Requirements Analysis and Derivation

Introduction

- Illustrate the approach to analysis of the Design reference Mission (DRM)
- Derivation of Functional Requirements
  - Concentrate on areas which provide greatest input to and constraint on requirements
  - Cannot be complete in this talk
- This is an SKA1 analysis

Widely used system requirements

Identification	Requirement	Applicability	Parent	Verification
SYS_REQ_1110	Electromagnetic frequency range. SKA1 shall be able to measure electromagnetic radiation in a frequency range from 70 MHz to 3 GHz.	Mandatory	*	Test

Bandwidth

Identification	Requirement	Applicability	Parent	Verification
SYS_REQ_1310	Sensitivity (Aeff/Tsys). The SKA1 shall have a sensitivity of:	Mandatory		
	10^3 m^2 K^{-1} in the frequency range 70 MHz - 240 MHz			
	10^3 m^2 K^{-1} in the frequency range 400 MHz - 3 GHz			
	10^5 m^2 K^{-1} in the frequency range 800 MHz - 3 GHz			

Number of collectors

Identification	Requirement	Applicability	Parent	Verification
SYS_REQ_1430	The SKA Phase 1 shall be designed so that a deep field can be completed in 1000 hr of integration time.	Mandatory		Analysis

Survey speed

Identification	Requirement	Applicability	Parent	Verification
SYS_REQ_1420	The SKA Phase 1 shall be designed so that a major survey can be completed in 2 years of “on-sky” observation time.			Analysis

Archive

Identification	Requirement	Applicability	Parent	Verification
SYS_REQ_1510	Baseline. The SKA1 minimum baseline requirement is:	Mandatory		
	200 km for the range 70 to 240 MHz	Mandatory		Test

Integration time

Overall requirements from DRM

Identification	Requirement	Applicability	Parent	Verification
SC_REQ_1000	Imaging pipeline. The processing system shall provide an imaging pipeline for full Stokes imaging with multiple spectral channels.	Mandatory		Test

Identification	Requirement	Applicability	Parent	Verification
SC_REQ_2000	Time-series processing. The processing system shall provide a pipeline for the analysis of phased-array beam-formed time-series data	Mandatory		Test

Science cases

Identification	Requirement	Applicability	Parent	Verification
SC_REQ_3000	Statistical processing. The processing system shall provide a pipeline for statistical analysis of UV data	Mandatory		Test

Identification	Requirement	Applicability	Parent	Verification
SC_REQ_4000	Ingest processing. The processing system shall provide an ingest pipeline for preconditioning and initial analysis of data leaving the correlator	Mandatory		Test

Inferred from processing needs

Identification	Requirement	Applicability	Parent	Verification
SC_REQ_5000	Astrometric pipeline. The processing system shall provide an astrometric pipeline		SCI_T_REQ_0500 ; SCI_T_REQ_0505	

Science case

Processing required

Identification	Requirement	Applicability	Parent	Verification
SC_REQ_0010	Simultaneous pipeline operation. The processing system shall be able to support simultaneous operation of the imaging and time-series analysis pipeline	Mandatory	SCI_D_0010	Test

Identification	Requirement	Applicability	Parent	Verification
SC_REQ_0020	Simultaneous receptor operation. The processing system shall be able to support simultaneous analysis pipelines processing data from each collector type	Mandatory	SCI_D_0020	Test

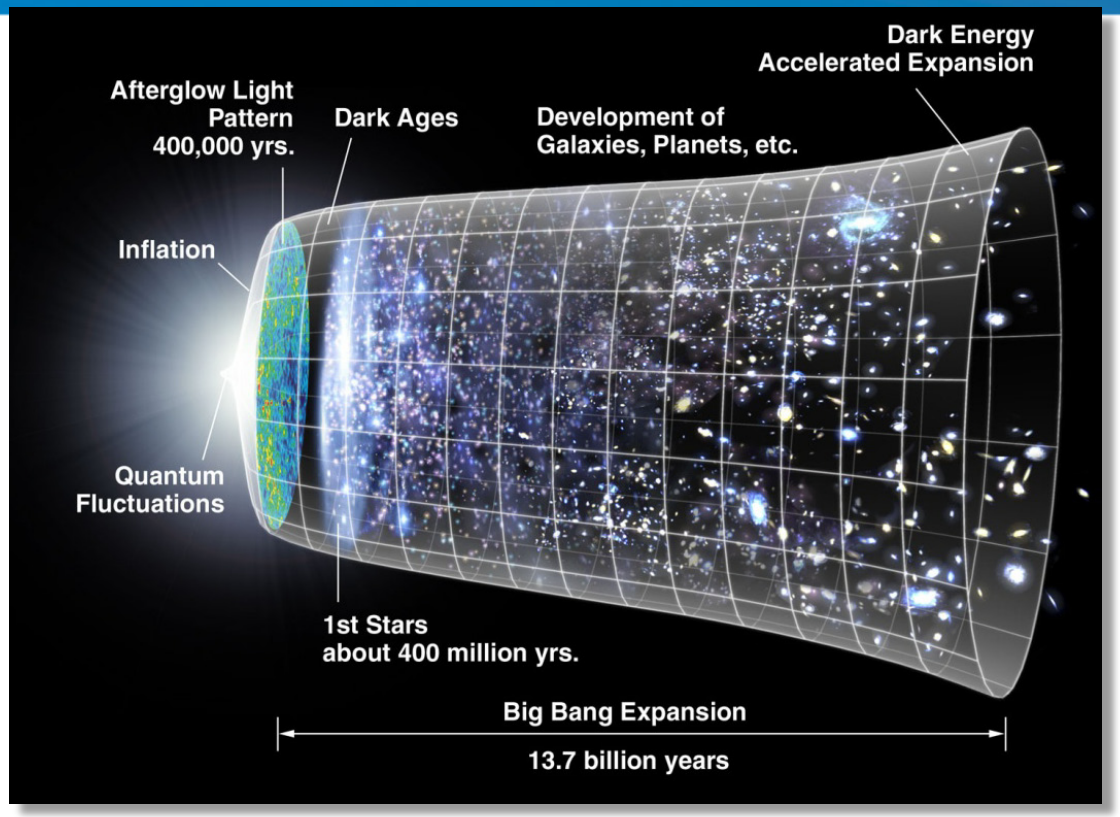
Identification	Requirement	Applicability	Parent	Verification
SC_REQ_0030	Top-level performance of the processing system. The processing system shall operate such that it is able to deal with the required throughput of the telescope and assuming that operational availability of the telescope is at least 85%	Mandatory	SCI_SYSR_0050	Test

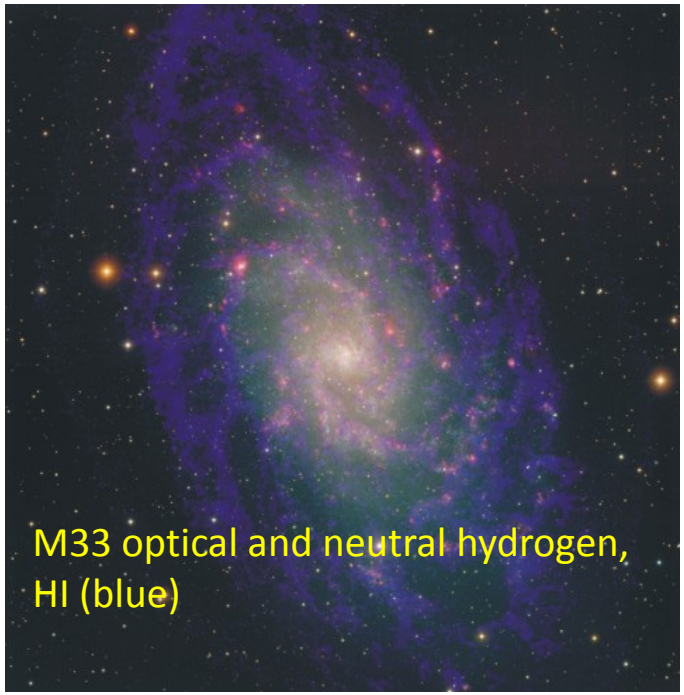
Need to be able to make full use of the telescope all of the time

DRM: Epoch of Reionistion

- A key SKA1 science case and hence important part of DRM
- Drives many of the imaging requirements

