The SKA Observatory

Tirthankar Roy Choudhury
National Centre for Radio Astrophysics
Tata Institute of Fundamental Research
Pune

NCRA • TIFR

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Topics

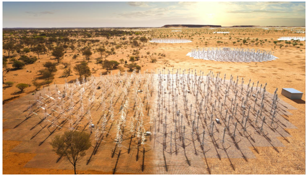
- The SKAO
- Indian participation
- One science case: the first stars

The SKAO

The next-generation radio astronomy-driven Big Data facility
that will revolutionise our understanding of the Universe and the laws of fundamental physics.

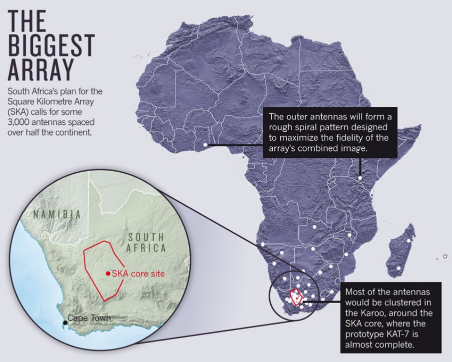
Global HQ at Jodrell Bank, UK

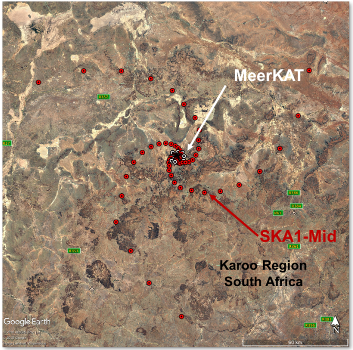
197 mid-frequency dishes in South Africa



1,31,072 low-frequency antennas in Western Australia

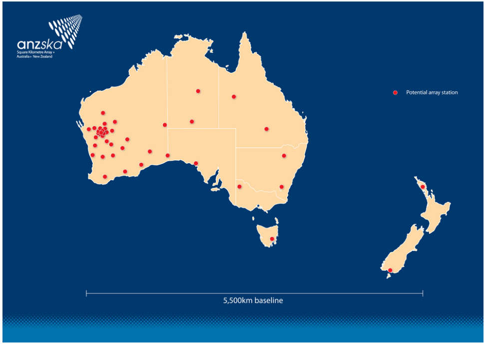
SKA-Mid

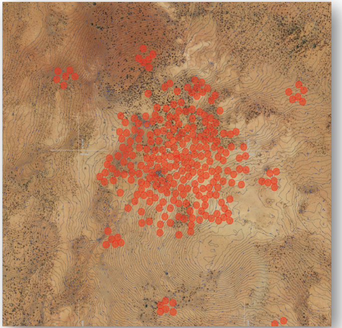




- Karoo site in South Africa
- Frequency range: 350 MHz – 15.4 GHz
- 133 15 m SKA dishes and 64 13.5 m MeerKAT dishes
- Baseline design: core of around 50% of the dishes, randomly distributed within 2 km, three logarithmic spiral arms with a maximum baseline extending out to 150 km

