Constraining Gas Flows with Metallicities

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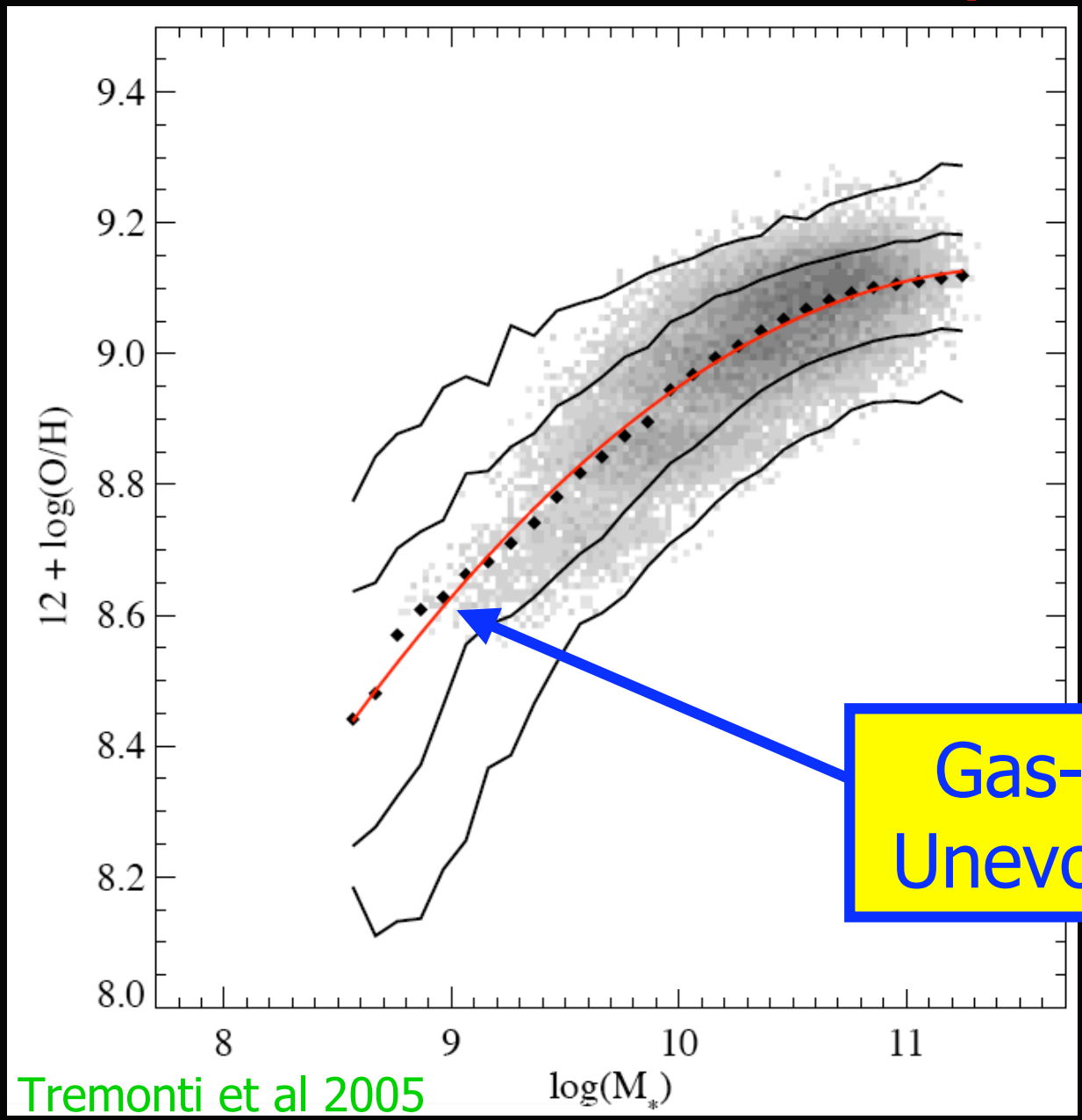
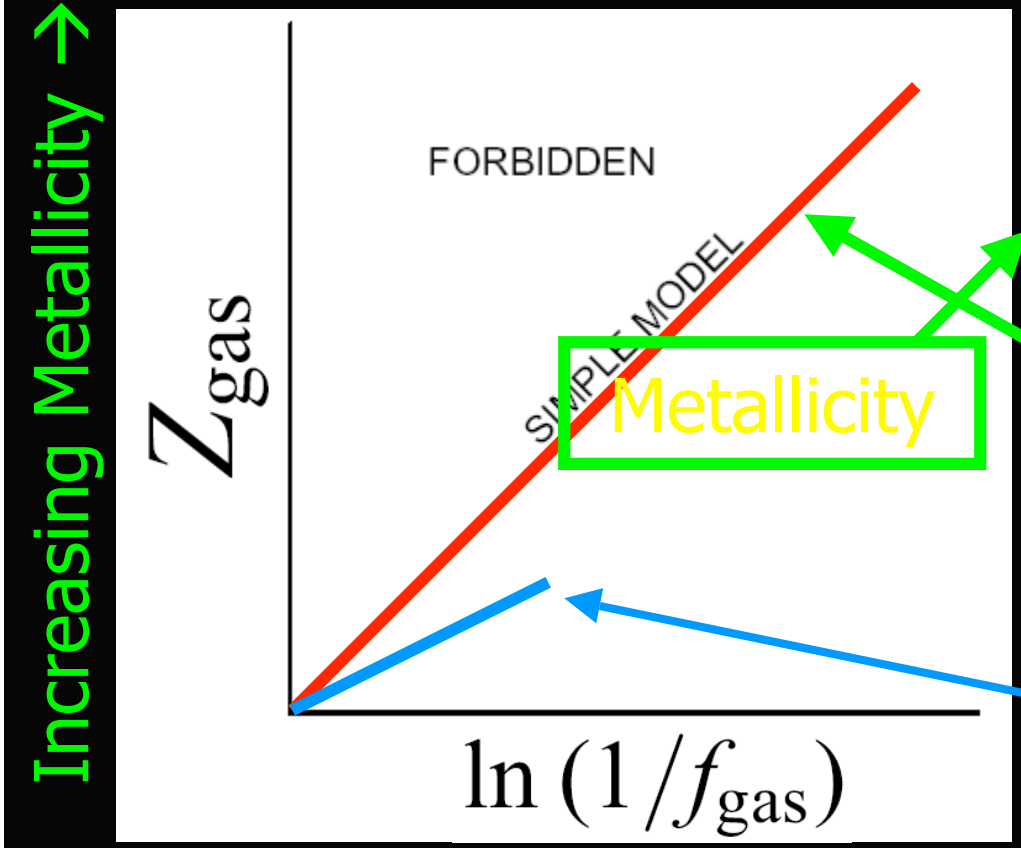
See talks by R. Dave & D. Erb

Disks Follow a Mass-Metallicity Relation



Tremonti et al 2005

What sets the metallicity?



Increasing Metallicity →

Decreasing Gas Fraction →

Edmunds 1990

Closed Box Model

$$Z_{gas} = y_{true} \ln(1/f_{gas})$$

Metallicity

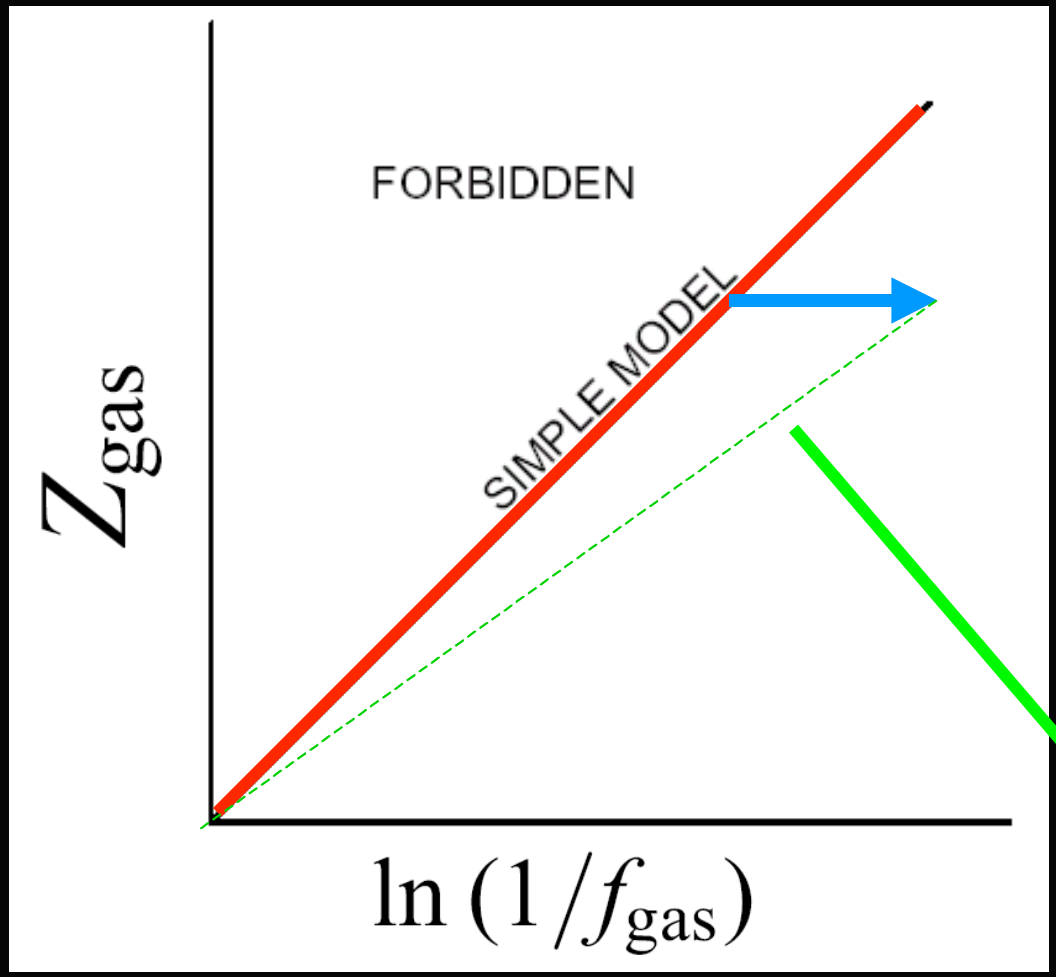
Nucleosynthetic "yield"

Gas Mass Fraction

$$y_{eff} \equiv \frac{Z_{gas}}{\ln(1/f_{gas})}$$

"Effective Yield"

What sets the metallicity?



