The Extended Chandra Deep Field South -

Submillimetre properties of near-IR selected galaxies

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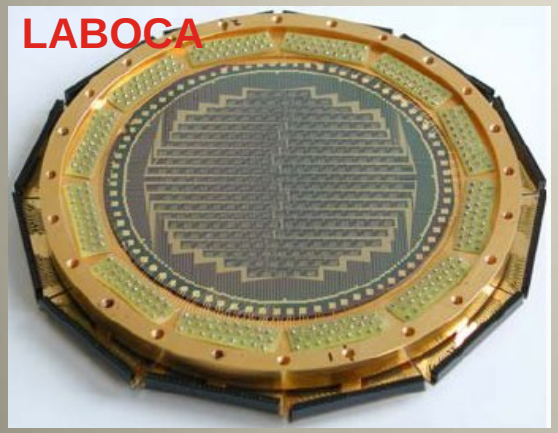
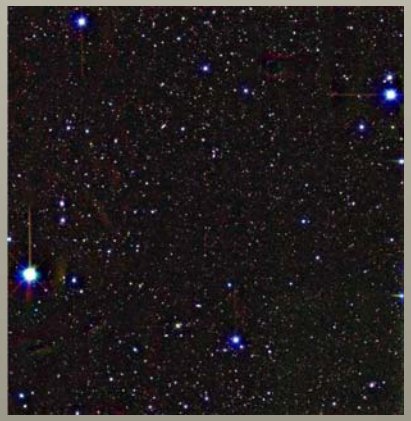
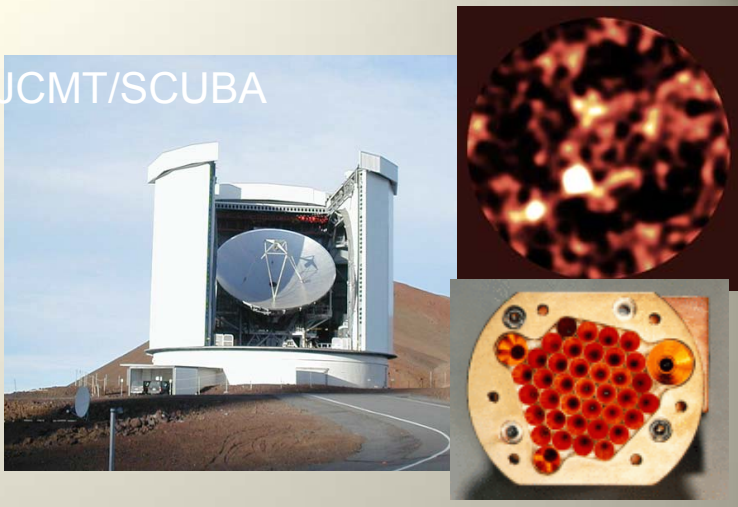


