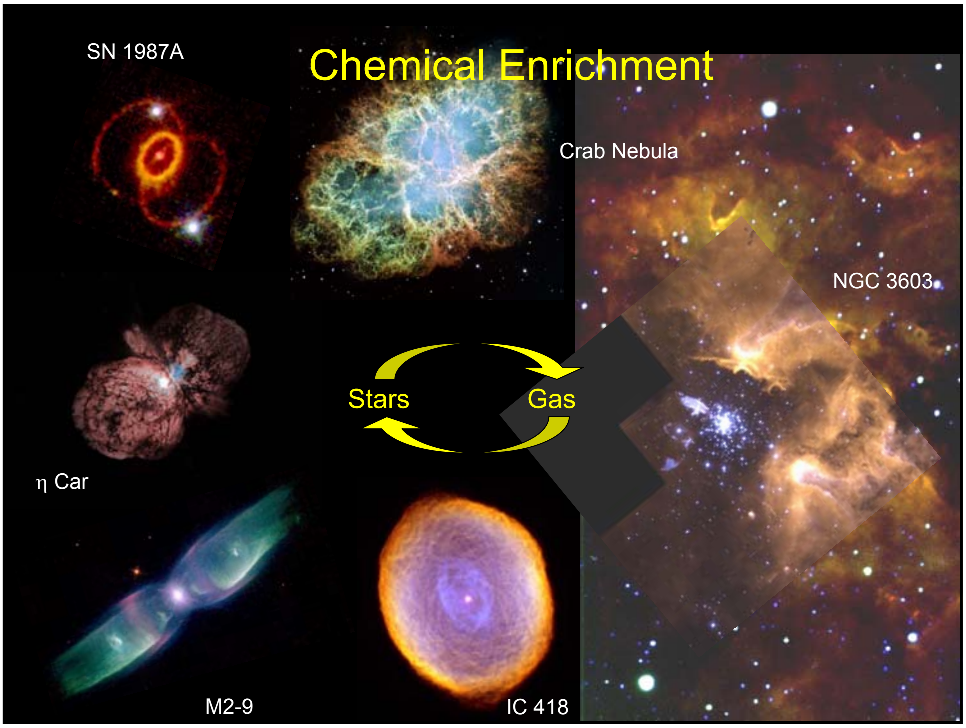


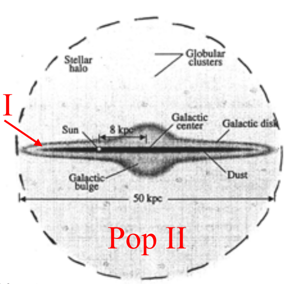
Baade (1944)

Stellar Populations

X,Y,Z = mass fractions
X ~ 0.73 (H)
Y ~ 0.25 (He)
Z ~ 0.02 (metals)

- Abundances
- Kinematics
- Ages

- Pop I : Metal rich (Z ~ 0.02), disk, younger
  - Disk field stars (up to 10-12 Gyr old)
  - Open clusters
  - Gas
  - Star formation regions
- Pop II: Metal poor (Z ~ 0.001), halo, older
  - Globular clusters (12-15 Gyr)
  - Halo field stars
  - Bulge??? ….but includes Super Metal Rich (SMR) stars.
- Abundance Determinations
  - Stellar spectroscopy
    - [Fe/H], etc. ➔ $\log(N_{Fe}/N_H) - \log(\text{solar})$
    - Iron ejected by Sne Ia after about 10^9 yrs.
  - Stellar colors
  - HII regions



	[Fe/H]
Thin Disk	-0.5➔ +0.3
Thick Disk	-0.6➔ -0.4
Halo	-2.5➔ -0.8
Bulge	-1.0➔+1.0

Closed Box Model

(and friends and relatives)

Metallicity
$Z = M/G$
$Z_{\odot} \sim 0.02$

Gas ➔ stars ➔ enriched gas

S = mass of stars
M = mass of metals (heavy elements) in ISM
G = total mass of gas in ISM

Assume instantaneous recycling.

From each new generation of stars:

dS = mass of low mass stars added to S

$p\ dS$ = mass of heavy elements added to M from massive stars in this generation.
where p = *yield*.

