IRAS 16253-2429: The First Proto-Brown Dwarf Binary Candiate Identified through The Dynamics of Jet

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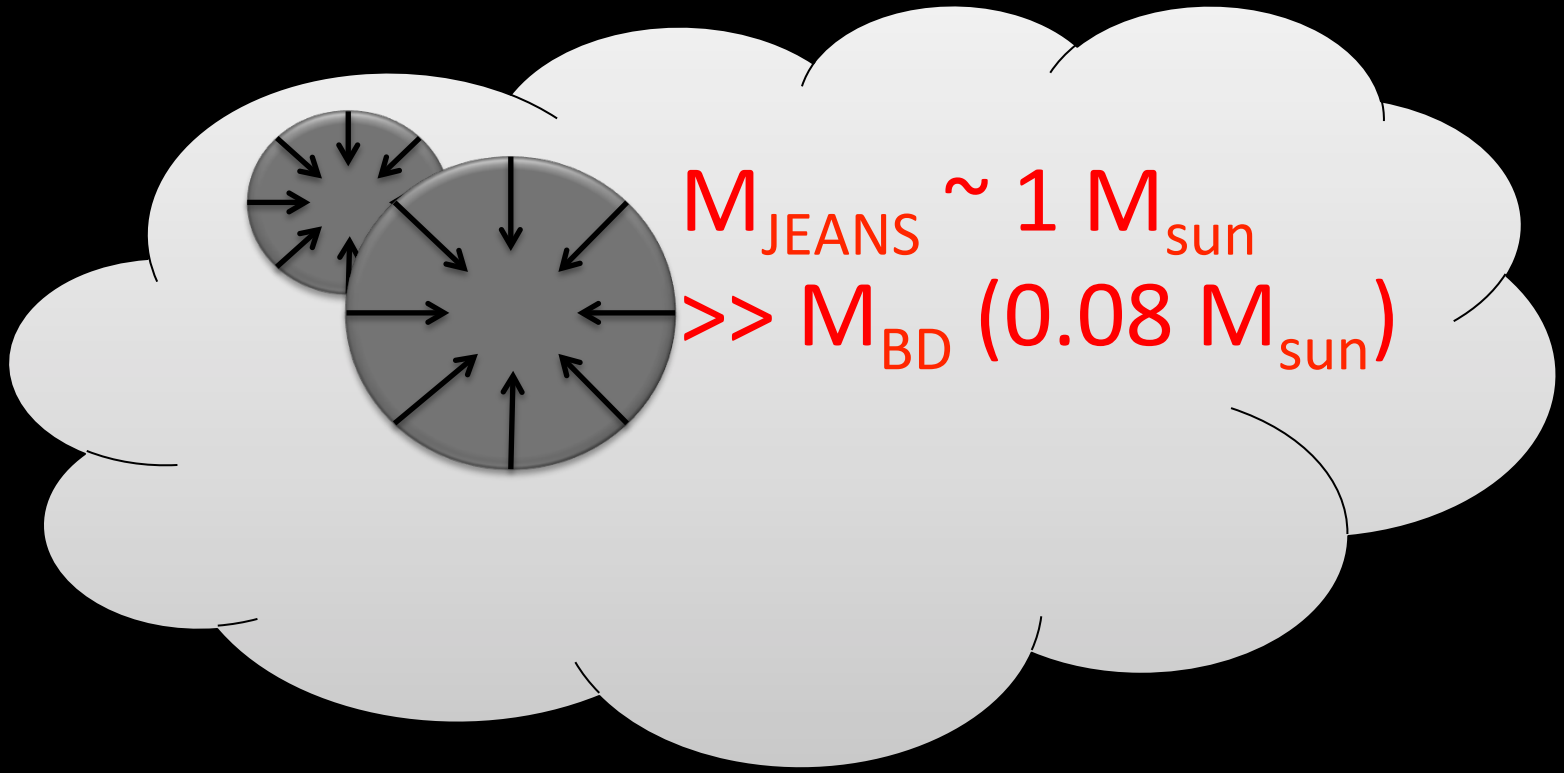
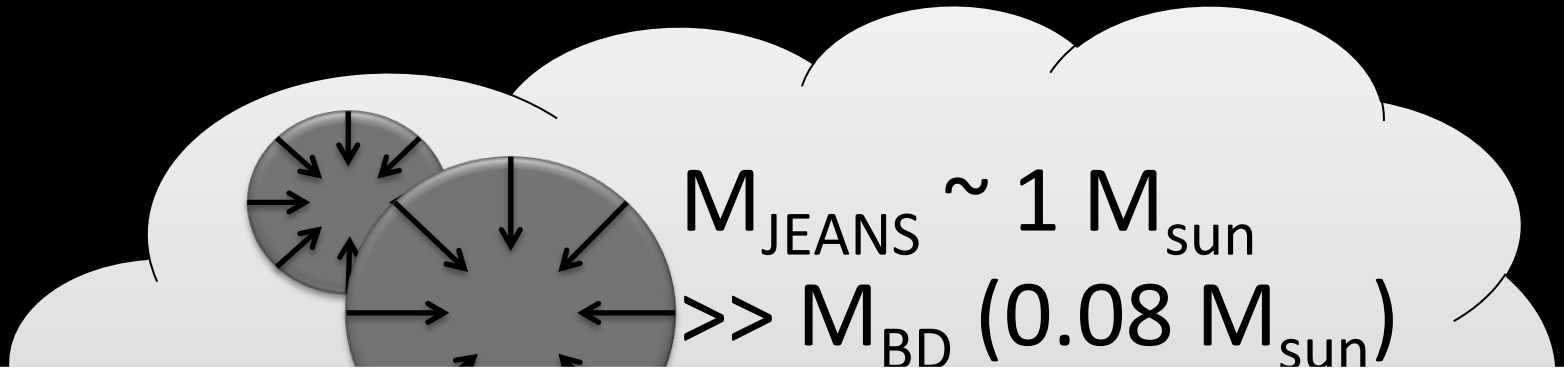
Mystery of Brown Dwarf formation



Padoan & Nordlund 2004, Bate+ 2002, Whitworth & Zinnecker 2004, Stamatellos 2013, Barrado+ (2009)

