McGill Global 21cm Workshop Summary

State of the Field

Experimental measurements are leading theory. (It is yet to be seen if we are being led in the right direction, as the lamp-post is bright).

Healthy skepticism within the community and outside.

Sign of a robust community: dialogue is open and academic.

Remarkable flexibility of the theoretical community

(Matt)

The EDGES result “anomaly”

Three possibilities explored:

- Excess radio background (black holes, superconducting cosmic strings …)
- Additional cooling mechanism (millicharged dark matter particles …)
- EDGES result is wrong

(Colin)

Accounting for Edges, naturally motivated theories

(Matt)

Accounting for Edges, in Theory

Three common avenues, all present at this meeting:

- Particle Physics
  - Milli-charged dark matter
    - Window to the dark sector! …. With solutions to CDM observations tuned away
  -
- Astrophysics
  - Early injection from radio background ala Feng/Holder
    - Radio loud black holes @ high redshift
  -
- Cosmology
  - Cosmic Strings
  -

Each of these makes (or will make) bold new predictions (some of which are observable!) while explaining the Edges signal.

(Matt)

Is the theory landscape creative enough?

Is plain, Standard Model, lambda-CDM, vanilla astrophysics really insufficient?

Theory: could the models be missing something basic?

- Effect of inhomogeneities? Models mostly adopt uniform IGM approximation. Detailed radiative transfer of Ly-a and X-ray photons? Impact of density inhomogeneities on global averages? Probably makes it *harder* to explain EDGES.
- Could X-rays be absorbed locally in dense regions and not be efficient at heating the IGM initially? This would help, but still need the gas to be heated rapidly by z~15. Also need ionizing photons to escape from host halos to reionize the IGM!

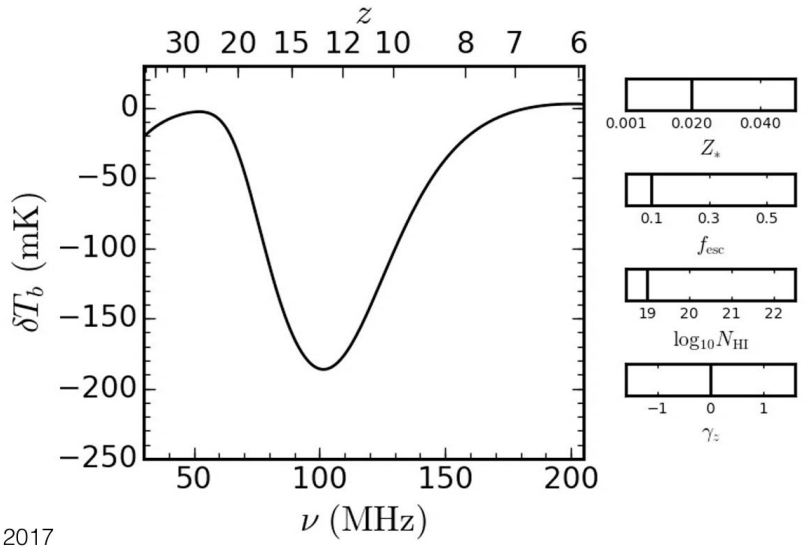
(Adam)

Mirocha: UVLF calibrated models prefer higher frequency (lower z) absorption trough...

Way out for EDGES is strong redshift and/or halo mass dependent star-formation efficiency…

Are these models in conflict with e.g. SARAS-2 results?

