S K A

Square Kilometer Array

The future of radio astronomy

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Parameter	Design Goal
A_{eff}/T_{sys}	2×10^4 m^2K^{-1}
Total Frequency Range	f = 0.15 - 20 GHz **(35 GHz ?)**
Imaging Field of View	1 square degree at 1.4 GHz
Independent Beams	> 4
Maximum Primary Beam Separation low frequency high frequency	 100 degrees 1 degree at 1.4 GHz
Angular Resolution	0.1 arcsec at 1.4 GHz
Surface Brightness Sensitivity	1 K at 0.1 arcsec (continuum)
Instantaneous Bandwidth	0.5 + f/5 GHz
Number of Spectral Channels	10^4
Number of Simultaneous Frequency Bands	2
Imaging Dynamic Range	10^6 at 1.4 GHz
Polarization Purity	-40 dB

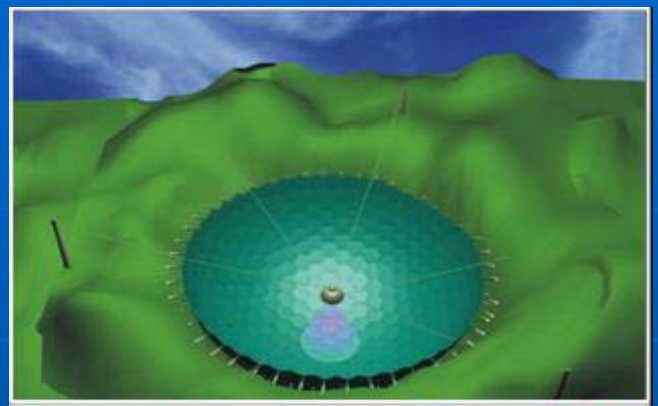
The EU SKA Consortium

- Signed by over 10 European institutes on 1 July 2000
  - _ yearly meetings
  - Monthly Telephone conferences
  - Chair and Secretariat office in place
- Institutes:
  - Jodrell Bank Observatory and Merlin — UK
  - ASTRON and JIVE — Neth.
  - Observatoire de Bordeaux — France
  - Torun Center for Astronomy — Poland
  - CNR Institute for Radio Astronomy — Italy
  - Onsala Space Observatory — Sweden
  - Internat. Astronomical Obs.at Yebes — Spain
  - Metsahovi Radio Observatory — Finland
  - Max Planck Institute for Radio Astronomy — Germany

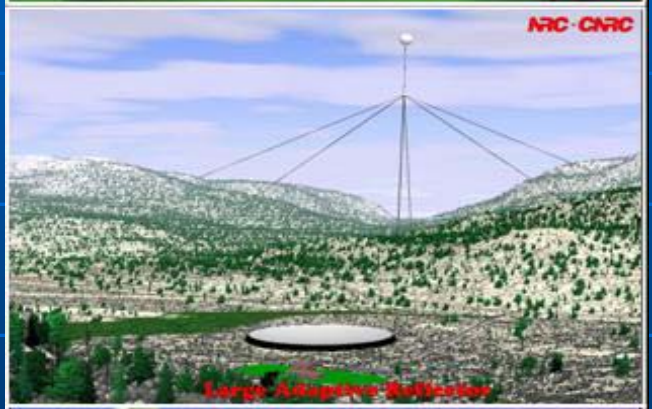
SKA Concepts

- *Small parabolic mirrors*
  (India, USA, Australia)
- *Large cylindrical mirrors (Australia)*
- *Large spherical mirrors ("KARST") (China)*
- *Large flat spherical mirrors + aerostat - supported receiver cabin ("LAR") (Canada)*
- *Aperture array (Netherlands / Europe)*

