Episodic ejection in massive young stellar objects: S255IR-SMA1 and AFGL 5142 MM1

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Introduction
Massive star formation is deeply embedded in issues of theory and observation. Presently, it is unclear if massive stars undergo a distinct formation mechanism, or if they follow a scaled-up version of low mass star formation. Theory suggests the former on account of the intense radiation pressure emitted by the star which is thought to limit accretion. However, observationally there are several common traits which suggest some degree of likeness.

Outflow driving in MYSOs
Massive young stellar objects (MYSOs) produce bipolar molecular outflows. However, whether these are driven in a similar manner those that are seen in low mass stars i.e. a narrow disk-launched jet entraining a wider molecular outflow, is still uncertain.

Episodic accretion
Since ejection events are thought to trace accretion episodes the study of outflows in massive stars also reveals their accretion history. Thus outflows stand as an accessible and valuable point of comparison between low and high mass star formation models.

Target MYSOs
This work targets S255IR-SMA1, a 20 Mo MYsO, and AFGL 5142 MM1, a 10 Mo MYsO – both of which exhibit traits common to both massive star formation (6.7 GHz methanol masers, L > 1000 Ls, centimeter emission) and low mass star formation (bipolar outflows perpendicular to a rotating disk).

Observations
We observed 22 GHz water masers in S255IR-SMA1 over 12 epochs (covering 2.5 years) using VERA (VLBI Exploration of Radio Astrometry) in Japan. Using VERA’s dual beam capabilities we simultaneously observed the quasar, J0613+1708, which was used as phase reference – employing the inverse phase referencing technique.

Data reduction was done by hand in AIPS.

Observations: S255IR-SMA1

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These epochs were not used in parallax determination.

Launching outflows from massive stars
We compared the maser distribution and proper motions in our targets to hydrodynamic models (Lee et al., 2001; Ostriker et al., 2001) describing a wind driven outflow and a jet-bowshock driven outflow (pictured in Fig. 3) for the case of low-mass YSOs.

Model vs data: S255IR-SMA1

Our VLBI observations clearly show that both MYSO outflows are primarily driven by bow-shocks with some contribution from a disk wind. This is evidence that the ejection mechanisms seen in low-mass star formation appear similar at masses of at least 20 Mo.

Model vs data: AFGL 5142 MM1

Fig. 4: Multi-scale collimated ejections from S255IR-SMA1, showing (left) 2D molecular outflow with a dynamic timescale of 7000 yr from Zinchenko et al. (2012), (right) 3D velocity space showing the low mass star outflow from Wang et al. (2002). Right: Collimated (< 1 mas) 3D velocities of water masers tracing the 1000 yr outflow from Wang et al. (2002) made with VERA (left: S255IR-SMA1) showing water masers tracing the 1000 yr outflow.

The intimate relationship between accretion and ejection in young stellar objects reveals a history of episodic accretion bursts in S255IR-SMA1 working on timescales of a few thousand years. Here we supplement VERA data with VLBA data from Goddi et al. (2007).

Episodic accretion is rarely studied with regard to massive stars (contact me if you do!). Simulations by Hosokawa at al. 2015 discuss a mechanism whereby episodic accretion could suppress radiation pressure – allowing stars to be built up to 10s of Mo. The prospect of circumventing radiation pressure, along with evidence of episodic accretion could support the presence of a yet undefined ‘massive FUor’ type stage of star formation.

Episodic ejection is also seen in AFGL 5142 MM1, I will discuss it during my talk at Thursday 13:30.

References
AFGL 5142: Burns, R. A. et al., 2016, in prep.
Wang Y. et al., A&A, 527, A32

Background credit: ESO/L. Calçada/M. Kornmesser