Cosmic Star Formation History: Observations & Implications

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OUTLINE

- Why measuring Cosmic Star Formation History? (CSFR)
- How to measure Cosmic Star Formation History? & Where we have got?
- Why Cosmic Star Formation History looks like that?

Why measuring?

$$\psi(z) = \frac{dM_{\mathrm{new}}}{dt\ dV}$$

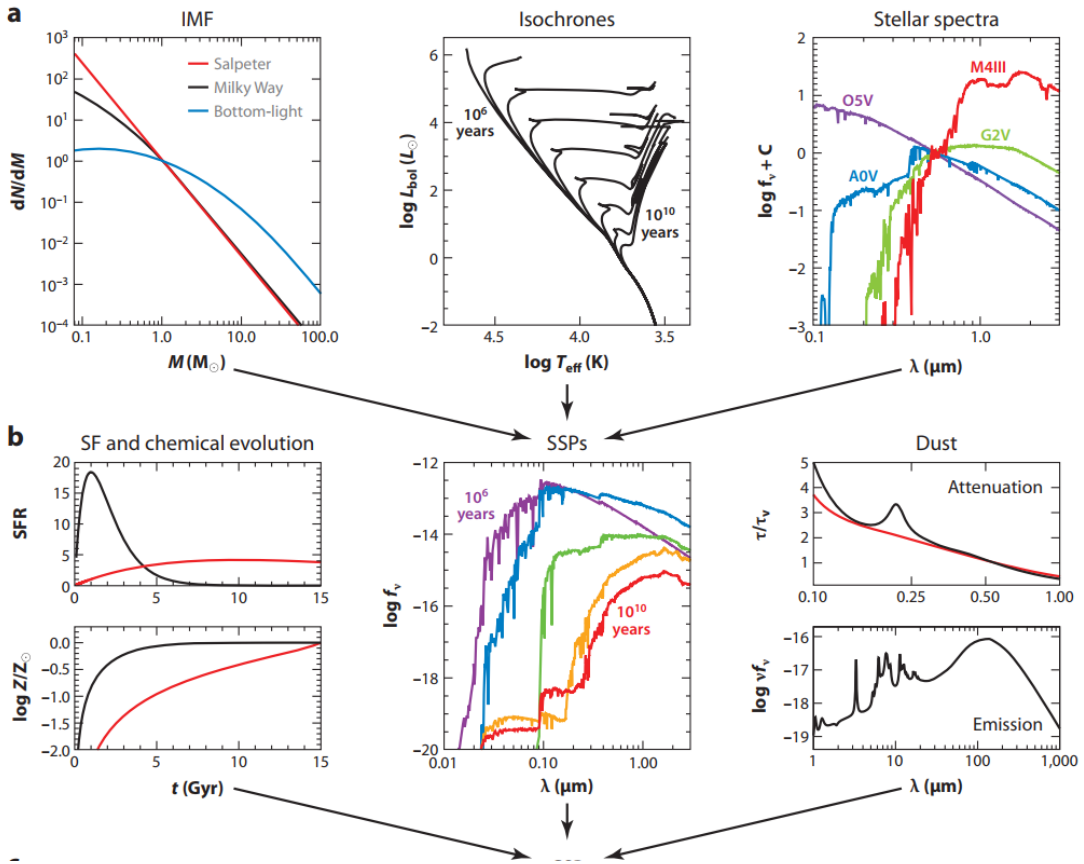
Star Formation Rate Density

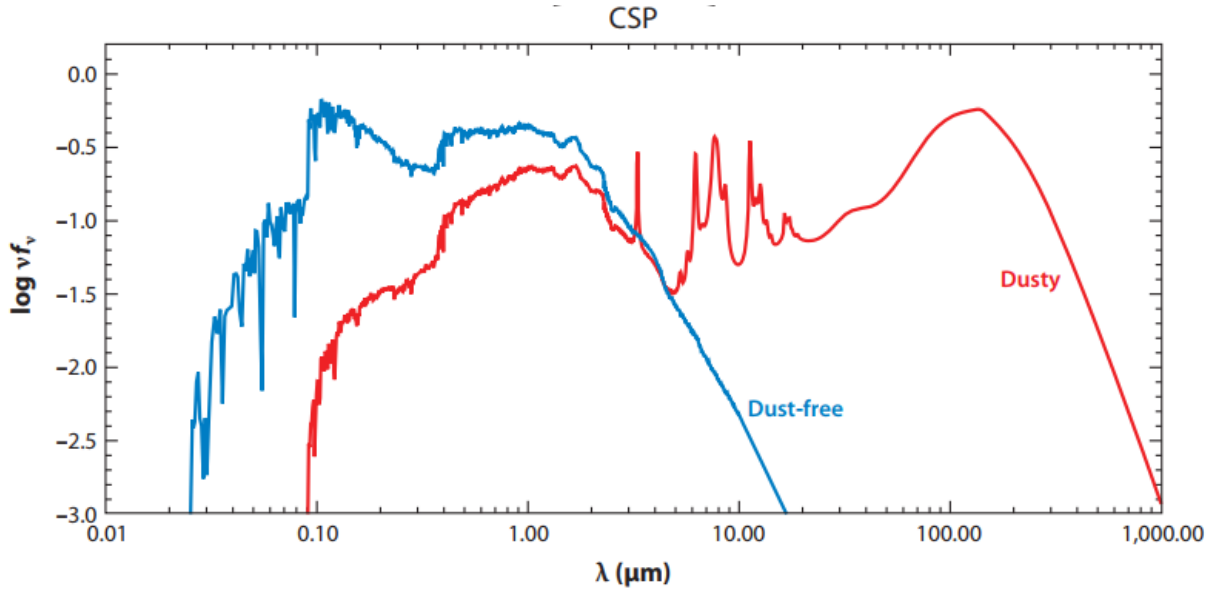
Integrate!

- Fraction of baryons locked in stars
- Cosmic metal amount
- Universal IMF?
- …

Observation Methods

Converting light to mass: Stellar Population Synthesis Models.