Increasing Metallicity →

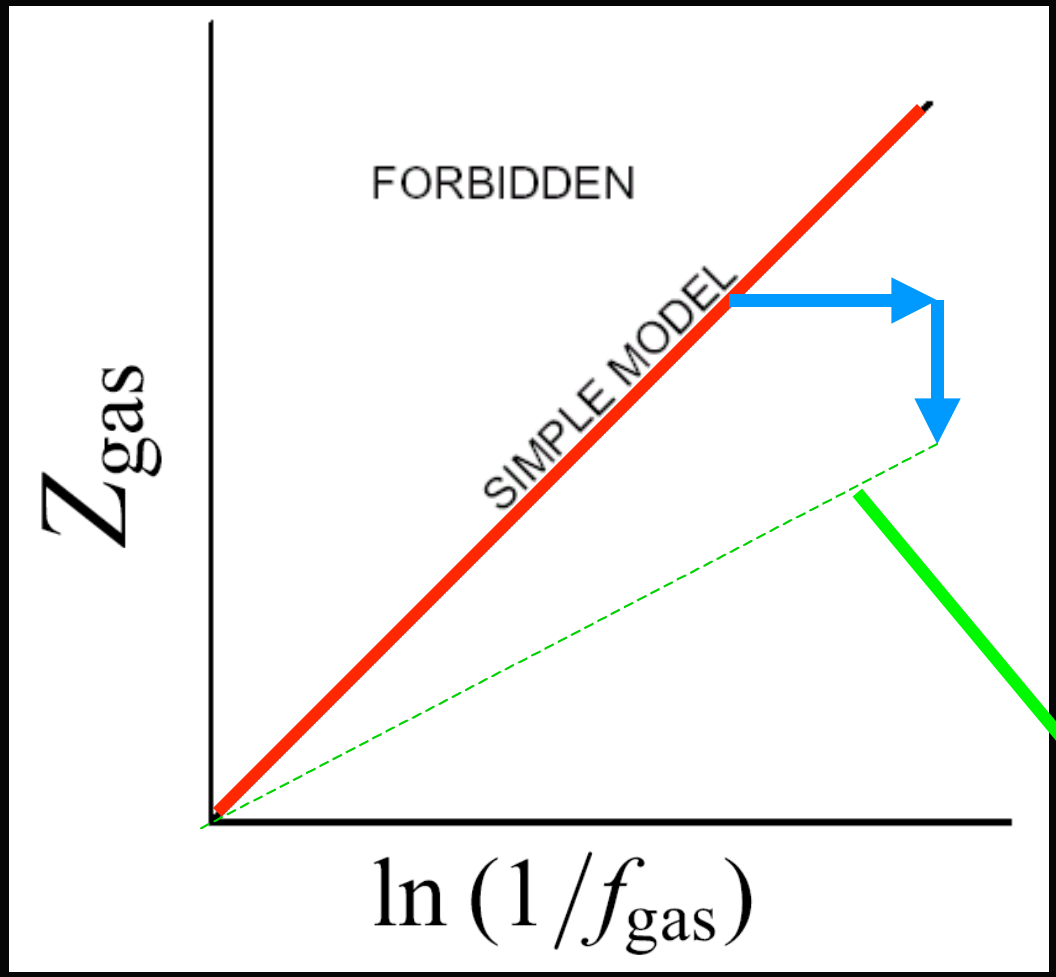
Decreasing Gas Fraction →

"Blast Wave Outflow"

$Z_{outflow} = Z_{ISM}$

Slope=y_{eff}

What sets the metallicity?



Increasing Metallicity →

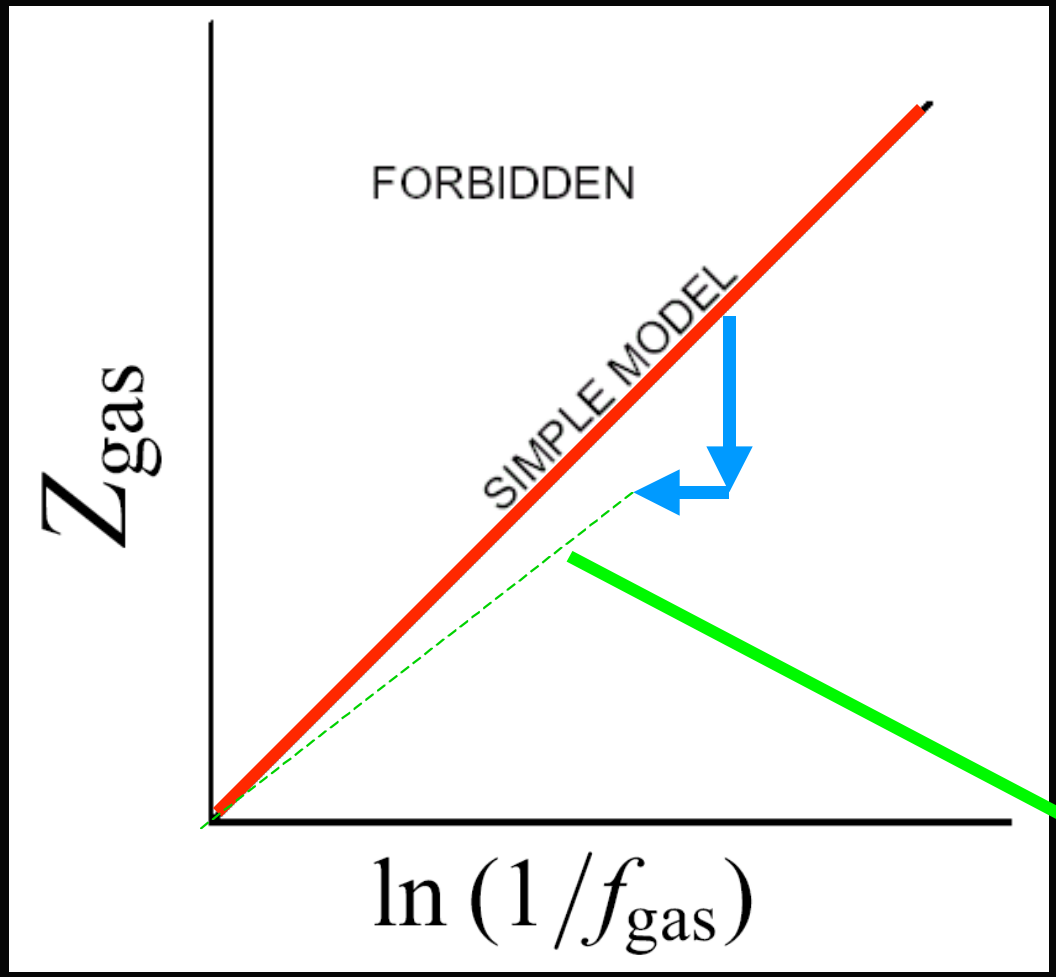
Decreasing Gas Fraction →

"Enriched Outflow"

$Z_{outflow} = Z_{SN}$

Slope=y_{eff}

What sets the metallicity?



Increasing Metallicity →

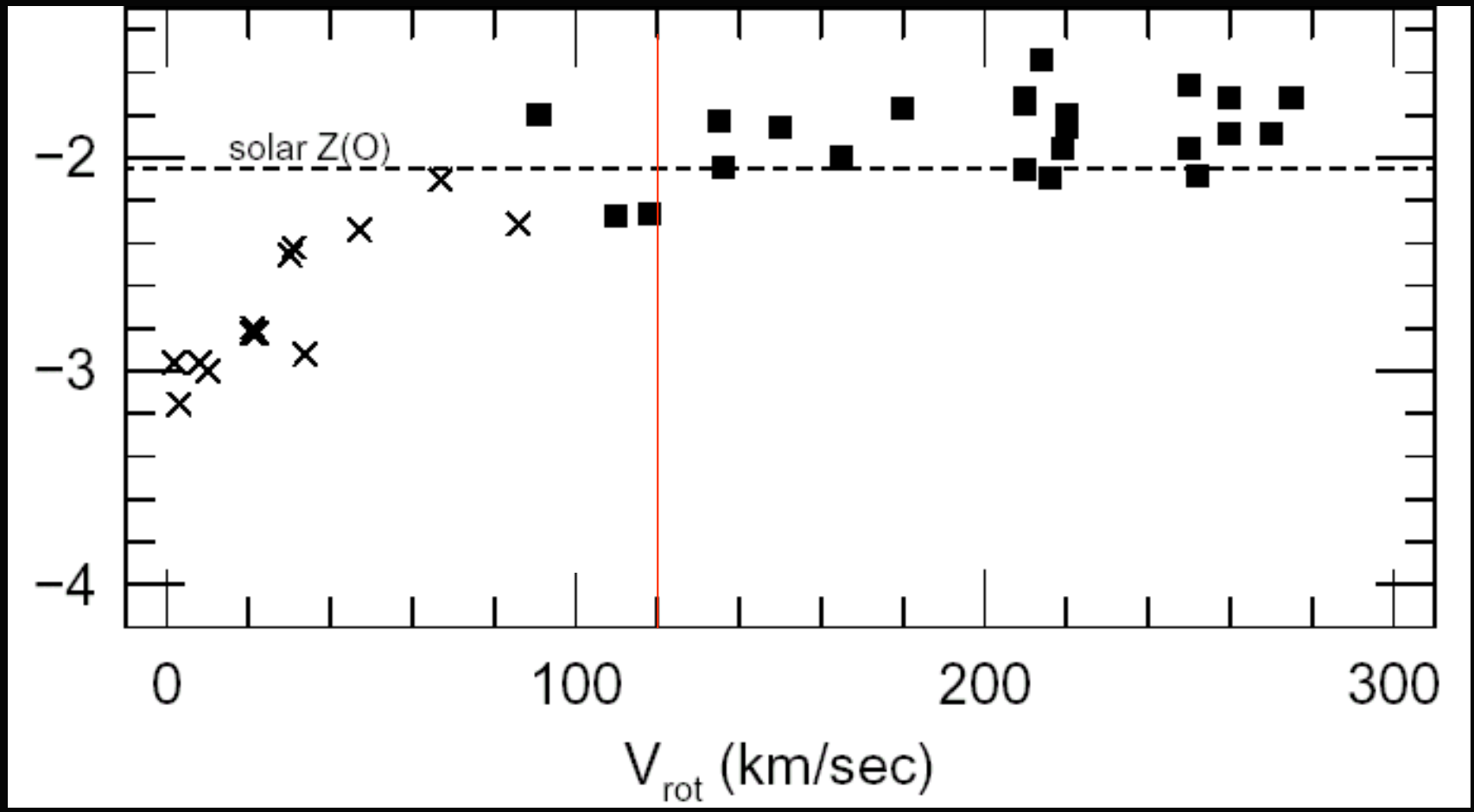
Decreasing Gas Fraction →

"Infall"

