Lecture 11

First stars

First black holes

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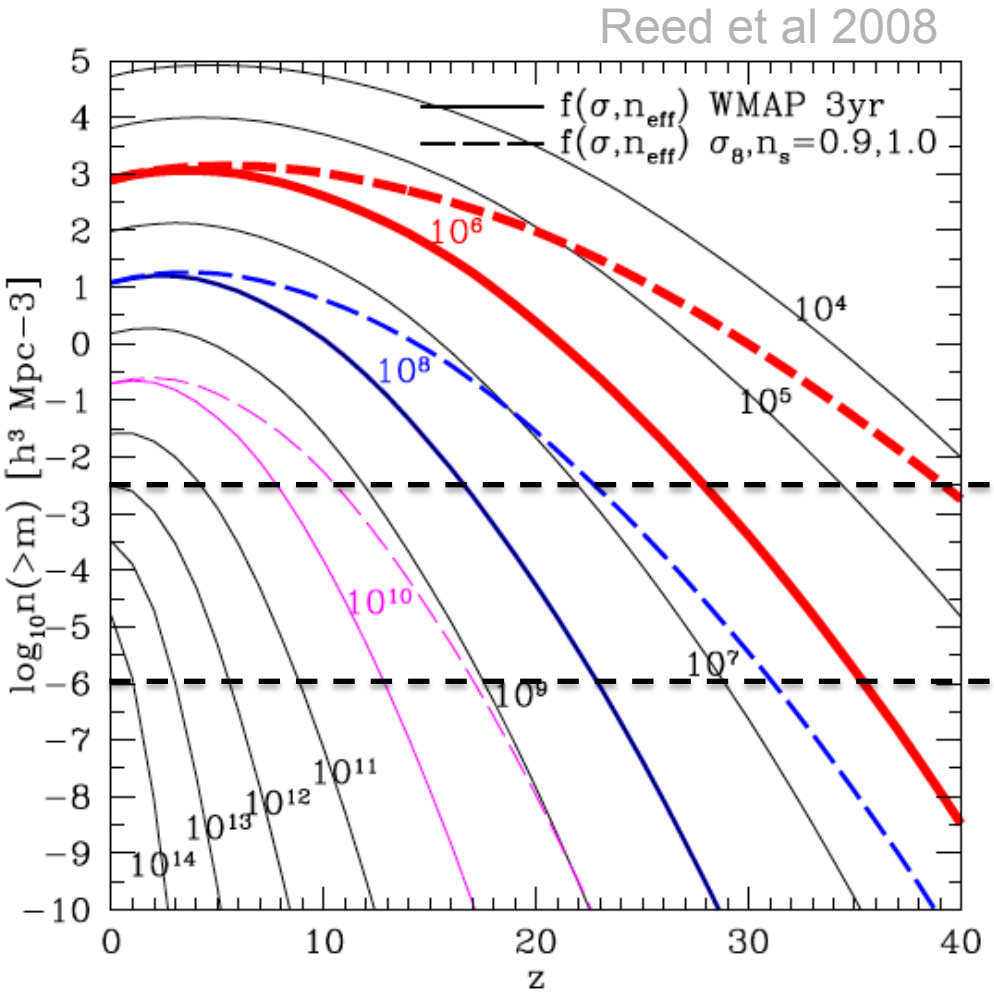
Structure formation in the early Universe

Some haloes of significant mass appear at very early times



number of 10^{12} $M_\odot$ haloes today

number of 10^{15} $M_\odot$ haloes (Coma clusters) today

The interest in Population III objects

Cooling is central to baryonic structure formation.

Line cooling from atomic transitions dominate cooling of e.g. 10^4 K gas.

BUT, primordial gas will be only H + ^{4}He (plus trace ^{7}Li, ^{3}He etc) so cooling will be much less efficient. Also, hard to make H_2 or other molecules.

How will this alter the properties of the first objects to form?
e.g. more massive stars, with different evolution (short lives etc).

