Submillimeter Array Observations of Molecular Outflows in Massive Star Forming Regions

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It has been years since we know that molecular outflows commonly exist in high-mass star forming regions (*Shepherd & Churchwell 1996; Zhang et al. 2001; Beuther et al. 2002*). They provide a statistical, maybe most compelling, argument in favor of accretion based scenario for massive star formation.

However, more detailed knowledge of massive molecular outflows are limited by poor statistics of high angular resolution studies, in particular for those in $\geqslant 10^5$ $L_\odot$ star foming regions.

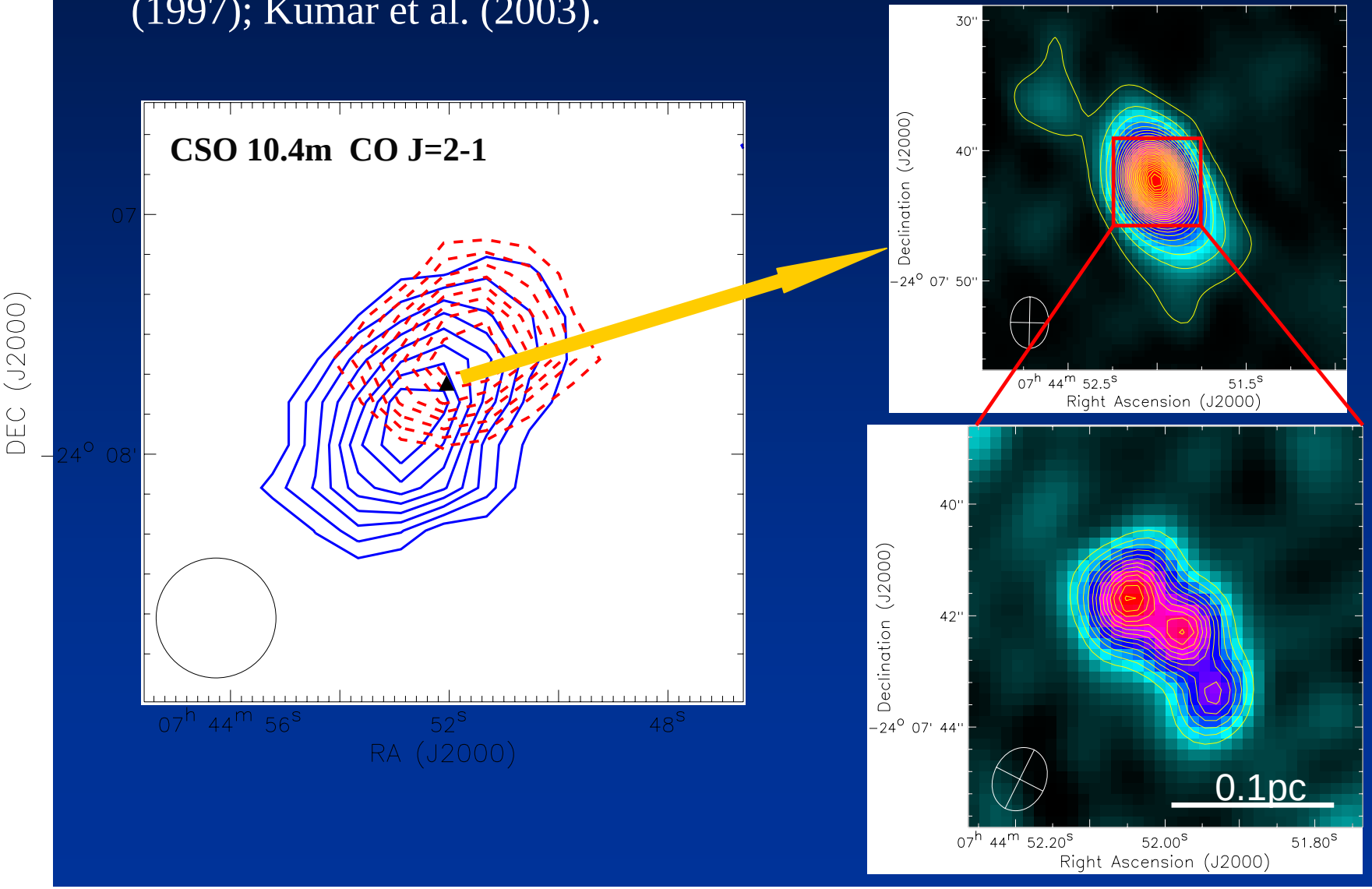
Is there any systematic difference in morphology and kinematics from low-mass outflows?
How do they correlate with the central driving source?
How are they driven?

With the SMA, we are undertaking a systematic, high angular resolution study of molecular outflows in star forming regions of 10^4 to 10^6 $L_\odot$.

