The Mass Function of the First Stars

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From First Light to Newborn Stars
HAPPY 50th, Kitt Peak!
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Collaborators:

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- Jason Tumlinson (STScI)
- Jim Truran (U. Chicago)

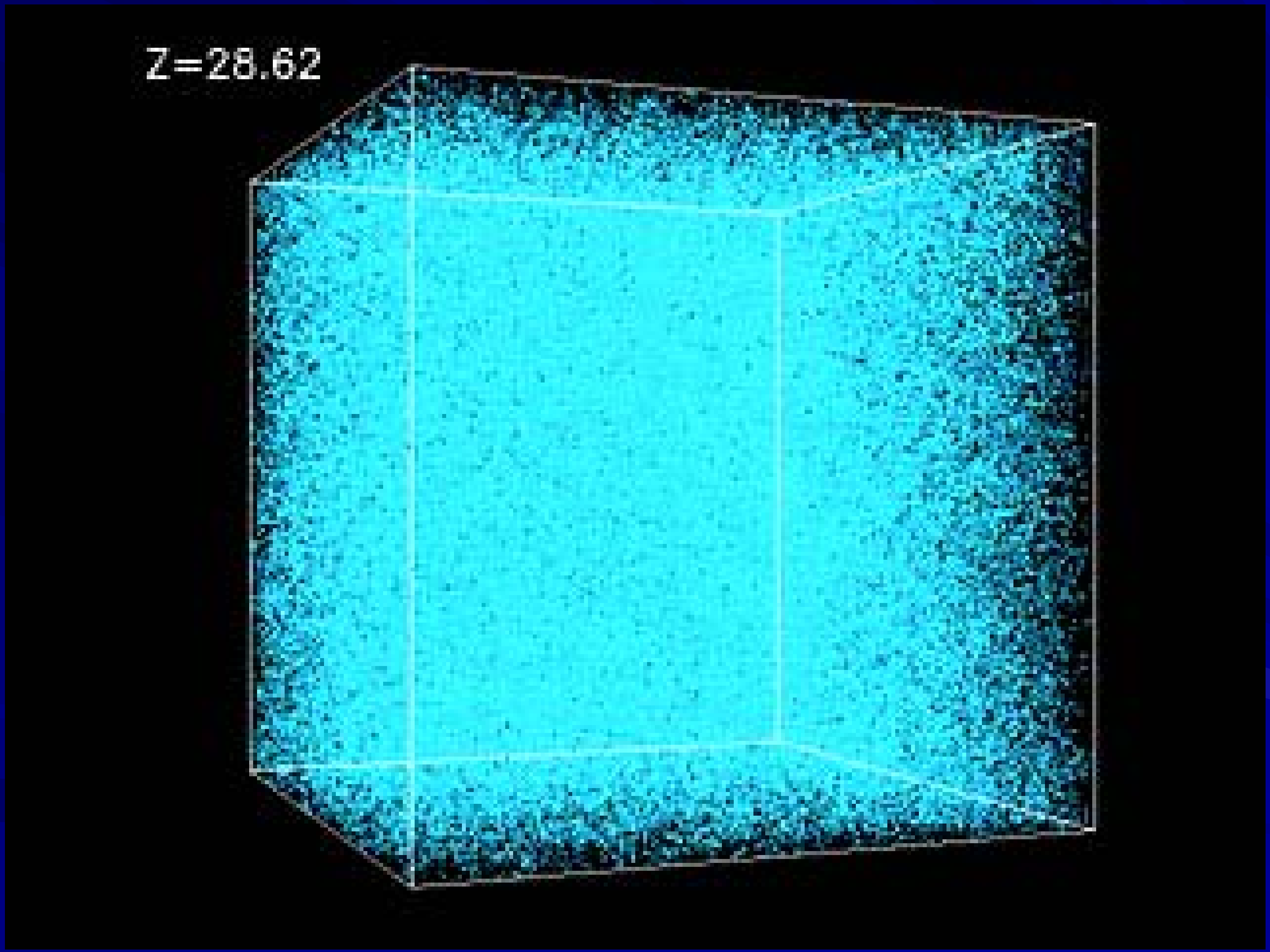
First Stars: Questions

- 1. What were they like?
- 2. Were they important?
- 3. Can we see them today?

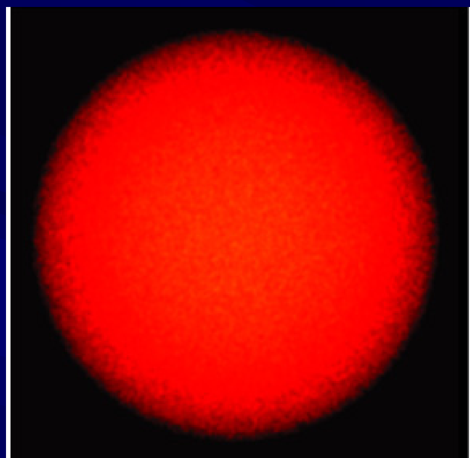
1. is an important input to 2. and 3.