Instantaneous recycling

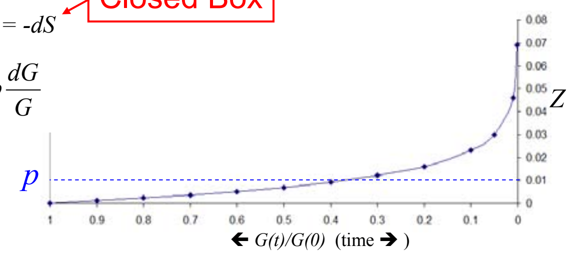
$dM = p\ dS - Z\ dS$
$= -p\ dG + Z\ dG$ since $dG = -dS$

Closed Box

$$dZ = d\left(\frac{M}{G}\right) = \frac{dM}{G} - \frac{M}{G^2}dG = -p\frac{dG}{G}$$

$Z(t) = -p \ln [G(t)/G(0)]$

$G(t)=G(0)\ e^{-Z(t)/p}$



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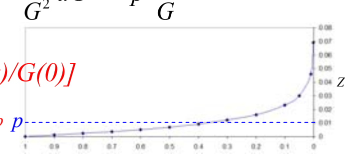


G dwarf problem

$S[Z<Z(t)] = S(t) = G(0) - G(t)$

$= G(0)\ \{ 1 - e^{-Z(t)/p} \}$

where $Z(t)$ = gas metallicity at time t

Compare to case when gas had some arbitrary fraction α of that metallicity:

$$\frac{S[Z<\alpha Z(t)]}{S[Z<Z(t)]} = \frac{1-X^{\alpha}}{1-X}$$

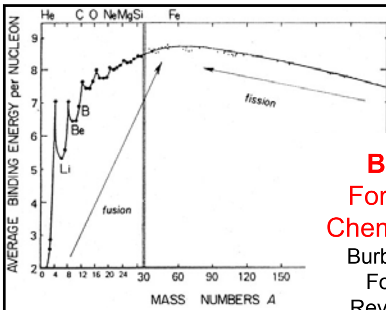
where $X = e^{-Z(t)/p} = \frac{G(t)}{G(0)} \sim 0.1 - 0.2$

Predicts broad distribution in metallicity of stars.

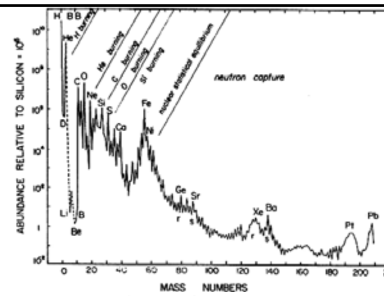
➔ $S[Z<1/4\ Z_{\odot}] = 0.4\ S[Z<Z_{\odot}]$

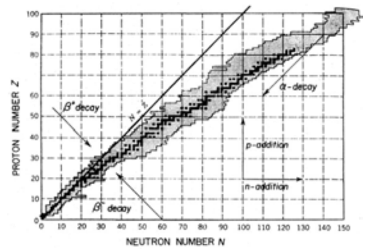
Very different than what is observed in solar neighborhood:

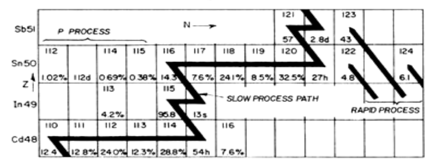
$S[Z<1/4\ Z_{\odot}] = 0.02\ S[Z<Z_{\odot}]$



B²FH (1957)
Formation of the Chemical Elements
Burbidge, Burbidge, Fowler & Hoyle. Reviews of Modern Physics, 29, 547.







Gradual processes in Interiors of Stars

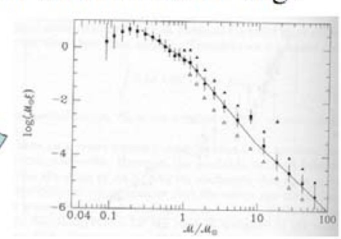
- H burning (4H ➔ He)
- α process (C,O,Ne,Mg,Si,S…)
- s process
  - slow neutron capture, relative to beta-decay timescale

Supernovae

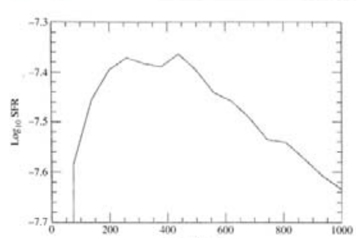
- e process
  - nuclear statistical equilibrium
  - iron peak elements
- r process
  - rapid neutron capture

The Initial Mass Function (IMF)

- $dN = N_o \xi(M) dM$ = number of stars born with masses in range $M, M+dM$
- Salpeter (1955) IMF: $\xi(M) \propto M^{-2.35}$
- Scalo (1986) IMF:
  - $\xi(M) \propto M^{-2.45}$ for $M > 10M_\odot$
  - $\xi(M) \propto M^{-3.27}$ for $1 < M < 10M_\odot$
  - $\xi(M) \propto M^{-1.83}$ for $0.2 < M < 1M_\odot$



- Others as well.



