Ionized jets toward high-mass young stellar objects

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The presence of collimated ionized jets in high-mass (M ≥ 8 $M_\odot$) young stellar objects (HMYSOs) supports two important astrophysical ideas:

1. High-mass stars form by disk-mediated accretion.

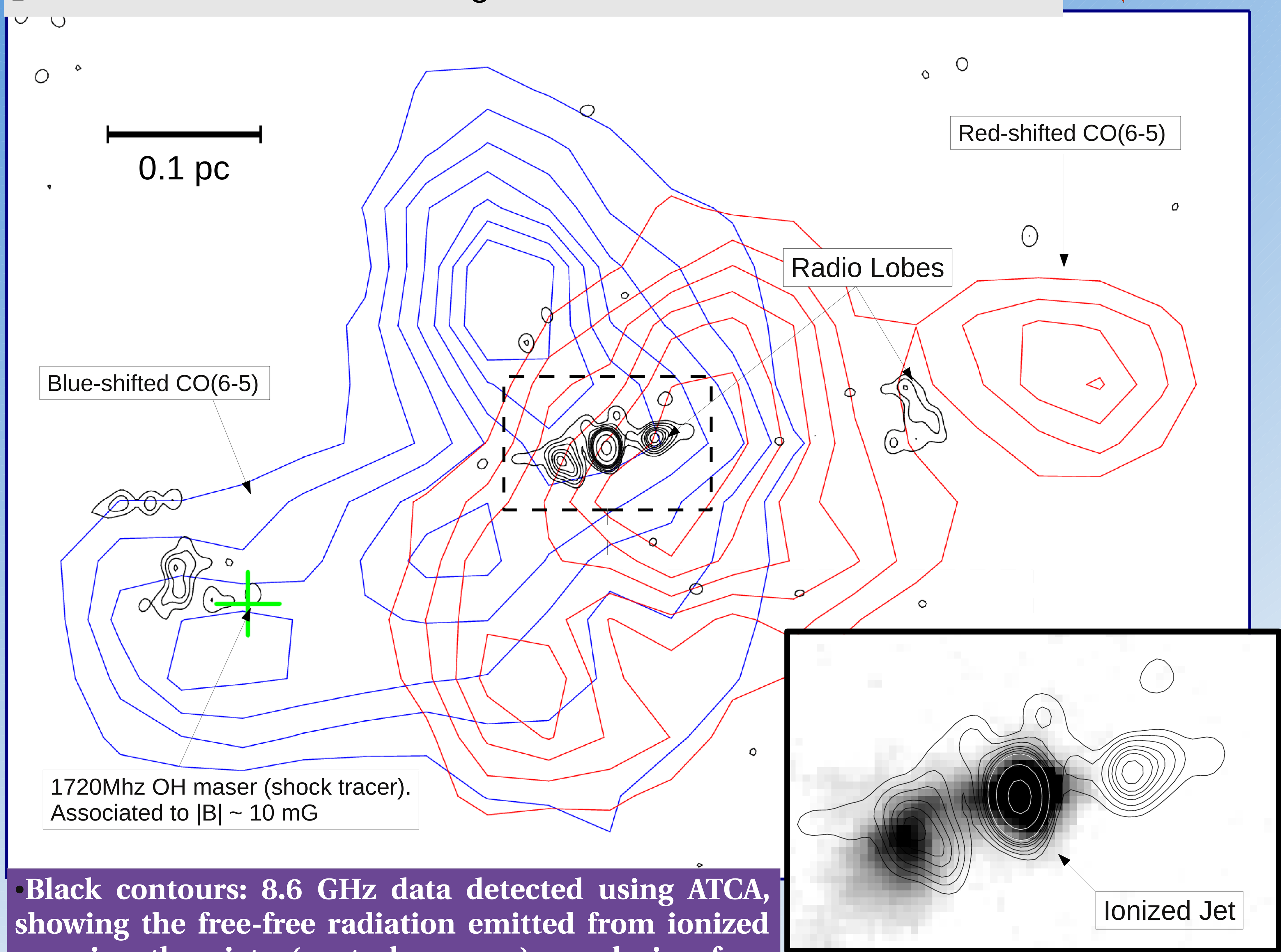
2. Molecular bipolar outflows are driven by collimated jets.

We embarked in a Systematic Search for ionized jets and molecular outflows toward selected, luminous HMYSOs candidates [2].

- **Emission mechanisms:**
  - Jets: Free-free from ionized gas.
  - Molecular outflows: line emission from shocks.
- **Methods:**
  - Jets: Interferometer at cm-wavelengths (ATCA & EVLA), observations.
  - Molecular Outflow: Single dish submillimeter (APEX & ASTE) observations.

