What can we really learn from global 21-cm observations of the cosmic dawn?

Geraint Harker

Marie Curie Fellow

University College London

Global 21-cm signal, summarised by ‘turning points’

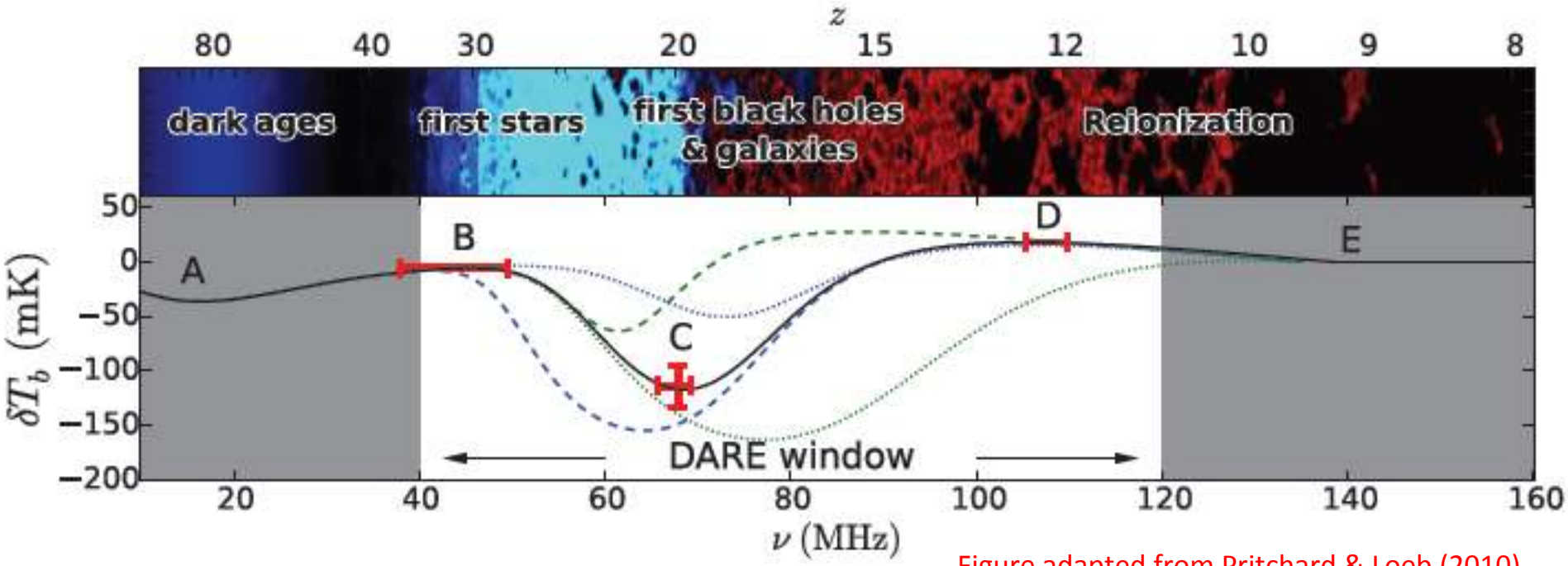
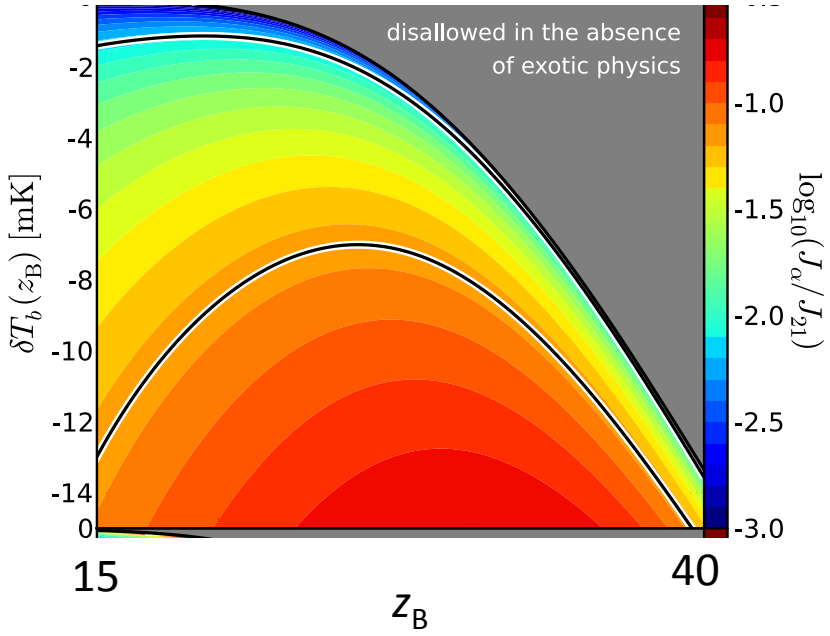
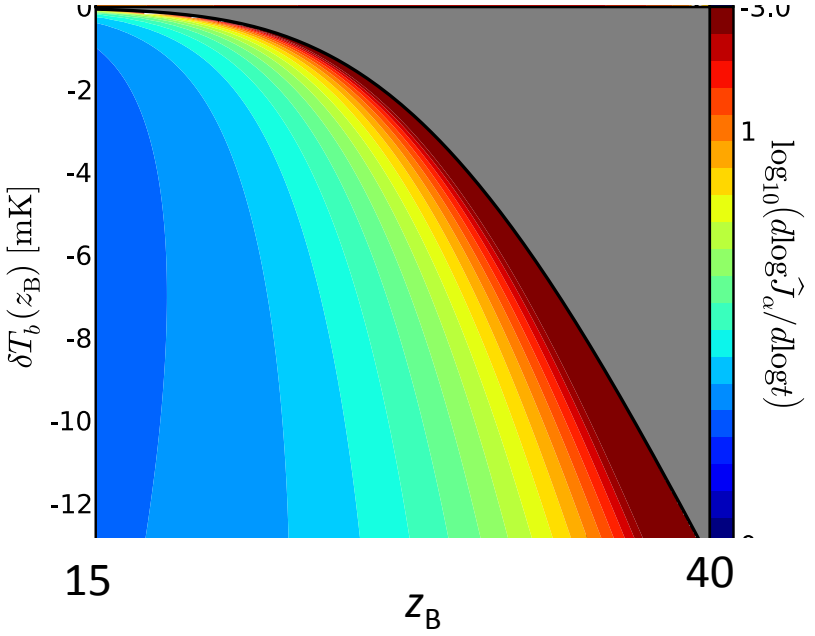


