MOLECULAR OUTFLOWS TOWARDS O-TYPE YOUNG STELLAR OBJECTS

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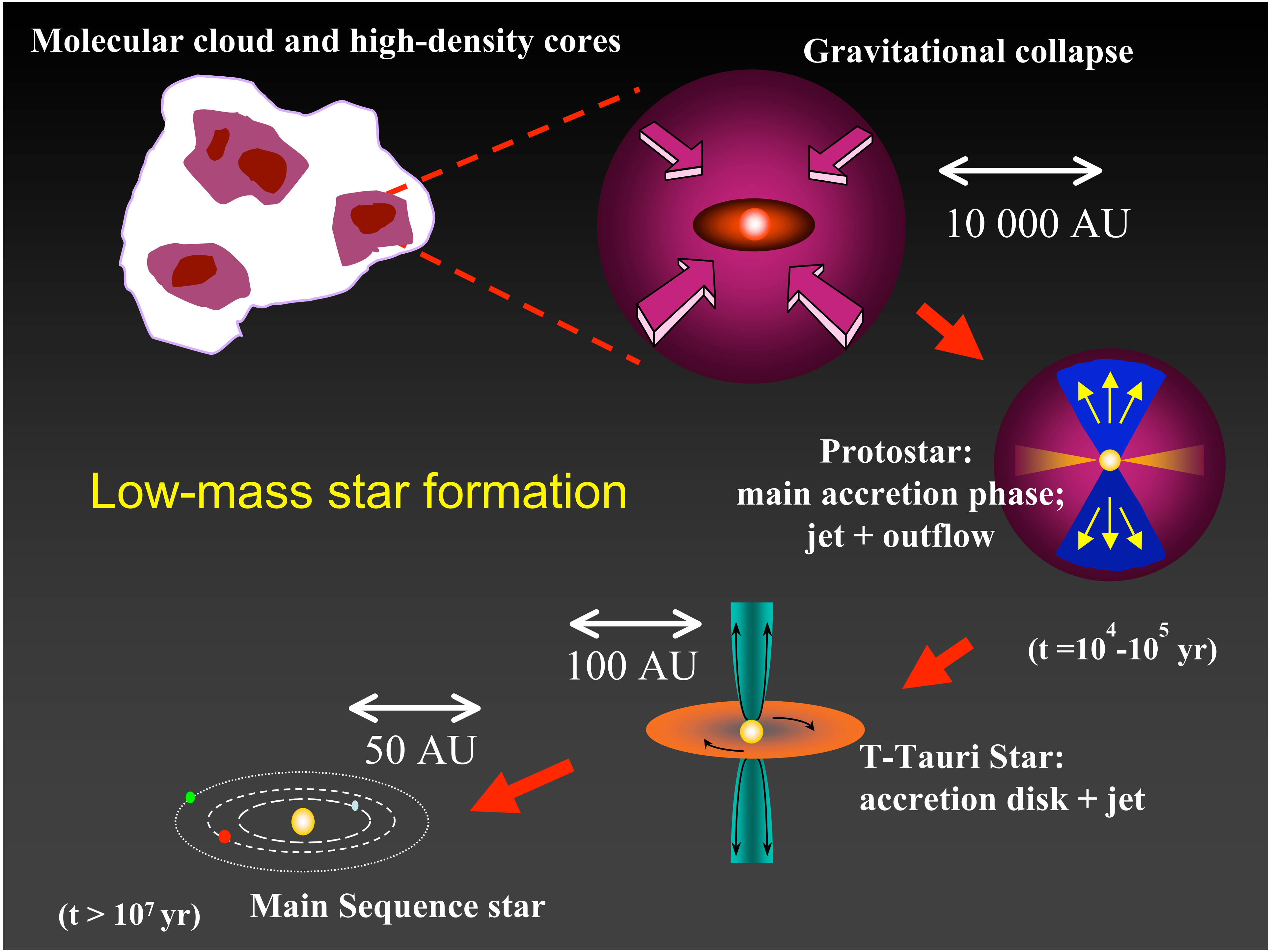


Molecular cloud and high-density cores
Gravitational collapse
10 000 AU
Low-mass star formation
Protostar:
main accretion phase;
jet + outflow
100 AU
(t =10^4-10^5 yr)
50 AU
T-Tauri Star:
accretion disk + jet
(t > 10^7 yr)
Main Sequence star

