21cm Cosmology as a probe of the high redshift Universe

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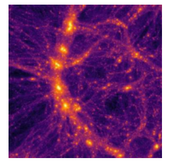
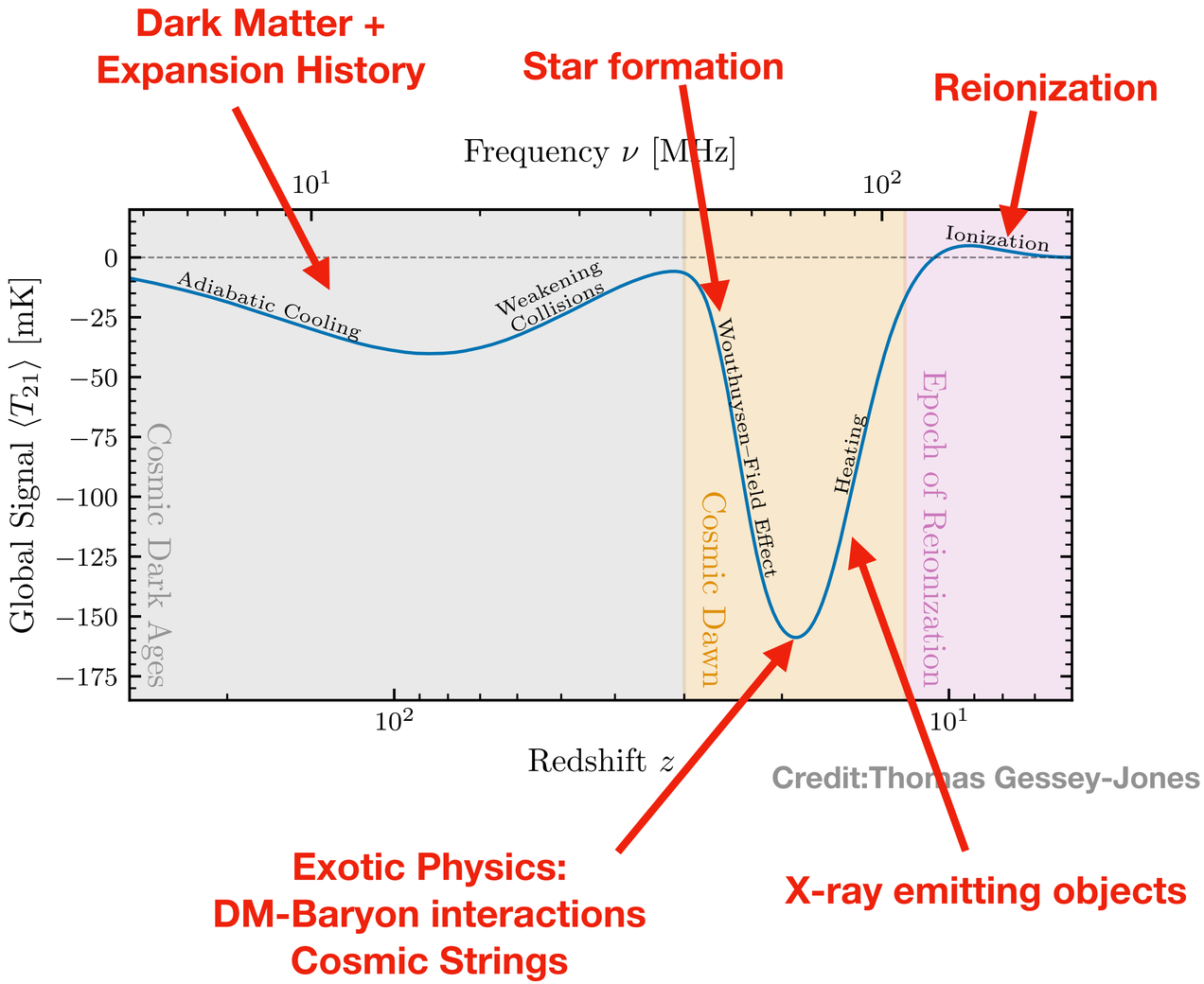


CosmicDawnLab

What can the signal tell us?

