# What Can Future Lunar Observatories Teach Us About Population III Star Formation?

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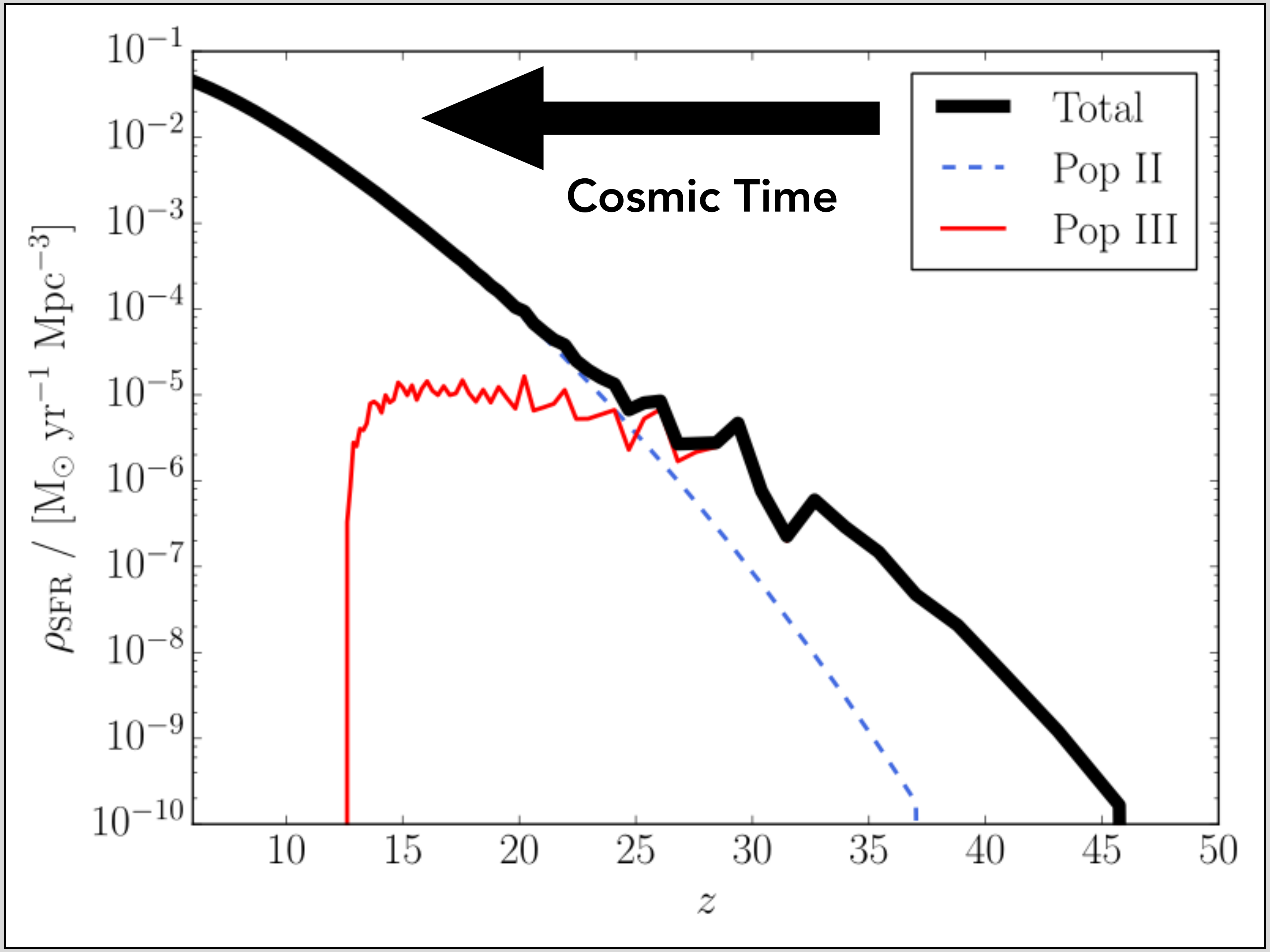
# The first stars formed in small dark matter halos that eventually evolved into galaxies.

