Observational studies of high mass star formation

E.L. Hulsen, supervised by Dr C. Cyganowski
School of Physics and Astronomy, University of St Andrews

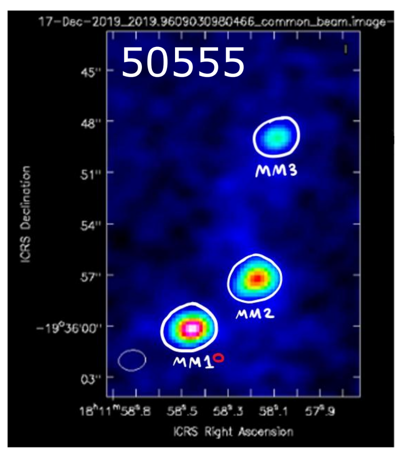
Introduction

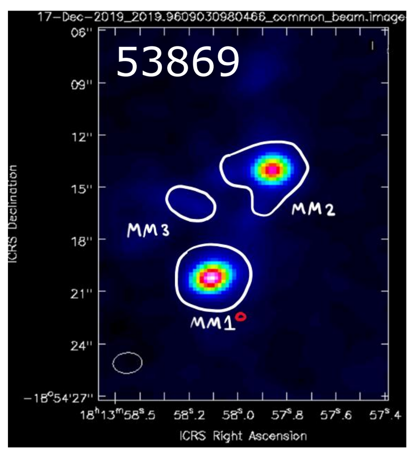
Using data from the ALMA (Atacama Large Millimetre/Submillimetre) telescopes, this research aims to characterise high mass star formation.

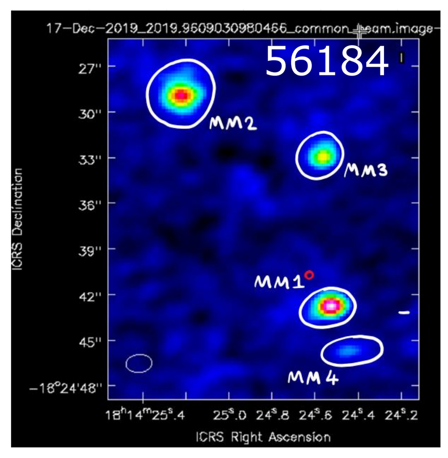
We are looking for accretion bursts; periods of rapid mass gain that make the protostar larger and brighter. These were first observed in high mass star formation in 2017 [1].

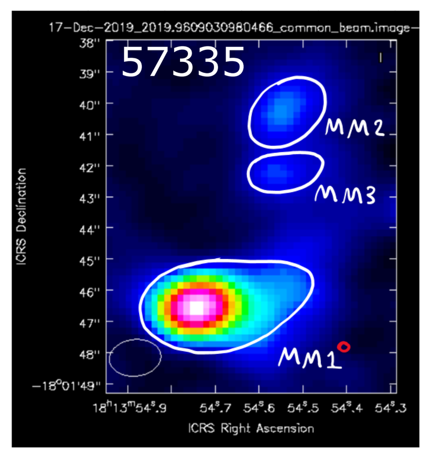
The 16 sources spread across 5 fields (pictured opposite) were observed by ALMA over COVID, resulting in measurements taken with a 2.3-year gap in between. The 3 epochs (dates) used are 17th Dec 2019 and the 28th, 29th Mar 2022. An accretion burst would cause a difference in brightness between 2019 and 2022 and the two March dates are expected to match.

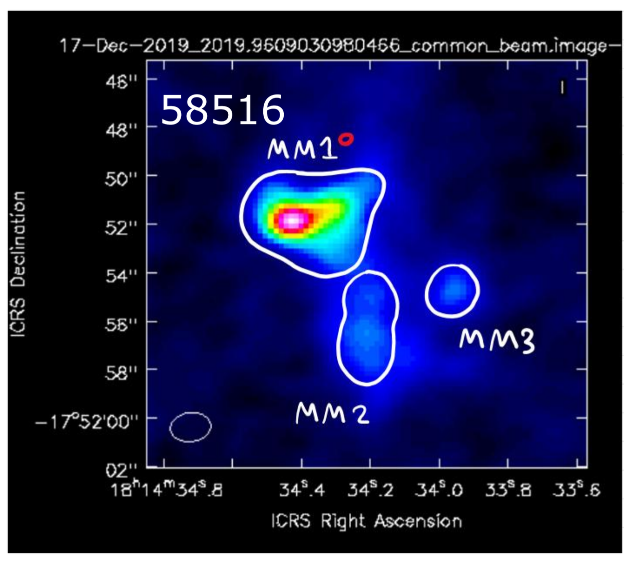
The CASA (Common Astronomy Software Application) is used in all three analysis methods, and the research follows a similar method to [2].











