The Low End of the Protostellar Luminosity Distribution

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Very Low Mass Stars and Brown Dwarfs
ESO, Garching, Germany
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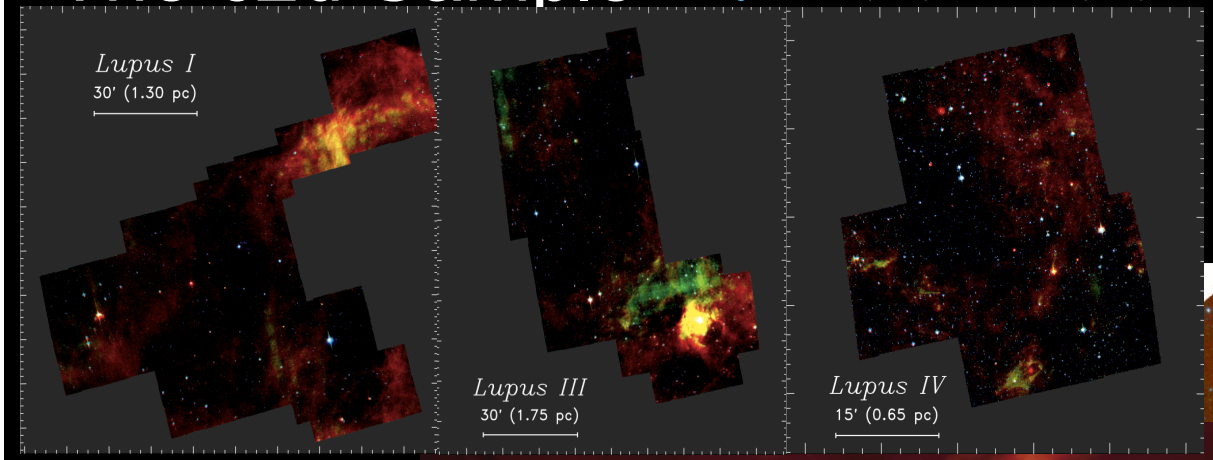
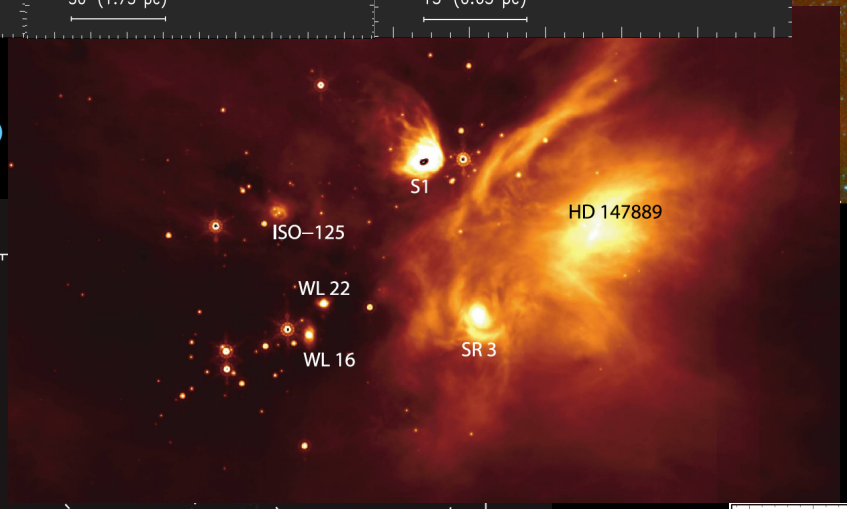
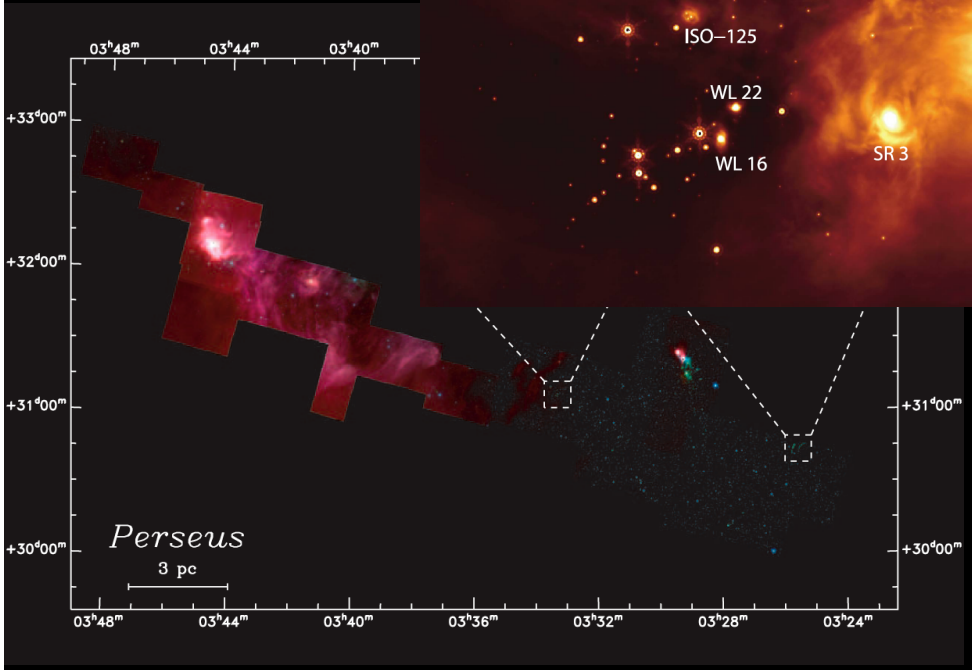
The c2d Sample

Chapman et al. (2007); Merin et al. (2008)



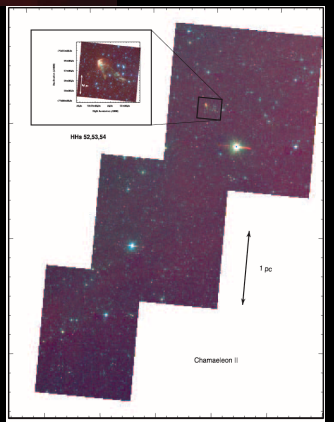
Padgett et al. (2008)

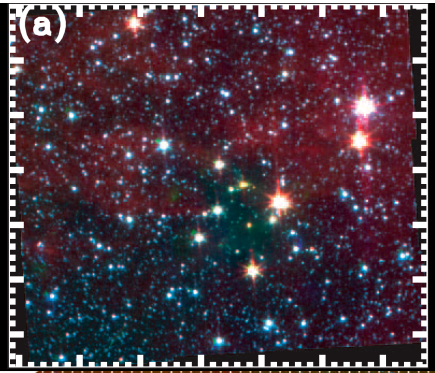




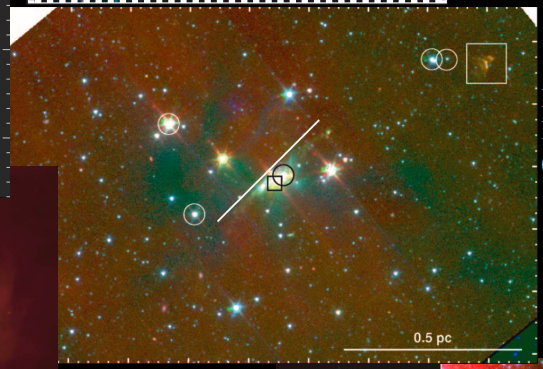
Jorgensen et al. (2006); Rebull et al. (2007)

