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DISCOVERY AND STUDY OF THE PHYSICAL PROPERTIES OF MASSIVE STARS PRECURSORS

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Abstract. The search for massive prestellar core (MPSC) candidates is essential to elucidate what physical processes lead to the formation of high mass stars. We build here an automatic method to detect protostellar outflows to discriminate prestellar from protostellar cores in the large statistical sample of dust cores of the ALMA-IMF large program. We find 40 MPSC candidates, ranging from 8 to 63 solar masses. This unique sample of cores will allow us to better understand the process leading to the formation of high-mass stars and their time-scales.

Keywords: ISM : outflows, stars : formation, stars : prestellar and protostellar cores

1 Introduction

The study of the early phases of high-mass star formation is a major topic in astrophysics that is still poorly understood. Several formation scenarios are still in competition (McKee & Tan (2003), Bonnell & Bate (2006)). To elucidate which precise processes of formation are in action, it is necessary to identify the youngest precursors of massive stars ($M > 8M_{\odot}$), on the verge of collapse (so-called pre-stellar cores), within high-mass star-forming regions. Here we search for MPSC candidates in a large sample of dust cores at a resolution of $\sim 2700\,au$ in the large program ALMA-IMF dataset (Motte et al. (2022)). To deal with such high statistics, we build a new method to detect protostellar outflows. We use ALMA Band 6 datacubes to study the CO and SiO lines. The data reduction process is presented in Cunningham et al. (2023) for the linecubes and in Ginsburg et al. (2022) for the continuum maps.

2 A new automatic method to detect protostellar outflows

2.1 On-Off spectra

Comparing the spectra On the source (computed in its ellipse) with the spectra Off the source, i.e. of its environment (computed in an annulus around the source), we search automatically for blue and red-shifted line wings, representative of a protostellar outflow. CO(2-1) and SiO(5-4) lines are used, as they are the best tracers of protostellar ejections. We use the On-Off spectra to detect automatically the protostellar outflows, which is the best spectra to trace the emission from the source as the environment contribution has been retrieved. Figure 1 presents the CO and SiO On, Off and On-Off spectra of a protostellar core showing clear line wings.

2.2 Molecular outflow maps

In addition to the automatic spectral analysis, moment 0 maps of the blue- and red-shifted CO(2-1) and SiO(5-4) lines overlaid to the continuum emission are used. This classical method has already been used in several studies to identify protostellar cores (see e.g. Duarte-Cabral et al. (2013), Nony et al. (2020), Nony et al. (2023)). It gives spatial information on the possible outflows that are driven by the continuum cores in the field. Figure 2 presents the molecular outflow maps of the two lines (CO on the left panel and SiO on the right one) for the W43-MM2 region. Using these two complementary tools, we search for MPSC candidates in the ALMA-IMF continuum cores catalogs.

