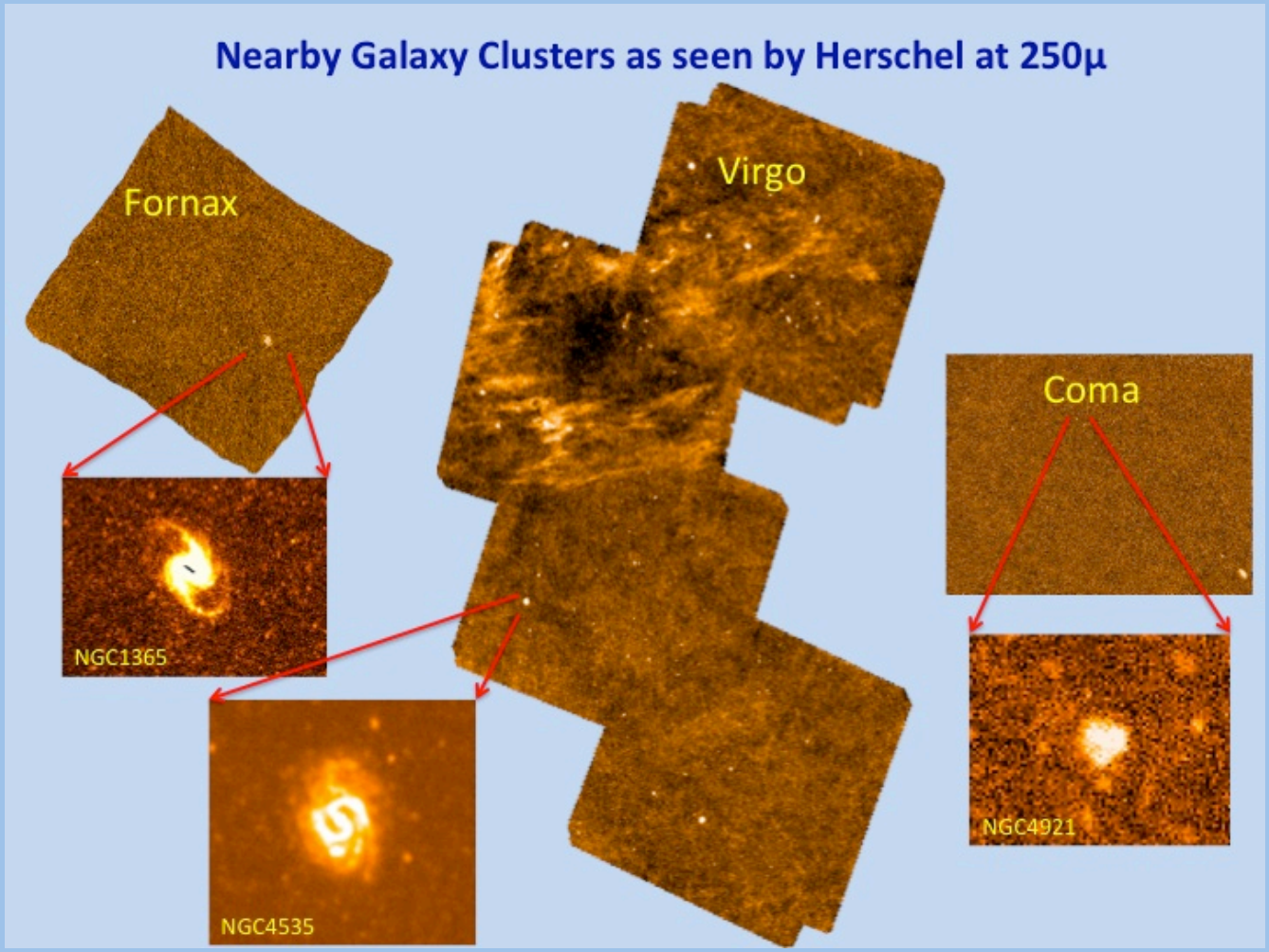
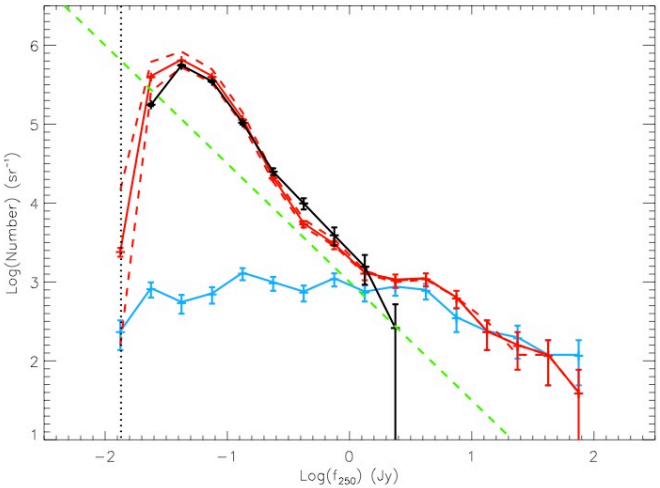
Herschel far-infrared surveys of nearby galaxy clusters