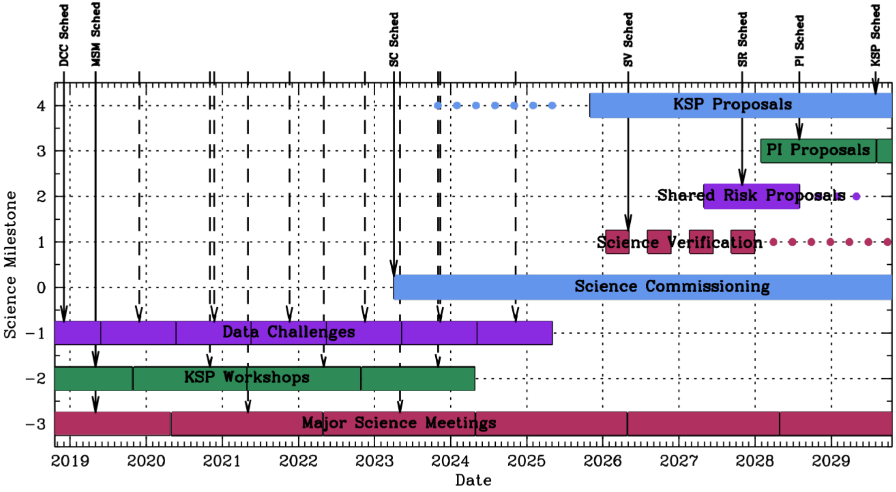
SKA-Low





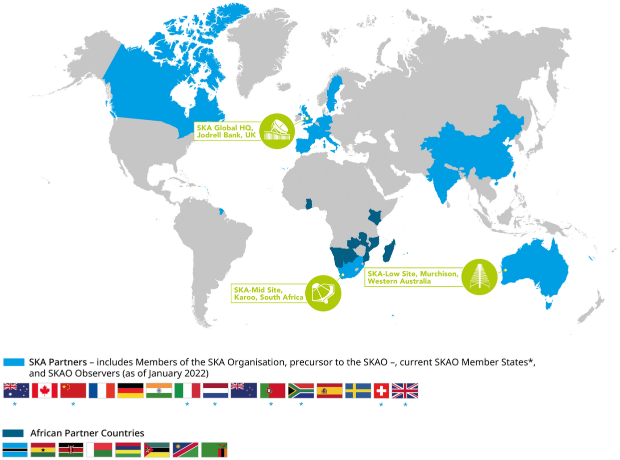
- Murchison Radio-astronomy Observatory, Western Australia
- Frequency coverage: 50 – 350 MHz
- Log-periodic dipole antennas distributed across 512 aperture array stations of 256 antennas each
- Baseline design: around 50% of the stations within a 1 km diameter core, remaining stations organised in clusters of 6 stations on three modified spiral arms. The maximum baseline $\sim$ 70 km.

SKA timeline



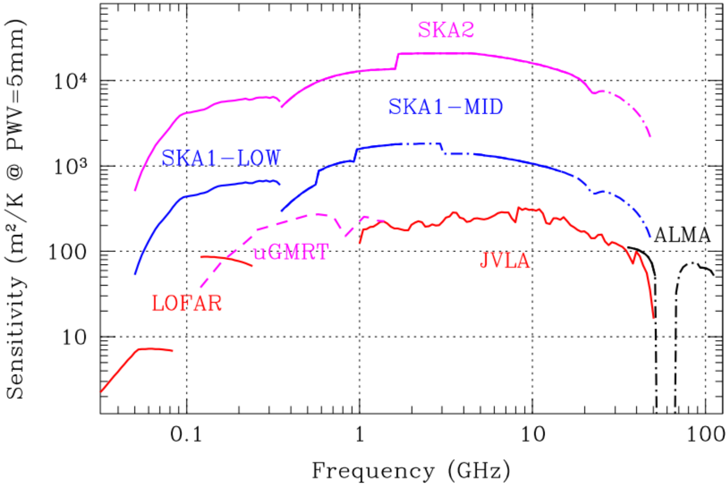
Assumes construction start date July 2021, in reality December 2022.

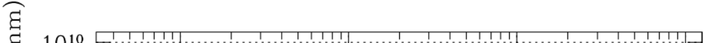
Countries participating in the SKA



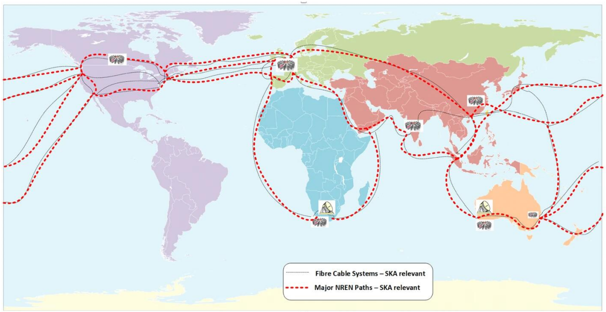
- Members: Australia, China, Italy, The Netherlands, Portugal, South Africa, Switzerland, United Kingdom.
- Prospective Members: Canada, France, Germany, India, Japan, South Korea, Spain, Sweden.