Young et al. (2005); Porras et al. (2007); Alcala et al. (2008)

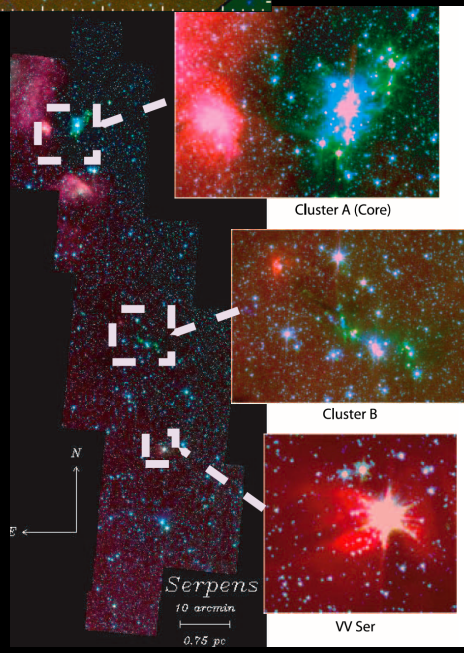




B59; Brooke et al. (2007)



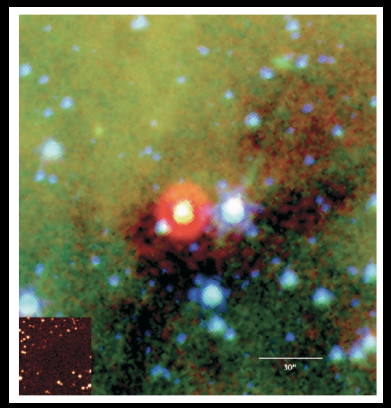
L1251B/E Lee et al. (2006)



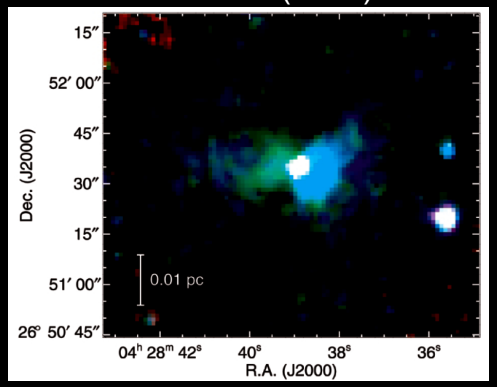
Harvey et al. (2006); Harvey et al. (2007a); Harvey et al. (2007b)

VeLLOs

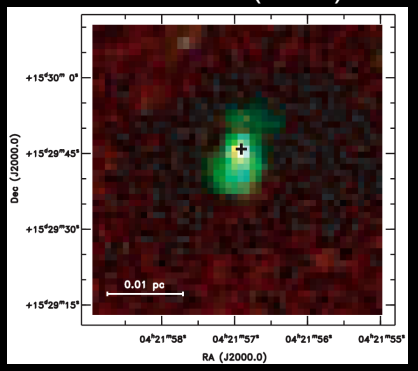
L1014-IRS
L_{int} ~ 0.09 L_{sun}
Young et al. (2004)



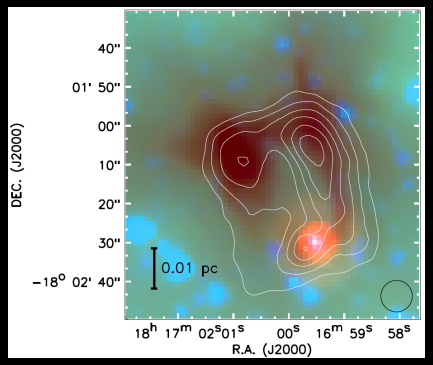
L1521F-IRS
L_{int} ~ 0.05 L_{sun}
Bourke et al. (2006)



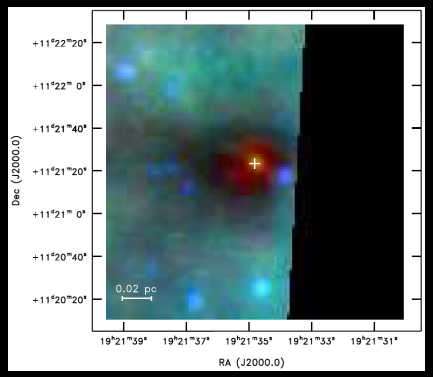
IRAM 04191-IRS
L_{int} ~ 0.08 L_{sun}
Dunham et al. (2006)



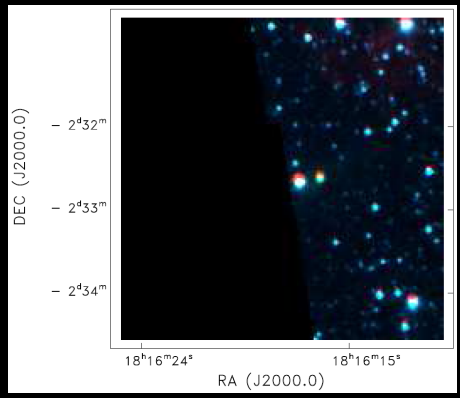
L328-IRS
L_{int} ~ 0.04 - 0.06 L_{sun}
Lee et al. (2009)



L673-7-IRS
L_{int} ~ 0.04 L_{sun}
Dunham et al. (2010b)