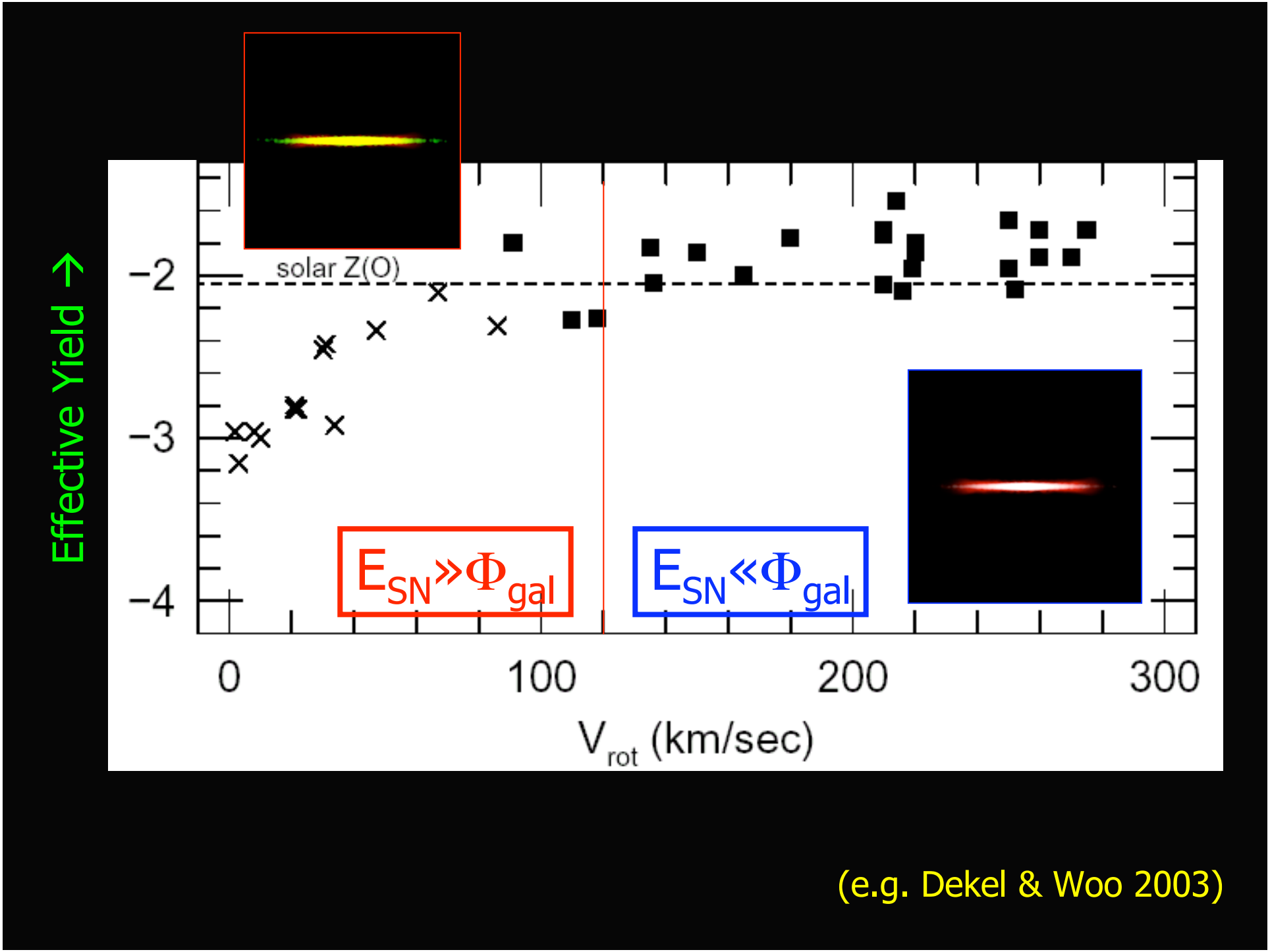
$Z_{infall} = 0$

Slope=y_{eff}

Effective yield is constant for V > 120 km/s



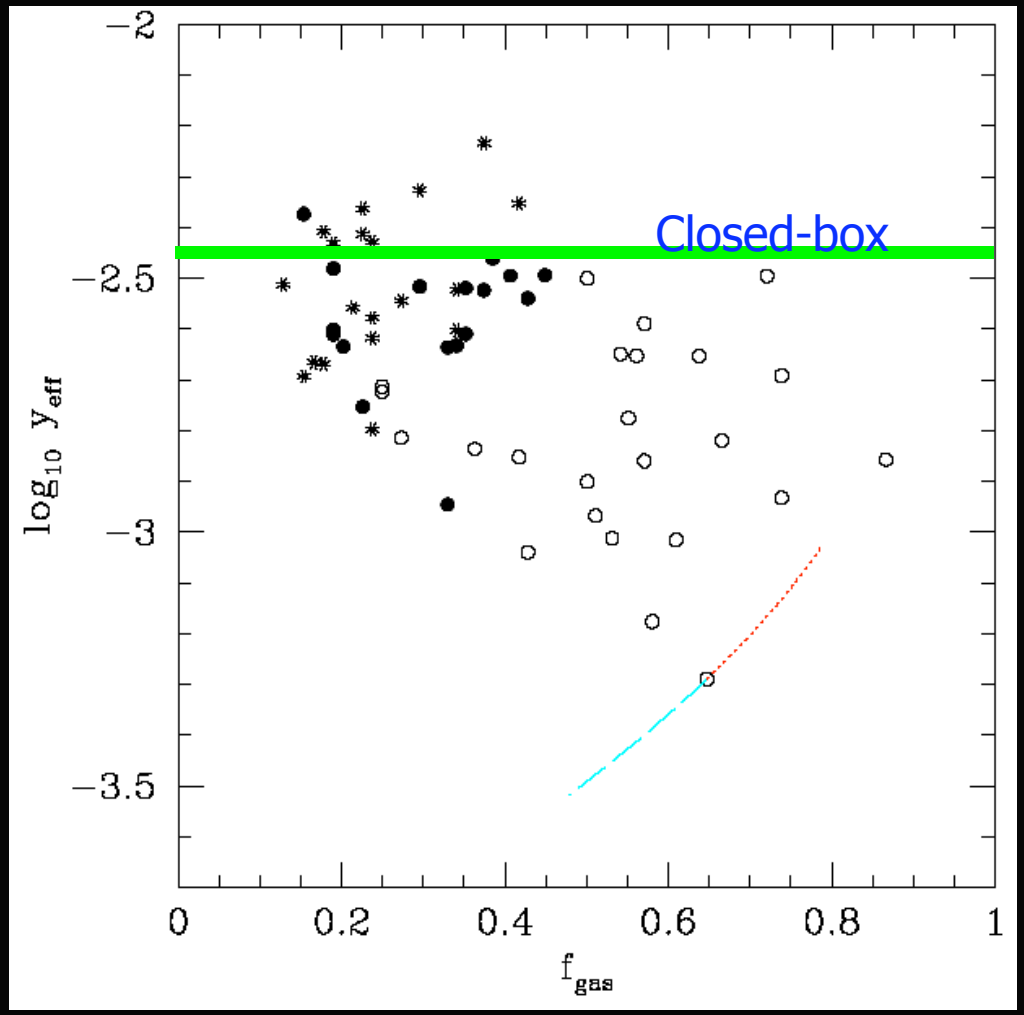
Garnett 2002



(e.g. Dekel & Woo 2003)

3 scenarios:

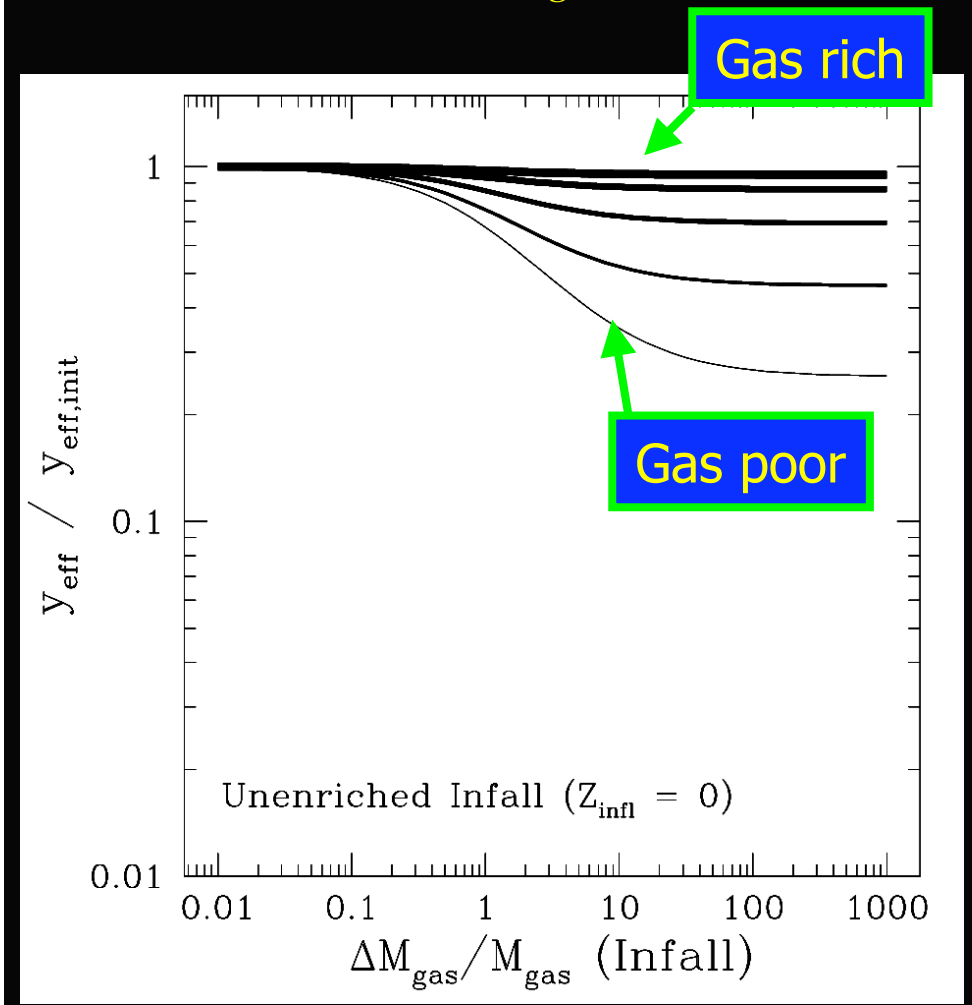
1. Infall
2. Blast wave outflow
3. Metal-enriched outflows (dominated by fresh production)

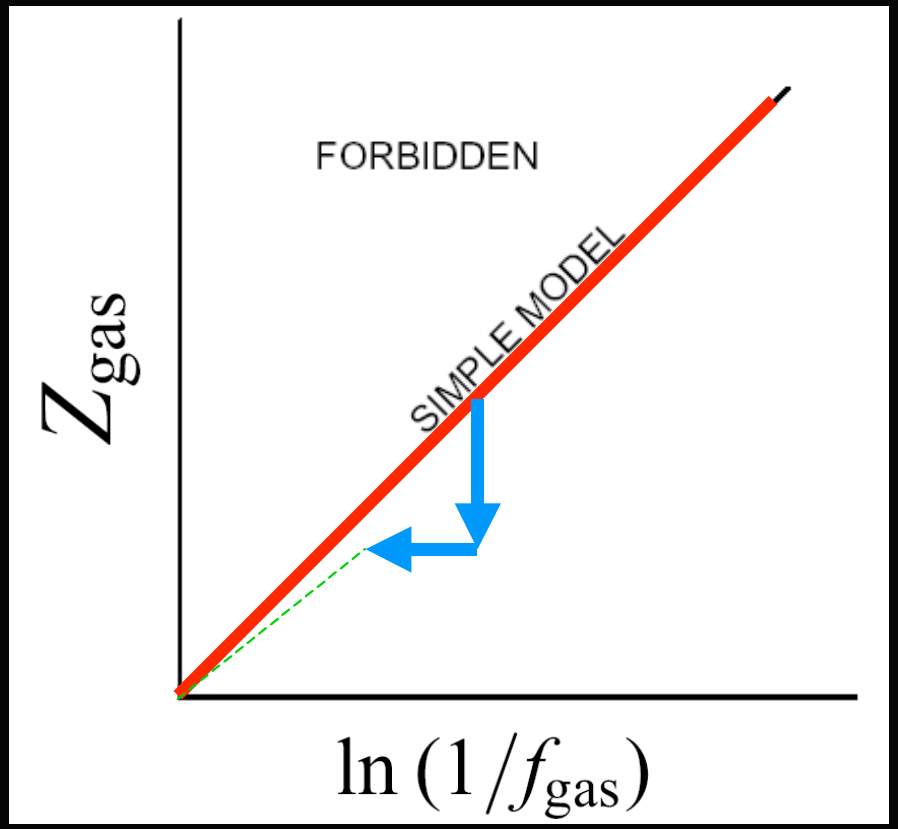


How do y_{eff} and f_{gas} vary with ΔM_{gas}, for different initial f_{gas}?