Galaxy formation begins…

simulation courtesy Andrey Kravtsov (CfCP, U. Chicago)



Stars form within galaxies in cold dense clouds of molecules and dust



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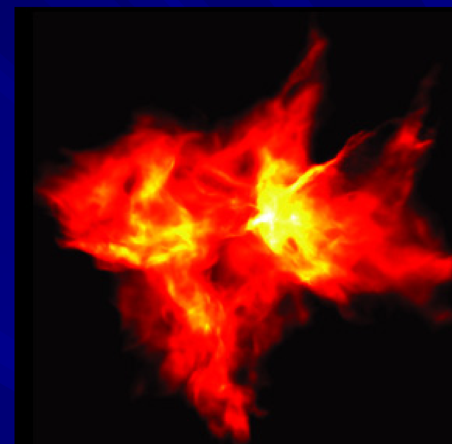

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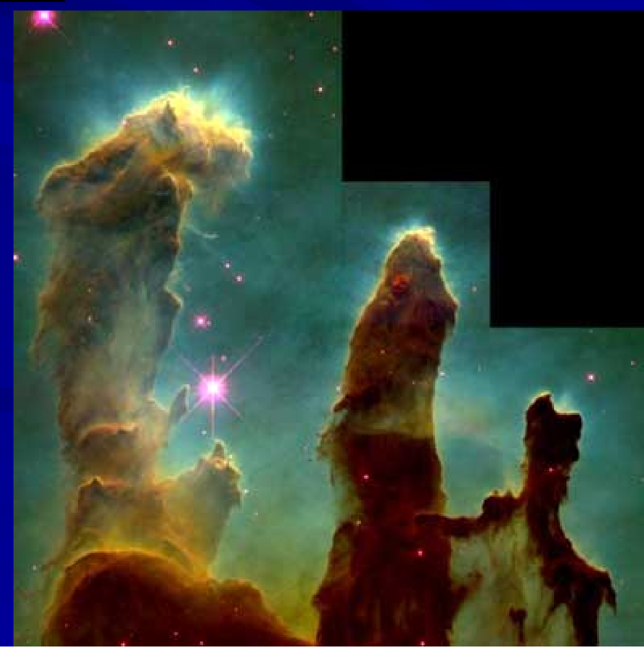
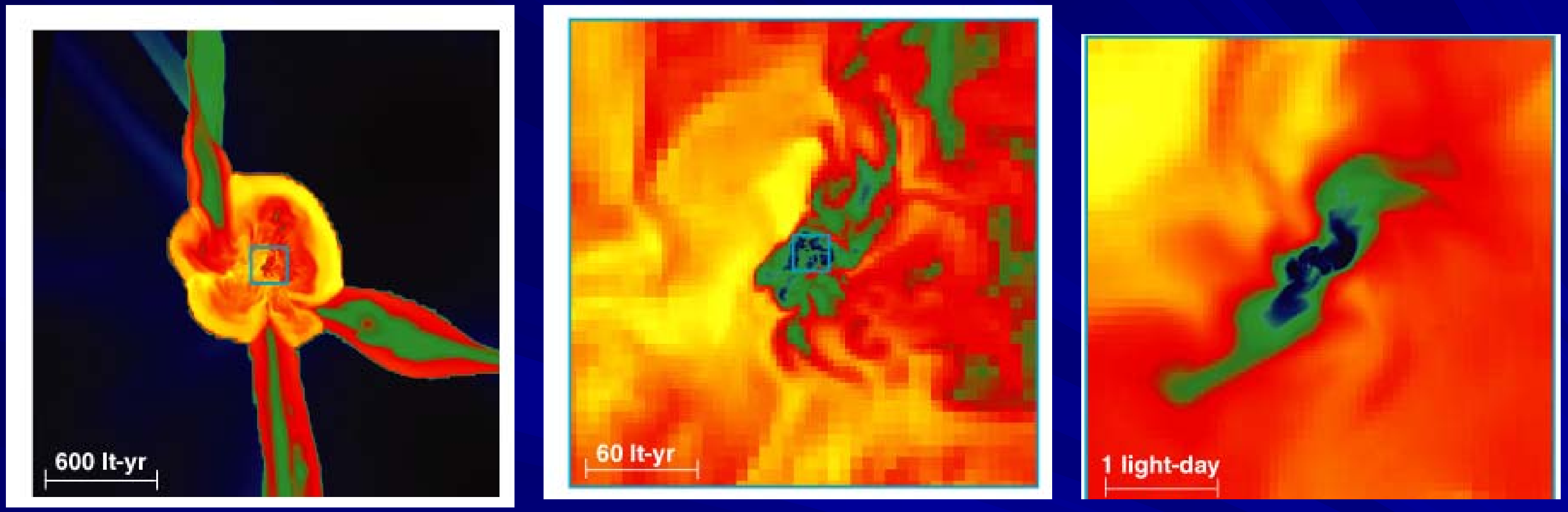
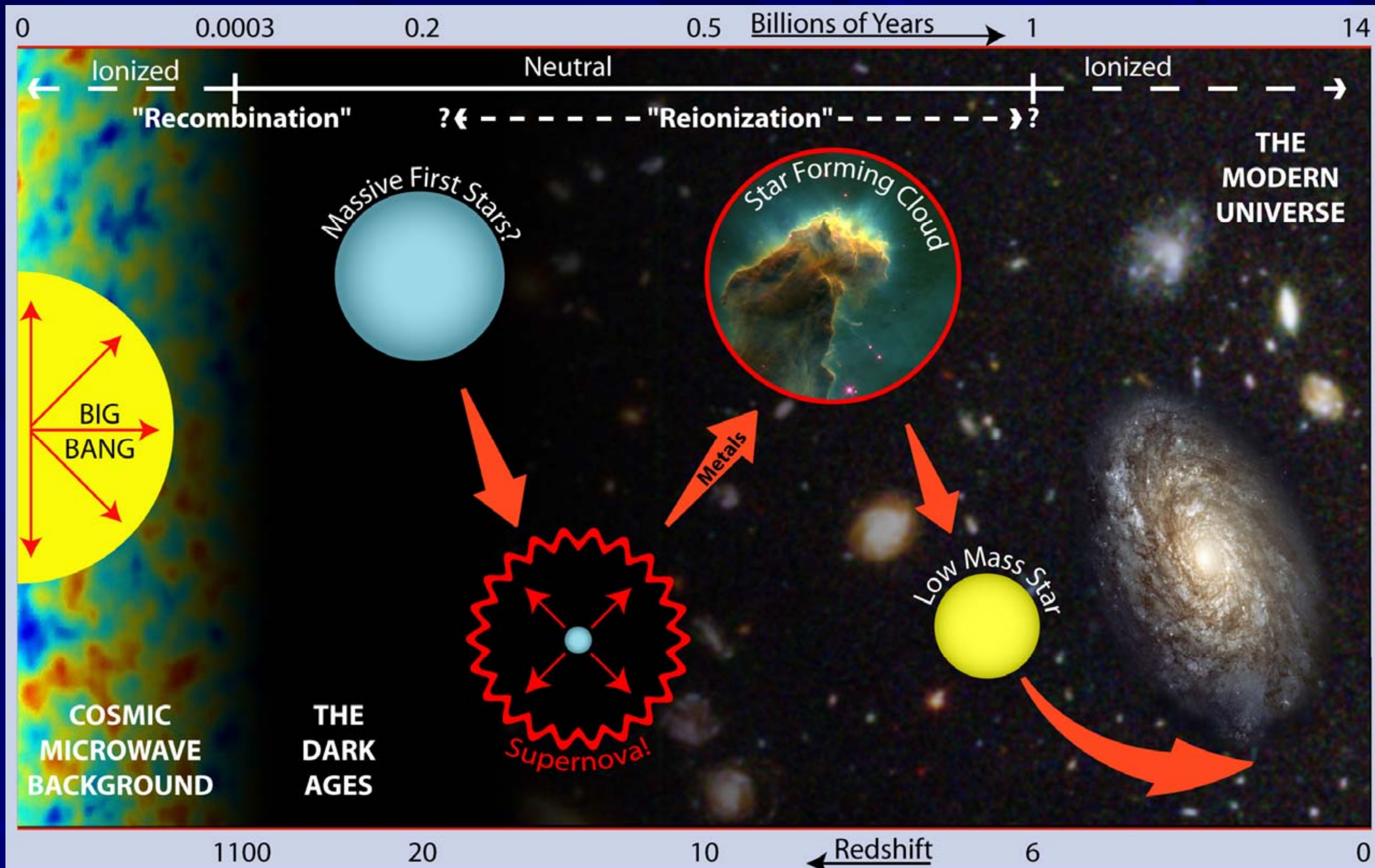