SKA Concepts



China: KARST



Canada: LAR

USA: ATA

Europe:
Phased Array

Table 1. **SKA concepts** (status: Sep. 2005), compiled by R.Beck

	Large D			Small D		New Technology
	China KARST	Canada LAR	Australia Cylindrical	India Preloaded	USA Off-axis Cass.	Europe Phased Array
Telescope diameter [m]	200	200	110×15	12	12	—
Telescope number	≈30	≈60	≈600	≈8000	≈4000	$\approx 10^5$
Stations	—	—	≈600	≈100	≈150	≈100
Max. baseline [km]	300	1000	3000	500	5000	4000
UV coverage	very low	low	high	very high	very high	very high
Field of view [deg^2] at λ21cm	0.5 (foc.plane array)	≤1 (foc.pl.array)	48 (foc.pl.array)	1	1	10–65 4 independent beams
Mapping speed [deg^2/h]	0.0012	0.6–150	200–12800	1	2–600	74
Frequency range [GHz]	0.2–6	0.1–22	0.1–22	0.15–10 (20)	0.1–35	0.12–1.5

Proposed SKA Sites

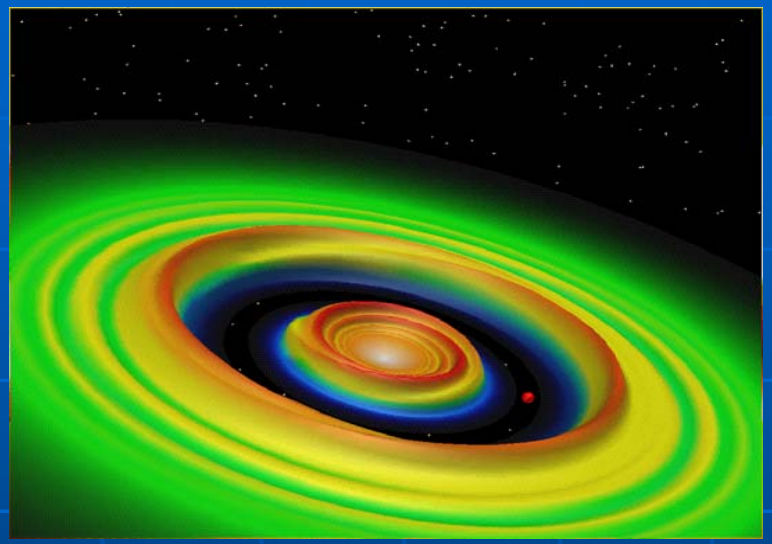
- *Western Australia*
- *South Africa (+ Mozambique + …)*
- *China (Karst region)*
- *Argentina (+ Brazil)*
- *New Mexico*

