Metallicity and the IMF

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Granada March 2007

Is there an invariable IMF?
$x = 1.35$ vs $x = 1.7$.

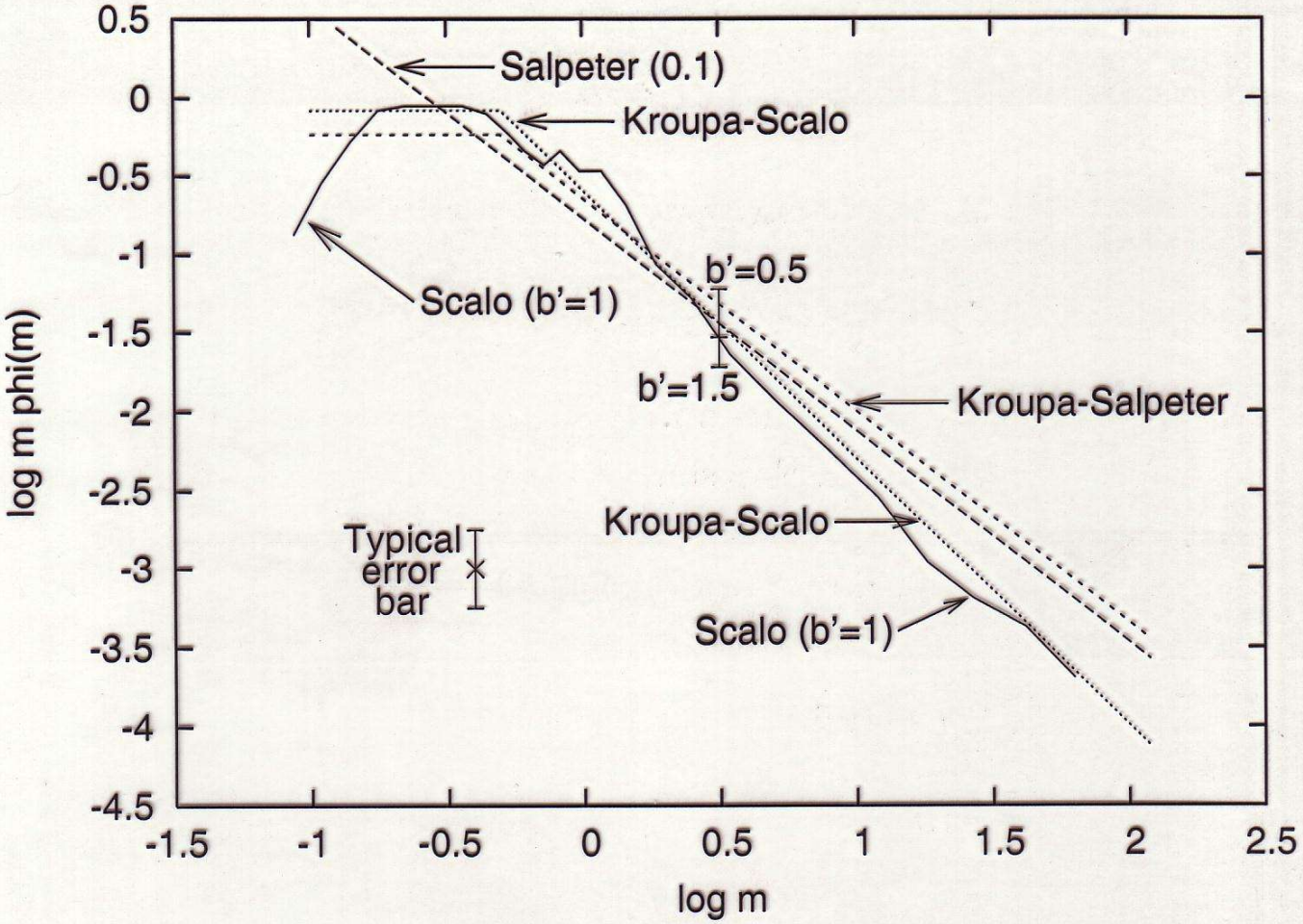
Does it depend on metallicity?
$\Delta Y/\Delta Z$ and α/Fe.

Does it depend on SFR? (Star cluster MF).
E-galaxies: IMF vs star formation history.
Problems with hierarchical clustering.

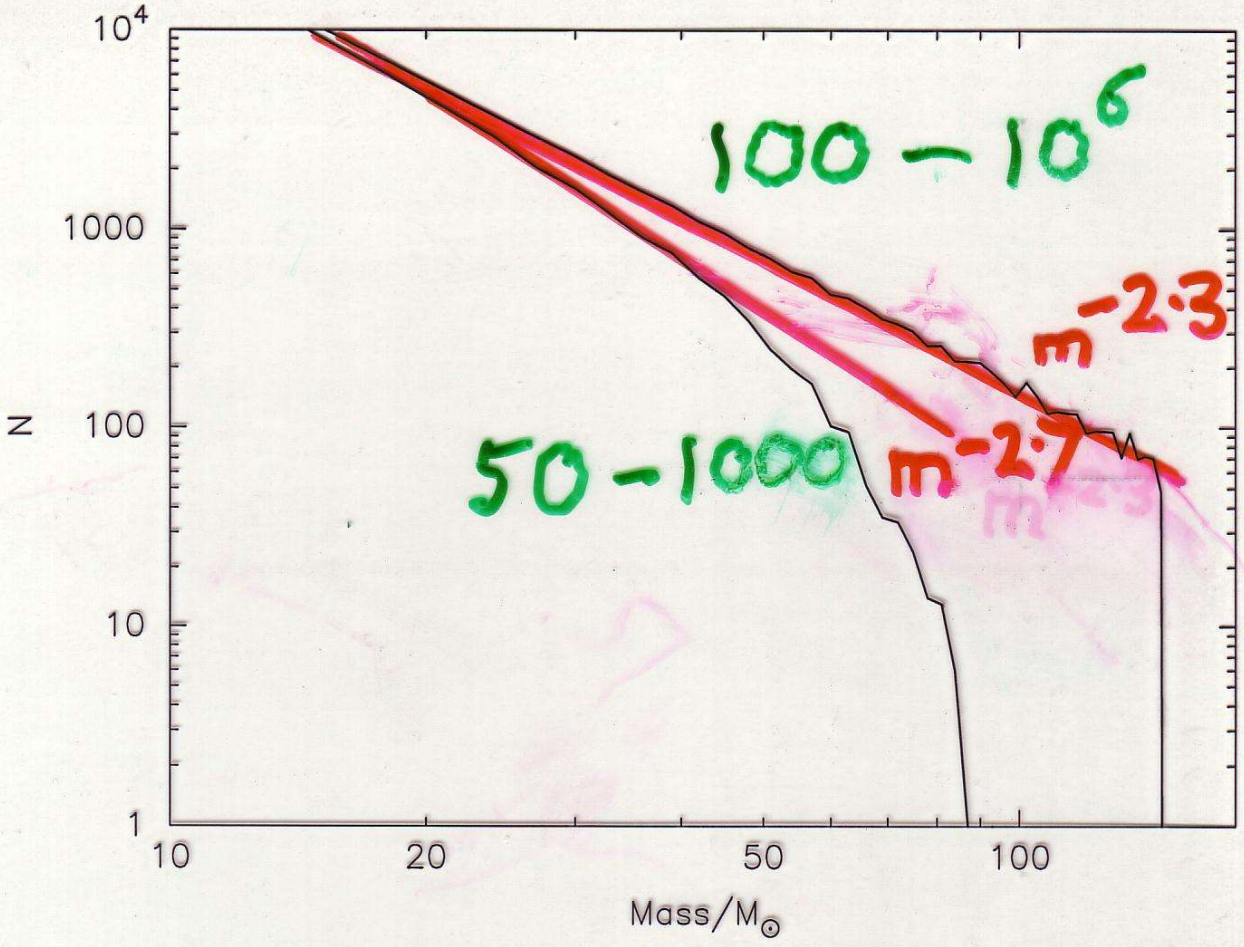
Estallidos!

Does it depend on environment?
QSOs. X-ray gas in galaxy clusters.

Is there evidence for Population III with massive stars only?
IR extragalactic background.