Results

G345.4938+01.4677 : an ionized jet associated to a very luminous (L~70,000 $L_\odot$) HMYSO. The central protostar has ~15-20 $M_\odot$ [3,4].



- Black contours: 8.6 GHz data detected using ATCA, showing the free-free radiation emitted from ionized gas in the jet (central source), and in four symmetrically located lobes flanking the central source.
- Blue and red contours show the molecular outflow detected in CO(6-5).
- The green cross shows the position of an 1720-MHz OH maser, associated to one of the blueshifted lobes. A magnetic field of ~ 10 mG was determined to be related to this maser.

Greyscale:Mid-Infrared emission detected at 10.4 μm [5]. There is emission associated to the central source and to the re-emission from the inner walls of the blueshifted half of the jet cavity.

Results

- Jets are present in luminous YSOs (L>50,000 $L_\odot$)
- From the incidence of jets found in our sample, we derive that the lifetime of ionized jets associated to HMYSOs of L> 20,000 $L_\odot$ is $t_{jet} \sim$ 40,000 yr.
- Strong morphological evidence that bipolar outflows are (or were) driven by ionized jets.

Implications, Conclusions, Questions & Future Work

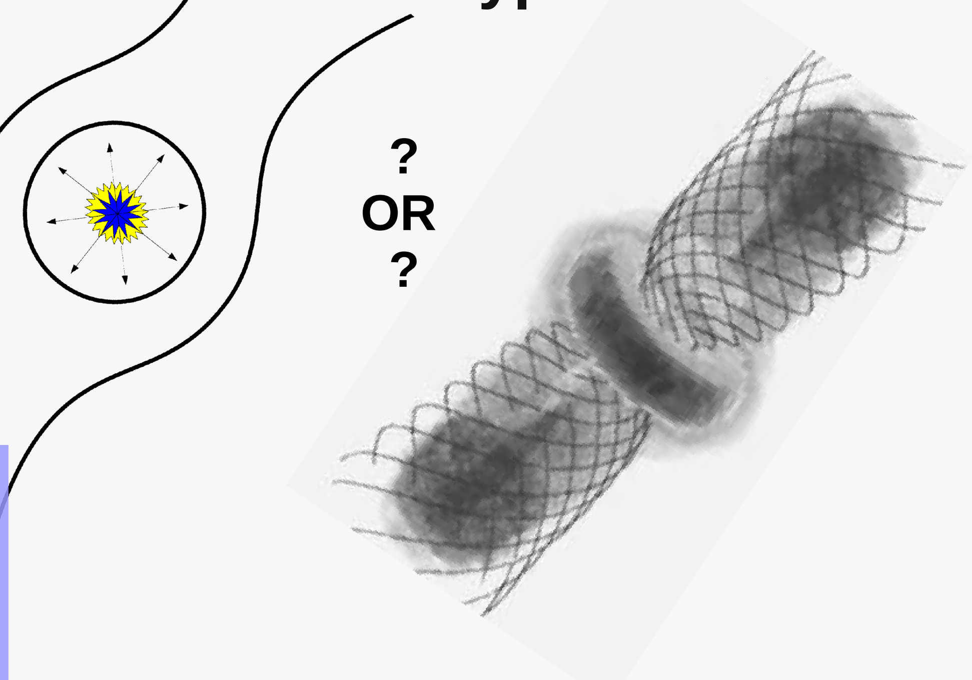
1)Disk mediated accretion in the high-mass SF case
2)The ionized jet has at most 40,000 yr to drive the observed bipolar molecular outflows.

But the momentum that ionized jets deliver (computed under several assumptions) falls short by a factor of ~10-100. Possible solutions to this discrepancy include:

- Very low ionization fractions
- Much more energy and momentum is delivered in discontinuous "bursts"

To solve this *"dark-matter and/or dark-energy" jet problem*, we need to know more about the velocityof the jet gas, its density, ionization fraction, and the distance from the protostar where collimation occurs.

Jet type?



Pressure confined? The high pressure in the host cores, makes it plausible. This model has been discarded for HH-jets in the low-mass case e.g. [1].
Magnetically driven? The consensus for the low-mass case.

ALMA will allow us to obtain a clarifying picture of these exciting objects. In the high-mass case, we need analogous tools to the ones that have been applied succesfully to the Herbig-Haro jets.

Our group have secured ALMA-ES time to observe the ionized jet described above in hydrogen recombination lines. We expect to estimate directly the velocity of the ionized gas itself close to the collimation zone.

www.almaobservatory.org/

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