Towards a Complete Census of Extreme Starbursts in the Early Universe

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Scott Chapman, Ian Smail, Rob Ivison, Andrew Blain, Roberto Neri, Frank Bertoldi, Linda Tacconi, Laura Hainline, Karin Menendez-Delmestre, Mark Swinbank, Kristen Coppin, Rob Beswick, Tom Muxlow, and others...

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Gainesville, FL, USA
1. Evolution of Ultra-luminous Galaxies
ULIRG evolution
(UltraLuminous InfraRed Galaxies)

1. Evolution of Ultra-luminous Galaxies

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1. Evolution of Ultra-luminous Galaxies

**BIG QUESTIONS:**
- Volume Density?
- Progenitors?
- Details of triggering mechanism?

ULIRGs build stellar mass very quickly, big contribution to the Cosmic SFRD at \( z \sim 2 \).

e.g. Narayanan et al. 2009

**SFR (M_\odot/yr)**

<table>
<thead>
<tr>
<th>Time (Gyr)</th>
<th>SFR (M_\odot/yr)</th>
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<tbody>
<tr>
<td>0.5</td>
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<tr>
<td>1</td>
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<tr>
<td>1.5</td>
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<td>2.0</td>
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<td>2.5</td>
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**Active ULIRG Phase**
- \( T \sim 100\text{Myr} \)

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Observing ULIRGs.

(at high-z)

1. Evolution of Ultra-luminous Galaxies

2. Far-IR Selection Effects
SubMillimeter Galaxies

$S_{850} \geq 5 \text{ mJy}$

SCUBA (JCMT) 850 $\mu$m
LABOCA (APEX) 870 $\mu$m

Radio ID Spec-z Subsample:
(~75 galaxies in multiple fields)

$\langle z \rangle \sim 2.2$

$SFR \geq 1000 \, M_\odot \, yr^{-1}$

$M \geq 10^{11} \, M_\odot$

Chapman et al. 2005, Pope et al. 2006

BUT...

BUT...

JCMT (SCUBA/SCUBA2)

2. Far-IR Selection Effects

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2. Far-IR Selection Effects

SMGs are cold and don’t represent all ULIRGs at $z \sim 2$.

$z \sim 2 \rightarrow S_{850} \propto T_d^{-3.5} L_{FIR}$

...also radio-ID sample is biased towards $z < 4$.

2. Far-IR Selection Effects
Select at $70\,\mu m$: (8 Galaxies)

MIPS hot-dust ULIRGs
Casey et al. 2009b (MNRAS 399, 121)

\[ T_d = 52 \pm 10 K \]

Select at $250\,\mu m$: (10 Galaxies)

BLAST warm-dust ULIRGs
Casey et al. 2010, in prep

\[ T_d = 36 \pm 7 K \]

70um identification of submm-faint radio galaxies

Redshift identification

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2. Far-IR Selection Effects

![Graph showing the selection effects in far-IR spectroscopy.](image-url)

- **250 µm** SOURCE
- **850 µm** DET, **250 µm** SOURCE
- Radio/850 inferred points
- 70 µm ULIRGs (C09)

**70 µm**

**250 µm**

Det limits for **250 µm**, **70 µm**, & **850 µm** at \(z = 1\) and \(z = 2\)

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Seeking ULIRG completeness...

finding submm-faint ULIRGs, and characterizing their evolution.

2. Far-IR Selection Effects

3. Observations of submm-faint ULIRGs

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3. Observations of submm-faint ULIRGs

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ULIRG Completeness
Identification + Characterization

Since this is an 8 minute talk...

1. Select diverse ULIRG populations
   - 70um - MIPS, Casey et al. 2009b
   - 250um - BLAST, Ivison et al., Dunlop et al. 2010
   - 850/870um - SCUBA, LABOCA, All SMG papers...
   - 1.1mm - AzTEC, Younger et al. 2007,09a
   - 1.2mm - MAMBO, Younger et al. 2009b
   - CO - Neri et al. 2003, Greve et al. 2005, Tacconi et al. 2006,08, Casey et al. 2010a

II. Secure Redshifts
Optical/UV spec-z's (e.g. Keck, VLT)
Optical/UV *and* blank CO redshifts (ALMA)

III. Characterize ULIRG evolution
Molecular Gas Observations (PdBI), mid-IR spectra (IRS), rest-UV spectra, x-ray, resolved MERLIN radio

ALMA, JWST, eMERLIN, eVLA...

3. Observations of submm-faint ULIRGs

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...Findings/Inklings.

Dearth of high-L ($\geq 10^{13} L_\odot$) hot-dust ULIRGs

Casey et al. 2010a (aph/0910.5756)
Casey et al. 2010, in prep

MAJOR MERGERS, ULIRGs at LAST INFALL STAGE?
HIGHEST SFRs in COLD, DIFFUSE ISM
$\tau \sim 100\text{Myr}$
$\sim 1000M_\odot\text{yr}^{-1}$

OBSERVATIONAL EVIDENCE NEEDED

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OBSERVATIONAL EVIDENCE NEEDED

HERSCHEL, SCUBA2
- Select diverse range of z~2 ULIRGs
- Find z~4 ULIRGs

Herschel SPIRE image of Abell 2218

ALMA
- Blind CO redshifts
- CO Survey of large ULIRG samples
- CO in MW-type Gals at z~2
- CO excitation: gas, dust interaction
- Resolved CO dynamics

KECK, VLT...
- ID spec-z’s
- winds, outflows, metallicities

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Summary

• STRONG TEMPERATURE BIAS OF SMGS
• Observations of hot-dust (and other submm-faint) ULIRGS:
  • FAR-IR observations in 50-500um (Herschel, SCUBA2)
  • Molecular Gas Observations (PdBI, ALMA)
  • AGN Diagnostics: Mid-IR PAH/continuum, X-ray, MERLIN
• Build sample, unify selection/characterization of ULIRGs
• Understand extreme, obscured SF at z~2

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