Global Bayesian Models for Global 21cm Experiments

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Outline

1. Motivation
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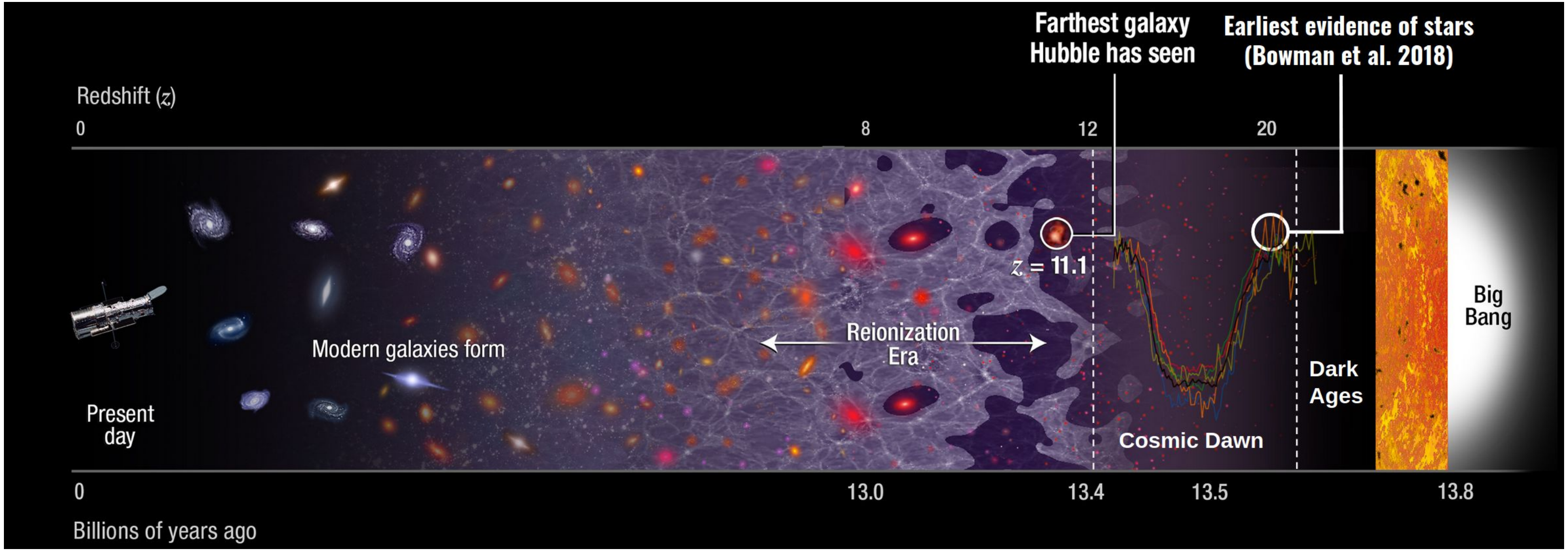
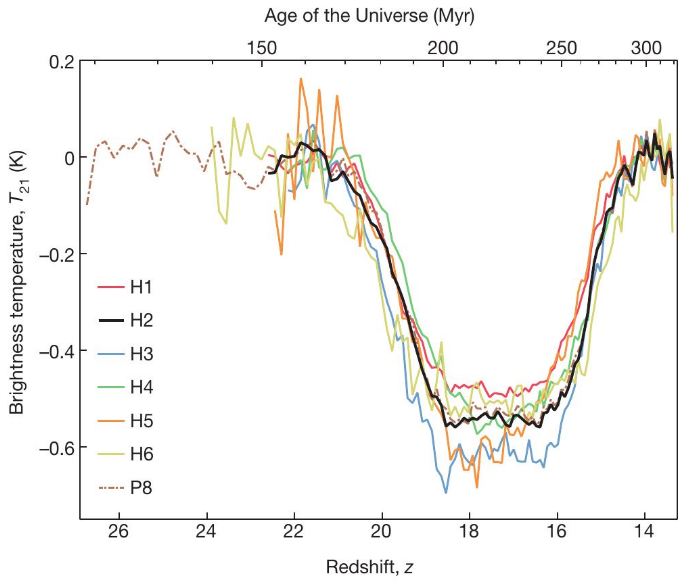
3. Why a Global Bayesian Model?
4. Challenges
5. How does it look for Global 21cm?
6. Application to Lunar Experiments