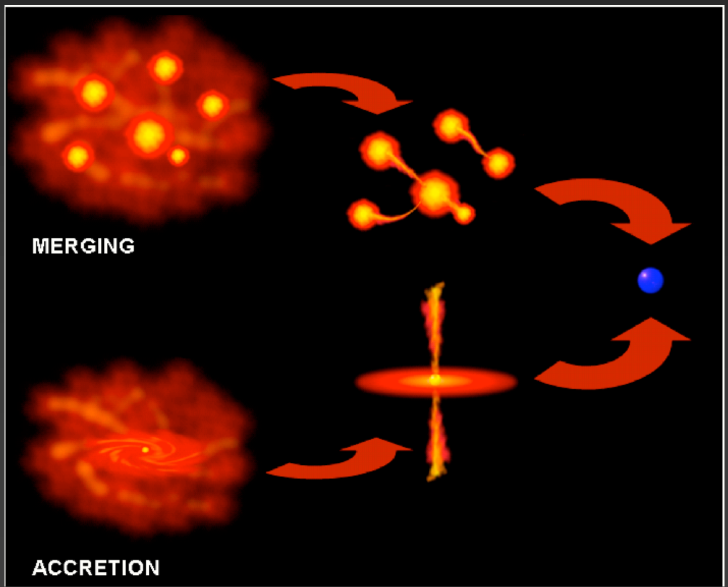
High-mass Star Formation: Problems & Solutions

Observational problems

Rare; high distances (~ 5 kpc), Fast evolution towards ZAMS, cluster (confusion)

Theoretical problem (Palla & Stahler 1993)

Stars with $M \geq 8M_{sun}$ reach the ZAMS while still accreting: radiation pressure should halt the accretion process $\Rightarrow$ **Stars with $M > 8M_{sun}$ cannot form (?!)**



Proposed scenarios

1. Merging of low-mass stars

Disks/outflows associated with the low-mass stars should be destroyed during merging

2. Accretion through disks and/or with larger accretion rates than those for low-mass stars

Well-defined disk/outflow system

So far, evidence supports accretion… General case???

The sample and observations

Observations

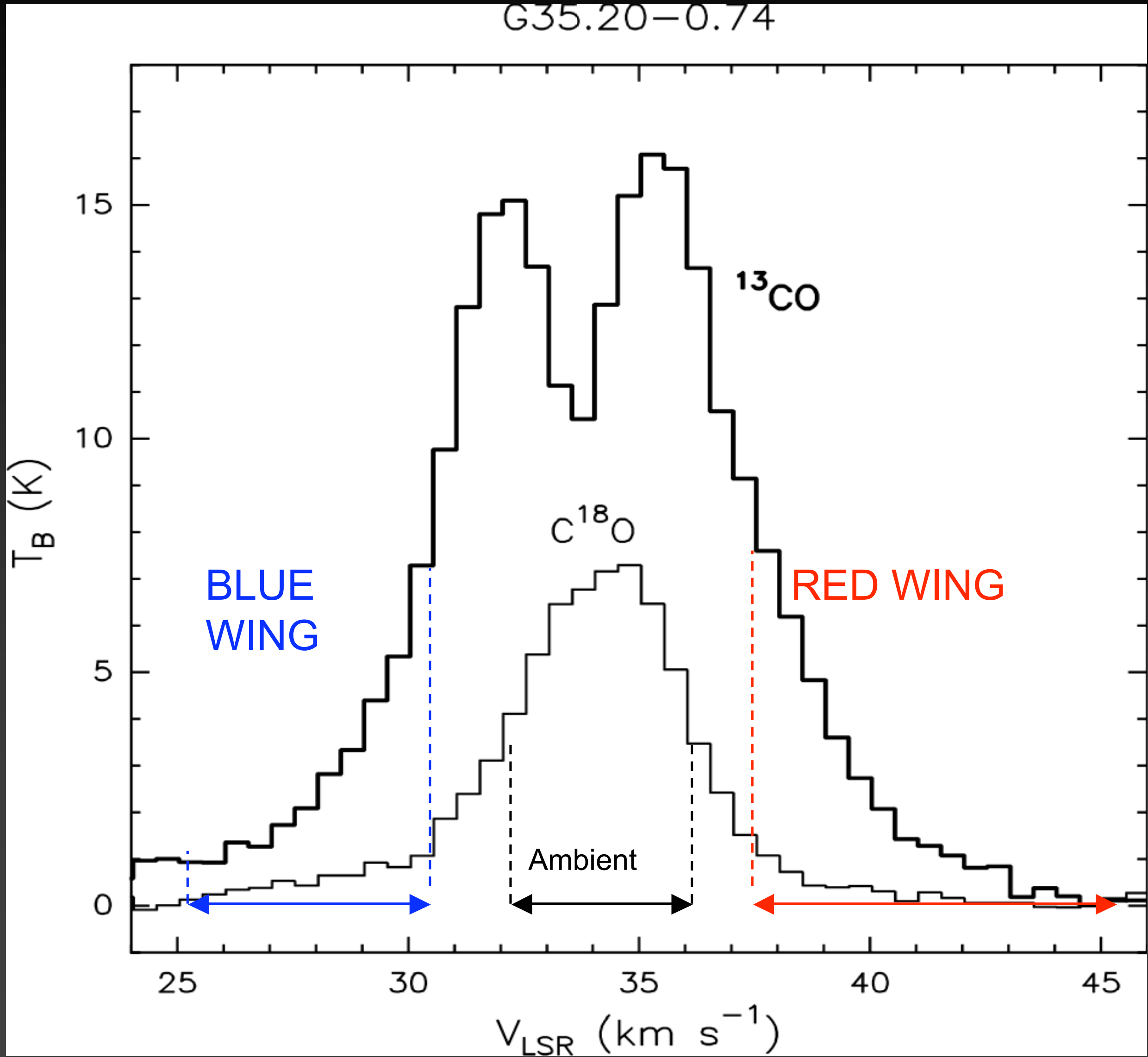
IRAM 30-m radio telescope (Spain)

