

An aerial photograph of a vast desert landscape filled with numerous circular, white, stepped structures. These structures are arranged in a grid-like pattern across the reddish-brown terrain. In the foreground, a white SUV is parked on a dirt road next to one of the larger structures. The background shows a clear blue sky and distant mountains.

Aperture Array Science Case

Ilse van Bemmelen

1. Cradle of life
2. Fundamental physics tests
3. Cosmic magnetism
4. Galaxy evolution and cosmological parameters
5. Epoch of Reionization

Carilli & Rawlings 2004 (Science with SKA)

Big Four (defined by Joe Lazio):

1. Baseline coverage
2. Frequency range
3. Point source sensitivity = A/T
4. Survey speed = $(A/T)^2 \times \Delta\Omega$

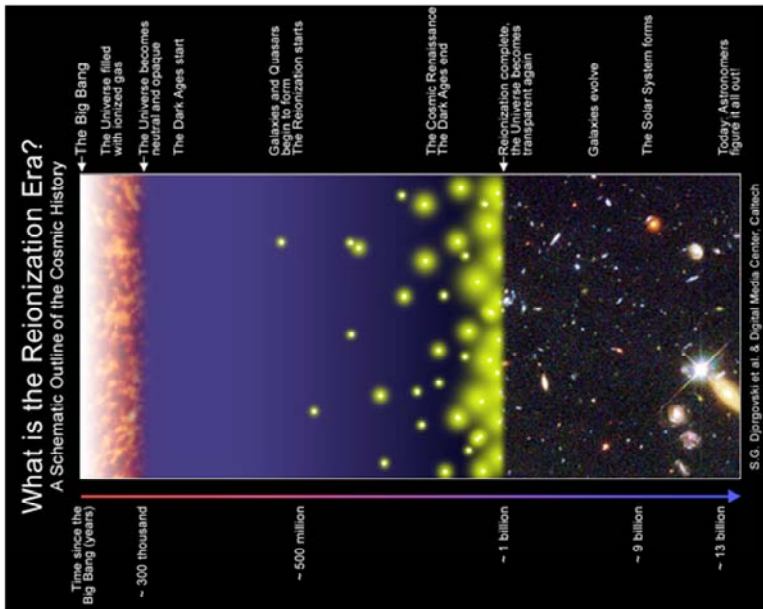
Additional requirements:

- Frequency resolution
- Instantaneous bandwidth
- Time resolution
- Spectral dynamic range
- Polarization purity

Discuss science with strongest constraints:

- Epoch of reionization
 - Statistical detection and tomography of EoR
 - Cosmic magnetism
- Galaxy evolution and cosmological parameters
 - HI from $z=0$ to $z=6$ (absorption and emission)
 - Cradle of life
- Fundamental physics tests
 - Gravitational waves
 - Theory of gravity
 - Cradle of life

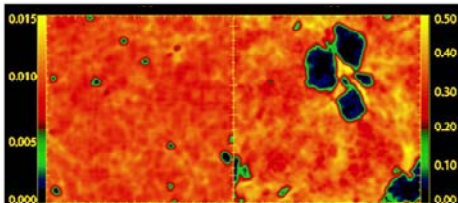
Epoch of Reionization



Field (20Mpc)

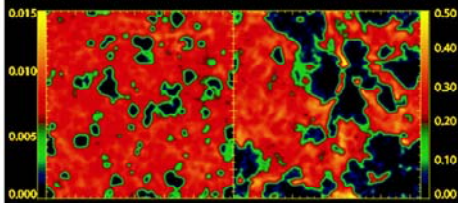
Cluster (10Mpc)

