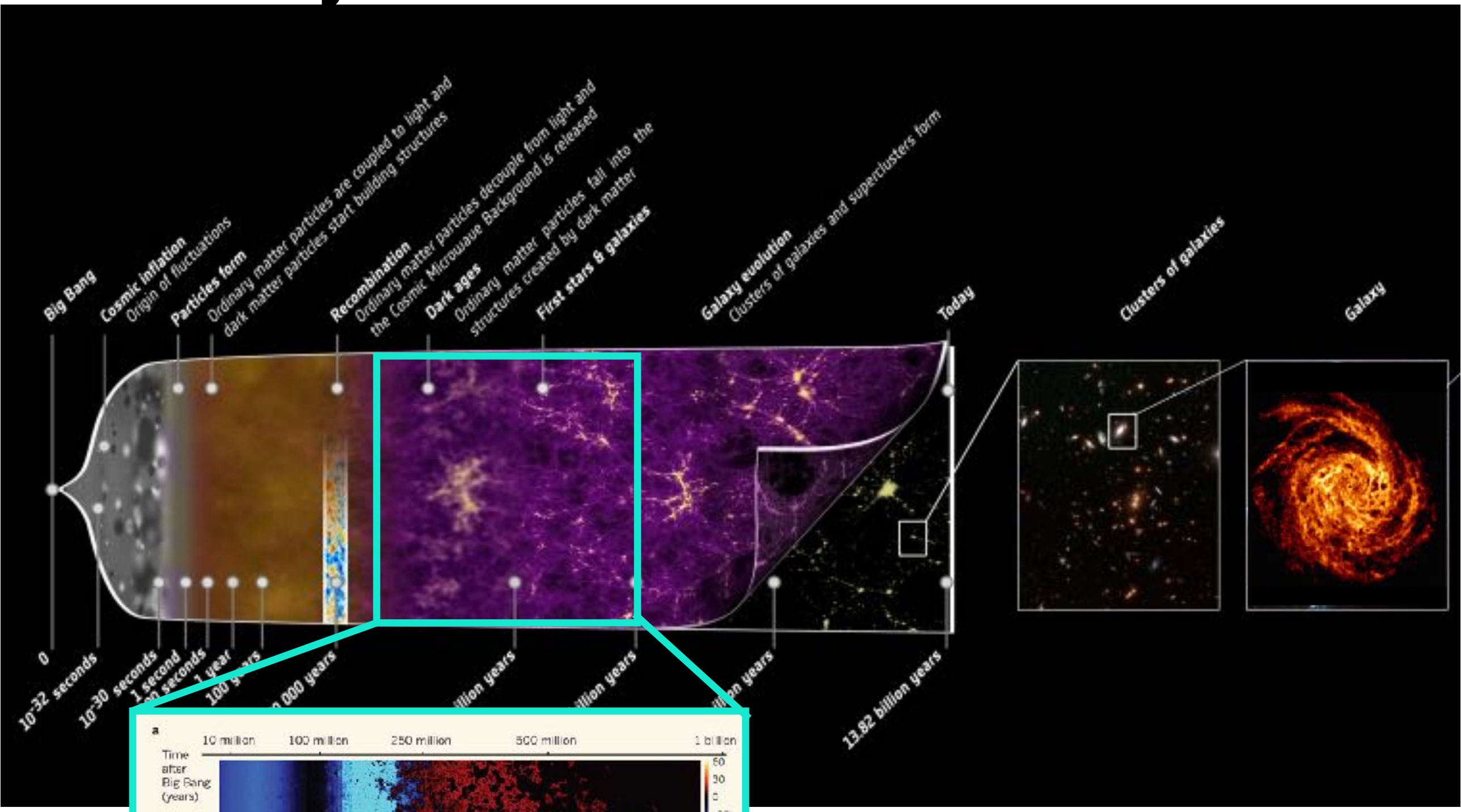
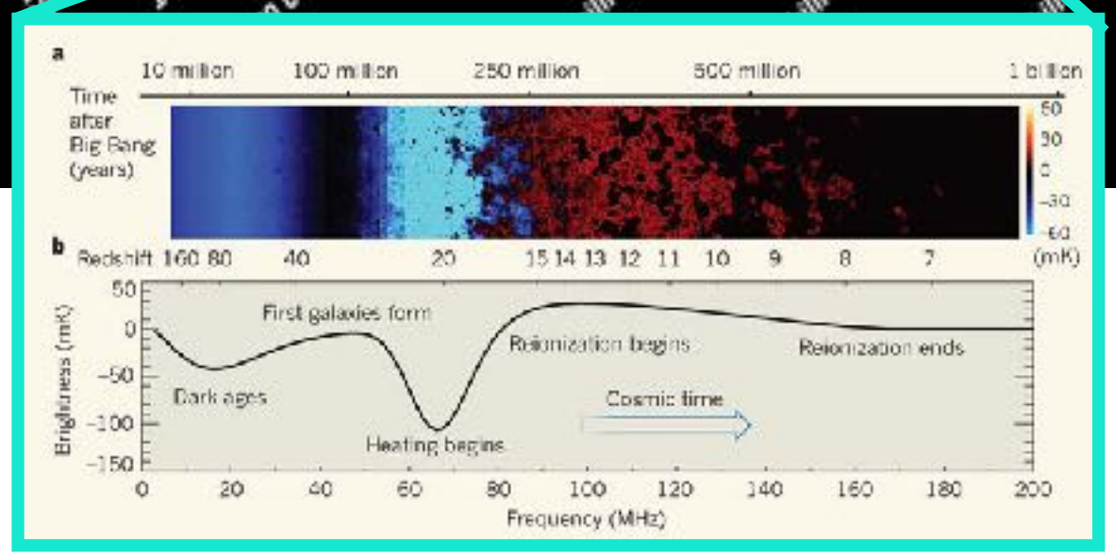
R&D for 21cm observatories

