Scaling Relations of Main Sequence and Green Valley Galaxies in ALMaQUEST

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on behalf of the ALMaQUEST team

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Star-Forming Main Sequence

- A tight correlation between the total star formation rate and stellar mass for star-forming galaxies (e.g., Brinchmann+04; Noeske+07; Daddi+07; Elbaz+07; Whitaker+12)

\[ M_* = \int SFR \, dt \]
From Global to Resolved Properties

“resolved main sequence” on kpc scales

credit: H.-A Pan

BPT Diagram

credit: H.-A Pan
From Global to Resolved Properties

— “resolved star-forming main sequence” (rSFMS) on kpc scales

Hsieh, Lin+2017

(Also see Cano-Diaz+16; Abdurrouf & Akiyama 17; Ellison+18; Pan+18; Medling+18; Cano-Diaz+19)
Schmidt-Kennicutt (SK) Relation

- A tight relation between star formation rate and gas (surface density)

Kennicutt & Evans 12
\[ \Sigma_{\text{stellar mass}} \rightarrow \Sigma_{\text{SFMS (empirical)}} \rightarrow \Sigma_{\text{SK Relation (physically driven)}} \rightarrow \Sigma_{\text{gas mass}} \]
ALMaQUEST: ALMA-MaNGA QUEnching and STar formation
(PIs: L. Lin & S. Ellison)

- ALMA CO(1-0) followups for 46 MaNGA selected sample
- $z \sim 0.03; 10 < \log(M*/M_\odot) < 11.5$
- ALMA Resolution:
  - $\sim 2.5''$ (spatial)
  - 11 km/s (spectral)
- Target classes:
  - 14 Main-sequence galaxies
  - 20 Green valley galaxies
  - 12 Central starburst galaxies

Lin et al. 2020, submitted

http://arc.phys.uvic.ca/~almaquest/
ALMaQUEST (Lin+2020, submitted)

A diversity in the contrast between Hα and CO emissions

- Star-formation efficiency: 
  \[ \text{SFE} = \frac{\text{SFR}}{M^*} \]

- Gas fraction: 
  \[ f_{\text{H}_2} = \frac{M_{\text{H}_2}}{M^*} \]
I. Resolved Star-Forming Main Sequence (rSFMS)

- The best fit using the HII spaxel of 14 MS galaxies is in good agreement with the full MaNGA SF sample.

Lin+19b
Ellison+, submitted

\[
\text{slope} = 1.19
\]
II. Schmidt-Kennicutt (SK) Relation

- A linear slope is found in the resolved SK relation

\[ \rho = 0.81 \]

slope = 1.05

Lin+19b
Ellison+, submitted
III. Molecular Gas Main Sequence (MGMS)

Lin+19b; Ellison+, submitted
(also see Wong+13)

- The surface density of the molecular gas mass traces the stellar mass surface density with slope ~ 1.
Which One is More Fundamental?

\[ \sum \text{SFR} \propto \sum \text{H}_2^a \] (SK)

\[ \sum \text{H}_2 \propto \sum \ast^b \] (MGMS)

\[ \sum \text{SFR} \propto \sum \ast^{a*b} = \sum \ast^c \] (rSFMS)

- Scatter: rSFMS > MGMS > SK
- Pearson’s correlation:
  - rSFMS < MGMS < SK

a = 1.05, b = 1.1 \Rightarrow c = 1.16

c (measured) = 1.19
For star-forming spaxels of main-sequence galaxies, rSFMS is a natural consequence of the combination of SK and MGMS.
What about GV galaxies?

GV contains non-negligible fraction of non-SF spaxels
=> need to consider those regions, too

- Galaxy type: MS vs. GV
- Spaxel type: SF vs. retired

Retired spaxels:
BPT-classified LINERs & EW(Ha) < 3A
By definition, GV has lower sSFR.
sSFR of GV is lower than that of MS for both SF or retired spaxels

Lin+, in prep.
$f_{H_2}$ of GV is lower in both SF and retired spaxels than that of MS

Lin+, in prep.
SFE of GV is lower in both SF and retired spaxels than that of MS.
SUMMARY

• ALMaQUEST (Lin et al. 2020, submitted).

  • ALMaQUEST provides dataset to simultaneously study the relationships between SFE, $M_\ast$, and $M_{\text{gas}}$ at kpc scales for starburst, main sequence, and green valley galaxies.

• Scaling relations of MS galaxies (Lin et al. 2019)

  • At kpc scales, the surface densities of SFR, $M_\ast$, and $M_{\text{gas}}$ are tightly correlated with each other. In addition to the known rSFMS and SK relations, there also exists a 3rd relation: molecular gas main sequence (MGMS).

  • rSFMS is a natural consequence of the combination of SK and MGMS.

• Scaling relations of GV and retired regions (Lin et al. in prep.):

  • GV galaxies not only have lower sSFR (by definition), but also lower gas fraction ($f_{\text{H}_2}$) and star formation efficiency (SFE), in either star-forming or retired spaxels.

See Sara’s talk this afternoon (scatters in the scaling relations)