SKA1 compared to other telescopes





Big data with the SKAO



- 8 Tbps from SKA-Low to Perth, 20 Tbps from SKA-Mid to Cape Town.
- Two high-performance supercomputers called Science Data Processors (SDPs), each $\sim$ 135 PFlops.
- SKAO will archive 300 petabytes of data per year.
- From the SDP supercomputers, data will be distributed via intercontinental telecommunications networks to SKA Regional Centres in the SKAO Member States where science products will be stored for access by the end users.

SKAO science data challenge

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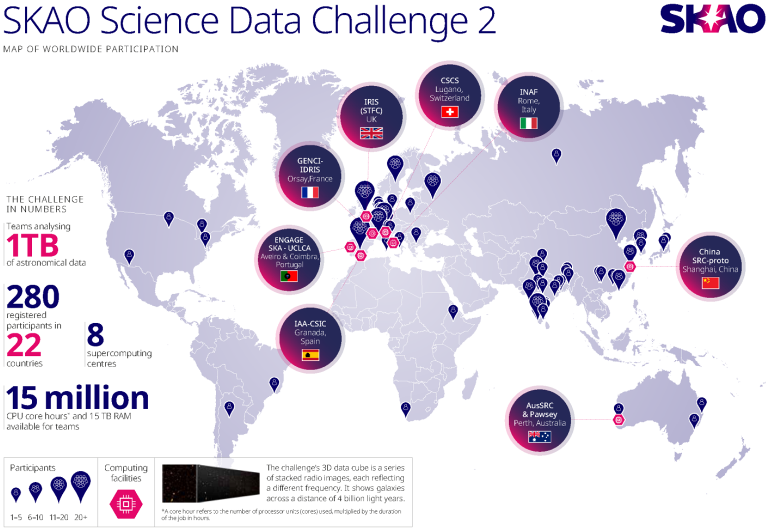

SKA: Indian involvement

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- India contributed heavily to the design phase of the project, leading role in the *Telescope Manager* system (controlling nerve centre and brains behind the functioning of the entire SKA observatory.).
- The proposal to join the construction and operation phase is pending with the Government of India.
- The activities within India are coordinated by the *SKA-India Consortium*, $\sim$ 20 organisation members.

SKA INDIA

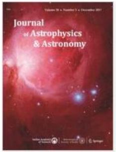
- Science activities coordinated by SKA-India *Science Working Groups.*

SKA-India science

Journal of Astrophysics and Astronomy
All Volumes & Issues

Indian Participation in the SKA

ISSN: 0973-7758 (Online)



In this topical collection (15 articles)

Scientific Review
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Chandra Shekhar Murmu, Raghunath Ghara...
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Published: 20 October 2022

Editorial

Tirthankar Roy Choudhury, Abhirup Datta, Preeti Kharb & Nirupam Roy

Journal of Astrophysics and Astronomy **43**, Article number: 78 (2022) | Cite this article

The Square Kilometre Array (SKA), when completed, will be the largest radio telescope in the world. The project is funded by an international collaboration consisting of more than a dozen countries across the world. The design of the facility has recently been completed and it has now entered the phase of construction. By the end of this decade, one expects the telescope to be largely complete and producing excellent scientific results.

