Measuring star formation rates in nearby dusty starburst galaxies using ALMA observations of millimeter recombination line and free-free emission

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ALMA can directly measure both millimeter recombination line emission and free-free continuum emission from star forming regions in nearby galaxies. As this emission directly traces the photoionizing light from young stellar populations while not being affected by dust attenuation, it can be used to calculate very accurate star formation rates (SFRs).

We present the first results from using ALMA to measure this line and continuum emission within the very dusty starbursts at the centers of NGC 253, NGC 4945, and NGC 5253. A comparison of the SFRs from the ALMA data to SFRs from other wavebands illustrate some of the problems with the other star formation tracers.

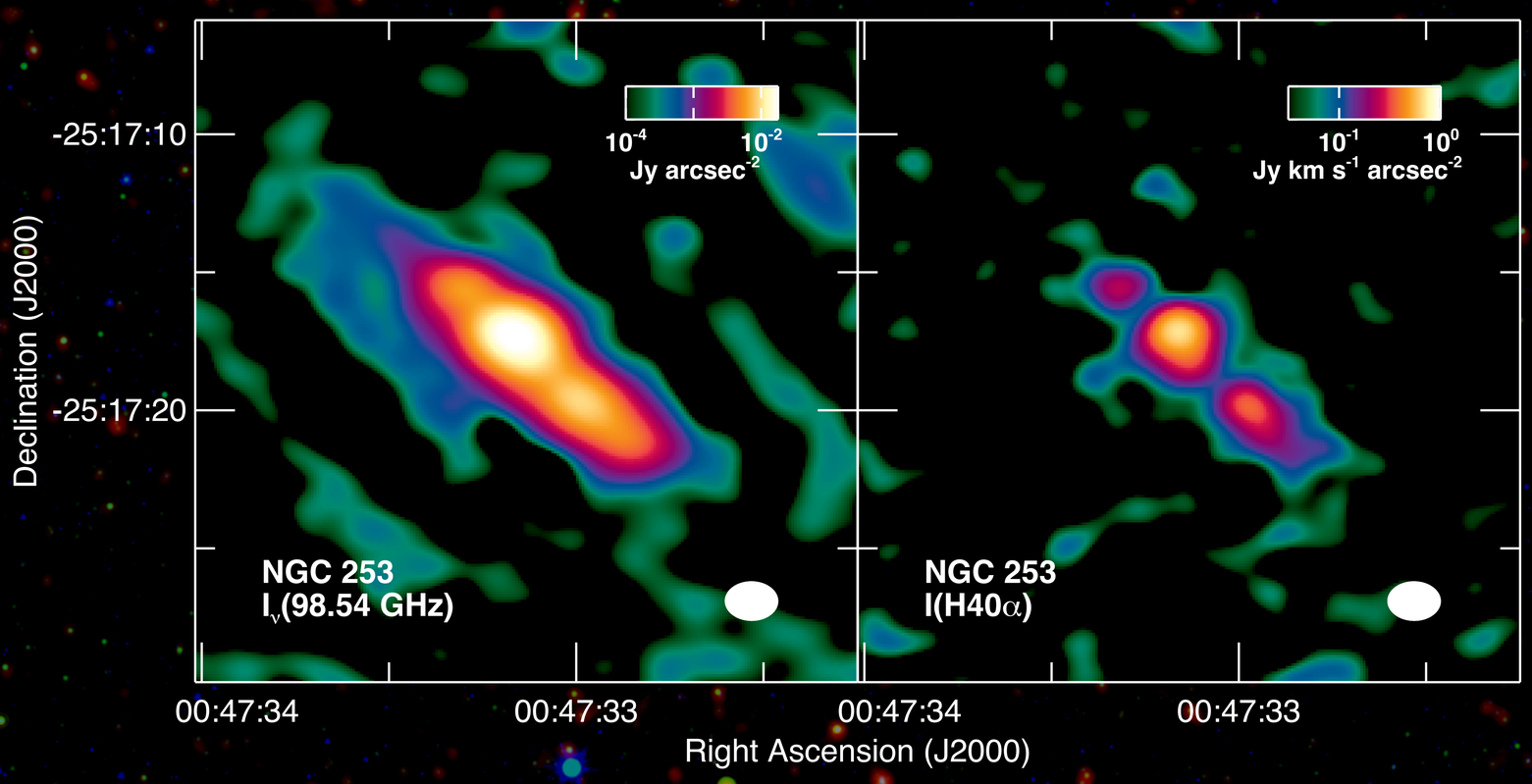
The most surprising result that SFRs from mid-infrared flux densities may differ from the ALMA measurements by 10× because of dust extinction and extreme heating effects. However, SFRs from total infrared emission are typically within ~30% of the ALMA measurements.

