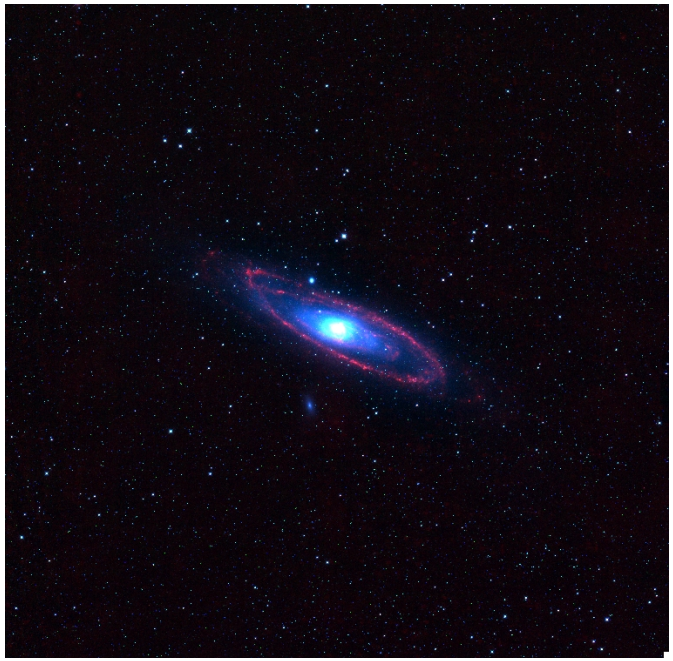
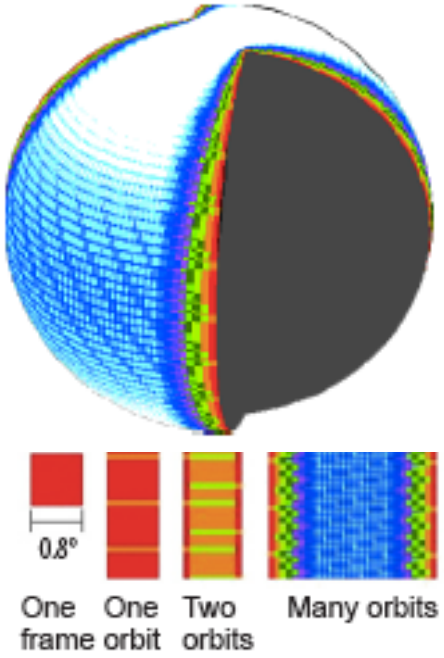
Contents

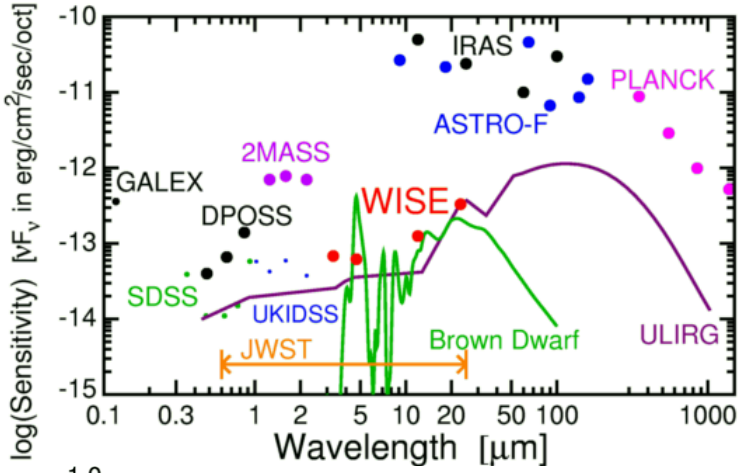
- WISE surveyed the whole sky and founds hundreds of very luminous galaxies at a few microns wavelength
  - Rare and red, rest optical to IR. “DOGs”
  - Most extreme objects, but with SEDs different from SMGs − much hotter − “Hot DOGs”
- Not lensed, and probably all AGNs
- Surrounded by SMGs, too many regular red galaxies.
- Protoclusters / location in cosmic web?

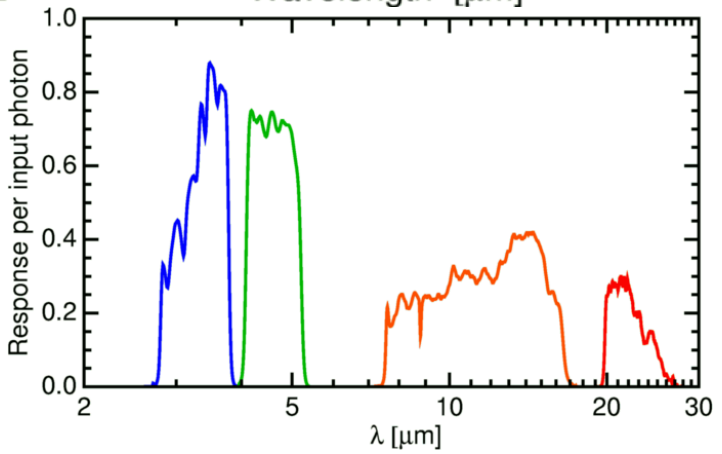
WISE: Dec 2009 to Jan 2011

- Finished 1st sky pass 17th July 2009
- All-sky releases 14/3/2012, 12/11/2013
- 3.4, 4.6, 12, 23μm (W1-4)
- 6, 6, 6, 12" resolution
- 0.08, 0.08, 0.8, 4mJy
- More data taking in 3.4, 4.6 μm (2014-2017)