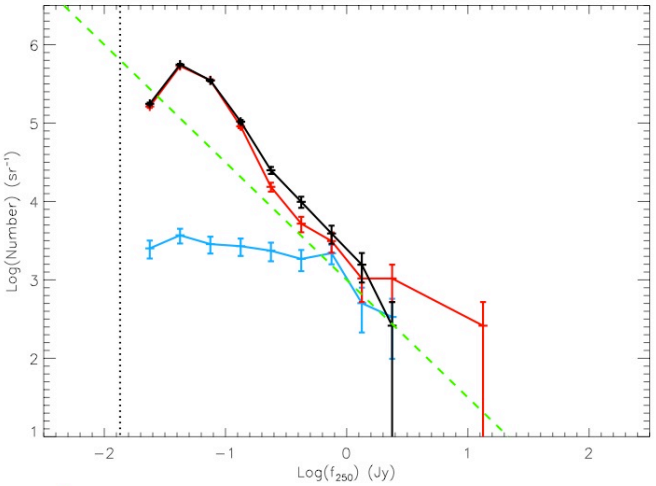
Jon Davies and the HeViCS team

Scan maps at:
100µ
160µ
250µ
350µ
500µ

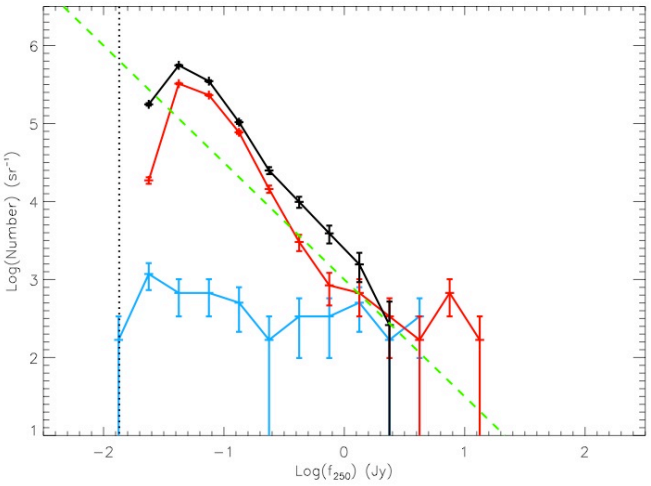




Virgo
251 galaxies
18 Mpc



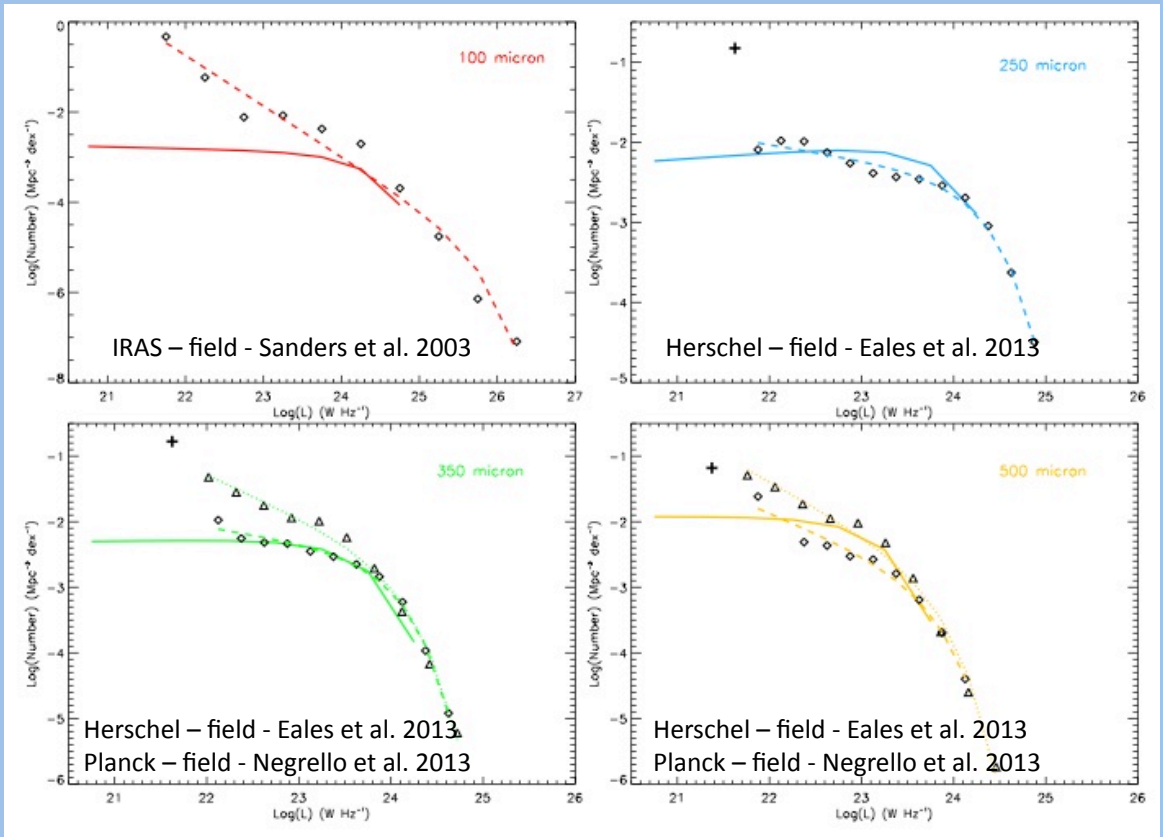
Coma
113 galaxies
96 Mpc



Fornax
30 galaxies
18 Mpc

Galaxy number counts (250μ)

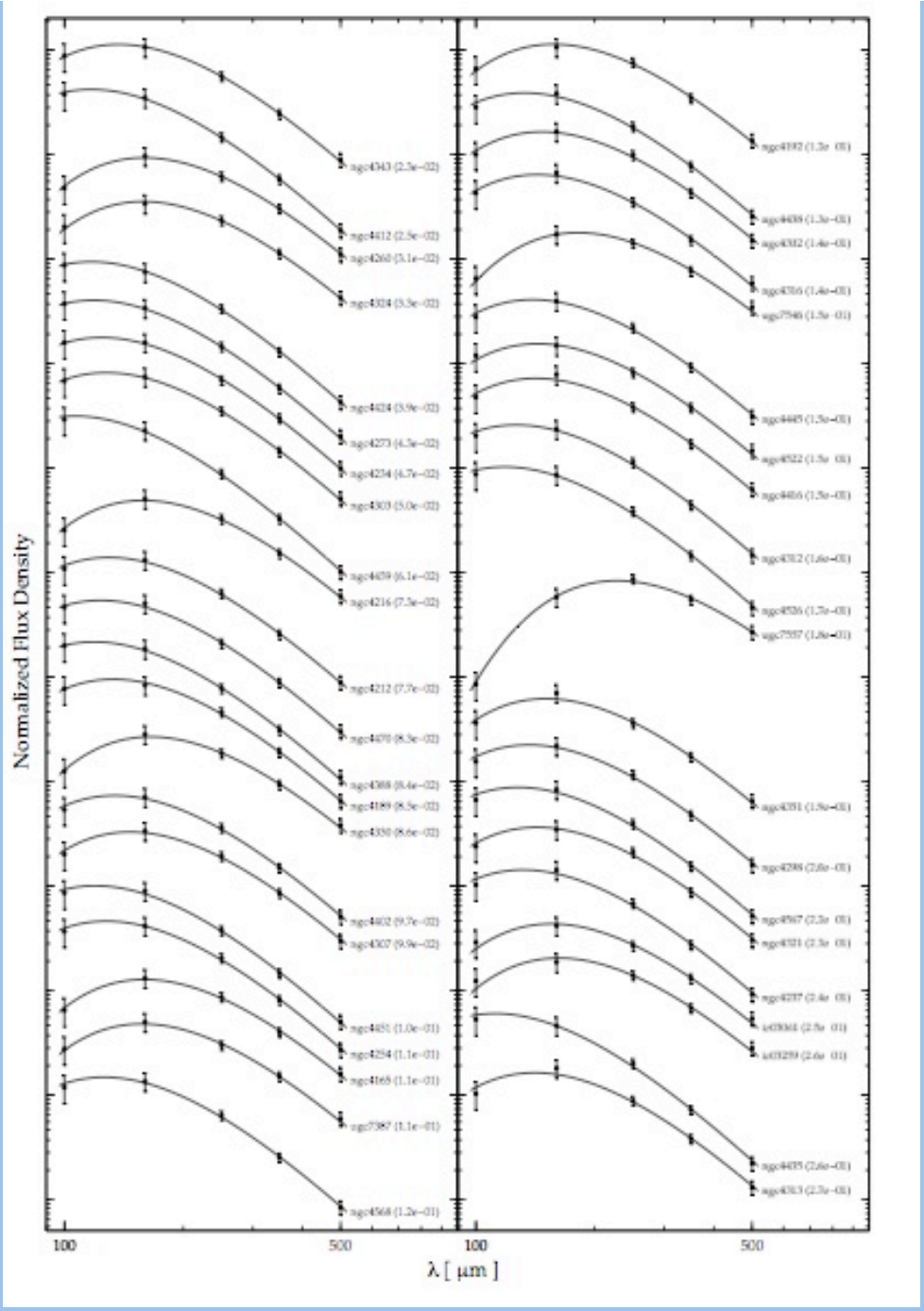
The rest of the talk will be about work we are doing on the Virgo cluster

