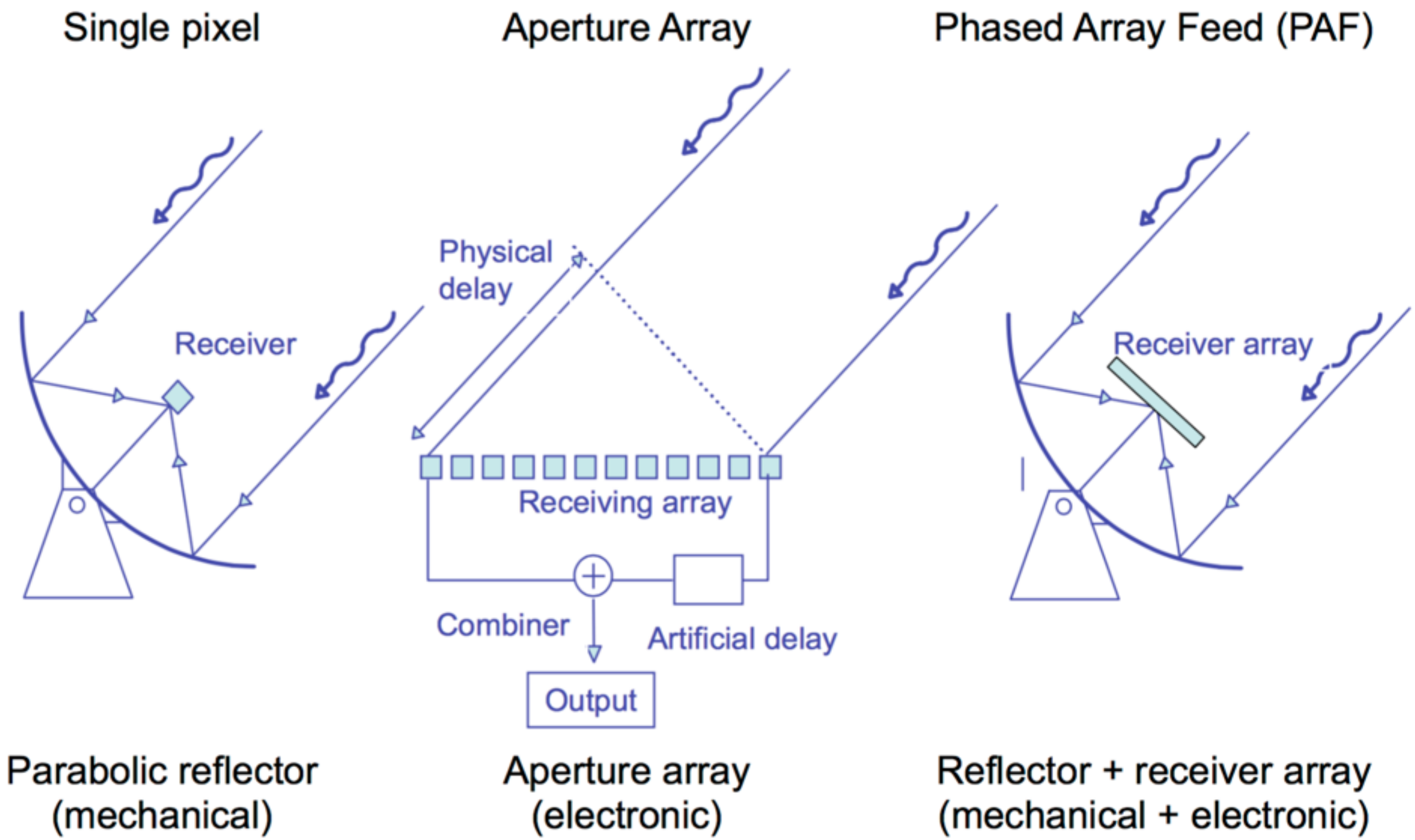
LWA & MWA DESIGN

LWA antenna

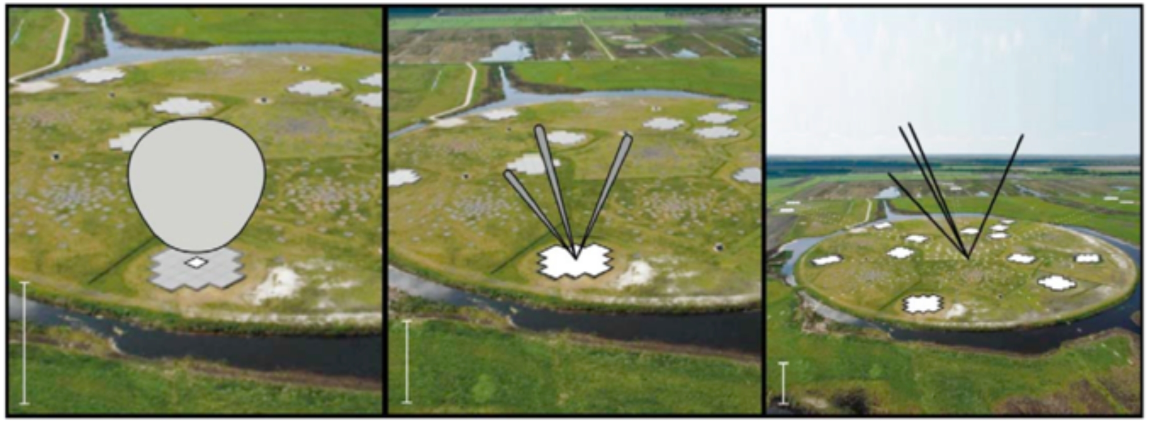


MWA antenna

VARYING TECHNOLOGIES (RECEIVERS)