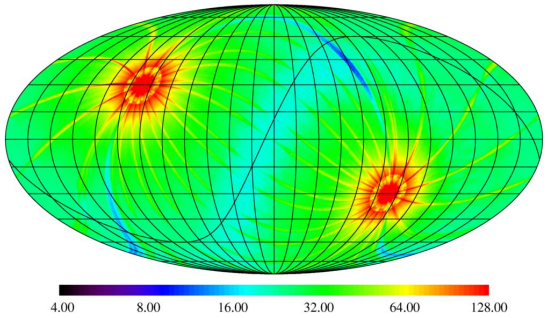




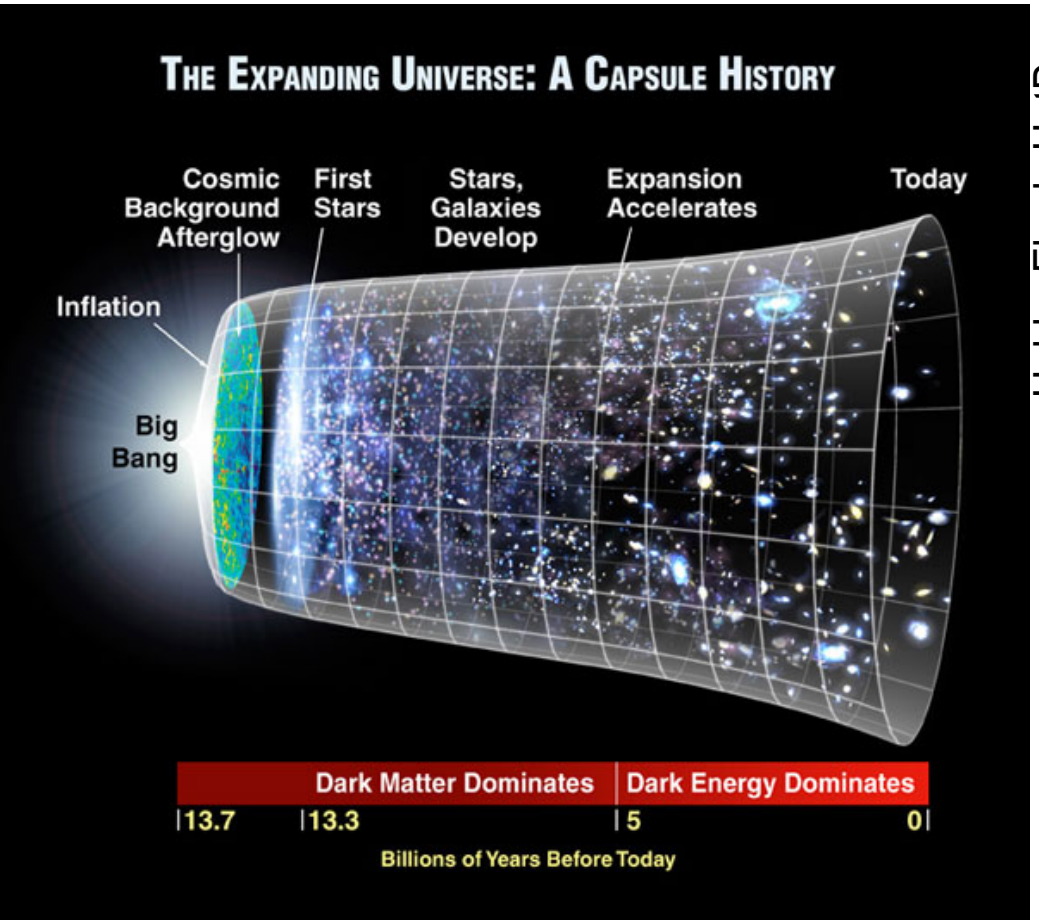




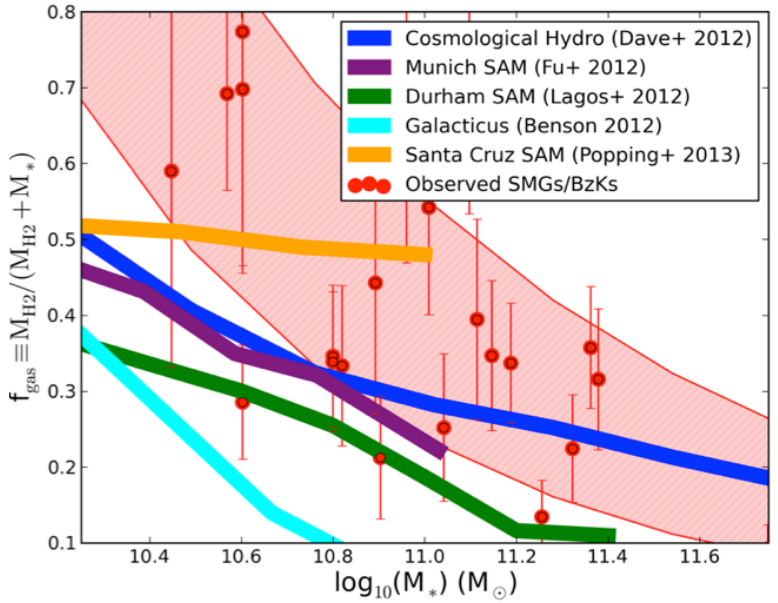
2589157 frames thru 11-005.5; 99.4% to 16x+



Pictures of galaxy evolution

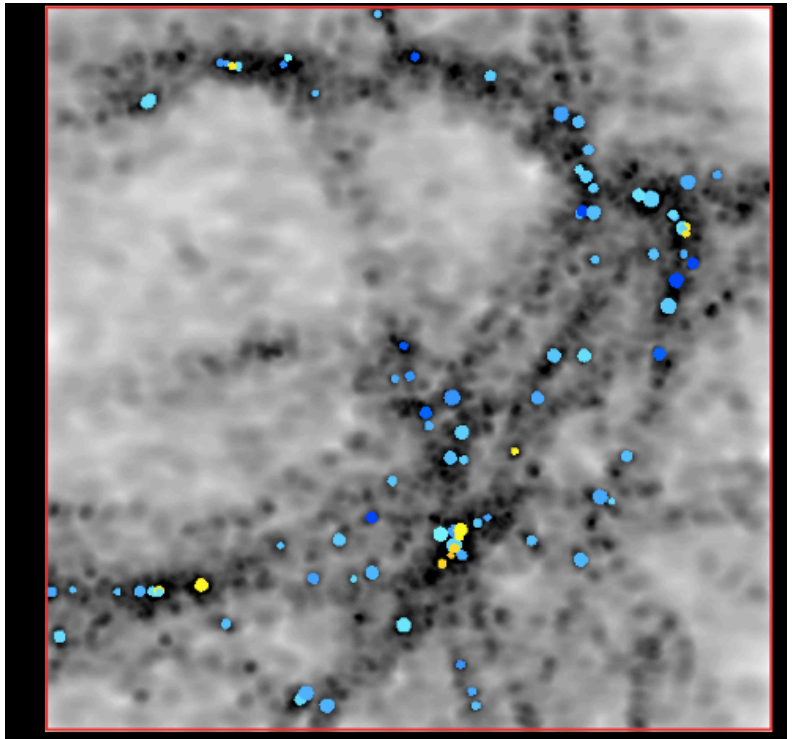


Hobby Eberly HetDex



Casey, Narayanan & Cooray (2014)