More rigid than past models

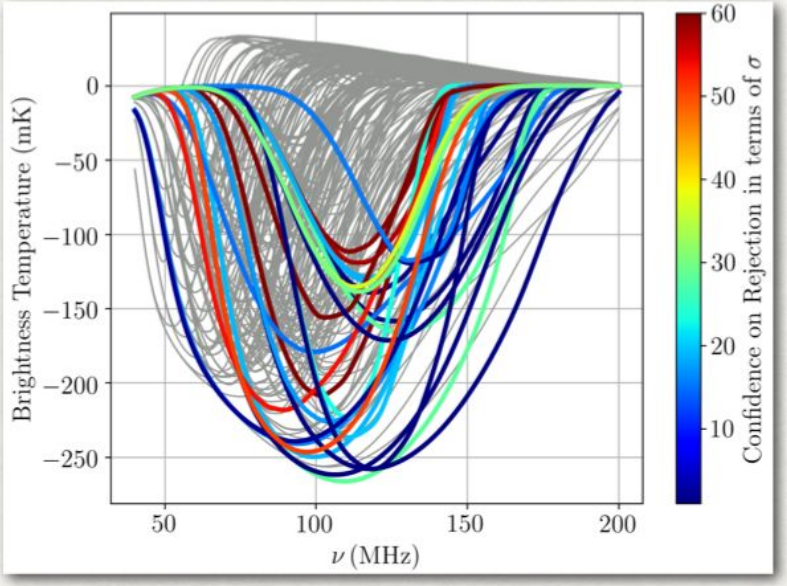


JM+ 2017

(Adam)

SARAS 2 RESULTS

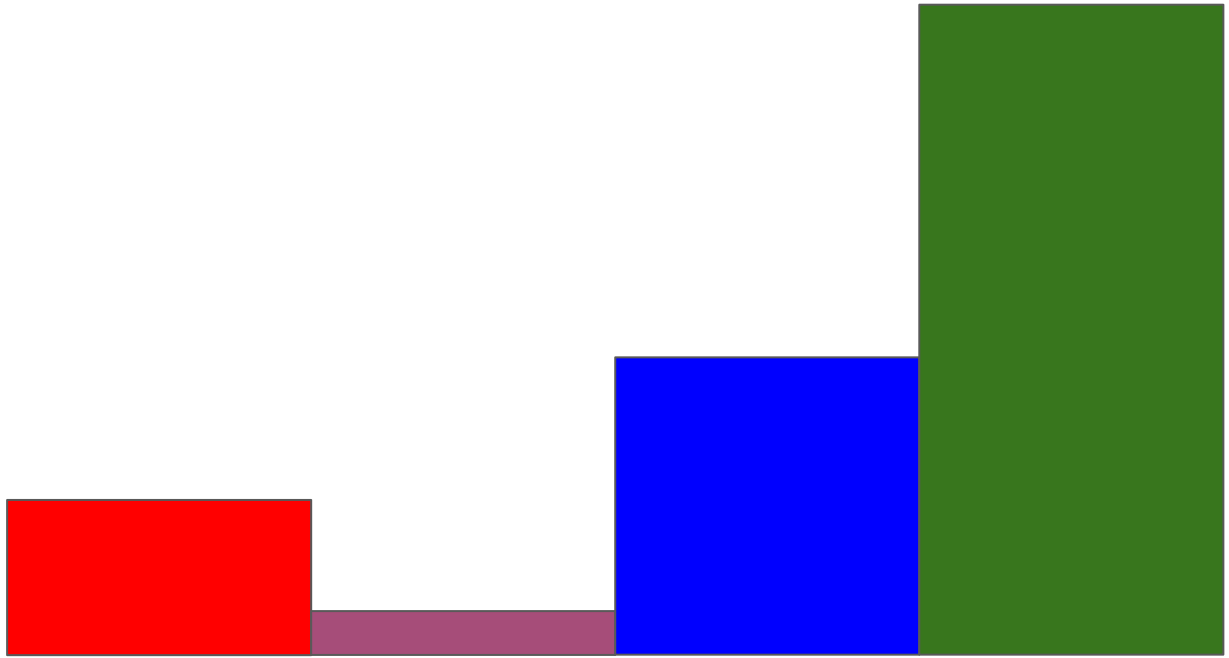
- SARAS 2 rejects the scenario of Rapid Reionization in tandem with either late X-ray heating



Singh et al. 2018

(Adam)

Funding Investment in Global 21cm signal



(Matt)

Next steps

Squarely in the experimental domain:

- SARAs
- LEDA
- PRIZM
- MIST (based on edges 2)
- REACH

- Must have verification of the EDGES signal by an independent group using a substantively different instrument.
- Independent analysis of EDGES data is useful and informative (but doesn't fulfill verification).