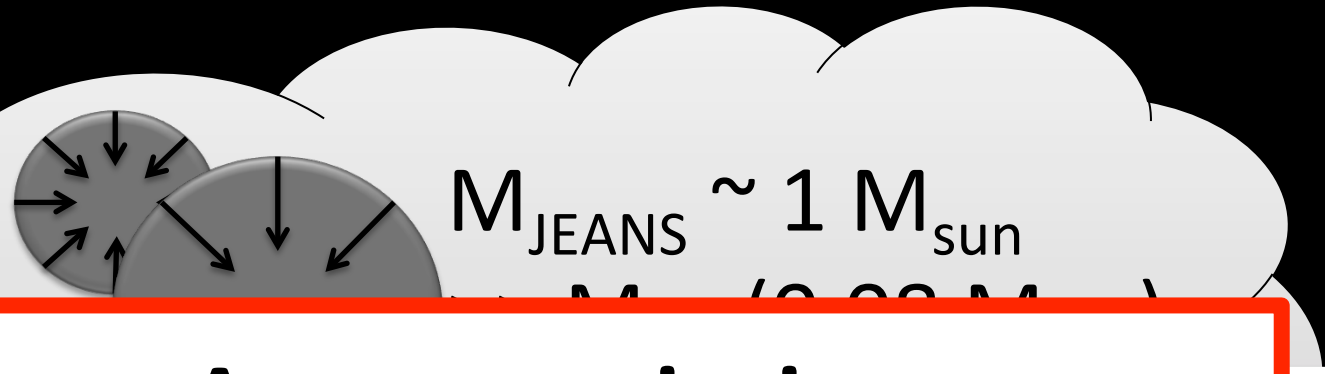
Mystery of Brown Dwarf formation



1. Form through gravitational collapse
2. Form like planet and ejected later
3. Parent core disrupted by nearby massive object

Padoan & Nordlund 2004, Bate+ 2002, Whitworth & Zinnecker 2004, Stamatellos 2013, Barrado+ (2009)

Mystery of Brown Dwarf formation



1. [illegible]
2. [illegible]
3. Parent core disrupted by nearby massive object

Answer is in

"Proto Brown Dwarf"!!

Padoan & Nordlund 2004, Bate+ 2002, Whitworth & Zinnecker 2004, Stamatellos 2013, Barrado+ (2009)

Only few proto-BD identified

1. L1014-IRS (Huard+ 2005; Bourke+ 2006)
2. J041757 (Barrado+ 2009)
3. L328-IRS (Lee+ 2009, 2013)
4. L1148-IRS (Kauffmann+ 2011)
5. IC348- SMM2E (Palau+ 2014)

✧ Oph B-11: “Pre-Brown Dwarf” (Starless)
André+ 2012, Sci, 337, 69

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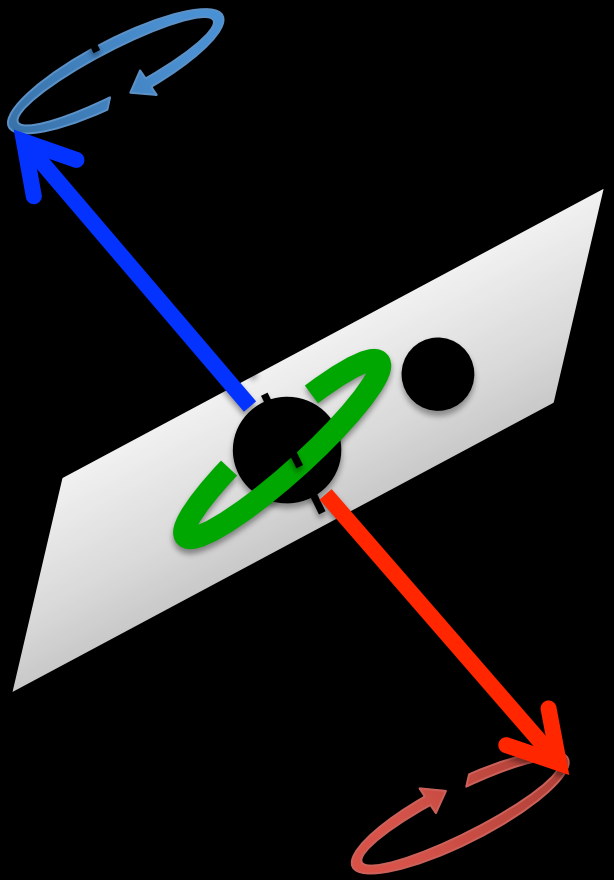
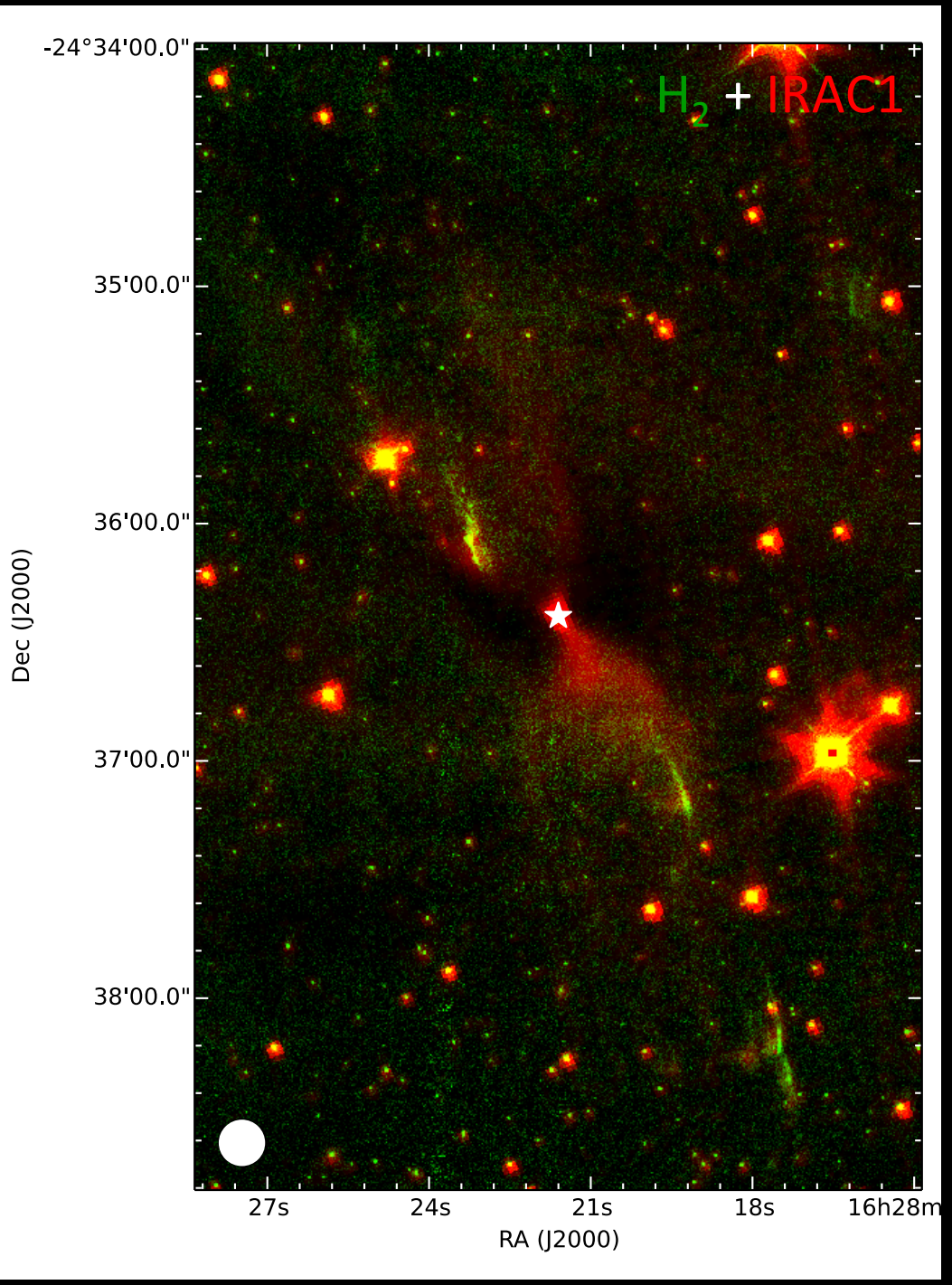
Binary system?