Metal-Free Infall:

- Decreases y_{eff} *only* for gas-poor systems
- For a given f_{gas} there is a minimum possible y_{eff}

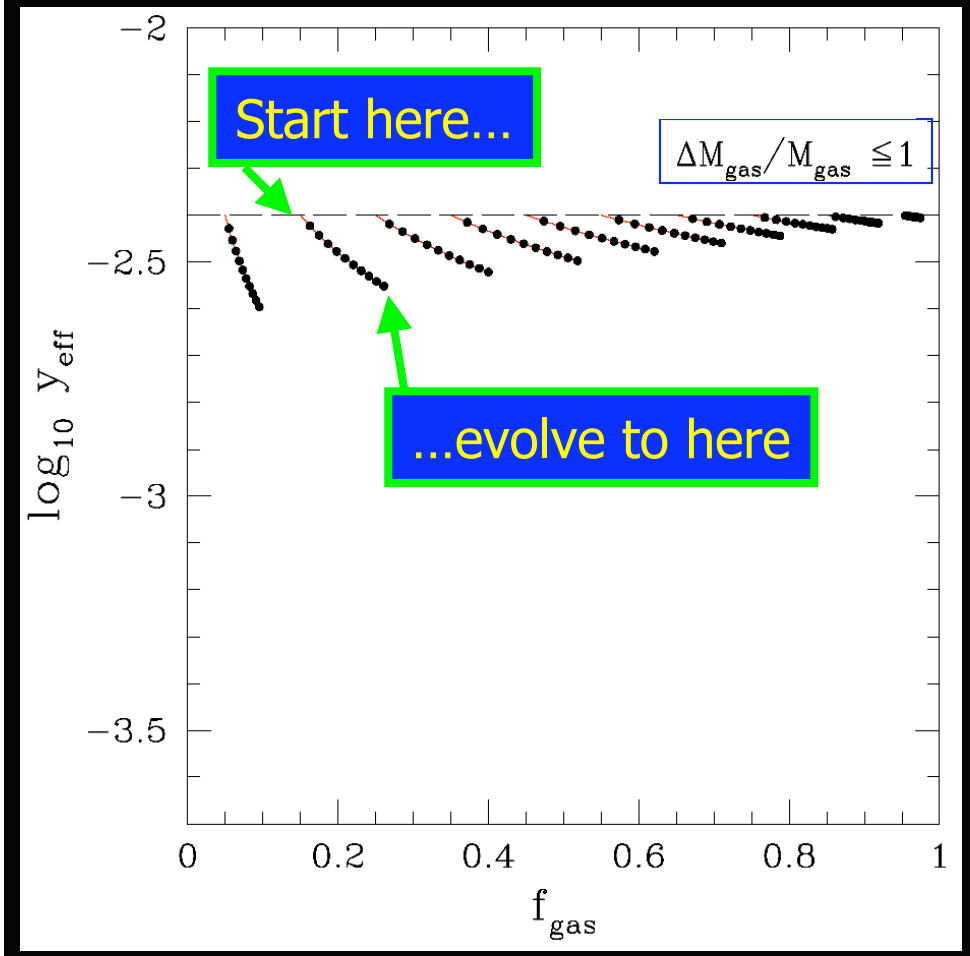


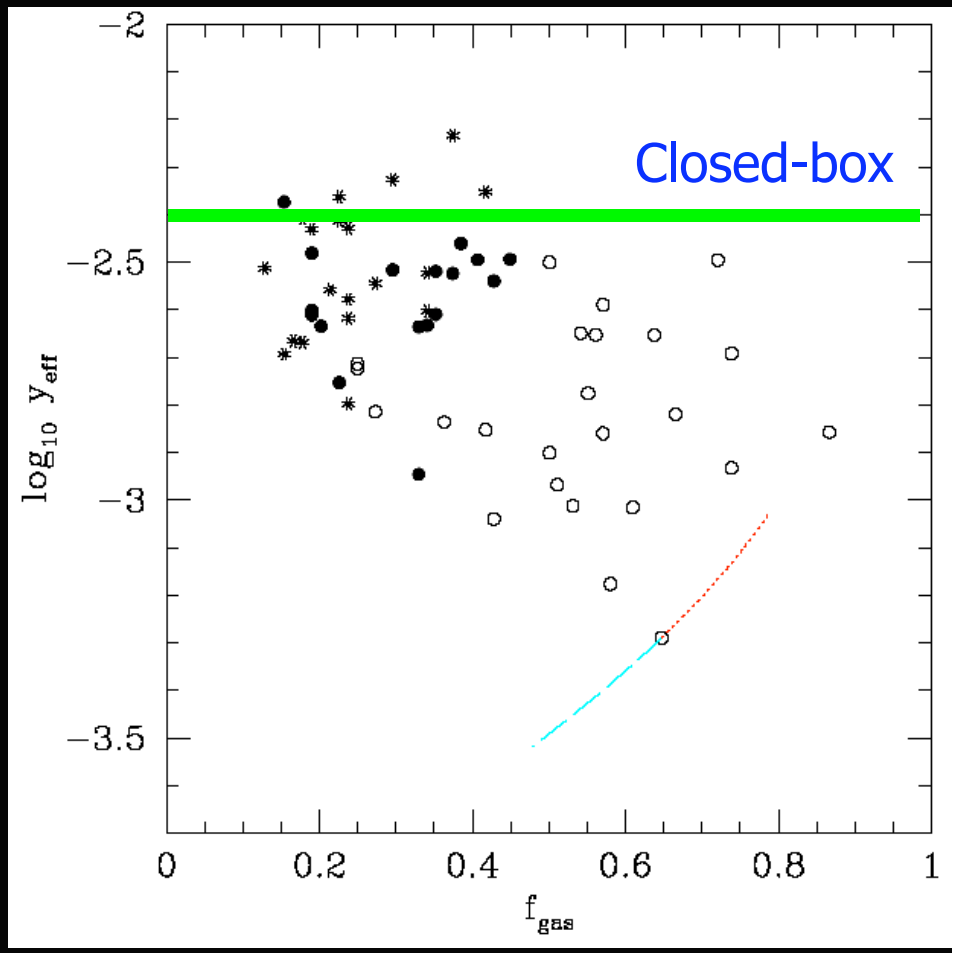


Increasing accretion →

Metal-Free Infall:

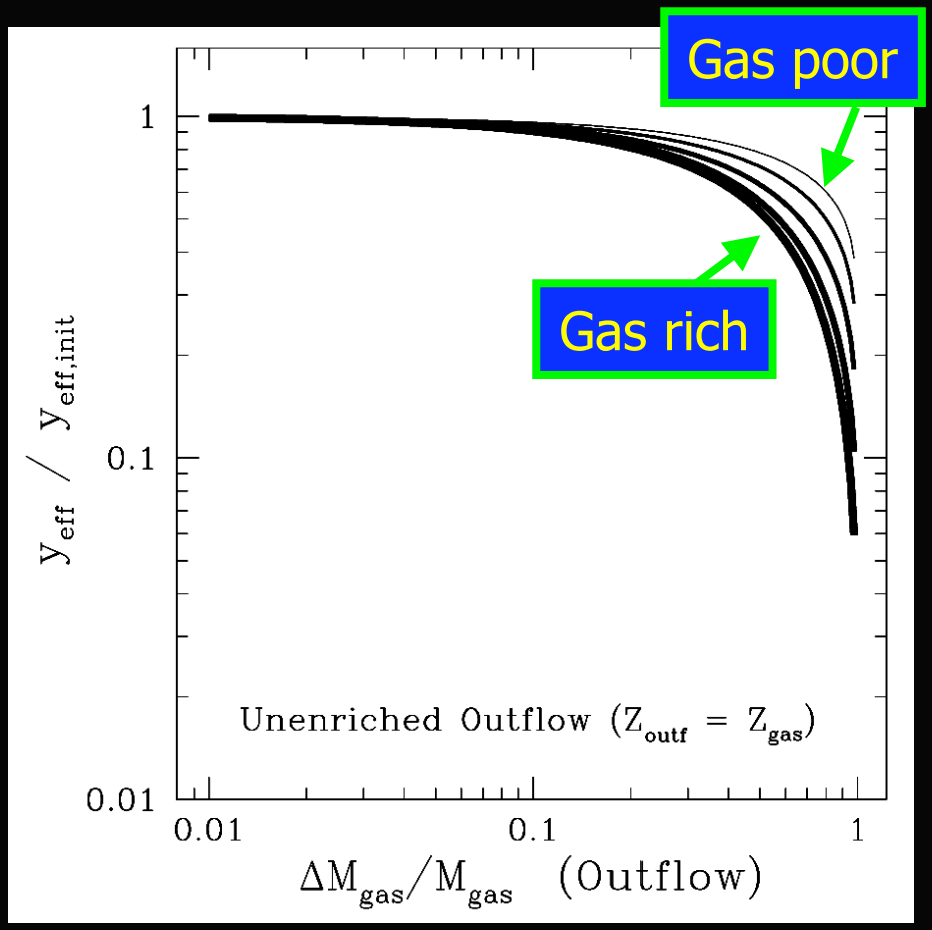
- Decreases y_{eff} *only* for gas-poor systems
- For a given f_{gas} there is a minimum possible y_{eff}

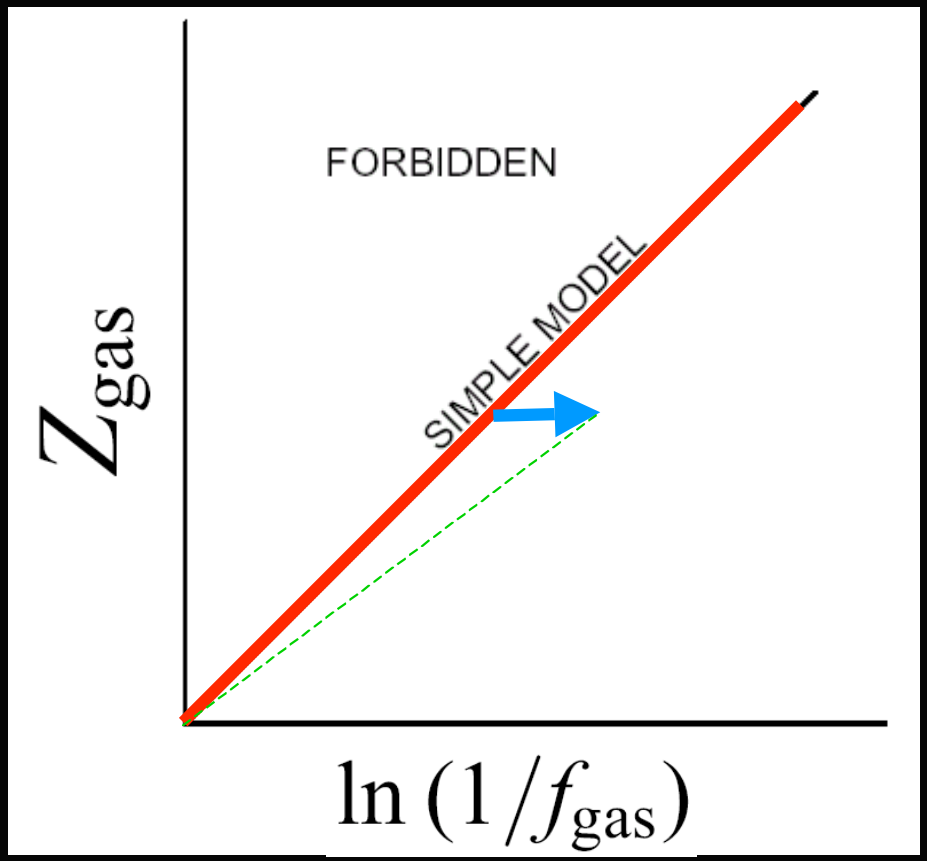




Unenriched "blast-wave" outflow:

- Reduced y_{eff} only for near total gas loss.

