



## Aperture Array station as an SKA demonstrator

- Intro
- SKA Background
- Aperture Arrays
- Demonstrator
- Summary

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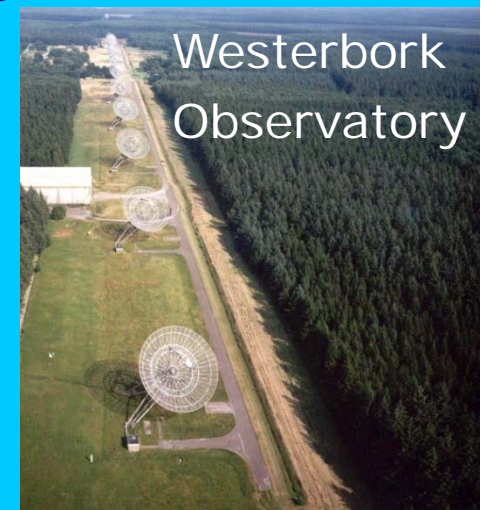
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# Briefly ASTRON



- ASTRON is the Netherlands Institute for Radio Astronomy.
  - Mission: **Making discoveries in radio astronomy happen**
    - Development of novel and innovative technologies
    - Operation of world-class radio astronomy facilities
    - Pursuit of fundamental astronomical research
- Departments:
  - Astronomy Group
  - Radio Observatory
  - Research & Development
- Overall priorities:
  - International LOFAR Telescope
  - SKA (leading role in technology, science & policy)
  - Fundamental research
- ASTRON hosts JIVE (the Joint Institute for VLBI in Europe) and the NOVA Optical/Infrared group.



# SKA dual site, SKA<sub>1</sub> design



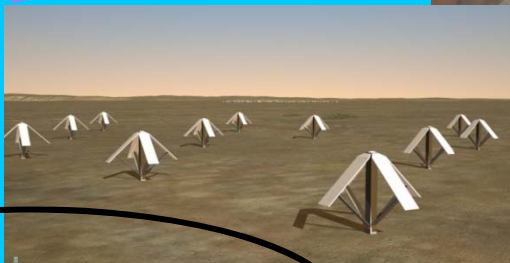
SKA1		SKA2	
SKA1_LOW	ANZ	SKA2_LOW	ANZ
SKA1_MID	RSA	SKA2_MID	RSA
SKA1_SURVEY	ANZ	SKA2_AA	RSA

250 Dishes;  
two designs

Central  
Region



50 Sparse Aperture  
Arrays



Survey capability  
with Phased Array  
Feed's ("PAF's")



Baseline technologies to be demonstrated in the  
SKA Precursors and Pathfinders



# Timeline



1995-00	Preliminary R&D
2000-07	Initial Concept Phase
2008-12	Preparatory Phase <ul style="list-style-type: none"><li>• System design, Site selection</li></ul>
2012-16	Pre-construction Phase <ul style="list-style-type: none"><li>• Detailed design, Production readiness</li></ul>
2016-23	Construction
2020-50+	Operations

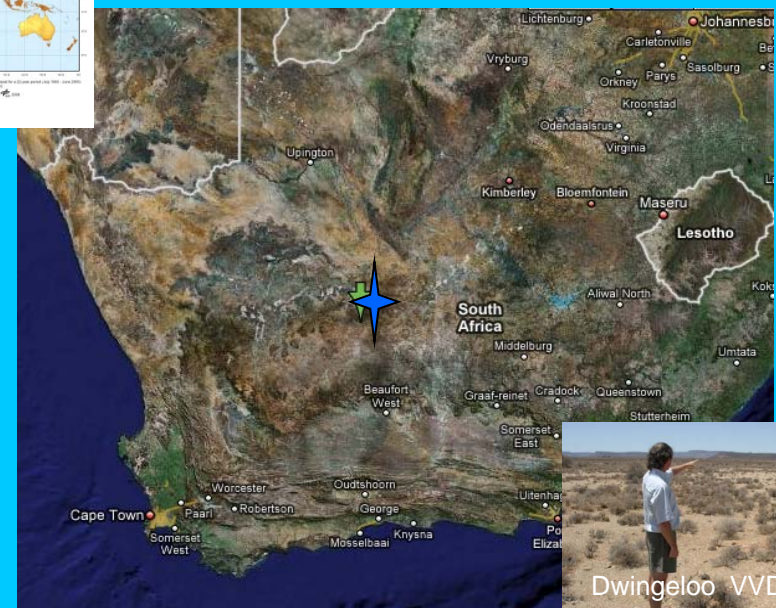
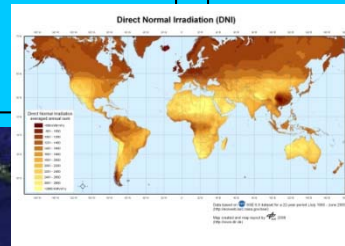
# The Square Kilometre Array; An International Telescope in:



- Technology development from
  - U.S. / Can. TDP (\$12M)
  - EC PrepSKA (EUR 5.5M + matching) + etc.
  - SKADS/AAVP (global)

## ■ Dual Siting:

- (Western) Australia/New Zealand
- South Africa + 7 countries



## **VISION:**

**SKA:** *Green Research Infrastructure of “Smart Antennas” in a wide-area network enabled by intense ICT infrastructure, SW and computing*

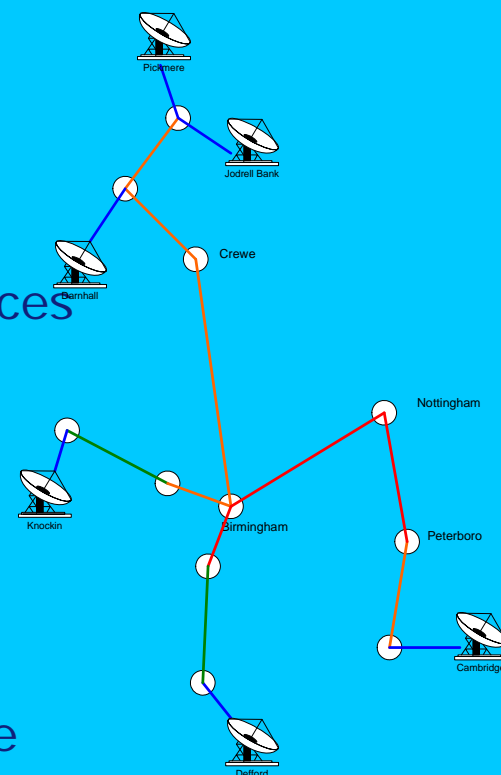
### **Broad Technology schemes:**

- ICT and high-performance computing
- Radio-technology and Embedded systems
- Wide area Sensor network
- Microsystem-technologies e.g. MMIC, RF photonics?
- Supervisory- and System health monitoring systems
- Durable energies, storage and –distribution
- Green Design & Smart manufacturing and –services
- Green High Performance Computing

# SKA: Communications



- Signal transport total  $>1$  Pb/s over few km - few 1000 km  
total  $>1$  Pb/s ..  $>100\times$  world's largest ip exchange  
cf. CERN  $\rightarrow$  T1  $<100$  Gb/s
- Compare with present large data volumes and distances  
EVLA  $\sim 3$ Tb/s 20km  
LOFAR  $\sim 100$ Gb/sec  $\sim 100$ km  
JIVE/e-VLBI  $\sim 10$ Gb/s  $\sim 1000$ km
- Industry: Many low cost field-reliable channels; close integration with digital electronics
- Plus: Monitor & Control and Time/phase synch



# The International LOFAR Telescope; Arrays <300MHz

ASTRON

- Pan-European collaborative project led by ASTRON founded in 2010
- Network combining thousands of simple dipole receivers with powerful digital signal processing and high-performance computing
- LOFAR surveys wide areas of the sky, looking in multiple directions simultaneously and operates at relatively unexplored low radio frequencies
- Opening up a new radio window
- *No green LOFAR station yet*



