Surveys of Clumps, Cores, and Condensations in Cygnus-X

Keping Qiu (NJU), Yue Cao (NJU), Yuwei Wang (NJU), Qizhou Zhang (CfA), Junhao Liu (NJU), Bo Hu (NJU)

Project Overview:

Cygnus-X is the most massive and active high-mass star-forming complex at a distance less than 3 kpc from the Sun (Motte et al. 2007, 2018). We are performing comprehensive surveys of Clumps, CorEs, and CoNdenSations in cygnUS-X (CENSUS, PI: K. Qiu), dedicated to a systemic study of the hierarchy of molecular cloud structures and high-mass star formation in the complex. **The SMA survey, which is the central part of the project, has been conducted in the 1.3 mm waveband with the Subcompact, Compact, and Extended configurations. So far we have completed most of the SMA observations with more than 200 hours of observing time.**

The scientific goals of this project are:

- to constrain the initial conditions of high-mass star formation by revealing how pc-sized massive molecular clumps form in giant molecular clouds, how they fragment to form ~0.1 pc massive dense cores (MDCs), and how MDCs further collapse and fragment into ~0.01 pc prestellar and protostellar condensations;
- to understand to what extent high-mass protostars acquire mass in a way similar to their low-mass counterparts through an unbiased survey of a large sample of outflows, rotational toroids and disks within a single molecular cloud complex.