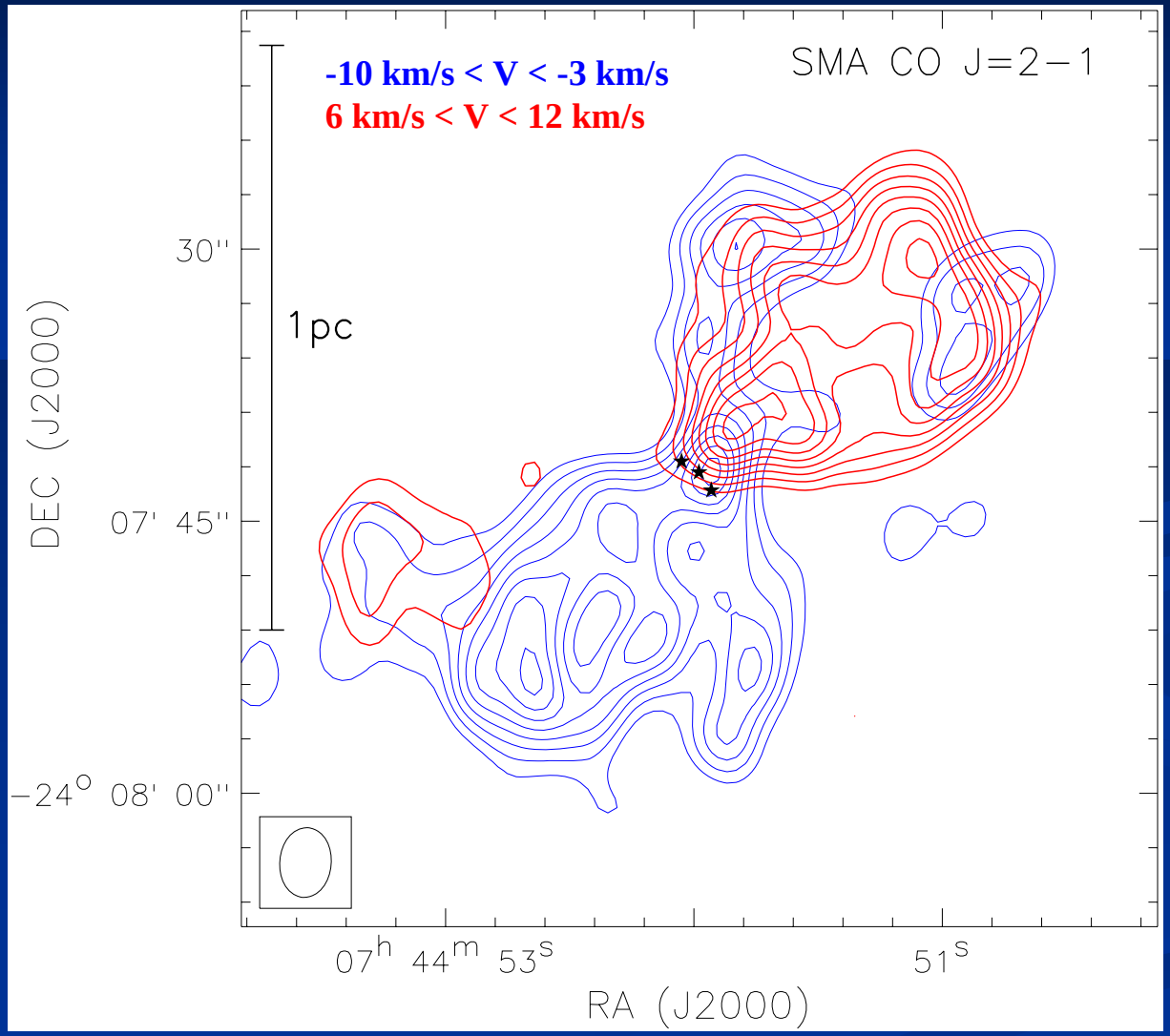
- G240.31+0.07 (5×10^4 $L_\odot$);
- NGC7538–IRS1 (10^5 $L_\odot$);
- HH 80/81 (2×10^4 $L_\odot$).

