SMA Survey of Low Luminosity YSOs in Perseus

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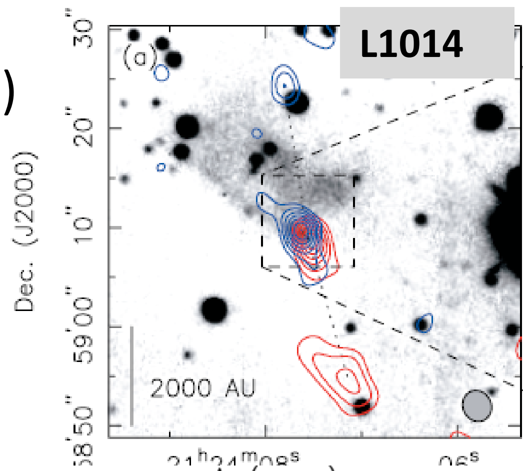
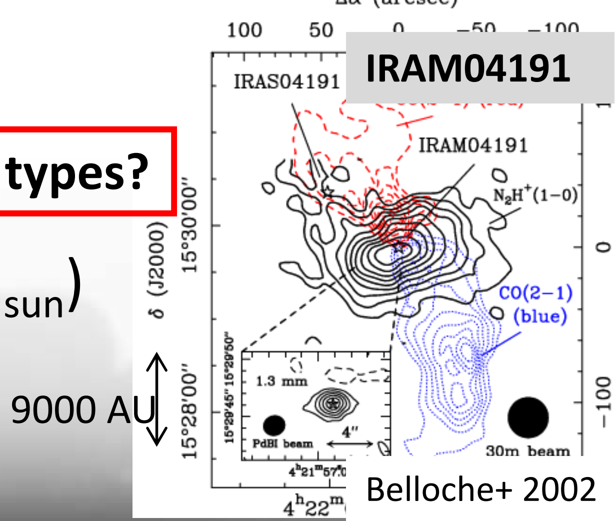
Introduction

- VeLLOs (Very Low Luminosity Objects)
  - Low luminosity object in “starless” cores (Young+ 2004)
  - Def: Internal luminosity < 0.1 L_{sun} (Di Francesco+ 2007)
- What is the nature of VeLLOs?
  - Extremely young protostar (Type 1)?
  - Proto-brown dwarf (Type 2) ?
- Large variation of the observed properties
  - IRAM04191 v.s L1014 IRS
  - Outflow (15,000AU, 0.03 M_{sun} v.s. 500AU, <10^{-4} M_{sun})
  - 230GHz continuum (29 mJy v.s. 7 mJy)

Mixture of 2 types?



