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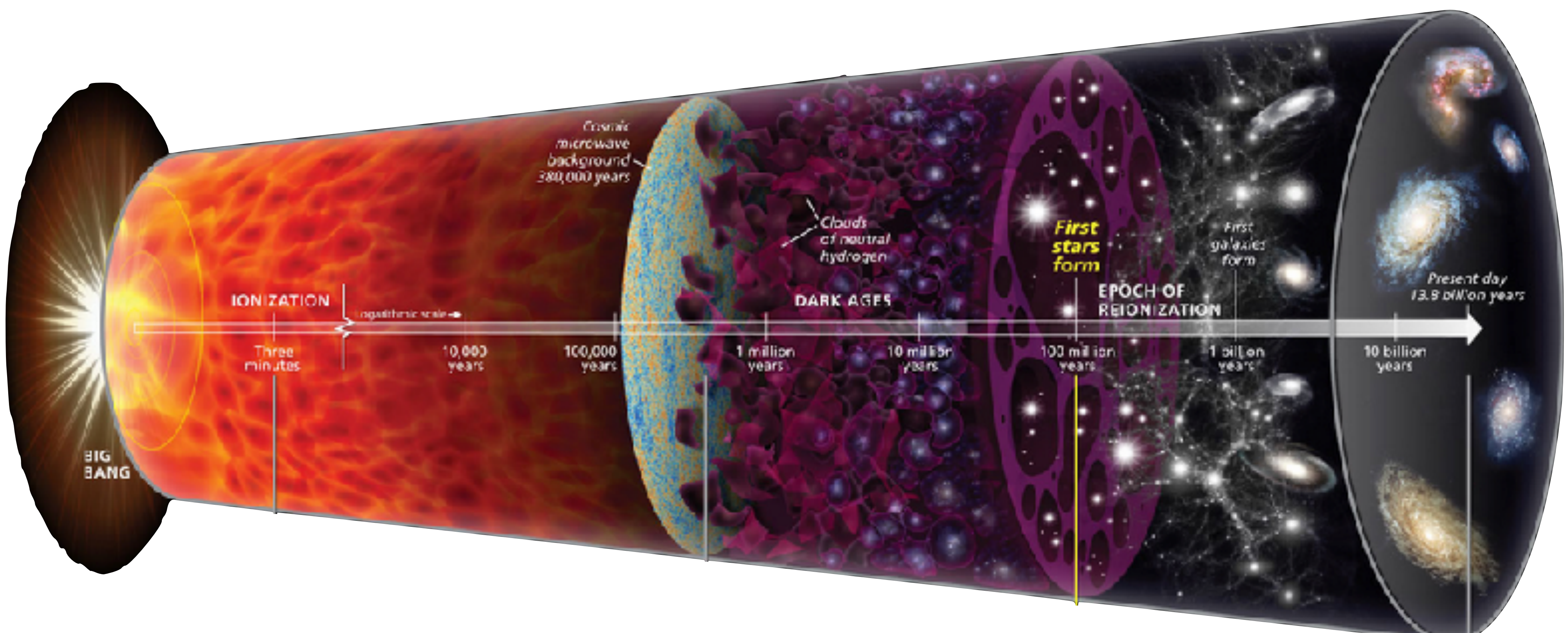
Cosmic Dawn & Epoch of Reionization with SKA1-low: SWG & Science Team

Léon V.E. Koopmans
(Kapteyn Astronomical Institute)



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Science Goals
SKA EoR/CD SWG/ST

NL-SKA May 24, 2018

Why and How Study the Universe's First Gyr?

z

30-200 — Dark Ages
- DM power-spectrum evolution
- DM annihilation physics
- Baryonic Bulk Flows
- Physics of Gravity/GR

12-30 — Cosmic Dawn
- Appearance of first stars/BHs (PopIII?)
- Ly-α radiation field
- Impact of Baryonic Bulk Flows
- First X-ray heating sources

6-12 — Reionization
- Reionization by stars & mini-quasars
- IGM feedback (e.g. metals)
- PopIII - PopII transition
- Emergence of the visible universe

0-6 — Post-Reionization
- BAO - DE EoS/Gravity
- Intensity Mapping - DE EoS/Gravity
- Galaxy Counts - Mass function ++

2030+: Space/Lunar based Interferometers (e.g. DEX)