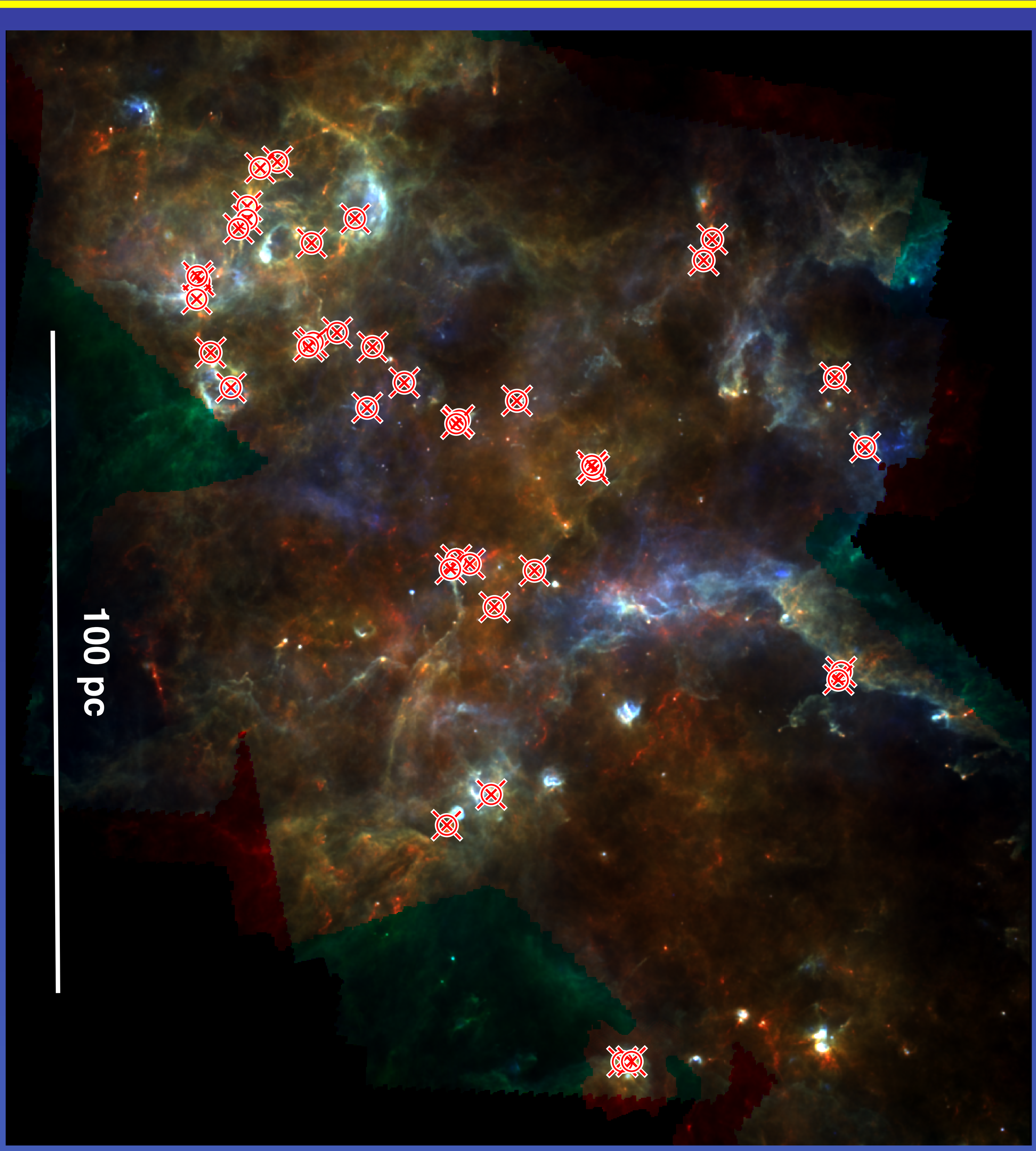
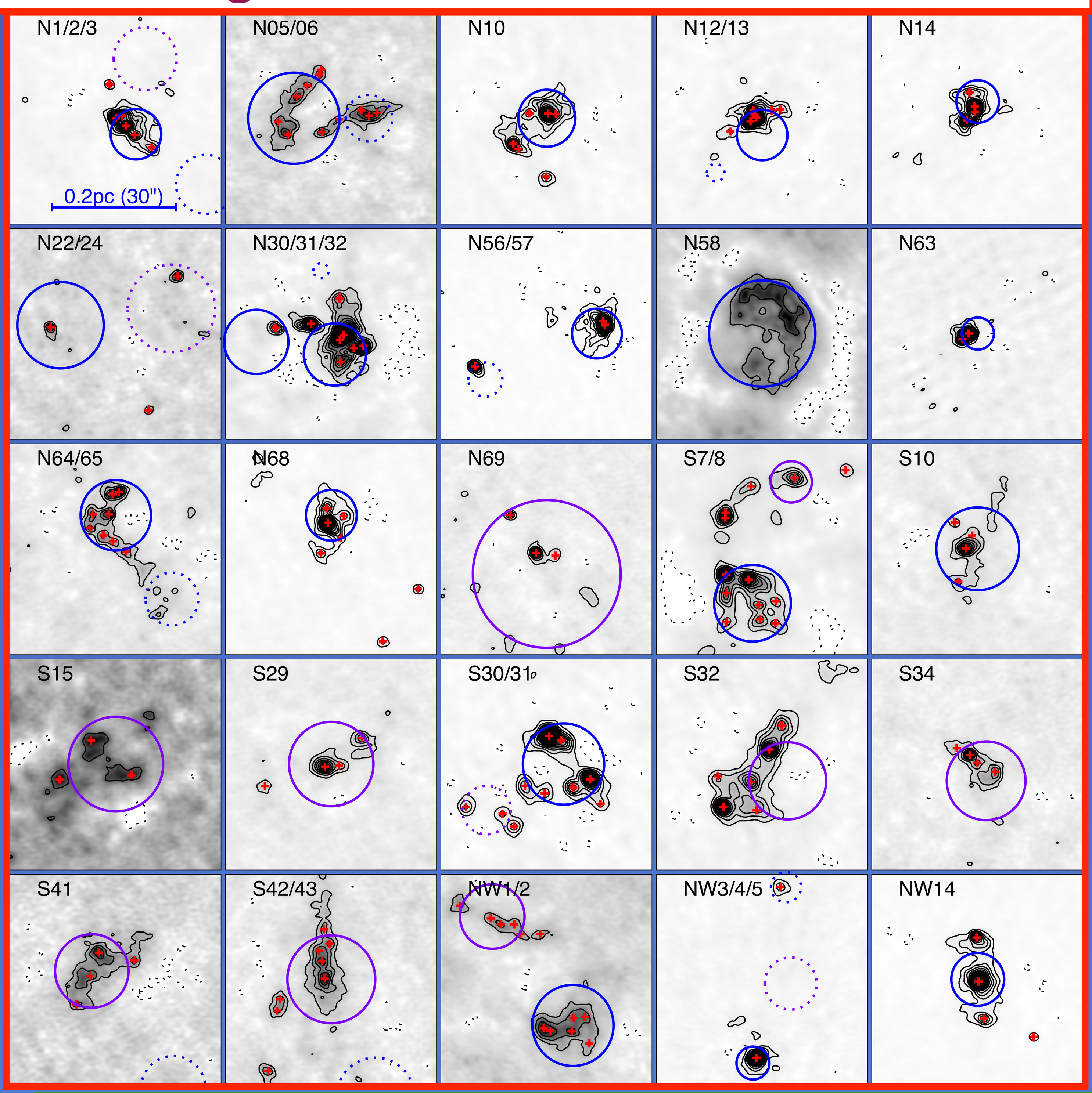