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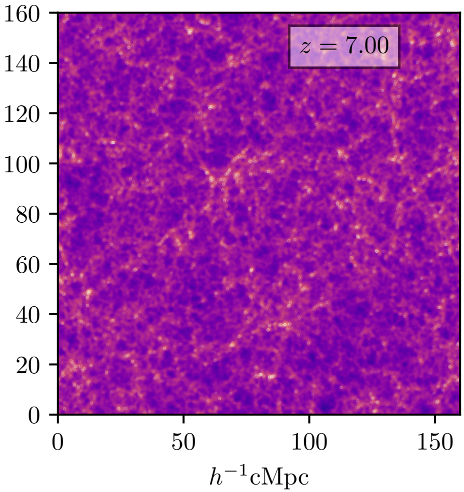
- Indian scientists involved in almost all the interesting science areas in the SKA.
- These cover areas starting from the Sun to our Galaxy to the largest scales in the Universe.
- The Indian science interests have been compiled in an upcoming issue of the *Journal of Astronomy & Astrophysics*.
- About 30 articles, all accepted, the volume under process at the moment.

Science with the SKA

	SKA1	SKA2
The Cradle of Life & Astrobiology Hoare, M. et al. 2015 PoS(AASKA14)115	Proto-planetary disks; imaging snow/ice line (@ < 100pc), Searches for amino acids.	Proto-planetary disks; sub-AU imaging (@ < 150 pc), Studies of amino acids.
	Targeted SETI: airport radar 10^4 nearby stars.	Ultra-sensitive SETI: airport radar 10^5 nearby star, TV ~10 stars.
Strong-field Tests of Gravity with Pulsars and Black Holes Kramer, M. & Stappers, B. 2015 PoS(AASKA14)036	1st detection of nHz-stochastic gravitational wave background.	Gravitational wave astronomy of discrete sources: constraining galaxy evolution, cosmological GWs and cosmic strings.
	Discover and use NS-NS and PSR-BH binaries to provide the best tests of gravity theories and General Relativity.	Find all ~40,000 visible pulsars in the Galaxy, use the most relativistic systems to test cosmic censorship and the no-hair theorem.
The Origin and Evolution of Cosmic Magnetism Johnston-Hollitt, M. et al. 2015 PoS(AASKA14)092	The role of magnetism from sub-galactic to Cosmic Web scales, the RM-grid @ 300/deg^2.	The origin and amplification of cosmic magnetic fields, the RM-grid @ 5000/deg^2.
	Faraday tomography of extended sources, 100pc resolution at 14Mpc, 1 kpc @ $z \approx 0.04$.	Faraday tomography of extended sources, 100pc resolution at 50Mpc, 1 kpc @ $z \approx 0.13$.
Galaxy Evolution probed by Neutral Hydrogen Staveley-Smith, L. & Oosterloo, T. 2015, PoS(AASKA14)167	Gas properties of 10^7 galaxies, $\langle z \rangle \approx 0.3$, evolution to $z \approx 1$, BAO complement to Euclid.	Gas properties of 10^9 galaxies, $\langle z \rangle \approx 1$, evolution to $z \approx 5$, world-class precision cosmology.
	Detailed interstellar medium of nearby galaxies (3 Mpc) at 50pc resolution, diffuse IGM down to $N_H < 10^{17}$ at 1 kpc.	Detailed interstellar medium of nearby galaxies (10 Mpc) at 50pc resolution, diffuse IGM down to $N_H < 10^{17}$ at 1 kpc.
The Transient Radio Sky Fender, R. et al. 2015 PoS(AASKA14)051	Use fast radio bursts to uncover the missing "normal" matter in the universe.	Fast radio bursts as unique probes of fundamental cosmological parameters and intergalactic magnetic fields.
	Study feedback from the most energetic cosmic explosions and the disruption of stars by super-massive black holes.	Exploring the unknown: new exotic astrophysical phenomena in discovery phase space.
Galaxy Evolution probed in the Radio Continuum Prandoni, I. & Seymour, N. 2015 PoS(AASKA14)067	Star formation rates (10 $M_\odot$/yr to $z \sim 4$).	Star formation rates (10 $M_\odot$/yr to $z \sim 10$).
	Resolved star formation astrophysics (sub-kpc active regions at $z \sim 1$).	Resolved star formation astrophysics (sub-kpc active regions at $z \sim 6$).
Cosmology & Dark Energy Maartens, R. et al. 2015 PoS(AASKA14)016	Constraints on DE, modified gravity, the distribution & evolution of matter on super-horizon scales: competitive to Euclid.	Constraints on DE, modified gravity, the distribution & evolution of matter on super-horizon scales: redefines state-of-art.
	Primordial non-Gaussianity and the matter dipole: 2× Euclid.	Primordial non-Gaussianity and the matter dipole: 10× Euclid.
Cosmic Dawn and the Epoch of Reionization	Direct imaging of EoR structures ($z = 6$ - 12).	Direct imaging of Cosmic Dawn structures ($z = 12$ - 30).
	Power spectra of Cosmic Dawn	