- Early Pop III halos were small ($10^5$ - $10^6$ $M_\odot$) and contained pristine gas
- Pop III stars produced the metals required for more traditional star formation
- As halos grew, they became more stable to feedback and began to form galaxies

# Early Pop III stars were likely very different than the stars we observe today.

- Form from pristine, metal-free gas
- Likely very massive due to less efficient molecular hydrogen cooling
- Form in “minihalos” where atomic hydrogen cooling is inefficient
- Likely only one or a few stars form at a time per halo due to extreme feedback effects

# Pop III star formation generally plateaus and ends well before z~6.




Mebane et al. 2018

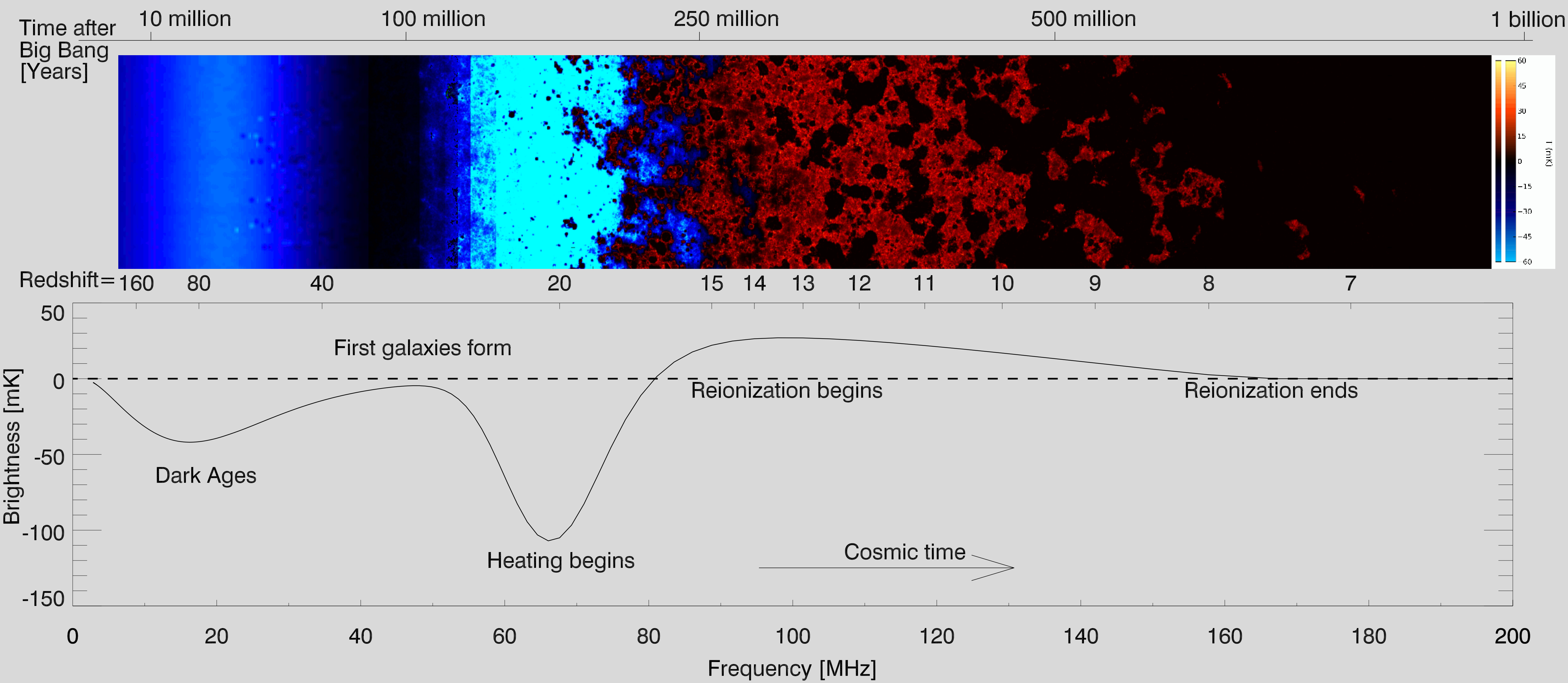
# The best chances for detection will come from indirect methods.

- Pop III halos too dim for direct detection
- Schauer et al. 2020 find we would need a 100m telescope in space!
- May see supernovae with Roman Space Telescope
- Possible signature of Pop III in cosmic 21-cm signal



Mebane et al. 2018

# The cosmic 21-cm signal can give us details on the first sources in the universe.




$$\delta T_b \simeq 27 x_{\mathrm{HI}} (1+\delta) \left(\frac{\Omega_{\mathrm{b}} h^2}{0.023}\right) \left(\frac{0.15}{\Omega_{\mathrm{m}} h^2} \frac{1+z}{10}\right)^{1/2} \left(\frac{T_{\mathrm{S}} - T_{\mathrm{radio}}}{T_{\mathrm{S}}}\right) \mathrm{mK}$$