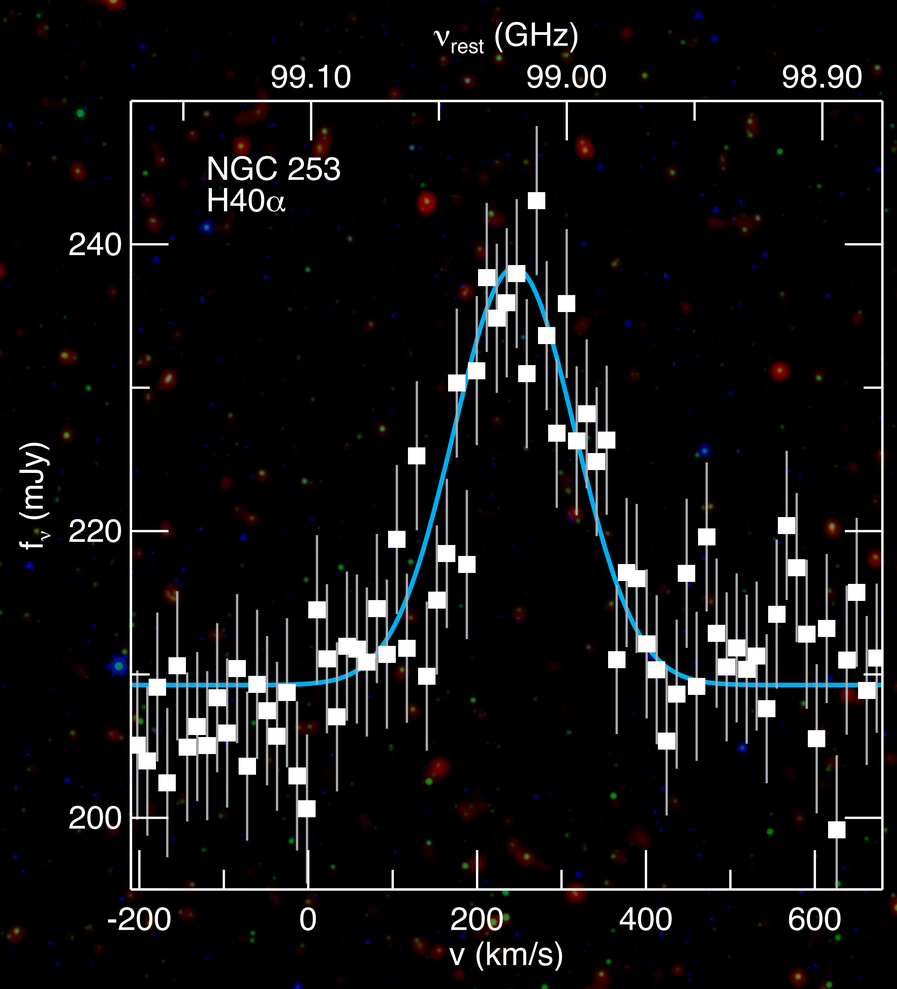
Additional comparisons show that near-infrared recombination line emission may be more heavily affected by dust extinction than previously expected, and lower frequency radio recombination lines are potentially affected by masing and gas opacity issues.

NGC 253

Bendo et al. 2015
MNRAS 450, L80

- The SFRs from free-free continuum and H40α line (1.73 ± 0.12 $M_\odot$/yr) fall within the broad range of SFR measurements based on radio data.
- Many lower frequency free-free continuum and recombination line measurements produce lower SFR measurements, possibly because of gas opacity issues.
- The near-infrared dust extinction is ~1.5 magnitudes higher than previously thought.

