MOLECULAR OUTFLOWS TOWARDS O-TYPE YOUNG STELLAR OBJECTS

Ana López Sepulcre

INAF - Osservatorio Astrofisico di Arcetri

(Firenze, ITALY)

Co-authors: C. Codella, R. Cesaroni, M. Walmsley (INAF - OAA),

N. Marcelino (CSIC, Madrid)

WP2 CONSTELLATION workshop, Prague, 15th September 2009

The sample and observations

Selection criteria

Association with:

(i) H_2O, OH and CH_3OH masers

(ii) High luminosity: $2x10^4$-10^6 L_{sun}

(iii) Compact or no free-free emission

11 SOURCES

d = 2 - 12 kpc

The sample and observations

Observations

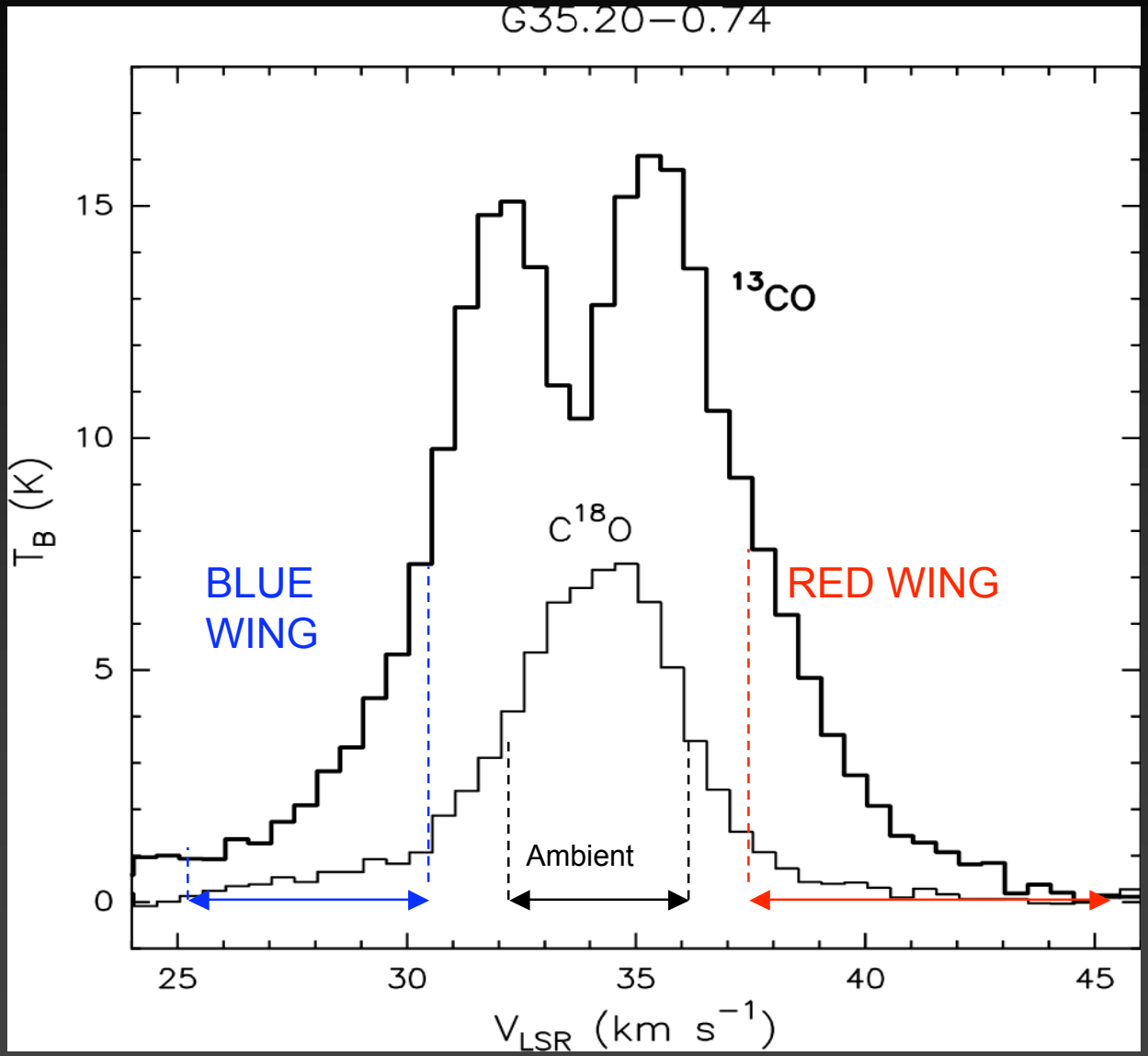
IRAM 30-m radio telescope (Spain)

On-The-Fly mapping with HERA (9-beam array working at 1.3 mm)