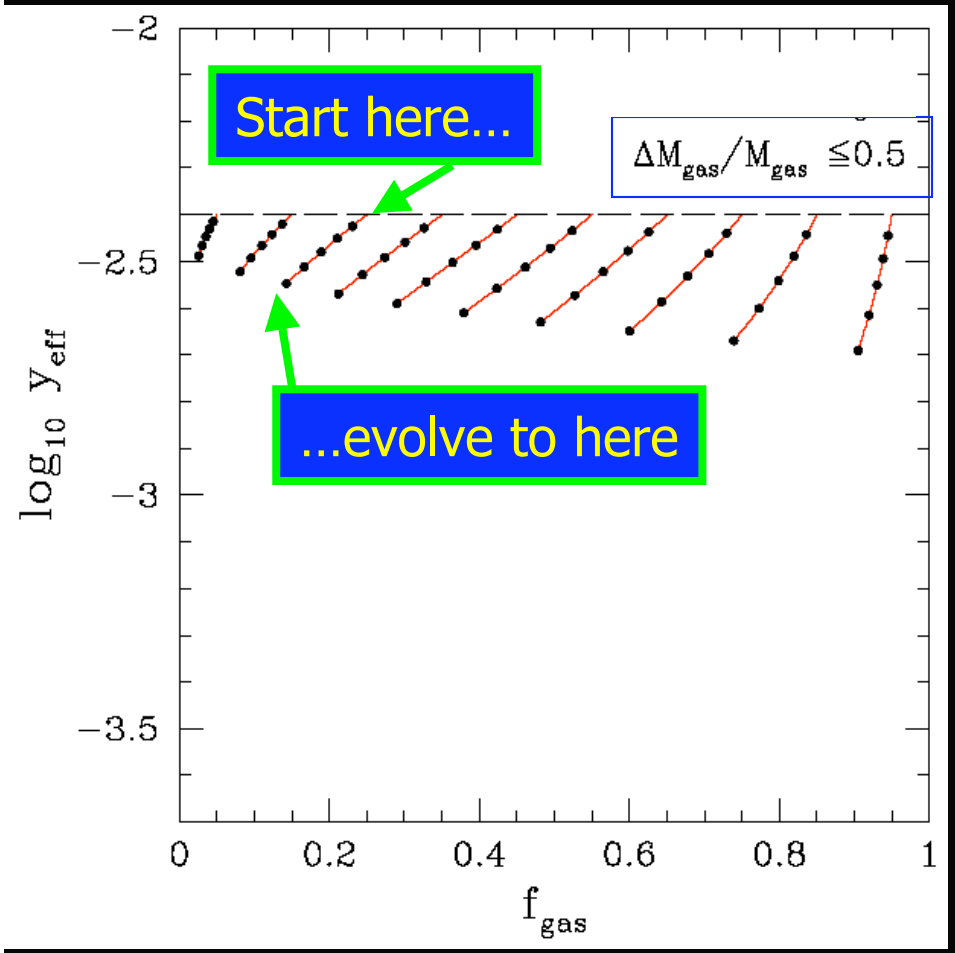


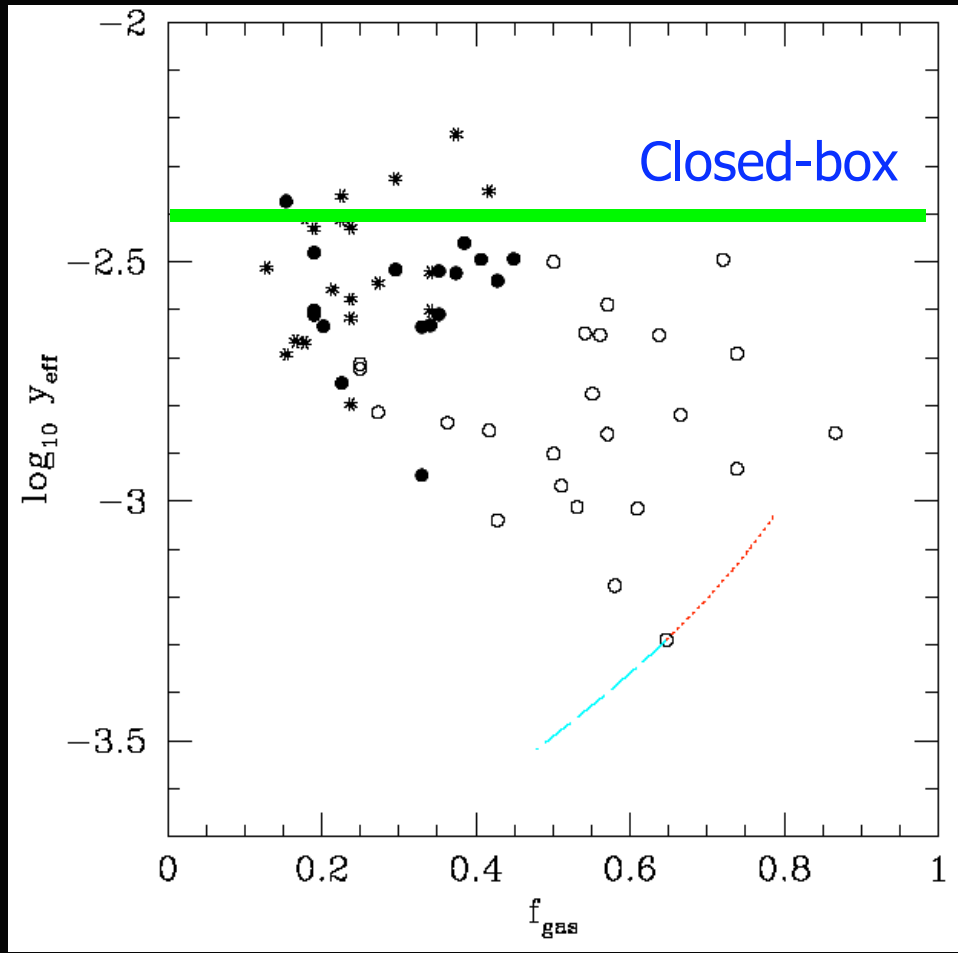


Increasing gas loss →

Unenriched "blast-wave" outflow:

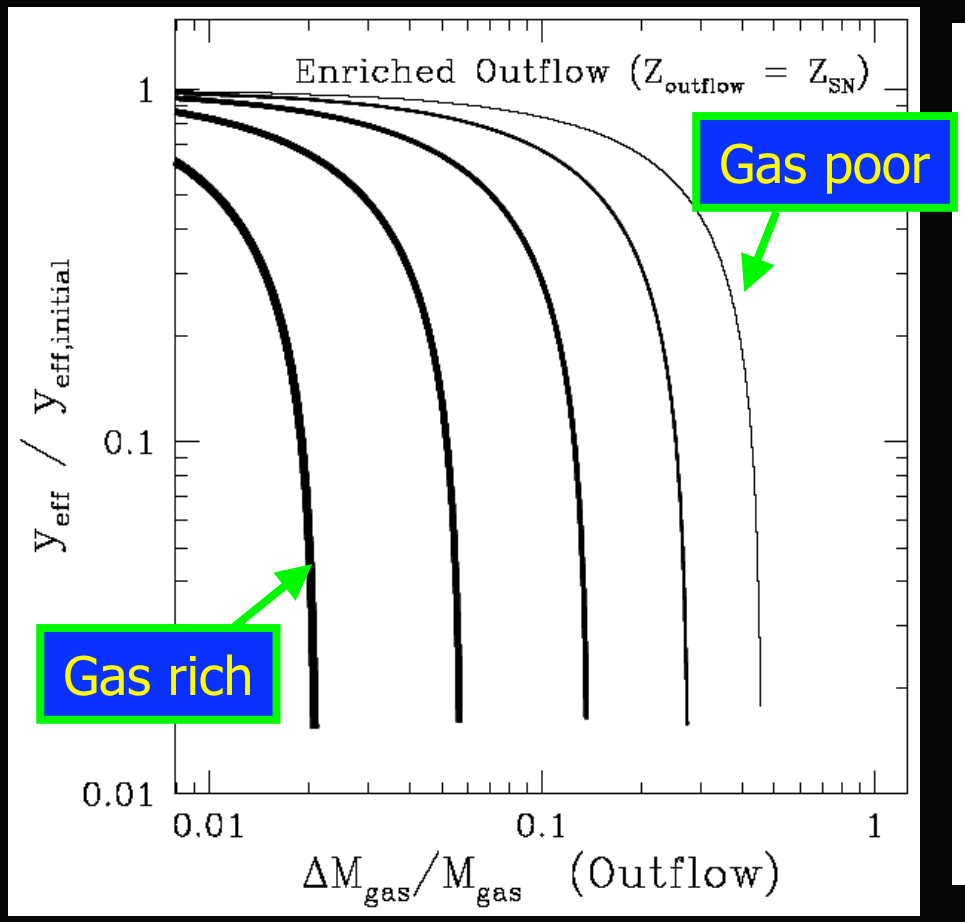
- Reduced y_{eff} only for near total gas loss.

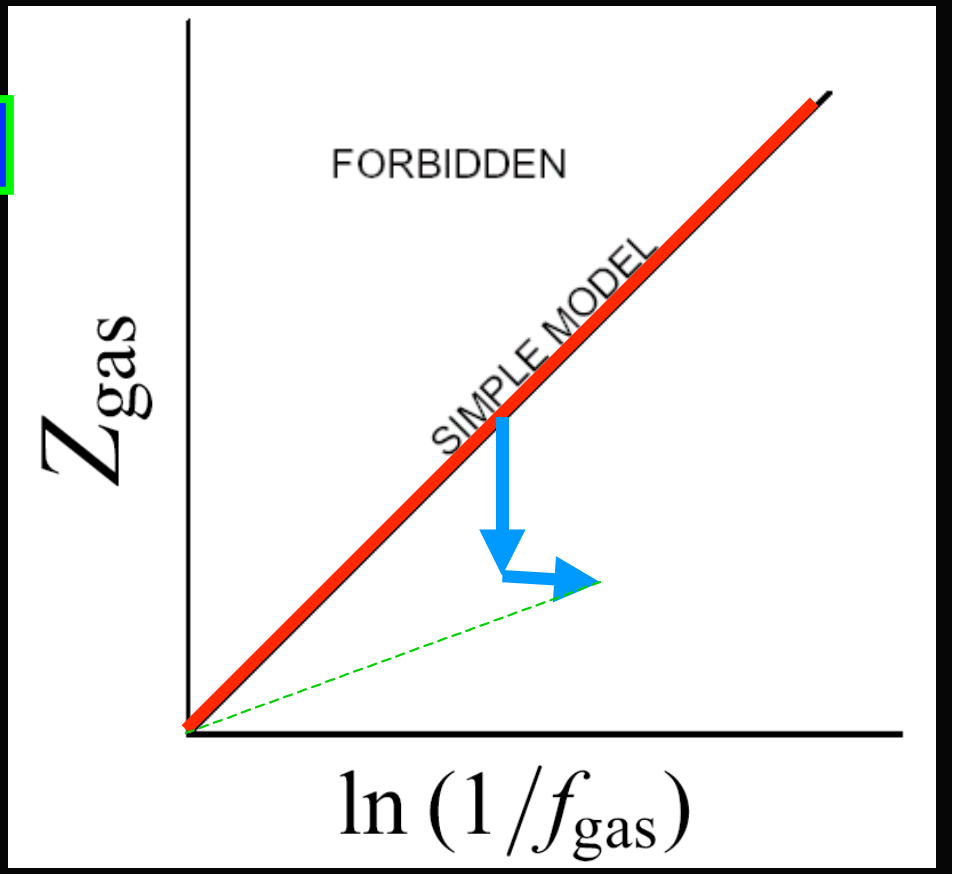




Enriched "SN-ejecta" outflow:

- Drops y_{eff} significantly for gas-rich systems.