Difficulty of confirming results is troubling from an outsider's perspective.

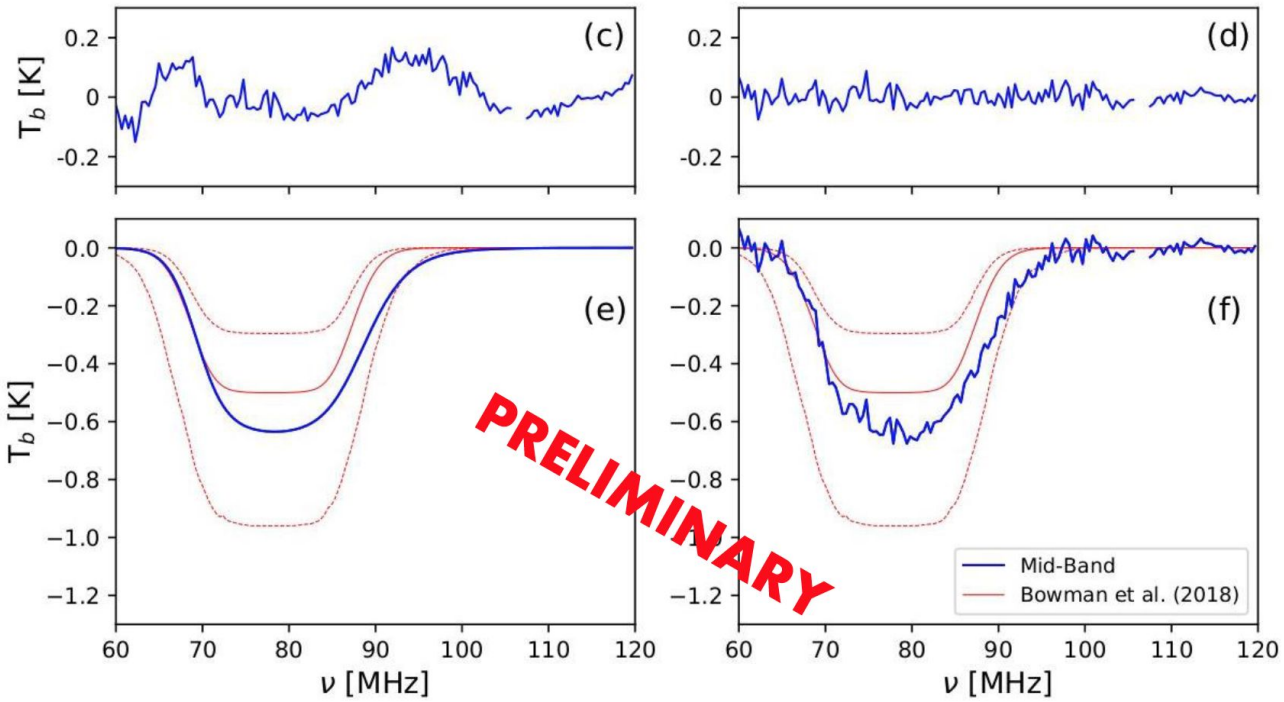
- A few days data is sufficient.
- Experiments are small and low-cost. Teams are small.
- Theoretical implications are enormous.

(Matt)

If an independent verification of the edges absorption feature was obtained (e.g. with SARAS), what is the next measurement that would cement the physics?

Provocation: No verification measurement that shares site, significant personnel, or significant instrument design will be considered robust.

Preliminary **Mid-Band** Results



Will the community accept this as exciting new 'verification' from within the team

Monsalve et al (2019, in preparation)

- Not identical but consistent with Bowman et al (2018).
- Rising slope less steep than Bowman et al (2018).

