The Substellar IMF - why Brown Dwarfs are special

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Mind the Gap, Hatfield 2013

Motivation: BD Myths

- BDs and stars form the same way,
- Binary statistics change smoothly from stars to BDs,
- One IMF for all will do.

R e a l l y ?

Facts

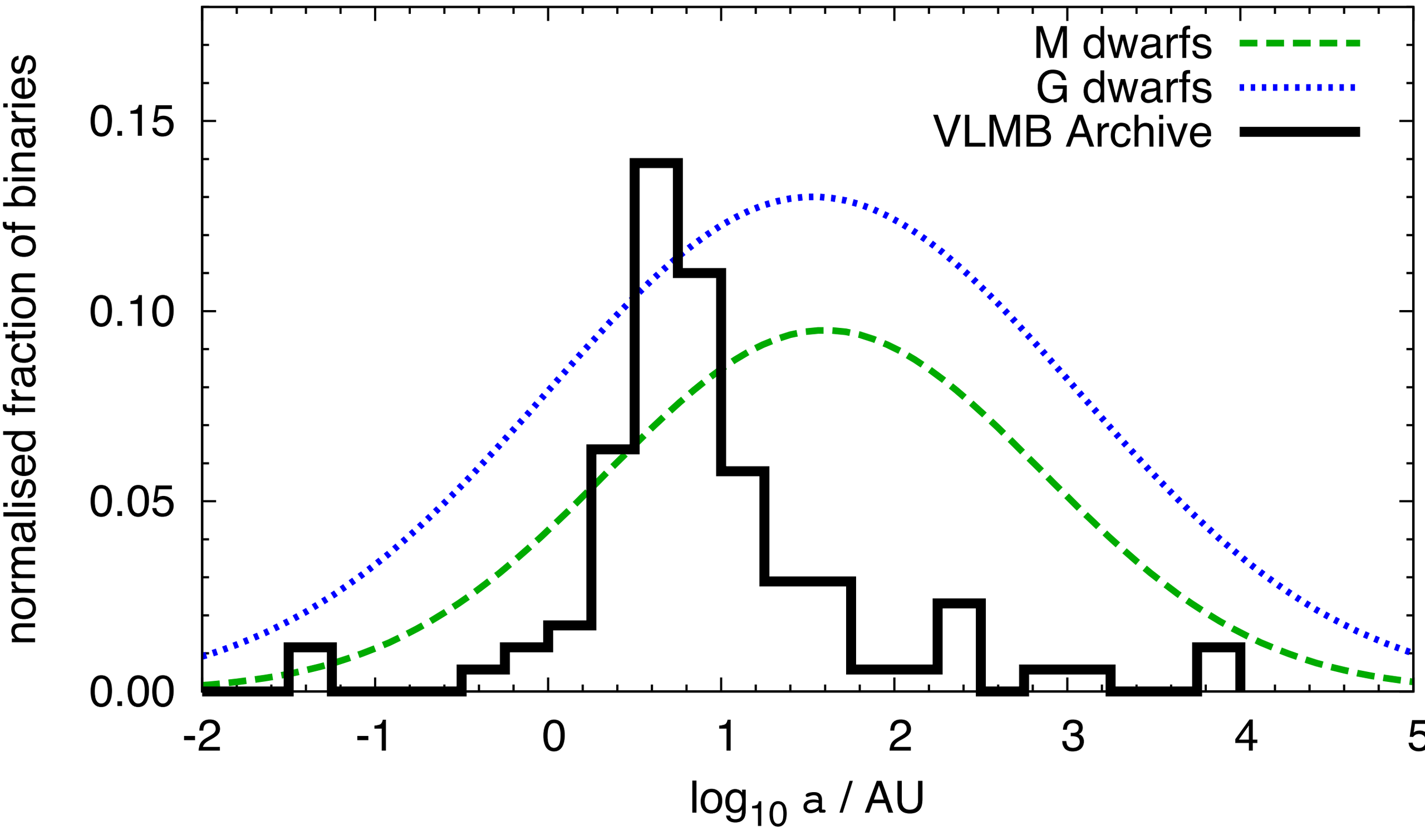
- BDs do exist (first discovery 1995),
- Star formation models cannot easily form BDs directly (unless accretion is truncated),

Where do the BDs come from?

