

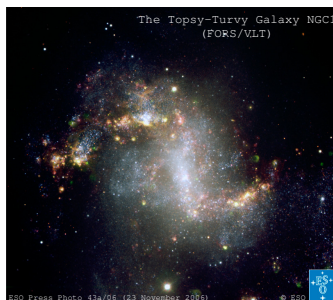
Star Formation in the J2142-4423 Ly-alpha Proto-cluster at $z = 2.38$

Alexandre Beelen

(alexandre.beelen@ias.u-psud.fr)

Martinique08 - When the Universe Formed Stars

Star Formation and Environment



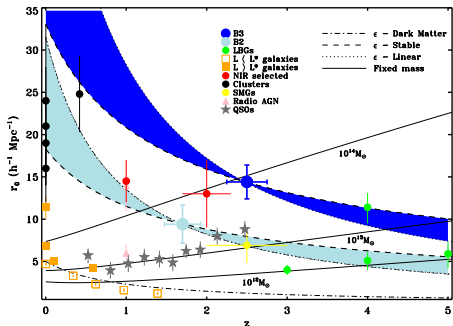
Small Scales

- fusion, fly-by...
- induce star formation

Large Scales

- Bump 2/Bump 3
- most massive halo ?

Farrah et al. (2006)

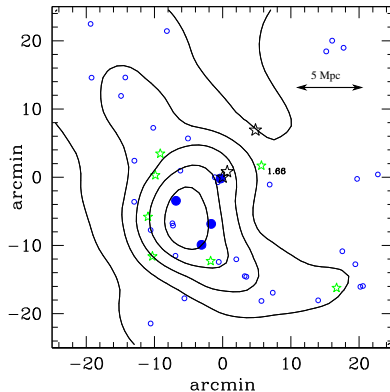
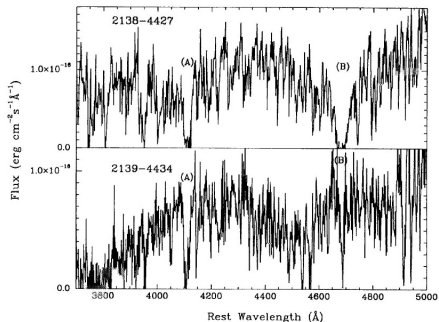


The Francis Cluster

a proto-cluster at $z = 2.38$

- 2 LBQS QSOs at $8'$ @ $z = 3.23$ & $z = 3.18$
- Ly- α narrow band Imaging $2.356 < z < 2.401$
- 110 Mpc comoving
- 37 Ly- α sources, 6 QSOs, 4 *Ly- α blobs*

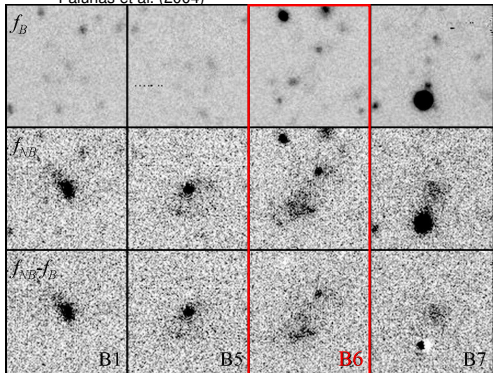
Francis & Hewett 1993



Lyman- α blobs

- $\Phi > 50$ kpc, often in high- z over-densities
- radio quiet but similar to radio galaxies
- bright SMG e.g. Chapman et al. 2001, Geach et al. 2005
- ULIRGs/HLIRGs Colbert et al. 2006

Palunas et al. (2004)



Power Source ?

- SN winds ?
- AGN ? Cooling flows ?
- Starburst & shocks ?