Simulation of the First Star

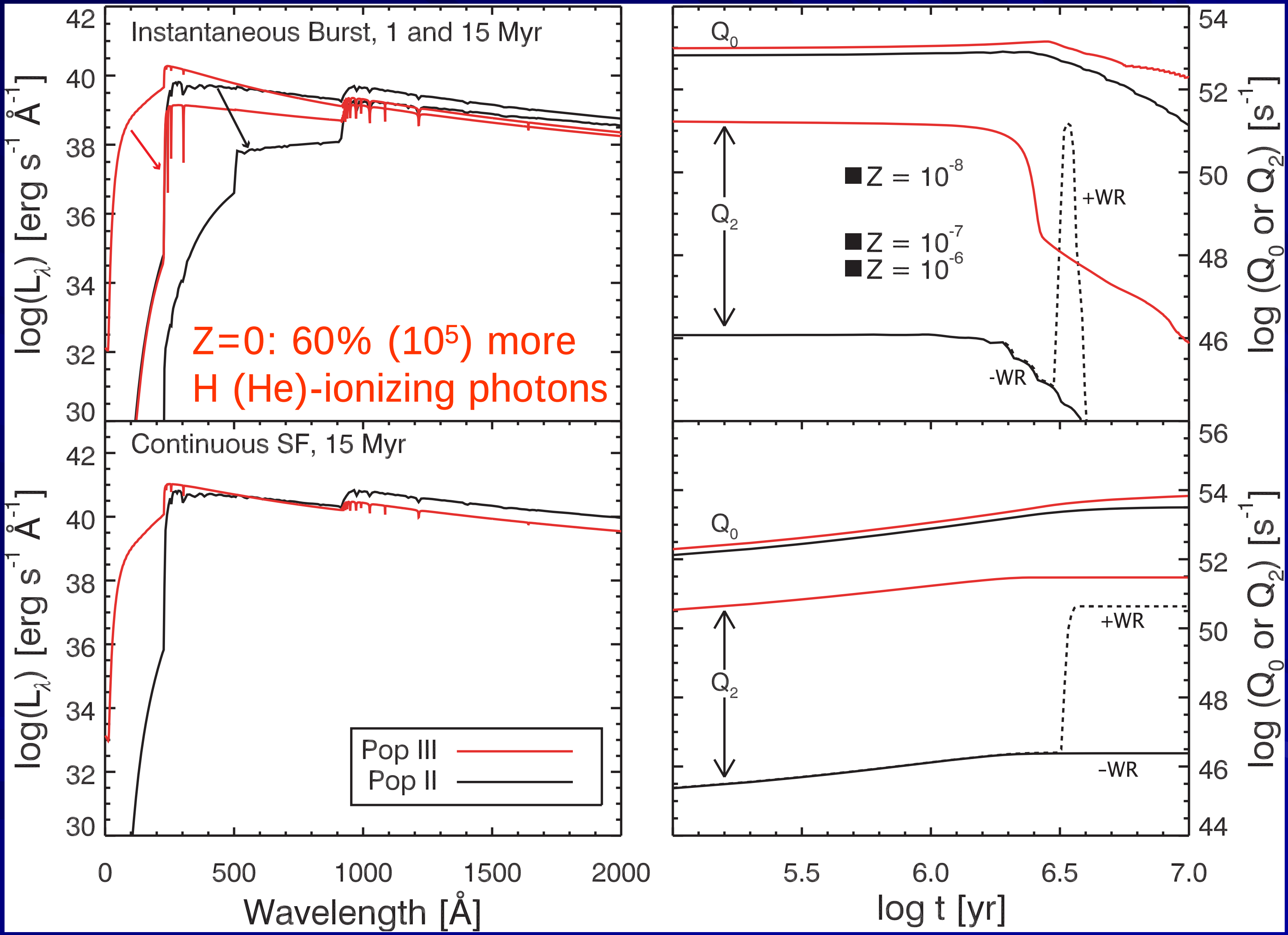


- Simulations of early star formation (T. Abel and others) suggest the first molecular clouds never cooled below 100 K (no metals or molecules to provide cooling), making stars of > 10 M_{Sun}, possibly up to ~100-300 M_{Sun}



From Tumlinson, Venkatesan & Shull 2004, as featured in Sky and Telescope

From Venkatesan, Tumlinson & Shull 2003; see also Schaerer 2002, Bromm et al. 2001



Detecting the First Stars:

Direct detections ideal:

- metal-free star in our galaxy – no pure hydrogen/helium star detected to date (hard observation!)
- metal-free star clusters in primordial galaxies through characteristic H and He emission lines
- Infrared or radio signals
- Gamma-ray bursts

Detecting First Stars:

Indirect constraints from:

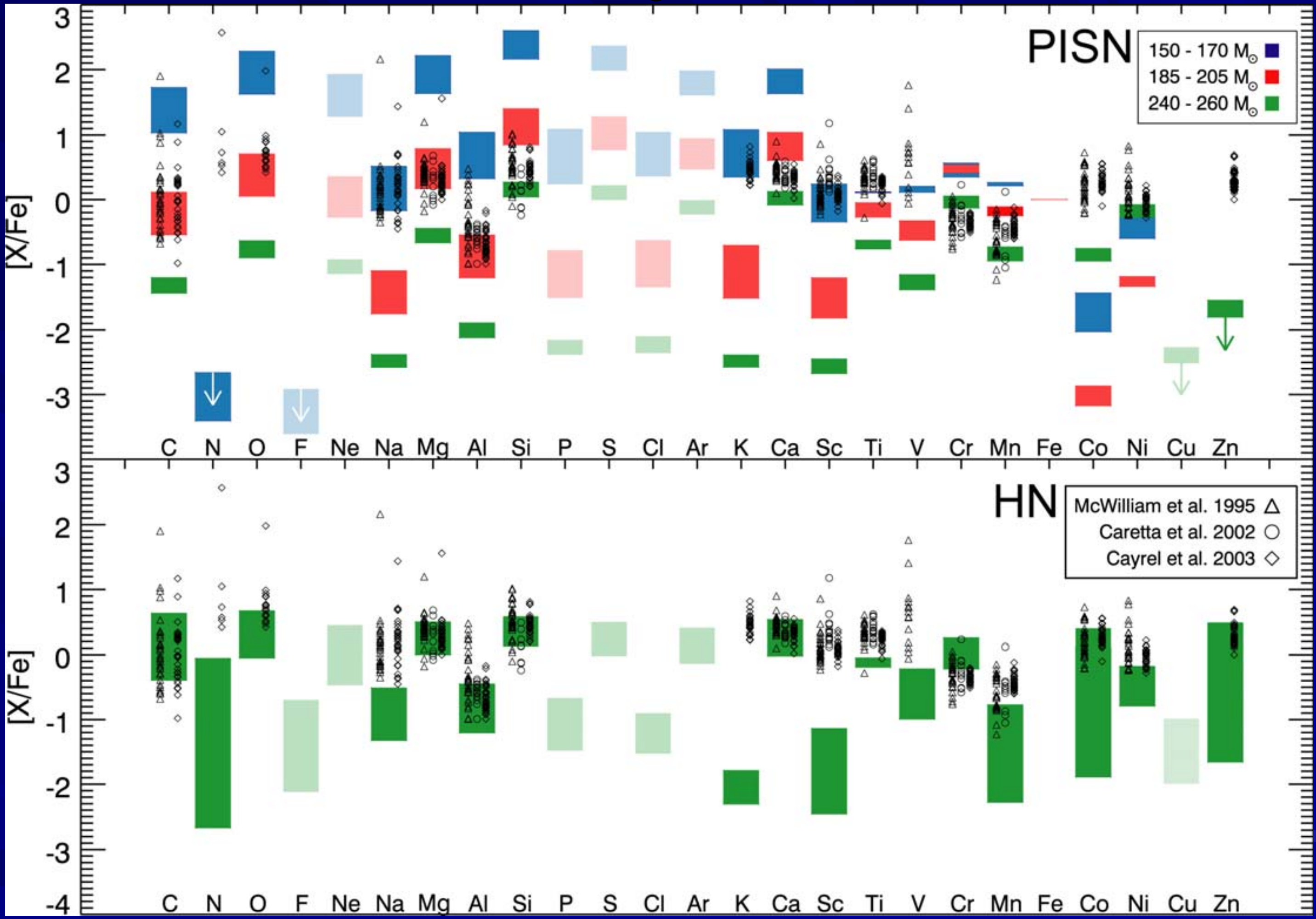
- Re-Ionization of H and He in first billion years – observed through spectra of distant universe and independently through the CMB.
- Metal abundance *ratios*: either in the most distant quasars and galaxies, OR in ancient metal-poor stars in our galactic halo, thought to contain "ashes" of first stars. Currently, best bet for "seeing" signatures of first stars but stay tuned!

- ALL OF THESE data over a large range in cosmic time and physical conditions indicate that first stars' masses spanned about 10-100 M_{sun}.

Clues on First Supernovae from Fossil Record in Nearby Ancient Stars

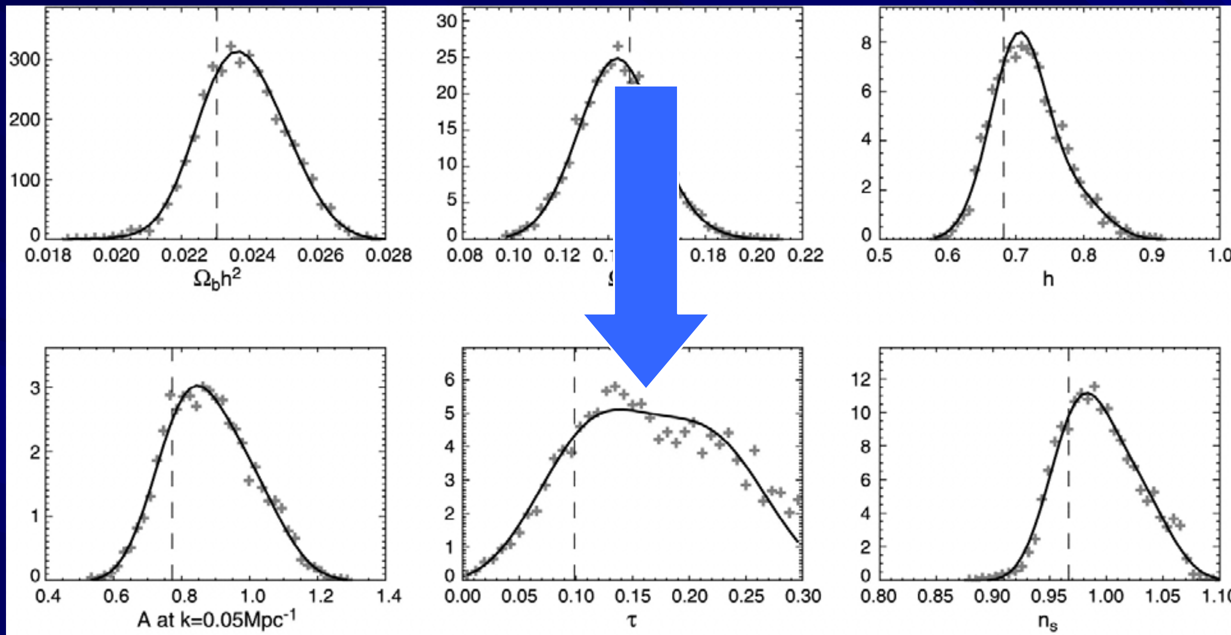
63 metal-poor halo stars with [Fe/H] = -2 to -4