Hint: Binary properties

- BDs and stars essentially don't mix (*brown dwarf desert*),
- Different binary fraction (BDs: ≈20%, stars: ≳40%),
- Binary orbit statistics of BDs and stars are incompatible.

Orbital separation



Hint: Binary properties

- BDs and stars essentially don't mix (*brown dwarf desert*),
- Different binary fraction (BDs: 15%, stars: ≳40%),
- Binary orbit statistics of BDs and stars are incompatible.

BDs form a separate population!

…so, where do they come from?

BD formation

- BDs typically form from preprocessed (fragmenting discs, globules, filaments...)
- Mass spectrum and binary properties constrained by formation/ejection mechanics

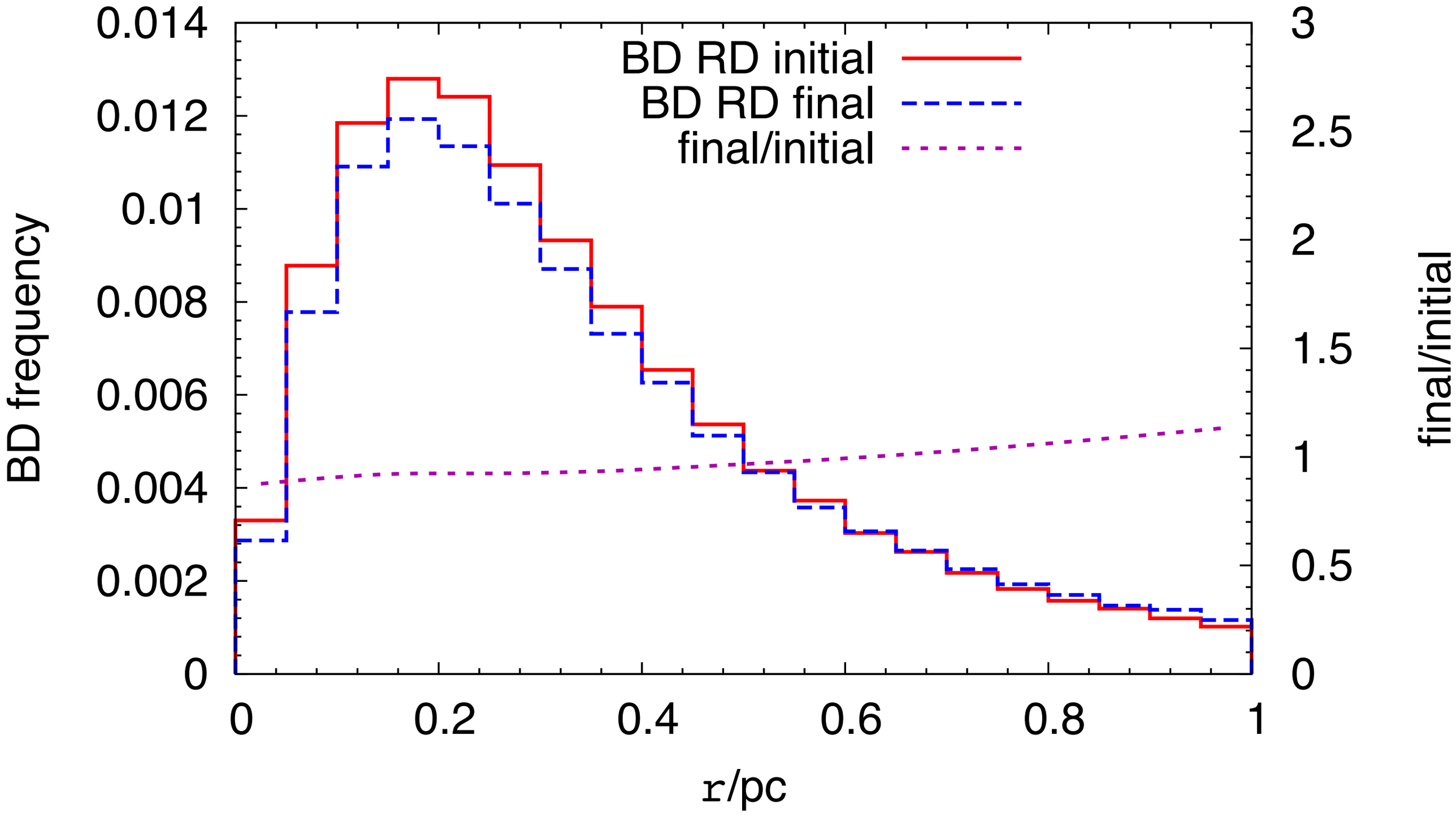
BDs have their own mass spectrum!