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Binary system

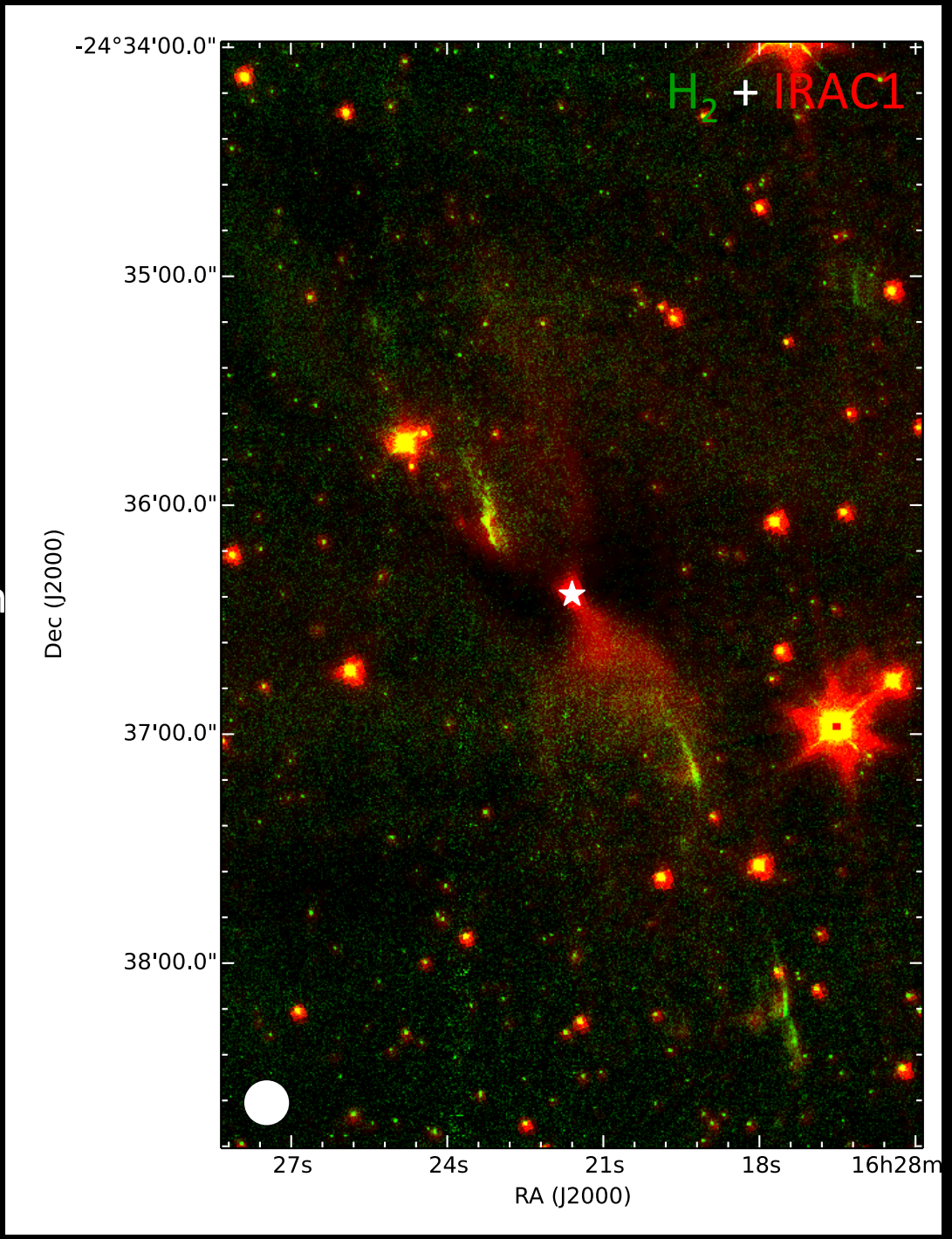
M_{env} =0.2-0.5 M_{sun}

SFE ~ 10-30%

M_{into} < 0.025-0.075 M_{sun}

Proto-BD binary?

M_{env}: Stanke+ 2006; Barsony+ 2010; Enoch+ 2008, SFE: Tachihara+ 2002; Jørgensen+ 2008



