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Kpc-scale Imaging of the CO(1-0)-traced Molecular Gas Reservoir in a z=3.4 SMG

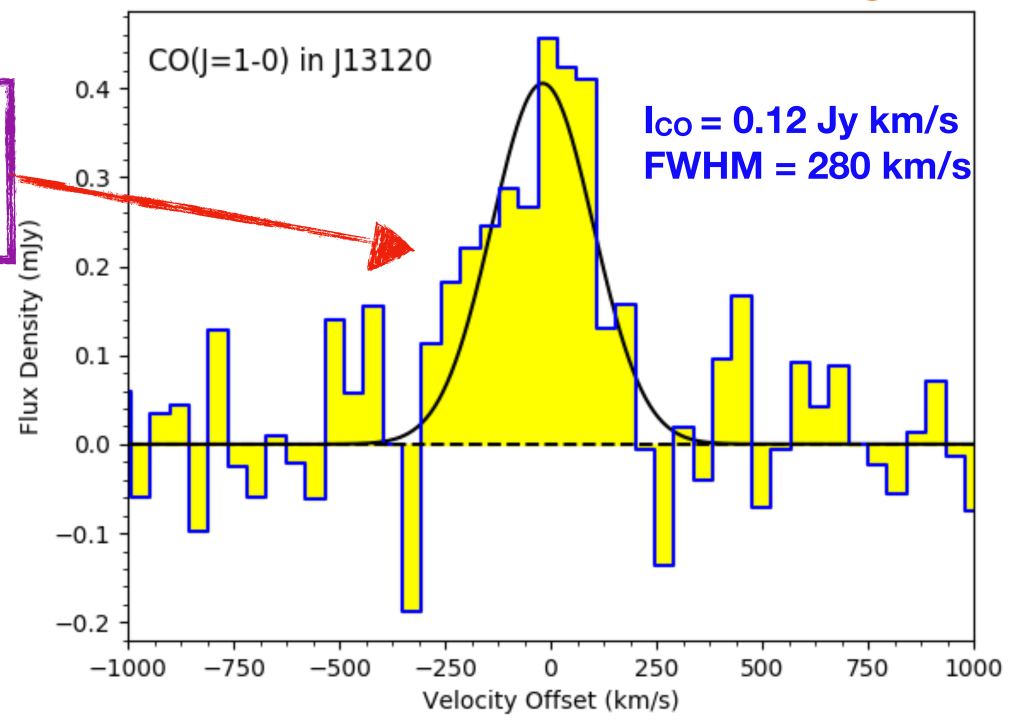
- Evolution of cosmic molecular gas density follows closely that of star formation rate density (SFRD)
  - ➔ Molecular gas drives star formation
  - ➔ Crucial for understanding galaxy formation/evolution
- How do we trace cold molecular gas at high-z?
  - ➔ CO(1-0): faint, need large time investments
  - ➔ Mid-J CO lines: brighter, but mostly trace dense gas and need excitation assumptions to convert flux to CO(1-0)
  - ➔ [CI]/[CII]: used only recently, further calibration needed at high-z
- Currently, there are no high-resolution studies of CO(1-0) in high-z unlensed SMGs.

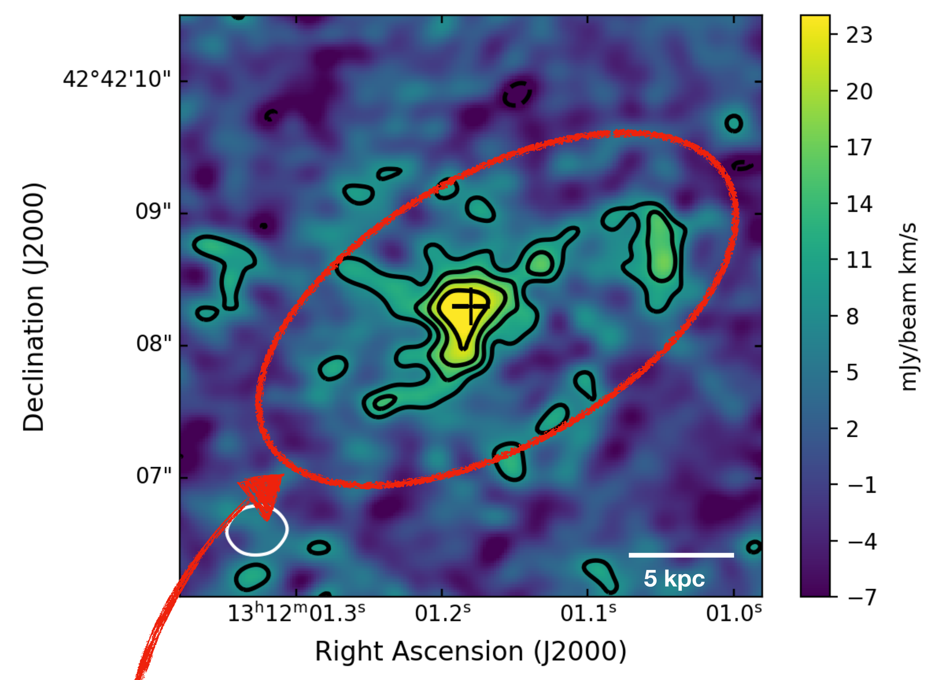
Why SMM J13120+4242?