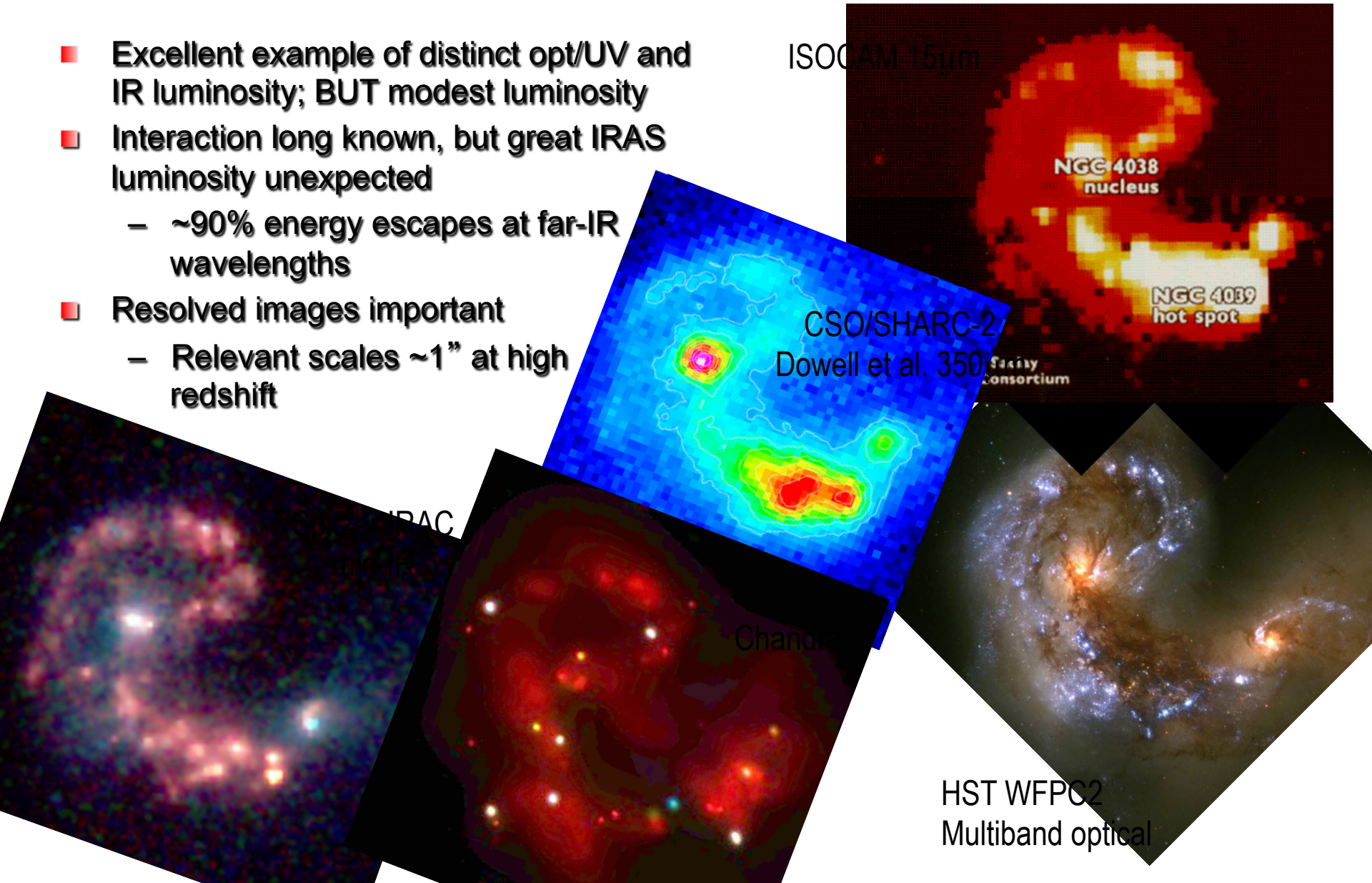
Benson et al. ~30 Mpc; z~2 cluster



Resolved imaging with ALMA shows that gas simulations are important. On ~10pc scales this might always be the case – factors of millions in density to handle

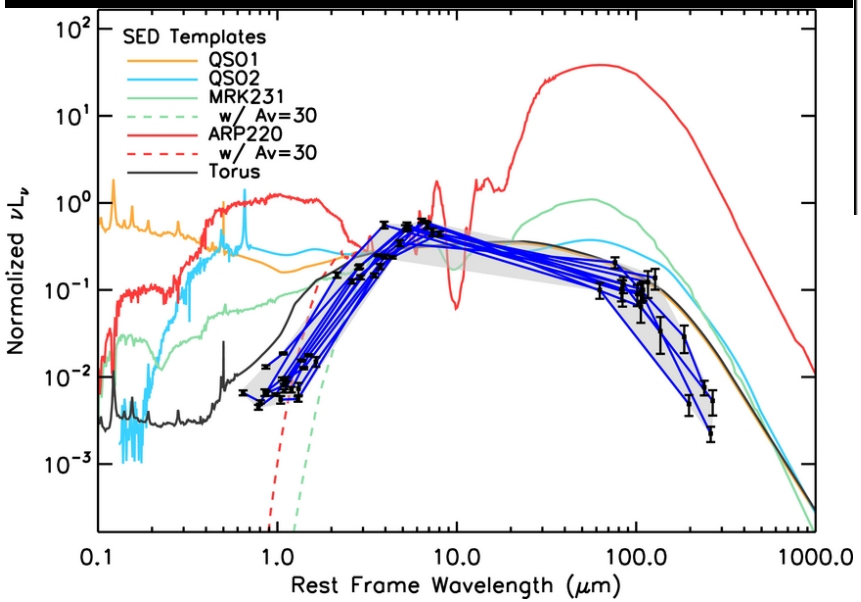
Resolved non-AGN: the Antennae

- Excellent example of distinct opt/UV and IR luminosity; BUT modest luminosity
- Interaction long known, but great IRAS luminosity unexpected
  - ~90% energy escapes at far-IR wavelengths
- Resolved images important
  - Relevant scales ~1” at high redshift

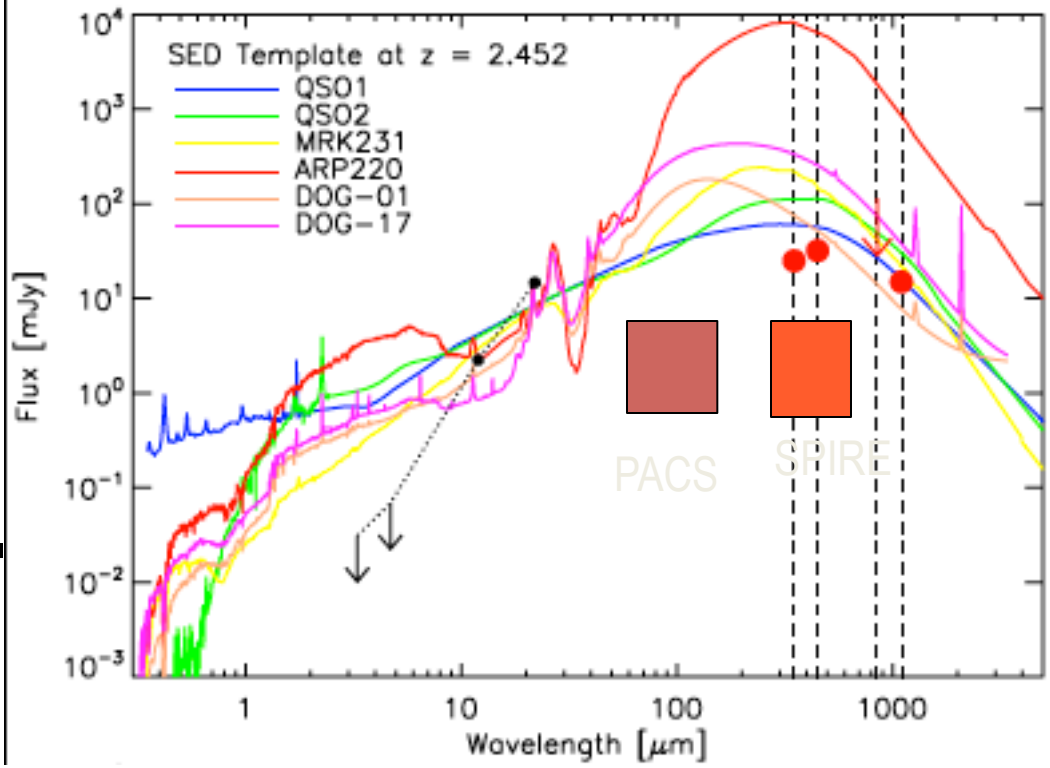


WISE "HotDOGs": odd SEDs

- WISE sources are sampling different regime of L,ρ (bright, rare!)
- Libraries of far-IR SEDs don't stretch far enough
  - Laura Hainline (2010)
  - WISE hot/blue far-IR objects