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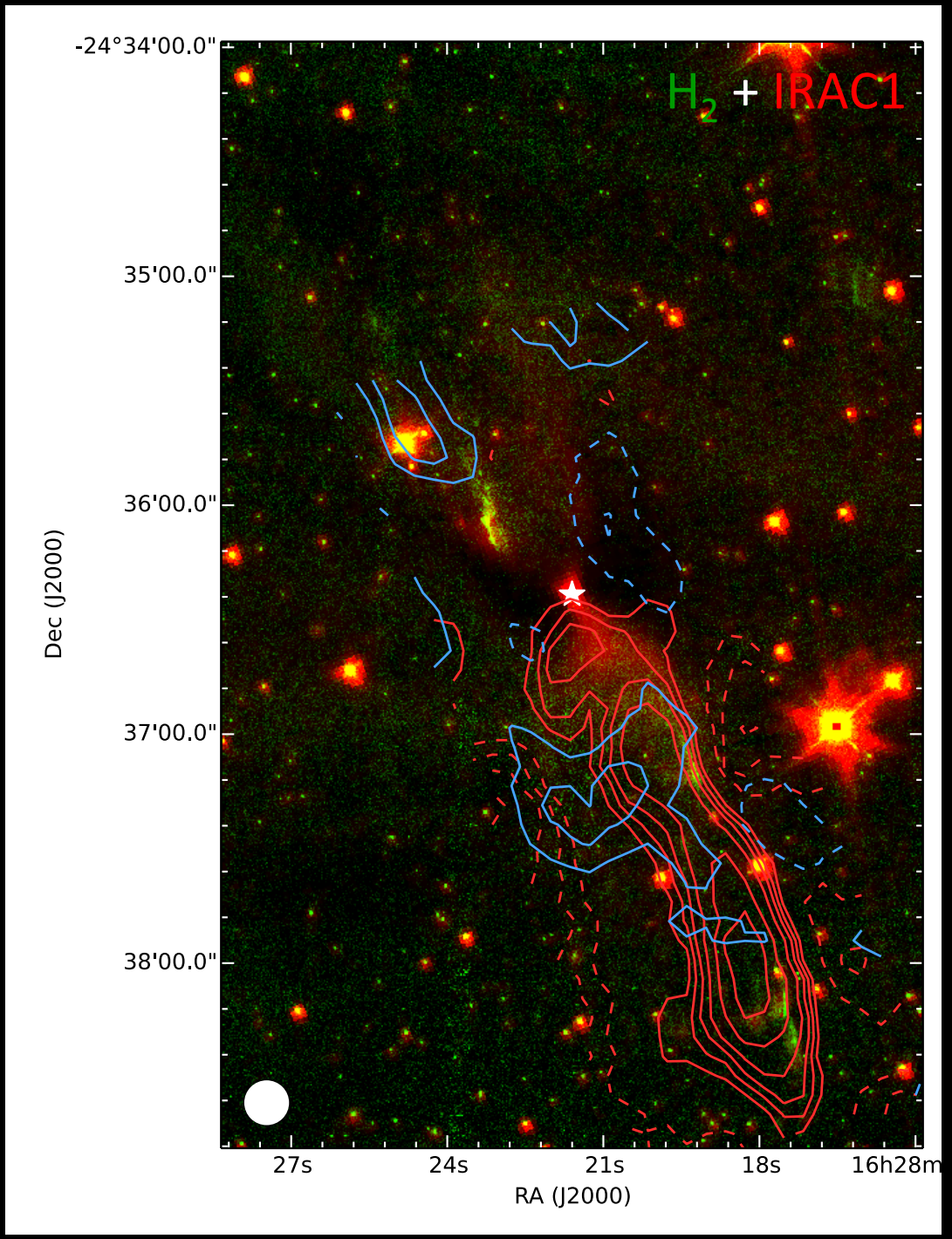
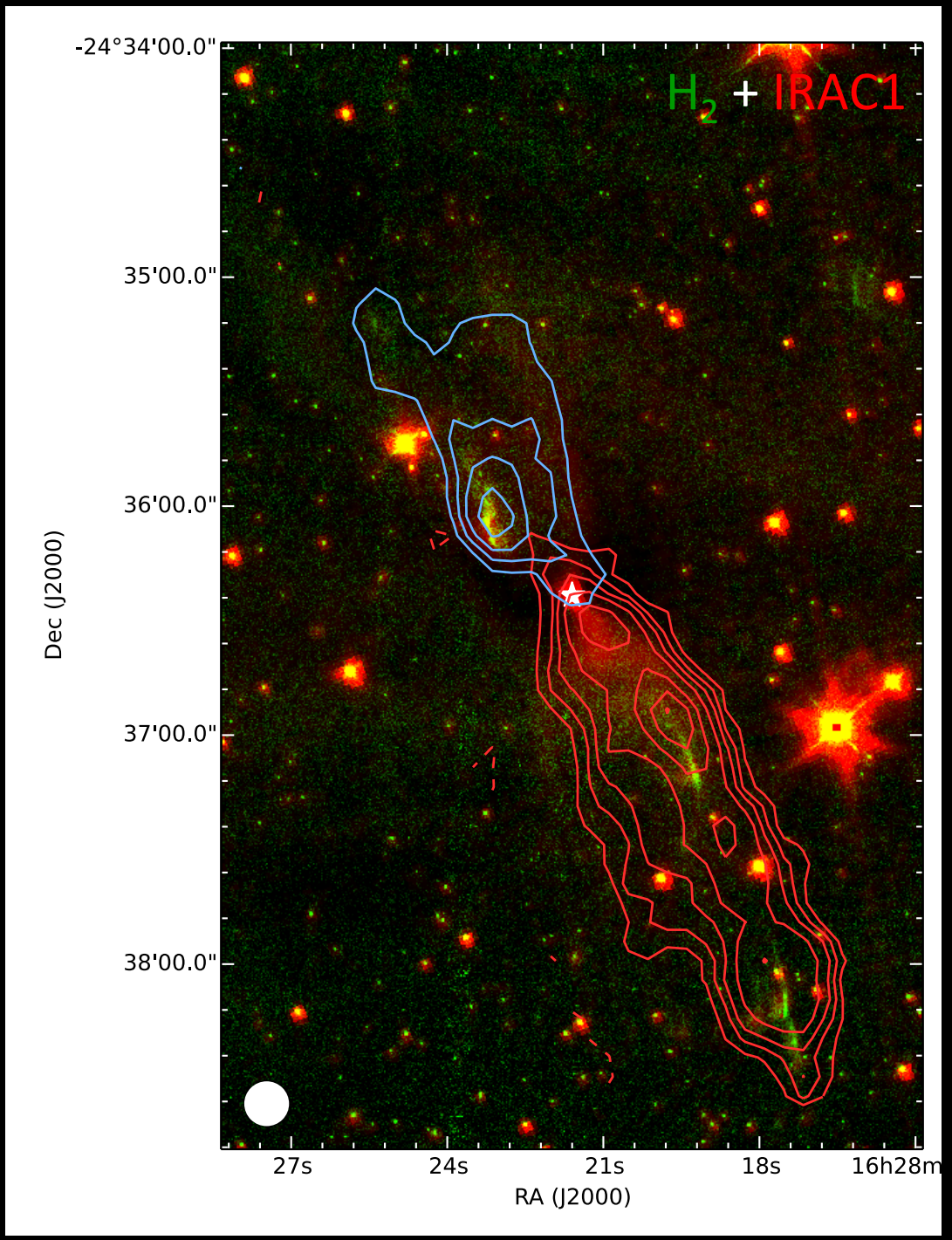
The outflow
IRAM 30m CO (2—1)
Cavity+Entrained gas

