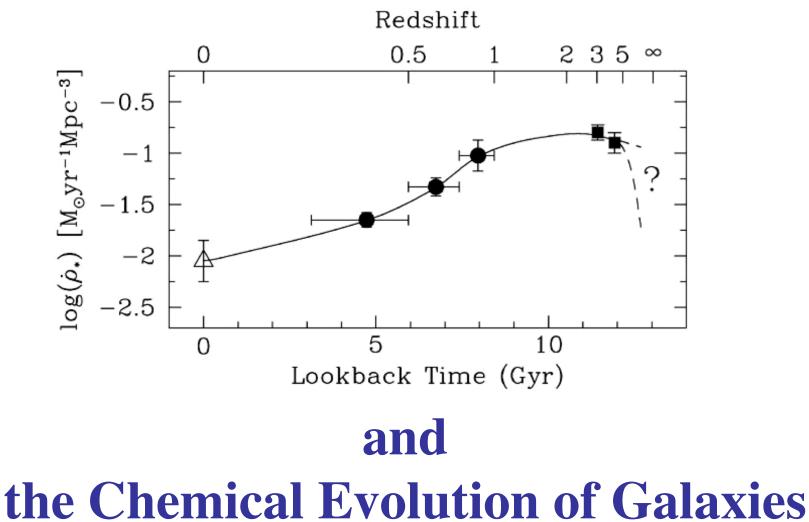
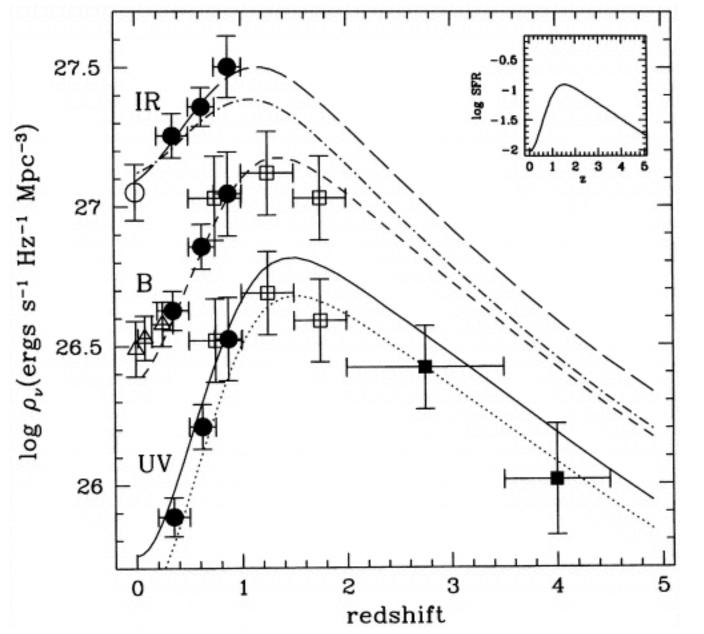
The Star Formation History of the Universe



The History of Star Formation



This is often called the "Madau diagram"

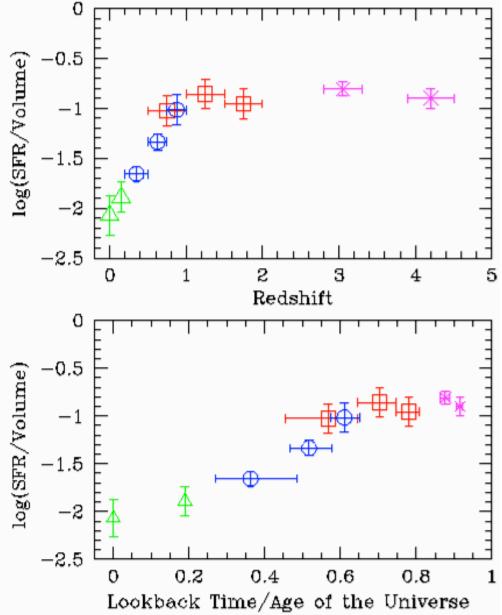
These data and models are *not* corrected for extinction

Cosmic Star Formation History

From various luminosity densities converted to star formation rates, we can construct a possible history of the comoving SFR density