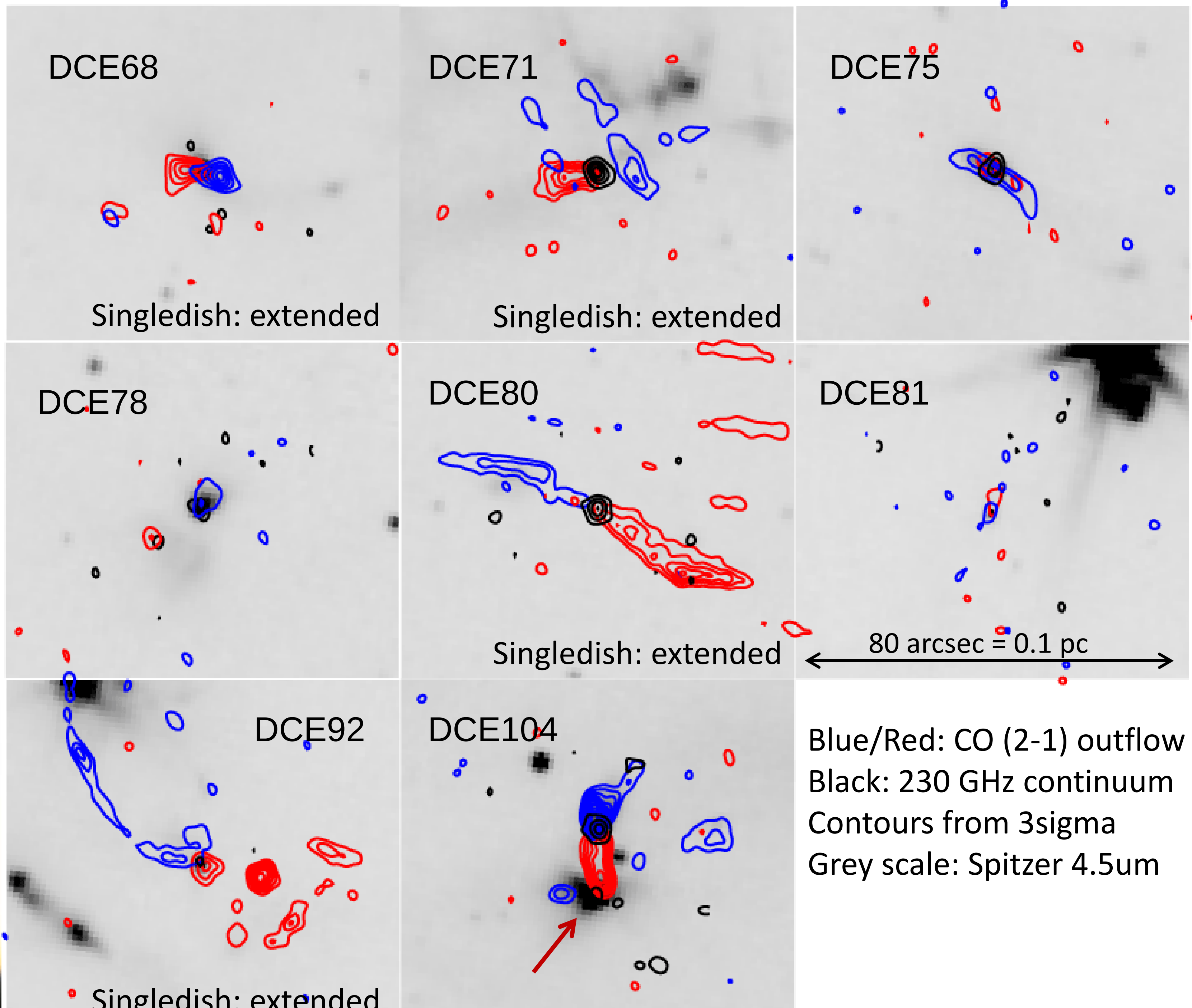


Belloche+ 2002

SMA Observation

- Purpose：
 Distinguish the very young protostar (Type 1) and Proto-brown dwarfs (Type 2) based on Continuum flux/CO outflow
- Observations：2009/11/27, 12/21, 2010/04/02:
 SMA compact-configuration, 230 GHz
- Targets: 8 low luminosity YSOs in Perseus (D = 250 pc),
 listed in Dunham et al. (2008):
  - Accompanied with mm/submm (SCUBA/Bolocam) cores
  - T_{bol} < 70 K
  - $L_{bol} < 1 L_{sun}$ (maximum L_{bol}: $0.64 L_{sun}$)：slightly brighter than VeLLOs
- Synthesized beam ~3.5” x 3.0” (~880 x 750 AU @ 250 pc)
- CLEANed with *Miriad*, imaging with Natural weighting