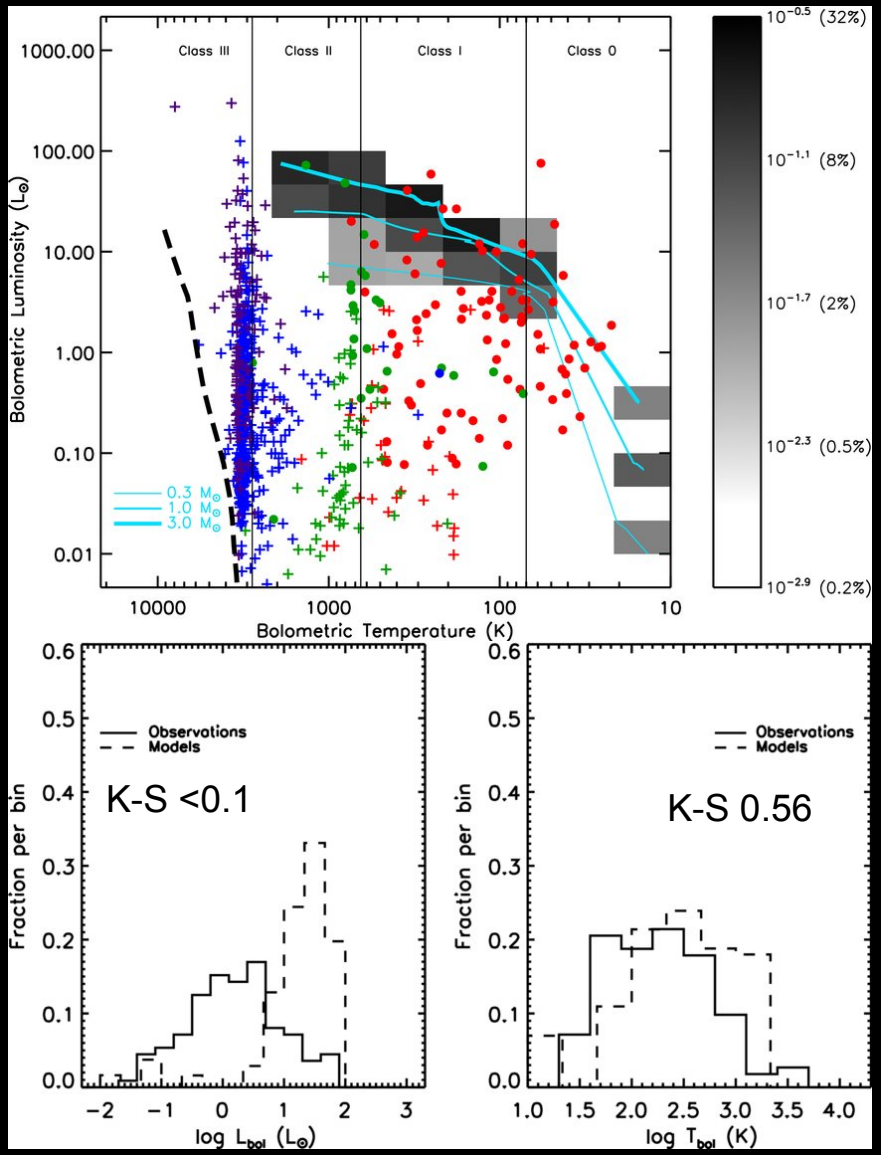
CB130-1-IRS1
L_{int} ~ 0.15 L_{sun}
Kim et al. (2011)



15% - 25% of starless cores not starless according to *Spitzer* c2d

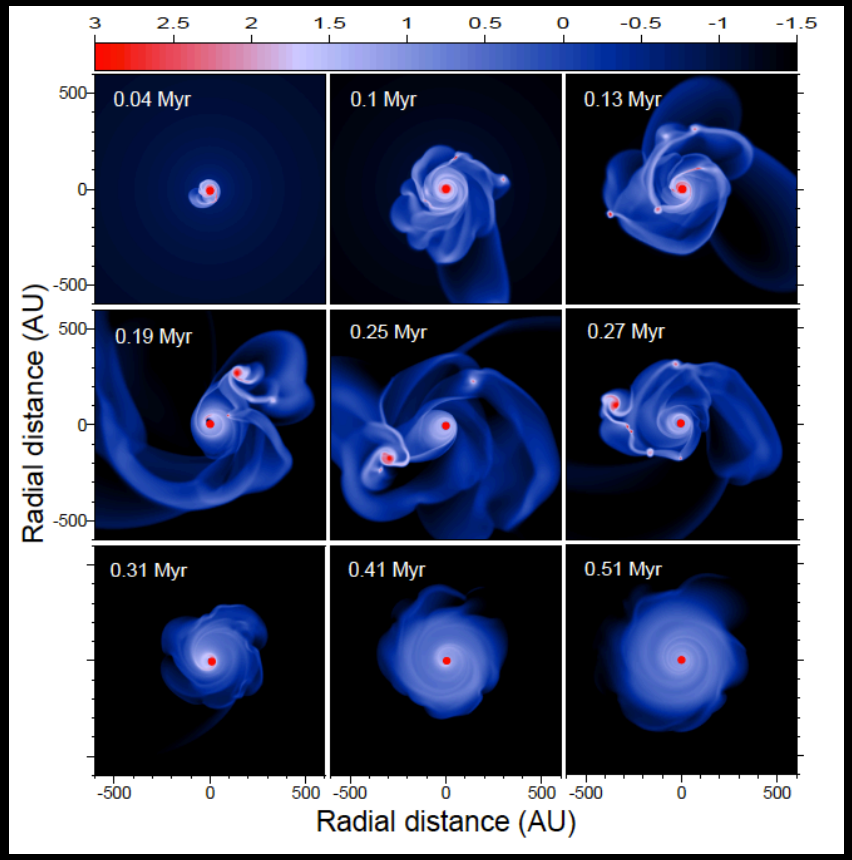
Dunham et al. (2008)

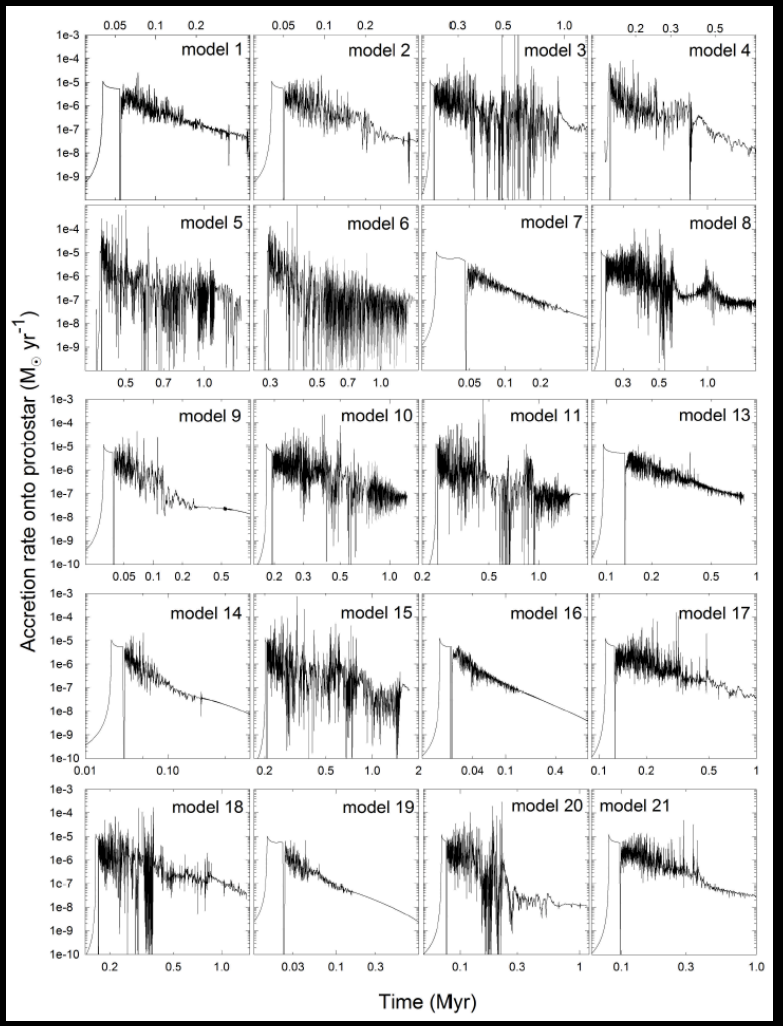
c2d Results



Evans, Dunham et al. (2009)
Dunham et al. (2010a)
Enoch et al. (2009)
Dunham et al. (2008)
Young & Evans (2005)