~2020+: SKA/HERA/JWST

2015: Present day Telescopes

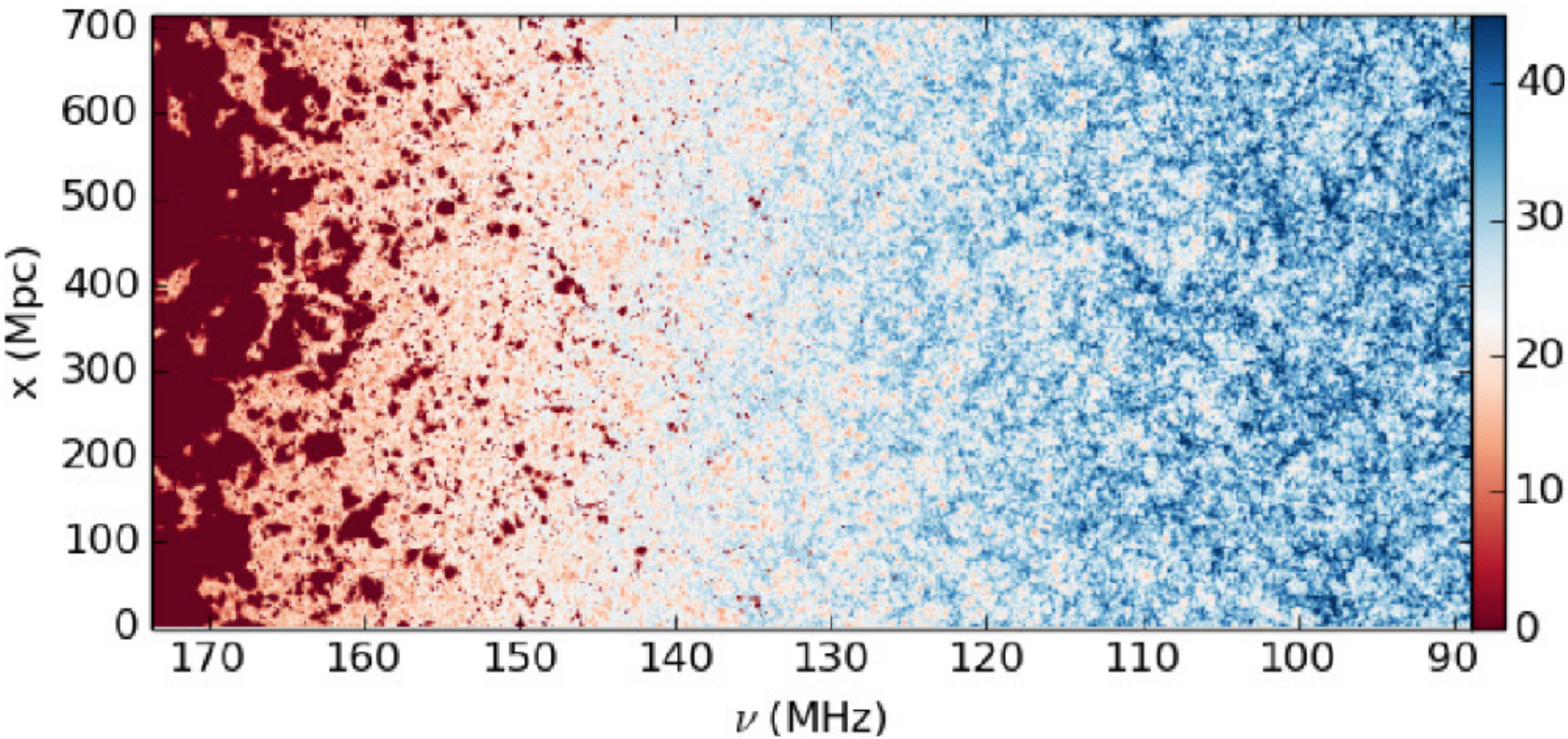
Studying HI Through Cosmic Time

The tomography of HI emission is a treasure trove of information for (astro)physics, cosmology & fundamental physics.

Post-Reionization

HI is found largely in galaxies ← HI has a filling factor of order unity

Dark Ages/Cosmic Dawn/Reionization



Credit: Dixon, Illiev et al.

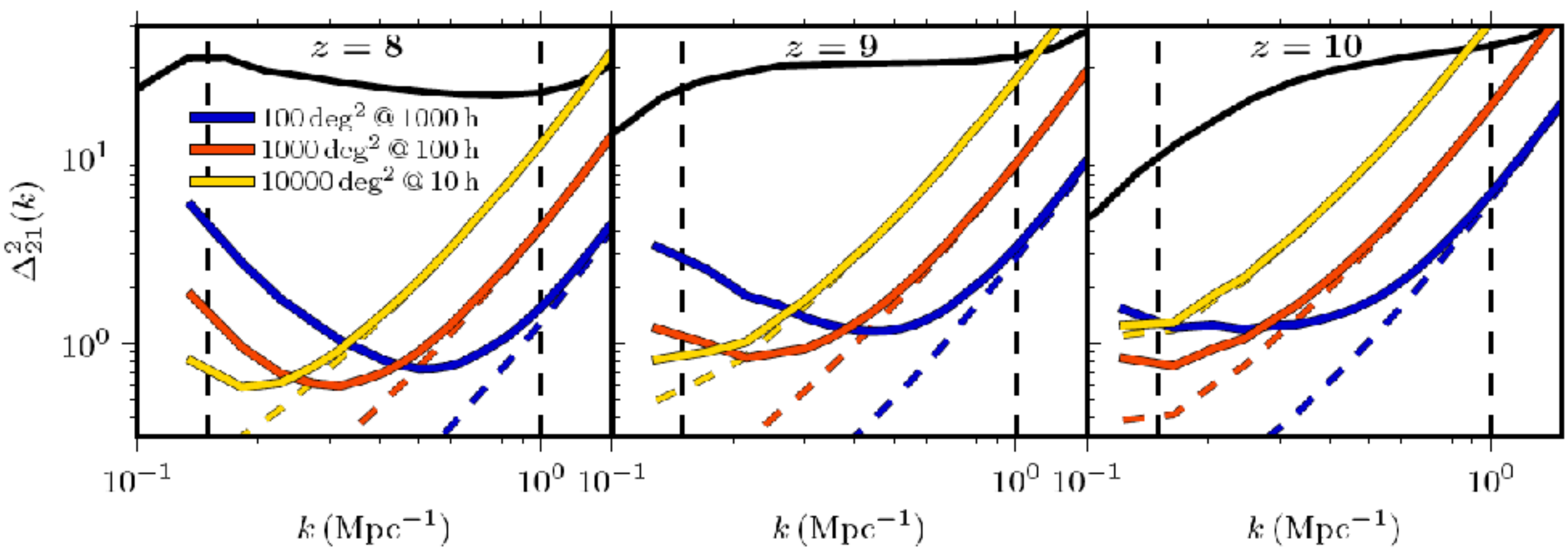
CD/EoR Survey Designs

Wider versus Deeper

A three tiered-survey (3x5,000hrs):