The History of Hydrogen

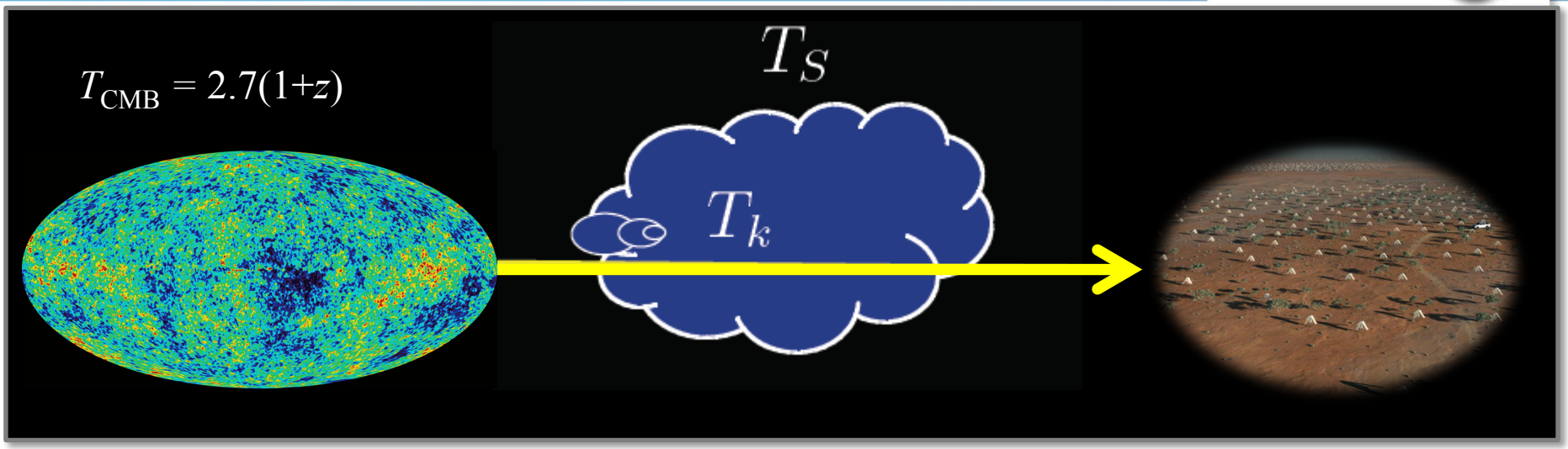




- After recombination (CMB) Universe if neutral, but we know that hydrogen (not in galaxies) is hot and ionised
- Re-ionization occurs when first objects (galaxies and AGN) form via UV- and X-ray emission
- Epoch of Reionisation – EoR next major challenge for Cosmology

21-cm line at 1420 MHz.

Hydrogen Evolution

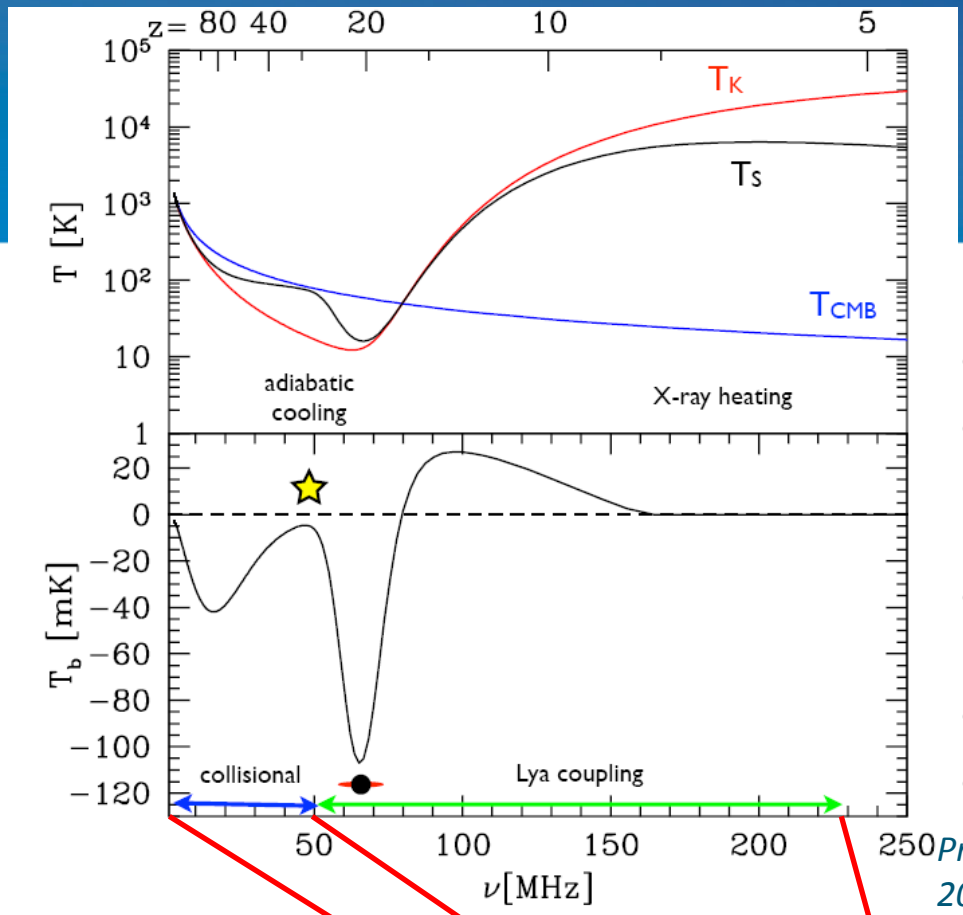


Spin temperature is defined via $\frac{n_2}{n_1} = \frac{g_2}{g_3} \exp\left(\frac{h\nu}{k_B T_S}\right)$ and determined by collisional and radiation processes

The HI intensity in Rayleigh-Jeans limit is given by

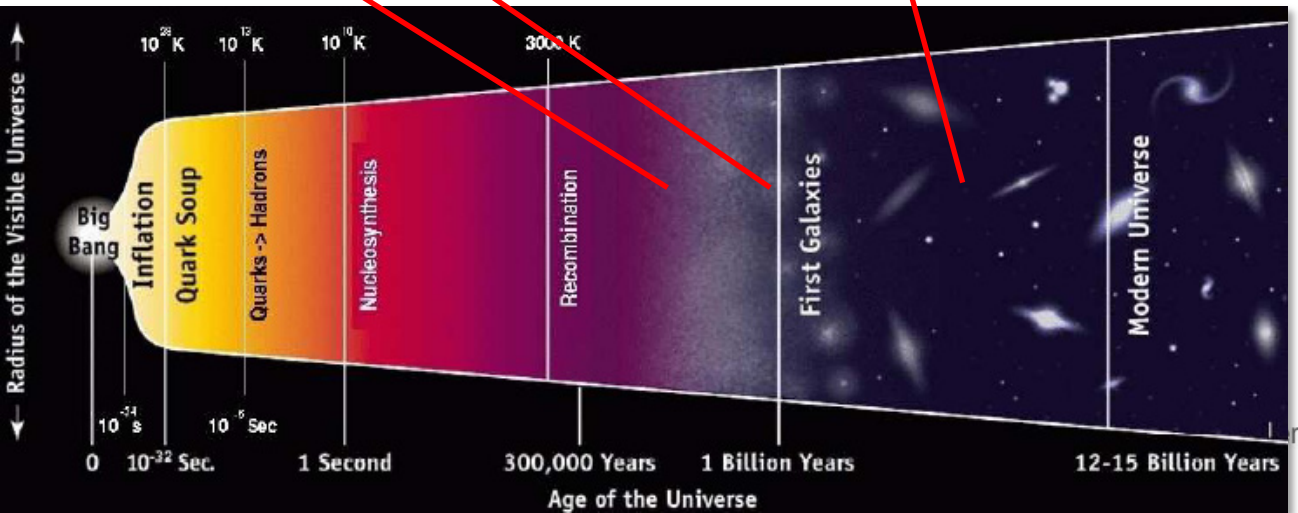
$$T_b = 27 x_{\rm HI}(1+\delta_B)\left(\frac{T_S - T_{\rm CMB}}{T_S}\right)\left(\frac{1+z}{10}\right)^{1/2}\left(\frac{\partial_r v_r}{(1+z)H(z)}\right)^{-1} \ {\rm mK}$$

- Ionisation fraction
- Baryon overdensity
- Peculiar velocity relative to Hubble flow



- Very weak signal
- Very much more challenging the detection of the Cosmic Microwave background fluctuations
- Calibration and reduction of systematic errors is critical
- Statistical detection of the signal
- Imaging of the signal