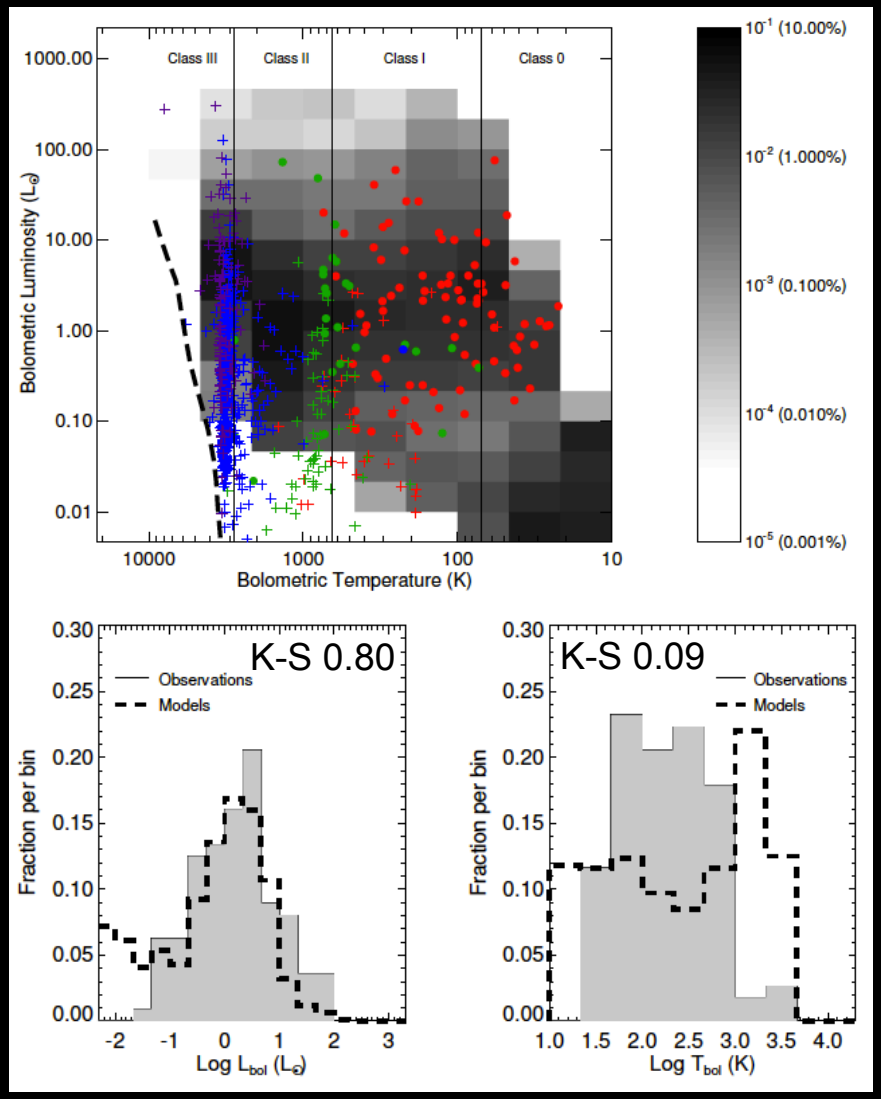
Variable Mass Accretion





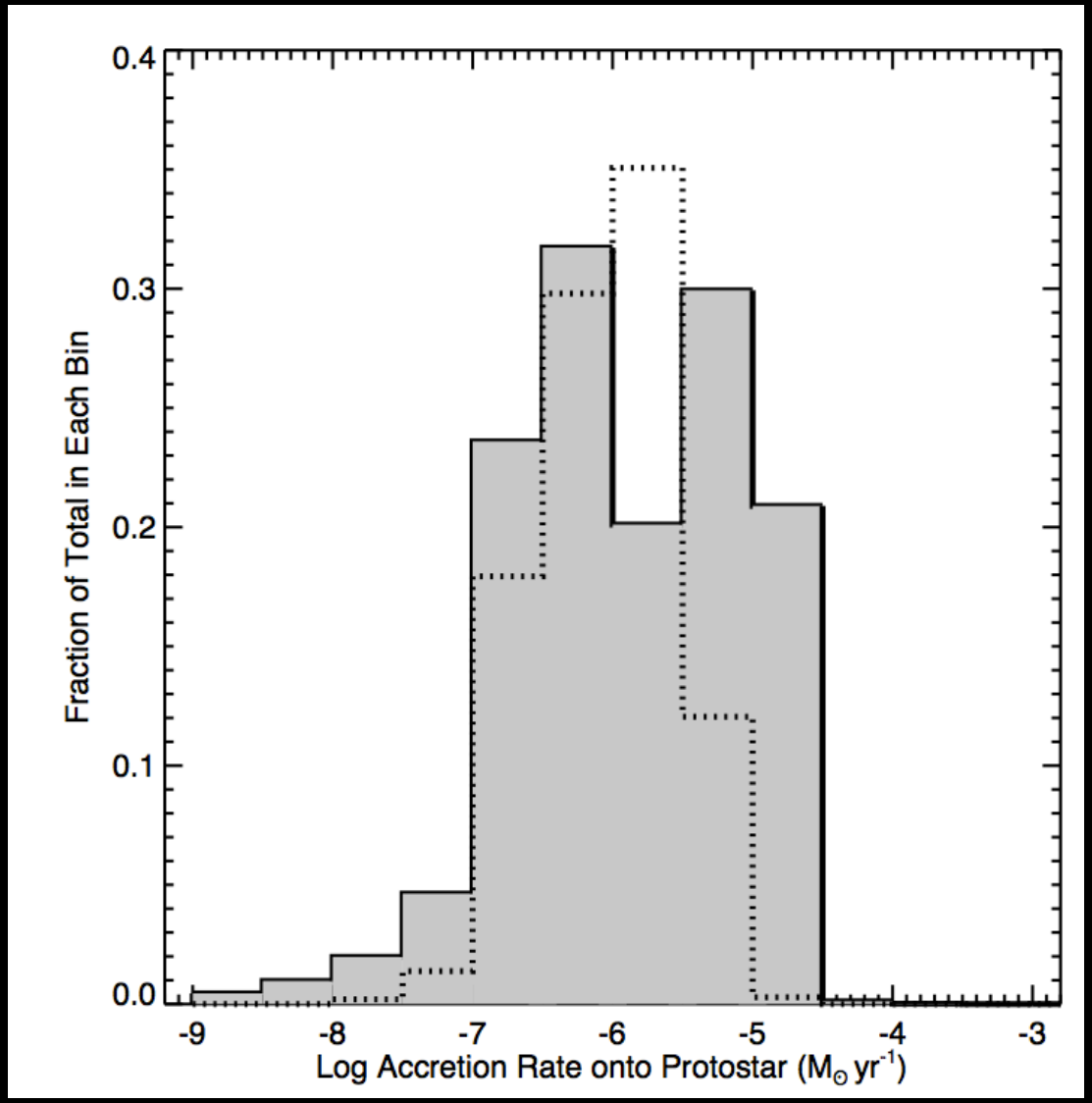
Vorobyov & Basu (2005, 2006, 2010)

Variable Mass Accretion



Dunham & Vorobyov (2011), submitted

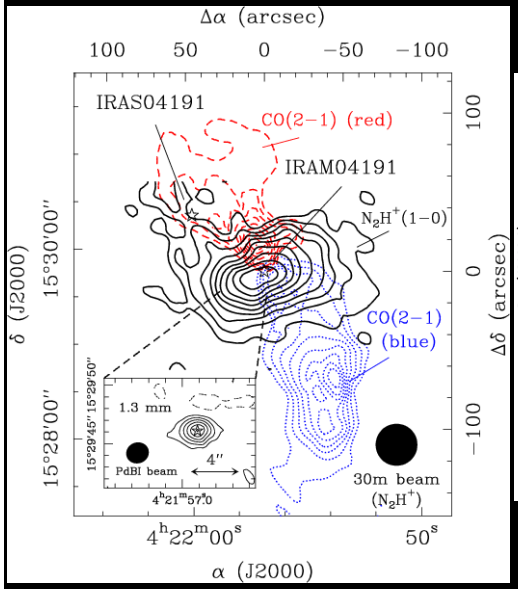
Do the Bursts Matter?



