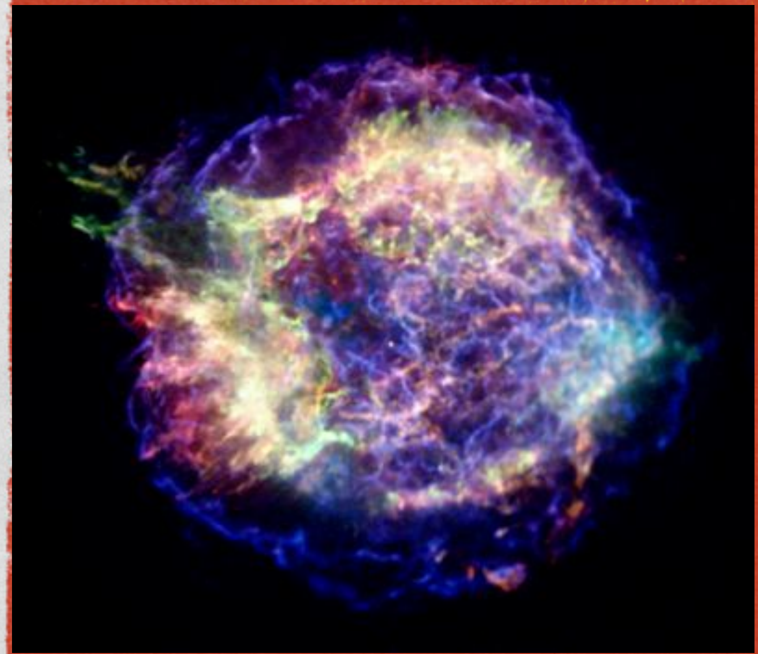
Supernova Feedback in Low and High Mass Galaxies: Luke Hovey 10 December 2009

- *Galactic Winds*: Mathews, W. et al. 1971
- *Effects of Supernovae on the Early Evolution of Galaxies*: Larson, R. 1974
- *The origin of Dwarf Galaxies, Cold Dark Matter, and Biased Galaxy Formation*: Dekel and Silk 1986
- *Starburst-Driven Mass Loss From Dwarf Galaxies: Efficiency and Metal Ejection*: Mac Low, M. et al. 1999
- *A Model of Supernova Feedback in Galaxy Formation*: Efstathiou, G. 2000
- *What Shapes the Luminosity Function of Galaxies?*: Benson, A.J. et al. 2003
- *Effects of Supernova Feedback on the Formation of Galaxies*: Scannapieco, C. et al. 2008

What Motivates SN Feedback?

