Probing the first luminous sources using the redshifted 21 cm line

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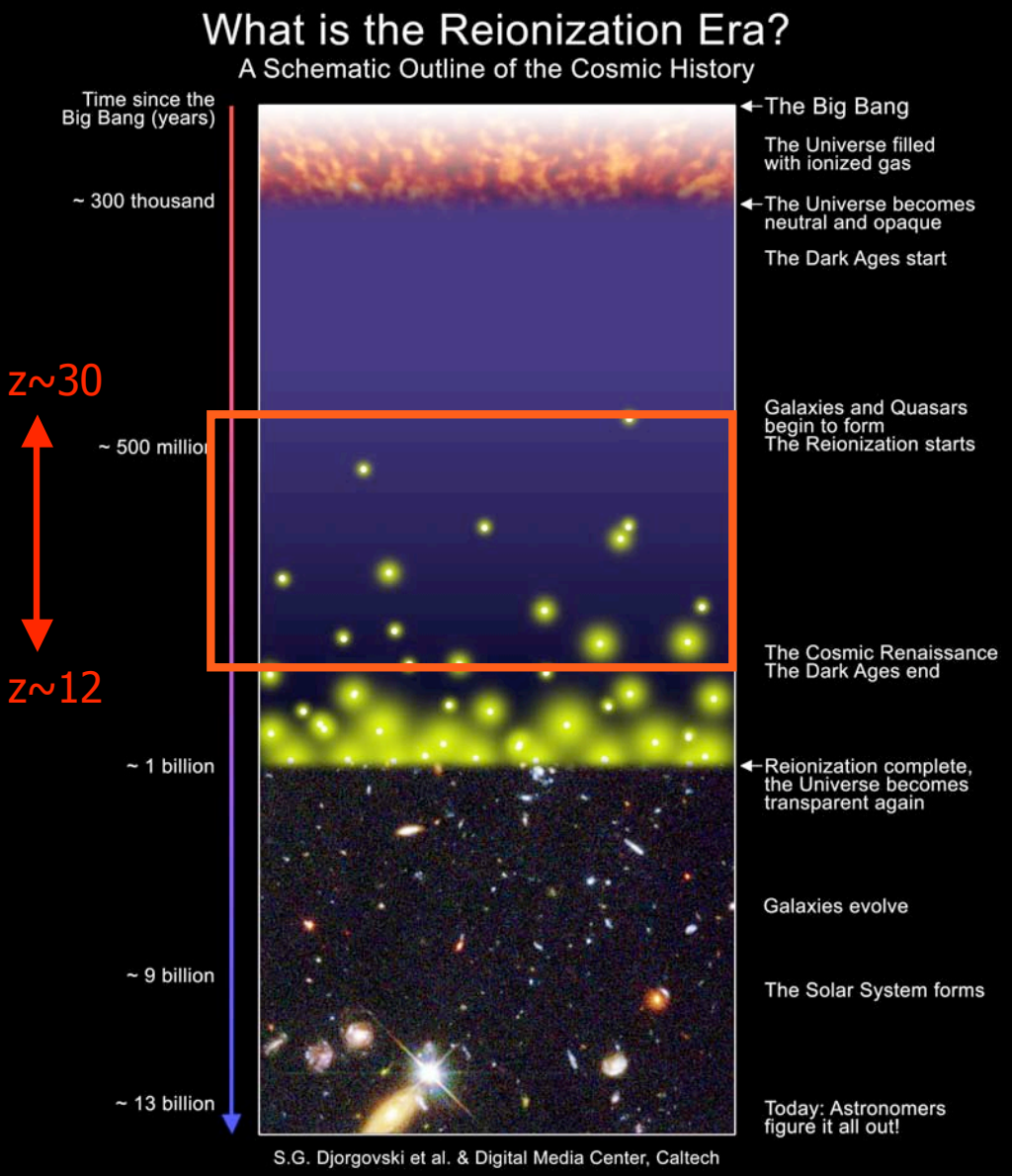
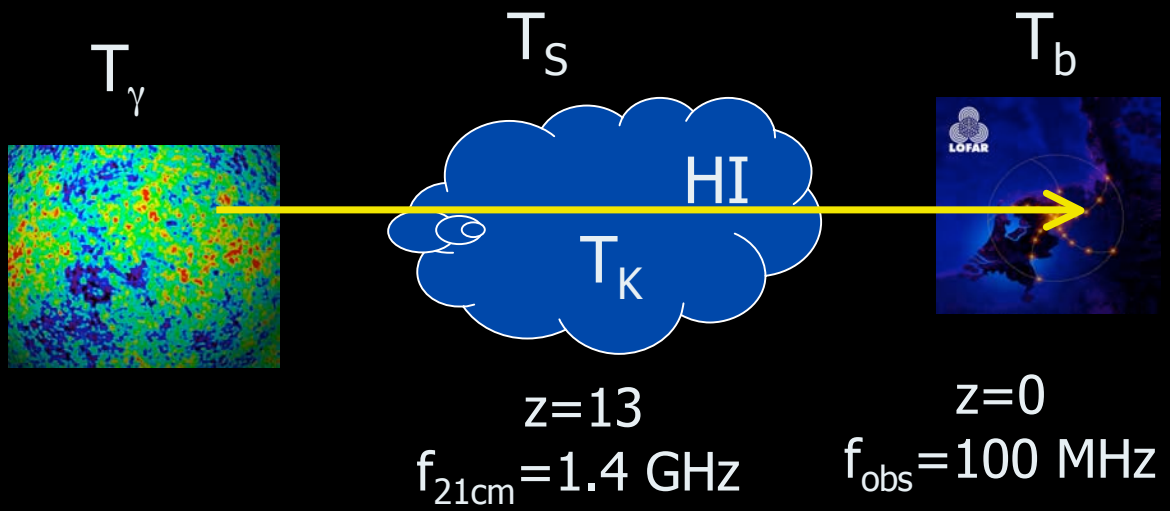
Overview