Figure adapted from Pritchard & Loeb (2010)

Turning point B

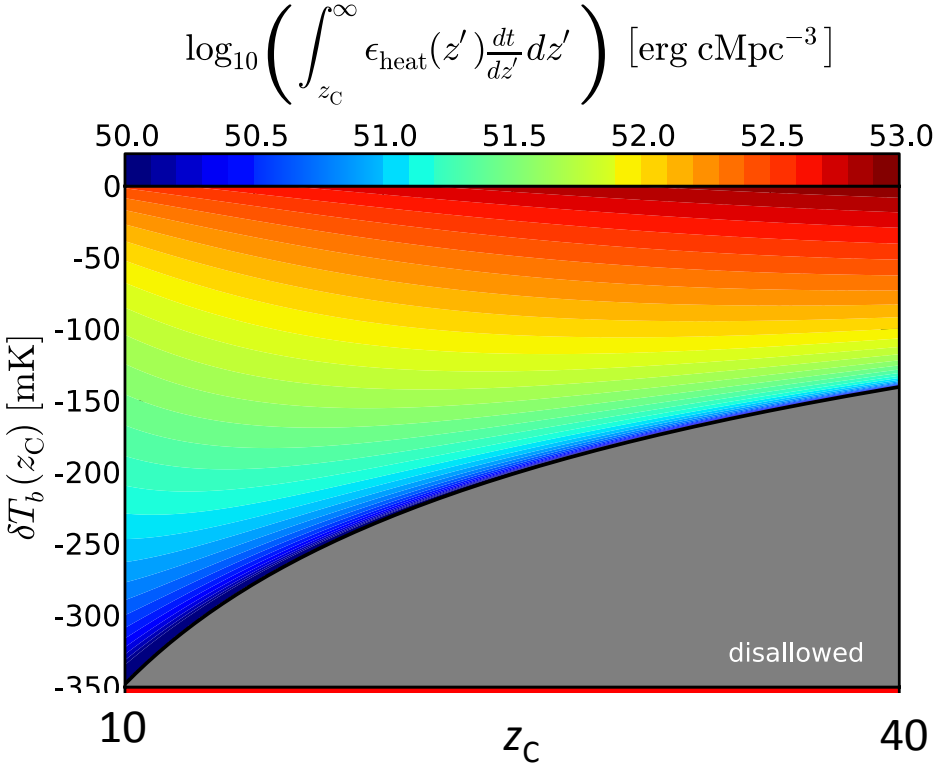


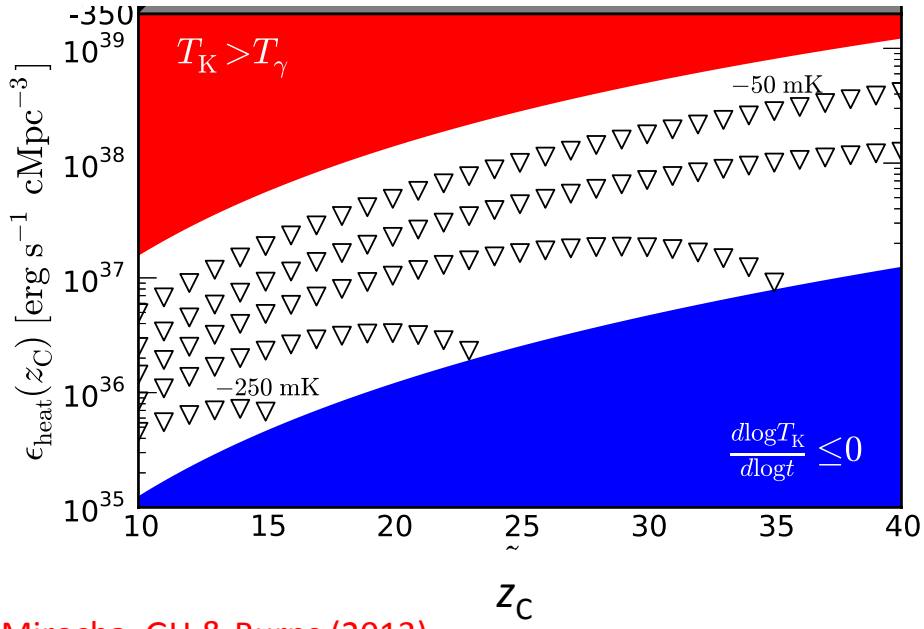


Mirocha, GH & Burns (2013)

Position of turning point B → constraints on global Lyman-alpha background

Turning point C



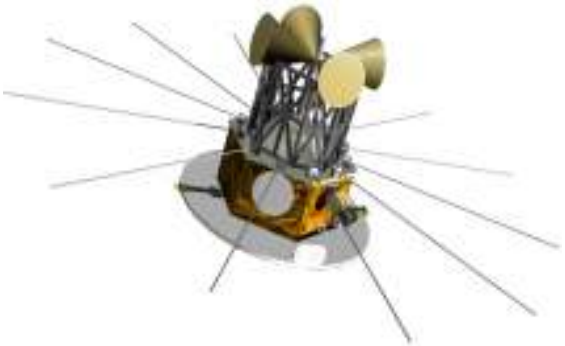


Mirocha, GH & Burns (2013)

Position of turning point C → constraints on global heating rate (X-ray background)