Evidence for Bursts?

- FU Ori objects
- Best confirmation: 0.1 - 1 L_{sun} protostar → 10 – 100 L_{sun} (or the reverse)
- Would we see this? (embedded!)
- Very little IR/(sub)mm time-domain monitoring, changing now (YSOVAR, etc)
- Chemistry
- Molecular Outflows

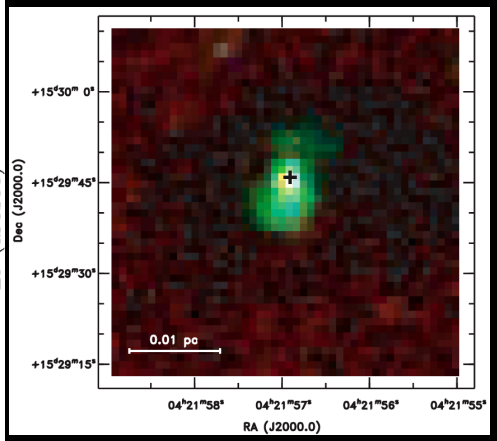
IRAM 04191+1522



Andre et al. (1999)

L_{int} ~ 0.08 L_{sun} (measured)

L_{acc} ~ 2 L_{sun} (inferred)

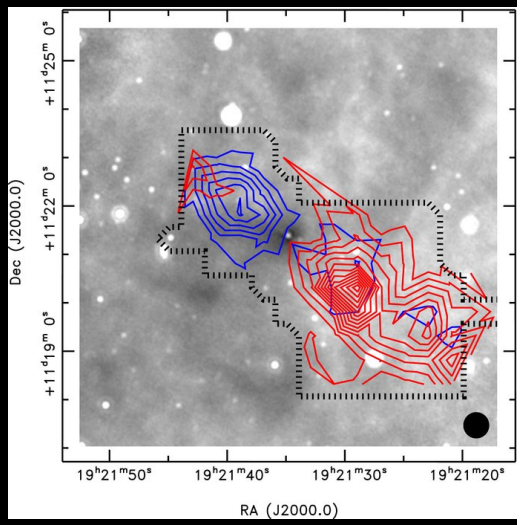


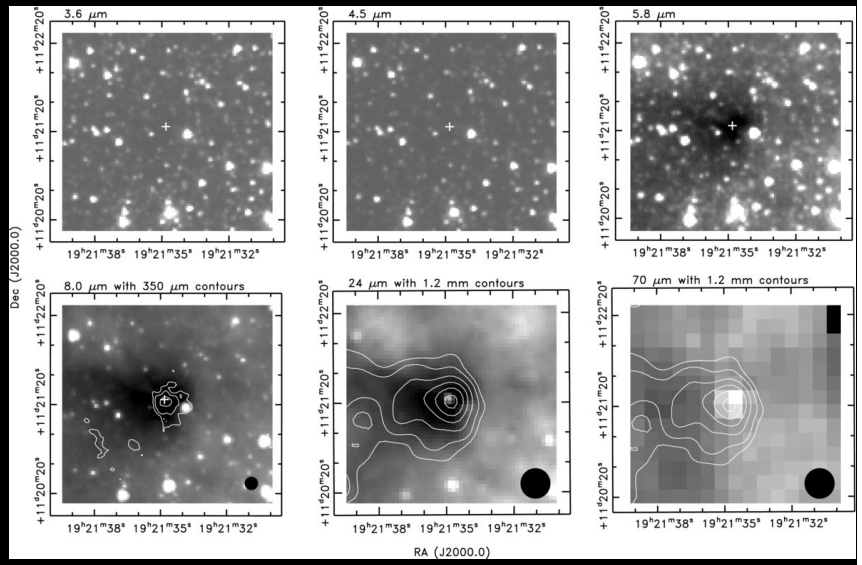
Dunham et al. (2006)

L_{int} ~ 0.04 L_{sun} (measured)

L_{acc} > 0.33 L_{sun} (inferred)

