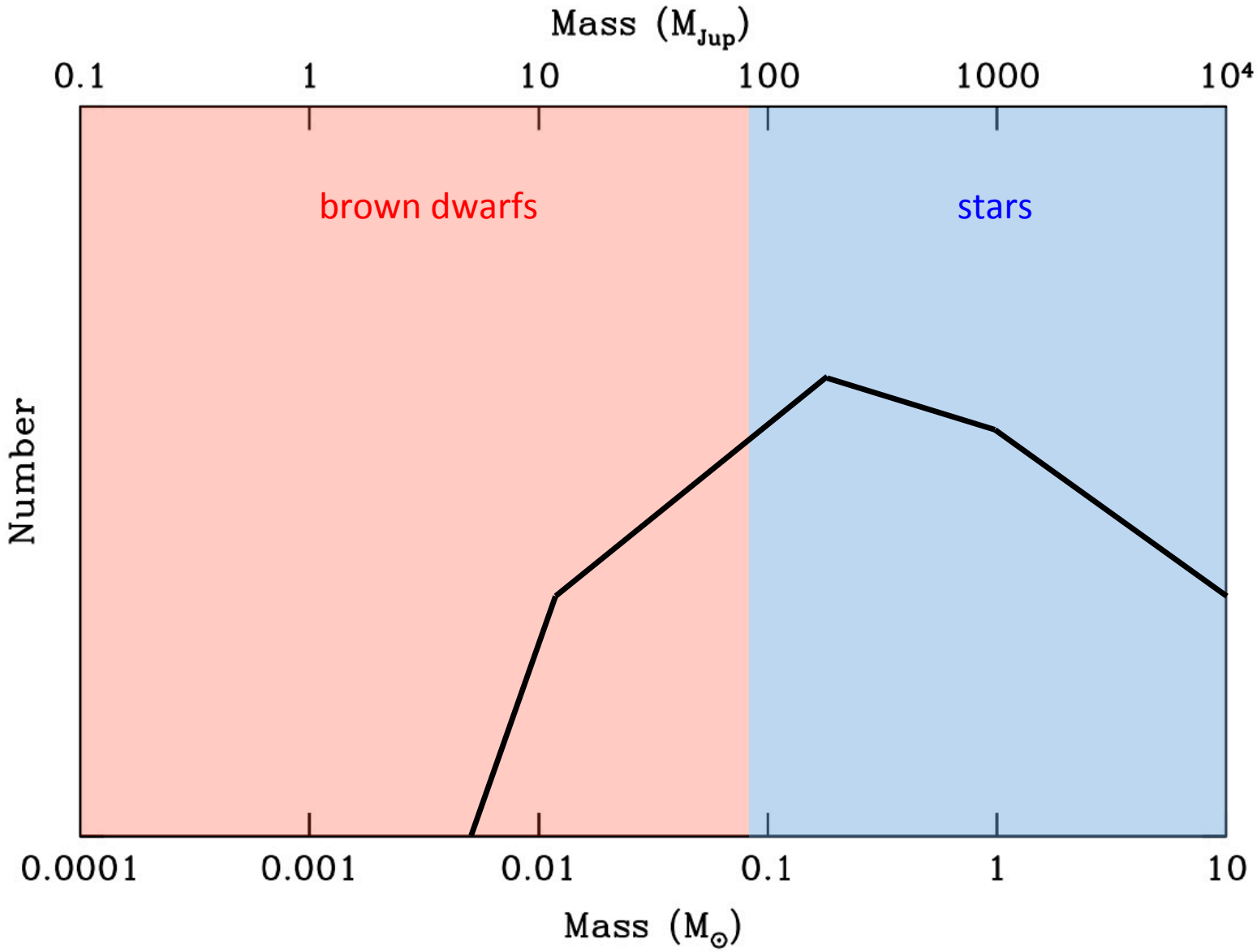
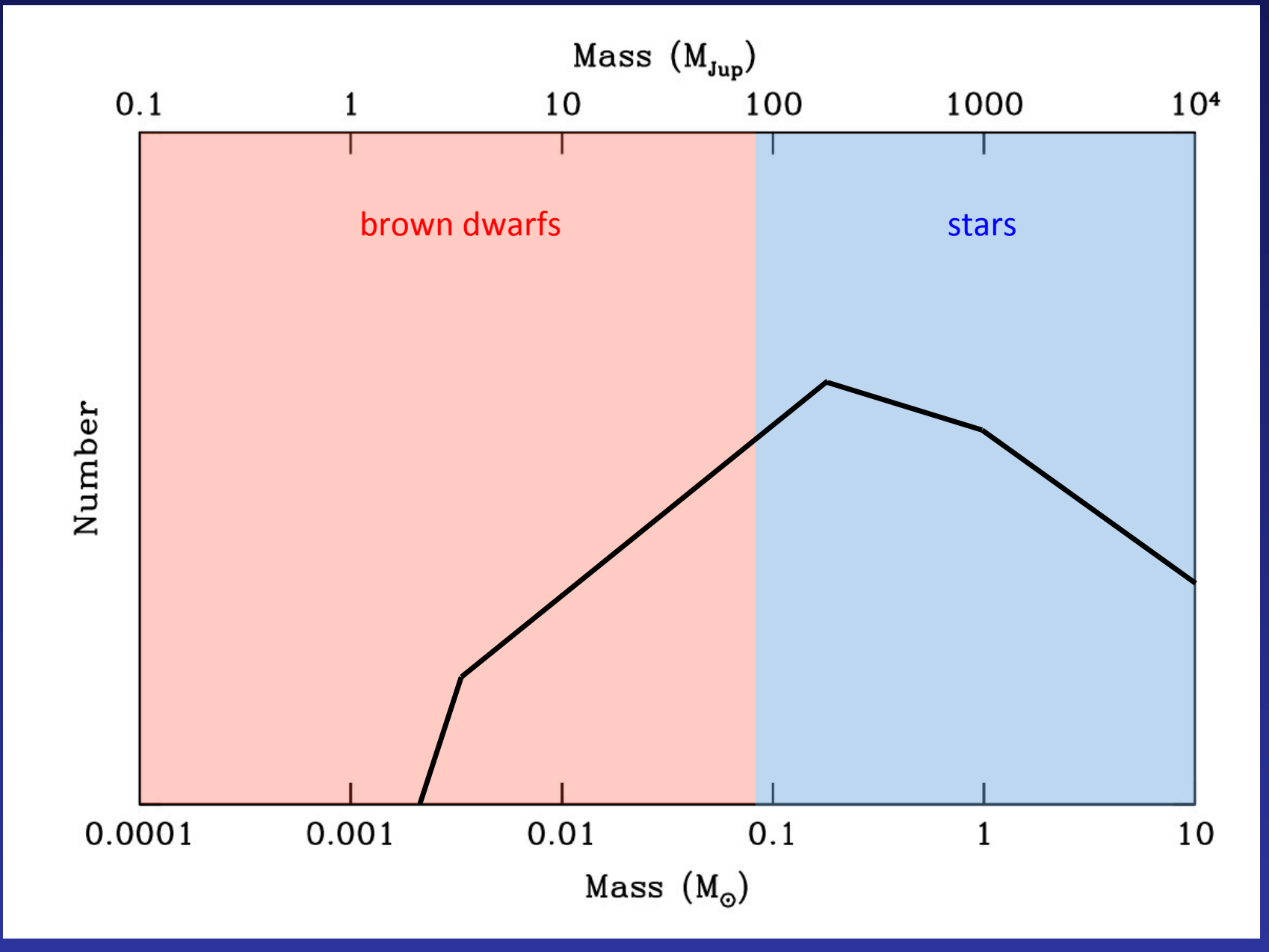
Pre-Main Sequence Stars and Stellar Populations with JWST

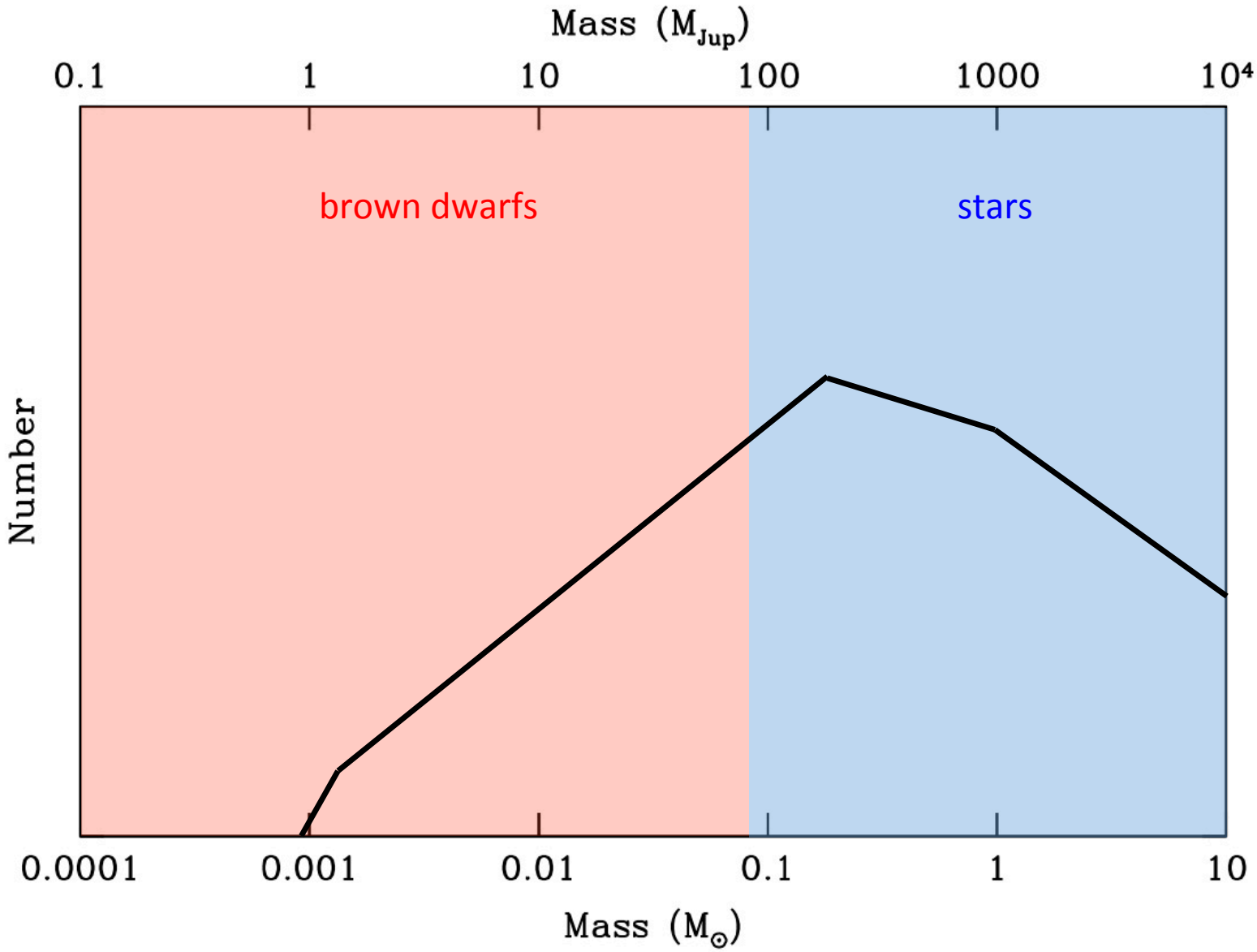
Kevin L. Luhman
Penn State University

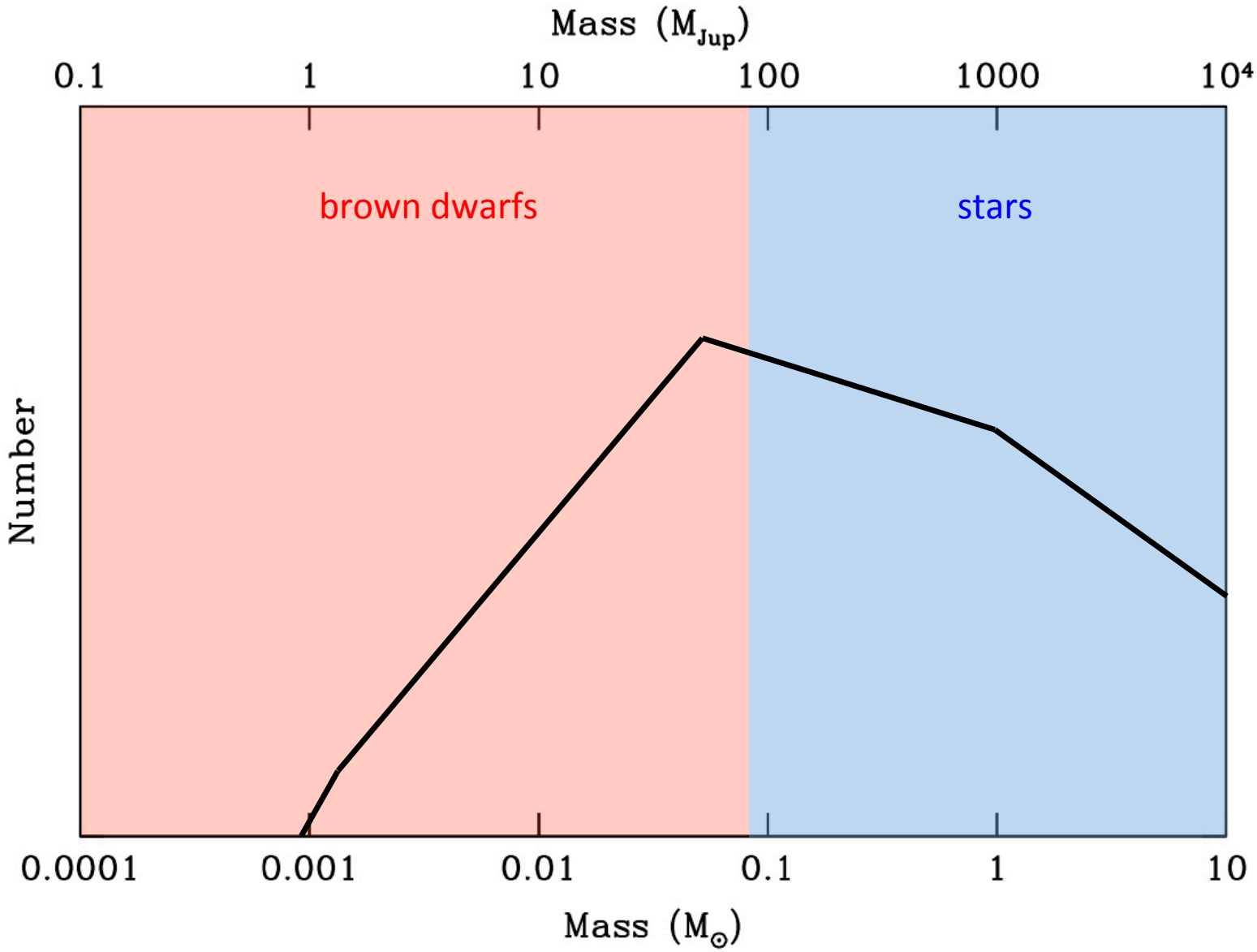
Outline

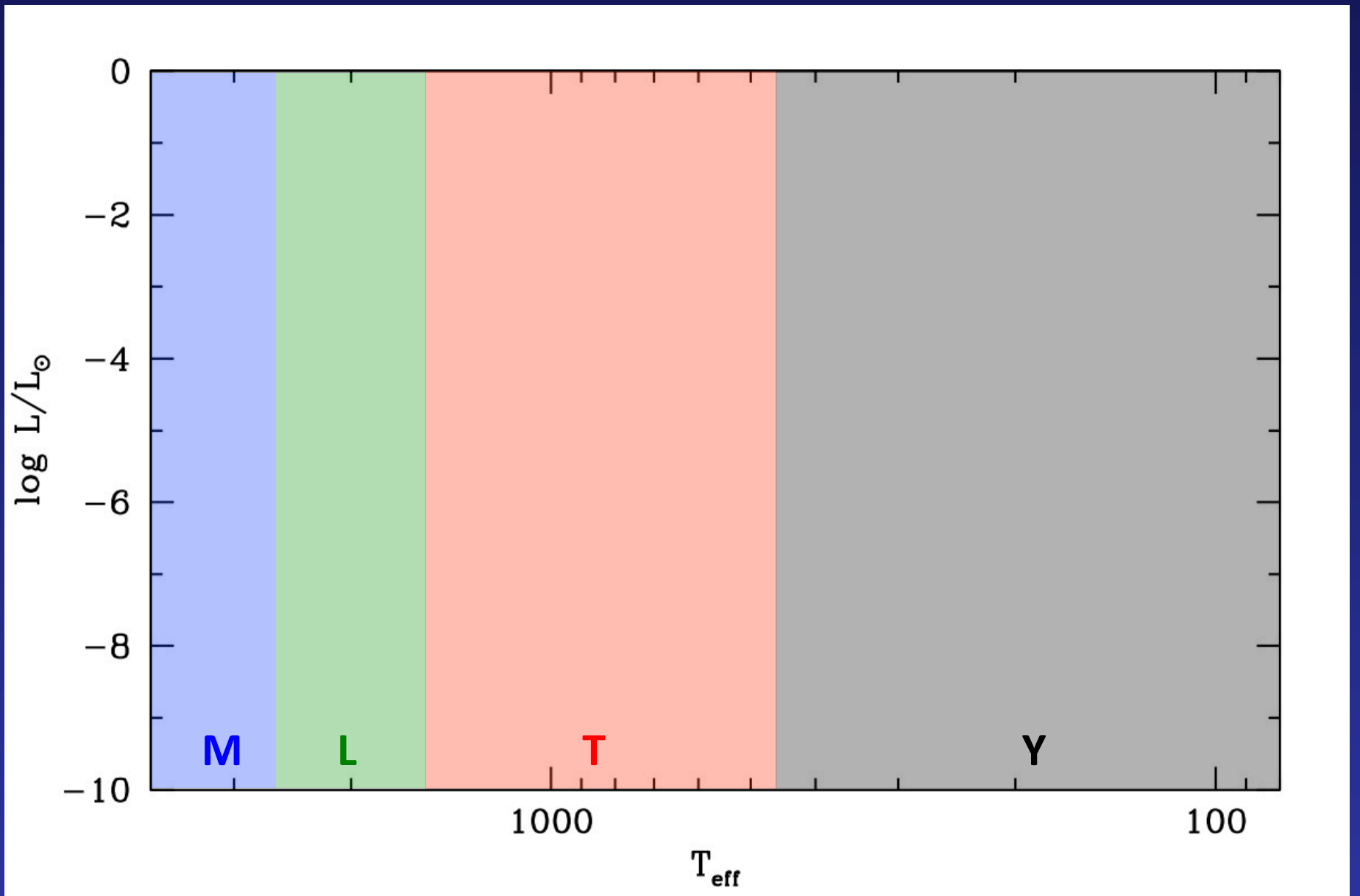
- IMF of brown dwarfs
- Circumstellar disks around brown dwarfs

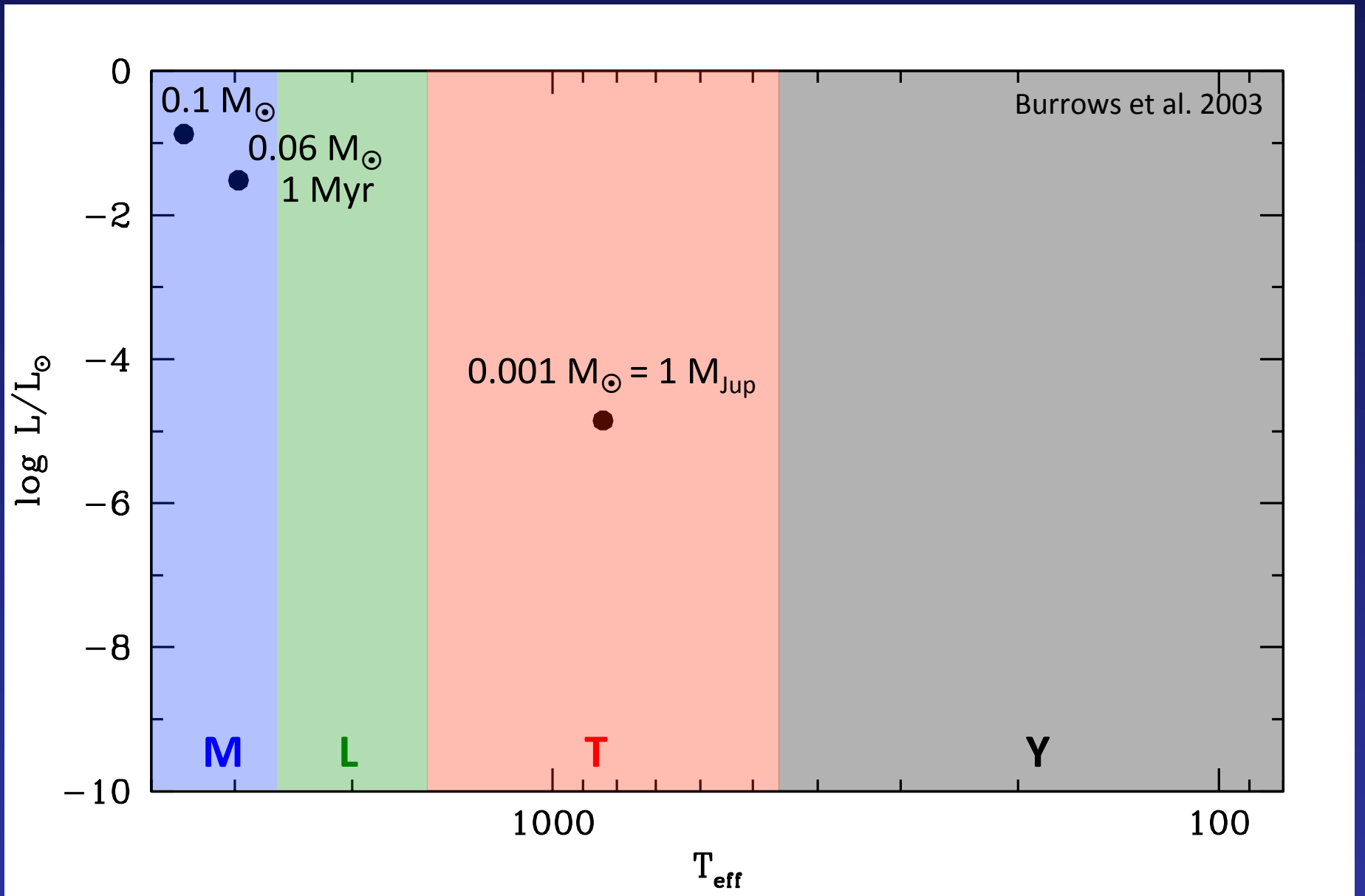

Mass (M_{Jup})
0.1
1
10
100
1000
10^4
brown dwarfs
stars
Number
0.0001
0.001
0.01
0.1
1
10
Mass ($M_\odot$)