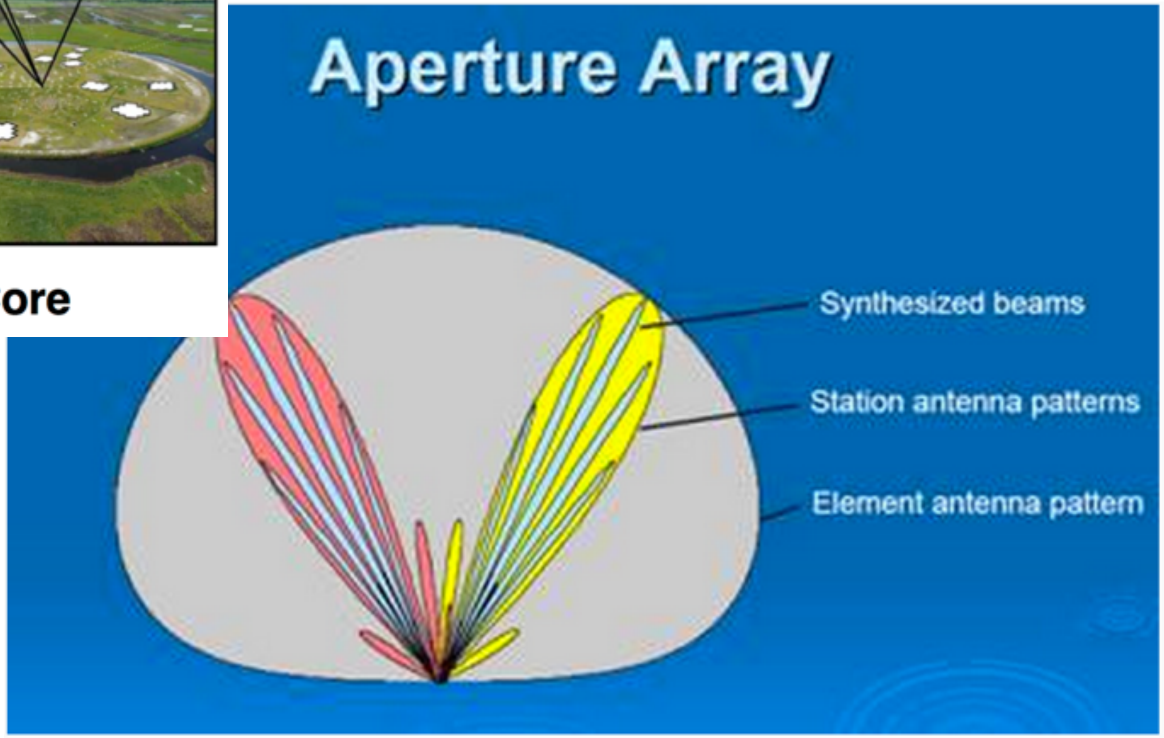


DIPOLE ARRAYS FOR LOW FREQUENCY



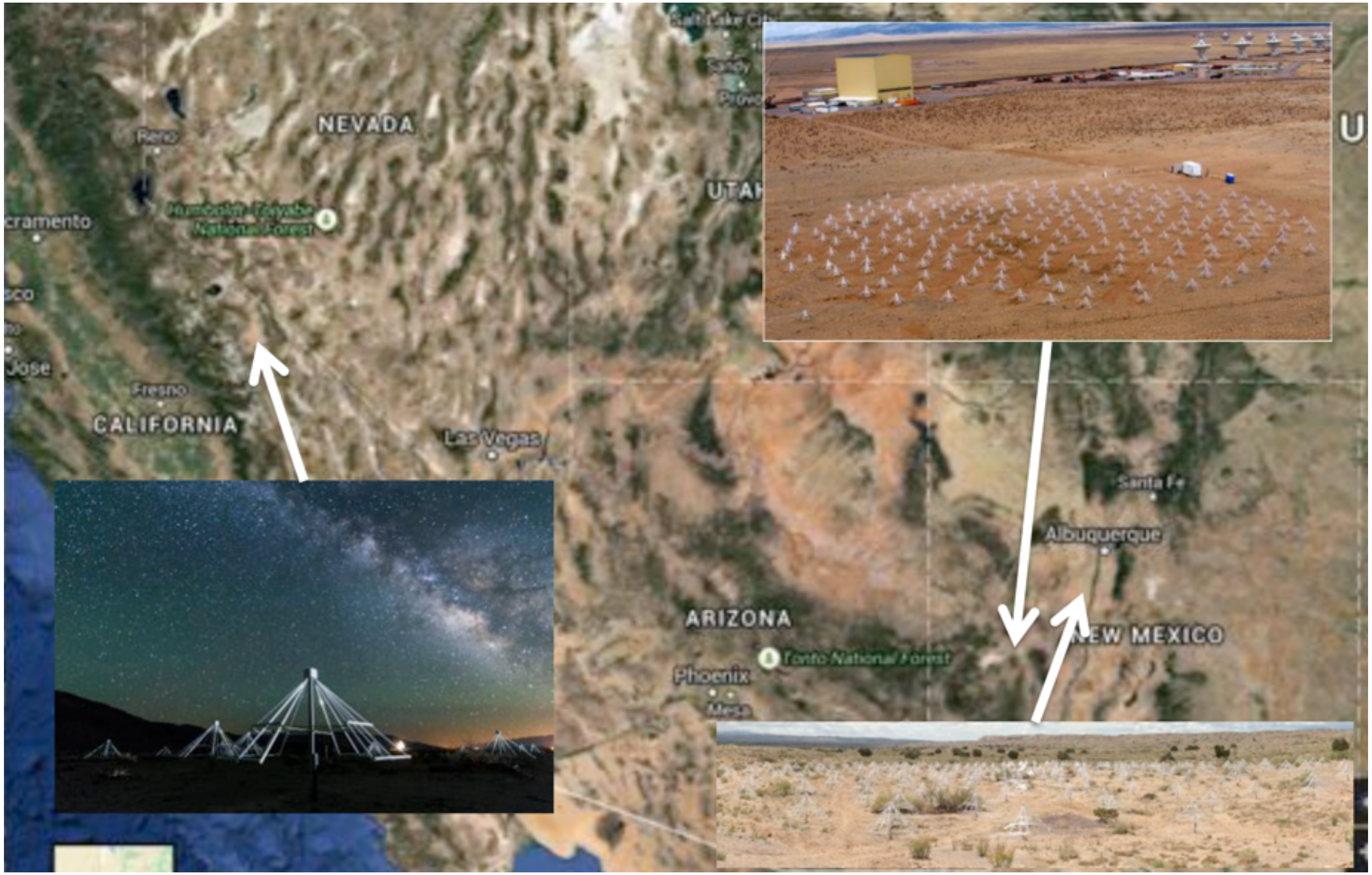
Tile Station Core

- A single dipole
- Station of dipoles
- Multiple stations combined



LWA STATION

LWA1



LWA-OVRO

LWA-SV

MWA STATION

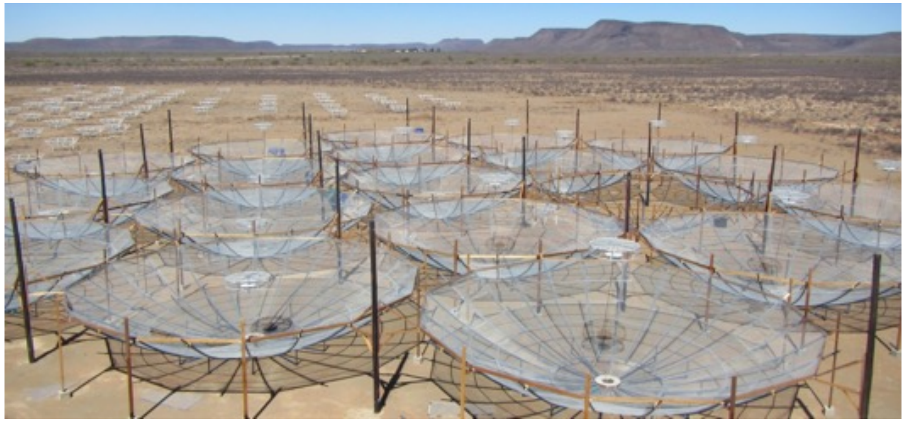

MWA
Murchison
Radio-astronomy
Observatory
Western
Australia
800km
Perth
Armadale
Rockingham
Mandurah
Bunbury
Busselton
Albany

LWA & MWA CONSTRUCTION

	LWA1	MWA I
Time	Since 2011	Since 2013
Cost	> $ 3.5M	$ 50M
Number of antennas	256	4 x 4 x 128
Station size	100 m x 110 m ellipse	Baseline up to 3km
Field of view	3 – 10 deg	15 - 50 deg
Spatial resolution	3.2 deg	1 arcmin
Spectral resolution	6 kHz	10 kHz
Time resolution	10 ms	100 μs
Collecting area	1500 - 5600 m^2	2000 m^2
Sensitivity	8 Jy (5σ) 1s, 16 MHz	10 mJy, 800s, 150 MHz (Δ=1 MHz)

SKA PRECURSORS AND PATHFINDERS

- Australian SKA Pathfinder (ASKAP)
- MeerKAT (South Africa)
- MWA
- LWA
- Hydrogen Epoch of Reionization (HERA)*
- …



* DeBoer, David R., et al. "Hydrogen epoch of reionization array (HERA)." *Publications of the Astronomical Society of the Pacific* 129.974 (2017): 045001.
* https://www.skatelescope.org/news/hera-ska-precursor/