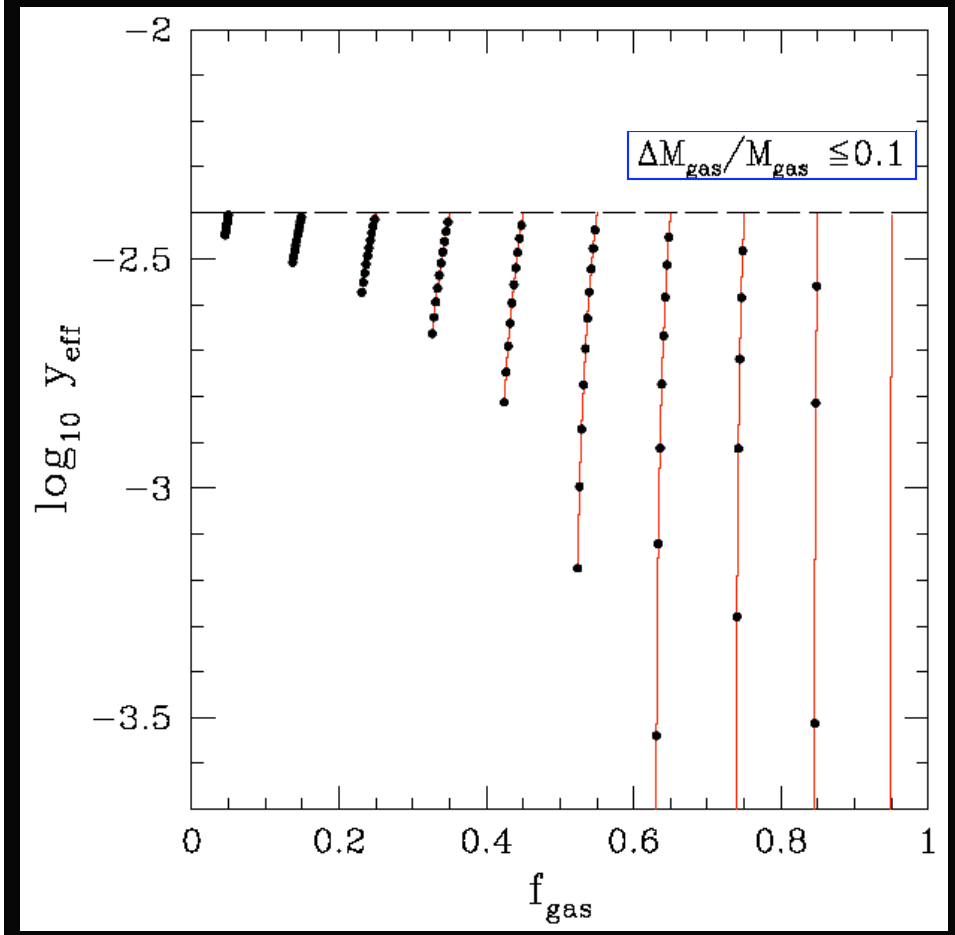


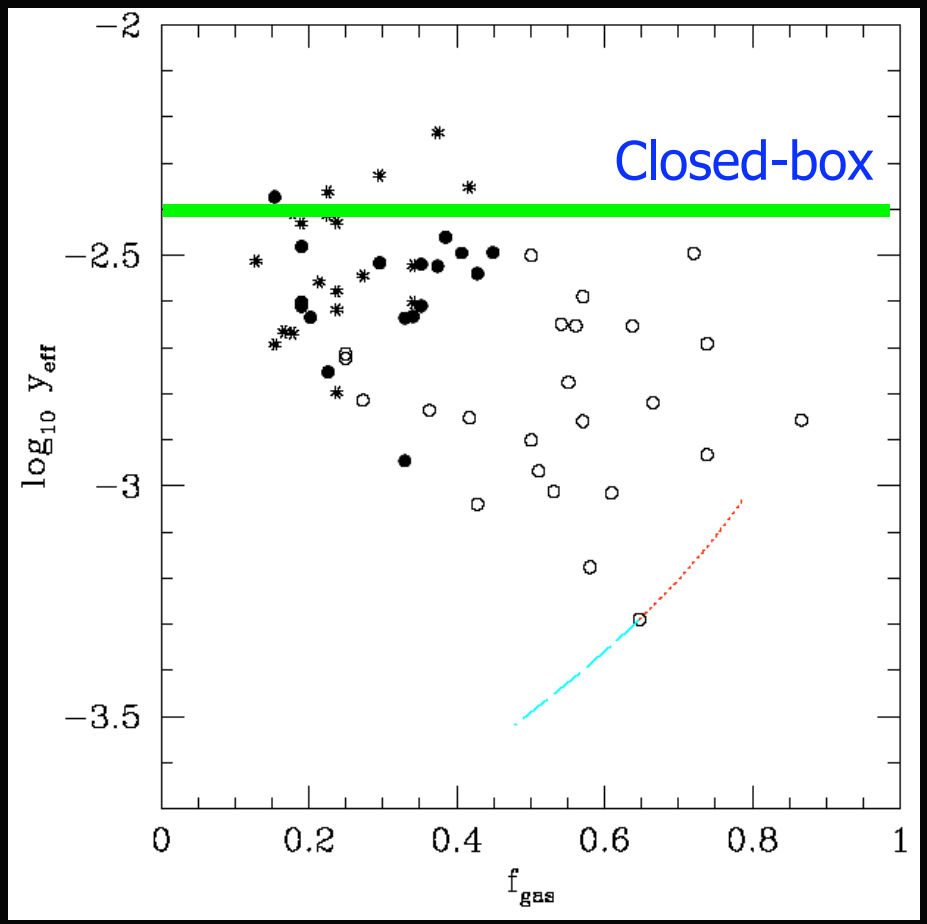


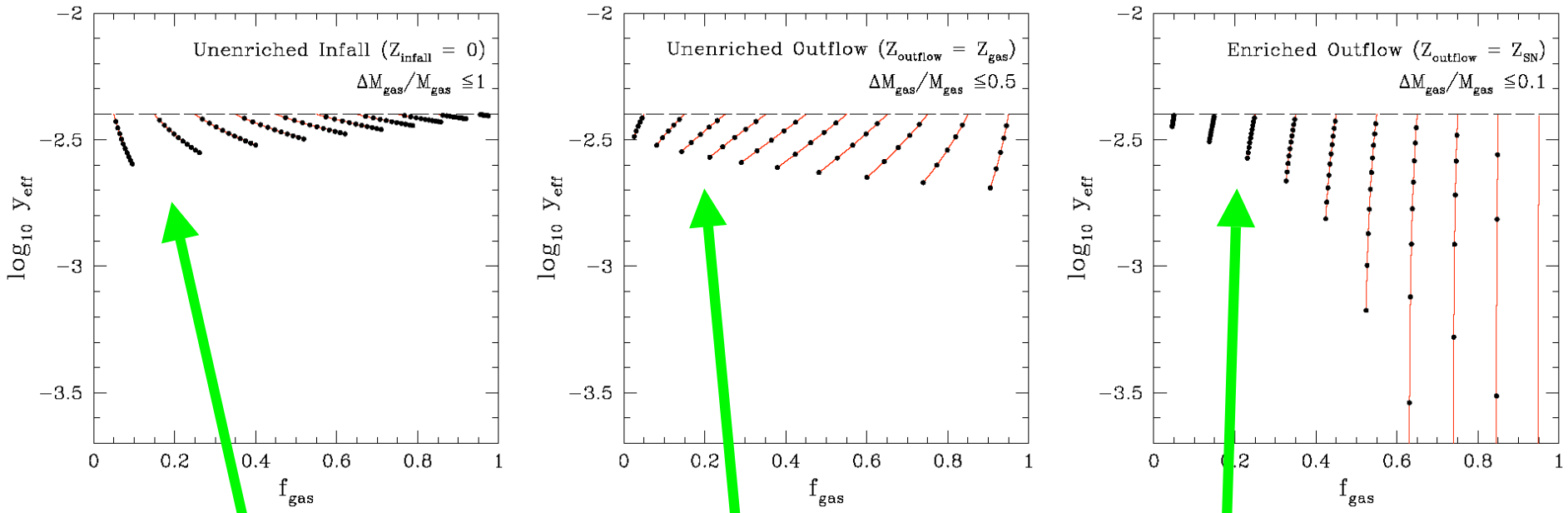
Increasing gas loss →

Enriched "SN-ejecta" outflow:

- Drops y_{eff} significantly for gas-rich systems.
- *Does not* significantly change y_{eff} for *gas-poor* galaxies.