Salpeter (0.1)
Kroupa-Scalo
Scalo (b'=1)
b'=0.5
b'=1.5
Kroupa-Salpeter
Kroupa-Scalo
Scalo (b'=1)
Typical error bar
log m phi(m)
log m
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5

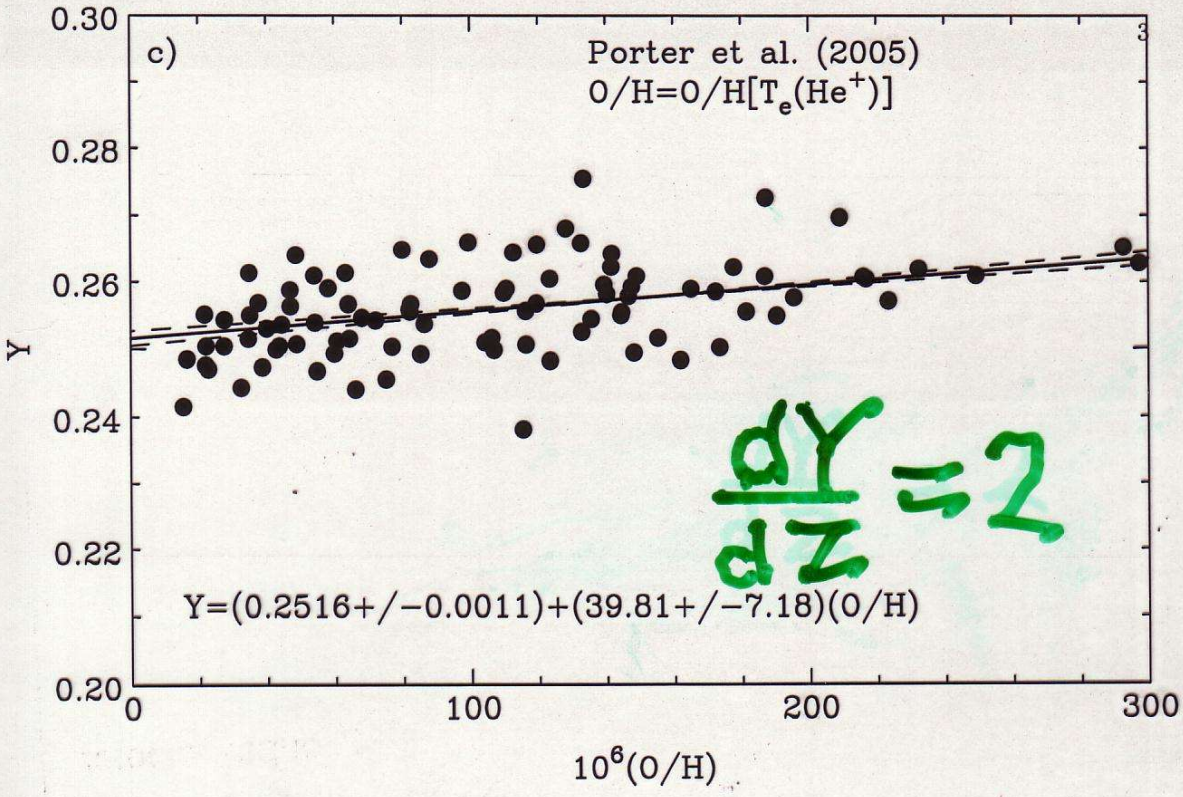
Dependence on cluster MF

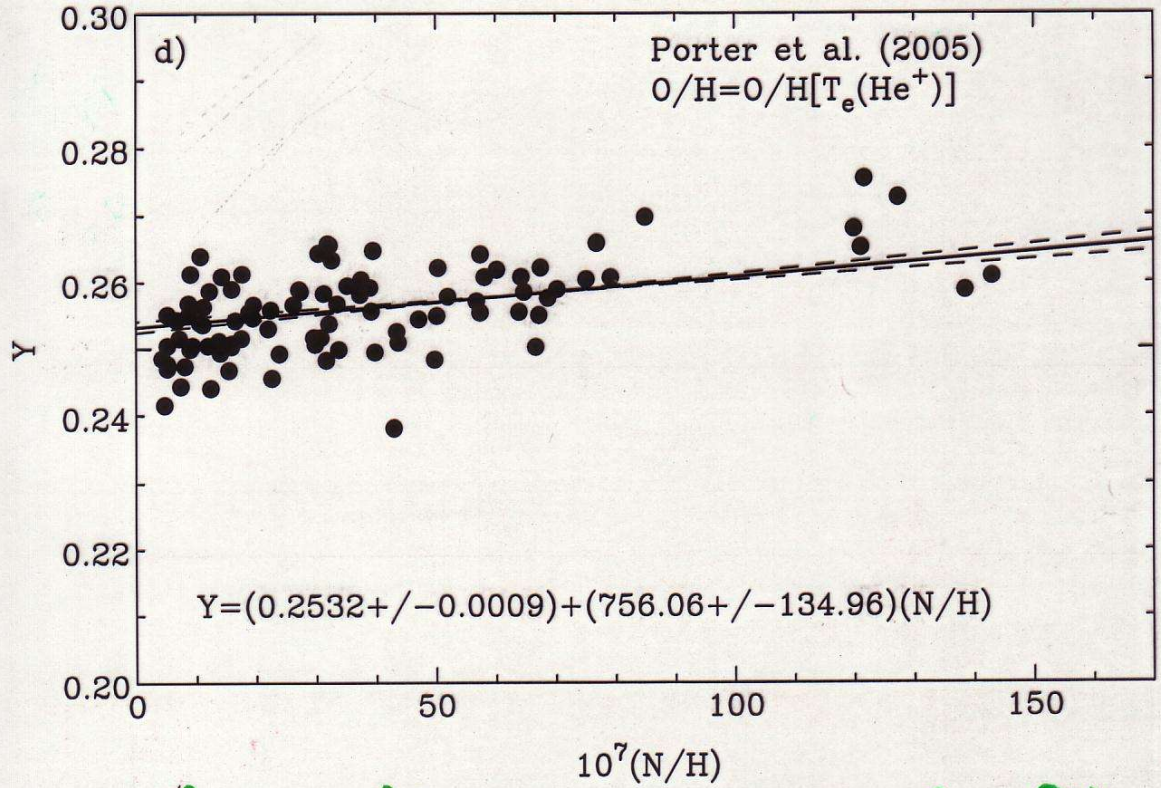


S. Goodwin & BP 2005

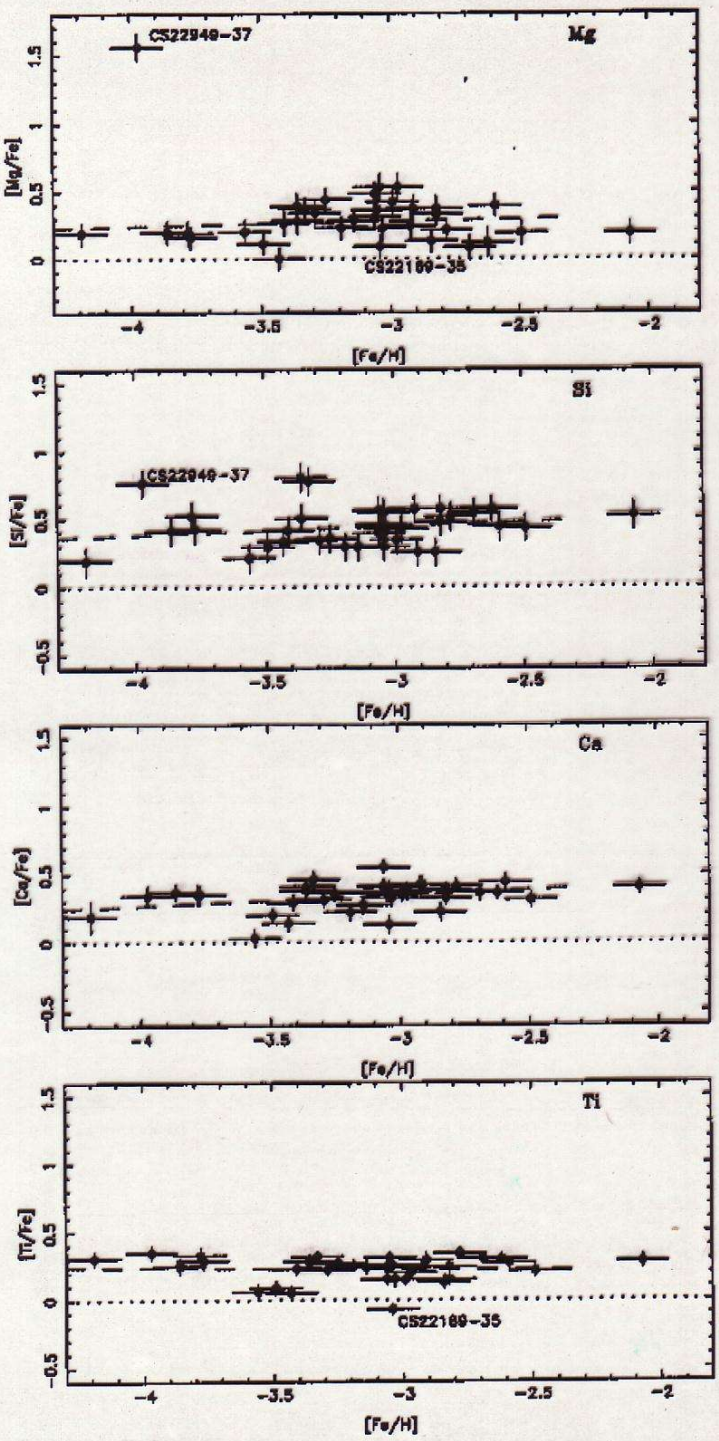
inspired by P. Kroupa

Pre-galactic = Primordial !