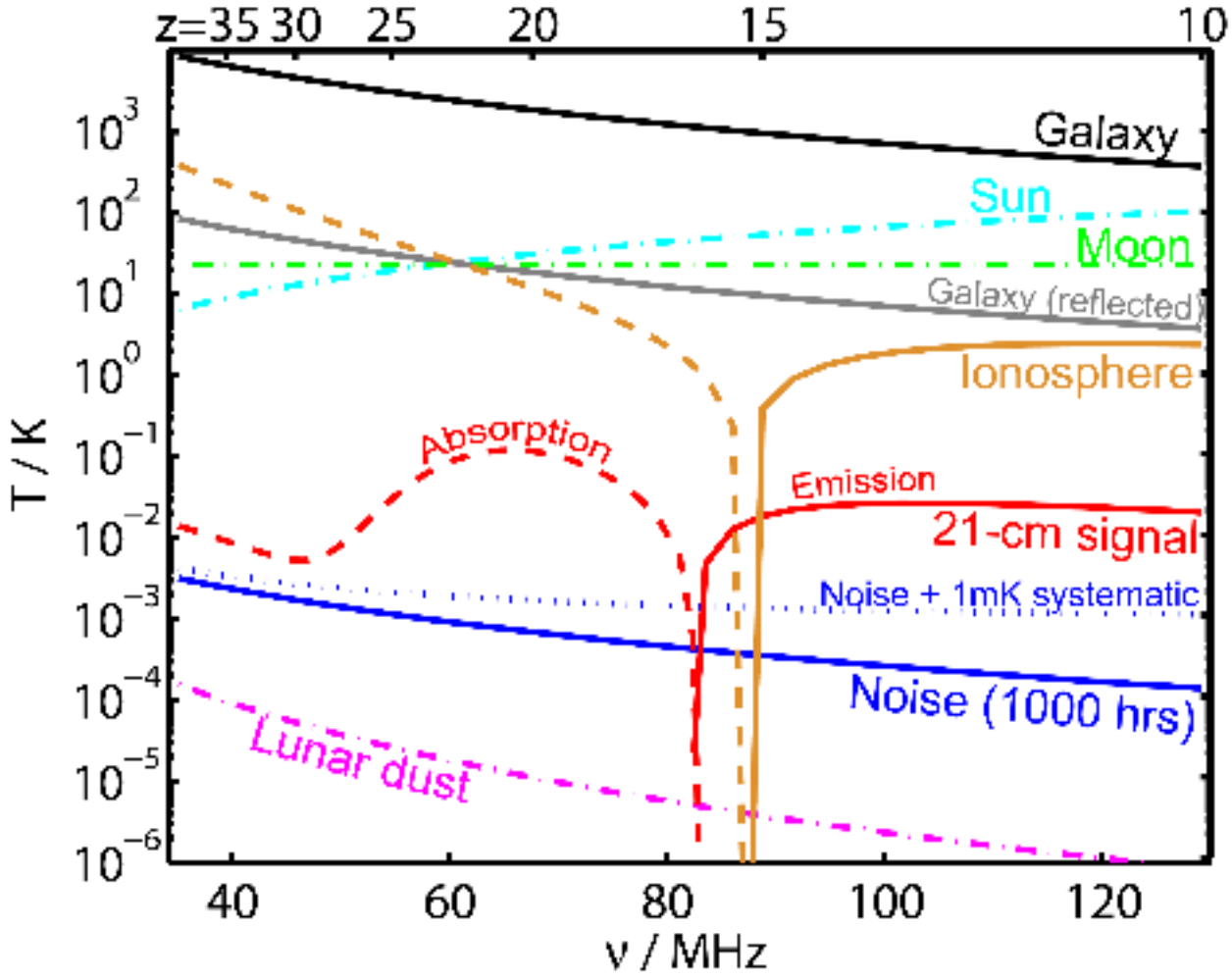
The Dark Ages Radio Explorer

- Proposed:
  - Global 21-cm mission.
  - Low lunar orbit, collects science data over the far side at 40-120 MHz, shadowed from RFI from Earth.
  - Deemed selectable in the last Explorer round, was reproposed as a Small Explorer (SMEX) in December.

