

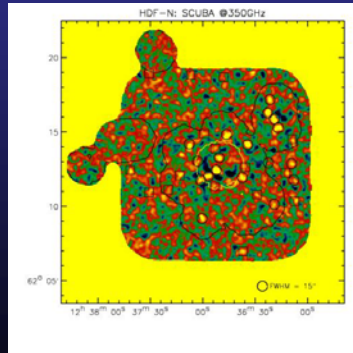
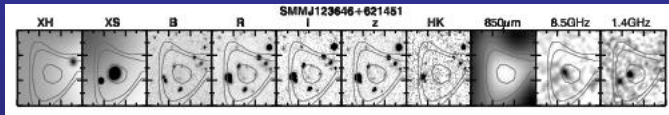


An overview of sub-mm extragalactic astronomy



Colin Borys

California Institute of Technology



Outline

History

- COBE and the detection of the CIB
- IRAS/ISO and the “local” *ULIRGS*
- SCUBA dives deeper

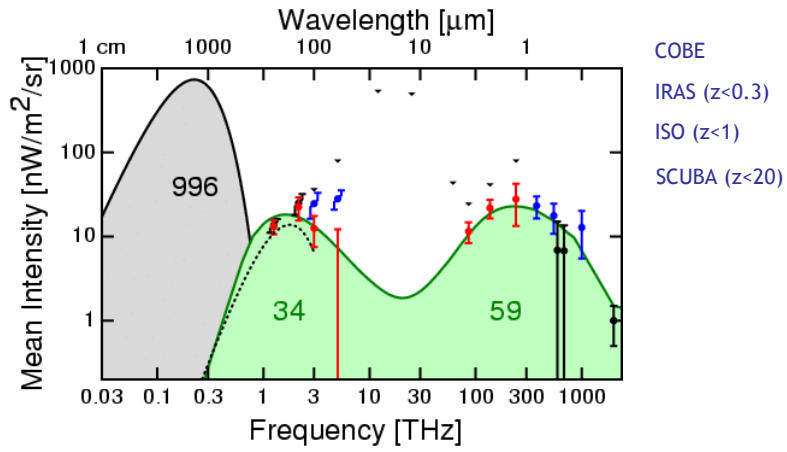
Perspective

- After the dust cleared...
- What are the SCUBA galaxies?
- The need for other telescopes. VLA + *Chandra* step up.

Current efforts

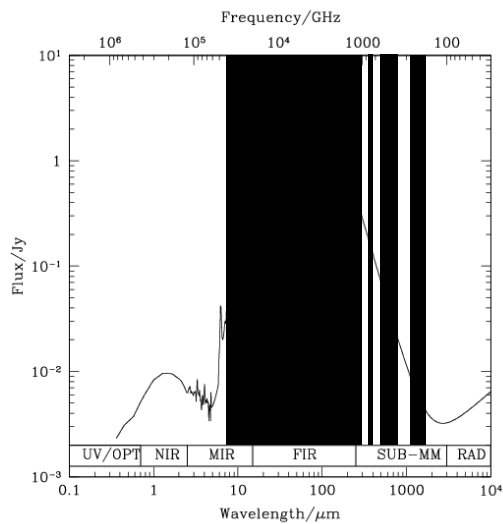
- Redshifts of the bright SMGs
- Sofia, *SIRTF*, SCUBA2, *Herschel*, ALMA

