Cosmology and high-redshift universe with the Square Kilometre Array

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Cosmology - The Next Decade
ICTS-TIFR, Bangalore
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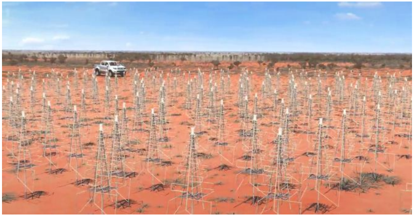
Square Kilometre Array Phase 1

- will be built in two phases: SKA1 should be completed by 2025

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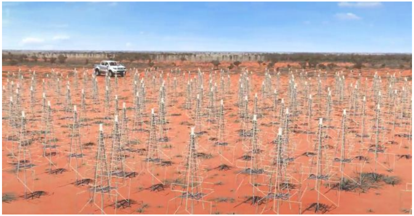

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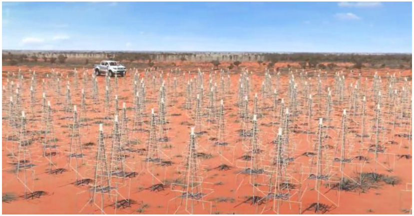

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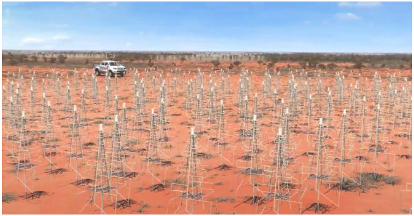

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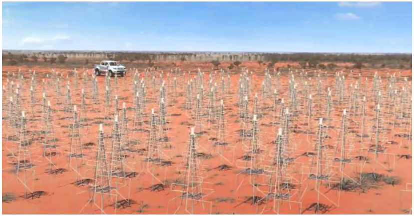
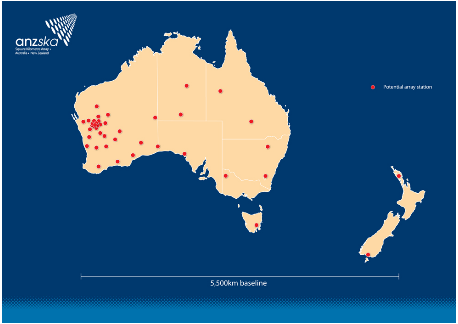
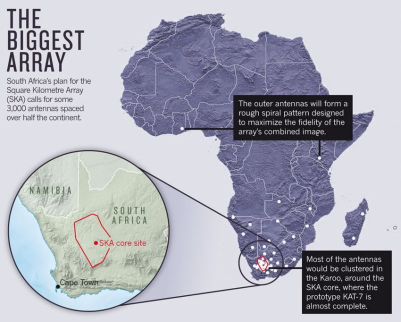
- effective collecting area $\sim$ km$^2 = 10^6$ m^2 $\sim 5 - 10$ times more collecting area than any existing telescope!