$z = 15.5$



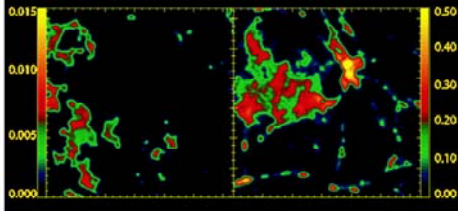
86 MHz

$z = 12$



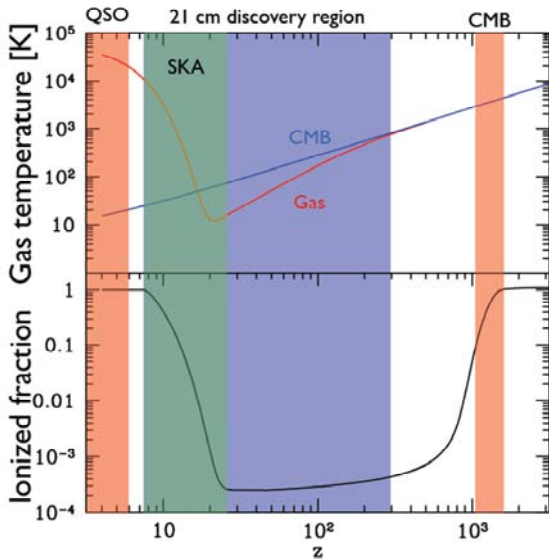
109 MHz

$z = 9$



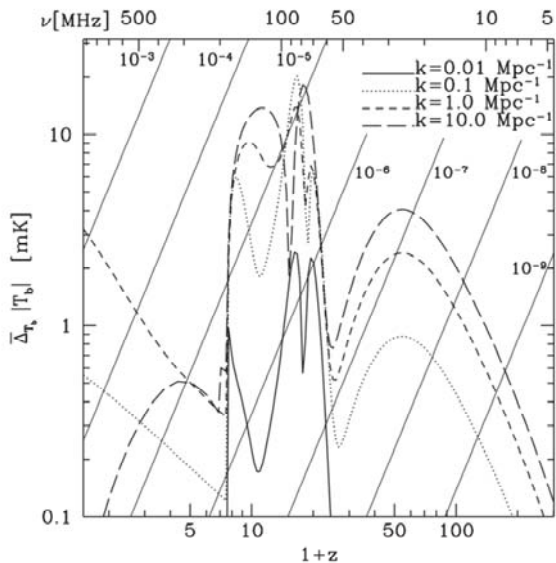
142 MHz

Ciardi et al 2003

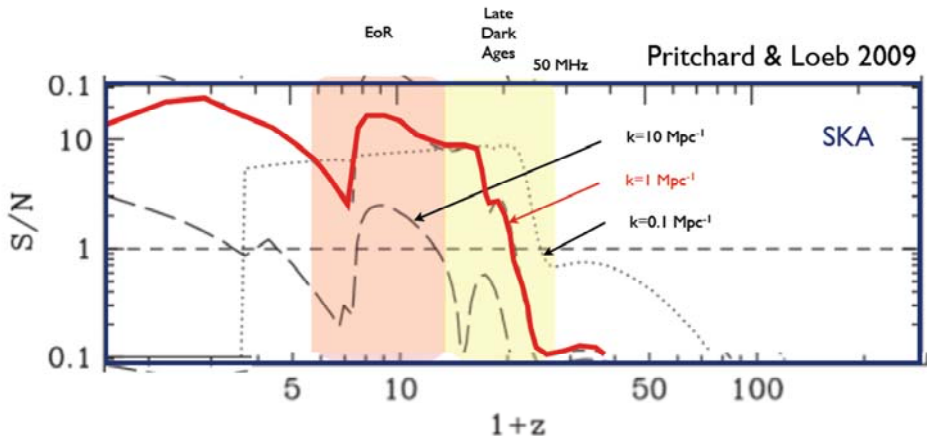


All-sky
Total intensity

Pritchard (Cambridge AAVP meeting 2010)



Pritchard & Loeb 2008



$$t_{\text{obs}}=1000\text{h}; \text{BW} = 1\text{MHz}; A_{\text{core}} = 0.6\text{km}^2$$