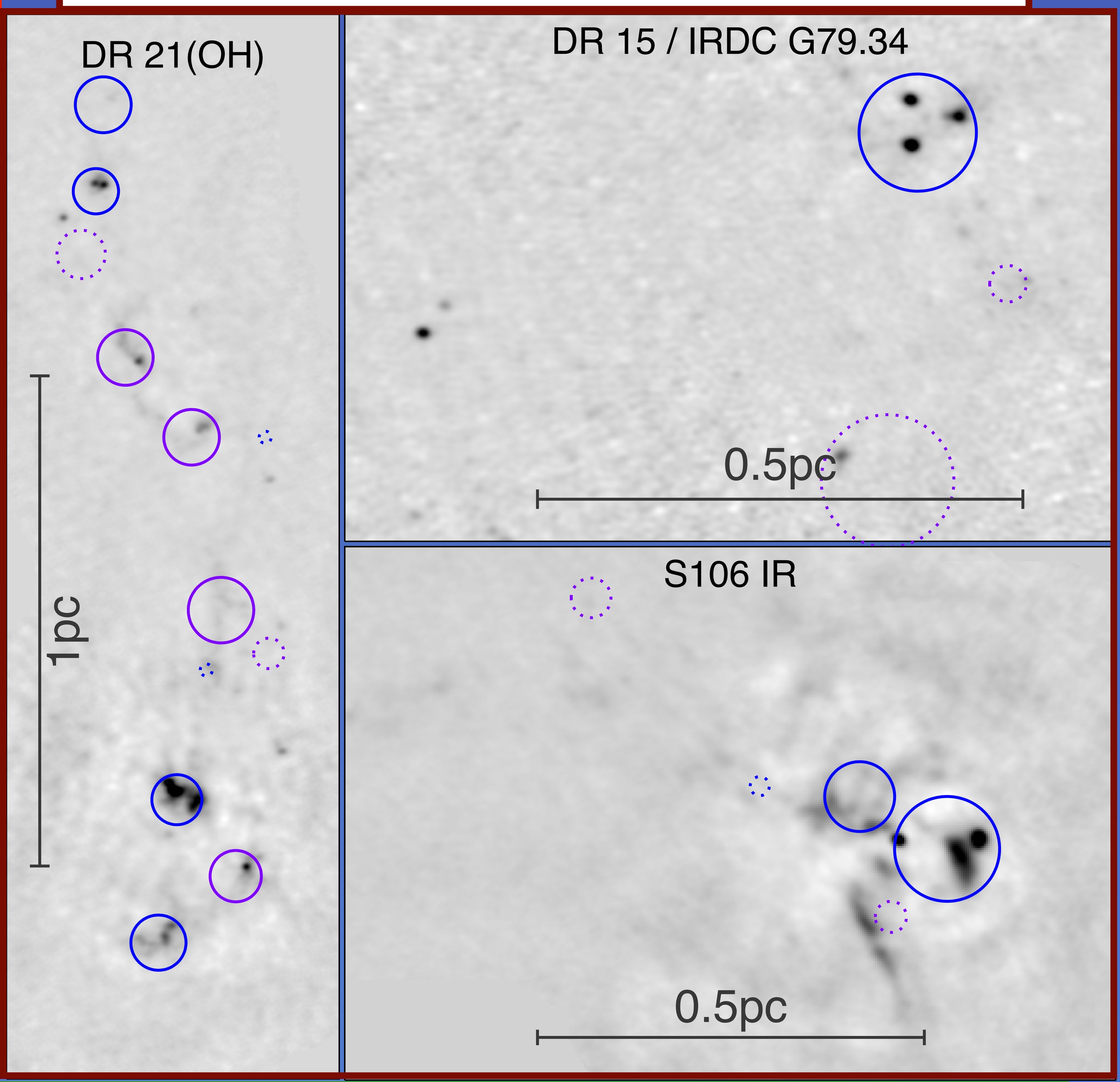