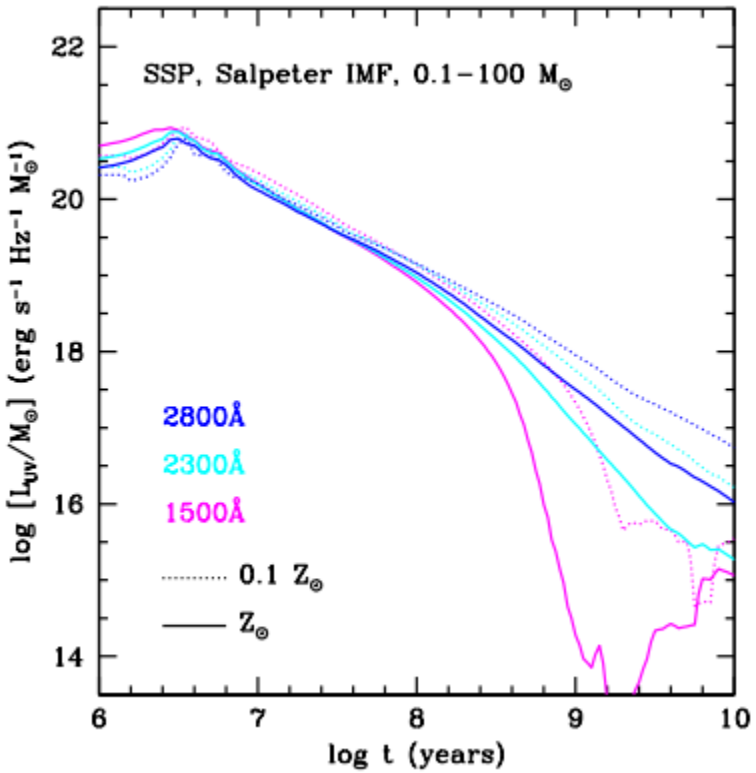
Conroy 2013

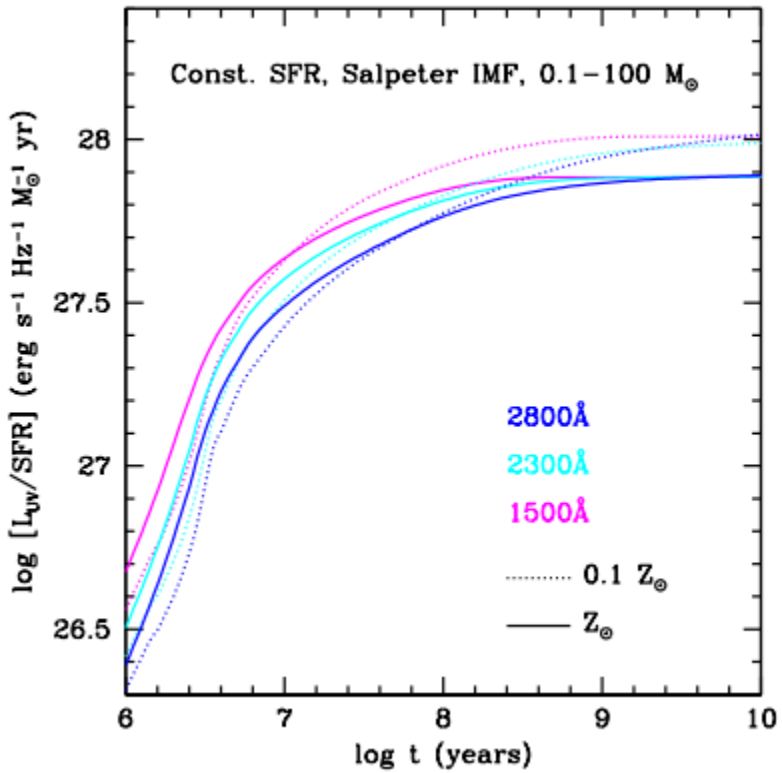
Observation Methods

1. UV Emission:

- From massive stars
- Dominate luminosity at young age

$$\mathrm{SFR} = \mathcal{K}_{\mathbf{FUV}} \times L_{\nu}(\mathrm{FUV})$$





Madau & Dickenson 2014

Observation Methods

2. IR Emission:

- From the dust absorbing the UV light

$$\mathrm{SFR} = \boldsymbol{\mathcal{K}_{IR}} \times L_{\nu}(\mathrm{IR})$$

$$\mathrm{SFR}_{\mathrm{tot}} = \mathcal{K}_{\mathrm{FUV}} \times L_{\nu}(\mathrm{FUV}) + \mathcal{K}_{\mathrm{IR}} \times L_{\nu}(\mathrm{IR})$$