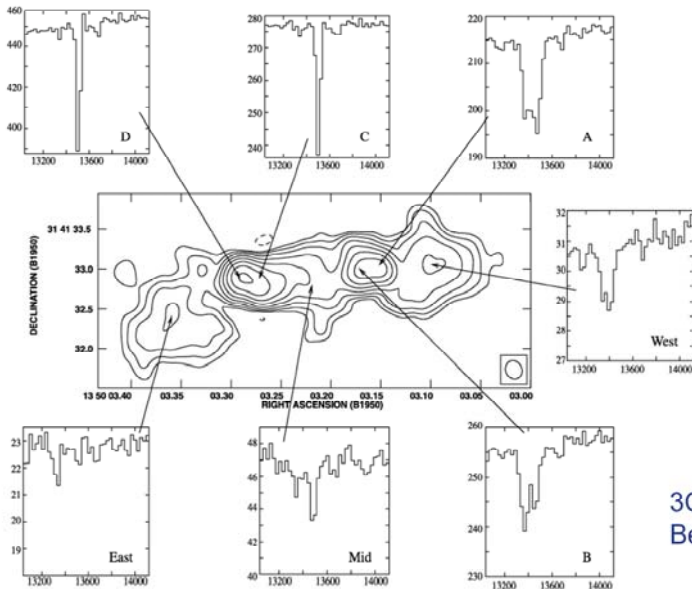
Remove all 'contaminations':

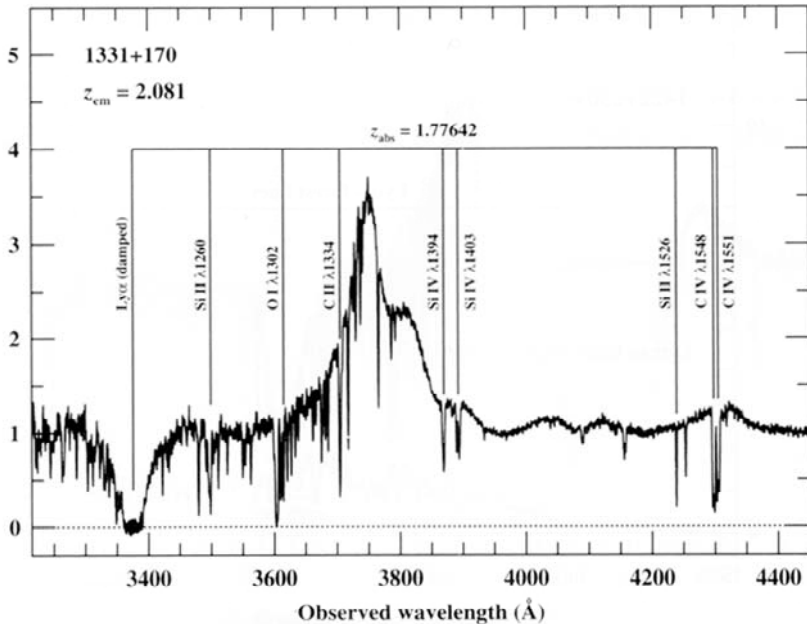
- RFI: time & frequency
- Ionosphere: time and uv-coverage
- Galactic foreground: large scale, polarized
- Intervening galaxies: small scale

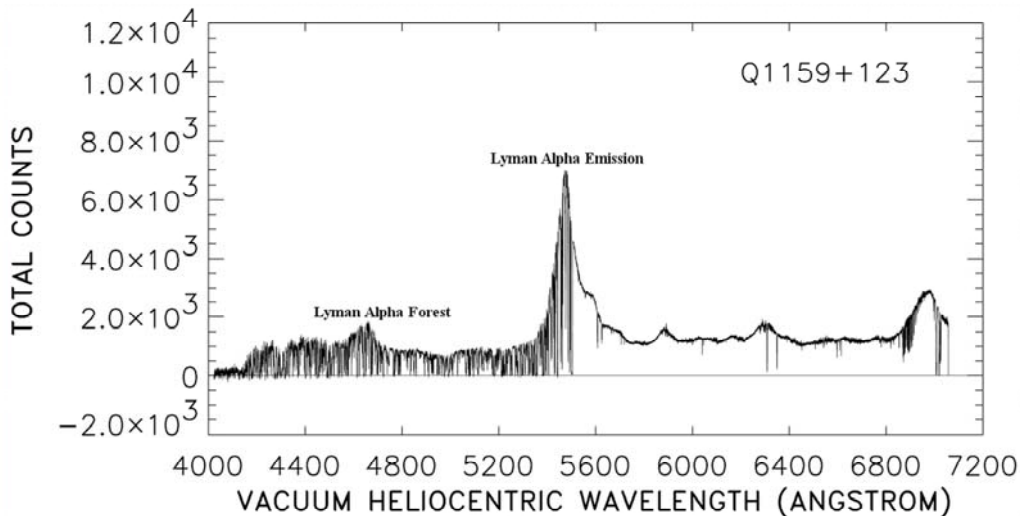
Also driven by calibration requirements!