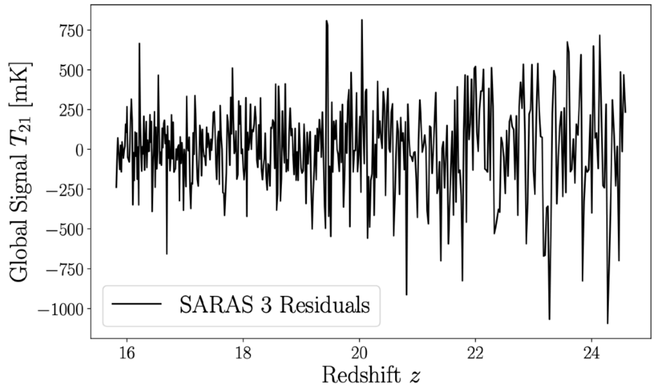
- In theory we can do tomography
- But focusing on two summary statistics for now
- Sky averaged 21-cm signal with single antennas
- Power spectrum with interferometers
- In house simulation suit called 21cmSPACE (A. Fialkov et al.)

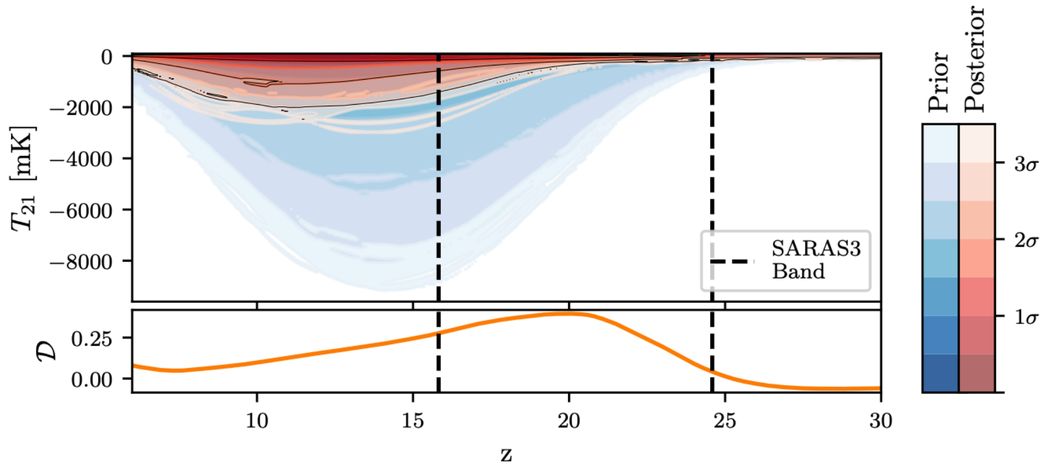


Constraints from global experiments

H. Bevins et al., Nature Astronomy, arXiv:2212.00464

- Upper limits on the sky-averaged signal from SARAS3 at z=15-25
- Working in a Bayesian framework with signal emulators
- Put weak limits on
  - the contribution of galaxies to radio background
  - X-ray luminosity of early sources
  - Star formation efficiency and minimum halo mass of early galaxies