Pritchard & Loeb 2012

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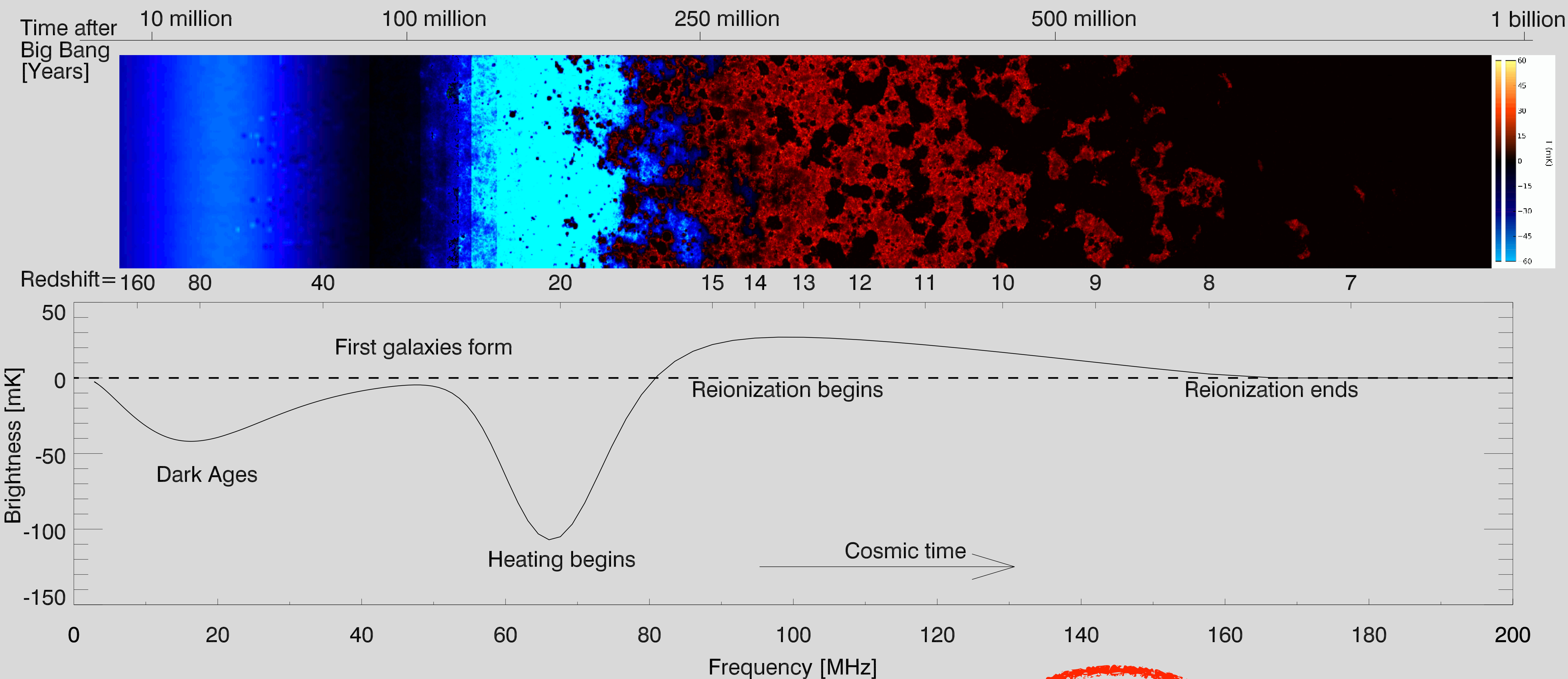