Observation Methods

3. Nebula Line (Hα, …) Emission:

- From the HII regions photoionized by UV radiation of OB stars

4. X-ray Emission:

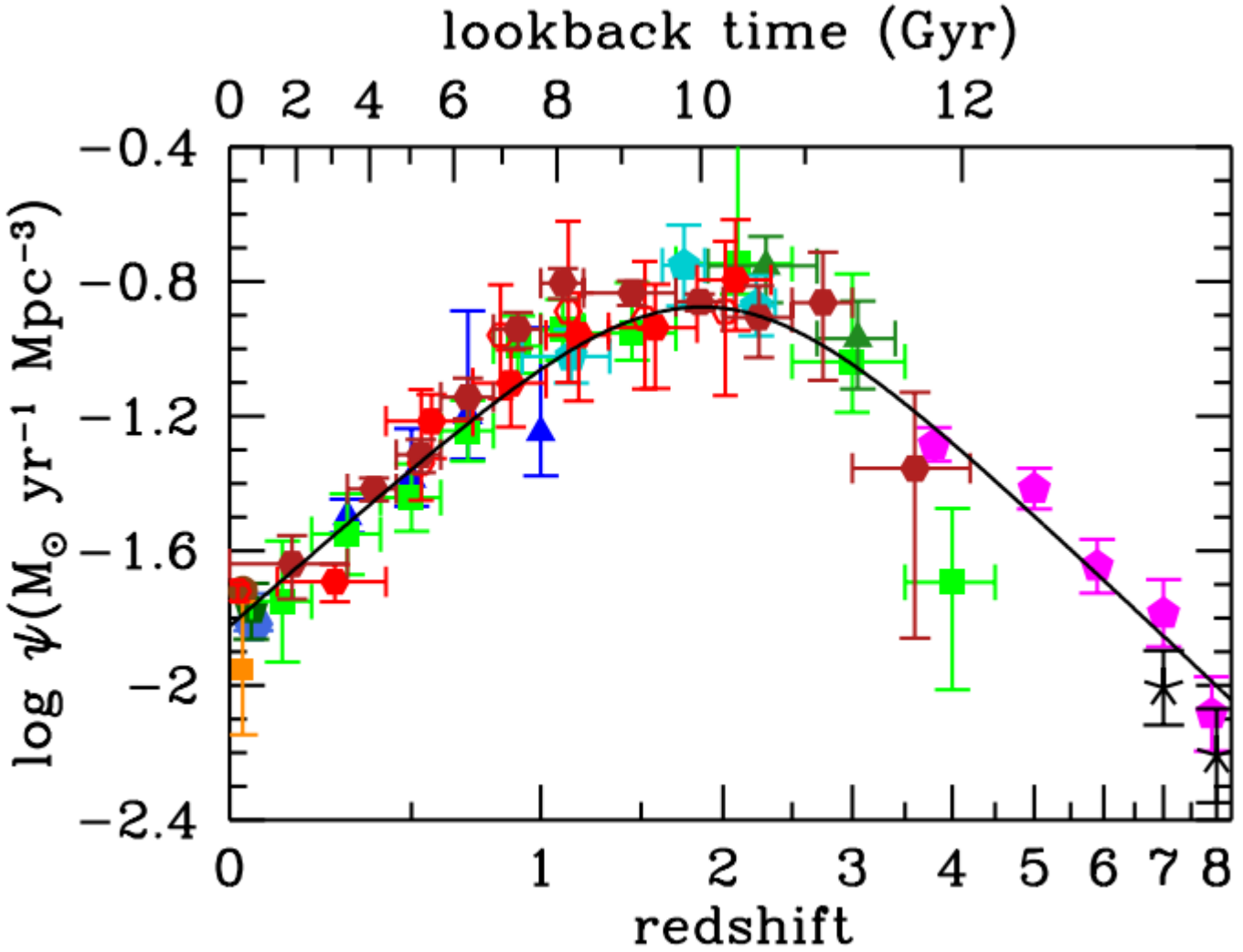
- From the X-ray binaries

5. Radio Emission, …

Observation Facts

$$\frac{\psi(z)}{\mathrm{M}_\odot\ \mathrm{yr}^{-1}\ \mathrm{Mpc}^{-3}} = \frac{0.015(1+z)^{2.7}}{1+\left(\frac{1+z}{2.9}\right)^{5.6}}$$

- Peaked at $z \approx 1.9$
- Peak SFR is ≈ 9 times higher than today
- $\approx 50\%$ stellar mass formed before $z = 1.3$