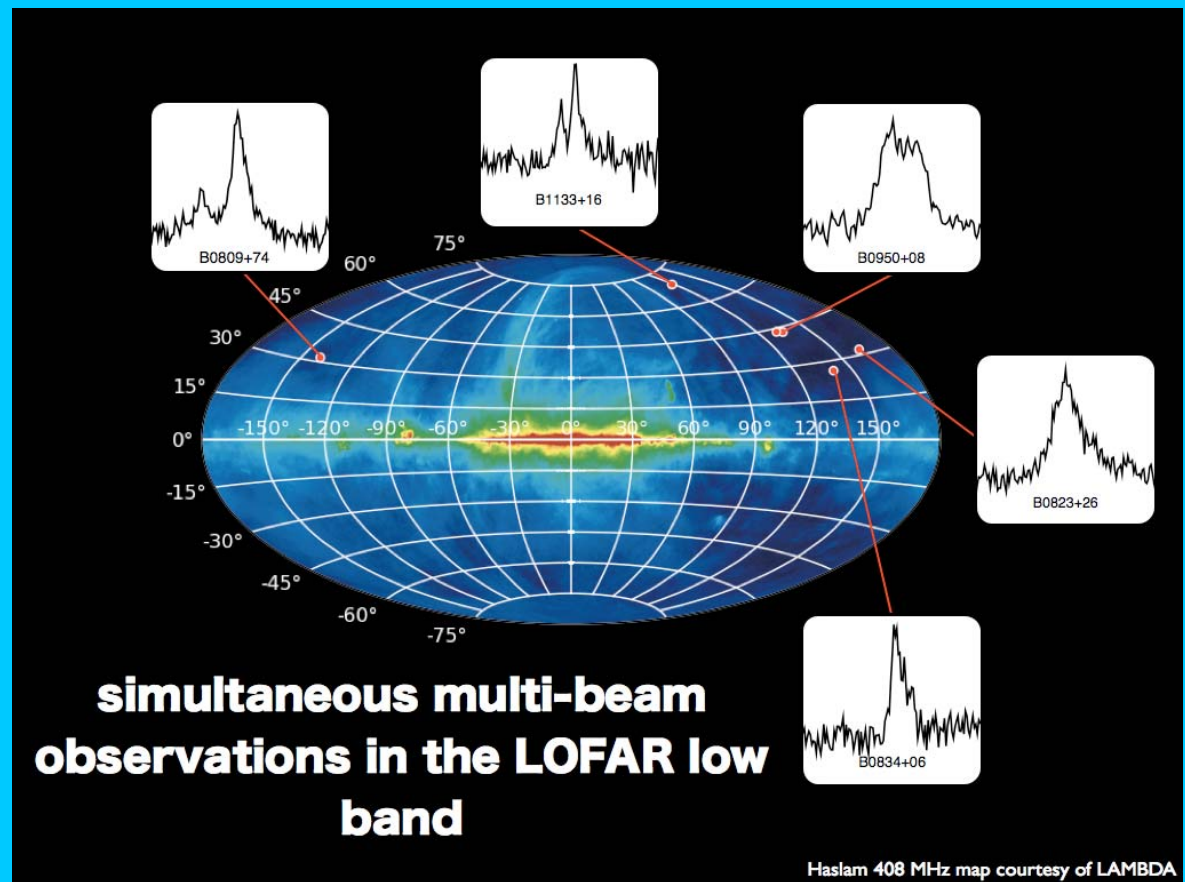






# Aperture Arrays

- Large Field of View
- Multi-directional
- Flexible
- SKA Technology



Hassall et al. 2011

# Low Frequency Arrays: Novel Approaches toward SKA1

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Aperture Array Teststation @Lords Bridge/  
Cambridge Univ.(UK)





# Novel Approaches toward SKA1; Vivaldi measurements with "Hexacopter"

ASTRON

AA Tests @ INAF/  
Torino Univ. (It.)