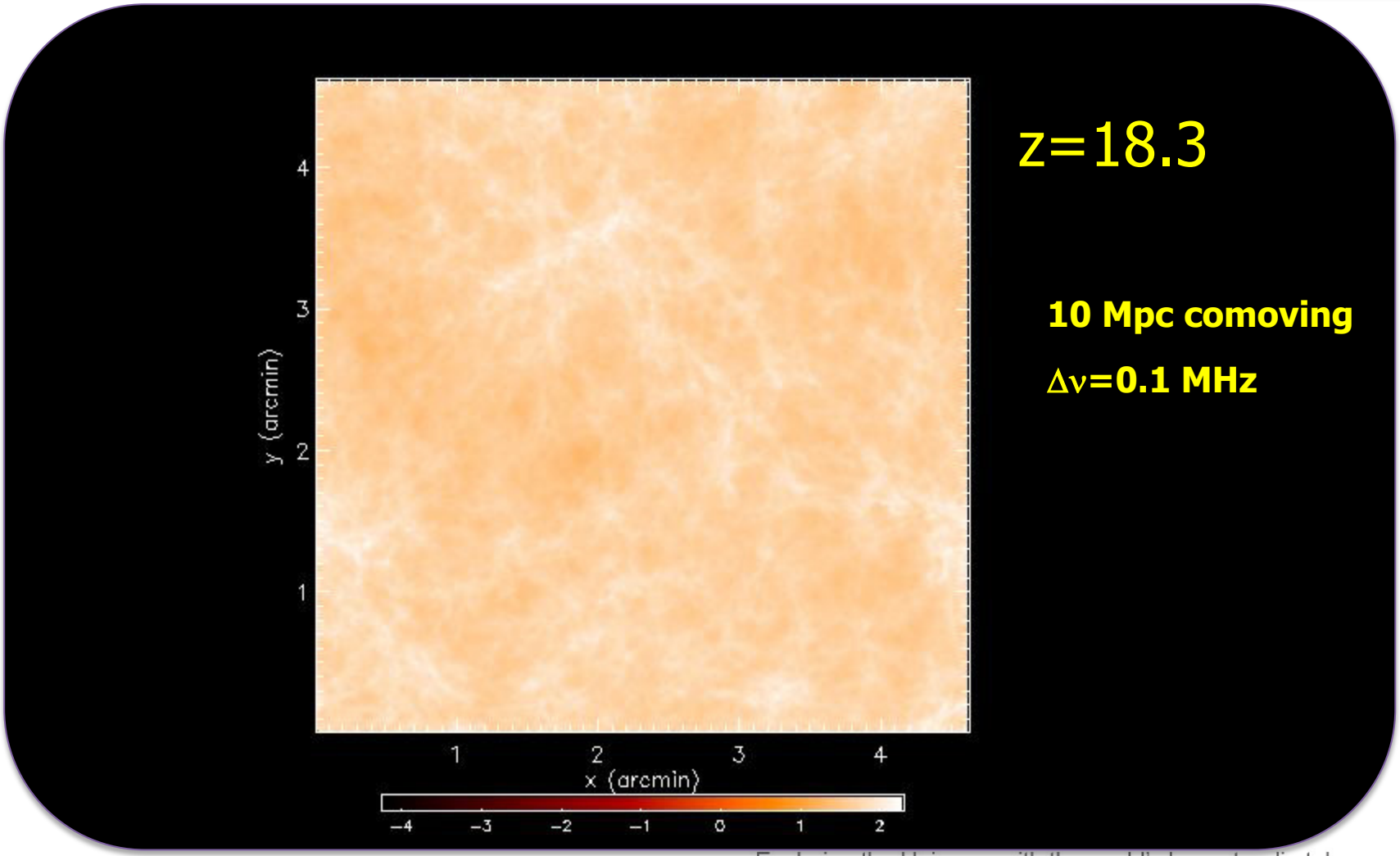
Prichard and Loeb, 2010



rse with the world's largest radio telescope

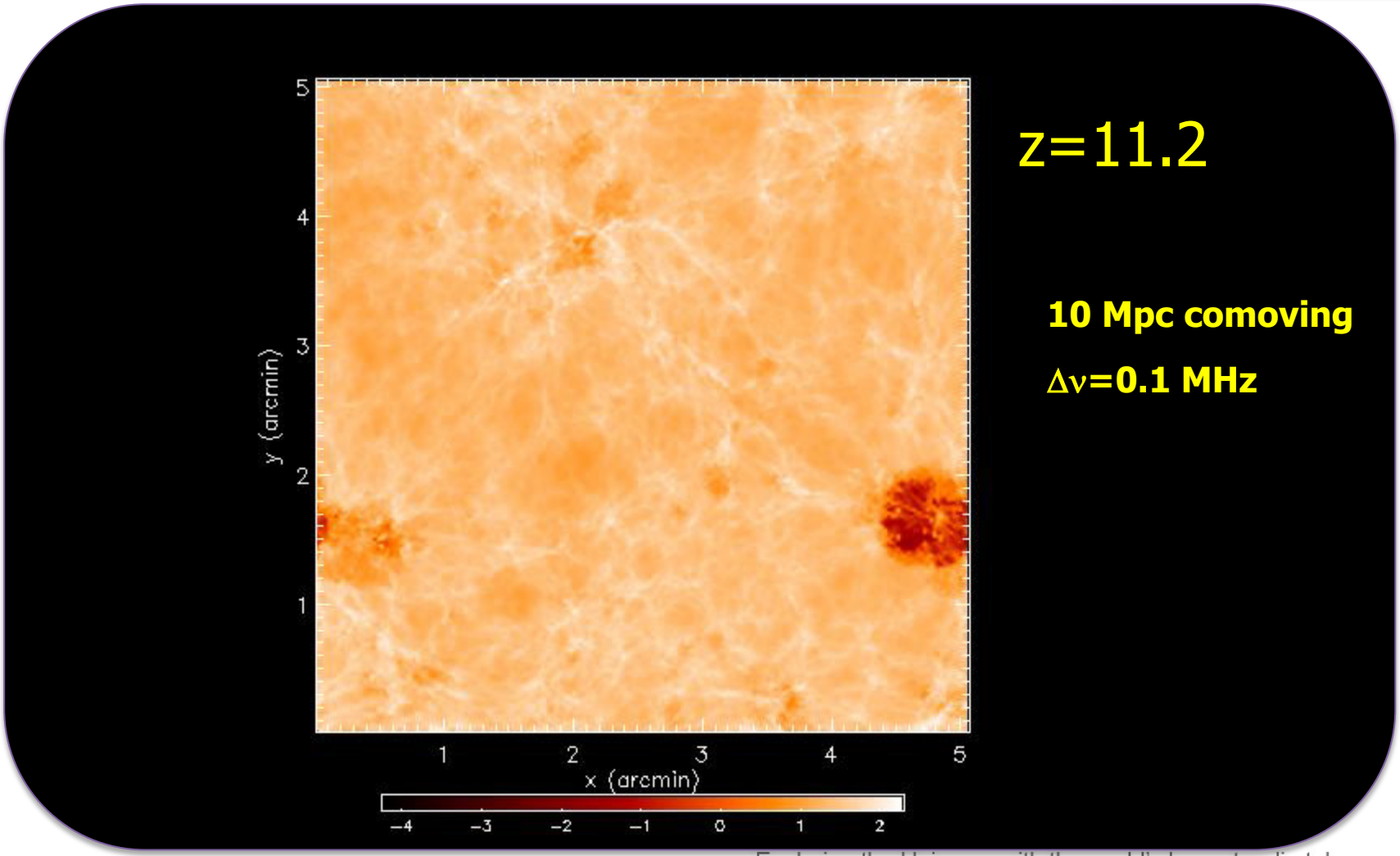
Epoch of Re-ionization

Furlanetto et al. (2003)



Epoch of Re-ionization

Furlanetto et al. (2003)