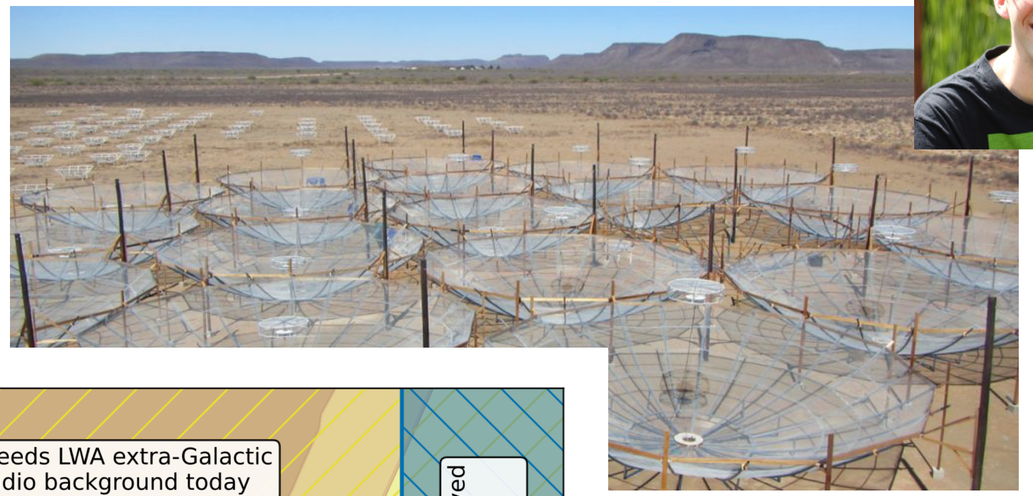


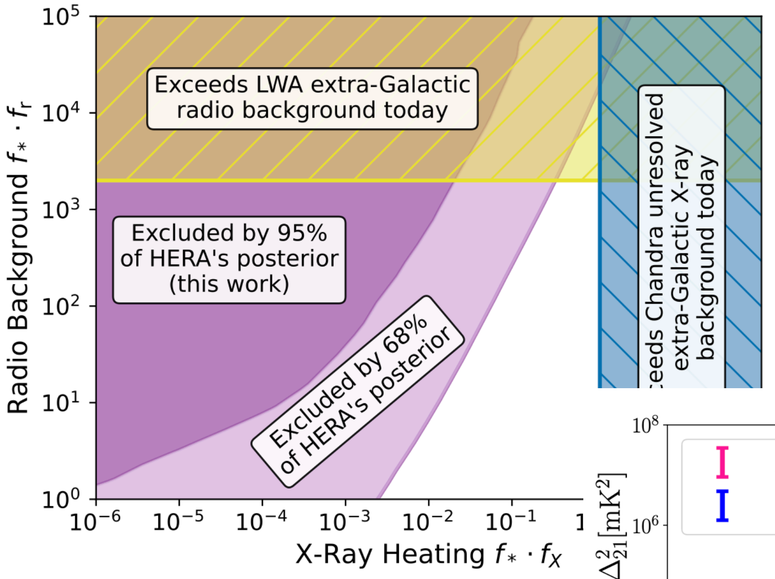


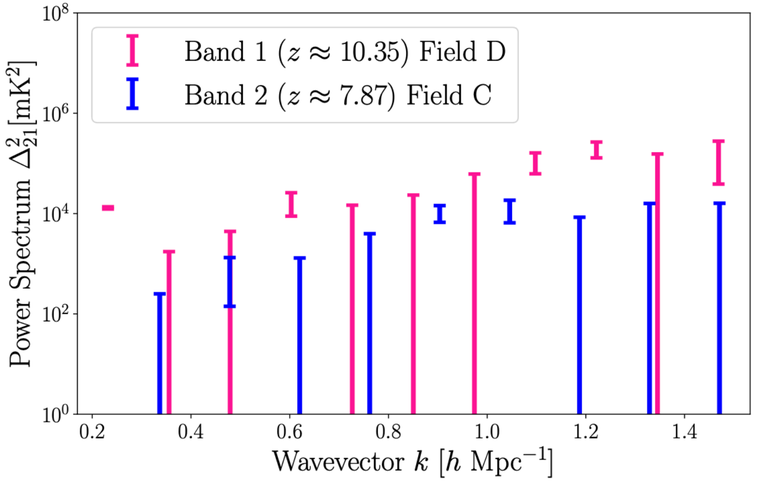
Constraints from the power spectrum

The HERA Collaboration, Stefan Heimersheim, ApJ, arXiv:2210.04912

- Using the HERA interferometer
- Upper limits on the power spectrum at z=8 and z=10
- Able to constrain contribution of radio galaxies to the background
- And constrain the X-ray luminosity of early galaxies
- Somewhat tighter than SARAS3 but at different redshifts