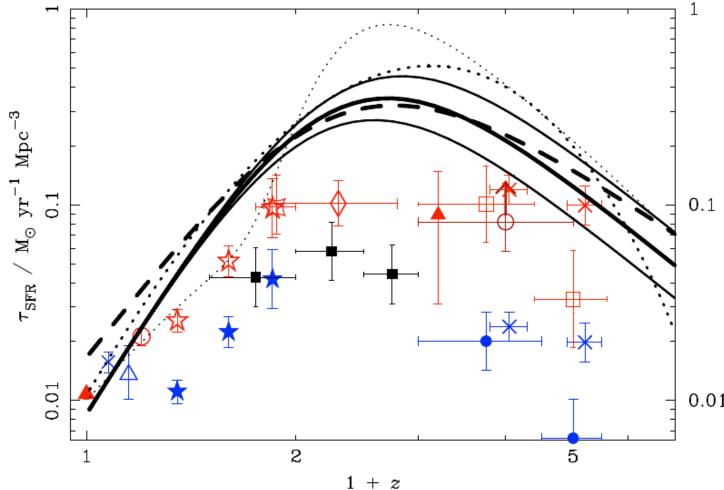
At face value it implies the universe was much more active in the past ($z \sim 1 - 2$) but what happens earlier is unclear

There are many complications of interpretation, including the reliability of each SFR diagnostic, dust extinction, incompleteness, etc.



Include the Obscured Component

Obscured star formation doubles the total SFR density!



for sub-mm population Red data points: UV/ visible, corrected for extinction

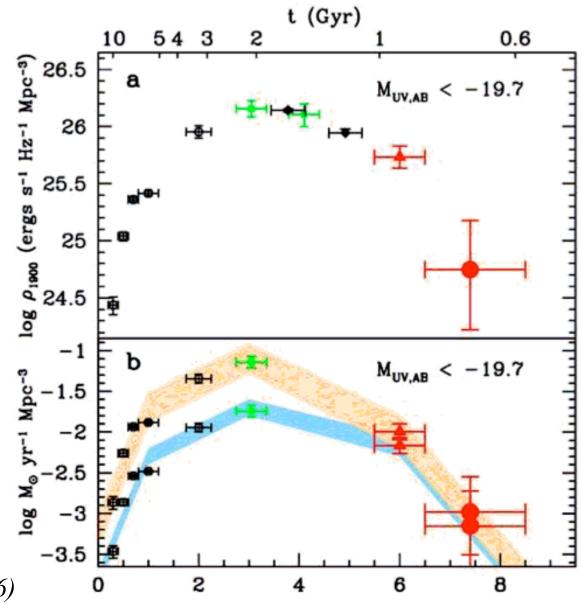
Lines: models

Blue data 0.01 points: UV/ visible, uncorrected

Now pushing to z ~ 6 (and beyond?)

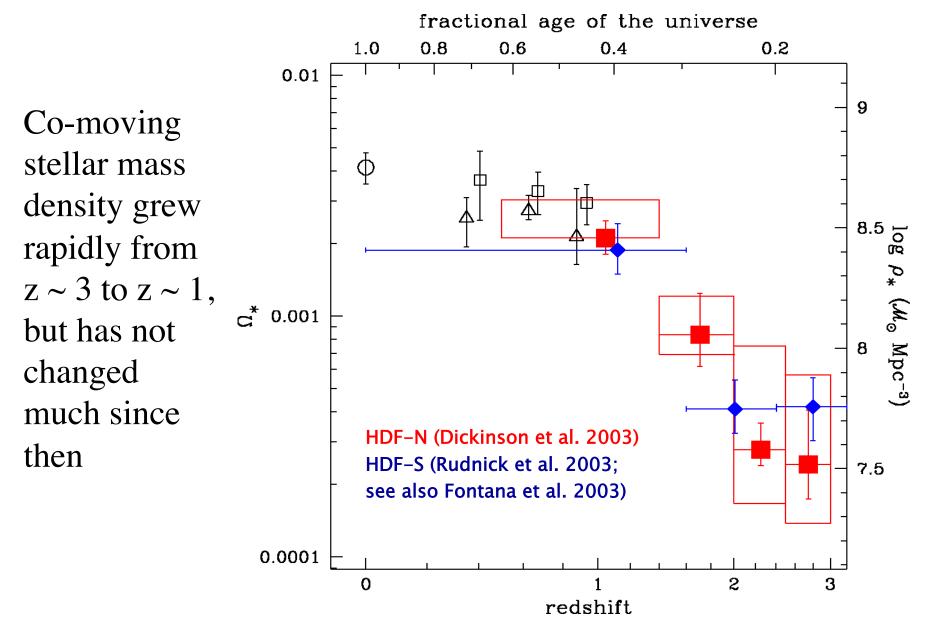
Use the color dropout technique to identify high-z galaxy candidates in deep HST images: different color bins give different redshift shells. Then add up the light.