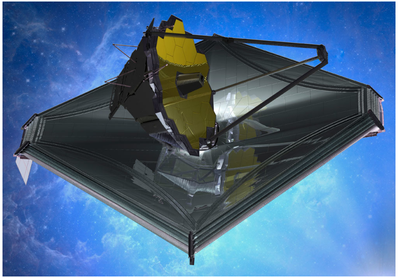
Growth of large-scale structures



N-body simulations using *GADGET-2* (Springel et al 2005), run on a NCRA Fujitsu server

Search for the first stars

Probes planned for detecting the first stars

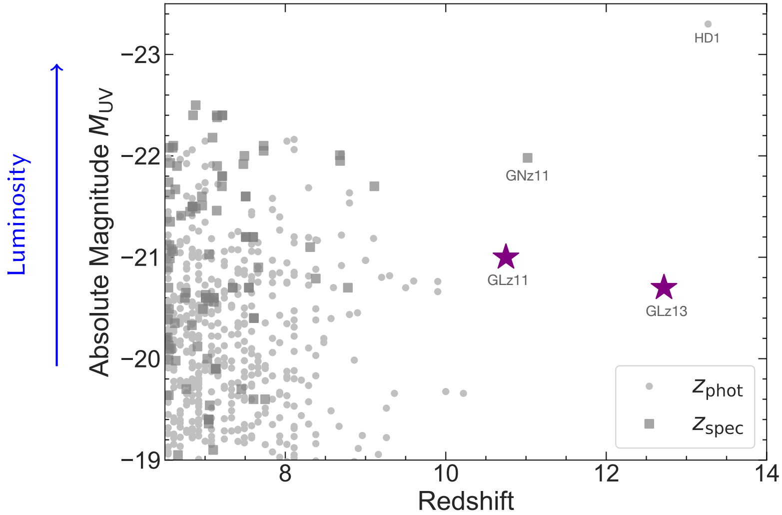


JWST

TMT

Brighter stars easier to detect, faithful distribution of the underlying population?