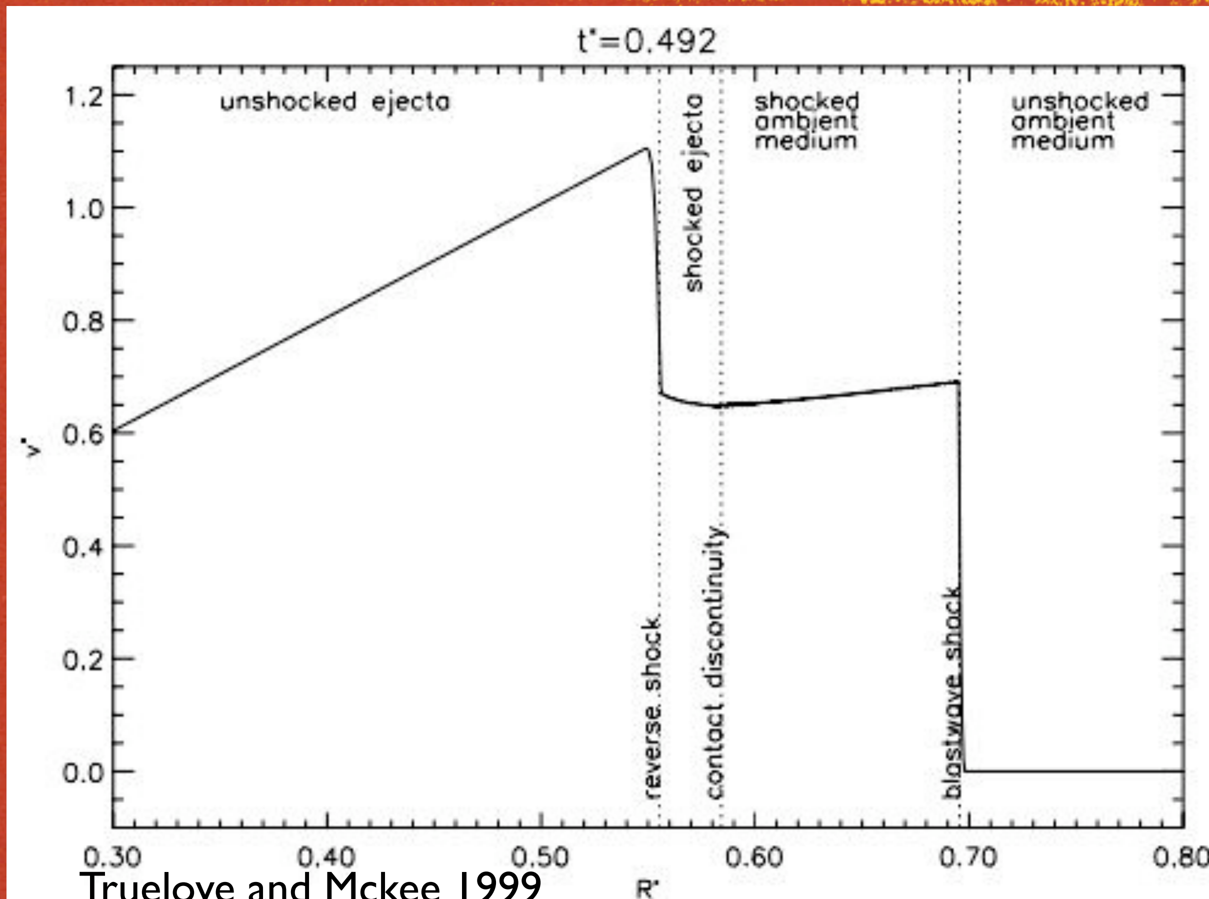
- Historically astronomers struggled to answer why elliptical galaxies are gas poor.
- Mathews et al. 1971 postulated supernova driven winds expel gas in elliptical galaxies.
- Dwarf Elliptical Galaxies are also gas poor and have low metalicities.
- Dekel and Silk 1986 postulate supernova driven winds are again responsible.

Supernovae in General



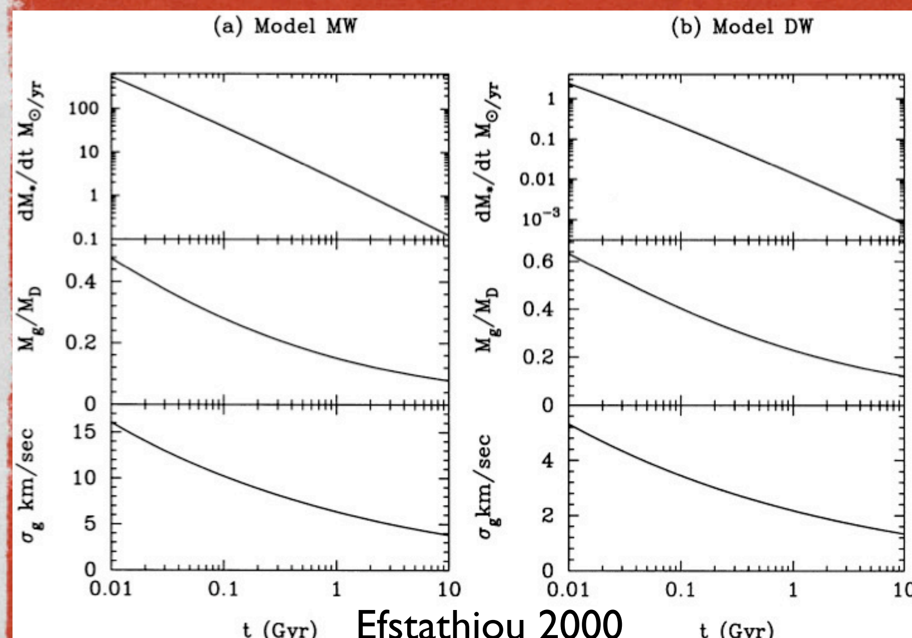
- Supernovae explode with energies on the order of 10^51 ergs.
- Shocks are driven into the interstellar medium which heat the gas and accelerate particles.
- Supernova Remnants propagate ~10,000 yrs before they begin to cool radiatively.