The problem of black hole growth

Eddington Luminosity: maximum luminosity before an accreting black hole blows away accreting material. Luminosity comes from accretion of mass with some radiative efficiency ε. Mass can then increase exponentially on the "Salpeter timescale"

$$t_{Salpeter} = \frac{\varepsilon \sigma_T c}{4\pi G m_p} \approx 4.5\, \varepsilon_{0.1} \times 10^7 \text{ yrs}$$

In 700 million years (z = 35 to z = 7), maximum growth through accretion is (for e ~ 0.1) "only" 15 e-folds, i.e. a factor of $10^{6.5}$.

We need to get 10^9 $M_\odot$ black holes by z ~ 7 to power luminous quasars.

How do we do this?

When did “first light” occur?

We don’t know:

March 2018: Claim to see feature in CMB spectrum correspomding to 21 cm at 15 < z < 20, indicative of presence of significant Lyα pumping of H atoms (Bowman et al, Nature, 2018).

Interesting, but not generally regarded as having been established at this time. Also, 2x expected signal!

Also, there are persistent claims of diffuse 2-5 μm background (Kashlinsky+, last 15 years).

Again, interesting, but very difficult to measure and interpret.

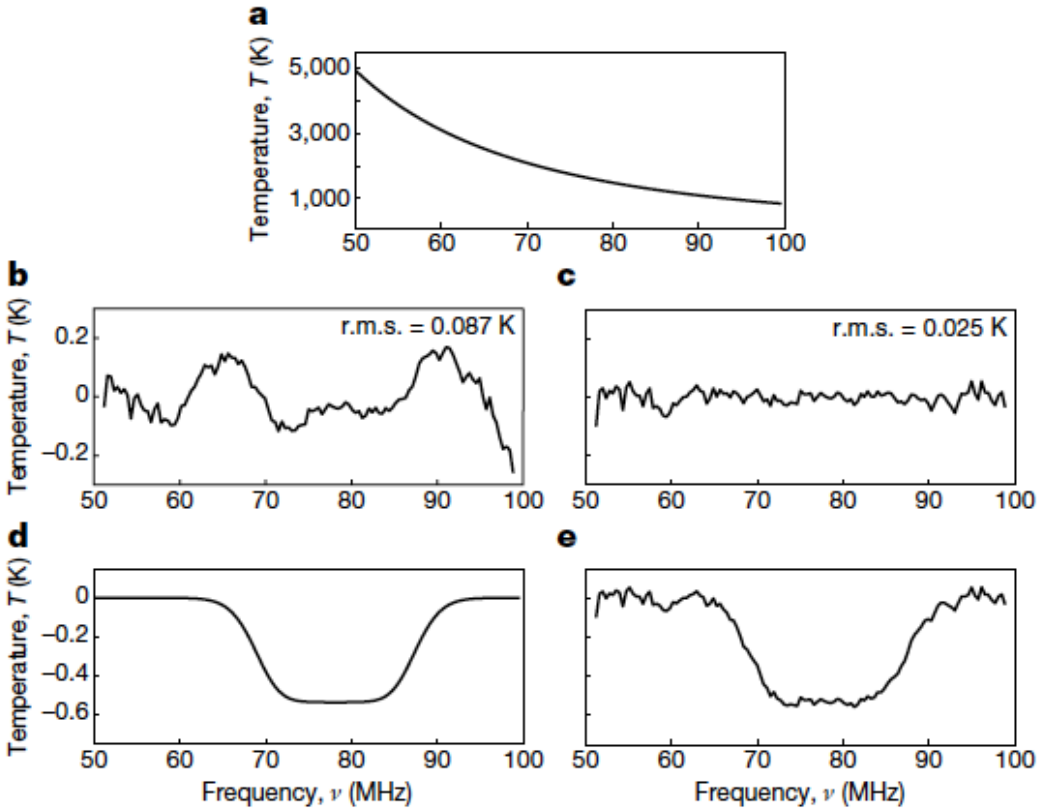


Figure 1 | Summary of detection. **a**, Measured spectrum for the reference dataset after filtering for data quality and radio-frequency interference. The spectrum is dominated by Galactic synchrotron emission. **b**, **c**, Residuals after fitting and removing only the foreground model (**b**) or the foreground and 21-cm models (**c**). **d**, Recovered model profile of the 21-cm absorption, with a signal-to-noise ratio of 37, amplitude of 0.53 K, centre frequency of 78.1 MHz and width of 18.7 MHz. **e**, Sum of the 21-cm model (**d**) and its residuals (**c**).