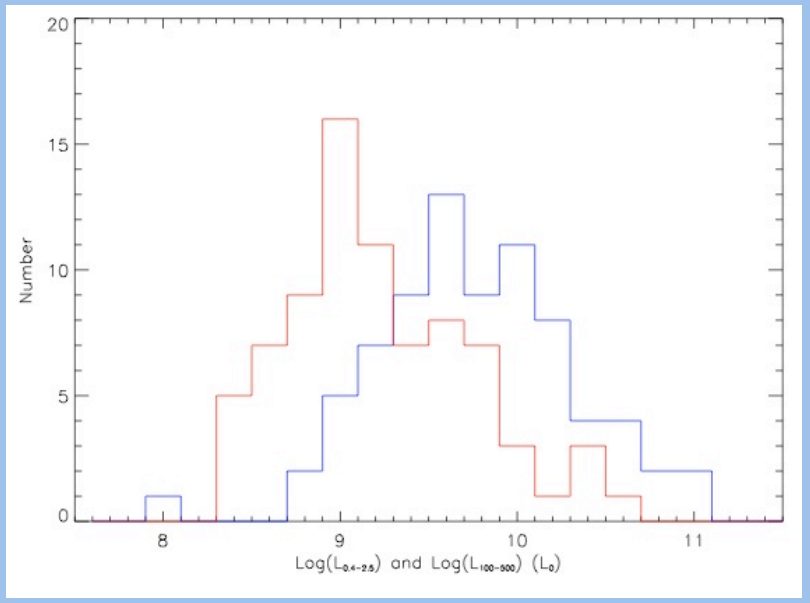


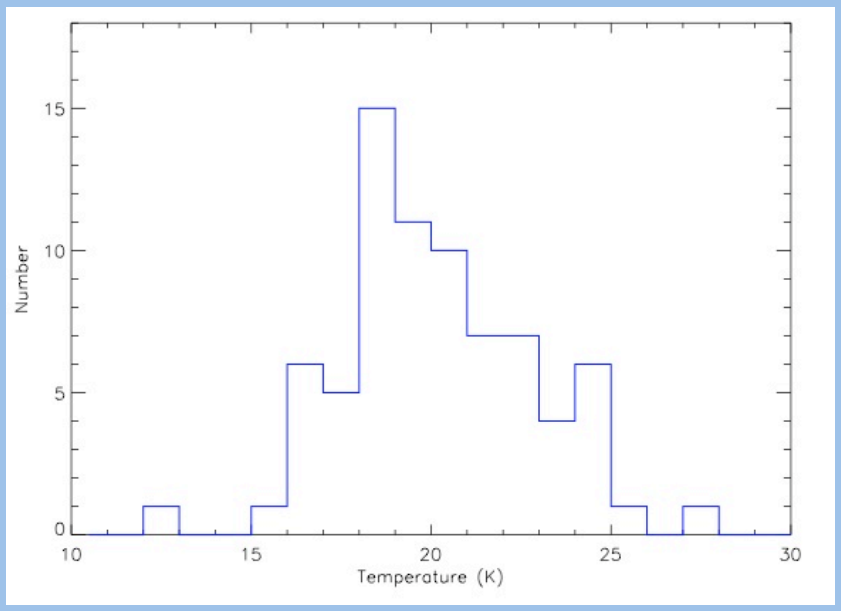
Virgo luminosity functions compared to the field