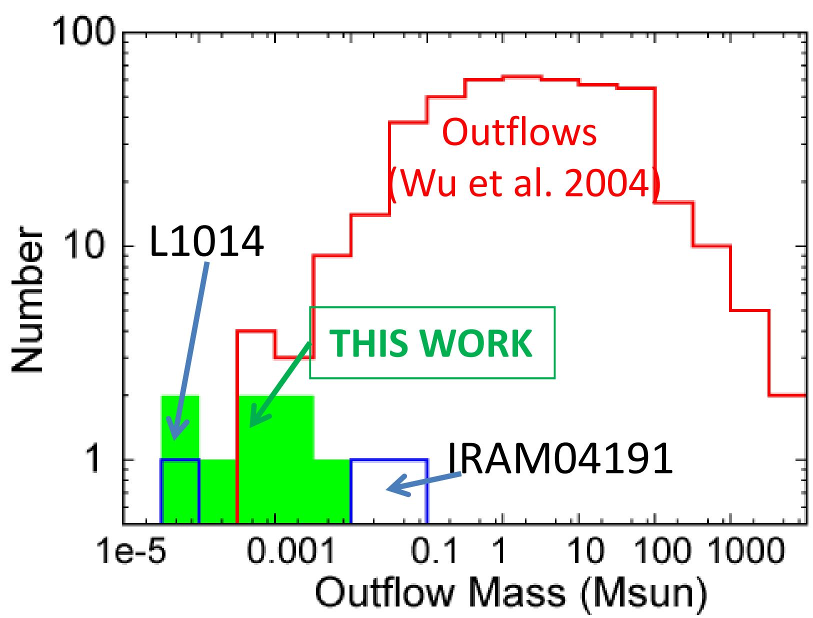
Results

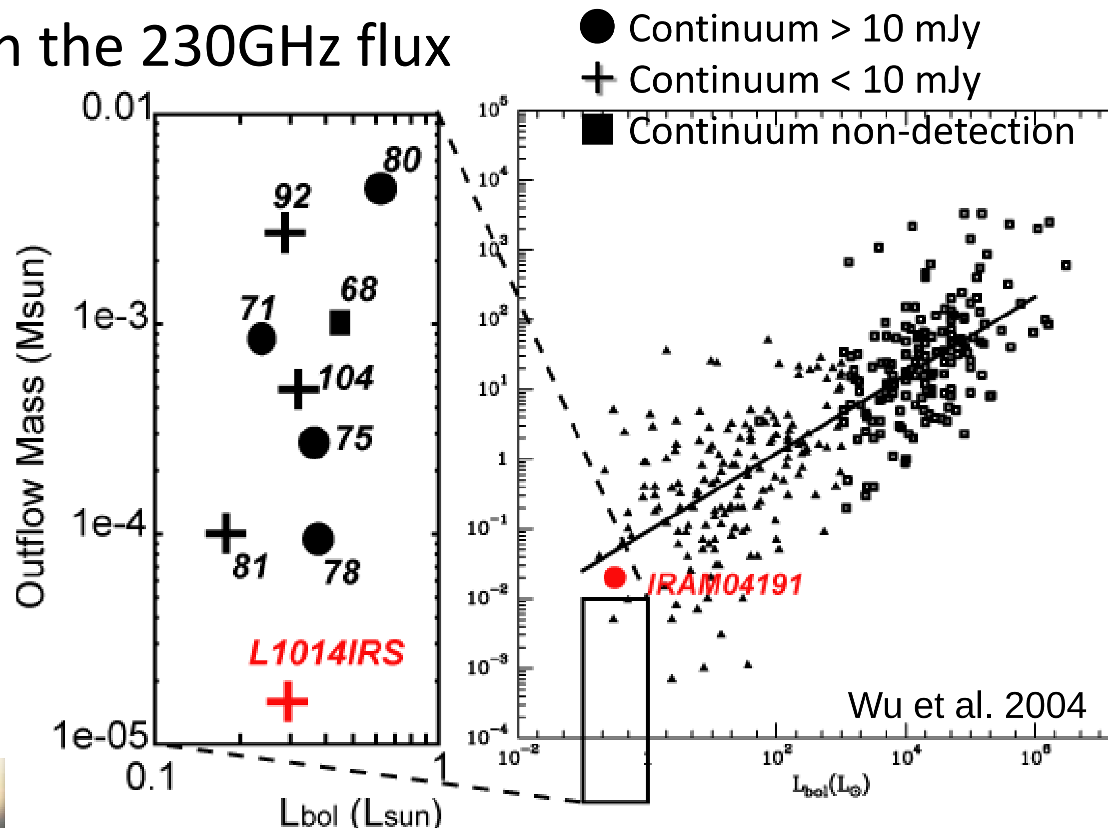


Blue/Red: CO (2-1) outflow
Black: 230 GHz continuum
Contours from 3sigma
Grey scale: Spitzer 4.5um

CO Outflow

- Less massive (< 1x10^{-4} ~ 4x10^{-3} M_{sun}) than those from typical YSOs
- Continuous distribution between L1014/IRAM04191
- Unclear relation between the 230GHz flux



