Universiteit Leiden

ASTRON

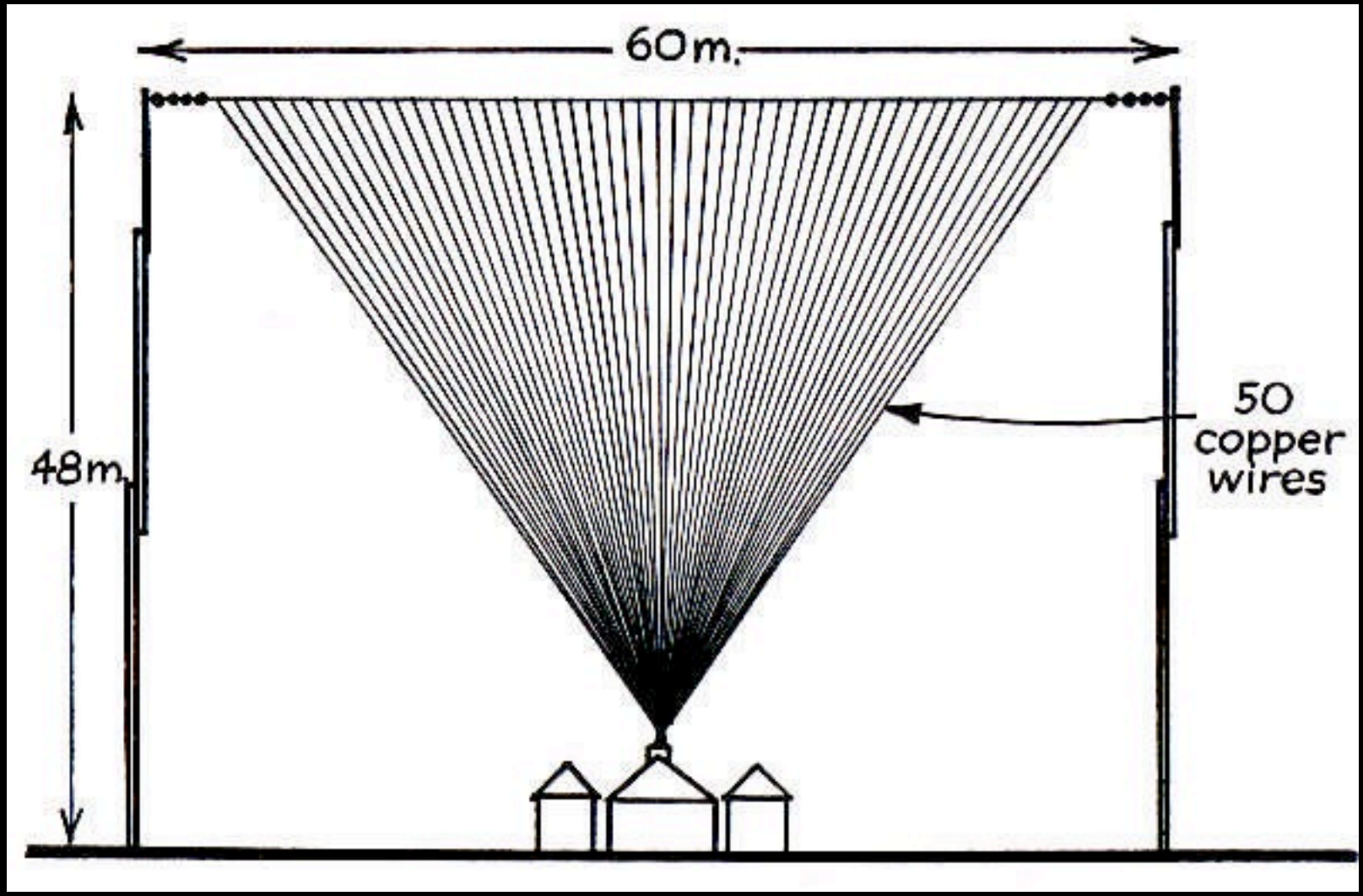
Radio Astronomy Transformed

- Aperture Arrays: Past, Present & Future

Prof. Michael Garrett

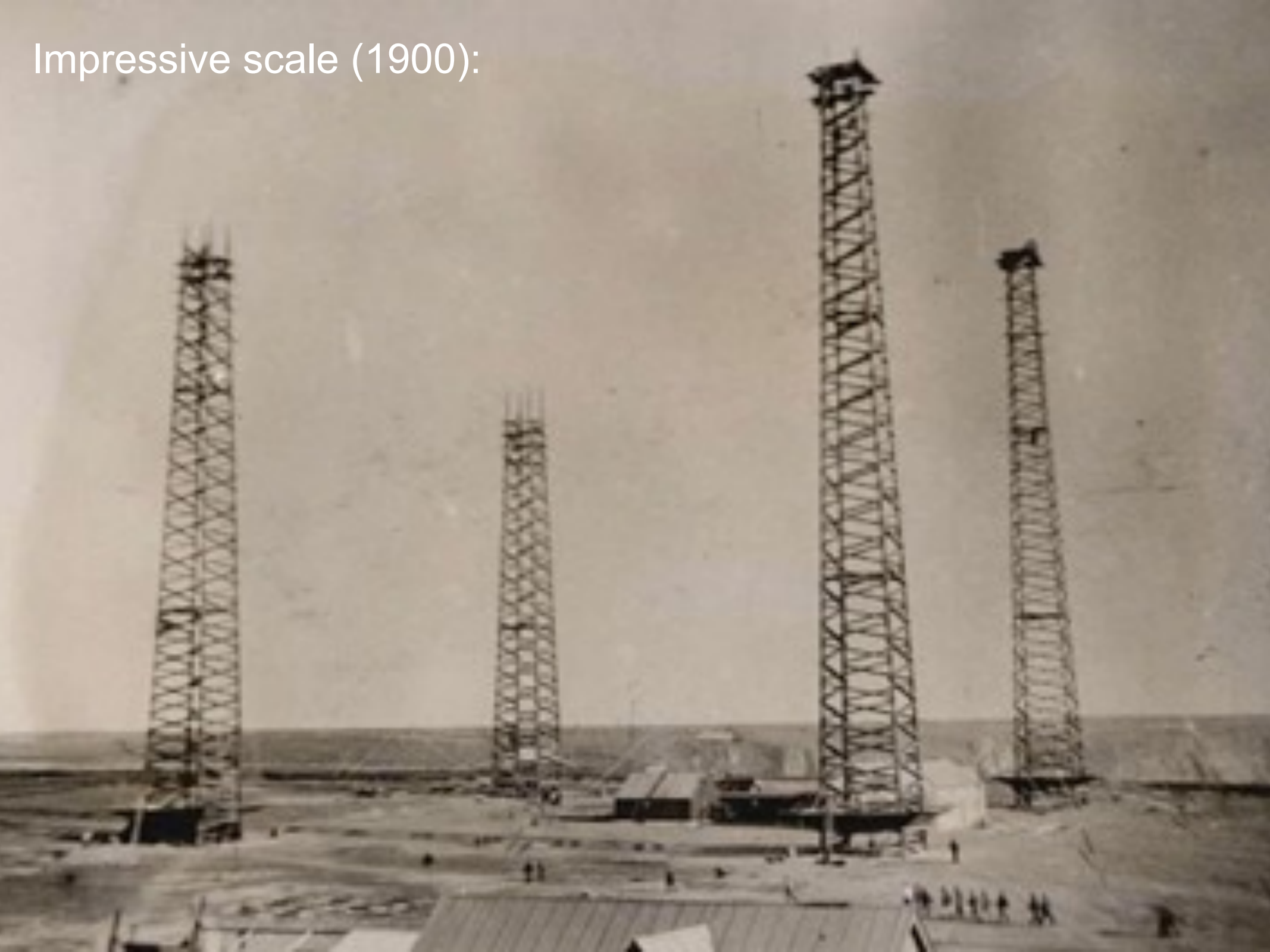
ASTRON, the Netherlands Institute for Radio Astronomy
Leiden University.

Early Antenna Arrays



Centrally fed ground antennas - G. Marconi (1901)

Impressive scale (1900):



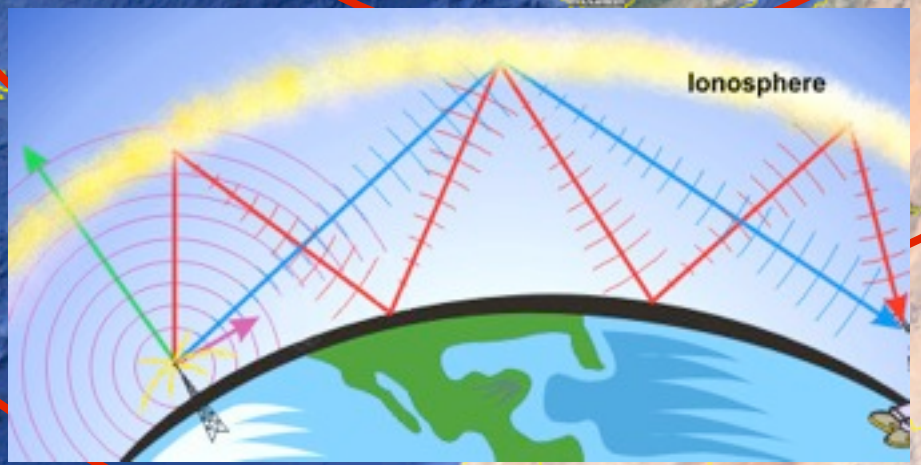
Poldhu, Cornwall, UK 1901:

“My previous tests had convinced me that when endeavouring to extend the distance of communication, it was not merely sufficient to augment the power of the electrical energy of the sender, but that it was also necessary to increase the area or height of the transmitting and receiving elevated conductors” - Marconi.

Some problems too...:

St. John's

Poldhu

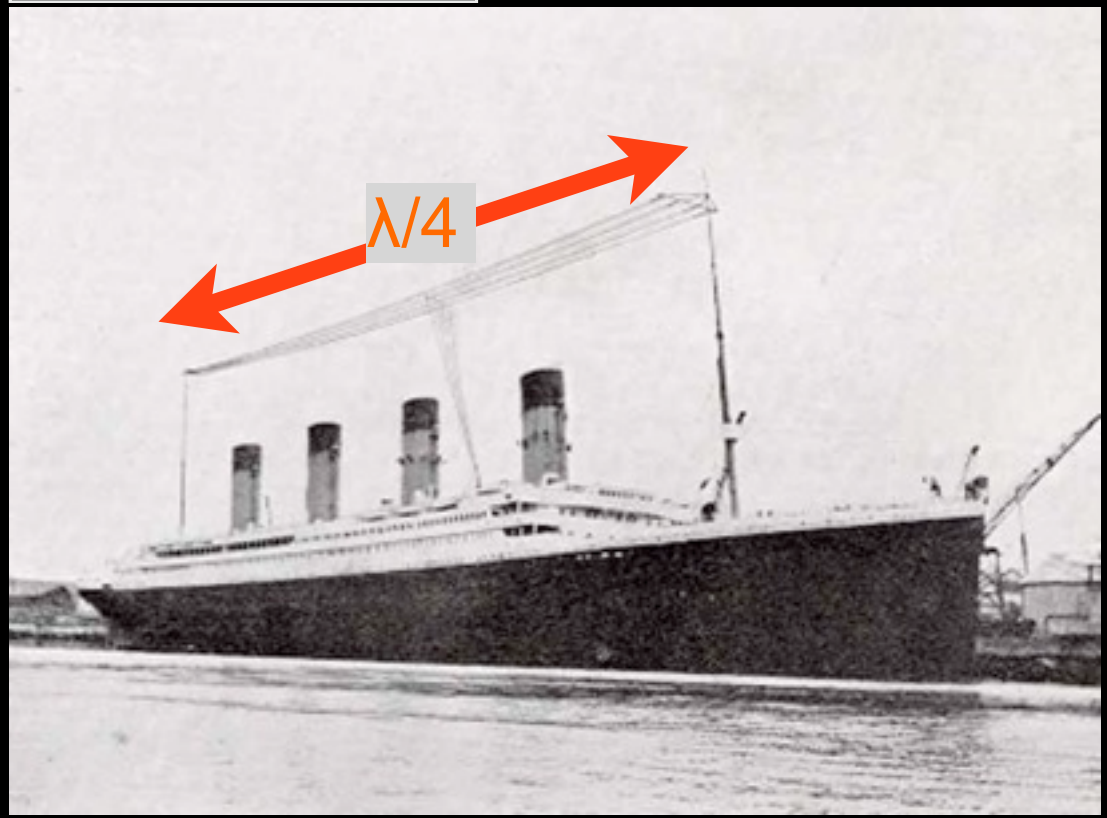


Eventual success despite a sceptical science community:


The New York Times.