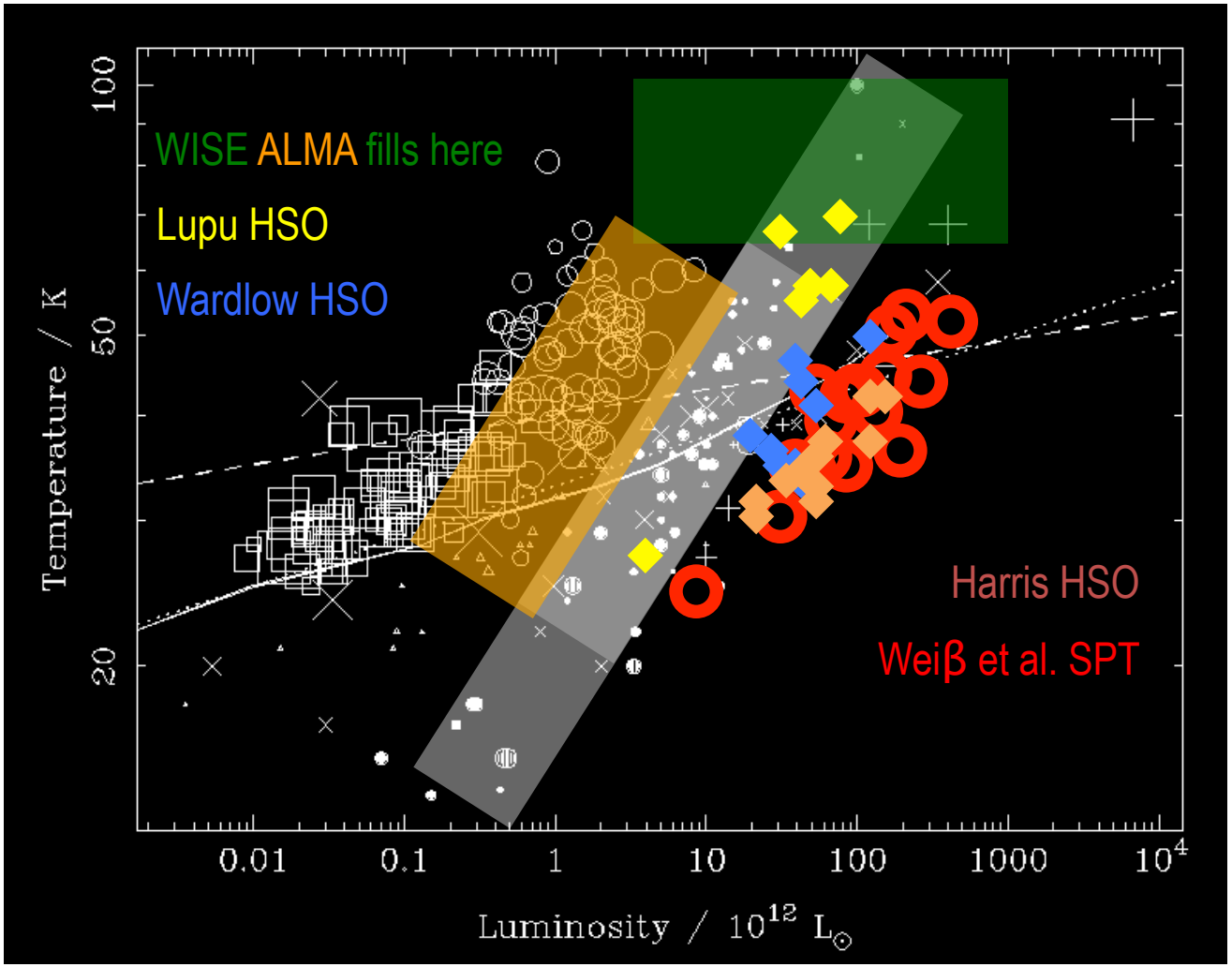
Jingwen Wu et al. (2012)



Compiled CSO results on 1814
Eisenhardt et al. (2012)
Tsai et al. (2015)

Plus JCMT from Suzy Jones (2014, 15)

High-z ULIRGs with redshifts/SEDs



Blain, Barnard & Chapman 2003 & Chapman et al. 2003

Uncapped magnification μ distribution?

2-5: 3, 5-10: 4, 10-20: 5, 20-50: 9, 50-100: 7

Squares: low-z, Dunne et al.

Empty circles: moderate z, mainly Stanford et al.

Crosses: variety of known redshifts (vertical = lensed)

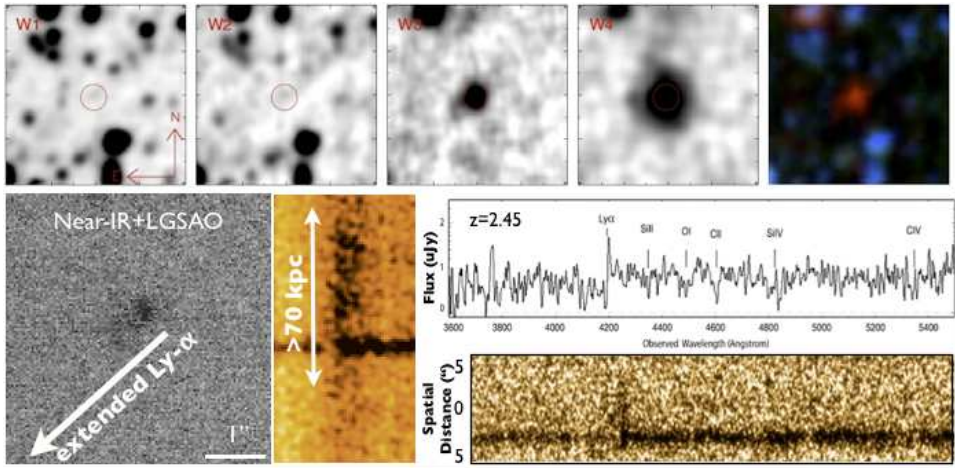
Lines: low-z trends

Scatter in T by at least ~40%

Argues for cap at mag' μ~50, Harris

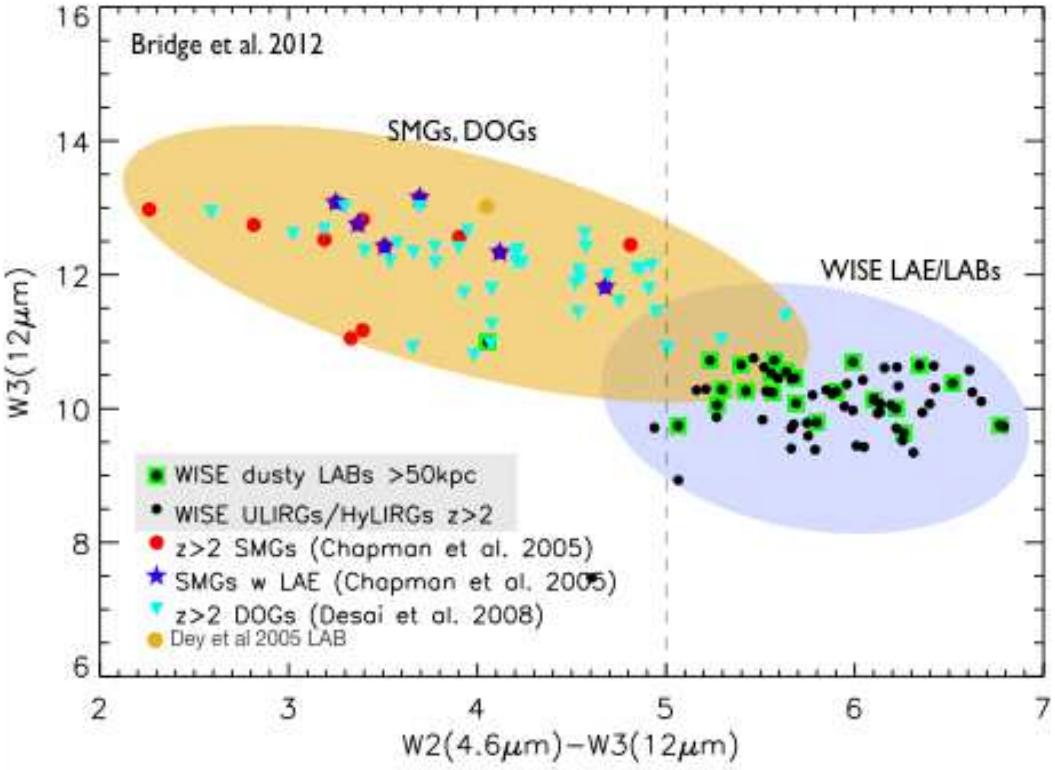
WISE Lyman-α blobs (WLABs)

- Follow-up spectra of hot dusty WISE ULIRGs at z~1-5
  - Bridge, Blain et al.
  - ApJ (2013) 769 91
- Unusually large No. of large (~50kpc) LA emitters
  - Including Eisenhardt's first WISE `HyLIRG'
- WISE colours alone can select ~1000
  - Red, bright in WISE
  - No other selection finds dusty LABs
  - Feedback in action?