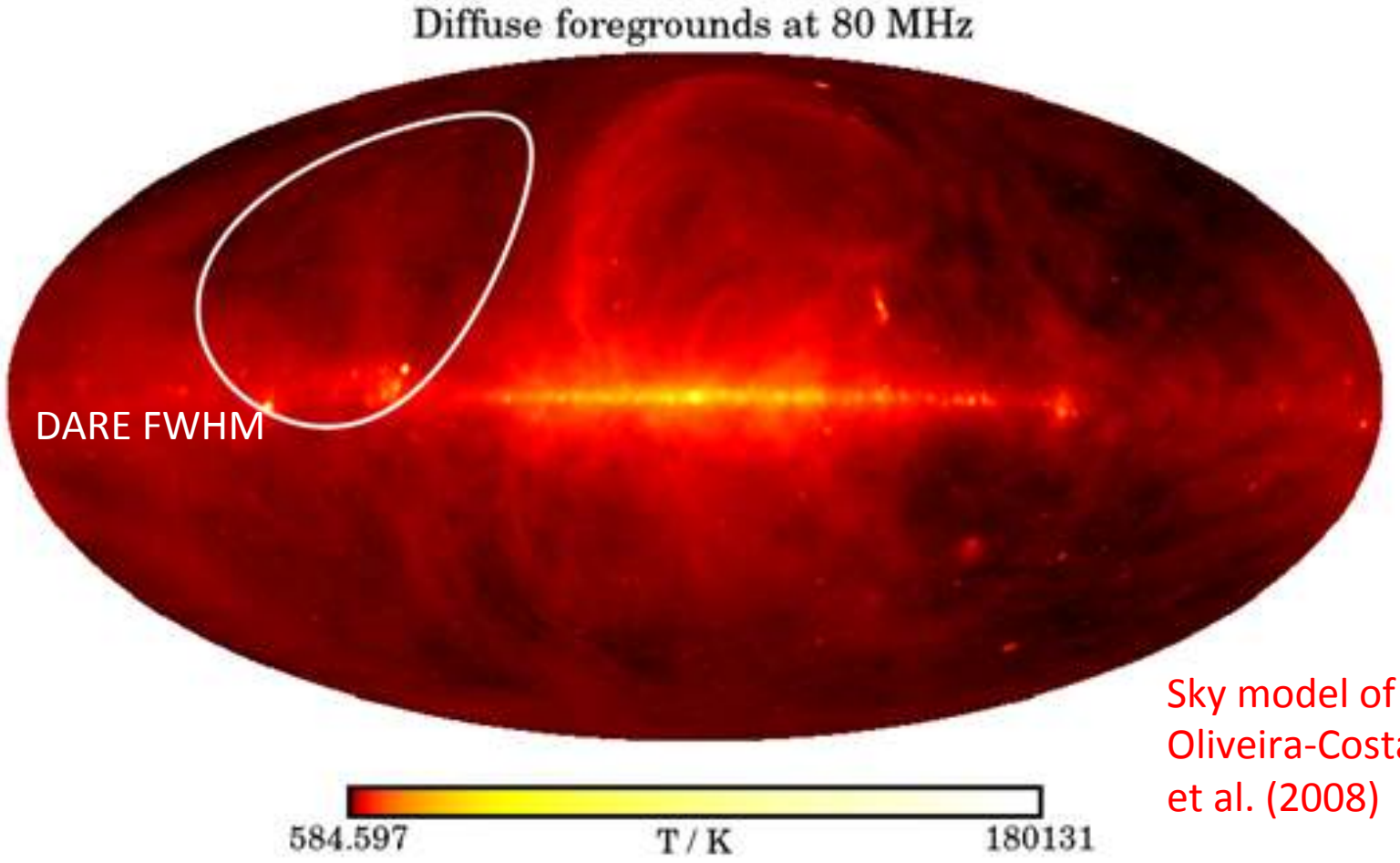


- Current status:
  - An initial field test of a *DARE*-like instrument in March 2012 showed effects of RFI and ionosphere.
  - We have deployed a next-generation prototype with an updated antenna and system, ready to test our new calibration approach, and study the ionosphere and low-frequency foregrounds in more detail.

Multiple strong foregrounds



Spatial structure of foregrounds



Sky model of de Oliveira-Costa et al. (2008)

Bayesian inference framework

Approach: parameterize 21-cm signal, foregrounds, instrument, ionosphere etc. and fit them all simultaneously

Can be computed given our model at a particular set of parameter values, Θ

Parameters

Data

$$\Pr(\mathbf{\Theta}|\mathbf{D}, H) = \frac{\Pr(\mathbf{D}|\mathbf{\Theta}, H)\Pr(\mathbf{\Theta}|H)}{\Pr(\mathbf{D}|H)}$$

Likelihood, (Θ)

Prior, π(Θ)