The sources in the fields are named in order of brightness.

The brightest source in each field (MM1) have all been previously identified as having variability in their continuum (overall brightness) by Claudia Cyganowski and Rodrigo H. Alvarez-Gutierrez.

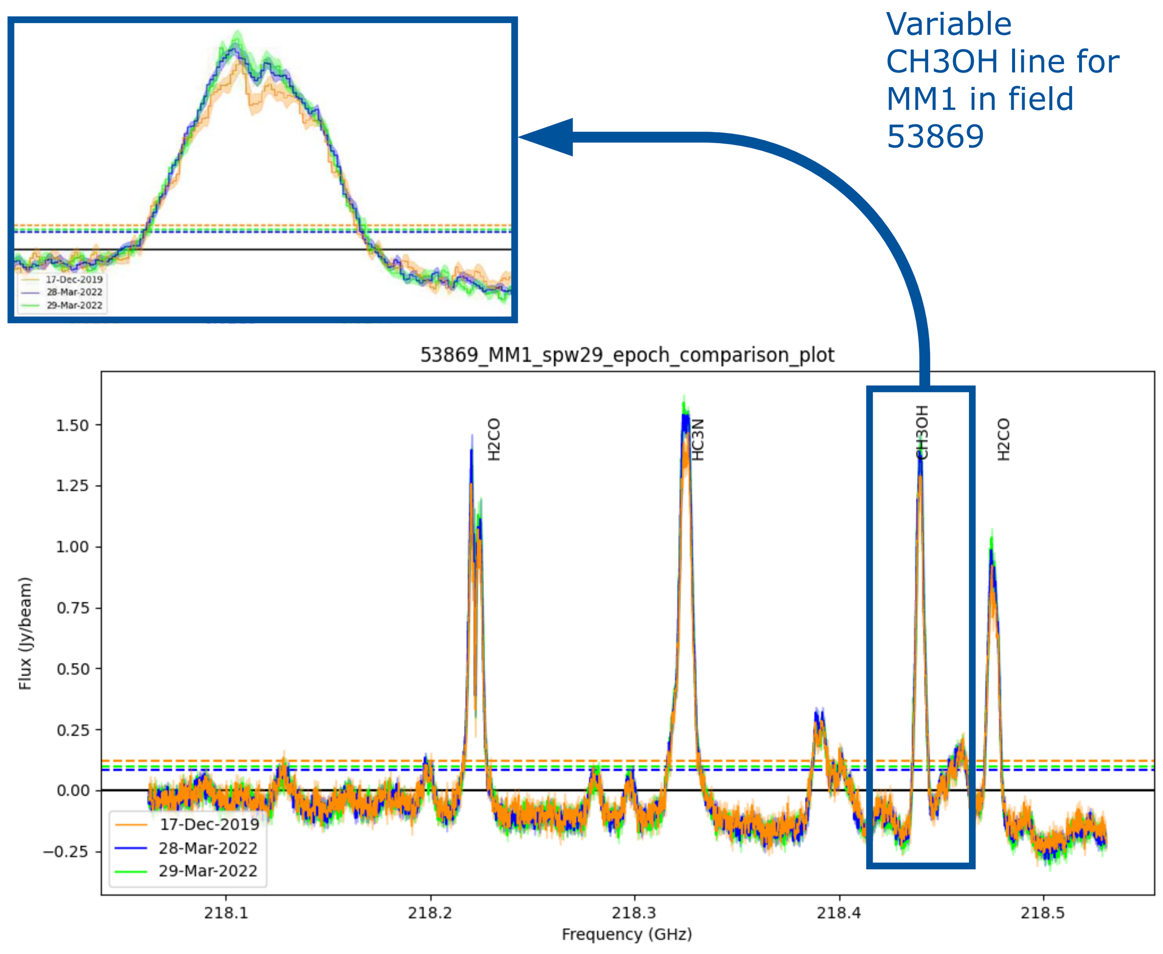
These sources are labelled with a red dot and highlighted in red in the table below.

Methods

Spectral Graphs

These graphs show the emission spectra of the source for the different epochs. The peaks correspond with the presence of certain chemicals in and around the source (i.e. a peak at a specific frequency indicates the presence of a specific chemical).

