Global 21-cm signal modelling and foreground separation

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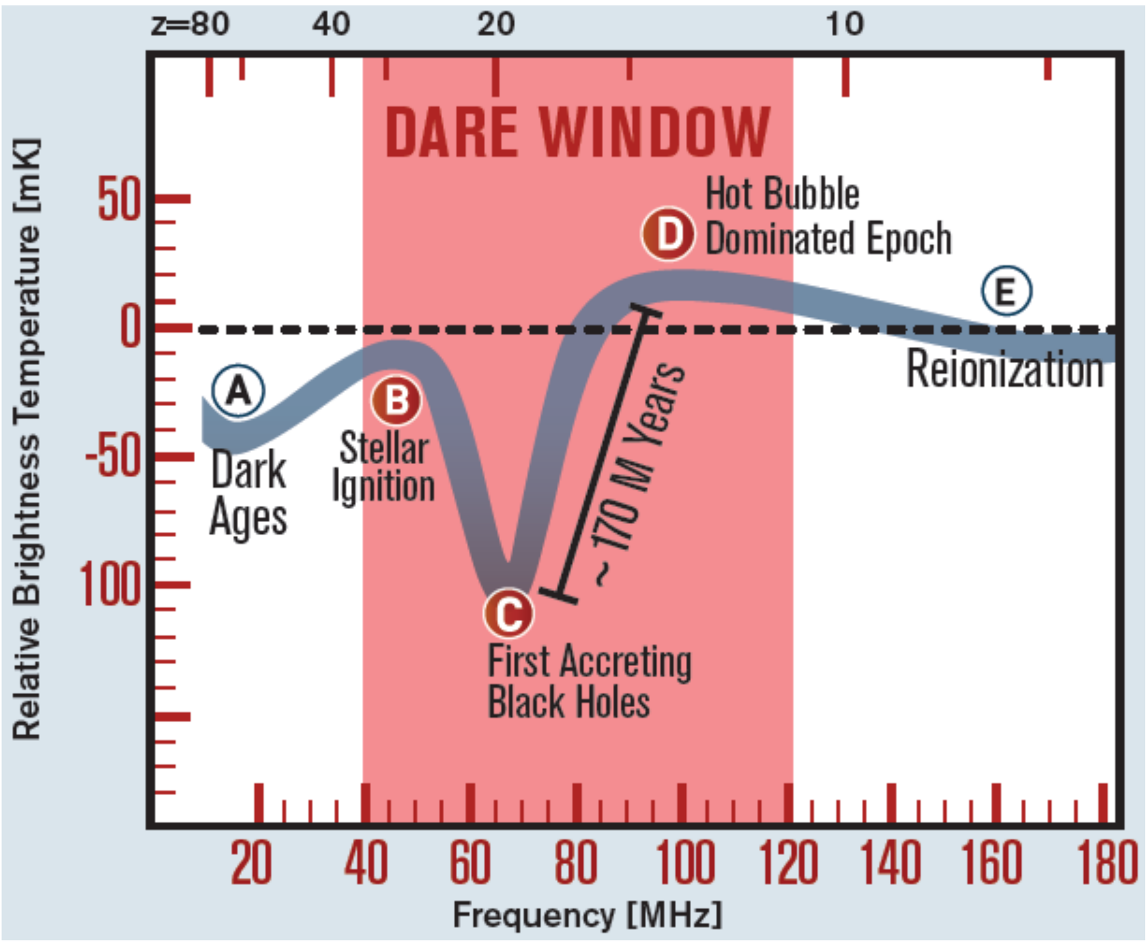
Summary

The sky -averaged 21-cm signal is perhaps the most promising near-term probe of the 'cosmic dawn', when the first stars and galaxies began to heat and ionize the Universe. Measurements are still challenging, however, because of the intense foregrounds at the relevant low radio frequencies, the exquisite instrumental calibration this necessitates, anthropogenic radio frequency interference (RFI), and the Earth's ionosphere. The latter three problems can be greatly mitigated by studying the cosmic dawn from the far side of the Moon. The proposed *Dark Ages Radio Explorer (DARE)* would do so by carrying a dipole antenna in a low lunar orbit. We show how such a mission can separate foregrounds from signal and thereby probe the cosmic dawn.