SNR Two Shock Structure



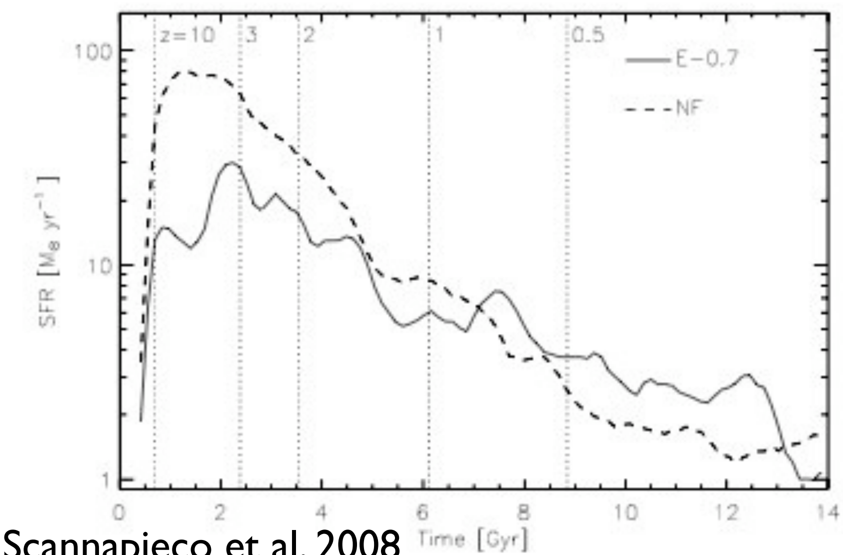
Truelove and Mckee 1999

In the Absence of SN Feedback



- In the Milky Way (MW) model the star formation rate at early epochs is too high to be consistent with observations of L* galaxies.
- In the Bright Dwarf (DW) model, most of the gas is converted into stars in early times. This fails to reproduce the flat faint-end luminosity function from CDM models.