There seems to be a rollover at z > 5 - 6: the epoch of the initial galaxy build-up?

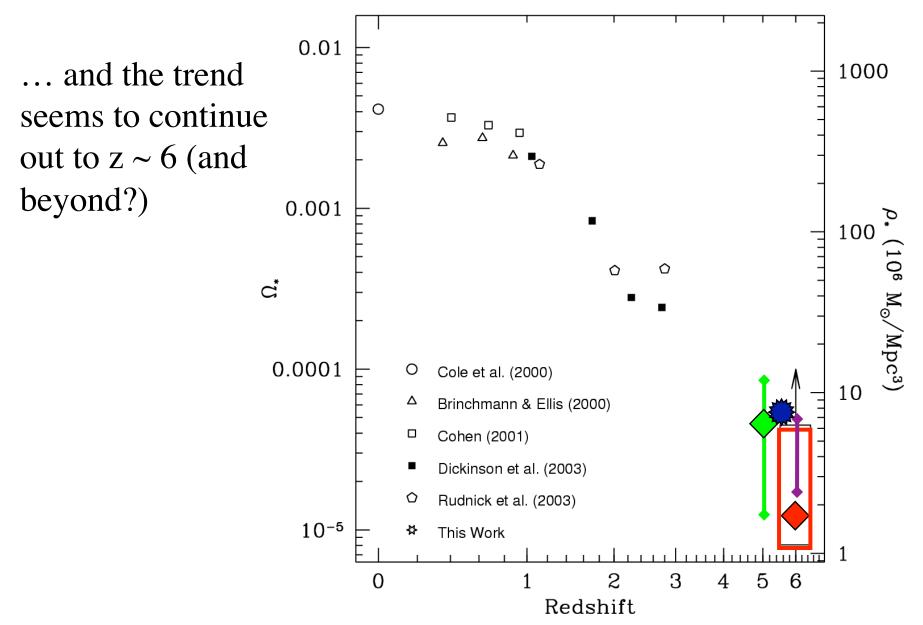


 \mathbf{z}

Build-up of Stellar Mass Density



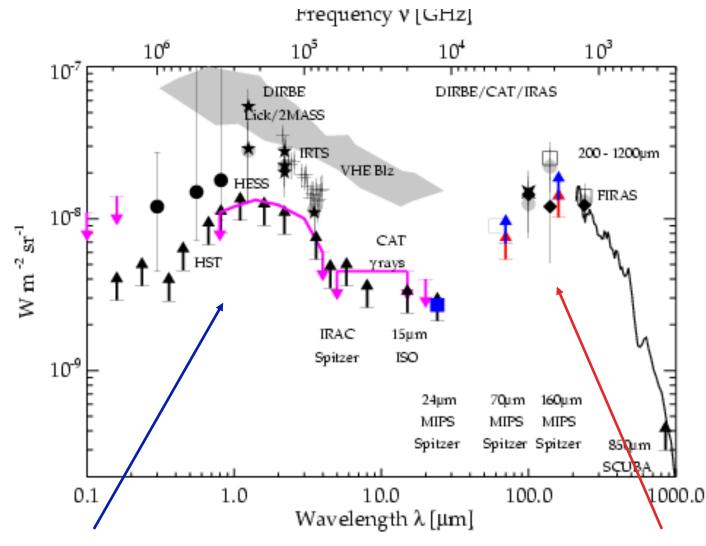
Build-up of Stellar Mass Density



All Starlight in the Universe

- Any deep survey is limited in flux and surface brightness: some fainter and/or more diffuse sources are likely missed; thus, our source counts give us only a lower limit to the total energy emitted by evolving galaxies
- An alternative approach is to measure *integrated diffuse backgrounds, due to all sources*
 - This is really hard to do, for many reasons
 - Redshifts are lost, but at least the energy census is complete
- The total energy in the diffuse extragalactic backgrounds from UV to sub-mm is ~ 100 nW m⁻² sr⁻¹ ($\pm 50\%$ or so)
 - This is distributed roughly equally between the UV/Opt (unobscured SF) and FIR/sub-mm (obscured SF)
 - A few percent of the total is contributed by AGN
 - This is only a few percent of the CMB