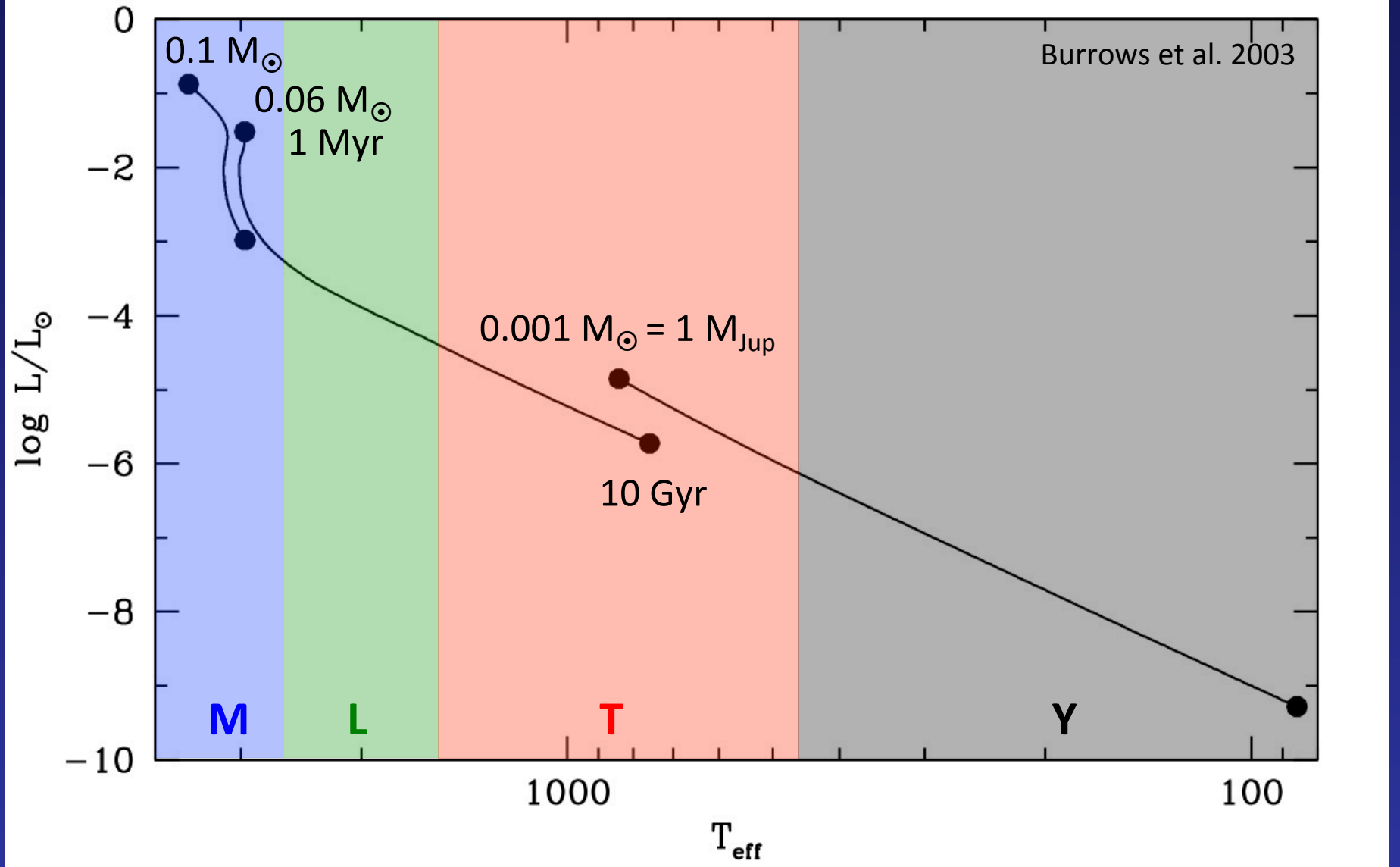

Mass (M_{Jup})
0.1
1
10
100
1000
10^4
brown dwarfs
stars
Number
0.0001
0.001
0.01
0.1
1
10
Mass ($M_\odot$)


Mass (M_{Jup})
0.1
1
10
100
1000
10^4
brown dwarfs
stars
Number
0.0001
0.001
0.01
0.1
1
10
Mass ($M_\odot$)


Mass (M_{Jup})
0.1
1
10
100
1000
10^4
brown dwarfs
stars
Number
0.0001
0.001
0.01
0.1
1
10
Mass ($M_\odot$)


0
−2
−4
−6
−8
−10
log L/L⊙
M
L
T
Y
1000
100
T eff

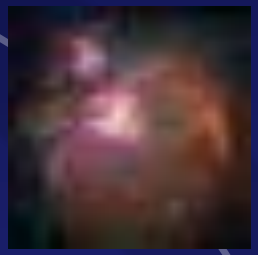

0.1 M⊙
0.06 M⊙
1 Myr
0.001 M⊙ = 1 MJup
Burrows et al. 2003
M
L
T
Y
0
−2
−4
−6
−8
−10
log L/L⊙
1000
100
Teff


0.1 M⊙
0.06 M⊙
1 Myr
Burrows et al. 2003
0.001 M⊙ = 1 MJup
10 Gyr
M
L
T
Y
0
−2
−4
−6
−8
−10
log L/L⊙
1000
100
Teff

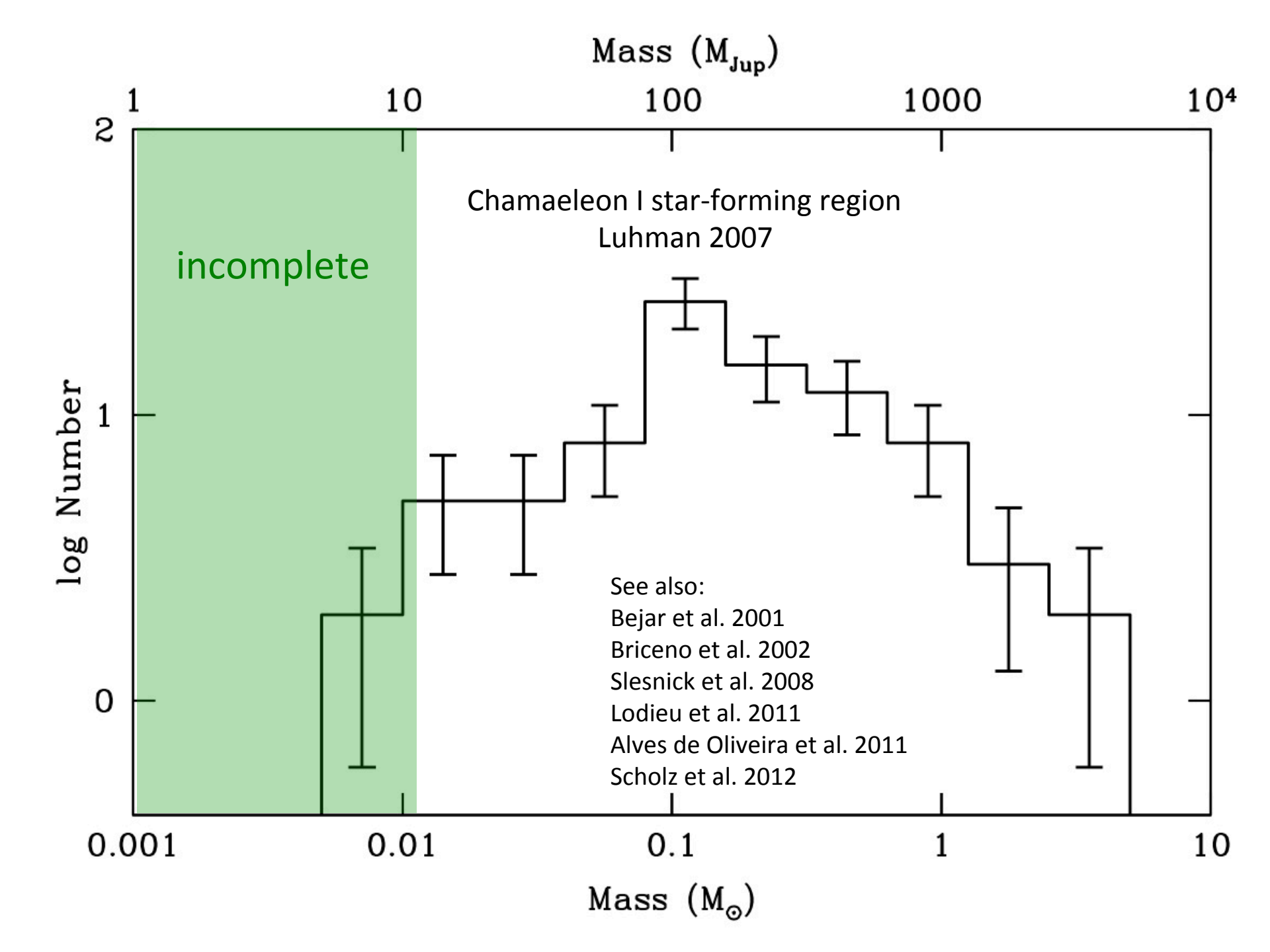
10-100 Myr

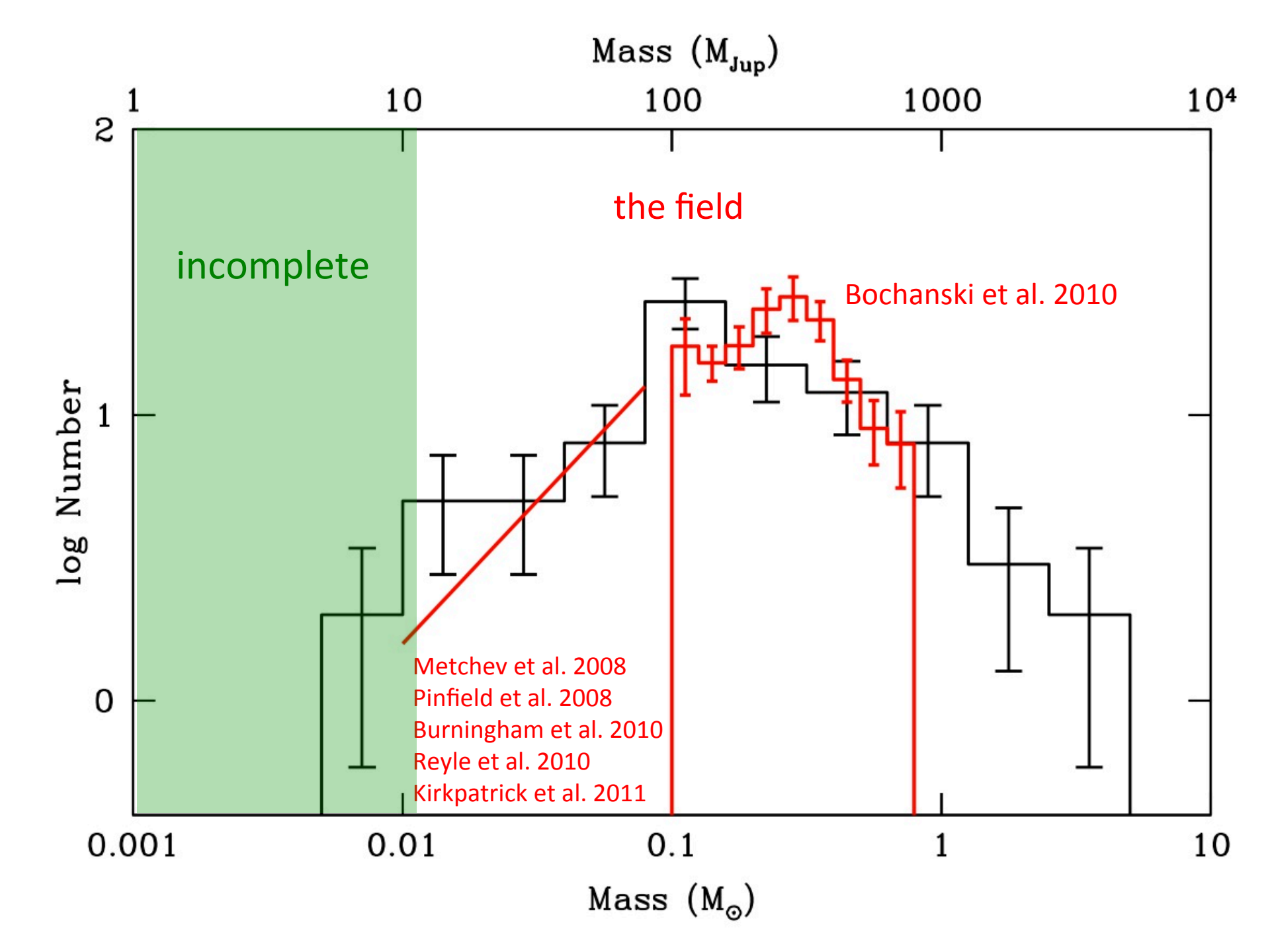
150-400 pc

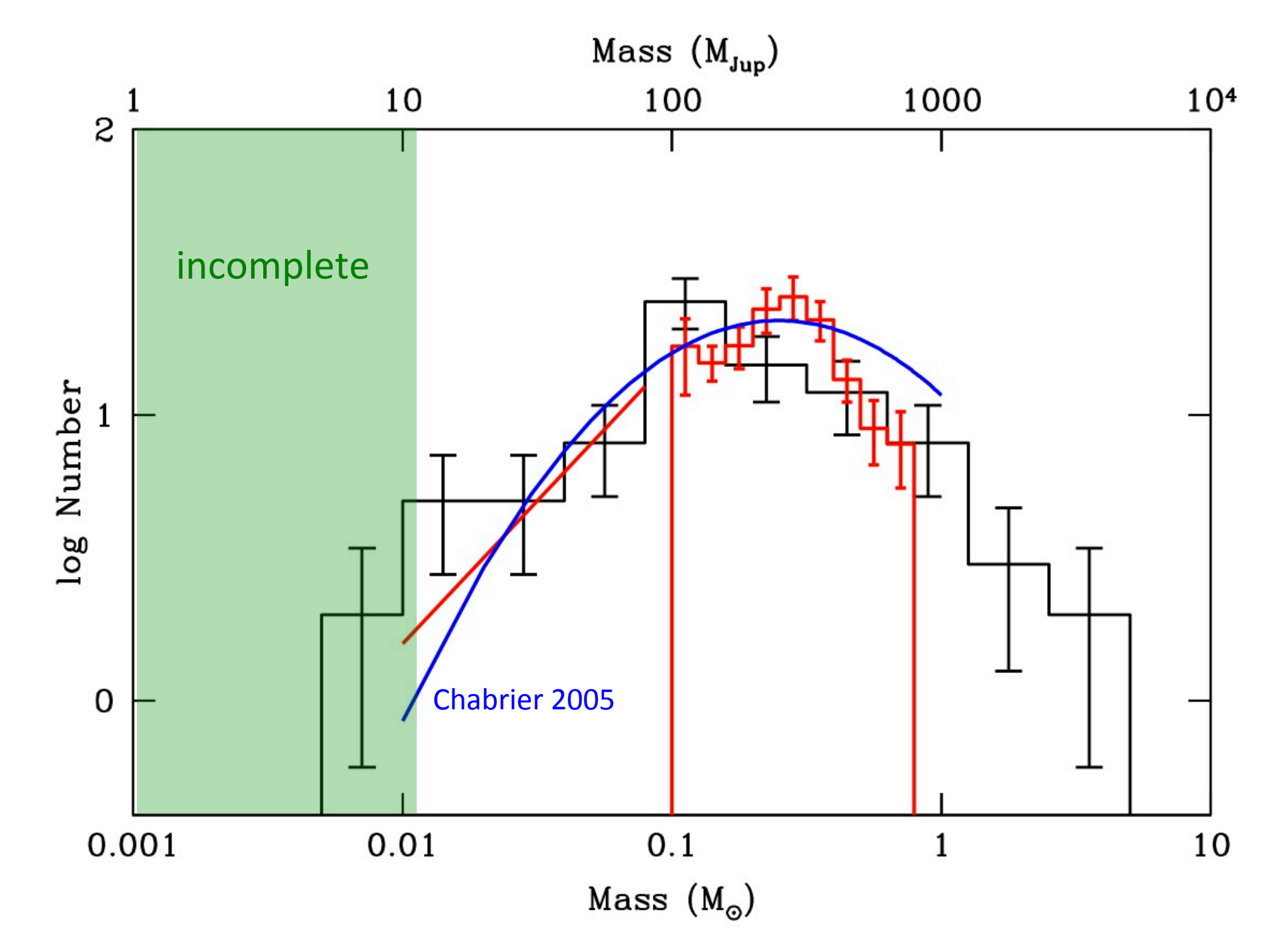
1-10 Myr

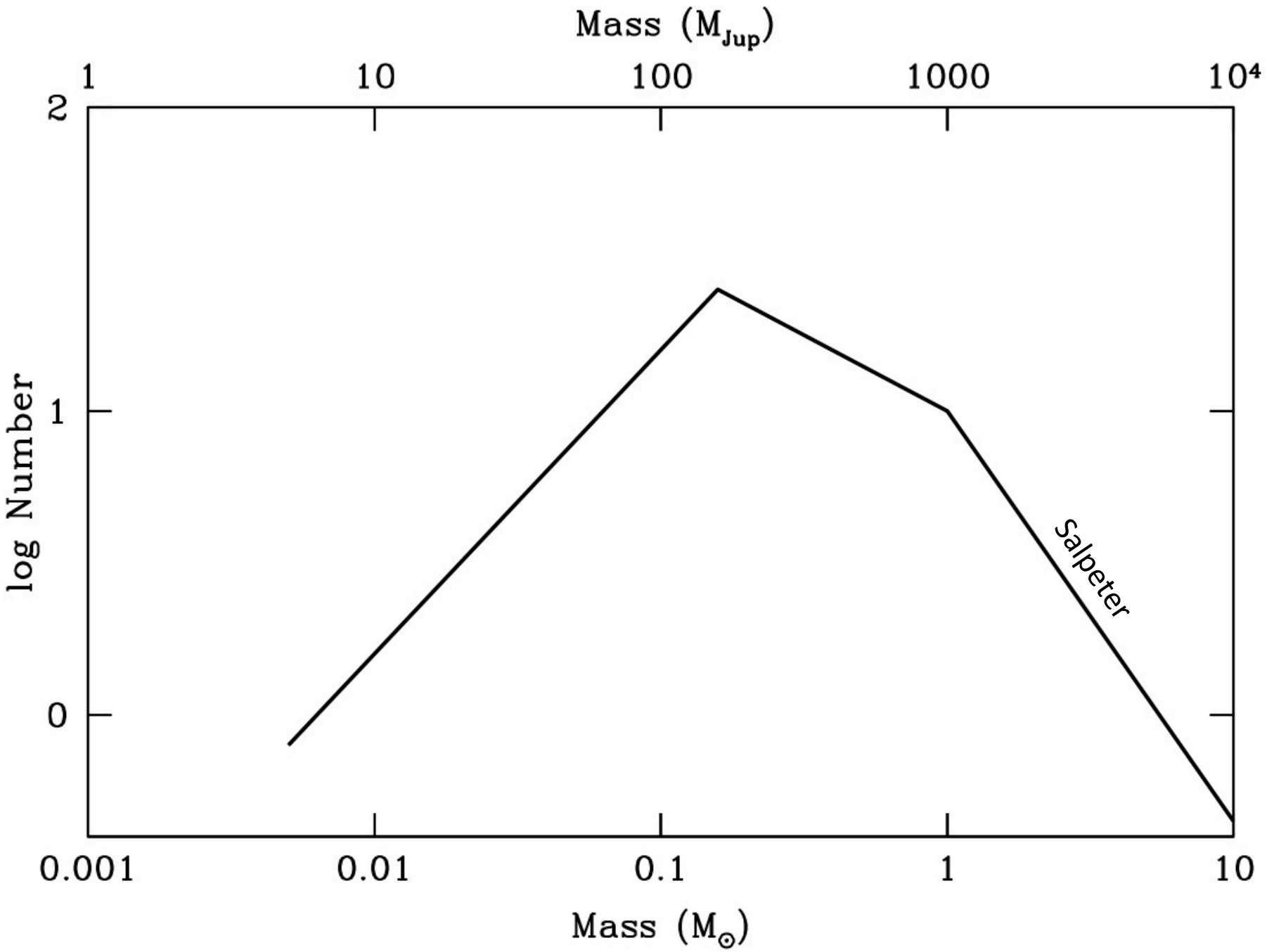


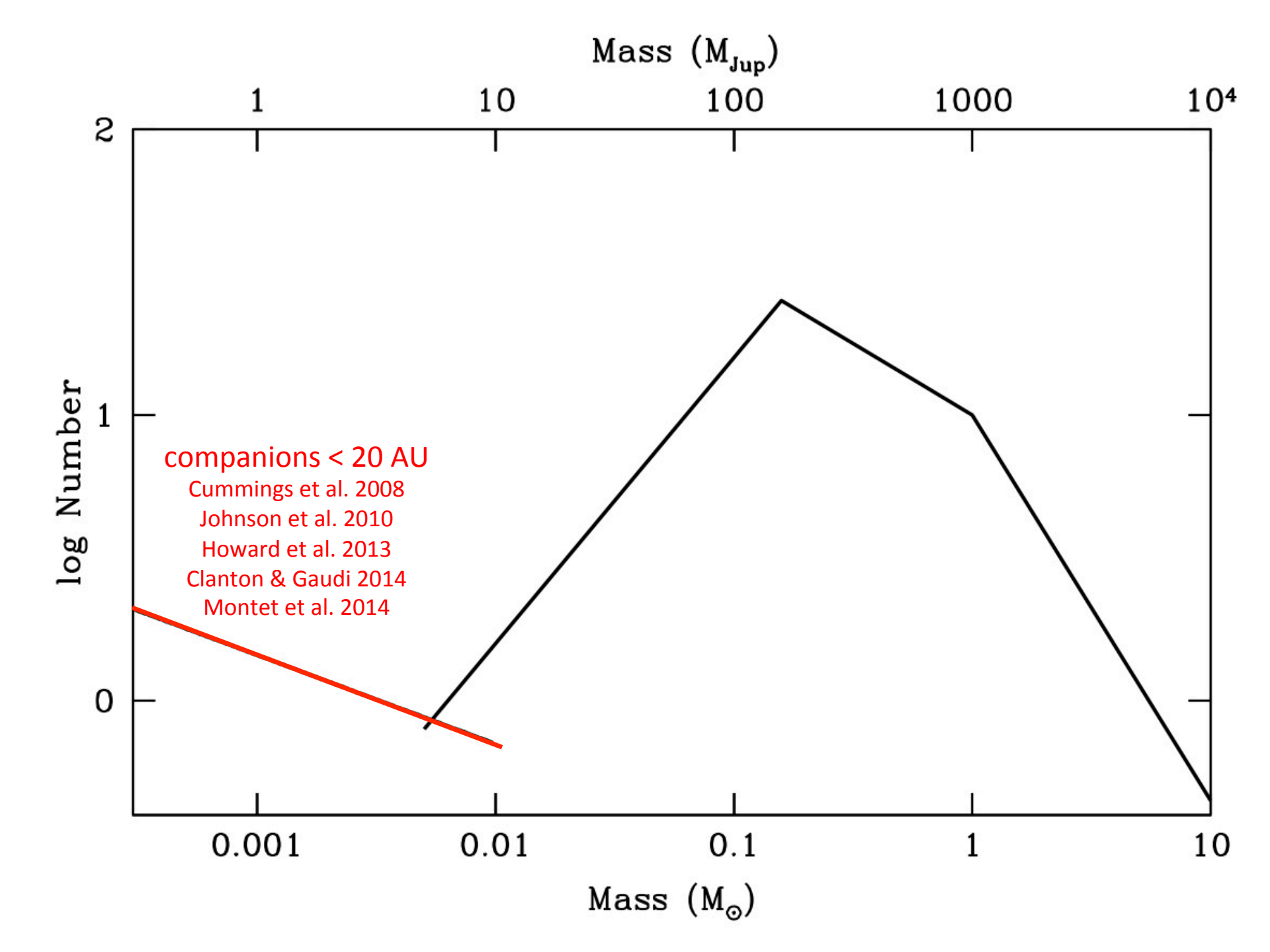
<30 pc

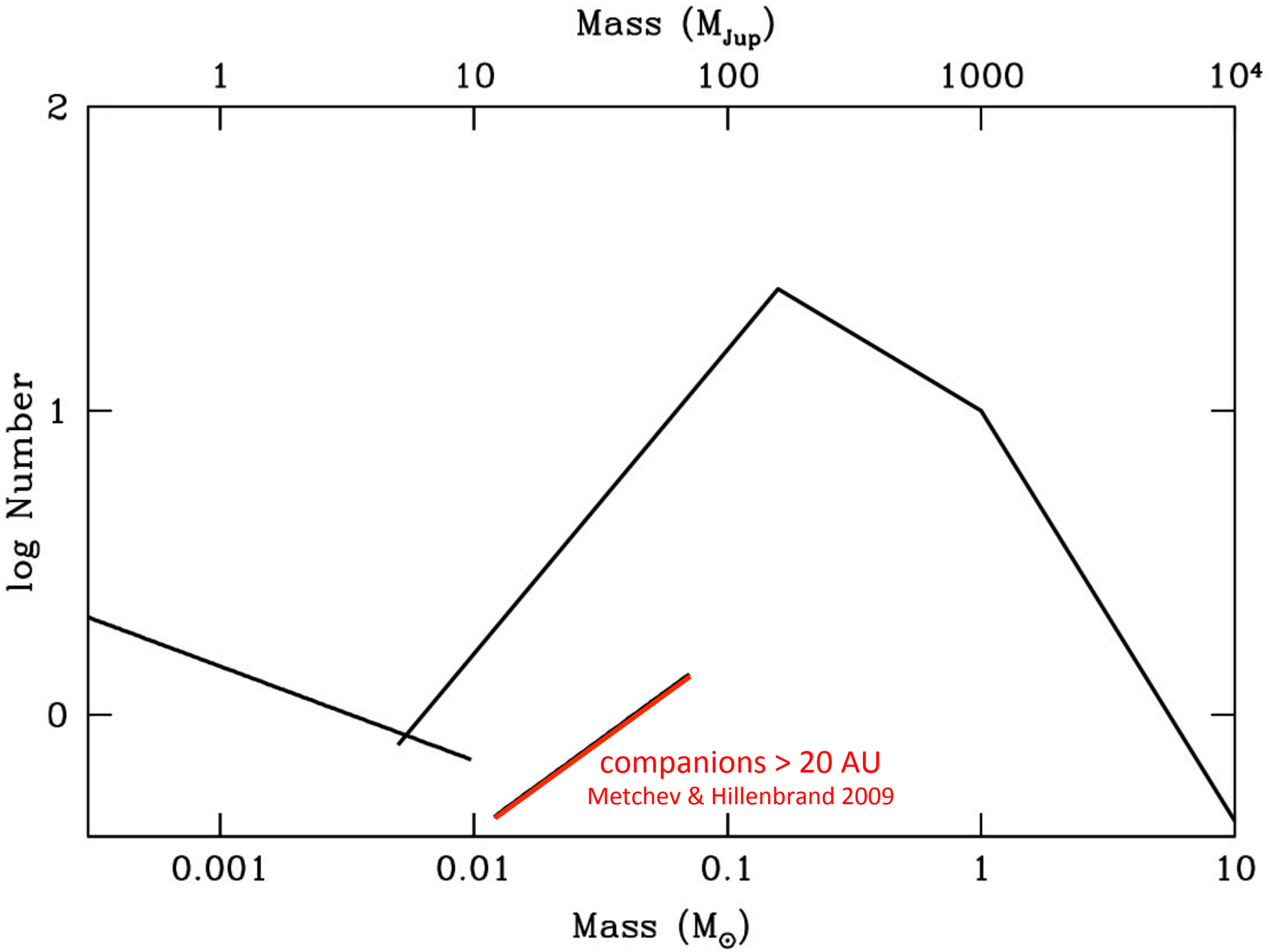

Mass (M_{Jup})
1
10
100
1000
10^4
2
1
0
log Number
incomplete
Chamaeleon I star-forming region
Luhman 2007
See also:
Bejar et al. 2001
Briceno et al. 2002
Slesnick et al. 2008
Lodieu et al. 2011
Alves de Oliveira et al. 2011
Scholz et al. 2012
0.001
0.01
0.1
1
10
Mass ($M_\odot$)