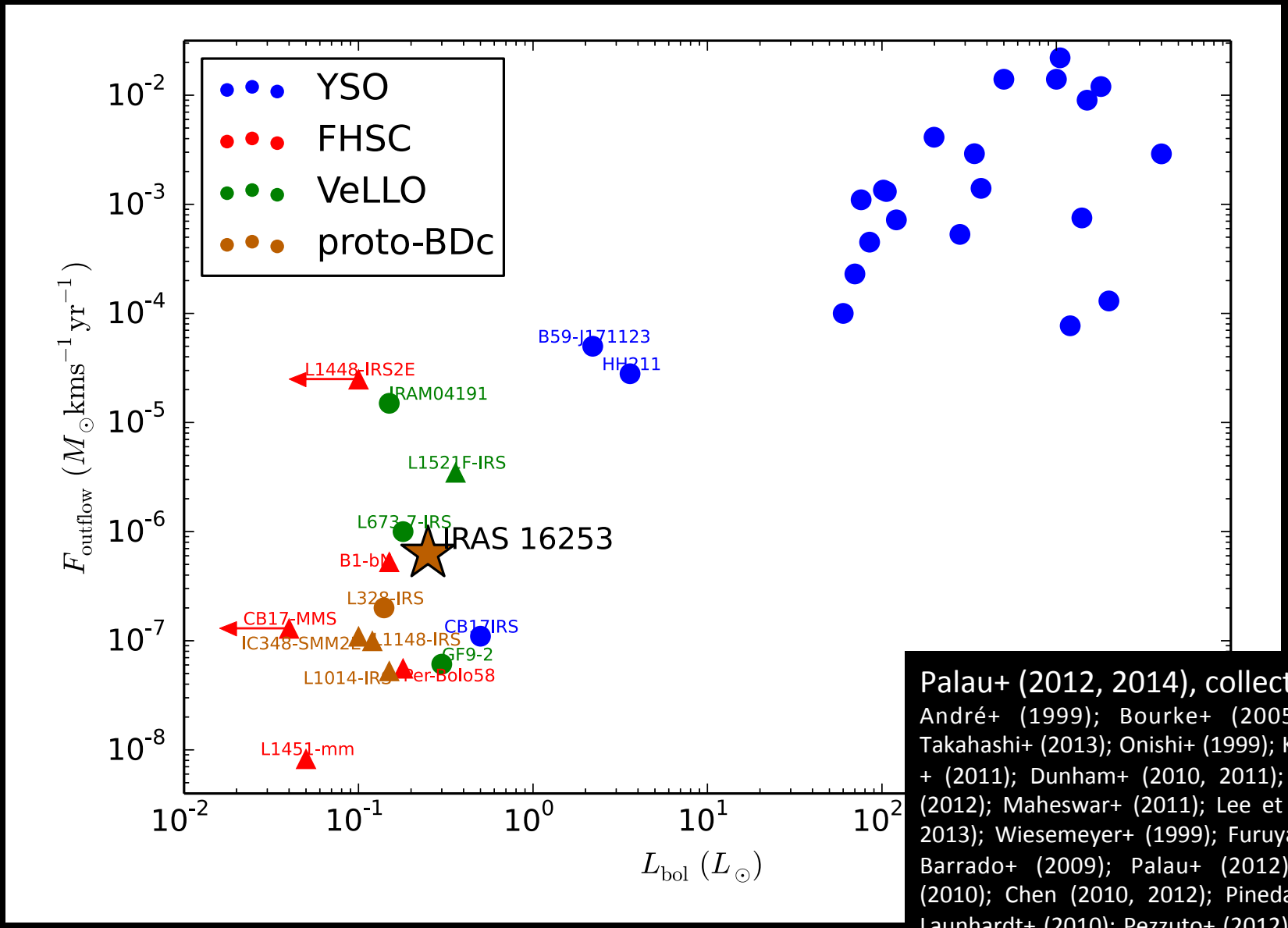


IRAS 16253

The outflow
IRAM 30m CO (2—1)
Cavity+Entrained gas
APEX CO (6—5)
Cavity+Collimated jet



Very low $F_{outflow}$



Palau+ (2012, 2014), collect from, André+ (1999); Bourke+ (2005, 2006); Takahashi+ (2013); Onishi+ (1999); Kauffmann + (2011); Dunham+ (2010, 2011); Schwarz+ (2012); Maheswar+ (2011); Lee et al. (2009, 2013); Wiesemeyer+ (1999); Furuya+ (2006); Barrado+ (2009); Palau+ (2012); Enoch+ (2010); Chen (2010, 2012); Pineda+ (2011); Launhardt+ (2010); Pezzuto+ (2012); Huang & Hirano (2013); Hirano & Liu (2014)…

