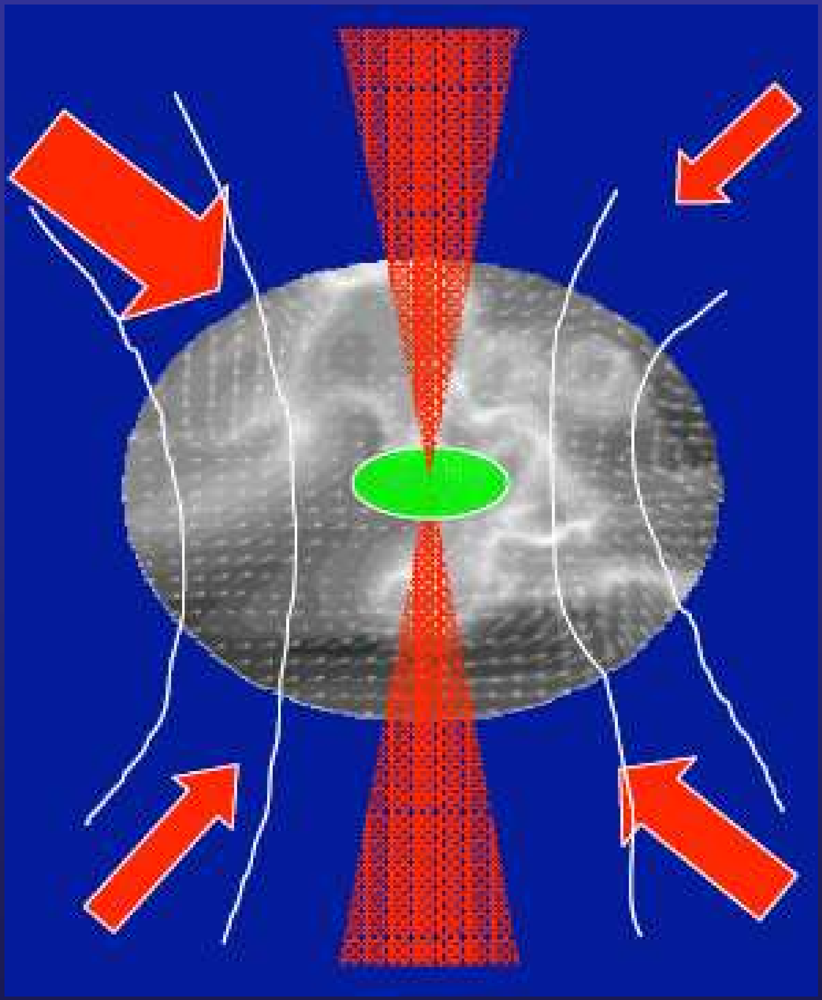


High-Resolution Imaging of Massive Outflows

Keping Qiu

Harvard-Smithsonian CfA

In low-mass star formation, molecular outflows are believed to be intrinsically coupled with disk-mediated accretion processes (Shu et al. 2000; Konigl & Pudritz 2000; Arce & Sargent 2006; Shang et al. 2007).

Recent single-disk surveys (Shepherd & Churchwell 1996; Zhang et al. 2001; Beuther et al. 2002) and high-angular-resolution followups (reviews of Shepherd 2005; Arce et al. 2007) found that molecular outflows are ubiquitous in high-mass star forming regions. However, the morphologies (especially collimation), kinematics and correlation with the central driving source are highly debated.

To achieve a comprehensive understanding of massive outflows and their impacts to high-mass star formation, multi-waveband high resolution observations over a large sample is needed.

We present mm interferometer and Spitzer/IRAC observations of:

- Highly collimated jet-like outflows:

  IRAS 05358+3543; IRAS 18507+0121; IRAS 18264-1152

- Bow-shaped outflows:

  W75 N

- Conical-shaped outflows with a moderate opening angle:

