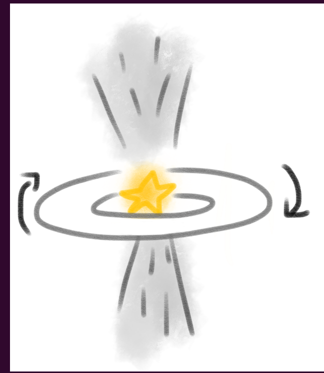
ALMA observations of a Keplerian disc around the proto-O star G19.01-0.03 MM1



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Abbreviated abstract

High mass stars ($M \geq 8M_{\odot}$) are key constituents of galaxies, yet much remains unknown about their formation and how they accrete their mass. We present new observations taken with the Atacama Large Millimetre/submillimetre Array (ALMA) of the proto-O star G19.01-0.03 MM1 (hereafter MM1) at a wavelength of 1.05mm, and 0.4″~1600AU angular resolution. We report the first detection of a high-mass circumstellar accretion disc around MM1, which adds it to the short list of high-mass disc-outflow candidates in the literature.

Related publications

- Cyganowski et al. (2011a), ApJ, 729, 124
- Williams et al. (2020), MNRAS, in prep

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MORE DETAILS:

Motivation

High-mass stars are a **key constituent of galaxies**, yet much remains **unknown** about their formation and **mass growth**.

Background

Low-mass stars accrete through rotationally supported circumstellar discs, with molecular outflows emanating from their poles expelling excess angular momentum from the infalling material.

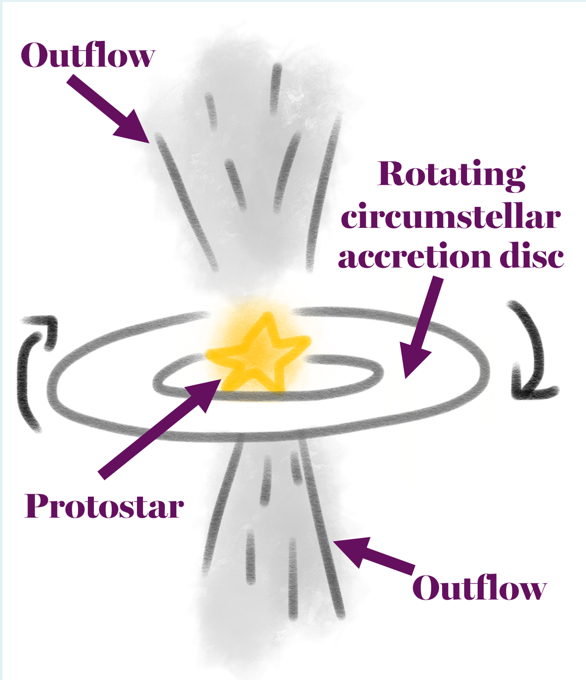
High-mass stars are theoretically thought to accrete in a scaled-up version of this low-mass scenario, but this remains observationally elusive.

The **observation of high-mass star formation is somewhat trickier than that of their low-mass counterparts**, with high-mass star formation regions lying **several kpc more distant**, and in **clustered and embedded environments**. High-angular resolution studies in the submillimetre wavelength regime now have the capability to resolve and disentangle these regions and aid us in understanding how high-mass stars gain their mass.

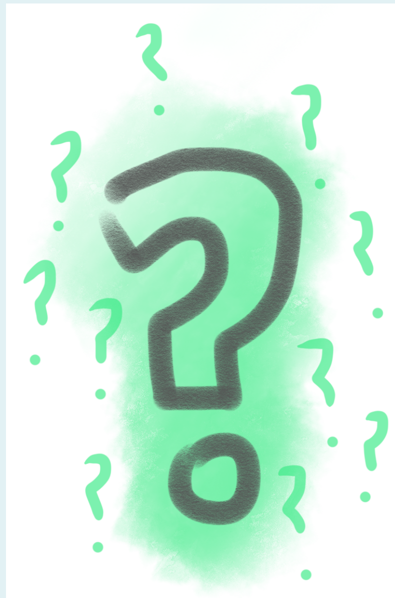
High-mass stars are thought to form like low-mass stars in theory, but in reality this is tricky to observe

How do stars gather their mass?