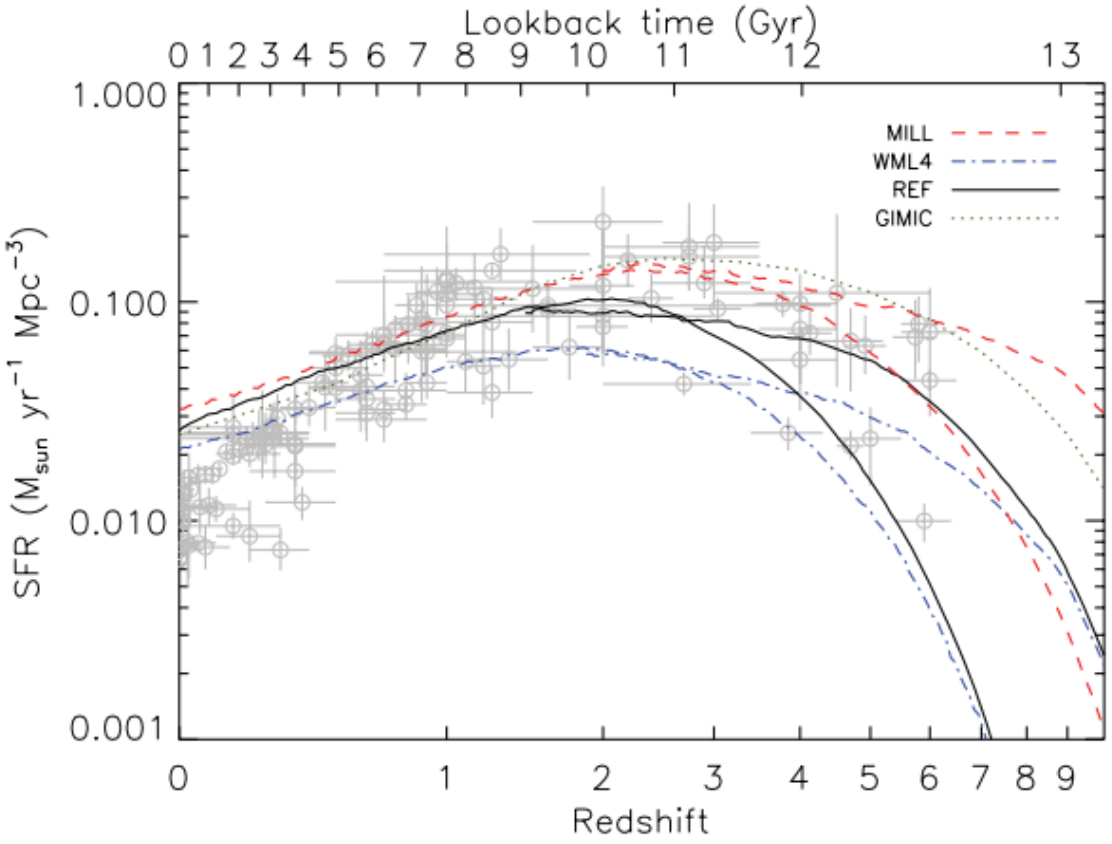
Madau & Dickenson 2014

Why the shape?

Use hydrodynamical simulations (OWLS):