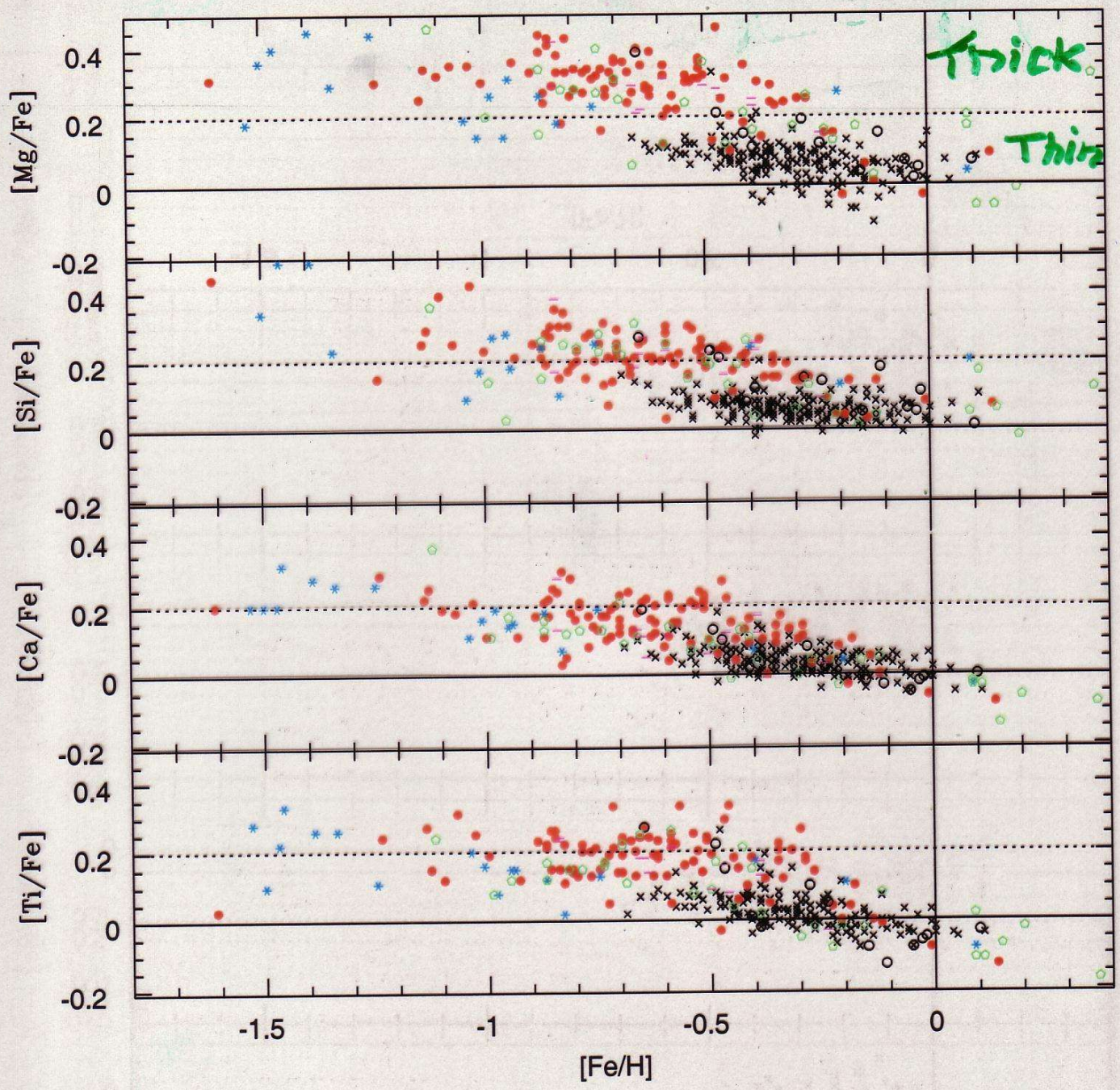




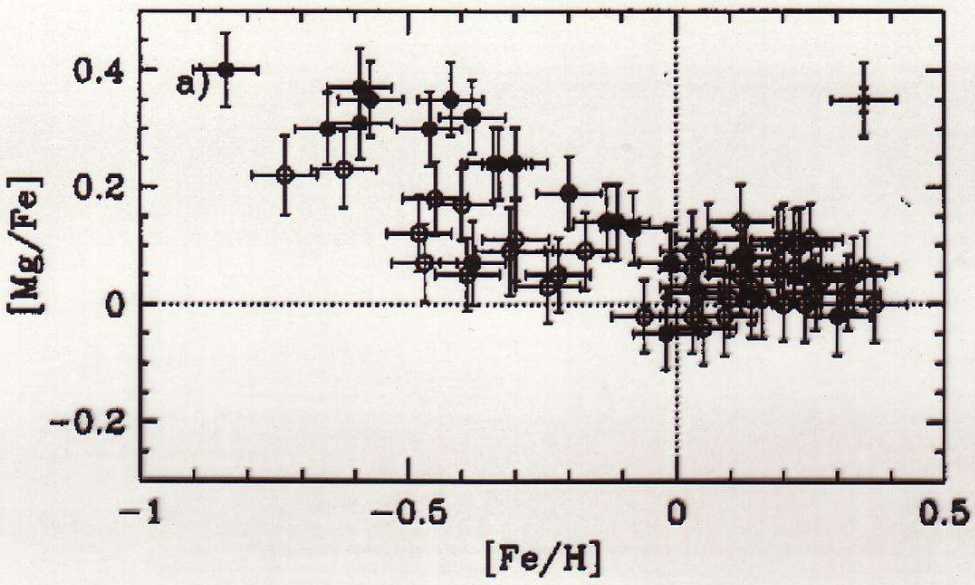
Izotov, Thuan & Stasinska 2007

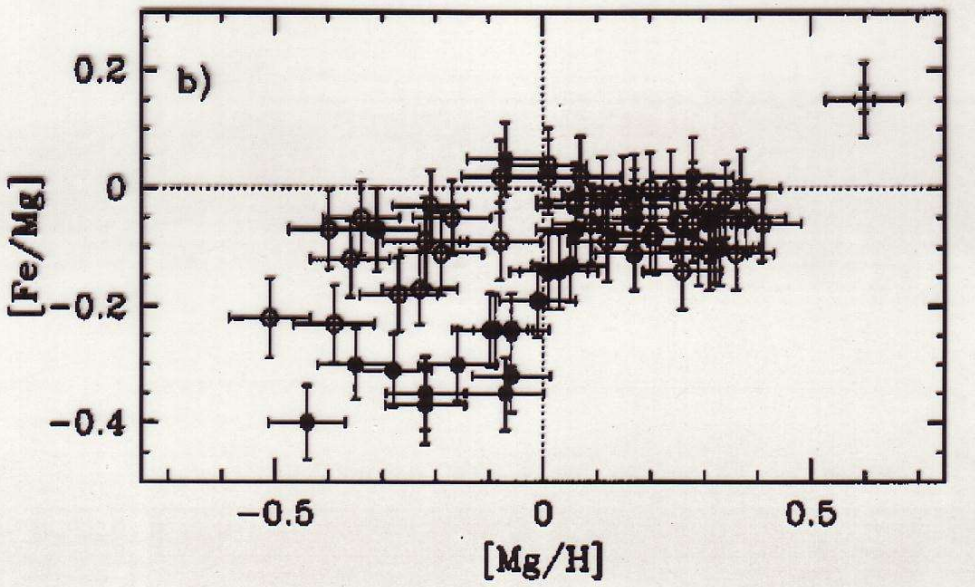


Cayrel et al. 2004



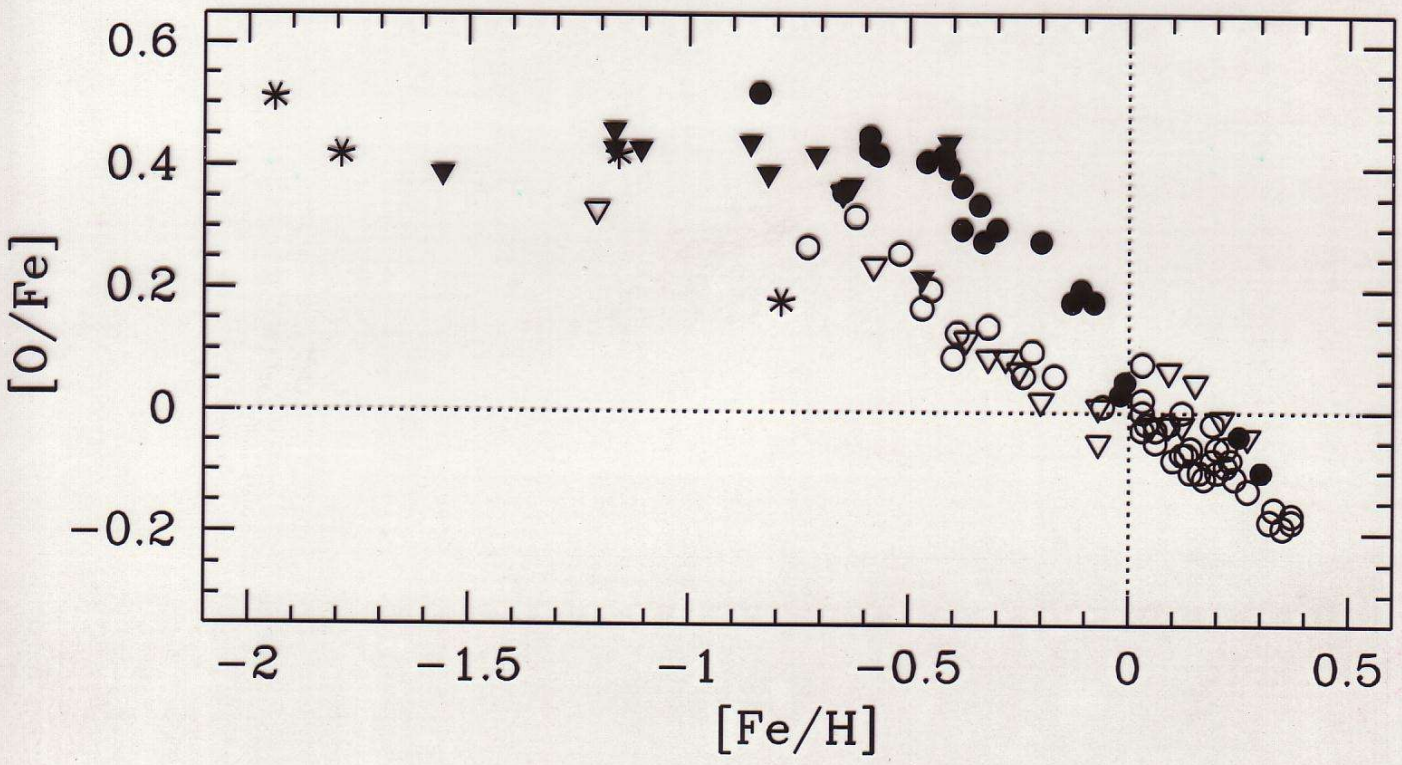