ONLY 400 TITANIC SURVIVORS NAMED BY CARPATHIA;
WIRELESS SEARCH OF THE SEAS FOR FURTHER NEWS

1912: HMS Titanic

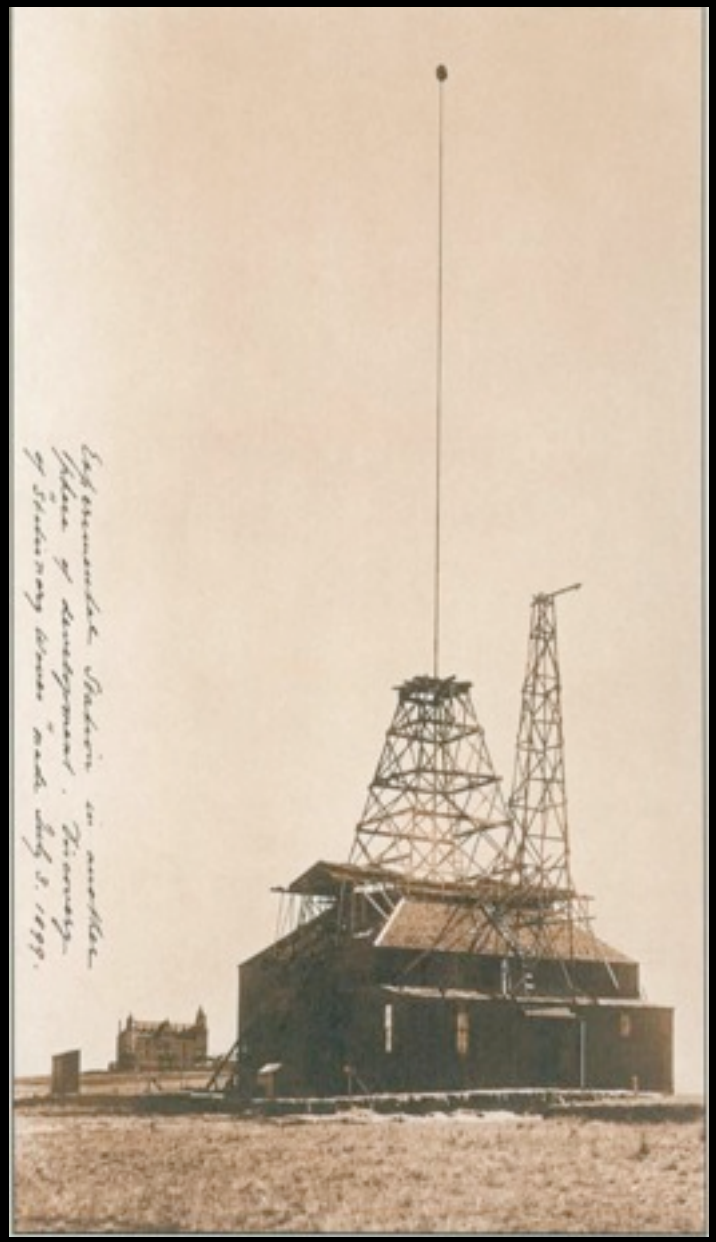


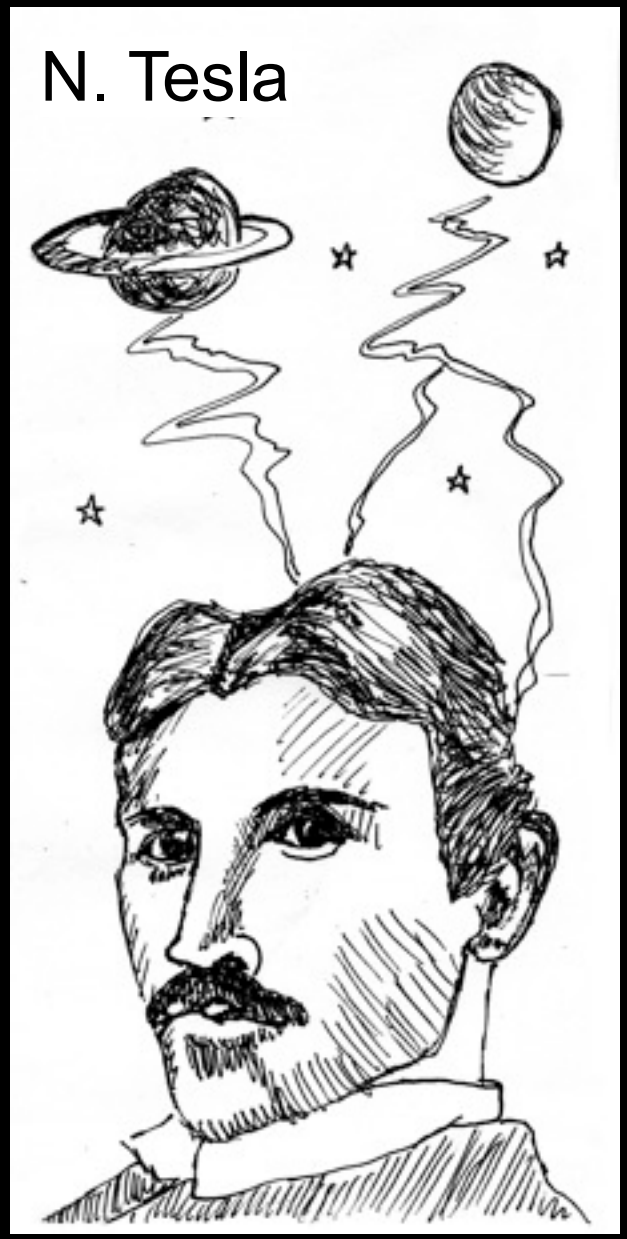
Radio Broadcasting
(post WWI)

Y-Stations WWI

Radio WWI trenches

Cosmic Radio Emission - first claims...





MARCONI SURE MARS FLASHES MESSAGES

Regularity of Signals, London Expert Says, Eliminates Atmospheric Disturbance Theory.

WAVES TEN TIMES OURS

J. H. C. Macbeth Declares It Would Be Simple Matter to Arrange a Code.

William Marconi is now convinced that he has intercepted wireless messages from Mars, J. H. C. Macbeth, London manager of the Marconi Wireless Telegraph Company, Ltd., said at a Rotary Club luncheon at the McAlpin yesterday. Mr. Macbeth added by way of prediction, that should this prove to be so, it will be only a question of time before inventive genius and ingenuity in deciphering unknown codes will evolve a method of communication between the two planets.

The first “phased arrays”:

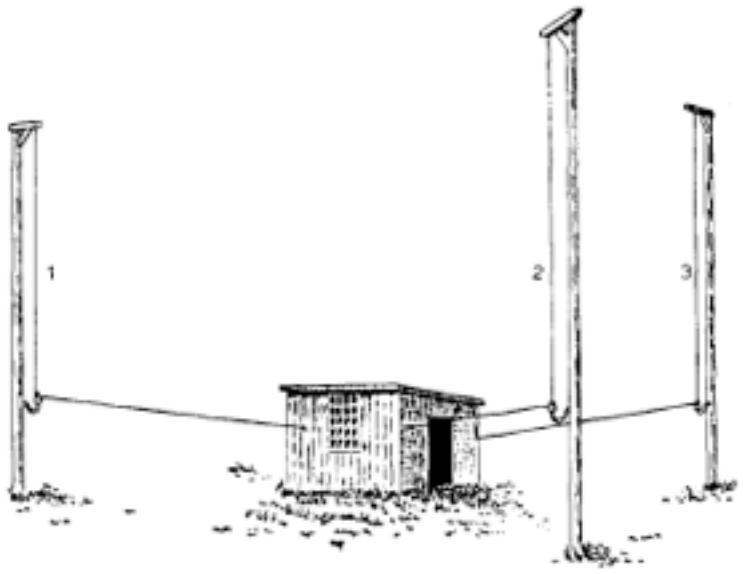
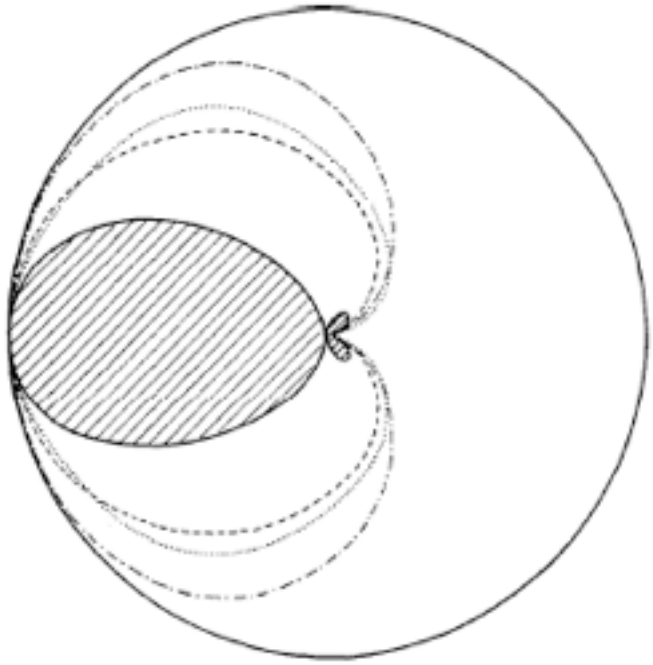
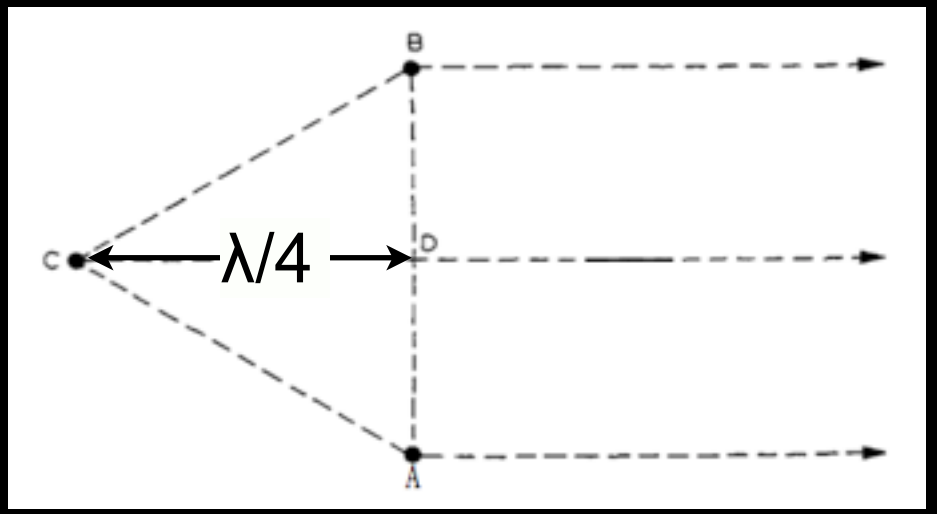


Fig. 13.





Braun et al. 1907

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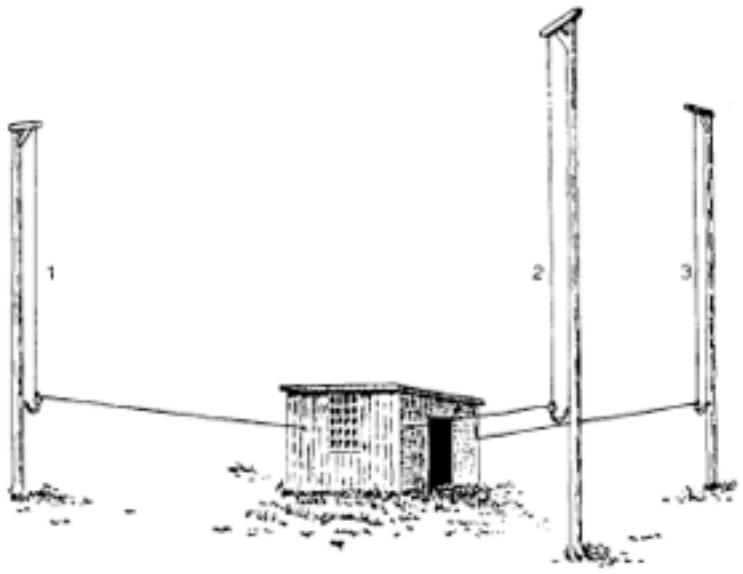

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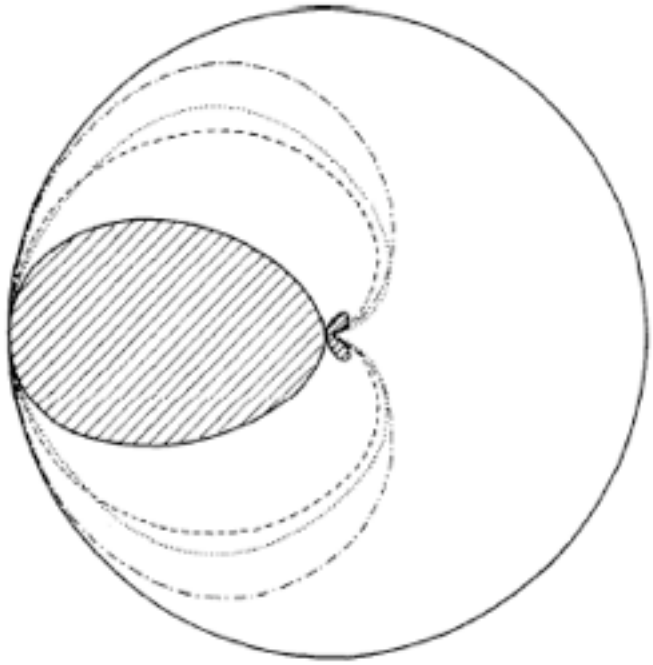

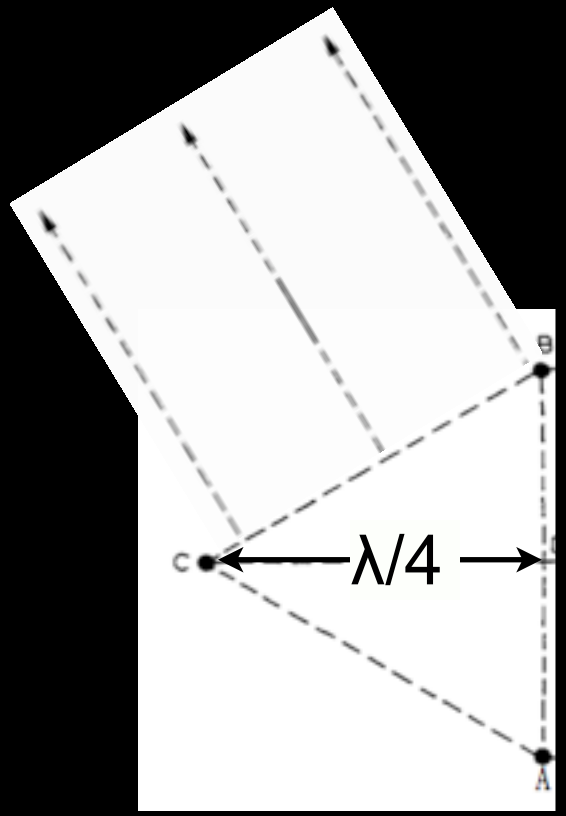

Braun et al. 1907

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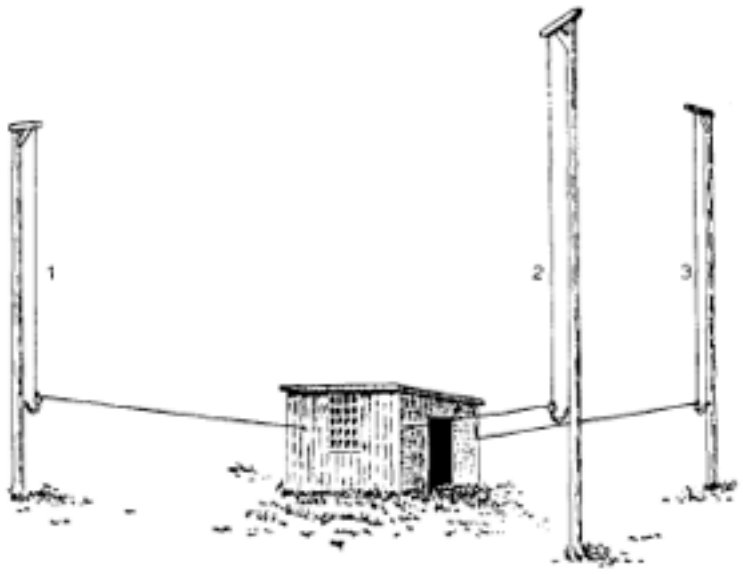