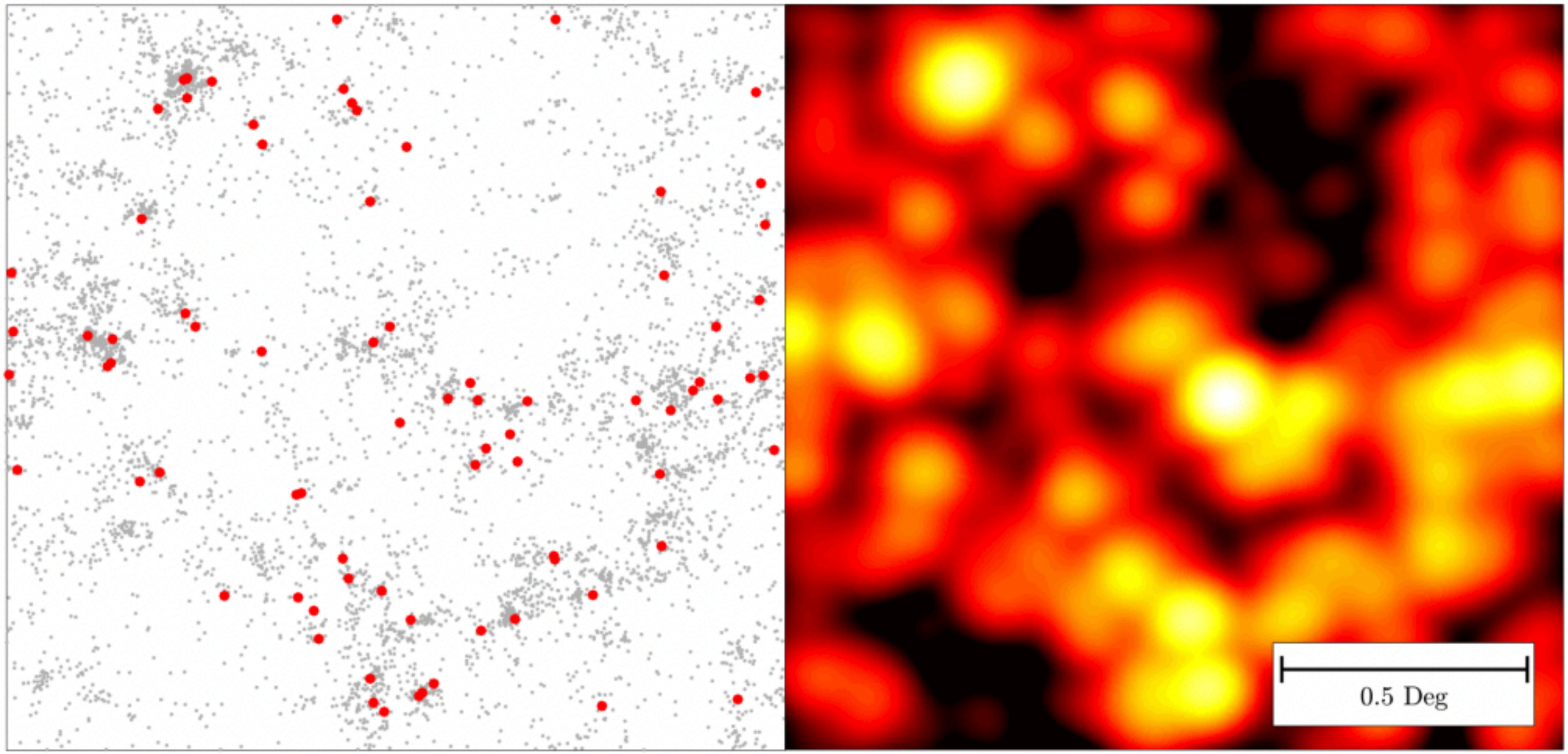
Laura Newburgh — May 6, 2022 — Snowmass CF5 instrumentation workshop