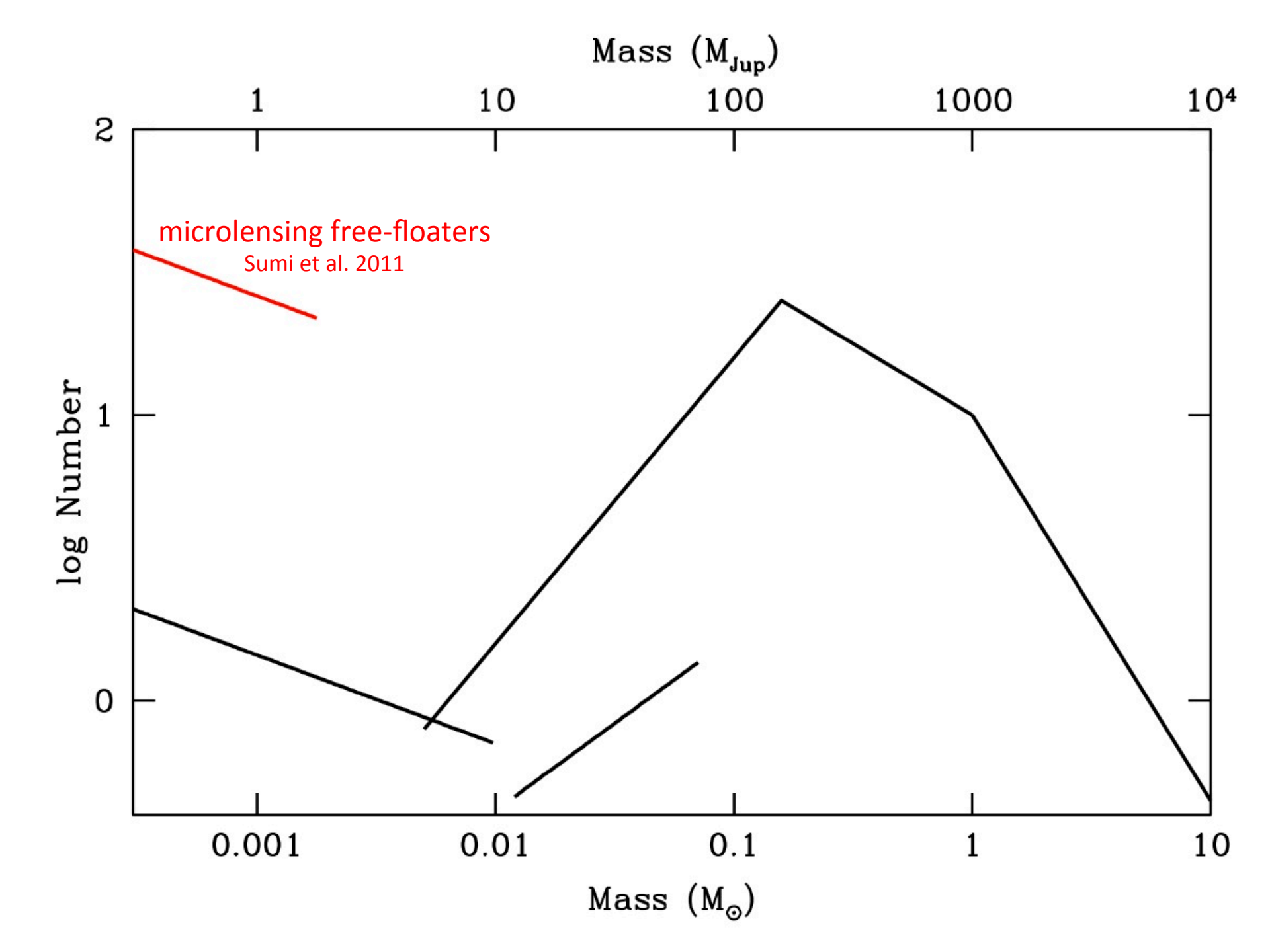

Mass (M_{Jup})
1
10
100
1000
10^4
2
1
0
log Number
incomplete
the field
Bochanski et al. 2010
Metchev et al. 2008
Pinfield et al. 2008
Burningham et al. 2010
Reyle et al. 2010
Kirkpatrick et al. 2011
0.001
0.01
0.1
1
10
Mass ($M_\odot$)

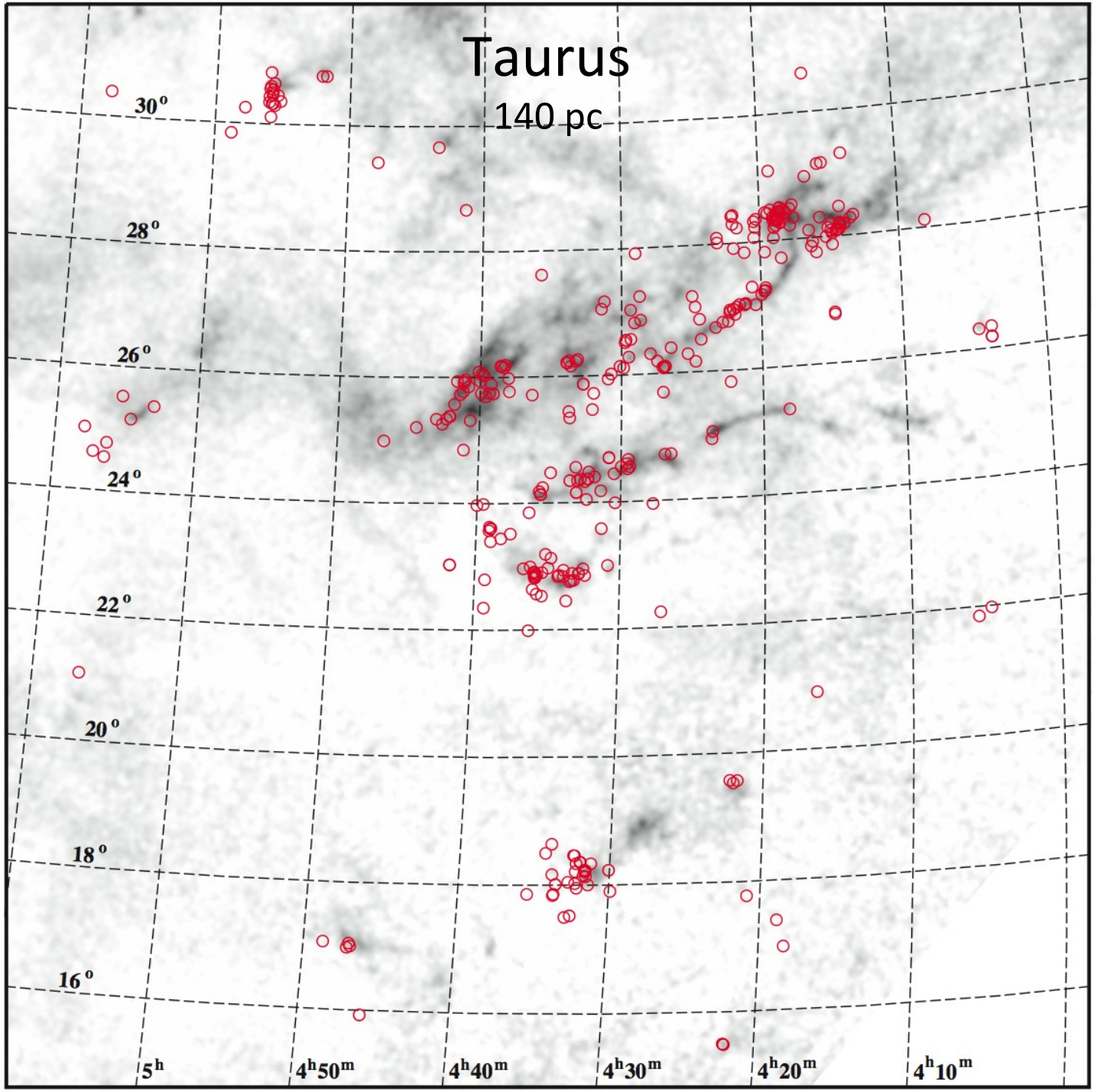

Mass (M_{Jup})
1
10
100
1000
10^4
2
1
0
log Number
incomplete
Chabrier 2005
0.001
0.01
0.1
1
10
Mass ($M_\odot$)


Mass (M_{Jup})
1
10
100
1000
10^4
2
1
0
log Number
Salpeter
0.001
0.01
0.1
1
10
Mass ($M_\odot$)


Mass (M_{Jup})
1
10
100
1000
10^4
2
1
0
log Number
companions < 20 AU
Cummings et al. 2008
Johnson et al. 2010
Howard et al. 2013
Clanton & Gaudi 2014
Montet et al. 2014
0.001
0.01
0.1
1
10
Mass ($M_\odot$)


Mass (M_{Jup})
1
10
100
1000
10^4
2
1
0
log Number
companions > 20 AU
Metchev & Hillenbrand 2009
0.001
0.01
0.1
1
10
Mass ($M_\odot$)


Mass (M_{Jup})
1
10
100
1000
10^4
2
1
0
log Number
microlensing free-floaters
Sumi et al. 2011
0.001
0.01
0.1
1
10
Mass ($M_\odot$)

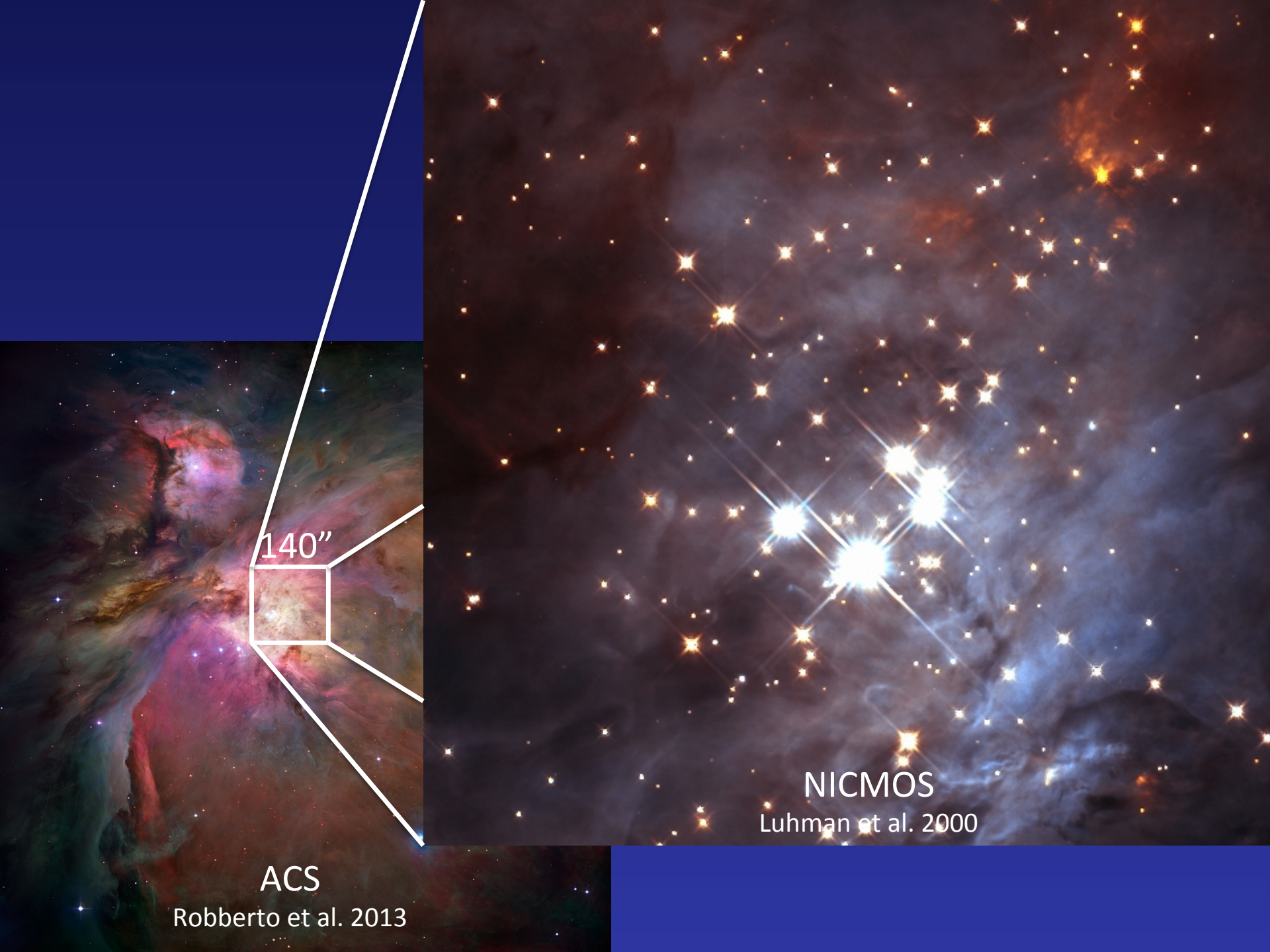


Orion

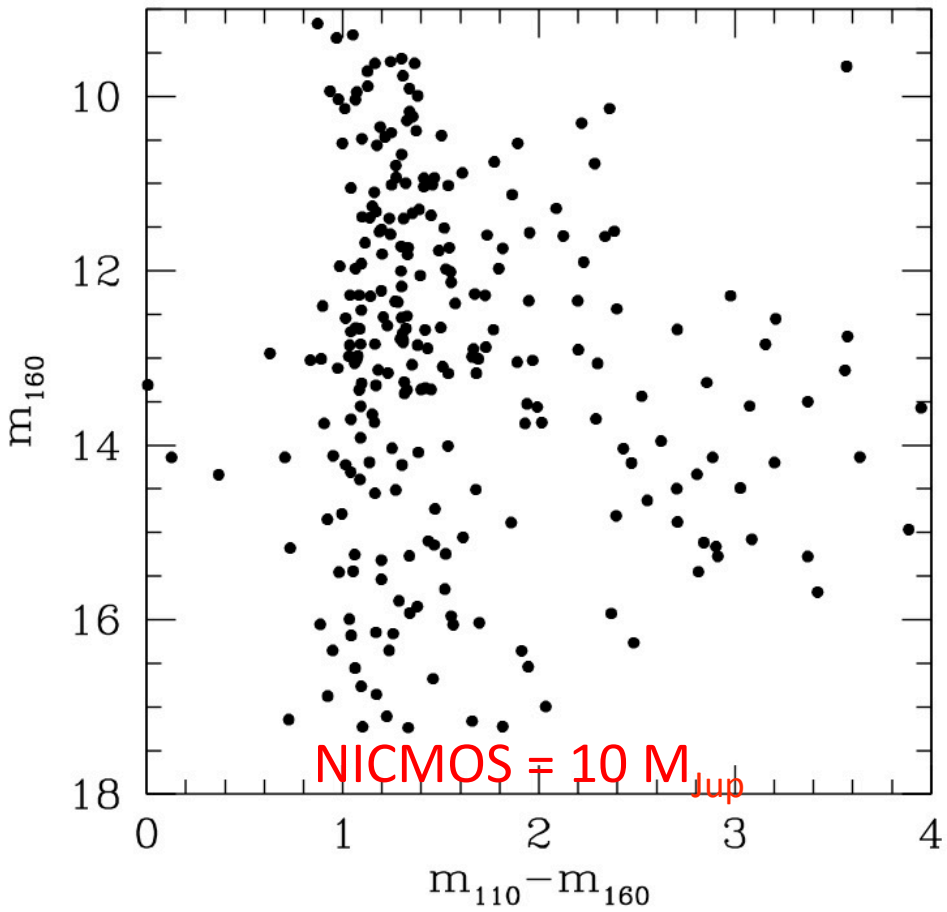
400 pc

IC 348

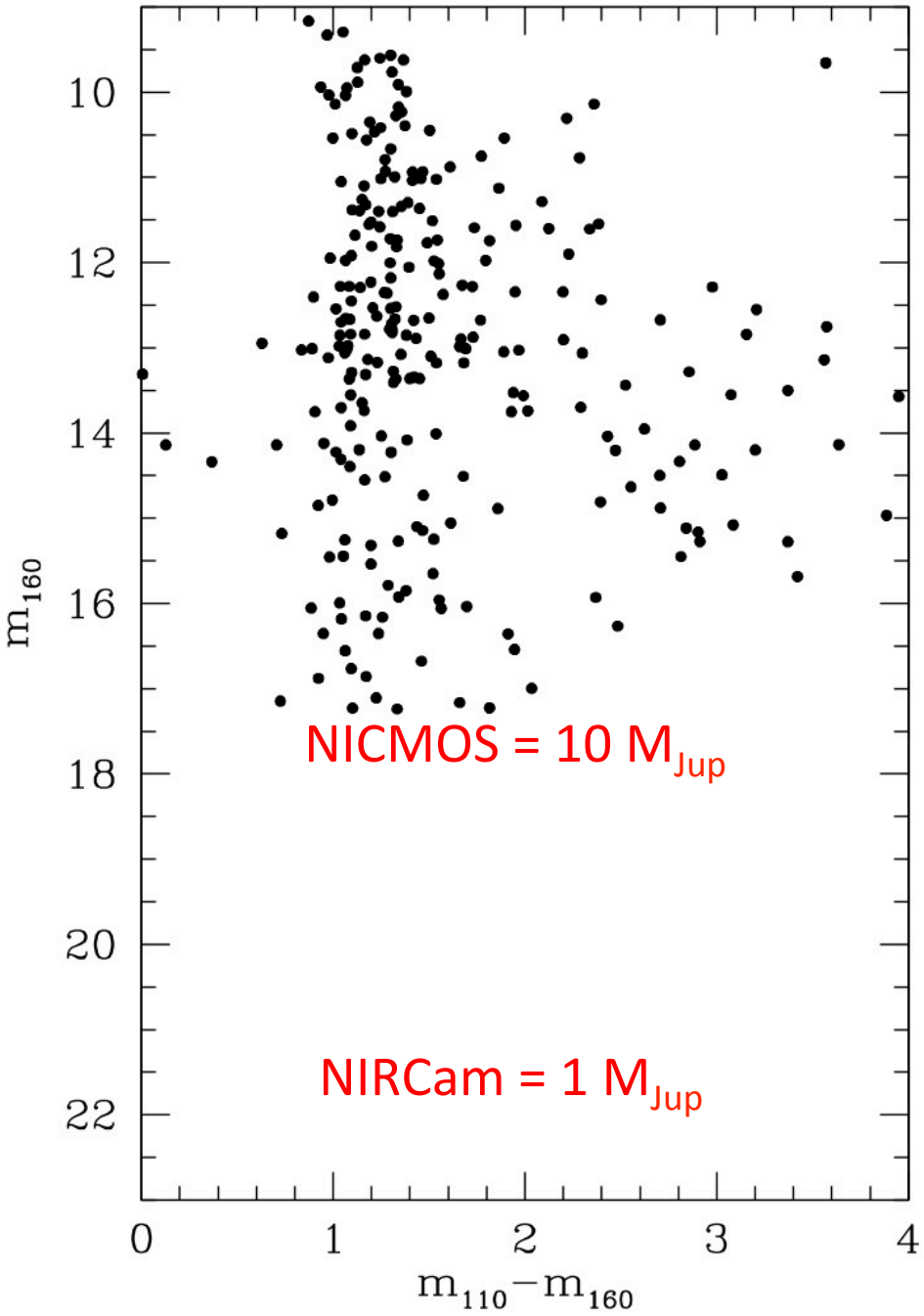
300 pc

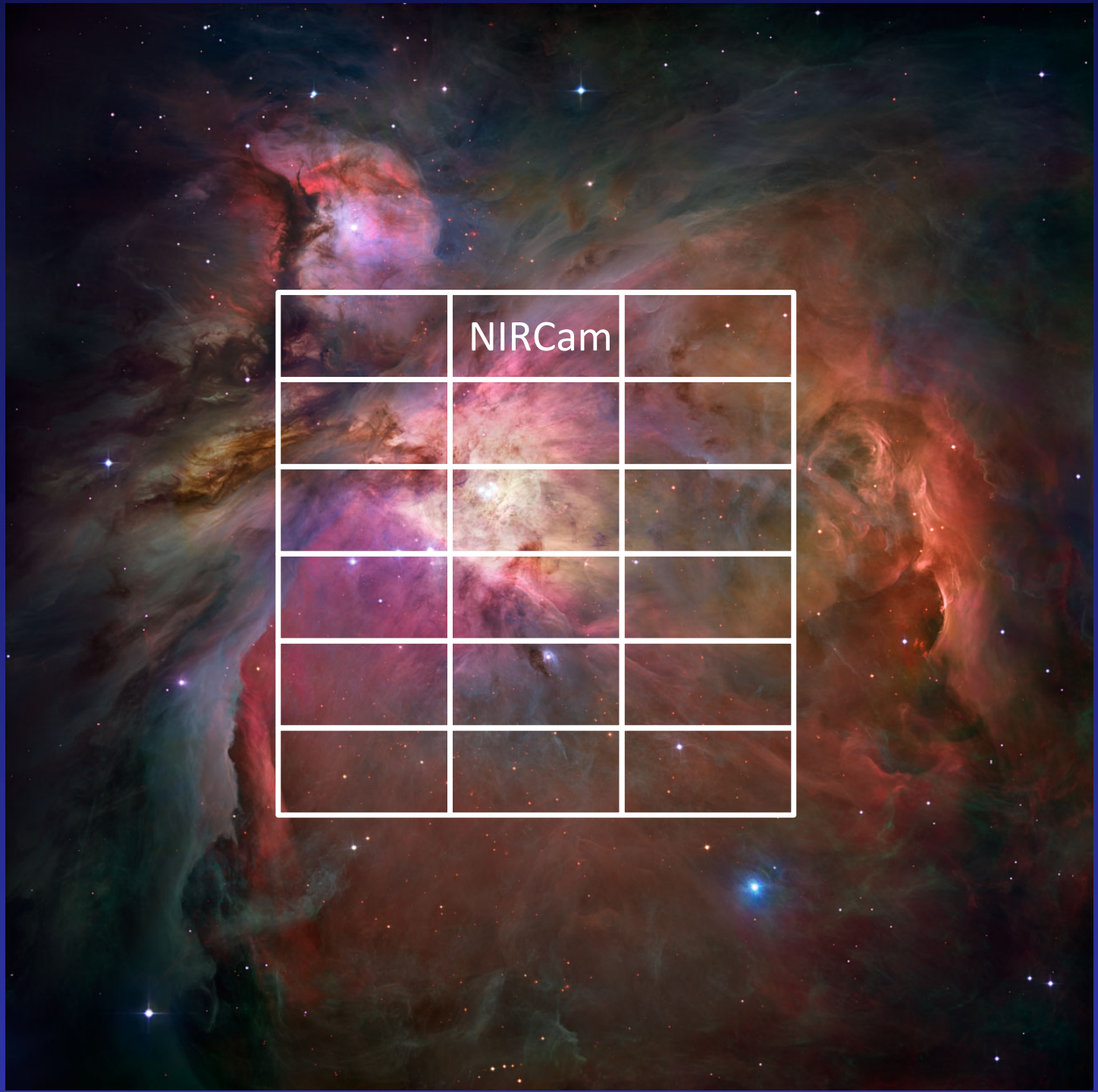

140”
NICMOS
Luhman et al. 2000
ACS
Robberto et al. 2013

Orion



Orion


10
12
14
16
18
20
22
m_{160}
0
1
2
3
4
$m_{110}-m_{160}$
NICMOS = 10 M_{Jup}
NIRCam = 1 M_{Jup}