- CO(6-5) observations revealed a complex spatial and velocity gas distributions, suggesting the system may be in an advanced merger state (Engel+2010).
- Low S/N CO(1-0) observations showed a very massive, extended low-excitation gas reservoir, with a very broad line (~1000 km/s, Hainline+2006, Riechers+2011).
- Best candidate to compare with the smoothly rotating disk observed in the only other starburst with high-resolution, low-J CO imaging, GN20 (Hodge+2012).

JVLA 0.35” mapping of CO(1-0) in SMM J13120+4242

We recover a narrower FWHM than expected

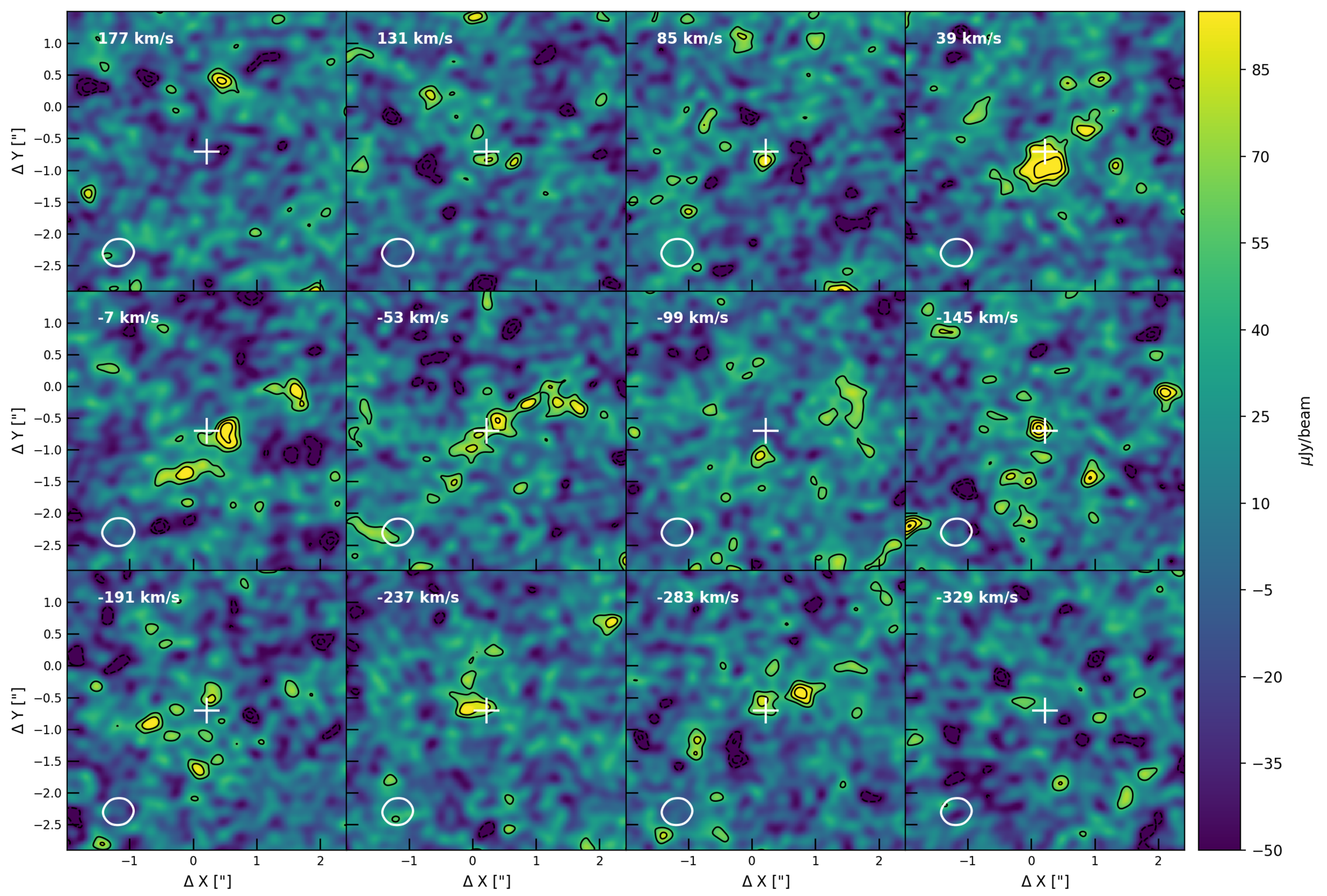


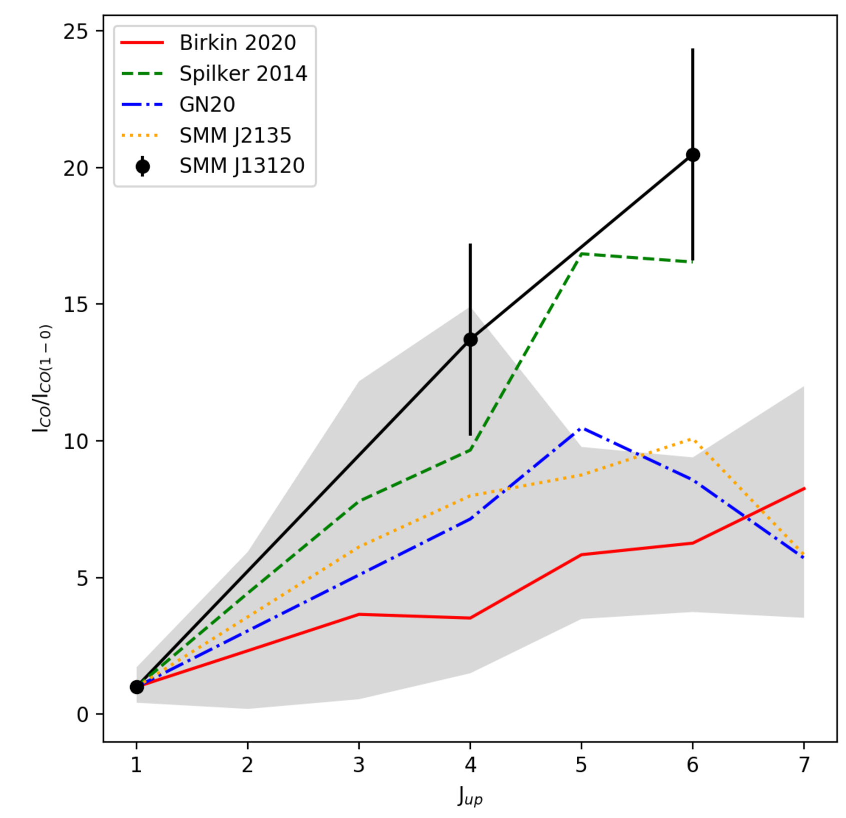


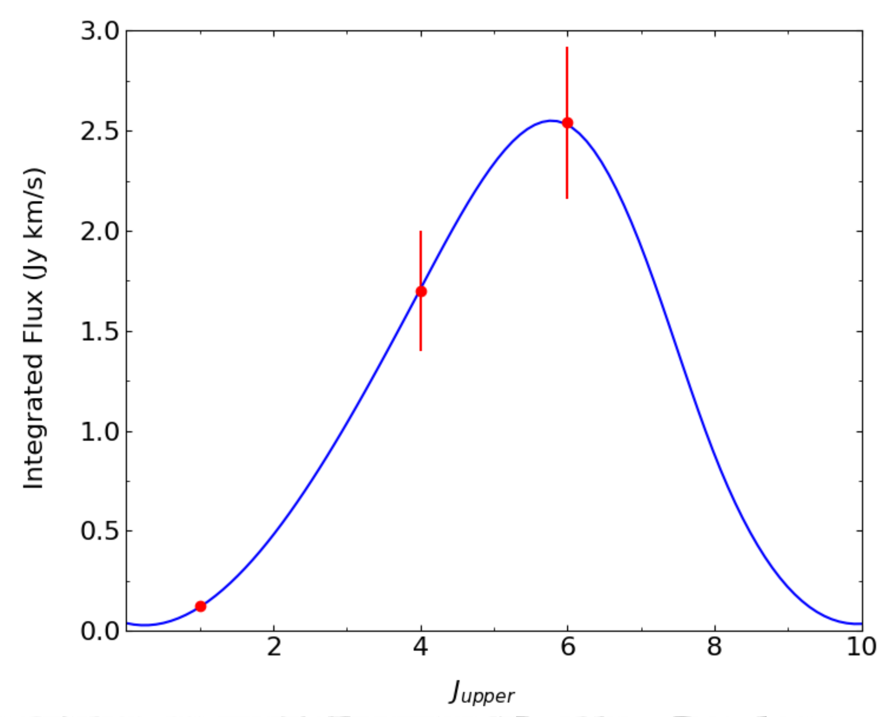
- $L'_{CO(1-0)}$ = 6 x 10^{10} K km/s pc^2
- M_{gas} = 8 x 10^{10} (α_{CO}/1) M⊙
- M_{dyn} = 3.5 x 10^{11} M⊙
- $R_{1/2}$ ~ 8 kpc
- Two components separated by ~11 kpc