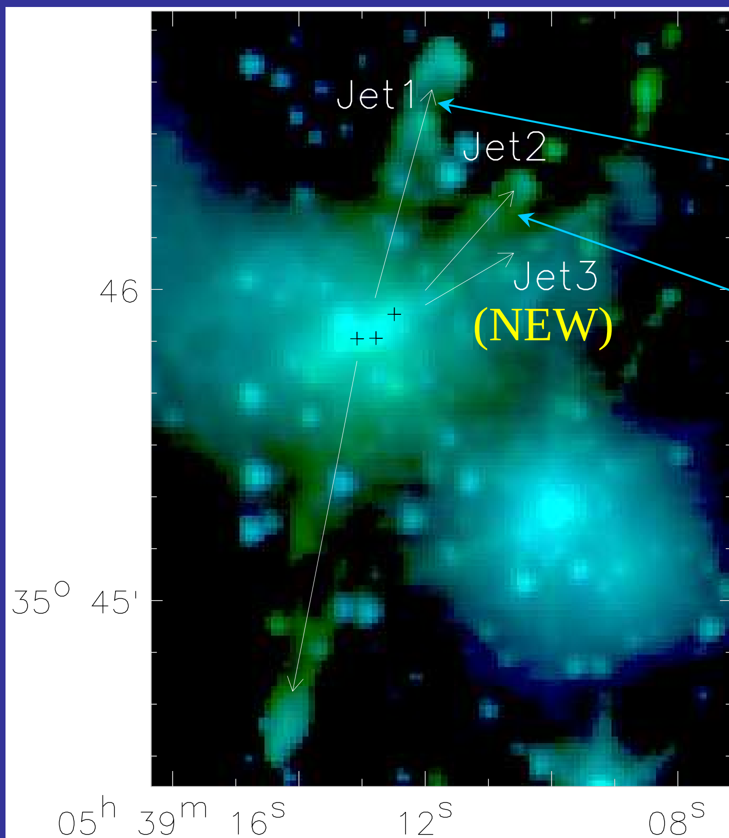
  IRAS 20126+4104; IRAS 18360-0537

- Conical-shaped outflows with a wide opening-angle:

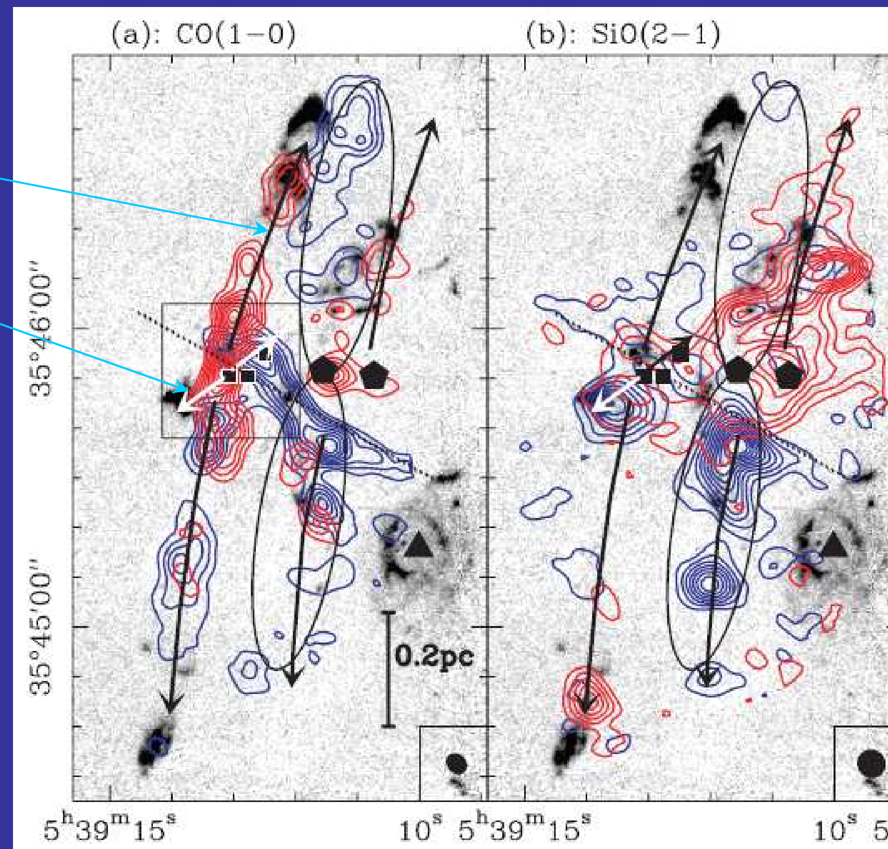
  G192.16-3.82; IRAS 23151+5912

Jet-like Morphology

IRAS 05358+3543 (L_{FIR}~$10^{3.8}L_{\odot}$, 1.8kpc)



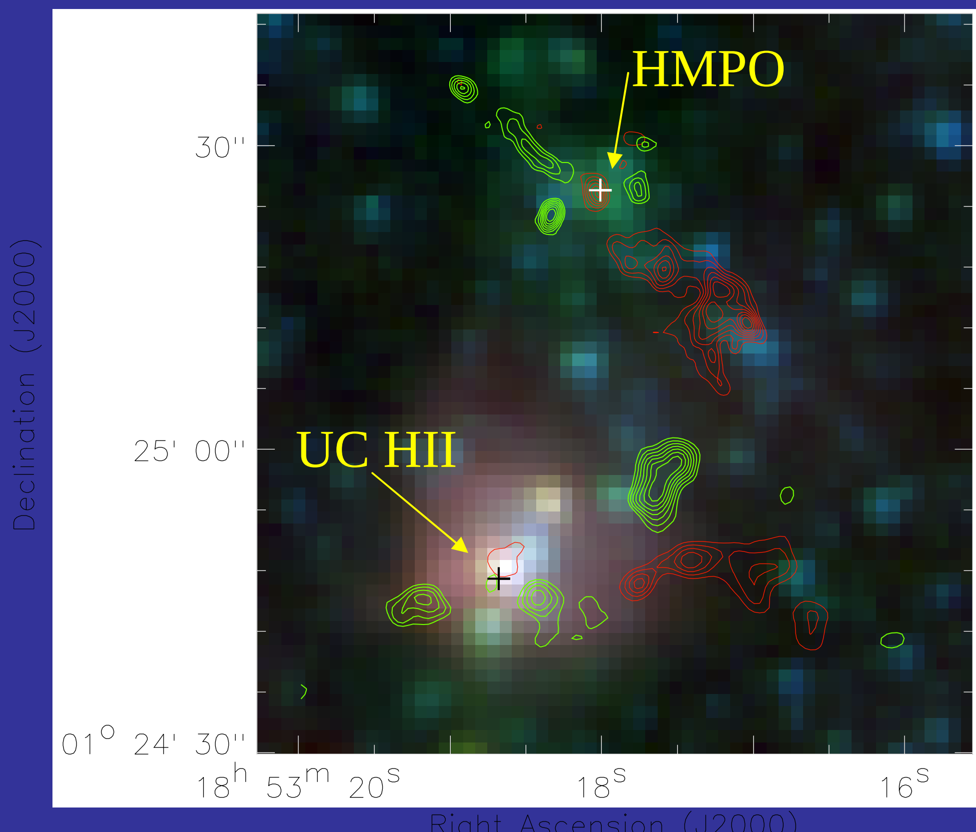
IRAC 3.6/4.5 μm (B/G) 2-color composite image.