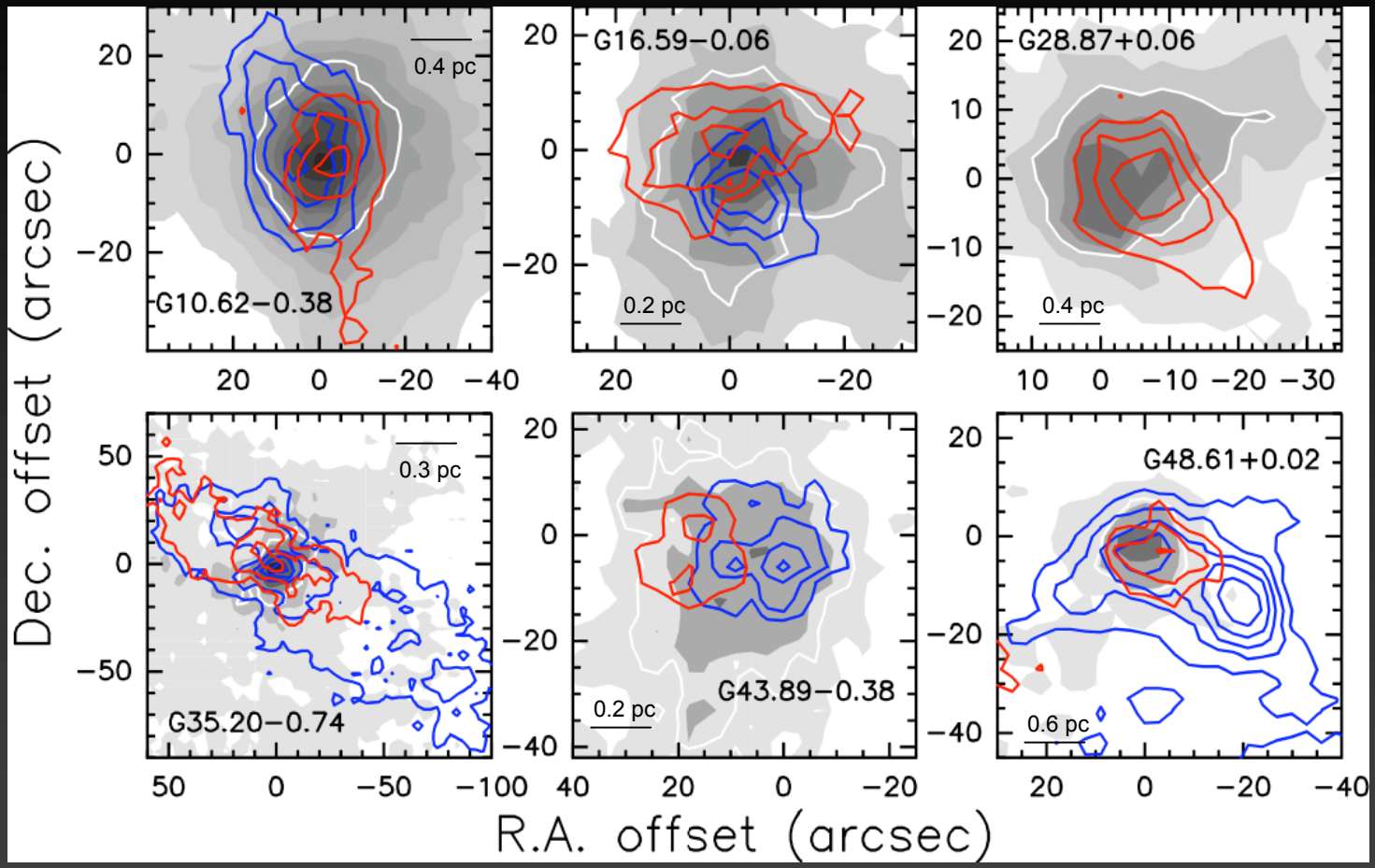
September 2006

^{13}CO(2-1) Outflow tracer
(220.4 GHz, HPBW = 11”)
C^{18}O(2-1) Ambient tracer
(219.6 GHz, HPBW = 11”)

The method


G35.20−0.74
15
10
5
0
T_B (K)
^{13}CO
C^{18}O
BLUE WING
RED WING
Ambient
25
30
35
40
45
V_{LSR} (km s^{-1})

Results: outflow maps



High-velocity wings in all the ^{13}CO(2-1) spectra

(López-Sepulcre et al. 2009)

Outflow maps for 9 out of 11 sources

Outflows common in high-mass star forming regions: accretion

Outflow parameters against luminosity

Outflow parameters determined from the $^{13}CO(2-1)$ emission in the high-velocity wings

Values corrected for optical depth (from $^{13}CO(2-1)$ to $C^{18}O(2-1)$ ratio

Continuity with data by Beuther et al. (2002); agreement with fits by Wu et al. (2004, 2005)