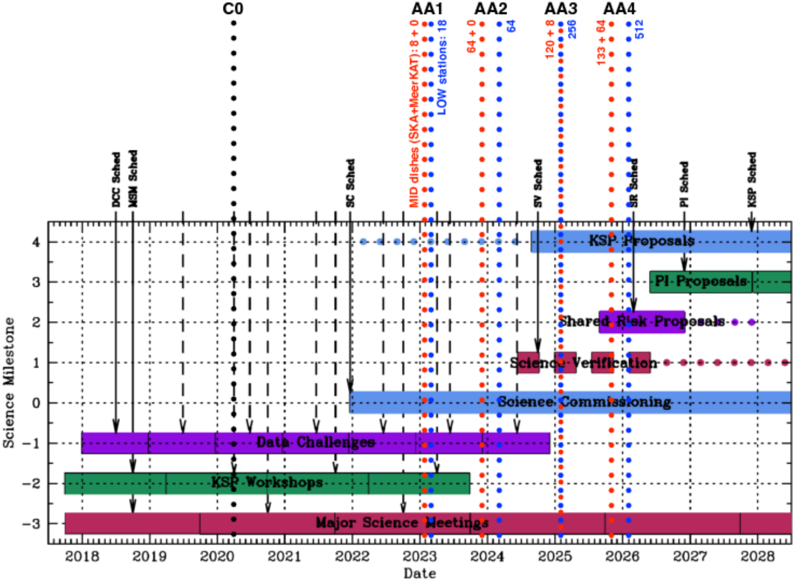
SKA: sites



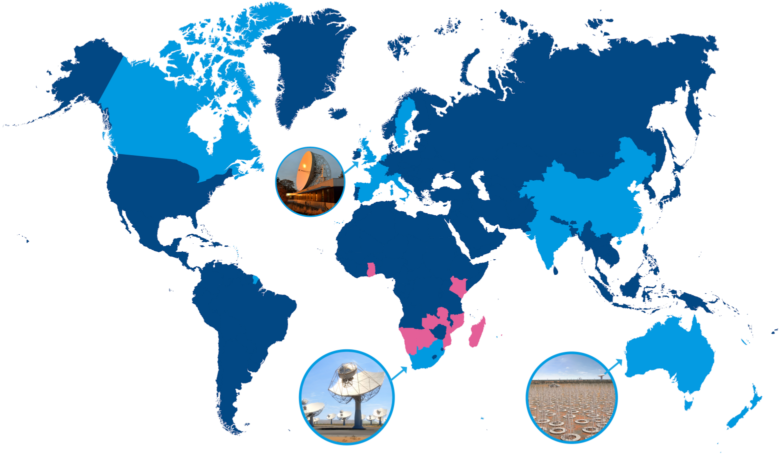


- Very low population density
- Large amount of empty space
- Western Australia, Karoo desert (South Africa)

SKA timeline



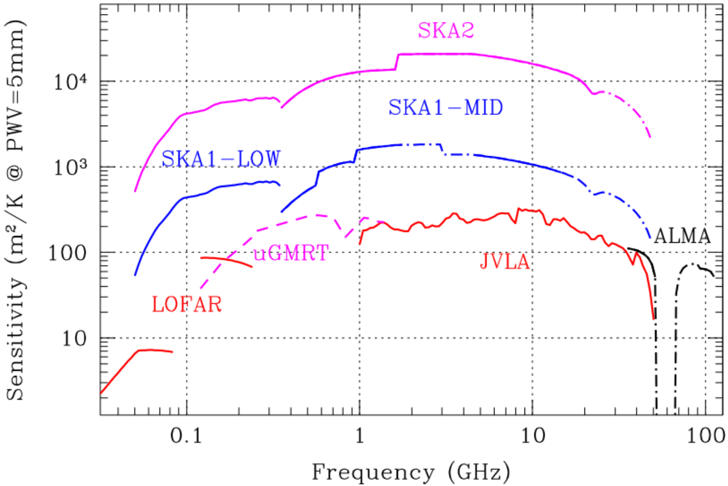
Countries participating in the SKA



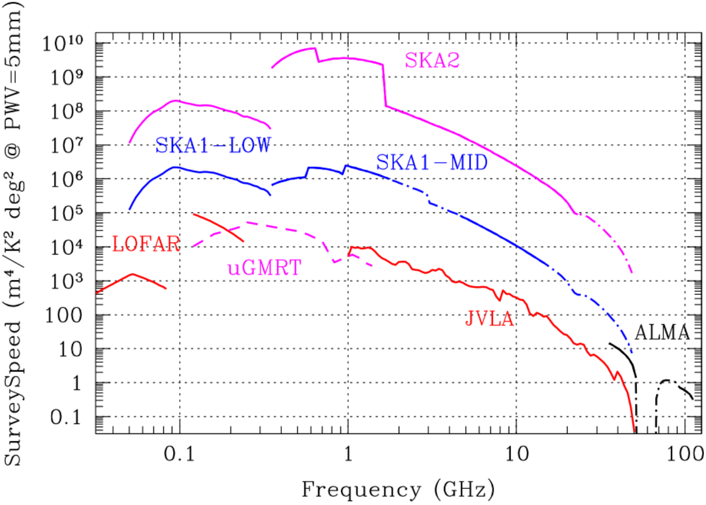
Members
Host Countries: Australia, South Africa, United Kingdom