What can you access w 21cm emission?



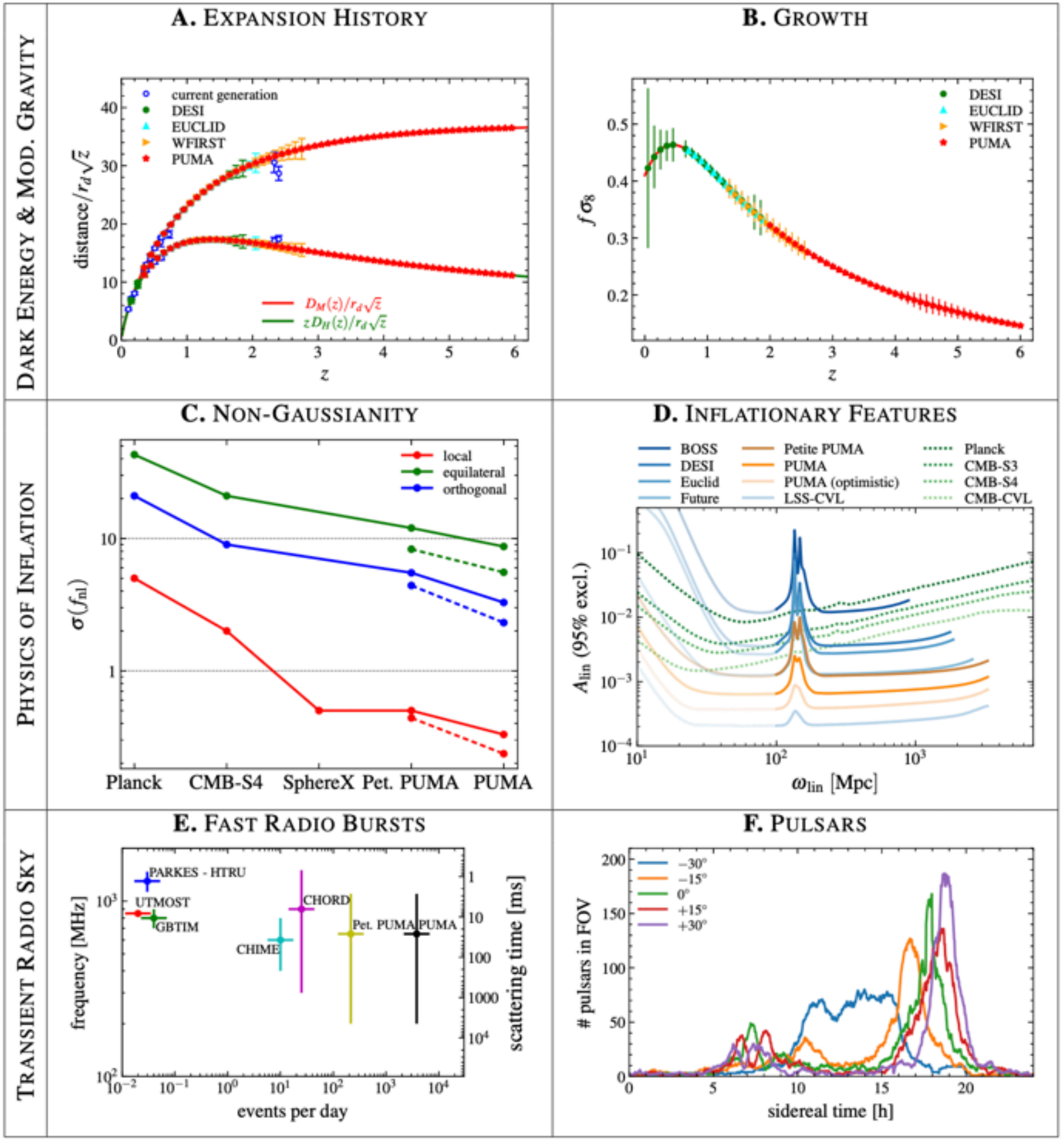


What can you access w 21cm emission?