L673-7

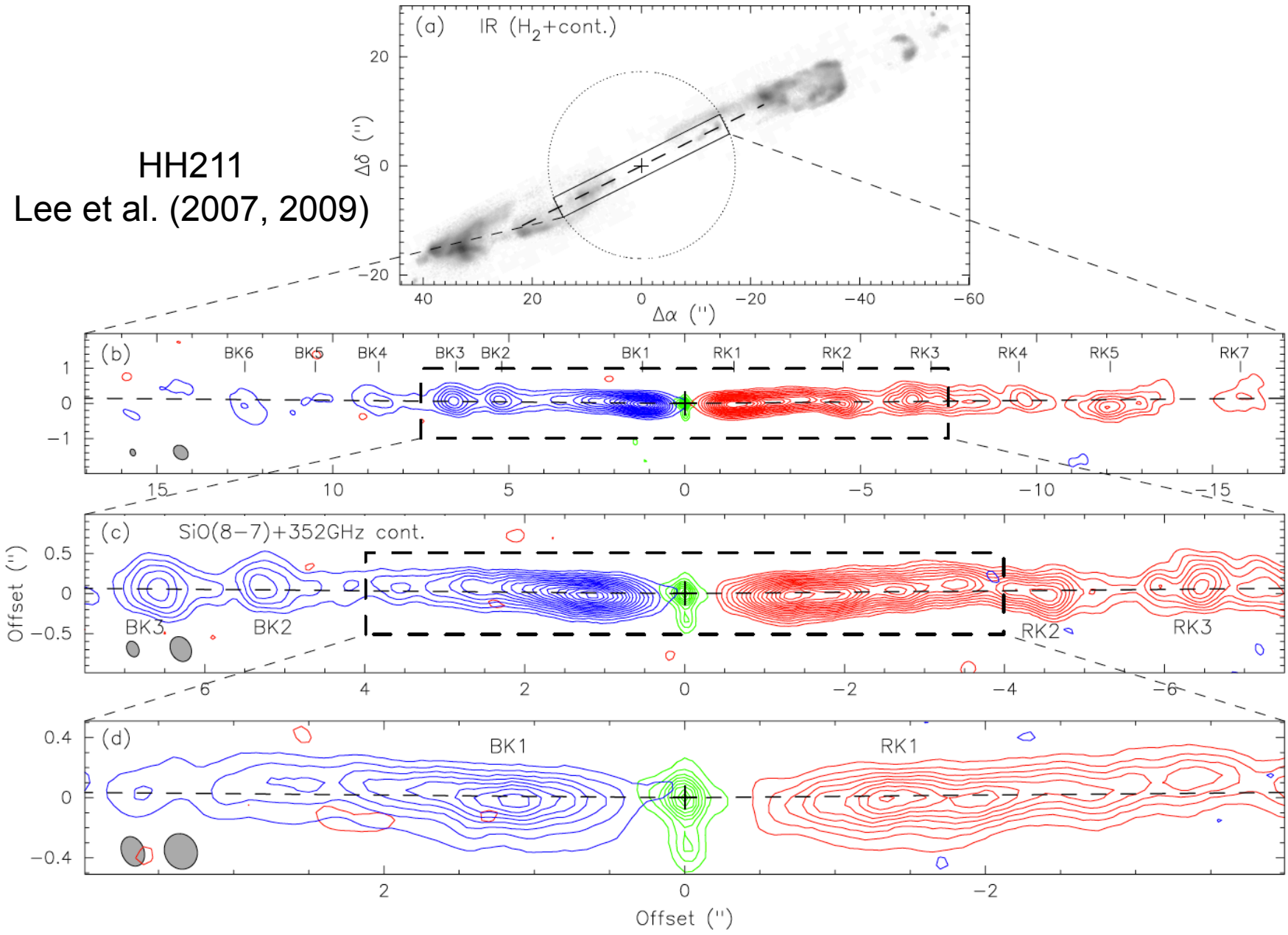




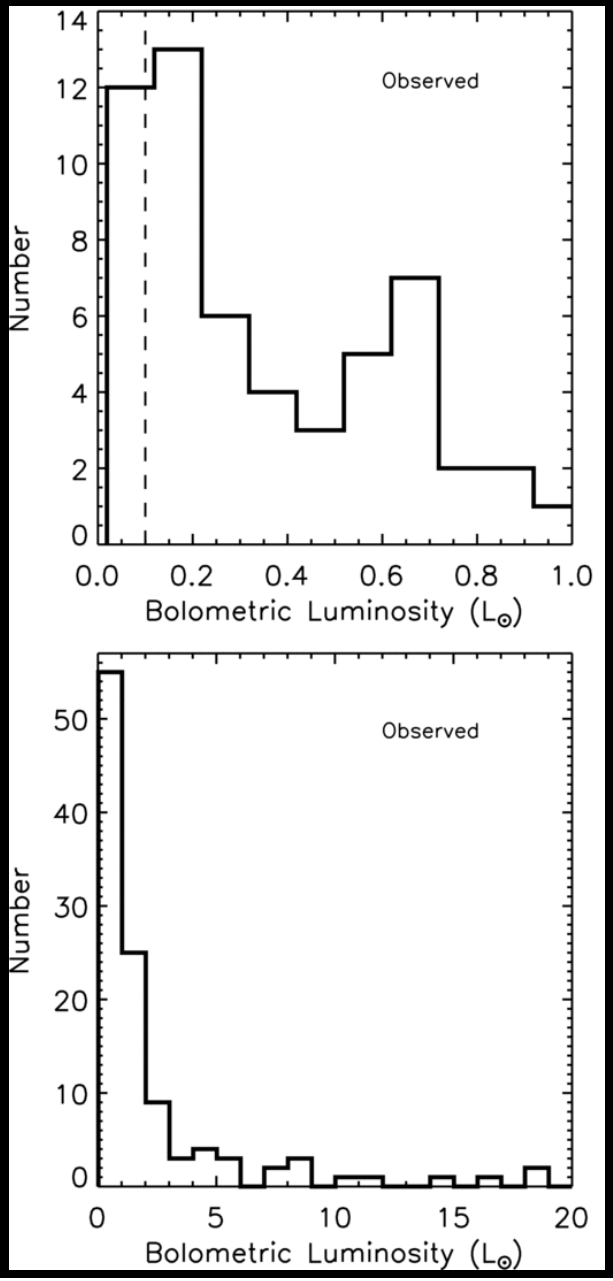
Dunham et al. (2010b)

Evidence for Bursts?

HH211
Lee et al. (2007, 2009)

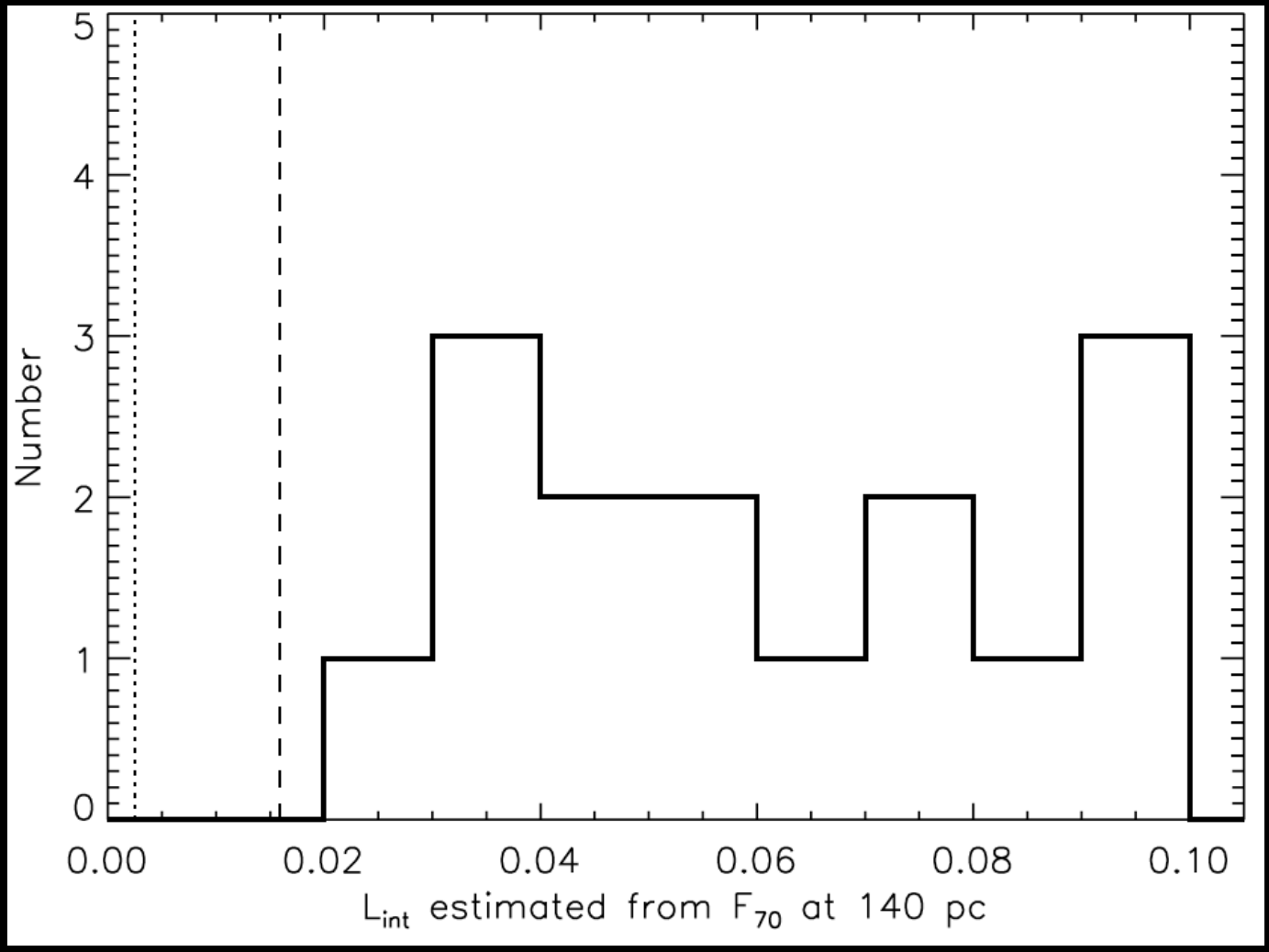


How Low?