The sources were analysed based on whether there was variability (difference in brightness between epochs) in the chemical peaks themselves. For variability to be noted there must be space in-between the lines (including noise measurements around the lines) between the 2019-2022 epochs.

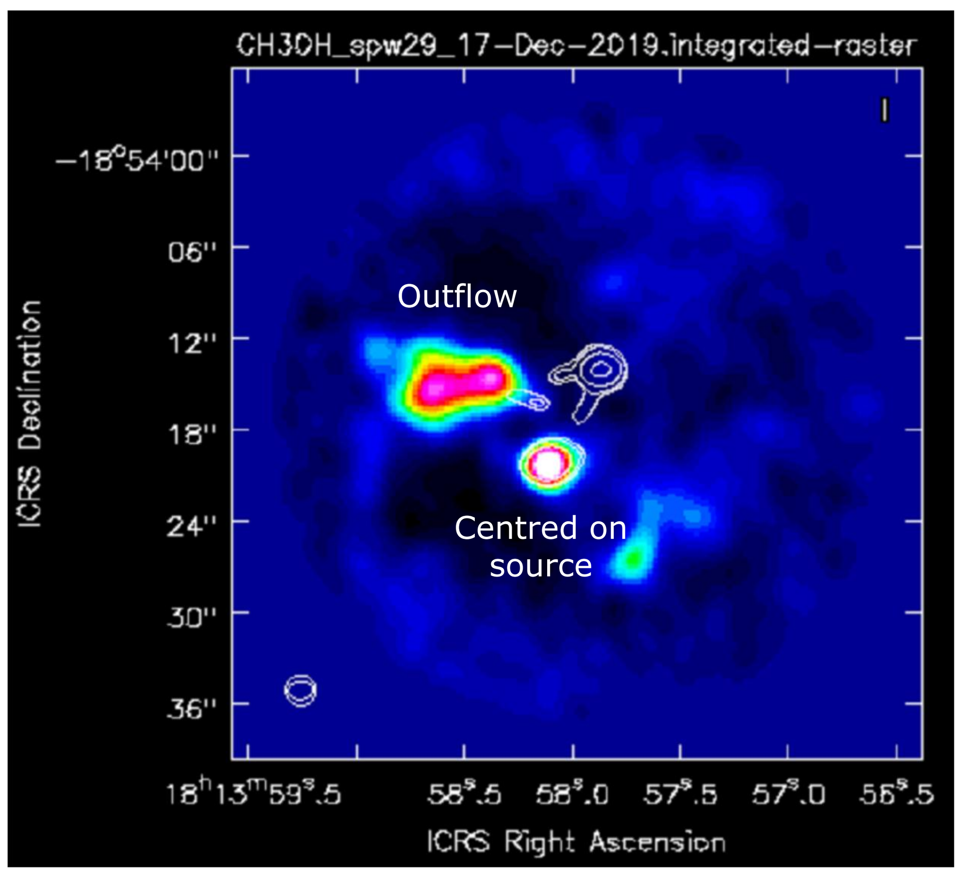


Moment Maps

Moment maps are representations of where the emission of a particular frequency is coming from in a field, and how strong it is. This means we can see where a chemical is located.

These maps tell us if emission is centred on a source or coming from an outflow. Outflows are less useful to us as they are gas ejected from the source in other parts of the field, so can't accurately show the changes in brightness of the protostar itself.

This is a map of the CH3OH in field 53869 on the 17th Dec 2019.