SMA CO (2—1) map

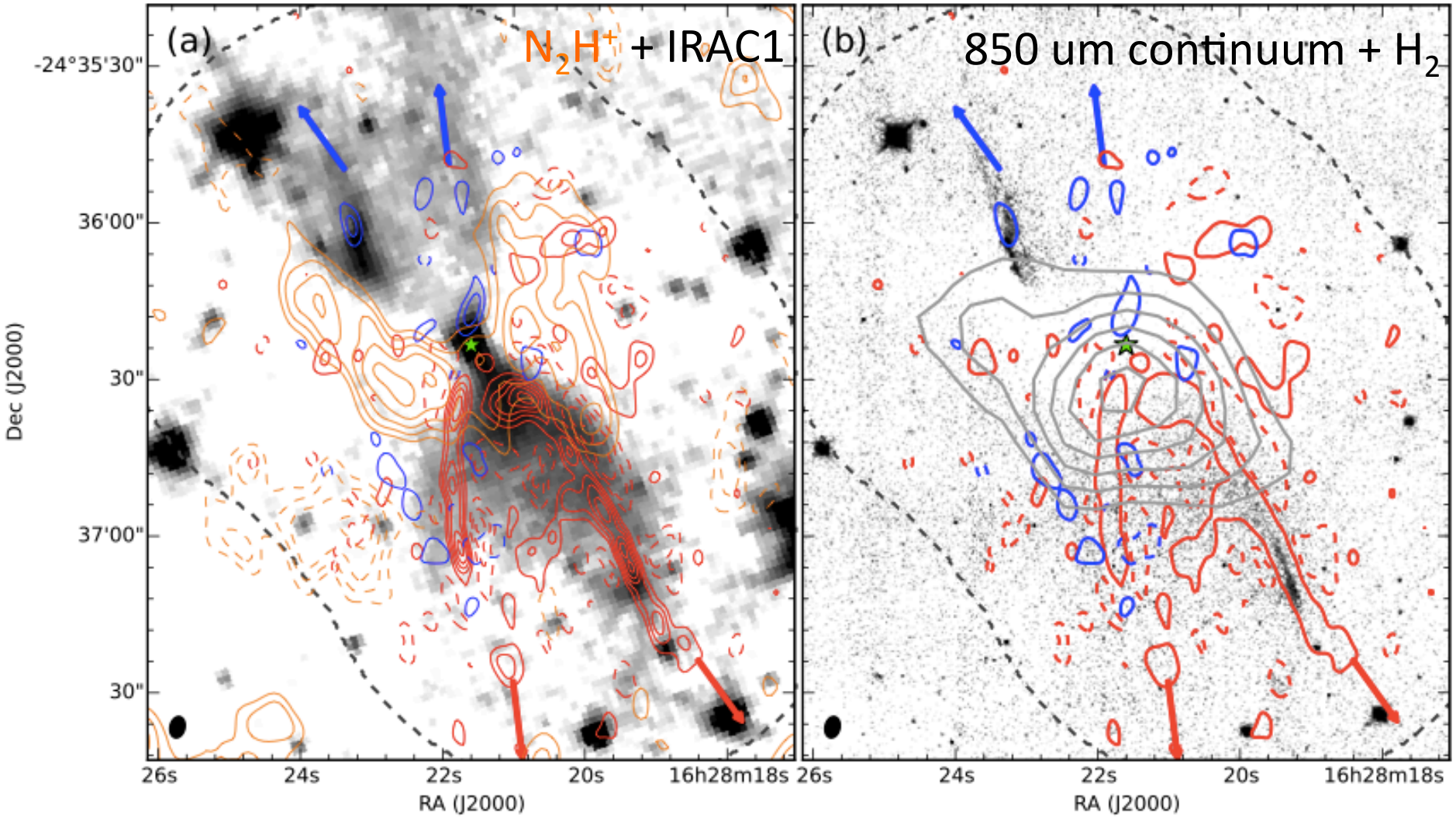
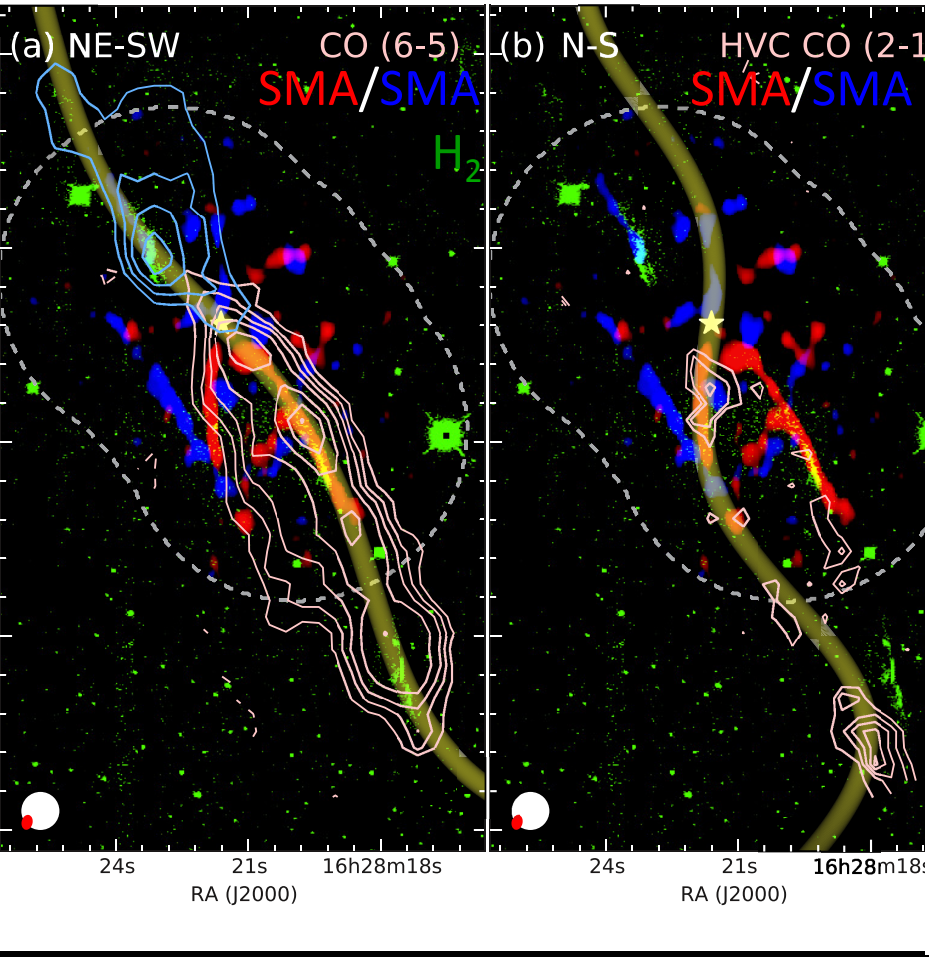
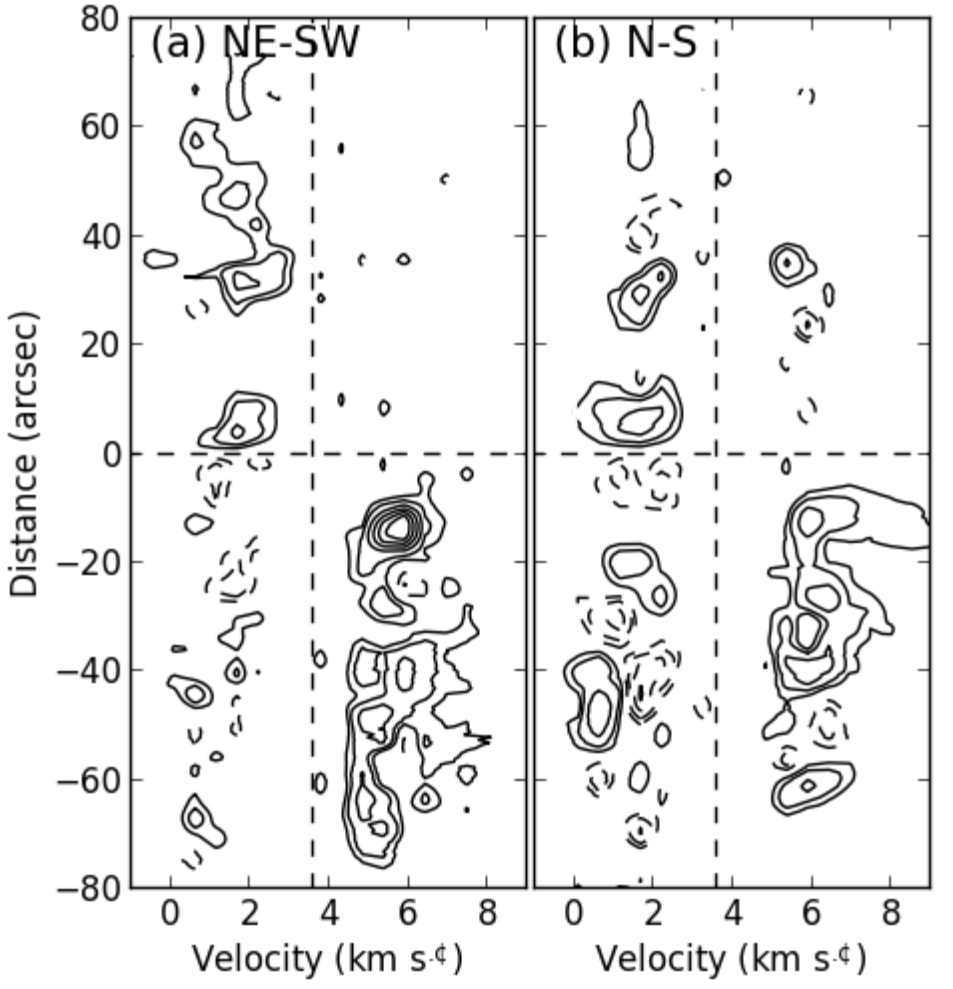