Parameter	Value	Requirement
Frequency	70-240 MHz	Redshift coverage
Bandwidth	$\Delta\nu/\nu \sim 1$	Foreground, ionosphere
Frequency resolution	1 kHz	RFI, ionosphere
Max. baseline	5km core	Angular resolution
Polarization	Full	Foreground
Sensitivity	$>1000 \text{ m}^2/\text{K}$	Brightness temperature

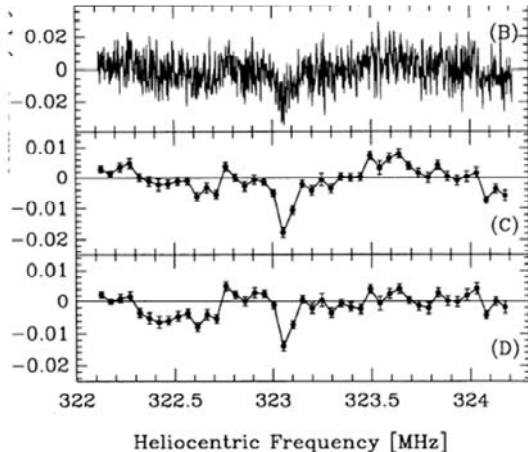
Neutral hydrogen







- Local Universe: 1420MHz
 - $z=2$: 473 MHz and at $z=5$: 236 MHz



$z=5$ regularly

riggs ea 1993, A/T~700)

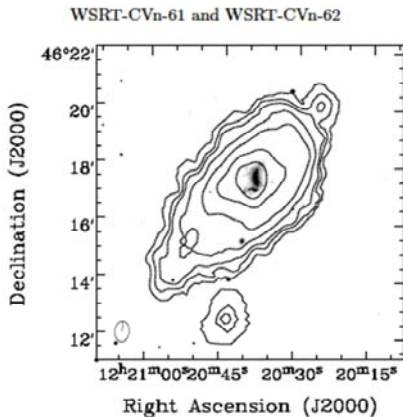
rs (400 sq degree):

10Jy

Search for faint signatures

- Lowest mass HI galaxies
N4288 and HI companion

Kovac et al (2009)

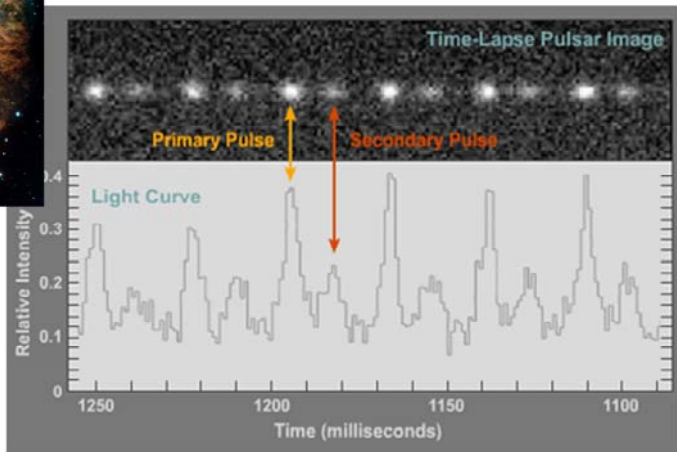
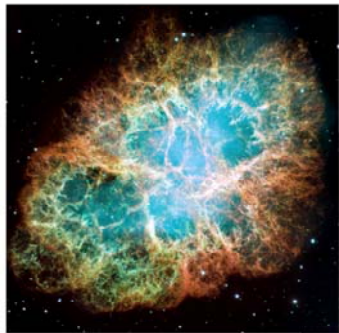


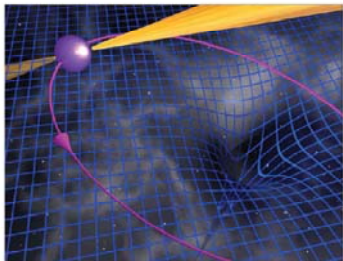
- Imaging the cosmic web ($<10^{17} \text{ cm}^{-2}$)