Reddy, Lambert & Allende Prieto 06





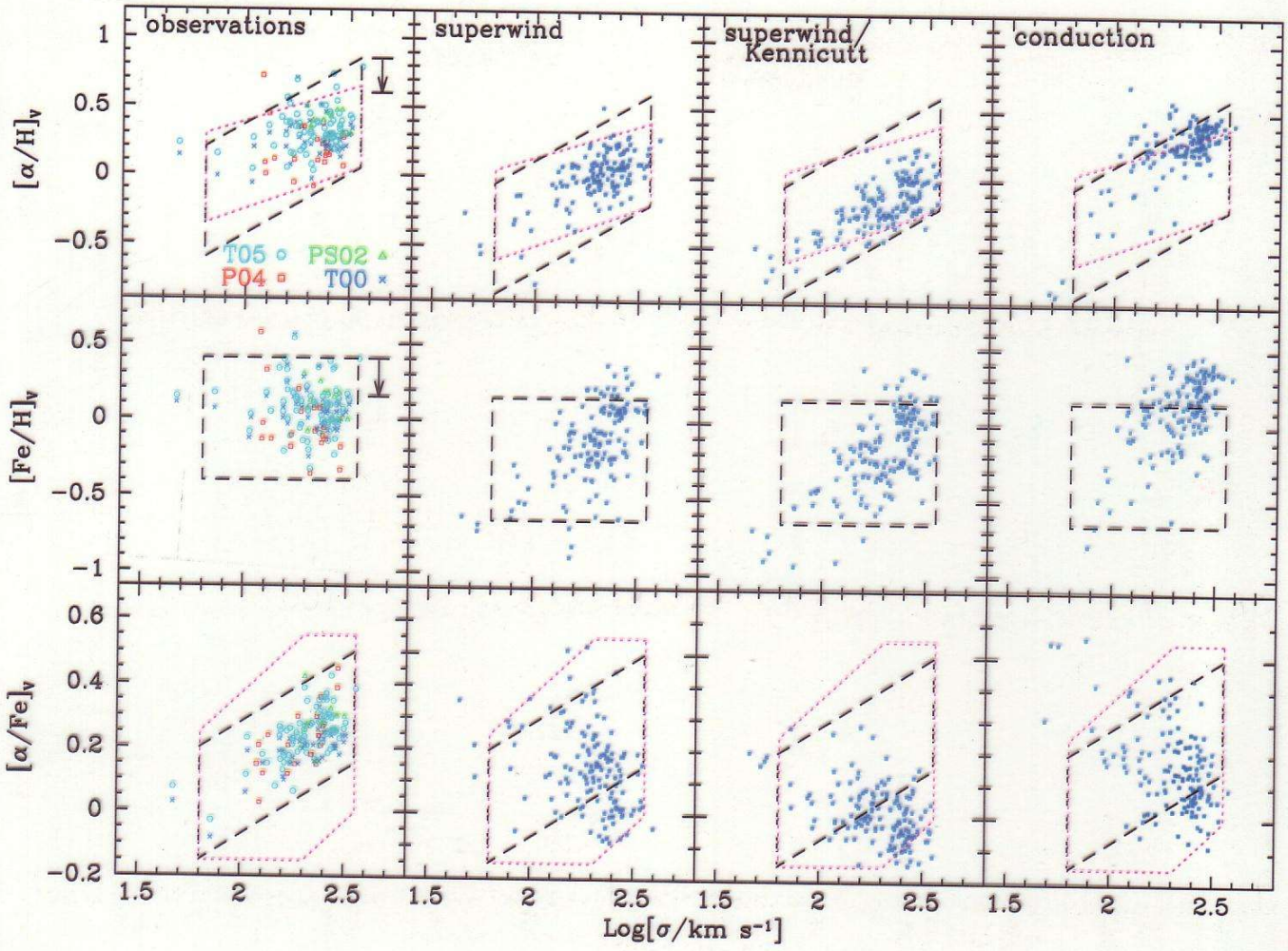
Bensby, Feltzing & Lundström

03



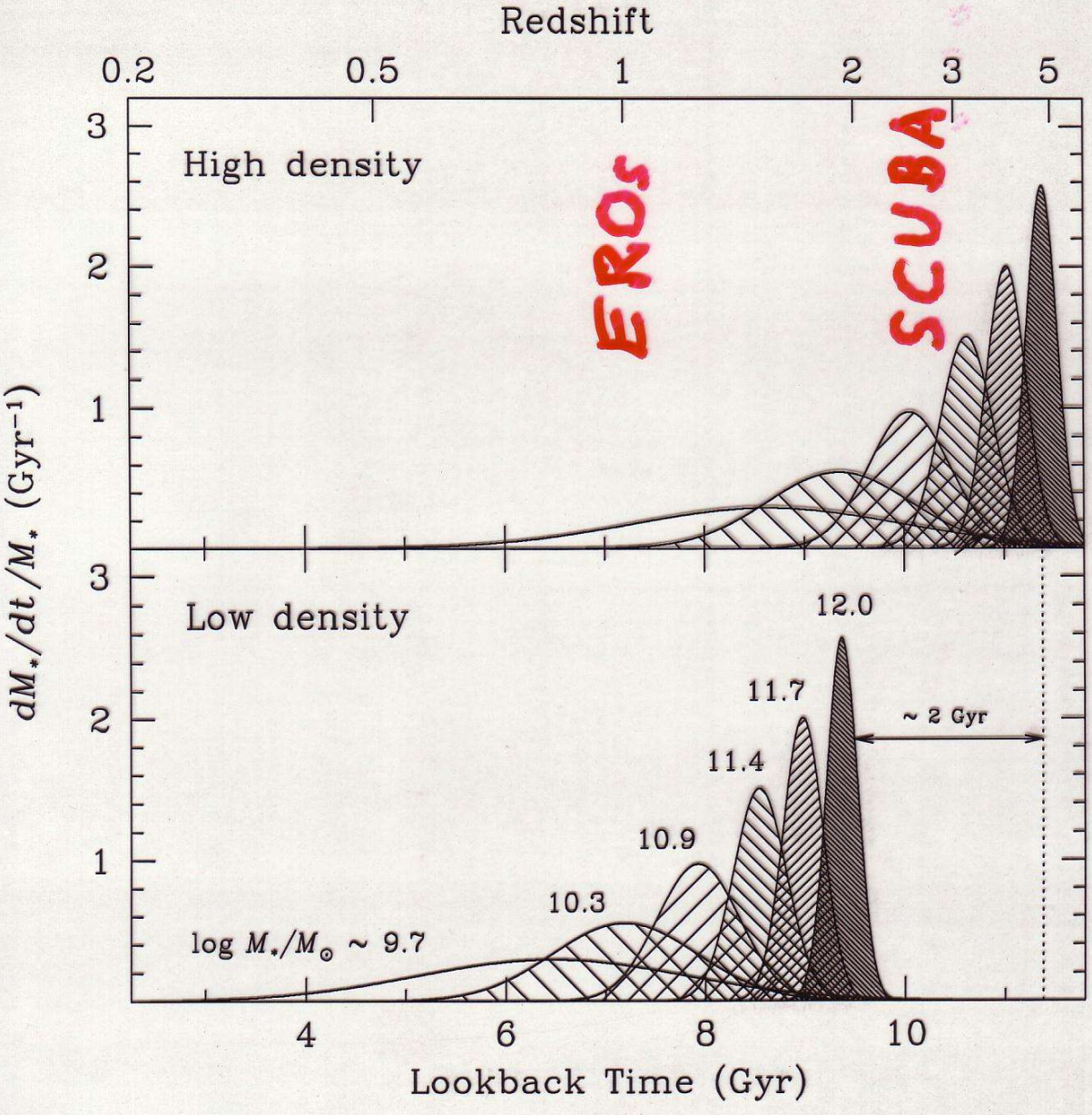
Bensby, Feltzing & Lundström 04

α/Fe in E-galaxies

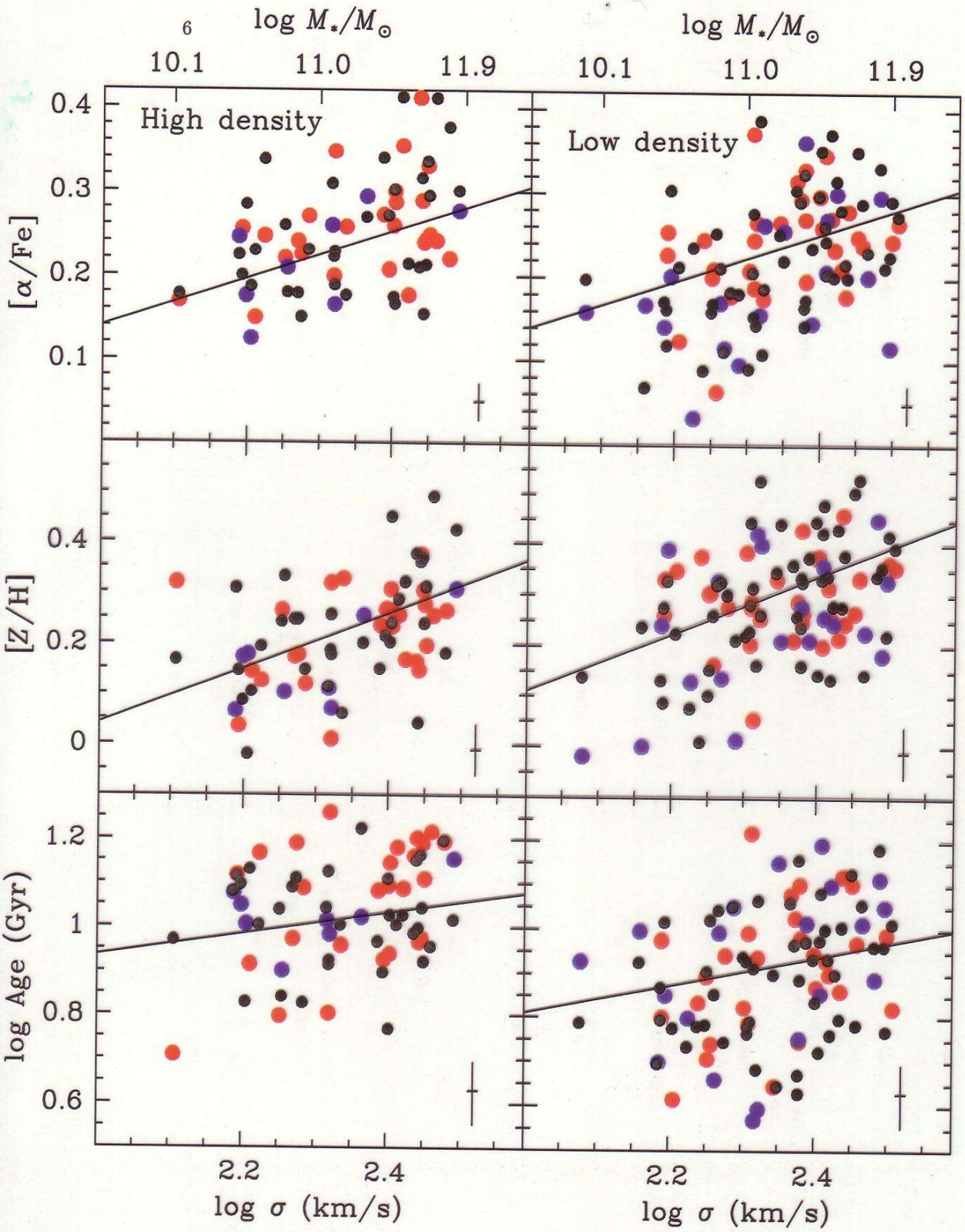