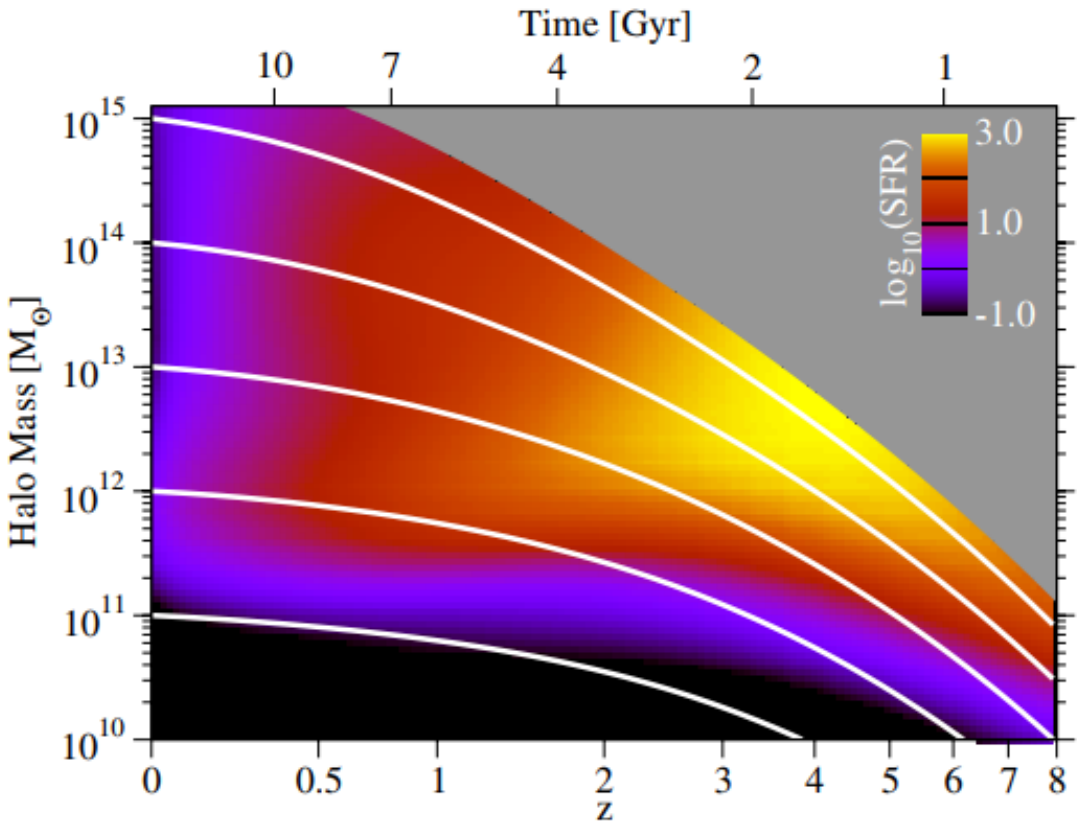
Increase Ω_b and $\boldsymbol{\sigma_8}$: (Red)