Background information

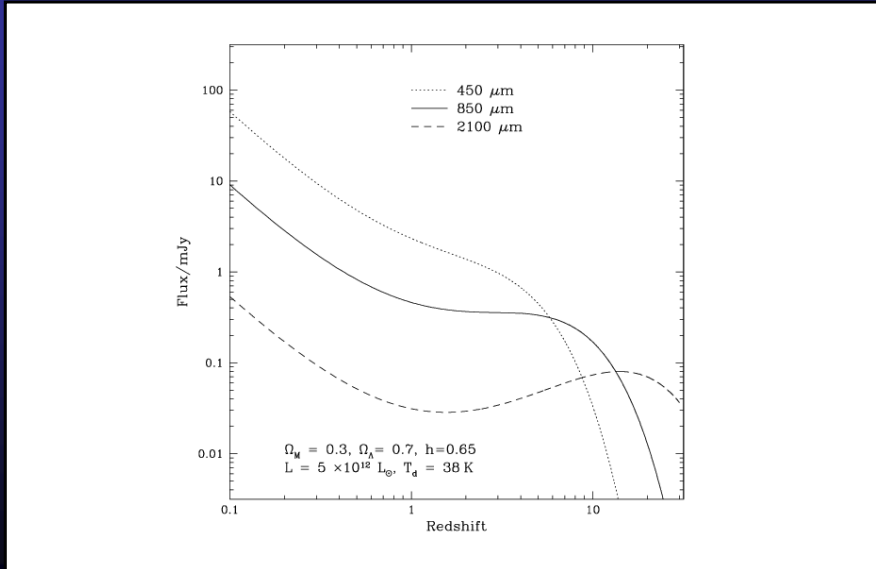


E.L. Wright astro-ph/030658

Dusty SEDs



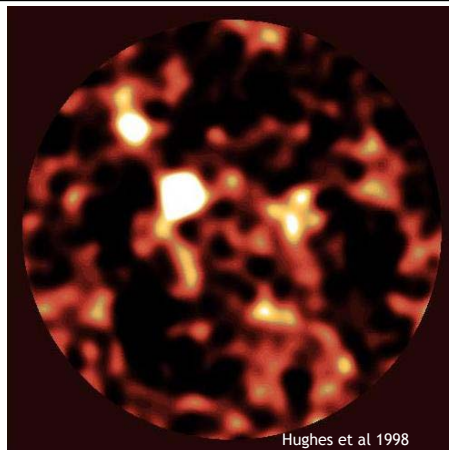
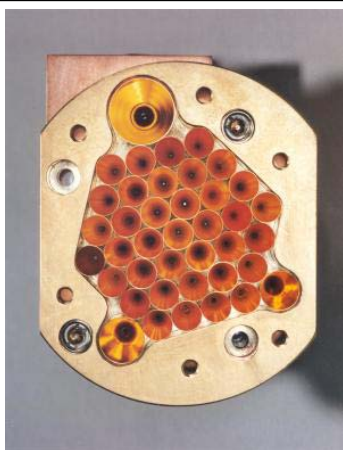
K-correction



SCUBA

Sub-mm Common User Bolometer Array

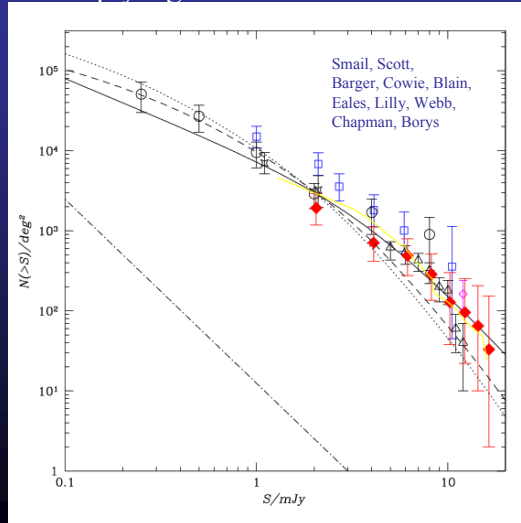
- 37/91 element array at 850/450 μm
- Atmospheric noise limited
- 15/7'' resolution



Hughes et al 1998

SCUBA : Source counts

- > 300 objects detected since 1998 through blank-field surveys
- 850 μm counts imply significant evolution of ULIRG pop.