Nagashima et al 05

$x = 0$

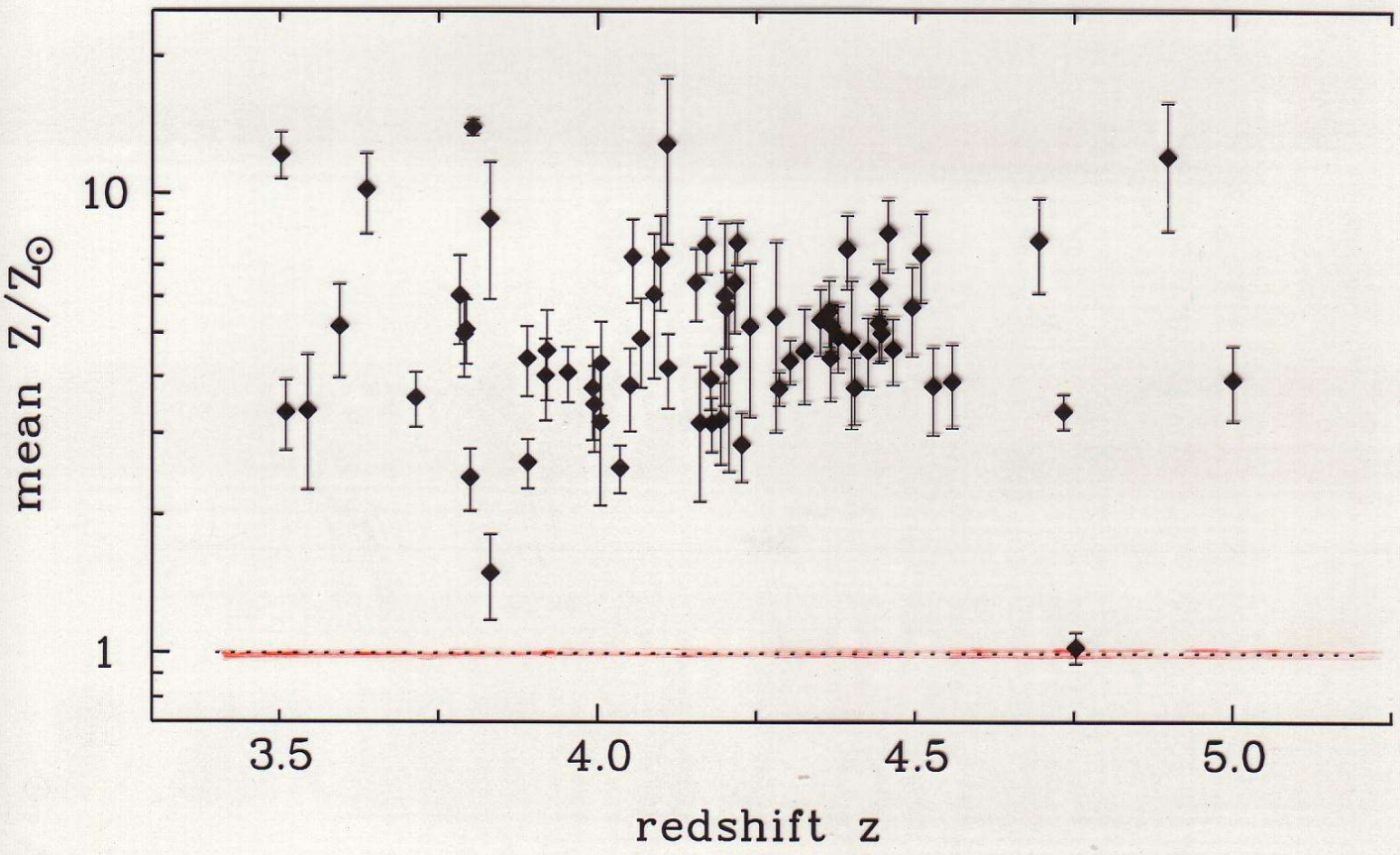


Thomas, Maraston, Bender & M de Oliveira 2005



Thomas et al. 2005

How metal-rich can you get?



Hamann et al. 04

X-ray gas in galaxy clusters