Evidence, *Z*

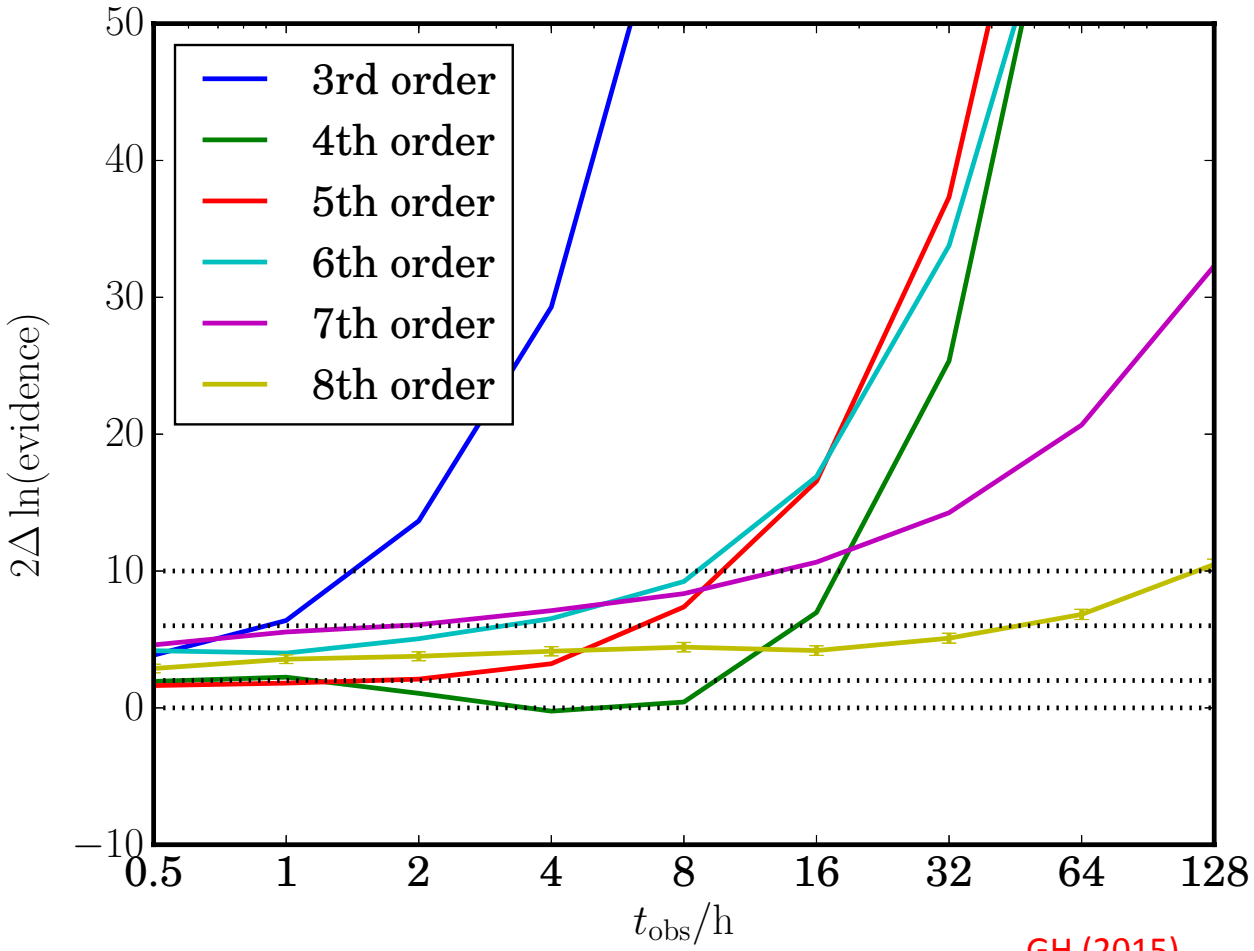
Posterior

Hypothesis or model

Computed as a function of Θ using Monte Carlo methods.