African partner countries

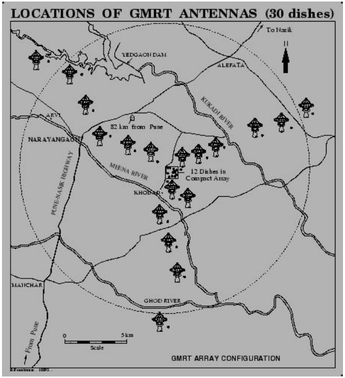
SKA1 compared to other telescopes



SKA1 compared to other telescopes

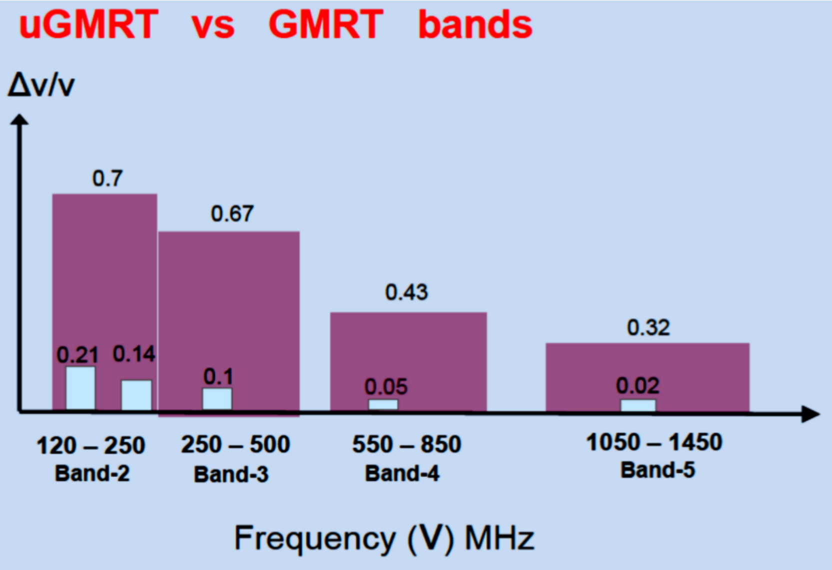


The GMRT



- **Giant Metrewave Radio Telescope**
- 30 antennas, 45 m diameter each. works in frequency range $\approx 150 - 1400$ MHz
- situated at *Narayangaon*, about 80 km from Pune.
- Currently being upgraded to uGMRT, one of the SKA pathfinders

GMRT → uGMRT



Courtesy: Ruta Kale

Advantages of the uGMRT

- **Spectral lines:** broadband coverage will give significant increase in the redshift space for HI lines & access to other lines
- **Continuum imaging:** sensitivity will improve by factor of ~ 3
- **Pulsar observations:** sensitivity will improve by factor of ~ 3
- Only SKA Phase 1 will do better than uGMRT at metre wavelengths

SKA: Indian involvement

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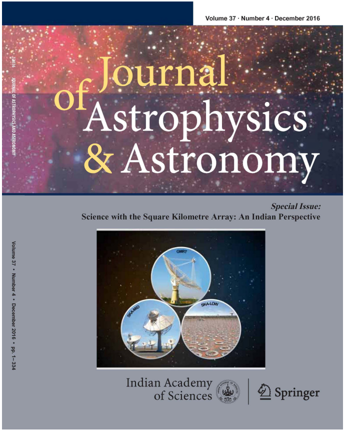

- India has been associated with the SKA from the beginning
- India formally joined the SKA on **Oct 5, 2015**
- The activities within India are coordinated by the SKA-India Consortium
- $\sim$ 20 organisations are members of the Consortium
- Science activities coordinated by *eight* SKA-India Science Working Groups
- India involved in all the key science projects in the SKA

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.
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Cosmic Dawn and the Epoch of Reionization Koopmans, L. et al. 2015 PoS(AASKA14)001	Direct imaging of EoR structures ($z = 6 - 12$).	Direct imaging of Cosmic Dawn structures ($z = 12 - 30$).
	Power spectra of Cosmic Dawn down to arcmin scales, possible imaging at 10 arcmin.	First glimpse of the Dark Ages ($z > 30$).