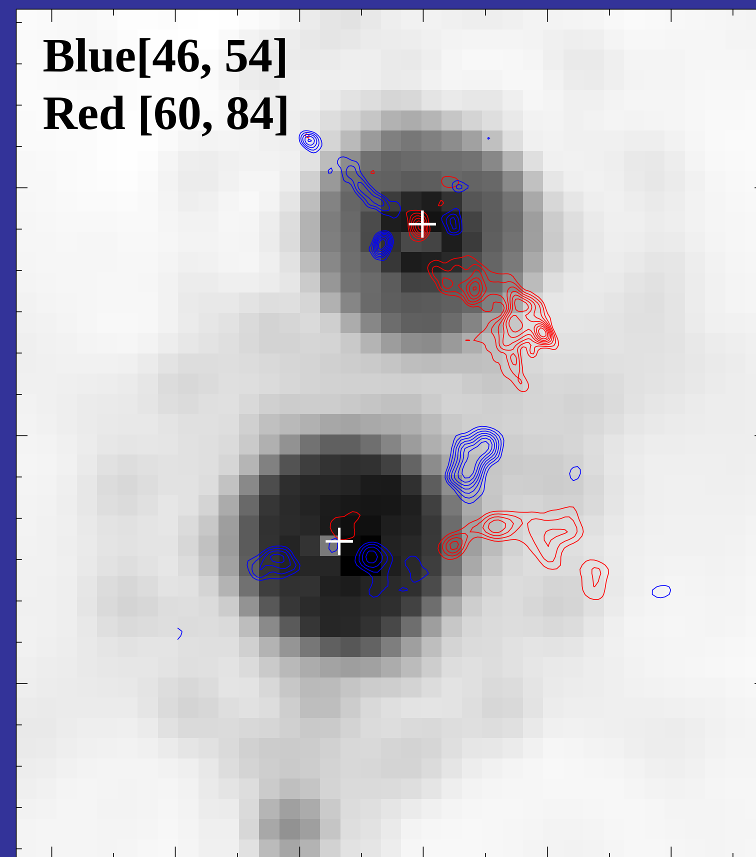
Grayscale: H_2 at 2.12 μm
Contours: PdBI CO and SiO outflows
Beuther et al. (2002)

Jet-like Morphology

IRAS 18507+0121 (L_{SED}~$10^{4.5}L_{\odot}$,3.9kpc)



GLIMPSE/IRAC 3.6/4.5/8.0 µm (B/G/R) 3-color composite image + VLA SiO 1-0 outflows