Motivation: **Confidence** & **Direction**

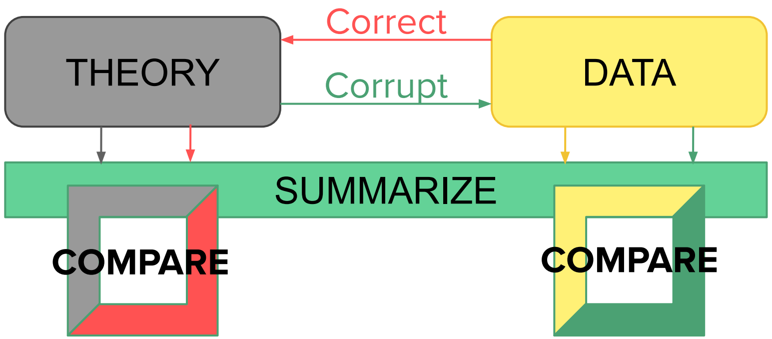
- Building **confidence** that a global signal detection is truly cosmological is ***hard***:
  - Limited information
  - Highly uncertain classes of systematics
  - Want reliable error-bars on final parameters of interest, accounting for all systematics.
- Which **direction** do we take the next-generation experiment in?
  - Which systematics hurt parameter estimates most?
  - What is our prior knowledge on these, and does that serve to build confidence?



Bowman *et al.*, 2018

Global Bayesian Models

- A fully end-to-end *forward model* of the entire observation process: cosmology, foregrounds, instrument, data processing.
- Combined with Bayesian sampling of the uncertain parameters at each stage.
- Yields joint *posteriors* for all parameters, plus correlations with systematics.
- New standard in CMB community: BeyondPlanck: arxiv/2011.05609
- Contrast with "corrective" models:



Why a Global Bayesian Model?

FORWARD (BAYESIAN) MODELS

- Full multi-dimensional distribution of uncertainties.
- Always solvable
- Connects all parameters