- Sensitivity (A/T)
 - Large FoV
 - Spectral dynamic range
 - RFI
 - Ionosphere (lower frequency)
- } Survey speed = $(A/T)^2 * \Delta\Omega$

Parameter	Value	Driver
Frequency	200-1450 MHz	Redshift range 0 – 6
Frequency resolution	5 kHz (~8 km/s)	Velocity resolution
Spectral dynamic range	43 dB	Optical depth sensitivity
Survey speed	$\sim 10^7 \text{ deg}^2\text{m}^4/\text{K}^2$	Sky coverage
Spatial resolution	$\sim 1''$ or better	Identification
Point source sensitivity	$> 1000 \text{ m}^2/\text{K}$	Detection at $z \sim 3$

Pulsars





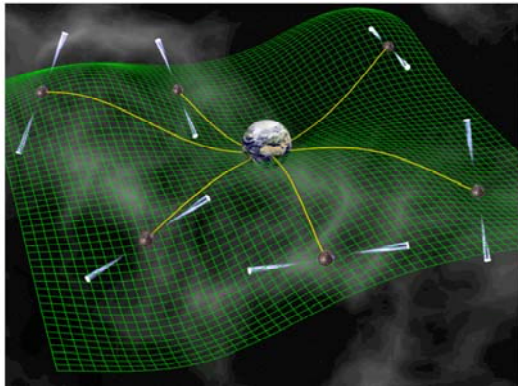
Gravitational wave detection:

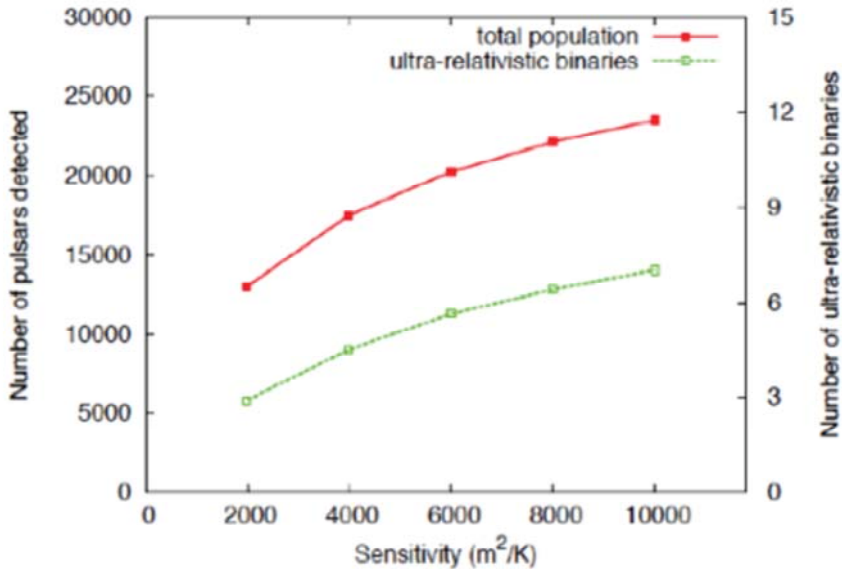
- More ms-pulsars: all-sky survey
- High precision timing: pointed observations

Theory of gravity test:

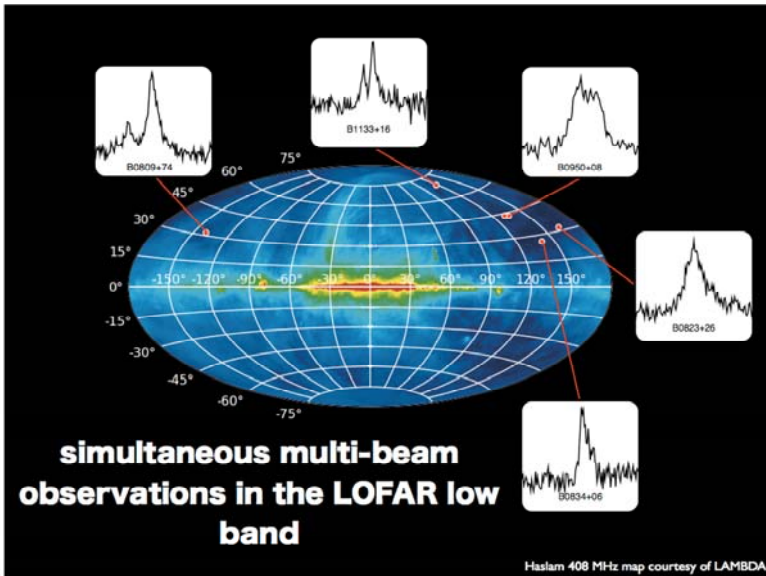
- Relativistic binary pulsars: all-sky survey
- High precision timing: pointed observations