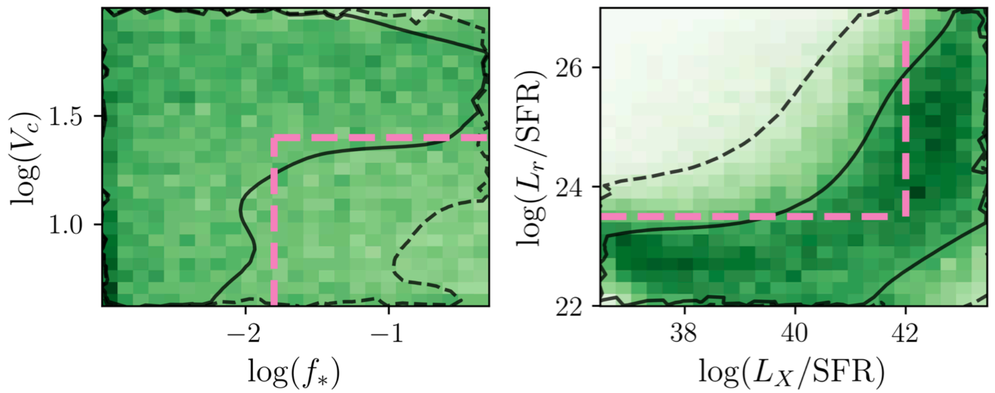


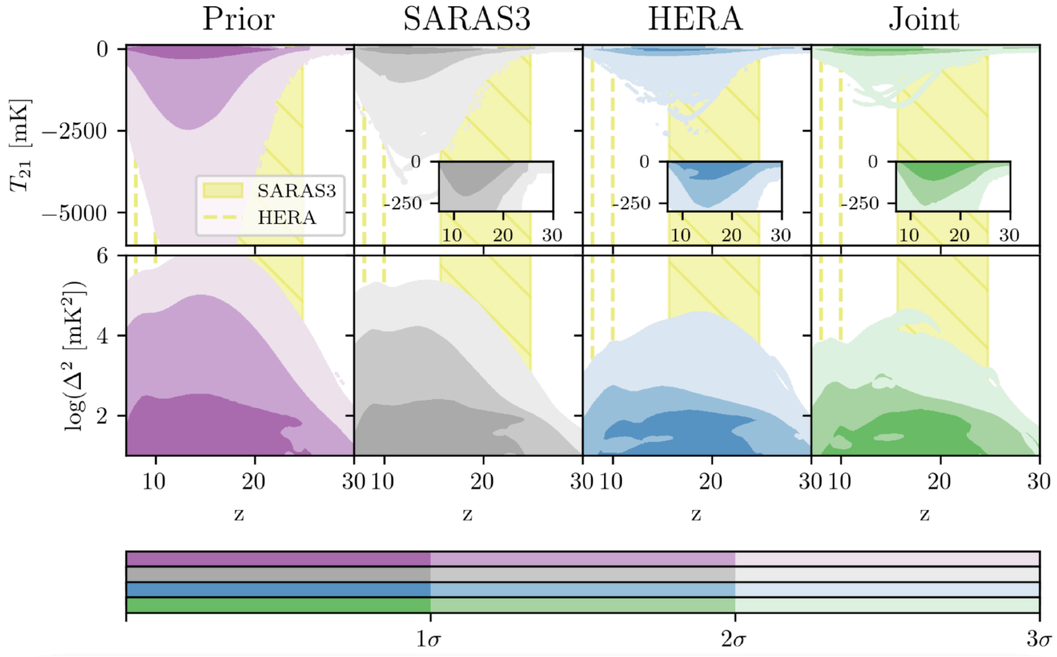


Combination of power spectrum and global signal

H. Bevins, S. Heimersheim et al., MNRAS, arXiv:2301.03298

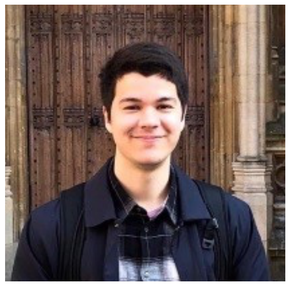
- Combination of SARAS3 and HERA limits
- Working in marginal parameter space using the existing results and normalising flows
- Combination gives us tighter constraints on L_X, L_r and the magnitude of the signals
- Interpolation between data points