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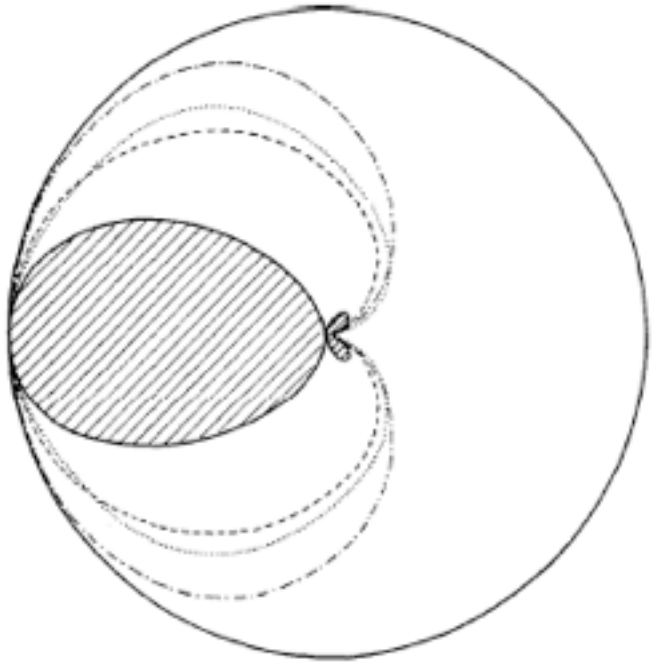

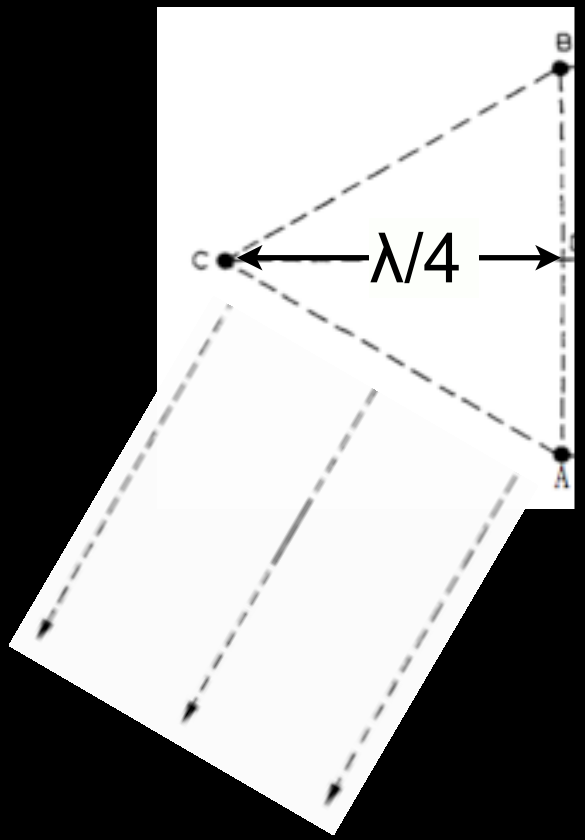

Braun et al. 1907

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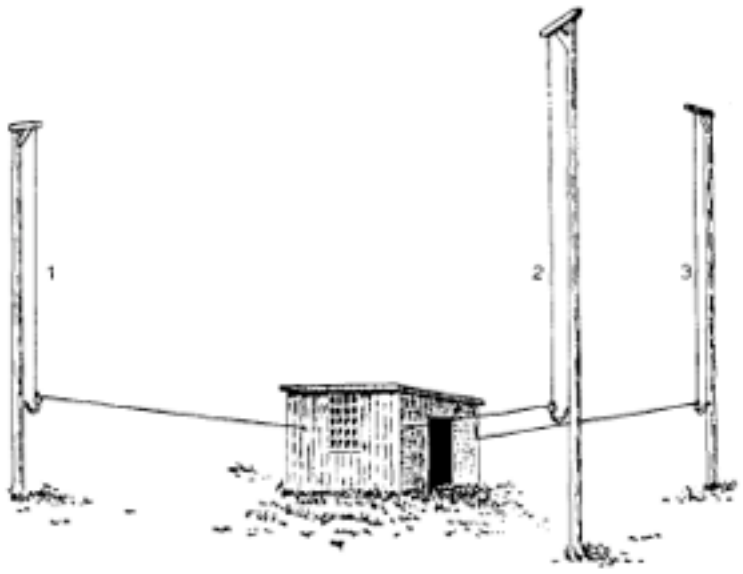

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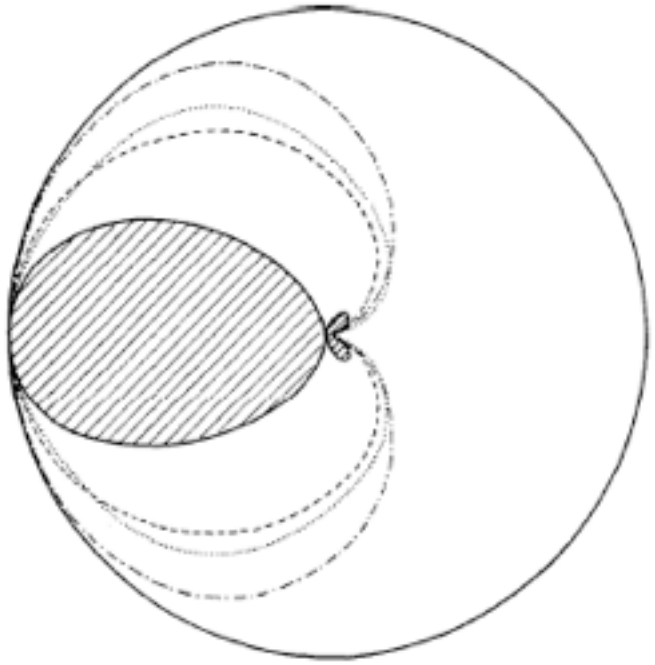
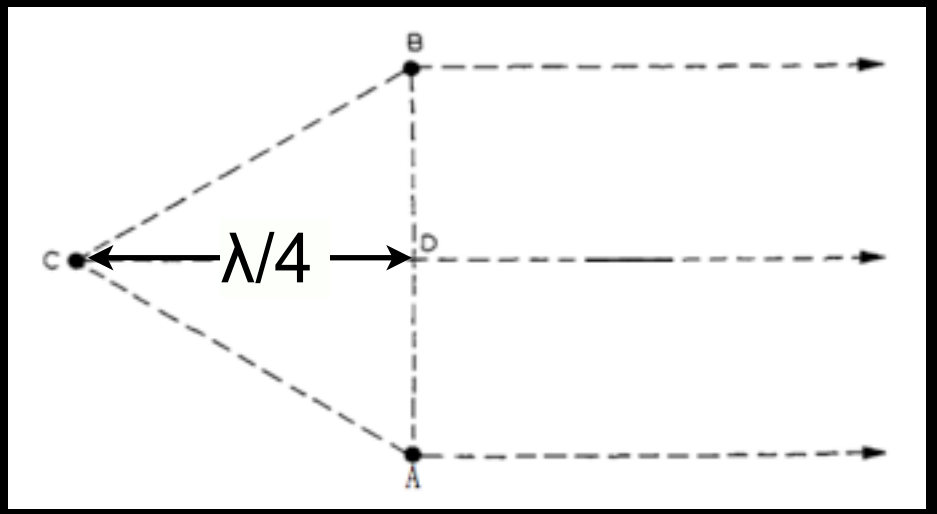
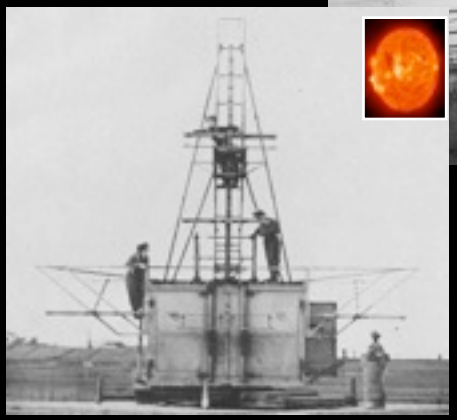




Braun et al. 1907

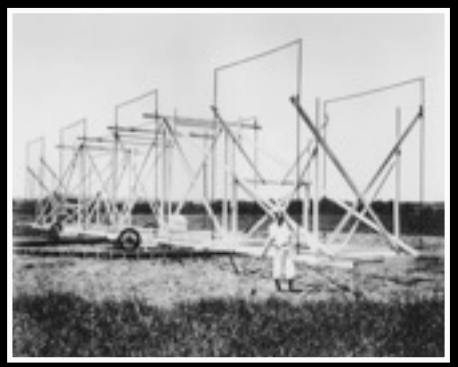
The first “phased arrays”:

Phased arrays and radio astronomy (1950/60s)



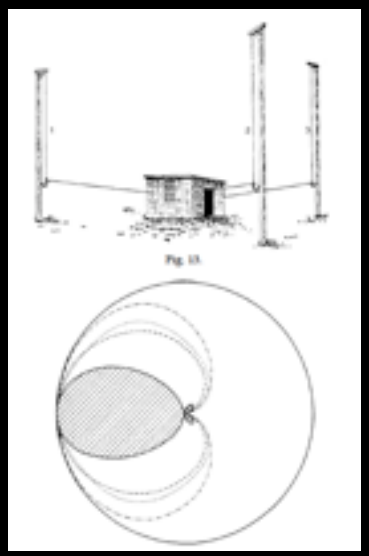
J.S. Hey et al. 1942

Friis & Feldman 1937 (Bell labs) - first phase shifted system.

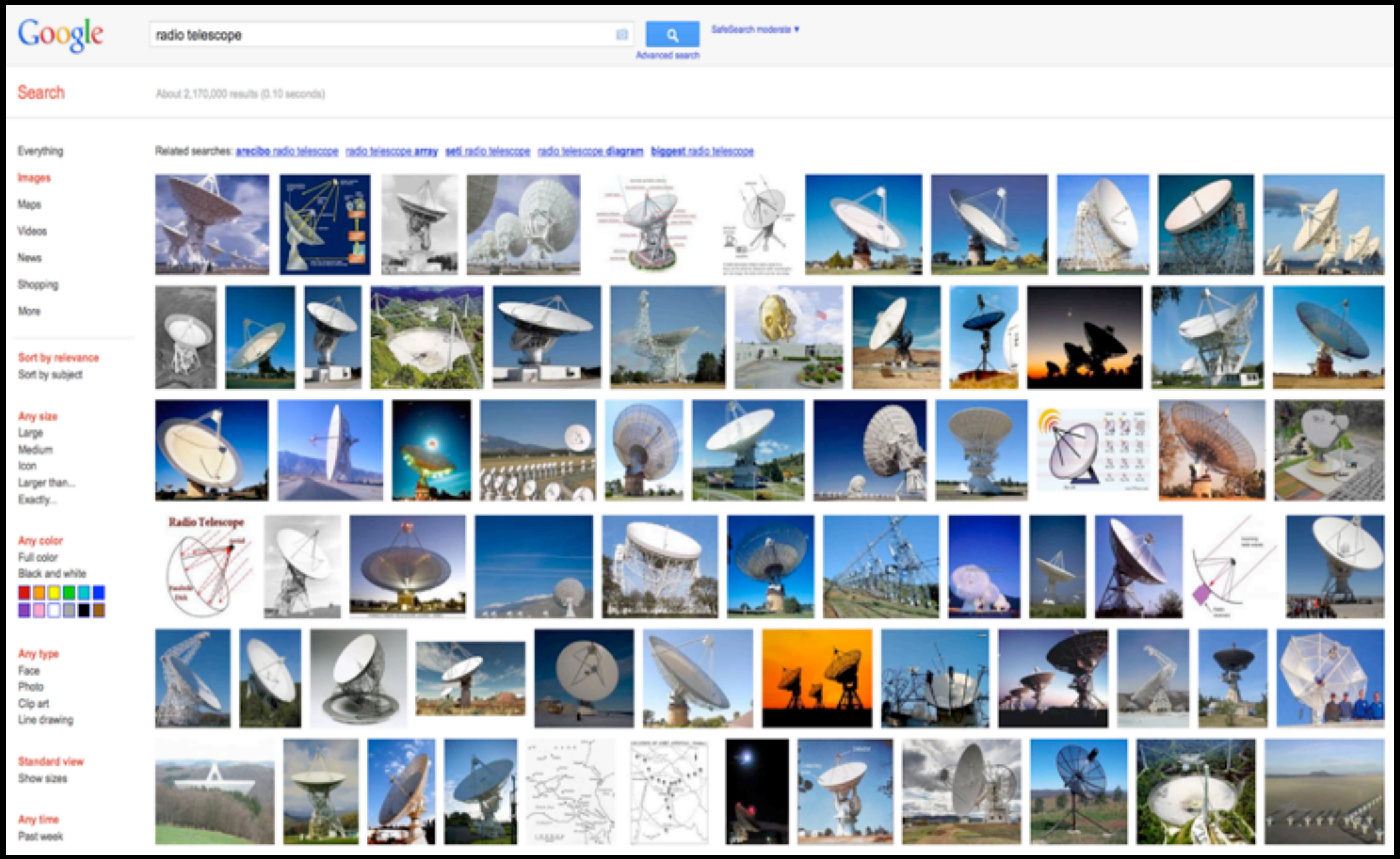


Jansky 1932, detects cosmic radio emission

Braun et al. 1907



Aperture Array "a lost technology": 1970-2010...?