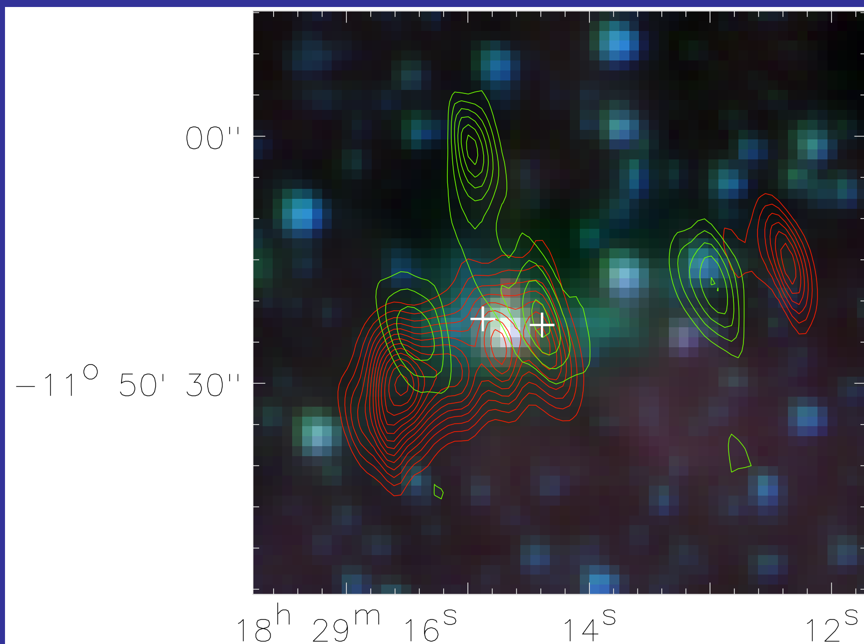


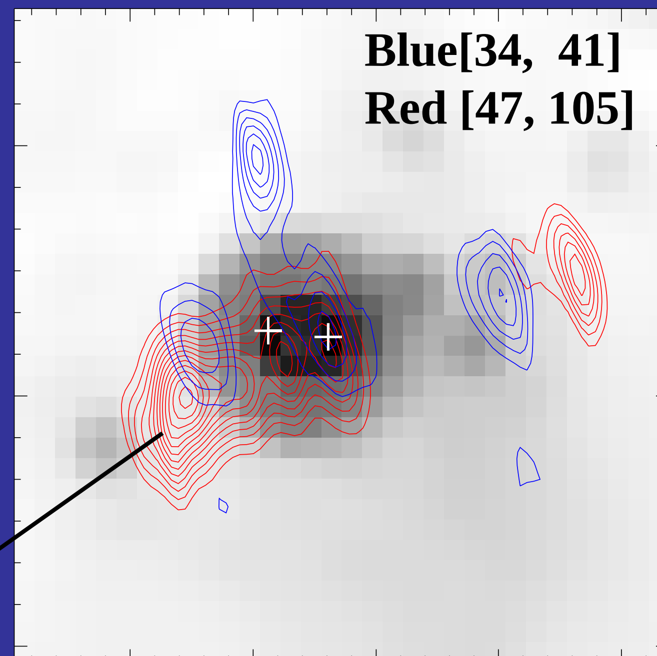
MIPSGAL 24 µm image + VLA SiO 1-0 outflows

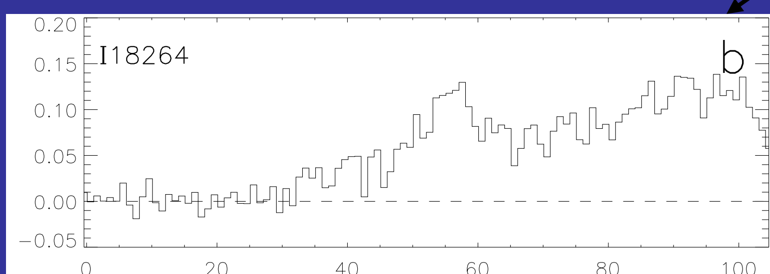
Jet-like Morphology

IRAS 18264-1152 (L_{FIR}~10^4, 3.5kpc)

GLIMPSE 3.6/4.5/8.0 μm + PdBI SiO 2-1 (Qiu et al. 2007)







MIPSGAL 24 μm + PdBI SiO 2-1

"Hubble-law" like feature detected in the PV

$|\Delta V|_{max}$ ~ 60 kms^{-1}

Bow-Shock Structures

W75 N (L_{FIR}~$10^{5.1}L_{\odot}$(cluster), 2kpc)