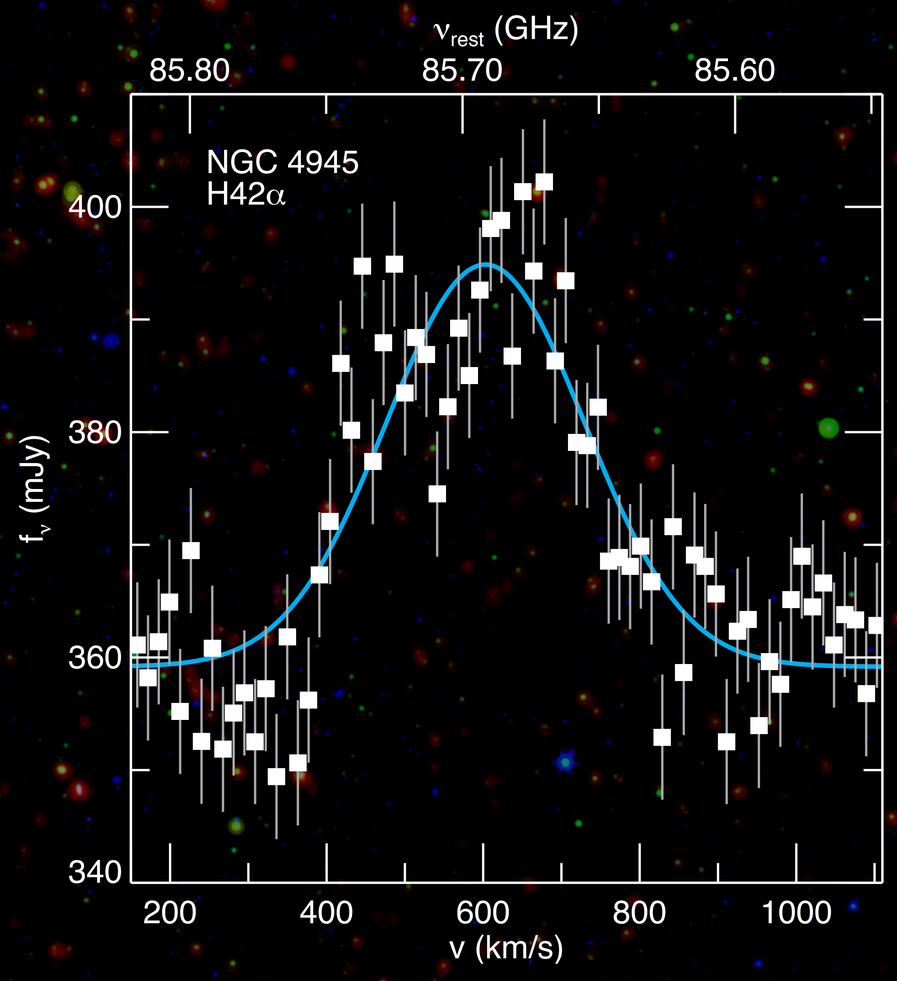




NGC 4945

Bendo et al. 2016
MNRAS 463, 252

- The SFRs from free-free continuum and H42α line (4.35 ± 0.25 $M_\odot$/yr) are comparable to the SFRs from total infrared and lower frequency radio data.
- The SFR from mid-infrared (22 and 24 μm) data is 10× lower than the ALMA measurements.
- Extreme dust densities in the center of the galaxy may make it optically thick to mid-infrared emission, which is why the SFR from the mid-infrared data is so low.



NGC 5253

Bendo et al. 2017
in preparation

- The SFR from H30α line (0.092 ± 0.018 $M_\odot$/yr) match SFRs from combining ultraviolet and total-infrared or Hα and total-infrared data.
- The SFRs from mid-infrared (22 μm) data yield SFRs that are ~3× higher.
- The low metallicity in NGC 5253 leads to low dust densities and lower attenuation of ultraviolet light. The dust that is present is very hot, which is why the mid-infrared emission does not scale with SFR.