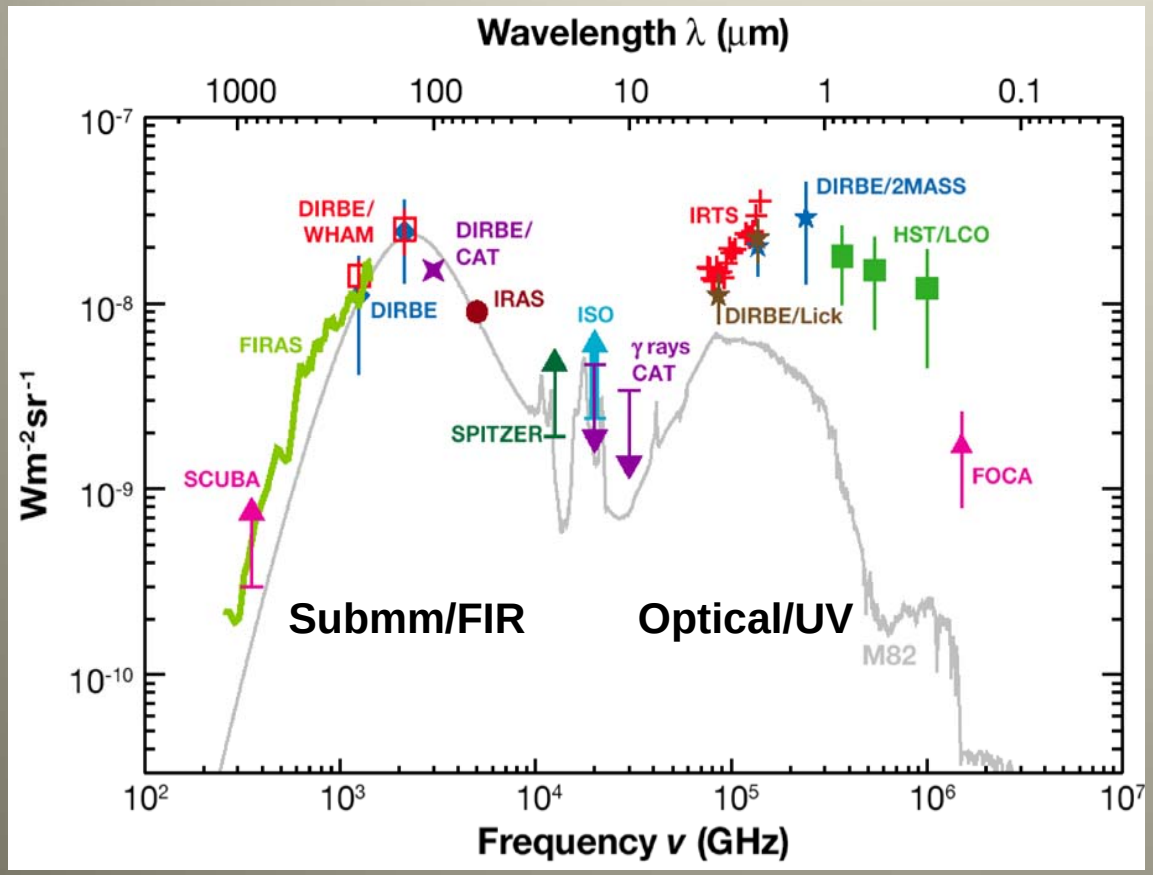


The submm Universe

~1 sq. degree of sky has been surveyed at submm wavelengths to date resulting in the detection of more than ~400 bright SMGs (>3mJy)

~20-30% of the (sub)mm background has been resolved by blank-field surveys. ~80% by galaxy cluster surveys but poor number statistics





What's the nature of the sub-mJy population responsible for >50% of the submm EBL?

Strategy: select high-z galaxies populations at other wavelengths than submm and search for a statistical signal

The near-IR is ideal:
- immune to dust and age effects (unlike UV/optical)
- large format near-IR cameras now available

The Extended Chandra Deep Field South (ECDF-S)

The Multi-wavelength Survey by Yale-Chile (MUSYC)

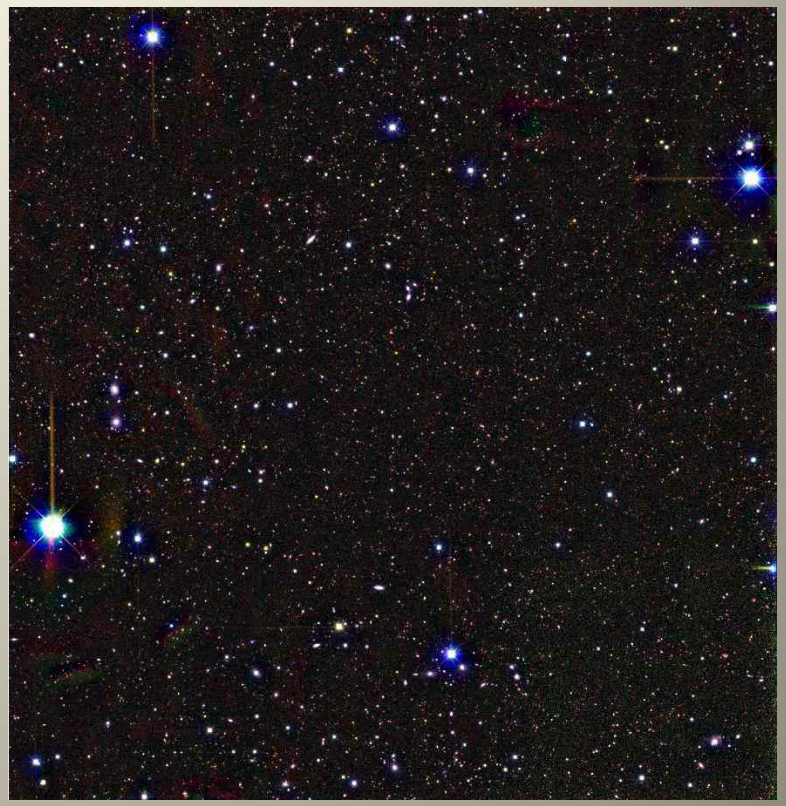
> UBVRIzJHK imaging covering the entire ECDF-S (30'x30')

> 5σ limiting (AB) magnitudes:

U (26.8)	B (27.0)
V (26.6)	R (26.4)
I (24.7)	z (24.0)
J (23.0)	H (21.6)
K (22.3)	