1. 21 cm as probe of high-z radiation backgrounds
2. Fluctuations in X-ray and Lyα backgrounds lead to 21 cm fluctuations
3. What might 21 cm observations tell us about first sources?

21 cm basics

- Use CMB backlight to probe 21cm transition



- 3D mapping of HI possible - angles + frequency
- 21 cm brightness temperature

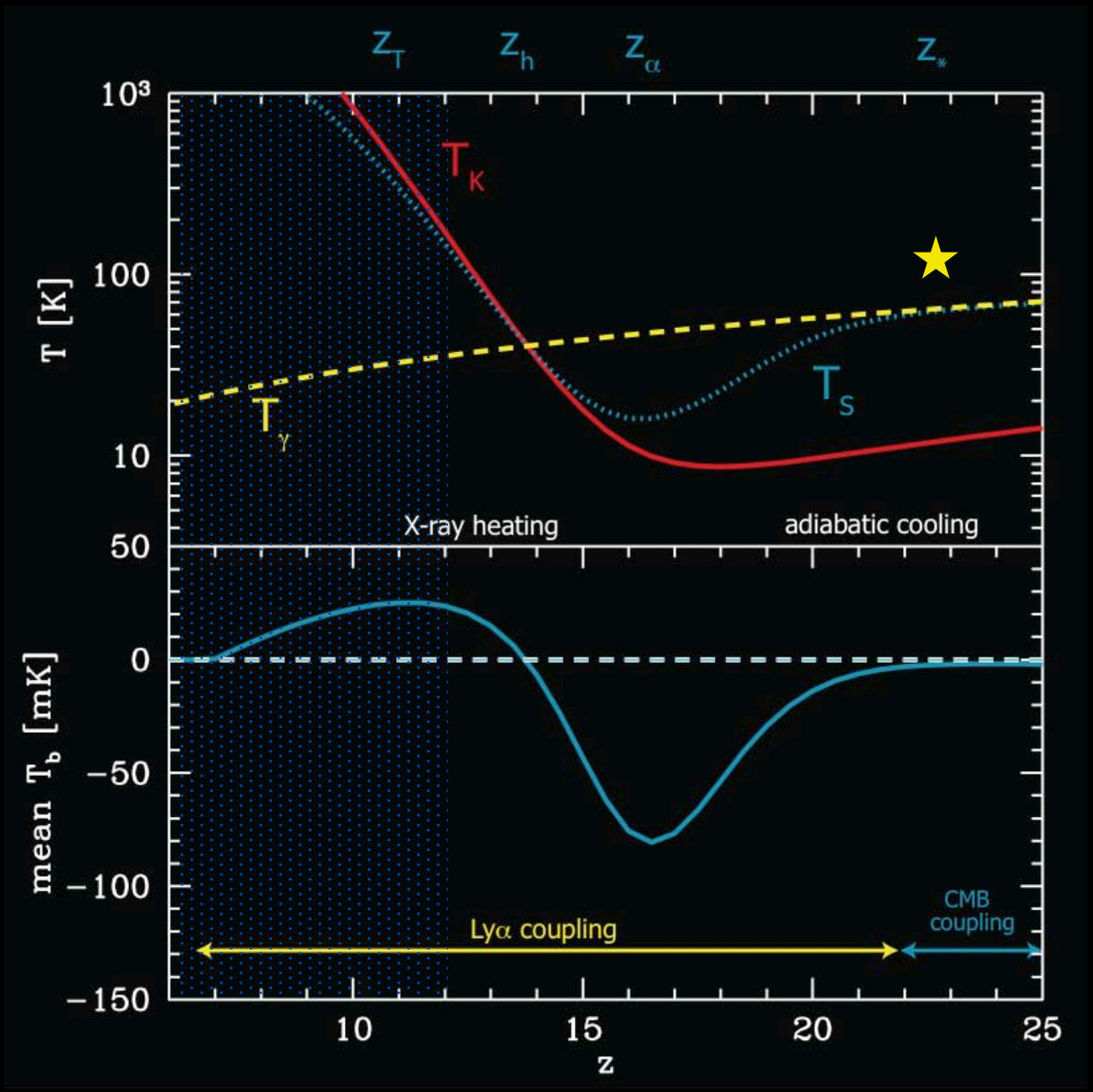
$$T_b = 27 x_{\rm HI}(1+\delta_b)\left(\frac{T_S - T_\gamma}{T_S}\right)\left(\frac{1+z}{10}\right)^{1/2} \ {\rm mK}$$

- 21 cm spin temperature

$$T_S^{-1} = \frac{T_\gamma^{-1} + x_\alpha T_\alpha^{-1} + x_c T_K^{-1}}{1 + x_\alpha + x_c}$$

- Coupling mechanisms:
  - Radiative transitions (CMB)
  - Collisions
  - Wouthuysen-Field