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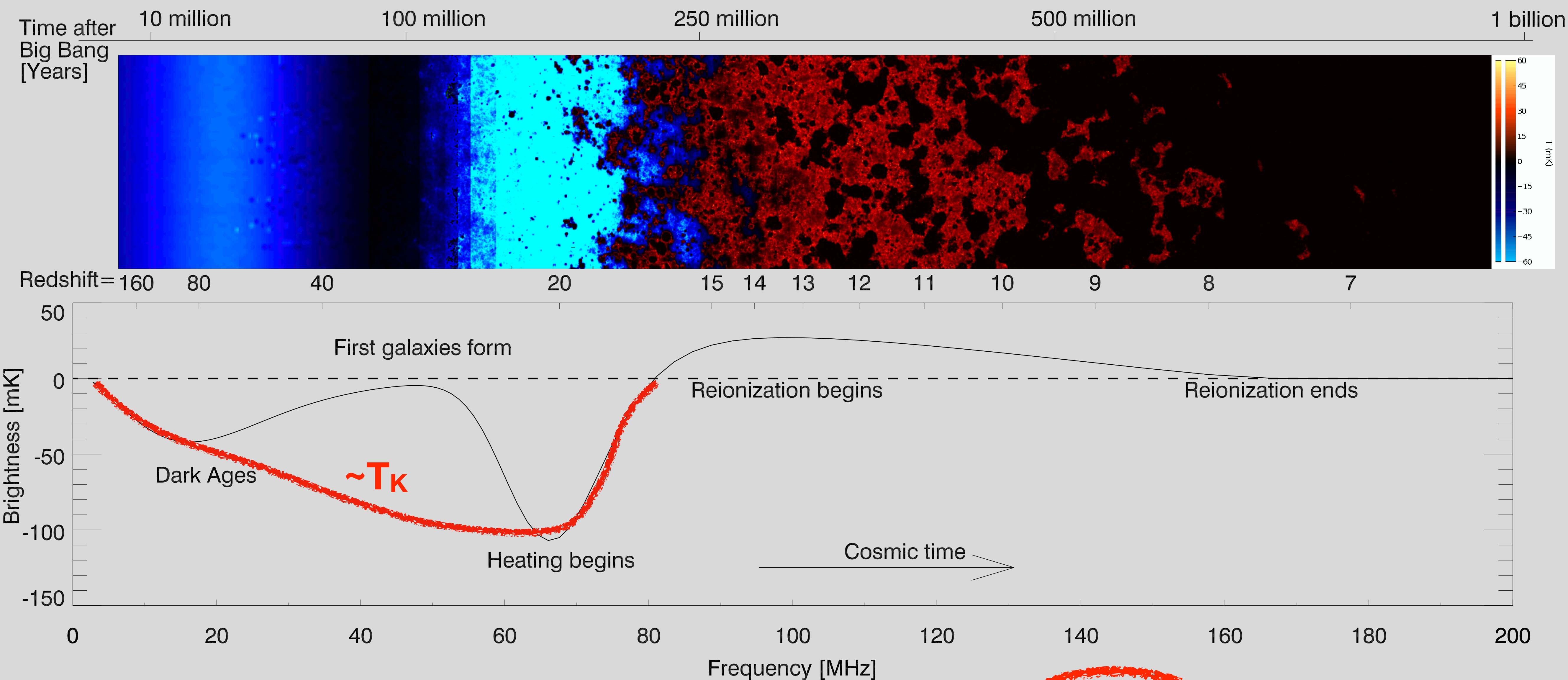


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Pritchard & Loeb 2012

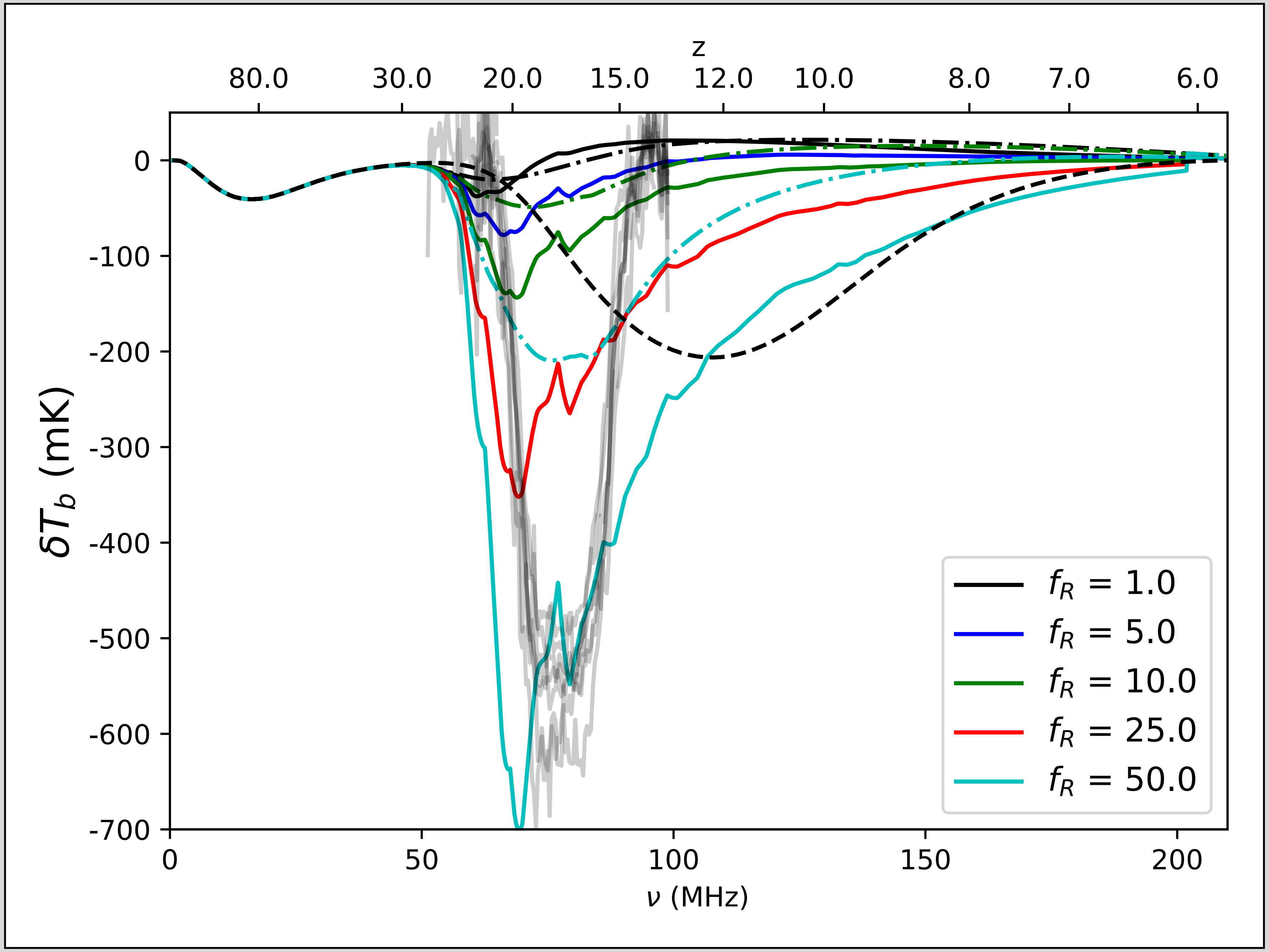
# Pop III star formation can strongly affect the 21-cm signal.