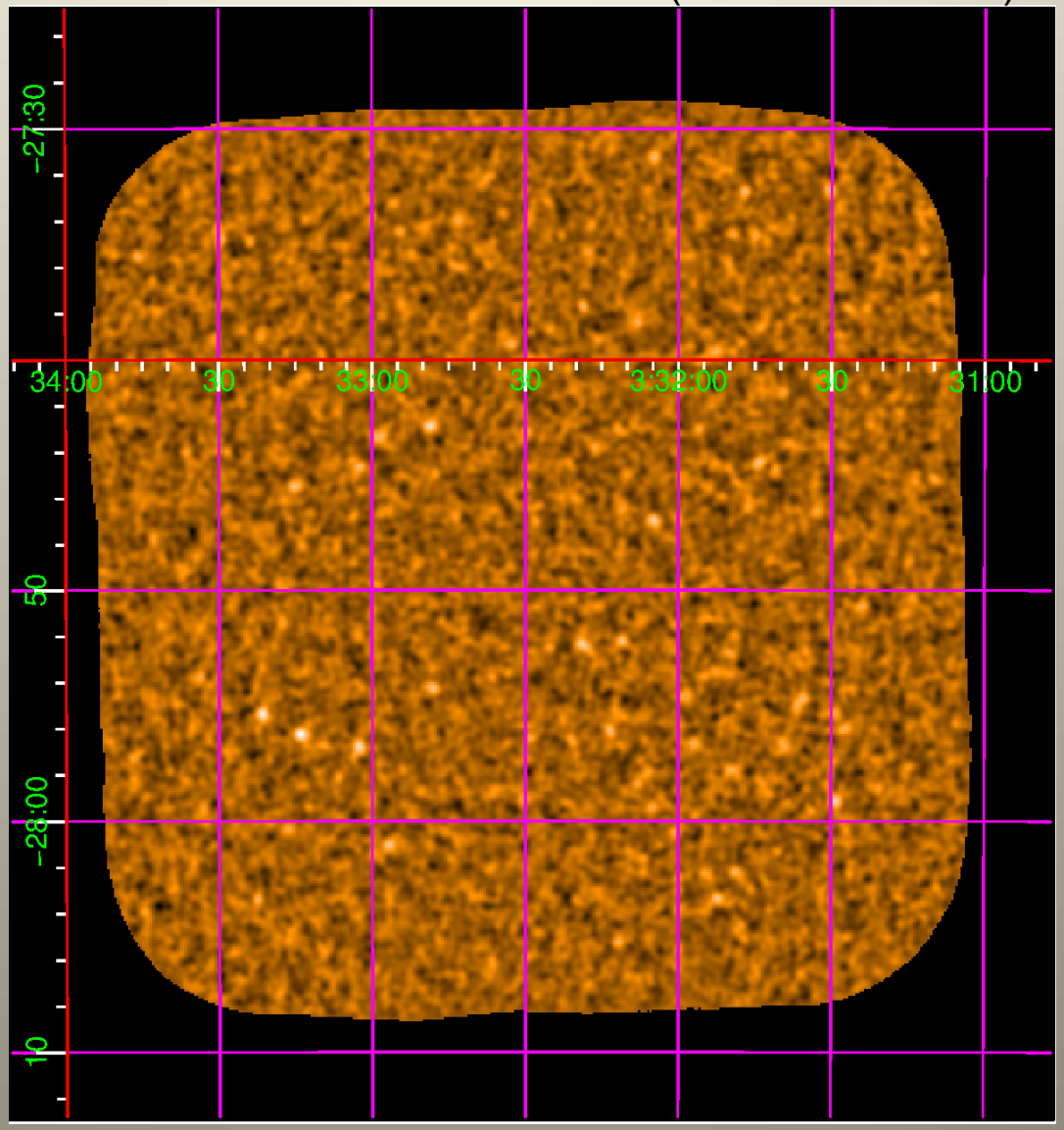
> Ready-to-go catalogues available on-line

900 sq. arcmin field.
Centered on CDF-S: 12:36:55 +62:14:16 (2000.0)



The APEX/LABOCA 870μm survey of the ECDF-S

The largest contiguous (sub)mm survey undertaken to date:
200hrs on-'source' integration time (σ_{rms}=1.2mJy)
>120 sources detected at 3.7σ (Weiss et al. 2009)



Near-IR selected galaxy samples

Samples selected from MUSYC:

> $K_{vega} \leq 20$ galaxies (8266)

> sBzK (744):

$BzK \equiv (z\text{-}K)_{AB} - (B\text{-}z)_{AB} \geq -0.2$

> pBzK (149)