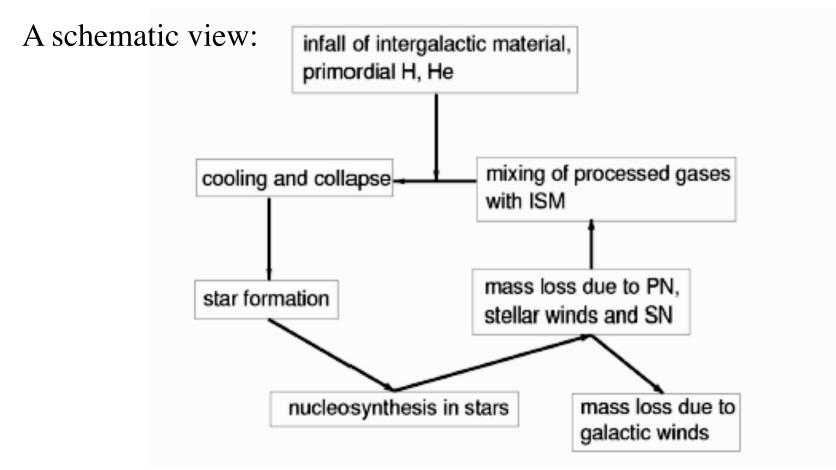
Diffuse Optical and IR Backgrounds



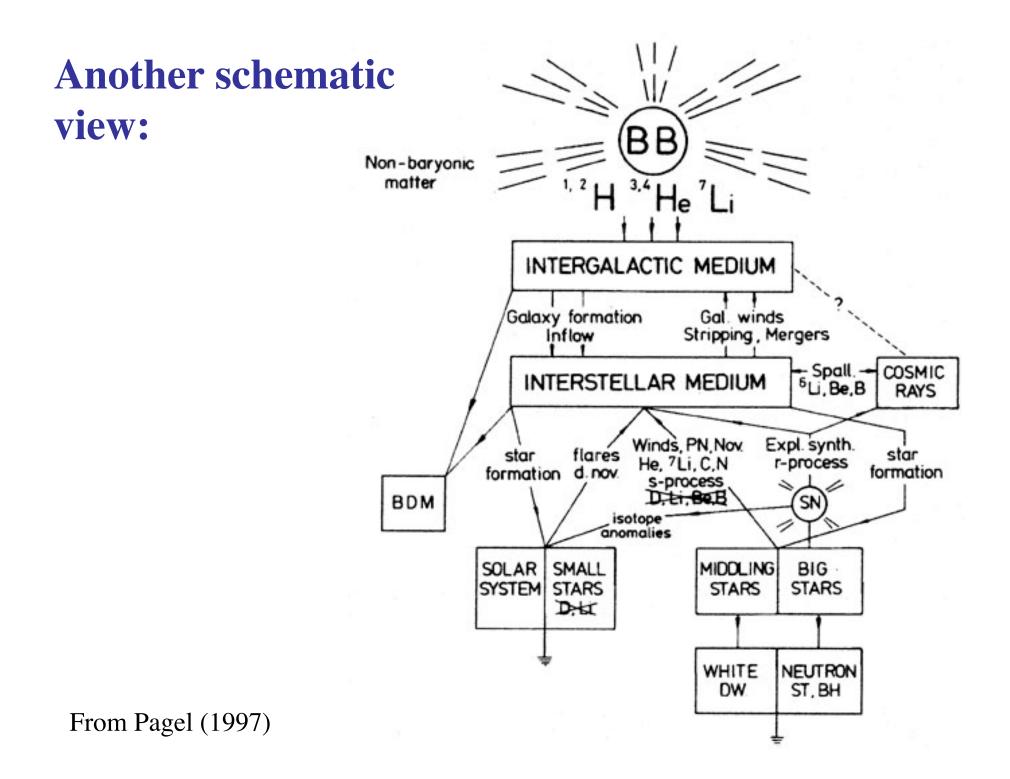
Unobscured component (restframe UV, obs. Optical/NIR)

Obscured component (restframe FIR, obs. FIR/sub-mm)