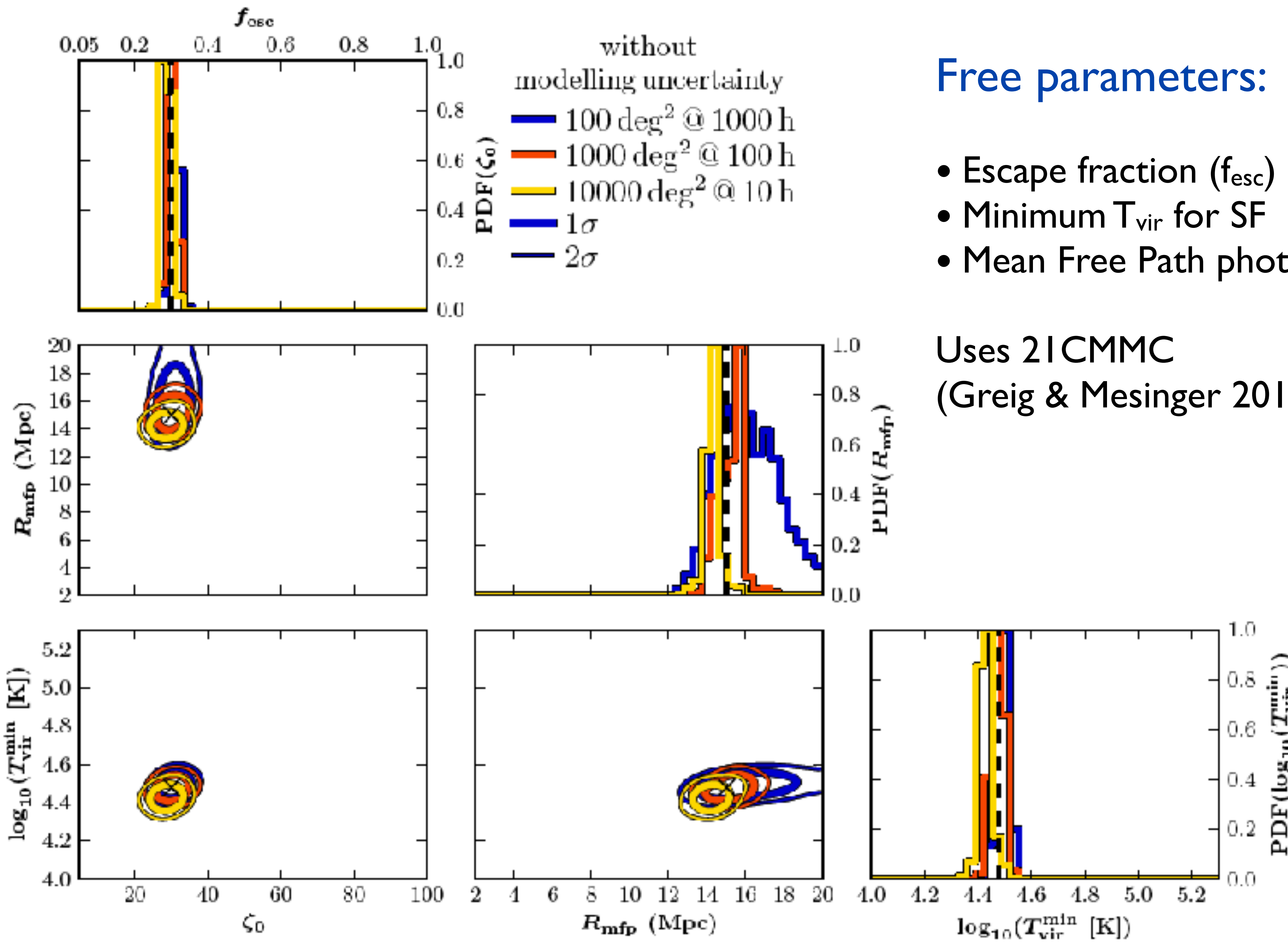
- DEEP: 100sdq with 1000hr/pointing
- MEDIUM: 1000sqd with 100hr/pointing
- SHALLOW: 10000sqd with 10hr/pointing

Deeper is better on small scales
(less thermal noise; bubbles)
Wider is better on large scales
(less sample variance)
Both are needed (PS+Tomography)



Greig, Mesinger & Koopmans (in prep)

EoR/CD: 21-cm Power-Spectrum



Free parameters:

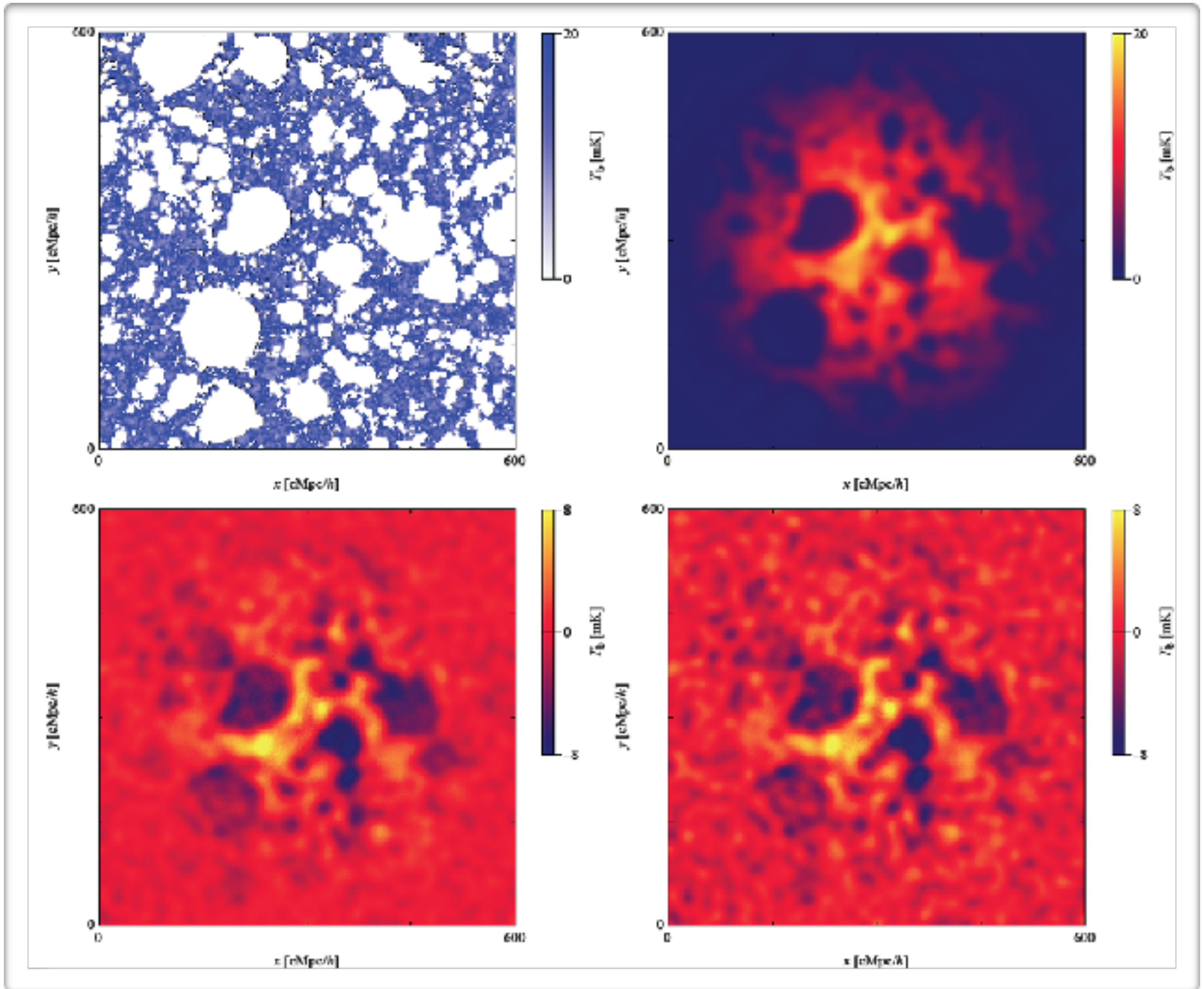
- Escape fraction (f_{esc})
- Minimum T_{vir} for SF
- Mean Free Path photons

Uses 21CMMC
(Greig & Mesinger 2015)

For model details see Greig, Mesinger & Koopmans (in prep)

Direct EoR Imaging: 21-cm Tomography

2 x SKA1 SKA1



Topology of EoR provides much more information on the sources than a power-spectrum, but requires a lot more sensitivity.