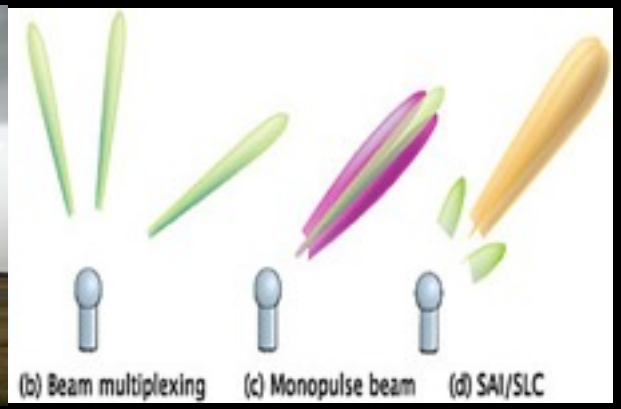


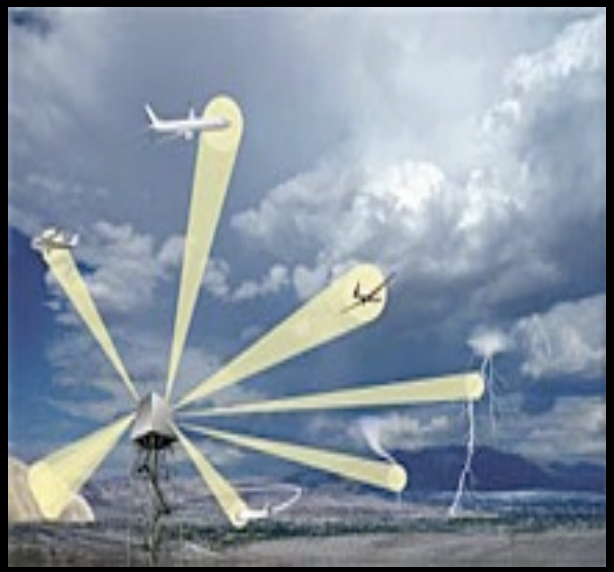
One exception - Reber... visionary

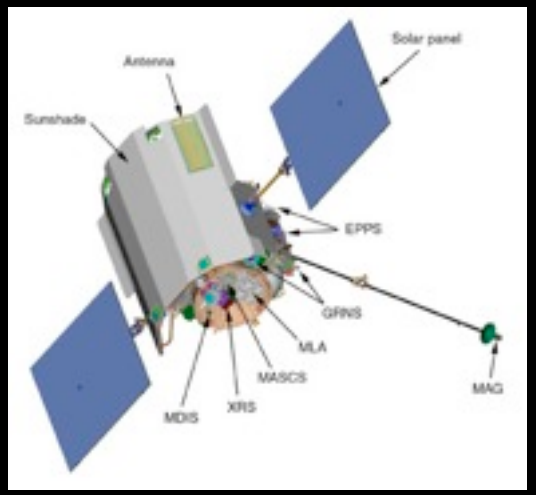
1937:

1970s:

Explosion of civilian and military applications using Aperture Arrays



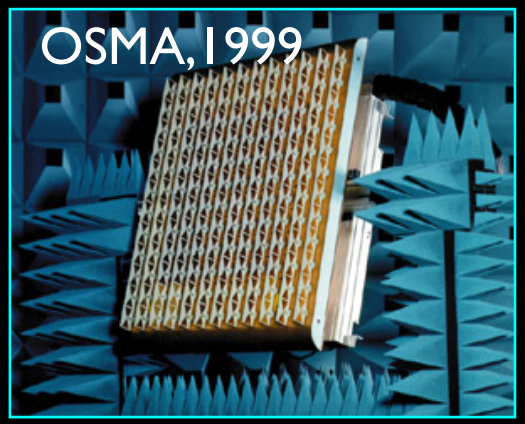


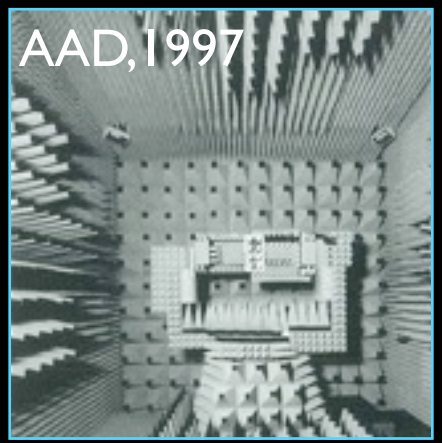


Mid-frequency Aperture Array R&D at ASTRON (1995-2010)

Aperture Arrays R&D focused on:

- concept demonstration,
- integration,
- cost reduction.

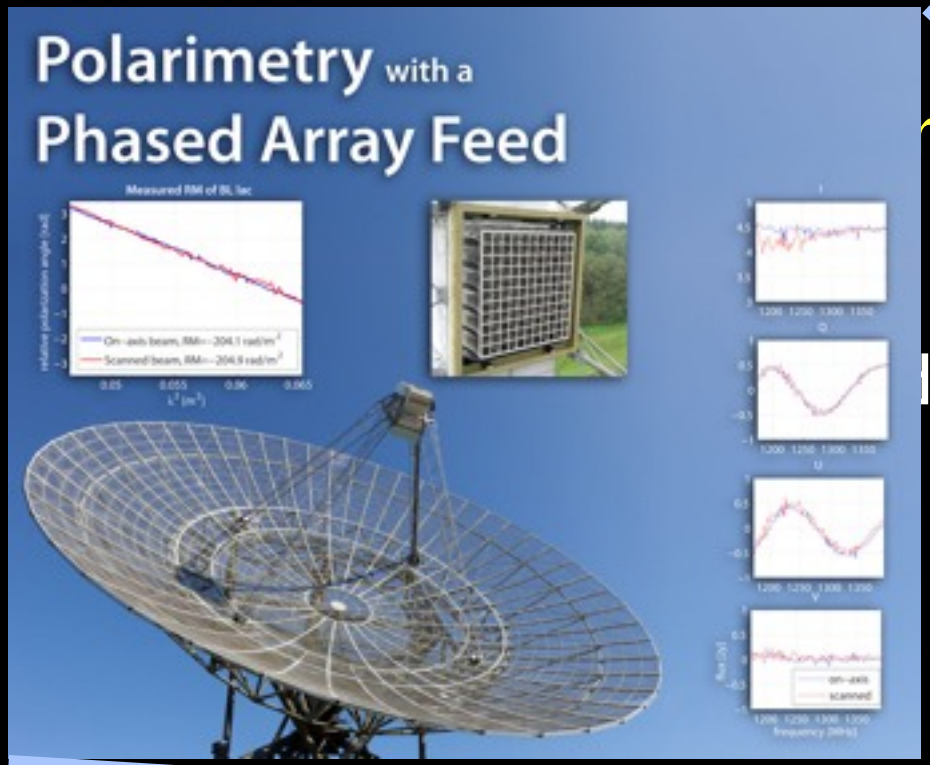


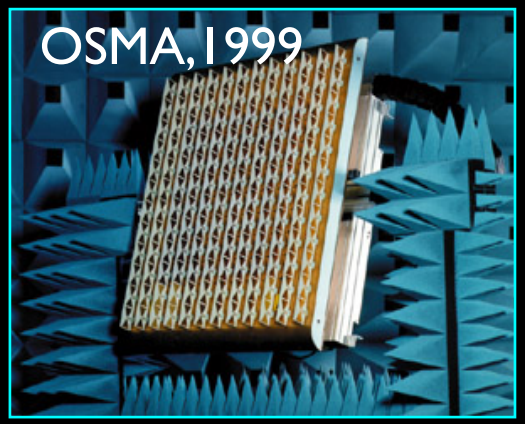


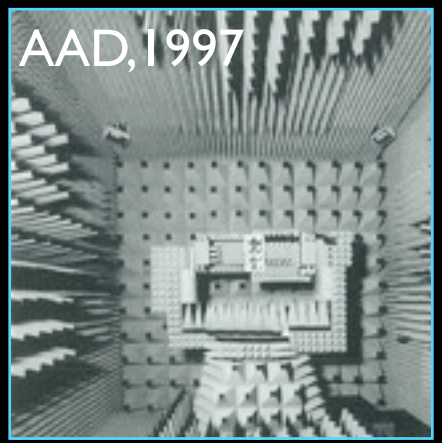
Ardenne et al.

ray R&D at ASTRON (1995-2010)

l on:

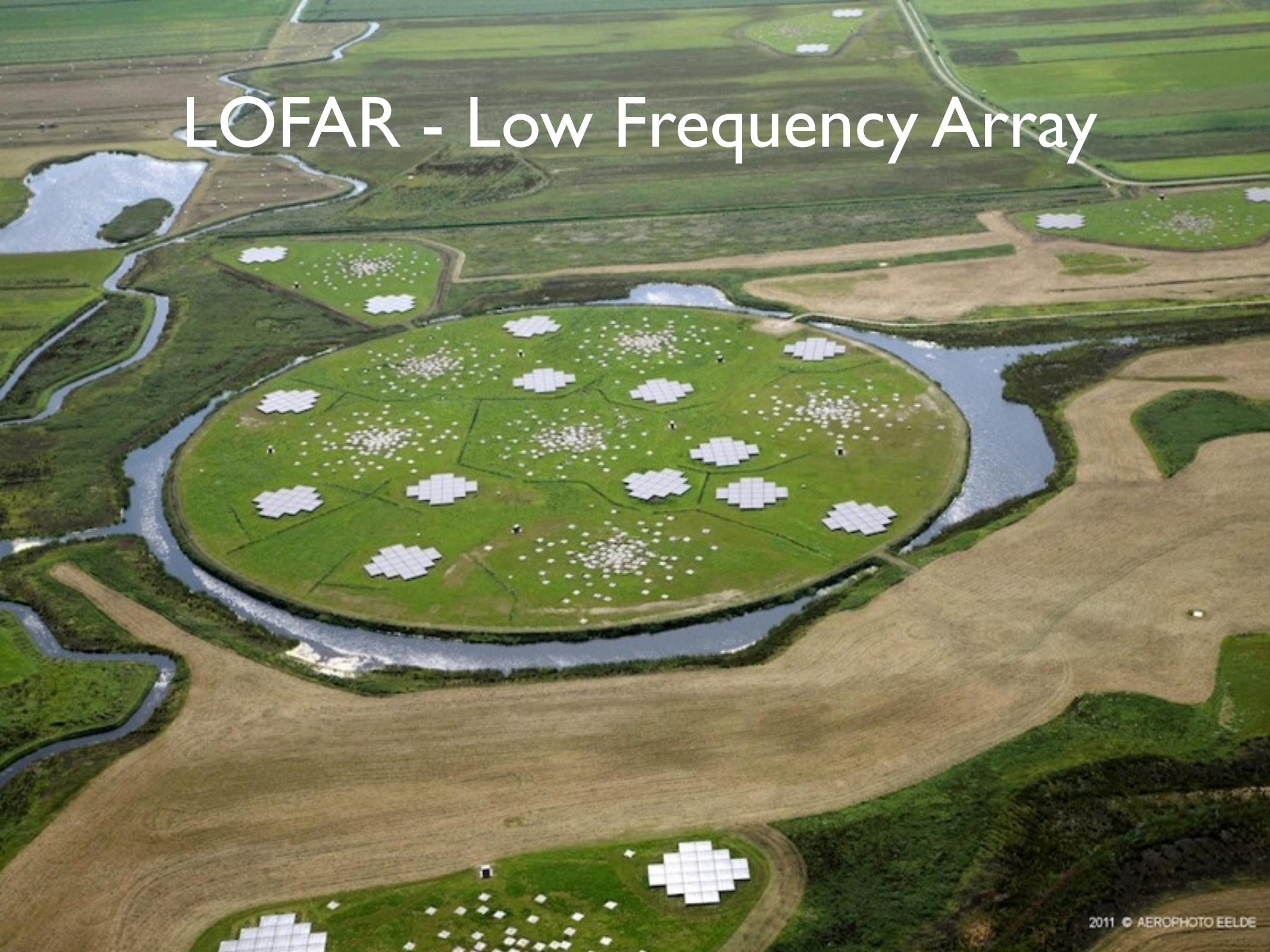






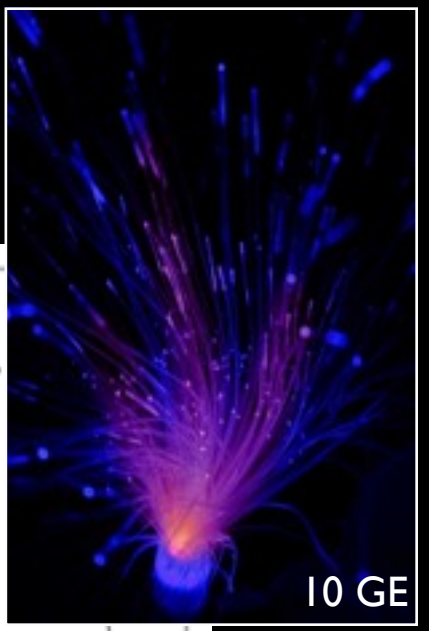
Ardenne et al.