Gas mass $\propto L_V$, i.e. star mass.

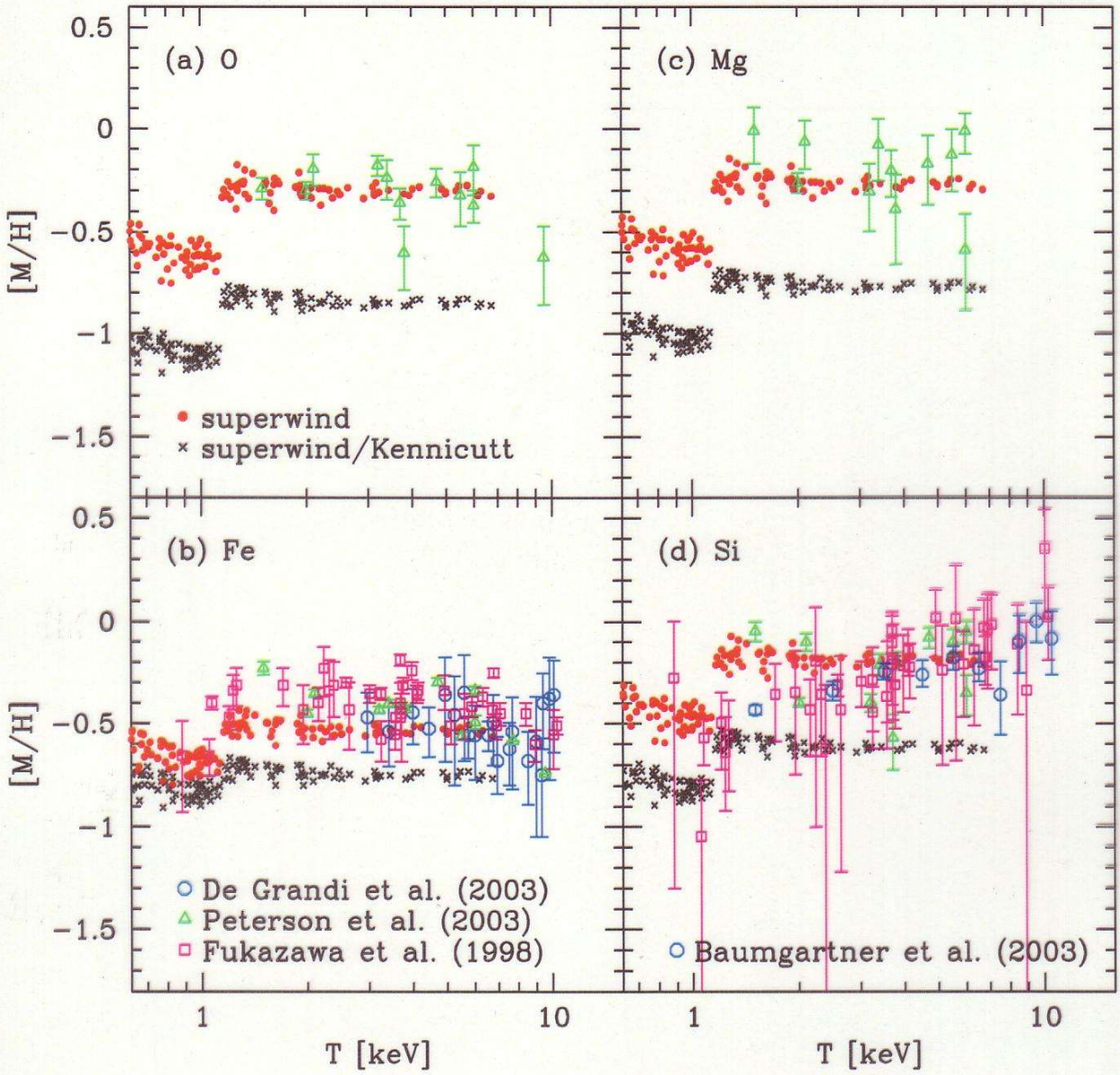
$g/s \geq 6$ if $M/L \leq 5$.

Fe/H $\simeq 1/3$ solar implies a yield

$p_{Fe} \simeq \frac{(g+s)Z_{Fe}}{s} \geq 2.3 Z_{Fe}^{\odot}$.