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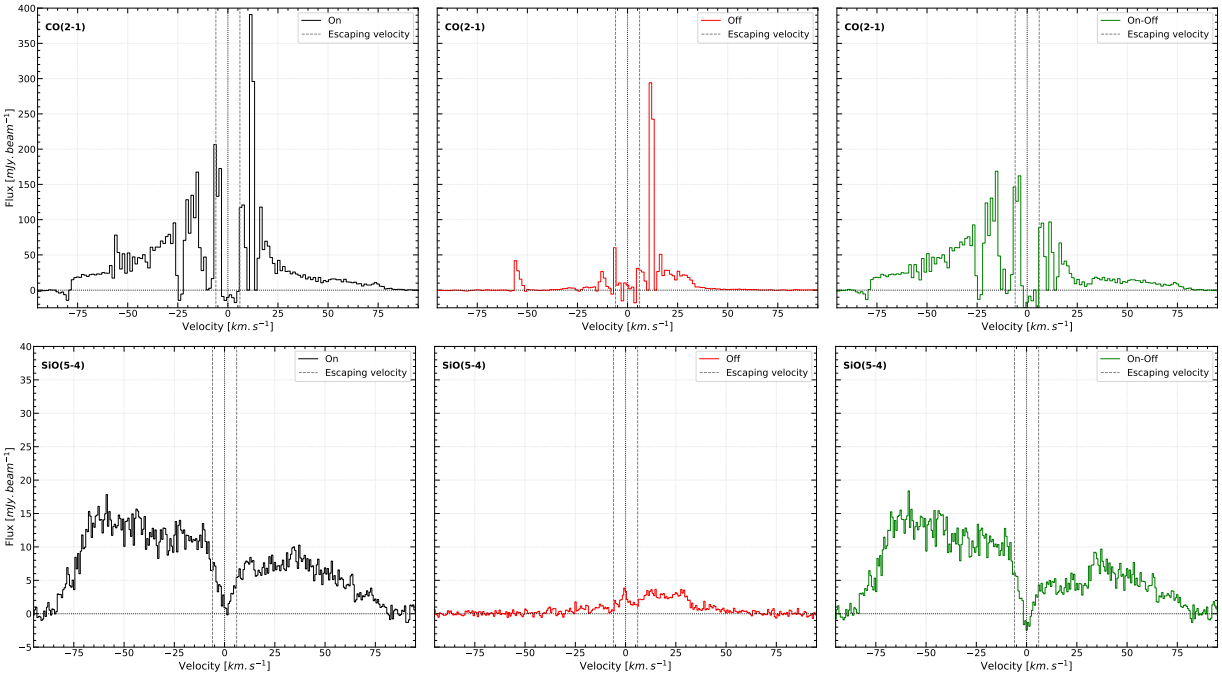

Fig. 1. On (black), Off (red), and On-Off (green) spectra of the CO(2-1) and SiO(5-4) lines of a protostellar core. The On-Off spectar displays line wings which are representative of the protostellar ejections of this core.

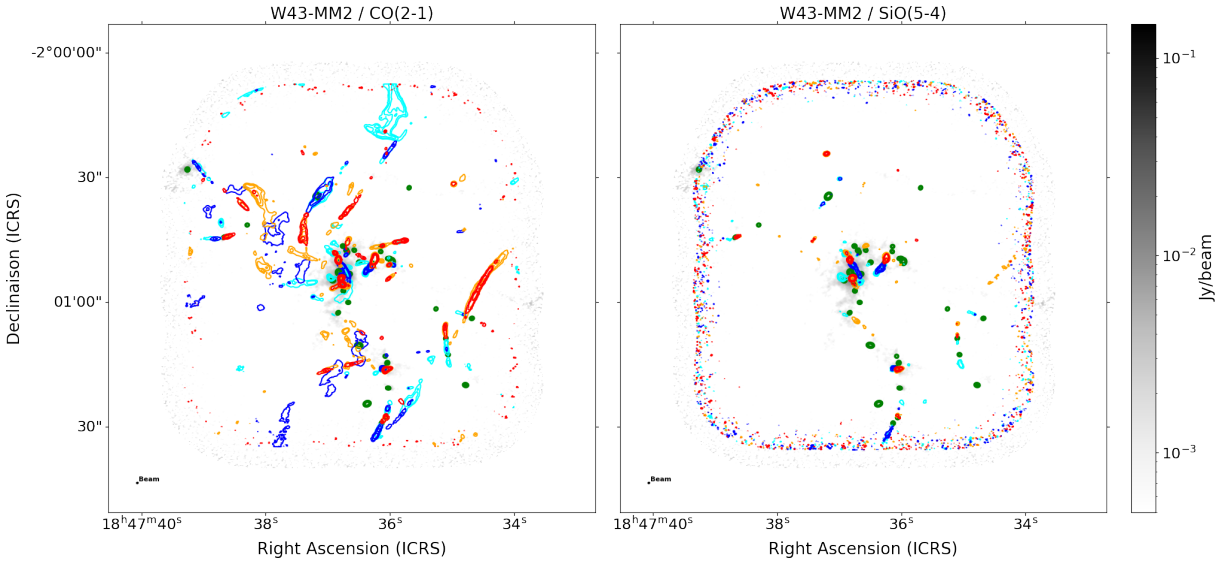

Fig. 2. CO and SiO molecular outflow maps of the W43-MM2 region. Cyan and blue contours represent low and high velocities blue-shifted lobes. Orange and red contours represent low and high velocities red-shifted lobes.