Figure 2. (a) SMA CO (2–1) integrated intensity maps with velocities spanning 0.7–2.7 km s^{-1} (blue) and 4.8–8.5 km s^{-1} (red) overlaid on the *Spitzer* IRAC 1 (3.6 μm) image. The contour levels are 5, 10, 15, 20, 25, and 30σ with rms noise levels of σ_{blue} = 0.326 Jy $beam^{-1}$ km s^{-1} and σ_{red} = 0.2 Jy $beam^{-1}$ km s^{-1}. The dashed line indicates the field of view of our SMA observations and the green star indicates the position of the infrared source. The orange contours show the same N_2H^+ (1–0) map as in Figure 1. (b) Same as (a), but with only the 5σ CO(2–1) contour overlaid on a CFHT H_2 image at 2.12 μm. The gray contours show the COMPLETE 850 μm continuum map with contour levels increasing from 3 to 8σ in steps of 1σ with σ = 0.056 Jy $beam^{-1}$.

SMA CO (2—1)

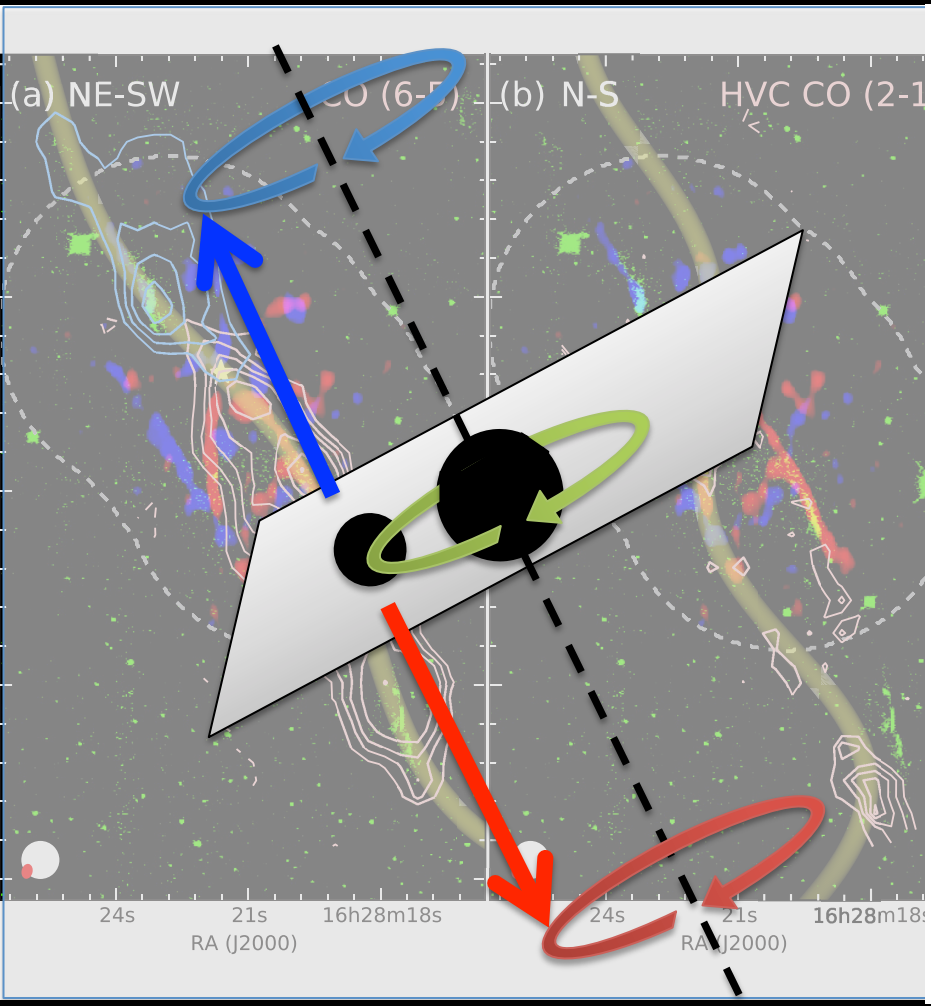
PV diagram
Wiggling?