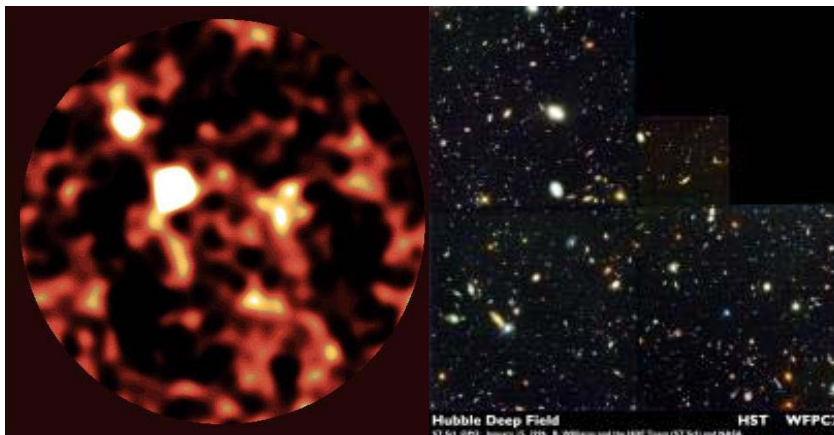
Monochromatic Results

- ULIRGS are 1000x more numerous in the past
- Locally, ULIRGS are observed to be merging systems (and seem to be at high- z as well... Conselice et al 2003)
- SCUBA galaxies, with high inferred SFR, and co-moving volume density, are likely the progenitors of massive ellipticals.
- Clustering would help here, but :
 - areas surveyed too small (SHADES)
 - too few sources observed (SHADES)
 - no redshift information to separate (SHADES + BLAST)

Open questions:

- What powers the extreme luminosities ? (AGN/SF)?
- What is their redshift distribution?
- Clustering?
- Morphology?

SCUBA: Counterpart ID



Case study: HDF-N

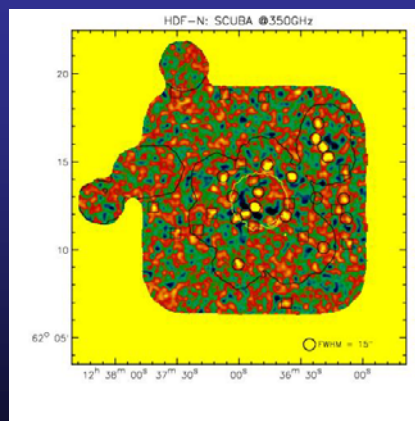
Aside from clustering, broadband comparisons are required to answer those questions.

SCUBA + HDF-N

- 19 sub-mm sources $>4\sigma$
- 17 more $> 3.5\sigma$
- 200 VLA 1.4 and 8.5 GHz
- 500 Chandra 2Ms
- 1000's Optical (ACS, etc)
- 1000's NIR (Subaru etc)
- 100 ISO $15\mu\text{m}$
- redshifts!