G240.31+0.07

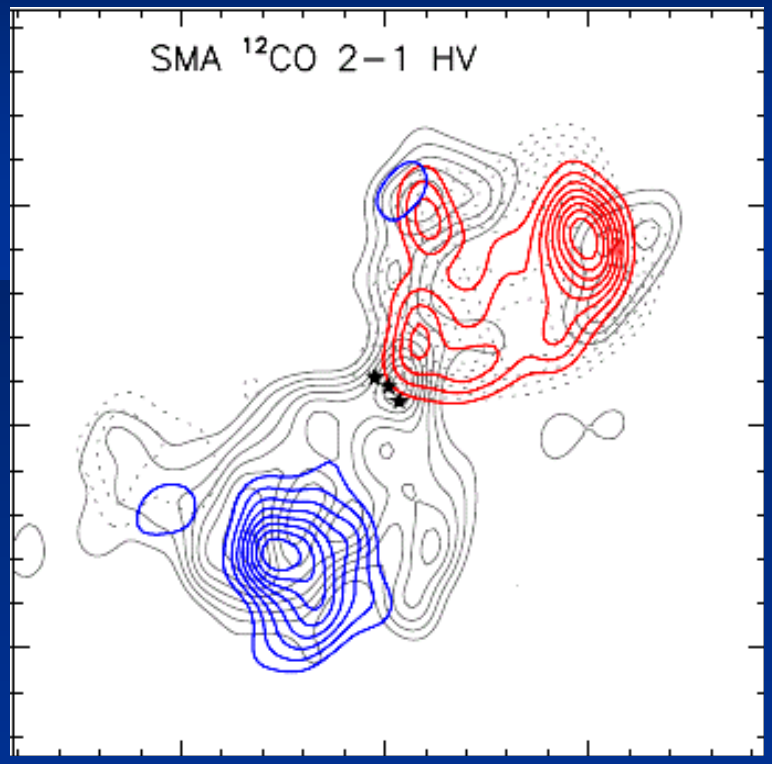
A $5 \times 10^4 L_\odot$ star forming region associated with an UC HII region.
Single-dish bipolar outflow — Shepherd & Churchwell (1996); Hunter (1997); Kumar et al. (2003).

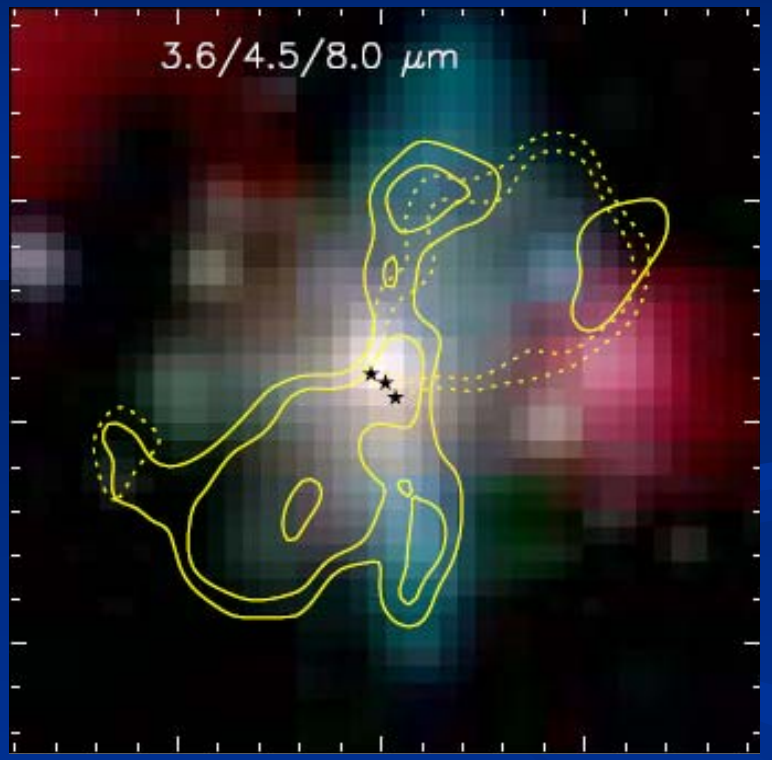


G240.31+0.07


-10 km/s < V < -3 km/s
6 km/s < V < 12 km/s
SMA CO J=2−1
30''
07' 45''
−24° 08' 00''
DEC (J2000)
1pc
07h 44m 53s
51s
RA (J2000)