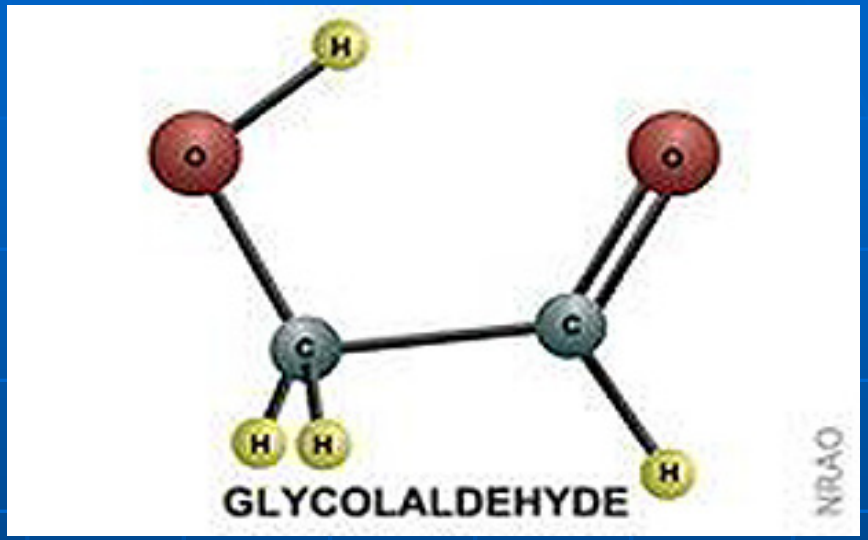
SKA Key Science

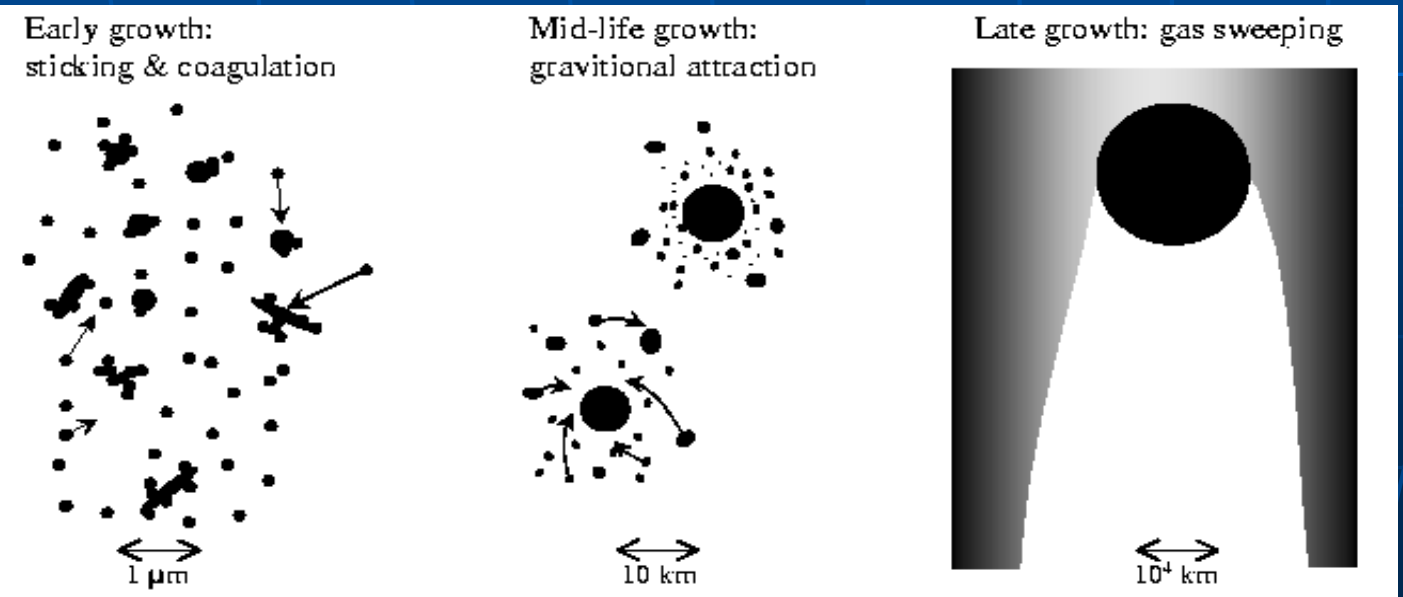
- ***Testing Theories of Gravitation*** *(using pulsars)*
  (ν ~ 0.5-15 GHz)
- ***The Dark Ages :*** *Epoch of re-ionisation, first black holes (using: HI and CO at high redshifts, VLBI)*
  (ν ~ 0.1-20 GHz)
- ***Cosmic Magnetism*** *: Primordial, intergalactic & galactic fields (Polarisation, Faraday rotation, Zeeman effect)*
  (ν ~ 0.3-20 GHz)
- ***The Cradle of Life :*** *Protoplanets, biomolecules, SETI (thermal emission, molecular lines, VLBI) (ν ~ 20-30 GHz)*
- ***Evolution & Large-scale Structure :*** *Galaxies, Hubble Flow & Dark Energy (HI surveys) (ν ~ 0.3-1.4 GHz)*
- ***Exploring the Unknown*** *(ν ~ 0 - ∞ Hz)*

KSP I: The Cradle of Life

SHEPHERDS: LAZIO & WERTHEIMER (USA)