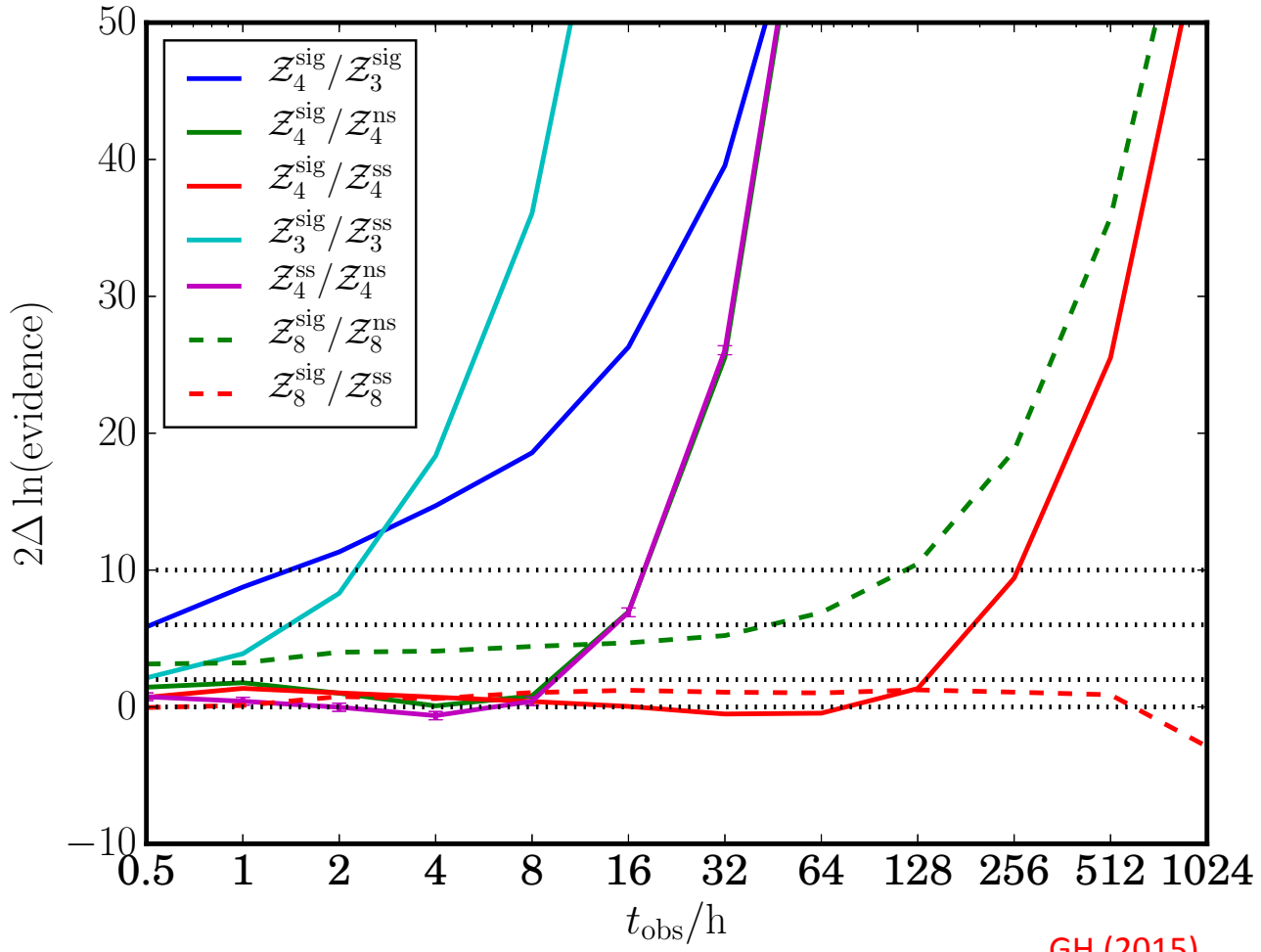
$$\mathcal{Z} = \int \pi(\Theta)\mathcal{L}(\Theta)\mathrm{d}^N\Theta$$