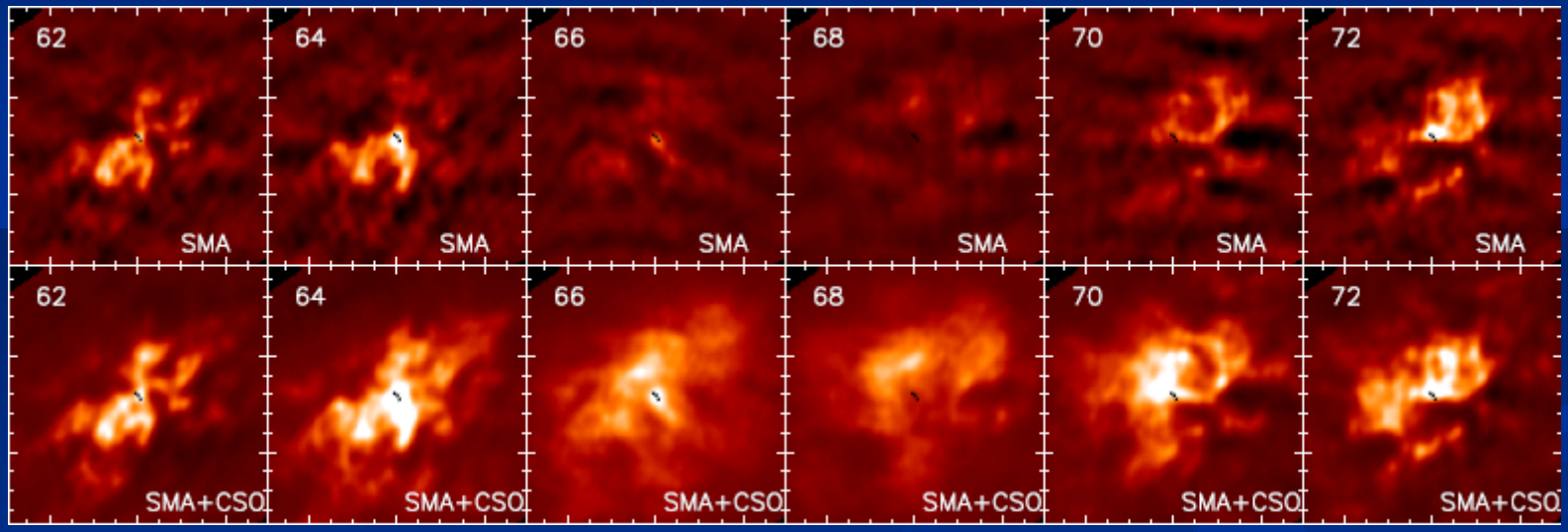
G240.31+0.07





G240.31+0.07

SMA + CSO



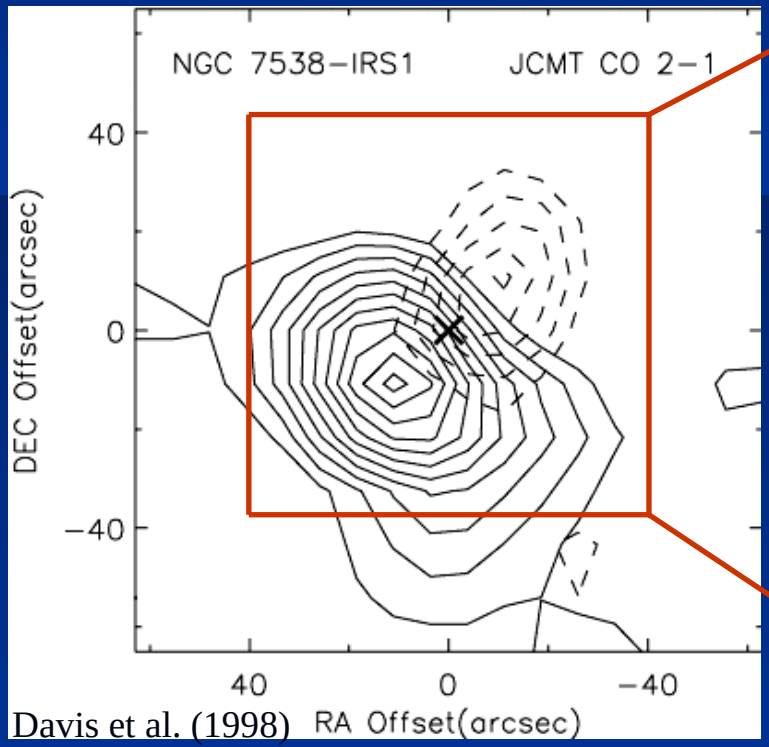
$M_{\rm out} \sim 91\ {\rm M}_\odot$!

$t_{\rm dvn} \sim 2.4 \times 10^4$ yr

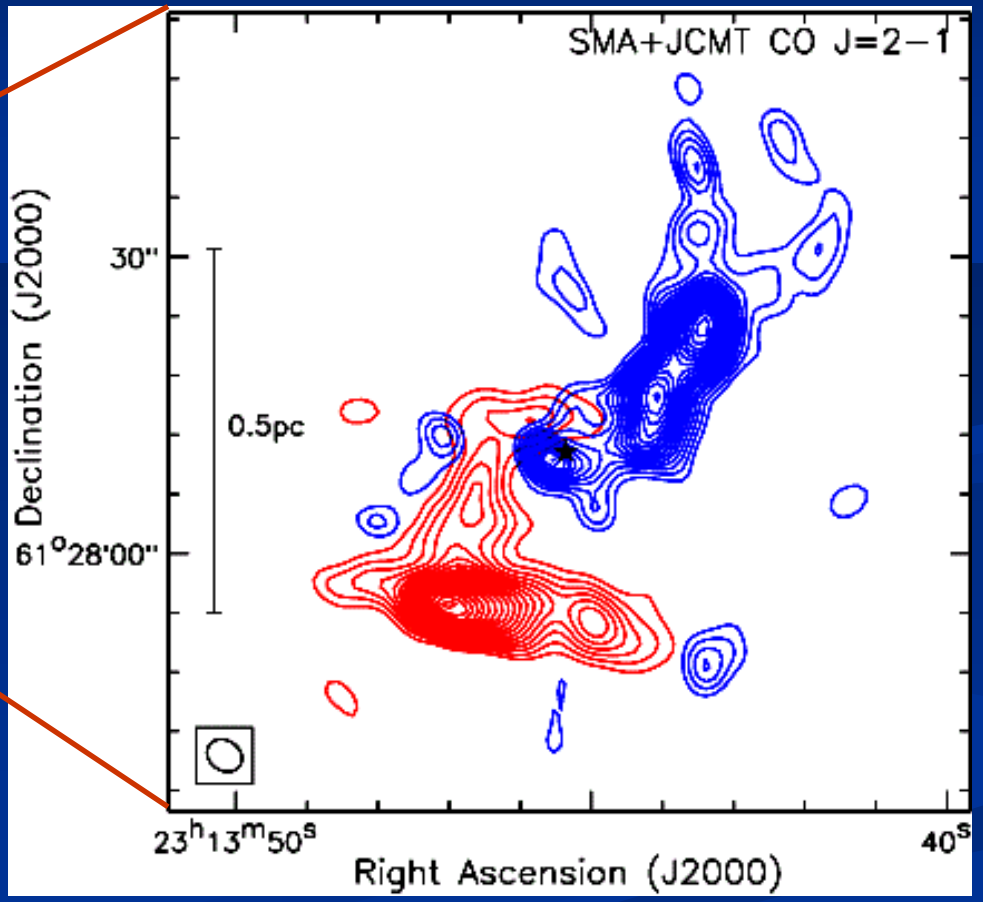
$\dot{M}_{out} \sim 3.8 \times 10^{-3}\ {\rm M}_\odot/{\rm yr}$