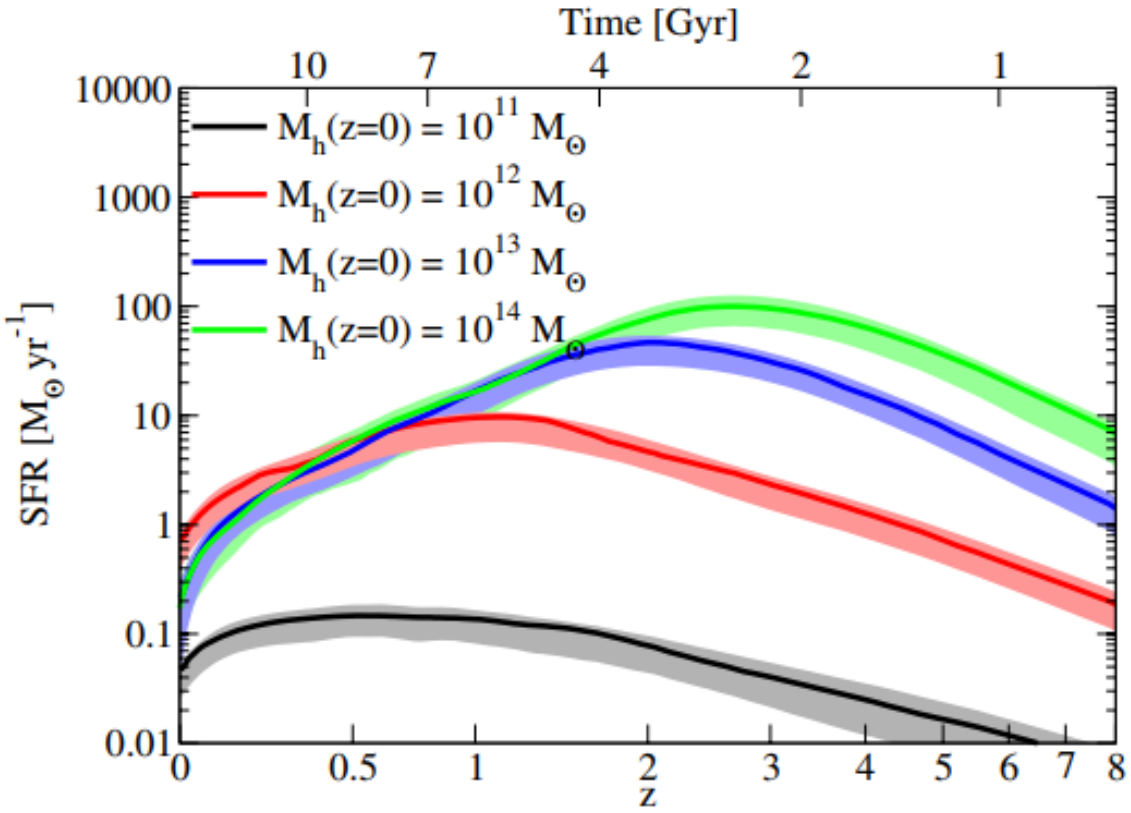
Early SFH is affected by the build up of dark matter halos.



Schaye et al. 2010

Why the shape?