ATACAMA PATHFINDER EXPERIMENT

- Max Planck Institut für Radioastronomie (MPIfR) – 50 %
- Observatoire Européen Austral (ESO) – 27 %
- Onsala Space Observatory (OSO) – 23 %



Heterodyne Receivers

- ~ 211-500 GHz
- FLASH/CHAMP+, CONDOR

Bolometer Array

- SABOCA, PARTEMIS, ASZCA
- LABOCA
 - 295 total-power pixels @ 345 GHz
 - 280 mK, He⁴/He³ closed cycle
 - HPBW ~ 19'' FOV ~ 11.4'

Observations & Data Reduction

Observations

LABoCa

- ESO Science Verification July 2007 – 17h
- MPIfR August 2007 – 7h
- spirals raster
- $\tau_{870\mu m} = 0.07 - 0.17$ (0.12)
- calibration on Mars 7 %

Data Reduction

Bolometer array Analysis software

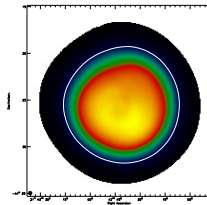
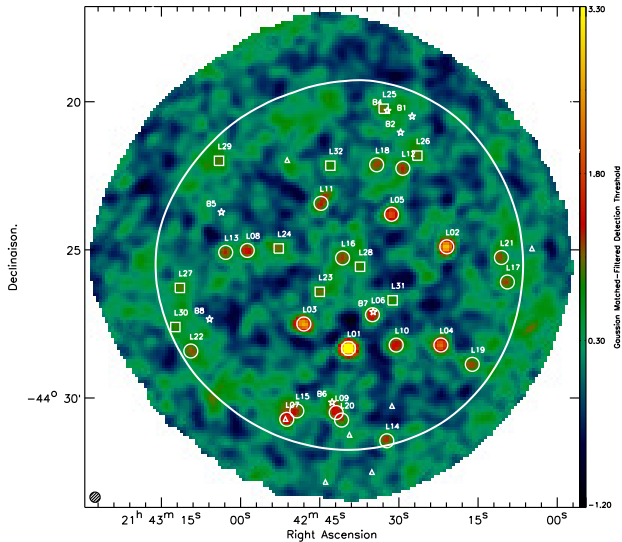
- telescope speed & acceleration flag
- temperature drifts blind bolometers
- sky emission median noise/correlated noise/PCA
- bad bolometers MAD flag
- map-making simple, bolometer noise weighted

Results

$$\bullet \quad F/\Delta F = \frac{(S W) \otimes \text{PSF}}{\sqrt{W \otimes \text{PSF}^2}}$$

• 120 arcmin² $\sigma_{\text{pix}} < 5$ mJy/beam

• **22 sources** ($F/\Delta F > 1.2$) + **10** ($F/\Delta F > 1.0$)



Number counts

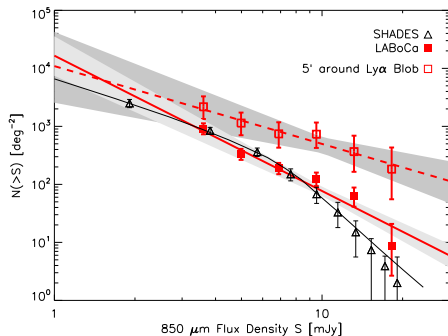
22 sources, $S_{870\mu m} > 3$ mJy

- $N(> S) = N_0 (S/S_0)^{-\alpha}$
- $S_0 = 10$ mJy,
 $N_0 = 70 \pm 12 \text{ deg}^{-2}$,
 $\alpha = 1.9 \pm 0.2$

SHADES

(Coppin, K. et al. 2006)

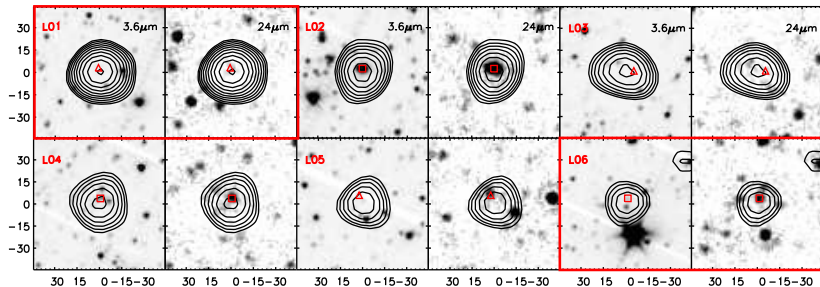
- $N_0 = 85$, $\alpha = 2$
- over-density at
 $S_{870\mu m} > 10$ mJy ?