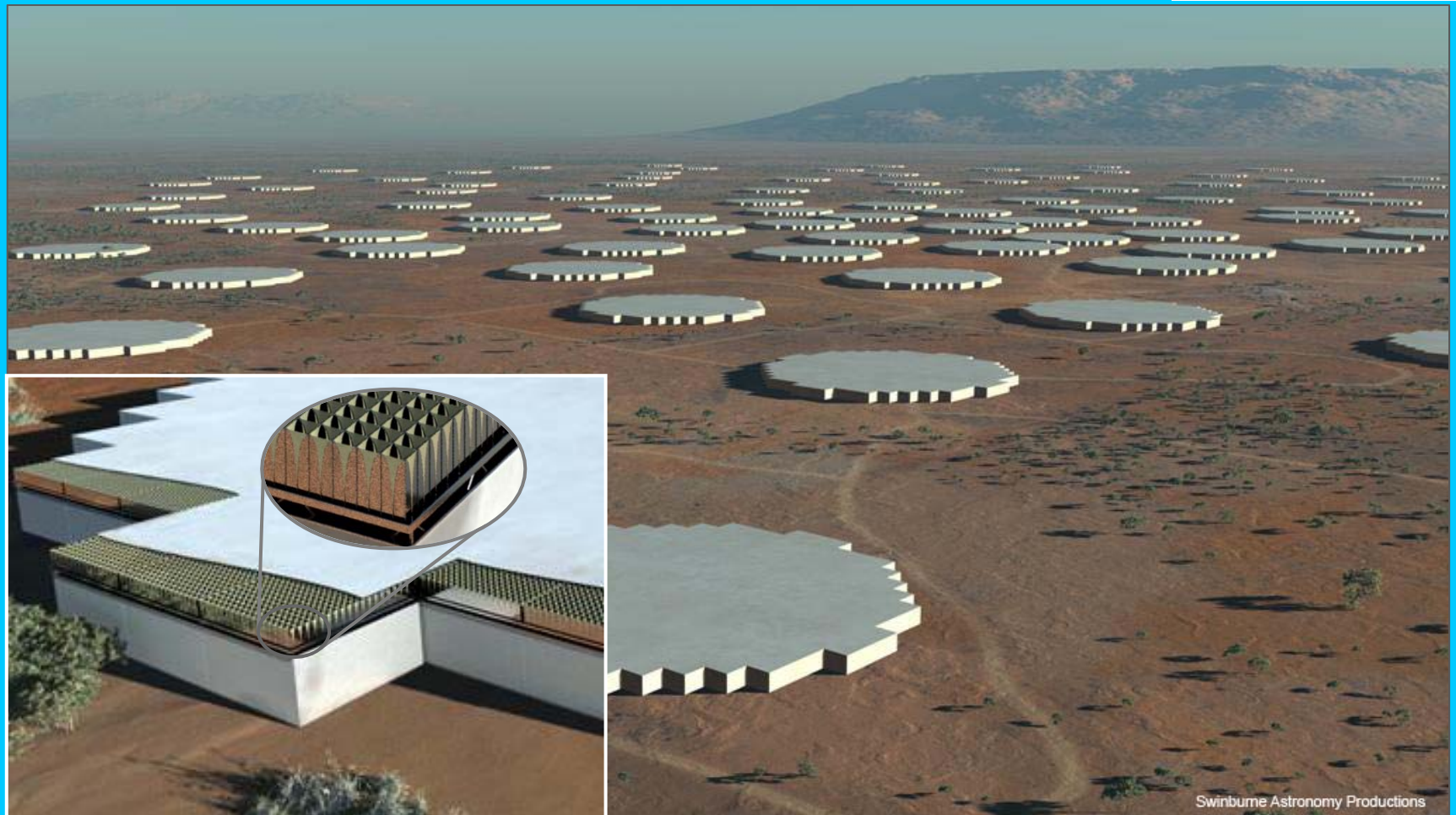


<http://www.mikrokopter.de>





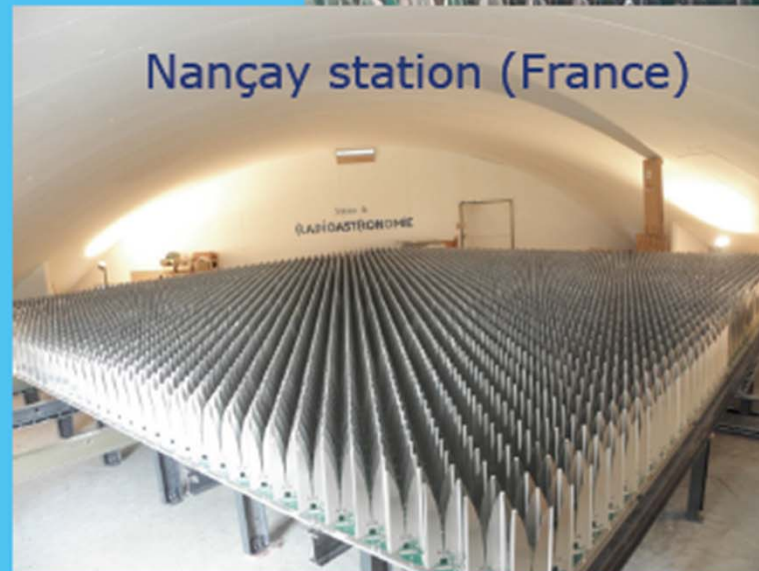
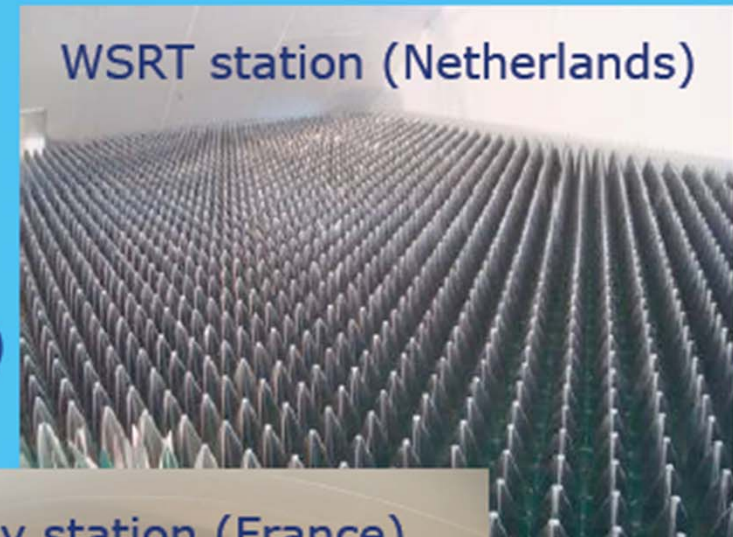
# High Frequency Aperture Array