$BzK < -0.2$

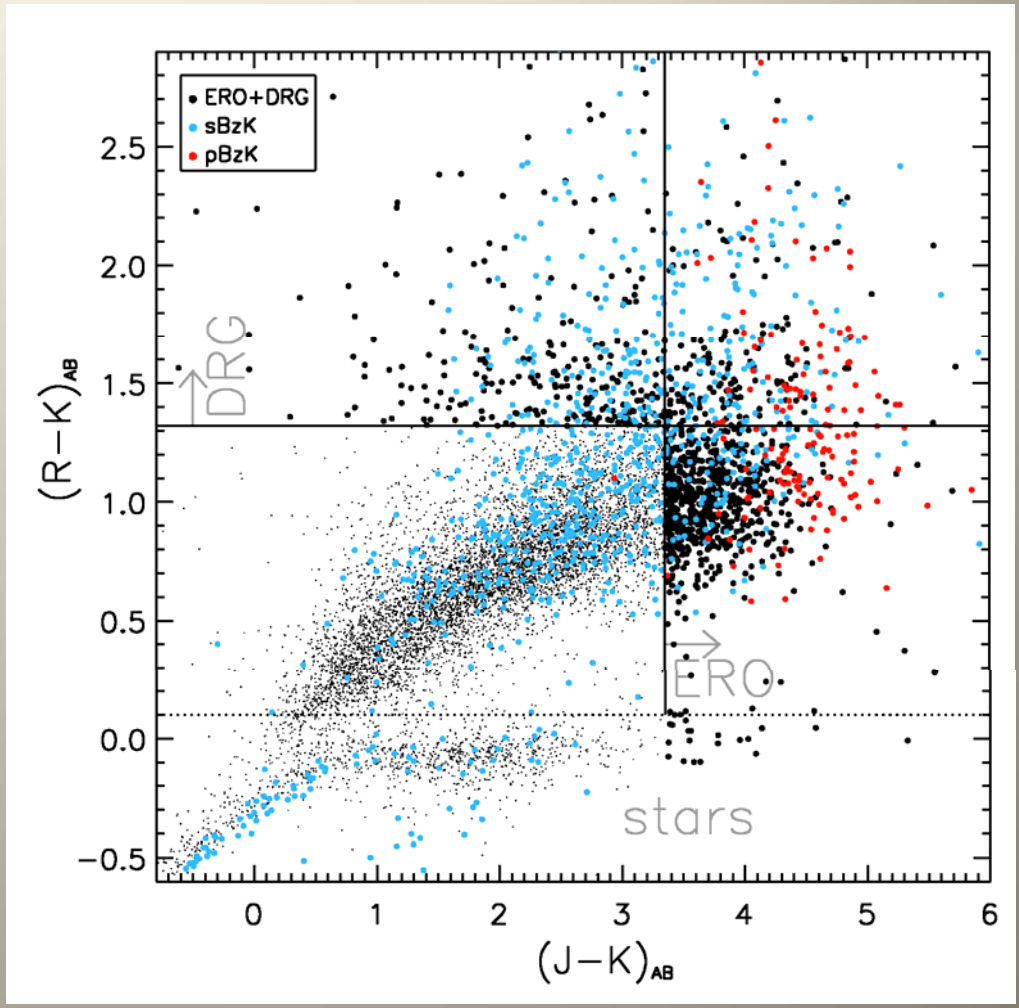
$(z\text{-}K)_{AB} < 2.5$

> ERO (1253)

$(R\text{-}K)_{AB} \geq 3.35$

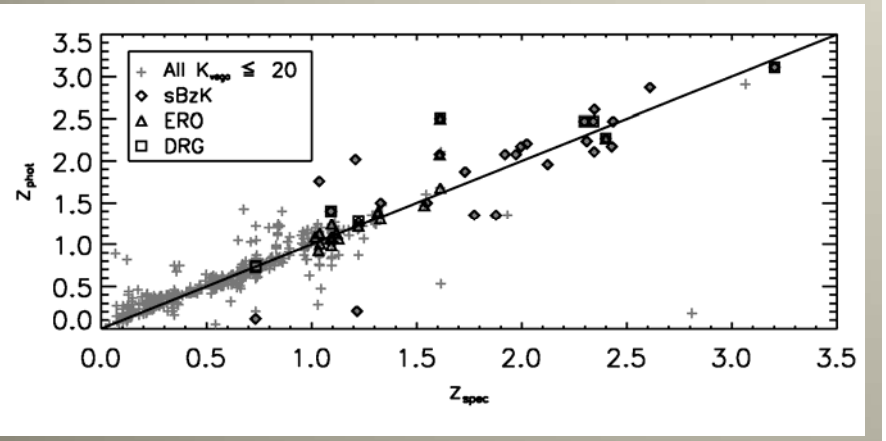
> DRG (737)