Wythe et al. (2015)

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Current Status 21-cm Cosmology

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Global 21-cm Signal Detection?

Correct redshift but 2.5x deeper than possible in standard model.

Spectacular but needs confirmation (e.g. by SARAS2).

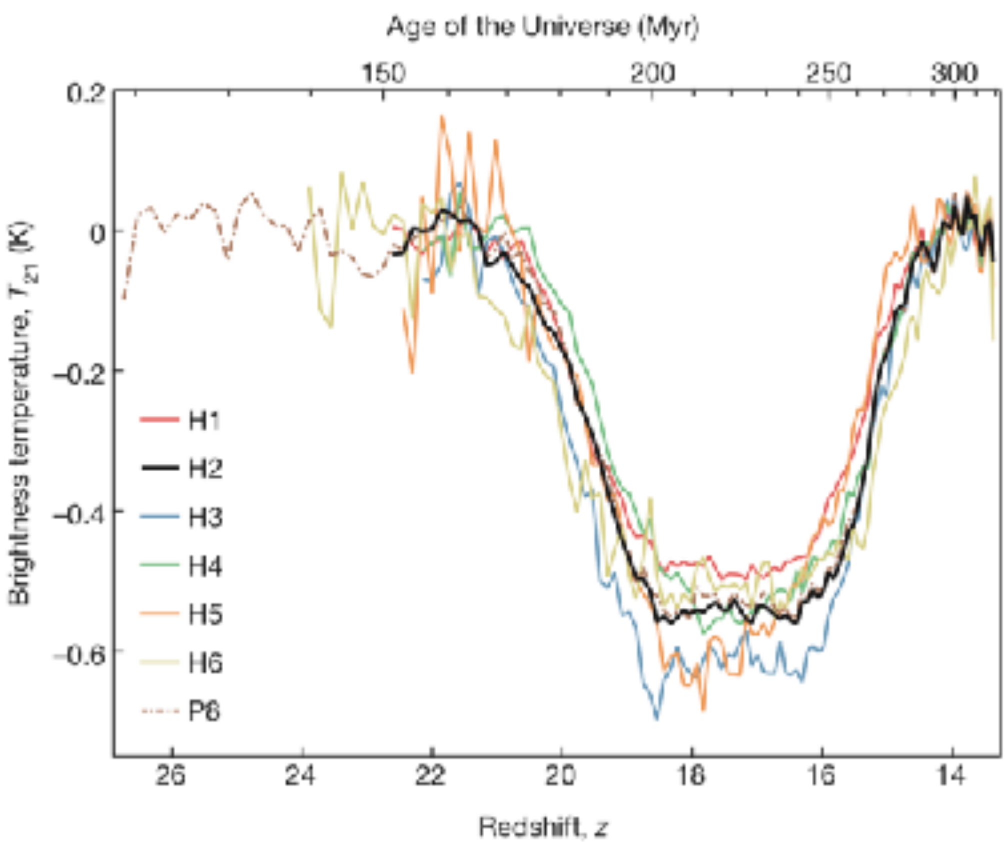
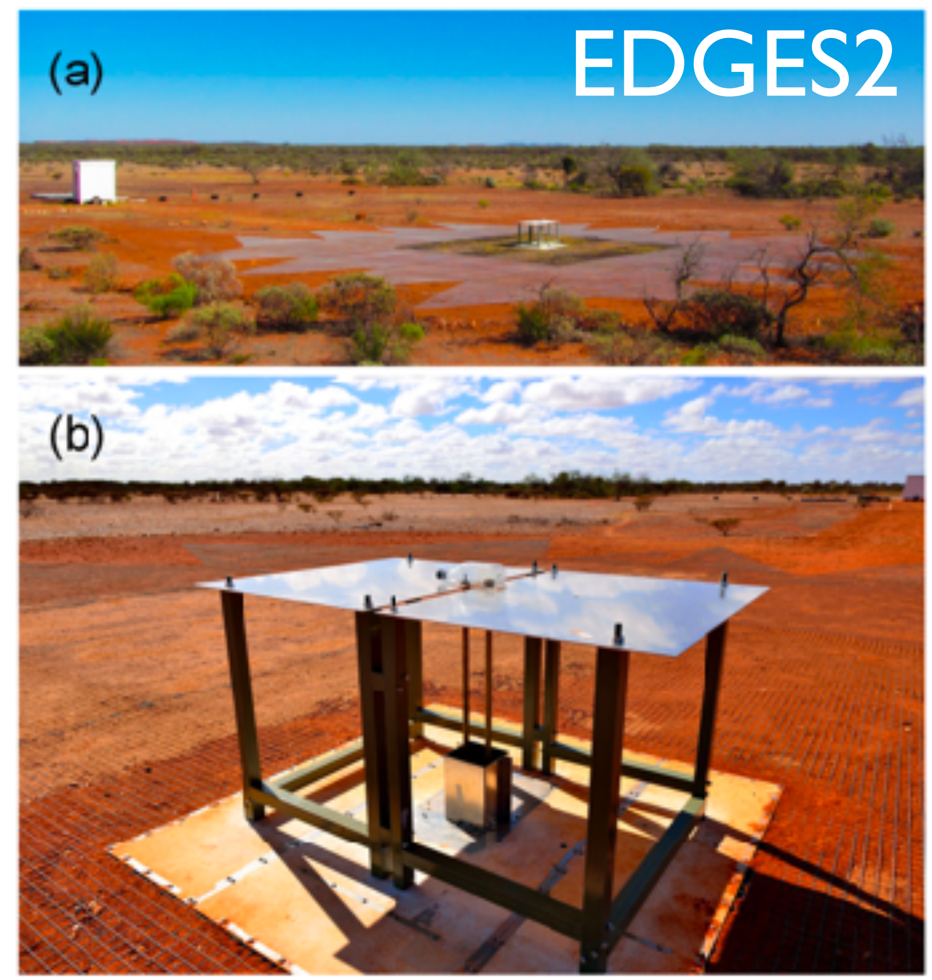


Figure 2 | Best-fitting 21-cm absorption profiles for each hardware case. Each profile for the brightness temperature T_{21} is added to its residuals and plotted against the redshift z and the corresponding age of the Universe. The thick black line is the model fit for the hardware and analysis configuration with the highest signal-to-noise ratio (equal to 52; H2; see Methods), processed using 60–99 MHz and a four-term polynomial (see equation (2) in Methods) for the foreground model. The thin solid lines are the best fits from each of the other hardware configurations (H1, H3–H6). The dash-dotted line (P8), which extends to $z > 26$, is reproduced from Fig. 1e and uses the same data as for the thick black line (H2), but a different foreground model and the full frequency band.