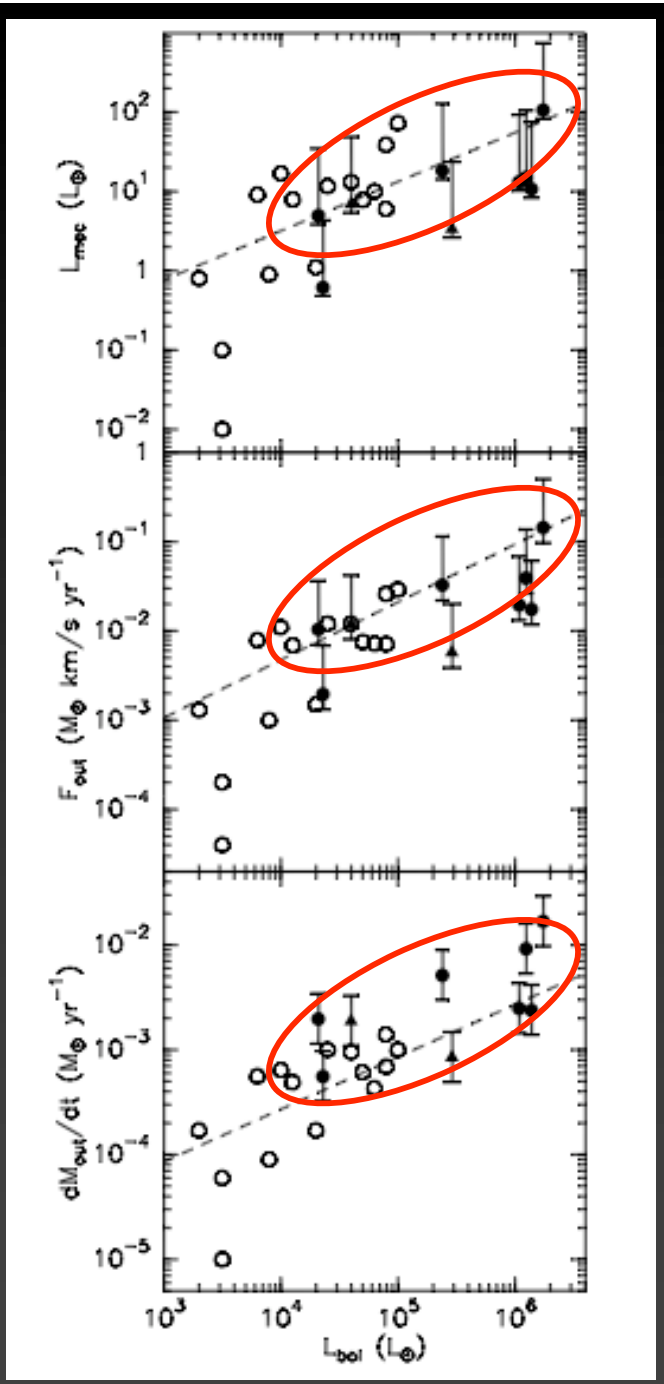
Our data complement those by Beuther et al. (2002), adding the highest luminosity sources, covering for the first time the O-type range

o : Beuther et al. (2002)

● : Our sample (corrected for τ)

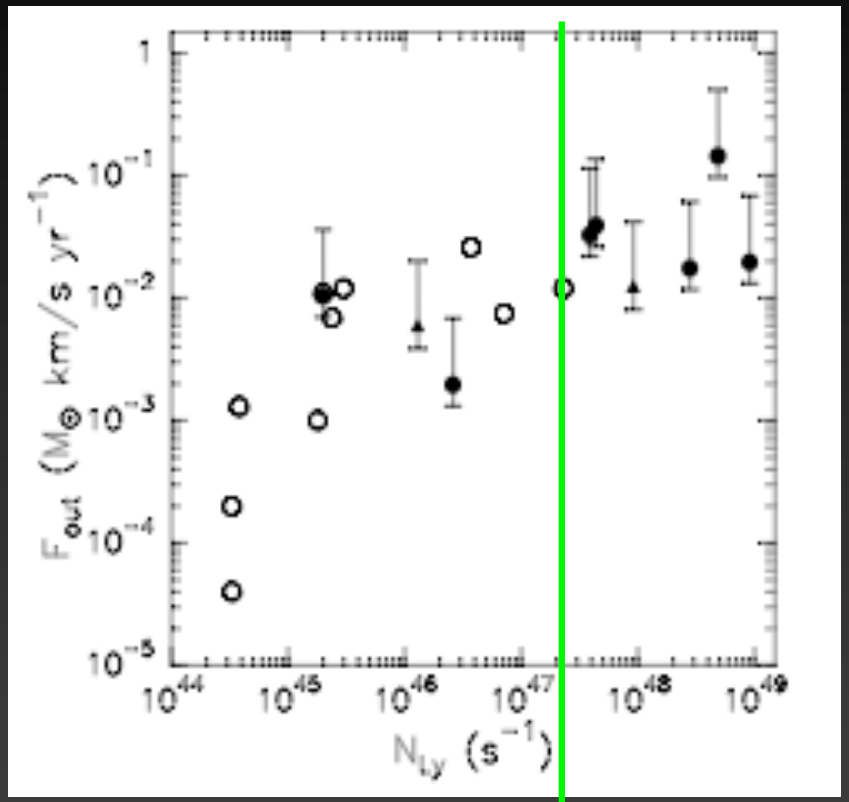
▲ : Our sample ($\tau << 1$)

-- : Fits by Wu et al. (2004, 2005)



(López-Sepulcre et al. 2009)

Outflow mechanical force against Lyman photon rate



(López-Sepulcre et al. 2009)

N_{Ly} ≠ whole cluster

N_{Ly} = massive YSOs

B-type | O-type

High angular resolution (<~ 1”) imaging needed to disentangle outflow multiplicity and associate them with individual sources within the clump