$(J\text{-}K)_{AB} \geq 1.32$



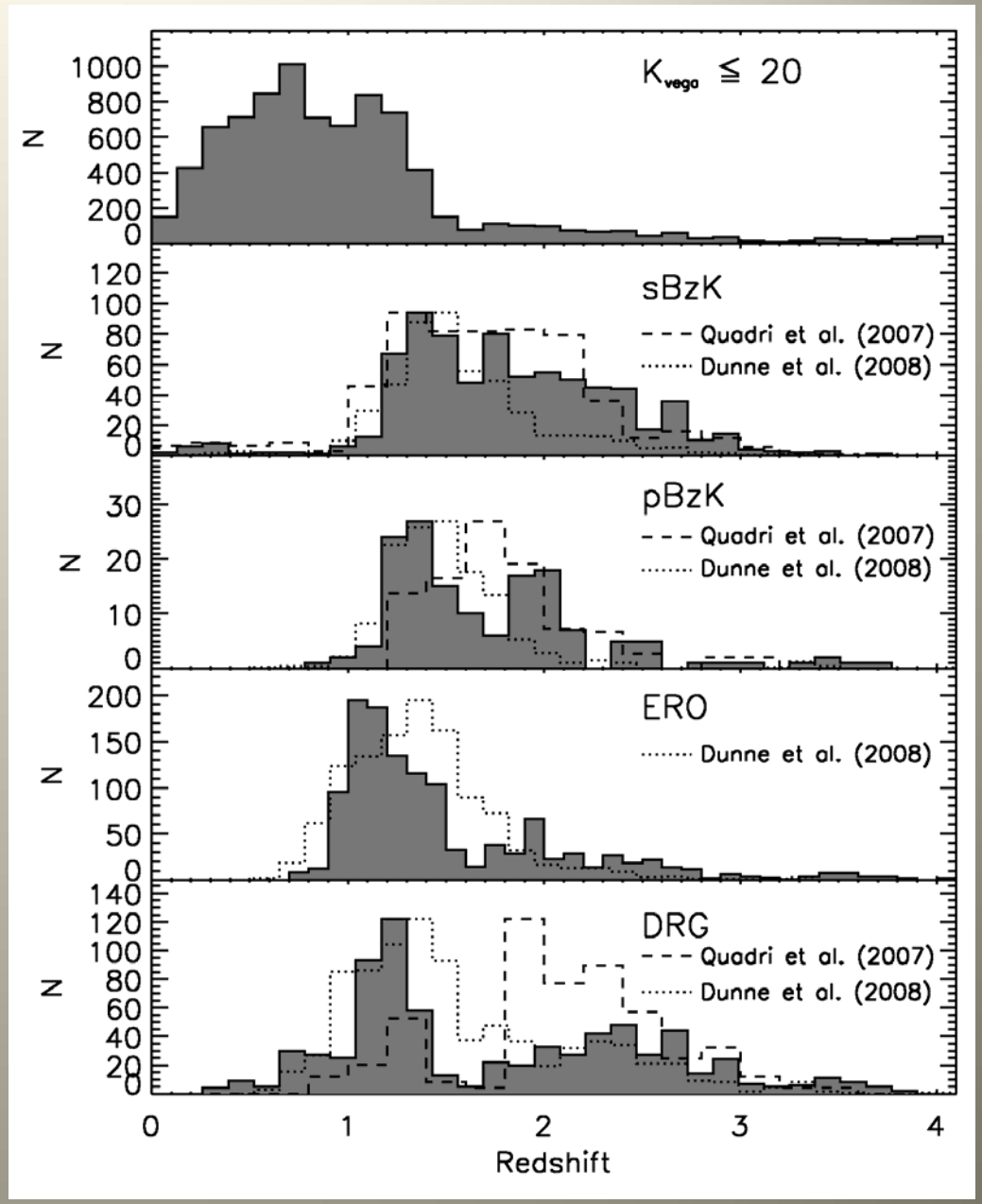
Photometric redshifts

Derived using EAZY code (Brammer, van Dokkum & Coppi 2008) and MUSYC photometry



$\sigma(|\Delta z|/(1+z_{spec})) = 0.037 \quad (z < 1.5)$

$\sigma(|\Delta z|/(1+z_{spec})) = 0.079 \quad (z > 1.5)$



Submm stacking technique

> Remove galaxies coinciding with robust submm sources (Weiss et al. 2009)

> Weighted mean stacked flux and noise

> Accounting for deblending in the process

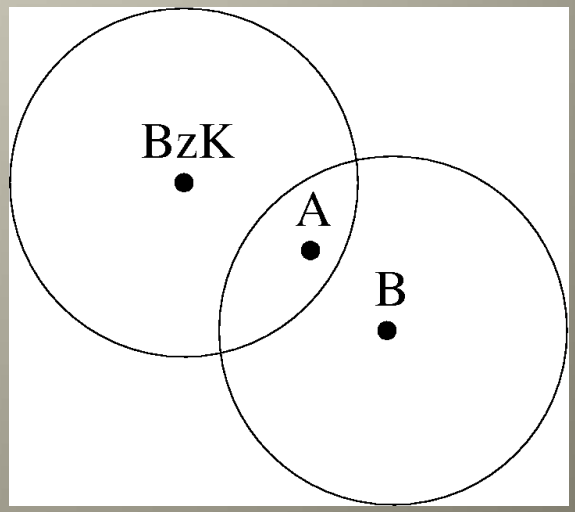
$$\langle S_{870\mu m} \rangle = \frac{\Sigma_i S_i/\sigma_i^2}{\Sigma_i 1/\sigma_i^2}$$