Science with the SKA

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HI intensity mapping

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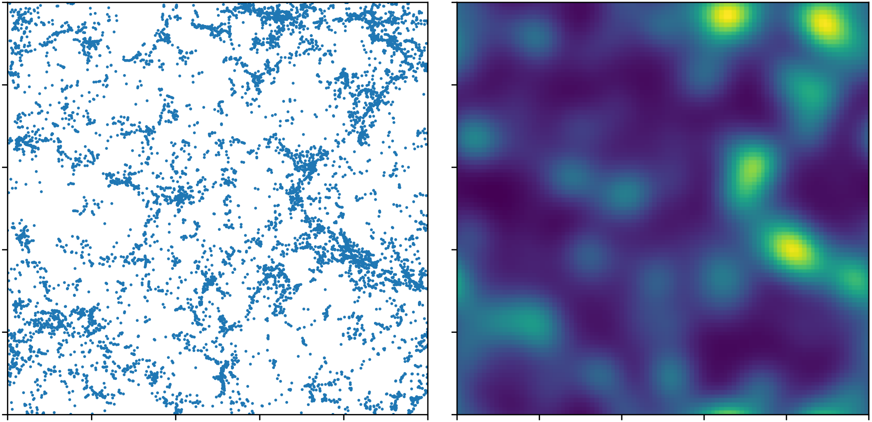
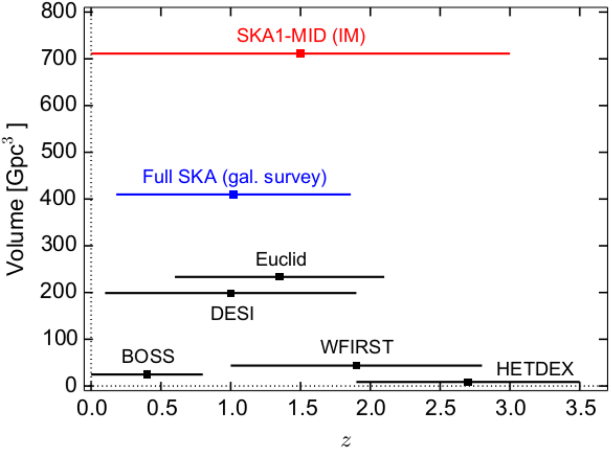


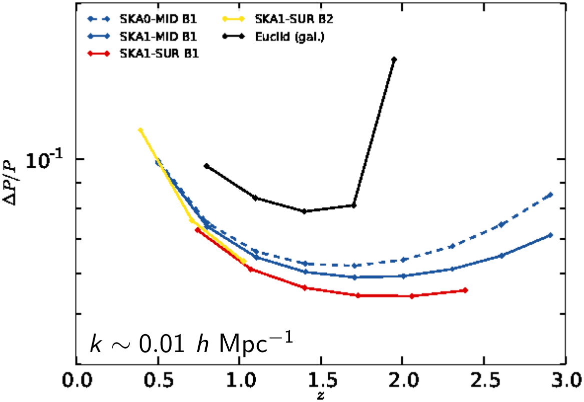
Based on ideas presented in Bharadwaj & Sethi (2001)

Cosmology with HI intensity mapping



Maartens et al (2015)

