**JINGLE**: JCMT dust and gas In Nearby Galaxies Legacy Exploration — Status update and science highlights

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Image Credit: William Montgomerie
The gas fraction and star formation efficiency (SFR/M_{gas}) are the keys to understand the mode regulating the star formation in galaxies.

Conventionally, the cold molecular gas mass M_{gas} can be derived from:

- M_{co} via \( \alpha_{co} \) (e.g., Saintonge+11; Tacconi+13; Sargent+14)
- M_{dust} via dust-to-gas ratio (e.g., Israel 1997; Leroy+11; Magdis+11; Scoville+14)
Survey Objectives of JINGLE

**JINGLE 780h legacy survey**

**SCUBA-2**
250 h, weather bands 2-4
850μm observations of 193 galaxies

**Dust:**
2) Dust mass and dust scaling relations

**RxA3m**
530 h, weather bands 4-5
CO(2-1) observations of 97 galaxies

**Gas:**
1) Star formation, star formation history and the total gas reservoir

**Dust + Gas:**
3) The relation between molecular gas and dust
JINGLE: sample overview (2016 - )

~200 nearby galaxies  
Redshift range: $0.01 < z < 0.05$

Multi-wavelength data:
- photometry: GALEX/SDSS/WISE/Herschel  
  (H-ATLAS)
- optical IFU maps: MaNGA/SAMI
- HI maps: Apertif/ASKAP
Status of JINGLE 1 Observations (as of Nov. 6, 2019)

★ SCUBA-2: 100% complete \([193/193\) galaxies observed]\)

★ RxA:

✦ 74% complete \([72/97\) observed]\)

✦ 79% complete for MaNGA galaxies \([52/66]\); 26 non-MaNGA galaxies to observe as “priority 2”

★ After the retirement of RxA, we started using Namakanui (“Big-Eyes”) receiver

SCUBA-2 (193 galaxies)

RxA (72 galaxies)
Complete and Active Science Papers

★ 4 papers published, 1 submitted, 1 to be submitted, 1 in prep.

✦ JINGLE I: Survey overview and first results (Saintonge+2018) - MNRAS, 481, 3497
✦ JINGLE II: SCUBA-2 data reduction and flux catalogs (Smith+2019) - MNRAS, 486, 4166
✦ JINGLE III: Molecular gas properties and scaling relations (Xiao+.) - in preparation
✦ JINGLE V: Dust properties from hierarchical Bayesian SED fitting (Lamperti+2019) - MNRAS, 489, 4389
✦ Molecular gas scaling relations in the JINGLE pilot sample (Gao et al.) - ApJ submitted
✦ JINGLE IV: Dust and HI scaling relations (De Looze+) - to be submitted
Approved JINGLE follow-up programmes

➢ **ALMA/ACA (C grade, cycle 6, 2018):**
  Mapping CO emission in galaxies from the JINGLE survey - **PI: C. Wilson (McMaster)**

➢ **IRAM 30m/NIKA2 (20.9 hrs, 2018):**
  Characterizing the millimeter emission in nearby galaxies using NIKA-2 - **PI: I. Lamberti (UCL)**

➢ **JCMT/SCUBA2 (60 hrs, Nov. 2017):**
  Dust Properties of Starbursts and Green Valley Galaxies in the Local Universe - **PI: H. S. Hwang (KIAS)**

➢ **JCMT/RxA (100 hrs, Nov. 2017):**
  Extending the JINGLE RxA Samples to Include” Red Mist” Galaxies - **PI: R. Chown (McMaster)**

➢ **ALMA (cycle 5):**
  Snapshots of 6 Ultra-Red z>6 SCUBA2 sources from the JINGLE survey - **PI: J. Greenslade (Imperial)**

➢ **IRAM 30 m/NIKA2 (3 hrs, May 2017):**
  The Brightest SPIRE dropout to date? Confirming a F850=18.9 mJy source not detected in Herschel - **PI: J. Greenslade (Imperial)**

➢ **Arecibo (37.6 hrs, Dec. 2016):**
  Atomic Gas Content of JINGLE Galaxies - **PI: M. Smith (Cardiff)**
Science Highlights 1: JINGLE Overview + Galaxy SEDs

Saintonge+18:
> 30 aperture matched photometry (UV to FIR) and derived products of all 193 JINGLE galaxies

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<th>Facility</th>
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Science Highlights 1: JINGLE Overview + Galaxy SEDs

Saintonge+18:
> 30 aperture matched photometry and derived products of JINGLE galaxies

<table>
<thead>
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<th>Table 2. Properties of the JINGLE galaxies (the full table is available electronically)</th>
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<td>JINGLE13</td>
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Science Highlights 2: IR & submm Data

Smith et al. 2019: 850 um data reduction

126 out of 193 galaxies (64%) are detected in 850um with S/N > 3
Science Highlights 2: IR & submm Data

Smith et al. 2019
Science Highlights 2: IR & submm Data

Smith et al. 2019
Science Highlights 3:
Dust Properties from more sophisticated SED fitting

**THEMIS models**
physically motivated dust models

**MBB:** modified black-body analytical functions

De Looze et al., in prep.