Bowman et al. 2018

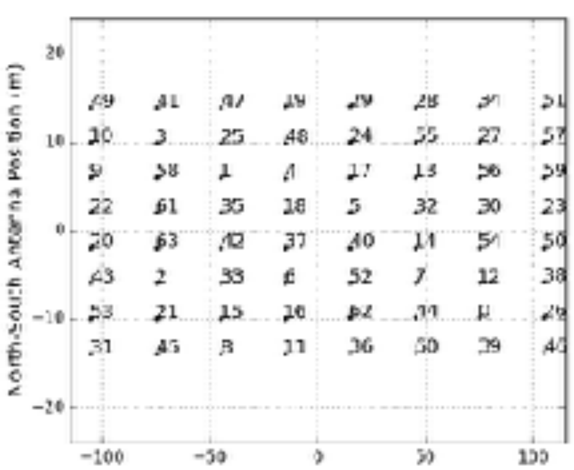
Current 21-cm Power-Spectrum Detection Experiments

Specs
- 40 hrs data [12/2007] on PSRB0823+26
- FWHM = 3.1d primary beam
- Resolution 20 arcsec
- Freq = 139.3-156.0 MHz [64x0.25MHz]
- Time resolution = 64 sec
- z = 8.1-9.2

Paciga et al. 2013

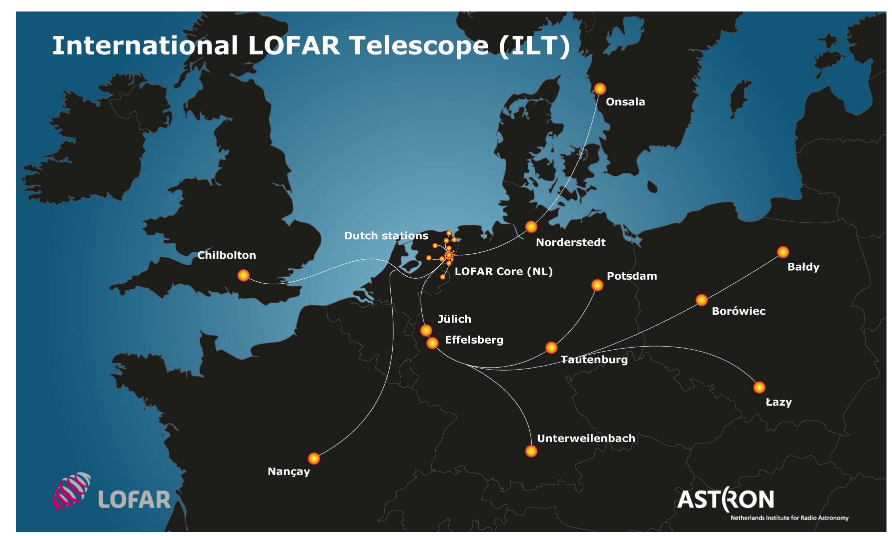
Specs:
- 3 hrs of data; - August 23 2013
- R.A.(J2000) = 0h 0m 0s,
  Decl.(J2000) = $-30^{\circ}\ 0'\ 0''$
- high-band of 30.72 MHz, centered at
  182 MHz i.e. $6.2 < z < 7.5$

Dillon et al. 2015



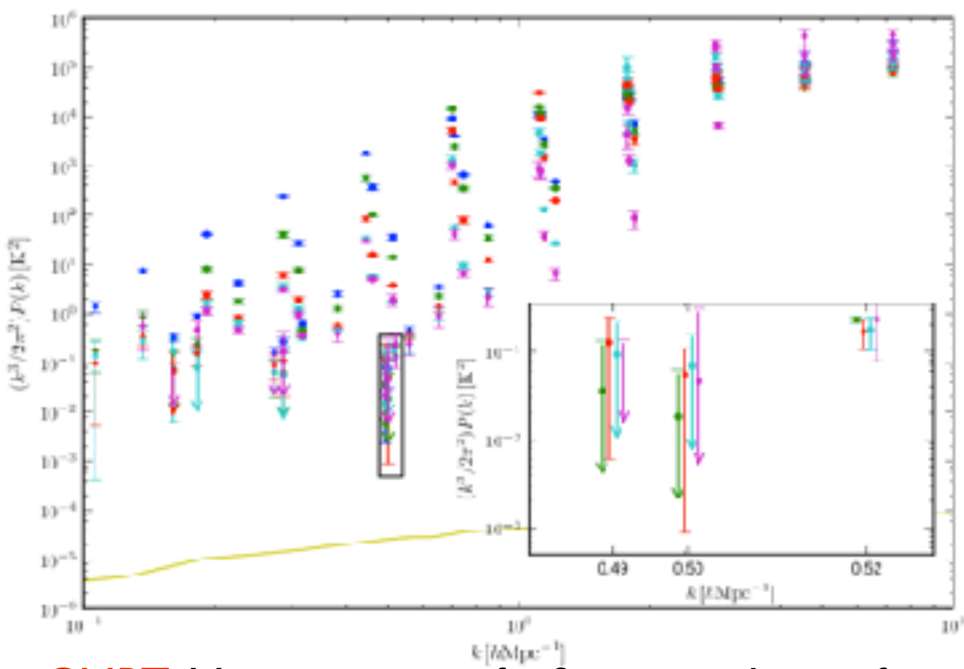
Specs:
- 1148 hrs of data
  (8/11/2012 to 23/3/2013)
- 100 to 200 MHz, 1024 chan
- visibility integr.: 10.7 seconds