Evans, Dunham et al. (2009)

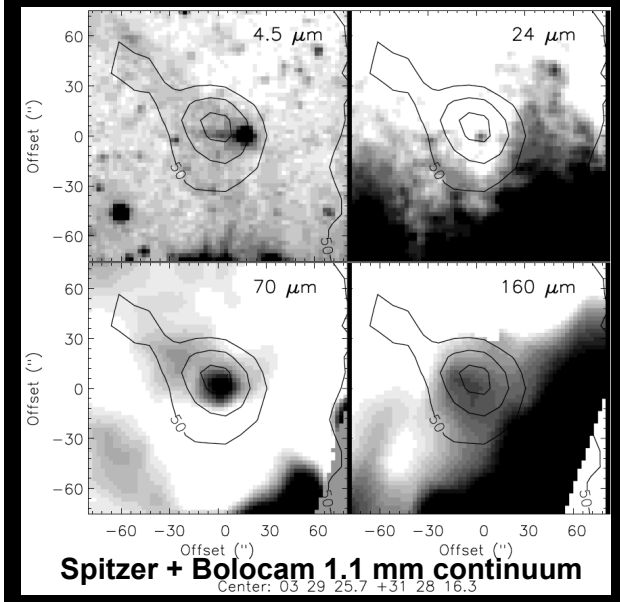
How Low?



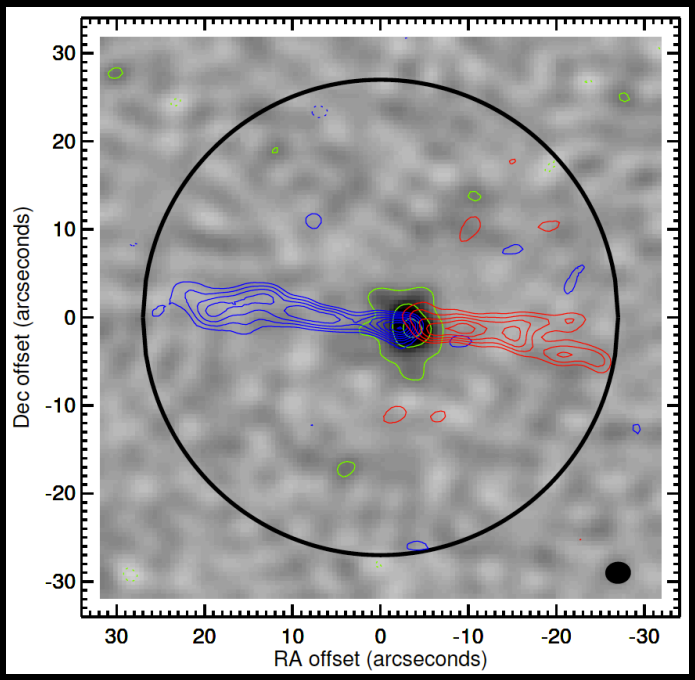
Dunham et al. (2008)

How Low?

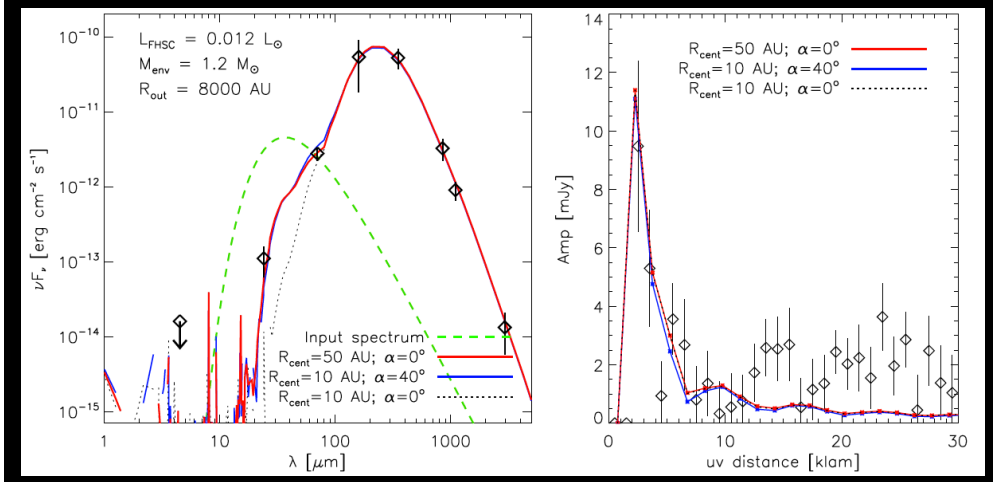
Perseus Bolo 58



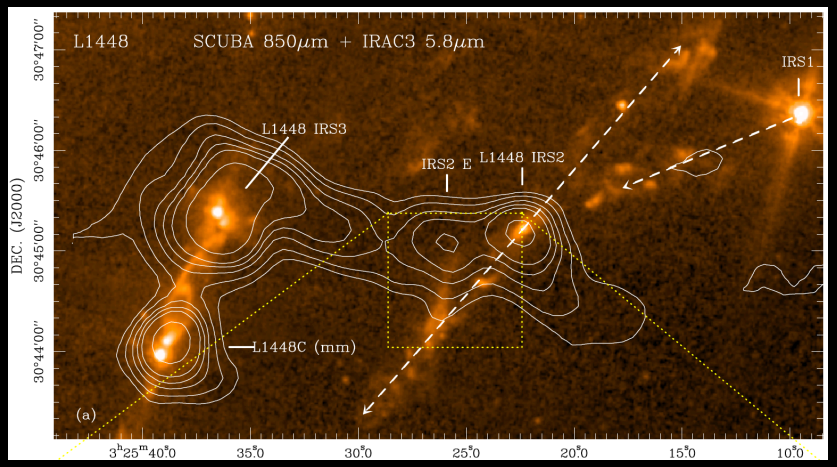
Enoch et al. (2010)