Conclusions

1. ^{13}CO(2-1) single-dish survey towards 11 high-mass SFRs in search for molecular outflows: FOUND in the whole sample
2. Molecular outflows as common in high-mass SFRs as in low-mass SFRs: supports accretion scenario
3. Outflow parameters determined and compared to those derived for the sample of Beuther et al. (2002, mostly B-type): continuity with their results, covering for the first time the O-type range
4. Higher luminosity sources associated with more energetic outflows
5. Correlation between outflow mechanical force, F_{out}, and rate of ionising photons, N_{Ly}, of the associated UC HII regions: supports association of the outflows with the ionising sources

More details in López-Sepulcre et al. 2009, A&A 499, 811

COMING SOON …

Outflow (and infall) in high-mass molecular clumps

General goals

- Compare the star formation activity of IRDCs with that present in known high-mass star forming clumps: **evolutionary trends?**

- Check observationally **Krumholtz & McKee's** result:

$\Sigma \sim 0.7$ g cm^{-2} is the **minimum surface density** required for high-mass star formation (*2008, Nature, 451, 1082*)

Outflow (and infall) in high-mass molecular clumps

General goals

- Compare the star formation activity of IRDCs with that present in known high-mass star forming clumps: **evolutionary trends?**

- Check observationally **Krumholtz & McKee's** result:

$\Sigma \sim 0.7$ g cm^{-2} is the **minimum surface density** required for high-mass star formation (*2008, Nature, 451, 1082*)

The sample

18 IR-dark clumps
31 IR-luminous clumps

Selection Criteria (from 1.2 mm surveys)

$\delta > -10°$

$M > 100\ M_{sun}$: massive

d < 4 kpc: angular diameters in the range 1'-2'

Outflow (and infall) in high-mass molecular clumps

General goals

- Compare the star formation activity of IRDCs with that present in known high-mass star forming clumps: **evolutionary trends?**

- Check observationally **Krumholtz & McKee's** result:

$\Sigma \sim 0.7$ g cm^{-2} is the **minimum surface density** required for high-mass star formation (*2008, Nature, 451, 1082*)

The sample

18 IR-dark clumps
31 IR-luminous clumps

Selection Criteria (from 1.2 mm surveys)

$\delta > -10°$

M > 100 M_{sun}: massive

d < 4 kpc: angular diameters in the range 1'-2'

IRAM 30-m observations

HCO^+(1-0) @ 89.2 GHz
HCN(1-0) @ 88.6 GHz
$C^{18}O$(2-1) @ 219.6 GHz

} OTF mapping: 1' x 1' maps

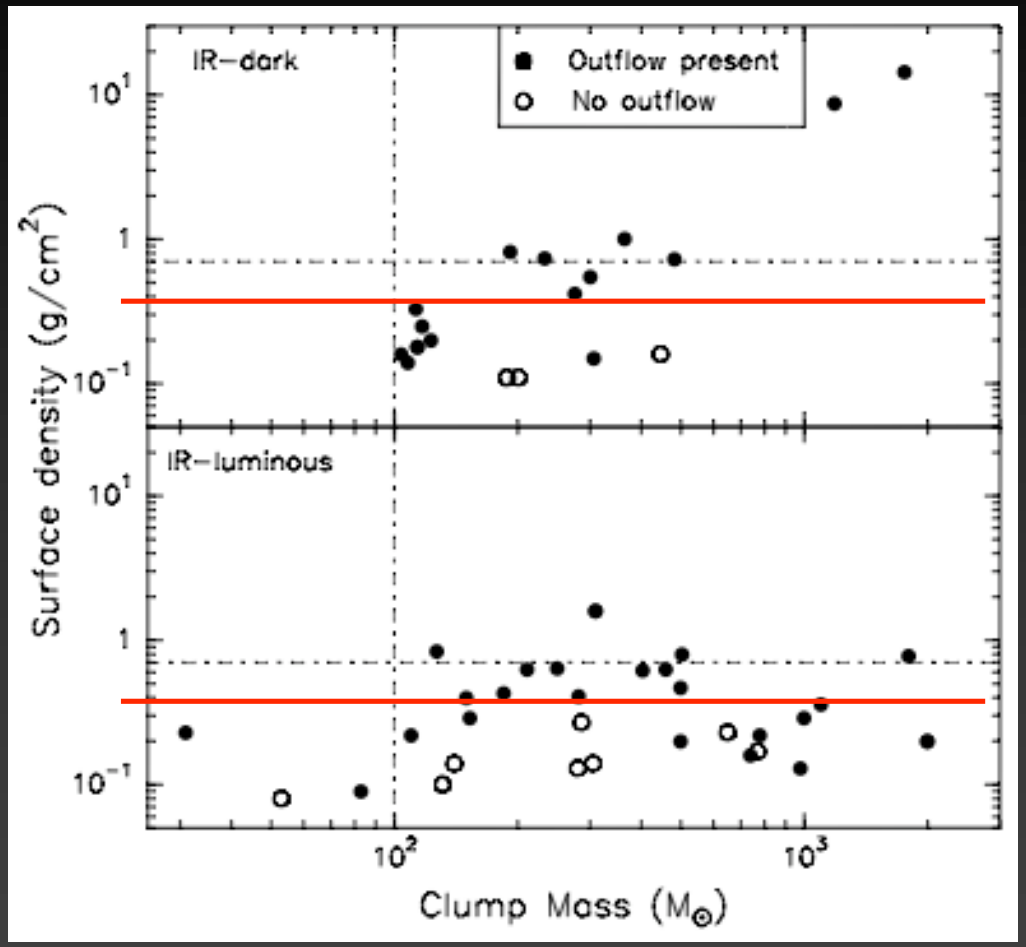
Outflow (and infall) in high-mass molecular clumps