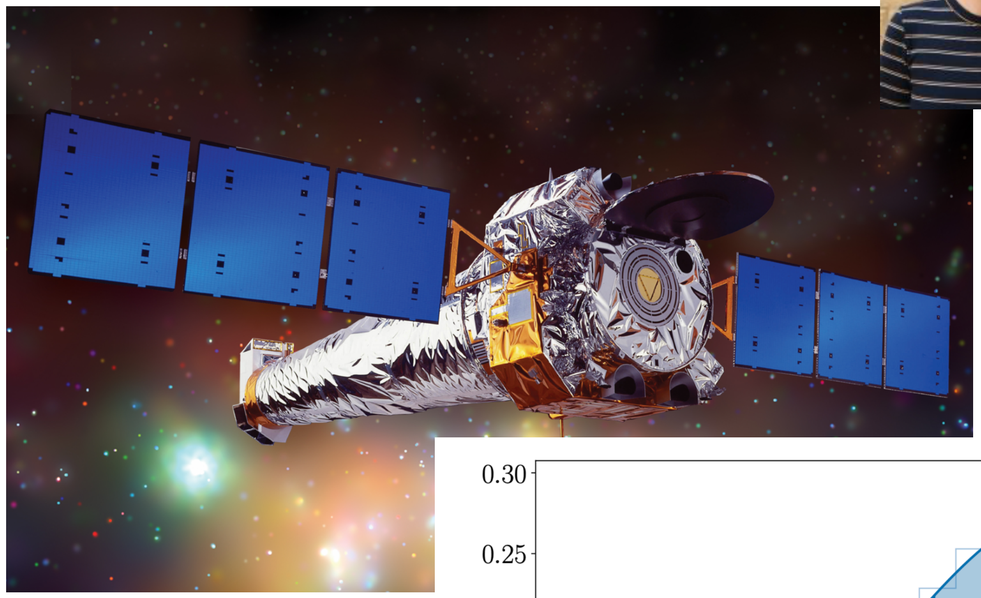


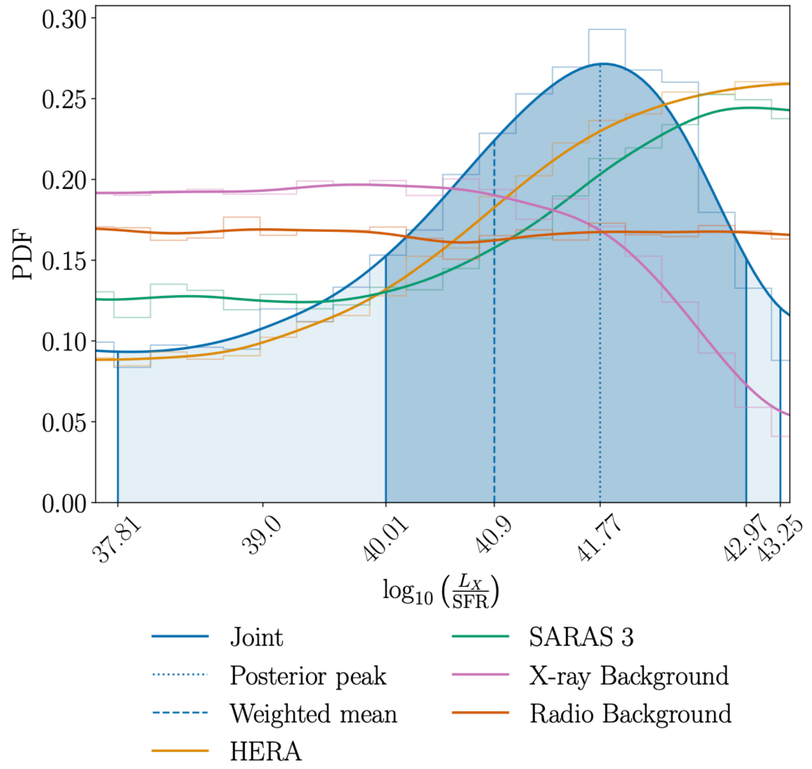
Inclusion of X-ray and radio backgrounds

S. Pochinda, …, H. Bevins, …, I. Abril Cabezas et al. arXiv:2312.08095



- Extending previous analysis
  - with X-ray background measurements from Chandra and other probes
  - with radio background measurements from ARCADE2 and LWA
  - PopII and PopIII star formation efficiency split
- Complementary constraints from X-ray background and 21-cm