NGC 7538 – IRS1

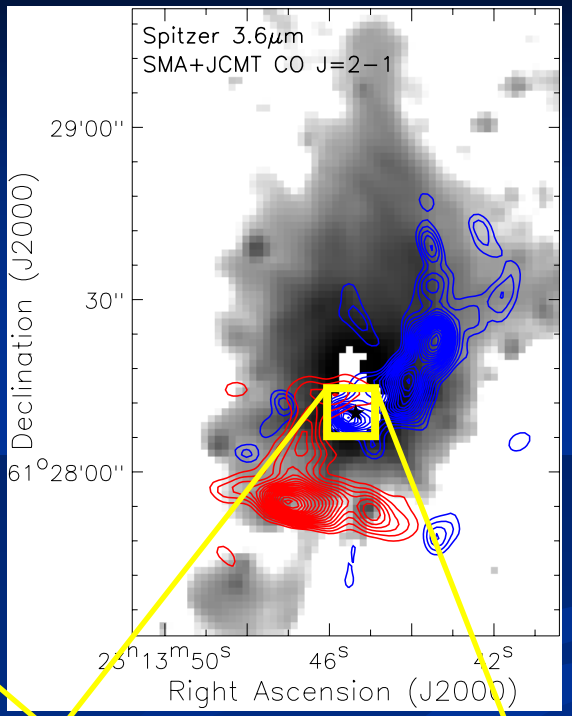
A bipolar, expanding UC HII region, with ~10^5 $L_\odot$.
Single-dish bipolar outflow — Davis et al. (1998)

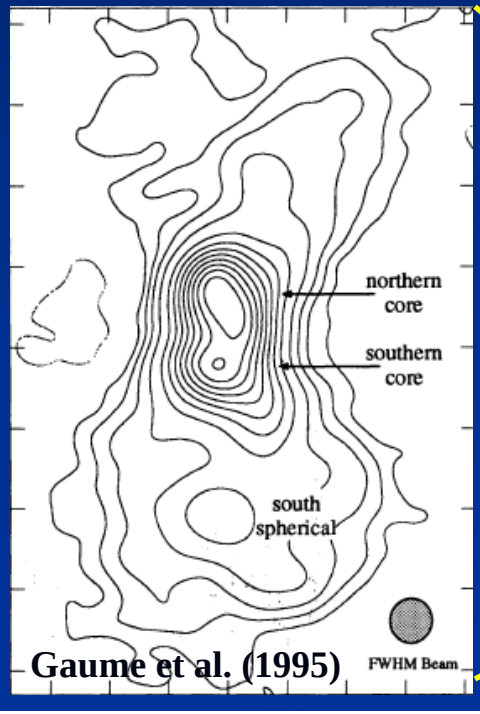


Davis et al. (1998)