Epoch of Re-ionization

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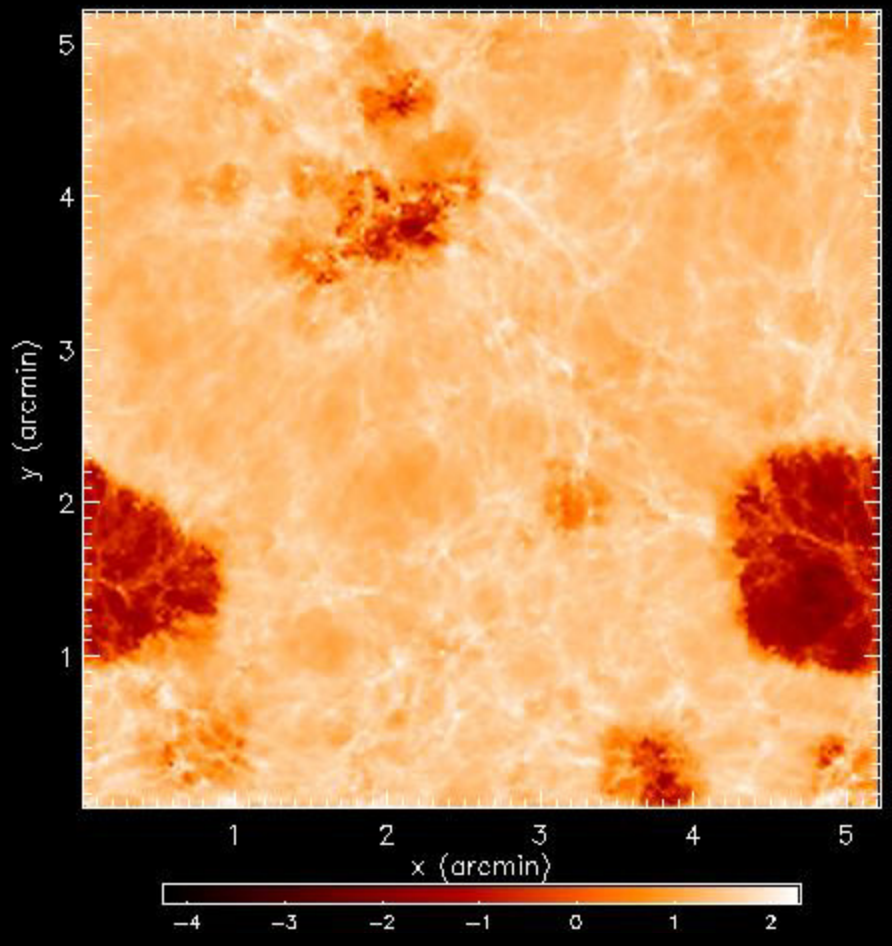


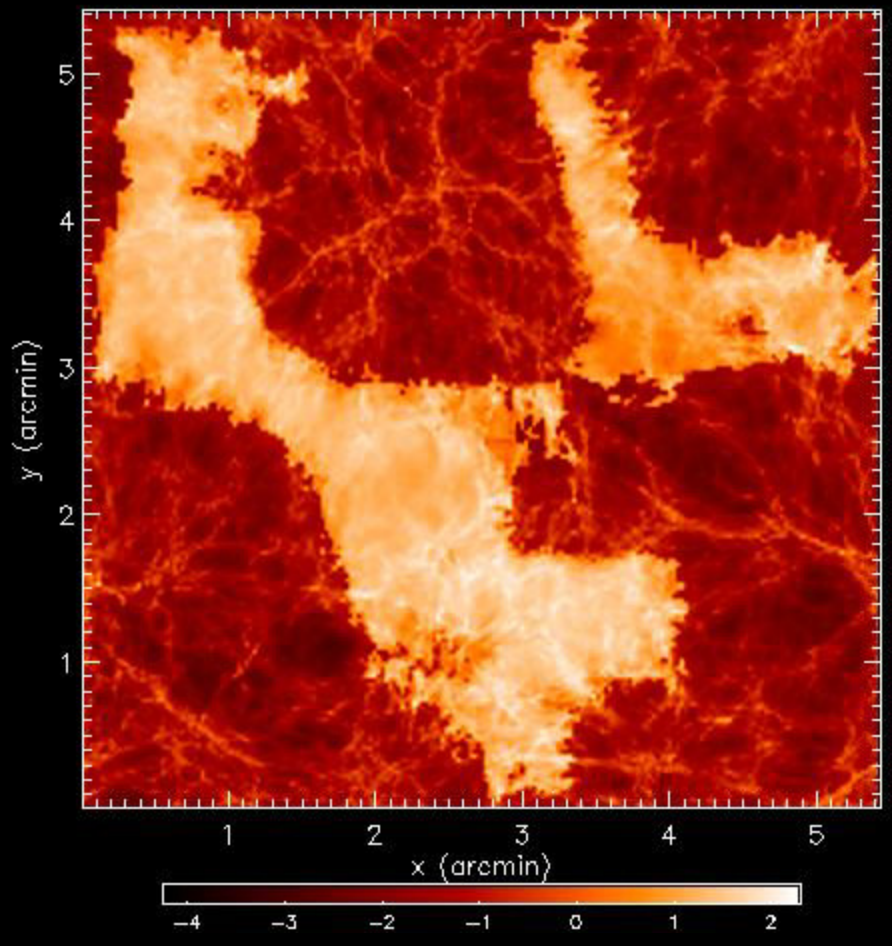
z=9.8

10 Mpc comoving

$\Delta\nu$=0.1 MHz

Epoch of Re-ionization

Furlanetto et al. (2003)



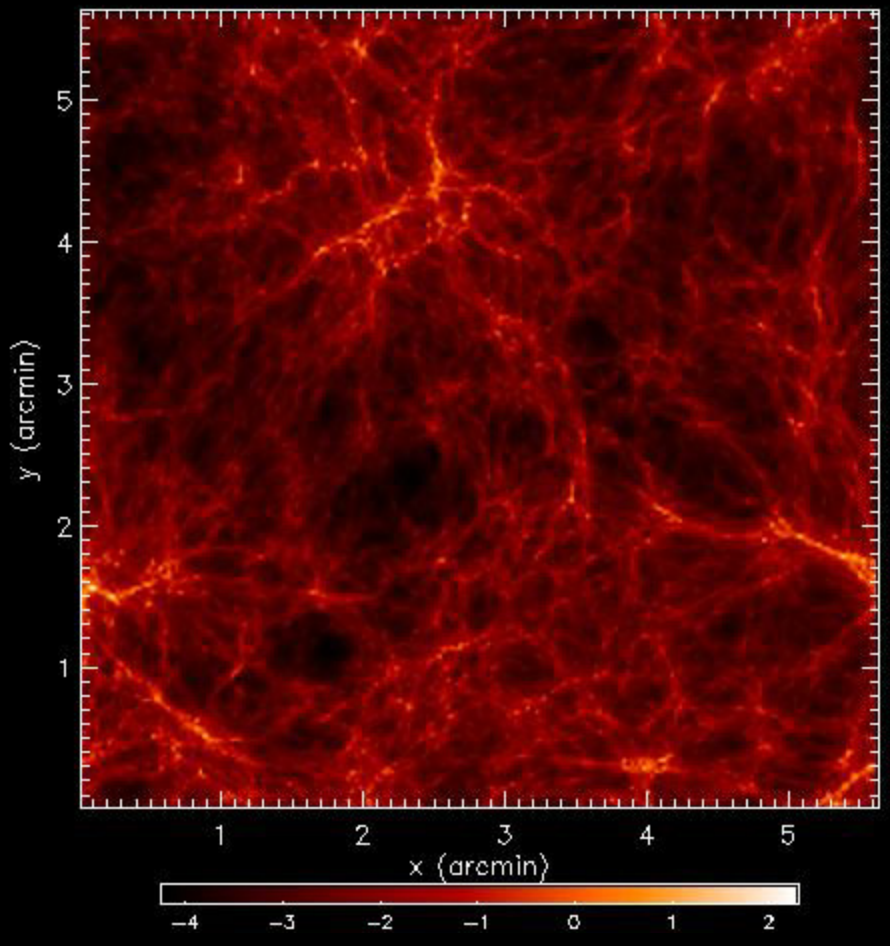
z=8.3

10 Mpc comoving

$\Delta\nu$=0.1 MHz

Epoch of Re-ionization

Furlanetto et al. (2003)