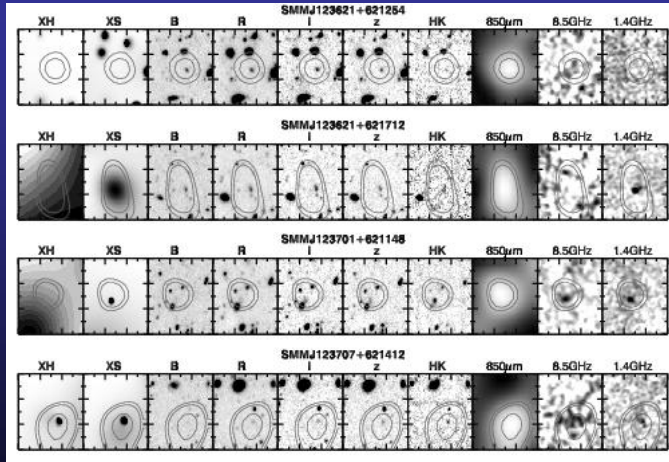
Other surveys

- 8 mJy, SA22, CUDSS
- SHADES



Borys et al 2003

Postage stamps of HDF-N SCUBA sources



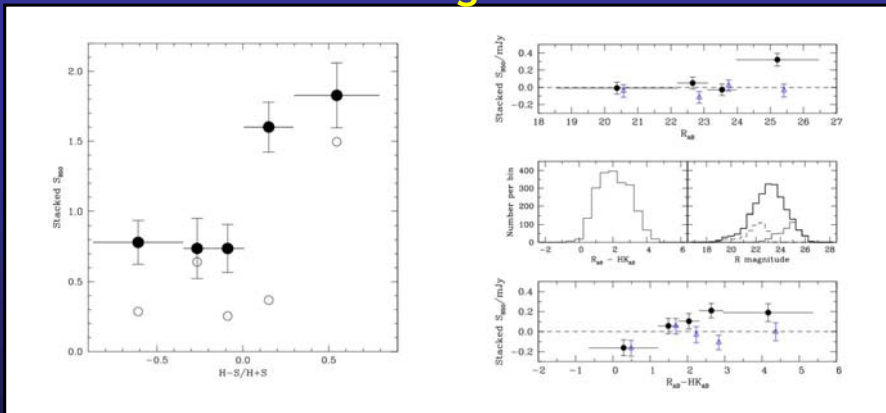
???

OFRS

ERO

ERO/AGN/RQ

Multiwavelength overview



Radio detected (50-70%)..not surprising given FIR/radio correlation.

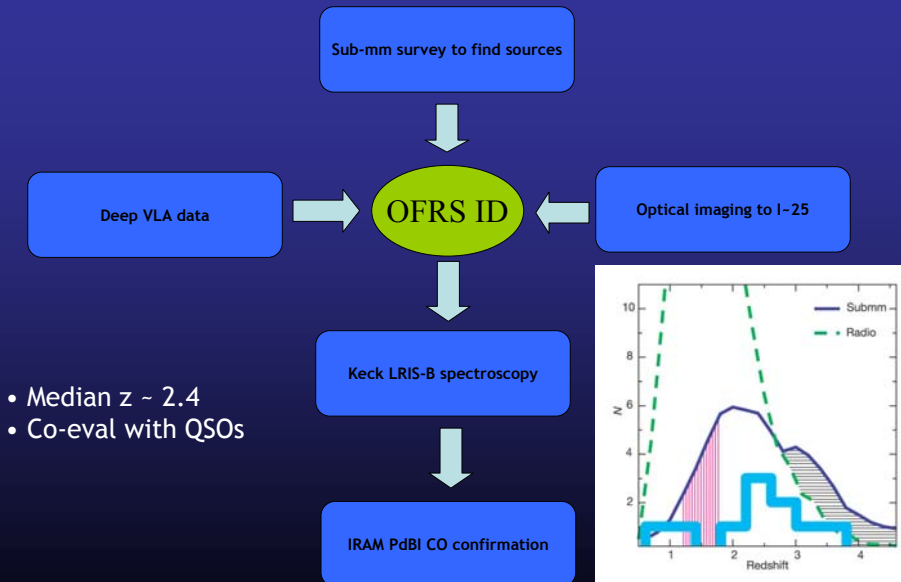
- Chandra detected (~50%), though not AGN powered. X-ray detected sources are also radio detected (Alexander et al 2003).
- Morphologically disturbed (Conselice et al. 2003)
- Generally “red” though not always. (Frayer et al 2003, Ivison et al 2001)
- Optically faint, therefore spec-z’s too difficult (2GHz/115GHz ~1% chance) or are they....

RADIO IDs

- The tight FIR-Radio Correlation allows one to use radio interferometry to find SCUBA sources.
- Need deep VLA data (1.4 GHz)
- Too faint past $z \sim 3$

- With accurate positions, we know where to lay down slits...