- Search for ms pulsars at high frequencies
- Measure ISM properties at low frequencies
- Time pulse arrival (<10 ns accuracy)
- Many sources
- Long term program

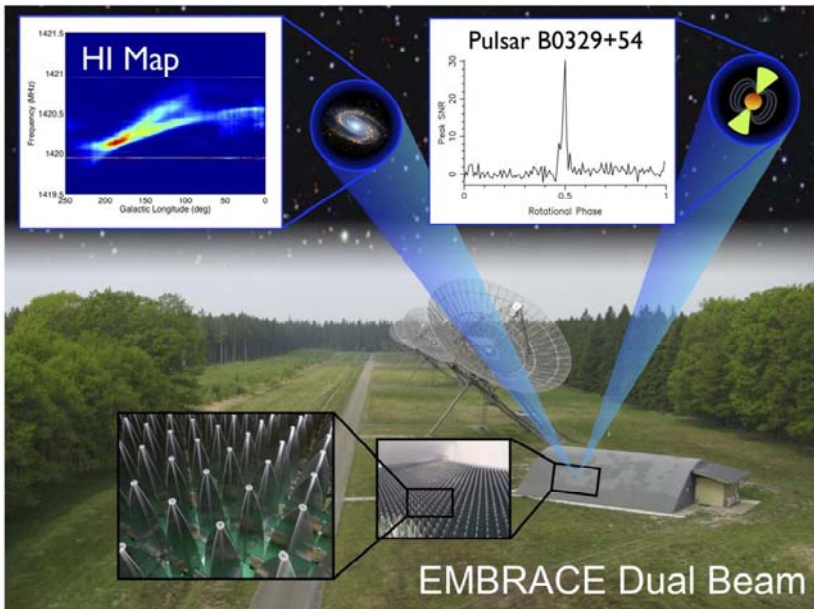




Stappers, Cambridge AAVP 2010



Hassall & LOFAR Pulsar Working Group, 2010



Parameter	Value	Driver
Frequency	350-3000 MHz	Spectrum, ISM
Polarization purity	40 dB	Timing precision
Sensitivity	1000 m ² /K	Pulsar brightness
Frequency resolution	<10 kHz	ISM effects
Time resolution	50 μs	Pulsar cycle
Array layout	high filling factor	Brightness, processing

Summary

- Cradle of life
- Cosmic Magnetism
- Gamma Ray Bursts
- Lensing experiments
- Baryonic Acoustic Oscillations
- Big Unknown

Parameter	EoR	HI	Pulsars
Baseline (km)	5	3000	5 (high ff)
Frequency (MHz)	70-240	200-1450	350-3000
Sensitivity (m^2/K)	>1000	>1000	1000
Survey speed	> 10^7	10^7	> 10^7
Frequency resolution (kHz)	1	5	<10
Bandwidth ($\Delta\nu/\nu$)	~ 1	~ 0.01	N.A.?
Time resolution	\sim second	\sim second	50 μ s
Spectral dyn. Range (dB)	?	43	N.A.
Polarization purity (dB)	-30	N.A.	-40

Parameter	AA-lo	AA-mid
Baseline (km)	5-1000	5-3000
Frequency (MHz)	70-450	450-1450
Sensitivity (m^2/K)	>1000	>10000
Survey speed	> 10^7	> 10^8
Frequency resolution (kHz)	1	5
Bandwidth ($\Delta\nu/\nu$)	~ 1	~ 0.01
Time resolution	50 μ s	50 μ s
Spectral dyn. Range (dB)	43	43
Polarization purity (dB)	-40	-40

"We haven't the money, so we've got to think."

— *Ernest Rutherford*