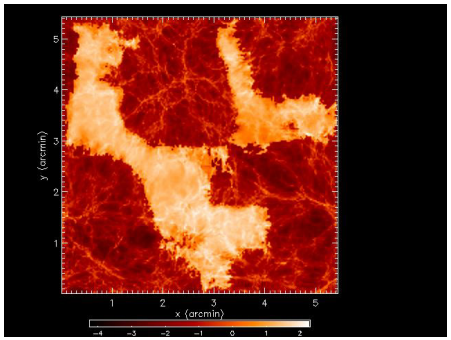
z=7.2

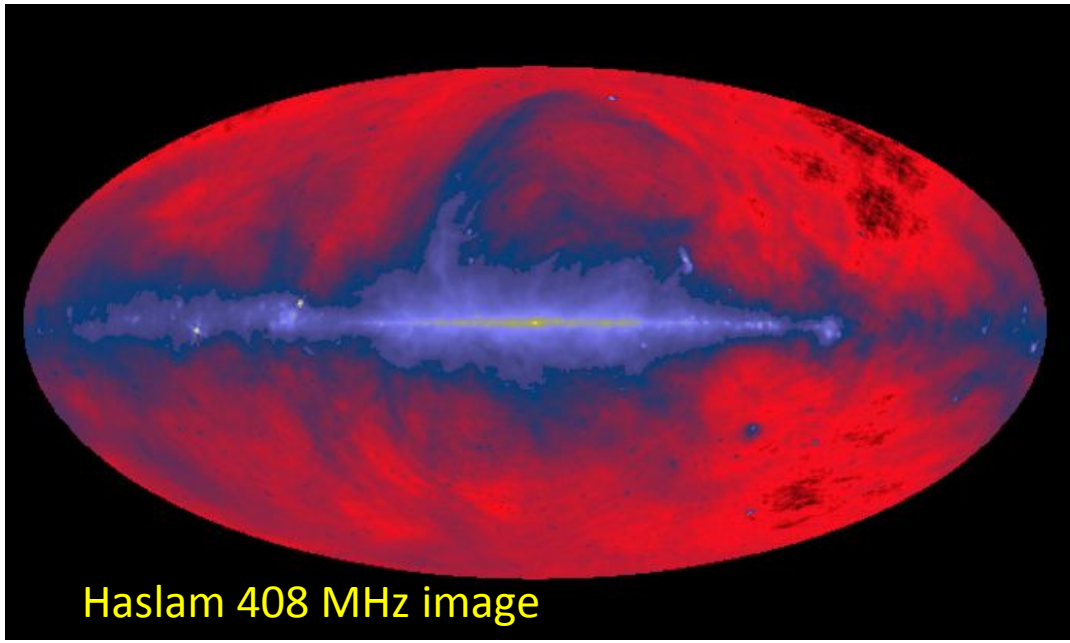
10 Mpc comoving

$\Delta\nu$=0.1 MHz

The Imaging and Data Processing Challenges of this Experiment

- Foreground is due to continuum emission from our own galaxy and discrete extragalactic sources
- Up to 10^5 times brighter than the signal we are measuring
- Need to filter or subtract this foreground
  - Frequency and spatial filtering
  - Challenge for calibration and imaging





EoR Imaging DRM Requirements

Science Requirements from the DRM		
Parameter	Value	Comment
Redshift coverage	6 – 30	
Brightness temperature sensitivity	1 – 3 mK	
Angular resolution	2’ – 5’	
Radial resolution	2 Mpc	
Field of view	> 5 deg	Set by cosmic variance

EoR Imaging DRM Requirements

Technical Requirements from the DRM		
Parameter	Value	Comment
Frequency range	50-240MHz	
Critical frequency	100 MHz	
Frequency resolution	100 kHz	RFI excision is critical and may need high resolution ~ 1 kHz
Bandwidth	$\Delta f/f \sim 1$	Cover complete frequency range in each observation
Maximum baseline (core)	5km	To provide angular resolution
Baseline source subtraction	~200km	
Integration time	>1000 hrs	Set by cosmic variance
A/T	>1000 m^2K^{-1}	
Antenna diameter	7m – 30m	
Core UV coverage	$N_d > 160$	

Analysis

Channel requirements

- Straight forward
  - 1.7×10^5 at 1 kHz resolution for RFI excision
  - 1.7×10^3 in the final data products
  - Data rate drops by this factor after the ingest pipeline

Analysis

Sensitivity and Collector distribution

- Requirement:

  10mK in a 5’ beam and 3.3mK in a 2’ beam

- From SYS_REQ_1310 the requirement is that A/T = 1000 m^2K^{-1} across the 70-450 MHz band of the AA-low.

- Translated in Memo 130 as a total collecting area of $1.25x10^6$ m^2 distributed in 50 180-m stations with a distribution of:

Core (r <0.5 km)	~50% (25 stations)	6.25 x 10^5 m^2	f = 0.81
Inner (1< r<2.5 km)	~20% (10 stations)	2.5 x 10^5 m^2	
Mid (2.5<r<100 km)	~30% (15 stations)	3.75 x 10^5 m^2	

Analysis

Sensitivity and Collector distribution

- High filling factor in core means *flexibility* in logical configuration
  - Very important to meet EoR requirement
  - *Extensibility* to SKA2 gives filling factor ~1 in inner region
- Resolution:

  2’ corresponds to ~ 6km at 70MHz
  2’ corresponds to ~ 2.5 km at 240MHz

N.B. would still need beam forming across the full band

- DRM1.3 matches “station” diameter to 5 degree FoV giving D = 30m

- In Inner region:
  N ~ 1200, but data rate scales as N^2
  Adopt instead requirement on UV coverage and take 200 75m stations
  Beyond 2.5km 85 70m stations or 15 180m stations

Analysis

Dynamic Range

N.B. may need to consider more sophisticated definition of dynamic range

DRM1.3 gives the flux densities of the faintest EoR structures to be imaged:

- ~0.3mJy/Beam (1σ) at 100 MHz.
- Jonathan made the point yesterday, source contamination is worse than smooth foregrounds
- in a 25 sq-degree field an order of magnitude estimate would suggest that we would expect to find a 3C brightness object
- even by selecting a region with no 3C-like source, consideration of the source counts suggest it seems very likely that the field will still be contaminated by a number of sources with a flux > 1Jy
- This implies a dynamic range requirement of >65dB.

Requirements

N_D	=	200
N_{ch}	=	1.7×10^5
N_b	=	16
B_{max}	=	5km

G_{out}(RFI)	=	27.5 GB/s
G_{out}	=	275 MB/s
δt	=	18 s
N_{ch}	=	1.7×10^5

N.B. 200 times larger for 30-m logical stations

- AA with 45 degree scan allows 5hr track per day
- 1000 hr total integration gives 200 days
- Each observation is 500 TB UV data (1kHz) reducing to 5 TB
- 150 GB per day of processed data cube at 100 kHz channels

Do we need to store UV data until complete 1000 hr integration complete?

YES Some analysis approaches will require this

Requirements: long baselines

75-m station

G_{out}(RFI)	=	2500 GB/s
G_{out}	=	250 GB/s
dt	=	0.45 s
N_{ch}	=	1.9×10^4

180-m station

G_{out}(RFI)	=	187 GB/s
G_{out}	=	8.9 GB/s
dt	=	1.08 s
N_B	=	67
N_{ch}	=	7.9×10^3

- Even for 180m station with 200 km baselines full imaging
  - 160 TB of UV data per 5-hr track
  - Image product 16k x 16k x 6k (24 TB per field) with 133 fields
- For 25 km baseline
  - 2k x 2k x 1k (64 GB) per field 133 fields

Precise requirements for the calibration and source subtraction need careful consideration as they could drive requirements for S&C domain and hence SKA

Imaging Pipeline

Wide-Field Imaging?

Fresnel number $R_F = B\lambda/D^2$

consider critical frequency 100 MHz

75-m station	
B	R_F
5 km	2.7
25 km	13
200 km	107

180-m station	
B	R_F
5	0.46
25 km	2.3
200 km	18.5

- The imaging problem is a wide-field problem but not severe
- For 30-m logical stations 6.25 larger

Derived requirements

Identification	Requirement	Applicability	Parent	Verification
SC_REQ_4100	RFI Excision. The ingest pipeline will be capable of performing RFI excision and flagging	Mandatory		Test
SC_REQ_4120	RFI Processing. Processing of data from the correlator for RFI excision at 1kHz resolution is required.			
SC_REQ_4140	RFI Processing. Sustained data rates for RFI processing up to 1.2 TB/s into the Ingest pipeline must be supported			

Identification	Requirement	Applicability	Parent	Verification
SC_REQ_3100	Statistical UV processing. The processing pipeline will be able to perform a statistical analysis of UV data to extract, for example a power spectrum, on at least 5 10^9 gridded data points.			
SC_REQ_3200	Statistical UV data. The processing system will be capable of archiving generalised data representing the results of statistical analysis [Details of these data products needs to be defined]			

Identification	Requirement	Applicability	Parent	Verification
SC_REQ_1100	Data rate for imaging. The processing system will be able to handle sustained data rates of up to 12.6 GB/s of UV-data through the imaging pipeline for full synthesis observations of at least 5 hrs duration in full Stokes.			Analysis
SC_REQ_1110	Data products. The system shall be capable of producing and archiving UV-data, and image cubes all in full Stokes as data products.			Analysis
SC_REQ_1120	Spectral-line Imaging. The processing system shall be capable of producing spectral-line data cubes of size at least 2k x 2k x 2k voxels in full Stokes			Analysis
SC_REQ_1130	Spectral-line Imaging. The processing system shall be capable of producing spectral-line data cubes of the maximum size in at least 25 simultaneous fields			
SC_REQ_1140	Continuum imaging. The processing system shall be capable of producing continuum data cubes in full Stokes of a maximum size of 4k x 4k x 8k [This exceeds the spectral-line requirement, but is included separately in the event that the requirement can be relaxed.]			
SC_REQ_1150	Continuum imaging. The processing system shall be capable of producing continuum data cubes in full Stokes of a at least 25 simultaneous fields. [This exceeds the spectral-line requirement, but is included separately in the event that the requirement can be relaxed.]			