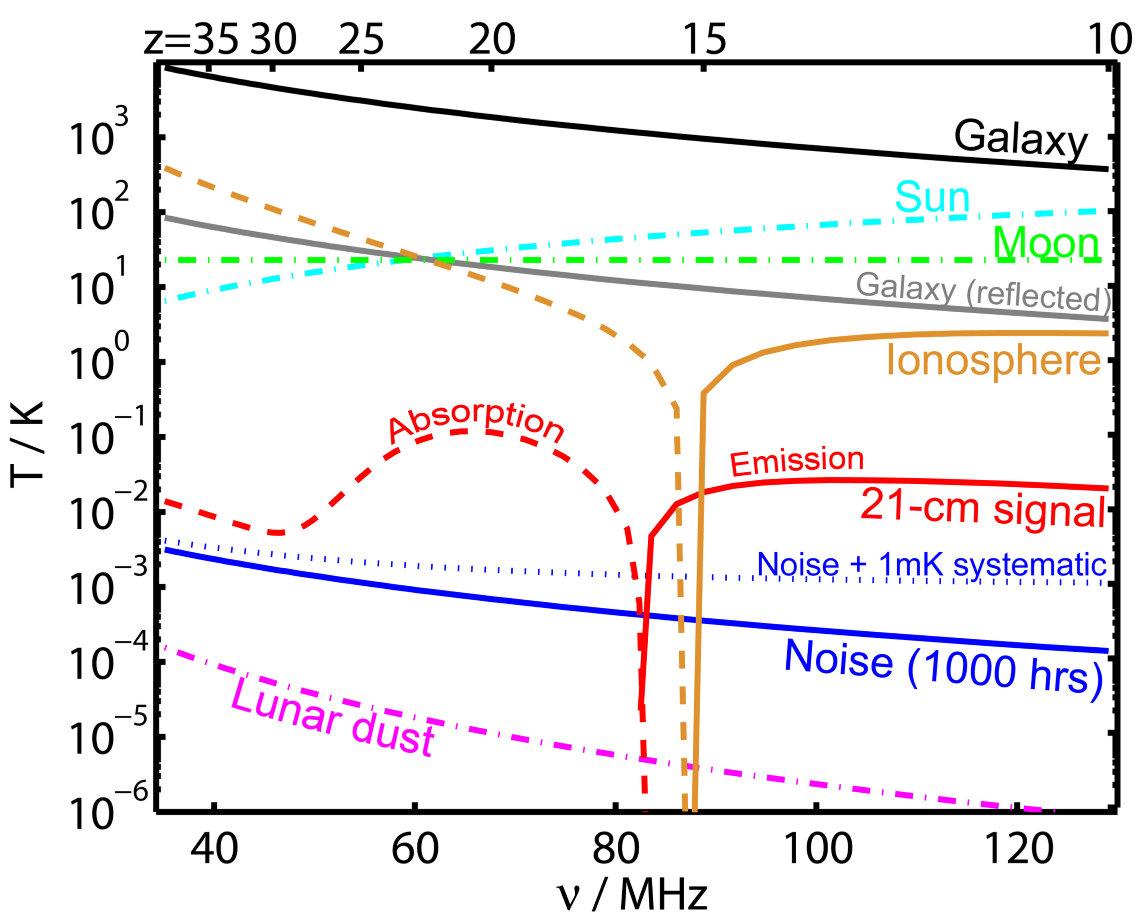
Introduction

Sky-averaged observations of the highly redshifted 21-cm line will yield information on the first stars and galaxies, and the first accreting black holes.



Foregrounds

Astrophysical sources at the redshifted 21-cm signal frequency exceed it in intensity by ≈10^4–10^6.



The ionospheric contribution shown here is due to absorption and emission. In reality, we must also deal with refraction, which effectively makes the beam frequency- and time-dependent. Horizon cutoff can lead to sharp (problematic) features in the spectrum during moderately active conditions.