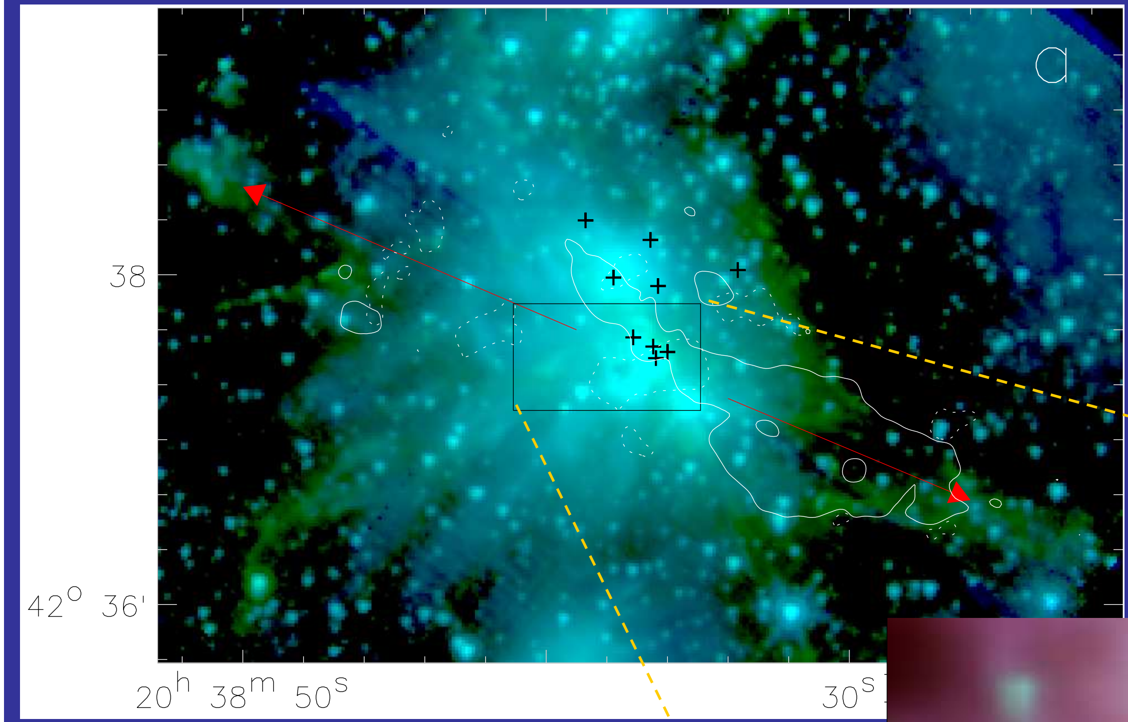
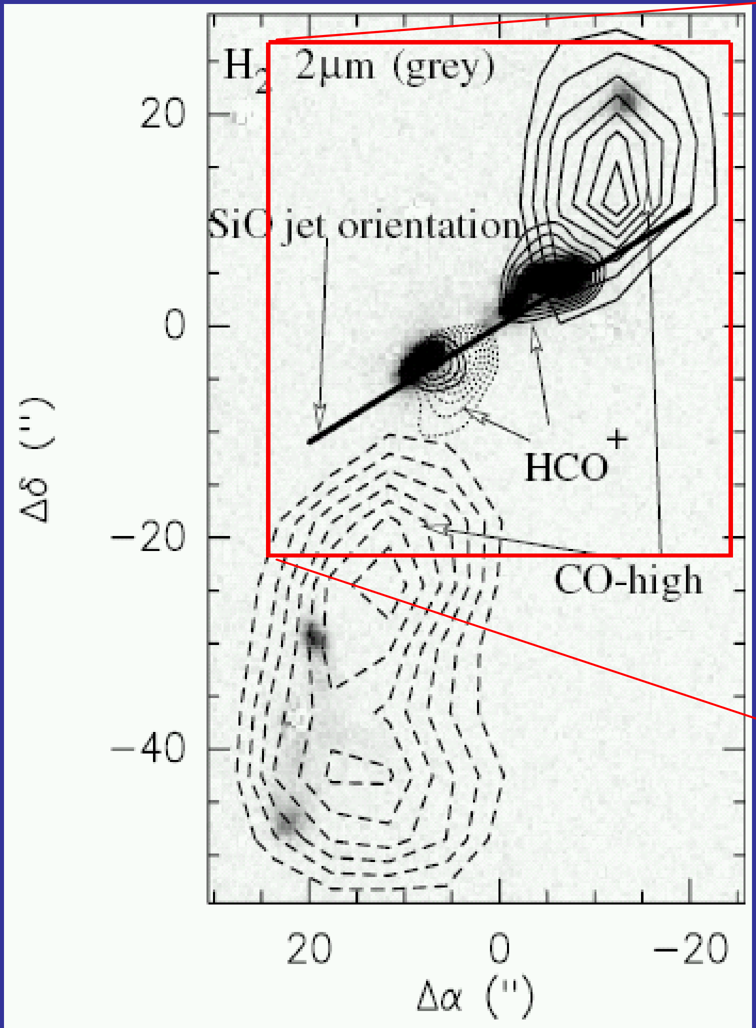


Image: IRAC 3.6/4.5 μm (B/G) 2-color composite image

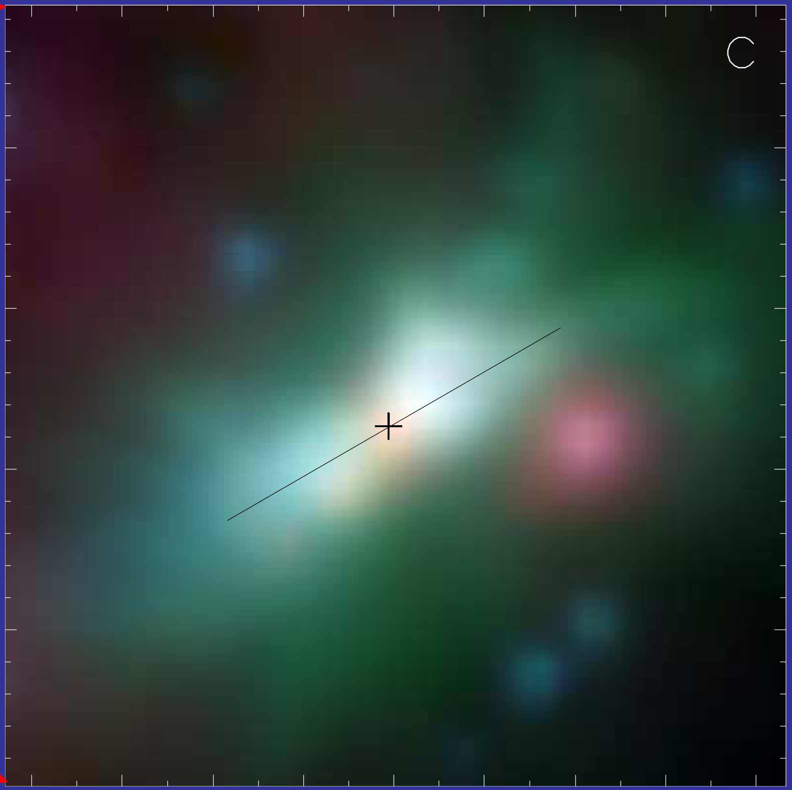
Contours: the lowest contour of CO outflow from Shepherd et al. (2003).