- Moreover: Velocity dispersion increased by ejection!

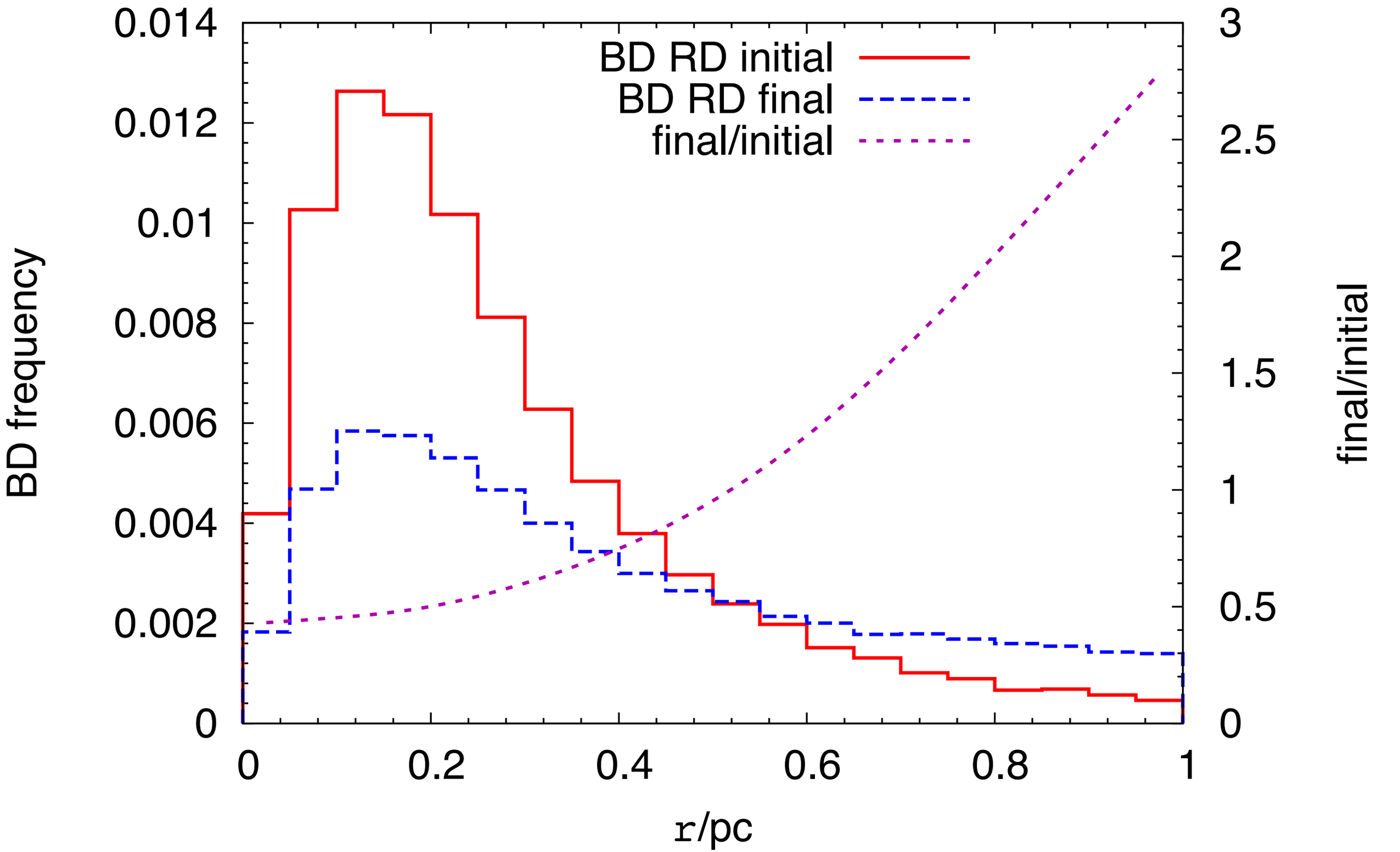
Spatial distribution

- Ejection “kick” should increase the velocity dispersion
- BDs spread wider than stars