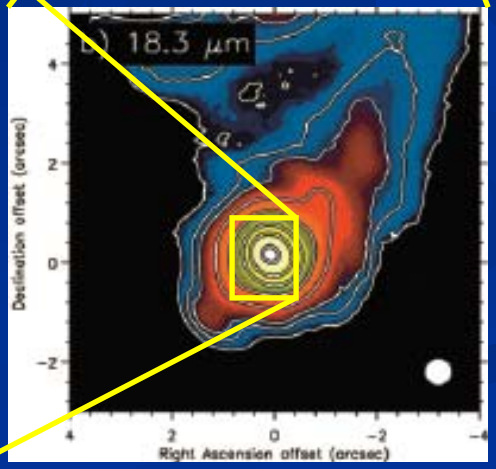


NGC 7538 – IRS1



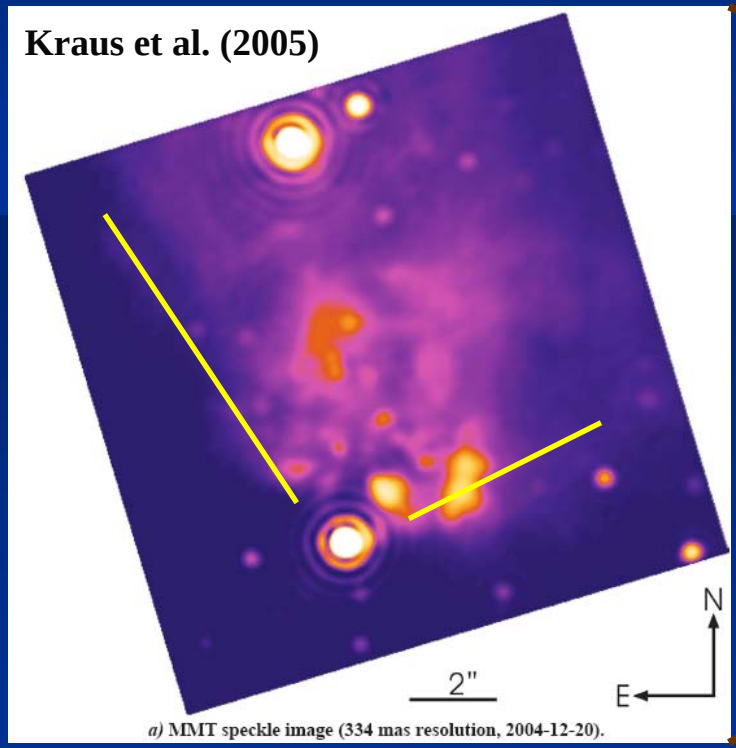


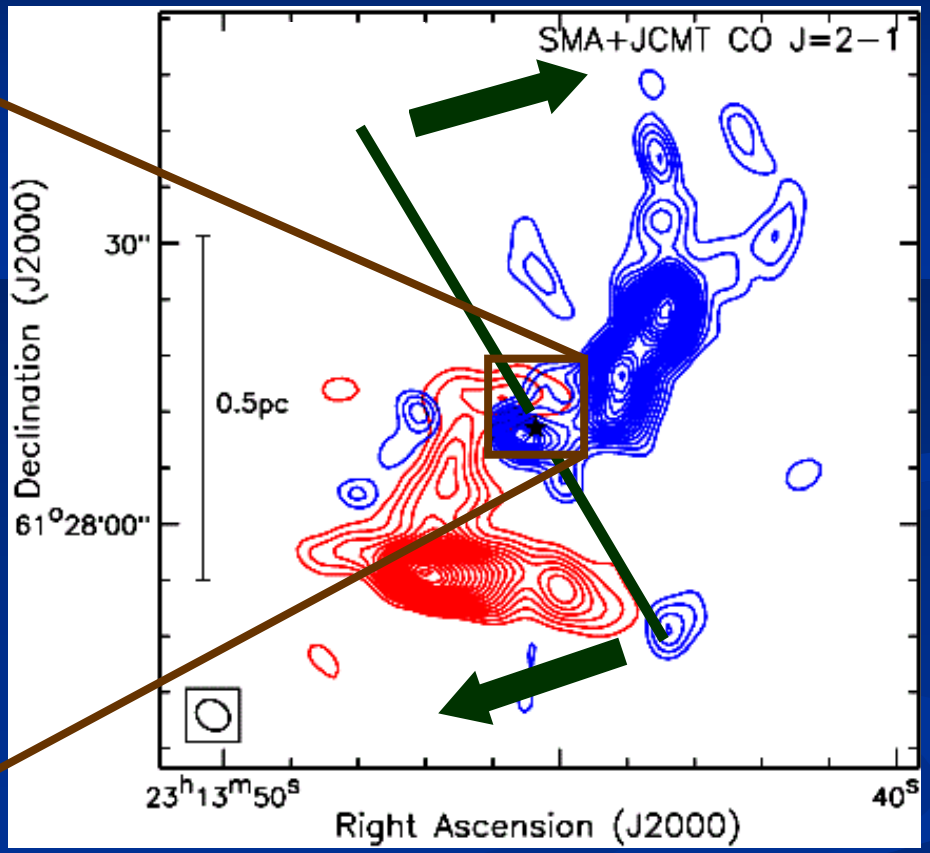
Gaume et al. (1995)