NIRCam

James Webb Space Telescope
Science Operations Design Reference Mission

- JWST Overview
- Advisory Committee
- Science
  - JWST Science
  - Goals
  - Data Simulation Resources
  - SODRM
  - Science Planning Timeline
  - JWST Science Corner
- Optical Telescope Element
- Instruments
- Operations
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- Meetings

JWST SODRM Galactic Programs Summary

TITLE: JWST survey of the Orion Nebula

ID: 93080

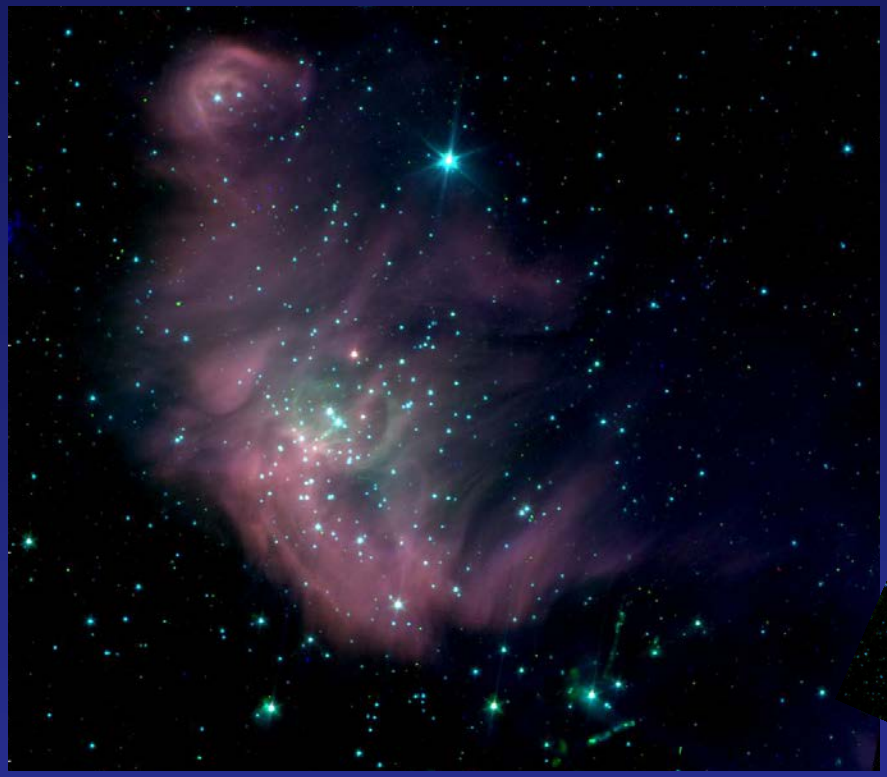
GOAL: We will use NIRCAM and MIRI to survey the Orion Nebula Cluster, the richest young stellar cluster in the solar vicinity (414 pc), over an area comparable to the HST Treasury Program at optical wavelengths. We will obtain a complete, unbiased sample of thousand of circumstellar disks in a variety of environments and evolutionary status, e.g. photoevaporated by external UV radiation (proplyds), by their central stars, or in a relatively quiescent status more germane to planet formation. The IR SEDs, reconstructed from 1 to 26 μm, will allow us to constrain the disk structure (flaring angle, gaps, dust settling,...) from a few stellar radii to beyond the habitable zone. We will use color-color diagrams to disentangle the population of young stars from reddened background sources and then reconstruct a reliable, unbiased IMF of the cluster, analyzing its variation vs. the distance from the center. We will discover an unknown but presumably significant number of infrared companions and free floating "Jupiters" down to 1 MJup. We will also trace embedded jets and HH objects from the youngest protostars, dusty "cometary tails" of photoevaporated mass loss, high density Class 0 cores, etc.

NOMINAL ALLOCATION (hours):

SODRM Programs

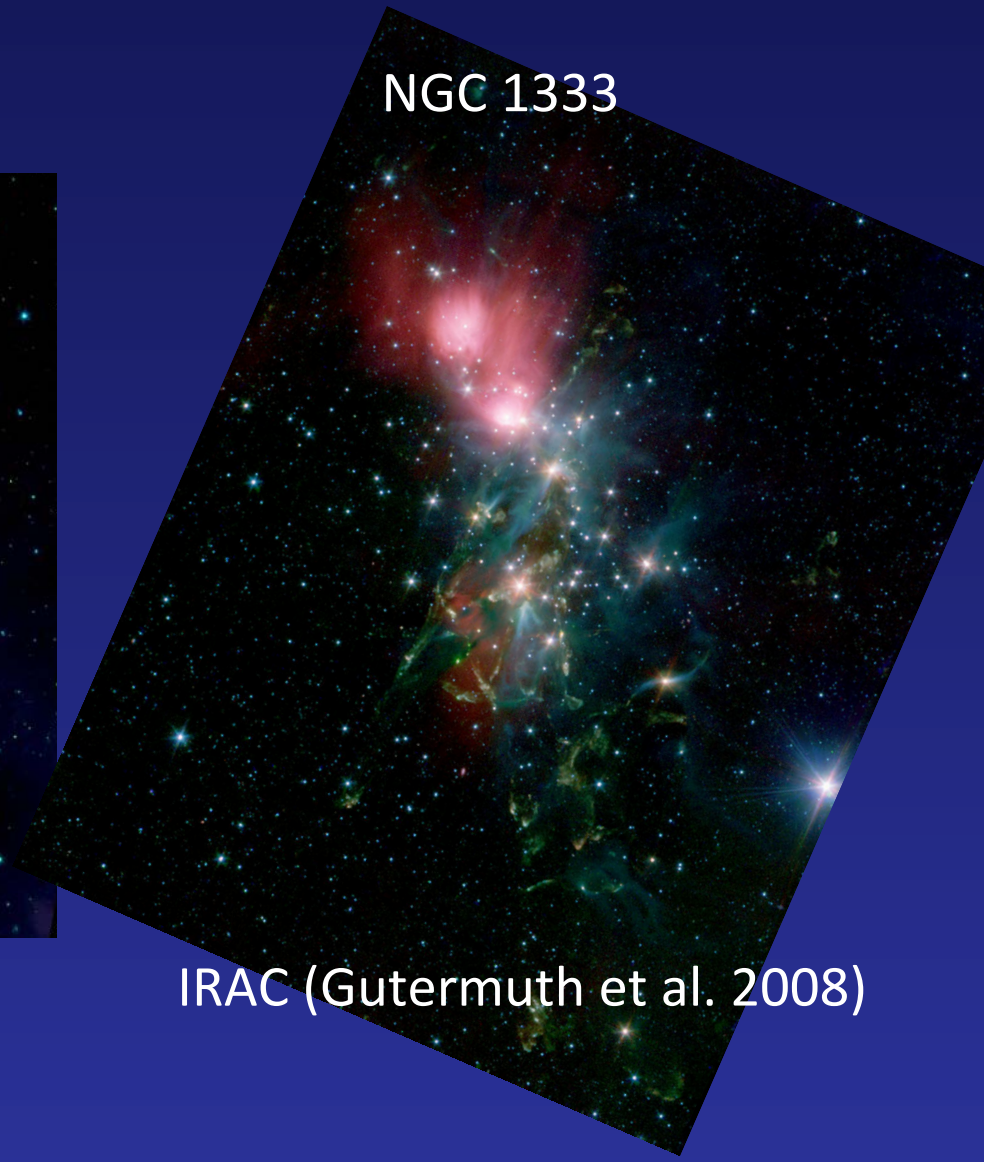
- Science Programs
- Science Programs Summaries
- Science Programs Higlights

IC 348



IRAC (Lada et al. 2006)

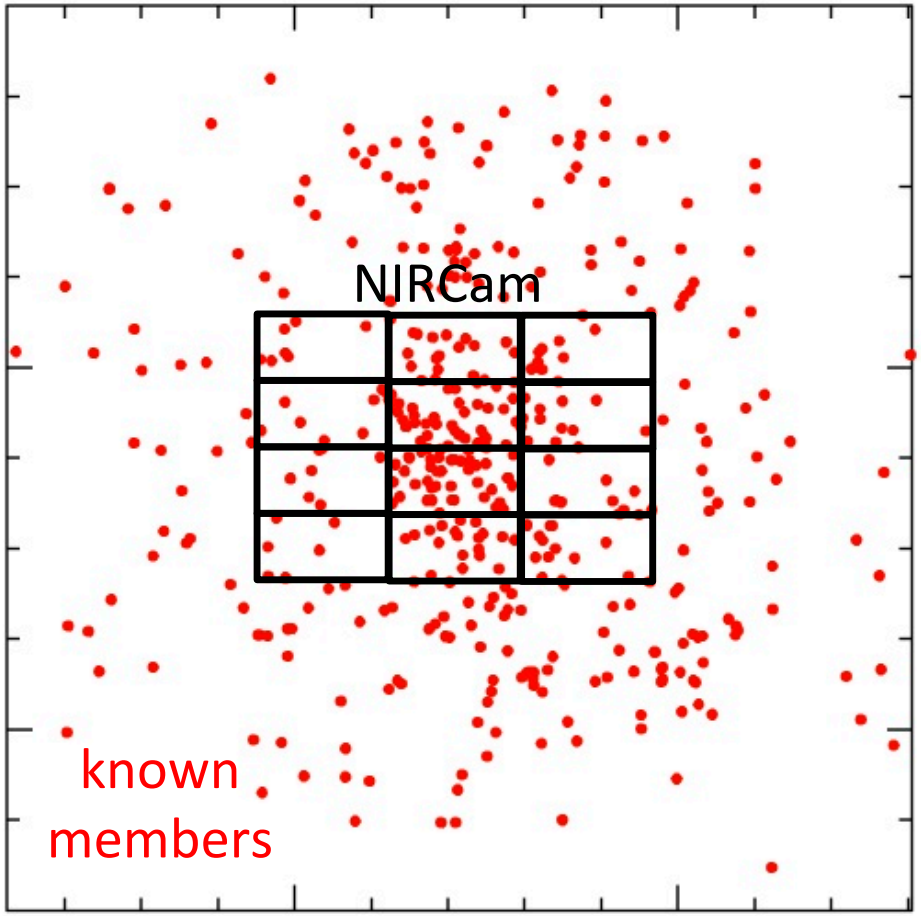
NGC 1333

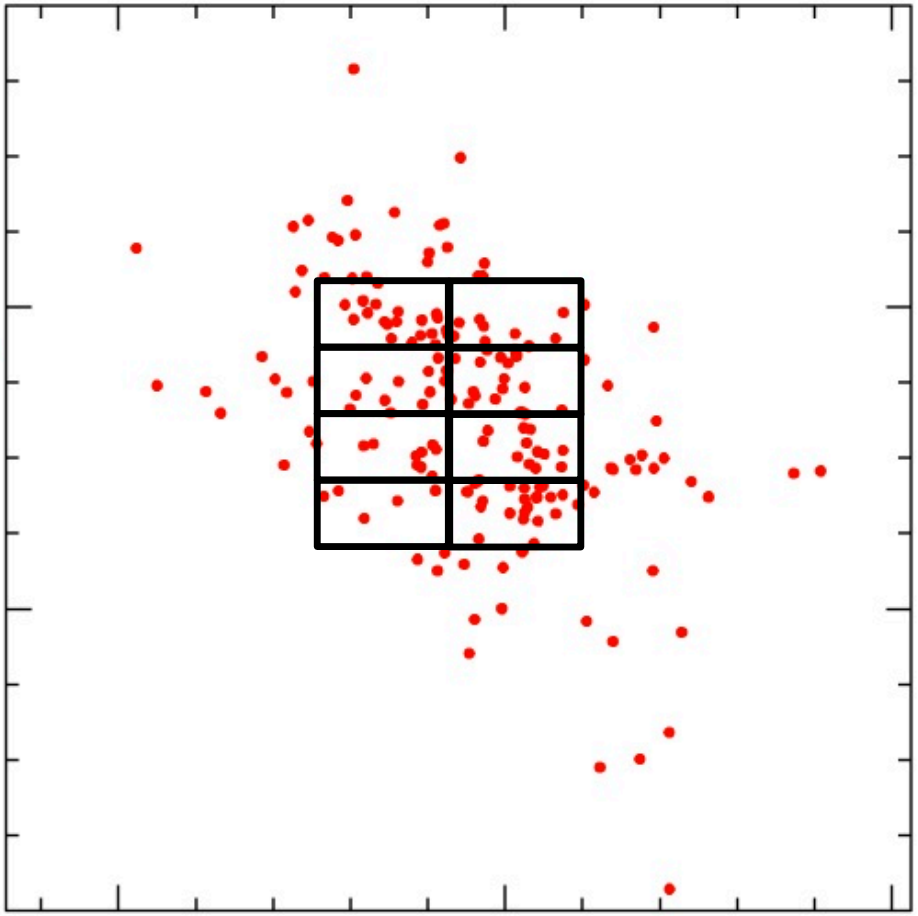


IRAC (Gutermuth et al. 2008)