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LWA SCIENCE DISCOVERY

- The Sun
- Ionospheric research and space weather
- Jupiter
- Meteors
- Pulsars

LWA SCIENCE DISCOVERY

Matching Game

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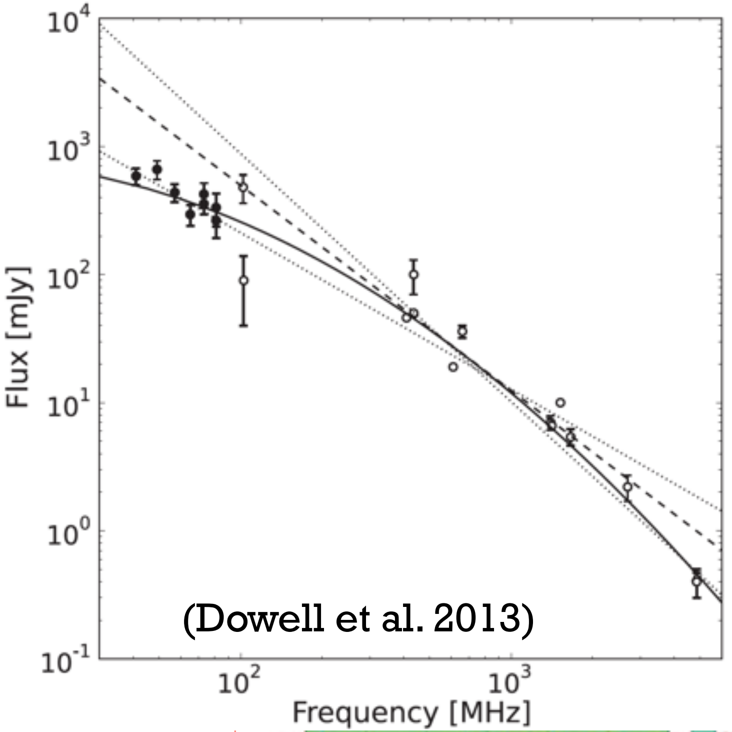
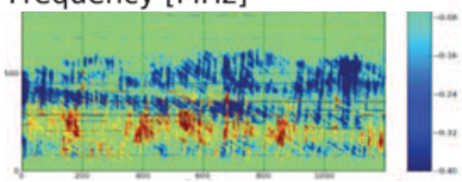
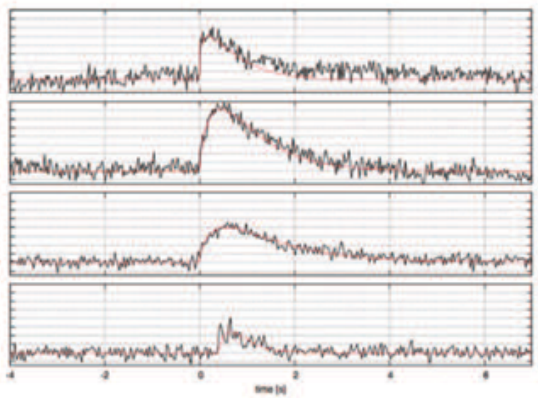
trans

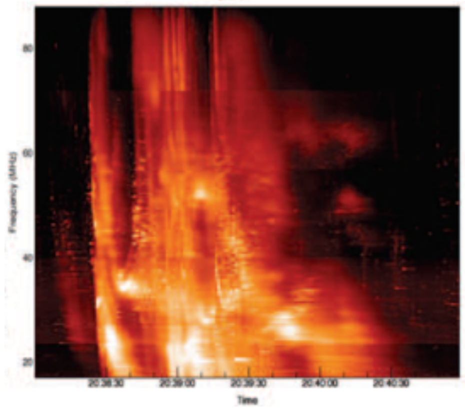
Light t
transients

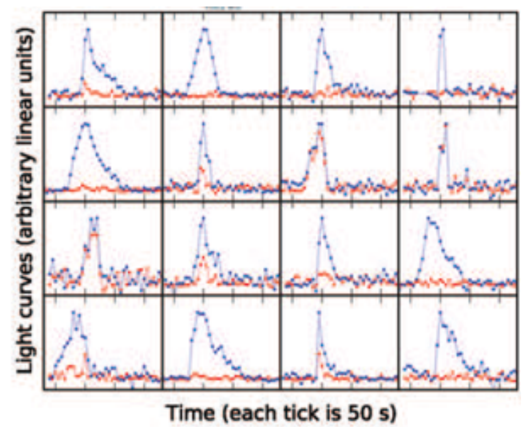
Stokes V
spectrogram of
a Jupiter burst

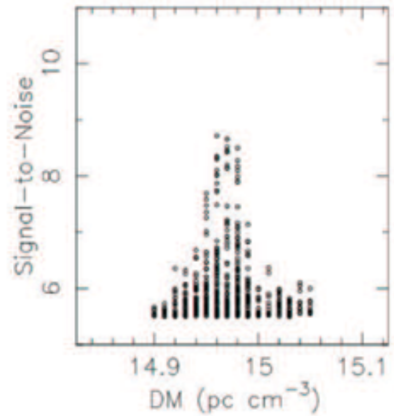












(All 6 panels from G. B. Taylor 2014)