$$\langle \sigma_{870\mu m} \rangle = \frac{1}{\sqrt{\Sigma_i 1/\sigma_i^2}}$$

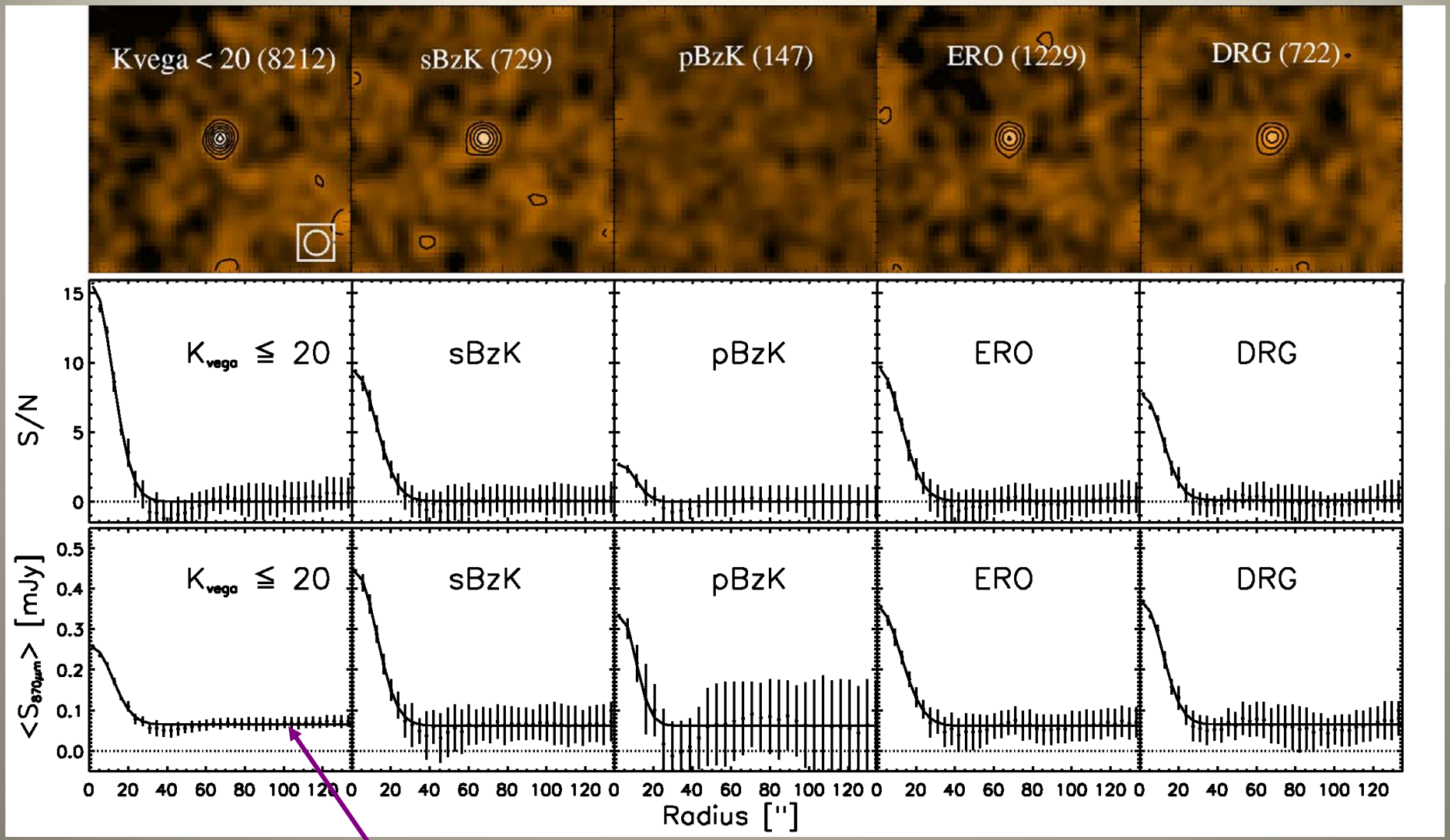
$$f_{BzK} = I_{BzK} + I_A e^{-r^2_{BzK,A}/(2\sigma^2)}$$

$$f_A = I_A + I_{BzK} e^{-r^2_{BzK,A}/(2\sigma^2)} + I_B e^{-r^2_{B,A}/(2\sigma^2)}$$

$$f_B = I_B + I_A e^{-r^2_{B,A}/(2\sigma^2)}$$



Submm stacking @ 870micron



Non-zero background level (0.065mJy) due to $K_{vega} \geq 20$ sources below the 870μm detection limit (must be subtracted from the stacked fluxes)

Submm stacking @ 870micron

Galaxy type	$\langle S_{870\mu m}\rangle^a$ [mJy]	$\langle S_{870\mu m}\rangle^b$ [mJy]	δN^b [sq. arcmin^{-1}]	$\langle \delta I_{870\mu m}\rangle^b$ [Jy sq. deg^{-1}]
$K_{vega} \leq 20$	0.18 ± 0.01 (8212, 18.0σ)	0.20 ± 0.01 (8266, 20.0σ)	9.18 ± 0.10	6.61 ± 0.34 (15.0 ± 5.2 %)
sBzK	0.47 ± 0.04 (729, 11.8σ)	0.57 ± 0.04 (744, 14.3σ)	0.83 ± 0.03	1.70 ± 0.24 (3.9 ± 1.4 %)
pBzK	0.20 ± 0.10 (147, 2.0σ)	0.27 ± 0.10 (149, 2.7σ)	0.17 ± 0.01	0.16 ± 0.11 (0.4 ± 0.3 %)
sBzK+pBzK	0.43 ± 0.04 (876, 10.8σ)	0.53 ± 0.04 (893, 13.3σ)	0.99 ± 0.03	1.89 ± 0.24 (4.3 ± 1.6 %)
ERO	0.31 ± 0.03 (1229, 10.3σ)	0.37 ± 0.03 (1253, 12.3σ)	1.39 ± 0.04	1.85 ± 0.20 (4.2 ± 1.5 %)
DRG	0.36 ± 0.04 (722, 9.0σ)	0.37 ± 0.04 (737, 9.3σ)	0.82 ± 0.03	1.09 ± 0.18 (2.5 ± 0.9 %)
BzK/ERO/DRG[c]	0.33 ± 0.03 (1964, 11.0σ)	0.46 ± 0.03 (1997, 15.3σ)	2.22 ± 0.06	3.67 ± 0.29 (8.4 ± 2.9 %)

Only a modest fraction of the EBL has been detected (deeper K-band data are needed, K_{AB}~24)