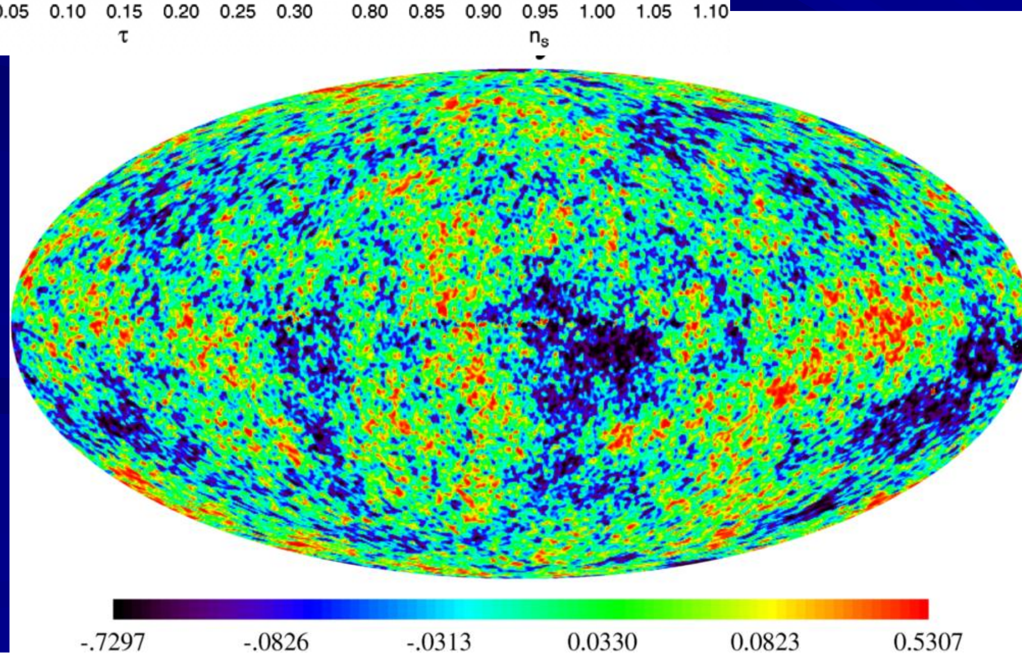
10-100 M_{sun} first stars are the best fit for various element abundance ratios



No single PISN can explain data, and 10-50 Msun HNe provide a much better fit, esp. for Fe-peak (Cr - Zn) elements. (Tumlinson, Venkatesan & Shull 2004, see also Venkatesan 2006)

