What GRBs (could, and do) reveal about the cosmic baryon history
Cosmic Composition

- Cycles of Matter, Light, ...
- Star Formation
- Nucleosynthesis
- Redistribution
- Light, neutrinos, ...

→ $\tau_\gamma$ (EBL)

Paul Klee. 1919. Oil on pasteboard. 48 x 41 cm.
Kunstsammlung Nordrhein-Westfalen, Düsseldorf, Germany.
Cosmic Matter Budget

A(Z)

Please don’t z,z,z,z ..... 

Metals
z=0.03%

Z(z) = ?

20% - 40%

“Missing Baryons”
Production and Distribution
Galactic and/or Cosmic Chemo-Dynamic Evolution

\[ \tau_{ff} \propto (G\rho)^{-1/2} \approx 10^8 \text{ yrs} \]

\[ \tau_{ff} \approx 10^5 \text{ yrs} \]
Simulations: e.g., OWLS (Schaye et al.) & several other collaborations: SPH+N-body (GADGET +)

\( \Lambda \)CDM
SF law (z)
IMF (z)
PopSyn (z)
Yields (z)
Cooling (z)
Feedback (z)
EBL(z)
Ionization
AGN feedback

- Numerical resolution still insufficient to address role of small galaxies
- Observational tests: Abundance ratios as f(z), but yields are uncertain!

Metals in lower density IGM was ejected earlier and by lower mass halos.

Dynamic mixing times are important, & fallback = f(M_{halo}) plays a role.
Probing high-z proto-galaxies, and the local “missing” Baryons.

Clusters are baryon traps, …

Emission imaging beyond $R_{\text{virial}}$

Feedback driven outflows

e.g., Rasheed, Bahcall, and Bode 2010

High Resolution X-ray Spectra of GRB afterglows
GRBs opportunities should not be wasted!

Galaxies form at $z \approx 10$ (Greif, Bromm, et al.)

Star formation 500 Myrs after the big bang.

HST: Bouwens et al. 2010 Candidates
VLT: Lehnert et al. 2010: $z = 8.6$
Cosmic Chemical Evolution: Taking advantage of GRBs

VLT/ISAAC: P. Vreeswijk et al. 2004
The Durham theoretical cosmology group

Savaglio et al. 2010

"Near Field Cosmology"
"Future Studies to Address Open GRB Questions and GRBs as Probes".

What are the key open areas for GRBs prompt and afterglow emission?

What the key open areas for central engines and hosts?

What are the opportunities to use GRBs to understand the universe?

What theory challenges the lie ahead?

What new capabilities are coming for ground and space?