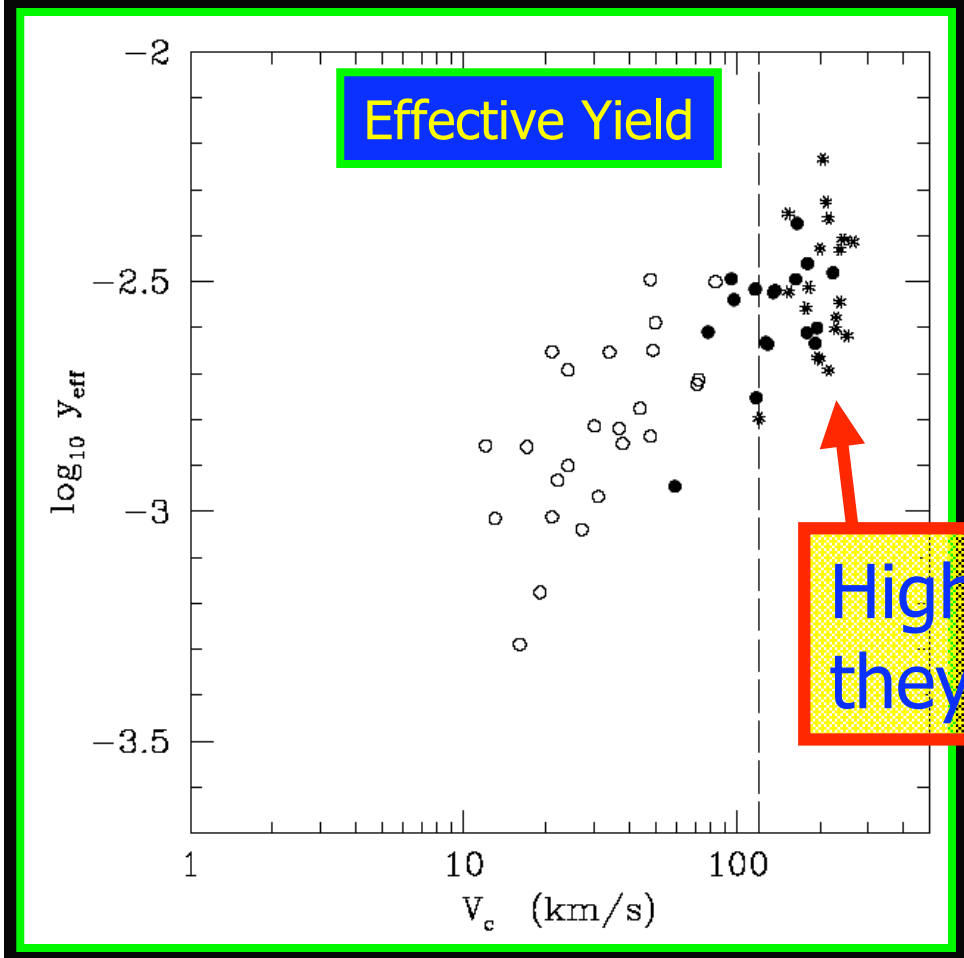


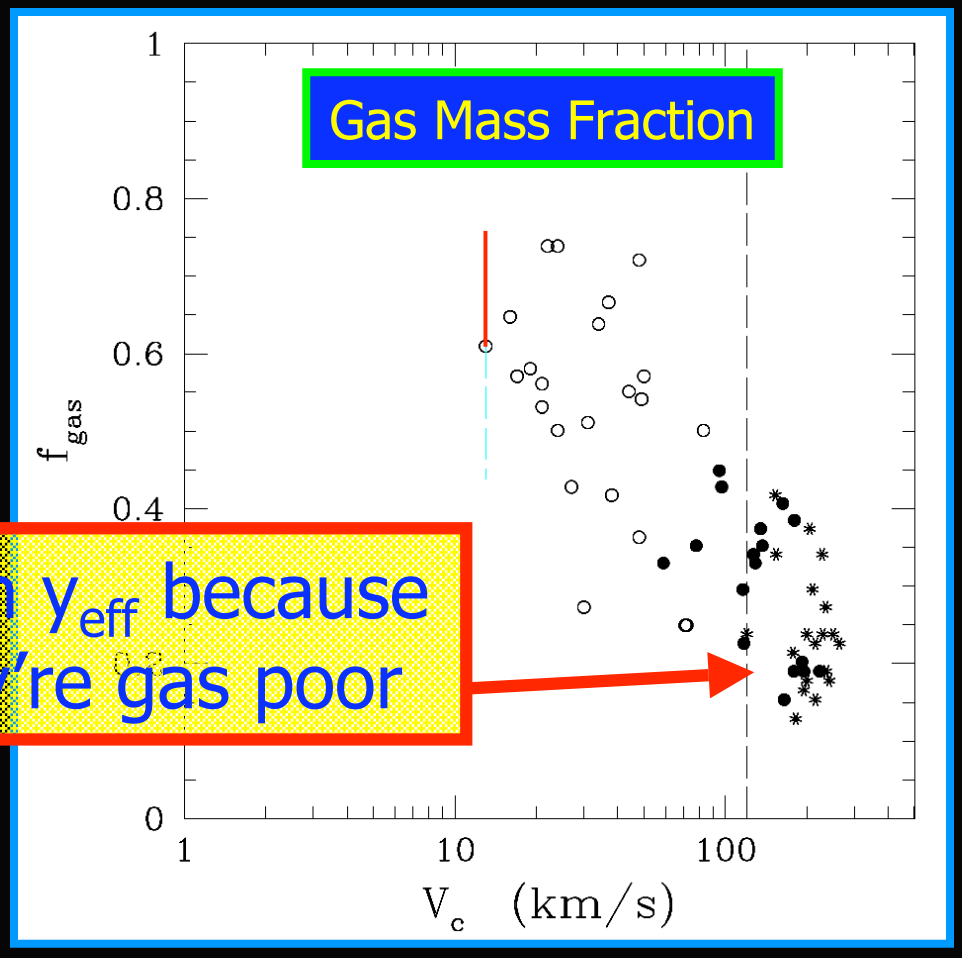




Gas flows *do not* change the effective yield of gas-poor systems!

The V_c ~ 120 km/s transition in y_{eff} does not necessarily indicate the mass scale at which winds stop!

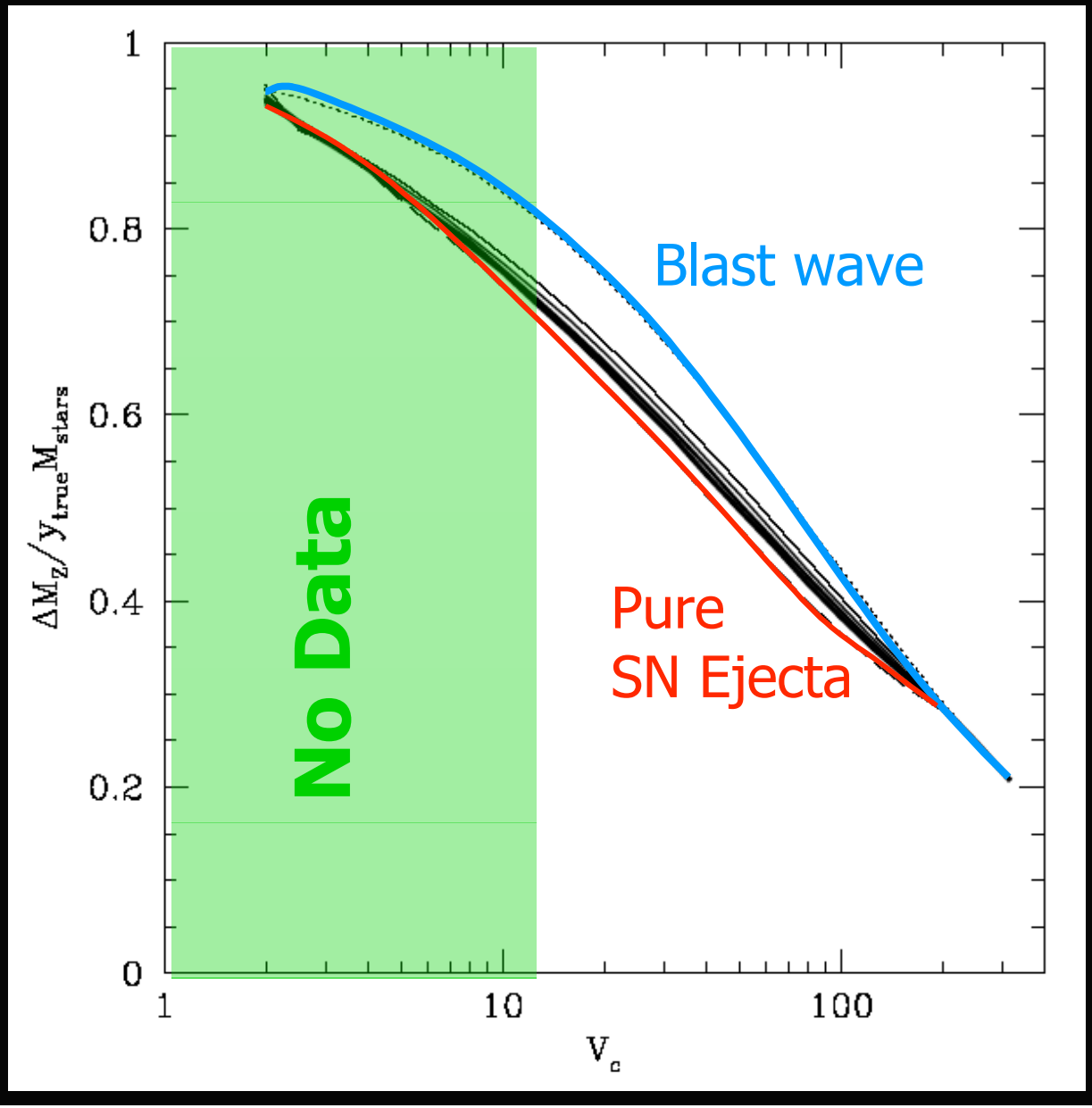




High y_{eff} because they're gas poor

What gas & metal loss produces these trends?

Fraction of metals lost:



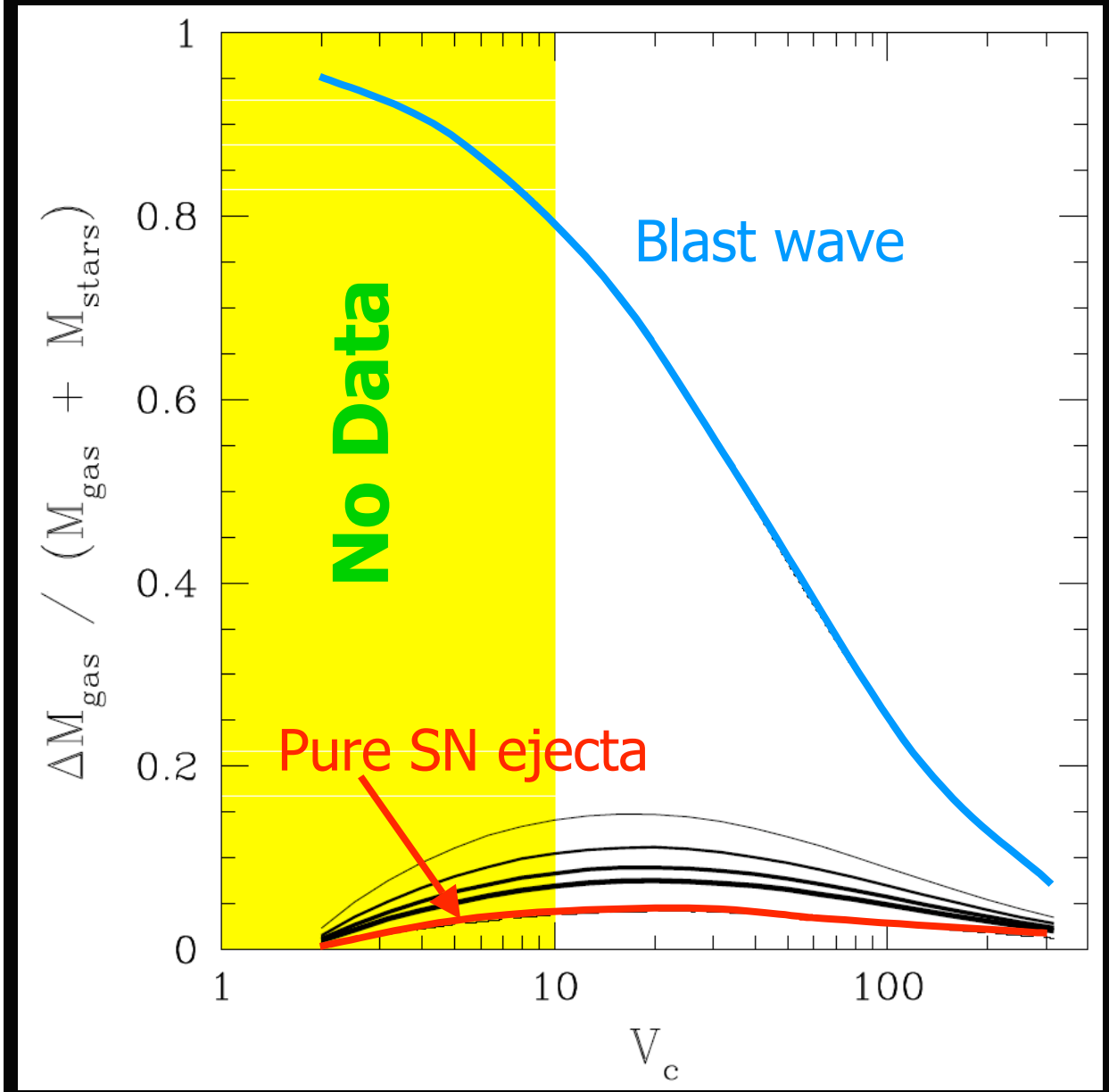
Depends on:

- Galaxy mass
- Amount of entrained ISM

No feature at 120 km/s

See also Tremonti et al 2004, Bouche et al 2007

Maximum Fractions of Baryons lost:

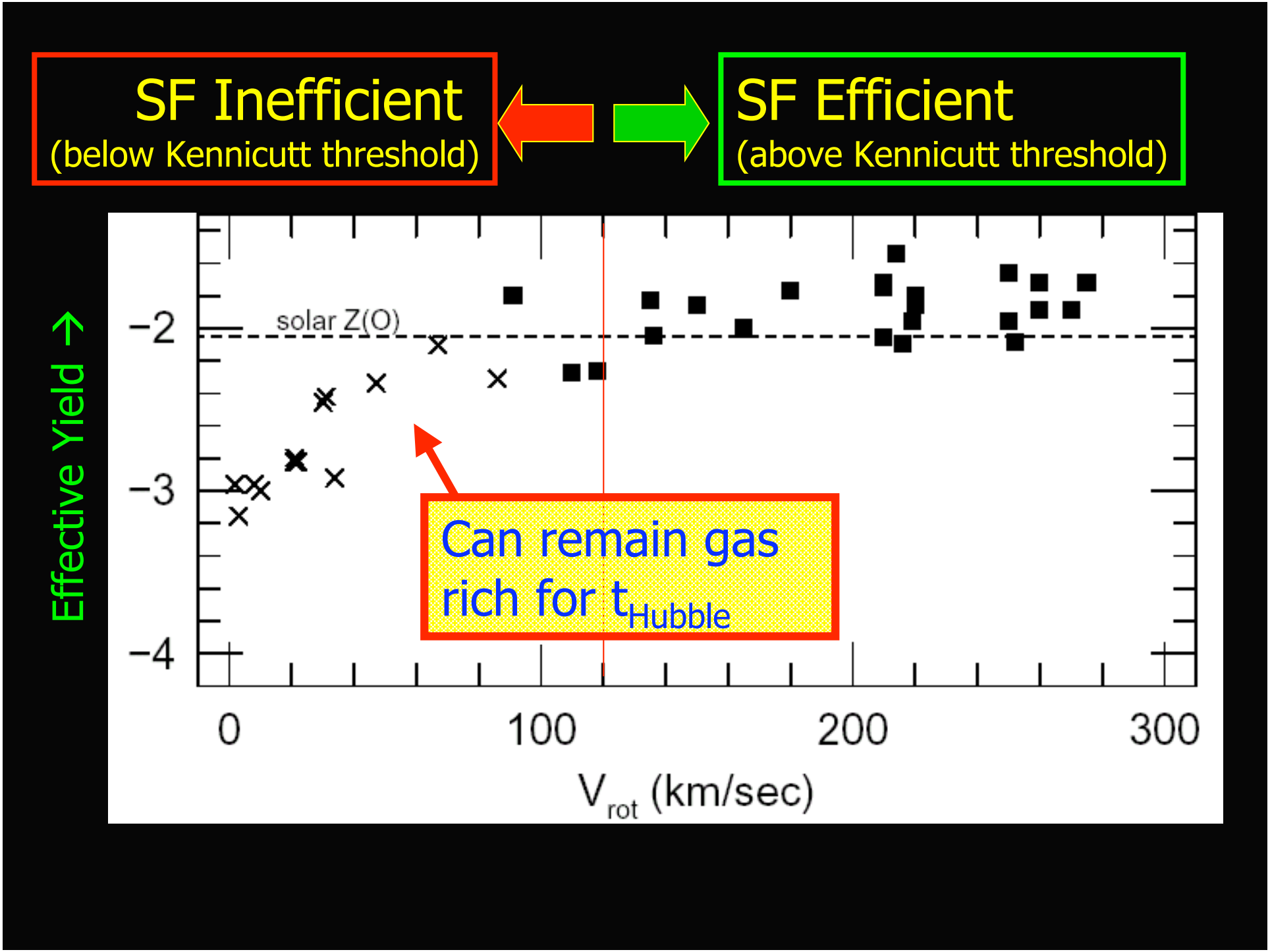


Overall gas loss is small

No feature at 120 km/s

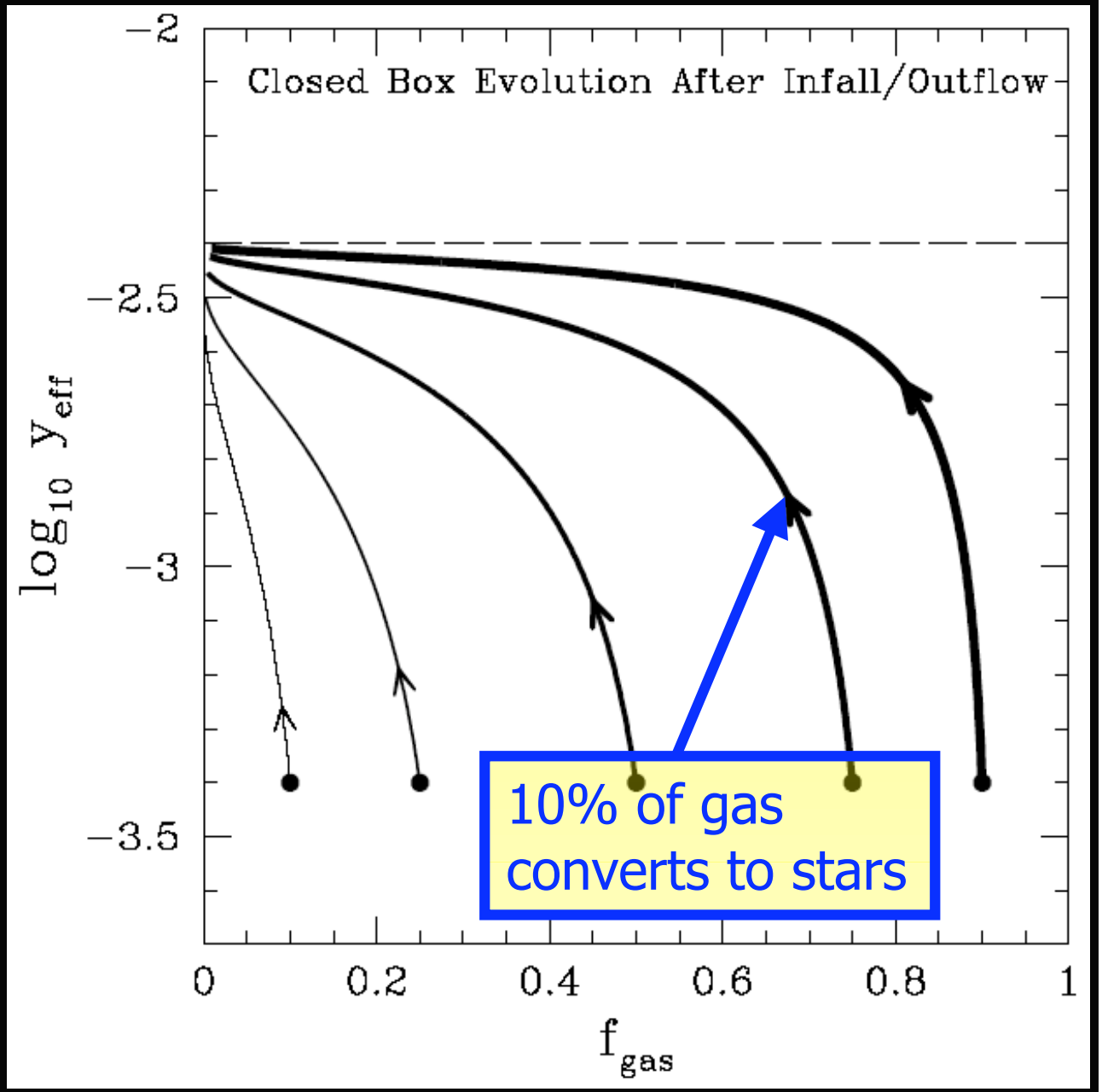
Varies only by factor of 2-3

See also Bouche et al 2007


SF Inefficient
(below Kennicutt threshold)
SF Efficient
(above Kennicutt threshold)
Effective Yield →
−2
−3
−4
solar Z(O)
Can remain gas rich for t_{Hubble}
0
100
200
300
V_{rot} (km/sec)

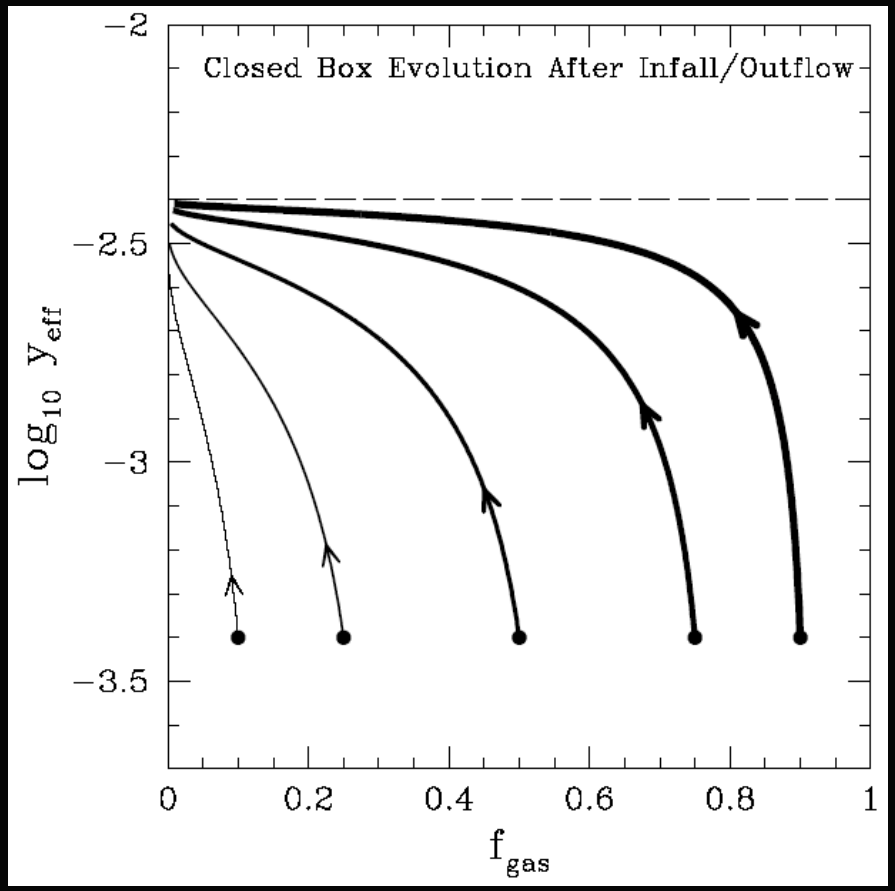
After gas flow stops, SF returns to closed-box

- Effective yield increases back towards y_{true}



Maintaining low y_{eff} *requires* low star formation efficiency:

Suppresses return to closed-box y_{eff}

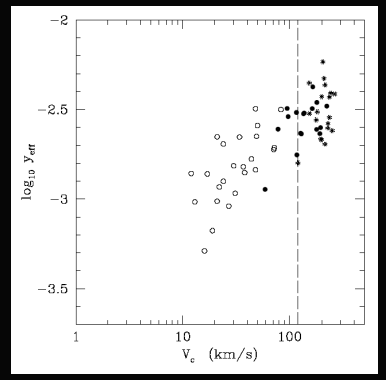


Low Star formation efficiency:

- Keeps galaxies gas rich
- Makes outflows effective at reducing y_{eff}
- Keeps y_{eff} low between episodes of mass-loss

Conclusions

- Drop in y_{eff} can only be produced by *metal-enriched winds* in *gas rich* systems



- Drop in SF efficiency at V~120 km/s:
  - Keeps f_{gas} large
  - Keeps subsequent SF low
- Metal & gas loss is modest but increases steadily with decreasing mass
- Gas flows in gas-poor systems have no impact on y_{eff}.