Derived requirements

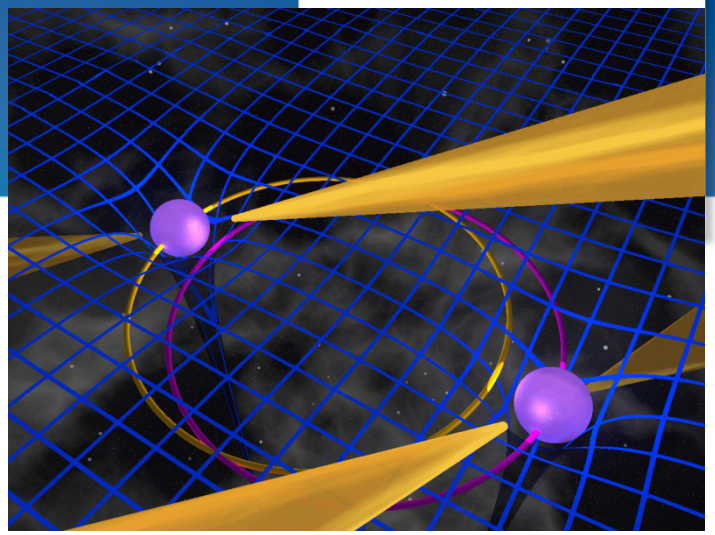
Identification	Requirement	Applicability	Parent	Verification
SC_REQ_1810	UV data products. The system shall be able to archive UV-data at a sustained rate of 400 MB/s for periods of at least 5 hrs.			
SC_REQ_1820	UV data products. The system shall be able to archive UV-data of at least 5TB per dataset per day for at least 200 days.			
SC_REQ_1825	Data retention: These data will be retained in the archive for at least 30 months			
SC_REQ_1830	Data-volume data products. The system shall be capable of archiving image-volume data products of at least 12TB in size and at a sustained rate of at least 16 TB/day for at least 200 days.			
SC_REQ_1835	Data retention: These data will be retained in the archive for at least 30 months			
Identification	**Requirement**	**Applicability**	**Parent**	**Verification**
SC_REQ_1020	Spectral dynamic range. Final data products with a spectral dynamic range of >65 dB are required			
SC_REQ_1030	Imaging dynamic range. Final data products with a dynamic range of >65 dB are required [As discussed this should be verified as a requirement]			

DRM: Pulsars

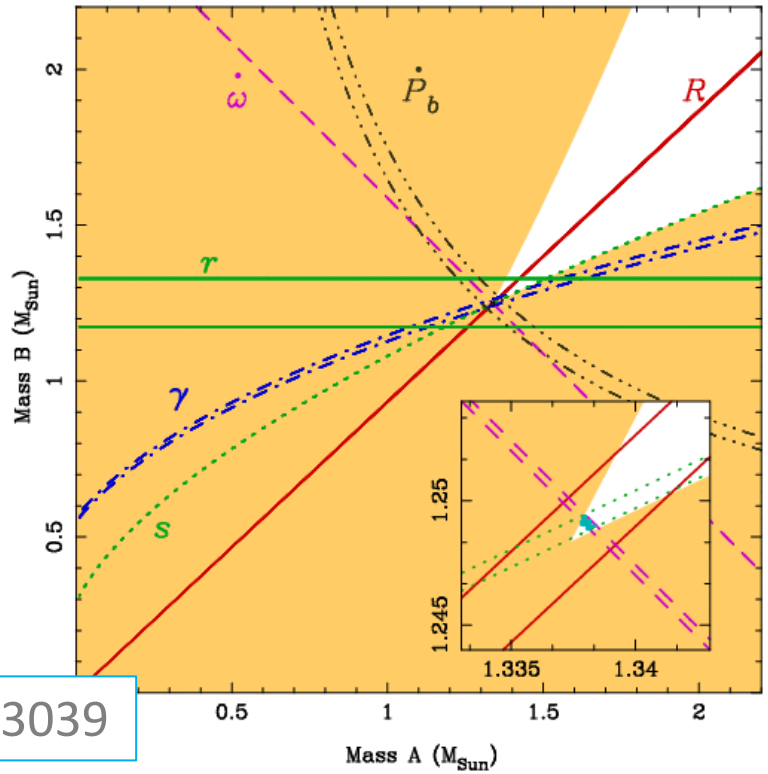
- The other key SKA1 science case.
- Pulsars use *time series* data created by beamforming

- Need **SEARCH** to find many pulsars
- Followed by **TIMING** to:
  1. Identify “interesting” pulsars
  2. Use precision timing to extract science

Pulsars



- Direct observation of collapsed stellar objects, cores, which become rapidly rotating neutron-stars
- Produce precise signal pulses at rotational rate of pulsar: 0.5ms – 10s
- Exceptionally accurate natural clocks
- Pulsars in a binary orbit enables precise physical measurements