# From FP7 SKADS: EMBRACE; Worlds first High Freq. AA technical demonstrator

**ASTRON**

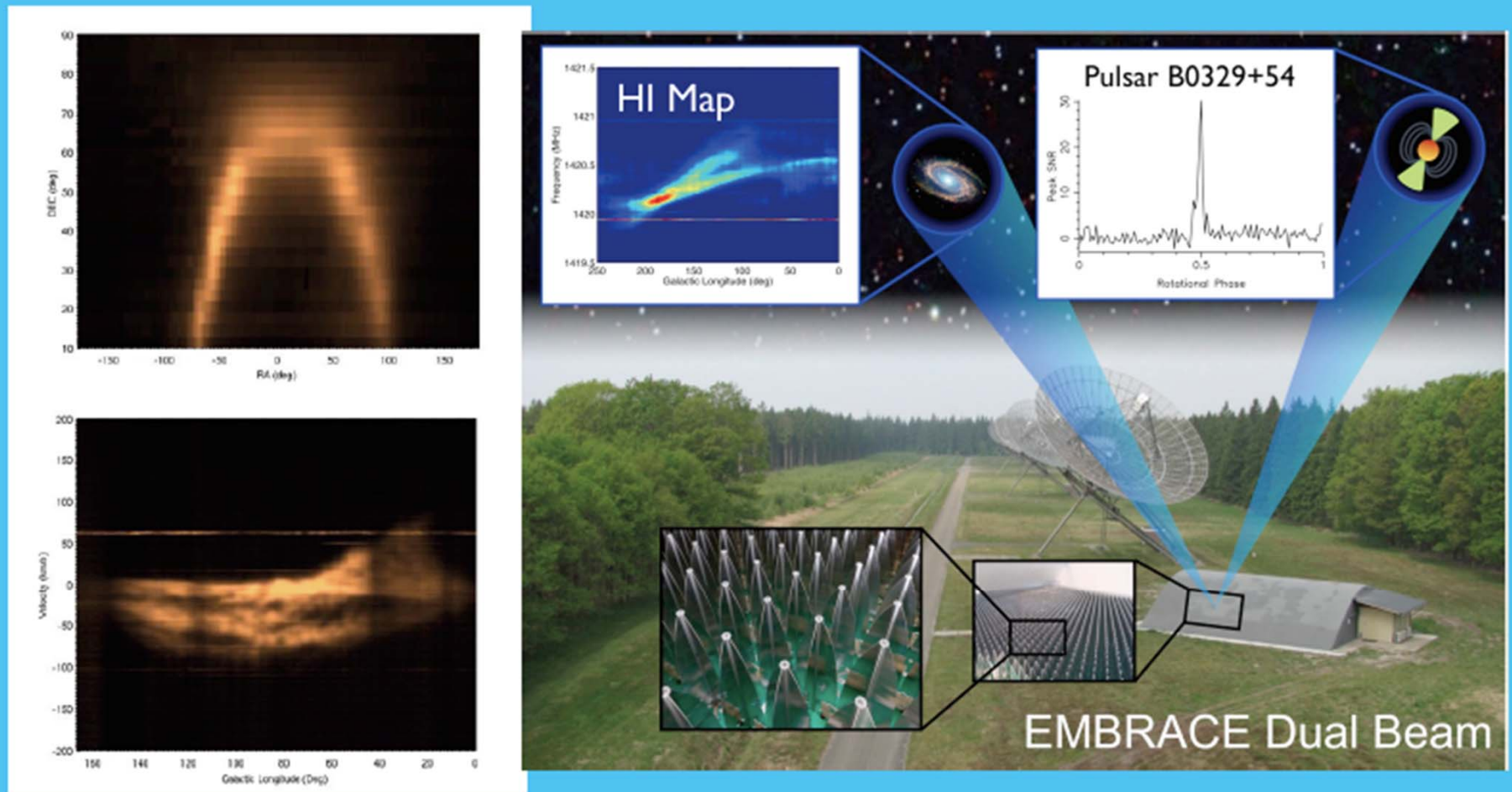
- $A/T \sim 1 \text{ m}^2/\text{K}$
- 400-1500MHz
- TWO analogue beams
- $\sim 200$  digital beams (195.3kHz wide)
- $\sim 40\text{MHz}$  bandwidth
- single pol





# EMBRACE results from WSRT

ASTRON



# The Advanced Instrumentation Program; line-up with Dual site?



- Further development of innovative wide-field *“radio camera”* technologies with the potential to enhance Phase 1 and be a major part of Phase 2:
  - dense aperture array (FoV  $\sim 200 \text{ deg}^2$ )
  - phased array feeds (PAFs) on the dishes (FoV  $\sim 30 \text{ deg}^2$ )
- Development of ultrawideband feeds
- Enhancing SKA<sub>1</sub> and being a major part of SKA<sub>2</sub> ; tbd 2014