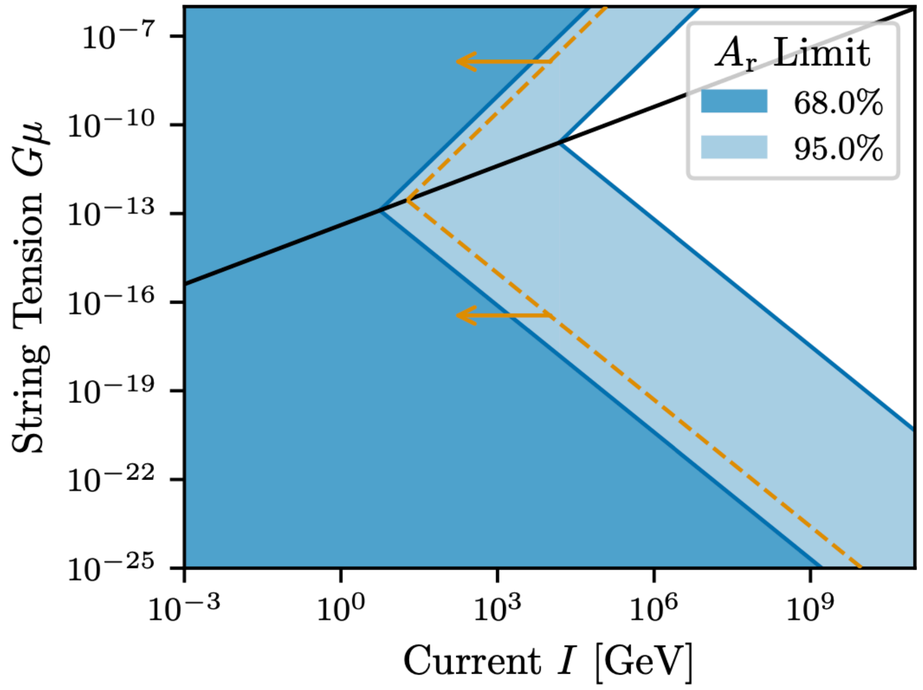




Exotic physics?

T. Gessey-Jones, S. Pochinda, H. Bevins et al., arXiv:2312.08828

- Radio background from Superconducting Cosmic Strings
- Single additional model parameter
- Using SARAS3, HERA and the X-ray limits
- No strong constraints
- Inclusion of astrophysical uncertainties