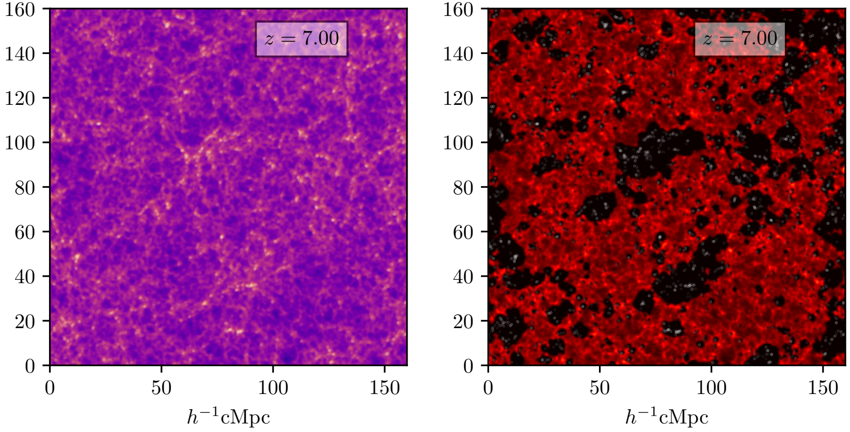
JWST already breaking records



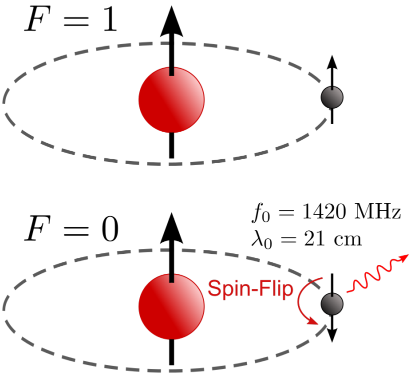
Naidu et al (2022)

Alternate method: hydrogen

- The galaxies are surrounded by hydrogen, the most abundant element in the Universe.
- Is it possible to infer about the stars using the hydrogen?
- Yes, several methods. One promising way is through the 21 cm radiation.

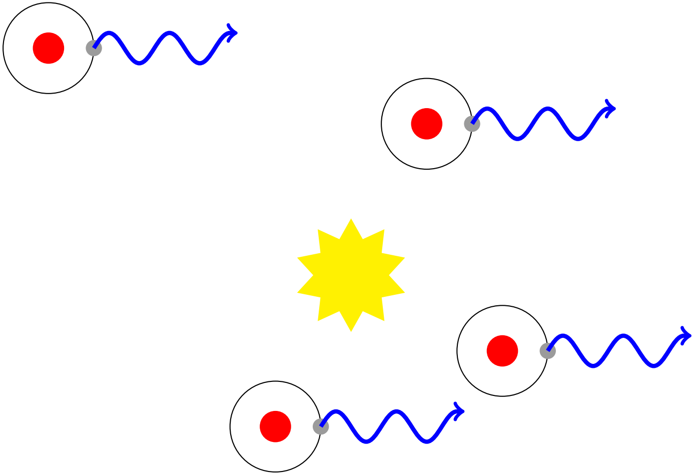


21 cm radiation



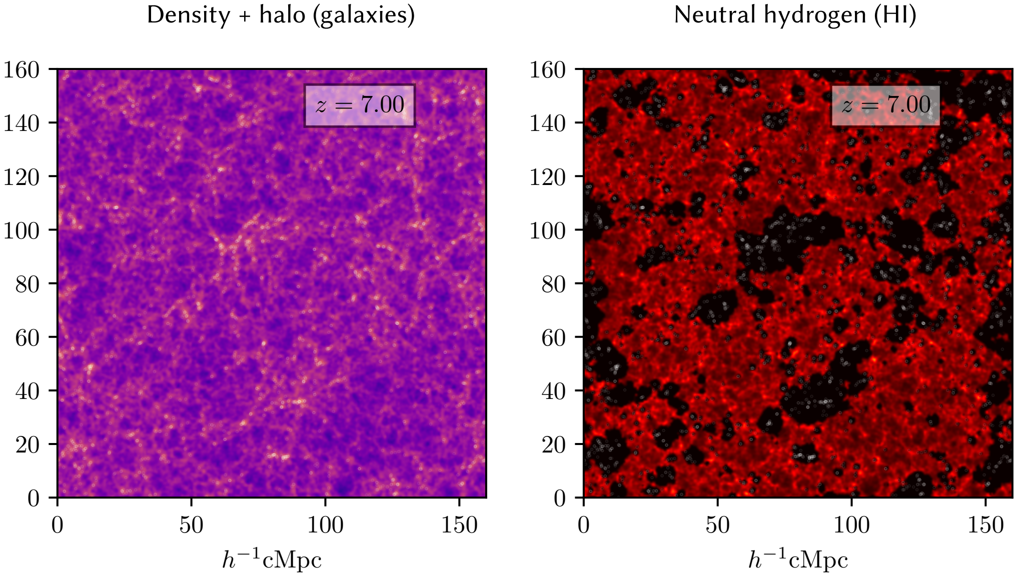
- Radiation originates due to “spin flip”.
- Only possible when hydrogen is neutral, no radiation when ionization happens (i.e., the electron dissociates).