Ali et al. 2015



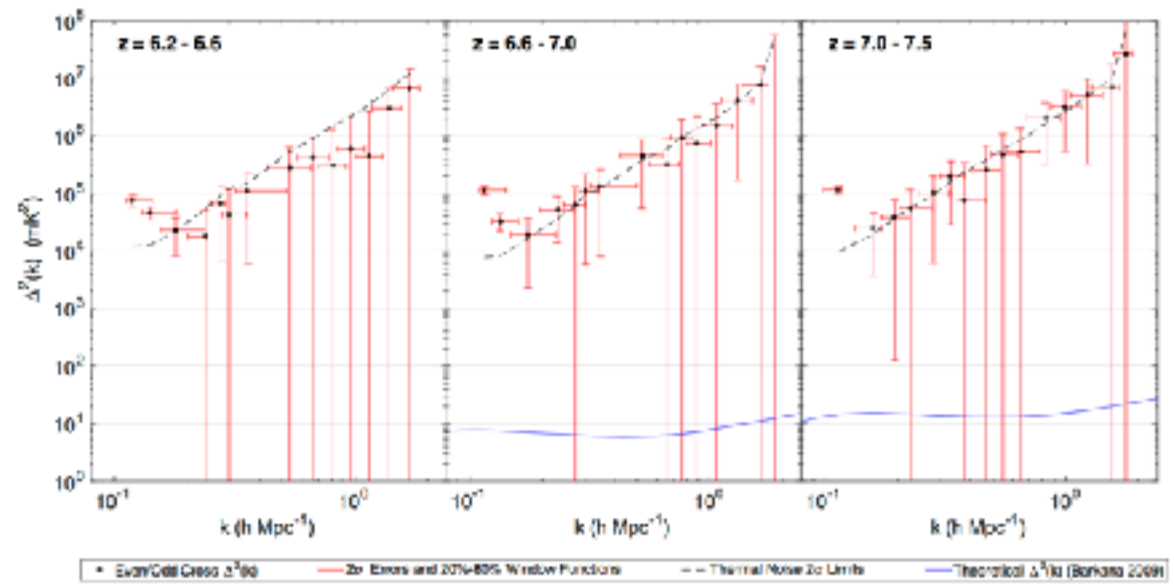
Specs:
- 13 hrs of data; - Feb11/12 2013
- R.A.(J2000) = 0h 0m 0s,
  Decl.(J2000) = $90^{\circ}\ 0'\ 0''$
- high-band of 115-189 MHz

Current 21-cm Power-Spectrum Detection Experiments



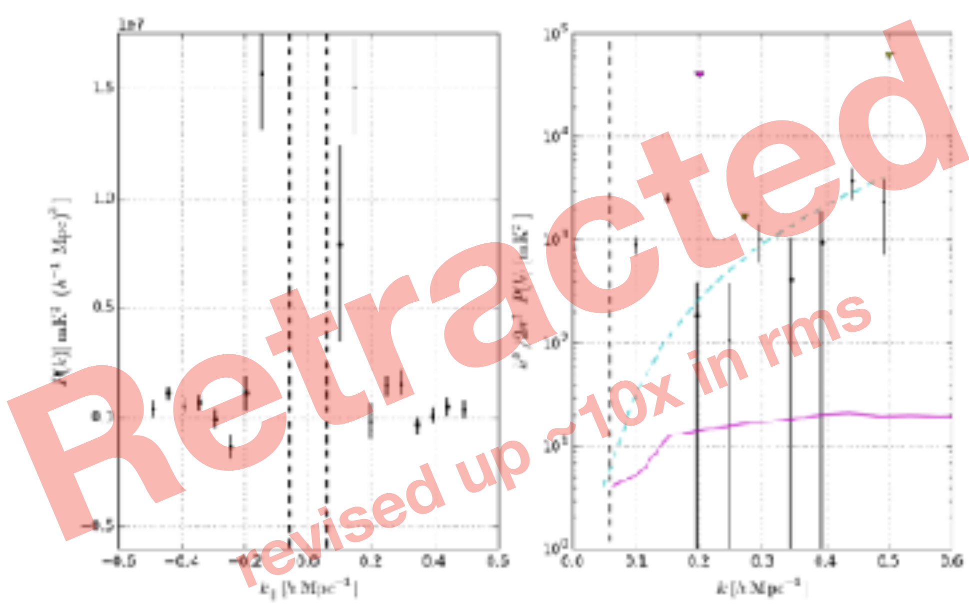
GMRT: Measurement of a 2σ upper limit of $\Delta(k) < 248$ mK for $k = 0.50\ h\ \mathrm{Mpc}^{-1}$ at $z = 8.6$.

Paciga et al. 2013



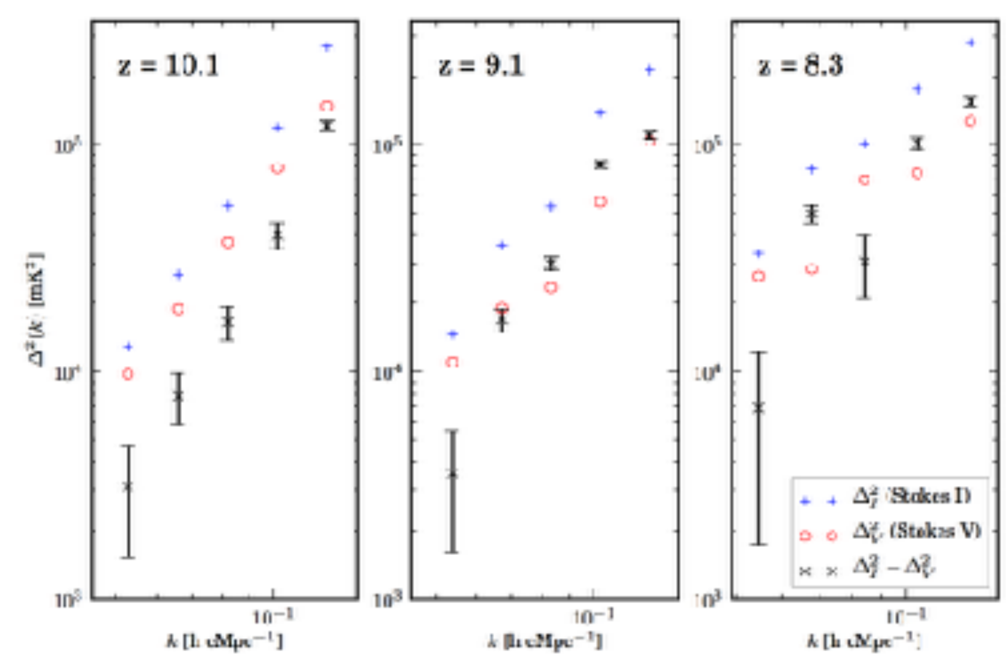
MWA-128T: Upper limits on the power spectrum from $z = 6.2$ to $z = 7.5$. The lowest limit is $\Delta(k) < 192$ mK at 95% confidence at a co-moving scale $k = 0.18\ \mathrm{Mpc}^{-1}$ at $z = 6.8$.

Dillon et al. 2015



PAPER 64-antenna: A best 2σ upper limit of $\Delta(k) < 22$ mK for $k = 0.15\text{-}0.5\ h\ \mathrm{Mpc}^{-1}$ at $z = 8.4$.