Preliminary results

Outflow detection rate

	IR-dark	IR-lum
Σ > 0.3 g/cm^2	100 %	100 %
Σ < 0.3 g/cm^2	67 %	56 %
Total	**83 %**	**74 %**

—— Σ = 0.3 g cm^{-2}



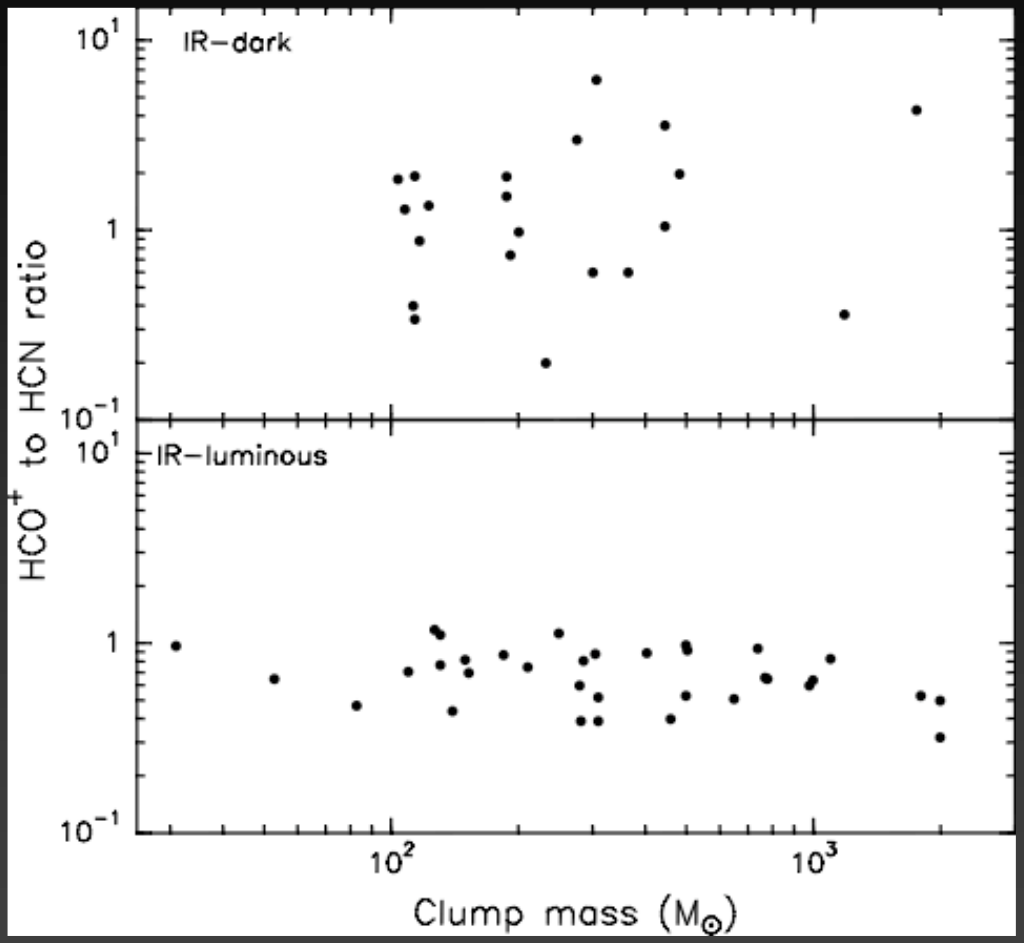
Derivation of outflow parameters in progress …