Lamperti et al., 2019.
Single Modified Black Body (SMBB)

\[ F_\lambda (M_{\text{dust}}, T_{\text{dust}}, \beta) = \frac{M_{\text{dust}}}{D^2} \kappa_0 \left( \frac{\lambda_0}{\lambda} \right)^\beta B_\lambda (T_{\text{dust}}) \]

By adding SCUBA-2 850\text{um} data, we can fit better for dust temperature \((T_{\text{dust}})\) and dust emissivity index \((\beta)\).
Correlation between $T_{\text{dust}}$ and $\beta$: Is it intrinsic correlation or degeneracy?

See also Désert et al. (2008), Paradis et al. (2010), Baracco et al. (2011), Smith et al. (2012)

Reference: Shetty et al. 2009a,b
Application to the JINGLE sample

Lamperti et al., 2019

The hierarchical method reduces the $T_{\text{dust}} - \beta$ anti-correlation in the JINGLE sample!
Dust Properties On the SFR-M* plane in JINGLE and HRS

Lamperti et al., 2019

dust emissivity index $\beta$

dust temperature $T_{\text{dust}}$
Dust scaling relations can be applied to derive dust properties for samples were fewer photometric data are available, for example at higher redshift.
The Effect of Galaxy Interactions on Molecular Gas Properties

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Abstract

Galaxy interactions are often accompanied by an enhanced star formation rate (SFR). Since molecular gas is essential for star formation, it is vital to establish whether and by how much galaxy interactions affect the molecular gas properties. We investigate the effect of interactions on global molecular gas properties by studying a sample of 58 galaxies in pairs and groups at z<0.4. Molecular gas properties are determined from observations with the JCMT, PMO, and CSO telescopes and supplemented with data from the xCOLD GASS and JINGLE surveys at 12CO(1–0) and 12CO(2–1). The SFR, gas mass (M_H2), and gas fraction (f_gas) are all enhanced in galaxies in pairs by ~2.5 times compared to the controls matched in redshift, mass, and effective radius, while the enhancement of star formation efficiency (SFE = SFR/M_H2) is less than a factor of 2. We also find that the enhancements in SFR, M_H2, and f_gas increase with decreasing pair separation and are larger in systems with smaller stellar mass ratio. Conversely, the SFE is only enhanced in close pairs (separation <20 kpc) and equal-mass systems; therefore, most galaxies in pairs lie in the same parameter space on the SFR–M_H2 plane as controls. This is the first time that the dependence of molecular gas properties on merger configurations is probed statistically with a relatively large sample and a carefully selected control sample for individual galaxies. We conclude that galaxy interactions do modify the molecular gas properties, although the strength of the effect is dependent on merger configuration.

Key words: galaxies: interactions – galaxies: ISM – ISM: molecules – galaxies: star formation
Science Highlights 4: Galaxy Interactions and Molecular Gas Properties

Pan, Lin et al. 2018

Table 1. Summary of the molecular gas data used in this work.

<table>
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<th>JCMT PI programs</th>
<th>JINGLE</th>
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<td>0.020 - 0.039</td>
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</table>

Hubble Space Telescope
Science Highlights 4: Galaxy Interactions and Molecular Gas Properties

Pan, Lin et al. 2018

![Diagram showing scatter plots with Kendall-$\tau$ values for different parameters related to galaxy interactions and molecular gas properties.](Hubble Space Telescope)
What’s Next?

**From JINGLE 1:**
- Not many galaxies with high and low sSFRs, which will the keys to fully calibrate the scaling relation for subsequent application at high redshift.
- Variations in $T_{\text{dust}}$ and $\beta$ are seen across the SFR-$M^*$ plane.
- CO(2-1) correlates well with L12um and L22um

**Unanswered Questions:**
- Do the scaling relations for main sequence galaxies hold for starburst or green valley galaxies?
- How do molecular gas fraction and SFE vary with galaxy properties? Are the star formation modes similar across different populations?

Expand the sample to galaxies above and below the main sequence!
JINGLE 2 (Willson, Lin, Xiao, Hwang, Sargent, Koyama)

- B-ranked: Received only RxA3m time (2017.8 - 2020.1)
  - Band 4: 285.0 hours
  - Band 5: 169.0 hours
  - Follow-up Proposal (PI: H.S.Hwang): 60 hours of SCUBA-2

- Targets
  - 21 starburst galaxies
  - 21 green-valley galaxies: 9 in MaNGA

- Requested Observations
  - 185 hours of RxA3m observations
  - 124 hours of SCUBA-2 observations
SUMMARY

- JINGLE represents the first and largest systematic survey of cold ISM in nearby star-forming main galaxies with both 850um and CO observations, enabling independent estimates of gas mass and improved constraints on the dust properties.

- JINGLE 850 data:
  - help constrain SED in combination with other NIR and submm data
  - reveal variations in $T_{\text{dust}}$ and $\beta$ across the main sequence
  - reveal strong correlation between 1) $T_{\text{dust}}$ and SFR per unit dust mass; 2) $\beta$ and HI gas fraction

- JINGLE 2 will expand the sample to starburst and green valley galaxies to complete the full picture in the role of dust and cold gas.