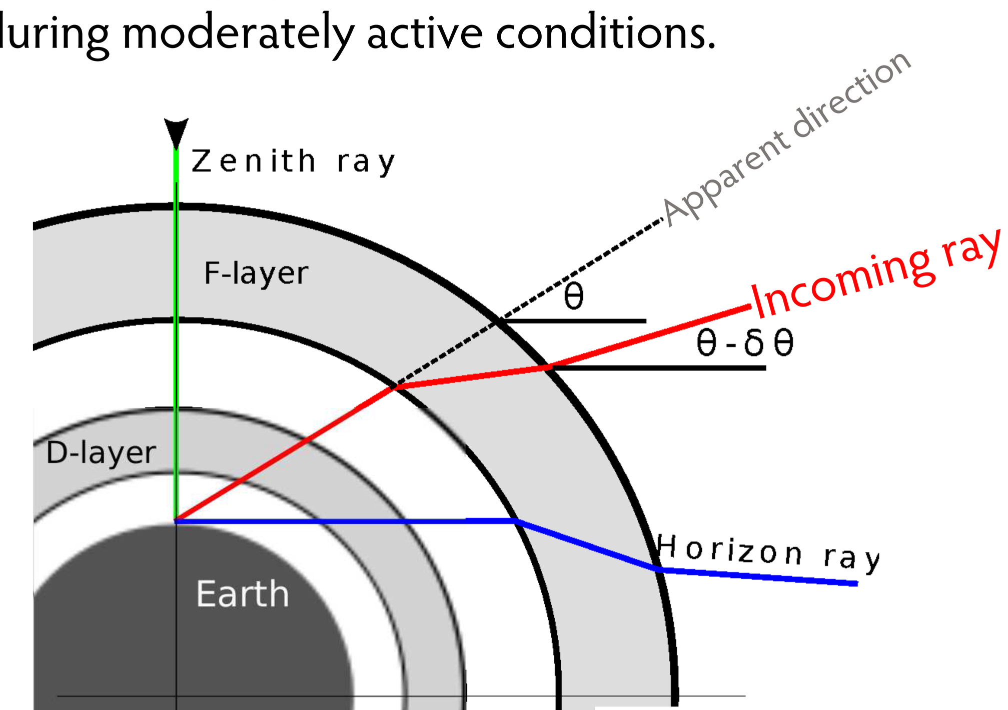
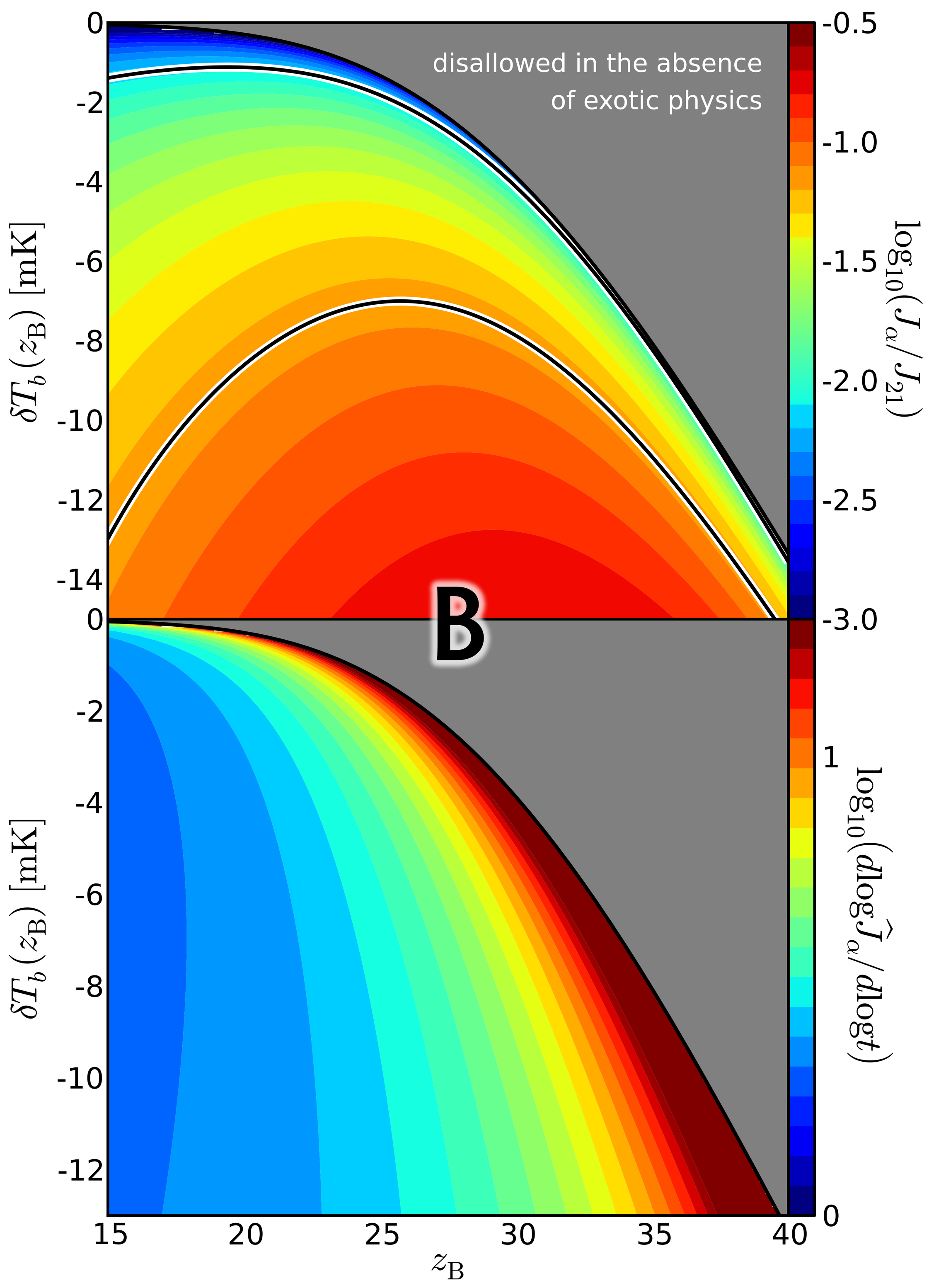