3 A unique sample of MPSC candidates

Using this automatic method we find 40 MPSC candidates in the ALMA-IMF dataset. It is the first sample of MPSC candidates, with such statistic and at a resolution high enough to study the candidates individually. The distribution in mass versus size of the candidates is presented in Fig. 3. The cores range in mass from 8 to 63 $M_\odot$, and in radii from $\sim$ 1200 au to $\sim$ 2700 au. Candidates are found in young, intermediate, and evolved regions in terms of evolutionary status. This suggests that several star formation bursts are possible in a massive protocluster, and that subregions in one protocluster could present different evolutionary stages.

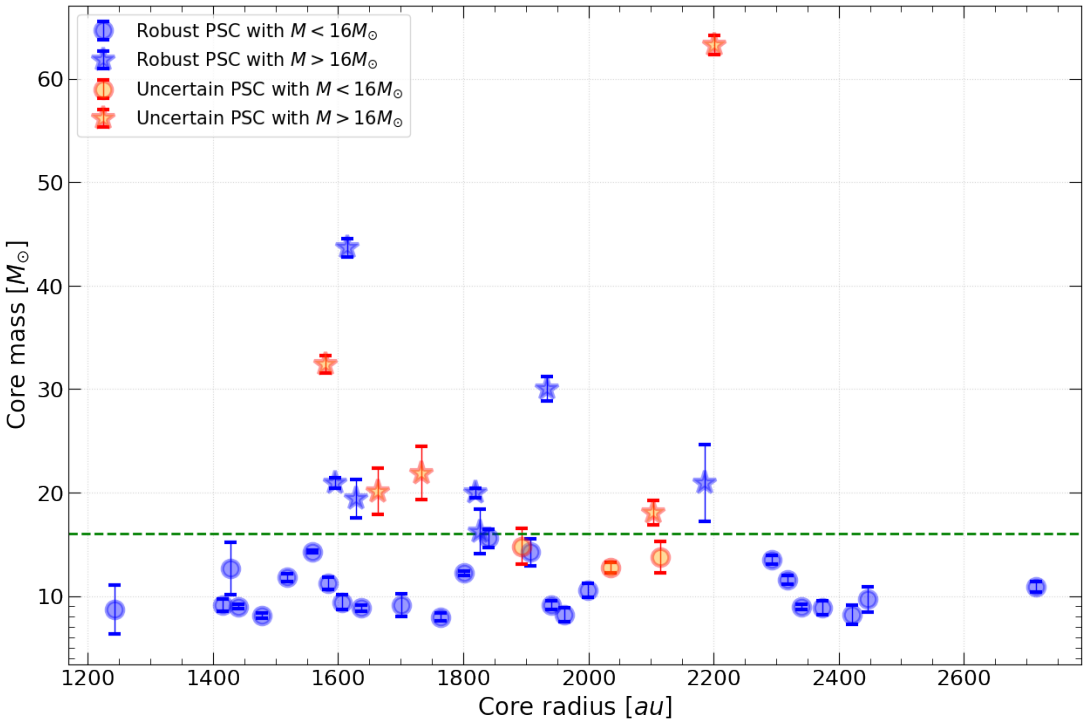

Fig. 3. Mass distribution versus core radius of the MPSC candidates.

4 Conclusions

Using this new automatic method of outflow detection, we detect 40 MPSC candidates in the ALMA-IMF massive protoclusters. This new sample will lead to new massive prestellar lifetime estimates and thus to a new vision of massive star formation.

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