- 100's of proto-planetary disks
- Biomolecules

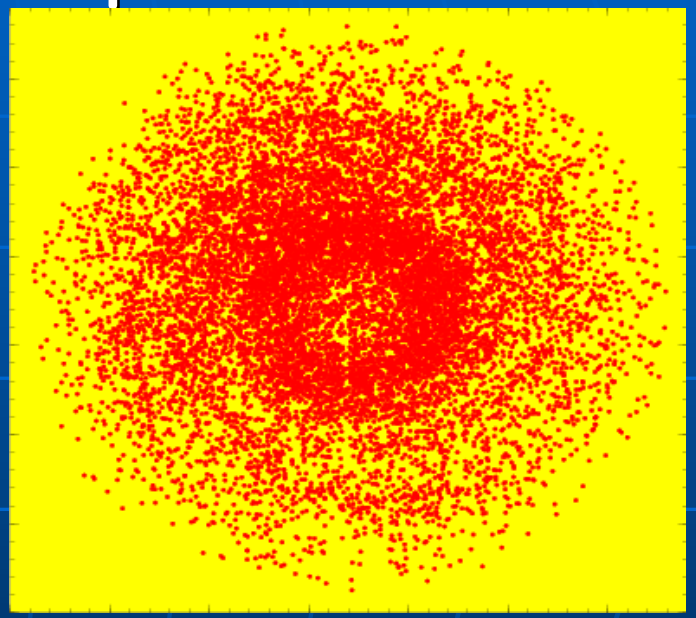
Are We Alone?

	Project Phoenix		SKA		
P_{EIRP} of analogs	$P_T \times G_T$	Range r in ly	# of stars within range	Range r in ly	# of stars within range
Cell phones: 1 W	1W x 1	$3x10^{-4}$	0	$3x10^{-3}$	0
FM radio: 10-100 KW	2 kW x 5 20 kW x 5	0.03 0.1	0 0	0.3 1	0 0
TV: 300 KW	60 kW x 5	0.2	0	2	0
1 MW	100 kW x 10	0.33	0	3.3	~1
Airport Radars: ~ 10^8 W	35 kW x 2200	3.3	~1 (Proxima Centauri is 4.3 ly)	33	310
Ionospheric Radars: $2x10^{11}$ W	150 kW x $1x10^6$	150	$\sim 3.5x10^5$	1500	$\sim 5x10^8$
Arecibo Radar: $2x10^{13}$ W	1 MW x 2×10^7	1500	$\sim 5x10^8$	15000	$\sim 5x10^{10}$

KSP II: Pulsars and General Relativity

SHEPHERDS: CORDES (USA) & KRAMER (UK)

- Blind survey for pulsars
- Time discovered binary and millisecond pulsars to very high precision:



- "Find them!"
- "Time them!"
- "VLBI them!"

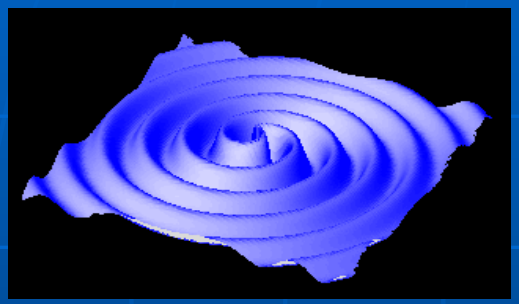
Benefiting from SKA twice:

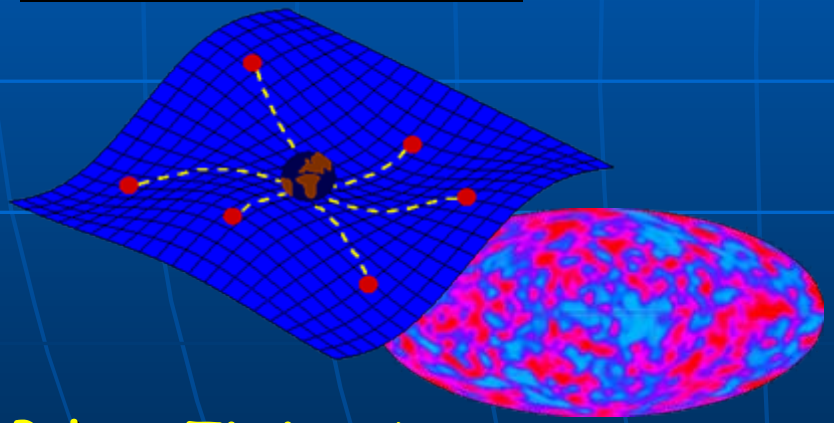
- Survey sensitivity: many pulsars, ~10,000-20,000 (including ~1000 MSPs and pulsar/BH systems ?)
- Unique timing precision and multiple beams !

FUNDAMENTAL PHYSICS: e.g. No-Hair theorem, Cosmic Censorship conjecture.

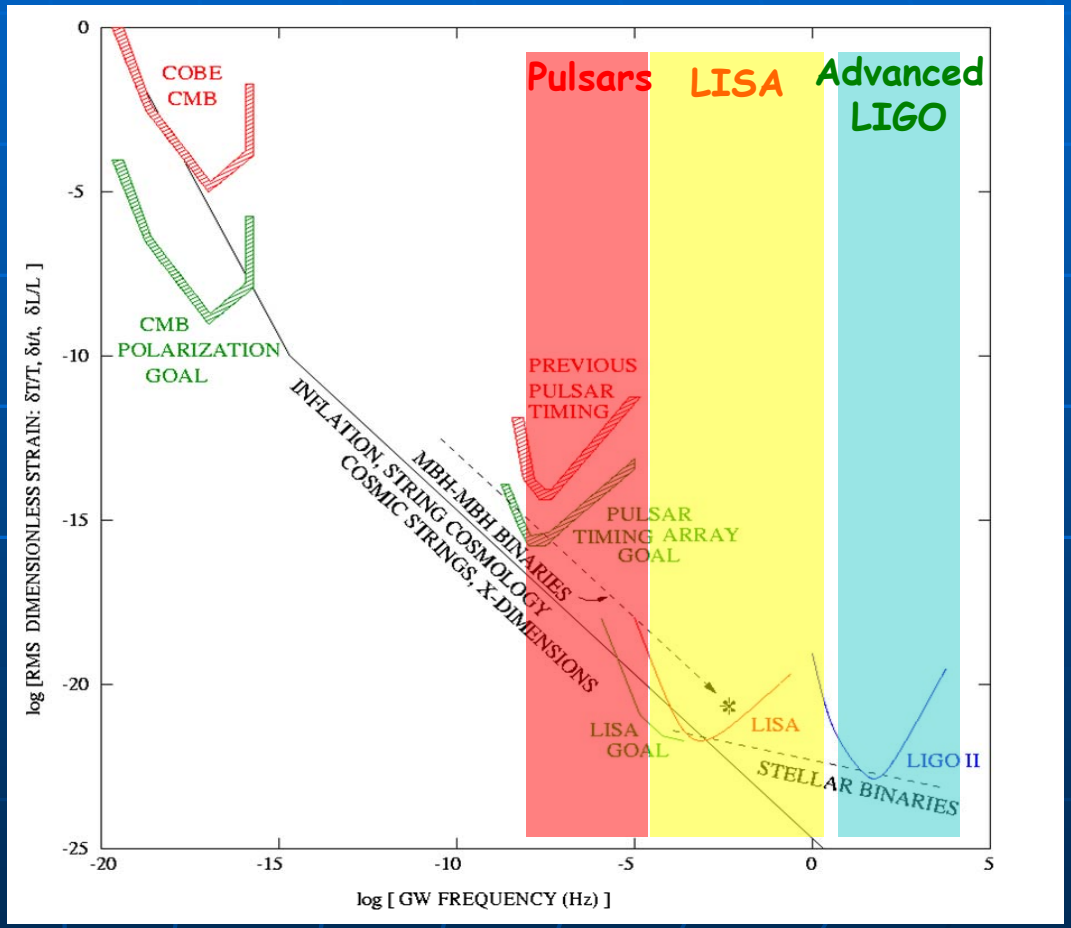
Cosmological Gravitational Wave Background

- Millisecond pulsars act as arms of huge detector:





Pulsar Timing Array:
Look for global spatial pattern in timing residuals!