Higher order FGs make the signal harder to extract (but not impossible)



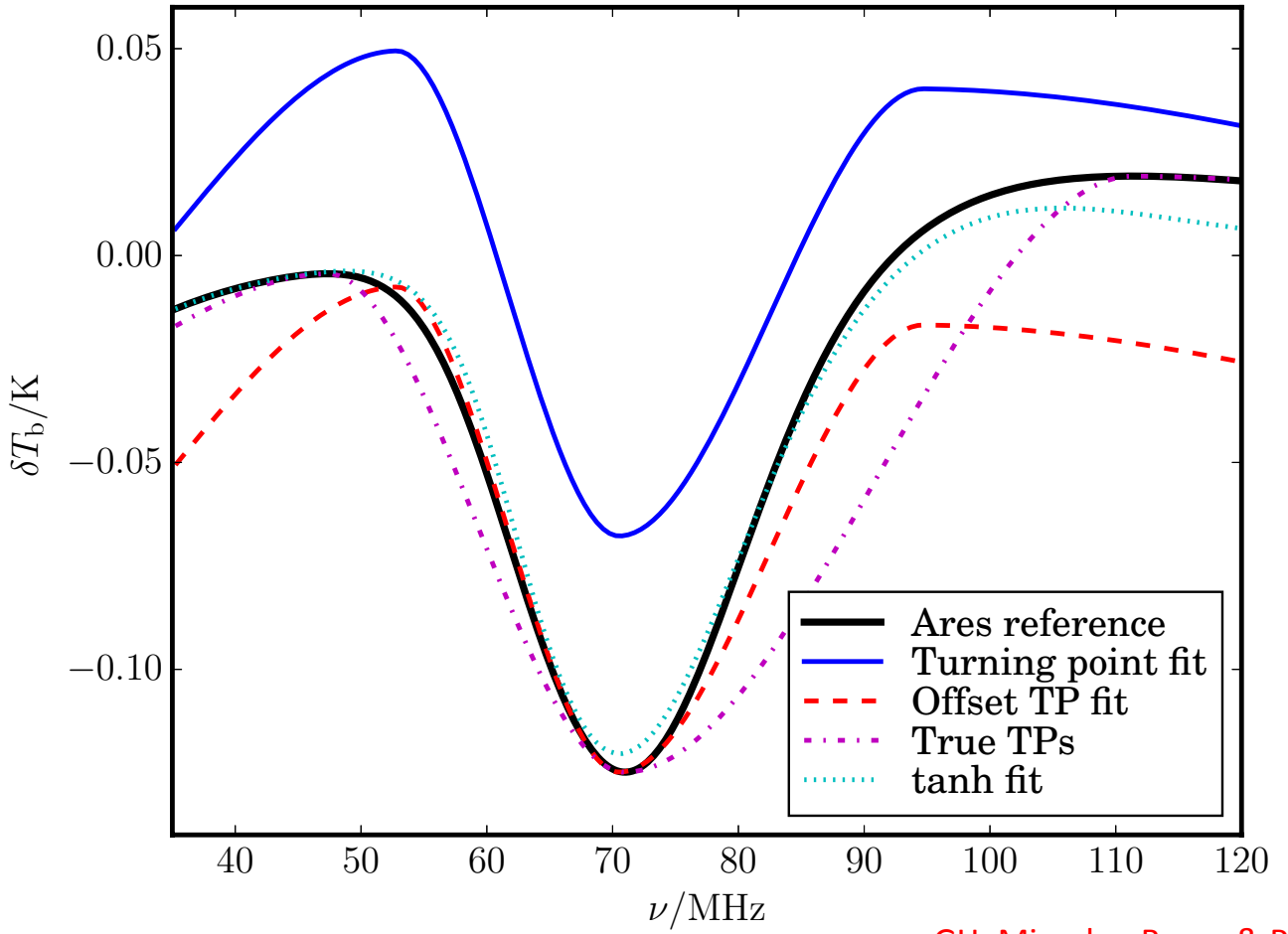
GH (2015)