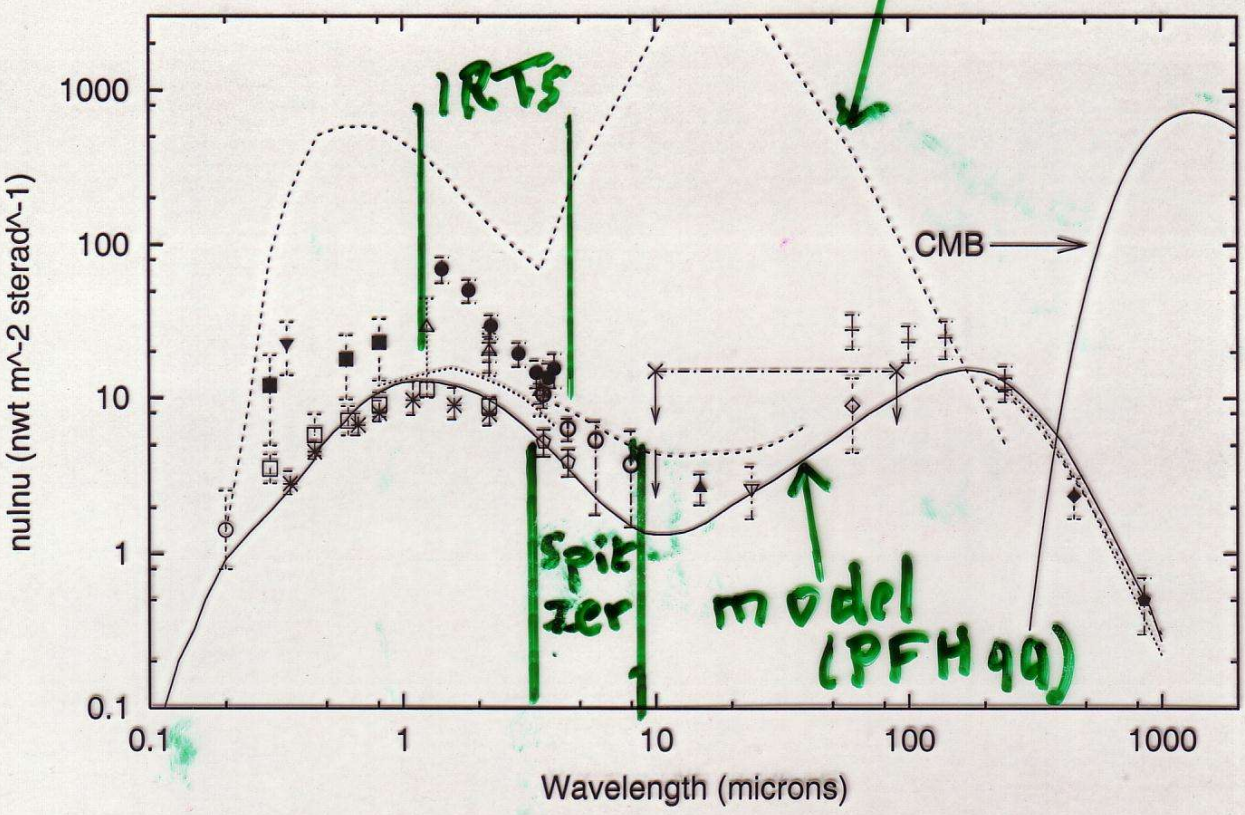
Can be done with Salpeter(0.1) IMF and high efficiency of expulsion of SNIa products, but problems with O, Mg etc (Pipino *et al.* 2002). Can flattened Salpeter do it? Probably not.

Nagashima *et al.* (2005) propose top-heavy IMF with $x = 0$ (!) in galaxy-merger induced starbursts.



Nagashima et al 2005

Zodiacal light



Ft gal cts or dir. diffuse.
≤ foregrounds

Extra from IRTS (Matsumoto *et al.* 00, 05) $\geq$ 30 nwt.

Possible origins:

- Galaxies underestimated?
- Population III ? (Kashlinsky 05)
- Interplan. dust ignored in zodiacal light models?

30 nwt $\Rightarrow \langle Z + \Delta Y \rangle \simeq 0.05$ to 0.1.

Hide in supermassive stars, say $1000 M_\odot \rightarrow$

Continuum above 1216A(1+z) and emission lines (Ly-α) from H II region.

Preferred models:

$$\text{Model 7} : \{z_{min}, z_{max}, \alpha, n_0\} = \{7, 15, -2,\ 7800\ \text{Mpc}^{-3}\}$$
$$\text{Model 9} : \qquad\qquad\quad = \{9, 30, -2,\ 8300\ \text{Mpc}^{-3}\}$$

Needs 10 per cent of all baryons in Pop III stars.

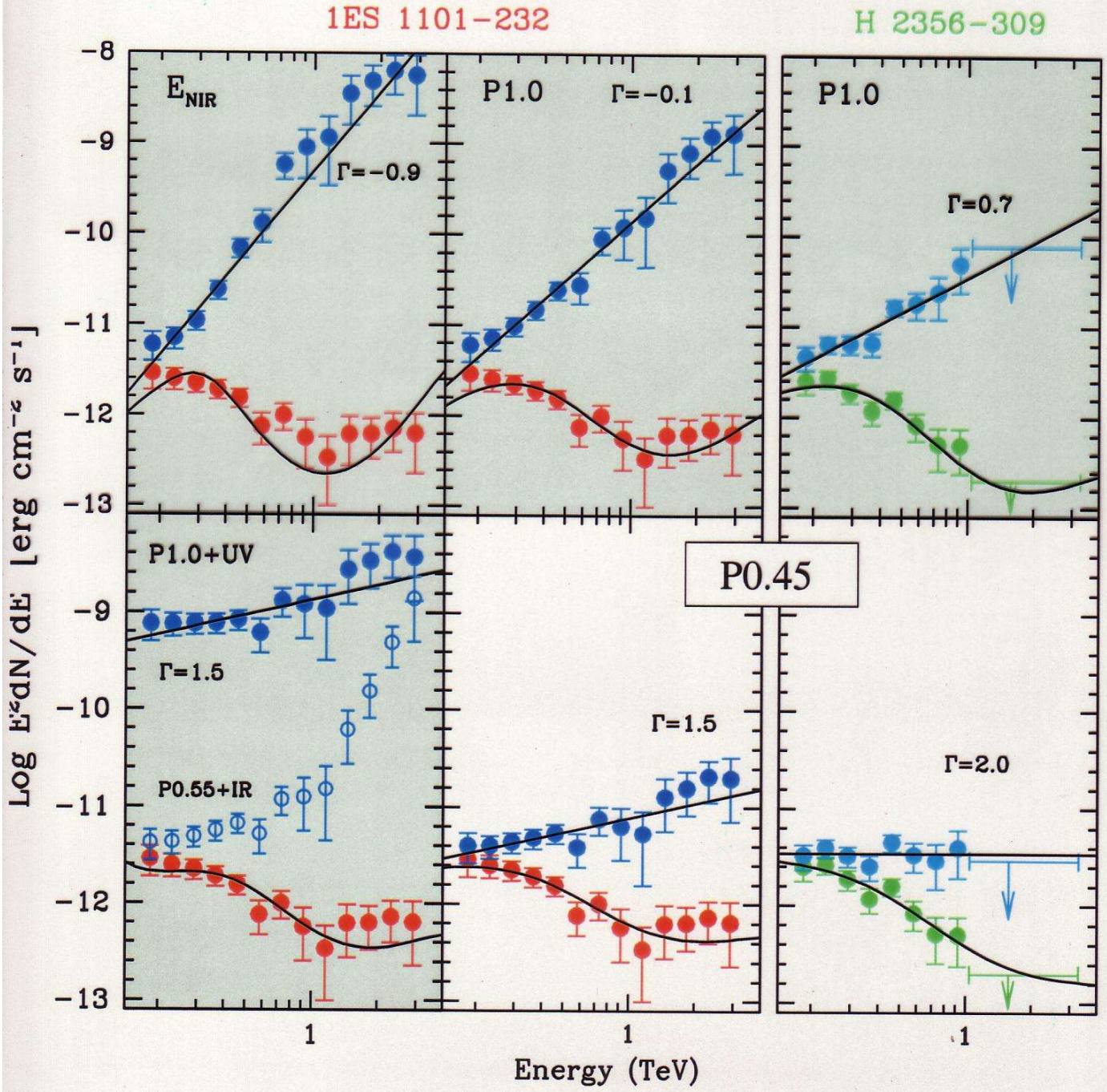
Mean SFR $\geq 1 M_\odot\ \text{yr}^{-1}$, 4 to 10$\times$ expected from halo collapse models.