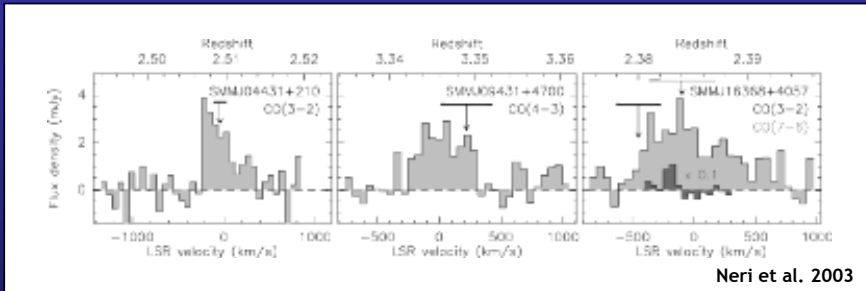
The path to redshifts



Chapman et al 2003

CO Confirmation

Also...Frayer (OVRO), Ivison, Greve, Genzel



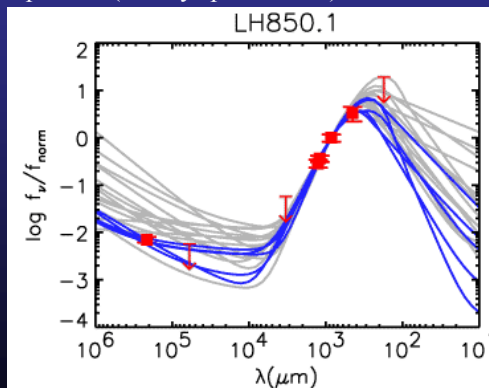
Neri et al. 2003

24 hours integration each for CO!!

- Redshifts support elliptical progenitor hypothesis
- “pairing” in z used to study clustering....detection? (Ivison et al. 2003)
- Larger sample (>100) being analyzed now.

Photometric redshifts

- Spec-z's suffer from the following:
 - Can only do radio ID'ed sources (selection effects?)
 - That in turn restricts the S850 flux to be > 5mJy ... that is only a small fraction of the number counts (< 10%...or a few % with z's after efficiency effects)
 - considerable investment in telescope time (~2 days per source!)
- Phot-z techniques show promise, but have their own problems:
 - $T/(1+z)$ degeneracy.
 - T/β degeneracy?
 - Which templates?
 - Local templates representative of high-z ones?



Arexaga et al. 2003

Need new instruments!

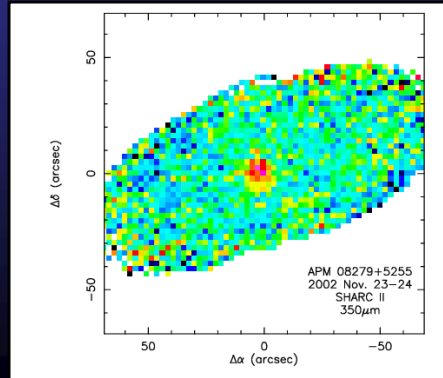
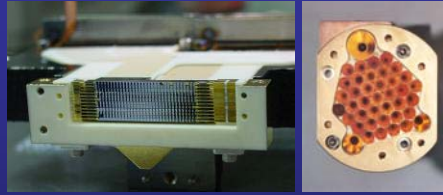
SHARC-II

Sub-mm High Angular Resolution Camera

- Total Power
- CCD style imaging
- Optimized for $350\mu\text{m}$..
Closer to the thermal peak!
- CMB-style data acquisition and reduction

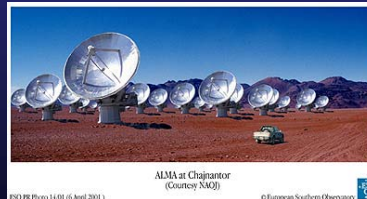
Relevant applications

- SED fitting
- $T/(1+z)$, T/β degeneracy
- Confronting Confusion (BLAST, SIRTf, etc)



The near future

- SHADES will be SCUBA's final send-off.
- SCUBA-2 will then do all the "hard" ground based observations.
- SIRTf will significantly improve our understanding of these objects.
- Sofia will fly in 2005, *Herschel* a few years later.
- SHARC-II/BOLOCAM, LABOCA, MAMBO
- LMT being built
- *THE ERA OF LARGE BANDWIDTH HETERODYNE RECEIVERS APPROACHES!*
- SMA is operating and taking data.
- ALMA will clean up ...



The importance of multi-spectral coverage cannot be understated.