Low-mass stars ($M < 8\ M_{\odot}$)



High-mass stars ($M \geq 8\ M_{\odot}$)

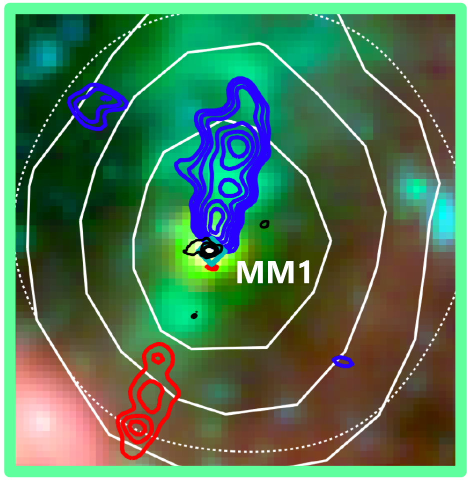


MORE DETAILS:

The target

Previous studies of the **proto-O star G19.01-0.03 MM1**(hereafter MM1) with the Submillimetre array (SMA) reveal it to **drive a high-velocity bipolar molecular outflows**, therefore can be inferred to represent a stage of **ongoing accretion**. This therefore makes MM1 a great candidate for harbouring a hidden high-mass circumstellar disc.

The previously published SMA **^{12}CO(2-1) outflow lobes** are marked by **blue and red contours** in the below Spitzer three-colour composite image (RGB: 8μm, 4.5μm, 3.6μm).

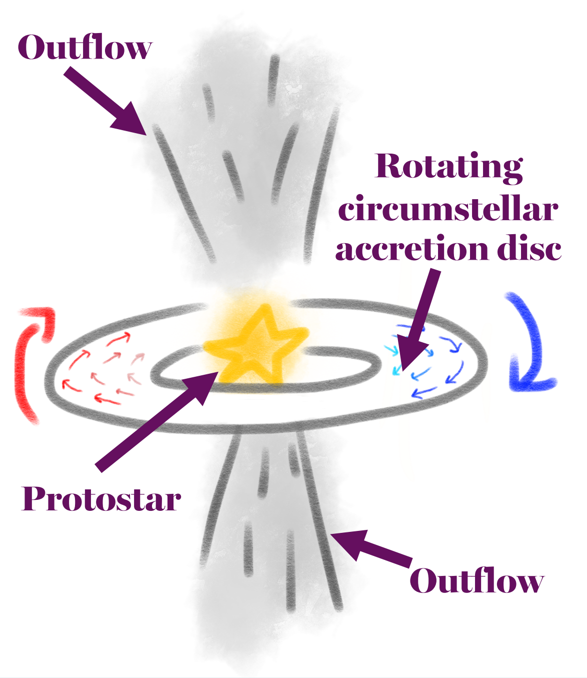


New data

We observe **MM1 with the Atacama Large Sub/millimeter Array (ALMA)** in Cycle 2 (PI: Cyganowski; 2013.1.00812.S) at **1.05mm,** with an angular resolution of **~0.4''~1600AU**. Our tuning contains two broad 1.875GHz bands centred on ~279GHz and ~291GHz, with the aim of detecting a forest of molecular lines.

The high-mass G19.01-0.03 MM1 proto-O star is known to drive an outflow, so it's possible it also has a candidate circumstellar disc

How does one probe hidden candidate circumstellar discs?



Using molecular line data, the gas in the rotating disc **moving towards us is blue shifted,** and the gas **moving away from us is red shifted,** thanks to the doppler effect.

MORE DETAILS:

Method

We identify 43 molecular transitions detected in our ALMA tuning.

We perform a **moment analysis** on 19 of the strongest, most unblended lines. **Moment one** maps show us the **velocity structure** of MM1, and the tentative detection of a disc is made should the velocity gradient show the red and blue-shifted pattern.

Result

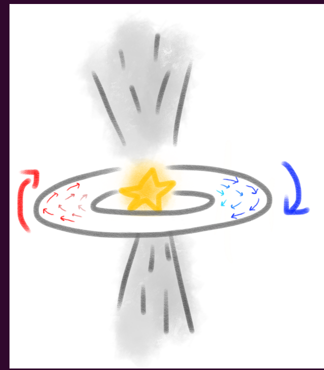
The **candidate disc is detected** towards the MM1 proto-O star for the first time, with **velocity gradient signatures consistently traced** by all 19 different molecular transitions *(8 are shown in the right figure)*.