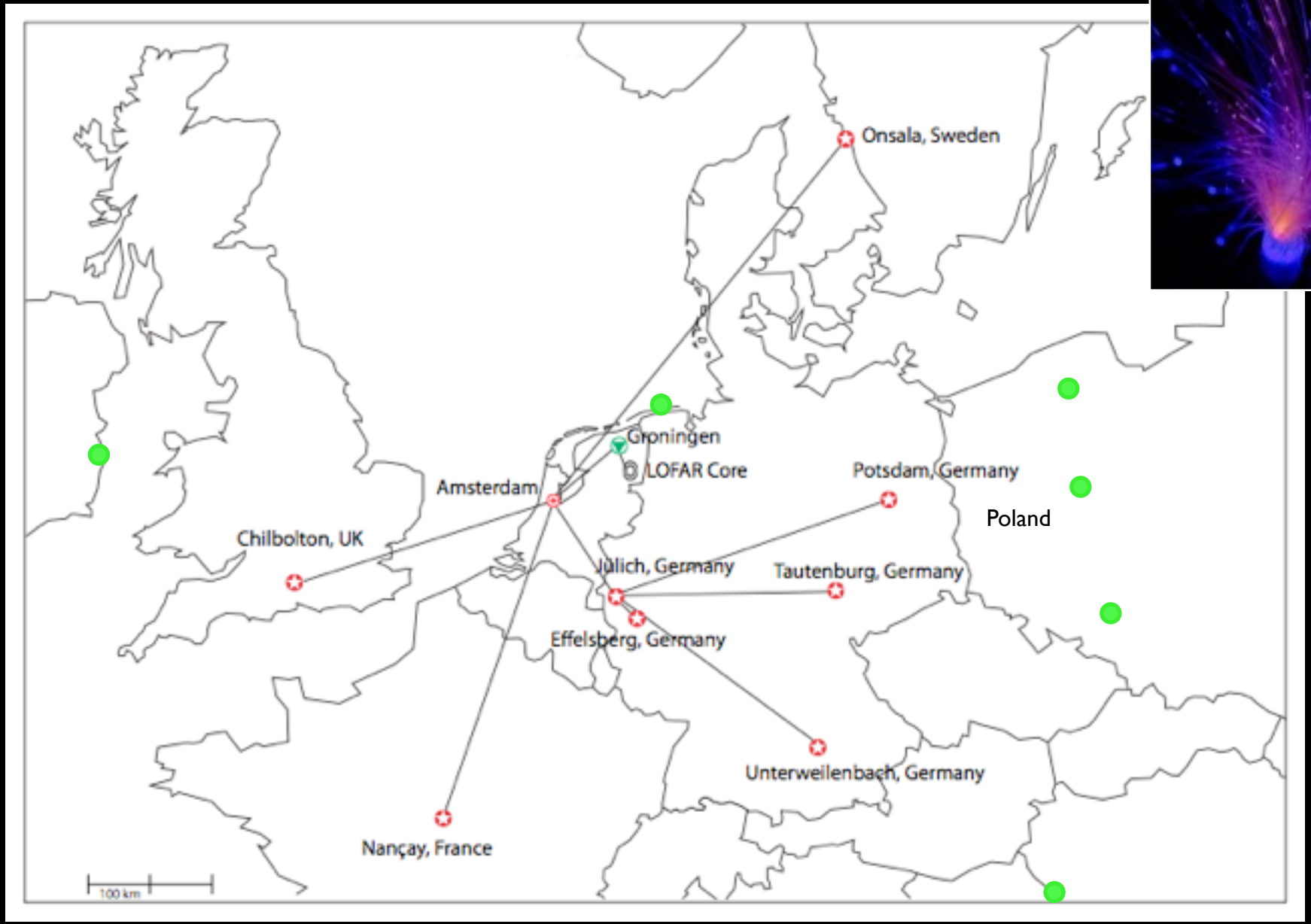
LOFAR - Low Frequency Array




World • Netherlands • Drenthe • Borger-Odoorn
Inner core, near Exloo.
Veldrijk
Exloërweg
Nieuwe Dijk
500 feet
250 m
© 2011 Microsoft Corporation Available Exclusively by DigitalGlobe © 2010 NAVTEQ

8+ European LOFAR stations:



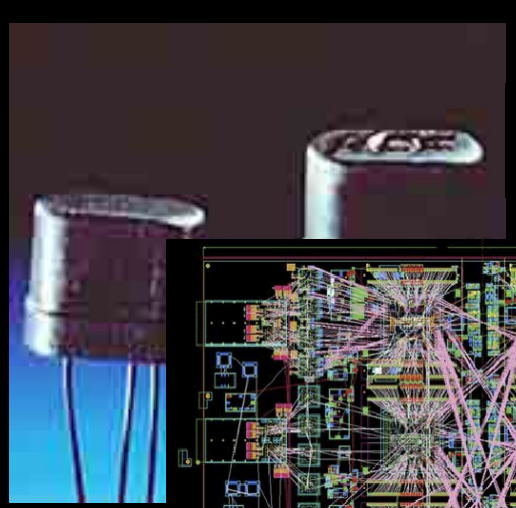


e.g. LOFAR UK station at Chilbolton, England.

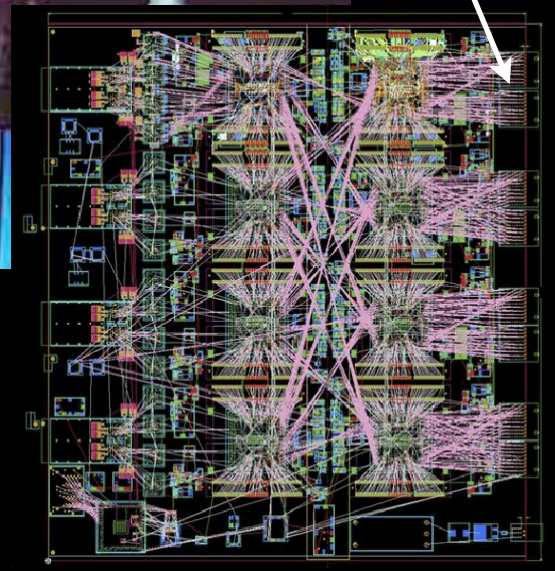
Radio Astronomy Transformed (I)

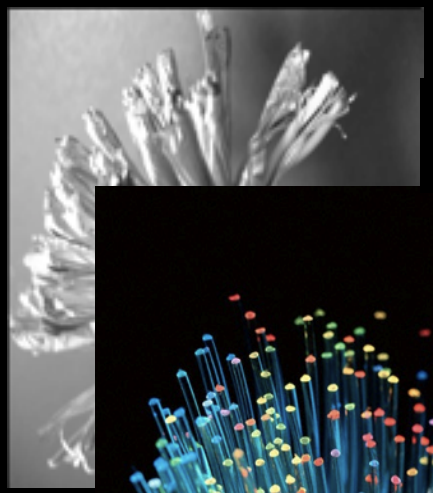
ICT capability explosion in:

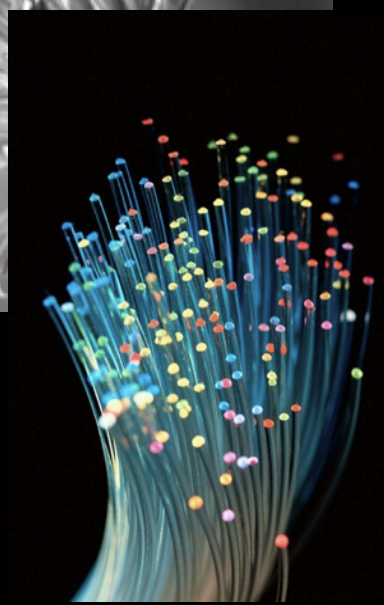
- direct sampling & digitisation
- high speed data transport
- super-computing
- archive capacity
- data mining



Moore's Law







Moore's Law

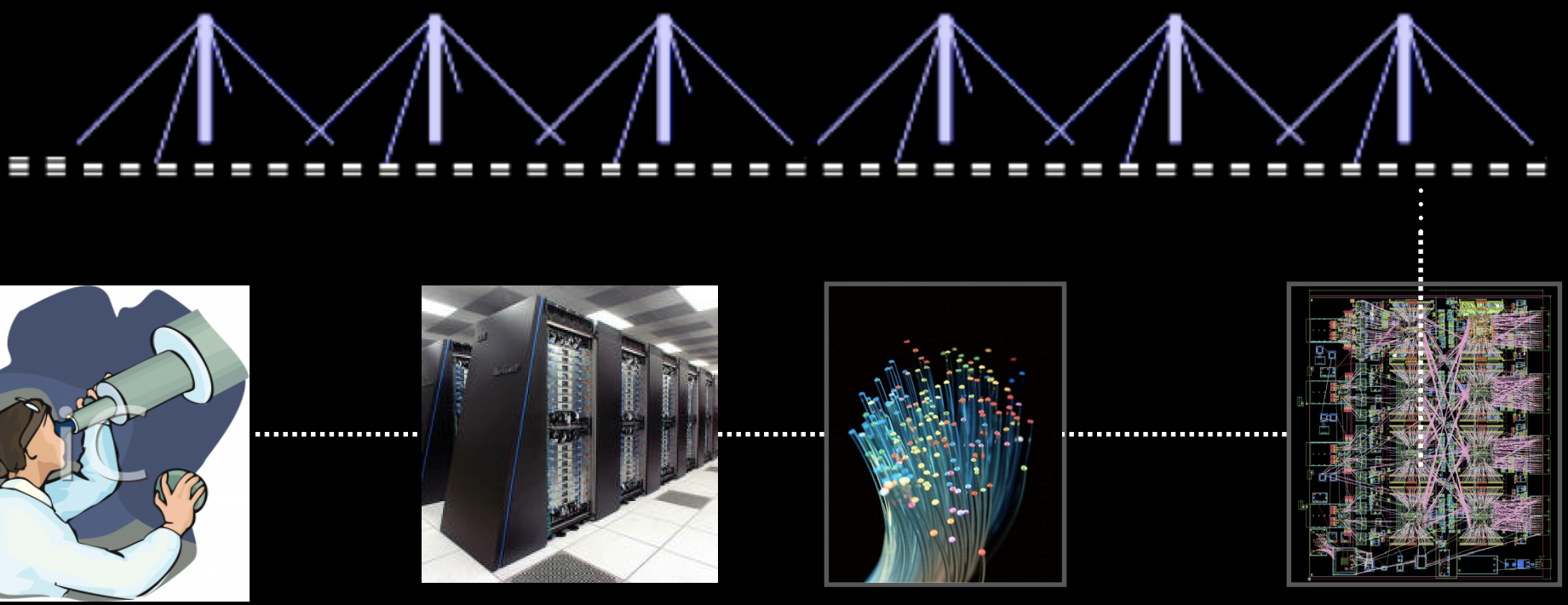
Moore's Law

Radio Astronomy Transformed (II)

New antenna technologies:

- Next Generation Aperture Array "Software Telescopes"

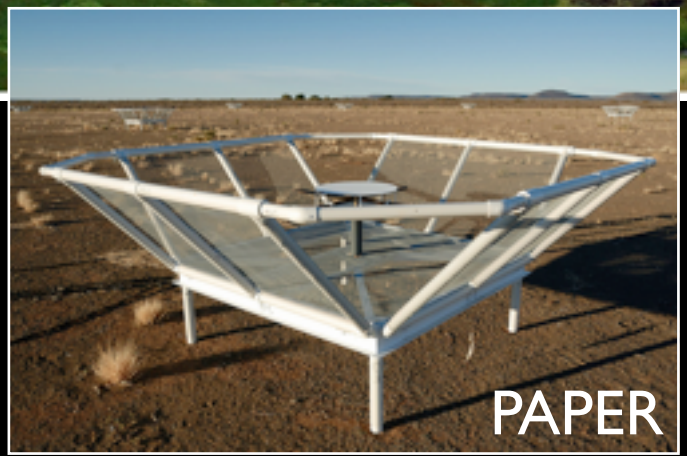
Cheap & cheerful dipoles married to the new technologies:



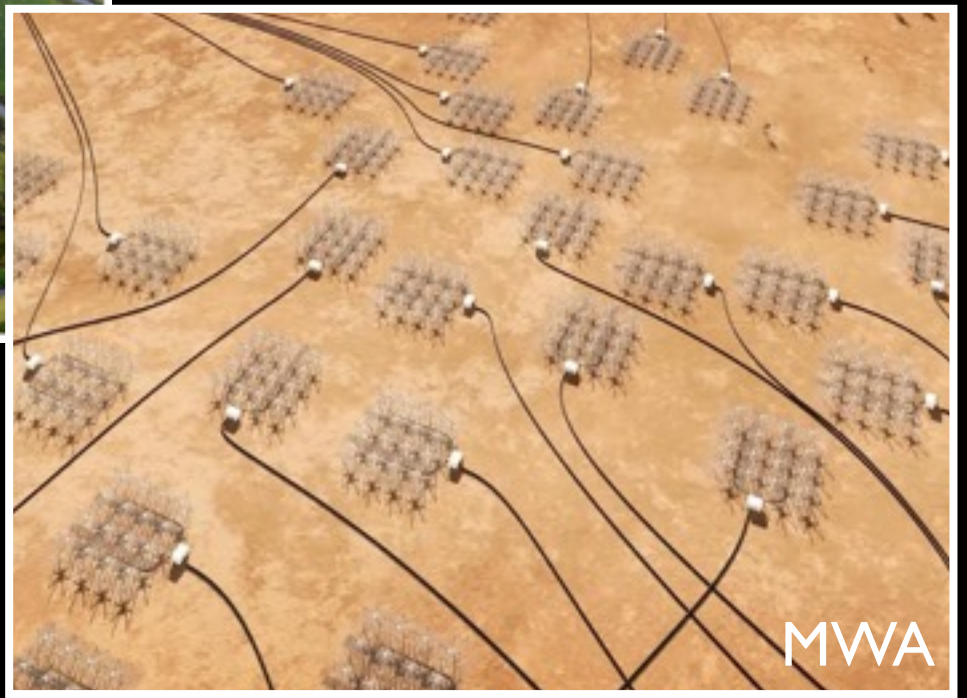
Aperture Array concept now firmly established as technology of choice at frequencies < ~ 400 MHz:

LOFAR

LWA



PAPER

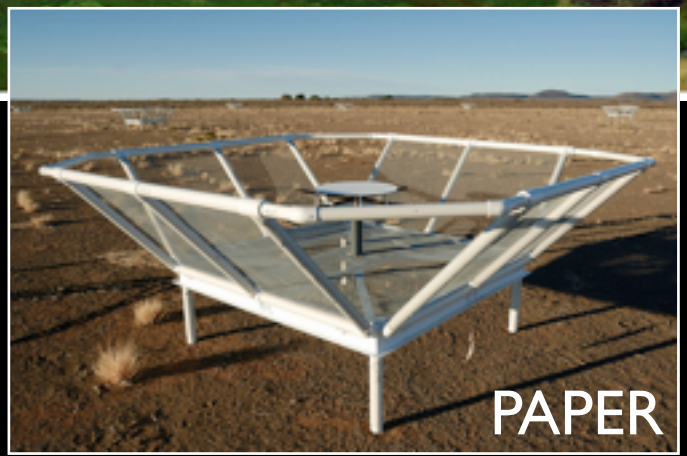


MWA

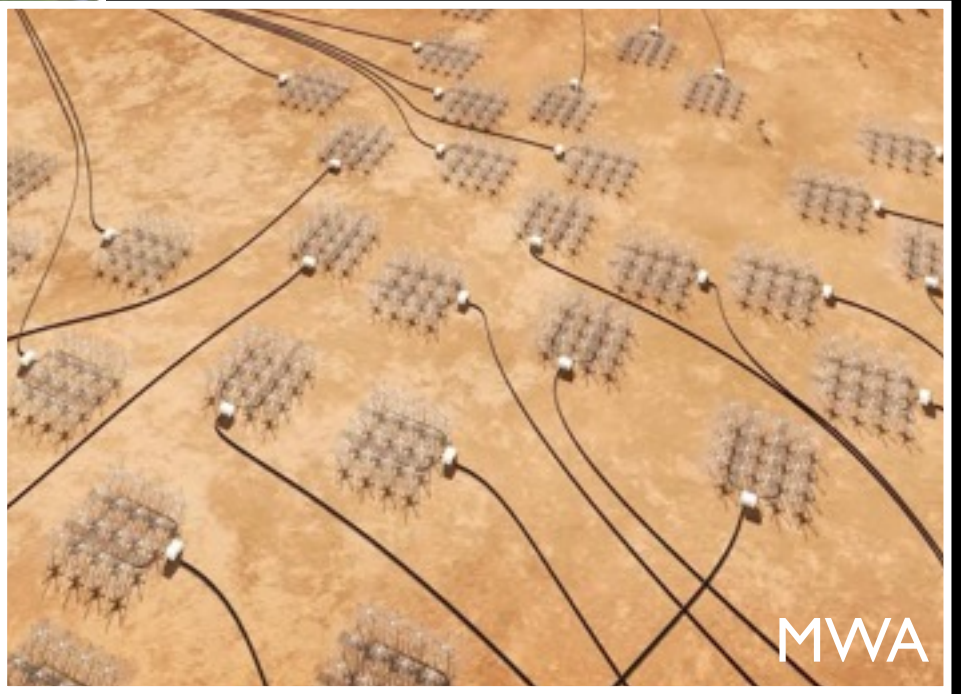
Aperture Array concept now firmly established as technology of choice at frequencies < ~ 1400 MHz:

LOFAR

LWA

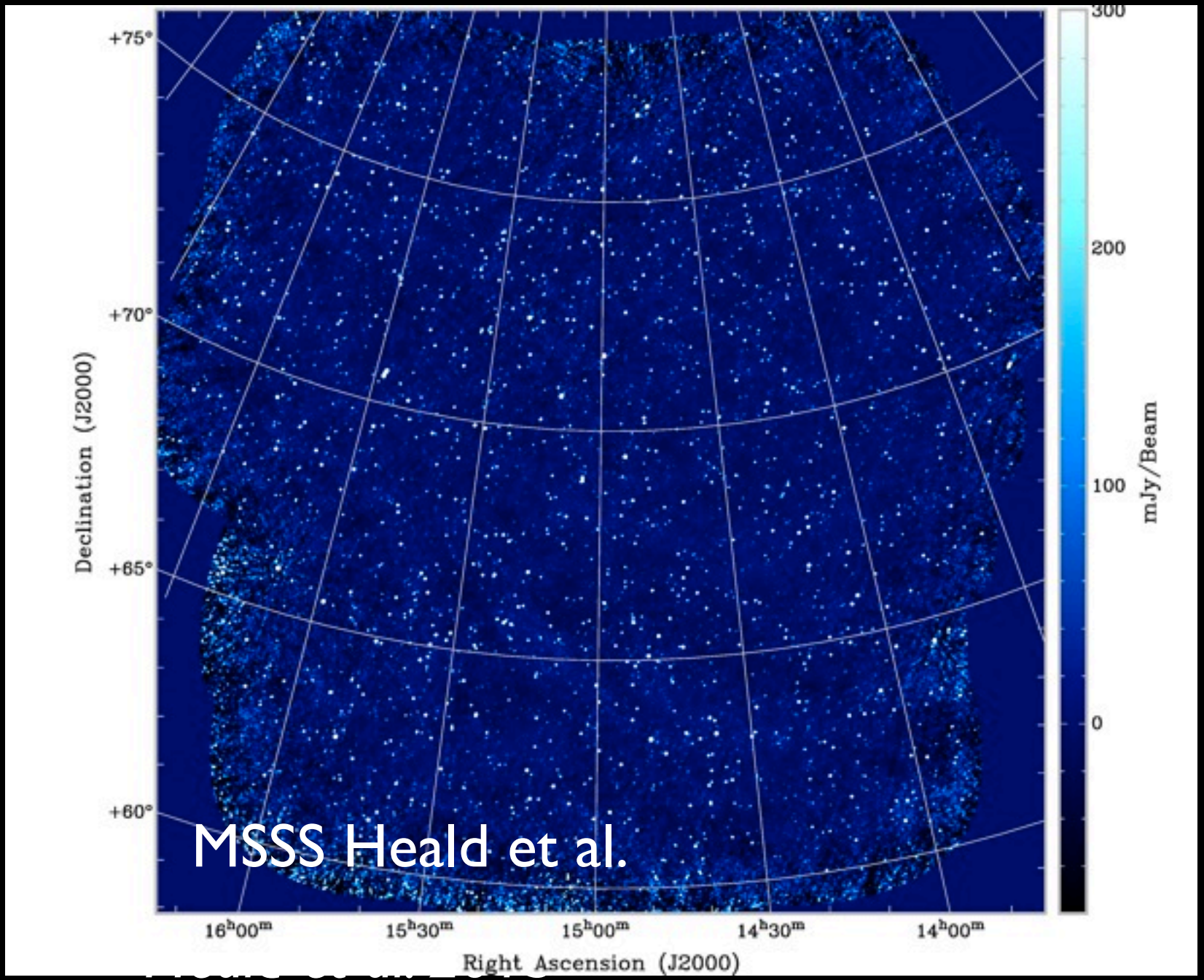


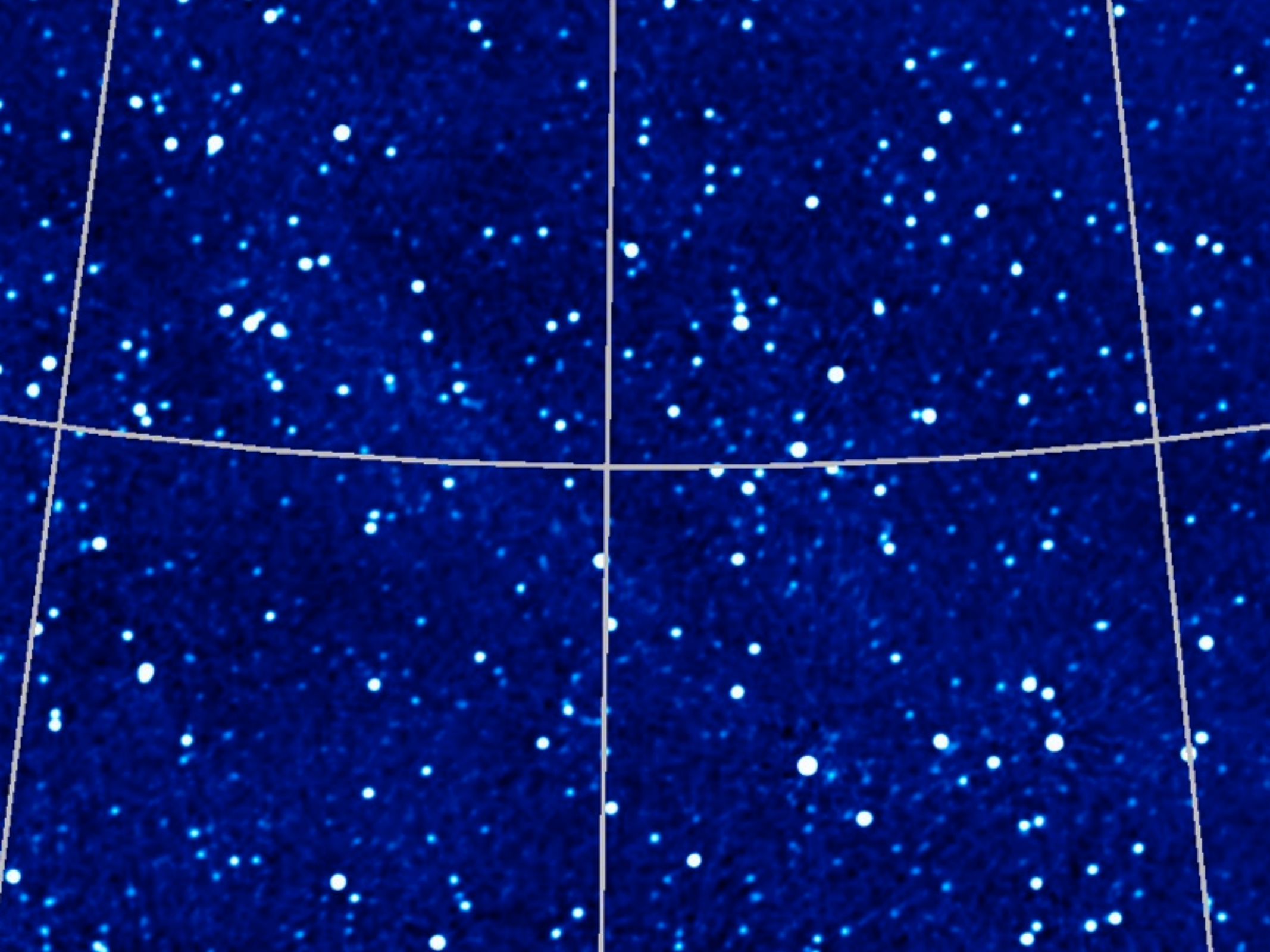
PAPER

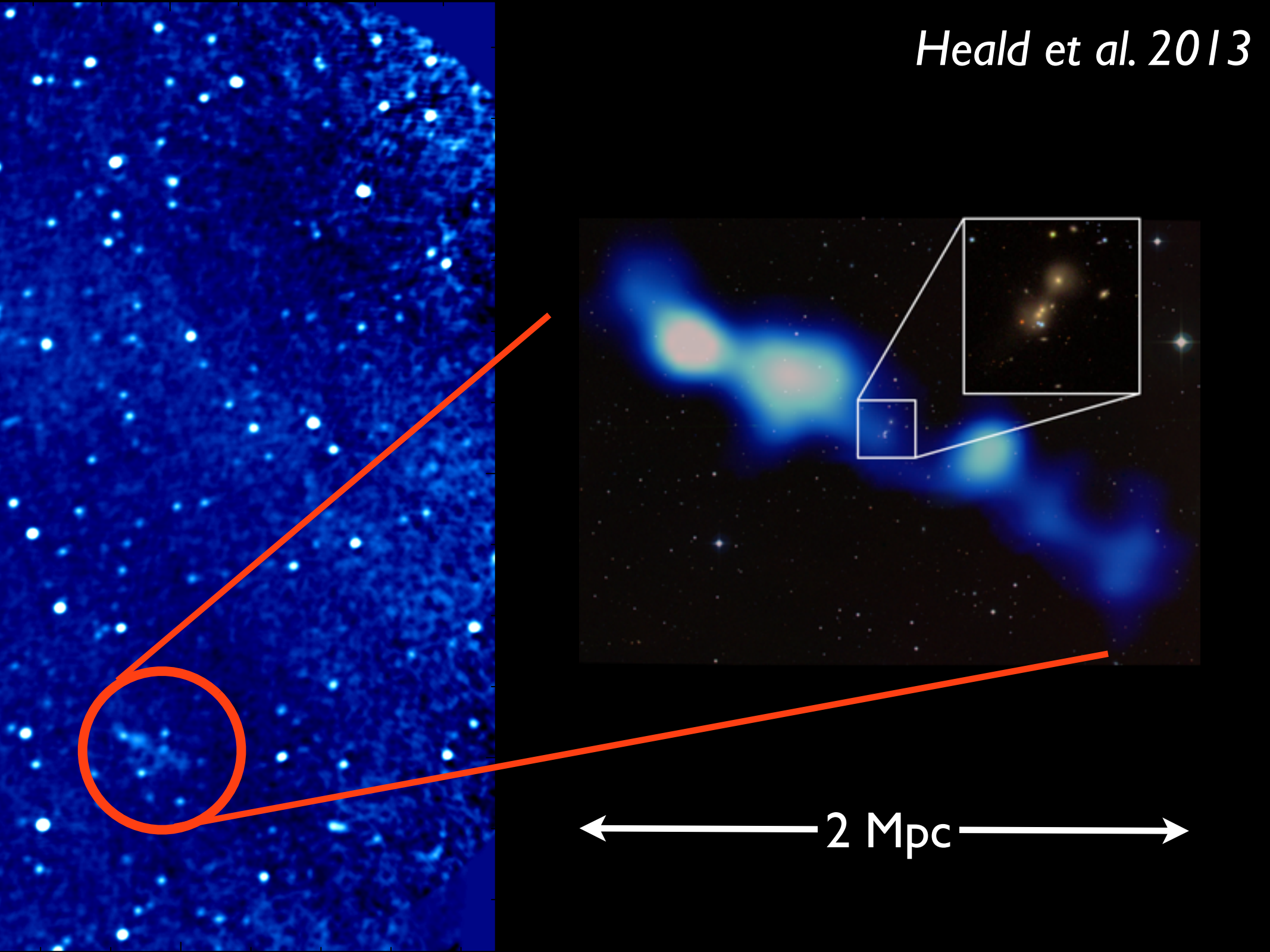


MWA

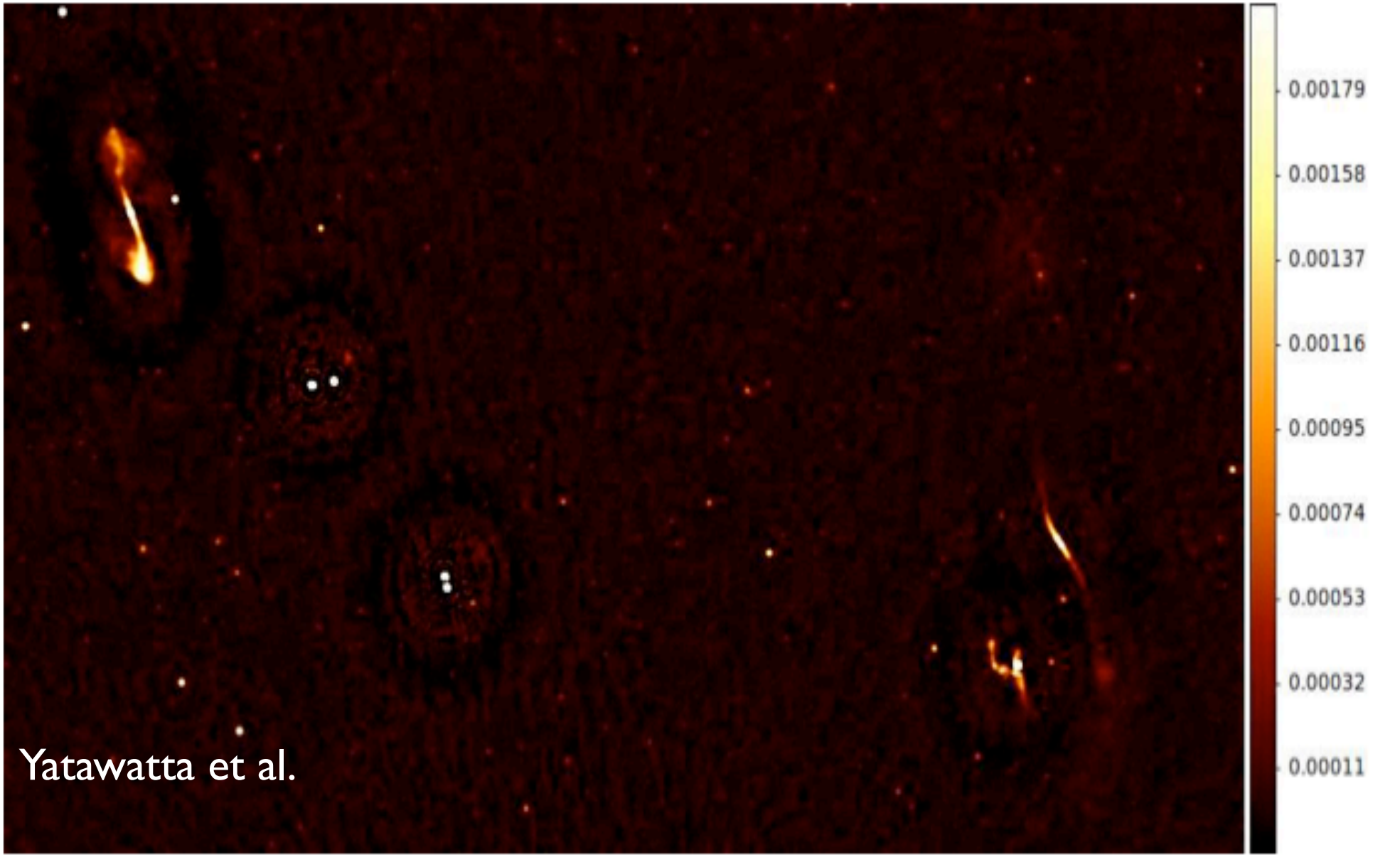
MSSS - LOFAR's first all-sky survey.





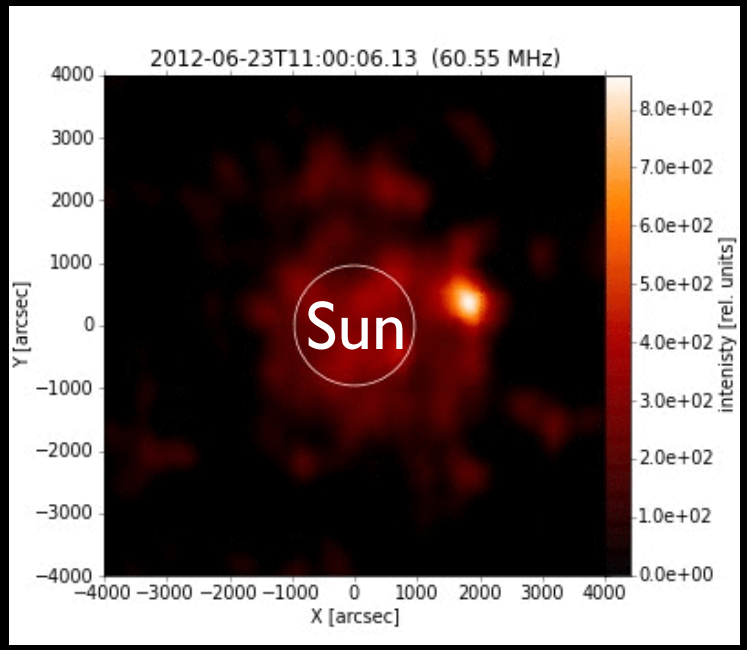

Heald et al. 2013
2 Mpc

Deep Field Surveys (EoR)



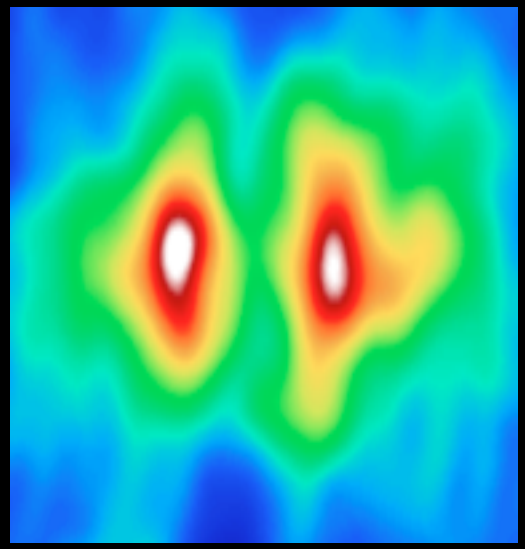
25-30 μJy, 6″ PSF, Dec 2012-Feb 2013, 80 km array, 0.5×0.25 degrees

Solar System Science



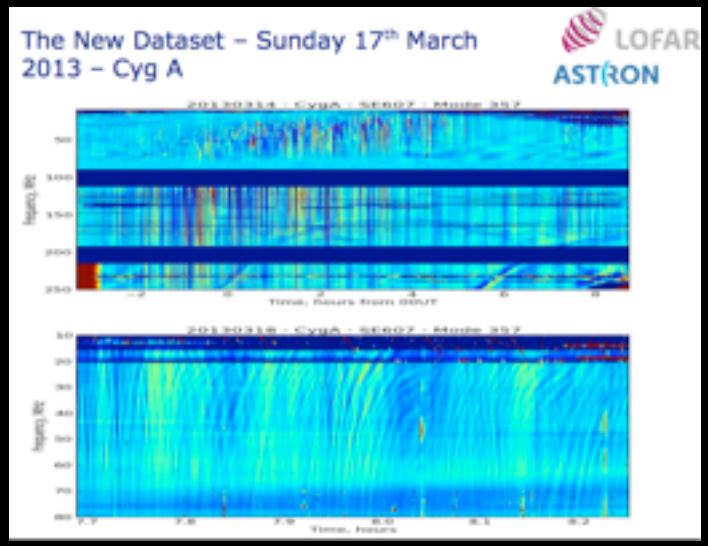
Type III burst propogating via open B-field lines - Mann et al.

Jupiter

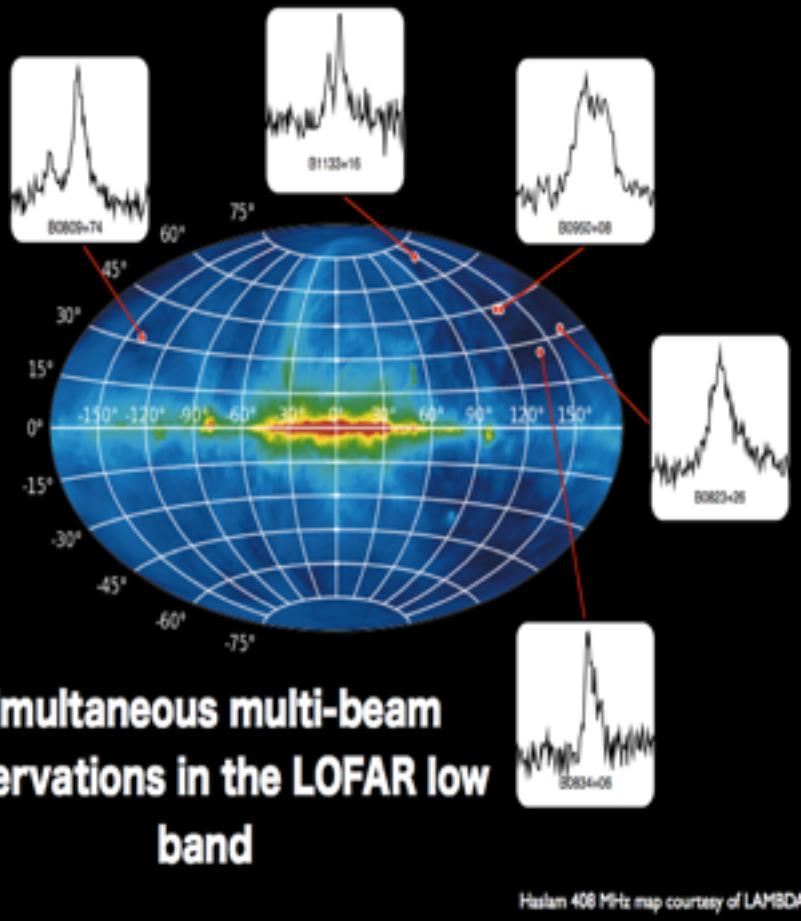


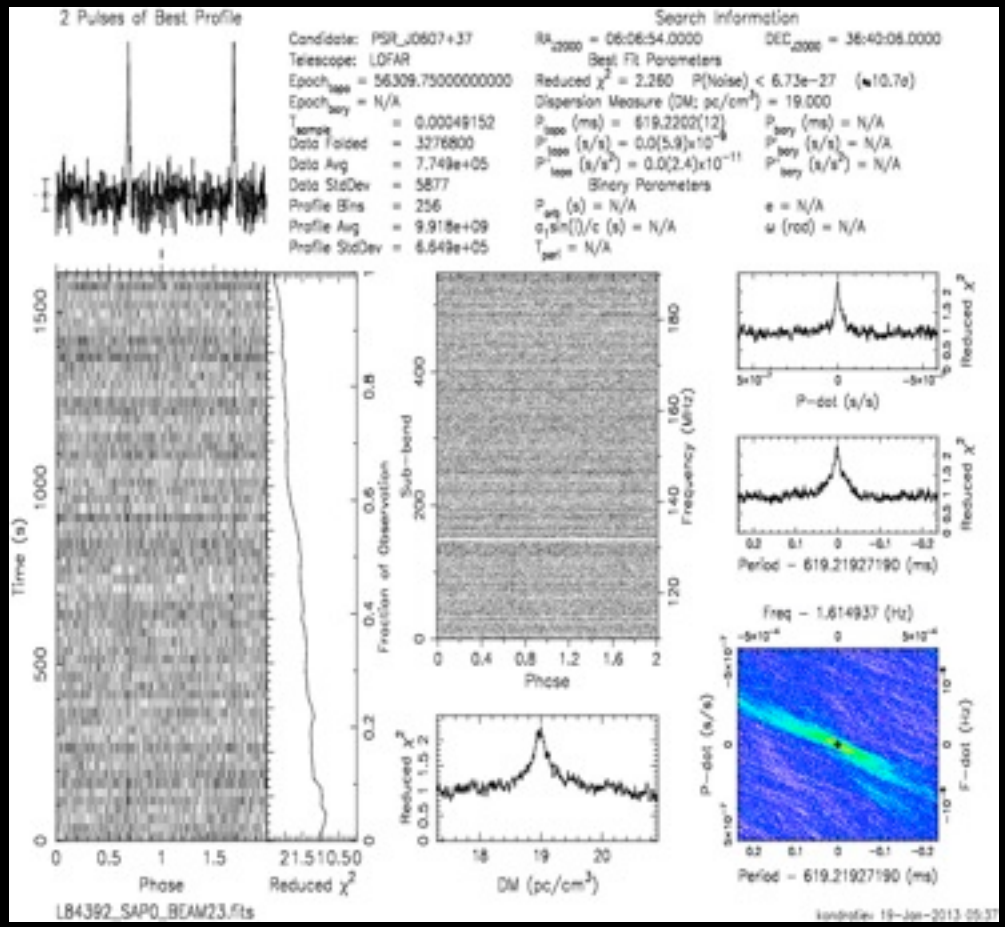
Girard et al.

Inter-planetary Scintillation. Fallows et al.