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

September 2006

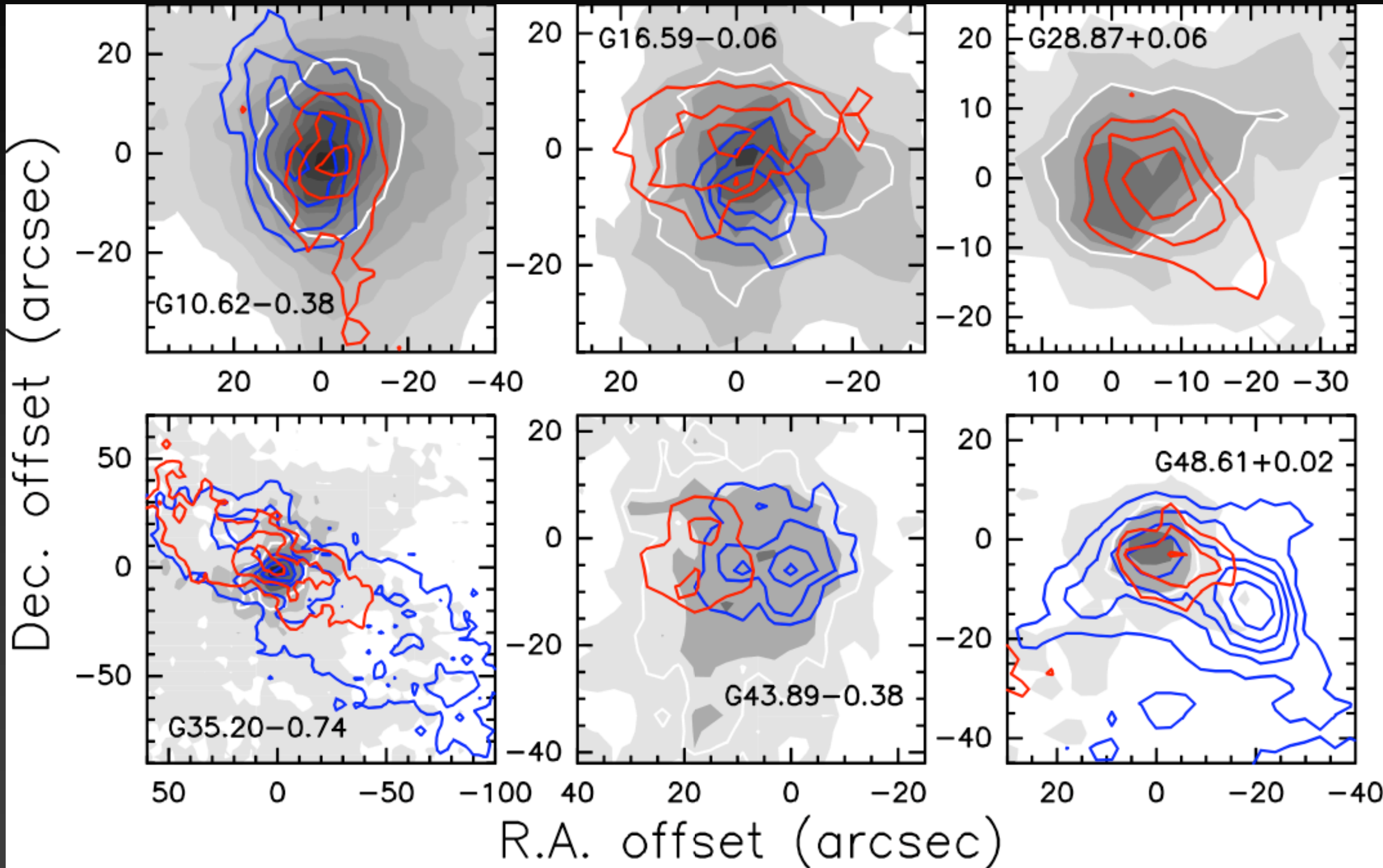
$^{13}CO(2\text{-}1)$ Outflow tracer
(220.4 GHz, HPBW = 11”)
$C^{18}O(2\text{-}1)$ Ambient tracer
(219.6 GHz, HPBW = 11”)