The Cosmic Chemical Evolution

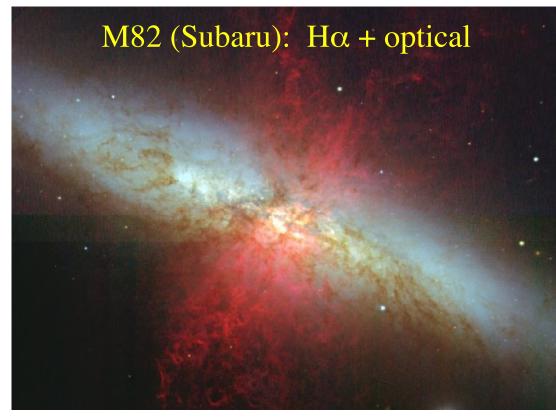


Details of these processes are very messy and hard to model or simulate. So, simplified (semi)analytical models and assumptions are often used, e.g., the "closed box" model, or the "instanteneous recycling" approximation.



Galactic Winds

Starburst can drive winds of enriched gas (e.g., from supernova ejecta) out to the intergalactic medium. This gas can then be accreted again by galaxies. In a disk galaxy, the winds are generally bipolar outflows

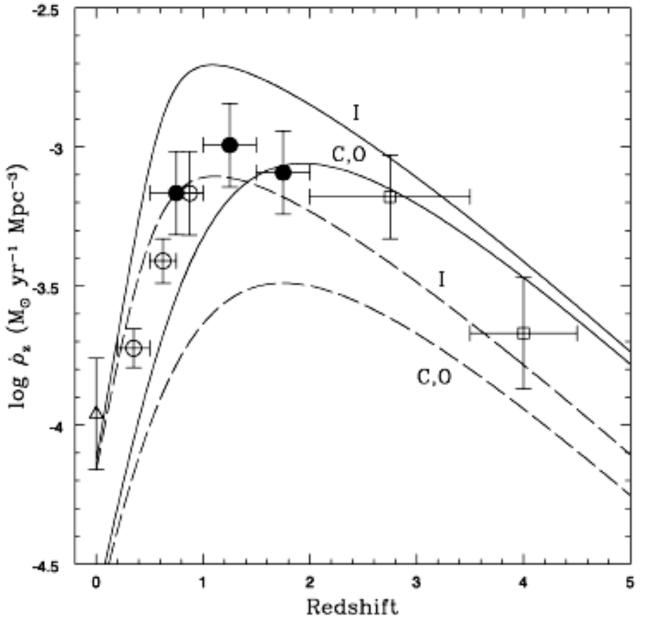


M82 (CXO): X-ray



Numerical Simulation

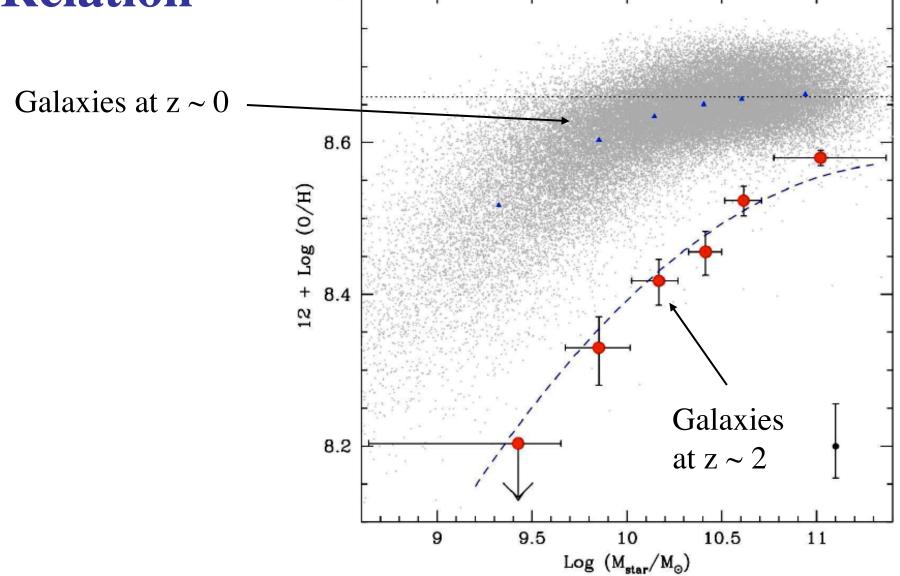
Evolution of the Metal Production



It must track the star formation in galaxies ...



The Evolution of the Mass-Metallicity Relation 8.8



Next: QSO Absorption Line Systems, Intergalactic Medium, and the Cosmic Web