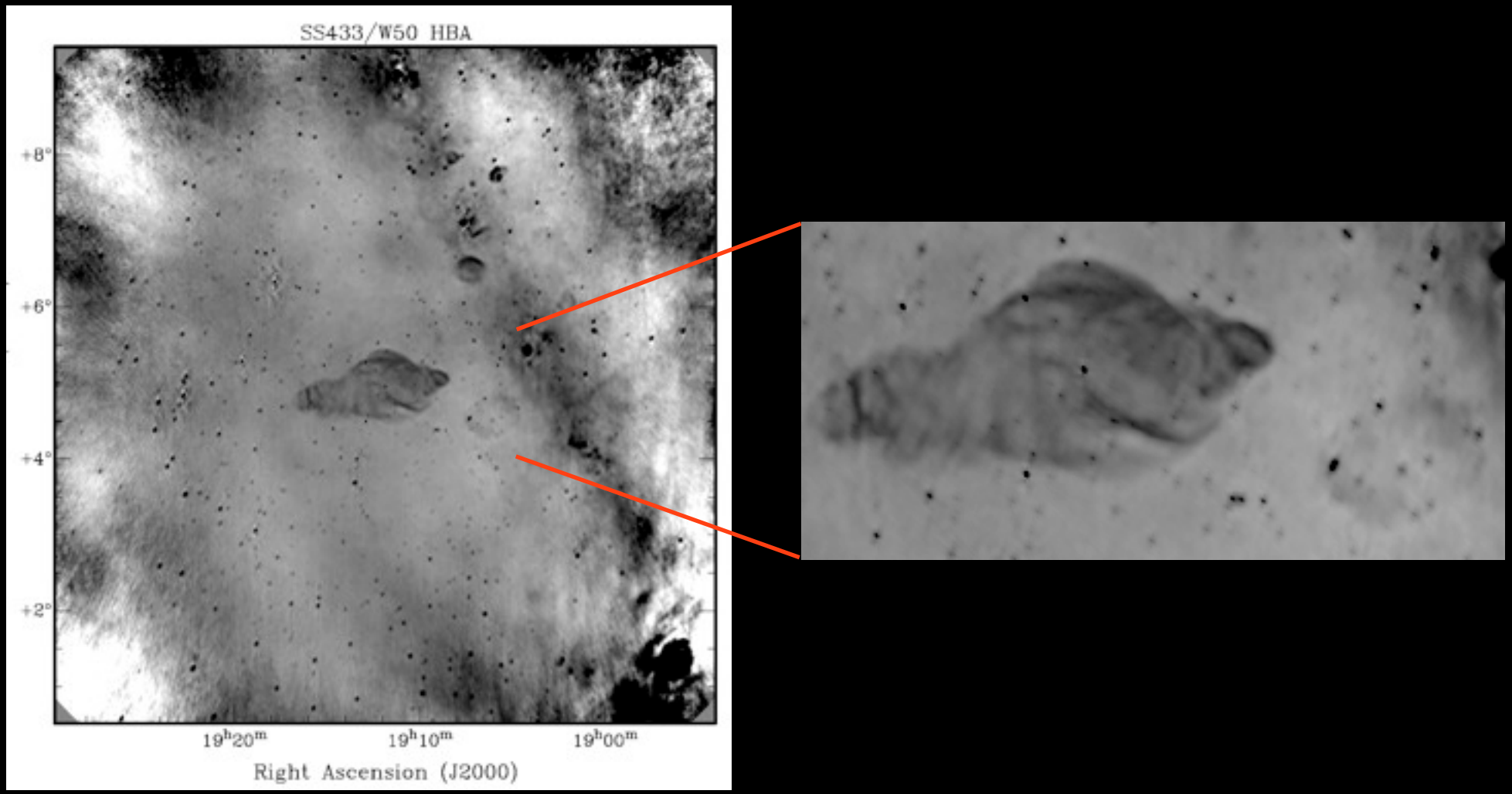
LOFAR: Pulsar discoveries





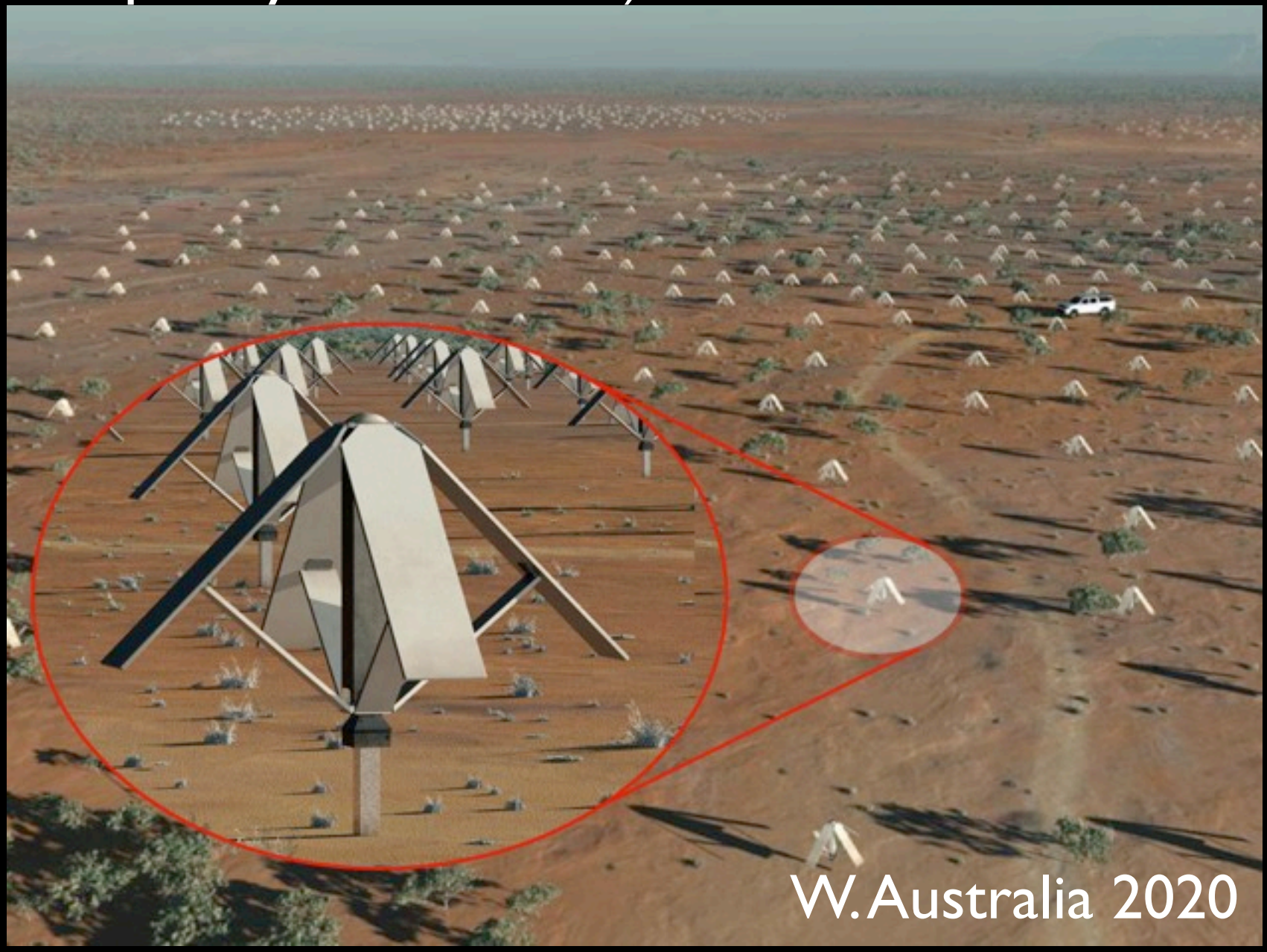
First Pulsars discovered by LOFAR (Dec. 2012 - Hessels et al.)

LOFAR: Galactic Science

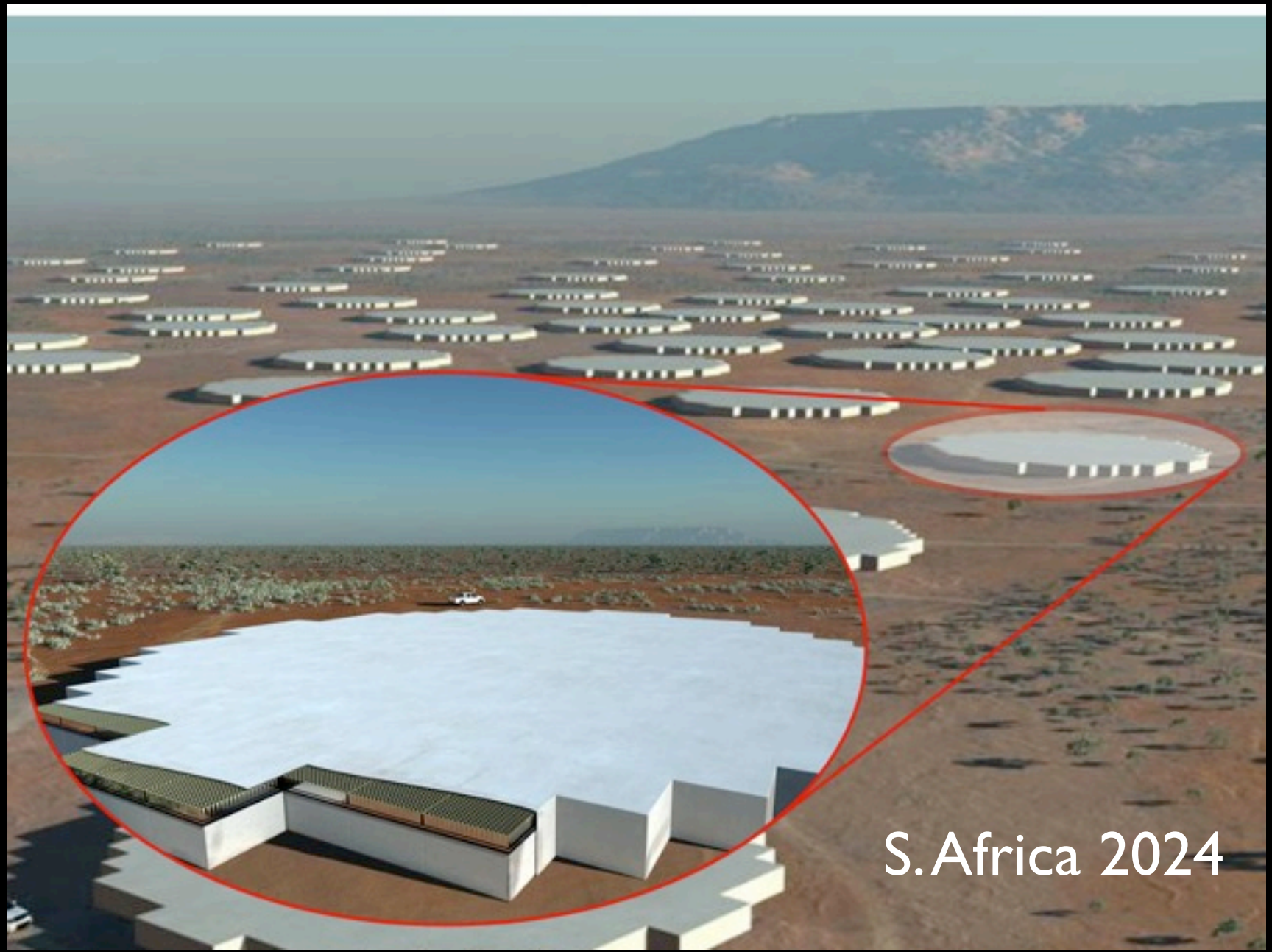


First Pulsars discovered by LOFAR (Dec. 2012 - Hessels et al.)

AAs major component of SKA Phase 1 (Low Frequency < 350 MHz):



AA's major component of SKA Phase 2 in Africa (< 1.4 GHz):



Aperture Arrays & Africa

Africa will host the SKA-2 mid-freq aperture array...

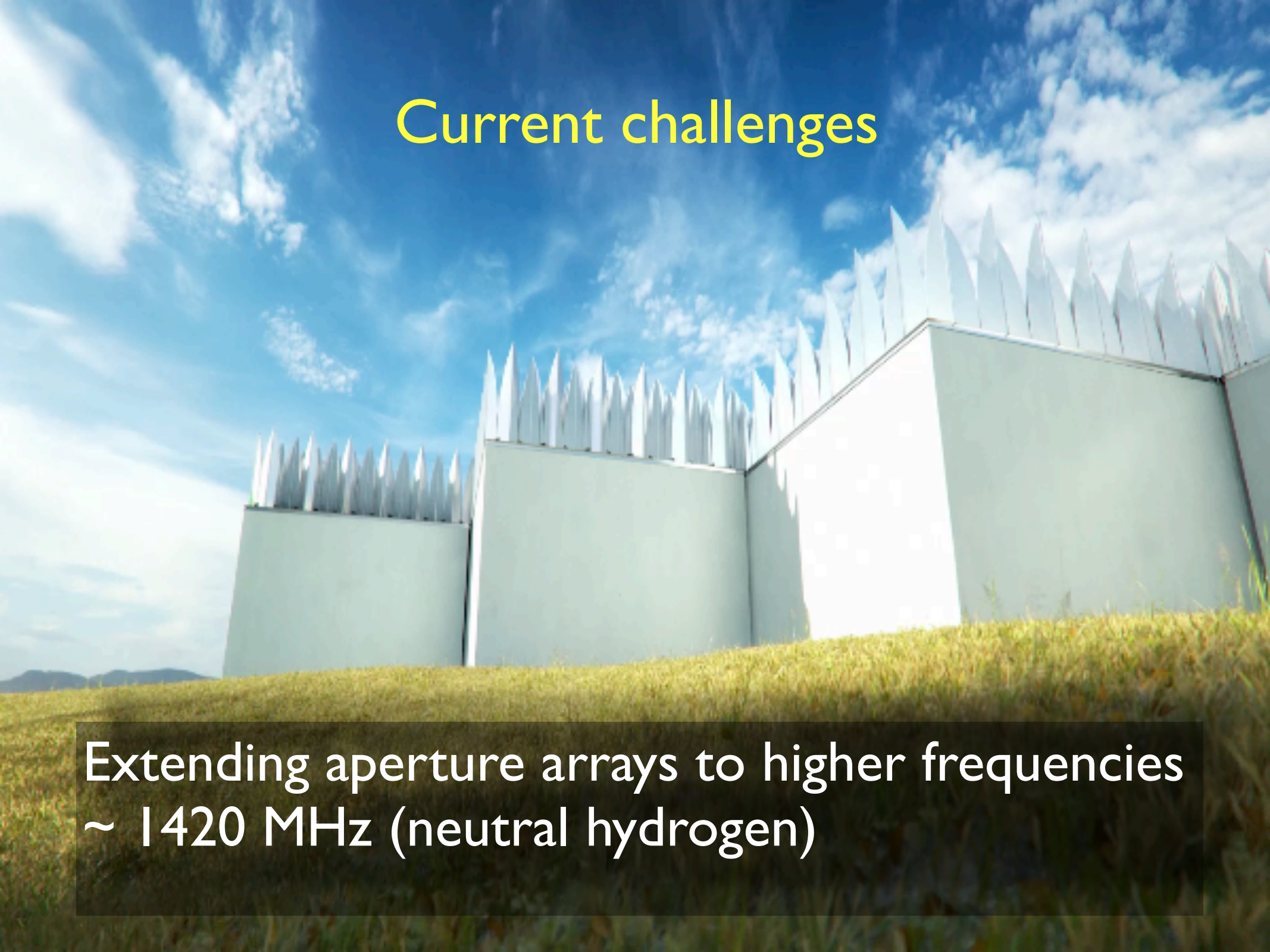
- *SKA-2 is 2024++*

- *Significant R&D, prototyping & demonstration efforts still required*

- *Major SKA-2 AA-mid Precursor needs to be built & tested soon!!!*

- *EC is interested in funding SKA R&D (not nuts & bolts for SKA-1)*

- *AERAP can be a vehicle to unite R&D efforts in Africa, Europe and beyond, and to realise an SKA2 mid-AA Precursor.*



Current challenges

Extending aperture arrays to higher frequencies
~ 1420 MHz (neutral hydrogen)