Effects of complex foregrounds



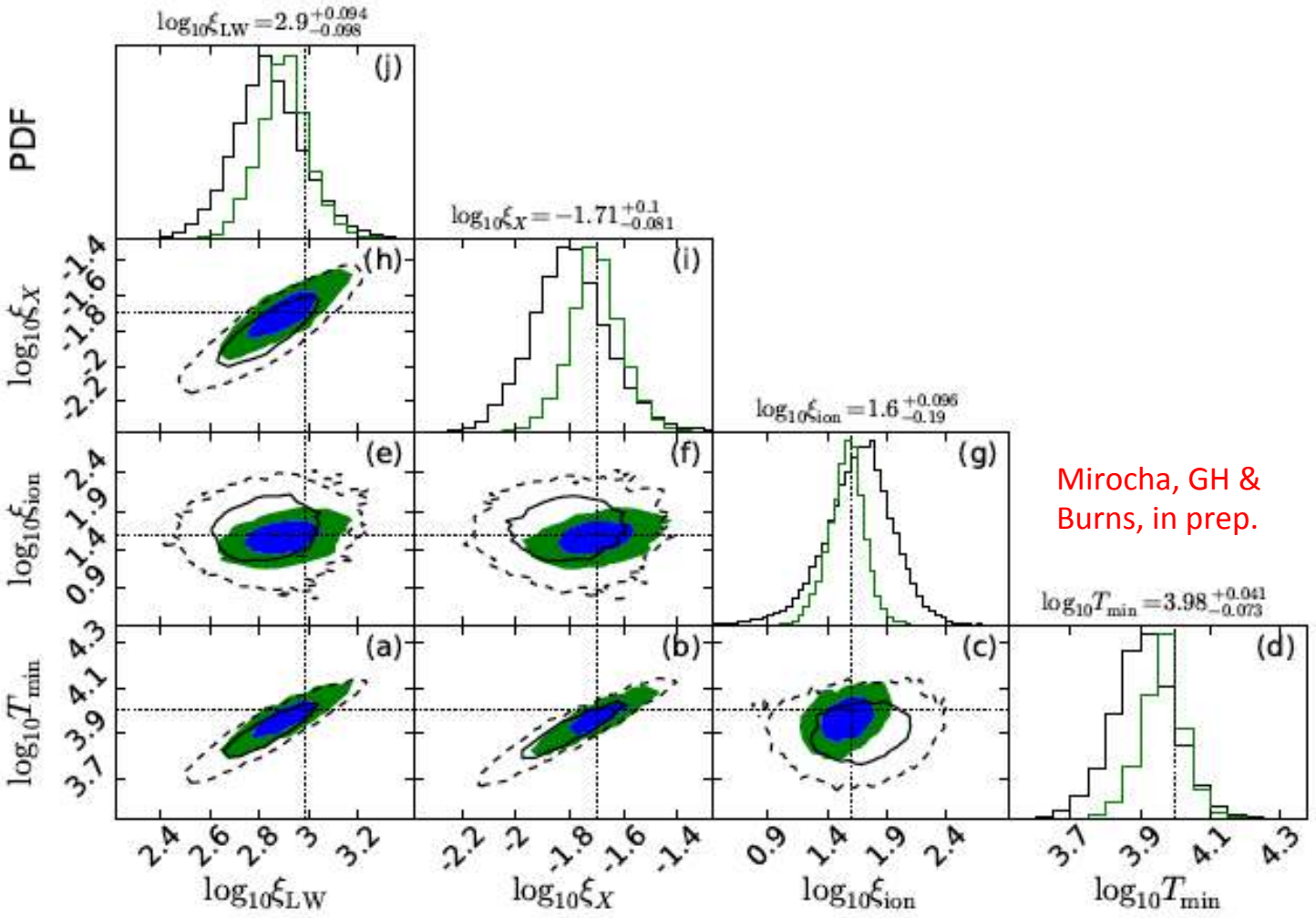
GH (2015)

Other signal parametrizations may match the signal shape more easily



GH, Mirocha, Burns & Pritchard, in prep.

Physical parameter constraints



Mirocha, GH & Burns, in prep.

Conclusions

- Turning points encode robust information about IGM properties…
- …but their positions may be biased unless the model can capture the true shape of the signal.
- Can test for this, and for foreground complexity, using Bayesian model selection.
- Nested sampling seems to work well for this, but we need fast, scalable codes.