- Early formation means earlier Lyman-alpha background

- Accreting Pop III remnants could produce a strong radio background

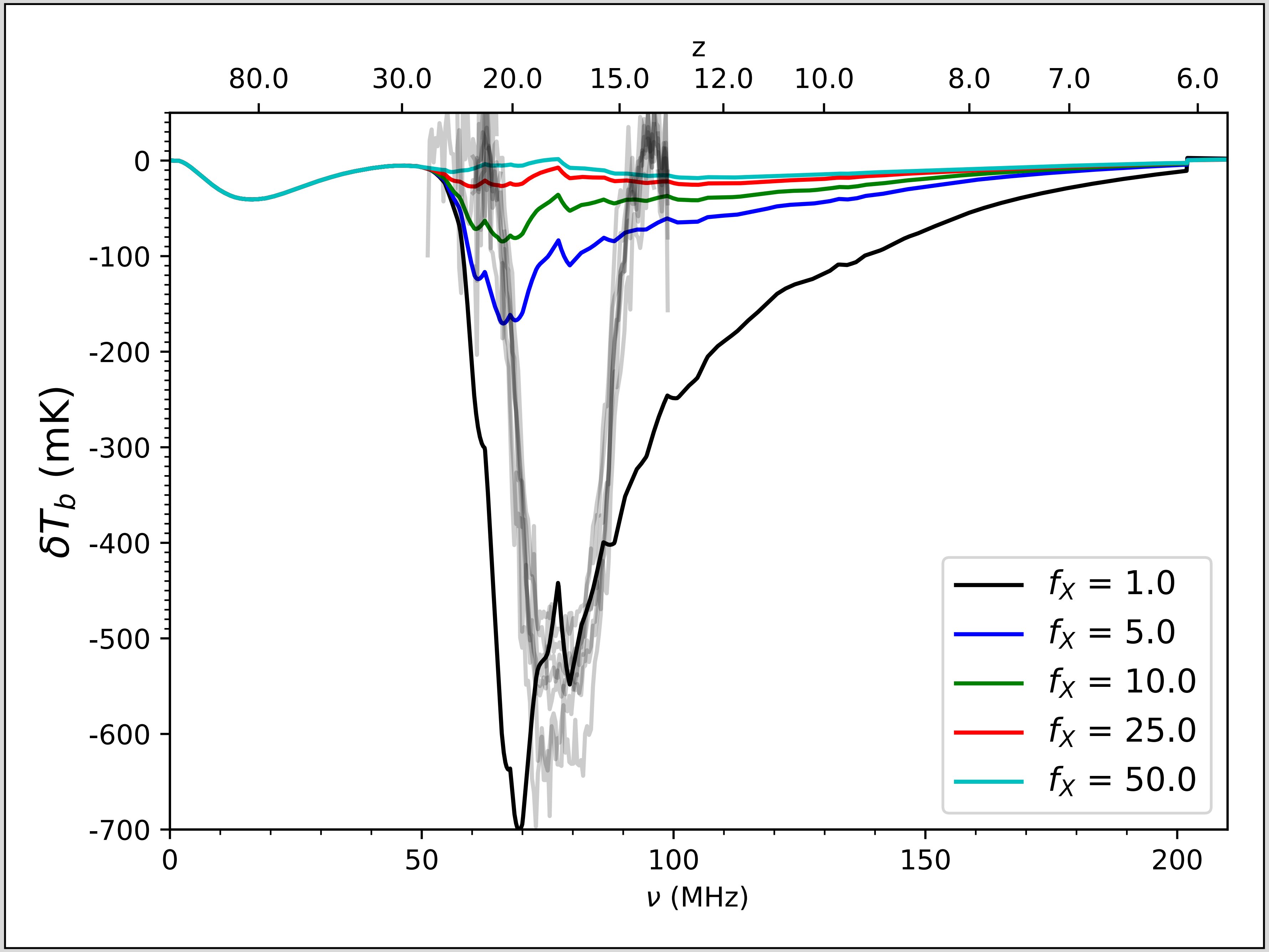
- X-ray emission can heat the gas, lessening the strength of the signal