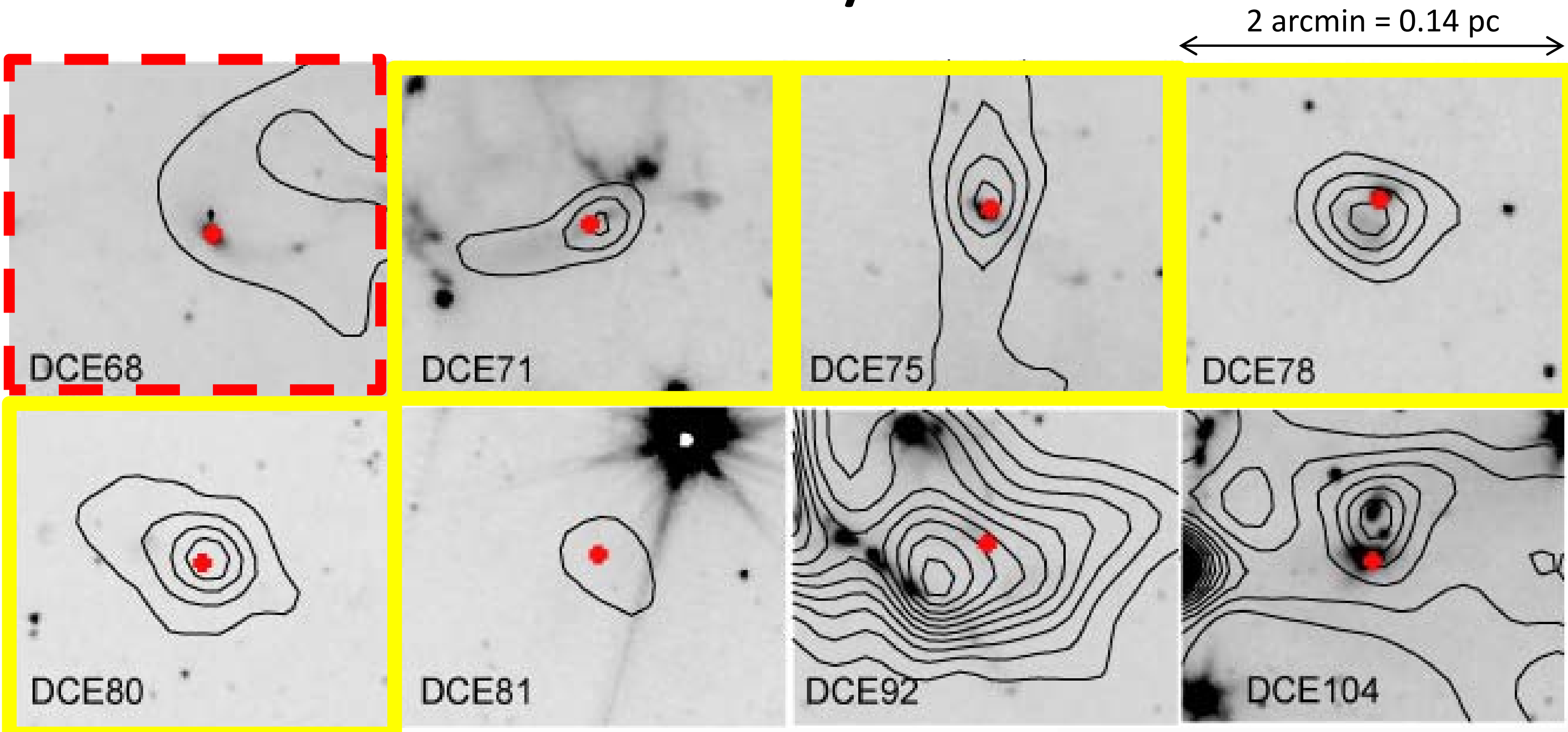


CO outflow and Mass accretion

- Outflow mass (< 1×10^{-4} ~ 4×10^{-3} M_{sun})
- Assuming *Outflow Mass-loss rate ~ Mass accretion rate to star* , the masses of the central YSO are also 1×10^{-4} ~ 4×10^{-3} M_{sun}

- The lifetime of Class 0 objects: 10^4 ~10^5 yr (Enoch et al. 2009)
- In order to obtain this mass in 10^4yr, $\dot{M}_{acc}$ = 4×10^{-7}~1×10^{-8} M_{sun}/yr (Assuming the inclination angle of 57.3, the dynamical timescales ~5×10^3 yr)
- 2 orders of magnitudes smaller than the typical accretion rate (~10^{-6} M_{sun}/yr, Shu 1977)