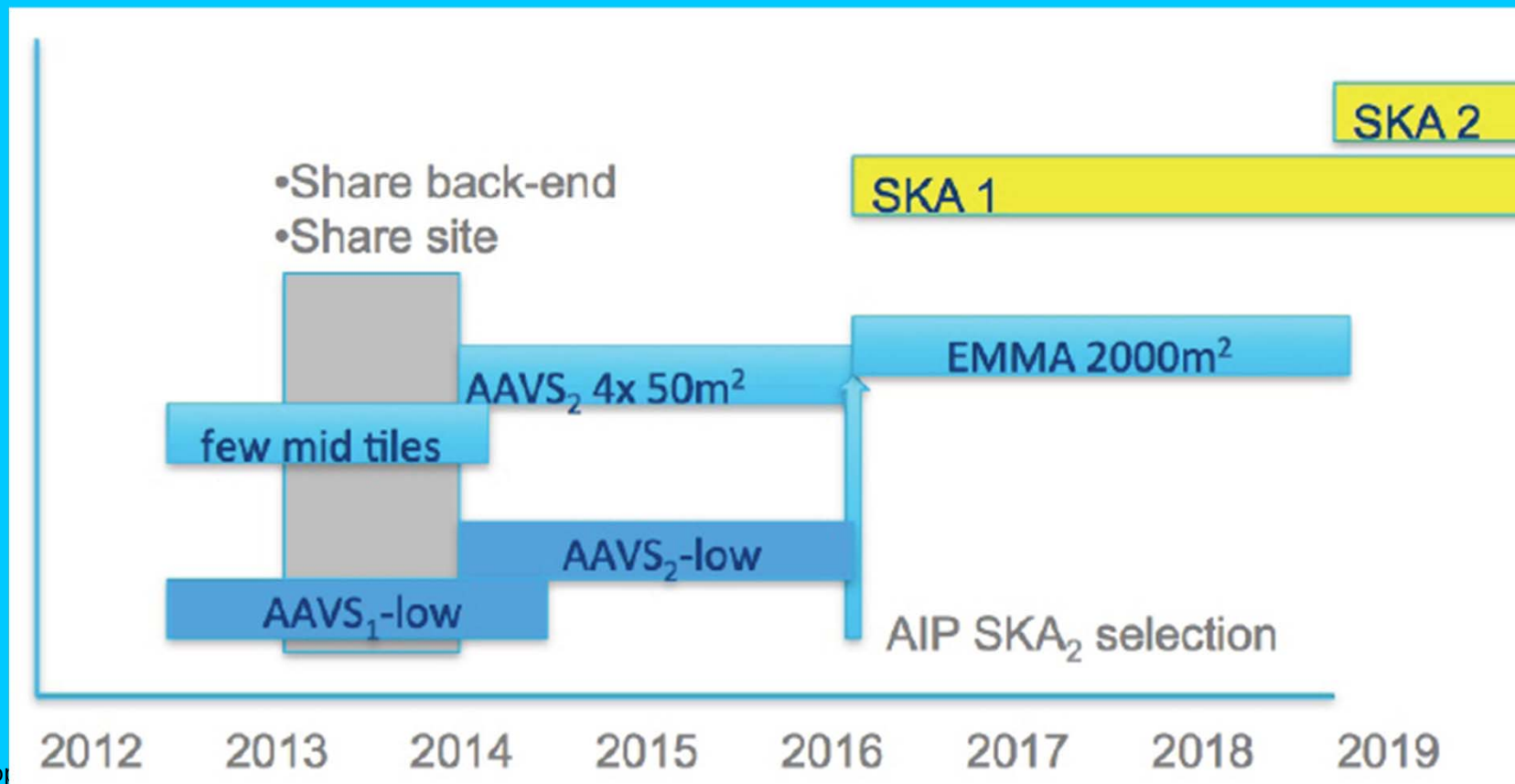
**Decision in 2016; still holds?**



# Aperture Array Demonstrators in SKA timeline



## High Frequency AA pathfinder demonstrator Emulating Single SKA Station



# Limits of EMBRACE

- Imaging Dynamic Range
- Instantaneous Frequency Bandwidth
- Sensitivity
- Polarization
- 
- (post-) Processing
- Technology step

***Closing the gap***  
*Need for science  
capable instrument @ SKA  
station level*

# EMMA; AAVS2-high frequency array demonstrator

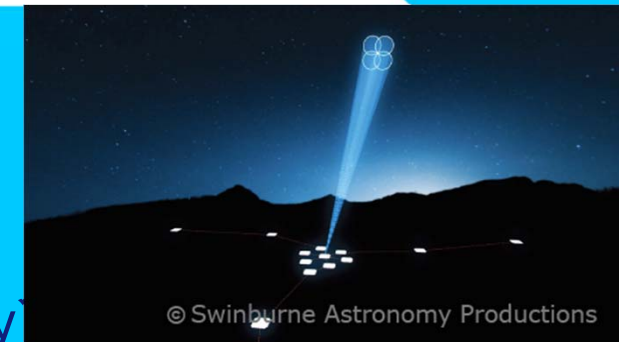
**ASTRON**

- Renewable aperture array radio telescope
- Science capable demonstrator
- Green Energy



# EMMA main goals

ASTRON



- Measure BAO signal (science)
- Transients/ HI local Universe
- Demonstrate imaging capability (technology)
- Minimise environmental impact of Big Science (sustainability)