Outflow (and infall) in high-mass molecular clumps

Preliminary results

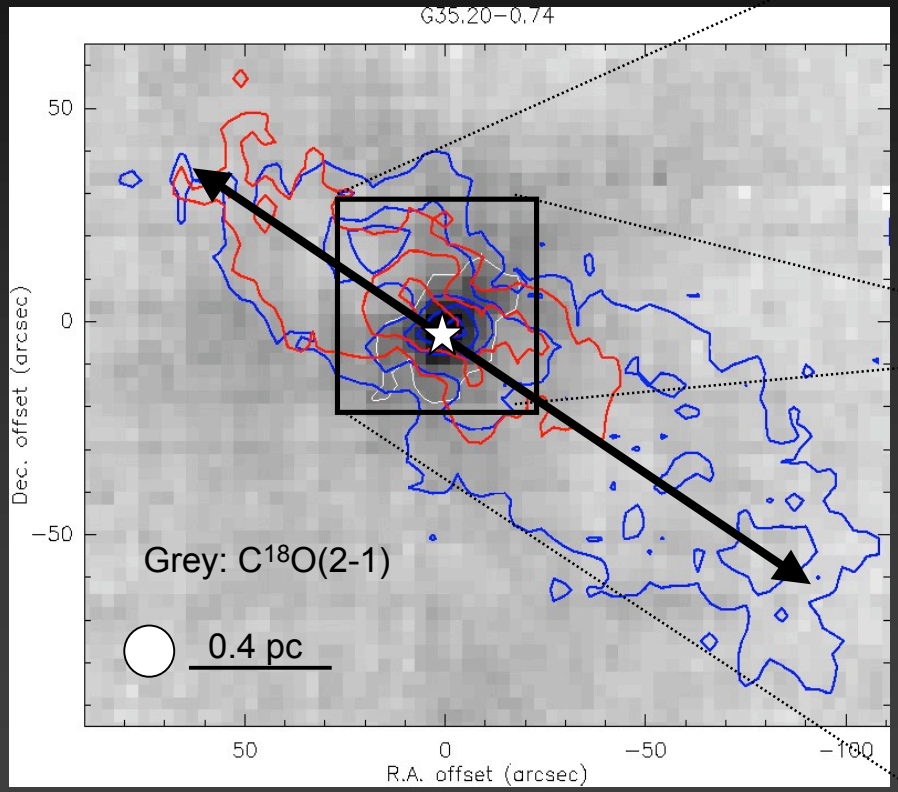
HCO+(1-0) to HCN(1-0) ratio

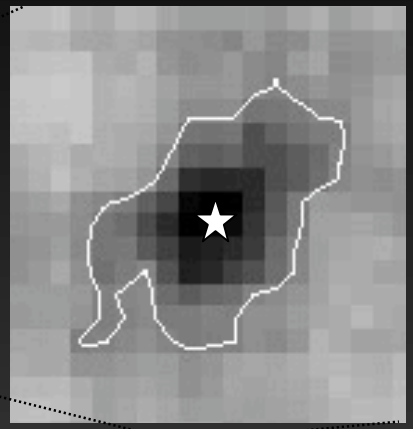
IR-dark: 1.7 ± 1.5
IR-lum: 0.71 ± 0.23

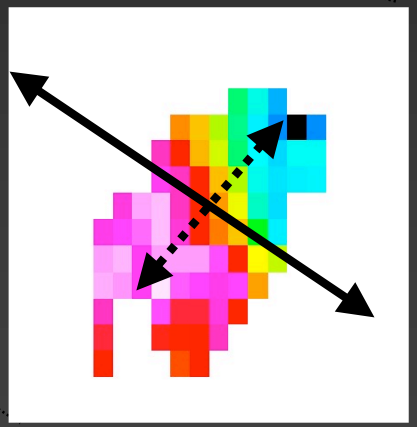


MORE DETAILS IN WP1 MEETING!