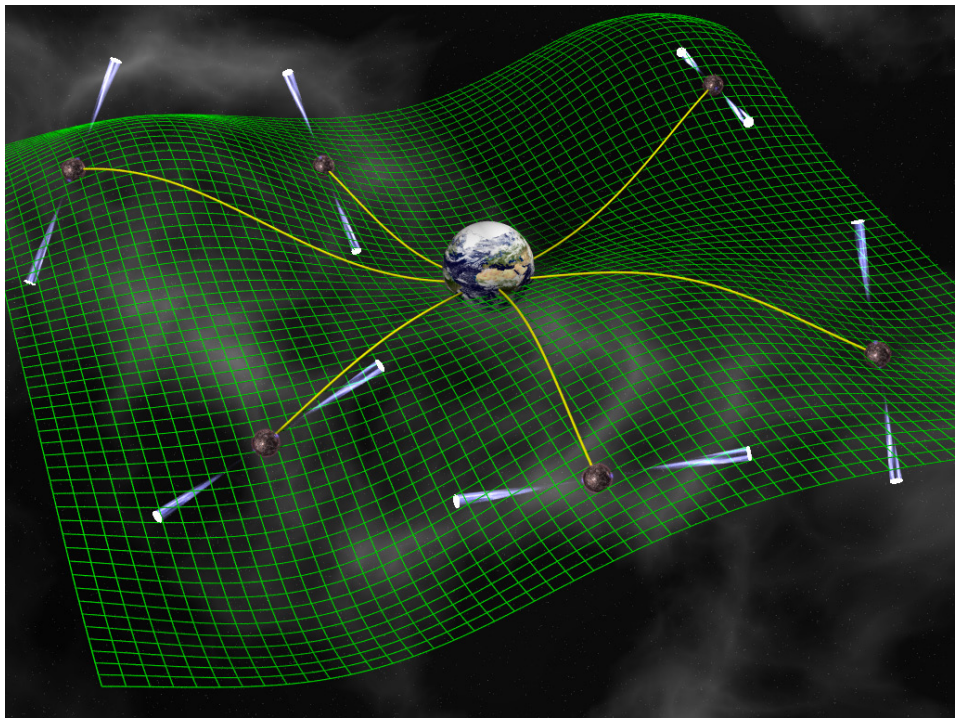


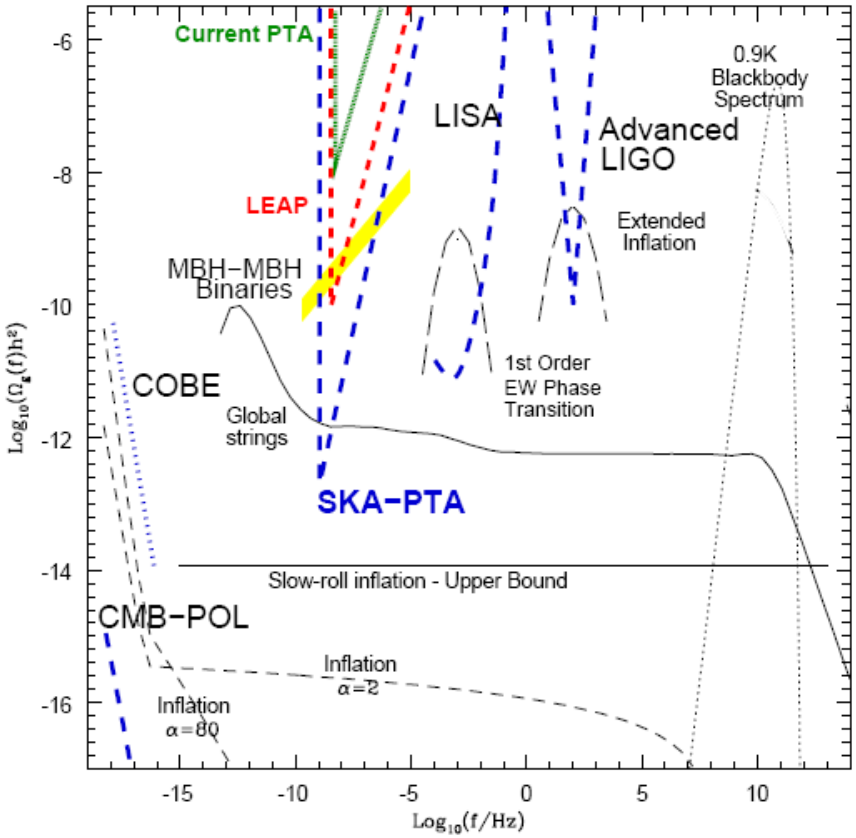
e.g. The “Double Pulsar” PSR J0737-3039

Detecting gravity waves

A “Precision Timing Array”, PTA, of milli-second pulsars

Can detect a nano-Hz gravitational wave passing through the Earth





Requires: high sensitivity and very precise timing from SKA1

Pulsar Key science goals:

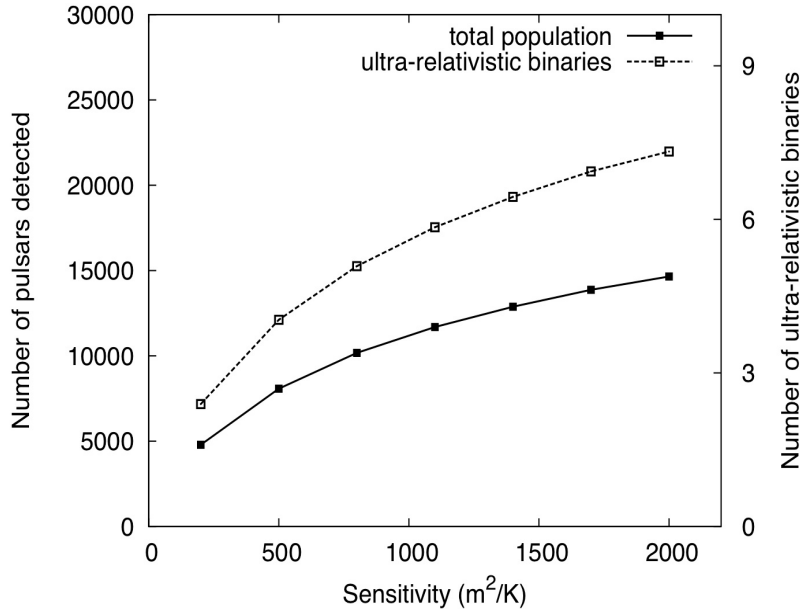
1. Increase by an order of magnitude the number of known radio pulsars
2. Conduct precision timing observations of a subset of these in order to extract constraints on fundamental physical theories

Pulsar search basis

- Accurately detect incoming pulses from a pulsar
- Signal is detected on a single beam, formed from collectors in a ~1km diameter core
  (Larger diameter → smaller beams → more processing)
- Assumes that the polarisations are summed
- Brute force search each beam at a wide range of Dispersion Measures (DMs)
- Need to search each DM at a number of “accelerations” to detect binary pulsars in arbitrary orbits

Pulsar Search: Science Requirements.

Science Requirements from the DRM		
Parameter	Value	Comment
Pulsar luminosity	0.1 mJy kpc^2	at 1400 MHz
Pulsar period	0.5 ms–10 s	
Dispersion measure	At least 1000 pc cm^{-3}	
Sky coverage	Entire sky visible from its latitude on Earth above notional elevation limit of 10 deg (TBC)	
Pulsar orbits	Orbital periods at least as short as 30 minutes	



Estimated number of pulsars detected as a function of available sensitivity.

Pulsar Search: Technical Requirements

Technical Requirements from the DRM		
Parameter	Value	Comment
A_{eff}/T_{sys}	500 m^2 K^{-1}	Pulsar luminosity, period, DM
Frequency range	0.3–3 GHz	Pulsar spectra, period, DM
Frequency resolution	< 10 kHz	DM
Temporal resolution	50 µs	Pulsar duty cycle, period, DM
Array filling factor	"high"	Pulsar luminosity, processing
Array data product	voltage time series	Processing, pulsar period, DM

Pulsar search approach

- Need to complete in 2 years “on-sky”
- Each beam is integrated for ~30mins
- Use the lowest frequency reasonable for the area of sky, hence largest beams to minimise processing. Three areas:
  - Galactic plane: |b| < 3° 0.8-1.6 GHz Dish
  - Intermediate latitudes: |b| ≈ <20° 0.45-0.9 GHz Dish
  - “All Sky”: ~2π steradians 0.3-0.45 GHz AA-low
- Calculate the number of concurrent beams required to achieve survey time: ~900 full bandwidth beams

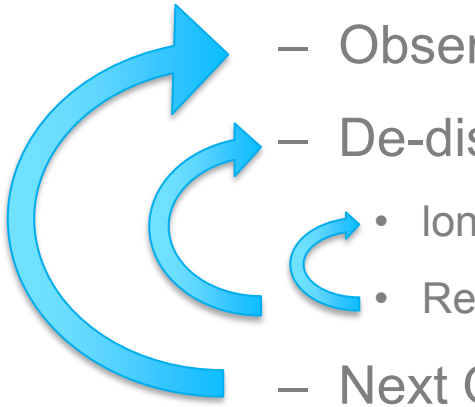
Pulsar Search: Communication

- Communications from beamformer to post-processor is a multiplication of (0.8-1.6 GHz observations):
  - Number of beams: 900
  - No. of channels: 80,000
  - Sample rate 55μs
  - Bits/sample 2
- Max data rate is ~ 360 GB/s
  - Could be reduced by:
    - increasing sample time, no. of channels
    - Reducing integration time

Pulsar Search: processing

Inherently highly parallel, beam processing is independent

- Requires:
  - Observation buffering for each beam
  - De-dispersion at many DMs
    - long FFTs (~2^{25}) for frequency searching.
    - Resample for a range of accelerations
  - Next Observation
- Correctly identify any known pulsar and all it's possible harmonics
- Discover new pulsars



Identification	Requirement	Applicability	Parent	Verification
SC_REQ_2110	Data rate beamformer to dedispersion: The data links shall support the a data rate of 364GB/s (900 beams with 10kHz channels, 0.8-1.6GHz) from the beamformer into the dedispersion system	Proposed	DRM SKA1 Analysis	Test
SC_REQ_2120	Channelised data buffering. The dedispersion system should “double buffer” data for pulsar searching. Each buffer half shall hold up to 604 TB of data.			
SC_REQ_2130	Pulsar de-dispersion. The processing system shall be capable of incoherently de-dispersing data streams from 900 beams for pulsar searching. Each data stream can have up to 80,000 channels. The number of DMs is TBD.			
SC_REQ_2140	Sampling time. The dedispersion system will increase the sampling time for higher DMs to reduce the processing requirements			
SC_REQ_2150	Pulsar Search beams. The processing system shall be capable of searching 900 incoming time series for pulsars. Each time series to consist of 2^{25} samples			
SC_REQ_2160	Pulsar Search, series The processing system will be able to search TBD dedispersed and acceleration corrected timeseries for putative pulsars			
SC_REQ_2170	Pulsar identification: known pulsars The processing system will be able to correctly identify a detection that is any known pulsar or its harmonics			
SC_REQ_2180	Pulsar identification: new pulsars The processing system must identify newly discovered pulsars and provide early parameters: position, DM, period, acceleration and pulse profile information.			
SC_REQ_2190	Accelerated pulsars search. The processing system shall be capable of searching re-sampled time series for linearly accelerated pulsars. The step size and number of acceleration steps is TBD.			