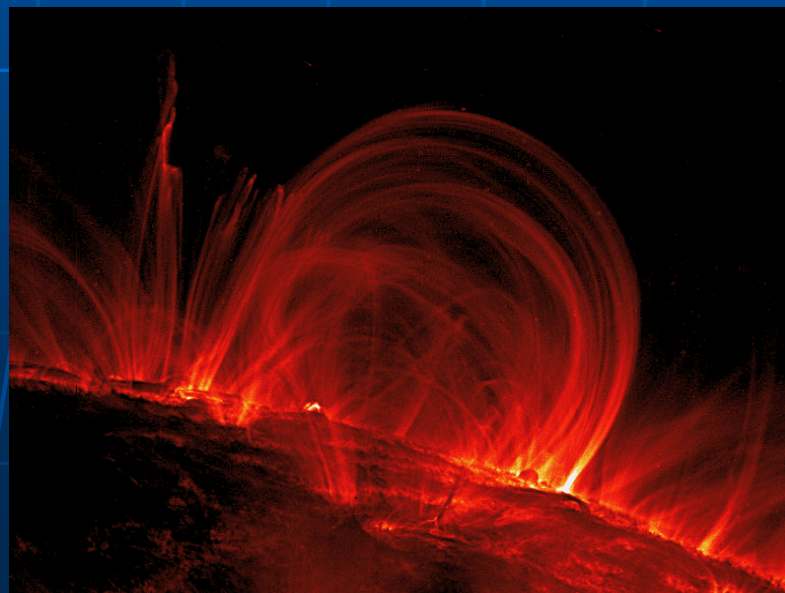


- Complementary in Frequency!

KSP III: The Magnetic Universe

SHEPHERDS: BECK (Germany) & GAENSLER (USA)

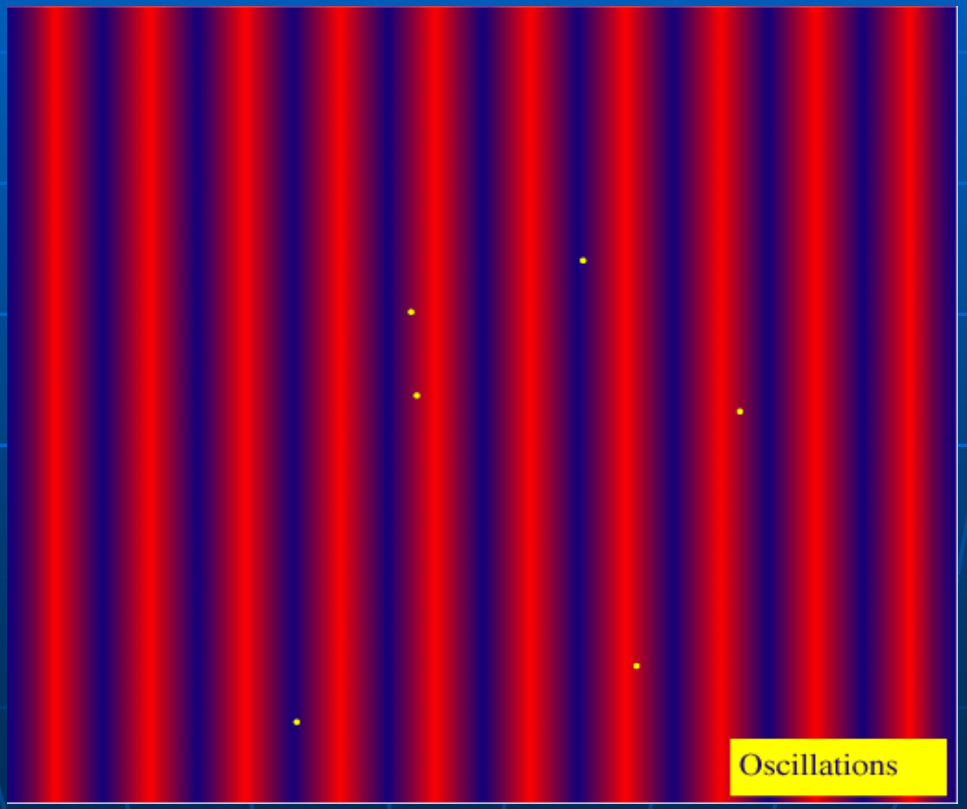
- All-sky survey of Faraday rotation measures
- High-resolution RM + polarization mapping of the Milky Way, nearby galaxies & clusters
- RM mapping of distant intervening galaxies
- Search for magnetic fields in the first galaxies and clusters
- Search for magnetic fields in the intergalactic medium
- Faraday rotation of the CMB ?