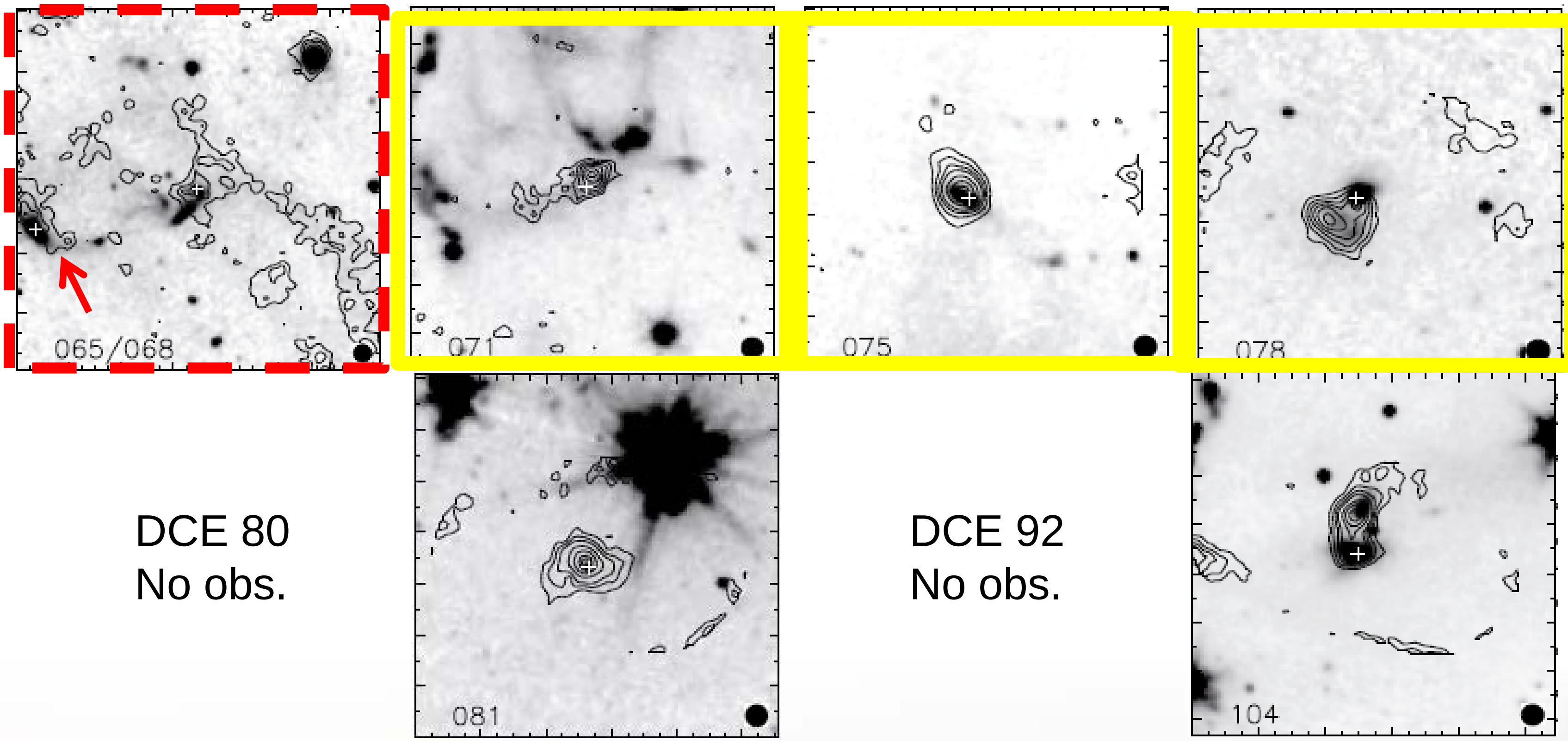
SMA continuum / SCUBA core



Contour: SCUBA 850um (Ridge+2006)
Lowest contour & interval: 100 mJy/beam

- Sources with > 10mJy [0.03M_{sun} @ 20K] SMA continuum (yellow box):
  - Located at the center of the well-shaped SCUBA core
- Sources with SMA continuum non-detection (3sigma: 3.6mJy/beam, red box)
  - Located at the periphery of the 850um emission

