High-resolution survey of massive cores in Cygnus-X

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a collaboration between CfA and NJU
Outline

• **Background** and Cygnus-X

• The **SMA** survey, and **JVLA, JCMT, ALMA, CARMA**

• Preliminary results

• **Summary** and **outlook**
Why high resolution?

Big Questions in high-mass star formation:

**initial conditions?**
**earliest stages?**

\[ \geq 10^4 M_\odot \text{ clouds } \rightarrow 10^3 M_\odot \text{ clumps} \]

\[ 10s - 100pc \rightarrow \sim 1 - 10pc \]

\[ \sim 0.1pc \text{ (10" for } D \sim 2kpc) \]

massive \( 10^2 M_\odot \) cores ?

Jeans-mass or super Jeans-mass \( \sim 1 - 10 M_\odot \) seeds ?

\(~0.01pc \text{ and smaller}\)

massive stars

**collapse/fragment governed by G/T/B/R?**

**further mass grow process?**

- How to break great barriers (radiation, ionization)?

**disks accretion (collimated jets and outflows)?**

**competitive accretion / merging?**
Why Cygnus X?

One of the richest molecular cloud and HII region complexes located at a distance <2kpc (~1.4 kpc, Rygl+2012);

The molecular cloud complex: mass ~ $10^6 \, M\odot$; size ~ 100 pc;

Already Mapped by various IR to mm telescopes (e.g., Spitzer, Herschel, JCMT, IRAM 30m).
Why Cygnus X?

MAMBO 1.2mm survey: discovered 129 cores (~0.1pc); 42 massive (>30 M☉)
(Motte+ 2007; also see followups by Schneider+ 2010; Bontemps+ 2010; Csengeri+ 2010; 2011; Duarte-Cabral+ 2013, 2014)

2MASS extinction map (Motte+ 2007)
The SMA survey of massive CygX cores

A collaboration between Nanjing University and Harvard-Smithsonian Center for Astrophysics (PI: K. Qiu)

1.3 mm, 2 × 6 GHz, continuum and various molecular spectral lines (e.g., CO, $^{13}$CO, C$^{18}$O, SiO, H$_2$CO, SO, CH$_3$OH, CH$_3$CN, ...);

Subcompact + Compact + Extended + Very Extended

Angular resolution $\sim$1", or $\sim$1500 AU, “core” thermal Jeans length $\sim$ 10,000 AU

Continuum sensitivity $\leq$1mJy, or <0.1 M$,^\odot$, “core” thermal Jeans mass $\sim$ 0.5 M$,^\odot$
Complementary survey and observations

JVLA
radio continuum, NH$_3$

JCMT
CO(2-1), dust continuum

ALMA (selected sources)

CARMA (selected sources)
The SMA survey of massive CygX cores

Herschel 250µm

SCUBA2 850µm (credit to M. Thompson)

Cyg OB2

100 pc

W75N  DR21(OH)  IRDC G79.43  AFGL2591
Preliminary results - [dust] continuum
source finding: dendrogram

Compared with other programs (e.g., SExtractor, Clumpfind), dendrogram works well in a hierarchical system, such as a fragmented core, and is better for sources with different structures (point-like, extended).

![Graph showing flux vs position with labels: leaf ➟ branch ➟ trunk]
statistical analysis: MST? NNS?
Preliminary results - CO outflows
CO outflows: SMA + JCMT
Summary

- **40+ massive cores** (how many to from massive stars?) & 10+ lower mass cores
- **fragmentation** seen in almost all the cores; ~1/2 cores have fragments nearly linearly distributed
  a characteristic length \( L_{\text{Jeans}} \) between fragments?
- **singly peaked** (down to 0.01pc) sources, though very rare, also seen (why, fragmentation suppressed? how?)
- **starless sources** also fragment (why no SF, not yet or would never happen?)
- **bipolar outflows** seen toward most sources
followup analysis and future plan

core fragmentation

kinematics

chemistry & evolutionary sequence

future plan

**SMA:** VEX & 345GHz for the whole sample, selected sources for mosaics, polarization for bright sources

**ALMA/NOEMA:** sub-sample or selected sources for particular interests