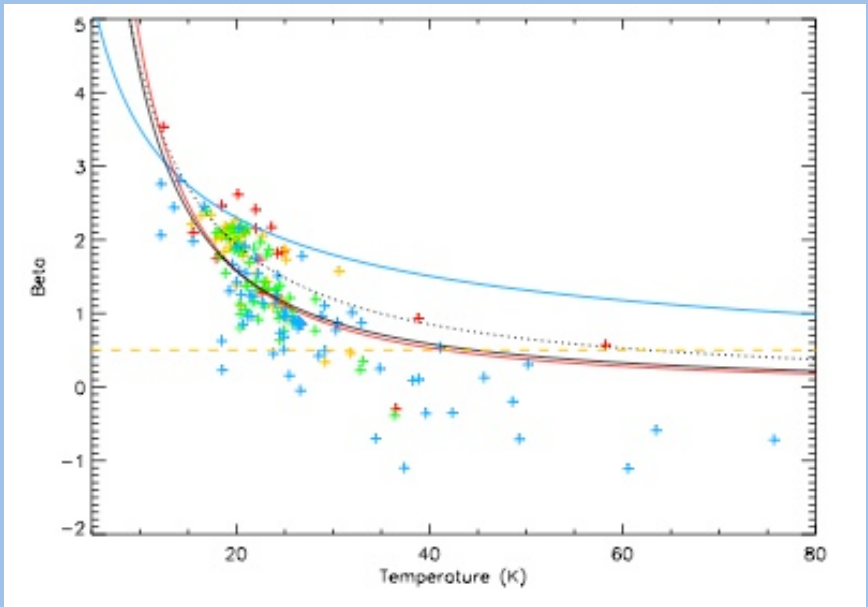
Band (μm)	Instrument	Region	α	L^* (10^{24} W Hz^{-1})	ϕ (Mpc^{-3} dex^{-1})	ρ_{FIR} (10^{23} W Hz^{-1} Mpc^{-3})
100	Herschel	Virgo	-1.0 ± 0.1	2.1 ± 0.6	0.3 ± 0.1	3.3
160	Herschel	Virgo	-1.0 ± 0.1	2.8 ± 1.0	0.3 ± 0.1	4.5
250	Herschel	Virgo	-0.9 ± 0.1	0.8 ± 0.2	0.6 ± 0.1	2.2
350	Herschel	Virgo	-1.0 ± 0.1	0.5 ± 0.1	0.5 ± 0.1	1.2
500	Herschel	Virgo	-1.0 ± 0.1	0.2 ± 0.01	0.5 ± 0.1	0.4
100	IRAS	Field	-2.1 ± 0.1	46 ± 15	0.000012 ± 0.000007	-
250	Herschel	Field	-1.19 ± 0.04	1.6 ± 0.1	0.0017 ± 0.0002	0.03
350	Herschel	Field	-1.22 ± 0.05	0.7 ± 0.1	0.0014 ± 0.0002	0.01
500	Herschel	Field	-1.58 ± 0.12	0.4 ± 0.1	0.0067 ± 0.0003	0.01
350	Planck	Field	-1.65 ± 0.08	0.9 ± 0.1	0.0013 ± 0.0003	0.03
550	Planck	Field	-1.78 ± 0.1	0.4 ± 0.1	0.0010 ± 0.0003	0.02

Spectral energy distributions

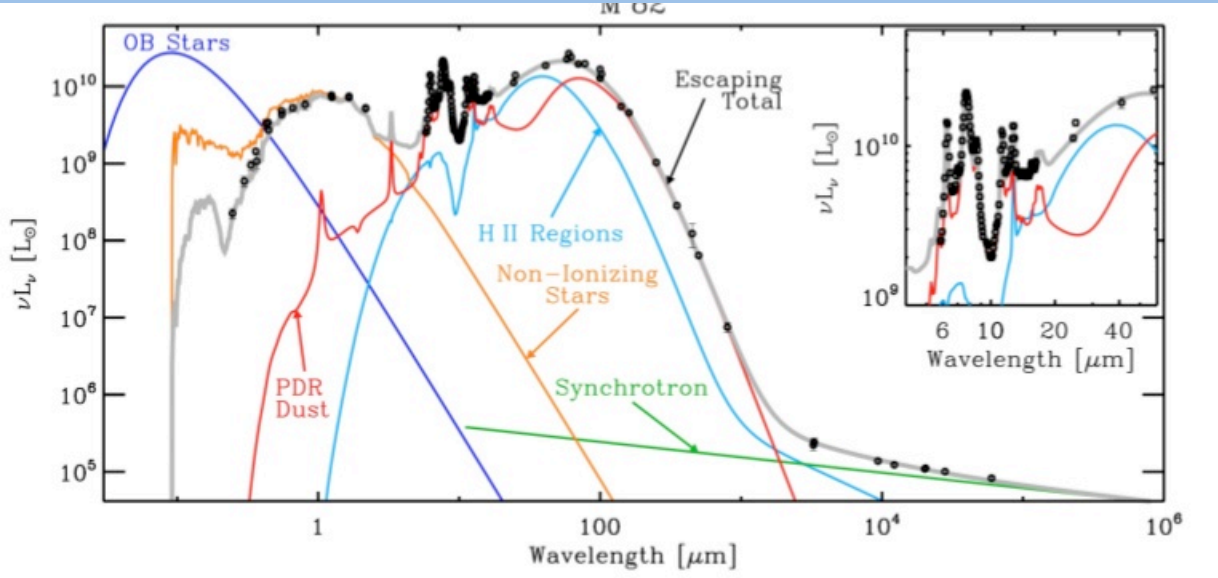








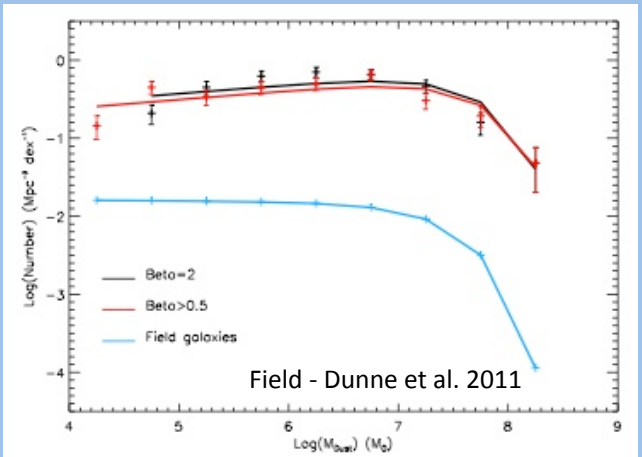
Dust properties?