Cosmology with HI intensity mapping



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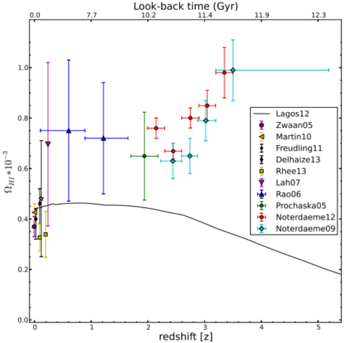
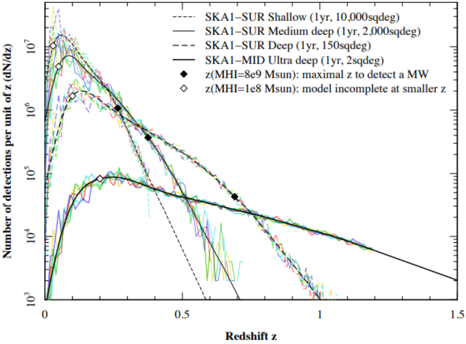
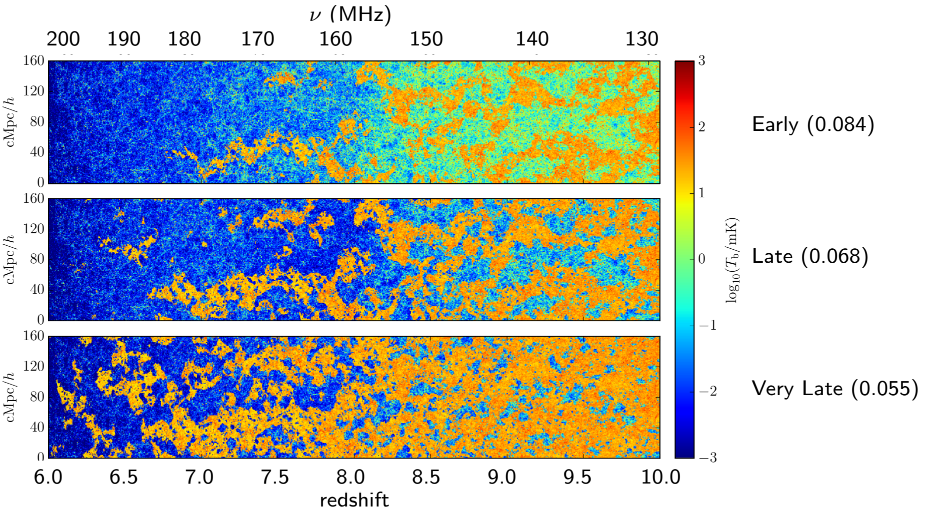
HI absorbers and galaxy evolution





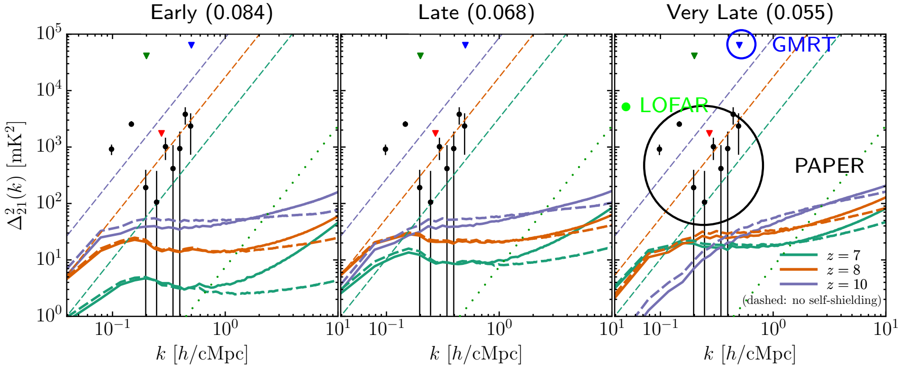
Blyth et al (2015)

21 cm signal from EoR



Kulkarni, **TRC**, Puchwein & Haehnelt (2016)

EoR 21 cm power spectra



$z = 7$

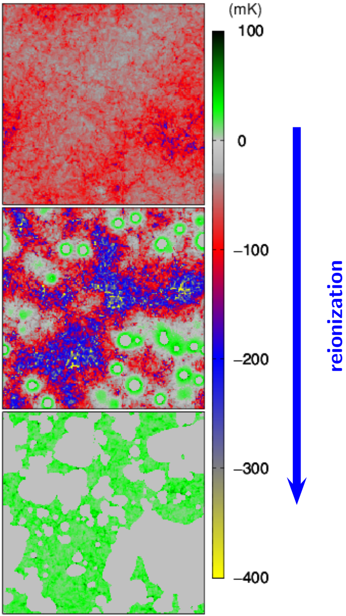
$z = 8$

$z = 10$

Kulkarni, **TRC**, Puchwein & Haehnelt (2016)

