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, 23 µm (W1-4)
- 6, 6, 6, 12” resolution
- 0.08, 0.08, 0.8, 4 mJy
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

[Images of various astronomical observations and data sources, including HST WFPC2, ISOCAM 1.5μm, CSO/SHARC-2, Dowell et al. 350 μm, Spitzer IRAC mid-IR, Chandra, and HST WFPC2 Multiband optical.]
WISE “HotDOGs”: odd SEDs

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

Compiled CSO results on 1814
Eisenhardt et al. (2012)
Tsai et al. (2015)
Jingwen Wu et al. (2012)
Plus JCMT from Suzy Jones (2014, 15)
High-z ULIRGs with redshifts/SEDs

Uncapped magnification $\mu$ 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 $\sim 40\%$

Argues for cap at mag’ $\mu \sim 50$, Harris


WISE ALMA fills here

Lupu HSO

Wardlow HSO

Harris HSO

Weiβ et al. SPT


Uncapped magnification $\mu$ distribution?
WISE Lyman-α blobs (WLABs)

- Follow-up spectra of hot dusty WISE ULIRGs at z~1-5
  - Bridge, Blain et al.
- 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.

Figure 1: WISE 4.5 and 12 µm colors can efficiently select rare, dusty LAEs and LABs at z>2 (left; black circles, green squares). For comparison z=2−3 WISE detected SMGs and DOGs are highlighted. The WISE LABs/LAEs exhibit unique mid-IR colors, with a source density of a few hundred on the sky. W2-W3 color selection criteria (with r>22) has an ∼85% success rate in identifying z>2 dusty LAEs/LABs (dashed line). One third of WISE-LAEs have Ly-α blobs extending >50kpc. (Bridge et al. 2012) (Right) WISE Ly-α-blobs and emitters have similar redshift distribution to SMGs. Proposed HST sample of WISE Ly-α-blobs (blue shaded), full WISE LAE sample (white), SMGs (Chapman et al. 2005; dashed).

Figure 2: Example of a WISE selected Ly-α blob at z=2.452. (Top) WISE images (2′×2′ stamps; circle 10′′) at 3.4/4.6/12/22 µm and a color composite. (Left): Ks NIRC2+LGSAO image highlighting the irregular IR morphology of the WISE LAB. Multiple long-slit positions reveal an asymmetric, filamentary >70kpc Ly-α blob that is aligned (arrow) with the galaxy’s irregular morphology. Right: 1-D and 2-D LRIS spectrum, spatially extended Ly-α emission (>7′′; line flux ∼5×10^{-16} erg cm^{-2} s^{-1}). (Eisenhardt et al. 2012, Bridge et al. 2012)
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

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

Diaz-Santos et al (2015)
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

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
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

- $I_1/I_2$ 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 observations to reveal the companions