KSP IV: Galaxy Evolution & Cosmology

SHEPHERDS: RAWLINGS (UK) & VAN DER HULST (Netherlands)

Comoving scale ~ $(1+1000)\, c_s\, t$ ~ 100 Mpc



(from Wayne Hu's superb web page)

Dark Energy: What is it?

- Vacuum energy (cosmological constant)

  with $w=-1$?
- Quintessence with $-1/3 > w > -1$?
- Phantom with $w < -1$?
- Or, in a nutshell, Physics beyond GR!

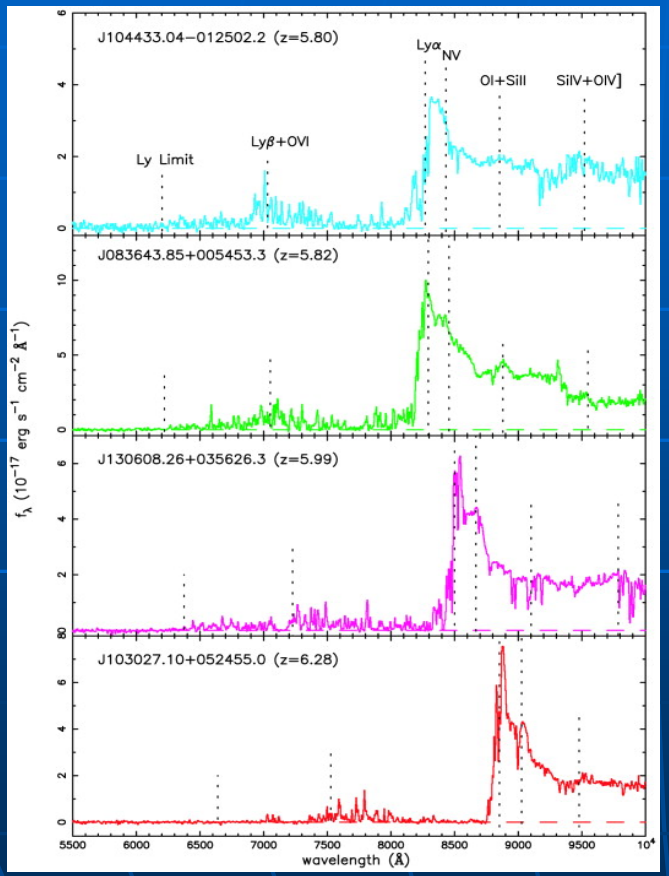
Progress needs MEASUREMENTS of w and its time evolution.