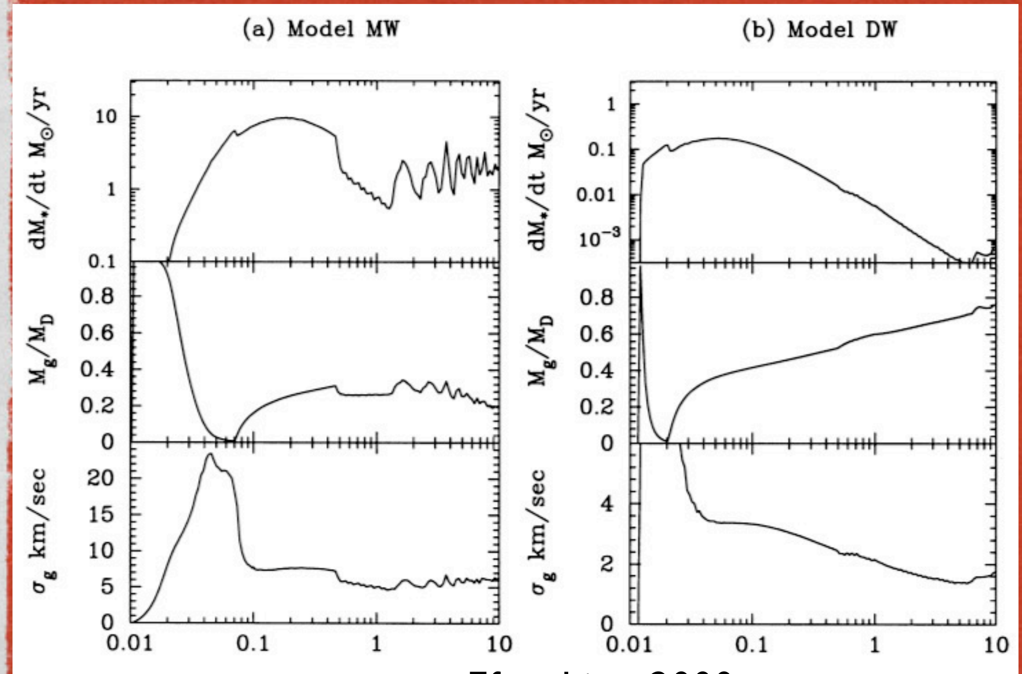
Effect of Feedback on SFR



Scannapieco et al. 2008

- In the absence of feedback SFR are extremely high in early times and fairly low in more recent epochs.
- With SN feedback, SFRs are initially lower so more gas is available for later periods of star formation.
- SN feedback self-regulates the process of star formation throughout the galaxies' history.

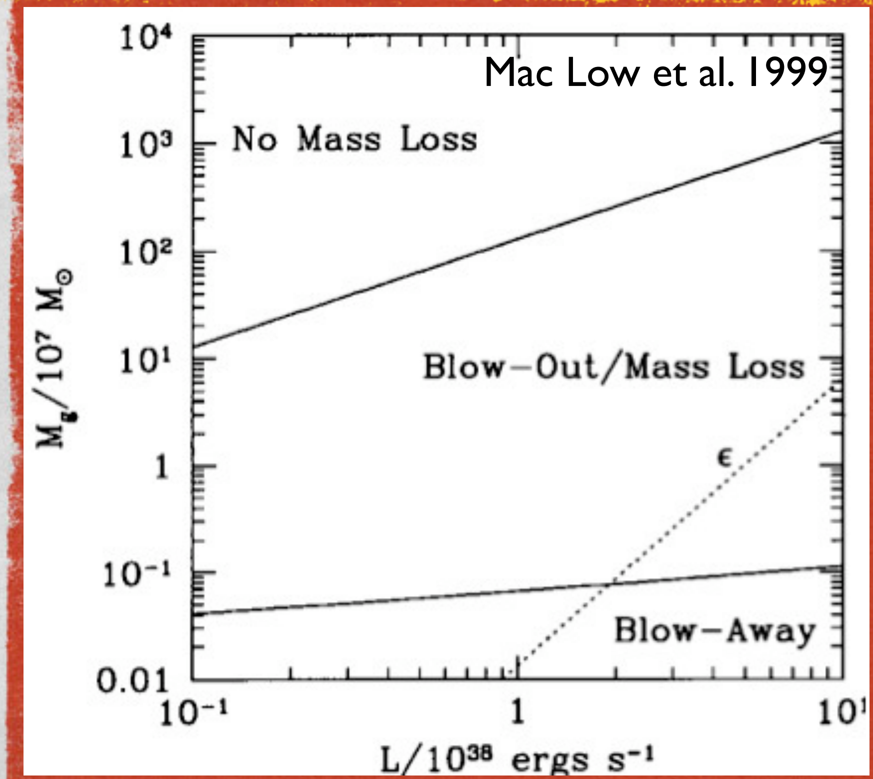
SN Feedback considering Gas Infall and Outflow



Efstathiou 2000

- In MW model 20-30% of the stellar mass is ejected from the galaxy during increased rates of star formation.
- In dwarf galaxies SNRs can efficiently heat the ISM which can then escape the halo through a cool wind.
- Gas accreted from the halo onto the dwarfs disk without triggering an epoch of star formation.
- Only modest rates of star formation are required to expel a large fraction of the dwarfs baryonic mass.