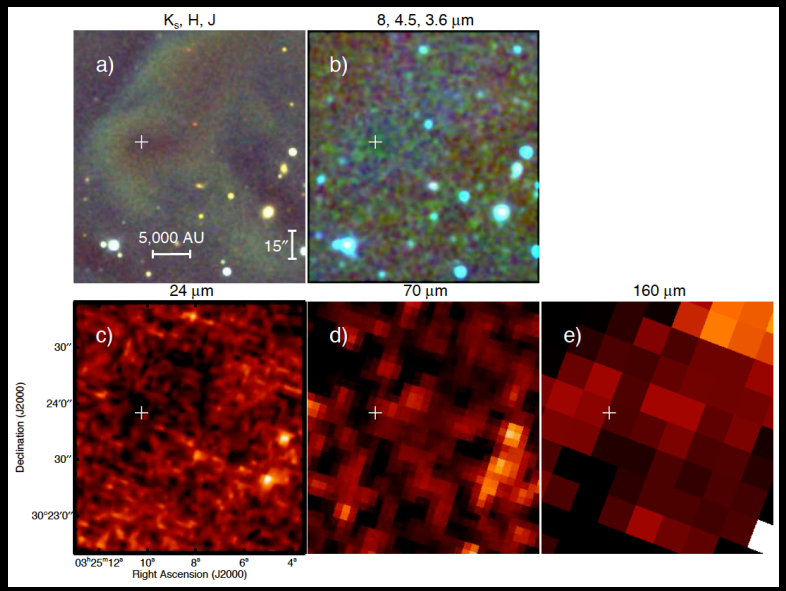


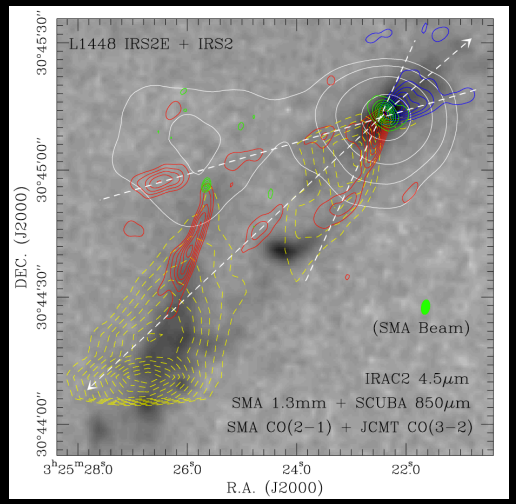
Dunham et al. (2011)



How Low?

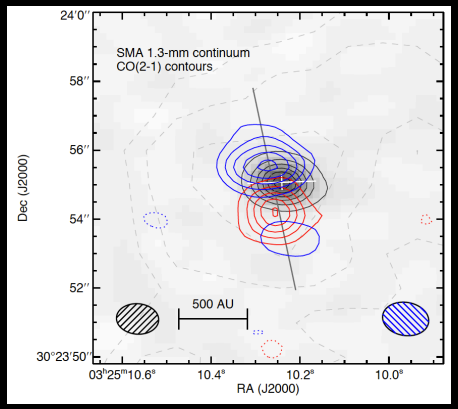






L1448 IRS2E

Chen et al. (2010)



L1451-mm

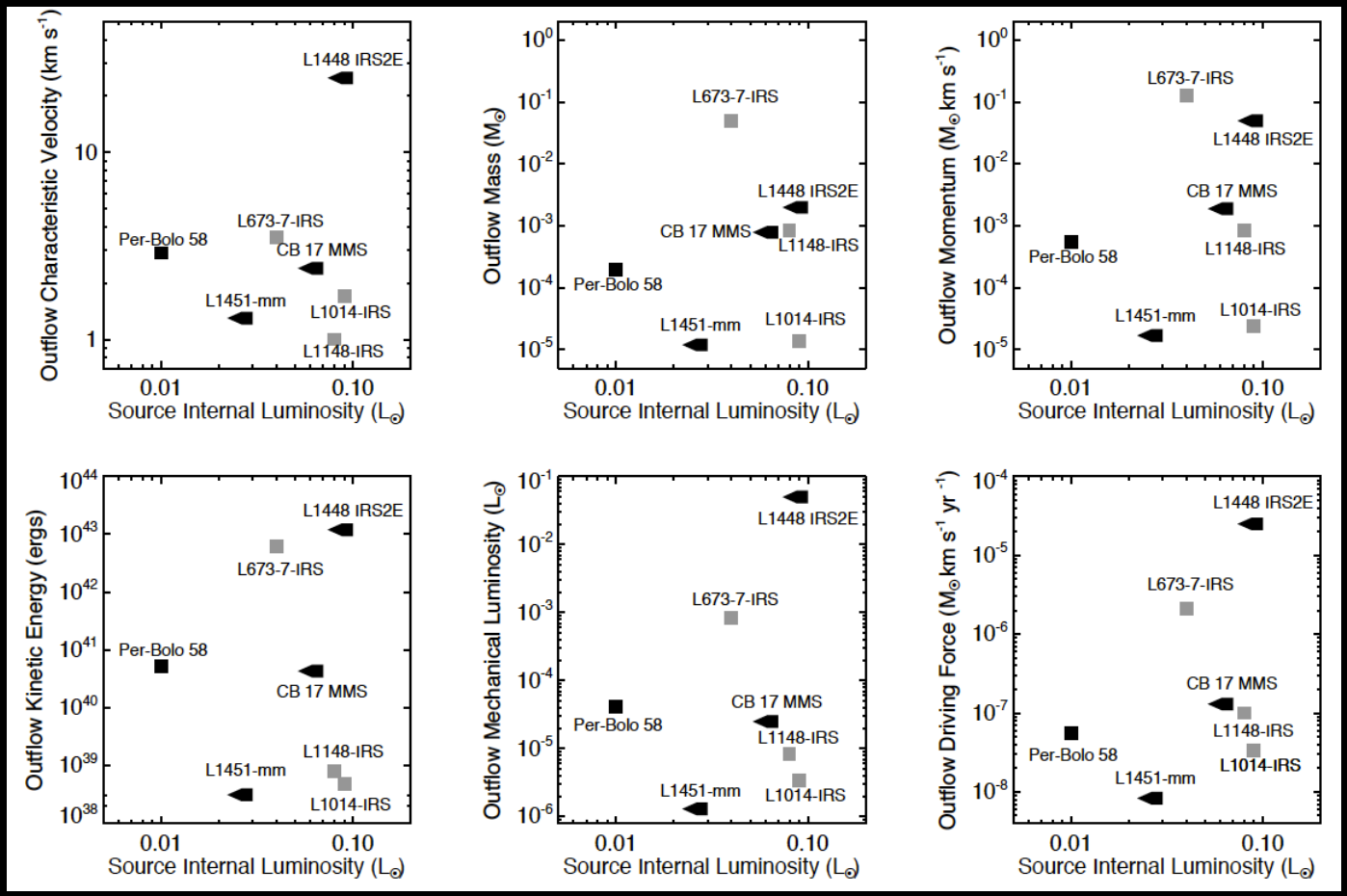
Pineda et al. (2011)

How Low?

Protostars below survey sensitivities?

First Hydrostatic Cores?

How many?



Dunham et al. (2011)

Summary

- The luminosity distribution is strongly peaked at low luminosities, shows >3 orders of magnitude spread, and is not consistent with constant mass accretion

- Evolutionary models suggest variable accretion can resolve luminosity problem
  Importance of bursts currently being evaluated
  Improved observational dataset coming soon

- Some sources have outflow properties suggesting bursts
  Need more sources
  Need higher spatial resolution with higher spatial dynamic range (ALMA)

- Lower limit to luminosity distribution still an open question

- Has the first hydrostatic core finally been found?