Ali et al. 2015



LOFAR: Measurement of a 2σ upper limit of $\Delta(k) < 80$ mK for $k = 0.05\ h\ \mathrm{Mpc}^{-1}$ at $z = 10.1$.

Patil et al. 2017

Current 21-cm Power-Spectrum Detection Experiments

By far the deepest 21-cm power spectrum results to date

Credit: Florent Mertens

SWG/ Science Team

Our SWG (advices SKAO) mirrors a single Science Team (prepares for KSP) that aims to transition to a single Key Science Project Team with internally various science goals/groups. No split!

Science Working Group/Science Team

https://sites.google.com/site/skacdeorscienceteam/

SKA CD/EoR Science Team

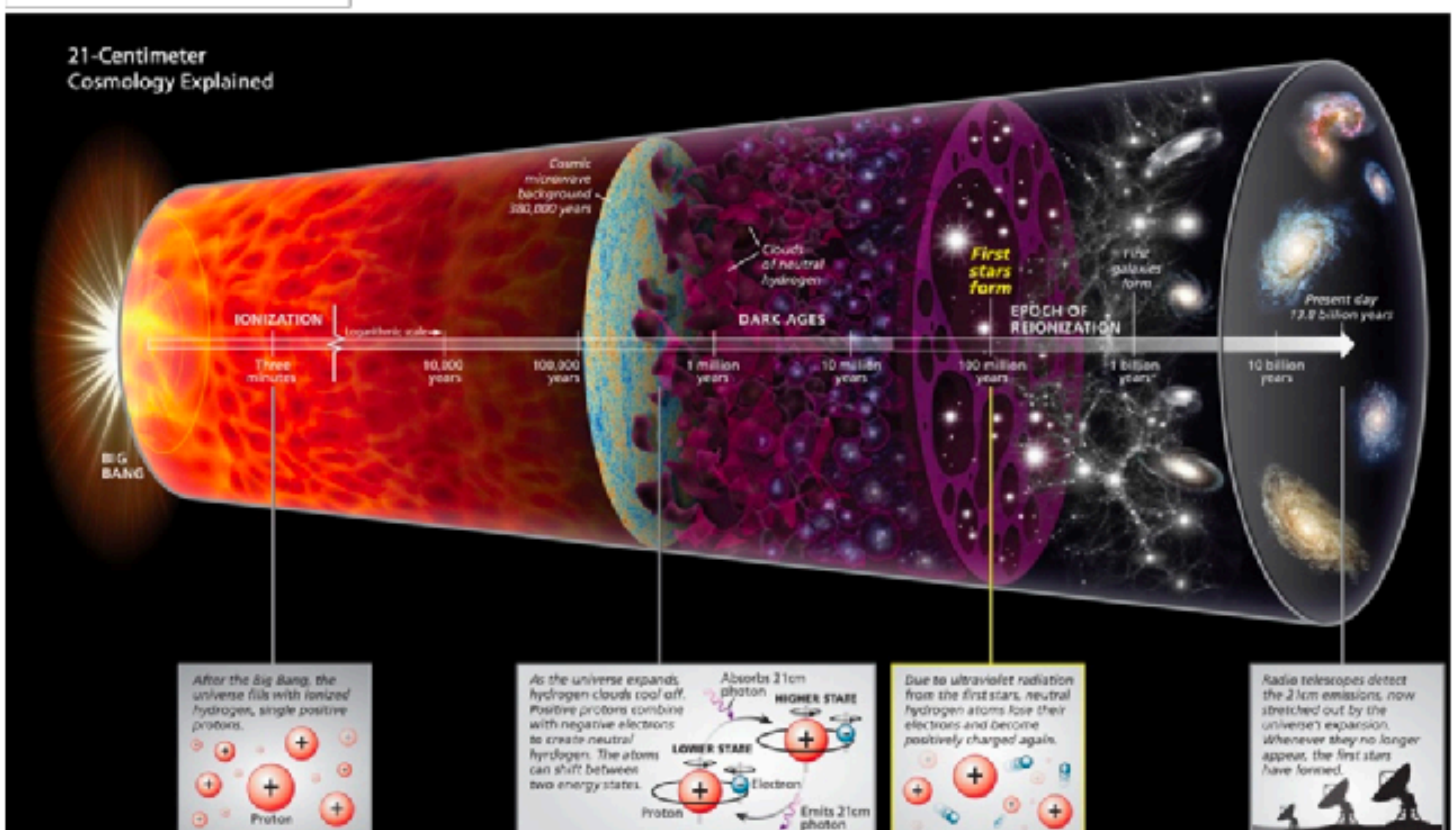
Search this site

Home | Membership | Focus Groups | Data | Documents | Meetings | Projects Page | Statutes | Sitemap

Home

Welcome to the Google Site for the **SKA CD/EoR Science team**. This site will be used as central information hub where we will place any information, documents, etc relevant for the SKA CD/EoR Science Team.

Our Google Group can be found by clicking here.



(Credit: Roen Kelly)

Science Working Group/Science Team

Focus Groups

This page lists the focus groups and a short description of their focus. The full list can found in the List of Focus Groups document

A) Theory/Numerical Simulations
A1: Theory/Physics for understanding model space/subgrid physics
A2: Full numerical simulations for calibration
A3: Fast simulations for analysis
A4: Foreground Studies and simulations

B) Observational Strategies
B1: Interferometric
B2: Global Signal
B3: 21cm Forest

C) Data Processing
C1: RFI Excision
C2: Calibration/Ionosphere
C3: Imaging/Sky-model building
C4: Foreground Fitting/Removal
C5: New Algorithmic Development
C6: Computational and Other Resources

D) Signal Extraction and Error Analysis

E) Signal Analysis and Interpretation

F) Synergy (SKA + Other instruments)