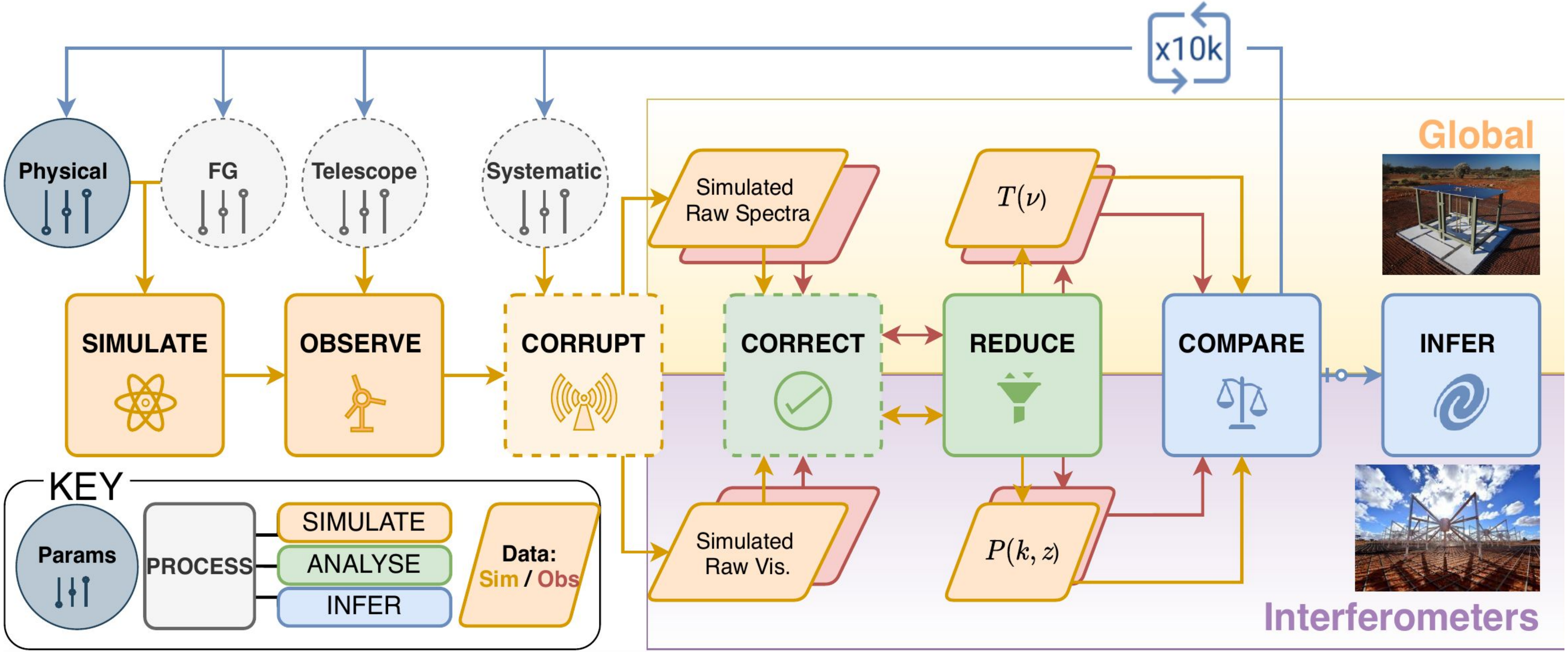
CORRECTIVE MODELS

- Almost never full distribution of uncertainties
- Not always correctable.
- Loses connection with systematics

Challenges

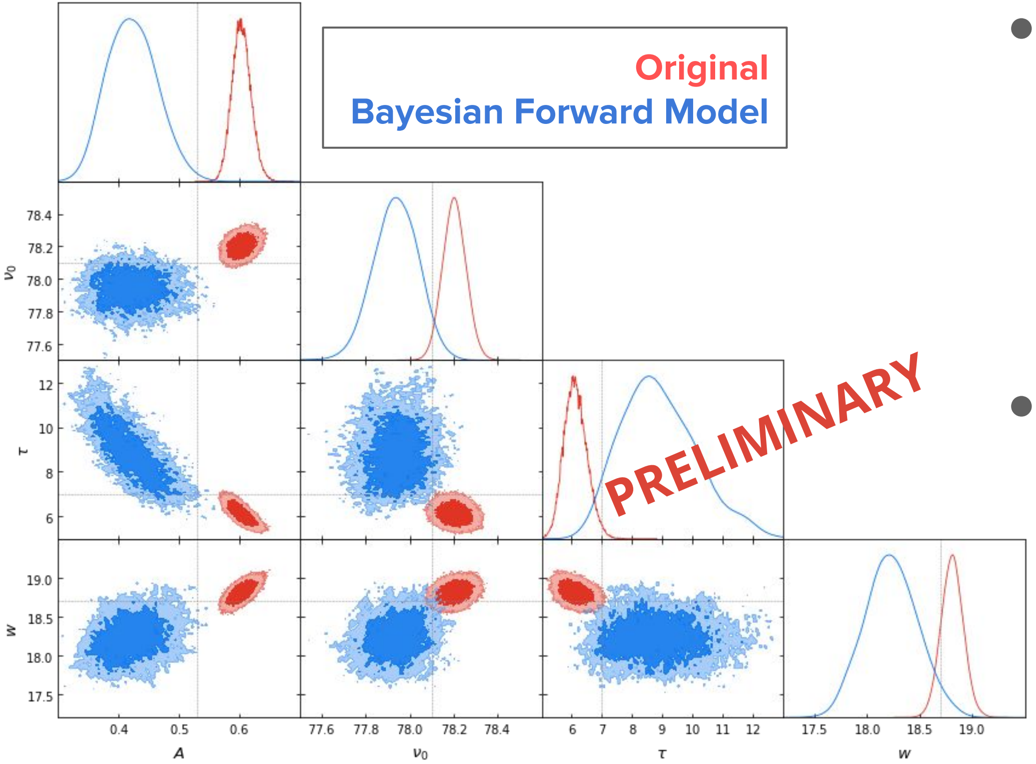
- Computationally demanding: thousands of full-sky simulations
- Tricky to implement:
    - Where do you make the hand-off between data and theory?
    - Which systematics are “localized enough” in some basis that they are best avoided?
    - What is the best representation of possible errors?