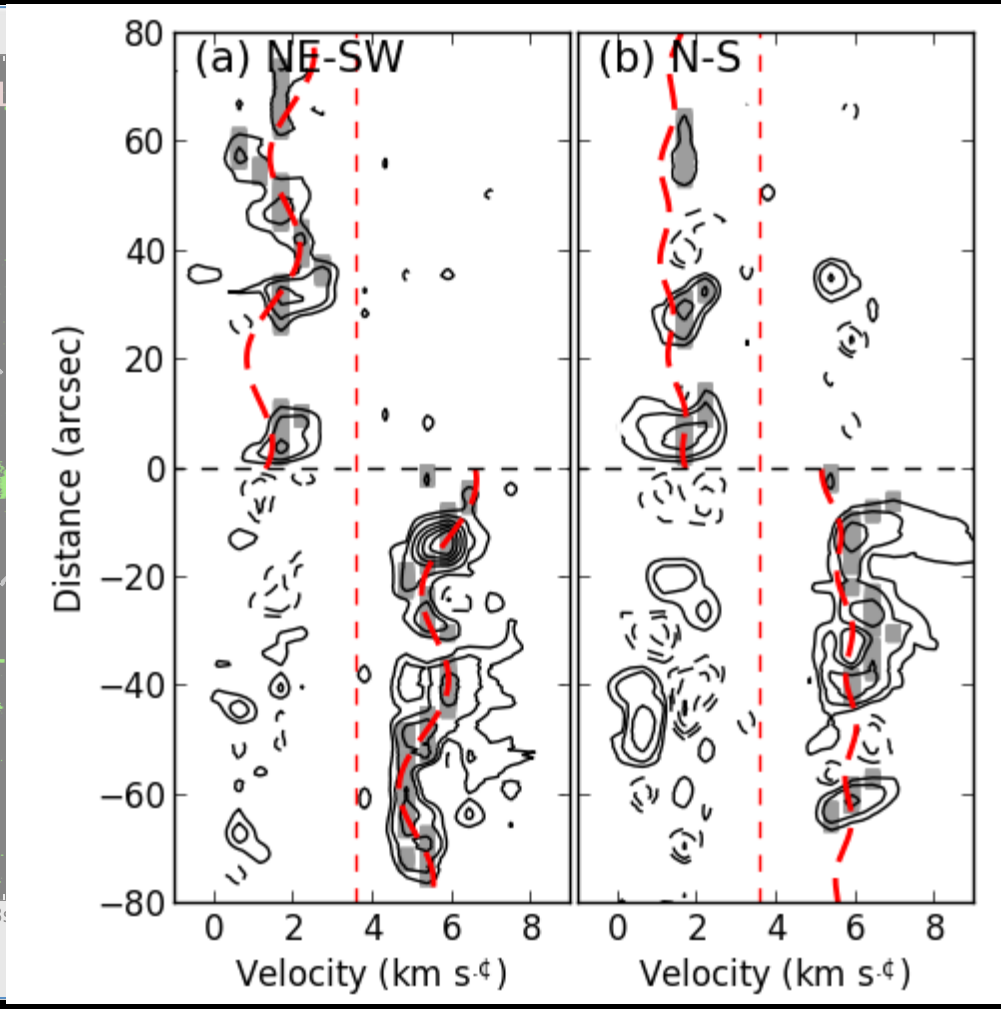




SMA CO (2—1)

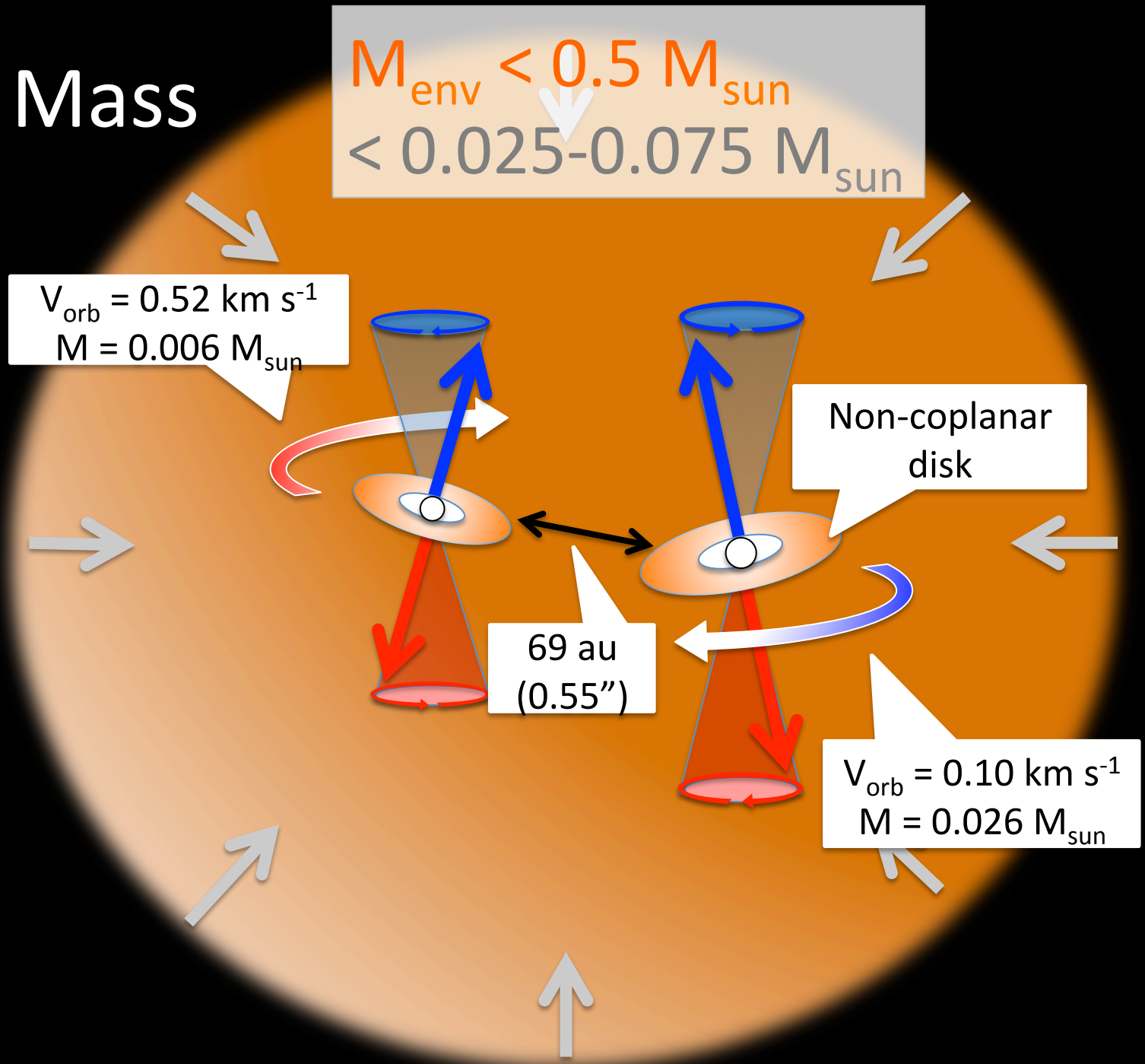
Orbital Wiggling Models





Lee et al. 2010; Raga et al. 2009

Final Mass


$M_{env} < 0.5\ M_{sun}$
$< 0.025\text{-}0.075\ M_{sun}$
$V_{orb} = 0.52\ km\ s^{-1}$
$M = 0.006\ M_{sun}$
Non-coplanar disk
69 au
(0.55”)
$V_{orb} = 0.10\ km\ s^{-1}$
$M = 0.026\ M_{sun}$

Summary

A proto-brown dwarf candidate – IRAS 16253-2429:

1. Outflow physical properties
   CO (2-1): Cavity+Entrained gas
   CO (6-5): Cavity+collimated jet
   Very low outflow force as proto-BDs or FHSC
2. Outflow dynamics:
   Orbital wiggling shown in PV diagram
   Keplers' law => M_{stars}: 0.026 and 0.006 M_{sun}

Thank you for your attention