The method



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

Results: outflow maps



(López-Sepulcre et al. 2009)

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

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 $^{13}CO(2\text{-}1)$ emission in the high-velocity wings

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

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

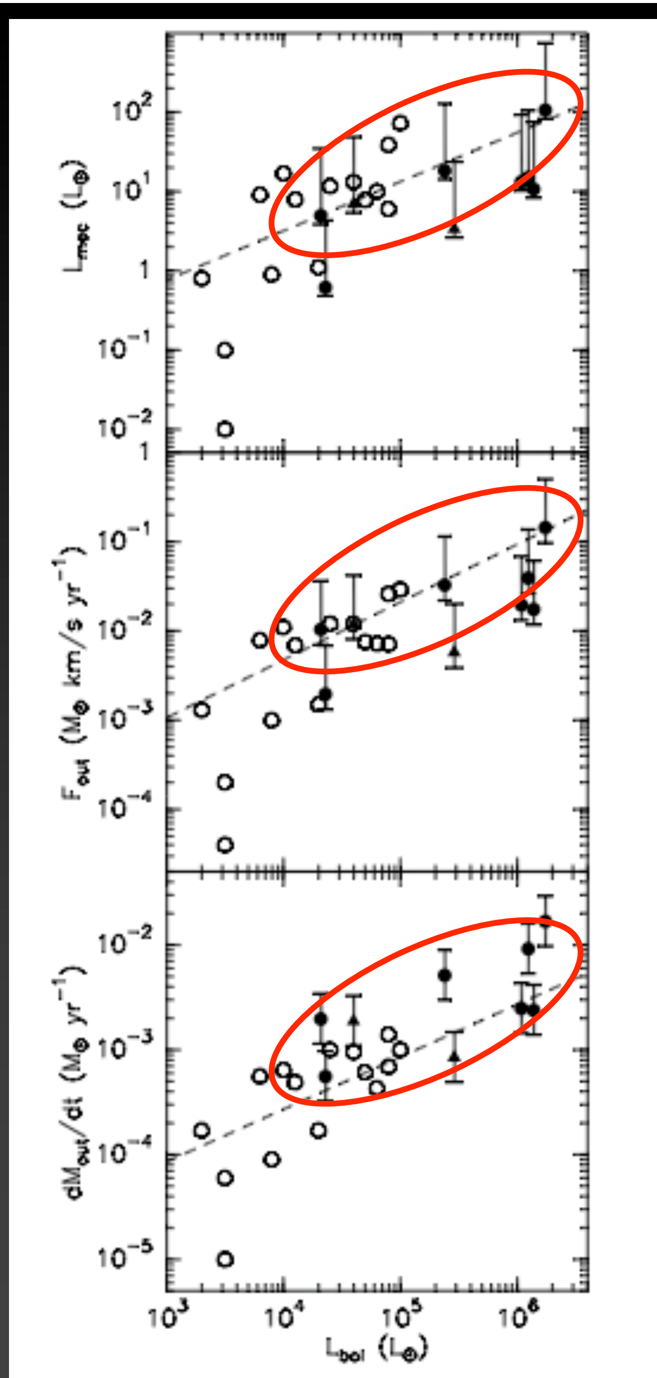
Our data complement those by Beuther et al. (2002), adding the highest luminosity sources, covering for the first time the O-type range

o : Beuther et al. (2002)

● : Our sample (corrected for τ)

▲ : Our sample (τ << 1)