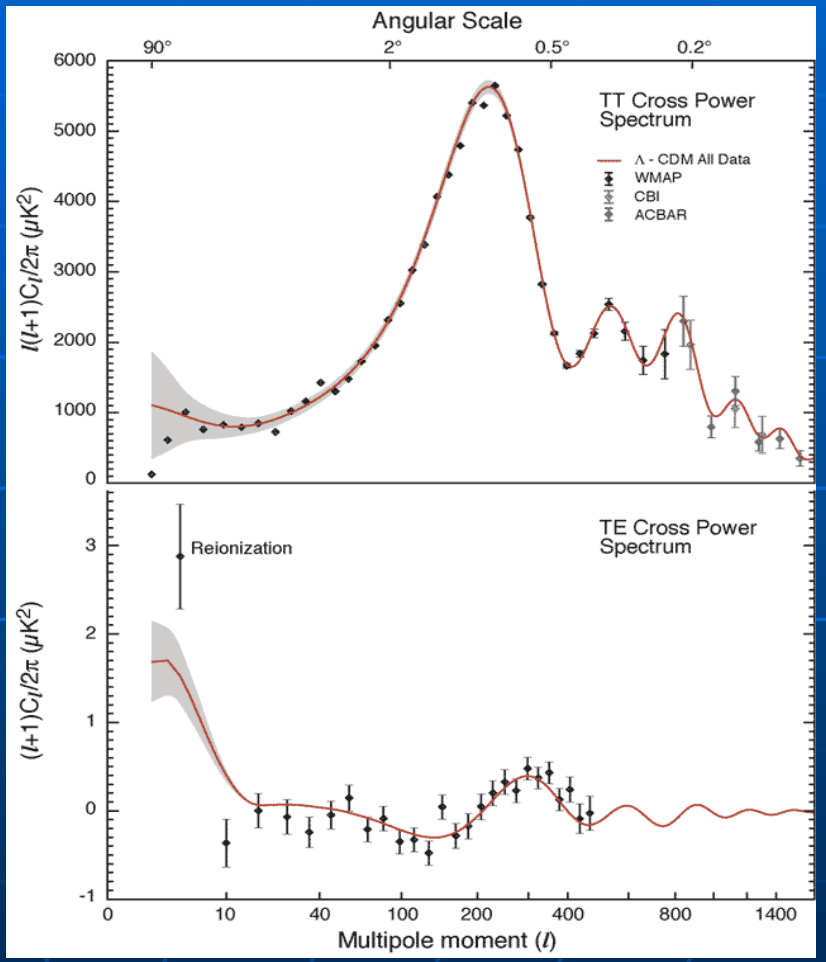
The Dark Energy Measuring machine will yield Nobel Prizes!

(See Peebles & Ratra 2003)

KSP V: Epoch of Reionization

SHEPHERDS: CARILLI (USA) & BRIGGS (Australia)





$$\tau_{GP} \approx 6x10^{5} x_{\mathrm{HI}} \left(\frac{1+z}{10} \right)^{3/2}$$

SKA Schedule

- *2005: Deadline for site proposals*
- *2006: Selection of site*
- *2007: Deadline for design proposals*
- *2009: Selection of design*
- *2012-15: Construction of Phase 1 (10% of full array)*
- *2015-20: Construction of full array*

SKA Prototypes

- Europe: LOFAR (30-240 MHz), *SKA Design Study* (SKADS), with *Electronic Multi-Beam Radio Astronomy Concept* (EMBRACE) (0.6-1.7 GHz)
- Australia: *Extended New Technology Demonstrator* (xNTD) (0.7-1.5 GHz)
- China: *Five hundred meter Aperture Spherical Telescope* (FAST) (0.3-2 GHz)
- South Africa: *Karoo Array Telescope* (KAT) (0.7-1.75 GHz)
- USA: *Long Wavelength Array* (LWA) (20-80 MHz), *Alan Telescope Array* (ATA) (1-10 GHz)

German Contributions

- *Science input:*

  EoR modelling, clusters, halos, magnetic fields, surveys, AGNs
  (see German LOFAR White Paper)

- *Technology input:*

  Contribution to European prototype (SKADS), low-cost antenna design, data grids, supercomputers

- ***Experience with German LOFAR stations is essential !***