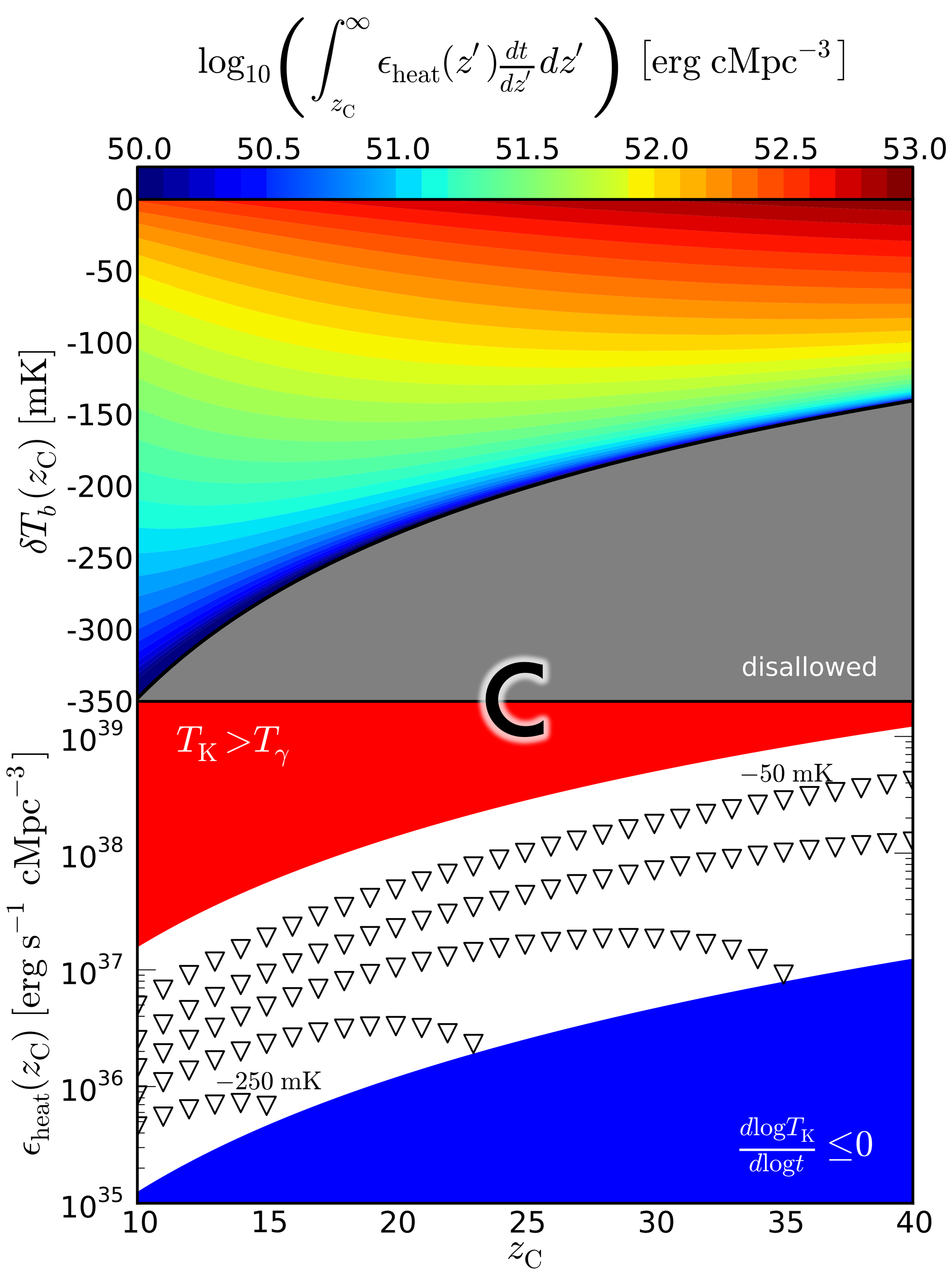
Figure from Vedantham et al. (2013)

