Galaxy Evolution from the Herschel + HST CANDELS programs

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Galaxy Evolution

- The peak era of galaxy growth took place at $z \sim 1-3$
- Dusty star formation
- SFRD of (U)LIRGs increase dramatically towards higher redshifts.

Burgarella et al. 2013
Magnelli et al. 2013
The CANDELS project

- Cosmic Assembly Near-Infrared Deep Extragalactic Legacy Survey (PIs: S. Faber & H. Ferguson)
- HST ACS & WFC3 deep imaging for GOODS-S and N, EGS, UDS, and COSMOS
  - High resolution (galaxy structure)
  - Deep imaging (detect all Herschel counterparts)

Rest-frame

UV Optical

z~2

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<th>Emergent</th>
<th>Spheroids</th>
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<th>Disks</th>
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GOODS- & CANDELS-Herschel

- GOODS-Herschel (PI D. Elbaz, OTKP)
  - [Hedam](http://hedam.oamp.fr/GOODS-Herschel/index.php)
- CANDELS-Herschel (PI M. Dickinson, OT2)
  - COSMOS & UDS
  - PACS & SPIRE
  - Fully cover the CANDELS WFC3 fields
- PEP & HerMES
  - Coverage of the CANDELS fields
GOODS- & CANDELS-Herschel

- Deepest 100-500µm data
  - Typical star-forming galaxies up to z~2
- Covering 4/5 CANDELS fields
  - Improved statistics and good control over cosmic variance
  - Increase accessible fields from ALMA
    - GOODS-S, UDS, & COSMOS
Deepest 100–500µm data

Typical star-forming galaxies up to z~2

Covering 4/5 CANDELS fields

Improved statistics and good control over cosmic variance

Increase accessible fields from ALMA

GOODS- & CANDELS-Herschel
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Controlling cosmic variance: Number counts (160µm)
IR luminosity functions

- Herschel measures near the peak of the FIR dust emission, minimizing uncertainties in the bolometric corrections.
- Good control over cosmic variance
- Increased number of typical SF galaxies ($\leq L_{IR}^*$)
  - Constrain Faint-end slope
  - At z~1.5
    - GOODS-H only: ~100 sources
    - GOODS-H + CANDELS-H (UDS+COSMOS): ~180 sources
IR luminosity functions

Inami et al. (in prep.)
Evolution in LFs

Inami et al. (in prep.)
“Main Sequence” and Starburst Galaxies

How does morphology relate to the star formation modes at z~2?
Galaxy Structure

z~2

Rest-frame Optical
UV

Emergent Spheroids
F160W (H)
F775W (i)

Emergent Disks
Hidden Mergers

GOODS-S
GOODS-N
COSMOS
UDS

Kartaltepe et al. 2012
Kartaltepe et al. (in prep.)
SFR/Stellar Mass Relation

See poster by Kartaltepe (Session A, P23)

Kartaltepe et al. 2012
Star Formation Rates: Optical/NIR SEDs vs. IR

- SFR estimates using SED fitting
  - CANDELS Multi-wavelength catalogs
    - Optical to IR (Spitzer IRAC)
  - CANDELS spec-z + photo-z (Dahlen et al. 2013)
  - Maraston 2005 based templates
  - Fitting setups as in Pforr et al. 2012
  - Calzetti reddening
Star Formation Rates: Optical/NIR SED-fit vs. LIR

Pforr et al. (in prep.)

GOODS–S, UDS, COSMOS

$1 \leq z \leq 2$

Pforr et al. (in prep.)
Star Formation Rates: Optical/NIR SED-fit vs. LIR

GOODS–S, UDS, COSMOS
1<=z<=2

Outliers

SFR_{SED-fit}=0

Pforr et al. (in prep.)
Summary

- 4/5 CANDELS fields have the deepest 100-500µm data
  - Improved statistics and good control over cosmic variance
  - 3x more typical SF galaxies can be observed from ALMA

- Dust-obscured star formation at high redshifts
  - IR luminosity functions
  - Better constrain on IR LF < \( L_{\text{IR}}^* \)
  - Direct measurement of the faint-end slopes at \( z \leq 1 \)
  - SFR measurements using optical SED fits and LIR

- Galaxy structure from HST WFC3 H-band data
  - “Main sequence” vs. starburst