IC 348

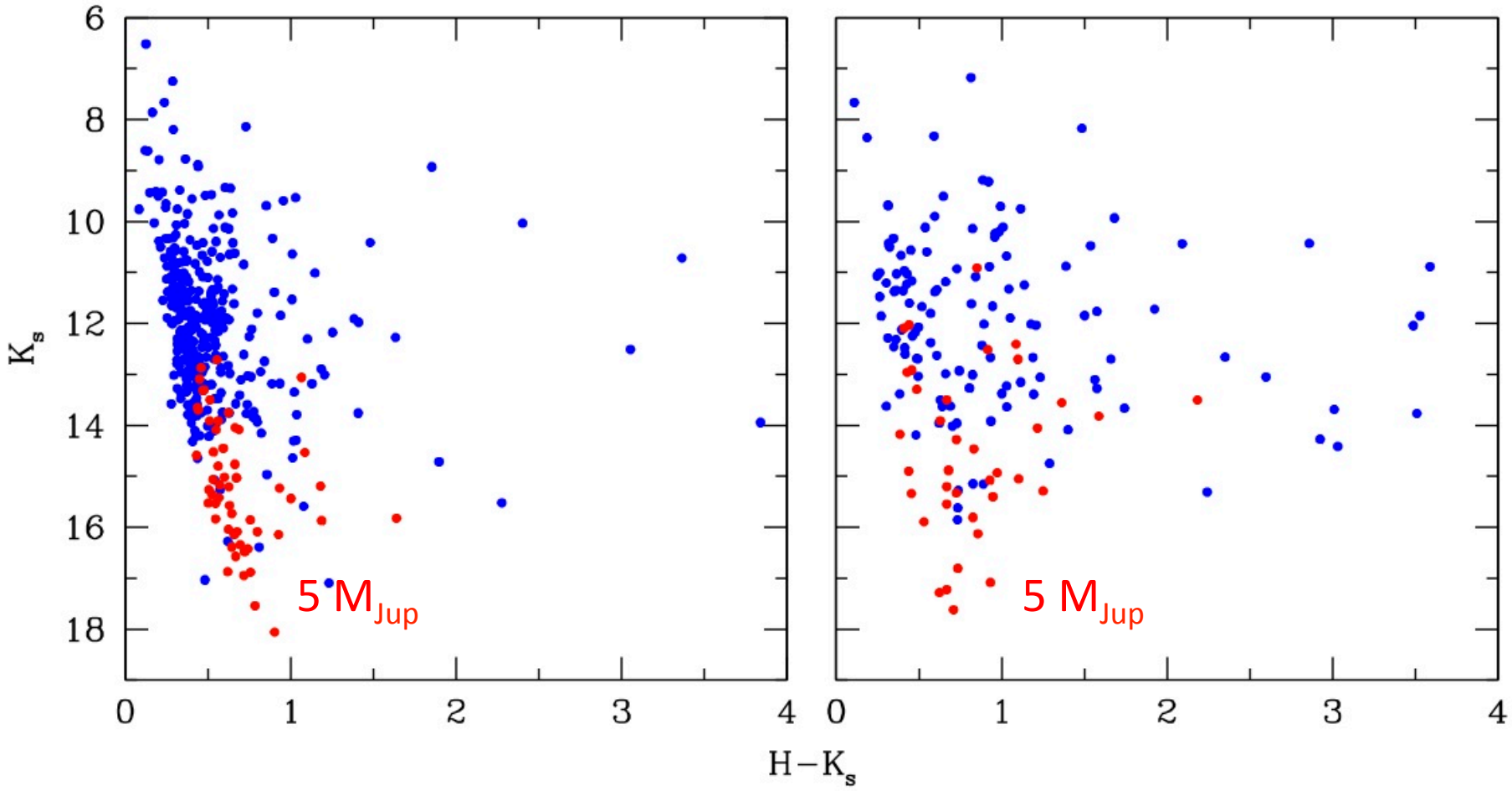
NGC 1333





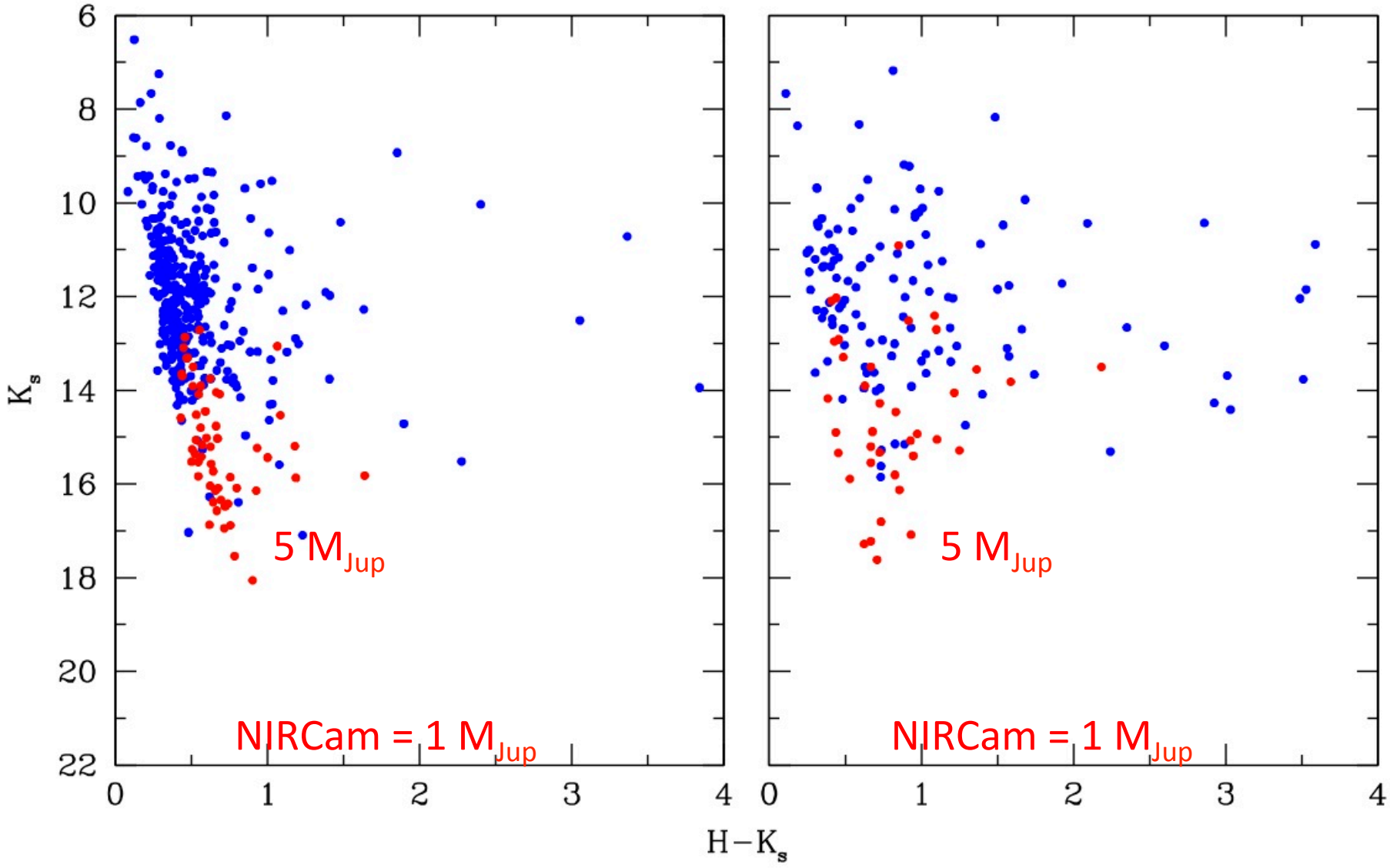
IC 348

NGC 1333



IC 348

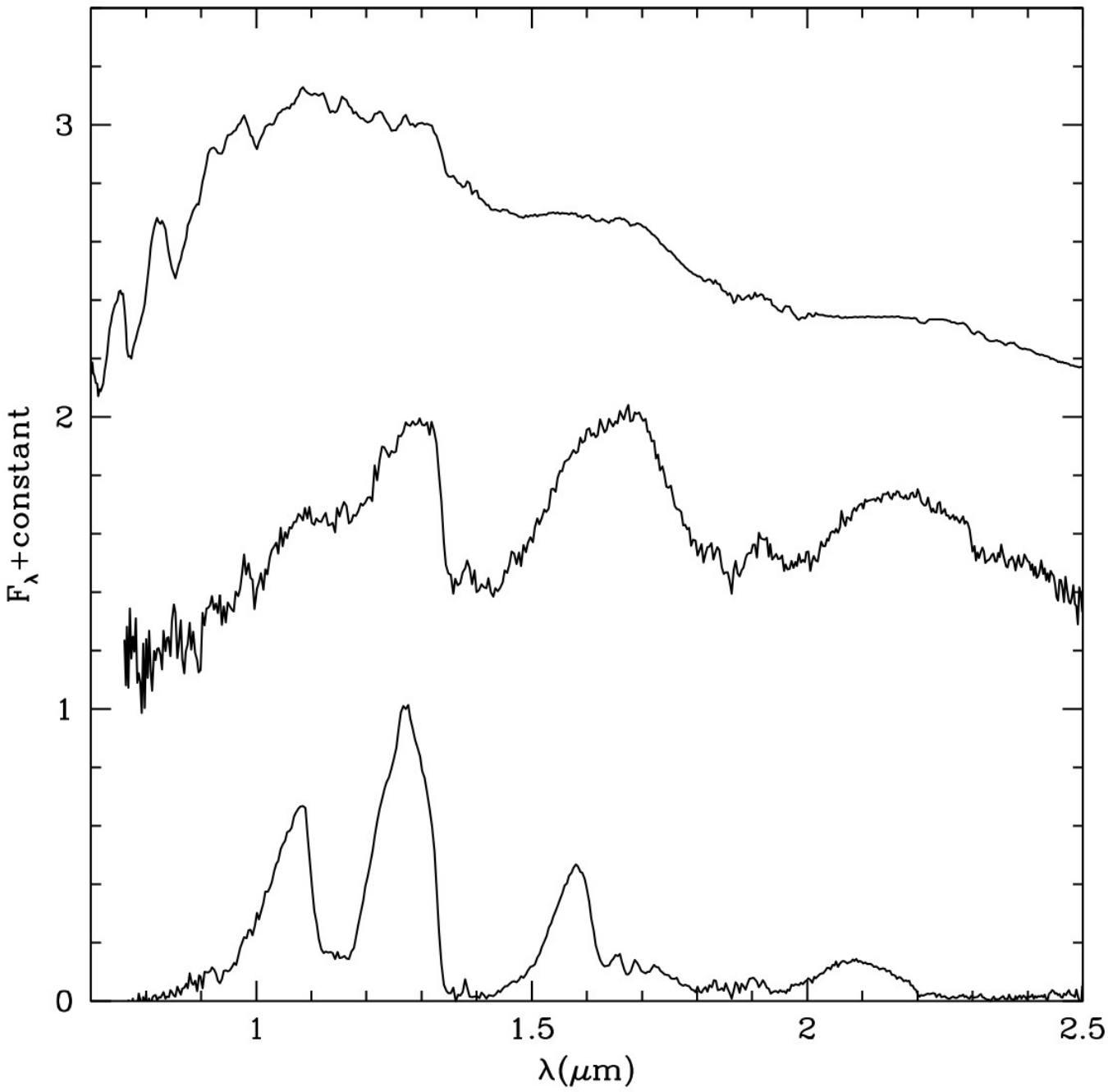
NGC 1333

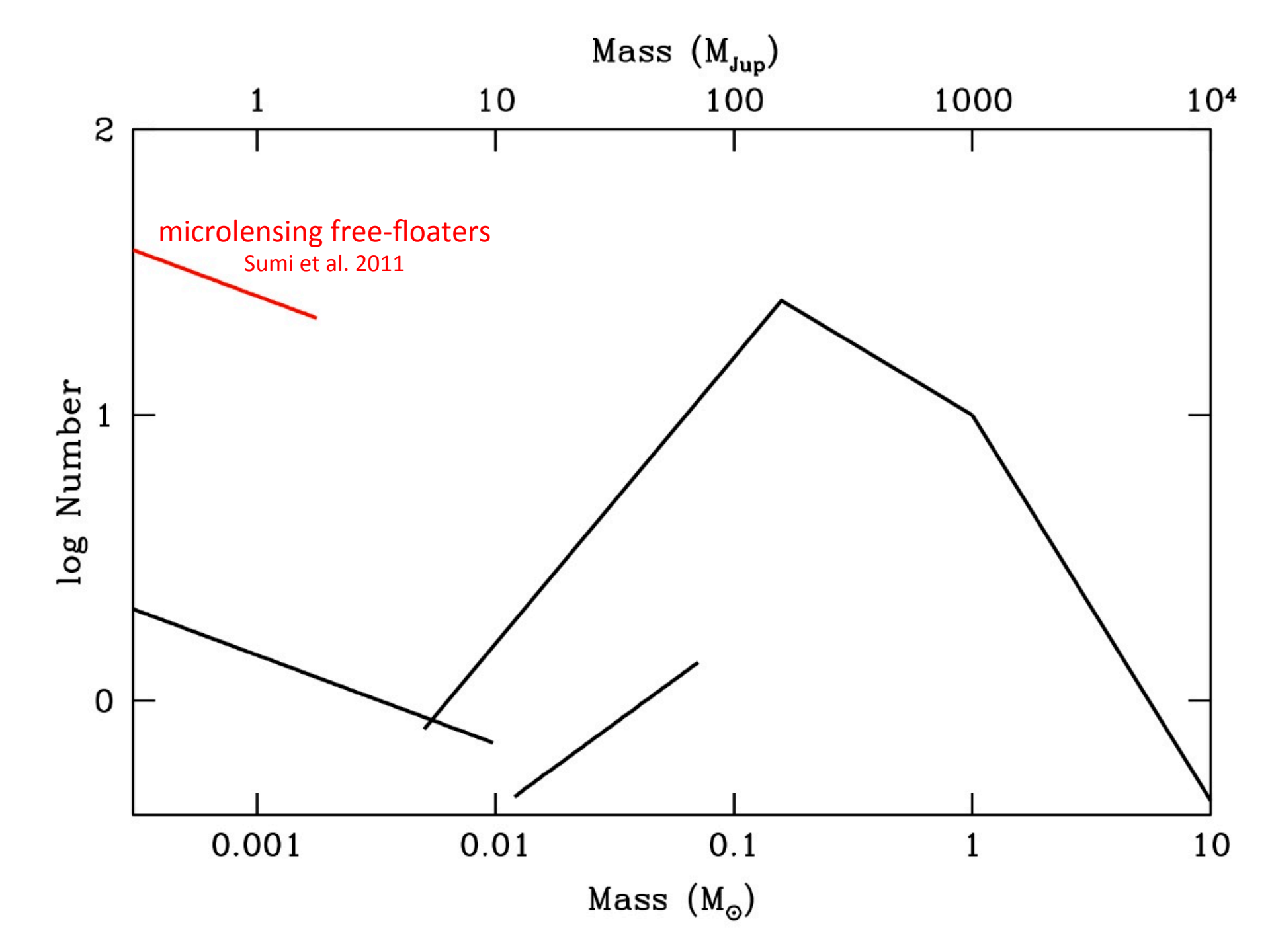


M dwarf

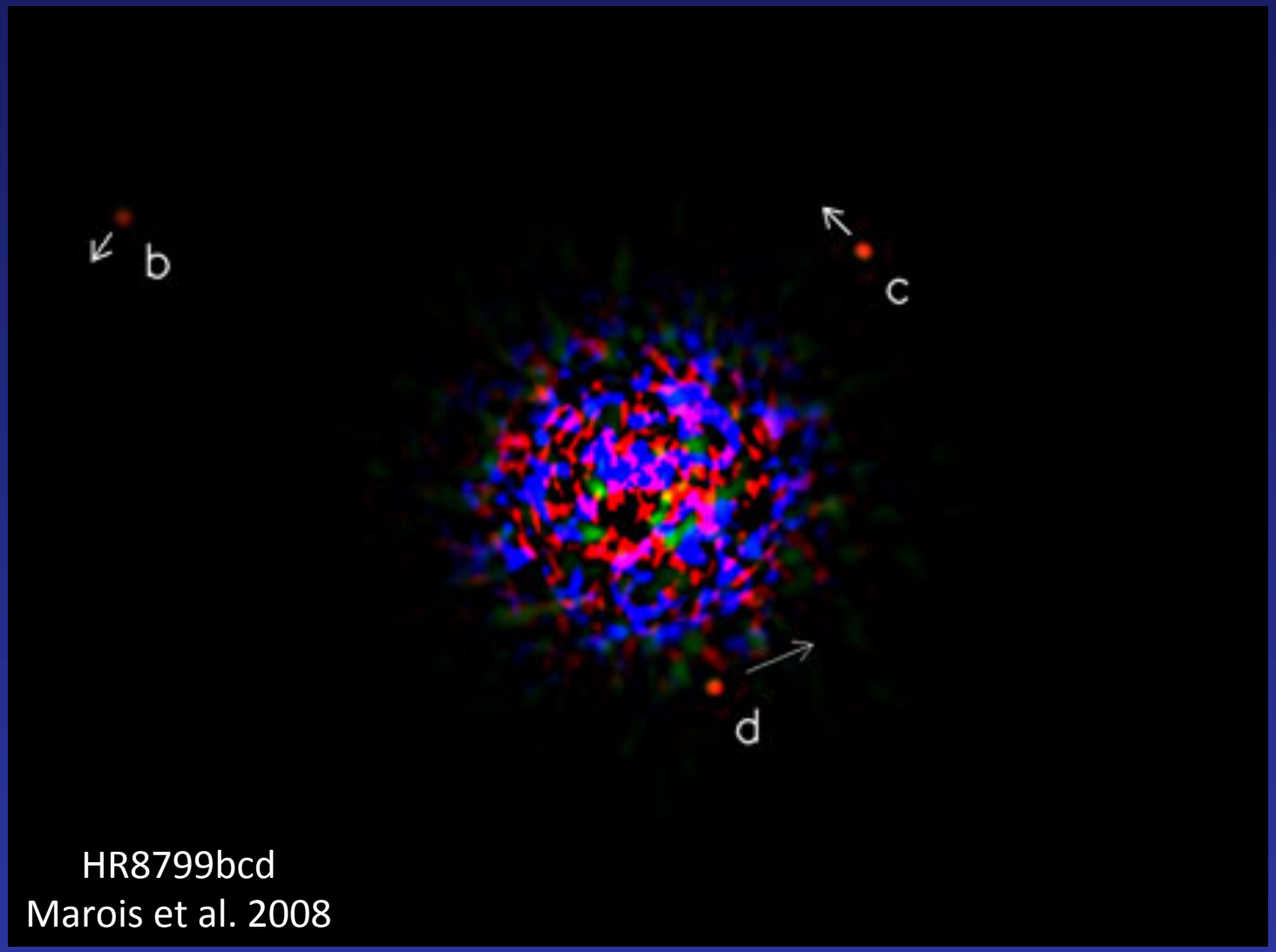
L dwarf

T dwarf




Mass (M_{Jup})
1
10
100
1000
10^4
2
1
0
log Number
microlensing free-floaters
Sumi et al. 2011
0.001
0.01
0.1
1
10
Mass ($M_\odot$)

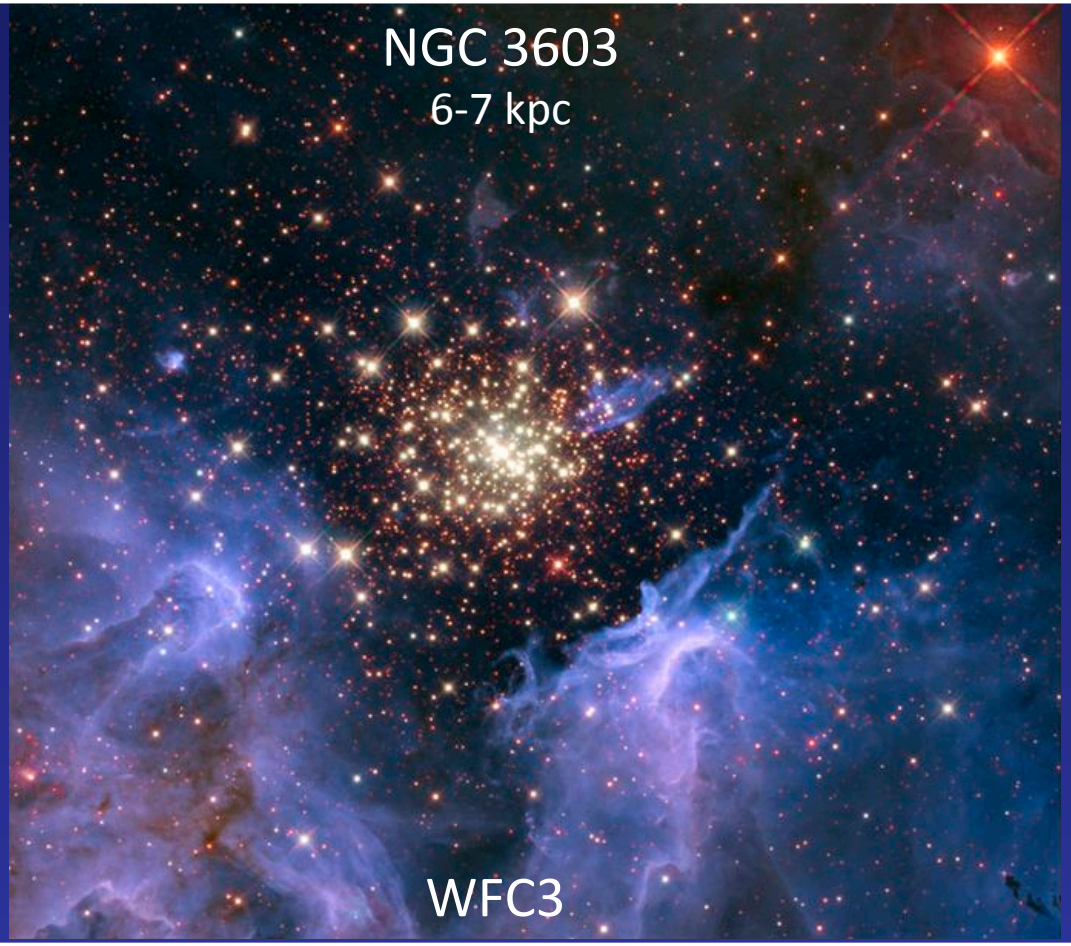
Use spectra of 1-10 M_{Jup} objects in clusters to help interpret spectra of young planets

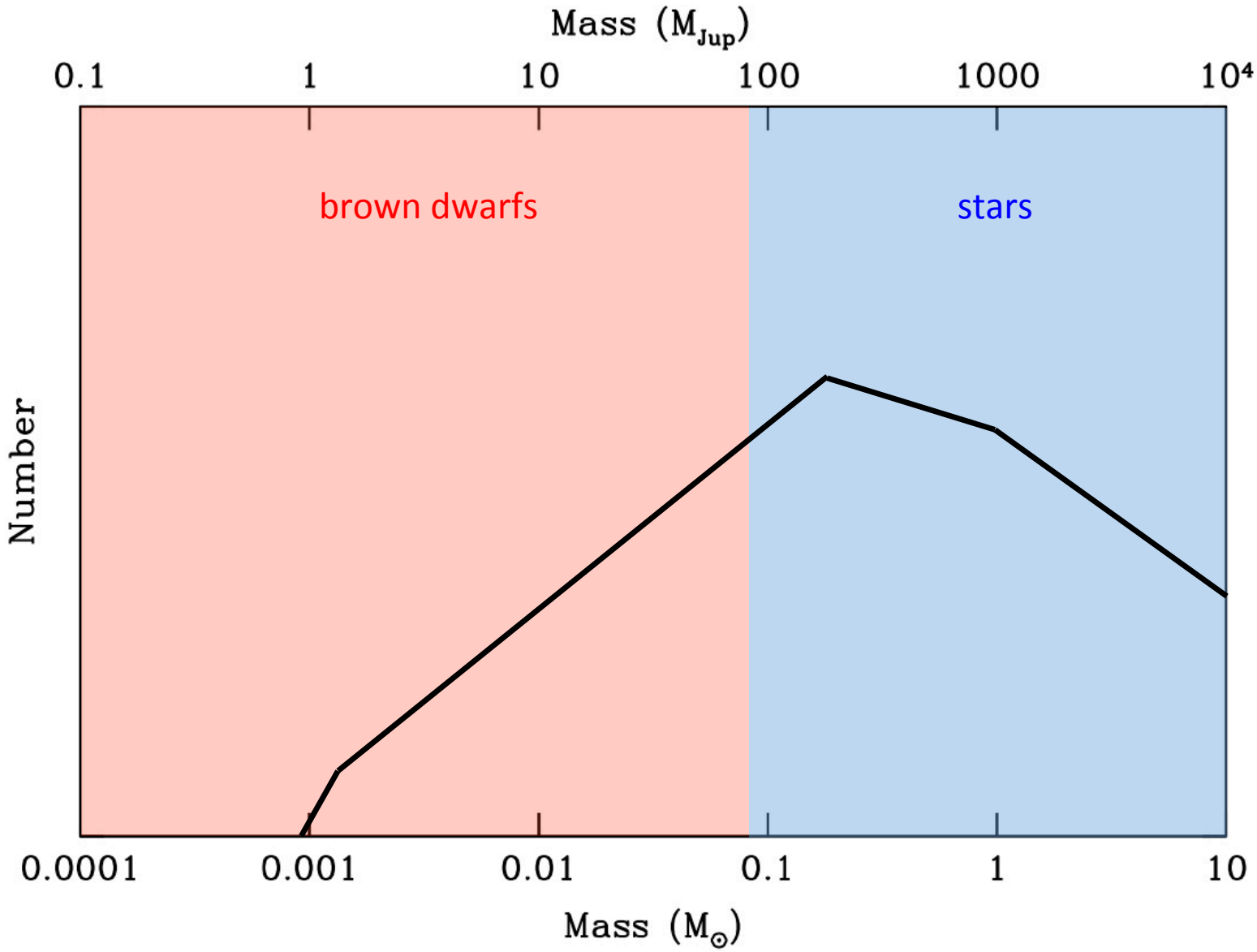


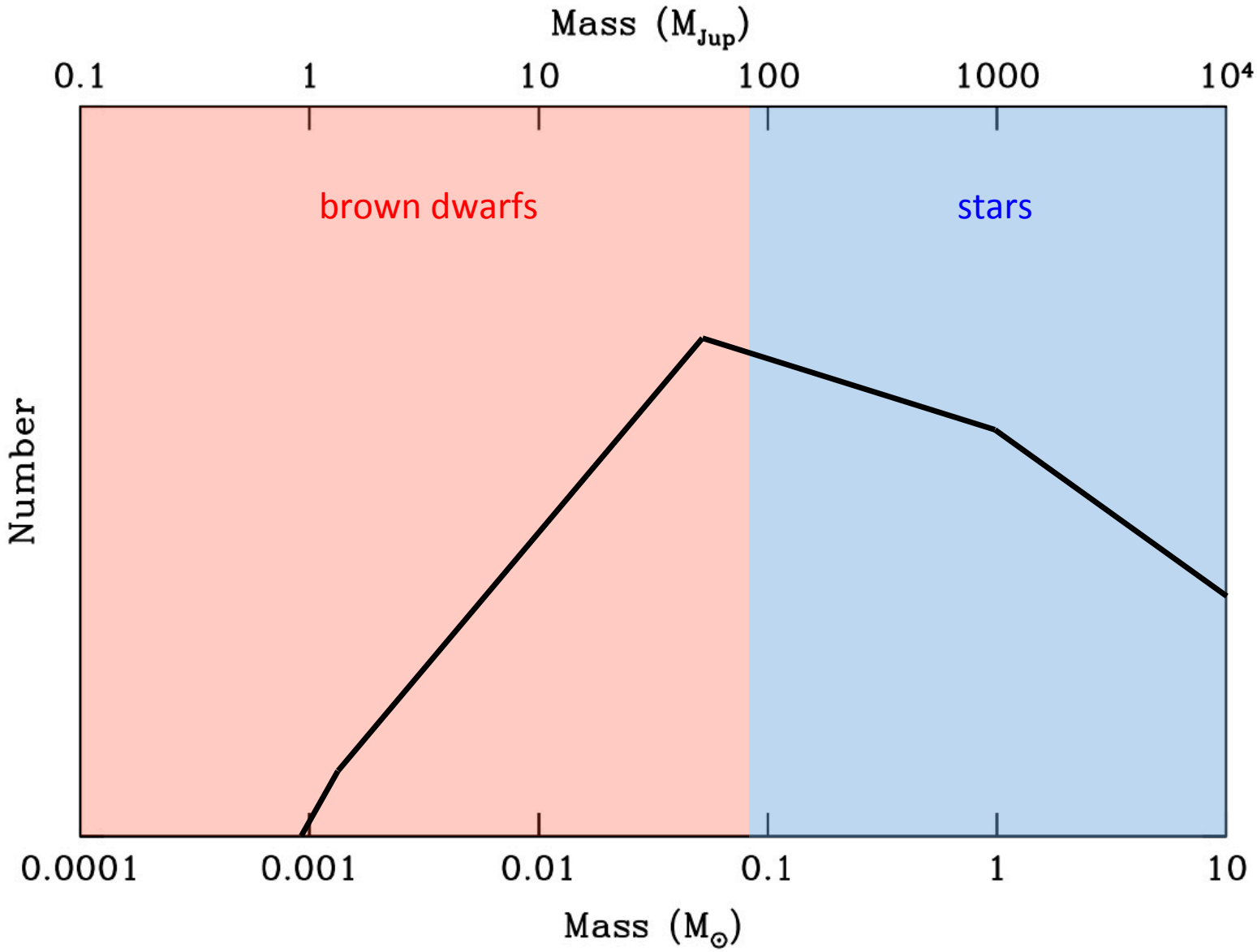
HR8799bcd
Marois et al. 2008

The substellar IMF in massive clusters

NIRCam




Mass (M_{Jup})
0.1
1
10
100
1000
10^4
brown dwarfs
stars
Number
0.0001
0.001
0.01
0.1
1
10
Mass ($M_\odot$)


Mass (M_{Jup})
0.1
1
10
100
1000
10^4
brown dwarfs
stars
Number
0.0001
0.001
0.01
0.1
1
10
Mass ($M_\odot$)

James Webb Space Telescope
Science Operations Design Reference Mission

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JWST SODRM Galactic Programs Summary

TITLE: Imaging of Galactic Massive Star Forming Regions and Young Clusters

ID: 93060

GOAL: This program will survey young massive clusters and star forming regions in the Milky Way, with the goal of determining YSO classifications and characterizing circumstellar disk emission for the full stellar mass range (and, in many cases, into the brown dwarf regime). A total of 11 regions have been selected, with distances ranging from ~ 2 to 7 kpc. The sample includes a range of cluster sizes, from thousands to tens of thousands of stars, and apparent ages ranging from <1 to ~5 Myr. The NIRCam images will be used primarily for characterization of very young and low mass stellar objects, as well as target identification for follow-up NIRSpec MSA observations (using the F187N filter in order to measure positions for the brightest possible stars). We selected 6 MIRI broad band filters in order to sample both dust continuum emission and 10 and 18 μm silicate features for the most detailed possible spectral energy distributions of protostars and Class II possible spectral energy distributions of protostars and Class II disked stars.