Kovetz, Line Intensity Mapping Status Report (2017)

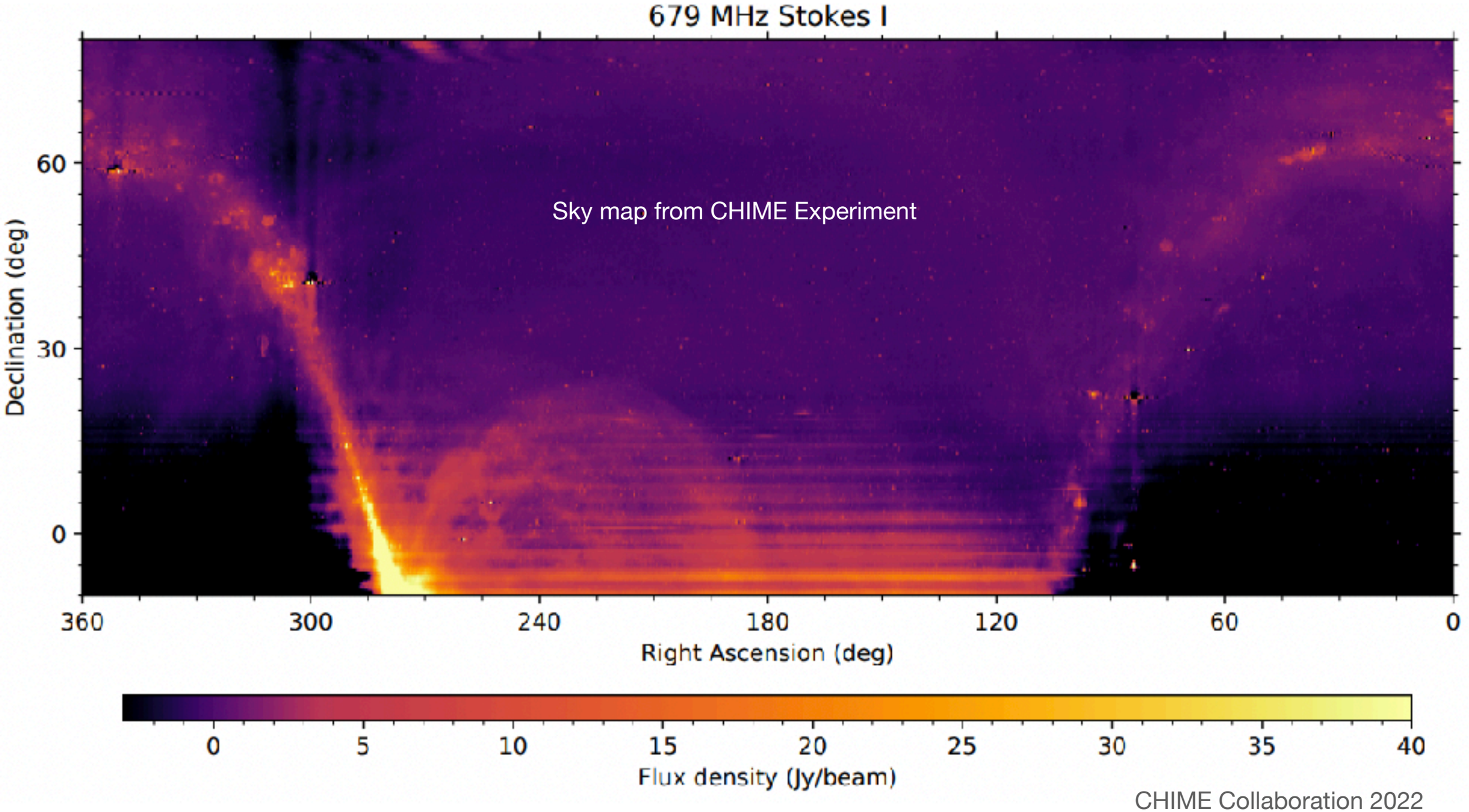
Briefly: why bother ("low" redshift case)



What do you need in an instrument

- Small signal = lots of detectors
- Access to wide range of scales with lots of detectors, so… radio interferometry
    - many telescopes, across at least 1km x 1km
    - big correlator
- Large volume =
    - wide survey : large FOV, or ability to steer (or both)
    - redshift range: wide bandwidth feeds (200-1100MHz) with well-controlled bandpass response