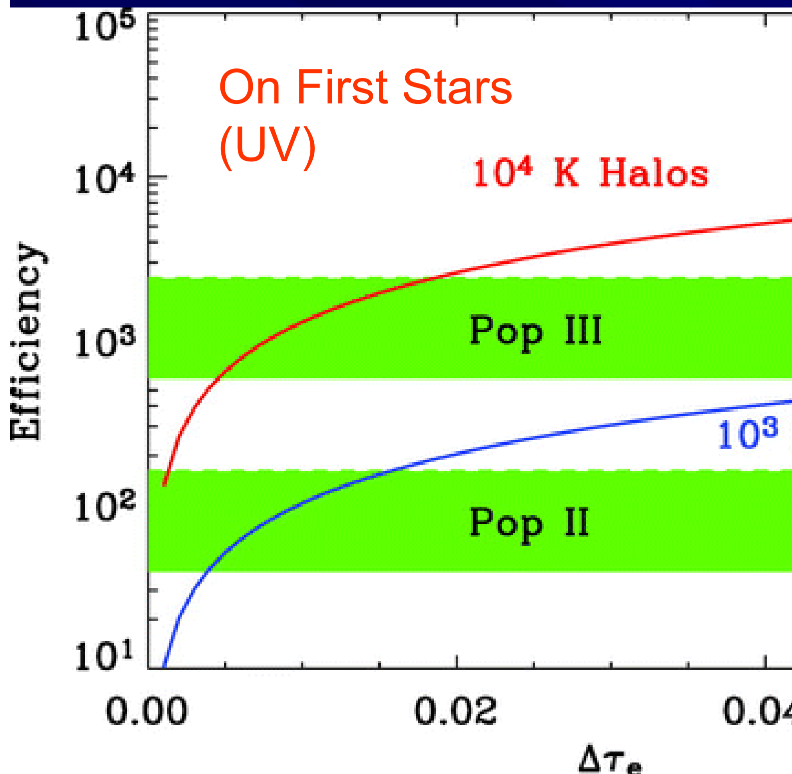
Constraints from the CMB

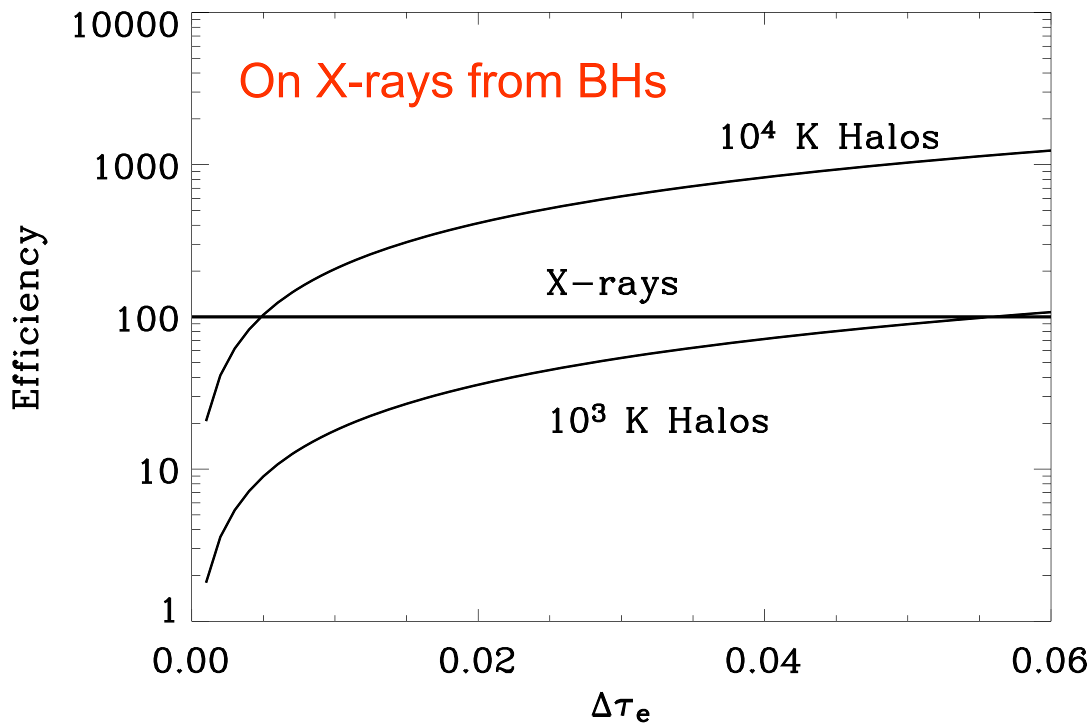




Constraints from the CMB

From Shull & Venkatesan 2008, for WMAP-5 data

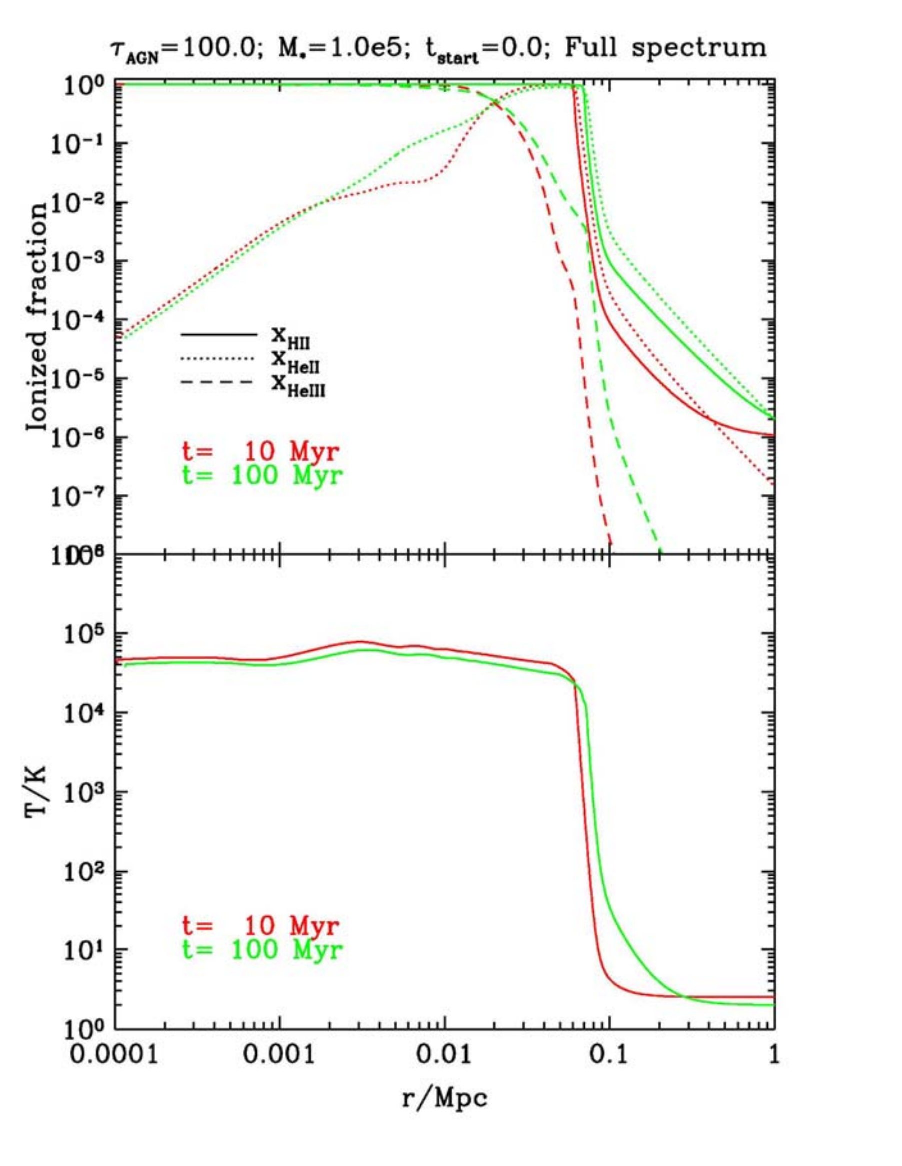


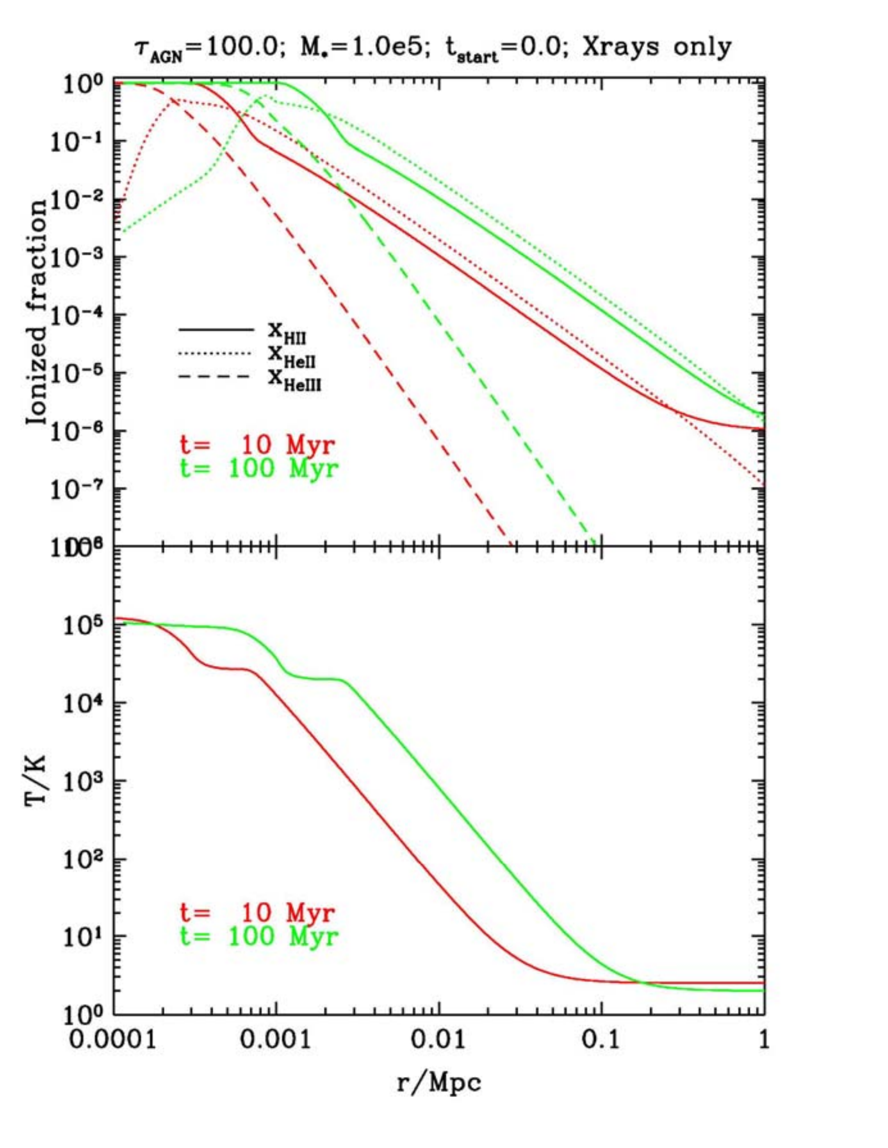


- $\varepsilon_{UV} = N_{gamma}\ f_{star}\ f_{esc}$
- $\varepsilon_{UV} \sim 6x10^4\ (0.1)\ (.1\text{-}.4) \sim 10^3$ (Pop III)
- $\varepsilon_{UV} \sim 4x10^3\ (0.1)\ (.1\text{-}.4) \sim 10^2$ (Pop II)

- $\varepsilon_X = N_X\ f_{BH}\ f_{esc}$
- $\varepsilon_X \sim 10^6\ .10^{-4}\ .1 \sim 100$ (solid line)

X-rays and Helium ionization





Benson & Venkatesan, in prep.

First Stars: Current Best Answers

- What were they like?

Hotter, smaller, about ~10-100 M_{sun} mass range indicated by data

- Were they important?

Yes, for cosmic ionization and element synthesis, despite their brief existence

- Can we see them today?

Not yet directly but perhaps very soon