Thermal History



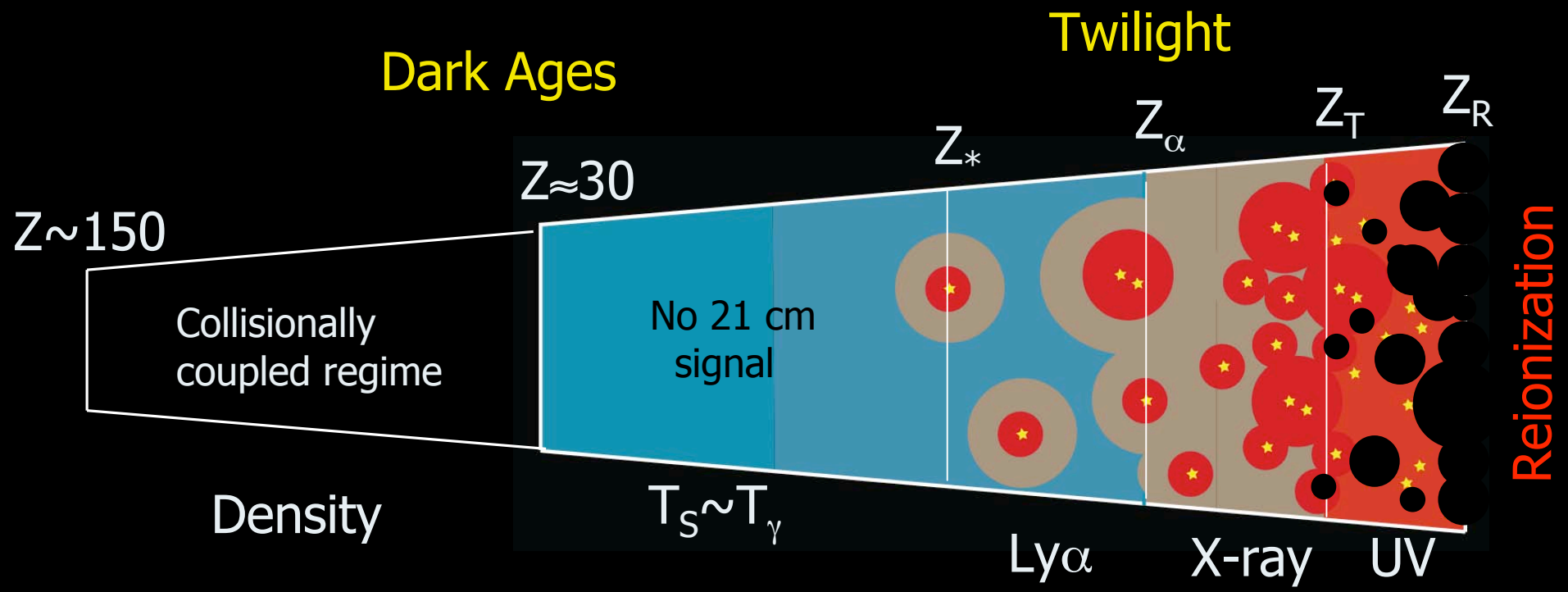
e.g. Furlanetto 2006

21 cm fluctuations

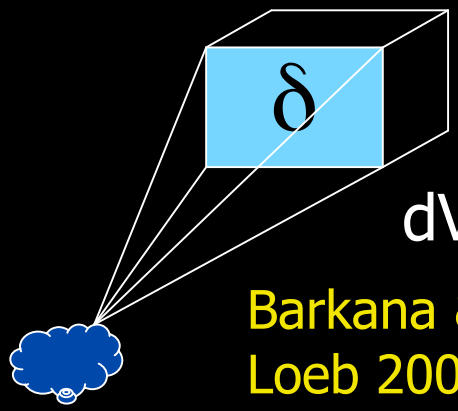
Baryon Density	Neutral fraction	Gas Temperature	W-F Coupling	Velocity gradient

$$\delta_{T_b} = \beta\delta + \beta_x\delta_{x_{HI}} + \beta_T\delta_{T_k} + \beta_\alpha\delta_\alpha - \delta_{\partial v}$$