# An excess radio background can increase the strength of the signal.




Mebane et al. 2020

# The x-ray background comes from the same sources but heats the gas.





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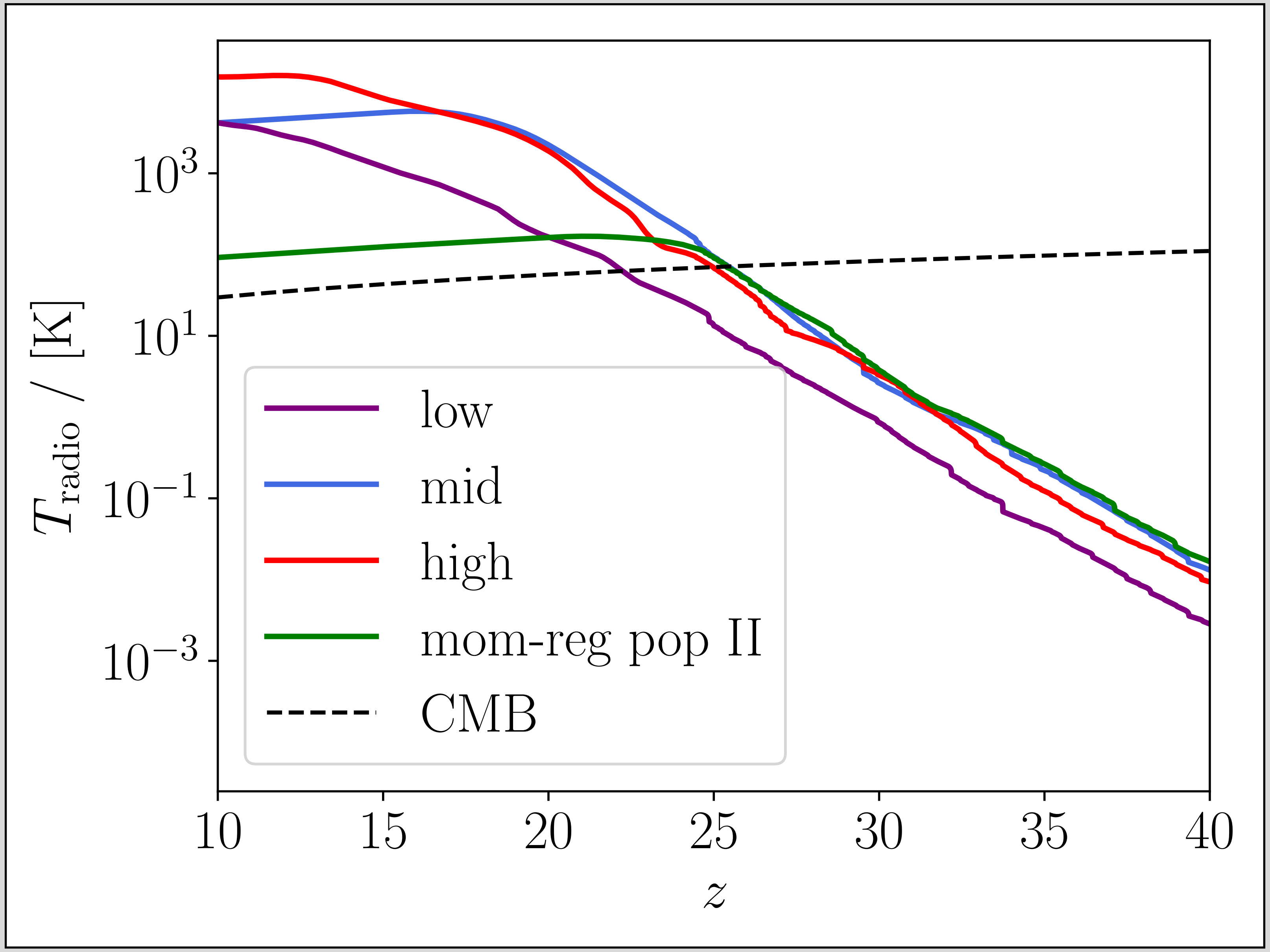
# Summary