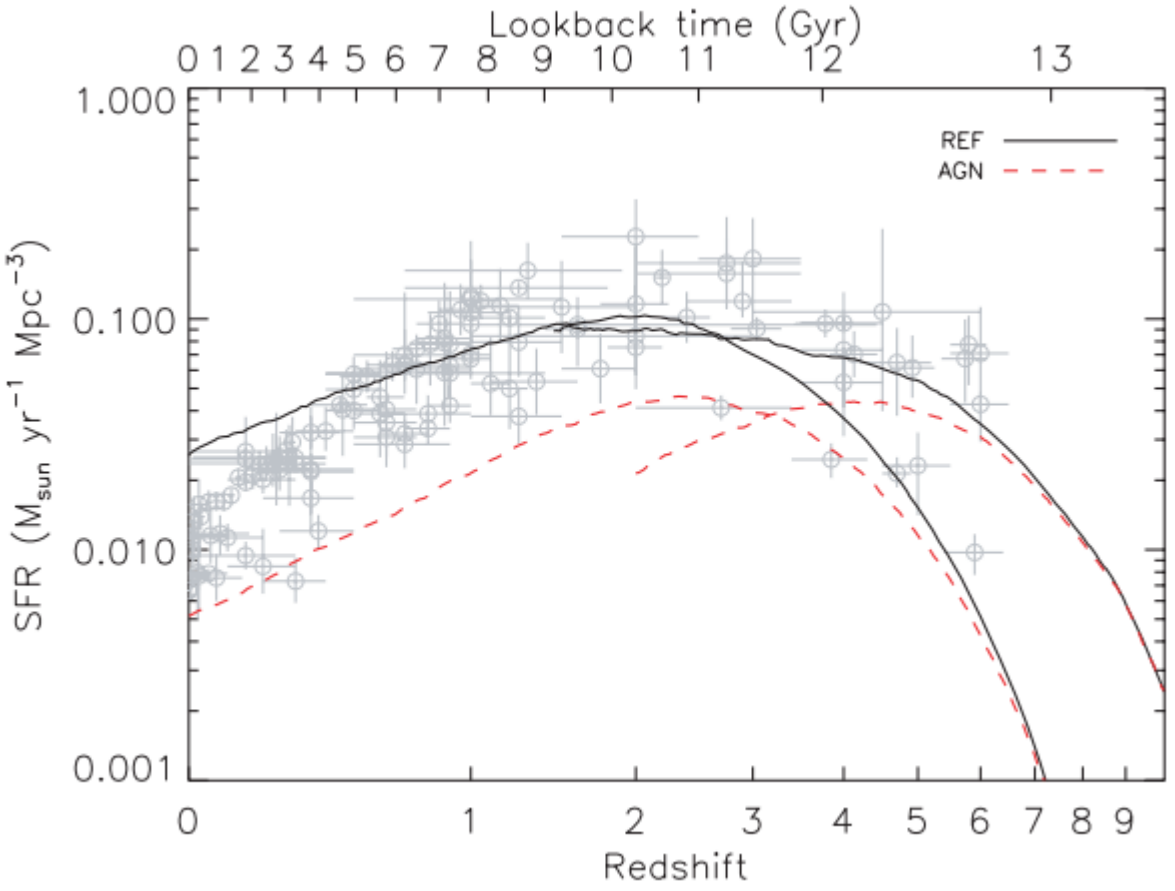
Behroozi et al. 2010

Why the shape?

Use hydrodynamical simulations (OWLS):

Include AGN feedback: (Red)

Late SFH is affected by the suppression of AGN feedback.

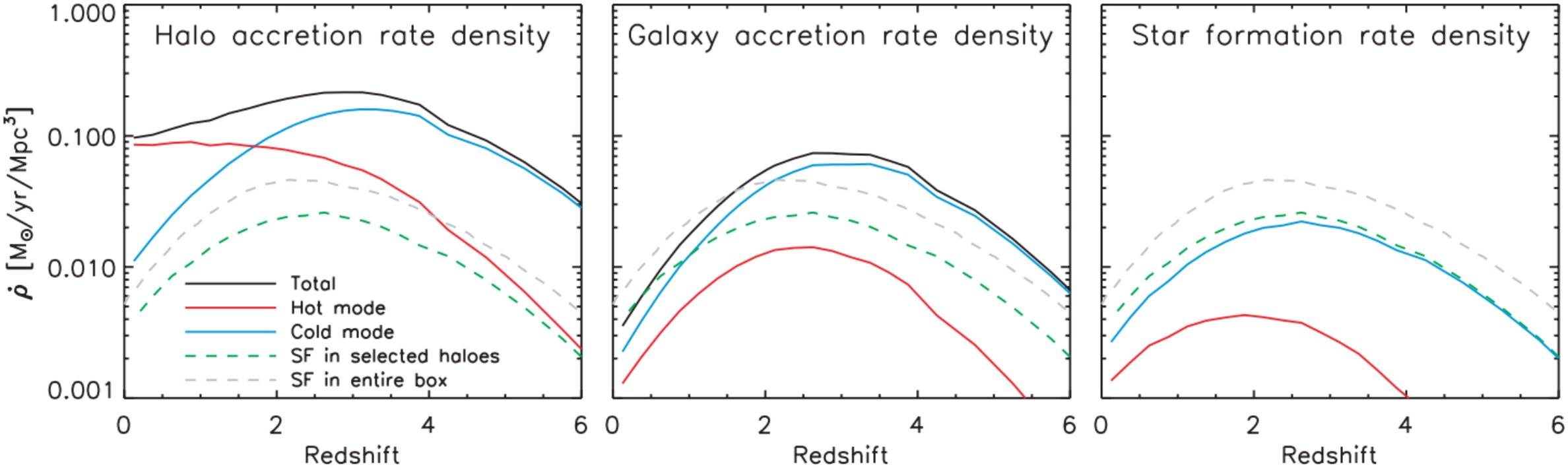


Schaye et al. 2010

Why the shape?