TARGET(S):

NGC 3603
RCW 49
M 16
M 17

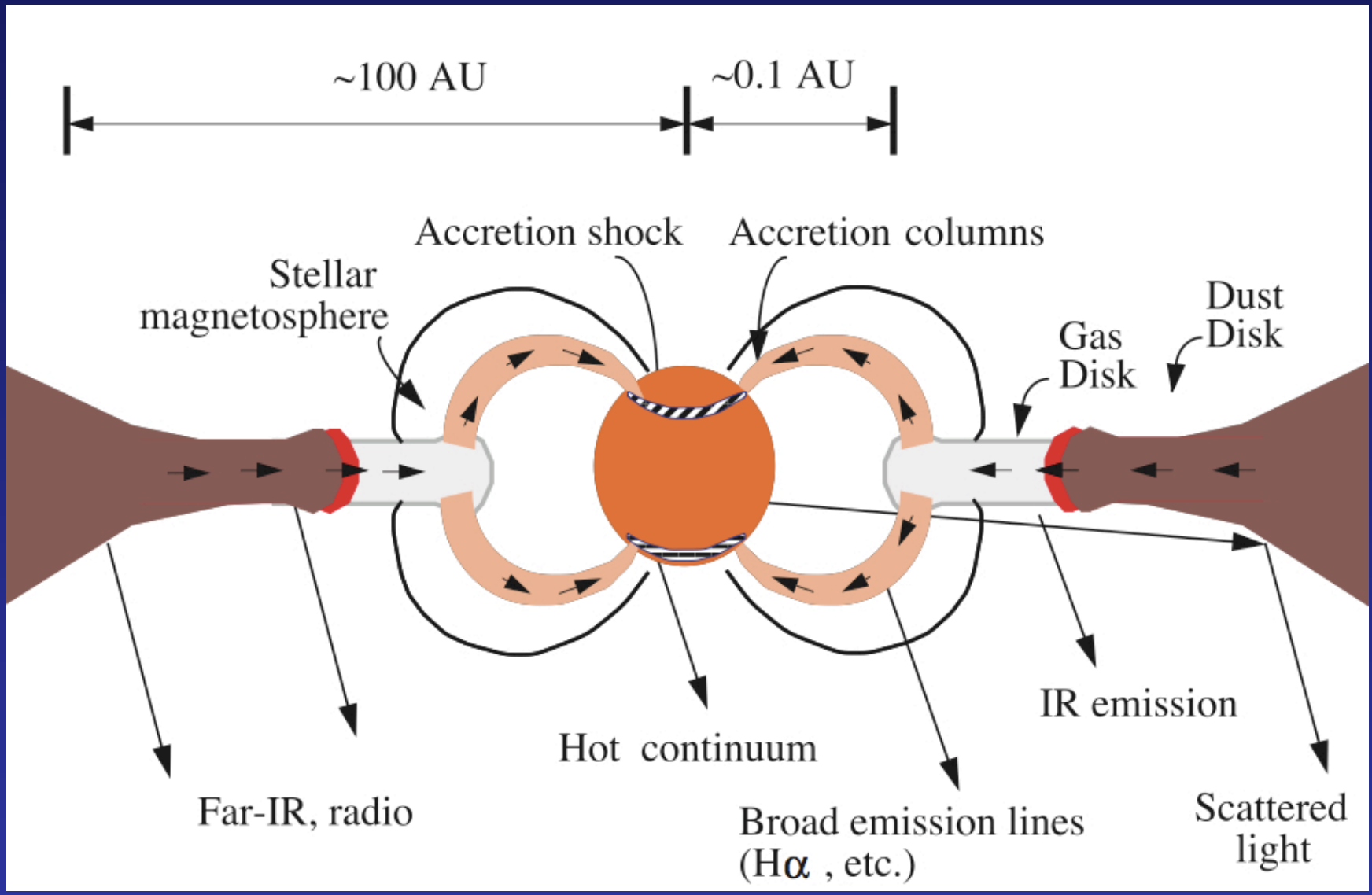
SODRM Programs

- Science Programs
- Science Programs Summaries
- Science Programs Higlights

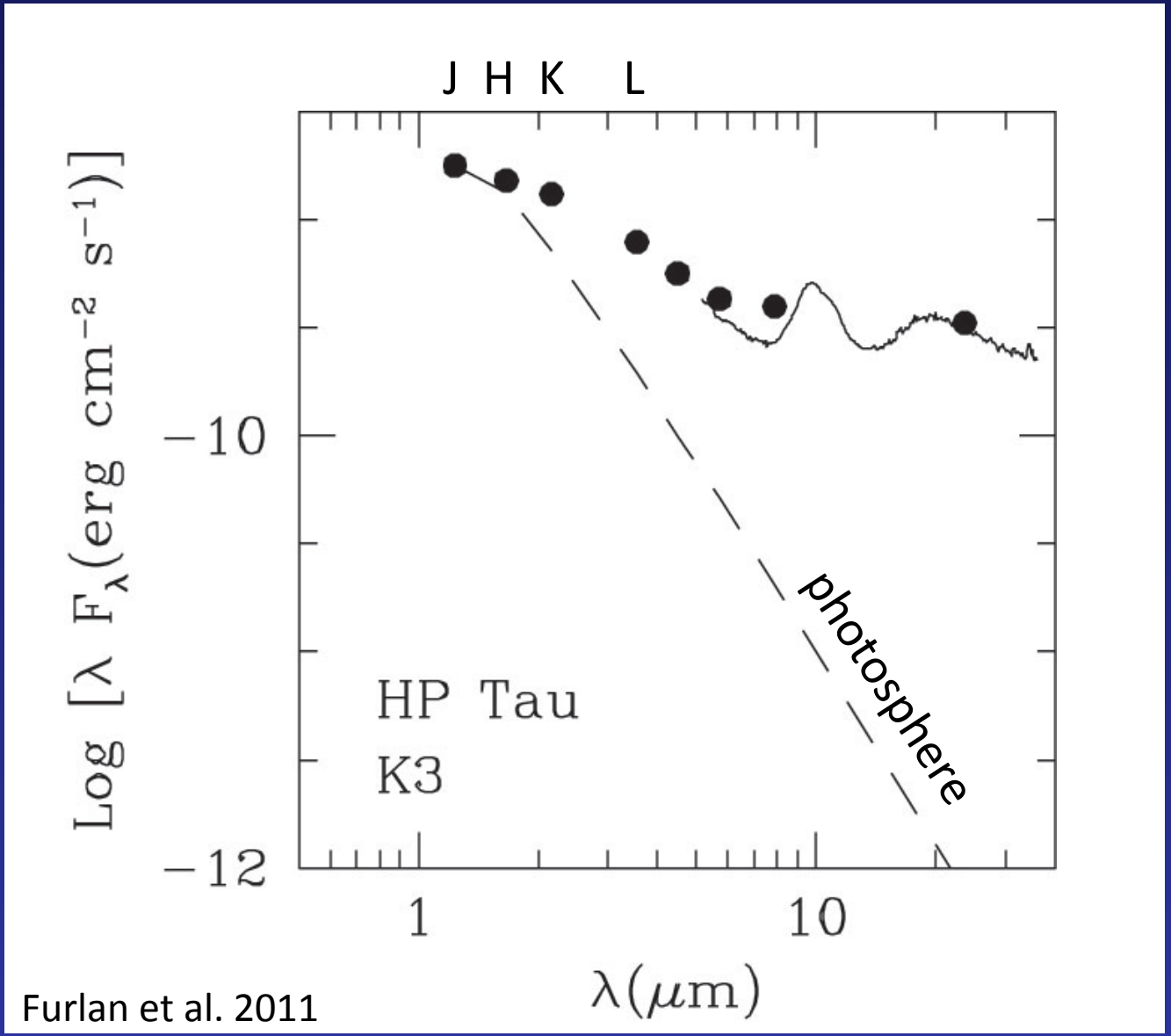
Outline

- IMF of brown dwarfs
- Circumstellar disks around brown dwarfs

Easiest method of detecting disks: mid-IR photometry

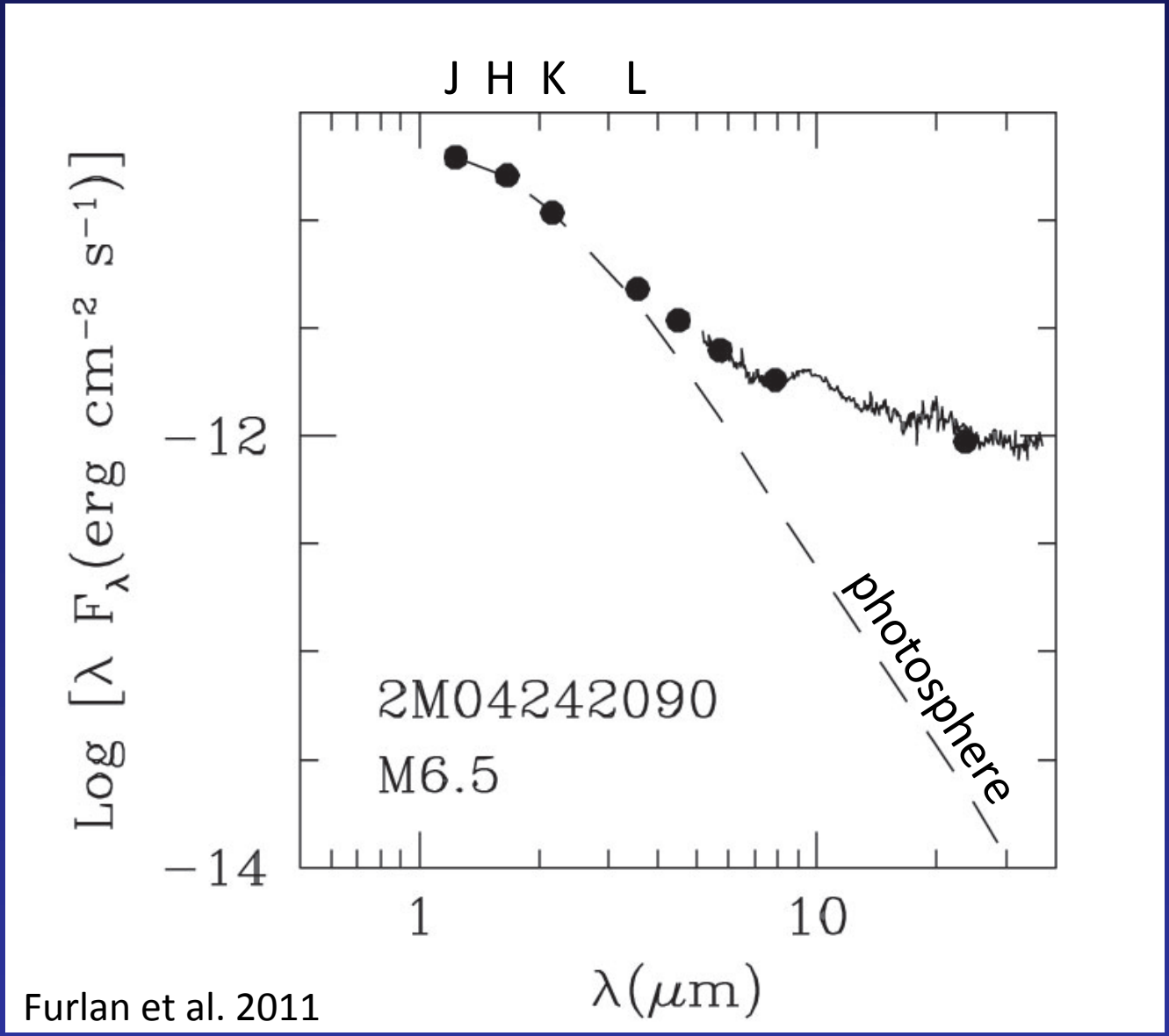


Disks detected around solar-type stars with JHKL



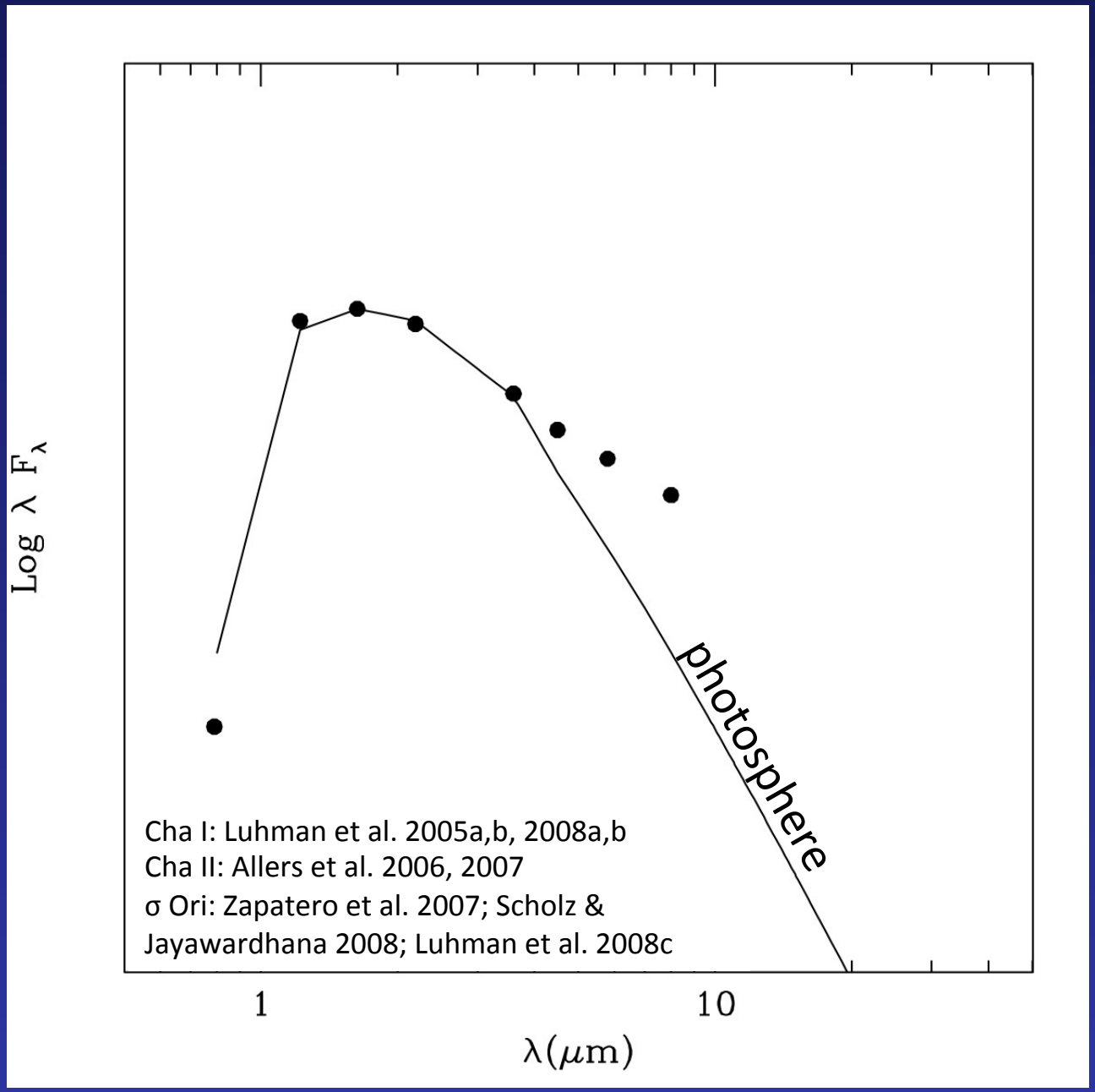
Furlan et al. 2011

Longer wavelengths needed for brown dwarf disks

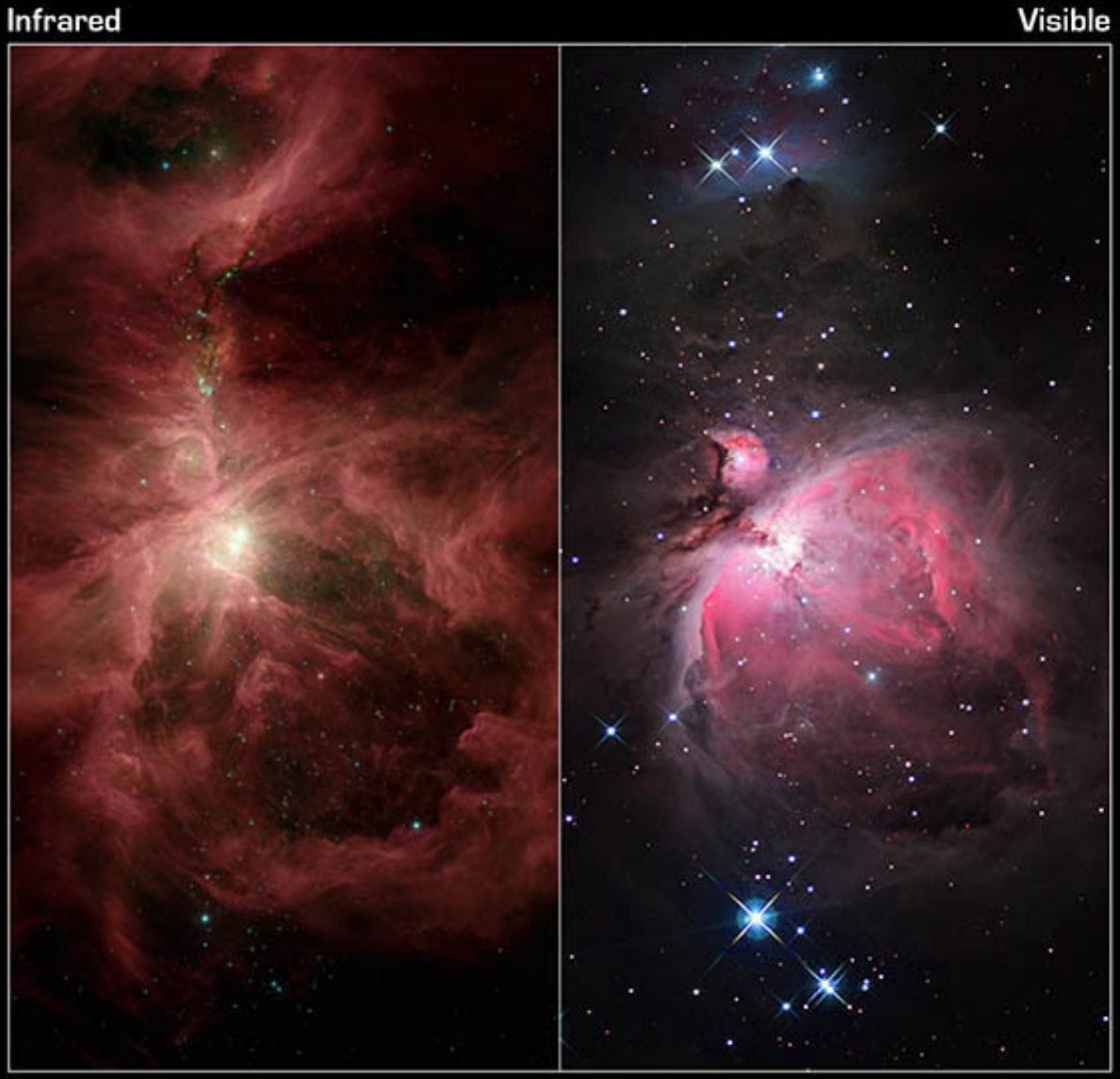


Furlan et al. 2011

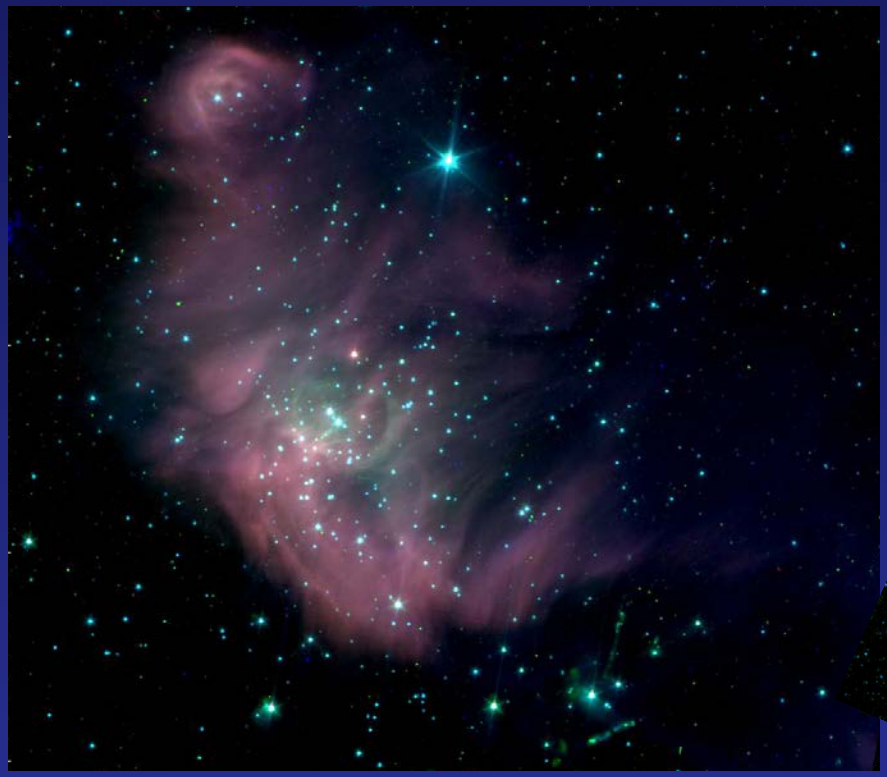
Spitzer detected disks for brown dwarfs at ~10 M_{Jup}



Orion: very bright in mid-IR

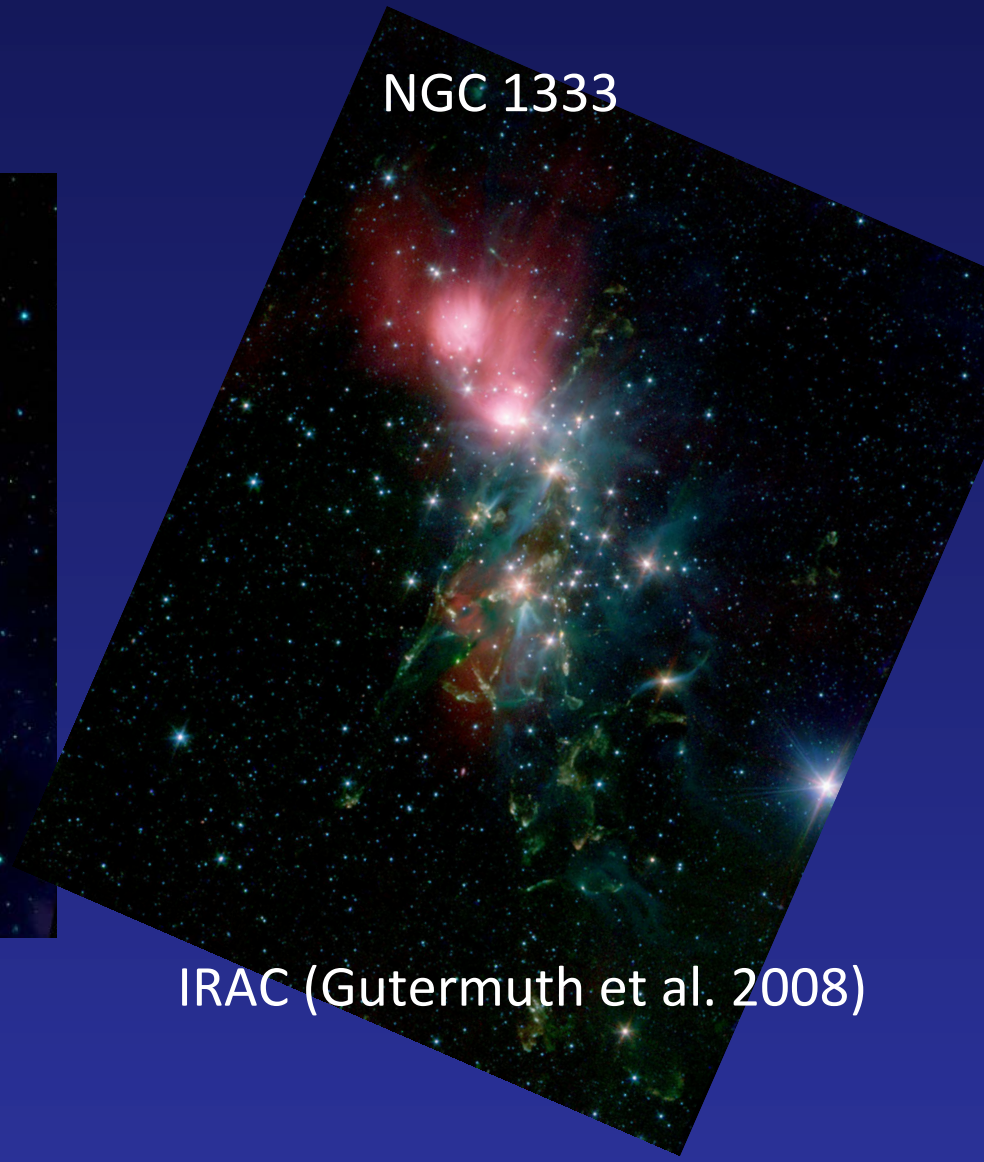


IC 348



IRAC (Lada et al. 2006)