How much gas escapes from SN winds?



- Mass is ejected through the galactic disk in a SN driven bubble which carves a hole through the galactic disk- Blow-out.
- A blow-away is when the ambient gas is maximally accelerated above the escape velocity

Metal Ejection Efficiencies

TABLE 2

MASS EJECTION EFFICIENCY ξ

VISIBLE MASS ($M_g/M_\odot$)	LUMINOSITY (10^{38} ergs s^{-1}) 0.1	1.0	10
10^6	0.18	1.0	1.0
10^7	3.5E−3	8.4E−3	4.8E−2
10^8	1.1E−4	3.4E−4	1.3E−3
10^9	0.0	7.6E−6	1.9E−5

TABLE 3

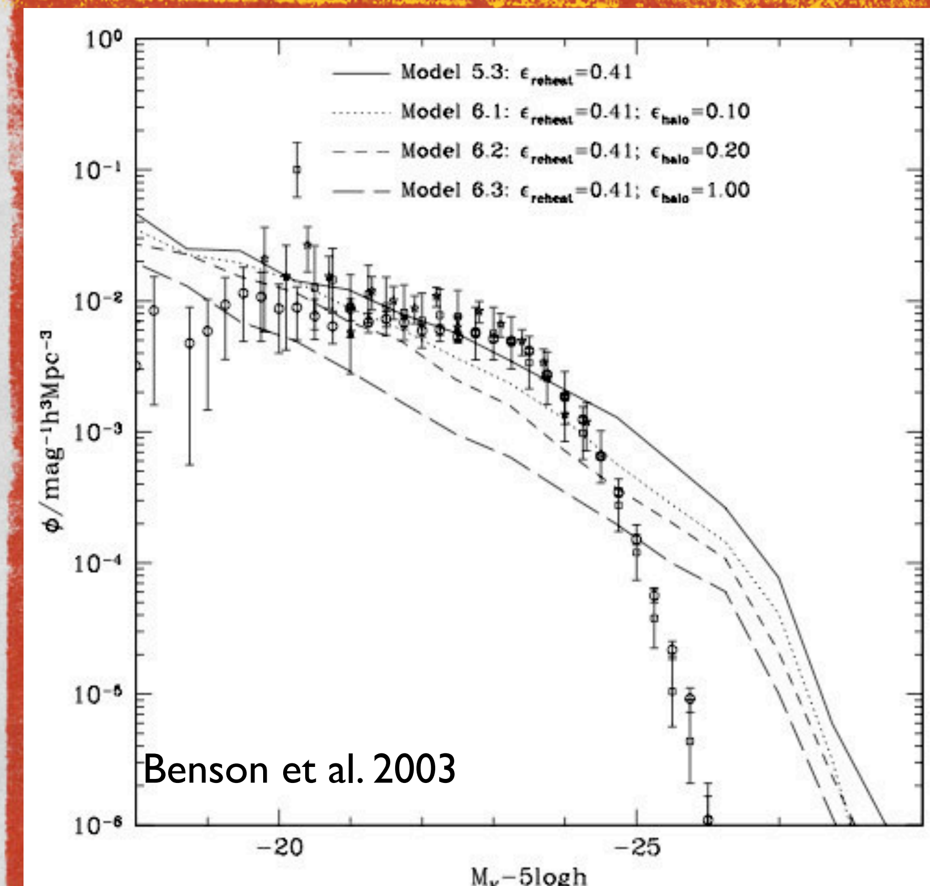
METAL EJECTION EFFICIENCY ξ_Z

VISIBLE MASS ($M_g/M_\odot$)	LUMINOSITY (10^{38} ergs s^{-1}) 0.1	1.0	10
10^6	1.0	0.99	1.0
10^7	1.0	1.0	1.0
10^8	0.80	1.0	1.0
10^9	0.0	0.69	0.97