## ■ Configured as:

- 14 (sub)tations
- 13.5m diam.
- >50% in core
- Max. BL <1km



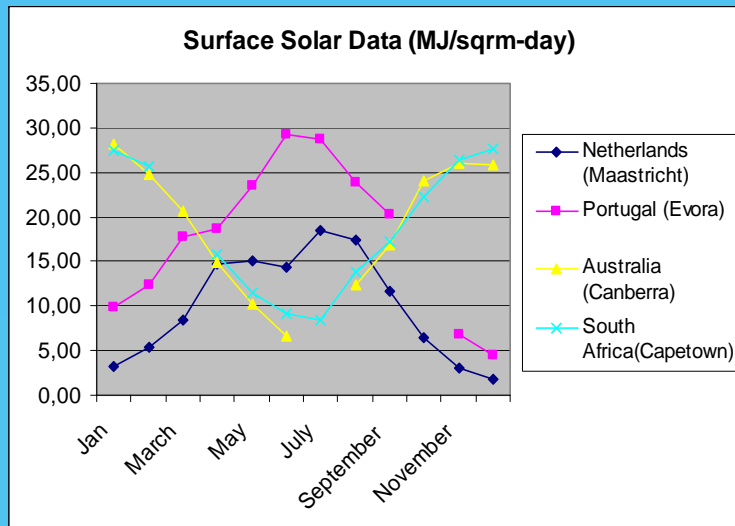
	EMMA	APERTIF	ASKAP	EVLA	MeerKAT-1
Frequency (GHz)	0.450-1.45	1.0-1.7	0.7-1.8	1.0-50	0.9-1.75
Bandwidth (GHz)	0.5 (1.0)	0.3	0.3	0.5 (8.0)	0.35
FoV (deg <sup>2</sup> , 1.4GHz)	78	8	30	0.3	0.6
$z_{\text{max}}$ for HI absorption	2.16	0.42	1.03	0.42	0.58
$S_{\text{rms}}$ (μJy, 1h, full BW)	37 (27)	30	35	7.6	14.6
$S_{\text{rms}}$ (μJy, 1h, 100MHz)	84	49	61	17	27
$S_{\text{rms}}$ (mJy, 1h, 5 km/s)	5.5	3.7	4.0	1.1	1.8
A/T (m <sup>2</sup> /K)	40	105	58	246	150
SSFOM x10 <sup>4</sup> (m <sup>4</sup> /K <sup>2</sup> / deg <sup>2</sup> )	12.5	8.9	13.8	1.8	1.4
SSL( $\tau < \tau_0$ )/N <sub>t</sub>	1	0.92	0.73	5.3	5.6



# Possible location:

ASTRON

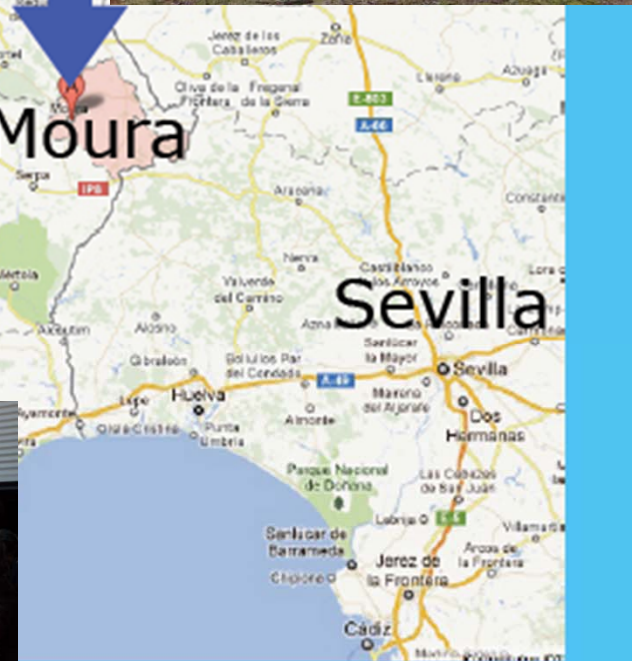
- SKA site
- EU site



Lisboa

Moura

Sevilla



# EMMA main specs

ASTRON

- 2000 m<sup>2</sup> (A/T ~ 40 m<sup>2</sup>/K)
- Multiple stations
- Full Stokes
- 2 FoV, 64 digital beams
- ~80 deg<sup>2</sup> per FoV
- 450 – 1450 MHz
- T<sub>sys</sub> ~ 50K
- Bandwidth 500 MHz