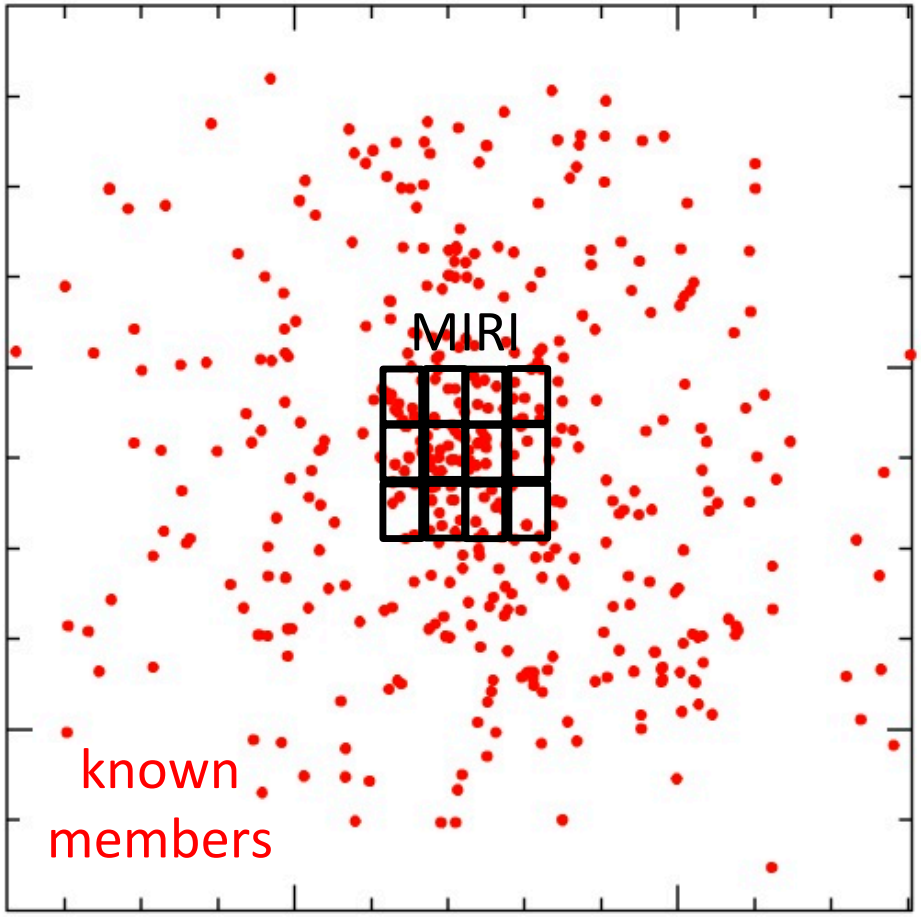
NGC 1333

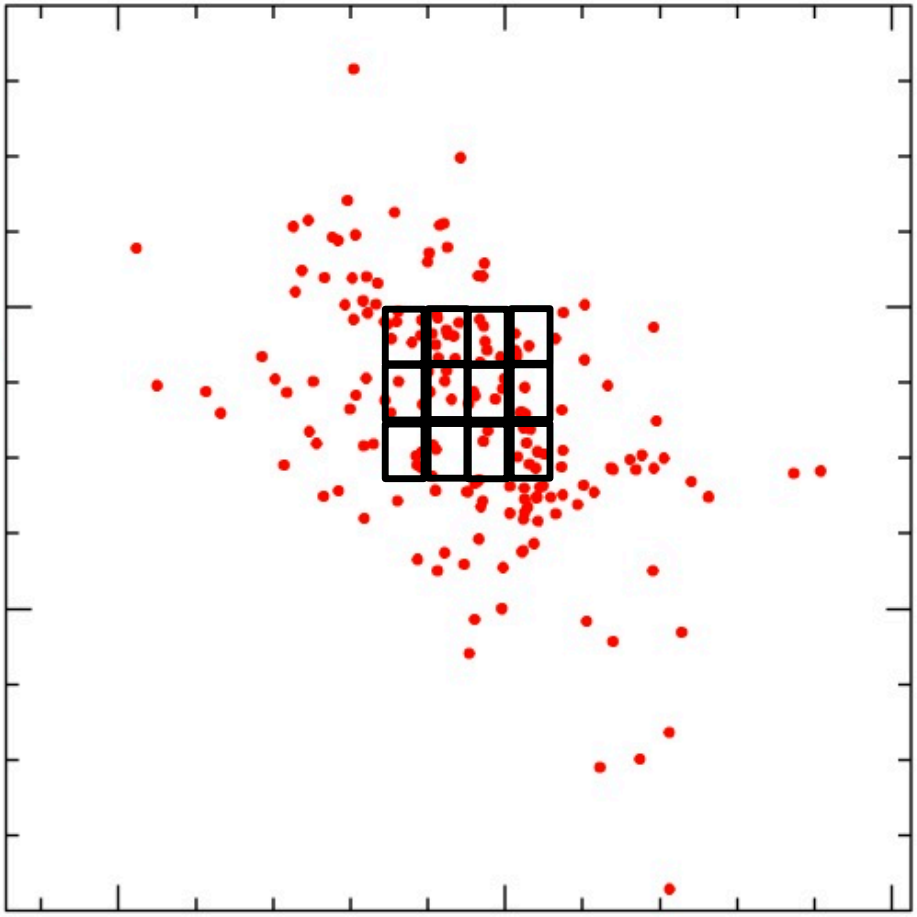


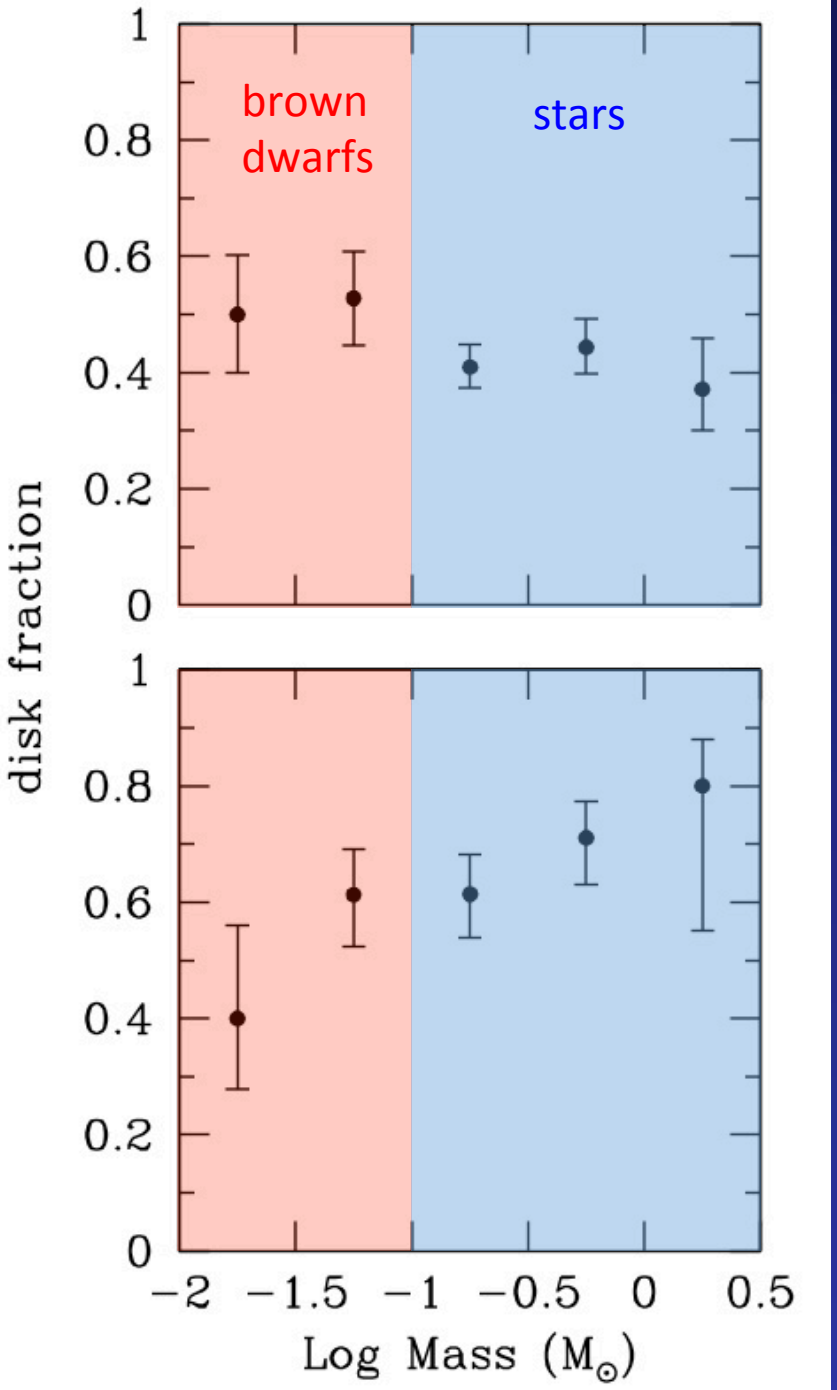
IRAC (Gutermuth et al. 2008)

IC 348

NGC 1333

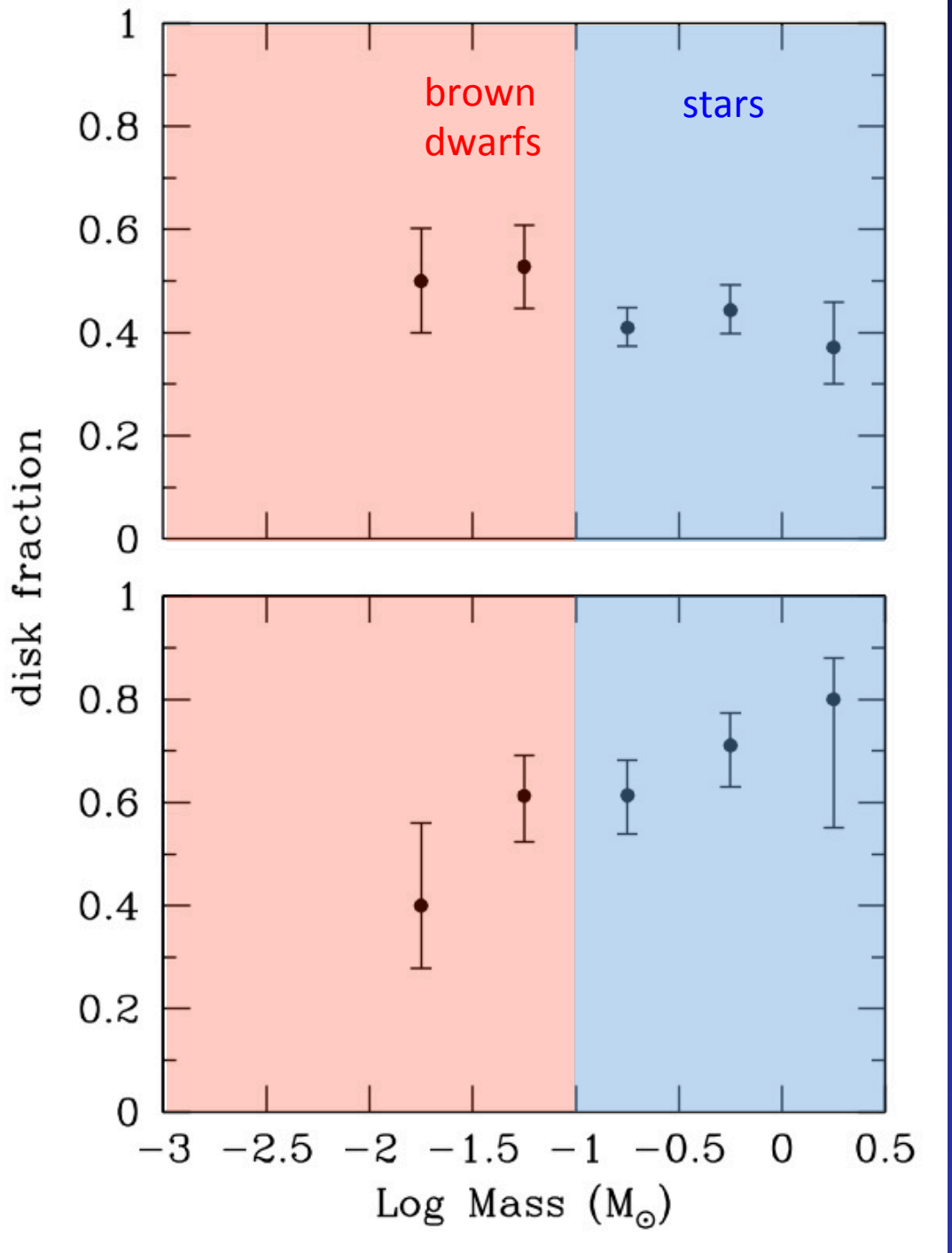






IC 348

NGC 1333

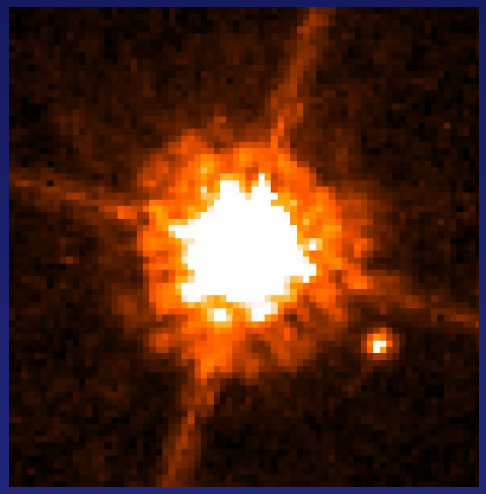


IC 348

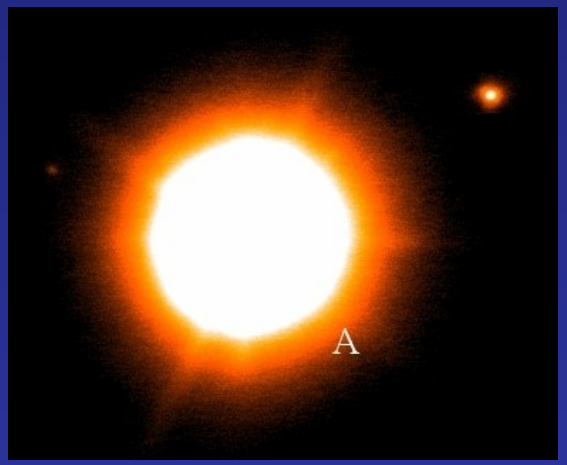
NGC 1333

Young planetary-mass companions (<20 M_{Jup})

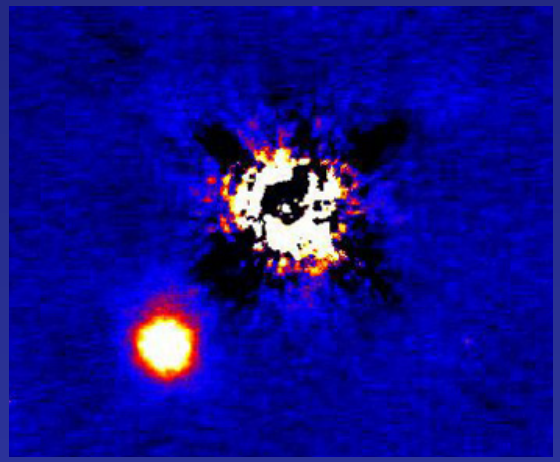
2M 1207B
Chauvin et al. 2004



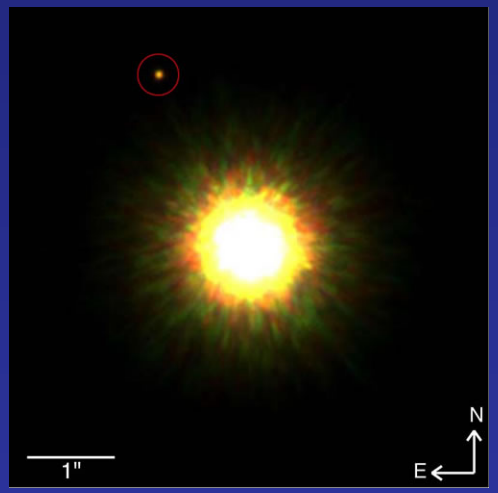
CHXR73B
Luhman et al. 2006



CT Cha B
Schmidt et al. 2008

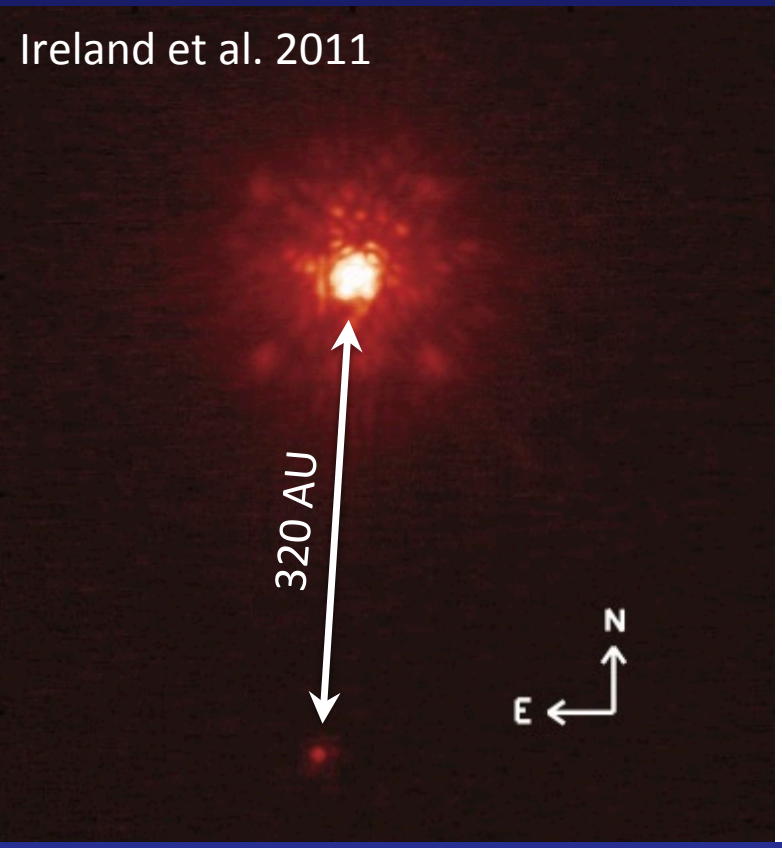


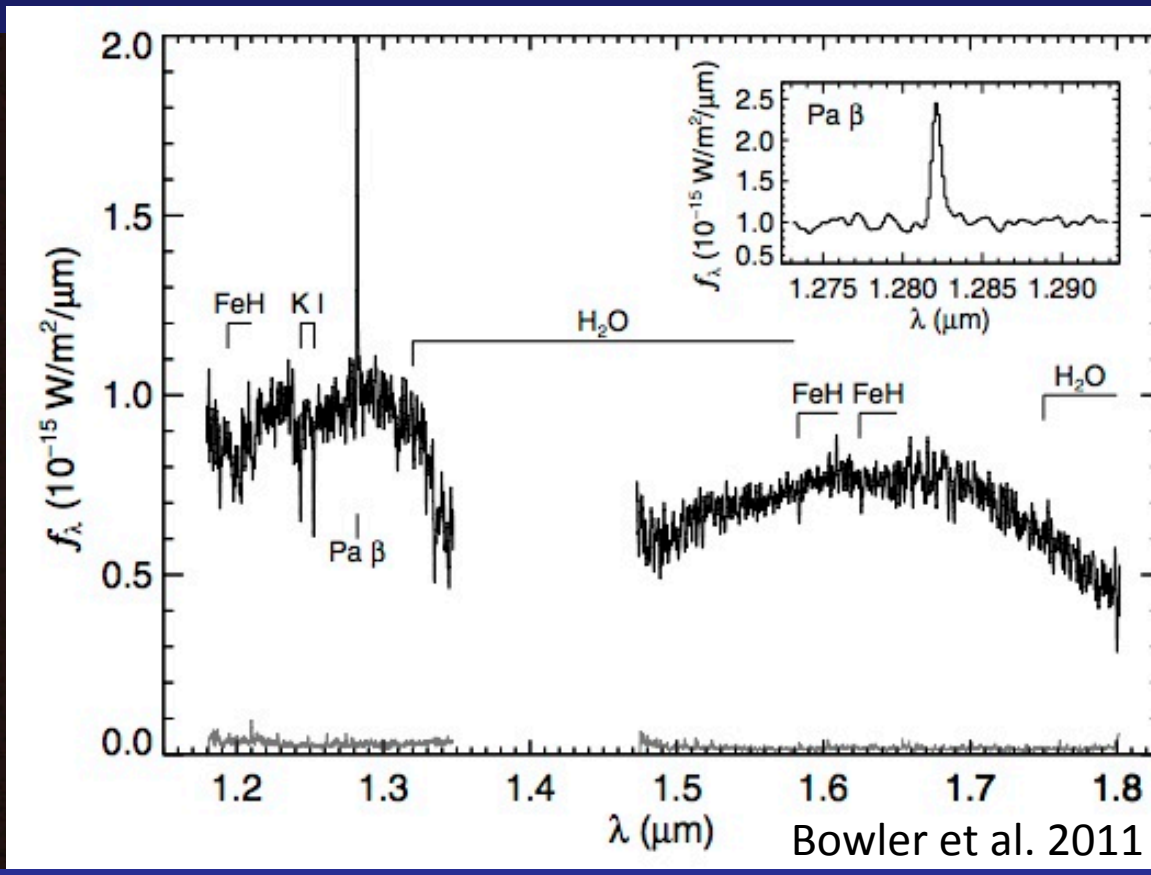
DH Tau B
Itoh et al. 2005



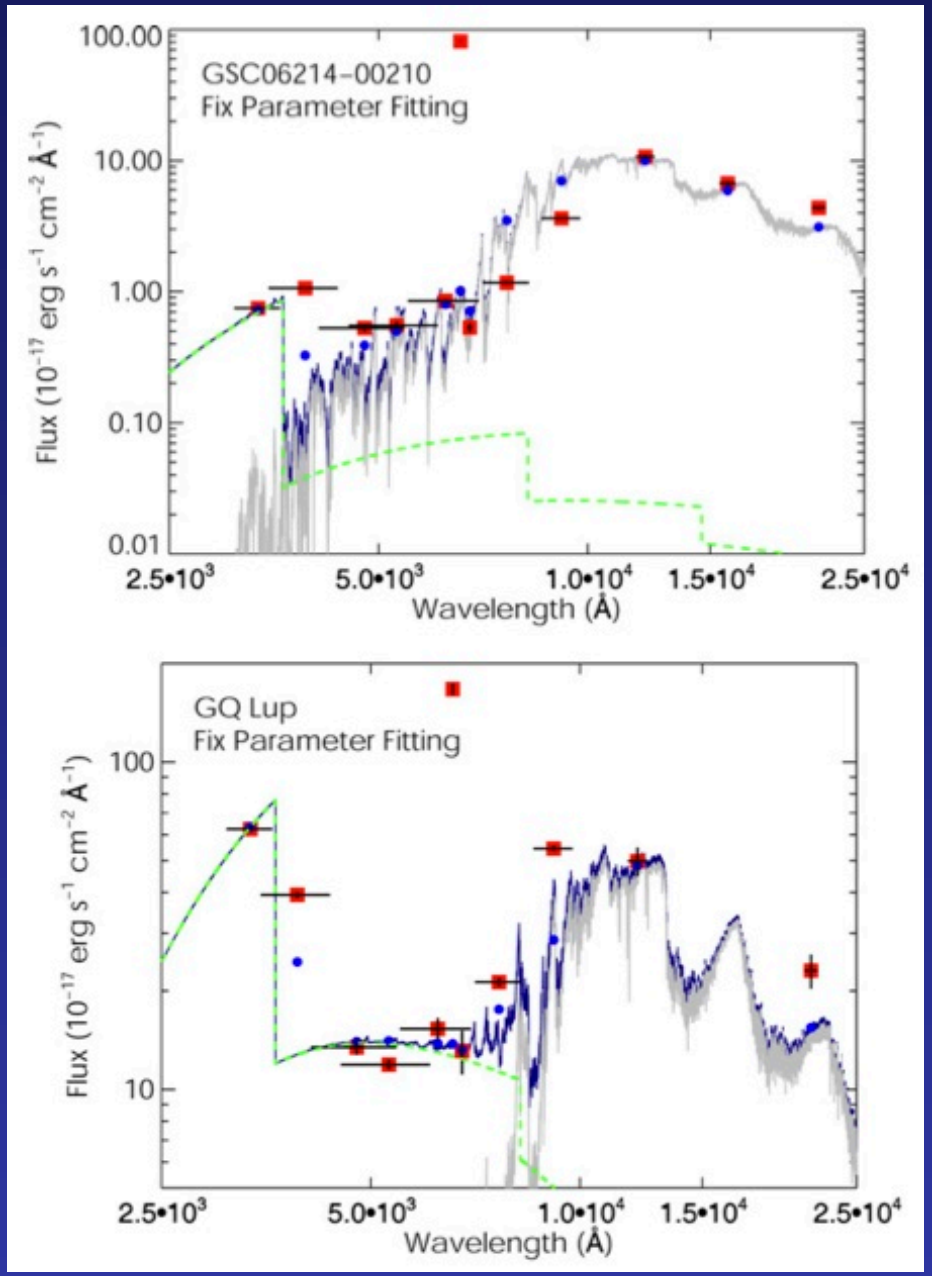
1609-2105B
Lafreniere et al. 2008

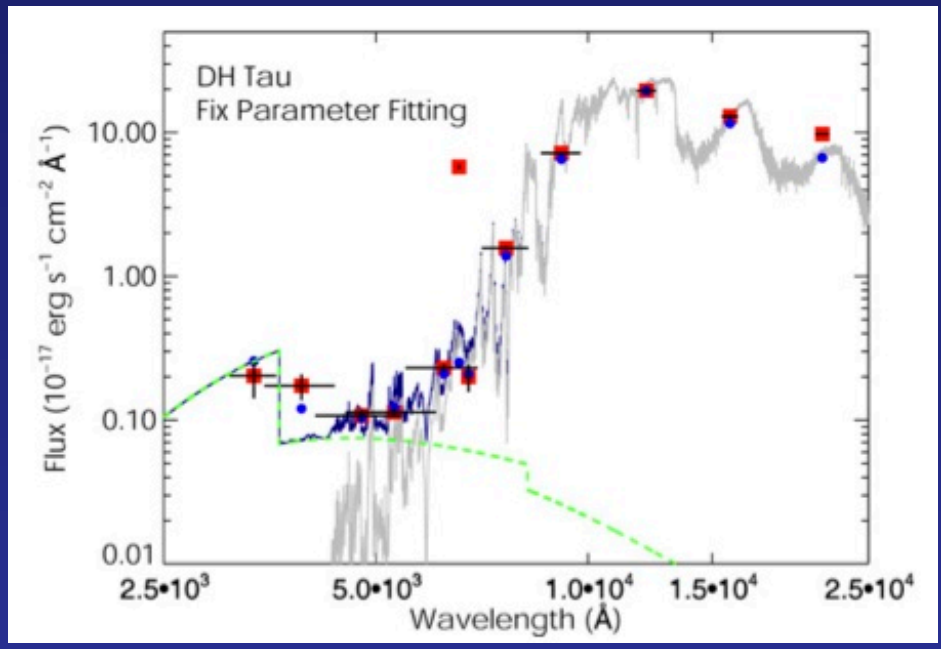
Accretion detected with IR line emission