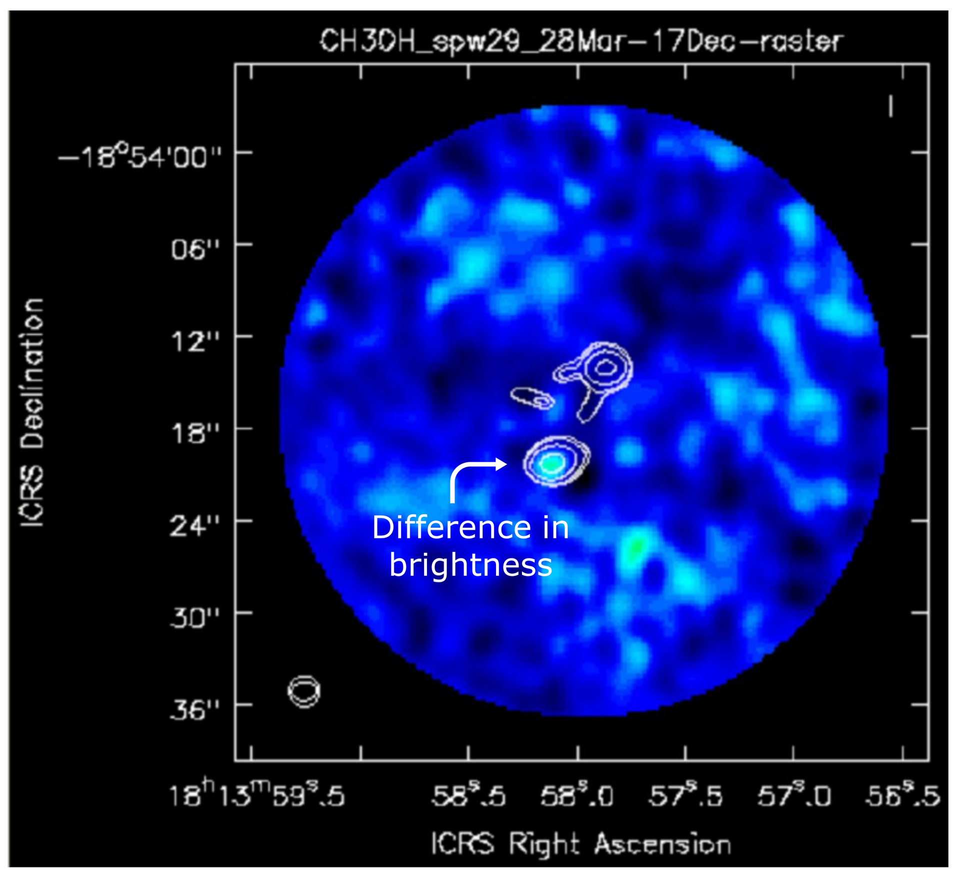
Subtraction Maps

Subtraction maps show the difference in brightness in the field between two epochs.

We can use the subtraction maps to confirm the variability spotted in the spectral graphs.

Variability in a chemical line would lead to a difference in brightness for a subtraction map of the 2022-2019 epoch difference, and no difference in brightness for a subtraction map of the two 2022 dates epoch difference.

The subtraction map below is for CH3OH in field 53869, for the epoch difference 28th Mar 2022 – 17th Dec 2019.



Conclusion

After all 4 processes, the 2 sources left (53869 MM1, 57335 MM1) both have variability in their continuum and are particularly bright and line rich (lots of visible chemical lines). However, any sources showing variability in their spectra (group of 7 sources in table) could be useful for further studies into accretion bursts.

This study has found that **the brightest and most line-rich protostars are the most promising sources of variability**, which in turn indicates that they are the **most likely to be useful for future study of accretion bursts in high mass star formation**.

Initial group of sources		*With variability in spectra*	*+ Emission centred on source*	*+ Variability confirmed by subtraction moment maps*
50555 MM1	56184 MM3	50555 MM1	50555 MM2	53869 MM1
50555 MM2	56184 MM4	50555 MM2	53869 MM1	57335 MM1
50555 MM3	57335 MM1	53869 MM1	57335 MM1	
53869 MM1	57335 MM2	53869 MM2	58516 MM1	
53869 MM2	57335 MM3	57335 MM1		
53869 MM3	58516 MM1	57335 MM2		
56184 MM1	58516 MM2	58516 MM1		
56184 MM2	58516 MM3			
16		**7**	**4**	**2**

Acknowledgements

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References

[1] D. M.-A. Meyer et al. "On the existence of accretion-driven bursts in massive star formation". In: Monthly Notices of the Royal Astronomical Society: Letters 464.1 (Jan. 2017), pp. L90–L94. issn: 1745-3925. doi: 10.1093/mnrasl/slw187. eprint: https://academic.oup.com/mnrasl/article-pdf/464/1/L90/ 56943686/mnrasl_464_1_l90.pdf. url: https://doi.org/10.1093/mnrasl/slw187.
[2] Yuhan Yang et al. "Tracking Protostellar Variability in Massive Protoclusters with ALMA. I. Insights from QUARKS and MaMMOtH". In: 1003.1, 60 (May 2026), p. 60. doi: 10.3847/1538-4357/ae5c08. arXiv: 2512.10298 [astro-ph.GA].

Data Availability

The complete set of spectral graphs, moment maps and subtraction moment maps available by contacting me via emeline.hulsen@gmail.com, or on the Laidlaw student network. Any questions can also be sent this way.