Turning points

Turning point B constrains the buildup of the Lyman-alpha background; C constrains the amount of heat deposited in the IGM (e.g. by X-rays). D signals the start of the Epoch of Reionization and is more complex.

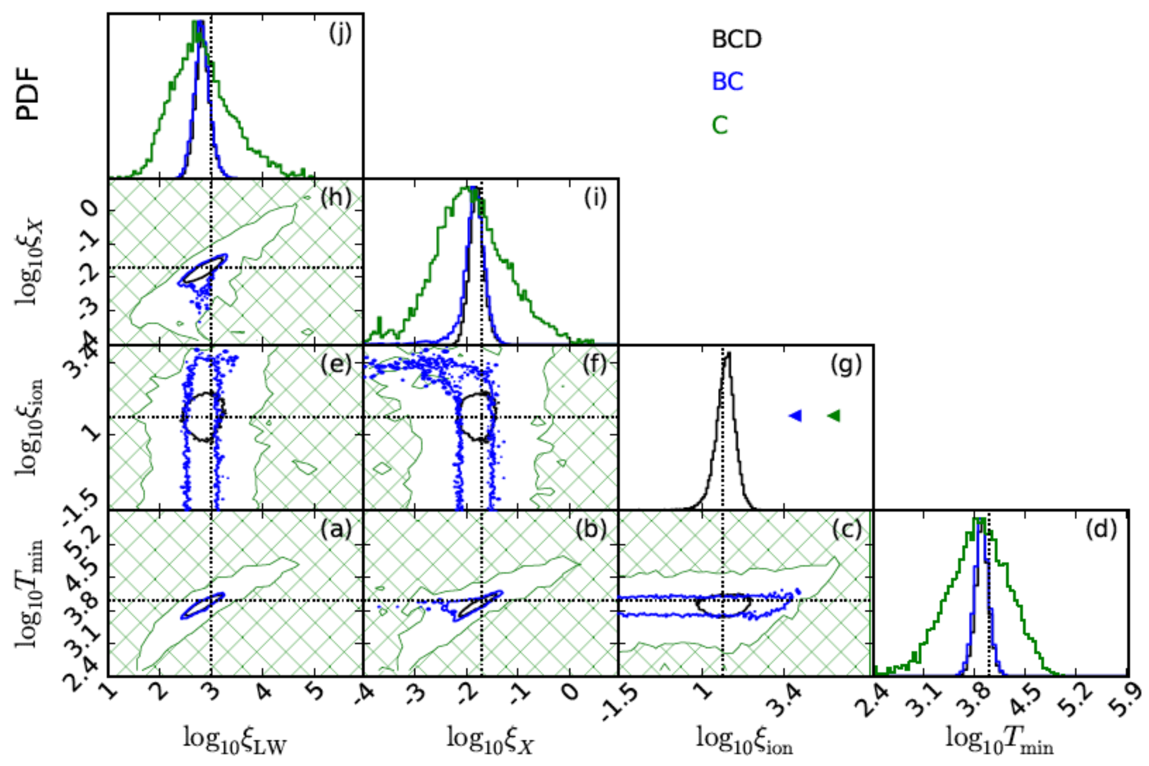


Figures from Mirocha, Harker & Burns (2013)