Late SFH is affected by the change of gas accretion mode.

van de Voort et al. 2011

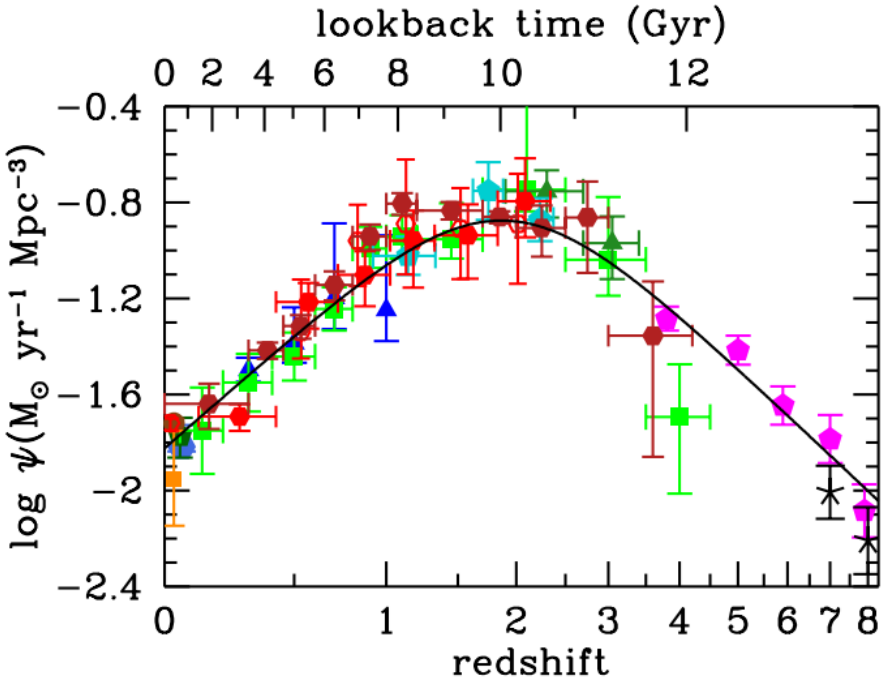


Take-Home Message

- The cosmic star formation history helps answer the baryon deposit the metal enrichment problems in our universe.

- The cosmic star formation history is measured through UV, IR and many other wavelength bands.

- The cosmic star formation history peaks at $z\sim2$ and declines thereafter.



- The cosmic star formation history is heavily affected by the growth of dark matter halos, the AGN feedback and the gas accretion mode.

References

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[2] Conroy, Charlie. "Modeling the panchromatic spectral energy distributions of galaxies." Annual Review of Astronomy and Astrophysics 51 (2013): 393-455.

[3] Fermi-LAT Collaboration. "A gamma-ray determination of the Universe's star formation history." Science 362.6418 (2018): 1031-1034.

[4] Harikane, Yuichi, et al. "A Comprehensive Study of Galaxies at z∼ 9–16 Found in the Early JWST Data: Ultraviolet Luminosity Functions and Cosmic Star Formation History at the Pre-reionization Epoch." The Astrophysical Journal Supplement Series 265.1 (2023): 5.

[5] Schaye, Joop, et al. "The physics driving the cosmic star formation history." Monthly Notices of the Royal Astronomical Society 402.3 (2010): 1536-1560.

[6] van de Voort, Freeke, et al. "The drop in the cosmic star formation rate below redshift 2 is caused by a change in the mode of gas accretion and by active galactic nucleus feedback." Monthly Notices of the Royal Astronomical Society 415.3 (2011): 2782-2789.

[7] Behroozi, Peter S., Risa H. Wechsler, and Charlie Conroy. "The average star formation histories of galaxies in dark matter halos from z= 0–8." The Astrophysical Journal 770.1 (2013): 57.