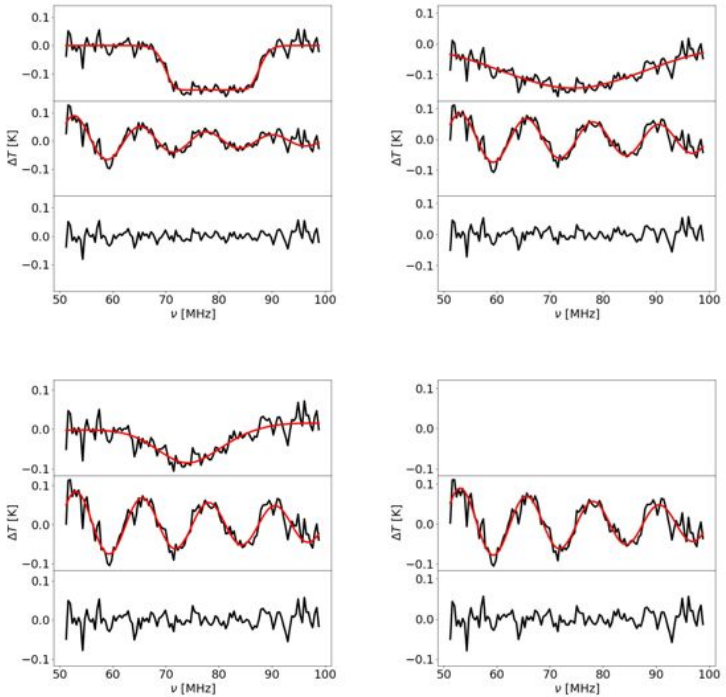
(Adam)

Paths for Validation?

- Re-analysis of entire EDGES data set by independent team?
- Independent measurement with a different instrument by another group?
- 21 cm fluctuation measurements at z~15-20?
- Big 21 cm absorption feature at z~100 from collisionally-coupled era?
- Star-formation efficiency at z~15 from JWST (e.g. Mirocha & Furlanetto 2018)?
- Detect Ly-a or H-a fluctuations from z~15-20 sources: extremely faint, looks way-out-of reach for e.g. CDIM?
- Improved radio background measurements?
- High-z contribution to tau_e from CMB (Heinrich, Miranda, Hu 2017)?
- Is deuterium 92 cm completely hopeless? Collisionally coupled at EDGES redshifts (Sigurdson & Furlanetto 2005) but ~ 10^{-5} times weaker!!!

Analysis Concerns

Sims: Models with no absorption feature but damped sinusoidal systematic fit publicly available EDGES data.



Does the EDGES team accept this statement?

(Adam)

Moving forward

- Each elapsed month without verification reduces the public confidence in the signal.
- Scientific reward to cost ratio is enormous.
  - Driving exploration in many theoretical fields.
  - The field is strongly data-starved.
- Experiments seeking detection
  - Do the international teams have enough resources?
    - (especially in bright minds for analysis, instrument characterization, and null tests?)
    - Limited communication internationally, concerns are not always common.
  - Is the information and expertise flow sufficient? How can it be further improved?
    - The most important progress for the EDGES detection this year must come from outside EDGES team. Anything they can do to disseminate expertise could be the best use of their time(?)
- Is the release of EDGES full low-band data a possibility? Is it useful? *(Matt)*

A Desirable Sequence

The theory talks consistently underlined the importance of the detailed line profile shape - steep edges, flat bottom, amplitude. Refining these parameters will be a persistent long-term goal

1. Confirmation via some combination of tests/experiments
2. Pooling of knowledge, designs, insights (e.g. meetings like this one)
3. Consensus on full range of new efforts that are warranted
4. Scale-up of effort to focus on refinement of profile measurement, tolerances on fit parameters

(colin)

What about brute force experimental approaches?