21 cm signal from the cosmic dawn

Ghara, **TRC** & Datta (2014)



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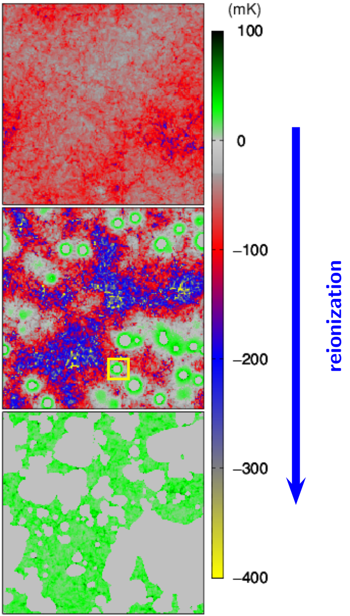

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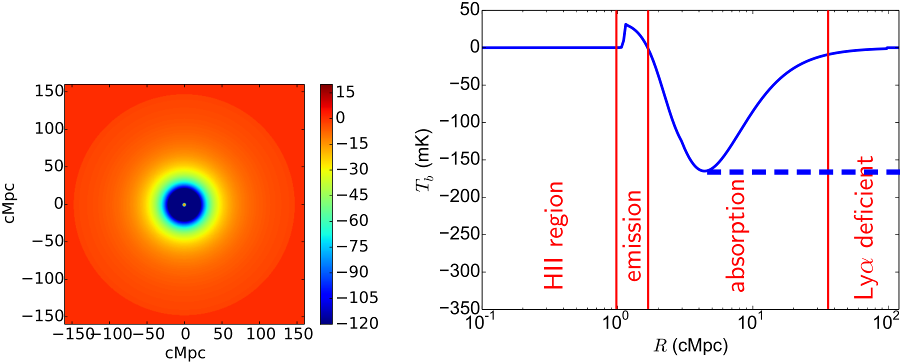
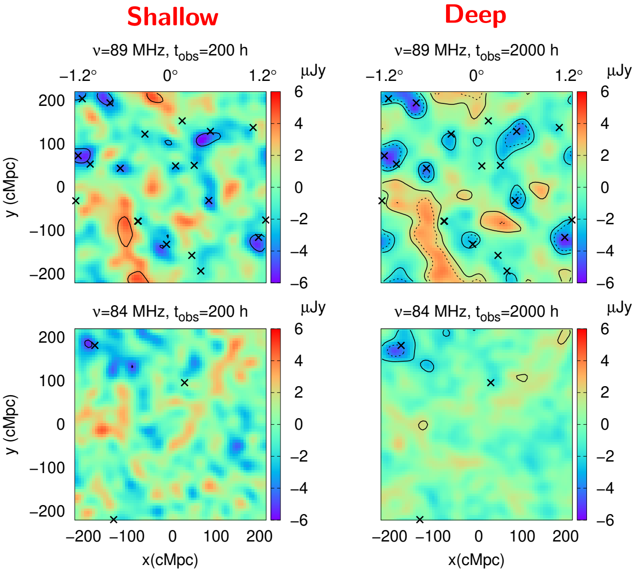
Image of the 21cm pattern

Galaxy + power-law X-ray source ($M_\star \sim 10^7 M_\odot$, $f_{\rm esc} \sim 0.1$, $t_{\rm age} \sim 10^7$ yr)



Alvarez, Pen & Chang (2010)
Yajima & Li (2014)
Ghara, **TRC** & Datta (2015)
Ghara & **TRC** (in prep)

Survey planning



Ghara, **TRC**, Datta & Choudhuri (2016), Ghara & **TRC** (in prep)

Summary: Square Kilometre Array

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SQUARE KILOMETRE ARRAY

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