Cosmology	Reionization	X-ray sources	Lyα sources	Cosmology



Fluctuations from the first stars

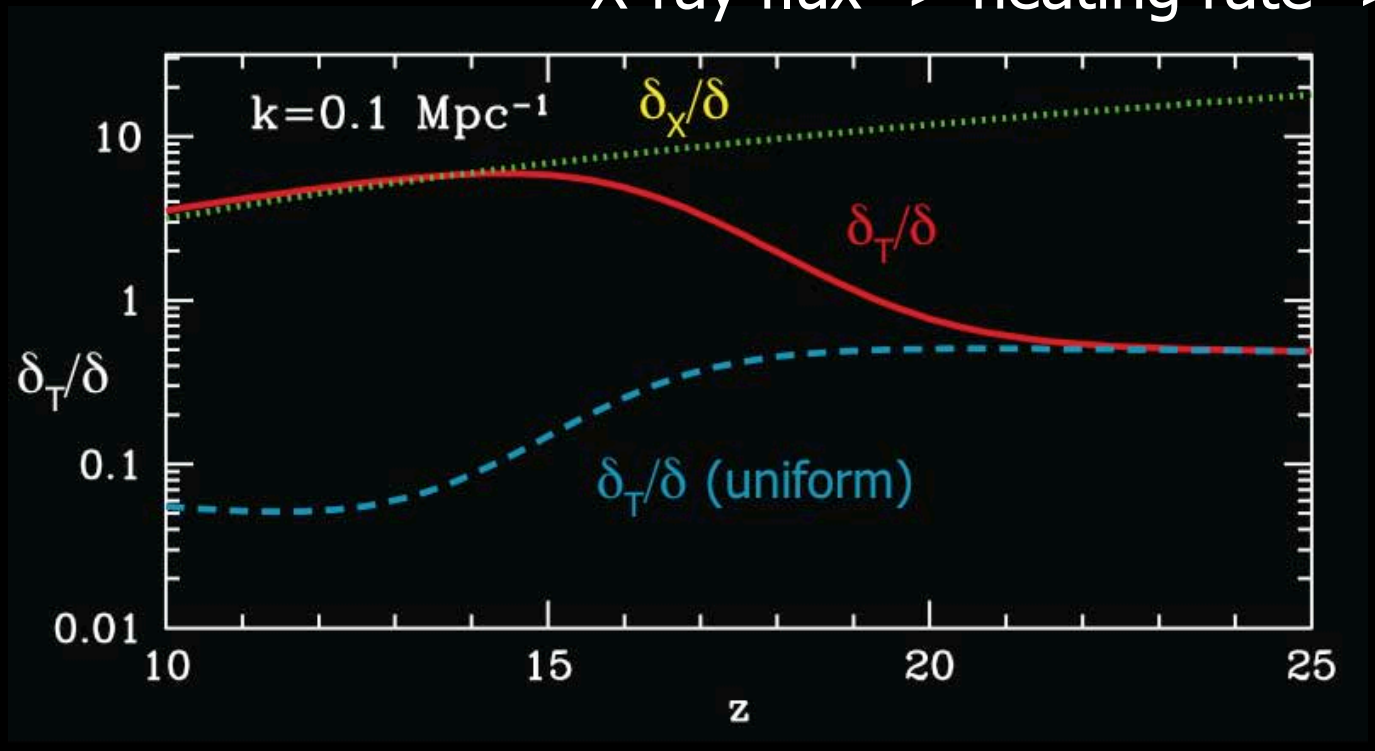


Barkana & Loeb 2005

- Fluctuations in flux from source clustering, $1/r^2$ law, optical depth,...
- Relate fluctuations in Lyα and X-ray flux to overdensities