G) End-to-End (Data) Simulations

1. Core Members

Ahn	Kyungjin	KR
Barkana	Rennan	IS
Bernardi	Gianni	SA
Bonaldi	Anna	UK
Chapman	Emma	UK
Chen	Xuelei	CN
Choudhury	Tirth	IN
Ciardi	Benedetta	DE
Colafrancesco	Sergio	SA
Datta	Abhirup	IN
Datta	Kanan K.	IN
Dayal	Pratika	NL
Ferrara	Andrea	IT
Fialkov	Anastasia	US
Greig	Brad	IT
Hasegawa	Kenji	JP
Herranz	Diego	ES
Iliev	Ilian	UK
Jelic	Vibor	NL
Jones	Mike	UK
Koopmans	Léon	NL
Mack	Katie	AU
Maio	Umberto	IT
Majumdar	Suman	UK
Mao	Yi	CN
McKinley	Ben	AU
Mellema	Garrelt	SE
Mesinger	Andrei	IT
Mitchell	Daniel	AU
Offringa	Andre	NL
Pindor	Bart	AU
Pritchard	Jonathan	UK
Santos	Mario	SA
Semelin	Benoit	FR
Sethi	Sith	IN
Shankar	Udaya	IN
Subrahmanyan	Ravi	IN
Trott	Cathryn	AU
Vedantham	Harish	NL
Wayth	Randall	AU
Webster	Rachel	AU
Wyithe	Stuart	AU
Xu	Yidong	CN
Yatawatta	Sarod	NL
Zackrisson	Erik	SE
Zarb-Adami	Kris	UK
Zaroubi	Saleem	NL

2. Associate Members

			Member since
Aubert	Dominique	FR	Aug. 2016
Fiore	Fabrizio	IT	Aug. 2016
Ichiki	Kiyotomo	JP	Aug. 2016
Inoue	Susumu	JP	Aug. 2016
Jordan	Chris	AU	Aug. 2016
Mertens	Florent	NL	Jan. 2016
Sardarabadi	Milad	NL	Jan. 2016
Martin	Sahlén	UK	Jan. 2016
Anne	Hutter	AU	Jan. 2016
Catherine	Watkinson	UK	Aug. 2016
Nichole	Barry	US	Nov. 2016
Mayuri	Rao	IN	Jan. 2017
Shimabukuro	Hayato	JP	Jan. 2017
Mondal	Rajesh		Jan. 2017
Koki	Kakiichi	UK	Jan. 2017

3. Consulting Members

Aguirre	James	US
Bourke	Tyler	SKA
Briggs	Frank	AU
Chang	Tzu-Ching	TW
Chengalur	Jayaram	IN
de Souza	Rafael	KR
Greenhill	Lincoln	US
Harker	Geraint	UK
Lazio	Joseph	US
Leeuw	Lerothodi	SA
Morales	Miguel	USA
Parsons	Aaron	US
Pen	Ue-Li	CA
Schneider	Raffaella	IT
Shimabukuro	Hayato	JP
Takahari	Keitaro	JP
Takeuchi	Tsutomu	JP
van Bemmel	Ilse	NL
Wagg	Jeff	SKA
Yoshiura	Shintaro	JP

Membership/Dutch Involvment and leadership

- Membership SWG in principle open to all CD/EoR researchers (email Chairs: Mellema/Bernardi)

- Membership Science Team open to all all CD/EoR researchers (email Chair Koopmans) that want to actively participate in one or more Focus Group(s).

- First Associate Member and if genuinely active they become Core Member after ~1 year.

- Some guidelines by SKA board are that SKA member states are reasonably represented (<~10% from non-member states). Current ST board has member from each member state.

Regular SWG/Science Team Meetings

Current Focus: Data Challenges from raw data to 21-cm signal

First challenge will be announced in Sept. 2018

SKA CD/EoR Science Team

Search this site

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Meetings >

5th EoR/CD science team meeting - London, UK

Royal Astronomical Society, London, UK
September 24-25, 2018

The meeting will begin on Monday morning (24 Sept) and finish on Tuesday afternoon (25 Sept). If there's interest, space will be available on the Wednesday (26th) for anyone wanting to stay longer for informal collaboration.

If you are planning to attend please add your name to this list:
https://docs.google.com/document/d/13Xb5GM-TmbjjI3CDvI_izG8o5AkuGjqpcQJVrWIAfMw/edit?usp=sharing

Location:
Royal Astronomical Society
Burlington House
Piccadilly
London W1J 0BQ
United Kingdom

The RAS building is located close to Piccadilly Circus (Picadilly Line) and Green Park (District Line) underground stations.

(https://www.ras.org.uk/about-the-ras/burlington-house/240-welcome-to-burlington-house)

Program:
TBD - days start at 10am, end at 5pm. Lunch and coffee provided.

Workshop dinner:
TBD

Accommodation:
TBD

Contacts:
Jonathan Pritchard (j.pritchard@imperial.ac.uk)

Contributions SWG/ST to SKA1-low

- Propose (adopted) SKA1-low baselines design (Mellema, LVEK et al. 2013)
- Play central role in define HPSCs (High Priority Science Cases)
- Play central role in the (first) re-baselining effort, ensuring SKA1-low remains able to do transformational science (21-cm tomography, Cosmic Dawn)
- Help define many aspects (bandpass smoothness, layout, station size, etc)
- Help develop some of the data processing/analysis tools (NL Roadmap contribution by e.g. Koopmans++, DIRAC project by Yatawatta++, etc.)
- Help define transition point in SDP from SKAO -> Community
- Develop distributed processing/calibration/imaging (e.g. SageCal-CO can now run globally distributed, with successful test between NL-AU) and other processing tools/algorithms. Use lessons from LOFAR & MWA.

Challenges

- A 3 tiered survey will take ~5 years and collect ~1 exabyte of data !!
- Processing requires 10s-100s Pflops for many years with current algorithms.
- Where to place the data, centrally/distributed? Distribute per over time of over frequency? Task for SKA Regional Centres ?
- What algorithms/tools are needed to get the data to the ~thermal noise level on the shortest baselines (are current algorithms good enough)
- Incorporate lessons learned from all precursors/pathfinders in to a design/processing chain. SKA1-low is LOFAR on steroids! Perfect pathfinder!
- We are involved in SKAO "Data Challenge" discussion (reality check!)
- SWG/ST plans its own end-to-end "Data Challenges" in the next years that increase in complexity. Challenges on simulated data, real (LOFAR/MWA) data and also on early-science/release data from SKA1-low.
- Lack of people-power as always!

Issues

- A 3 tiered EoR/CD Survey program would be ~1 exabyte of data. SKA project will not be able to process this to mK depths w/o help from experts in the EoR community. SKAO does not have this expertise.

- Data processing needs handover point to community (either on SKA HPC or externally). What point? Discussion with SDP ongoing.

- Difficult sometimes to transfer knowledge from precursors/pathfinders to the SKAO (e.g. Roadmap/DIRAC/LOFAR-EoR, etc). Lack of people to handle all of this at SKAO and in external teams.

- We need clarity on KSPs sooner rather than later to start requesting resources (e.g. ERC, etc). Pre-allocation (w/clear requirements) would be extremely helpful to obtain these resources. Data in role-out phase is already useful to obtain power-spectra on large scales, but not for tomography.