Pulsar timing

There are two distinct flavours of Timing:

- Bulk timing: regular timing of all the newly discovered pulsars to measure their physical parameters:
  - Period, spin down, DM, orbital parameters etc
  - Performed less than every 2 weeks for a year or more
  - Not “high precision”, so can use any frequency

Many pulsars to time concurrently: **High** comms and processing load

- Precision Timing: some pulsars are valuable for exact timing to reveal science for testing GR or gravity waves
  - Typically at 2-3 GHz, dish collectors
  - Precise single beam required for excellent polarisation,
  - Can use the whole SKA for higher sensitivity

Probably one pulsar at a time: **Low** comms and processing load

Pulsar Timing requirements

Technical Requirements from the DRM		
Parameter	Value	Comment
A_{eff}/T_{sys}	1000 m^2 K^{-1}	Pulsar luminosity, period, DM
Array data product	time series, notionally at least 20 such data streams	Processing
Frequency range	0.8–3 GHz	Pulsar spectra, period, DM
Frequency agility	switch between observing frequencies within 10 minutes or less	Timing precision
Time resolution capability	100ns	Pulsar duty cycle, period, DM
Polarization purity	40 dB	Timing precision
Timing stability	connect pulse time of arrivals over at least 10 yr	Longer programs lead to ever higher precision tests;

Pulsar bulk timing

- The requirement is for volume timing observations.
  - New possible pulsars detected likely to be >12,000: which will result in multiple attempted confirmations observations each
  - New pulsars ~6000 anticipated
  - Each new pulsar will require ~26 observations for a full timing solution
- Expect ~200,000 observations required for ~600s each
- Share between dishes and AAs
- Requires up to 20 simultaneous pulsar observations (time series beams) using full SKA array concurrently for processing
- Each will use coherent de-dispersion
- Polarisation purity not critical

Pulsar precision timing

- Relatively few pulsars being timed ~40
- Only one pulsar per observation for:
  - Best possible polarisation characteristic
  - Highest sensitivity at centre of beam
- Observations at least every two weeks carried on indefinitely
- Will use all SKA 1 dishes at 2-3 GHz for precision
- May additionally use AA-low concurrently for precise DM measurement

Low processing and comms requirements

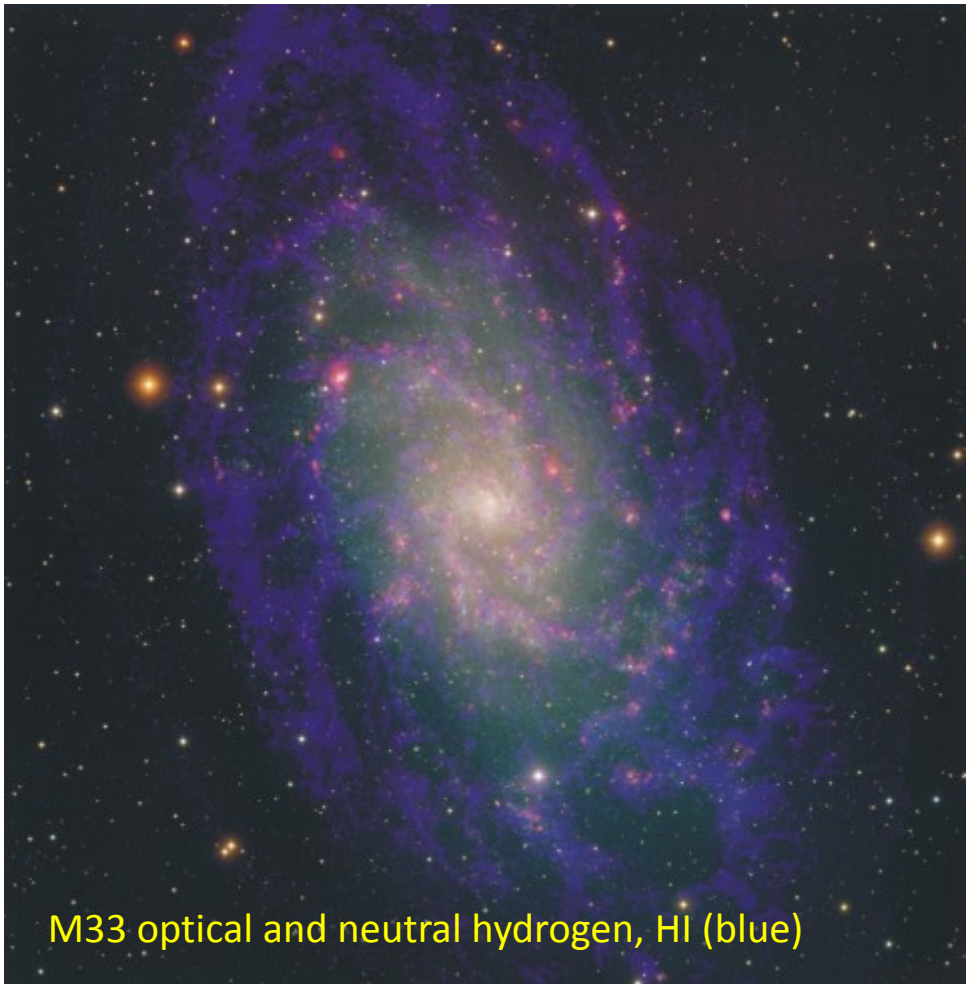
Must have extremely high accuracy time reference

Derived requirements

Identification	Requirement	Applicability	Parent	Verification
SC_REQ_2210	Pulsar de-dispersion. The time-series processing system shall be capable of coherently de-dispersing data streams from 20 concurrent pulsar observations of 800MHz bandwidth.	Proposed	DRM SKA1 Analysis	Test
SC_REQ_2220	Beamforming The time-series processing system shall be capable of handling beamformed data for at least 20 beams using the entire SKA_1 dish complement of 250 dishes.	Proposed	DRM SKA1 Analysis	Test
SC_REQ_2230	Beamforming polarisation The time-series processing system shall support full Stokes.			
SC_REQ_2240	Beamformer to dedispersion data rate The dedispersion system shall support a data rate from beamformer of at least 64GB/s			
SC_REQ_2250	Polarisation The time-series processing system shall correct polarisation purity to 40dB for the centre beam of dish observations. Precision shall be a minimum of TBD dB for any observation.			
SC_REQ_2260	Pulsar timing The processing system shall be capable of timing pulsars to 100ns. Using information from both polarisations.			
SC_REQ_2270	Concurrent observations The processing system shall be capable of making timing observations using both dish and AA-low collectors together			

Hydrogen in the local universe

- Wide-field high-fidelity imaging challenge
- Long integrations required to achieve sensitivity
- High angular resolution



HI Imaging DRM Requirements

Science Requirements from the DRM		
Parameter	Value	Comment
Linear resolution	300pc	
Redshift / distance	0-0.02 / 60 Mpc	
HI column density	5 x 10^{20} cm^{-2} (h)	High resolution < 300pc
	1 x 10^{18} cm^{-2} (l)	Low resolution 1 kpc or less
Velocity resolution	0.5 kms^{-1}	
Area of regard	500 kpc	

Technical Requirements from the DRM		
Parameter	Value	Comment
Frequency range	1390-1420 MHz	Set by redshift range
Baselines	50km	Linear Resolution
Spectral resolution	2 kHz	Velocity resolution
Brightness sensitivity	200 K for 50km baselines 0.3 K for 1.5 km baselines	Hi column density
Field of View	0.5 degrees FWHM	Goal of 5.7 degrees

Analysis

Imaging experiment – key aspect is to calculate data rate allowing for number of channels and angular resolution

N_B	=	1
G_{out}	=	50 GB/s
dt	=	0.36 s
N_{ch}	=	15×10^3

- In a full 12-hr synthesis produce **2.2 PB** of correlated data which we assume does not need to be stored, but may need to be buffered for the imaging pipeline
- Typical integration times are 30 hrs
- Major issue is whether PAFs are available as this will increase substantially the data rates for all experiments using baselines up to 50 km

- Data products:
  - 15k x 15k x 15k voxels
  - For single polarization size 13.5 TB (54 TB full polarization)

Derived requirements

Identification	Requirement	Applicability	Parent	Verification
SC_REQ_1310	Data rate for imaging for high resolution spectra imaging observations. The processing system will be able to handle data rates of up to 50 GB/s of UV-data for full synthesis observations.		SCI_T_REQ_0640; SCI_T_REQ_0620; SCI_T_REQ_0610	
SC_REQ_1320	Spectral-line Imaging. The processing system shall be capable of producing spectral-line data cubes of size at least 15k x 15k x 15k voxels in Stokes I		SCI_T_REQ_0640; SCI_T_REQ_0620; SCI_T_REQ_0610	
SC_REQ_1330	Data-volume data products. The system shall be capable of archiving image-volume data products of at least 15TB in size produced from full synthesis observations		SCI_T_REQ_0640; SCI_T_REQ_0620; SCI_T_REQ_0610	

Final comments

- First detailed analysis of DRM
  - Further analysis and iteration required during definition phase
- Some important questions raised
- Does DRM given full range of Science Data Processor requirements?
  - HI-imaging added to help and is pushing the boundaries
  - No formal science case, but can guess users will want wide-field continuum imaging in full Stokes