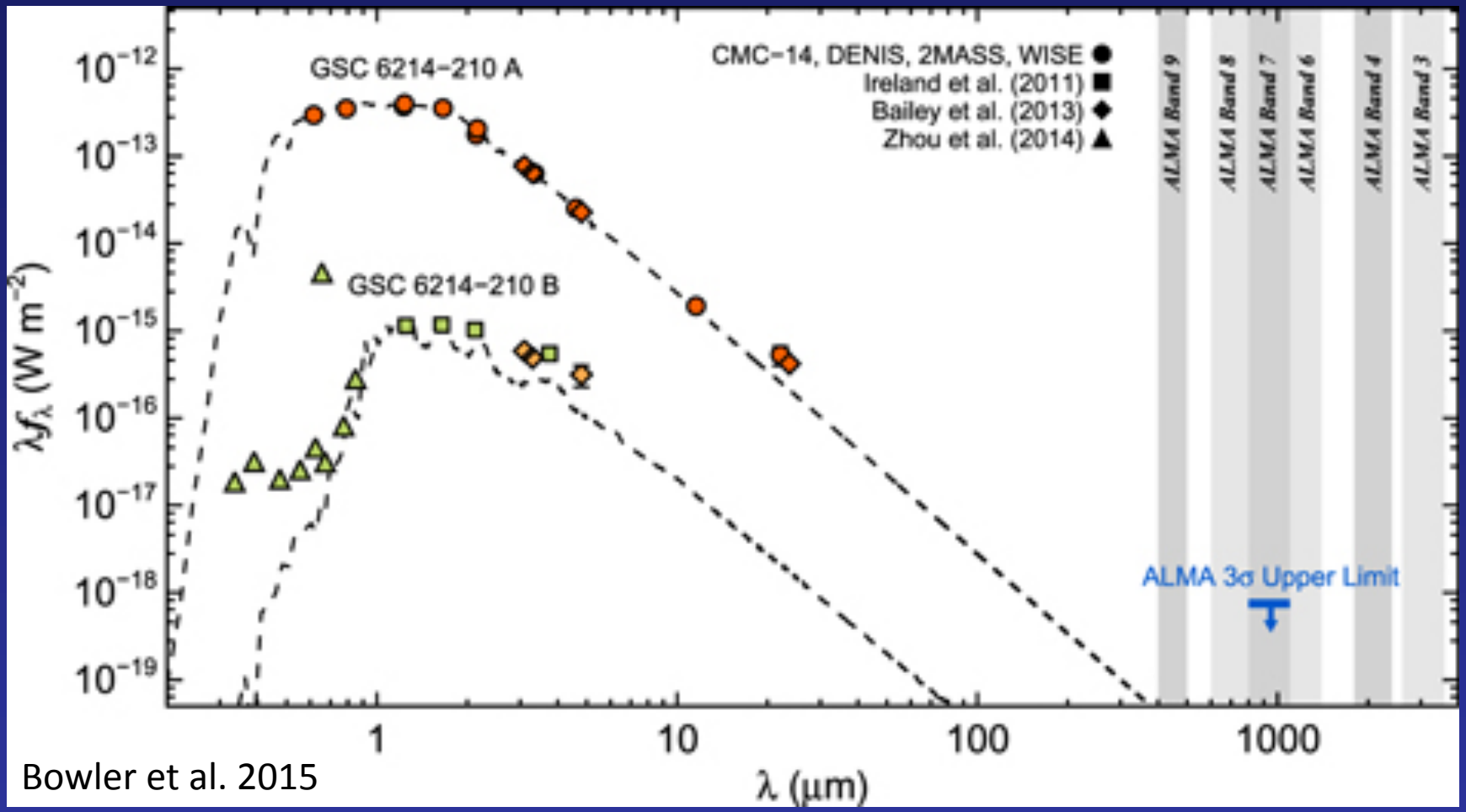
Accretion detected with UV excess





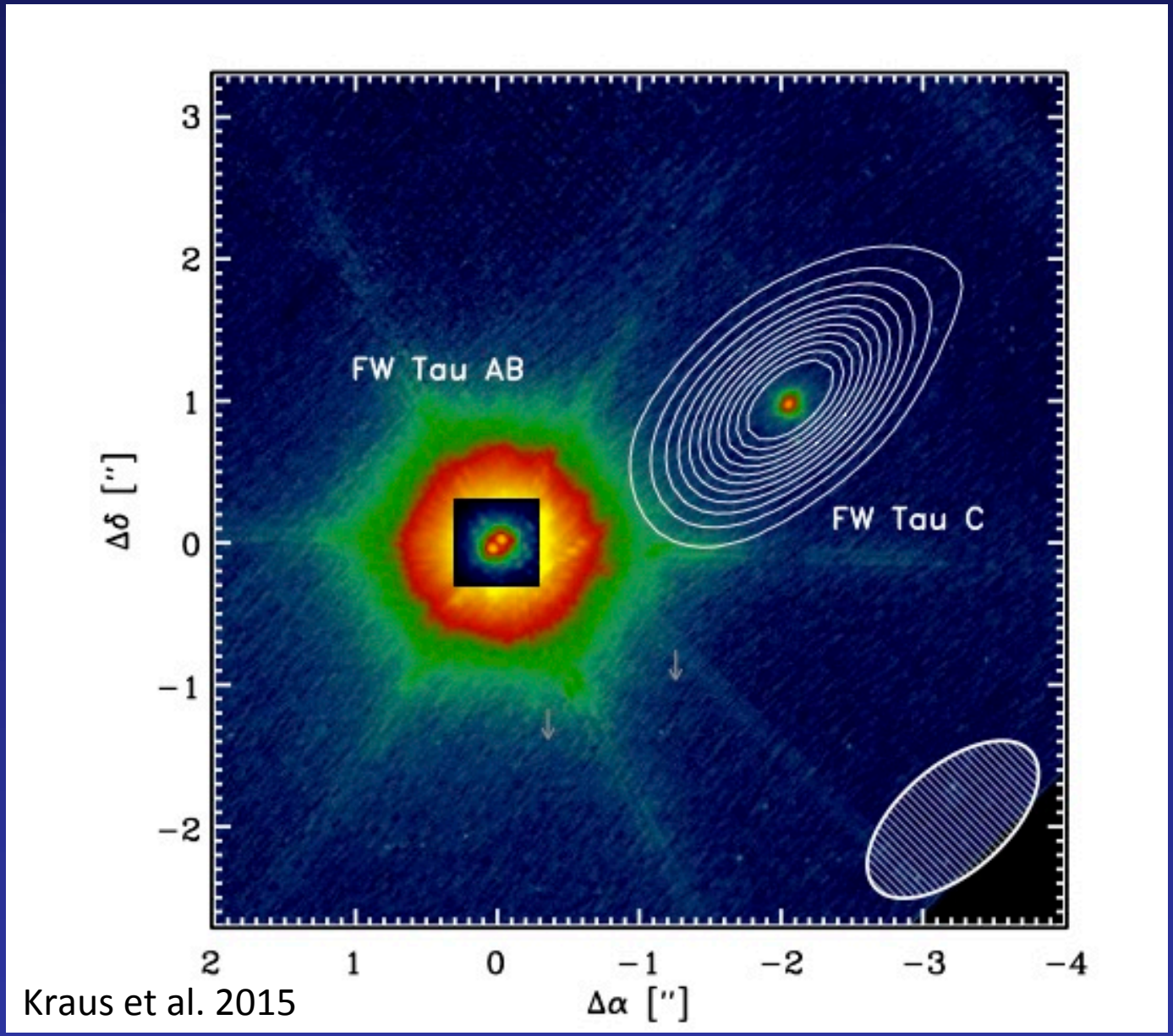
Zhou et al. 2014

ALMA non-detection: $M_{disk} < 0.05\ M_{Jup}$



Bowler et al. 2015

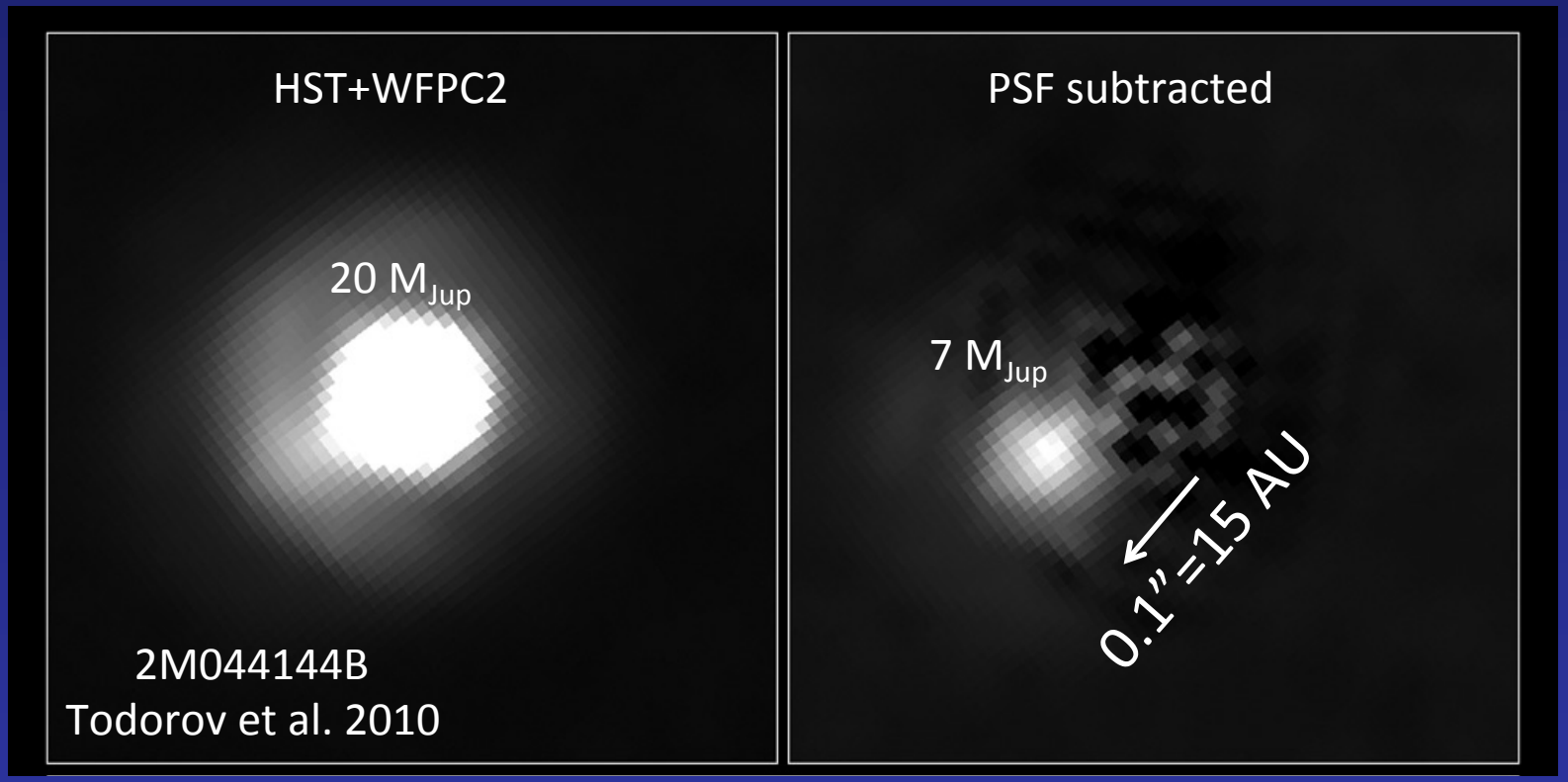
ALMA 1.3mm detection of FW Tau C
Dust mass = 1-2 M_{earth} (total mass ~ 0.5 M_{Jup})



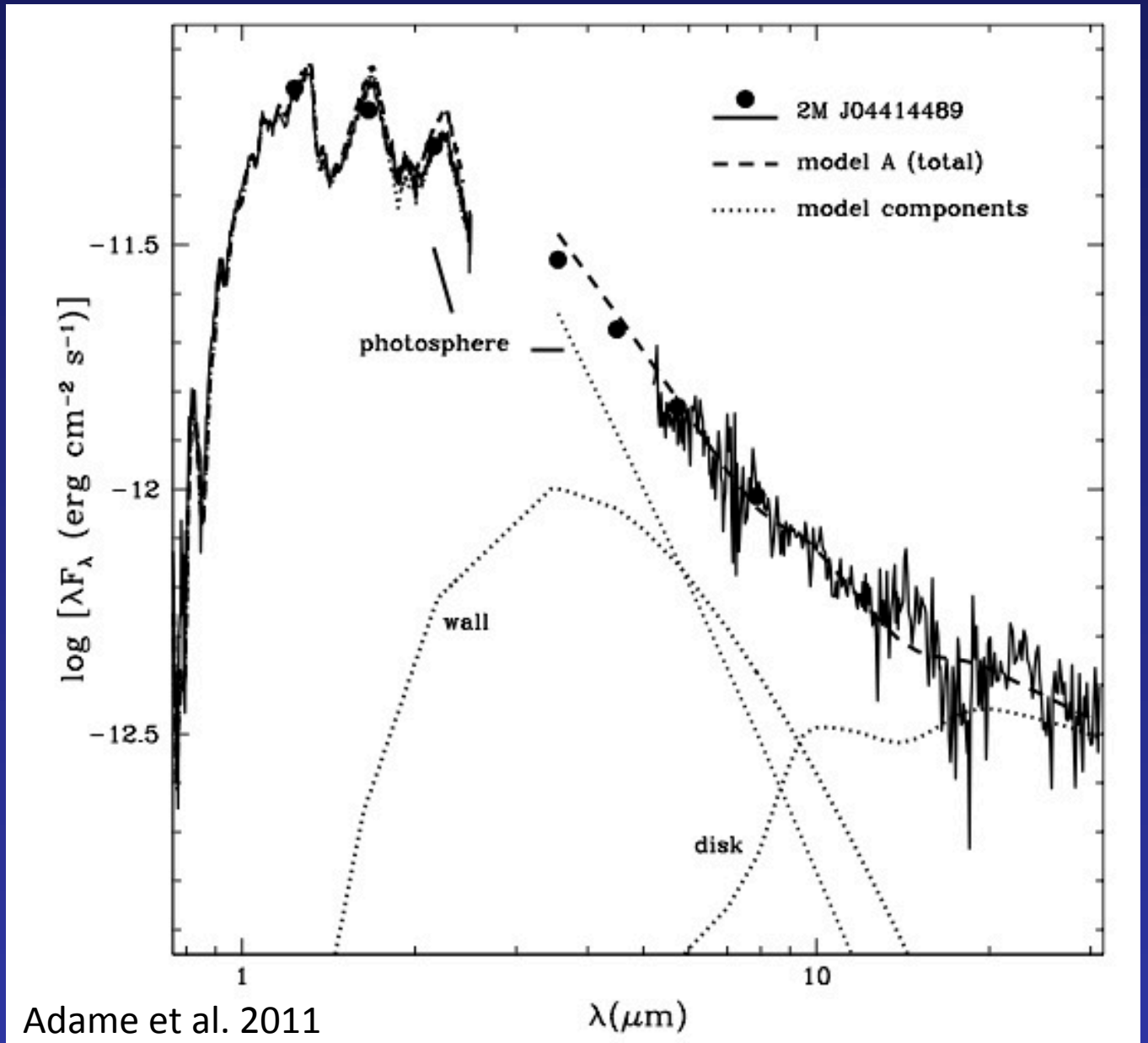
Kraus et al. 2015

MIRI offers greatest sensitivity to disks around planetary-mass companions

Example target in Taurus



Unresolved Spitzer IRS for primary + secondary

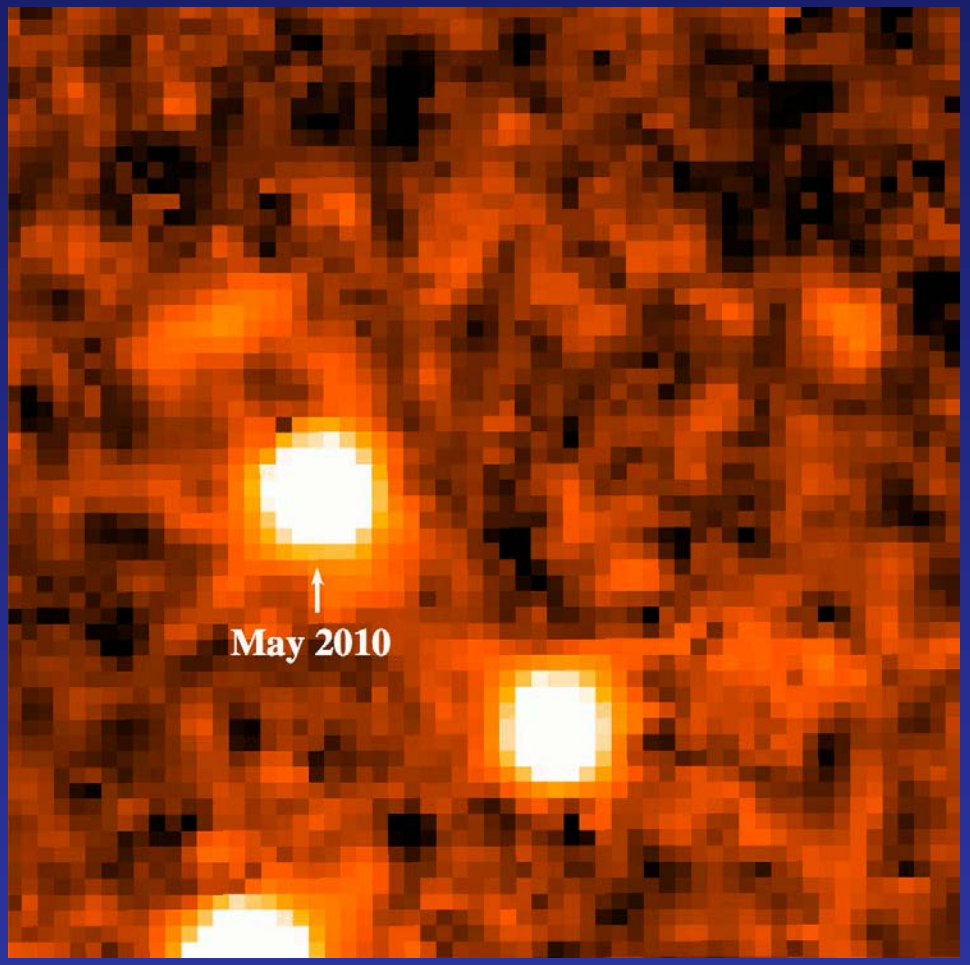


Adame et al. 2011

Outline

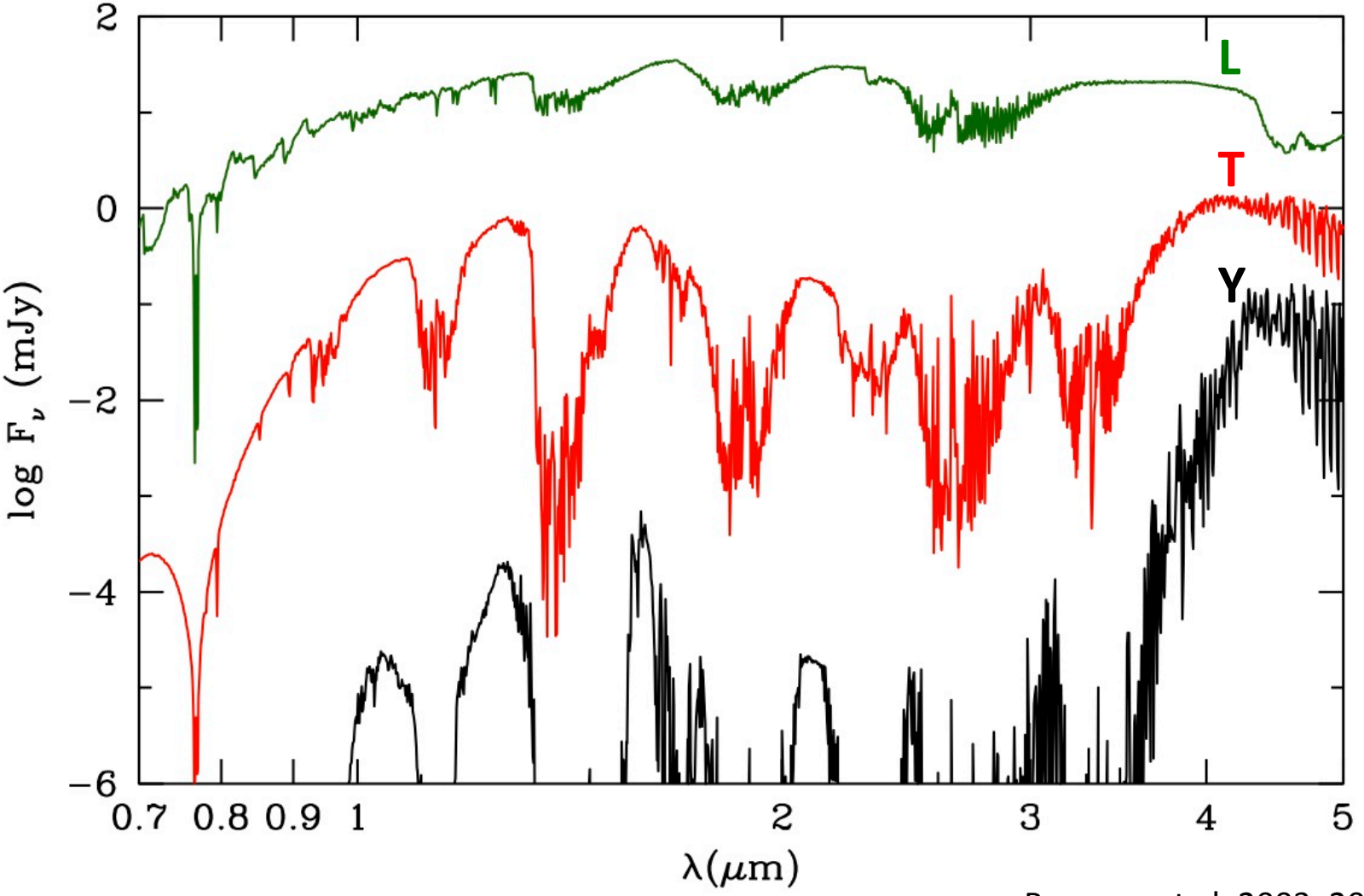
- IMF of brown dwarfs
- Circumstellar disks around brown dwarfs
- WISE 0855-0714

WISE 0855-0714:
4th closest system (2.3 pc)
coldest known brown dwarf (250 K)



WISE + IRAC

Near-IR fluxes collapse from T to Y



Burrows et al. 2003, 2006

JWST: only option for spectroscopy

(see talk by Alves de Oliveira)