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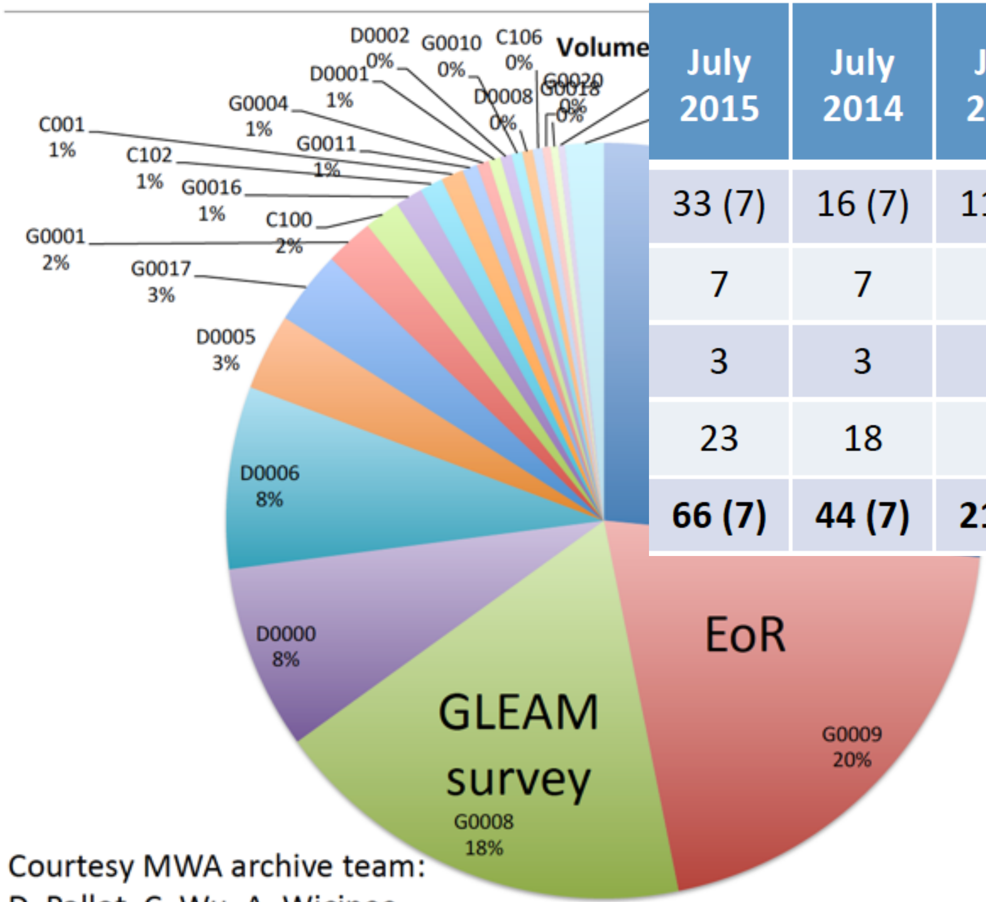
MWA SCIENCE DISCOVERY

Archive volume breakdown



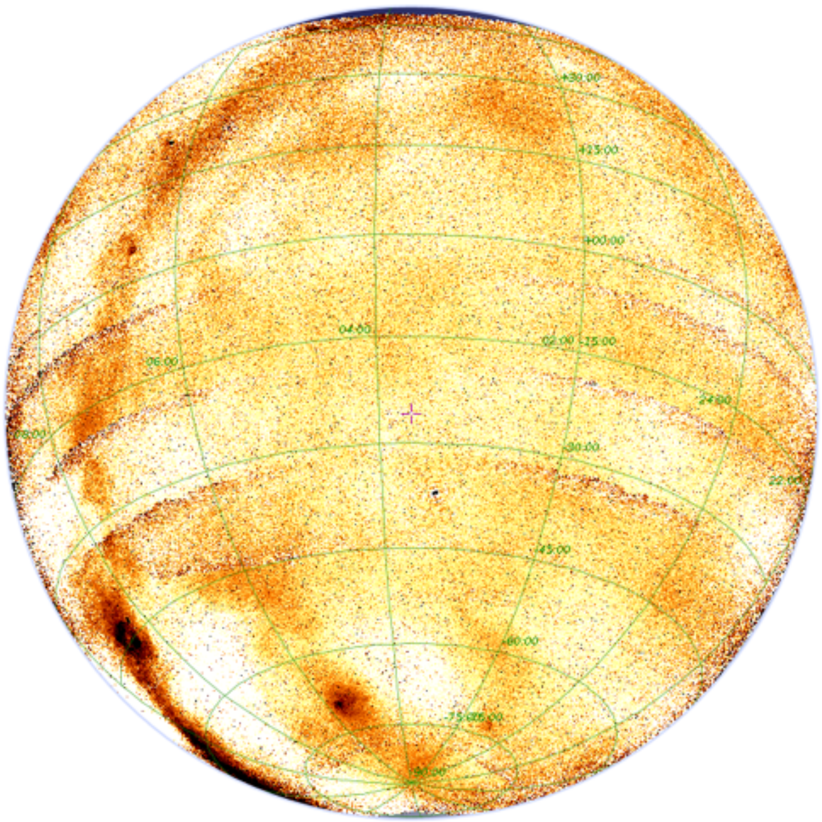
July 2015	July 2014	July 2013	July 2012	Stage
33 (7)	16 (7)	11 (3)	2 (1)	Accepted/published by journals (conferences)
7	7	2	2	Submitted to journals
3	3	3	6	Drafts posted for collaboration review
23	18	5	3	Proposals posted for collaboration review
66 (7)	**44 (7)**	**21 (3)**	**13 (1)**	**TOTAL** (@20151104)