Combining M_{dyn}, $M_\star$ and M_{DM} constrains the CO-to-H_2 mass conversion factor, α_{CO}, to 1.1-1.5 M⊙/(K km/s pc^2), similar to other high-z SMGs and local ULIRGs.

Channel maps show no indication of ordered motion, nor extended emission beyond the central 400 km/s.







CO SLED and LVG modelling

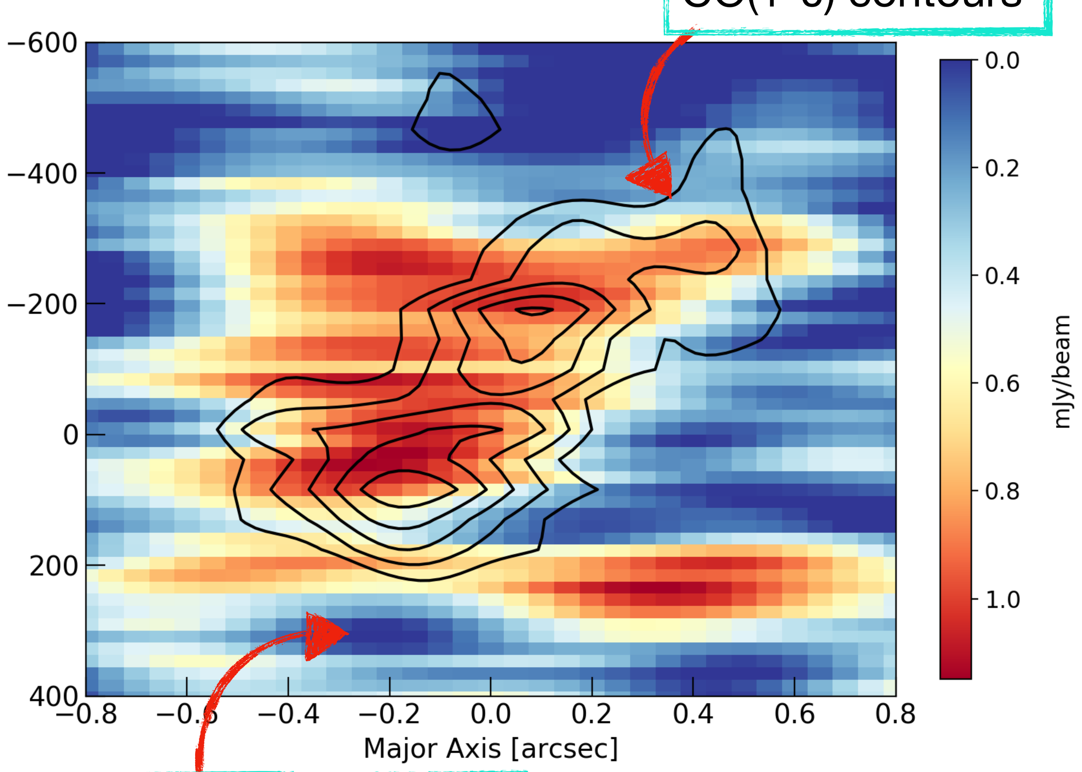
SMM J13120 has line luminosity ratios of r_{41} = 0.84 and r_{61} = 0.57. This is significantly more excited than the general SMG population and closer to AGNs and ULIRGs.