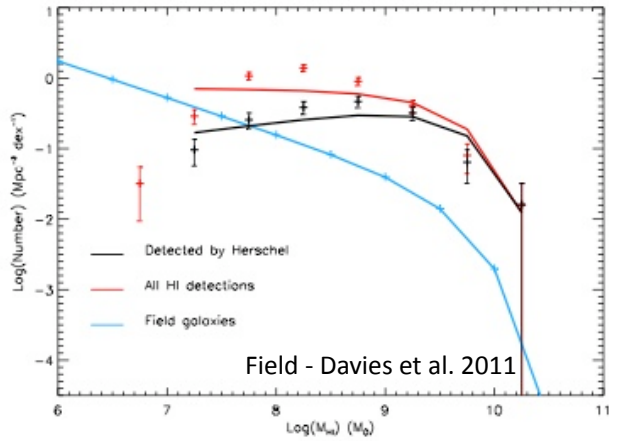
DustPedia

See DustPedia.com

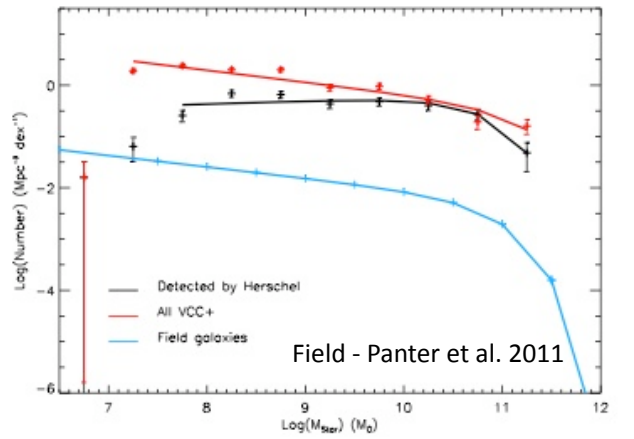
Baryonic mass Functions



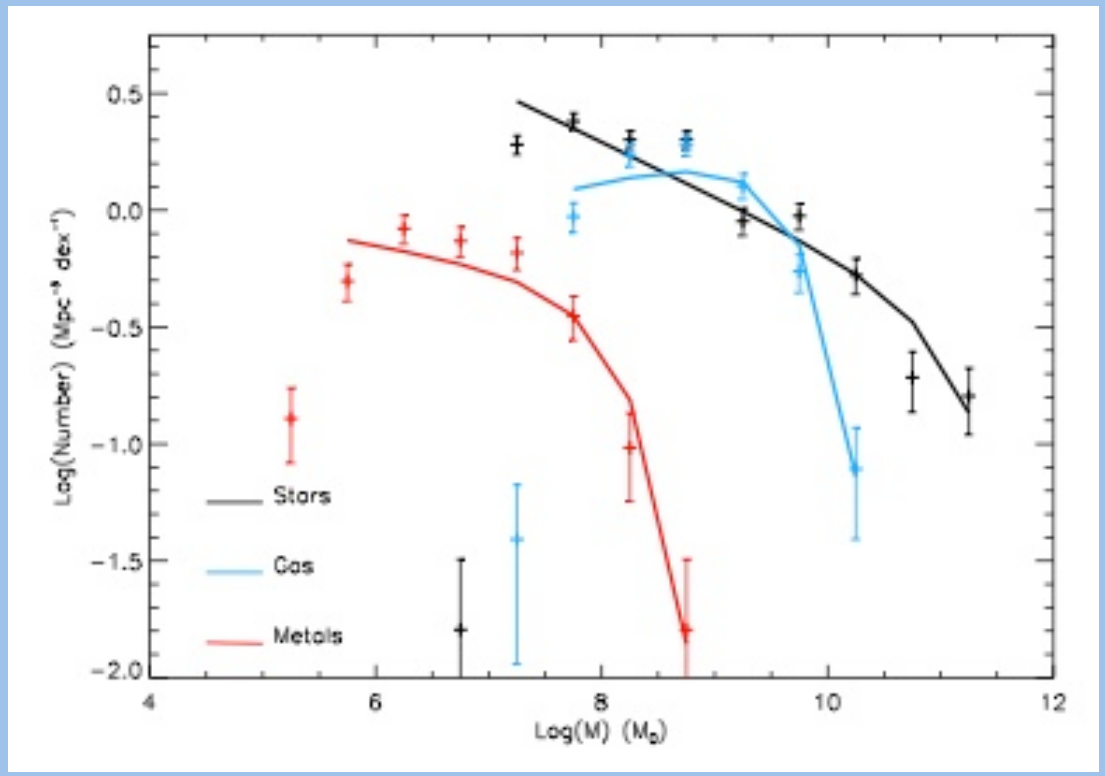
Field - Dunne et al. 2011



Field - Davies et al. 2011

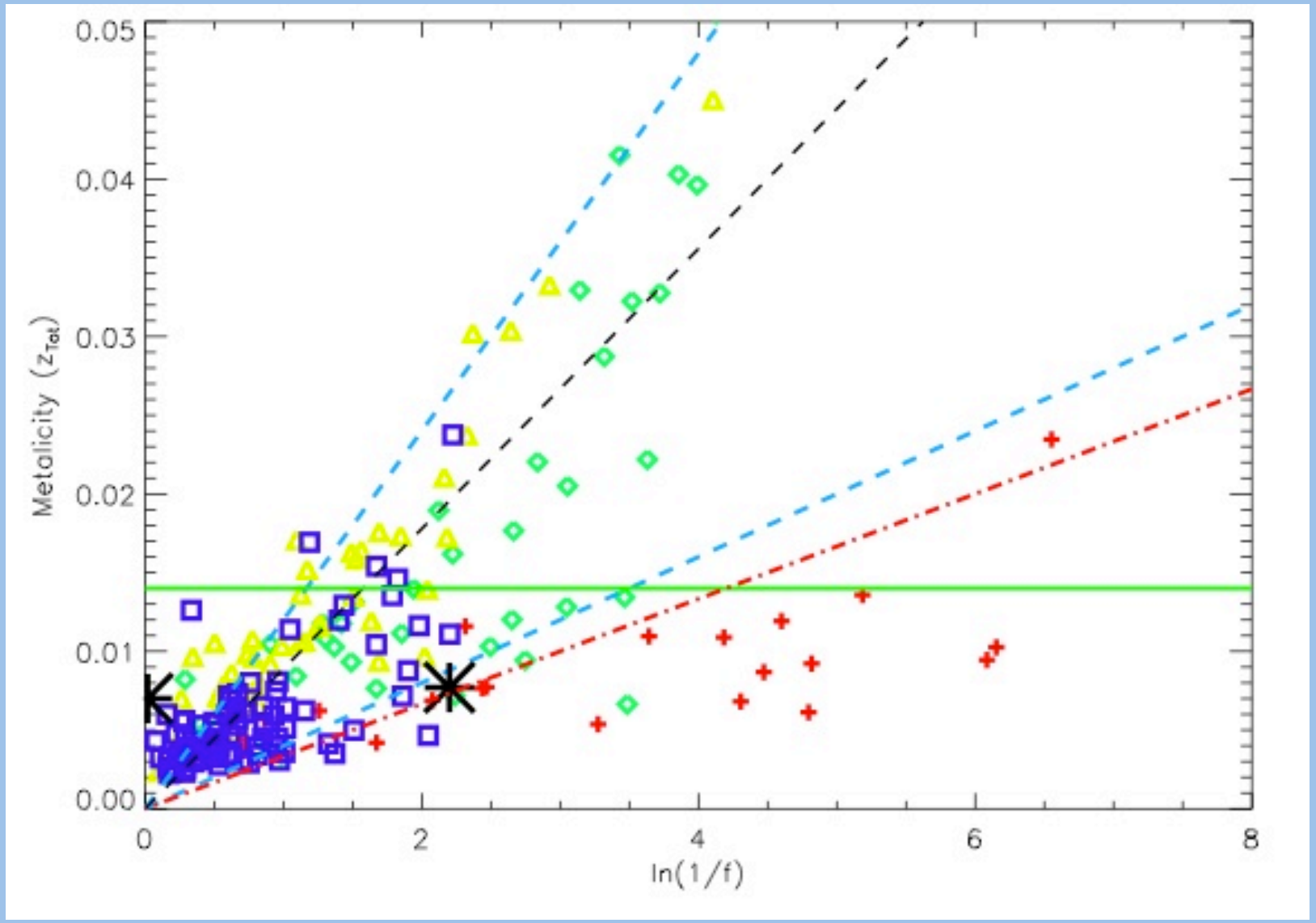


Field - Panter et al. 2011

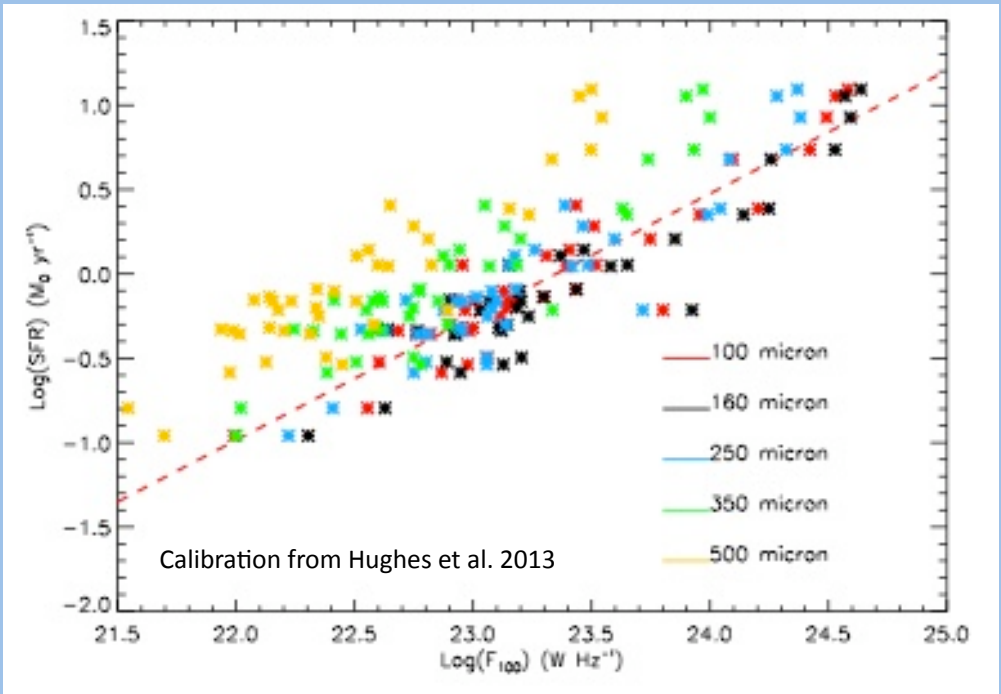