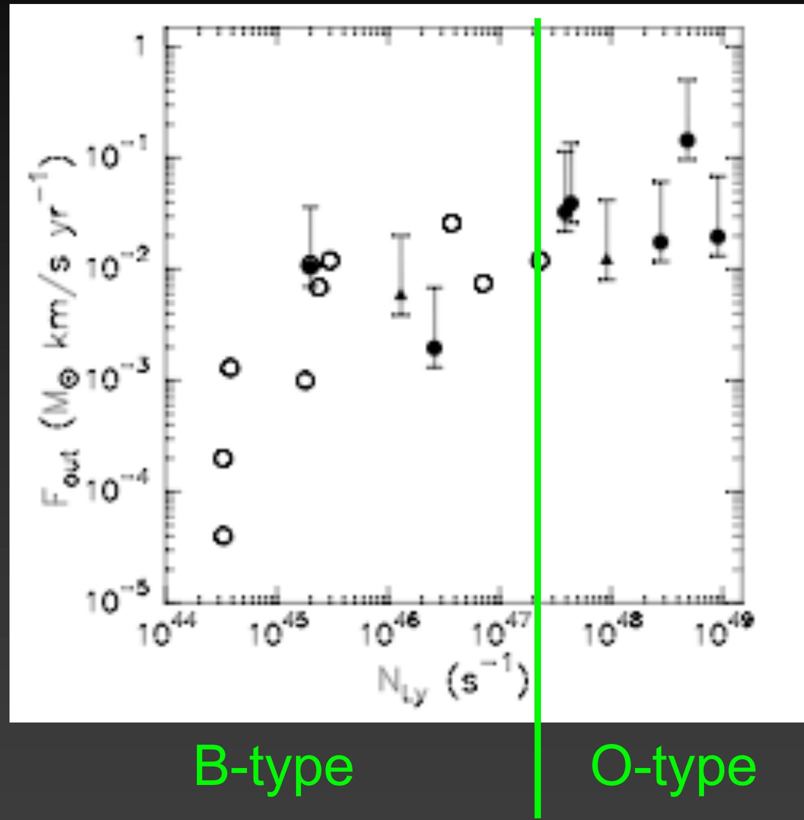
-- : Correlations by Wu et al. (2004, 2005)



(López-Sepulcre et al. 2009)

Outflow mechanical force against Lyman photon rate

(López-Sepulcre et al. 2009)



$N_{Ly} \neq$ whole cluster

N_{Ly} = massive YSOs

For sources associated with UC HII regions:

similar correlation to that found for L_{bol}

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

Conclusions

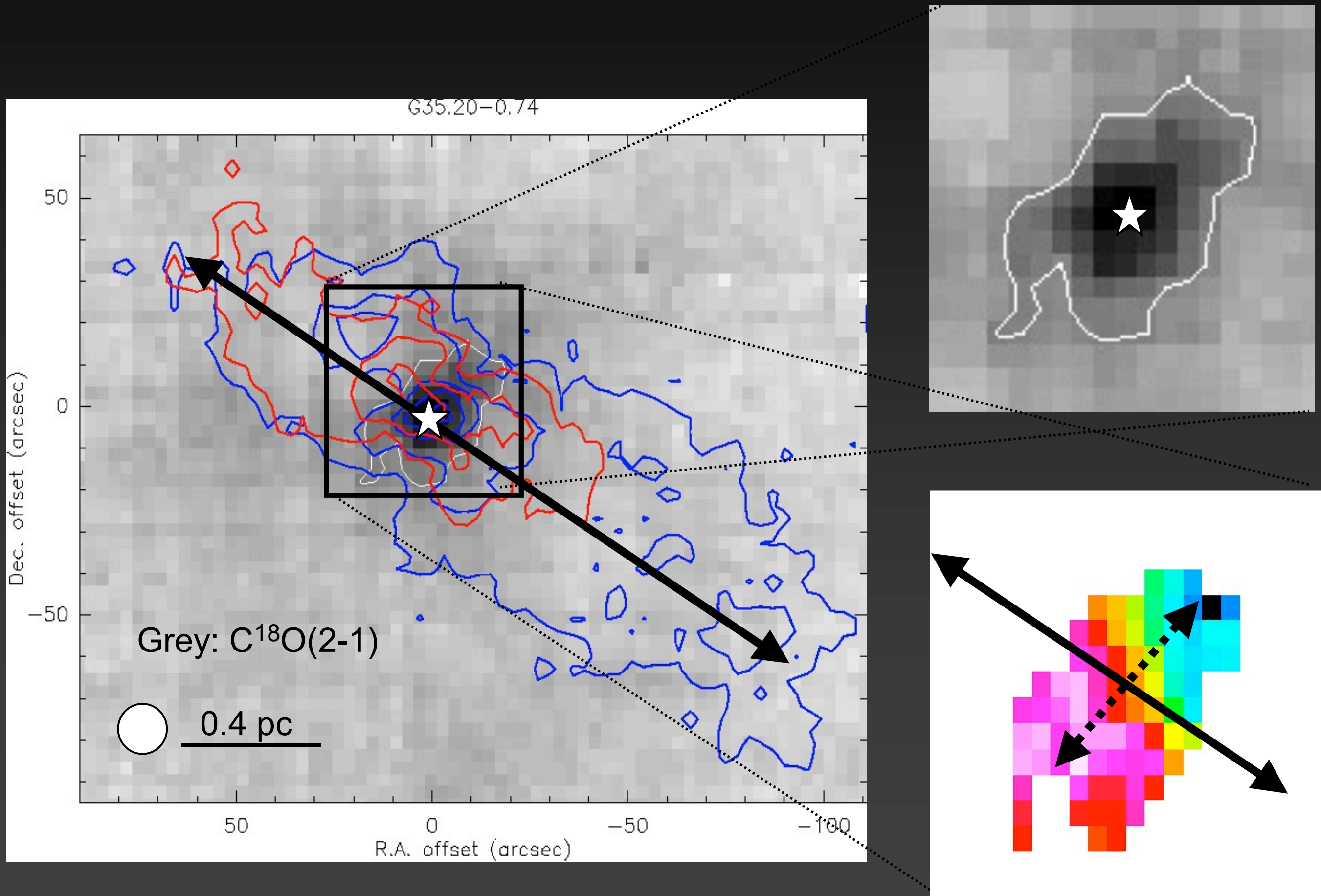
(López-Sepulcre et al. 2009)