SMA continuum / SHARC-II core

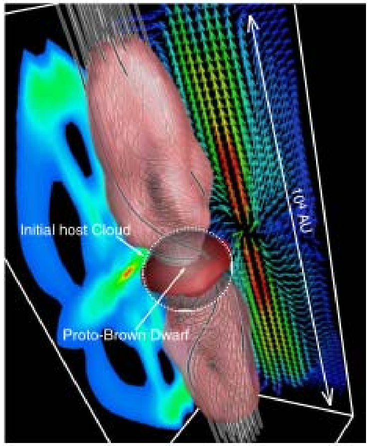


Contour: SHARC-II 350um (Hatchell & Dunham 09)

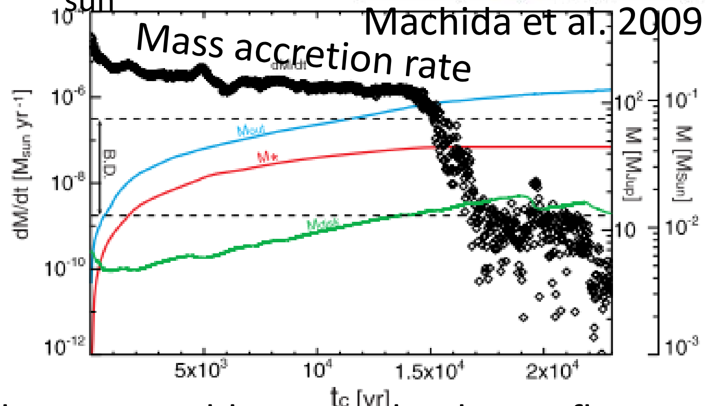
- DCE68 is located at the edge of the 350um emission
- DCE68 is the only source detected in NIR (*2MASS*) in our samples.

  -> smaller amount of the circumstellar component

DCE68 & Proto-BD



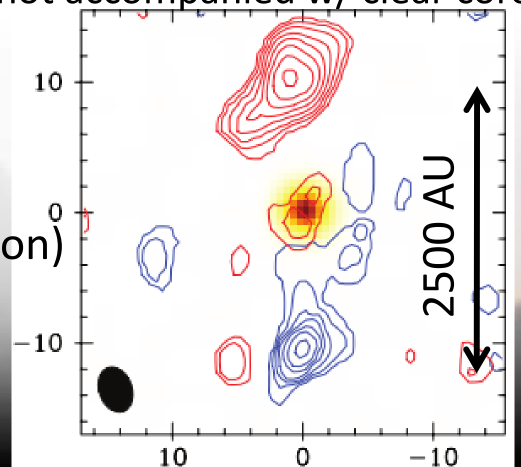
- BD formation simulation (Machida+2009)
  - Rotating, magnetized core: R=1300AU, 0.22M_{sun}
  - BD :Mass 0.045 M_{sun}
    Envelope: 0.1 M_{sun}, Disk: 0.01M_{sun}
    Outflow: 0.1M_{sun}, 5x10^3 AU



DCE68
- Envelope: 0.19 M_{sun} in 8000 AU
- SMA Cont. < 3.6mJy (0.01 M_{sun}@20K)
- Outflow: 1x10^{-3} M_{sun}, 6x10^3 AU

Half of the core are blown out by the outflow
-> Grav. Potential, Mass accretion rate decreases.
Similar to DCE68: not accompanied w/ clear core

- Outflow from BD (Phan-Bao et al. 2008)
  - M6-star ISO-Oph 102 (Mass: 0.06 M_{sun})
  - Outflow mass: 3.2x10^{-5} M_{sun} (without opacity correction)



Summary

- SMA Survey of 8 low-luminosity YSOs in Perseus
- We examined the classification of (Ve)LLOs into 2 types with compact continuum emission & CO outflow.
- CO outflow mass: continuous distribution b/w Type1/2 candidates (IRAM04191 & L1014). Less massive than the outflow from typical protostars.
- No continuum was detected around DCE68, which is located at the periphery of a SCUBA core. Envelope mass, disk mass, outflow size is comparable to those of the BD formation simulation (Machida et al. 2009): Good candidate for Type 2.
- Sources like DCE68 (offset from SCUBA peak): Type2 candidate? More samples are needed to confirm.

Unclear correlations