Courtesy MWA archive team:
D. Pallot, C. Wu, A. Wicinec

GALACTIC AND EXTRAGALACTIC ALL-SKY MWA SURVEY (GLEAM)

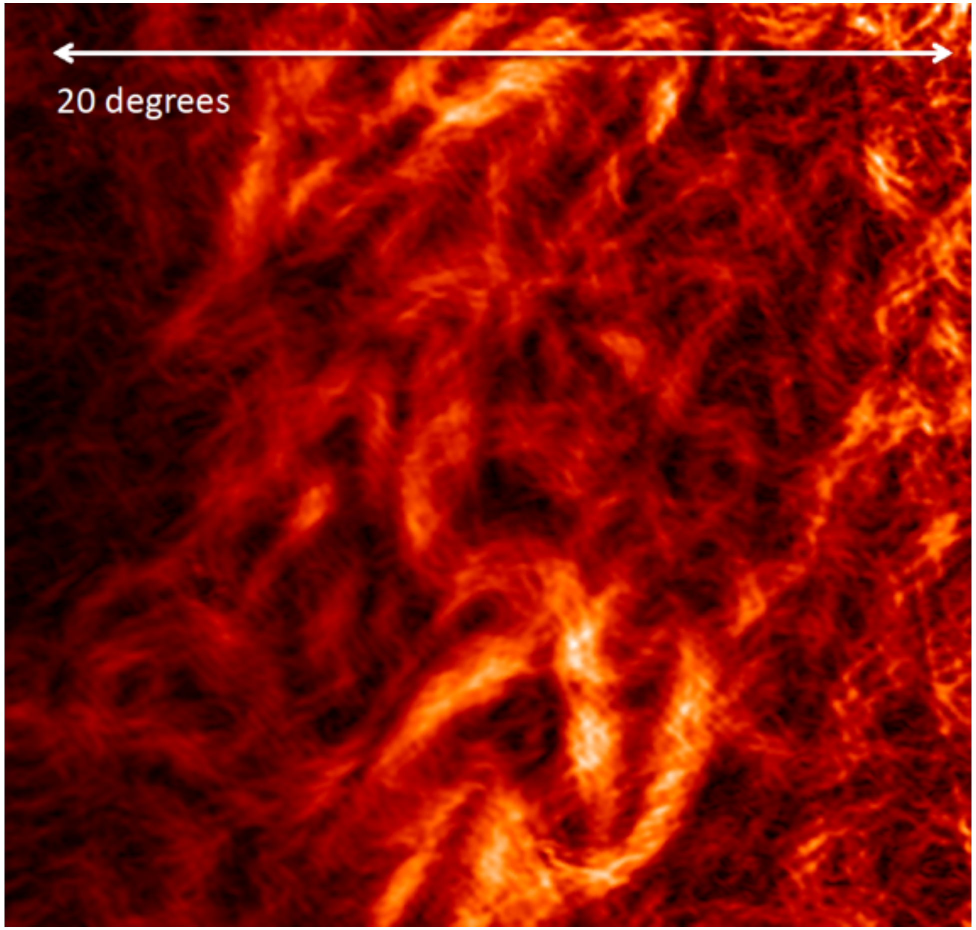
300,000+ sources
19 freq sub-bands
$\delta<+25$
$|b| > 10$

GLEAM



MWA SCIENCE

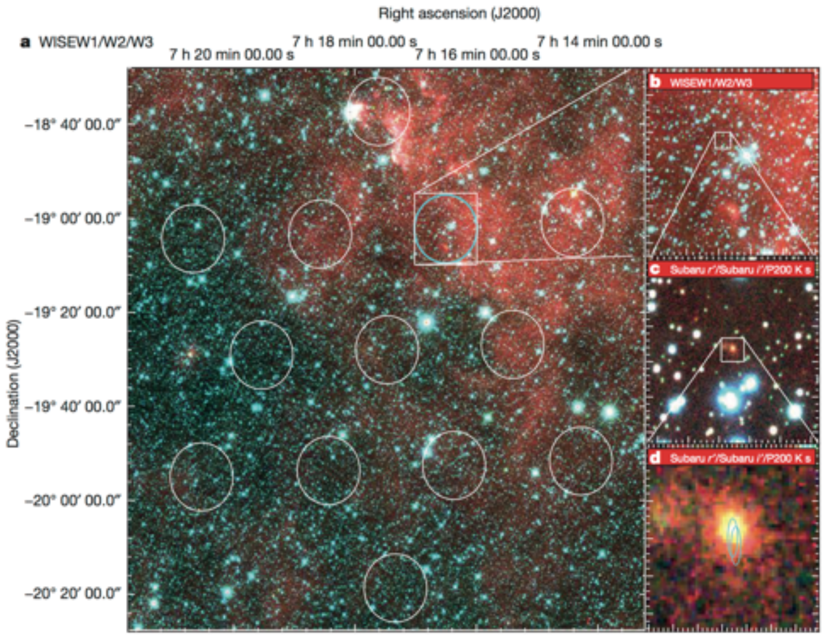
- Linear polarisation gradient maps
- Turbulence in the local ISM
- Important foreground for EoR experiments