[CO Fig. 26.18]

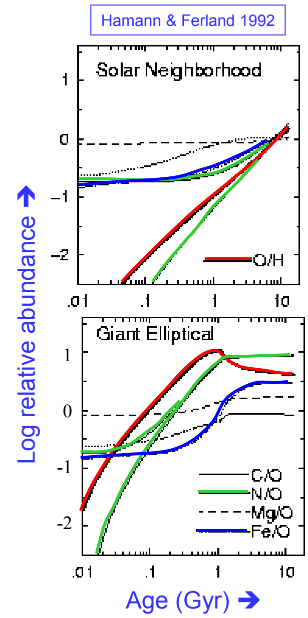
- Star Formation rate = $\psi(t)$
- Stellar birthrate function

$B(M,t) = \psi(t)\xi(M)\, dM\, dt$

= number of stars born per unit volume with masses in range $M, M+dM$ in time interval $t, t+dt$. [CO eqn. 26.4]

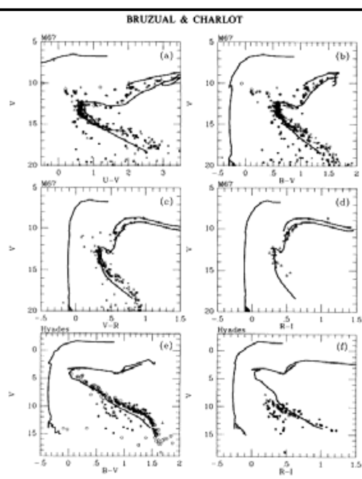
Modeling chemical enrichment

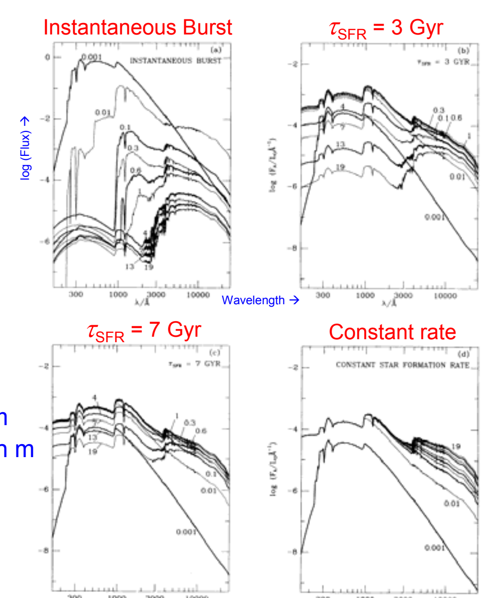
- One zone, accreting box model.
  - Start with pure H, He mix.
  - Further H, He falls in at specified rate.
- Follow evolution of individual elements H, He, C, N, O, Ne, Mg, Si, S, Ar, Ca and Fe.
- Subdivide stellar population into three classes of stars:
  - $< 1M_\odot$ nothing recycled
  - $1.0 – 8.0\ M_\odot$ fraction give white dwarf supernovae
  - $> 8M_\odot$ Core collapse supernovae.
- Assume that each class of stars spews specified % of its mass of each element back into ISM at end of a specified lifetime.
- Must provide IMF to specify mix of star masses.
- Two extreme models:
  - "Solar neighborhood": conventional IMF, slow stellar birthrate, slow infall (15% gas at 10 Gyr) .
  - "Giant Elliptical": flatter IMF, 100x higher birthrate, fast infall (15% gas at 0.5 Gyr).



Population Synthesis Models

Bruzual & Charlot (1993); Worthey et al (1994)

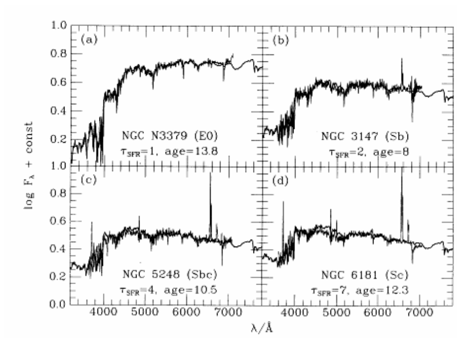




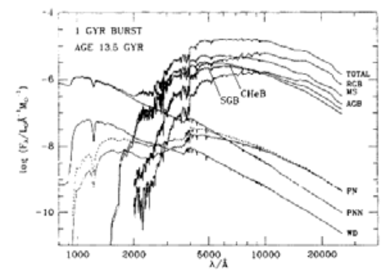
Ingredients:

- Isochrones = evolution of star of mass m
- IMF = number of stars formed with each m
- ➔ evolving composite spectrum $f_\lambda(\tau)$
- Star formation rate $\Psi(t) = \tau^{-1} \exp(-t/\tau)$
- $F_\lambda(t) = \int \Psi(t-\tau) f_\lambda(\tau) d\tau$

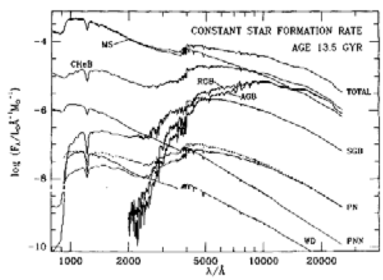
Some Bruzual & Charlot results



Models fitted to real spectra for different galaxy types.



Components of E galaxy spectrum



Components of late-type spiral galaxy spectrum