Mac Low et al. 1999

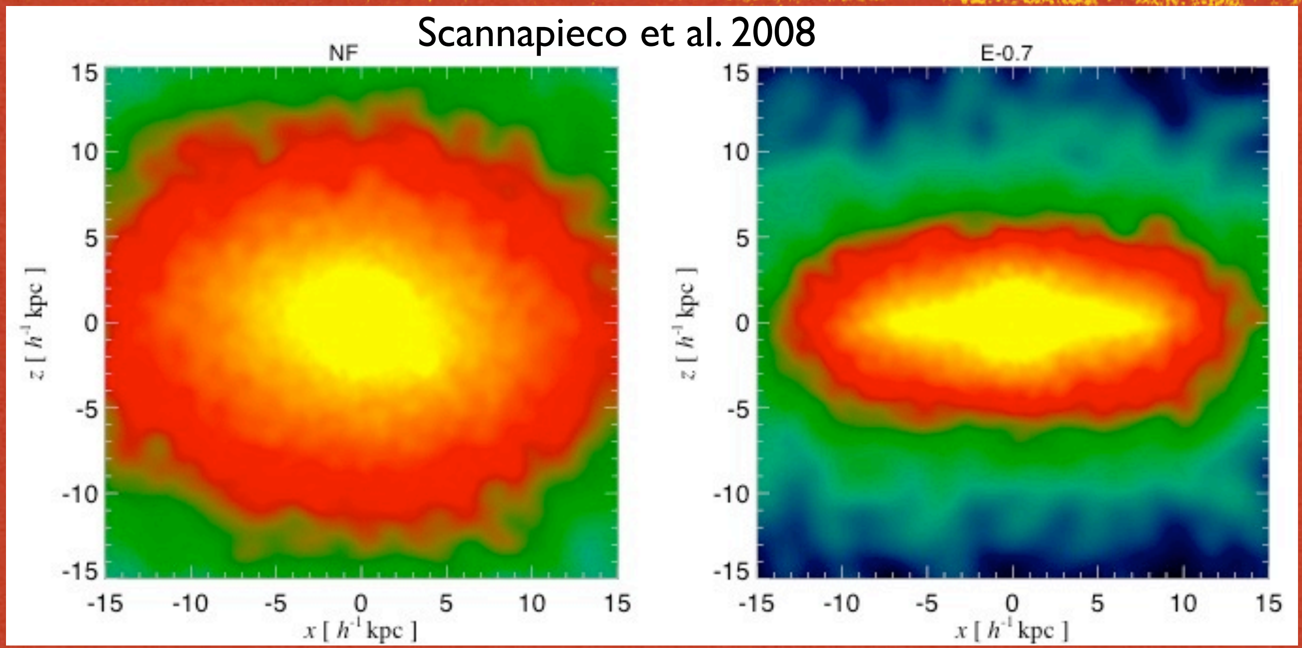
- Hot metals expelled in supernovae are much less bound to the galaxy than the cold ISM.
- Lower mass galaxies have greater efficiencies in ejecting metals.
- This is consistent with dwarf galaxies being metal poor.
- This is also consistent with intracluster gas containing the majority of the metals rather then the galaxies therein.

Feedback in High Mass Galaxies



- SN Feedback from energy injection appropriately suppresses the formation of bright and faint galaxies.
- This form of feedback fails to produce the break in the luminosity function which is observed.
- Superwinds may reproduce the luminosity function, but the energy budget is much greater than is available from supernovae.