Galaxy type	$\langle z\rangle$	L^a_{IR} (Arp 220) [$\times 10^{11} L_\odot$]	SFR^b (Arp 220) [$M_\odot$ yr^{-1}]	L^a_{IR} ($T_d = 35$ K) [$\times 10^{11} L_\odot$]	SFR^b ($T_d = 35$ K) [$M_\odot$ yr^{-1}]
sBzK	1.8	6.3 ± 0.4	109 ± 7	3.7 ± 0.3	65 ± 5
pBzK	1.6	2.9 ± 1.0	50 ± 17	1.7 ± 0.7	30 ± 11
ERO	1.3	3.6 ± 0.3	62 ± 5	2.3 ± 0.2	39 ± 3
DRG	1.4	3.6 ± 0.4	62 ± 7	2.3 ± 0.3	40 ± 4

sBzKs are moderately starforming galaxies

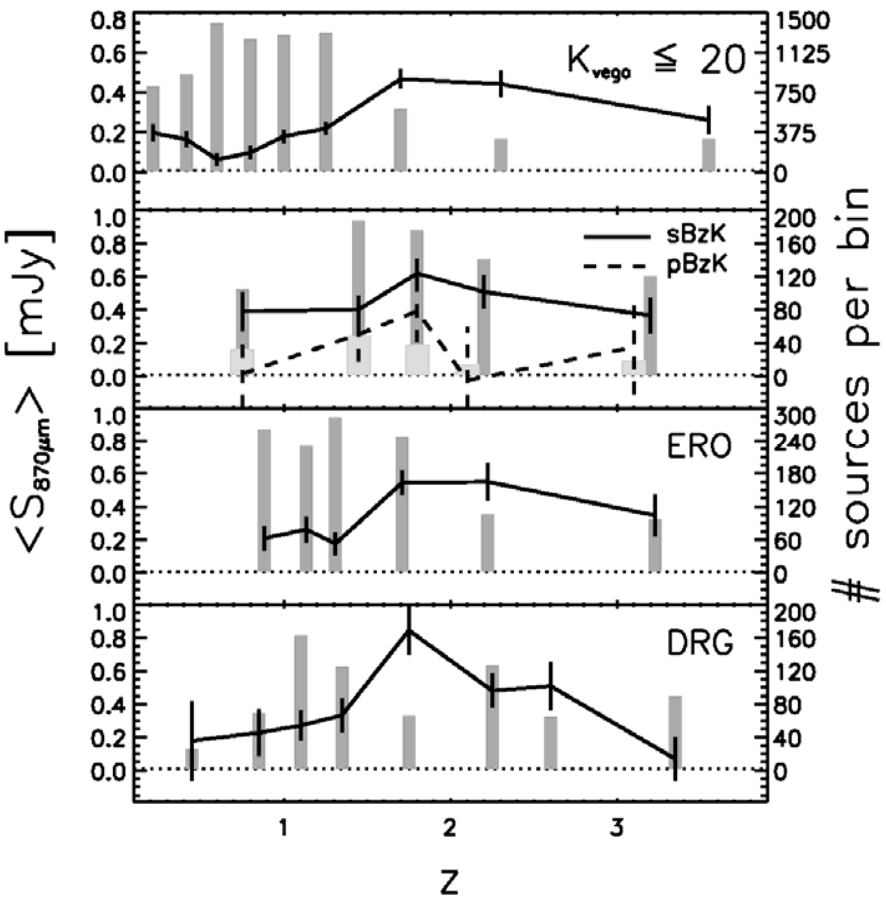
pBzKs are relatively quiescent systems

EROs and DRGs are ‘in between’ (a mix of old red galaxies and dust galaxies

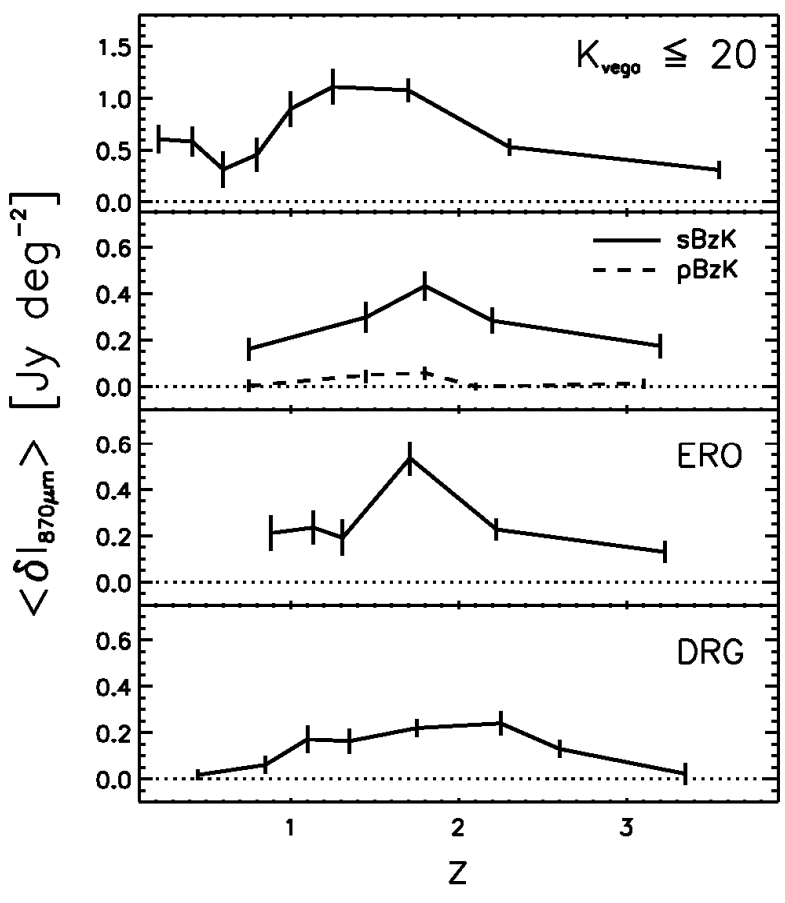
IR luminosities and star formation rates are consistent with values derived from mid-IR (IRAC+MIPS) data (Daddi et al. 2005)