SKA single station



Derek McKay-Bukowski

# Participants

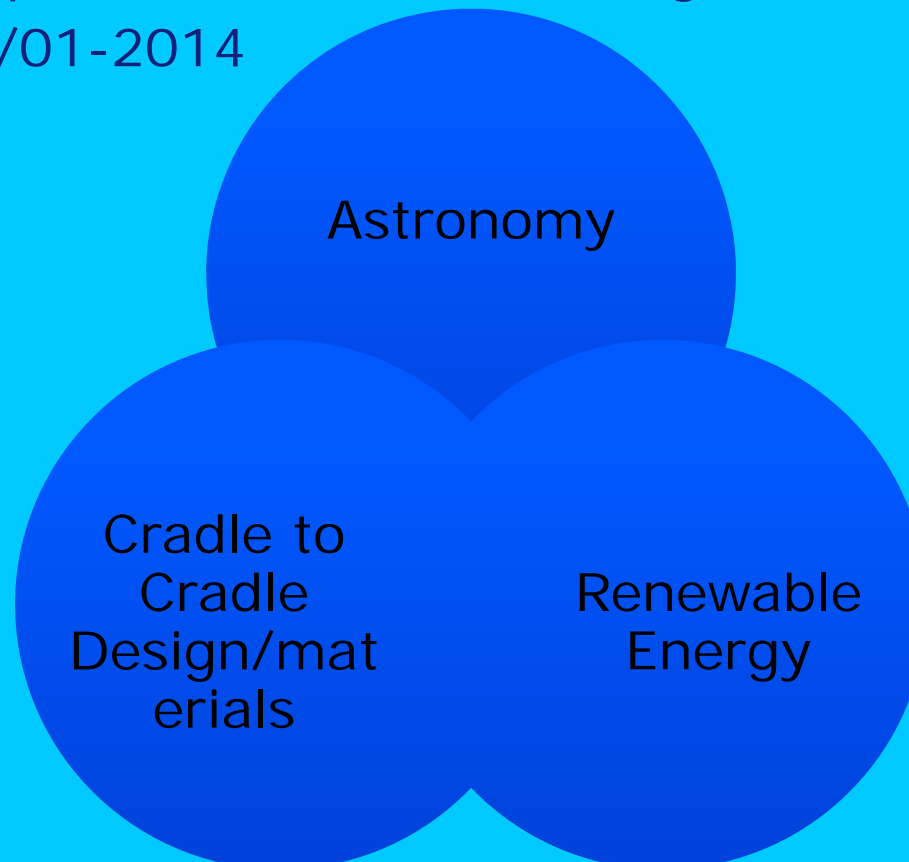


- Technical Developments
  - ASTRON
  - Observatoire de Paris/ Nancay Obs.
  - IRA/INAF
  - UK
  - Spain/Portugal green energy, site?
- Science team in the making
- EC funding opportunities being explored (FP7,H2020)





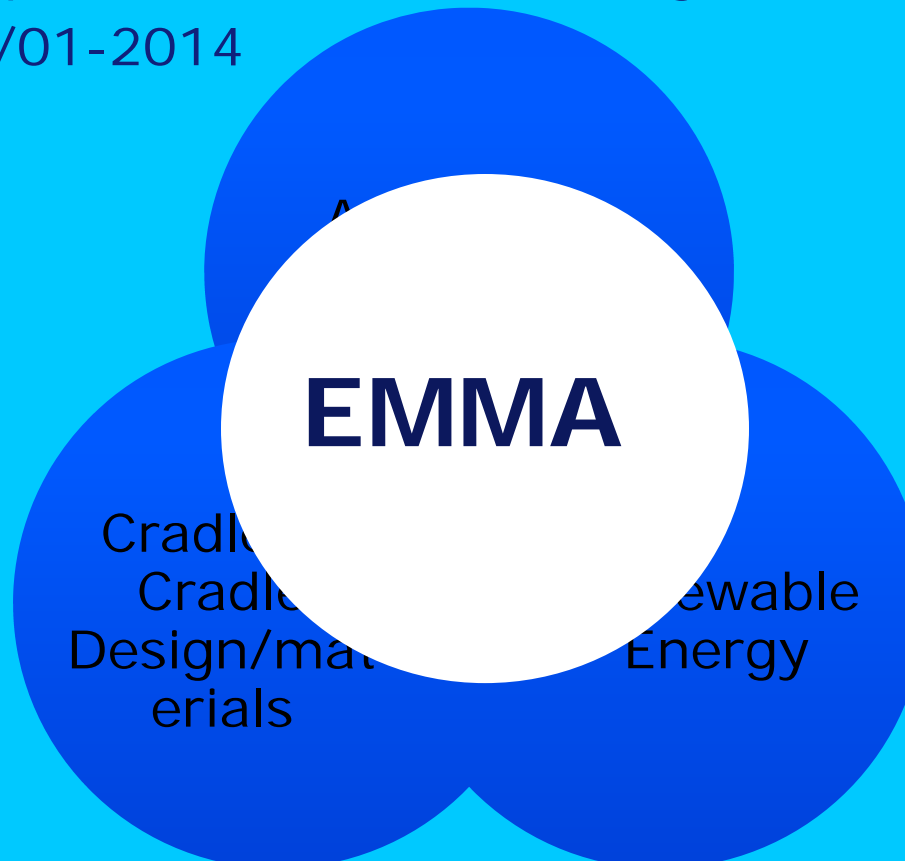
- Bringing 3 Scientific Disciplines together that create a breakthrough not achievable by the individual disciplines
- Timeline Proposal construction/writing etc. 2012/2013, to be funded 2013/01-2014



Courtesy:

Ilse van Bemmelen, André van Es

- Bringing 3 Scientific Disciplines together that create a breakthrough not achievable by the individual disciplines
- Timeline Proposal construction/writing etc. 2012/2013, to be funded 2013/01-2014



## Summary:

- AA-Demonstrator proposal in the making
- Synergy is starting point
- Hope (some of) you will be part(ner)!