- Pop III star formation is necessary to produce the metals required to form more traditional, metal-enriched stars.
- We will likely require indirect methods such as 21-cm observations to detect the presence of Pop III stars.
- Lyman-alpha emission from Pop-III star formation can cause an earlier absorption feature in the 21-cm global signal.
- The radio and x-ray backgrounds produced from accreting Pop III remnants can significantly affect the depth of the signal.

# Extra Slides

# The resulting radio background temperature from Pop III star formation can be much higher than the CMB.




$$\epsilon_\nu(z) \propto f_{\mathrm{duty}}(z) f_{\mathrm{edd}}(z) \rho_{\mathrm{bh}}(z)$$

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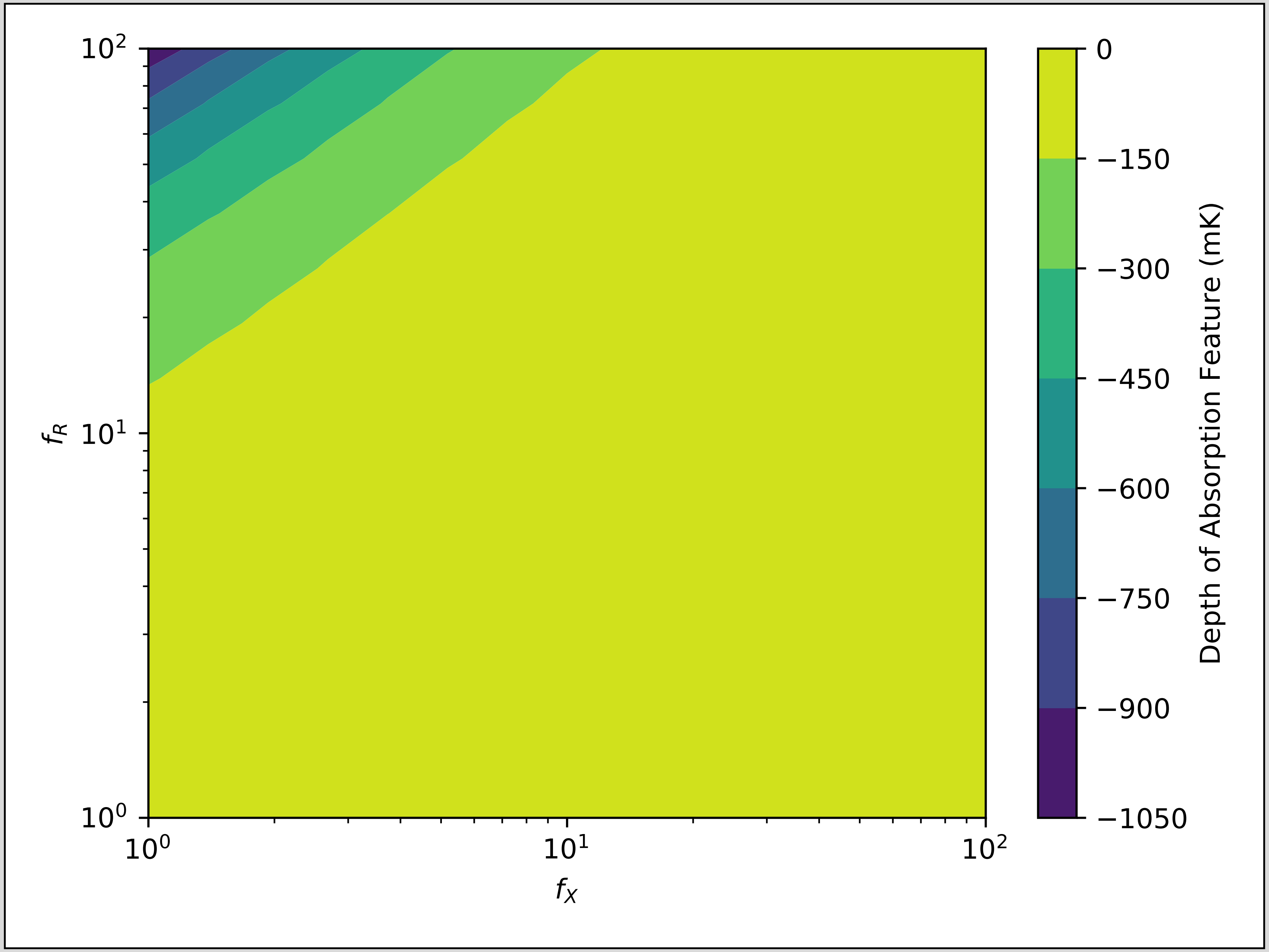
# The strongest signals come from models with high radio but low x-ray emission.