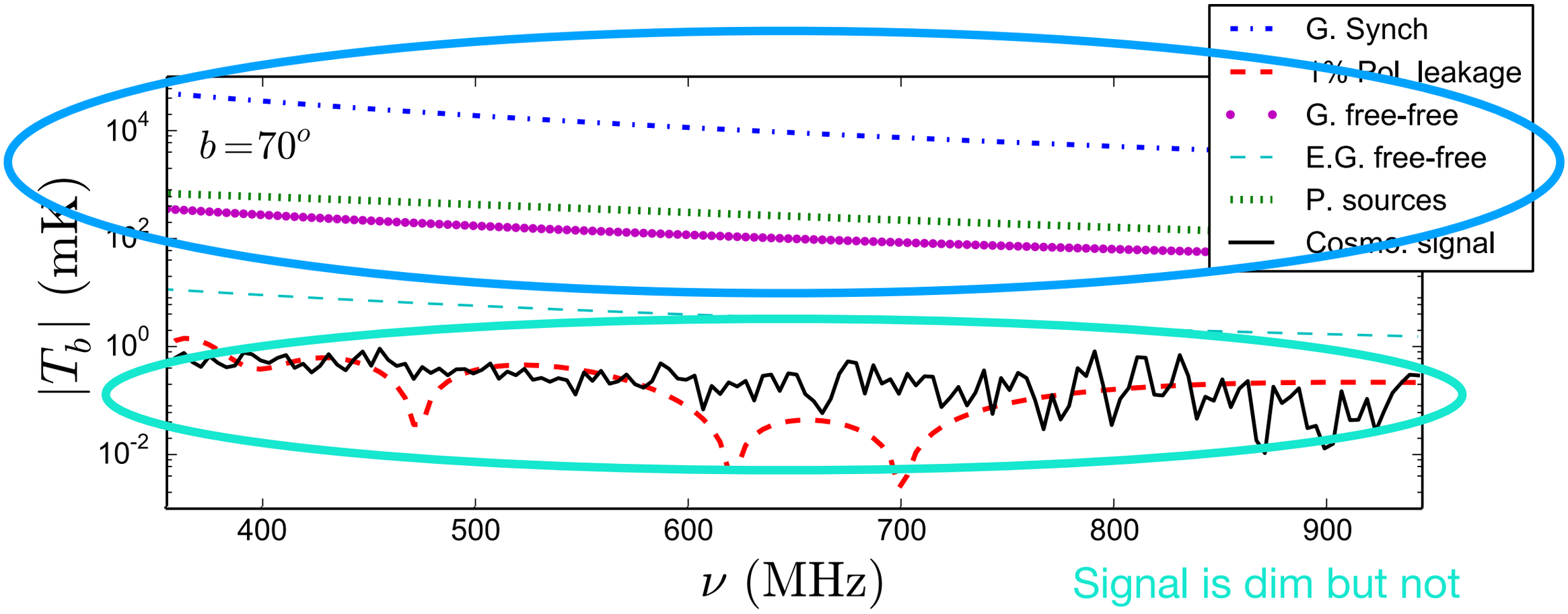
Biggest challenge: foreground emission



CHIME Collaboration 2022

Biggest challenge: foreground emission

Foregrounds are bright but smooth in frequency



Signal is dim but not smooth in frequency

Alonso+ 2014

What do you need in R&D to solve all of this?

- PUMA-32k would be ~7000PFlops for full correlation. Using FFT-based correlation reduces this to ~100Pflops. Requires:
  - uniform telescopes
    - Early demonstrations from fiberglass dishes developed in Canada (developed for SKA, will be used in HIRAX and CHORD)
  - real-time gain calibration
    - explore digitizing at the focus, also requires ps-timing distribution across km-scale interferometer. Allows flexible calibration, minimizes gain variations from analog signals carried on long fiber
- precise beam calibration
  - Current state of the art uses sky signals in varying ways (calibration off of celestial signals and satellites)
  - New directions mainly involve aerial platforms (drones, ‘helicopters’, fixed wing planes and gliders, etc)

What do you need in Analysis R&D to solve all of this?

- Calibration strategies: how to use the data we have more effectively
- Beam modelling (including EM sims at scale)
- Foreground removal strategies: Lots of ongoing work in developing and applying filters (eg CHIME used a filter based on HERA for recent results)
- end-to-end simulations at scale that can include a wide variety of systematics.
- RFI removal
- Real-time calibration needs development