Spitzer

IRAC & MIPS $24\ \mu\text{m}$

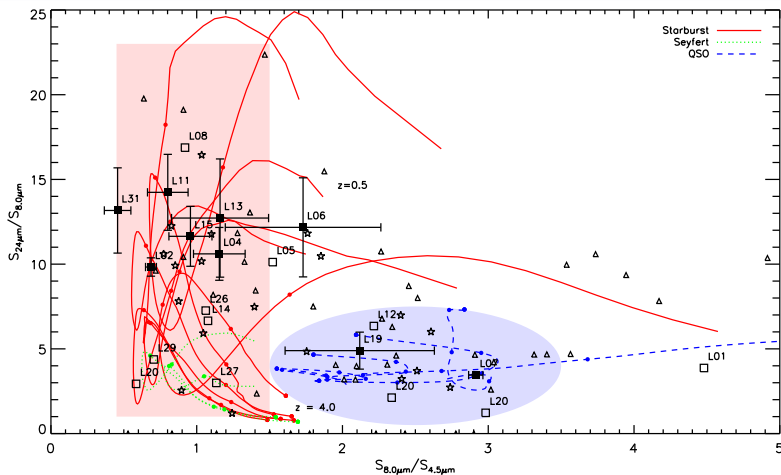
- $\Delta\alpha = \Delta\delta = 4''$, $\Delta\text{abs.} = 5''$
- $P = [1 - \exp(-E)]$, $E \sim \pi r_s^2 N$
- 10 associations ($P < 0.05$) with MIPS $24\ \mu\text{m}$
1/4 Lyman- α blob



SWIRE SEDs

Polletta et al. 2007

- 6 Starbursts
- 1 Optical QSO, 1 AGN



Sources Properties

- IR-z

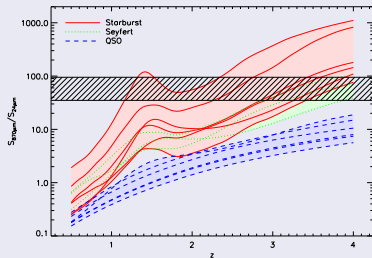
Pope et al. 2006

$$Z_{\text{IR}} = \sum_{\text{IRAC, MIPS24}} \alpha_i \log(S_i) \approx 2.0 - 2.8$$

- $L_{\text{IR}} = L_{5-1000 \mu\text{m}} \approx 5 \dots 20 \times 10^{12} L_{\odot}$

No Association ?

- $S_{24 \mu\text{m}} < 80 \mu\text{Jy}$
- $S_{870 \mu\text{m}} / S_{24 \mu\text{m}} > 35 - 95$
 - $z > 2.2$ (SB)
 - $z \approx 1.4$ (Arp 220)
 - $z > 5$ (QSO)



Individual Sources

L01 : $S_{870\mu m} = 21.1 \pm 1.0$ mJy

??

- Radio 843 MHz (SUMSS)

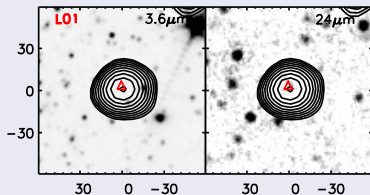
$$S_{843\text{MHz}} > 10 \text{ mJy}$$

$$\alpha_{843\text{MHz}}^{345\text{GHz}} > 0.13 : z > 0.7$$

- Spitzer

$$S_{870\mu m} / S_{24\mu m} > 270$$

SB @ $z > 2.38$?

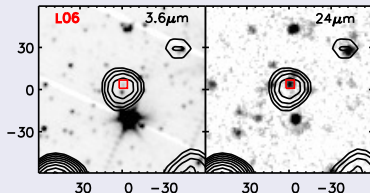


L06 : $S_{870\mu m} = 8.4 \pm 1.0$ mJy

Lyman- α blob B6 @ $z = 2.38$

- $L_{\text{IR}} \approx 5 \cdot 10^{12} L_{\odot}$

- $L_{\text{Ly}\alpha} / L_{\text{bol}} = 0.16\%$
(Geach et al. 2005)



Conclusions

Star formation & Environment

- > 20 SMGs @ $z \sim 2.3$
- over-density around L06 (?)
- characterize sources
- larger field on the filament

Hawk I, ATCA

LABoCa

Physics of Lyman- α blobs

- $1/4$, $L_{\text{IR}} \lesssim 10^{13} L_{\odot}$
- deeper sub-mm observations

ULIRGs/LIRGs

LABoCa

And more...

- confusion studies
- spectroscopic follow-up

ALMA...