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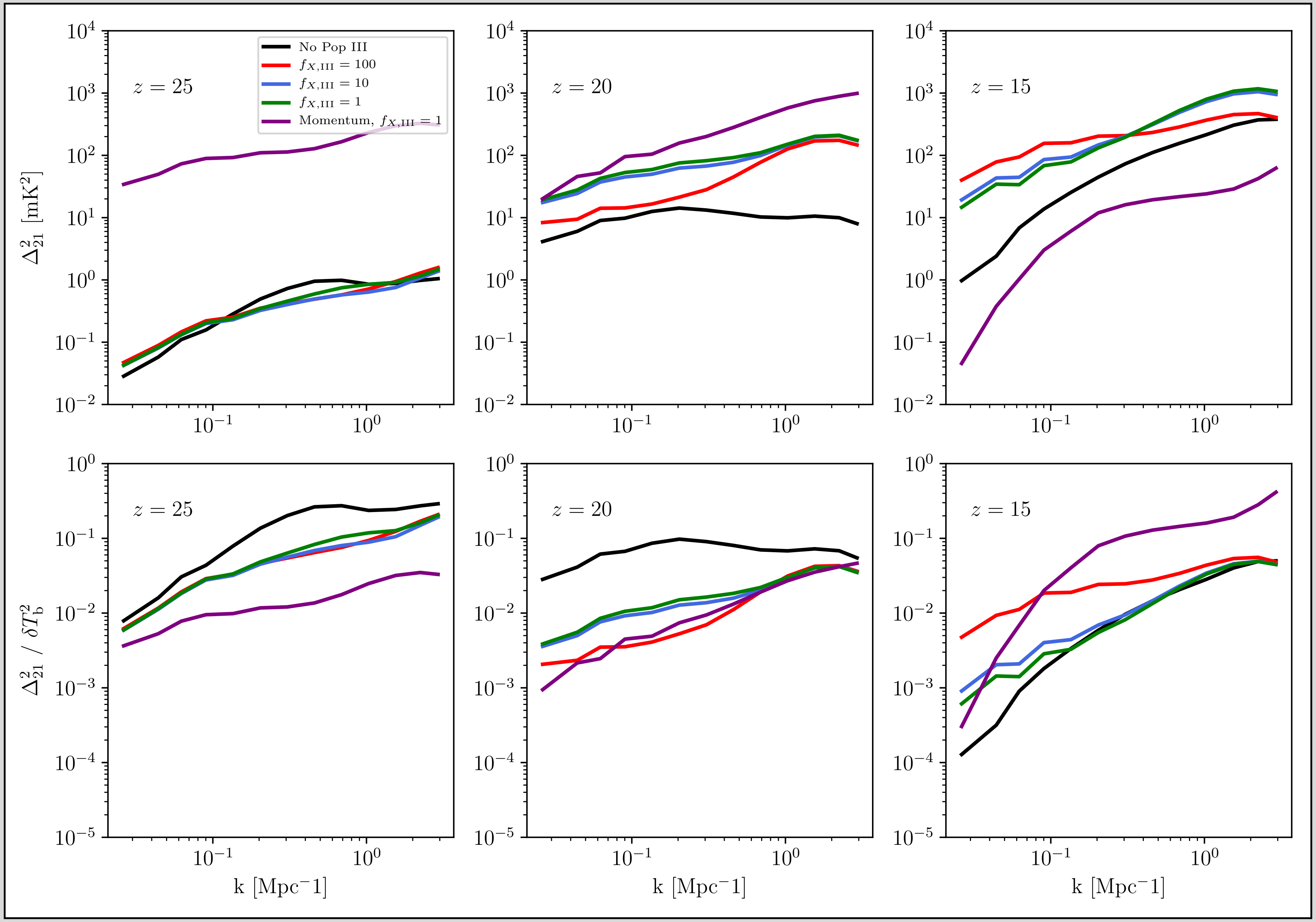
# Pop III star formation can cause subtle changes in the shape of the 21-cm power spectrum.




Mebane et al. in prep