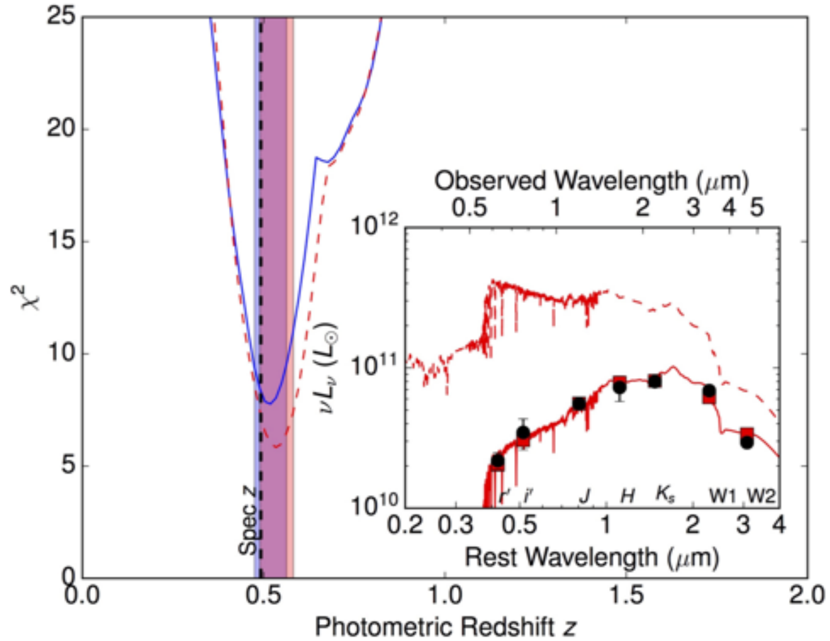


(Emil Lenc et al. 2016)

A FAST RADIO BURST HOST GALAXY

(E. F. Keane et al.2016)





FRB Location → Host Galaxy Redshift

FRB Dispersion → $\Omega_{\mathrm{IGM}} = 4.9 \pm 1.3\%$

MWA CONTRIBUTION

The MWA[34] was shadowing our Parkes observations but did not detect a counterpart. The resulting $3-\sigma$ fluence upper limit of 1050 Jy ms at 185 MHz gives us the first simultaneous multi-frequency observation of an FRB, and hence the first broadband limit on the spectral index. The spectral index limit from the Parkes and MWA data combined is $\alpha > -3.0$. Properties of the FRB are summarised below in Table 1.