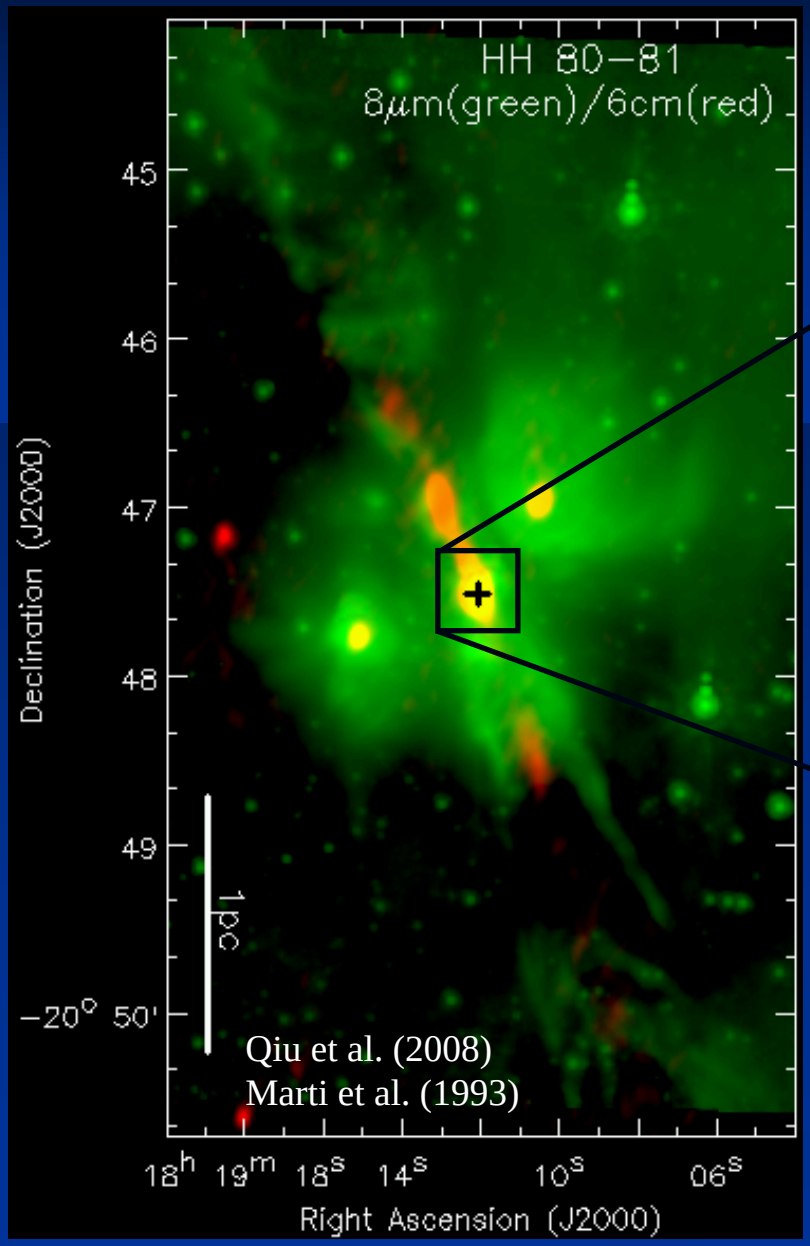
De Buizer & Minier 2005

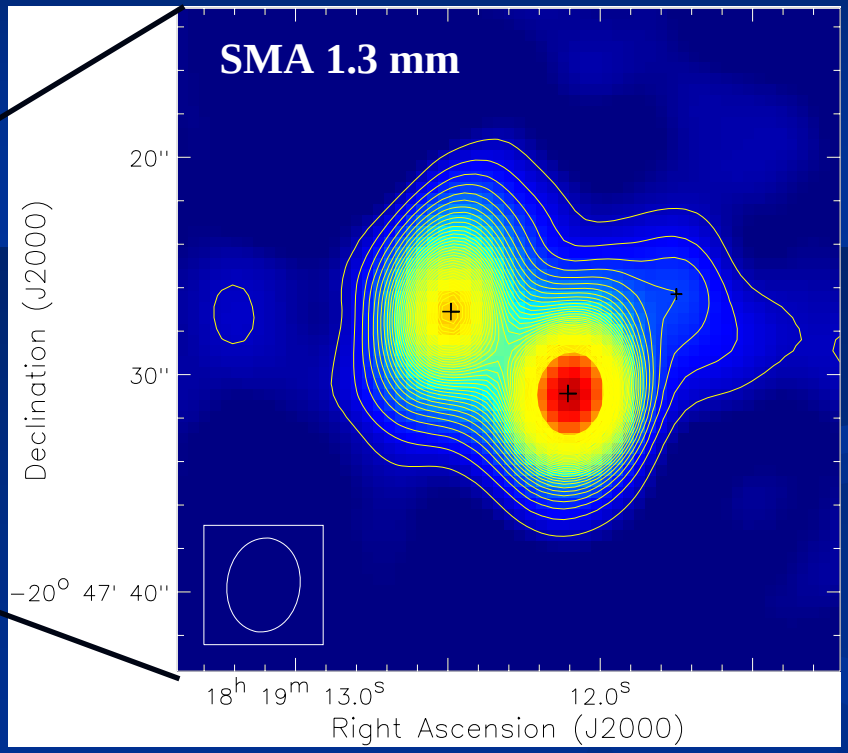
NGC 7538 – IRS1



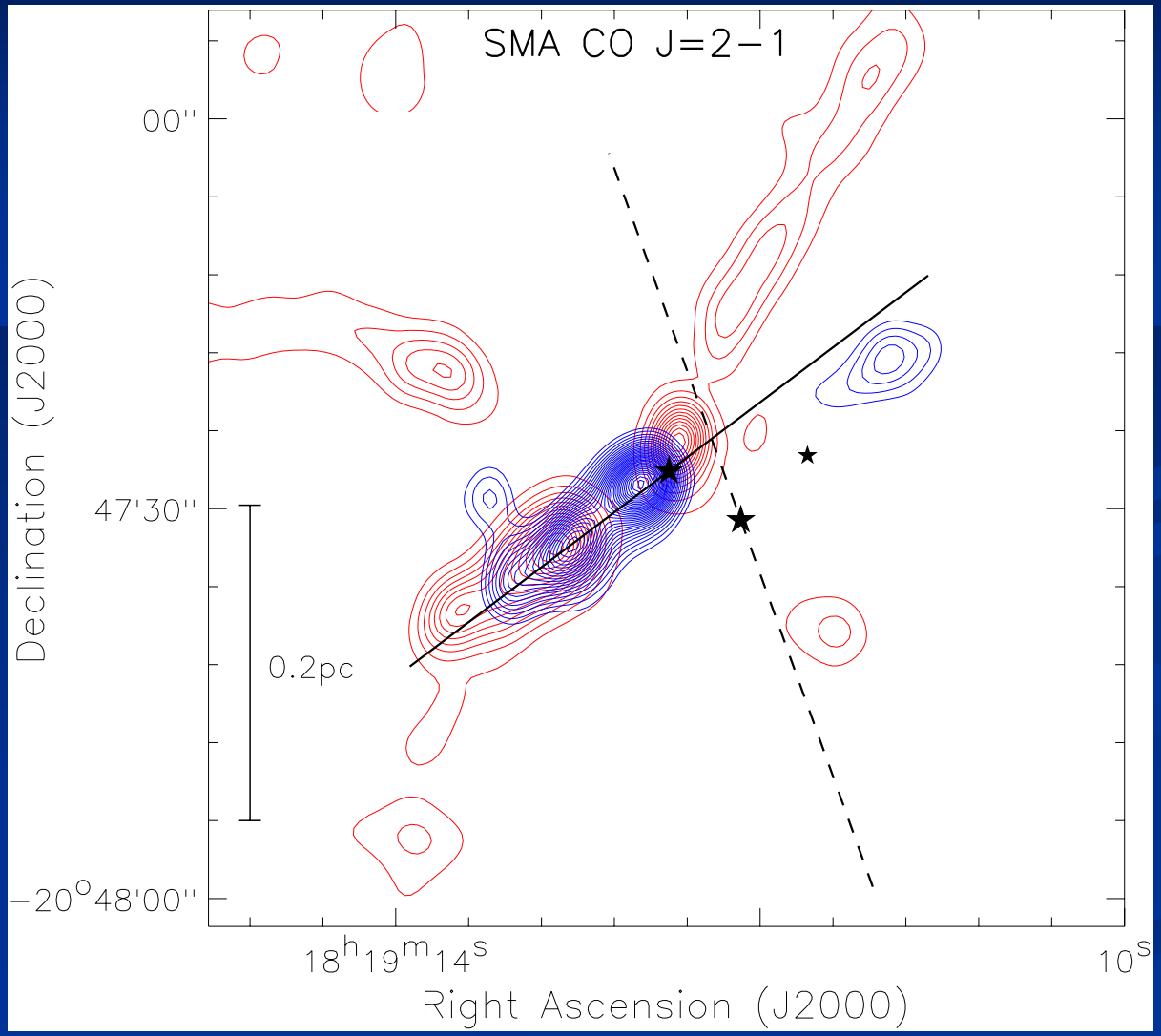


HH 80/81


HH 80−81
8μm(green)/6cm(red)
45
46
47
48
49
Declination (J2000)
1pc
−20° 50'
18h 19m 18s 14s 10s 06s
Right Ascension (J2000)
Qiu et al. (2008)
Marti et al. (1993)


SMA 1.3 mm
20"
30"
Declination (J2000)
−20° 47' 40"
18h 19m 13.0s 12.0s
Right Ascension (J2000)

HH 80/81


SMA CO J=2−1
00''
47'30''
−20°48'00''
Declination (J2000)
0.2pc
18h19m14s
10s
Right Ascension (J2000)

Remarks:

We do see collimated jet-like and wide-angle parabolic outflows, although still few, in high-mass star-forming regions; according to the standard paradigm of low-mass star formation, they all point to disk mediated accretion.

Morphologically these outflows seem to have a common driving mechanism as low-mass outflows, but about two orders of magnitude higher mass outflow rate, and the intense UV radiation, may be challenges.

With the ALMA … (Shepherd 2008)
Combining observations from the 12m array, 7m compact array, and the total power dishes, making high-fidelity images.