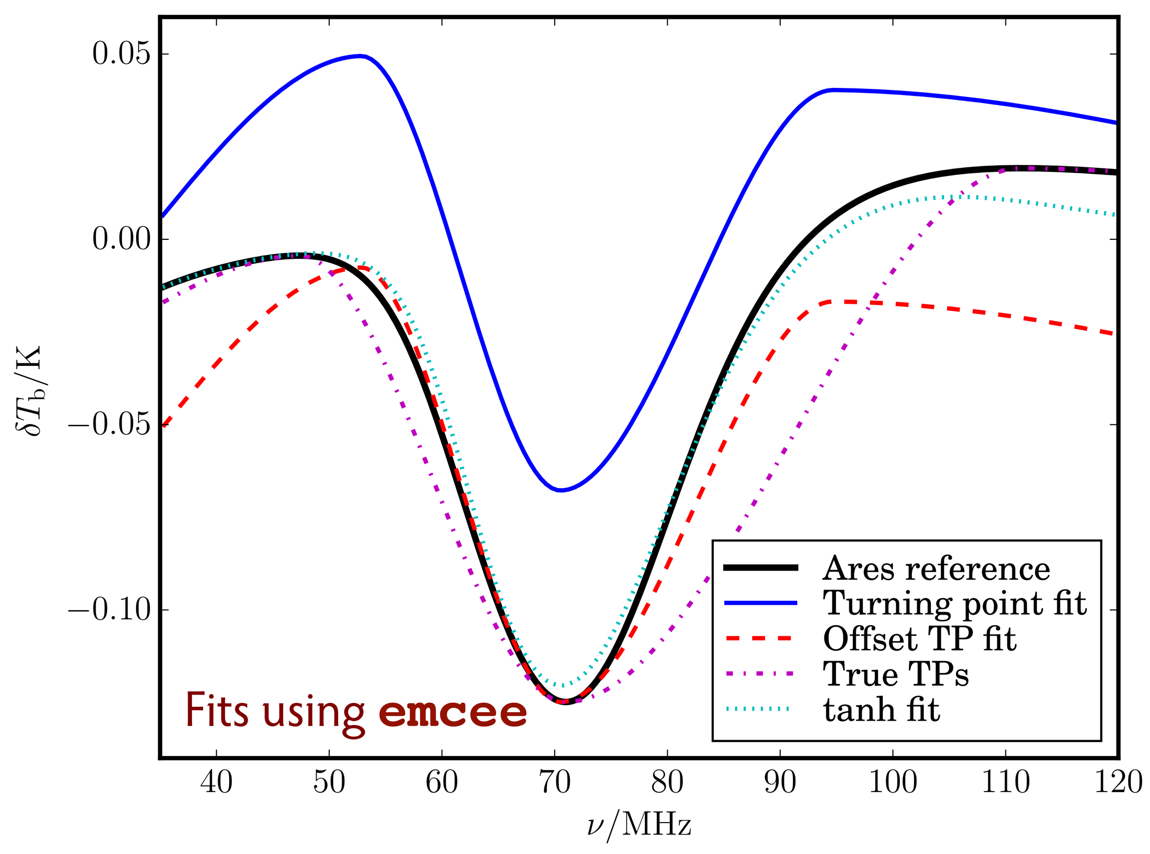
Fitting a physical model

Given errors on (one, two or three) measured turning points, we can obtain constraints on parameters of the physical model implemented by the **ares** code.