Large-scale fluctuations (few deg.) $>$ expectation (Matsumoto).

Spectrum parallels zodiacal light better than models.

HESS results

Aharonian et al. 2006



Kashlinsky *et al.* (2007). Spitzer GOODS survey 3.6, 4.5 μm 2-pt correlation

CLEAN algorithm, galaxies removed down to fixed level of shot noise, around 25.5m (200 nJy at 3.6 μm).

Corresponds to $L_V/L_\odot \simeq 5 \times 10^8$ at $z = 5$, so almost all contributions from $z > 5$, or $t \leq 1$ Gyr.

Via Limber eqn,

$\Delta(\theta_8) \sim A\sigma_8(1+z)^{-1}(r_8/c\Delta t)^{1/2} \simeq 0.02 A\sigma_8 \simeq$ 0.1 nwt m^{-2} sterad^{-1} $/F_{\rm CIB}$,

so $\Delta F_{\rm CIB} \simeq \frac{4.5(\Delta t/1{\rm Gyr})^{1/2}}{\langle A \frac{6}{1+z}\rangle} \geq 1$ nwt m^{-2} sterad^{-1},

consistent with high-energy γ-ray limits.

Implications for extra population

Luminosity density at $\overline{z}$ at (.36 to .45)μm$10/(1+\overline{z})$ is

$\overline{l} \simeq 10^9(1{\rm Gyr}/\Delta t)(1+\overline{z})/10\ L_\odot$ Mpc^{-3},

1 order of magnitude above present day, or

$\Omega = 8.3 \times 10^{-3}(M/L)(1\,{\rm Gyr}/\Delta t)(1+\overline{z})/10.$

Needs low M/L, e.g. Ω_* today only about 2×10^{-3}.

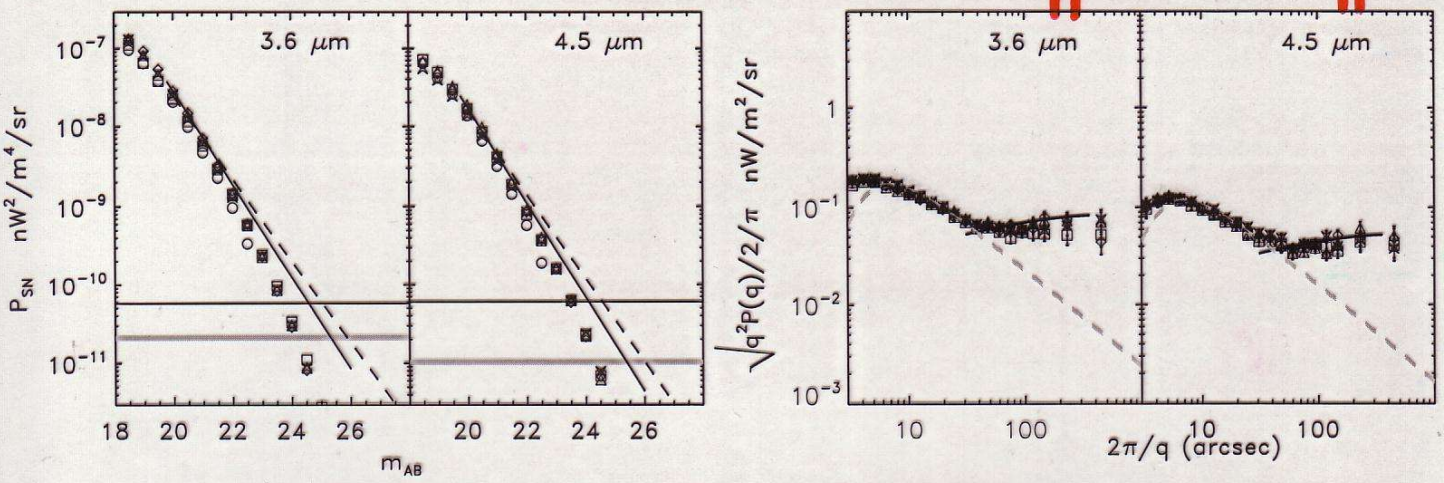
Pop III high-mass stars can have M/L down to 10^{-2}, or less, so

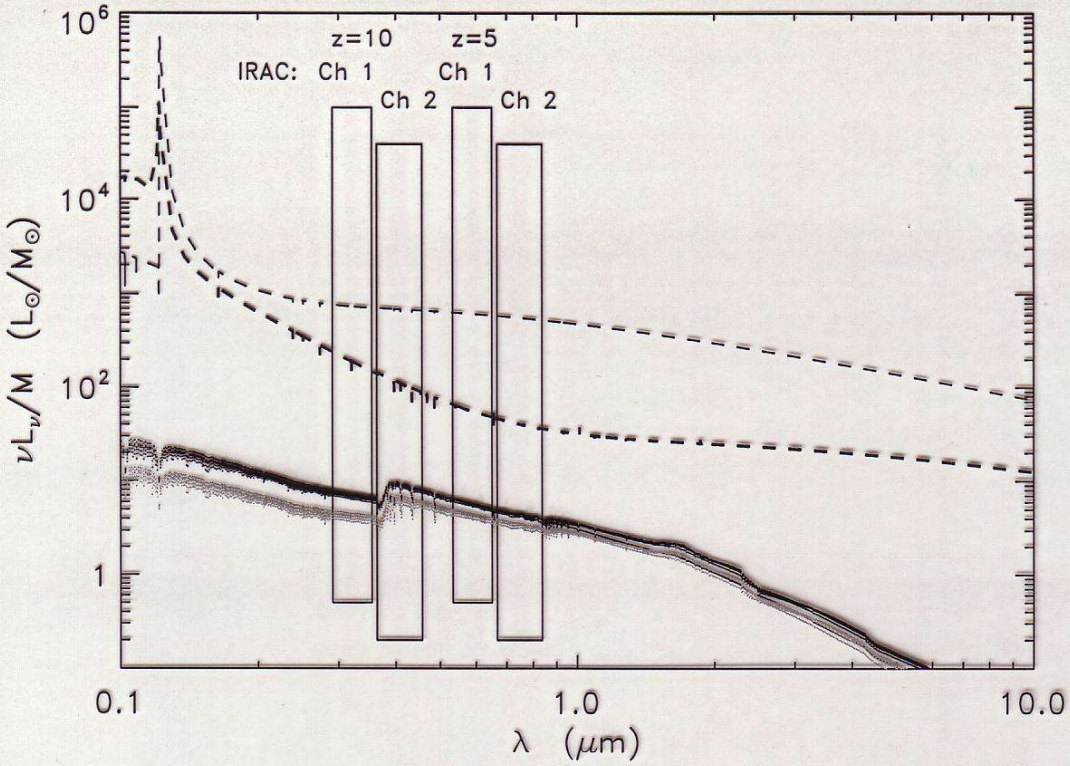
$\Omega \geq 6 \times 10^{-5}$, or 0.15 % of baryons.

Typical source with 20 nJy has mass $\sim 10^6 M_\odot$, hard to detect! JWST, ALMA?

Conclusion Pop III may be there, but nothing to do with IRTS.

$\theta_8 = 3' - 4'$


3.6 μm
4.5 μm
P_{SN} nW²/m⁴/sr
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
18 20 22 24 26
20 22 24 26
m_{AB}
$\sqrt{q^2P(q)/2/\pi}$ nW/m²/sr
1
10^{-1}
10^{-2}
10^{-3}
10 100
10 100
$2\pi/q$ (arcsec)


z=10
z=5
IRAC: Ch 1
Ch 1
Ch 2
Ch 2
10^6
10^4
10^2
1
$\nu L_\nu/M$ ($L_\odot/M_\odot$)
0.1
1.0
10.0
λ (μm)

Conclusions

- No evidence for dependence on metallicity.
  (Except Pop III?)
- But some dependence on cluster mass function and hence on SFR (quiescent vs bursty).
  May give range between Scalo and Salpeter slopes.
- Flatter slope probably needed in galaxy clusters.
  But doesn't by itself save hierarchical clustering.
- Some evidence for Pop III with low M/L.