Conical-Shaped, moderate opening angle

IRAS 20126+4104 (L_{FIR}~$10^4 L_{\odot}$,1.7kpc)



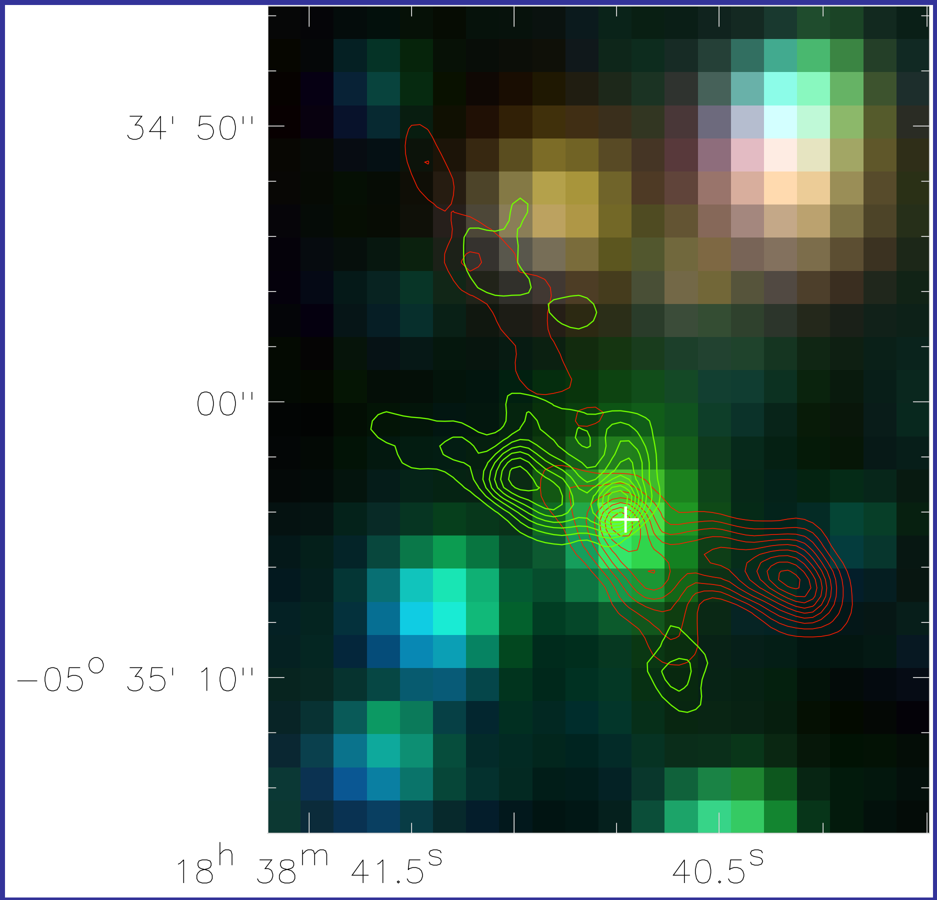
Lebron et al. 2006



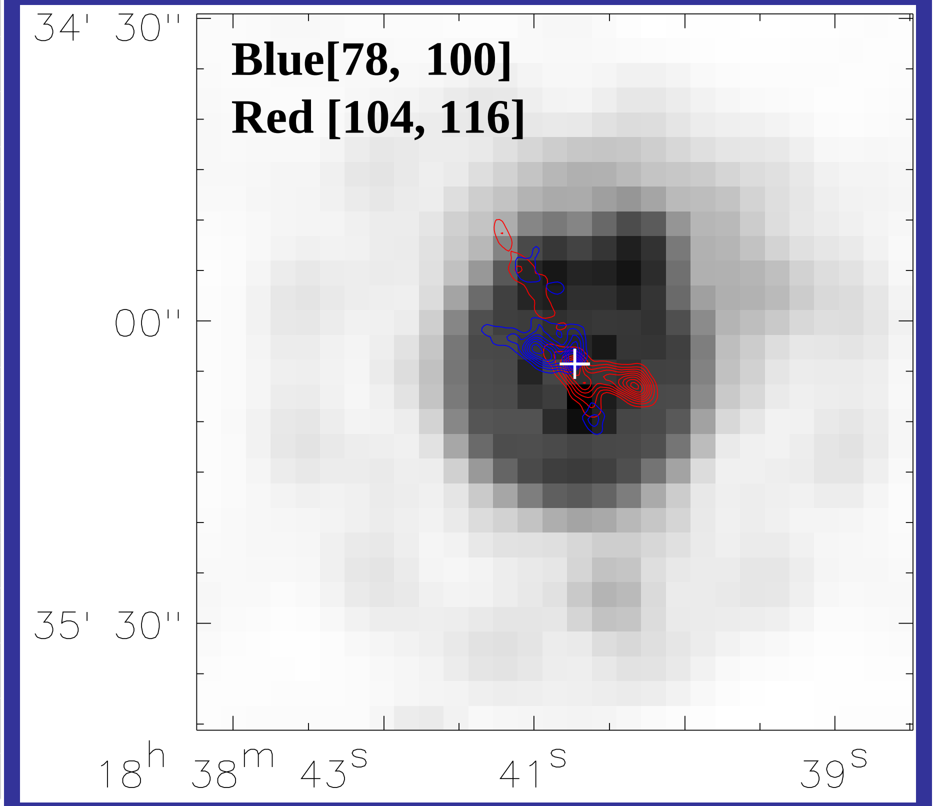
IRAC 3.6/4.5/8.0 μm: outflow in scattered light with an opening angle of ~30º, with limb-brightening.