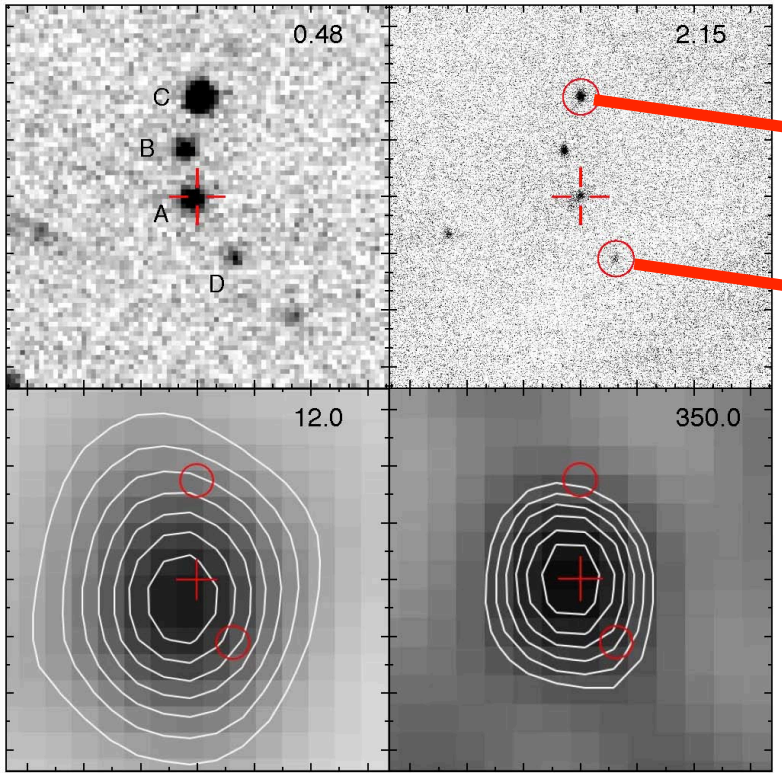


Top: WISE Bands, Bottom: NIR image & Spectra

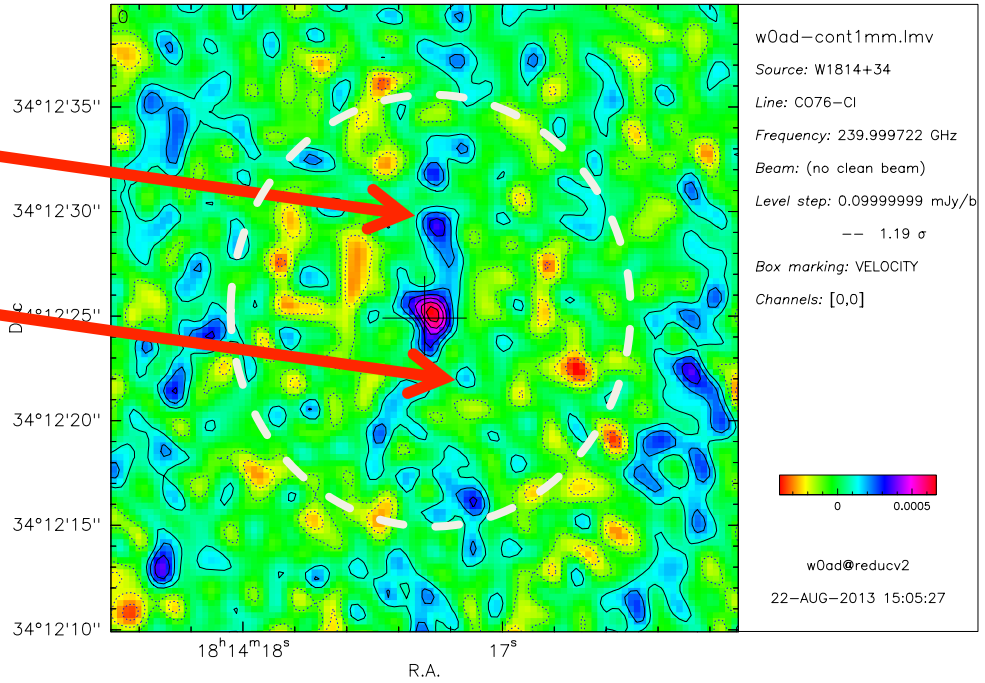
Bridge et al.



Imaging of WISE ULIRG W1814



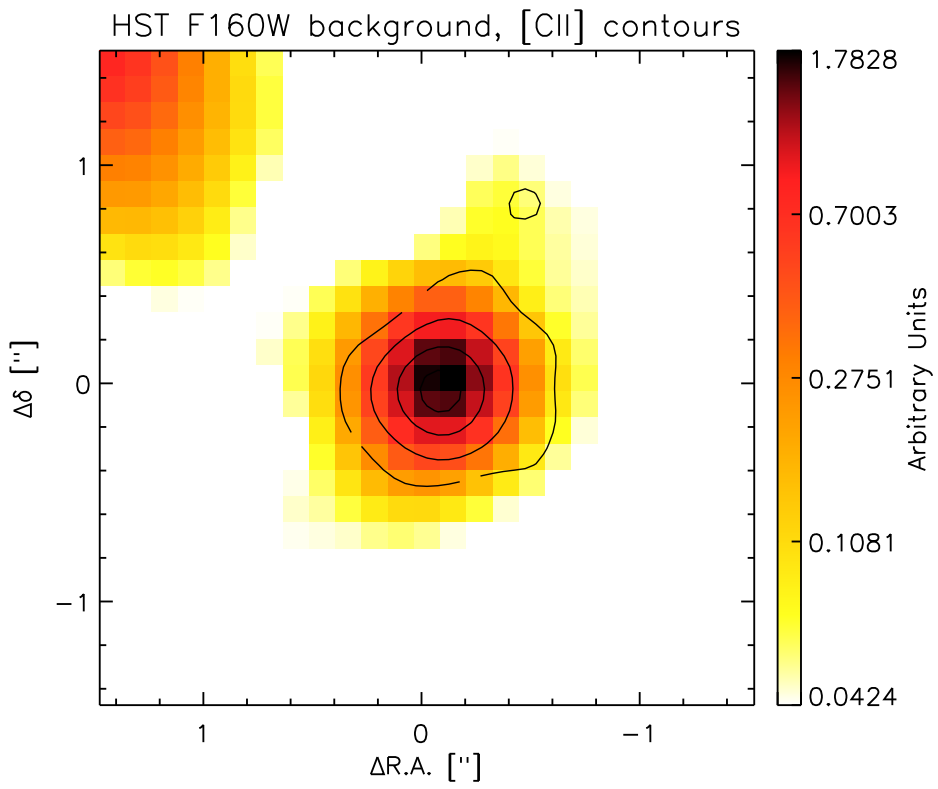
Keck z=2.54, optical, near-IR AO
WISE 12, CSO SHARC-2 images



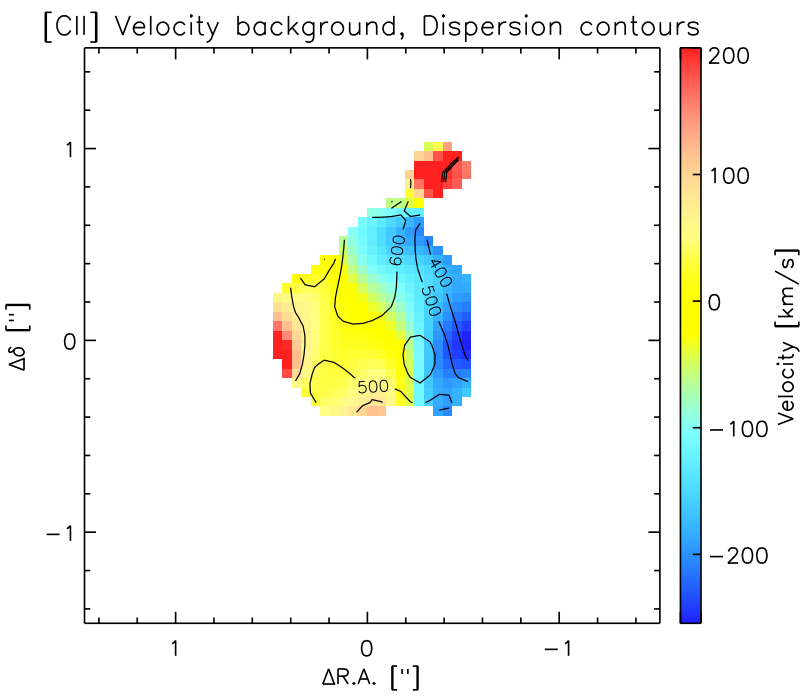
IRAM PdBI, ultrared A is dominant at 233GHz, not broad-line AGN C. Mystery D positive flux