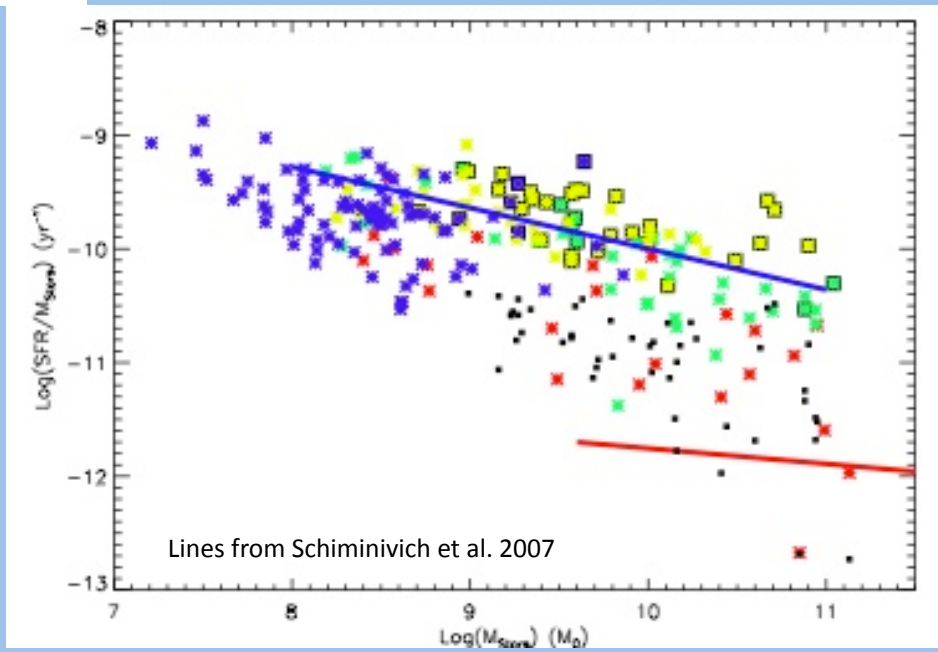
Baryonic Component	α	M^* ($M_\odot$)	ϕ (Mpc^{-3} dex^{-1})	ρ ($M_\odot$ Mpc^{-3})
Total stars	-1.2 ± 0.1	$1.9 \pm 1.2 \times 10^{11}$	0.3 ± 0.1	3.3×10^{10}
Total gas	-0.9 ± 0.1	$5.0 \pm 0.8 \times 10^{9}$	1.8 ± 0.3	4.3×10^{9}
Total metals	-1.1 ± 0.1	$1.7 \pm 0.3 \times 10^{8}$	0.4 ± 0.1	3.3×10^{7}