LVG modelling including CO(4-3) and CO(6-5) suggests the ISM is well characterised by a single gas-phase model. Other studies with CO(1-0)-traced gas reservoirs as extended as this one often need a multicomponent model to explain the CO SLED.

Late-stage merger in SMM J13120?

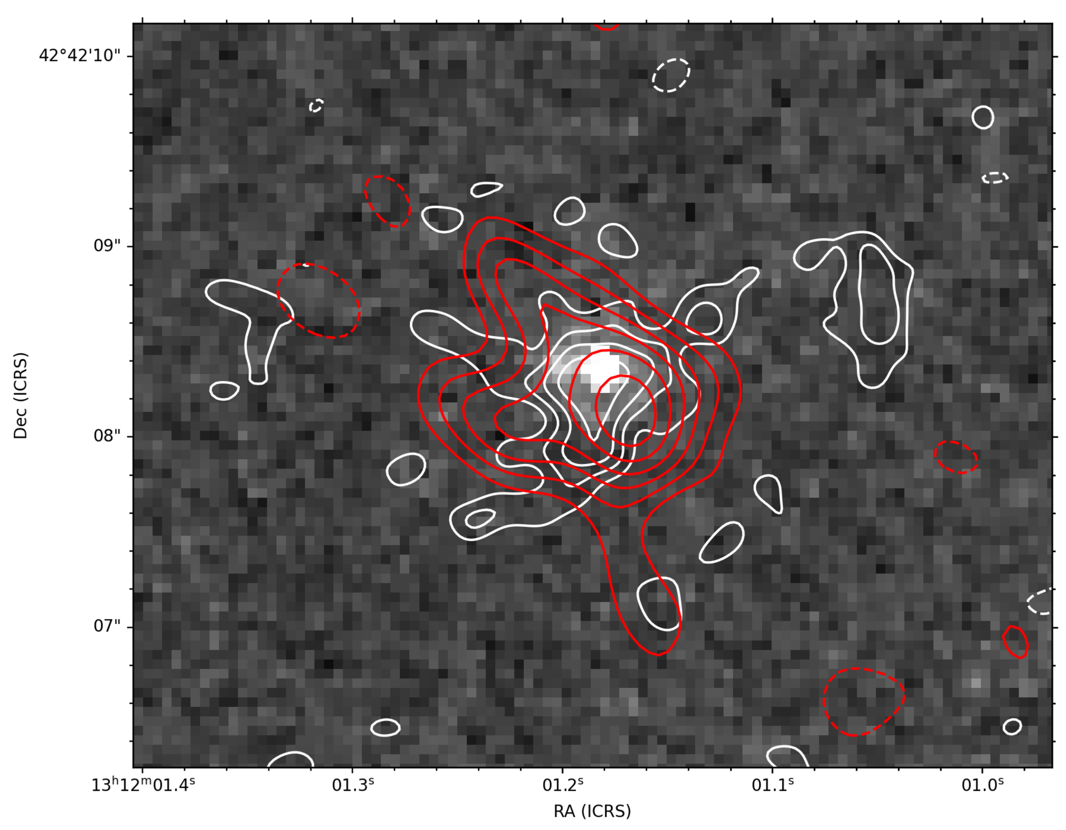
With a SFR of ~3700 M⊙/yr, SMM J13120 is over 1dex above the main sequence of star-forming galaxies at z = 3.4. The estimated gas mass will be consumed in t_{dep} = 23 Myr, indicative of a phase of rapid star formation seen in other high-z SMGs and starburst galaxies.

CO(1-0) contours



CO(6-5) emission

The CO(1-0) velocity field is chaotic, with no ordered structure. A PV-diagram extracted along the minor axis shows hints of a possible velocity gradient, which can also be seen in CO(6-5). This gradient could indicate that the molecular gas, now mostly concentrated in the central component seen in CO(1-0), has started to settle into a rotating disc.



CO(1-0) and CO(6-5) emission are coincident with stellar emission. The compact stellar distribution and disturbed gas reservoir suggest the merger is in a late stage.

CO(1-0) studies are key to accurately characterise the cold gas reservoirs fueling star formation at high redshift.
High-resolution kinematic studies like this one are also crucial to understand differences between gas phases of different excitation and interpret spatially unresolved gas excitation studies.
Future surveys of the CO(1-0) gas in larger samples of SMGs will shed light on their typical gas excitation conditions.