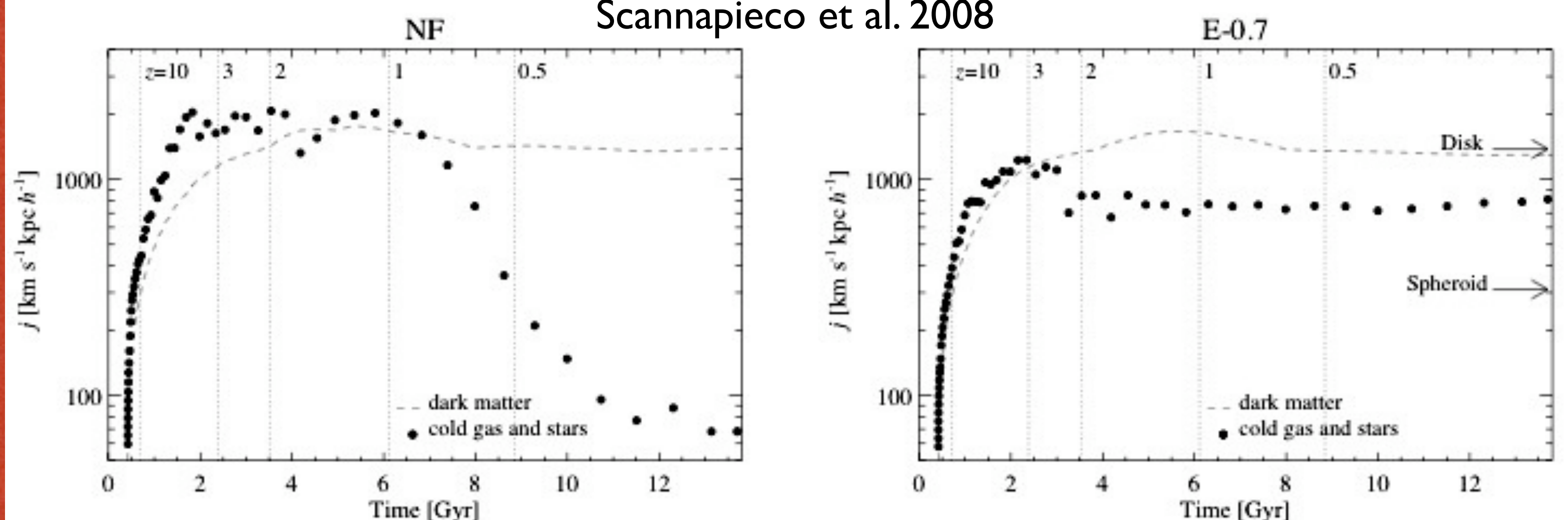
Feedback in Galaxy Formation



- SN Feedback aids in the development of a galactic disk.
- Lack of feedback leads to higher SFR at early times which feed the spheroid.

Our Friend-Angular Momentum

Scannapieco et al. 2008



- Dynamical friction is less important with SN feedback since accreted satellites are less massive.
- Specific angular momentum is conserved in the feedback case which provides a reservoir for later epochs of star formation.

Conclusions

Dwarf Galaxies

- Only modest rates of star formation are required to remove a large fraction of baryonic mass.
- Energy ejection from SNRs is sufficient to remove the galaxies gas.
- Metals are efficiently expelled into the IGM which is consistent with the intracluster gas containing the bulk of the iron.
- Star formation rates are more efficiently suppressed by SN feedback in low mass galaxies.

High Mass Galaxies

- SN Feedback does not play a dominant role in the SFRs of high mass galaxies.
- SN feedback may play an important role in the morphology of galaxies and the formation of the disk.
- SN feedback is still the driving force behind galactic enrichment of metals.
- SN feedback alone fails to reproduce the observed luminosity function of galaxies.
- Simulations show that a galaxy comparable to the milky way might eject 20-30% of its baryonic mass when SFRs are high.