$$\delta_{x_\alpha}(\mathbf{k}) = W(k)\delta(\mathbf{k})$$

- Lyα flux -> coupling strength
- X-ray flux -> heating rate -> temperature



Pritchard & Furlanetto 2006

Determining the first sources

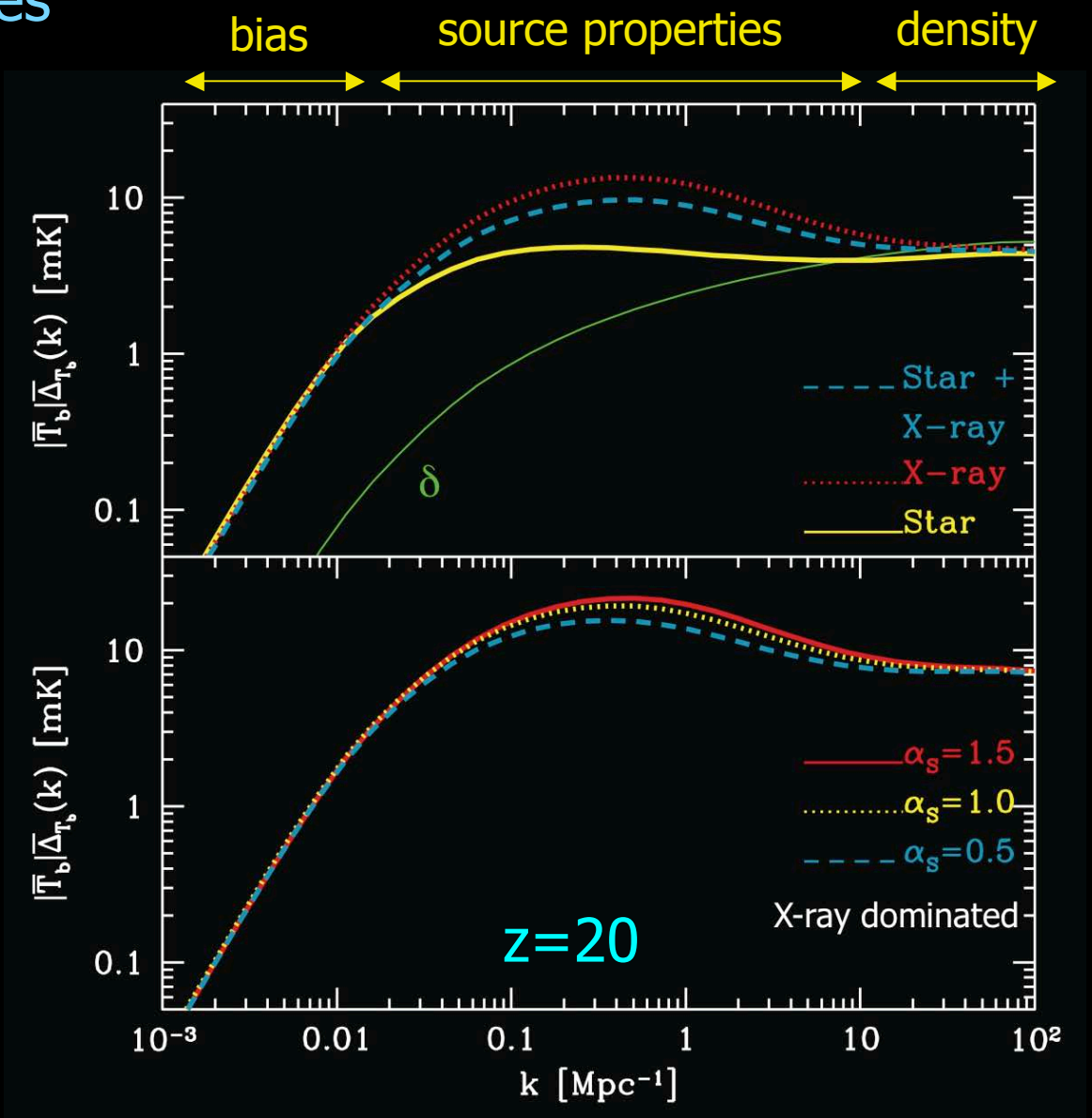
δ_α dominates

Sources

$J_{\alpha,*}$ vs $J_{\alpha,X}$

Spectra

α_S