- **WISE "HyLIRG"**
- **Very clear SED**
- **Complex – an AGN & dustier object**
- **Too far North for ALMA**

Example of resolved case



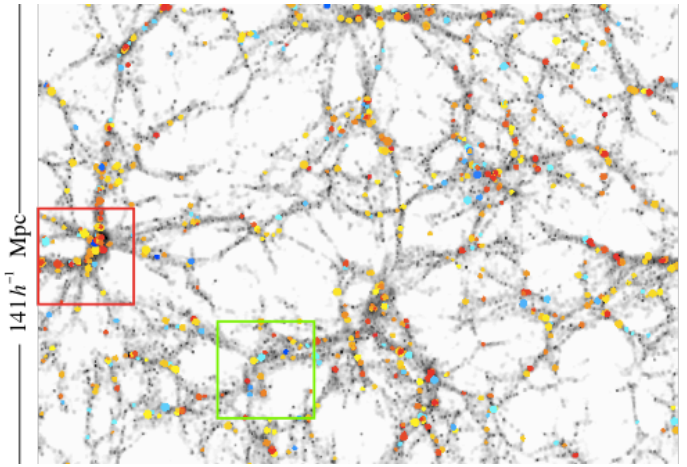
Diaz-Santos et al (2015)



- ALMA, CII & continuum; W2246
- ~600 km/s dispersion; uniform; CII less extended than UV; Companions (in CII). Nature of wind?

Clustering: comparing with models

- N-body simulations track mass well (greyscale)
- Red labelled galaxies (ellipticals) form earlier, and are most clustered
- Relating high-z ULIRGs is more difficult, and not so far done convincingly



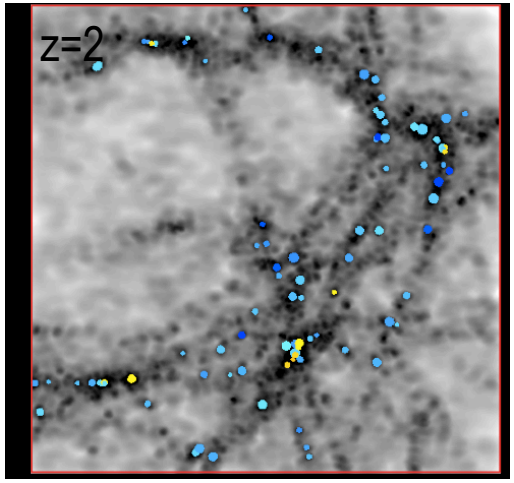
Prediction difficulties:

Strong feedback

Rare well-studied examples

Uncertain astrophysics

Caveat Antennae

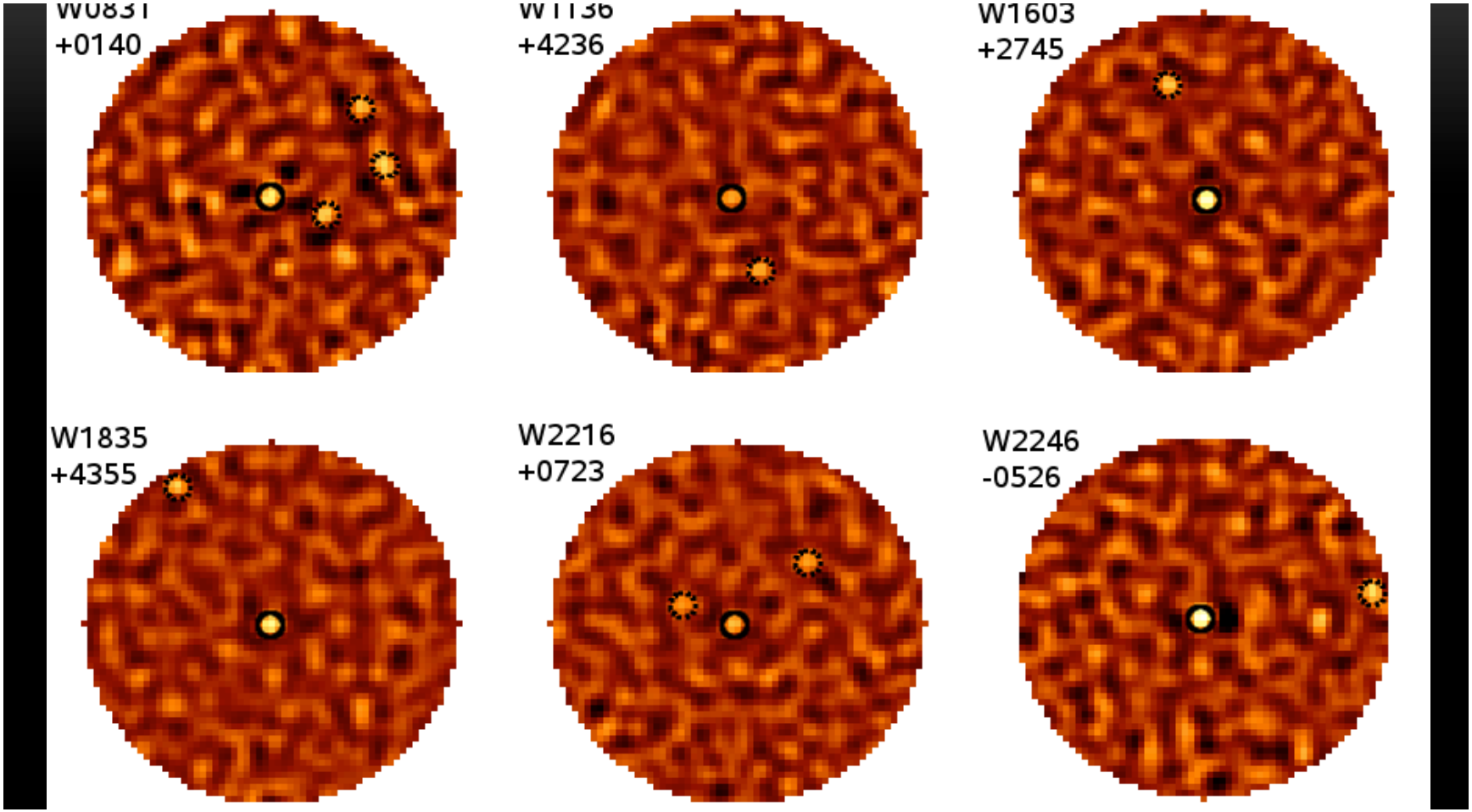


1 Mpc ~ 100 arcsec at high z
About 1 deg and 6 deg fields

Surroundings/environments

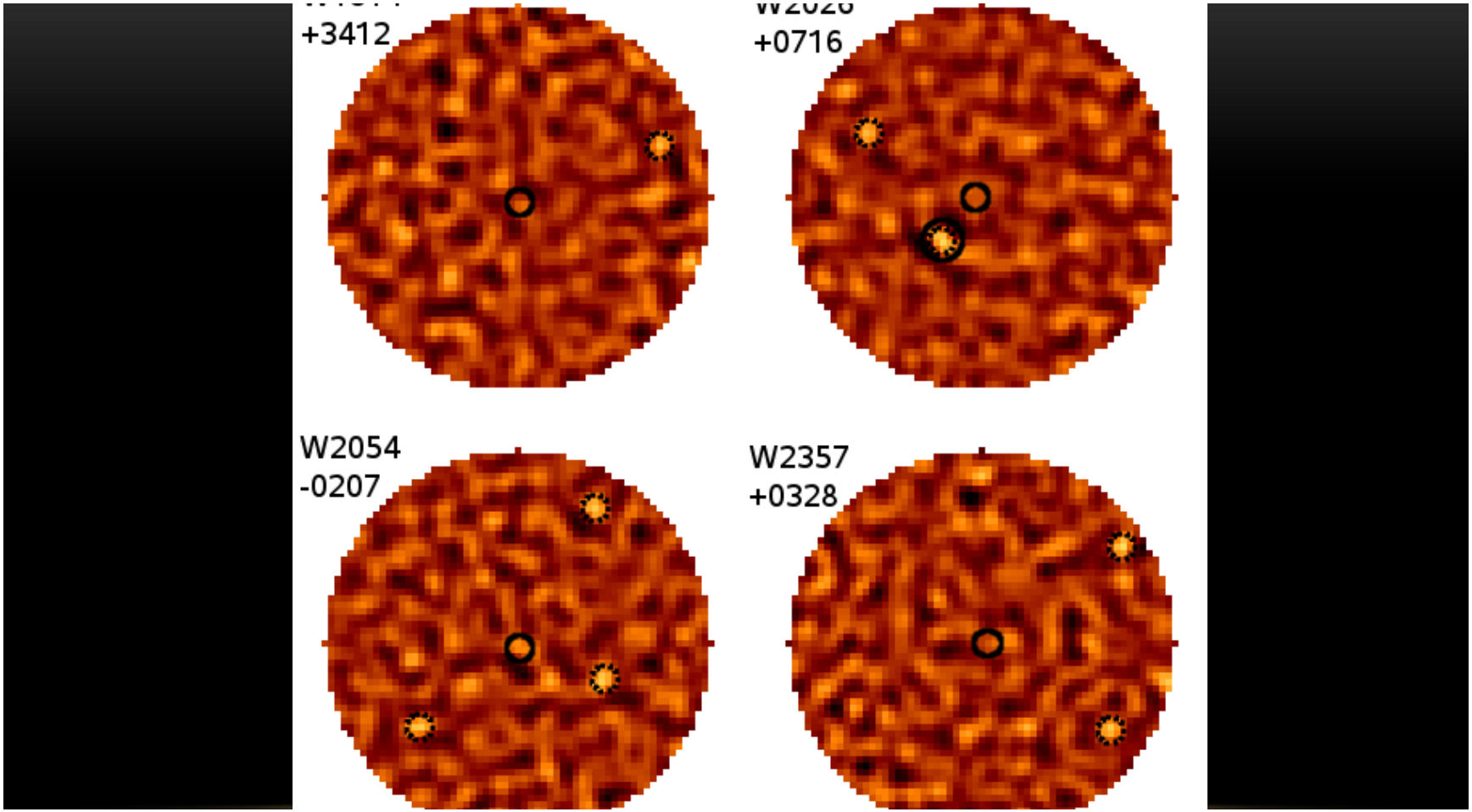
- Started by SCUBA2 − imaging to determine submm flux − to check “HotDOGs” aren’t SMGs, with colossal FIR fluxes
- Found more companions than expected. Colours consistent with SMGs, not HotDOGs
- Spread over >1.5’ − a Mpc extent. Comoving size of cluster today.

JCMT-detected HotDOGs



Jones et al.
1406.2506

JCMT HotDOG non-detections



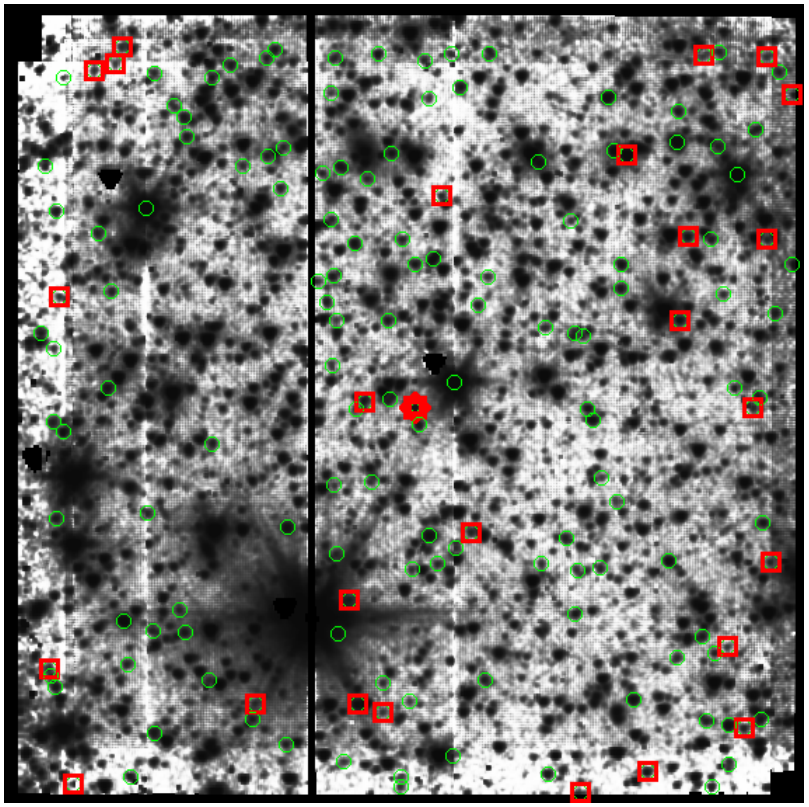
Jones et al.
1406.2506

SCUBA2 Images

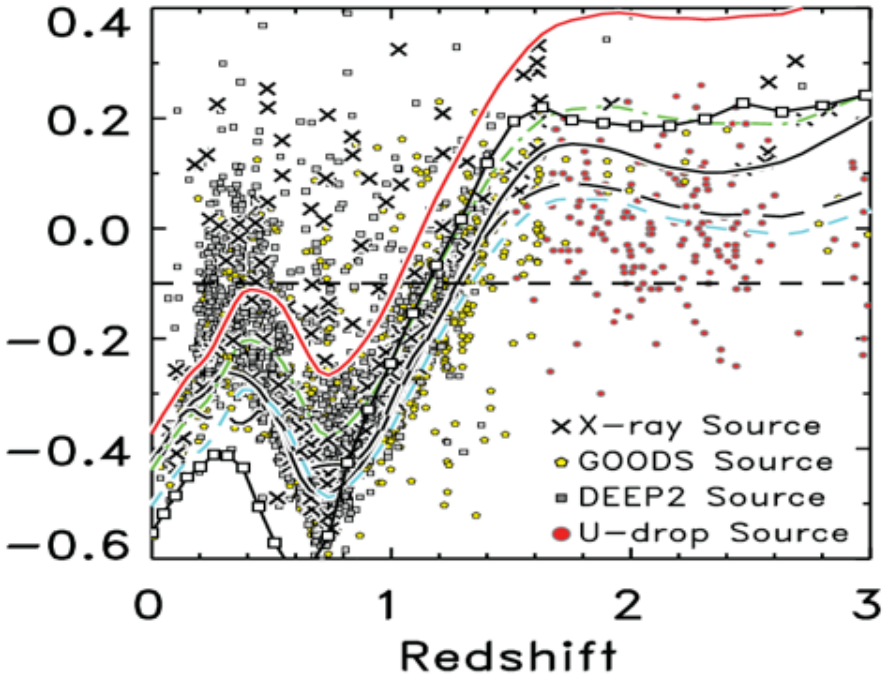
- About 2.5 and 6 times “overdense” as compared with large fields like S2CLS
- Yet the number of sources is measured in handfuls
  - They’re not close pairs or a cluster
  - Can’t be virialized, or would have a big mass
- Need to understand this huge “bias”
  - There are far too many luminous dusty galaxies
  - Spurred investigation of stellar sources with Spitzer
- See Spitzer overdensity too, around radio galaxies (CARLA), mixed picture around AGNs.