Chemical evolution

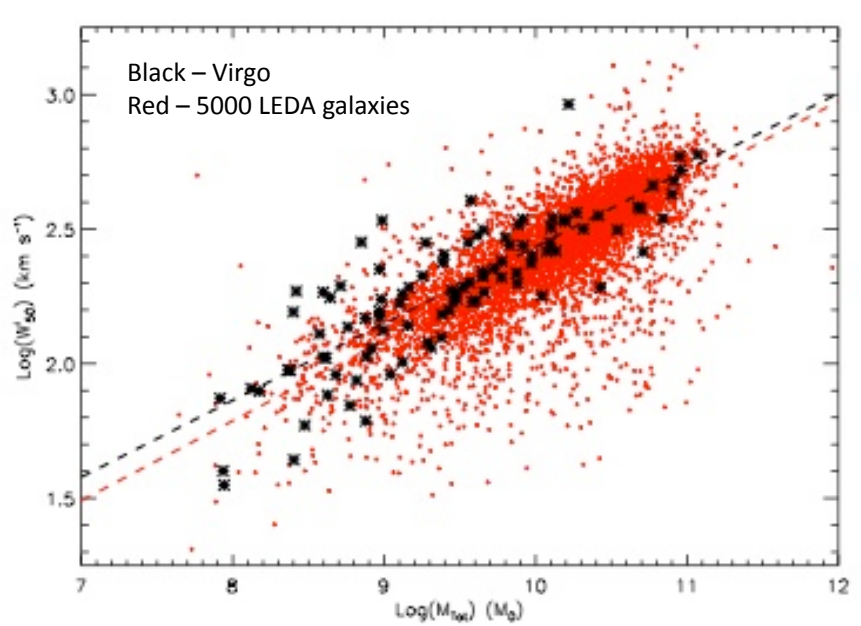


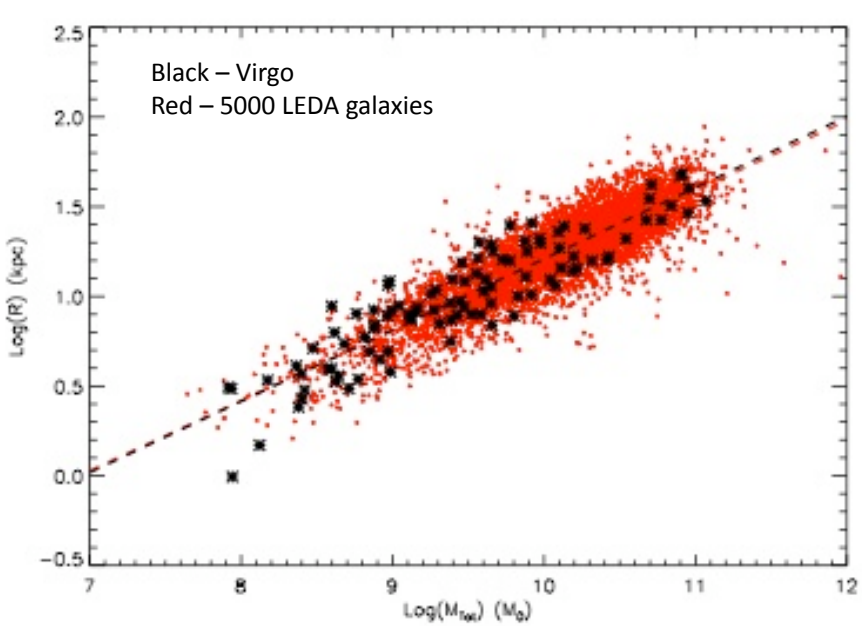
Star formation

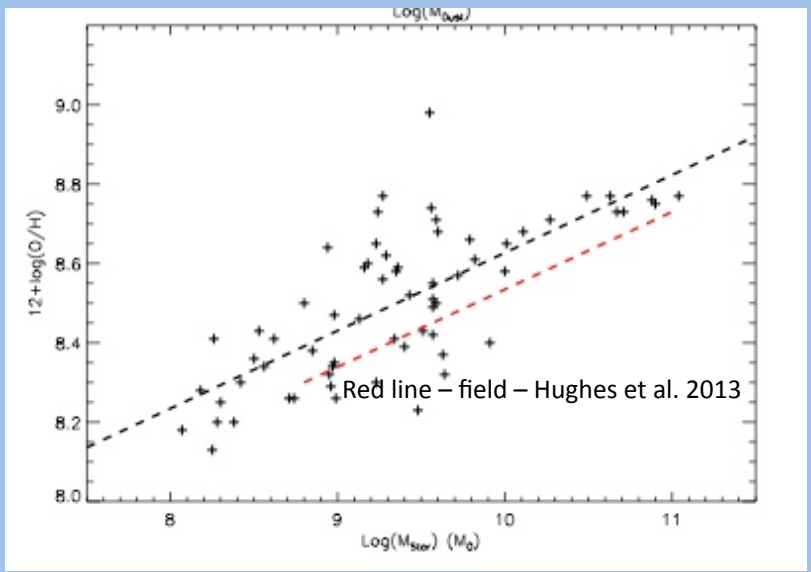


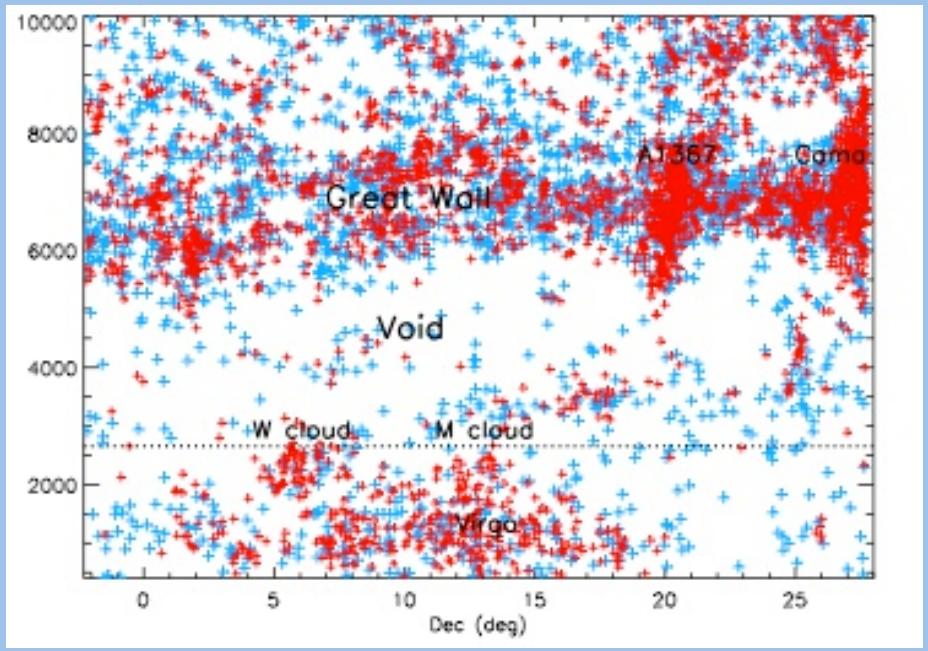


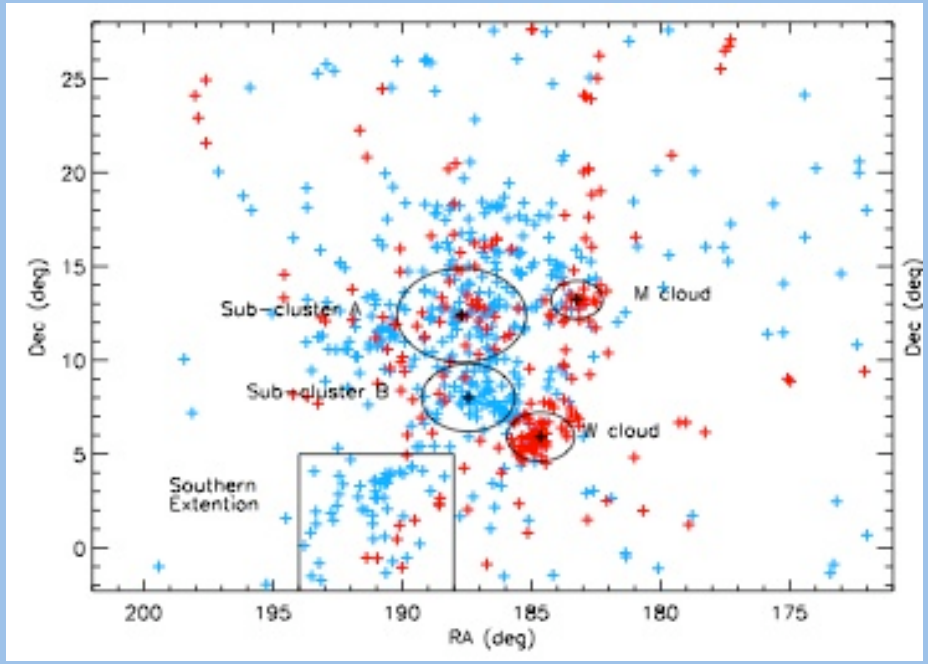
Other scaling relations









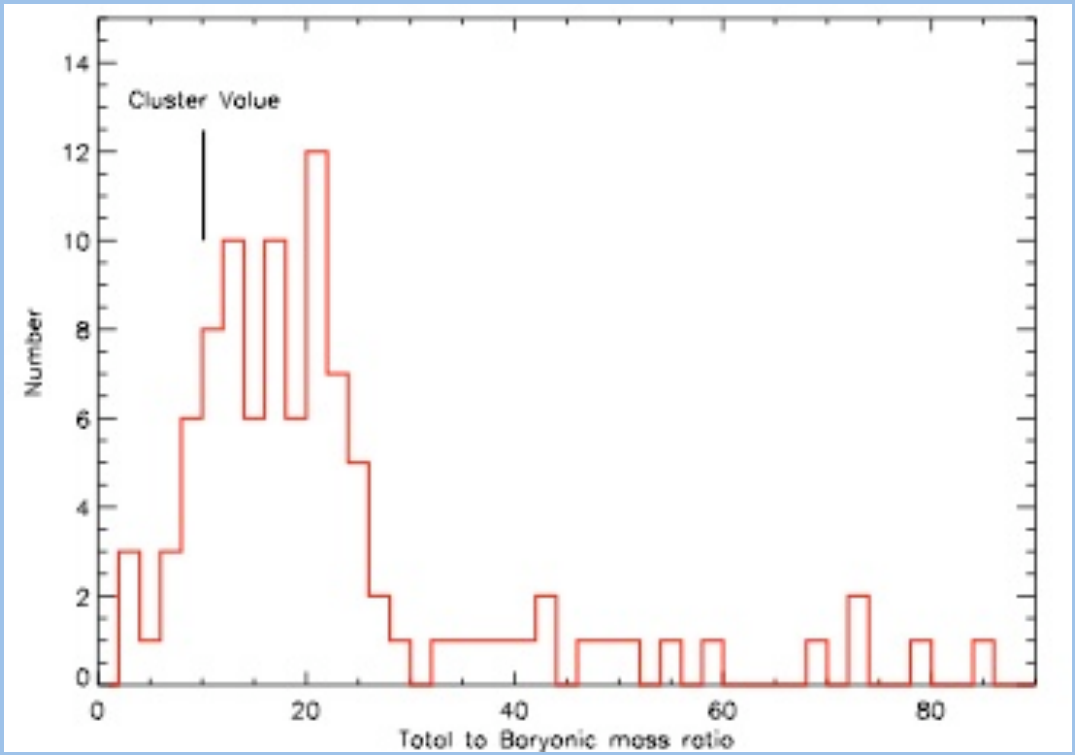


The cluster in context

What is there in addition to the galaxies?

1. Stars stripped from galaxies.
2. Stars formed in the intra-cluster medium.
3. Faint dwarf galaxies.
4. Gas stripped from galaxies.
5. The majority of the baryons are in the x-ray gas.

Baryonic Component	ρ ($M_\odot$ Mpc^{-3})
Total cluster stars	4×10^{10}
Total cluster gas	1×10^{12}
Total cluster metals	7×10^{9}



Dark Matter and Cosmology

Galaxies $\rho_M/\rho_B \approx 19$
Cluster $\rho_M/\rho_B \approx 7$
Universe $\rho_M/\rho_B \approx 6$

About a factor of 10 more dark matter in the cluster than can be accounted for in the galaxies.

Sample	Number in sample	$< v >$ (km s^{-1})	σ_v (km s^{-1})	R_e (Mpc)	$M_{Cluster}$ (10^{14} $M_\odot$)	ρ_{Dyn} (10^{12} $M_\odot$ Mpc^{-3})
Stars (VCC+)	546	1465	590	1.9	4.7	7.5
Gas (ALFALFA)	261	1552	616	1.8	4.7	7.5
Dust (Herschel)	146	1475	616	2.2	5.7	9.2
X-ray (Bohringer et al. 1994)	-	-	-	-	4.2	6.7

Summary

1. No evidence for FIR sources not associated with optical sources.
2. Flat luminosity functions compared to the field.
3. Very little can be said about physical dust properties from this data – DustPedia.
4. Can use extensive data on Virgo to get:
   a) Chemical evolution.
   b) Star formation rate mass relation.
   c) Mass metalicity relation.
   d) Baryonic Tully-Fisher relation.
   e) Mass radius relation.

   Gross properties of the cluster galaxies much the same as the field.
5. Difficult to see the link between the galaxies and the x-ray gas.
6. Ratio of dark to baryonic matter in the cluster same as that of the Universe as a whole.