Figure 1 — Pseudo three-color image of the Cygnus-X complex, with the Herschel 500 µm, 160 µm, and 70 µm maps coded in red, green, and blue, respectively. By jointly analyzing the *Herschel*, JCMT, and IRAM 30m observations of the dust continuum emissions, we identify and characterize more than 40 MDCs with sizes of order 0.2 pc and masses of ~20 to 1000 $M_\odot$. These MDCs cover a broad range of evolutionary stages (Cao, Qiu, et al., submitted), and provide targets for our SMA survey. Red circles and crosses mark the 38 fields covered by our SMA survey.

SMA single-field observations of MDCs



SMA mosaic observations of MDCs



SMA single-field observations of MDCs around the Cygus-X OB2 association

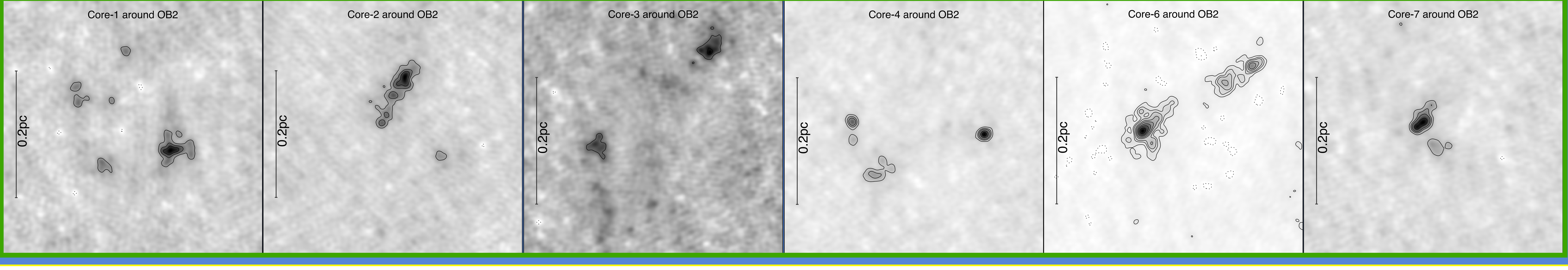


Figure 2 — SMA 1.3 mm continuum observations of the MDCs in Cygnus-X. The data reveal the fragments of the MDCs with a linear resolution of ~0.01 pc. ***Upper Left***: SMA single-field observations of the MDCs. We follow Motte et al. (2007) for the nomenclature of the MDCs. ***Upper Right***: SMA mosaic observations of the MDCs embedded within remarkable pc-sized clumps. Solid circles approximately show the sizes and locations of the MDCs. Dashed circles depict dense cores with masses less than 20 $M_\odot$. ***Lower***: SMA observations of the MDCs newly identified around the Cygnus-X OB2 association. A detailed analysis of the fragmentation of the MDCs based on the continuum maps is ongoing. We find that most MDCs fragment into a few to more than 10 condensations, but there are also a very few MDCs remaining singly peaked down to a size scale of 0.01 pc. Moreover, statistically, the fragmentation level dose not appear to correlate with properties of the MDCs (Qiu et al., in prep.).

Remarks:

We are completing an SMA survey of the Cygnus-X complex, and the ongoing analysis provides these preliminary results:

- **We detect ~0.01 pc fragments toward more than 90% of the MDCs, and find that the fragmentation of the MDCs cannot be understood as thermal Jeans or turbulent fragmentation.**
- **We detect high-velocity outflows in the SMA+JCMT CO maps in more than 90% of the MDCs; though most outflows are bipolar and/or collimated, only a few of them are associated with rotational structures seen in typical "disk-tracing" spectral lines, suggesting that (pseudo)disks around high-mass protostars are mostly smaller than 1000 AU.**
- **We find that expanding HII regions, strong UV radiation, and stellar winds are very inefficient in triggering nearby high-mass star formation.**