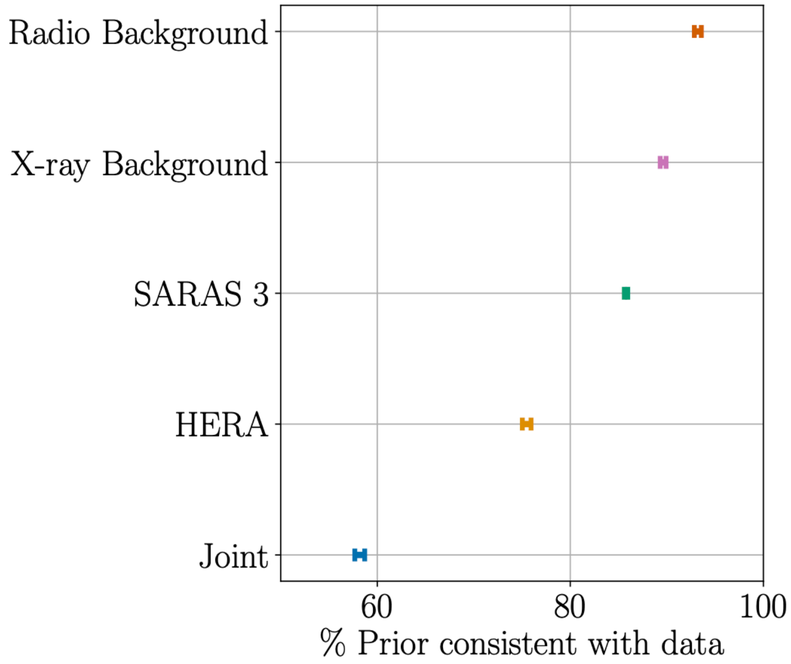


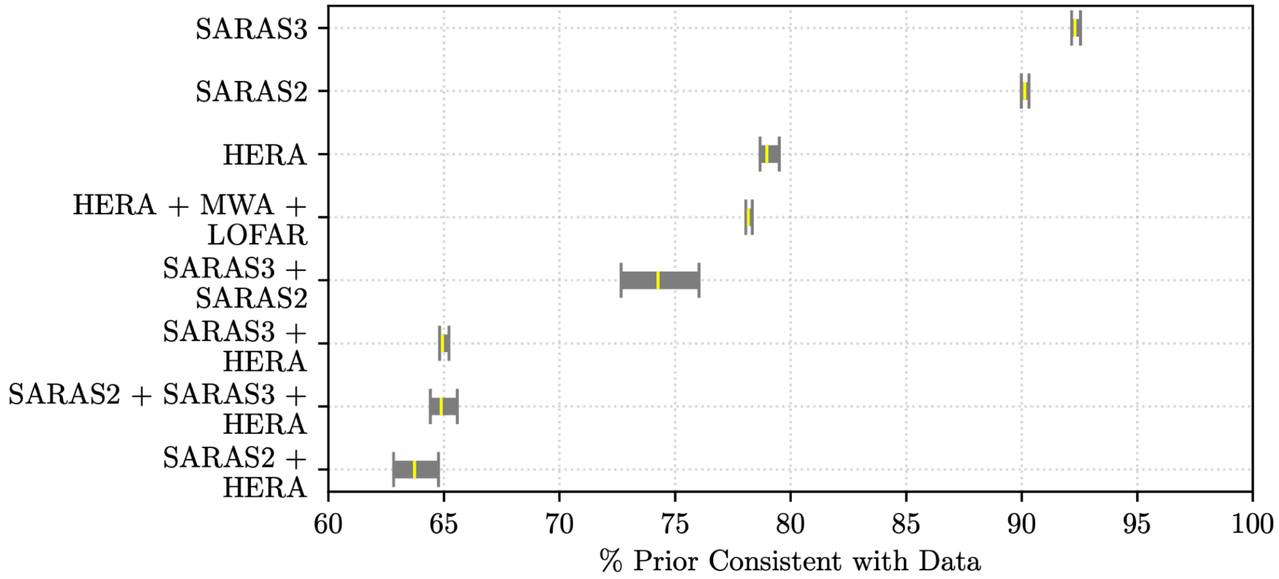
Constraining power of our data

H. Bevins, W. Handley et al., MNRAS, arXiv:2205.12841

- Calculate marginal KL-divergences over the common signal parameters
- Marginalising over nuisance parameters with normalising flows
- Assess the constraining power of the data sets in just the signal parameter space