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 are as common in high-mass SFRs as in low-mass SFRs, supporting the 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 are 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 (supporting the association of the outflows with the ionising sources)

Future

Complementary sub-arcsec CO imaging + use of jet tracers (e.g. SiO)

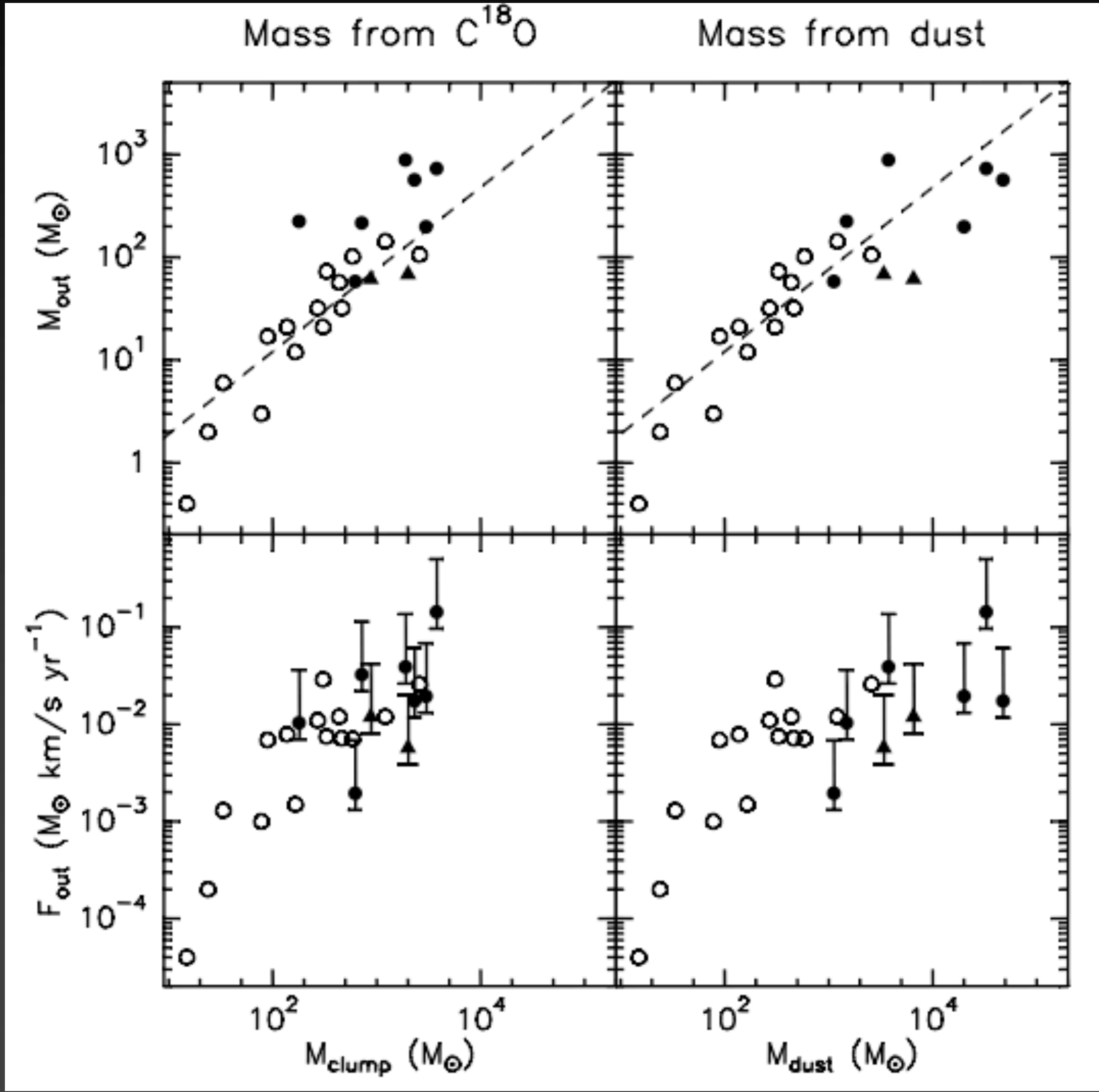
The case of G35.20-0.74



Velocity gradient perpendicular to outflow axis (rotation?)