The case of G35.20-0.74



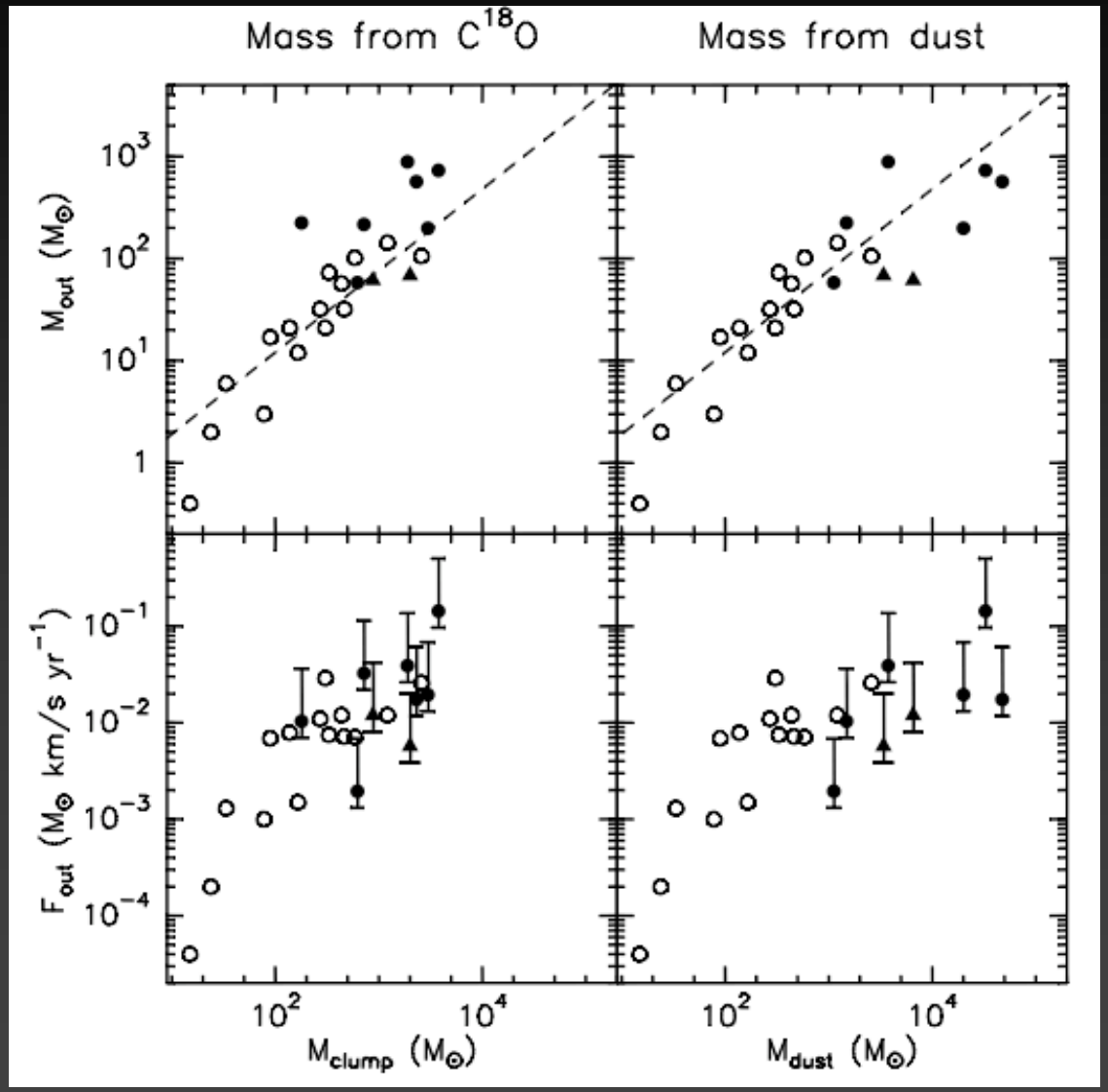




Velocity gradient perpendicular to outflow axis (rotation?)

Bipolar outflow detected

Outflow parameters against clump mass



Best fit to Beuther et al. (2002) data:

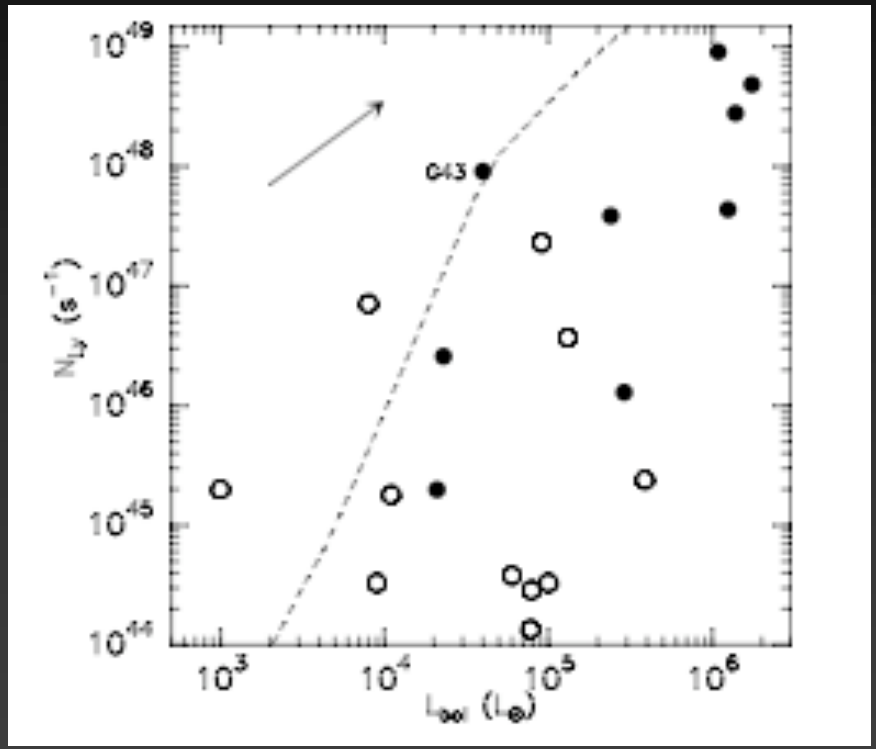
$$M_{out} = 0.3\ M_{dust}^{0.8}$$

Reasonable fit to our data

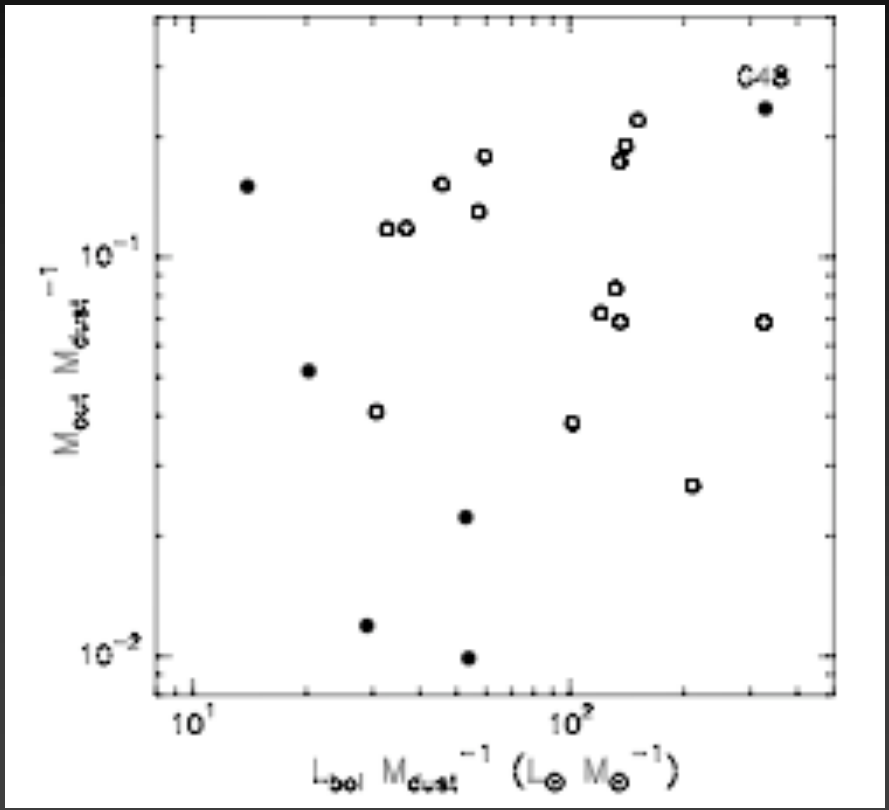
$M_{dust} > M_{clump}$

Hofner et al. 2000 (ApJ 536, 393)

Ionising photon rate against bolometric luminosity



Under-luminous clumps



Outflow parameters against luminosity

Outflow parameters determined from the $^{13}CO(2-1)$ emission in the high-velocity wings

Values corrected for optical depth (from $^{13}CO(2-1)$ to $C^{18}O(2-1)$ ratio)

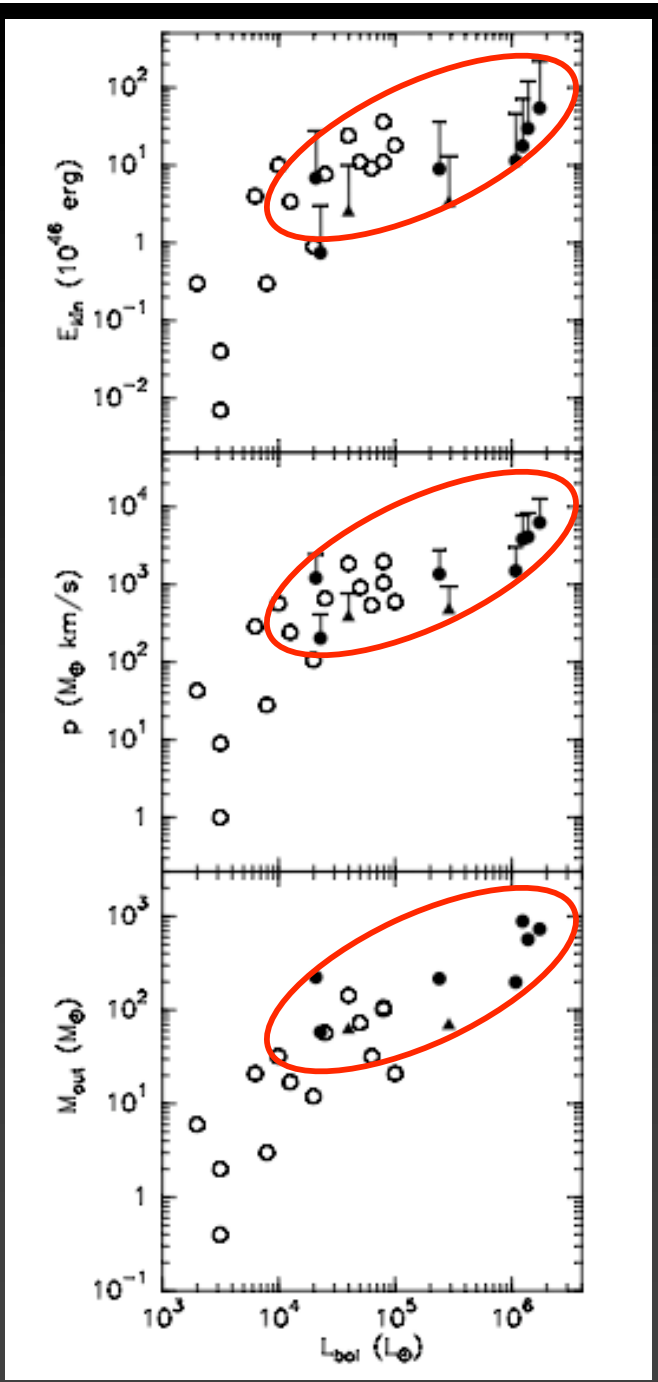
Continuity with data by Beuther et al. (2002); agreement with fits by Wu et al. (2004, 2005)

Our data complement those by Beuther et al. (2002), adding the highest luminosity sources, covering for the first time the O-type range

o : Beuther et al. (2002)

● : Our sample (corrected for τ)

▲ : Our sample (τ << 1)



(López-Sepulcre et al. 2009)