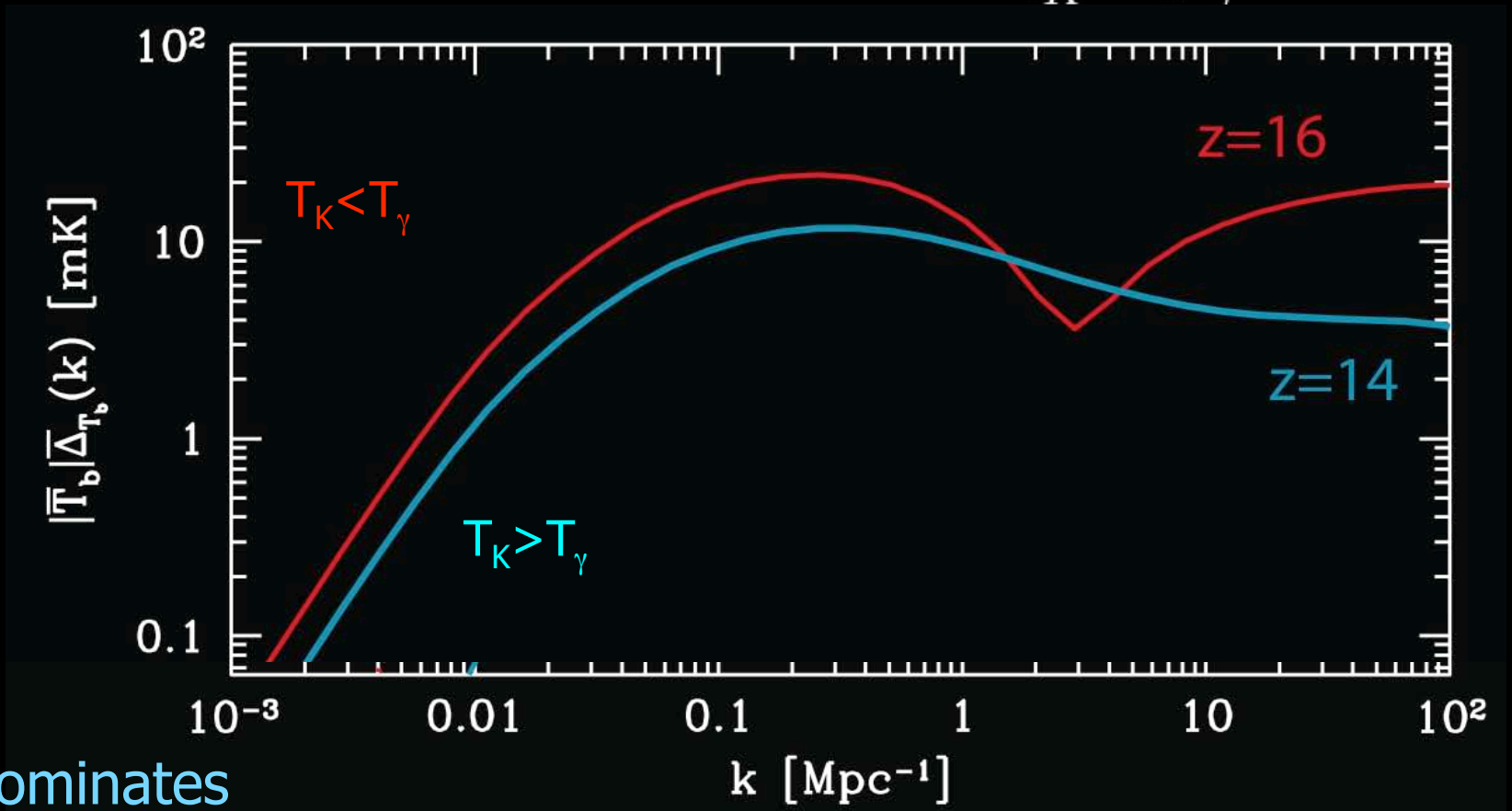
Chuzhoy, Alvarez, & Shapiro 2006

Pritchard & Furlanetto 2006

Indications of T_K

- Similar information about bias and spectrum of X-ray sources
- Constrain heating transition

$$\delta_{T_b} \approx \delta + \beta_T \delta_{T_k} \qquad \beta_T \approx \frac{T_\gamma}{T_K - T\gamma}$$