Bipolar outflow detected

Outflow parameters against clump mass



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

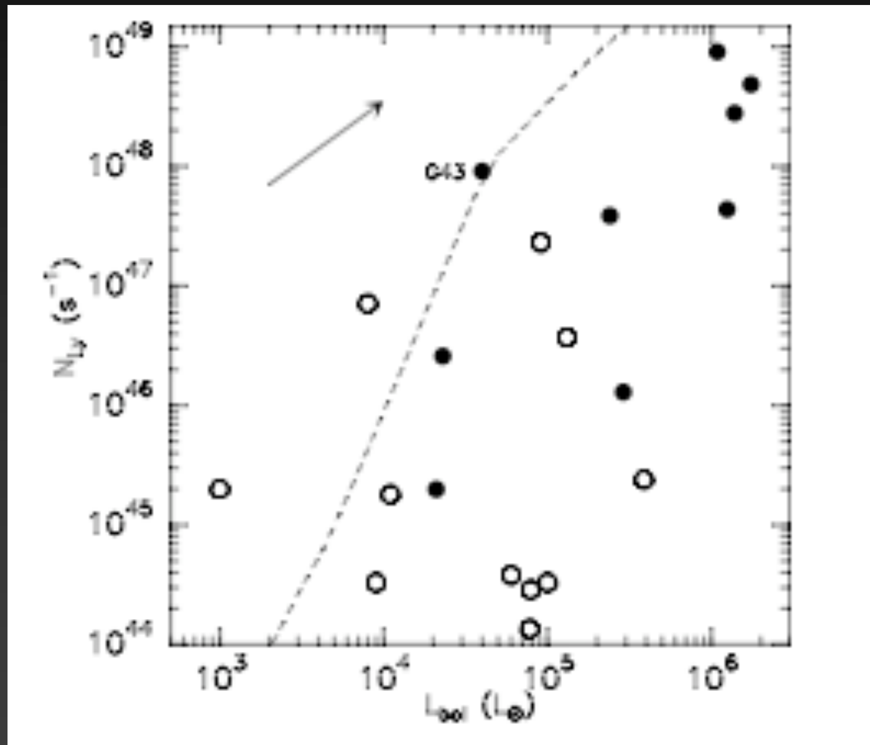
$M_{out} = 0.3\ M_{dust}^{\ 0.8}$

Reasonable fit to our data

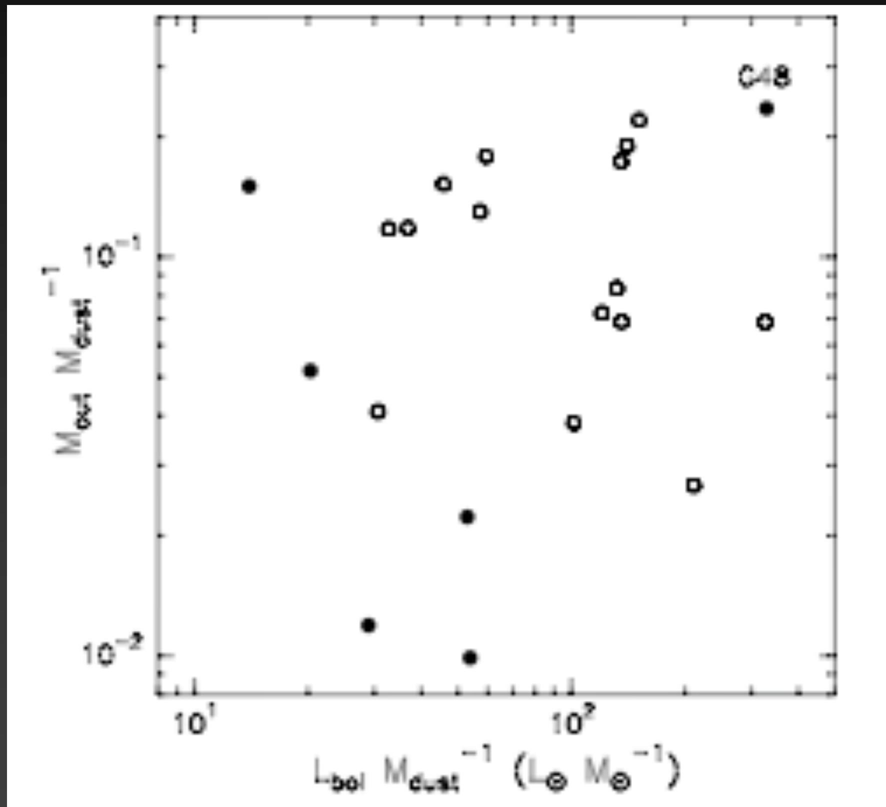