$$\kappa = 100 \exp(-\mathscr{D}_{KL}) \approx 100 \frac{V_\pi}{V_p}$$

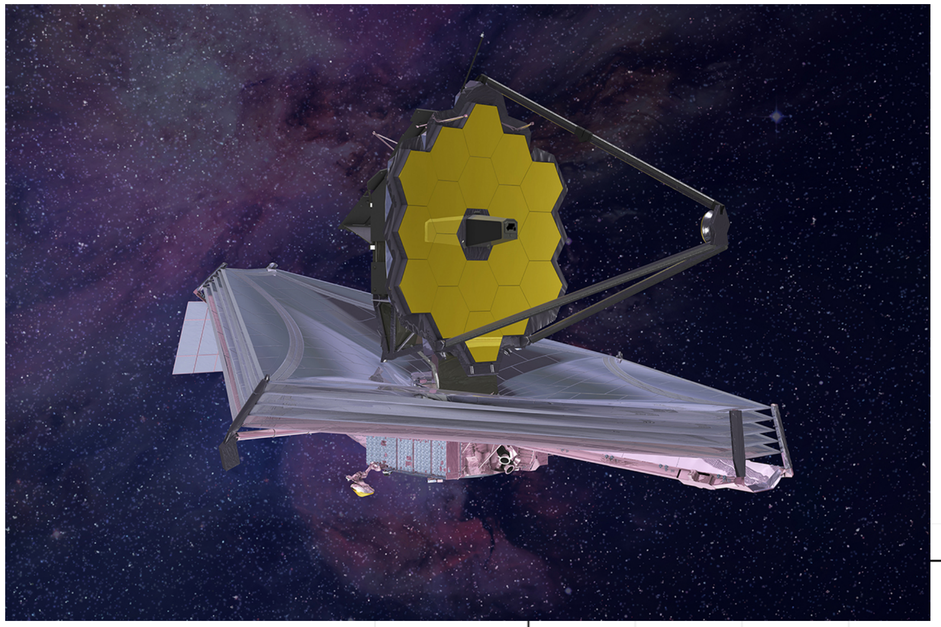


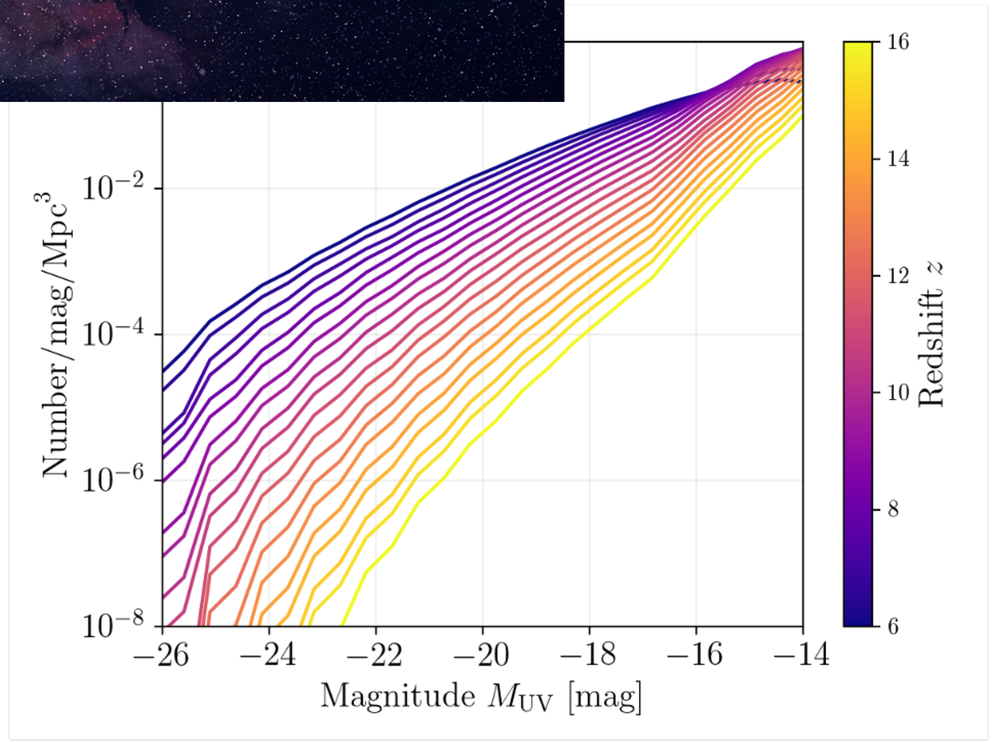


21cm X JWST?

J. Dhandha, S. Tacchella, A. Fialkov, H. Bevins et al. in prep.

- UV Luminosity Function and 21-cm signal are both strong functions of star formation
- Currently investigating joint constraints from HERA, SARAS3 and JWST
- Using self consistent semi-numerical simulations of both UVLF and 21-cm
- Bayesian framework

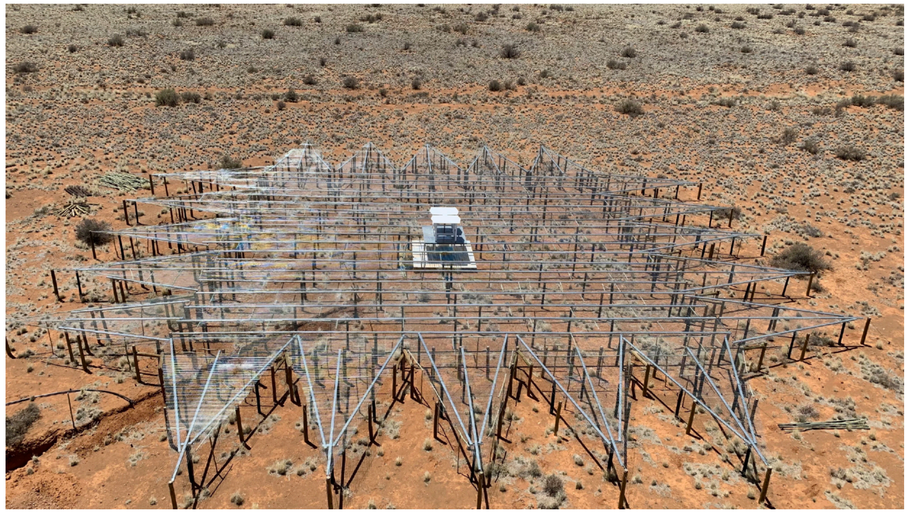




REACH

De Lera Acedo,.., H. Bevins et al., Nature Astronomy, arXiv:2210.07409

- Attempting to look for the global 21-cm signal
- Based in the Karoo Radio Observatory in South Africa
- Currently going through commissioning with our first antenna
- Multi-national collaboration with members in UK, across Europe, South Africa and America
- Strong contingent of junior researchers and PhD students



Conclusions

- Developing tools for analysis of 21-cm data
- Exploring synergies with other probes
  - X-ray and radio backgrounds
  - JWST
  - Intensity mapping
  - Lyman-α forest
  - etc
- Working on experimentation in Cambridge
- Preparing for the SKA and the big data era
- Talk available at: https://github.com/htjb/Talks