Conical Shaped, moderate opening angle

IRAS 18360-0537 (L_{FIR}~$10^{5.1}L_{\odot}$, 6.3kpc)



GLIMPSE 3.6/4.5/8.0 µm + VLA SiO 1-0 bipolar outflow



MIPSGAL 24 µm + VLA SiO 1-0

Conical Shaped, wide opening angle

G192.16-3.82 (L_{FIR}~$10^{3.5}L_{\odot}$, 2kpc)

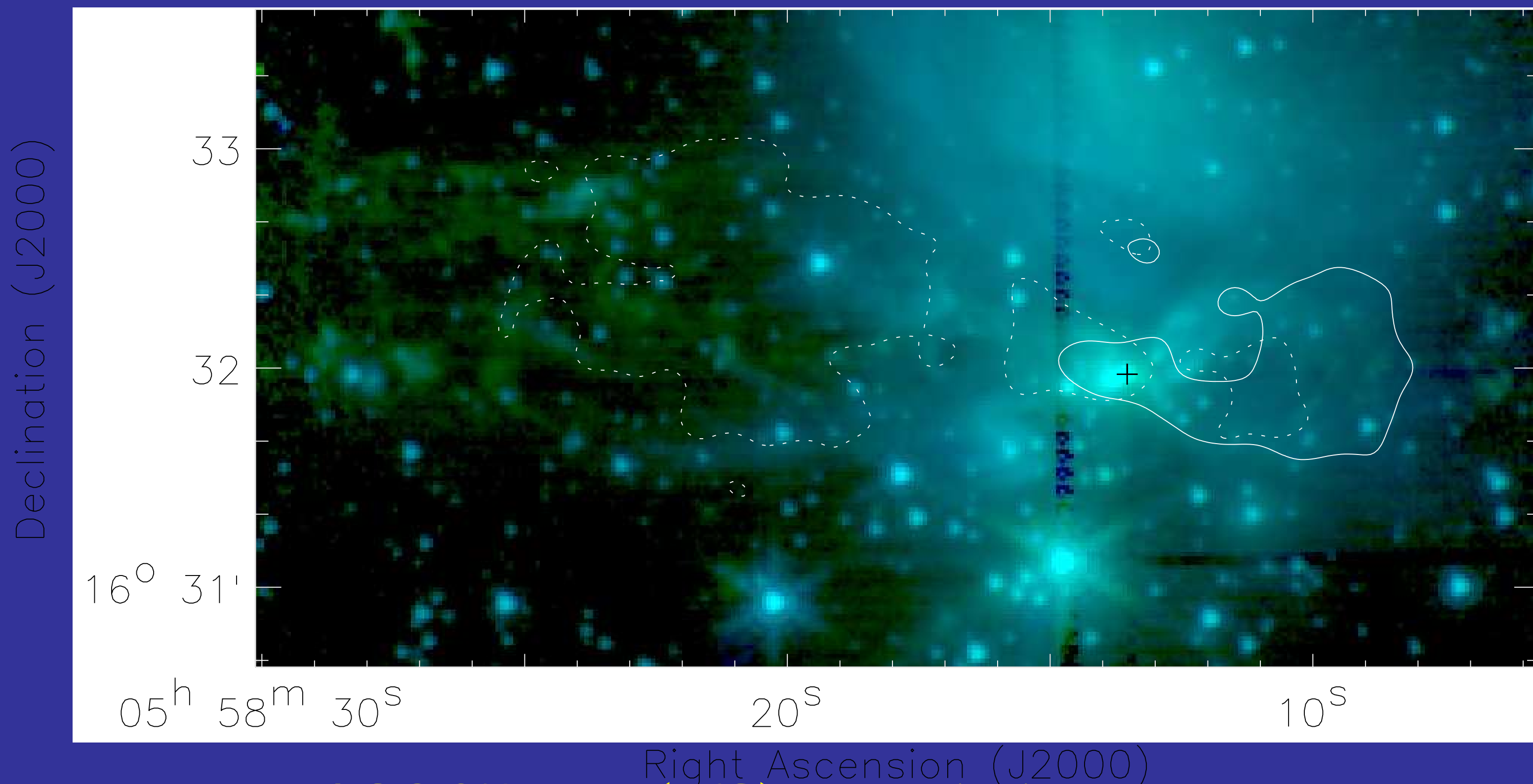


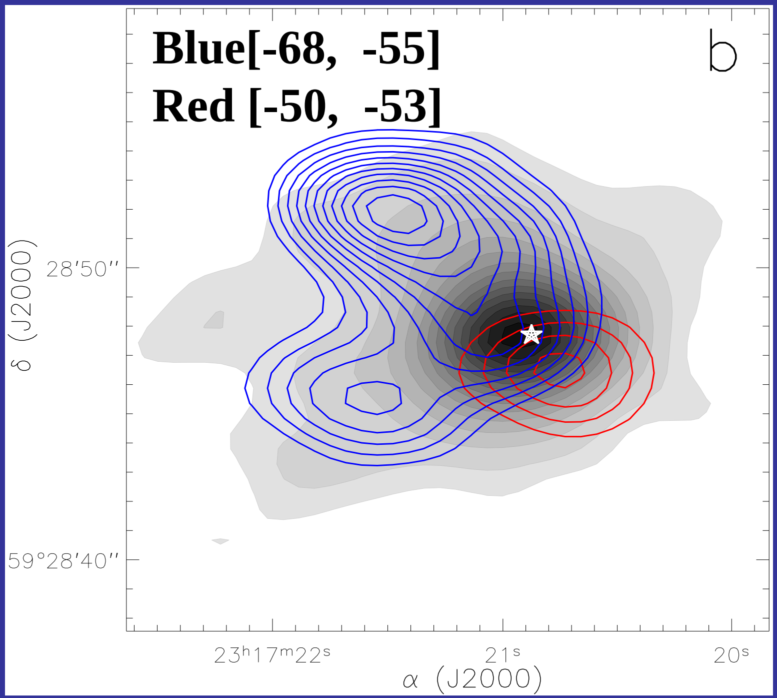
Image: IRAC 3.6/4.5 µm (B/G) composite image

Contours: the lowest contour of CO outflow from Shepherd et al. (1998).

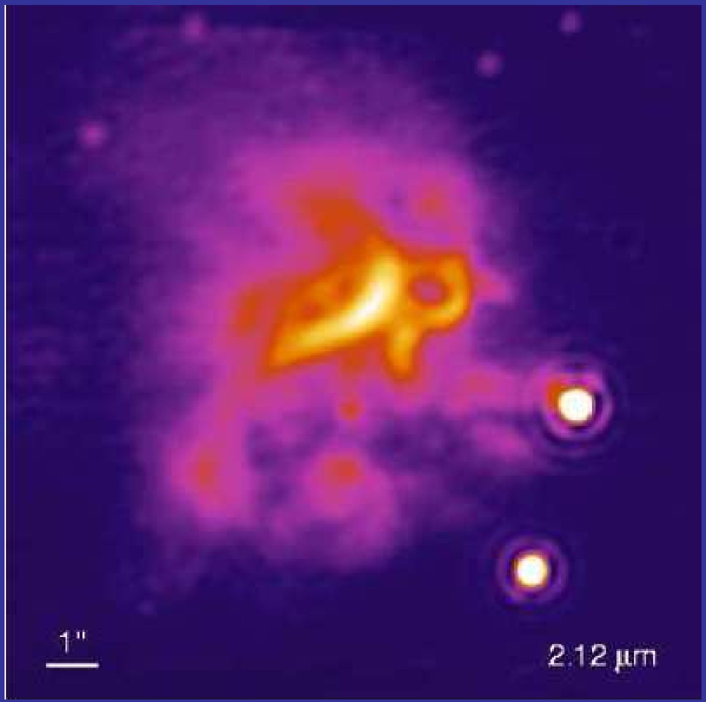
The large-scale “green” wind extends beyond the blue-shifted CO outflow.

Conical Shaped, wide opening angle

IRAS 23151+5912 (L_{FIR}~$10^5 L_\odot$, 5.7kpc)



Grayscale: 3mm continuum
Contours: PdBI SiO 2-1 outflow
Qiu et al. (2007)



K-band image
Weigelt et al. (2006)

Remarks

Most of current detected massive outflows show morphologies and kinematics similar to those of low-mass outflows. These outflows can be modeled as jet, bow-shock, or wide-angle wind entrainment.

Most of high-resolution observations are for early B to late O type stars. A few highly collimated outflows have been detected toward early B stars. Can outflows from most luminous O type stars be well collimated? Does there exist an evolutionary picture for massive outflows as an analogy to low-mass outflows (Beuther & Shepherd 2005; Arce et al. 2006)?

To address these questions, the very poor statistics of high-resolution observations of outflows from most luminous objects ($L \geq 10^5 L_\odot$) needs to be improved. We're obtaining observations toward objects in this luminosity range.