Time (UTC)	Telescope	Band	Tobs (s)	Mode	Level/limit
2015-04-18-04:21:15	Parkes	1.4 GHz	561	TD*	2.2 Jy
Shadowing	MWA	185 MHz	27000	TD	< 1050 Jy ms
2015-04-18-04:31:08	Parkes	1.4 GHz	465	TD	$< 0.17(W/0.9\ \text{ms})^{-0.5}$ Jy
2015-04-18-05:04:35	Parkes	1.4 GHz	1181	TD	$< 0.17(W/0.9\ \text{ms})^{-0.5}$ Jy
2015-04-18-06:30:15	ATCA	5.5,7.5 GHz	19800	RI*	0.27(5) mJy/beam, 0.18(3) mJy/beam
2015-04-18-07:46:27	Parkes	1.4 GHz	3618	TD	$< 0.17(W/0.9\ \text{ms})^{-0.5}$ Jy
2015-04-18-08:47:28	Parkes	1.4 GHz	3618	TD	$< 0.17(W/0.9\ \text{ms})^{-0.5}$ Jy
2015-04-18-09:48:09	Parkes	1.4 GHz	3617	TD	$< 0.17(W/0.9\ \text{ms})^{-0.5}$ Jy
2015-04-18-10:48:59	Parkes	1.4 GHz	3617	TD	$< 0.17(W/0.9\ \text{ms})^{-0.5}$ Jy
2015-04-18-11:49:37	Parkes	1.4 GHz	758	TD	$< 0.17(W/0.9\ \text{ms})^{-0.5}$ Jy
2015-04-18-12:20:57	*Swift*	X-ray	3976	PC	$< 7.1 \times 10^{-14}$ erg/cm^2/s
2015-04-18-14:22:52	Lovell	1.4 GHz	7200	TD	$< 0.11(W/0.9\ \text{ms})^{-0.5}$ Jy
2015-04-19-06:06:19	Subaru	i'	600	Ph*	22.06(31) mag (AB)
2015-04-19-06:37:12	Subaru	r'	900	Ph*	23.33(16) mag (AB)
2015-04-20-05:50:27	Subaru	i'	1200	Ph*	22.08(31) mag (AB)
2015-04-20-06:30:53	Subaru	r'	1200	Ph*	23.59(16) mag (AB)
2015-04-20-15:49:09	Effelsberg	1.4 GHz	8300	TD	$< 0.11(W/0.9\ \text{ms})^{-0.5}$ Jy
2015-04-21-06:40:42	Parkes	1.4 GHz	3600	TD	$< 0.17(W/0.9\ \text{ms})^{-0.5}$ Jy
2015-04-21-17:21:40	SRT	1.4 GHz	3600	TD	$< 0.61(W/0.9\ \text{ms})^{-0.5}$ Jy
2015-04-24-02:44:15	ATCA	5.5,7.5 GHz	72900	RI*	0.23(2) mJy/beam, < 0.08 mJy/beam
2015-04-26-01:45:05	ATCA	5.5,7.5 GHz	74700	RI*	0.09(2) mJy/beam, < 0.08 mJy/beam
2015-05-07-03:18:42	*Swift*	X-ray	2908	PC	$< 9.3 \times 10^{-14}$ erg/cm^2/s
2015-05-18-12:30:00	GMRT	0.61 GHz	7200	RI	< 0.35 mJy/beam
2015-05-22-12:42:00	GMRT	1.4 GHz	7140	RI	< 0.15 mJy/beam
2015-06-04-21:12:15	ATCA	5.5,7.5 GHz	26700	RI*	0.11(2) mJy/beam, < 0.09 mJy/beam
2015-10-15-05:32:23	Lovell	1.4 GHz	7200	TD	$< 0.14(W/0.9\ \text{ms})^{1/2}$ Jy ms
2015-10-21-00:14:15	Keck	OIR	3600	Sp*	see Subaru observation
2015-10-27-14:09:35	ATCA	5.5,7.5 GHz	30600	RI*	0.09(2) mJy/beam, < 0.07 mJy/beam
2015-10-31-11:15:54	P200	J	1080	Ph*	18.92(10) mag (Vega)

LWA & MWA SCIENCE

Multi-messenger Observations of a Binary Neutron Star Merger*

LIGO Scientific Collaboration and Virgo Collaboration, Fermi GBM, INTEGRAL, IceCube Collaboration, AstroSat Cadmium Zinc Telluride Imager Team, IPN Collaboration, The Insight-HXMT Collaboration, ANTARES Collaboration, The Swift Collaboration, AGILE Team, The 1M2H Team, The Dark Energy Camera GW-EM Collaboration and the DES Collaboration, The DLT40 Collaboration, GRAWITA: GRAvitational Wave Inaf TeAm, The Fermi Large Area Telescope Collaboration, ATCA: Australia Telescope Compact Array, ASKAP: Australian SKA Pathfinder, Las Cumbres Observatory Group, OzGrav, DWF (Deeper, Wider, Faster Program), AST3, and CAASTRO Collaborations, The VINROUGE Collaboration, MASTER Collaboration, J-GEM, GROWTH, JAGWAR, Caltech-NRAO, TTU-NRAO, and NuSTAR Collaborations, Pan-STARRS, The MAXI Team, TZAC Consortium, KU Collaboration, Nordic Optical Telescope, ePESSTO, GROND, Texas Tech University, SALT Group, TOROS: Transient Robotic Observatory of the South Collaboration, The BOOTES Collaboration, MWA: Murchison Widefield Array, The CALET Collaboration, IKI-GW Follow-up Collaboration, H.E.S.S. Collaboration, LOFAR Collaboration, LWA: Long Wavelength Array, HAWC Collaboration, The Pierre Auger Collaboration, ALMA Collaboration, Euro VLBI Team, Pi of the Sky Collaboration, The Chandra Team at McGill University, DFN: Desert Fireball Network, ATLAS, High Time Resolution Universe Survey, RIMAS and RATIR, and SKA South Africa/MeerKAT
(See the end matter for the full list of authors.)

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CONCLUSIONS

- Low frequency radio astronomy difficult and important

Difficulties: radio frequency interference, ionosphere instability

Importance: early universe, transients, magnetic fields

- A couple of current low frequency facilities
- Dipole telescope design for low frequency

Cheap, flexibility in beam pointing, simultaneous multi-beam pointing

- LWA & MWA basic properties
- Not much breaking discovery so far

FUTURE

- 53 LWA stations, with 400 km baseline(s)

- MWA phase II, double current size; phase III

- SKA-low

2020 Full science operations

- Low frequency radio astronomy in space or on the moon

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- (Slides) The Long Wavelength Array: Status and Updates, Jayce Dowell, 2016
- (Slides) The Murchison Widefield Array, Colin J. Lonsdale, 2010
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- (Slides) Ground Low Frequency (<40MHz) Observations: Past And Future, Zhou, Jianfeng, 2018
- (Slides) Low-Frequency Radio in Space, Willem A. Baan+
- Unlabeled figures not from refereed papers, from either the Internet or slides above

THANK YOU | Q&A