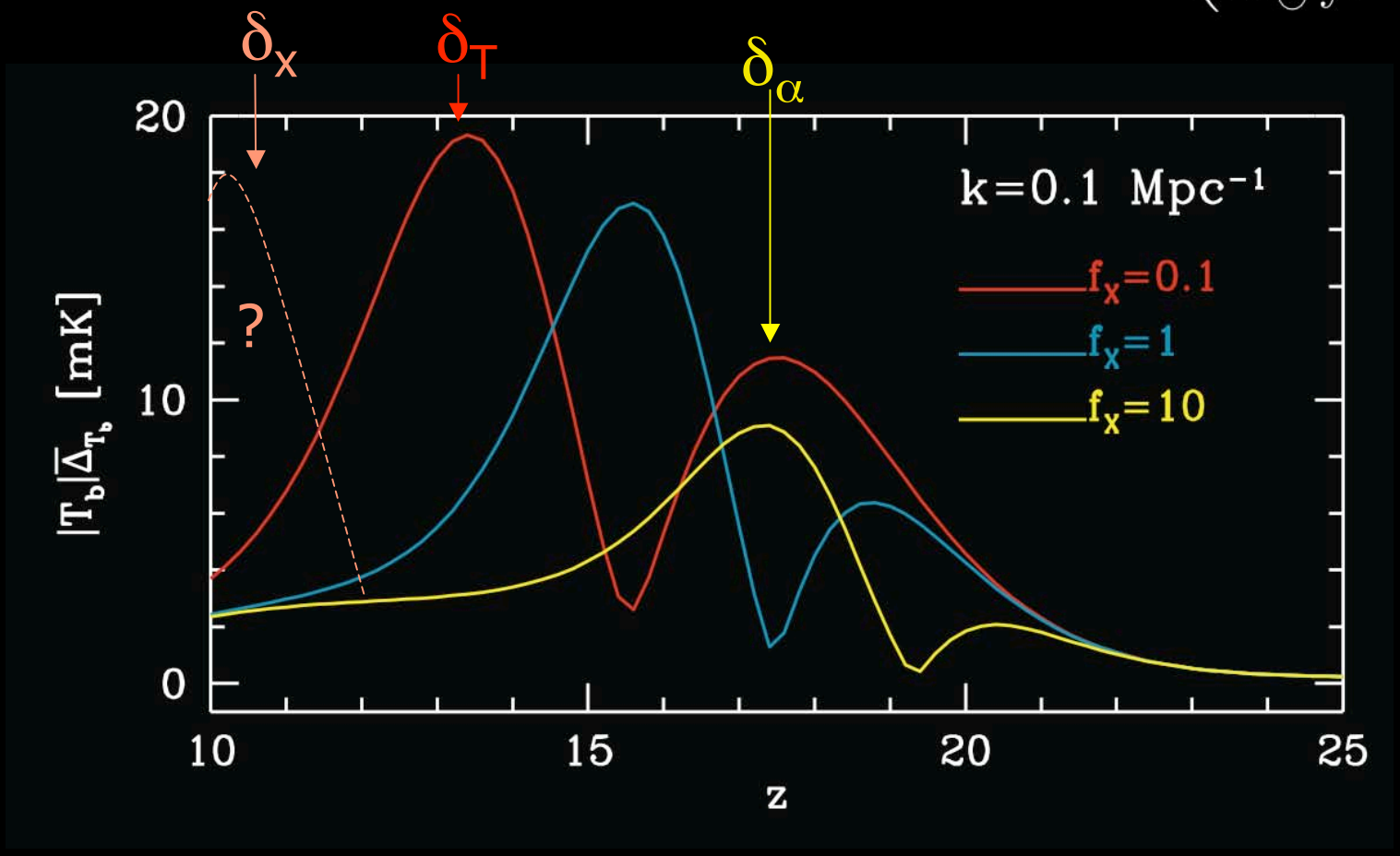
δ_T dominates

X-ray background?

- To avoid giving the idea of certainty…

Extrapolating low-z X-ray:IR correlation gives: Glover & Brand 2003

$$L_X = 3.4 \times 10^{40} f_X \left(\frac{\mathrm{SFR}}{\mathrm{M_\odot\ yr^{-1}}} \right) \mathrm{erg\ s^{-1}}$$



Conclusions

- Today told a simple story - lots of uncertainty in all attempts at modeling this period
- Can use 21 cm to learn about the first luminous sources via the Lyα background
- Temperature fluctuations should give insight into thermal evolution of IGM
- If X-ray heating important, then can learn about early X-ray sources
- Measurements discussed will require luck and the Square Kilometer Array
- Early days for 21 cm and still unclear what will and will not be possible - foregrounds will be determining factor
- For more details: astro-ph/0607234 + astro-ph/0508381

Observations

- Need SKA to probe these brightness fluctuations
- Observe scales k=0.025-3 Mpc^{-1}
- Can distinguish different models