Stacking in redshift bins

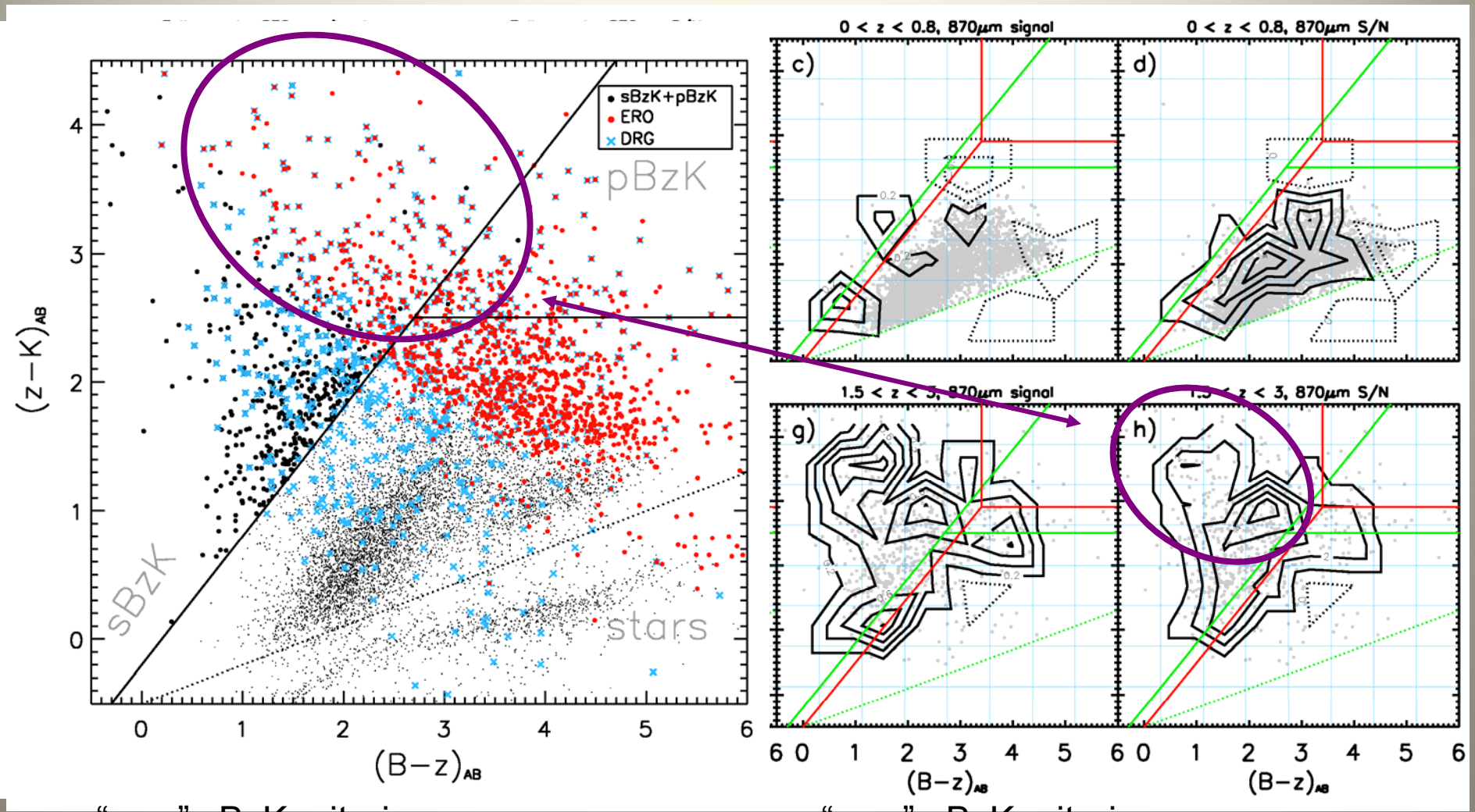
Average submm flux (SFR) vs. z



Average submm EBL contribution vs. z



Stacking across the BzK diagram



"new" sBzK criterion:

$(z-K)_{AB} \geq (B-z)_{AB} - 0.5$

$(B-z)_{AB} \leq 3.4$

"new" pBzK criterion:

$(z-K)_{AB} \geq 2.9$

$(B-z)_{AB} \leq 3.4$

Summary

> The LABOCA/ECDF-S represents the largest stacking analysis of K-selected galaxies at submm wavelengths (by a factor 5) - we probe 7x deeper than typical blank field submm surveys (and 3x times deeper than the HDF-N)

> Highly significant stacking signals are detected for sBzK, ERO and DRG galaxies. pBzKs are not detected (<0.3mJy)

> the sBzk, ERO and DRG populations (brighter than K_{vega} = 20) each make up <10% of the EBL at 870micron. $K_{vega} \leq 20$ galaxies make up 15-34% of the EBL

> The contribution to the 870micron EBL by $K_{vega} \leq 20$ galaxies occur at z=1-2.5

> We confirm the abllity of the sBzK-criterion to isolate z > 1 starforming galaxies - although our analysis suggests that the subset of sBzK which are also EROs (30%) produce 80% of the submm emission from the entire sBzK population