The Vision



x10k
Physical
FG
Telescope
Systematic
SIMULATE
OBSERVE
CORRUPT
Simulated Raw Spectra
Simulated Raw Vis.
CORRECT
$T(\nu)$
$P(k, z)$
REDUCE
COMPARE
INFER
Global
Interferometers
KEY
Params
PROCESS
SIMULATE
ANALYSE
INFER
Data:
Sim / Obs

How Does This Look For EDGES?

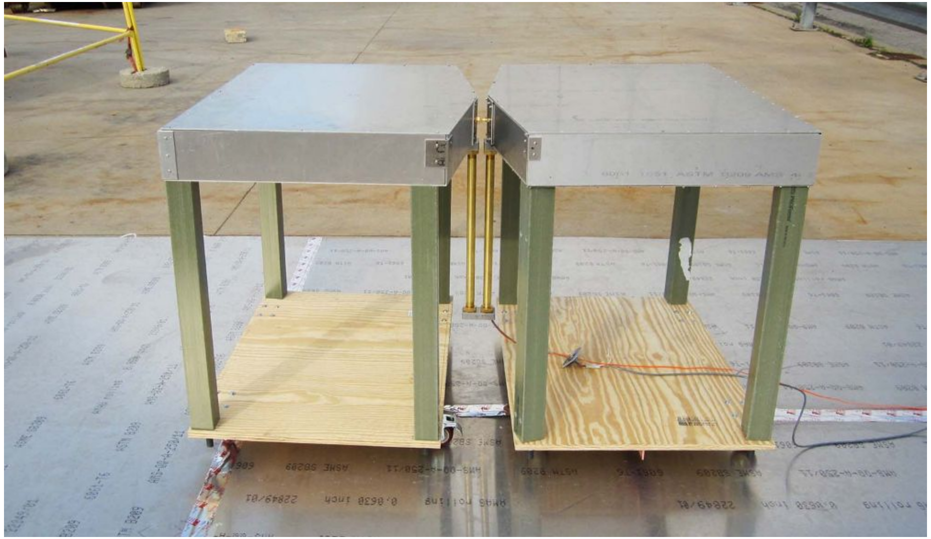


- De-coupled systematic components:
  i. gain reflections
  ii. **gain calibration**
  iii. beam model
  iv. foreground model
  v. cosmological model

- Redesign of EDGES pipeline: https://github.com/edges-collab allows for full forward-modelling.

The Vision for EDGES

- Automated real-time calibration/analysis for EDGES-3 (2021/22)
- All 5 components forward-modeled.
- Ability to perform null-tests on models without signal.



Application to Lunar Experiments

- Lunar global experiments should have well-understood instruments
- That “understanding” must be encapsulated in a *forward model*.
- Complete forward-model for EDGES becomes a test-bed for lunar experiments.

- Key Questions:
  - Which systematics are amenable to Bayesian modelling?
  - Can we mitigate the rest in instrument design?
  - What are the primary systematic impediments to tighter *scientific knowledge*?