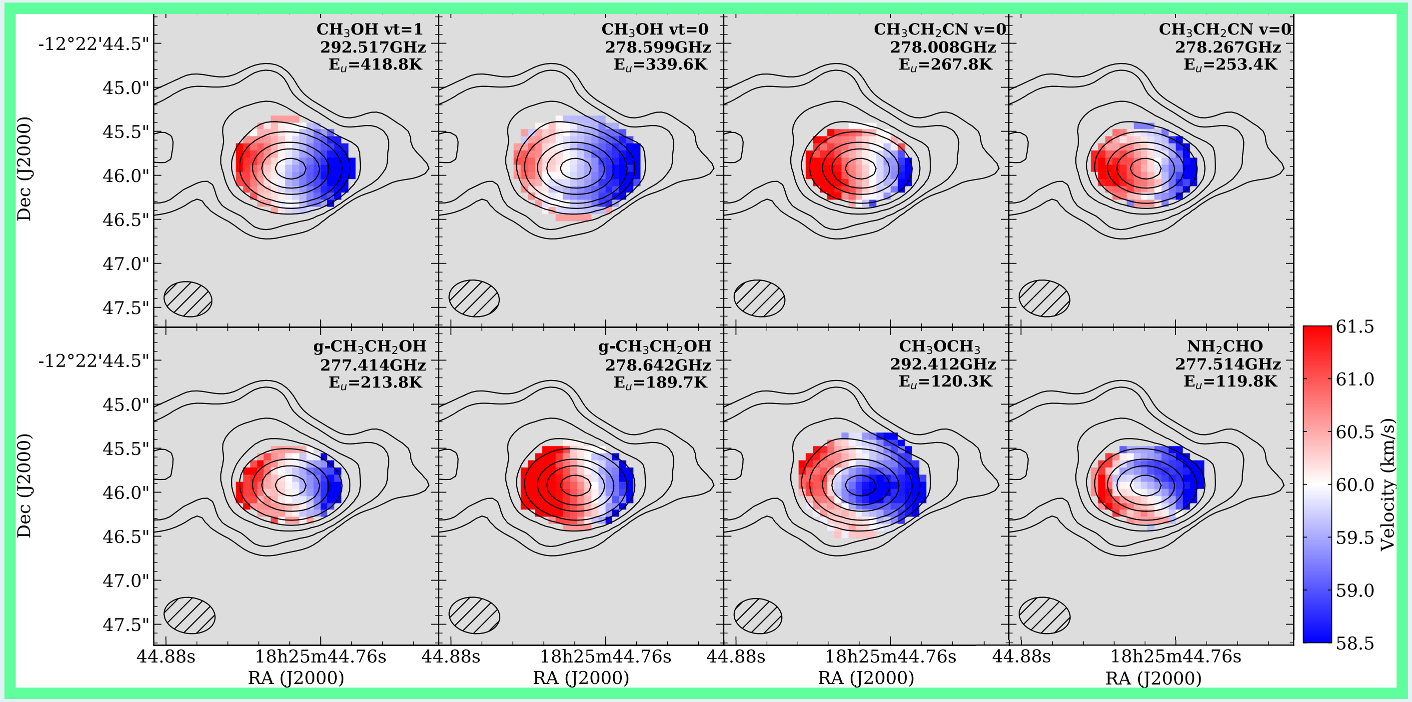
Further **kinematic modelling** (not shown here) of the disc shows the disc **encloses a mass of ~50±10M$_{\odot}$** of material. This is quite massive in comparison to the moderate bolometric luminosity of MM1 of $10^4 L_{\odot}$, therefore we speculate that this mass may be distributed **in a high-mass binary system.**

Conclusion

We add the proto-O star G19.01-0.03 MM1 to the short list of high-mass disc-outflow candidates in the literature, showing that **this high-mass star is likely to be accreting its mass like low-mass stars do.** Its high enclosed mass hints at this source harbouring a high-mass binary.

A rotating circumstellar accretion disc is detected around G19.01-0.03 MM1 for the first time





The **tell-tale velocity signature** of a rotating circumstellar disc is **revealed towards MM1** in the above **moment one velocity maps**, and is consistently traced by all 8 molecular transitions with ALMA

(Black contours in the figure are of the ALMA 1.05mm dust continuum.)

Williams et al. 2020, MNRAS, in prep