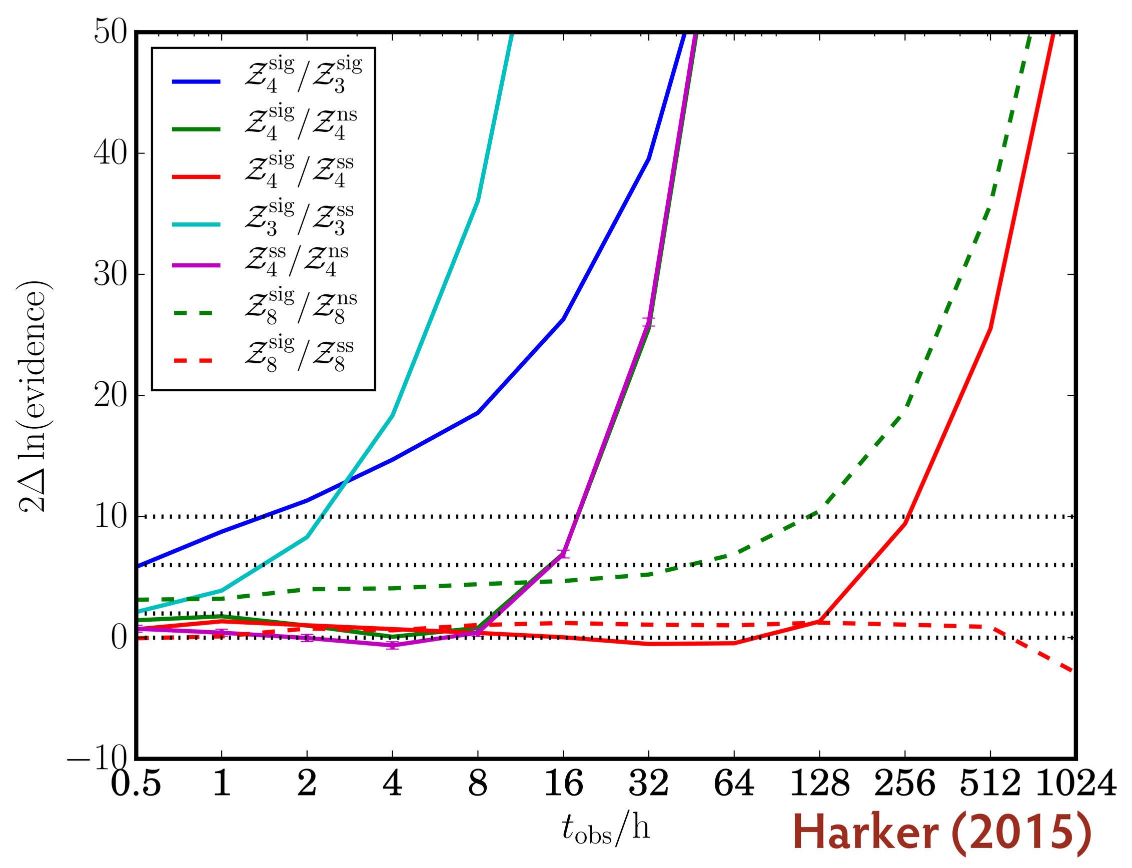
Different parametrizations

Fitting DARE data (40-120 MHz spectra in eight sky regions) with a full physical model is expensive. Simple parametrized models may be used but not all can fully capture the shape of the **ares** curve.



Selection of foreground and signal complexity using the Bayesian evidence

- Foregrounds modelled with a log-log polynomial of varying degree.
- Signal models:
  - Cubic spline interpolating between three turning points.
  - 'Simple signal' with no turning point 'D' (no emission).
  - Null signal.
- Compute evidence using **MultiNest.**



Harker (2015)

- Can detect the need for 4th-order rather than 3rd-order foregrounds in just a few hours.
- Higher-order foregrounds make distinguishing the 'full' from the 'simple' signal much more difficult.

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Acknowledgements

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Further information

- *Selection between foreground models for global 21-cm experiments*; Geraint J. A. Harker, *MNRAS* (2015), **449**, L21-L25
- DARE: `http://lunar.colorado.edu/dare`
- **ares** (Accelerated Reionization Era Simulations): `https://bitbucket.org/mirochaj/ares`
- **emcee:** `http://dan.iel.fm/emcee`
- **MultiNest:** `https://ccpforge.cse.rl.ac.uk/gf/project/multinest`

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