Reionization of hydrogen by first stars



Neutral hydrogen atoms emitting 21cm radiation
First stars form, emit ionizing radiation

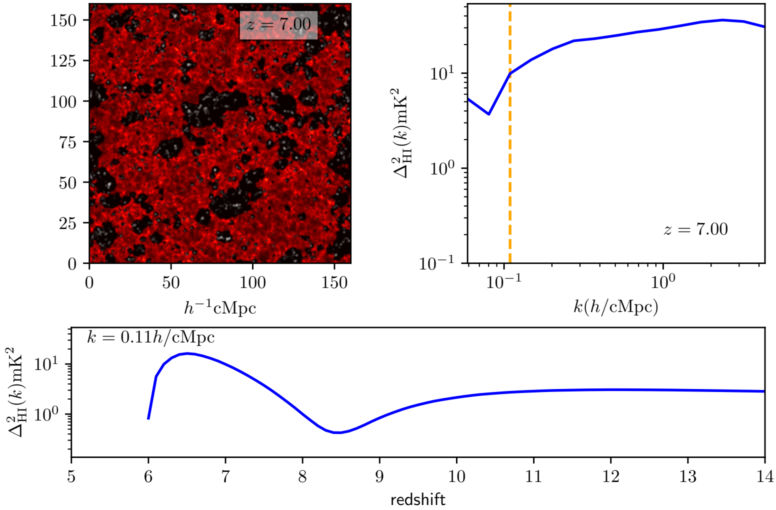
Galaxies and reionization



21 cm maps and power spectra

SCRIPT (**S**emi-numerical **C**ode for **R**e**I**onization with **P**ho**T**on-conservation)

`https://bitbucket.org/rctirthankar/script` (**TRC** & Paranjape 2018)



Present constraints on the 21 cm power spectrum

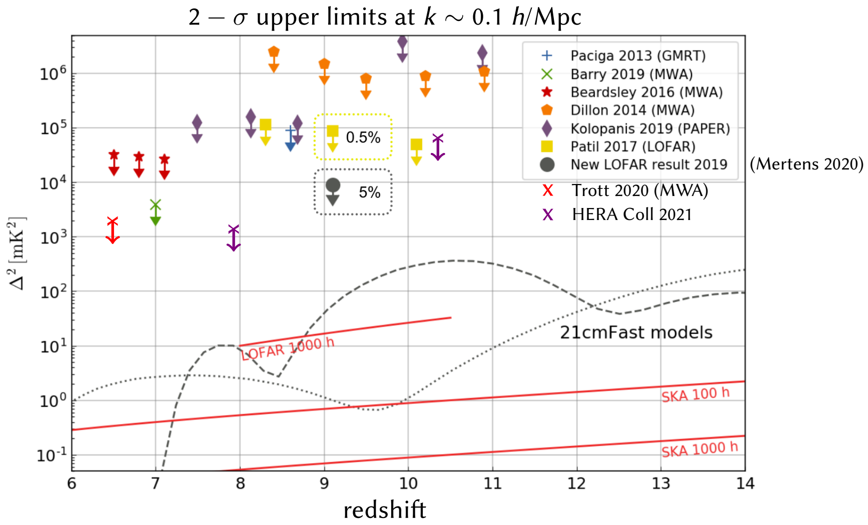


Figure courtesy Leon Koopmans

Summary

- *Most ambitious radio astronomy project* ever attempted.
- To be built in Australia and South Africa.
- First science expected around 2029. One of the main science cases is the detection of HI signal from the epoch of reionization.
- India is a member of the SKA international collaboration (lead by NCRA-TIFR). uGMRT, an SKA pathfinder, often provides useful test-bed for SKA.

Thank you

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