$M_{dust} > M_{clump}$

Hofner et al. 2000 (ApJ 536, 393)

Ionising photon rate against bolometric luminosity



Under-luminous clumps



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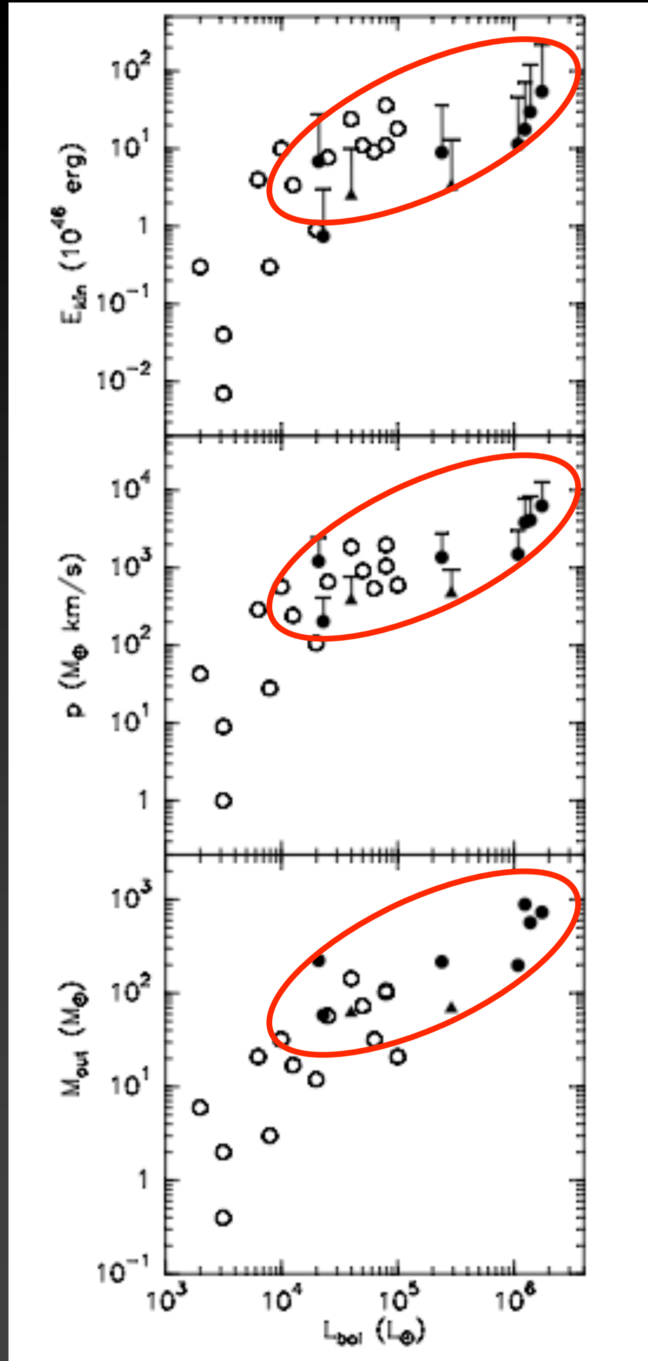

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