- Currently, systems are one-off efforts, occasional deployments
  - Number of field activities ~ number of projects/teams
  - Parameter space of designs, environments, analyses is being explored slowly
- Maybe tak
  - Makes s
  - Replicat
  - Run mu
  - Accelera
- Bottleneck
  - To deploy and run multiple experiments at a site
  - To perform data analyses and plot the next steps, post-expedition
  - Cannot easily be solved by just adding money

Goal: Pursue N experimental thrusts simultaneously

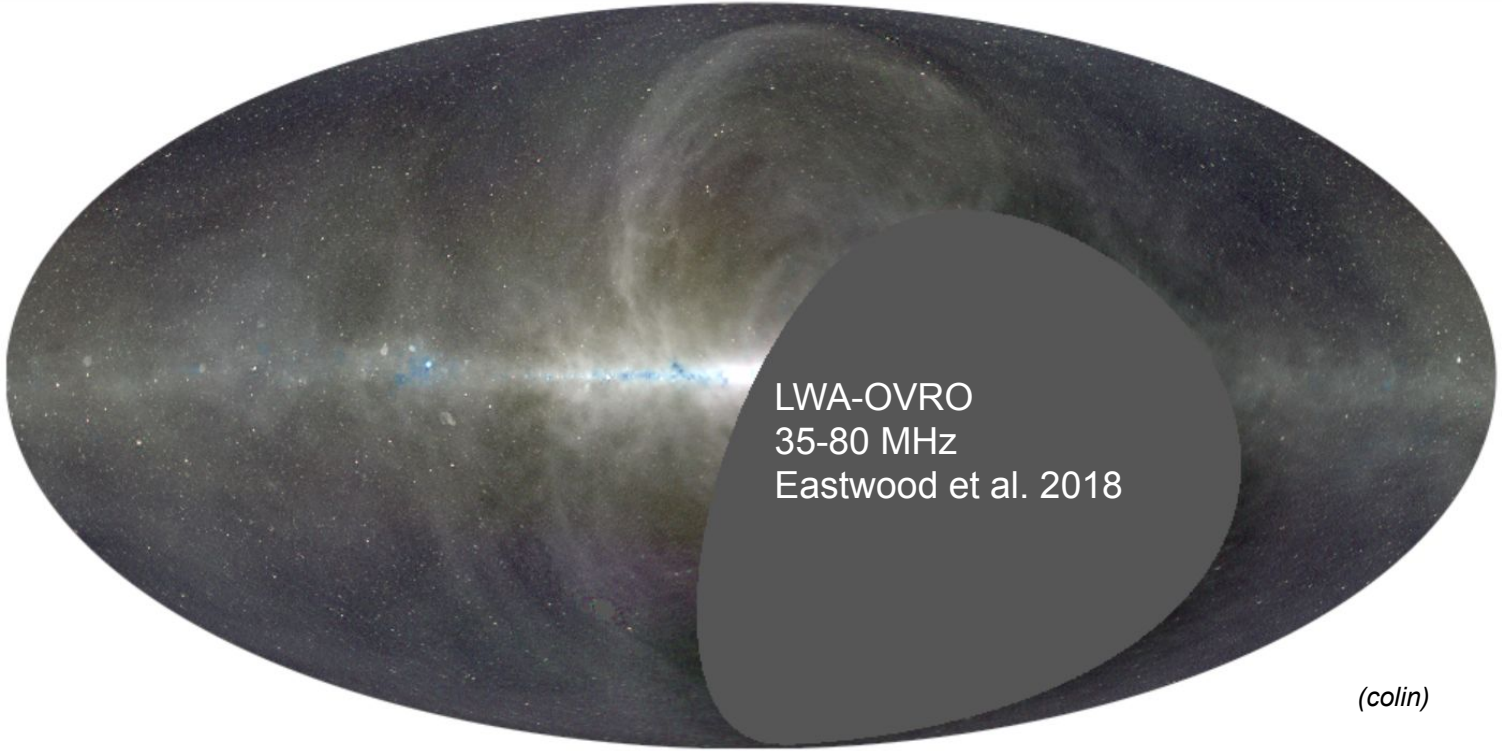
where N >> N_teams

Accelerate progress on understanding systematics

(colin)

Better Sky Models

Now possible to implement arrays that do MUCH better than GSM ...



(colin)

Moving Forward - long term

- Larger, redundant observatories
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