Spitzer follow up

- Jordan Penney PhD Leicester student
- 33 WISE-NVSS galaxies. Warm Spitzer 3.5, 4.6 microns
- Star is WISE target, green are “Papovich” z>1.3 colors
- Red squares are 0.3 mag. redder than this

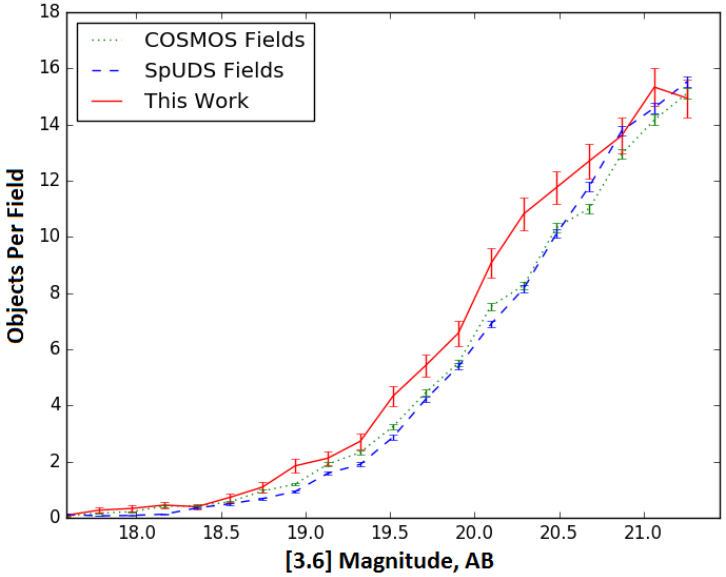


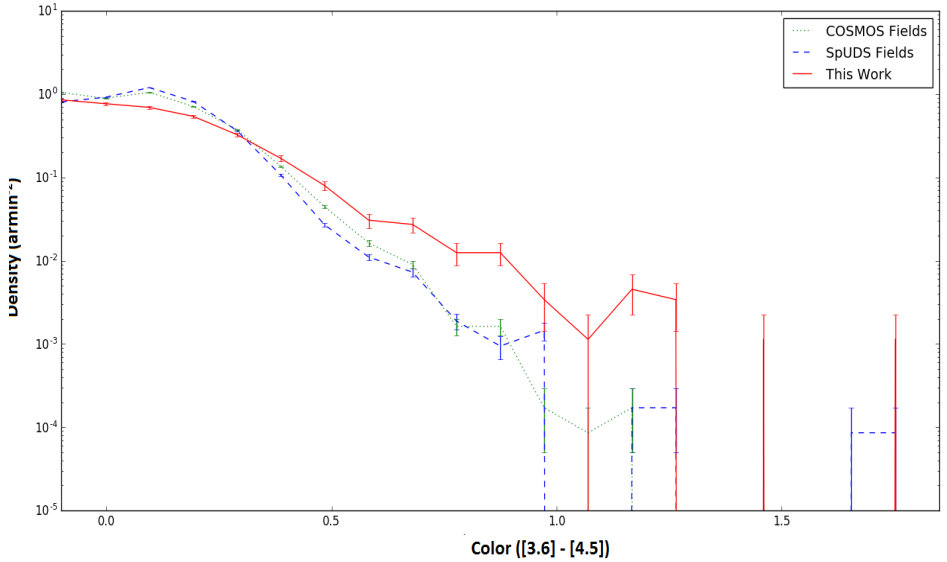
WISE W1951



Papovich 2009 (I1-I2 color)

Spitzer fields





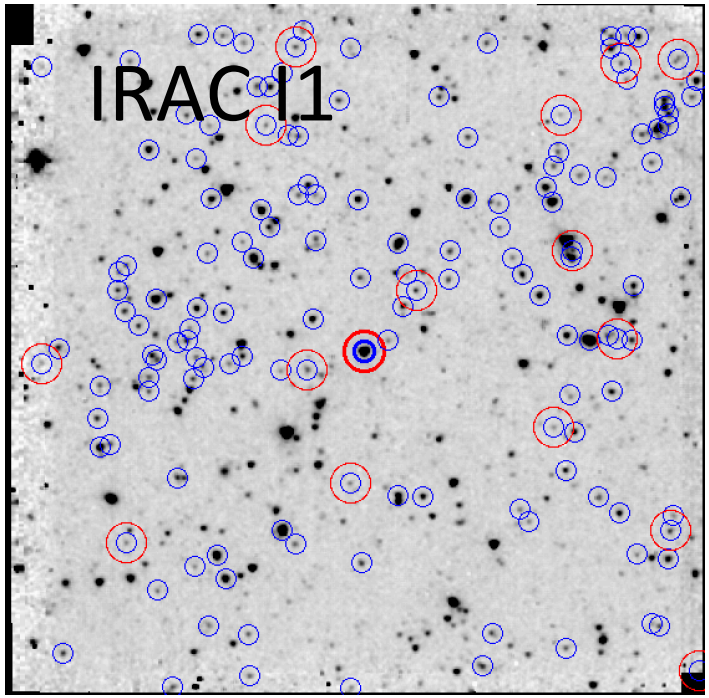
Larger, deeper comparison fields are available – SpUDS, COSMOS

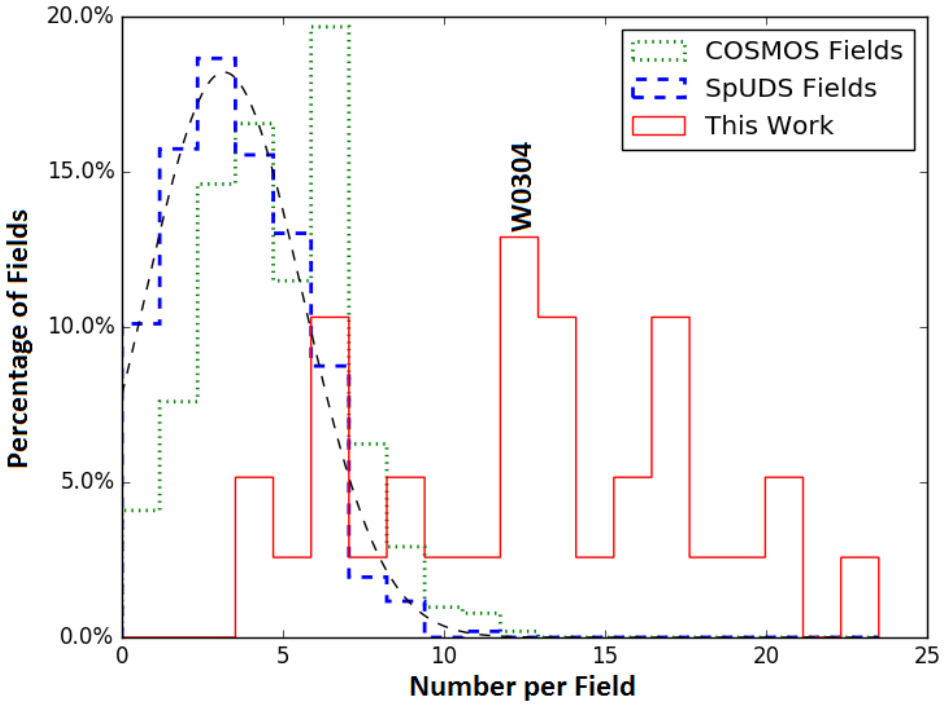
Our (33) fields show ~30% excess, much less than for SMGs

Again no “core”

Spitzer “red” sources

- I1/I2 color 0.1 mag, **blue circle** indicates z>1.3, but some redder **red circle** galaxies too – extinction, or redder intrinsic spectrum than stars. WISE Field W0304:





Summary

- WISE found some extremely luminous galaxies
- Relevant to powerful QSOs and SMGs
- Seem to be in overdense, but extended, plausibly unvirialized regions
- Challenge − they're too rare to be in deeper fields, and need deep observatiosn to reveal the companions