Model: Trapezium/ONC



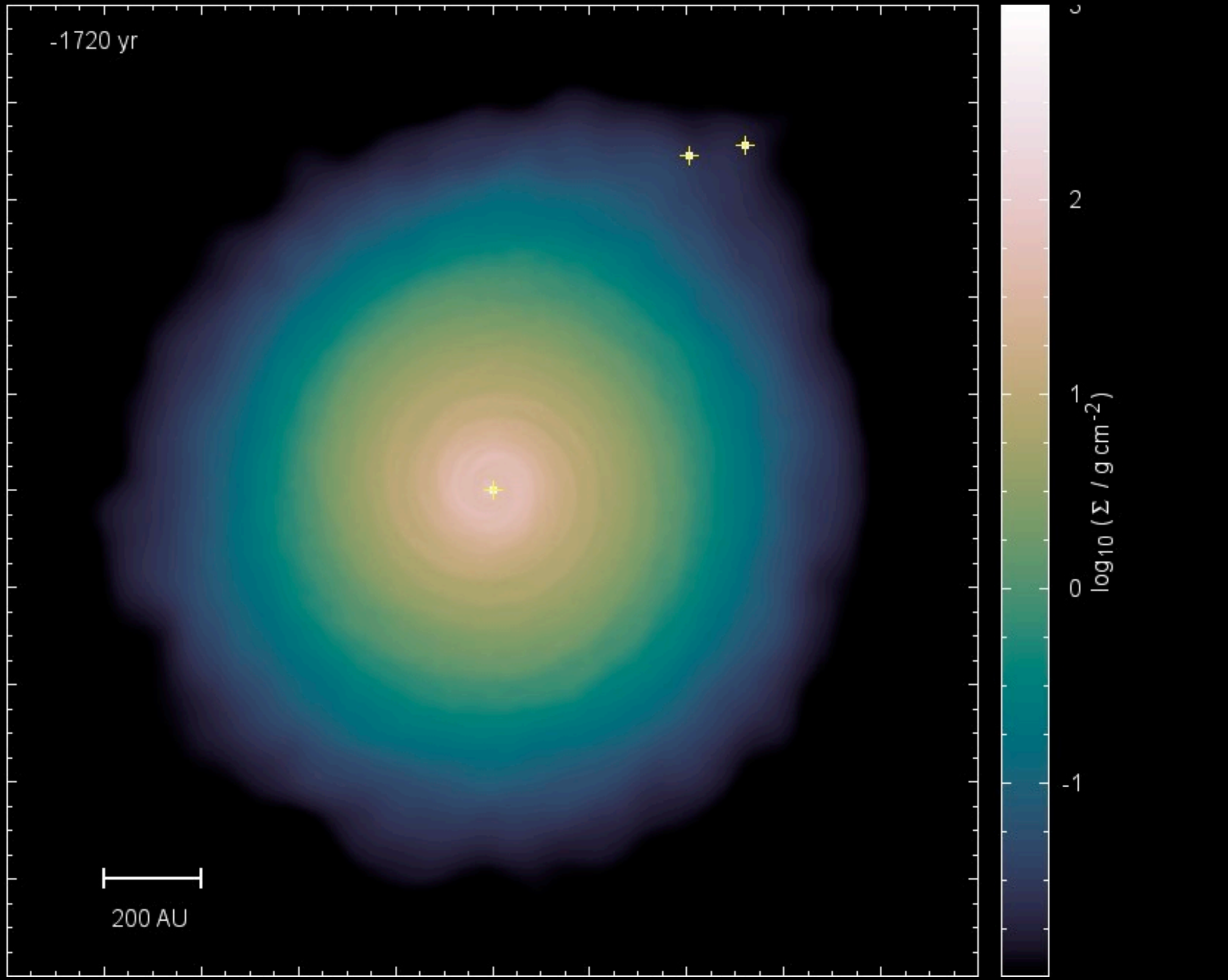
Model: Taurus-Auriga



BDs from disc fragmentation

(cf. Stamatellos et al. 2007+, Thies et al. 2010)

- Protostar with extended disc
- Low-mass perturber (here an M-dwarf binary)
- 250,000 SPH particles + radiative cooling


-1720 yr
200 AU
3
2
1
0
-1
log10 (Σ / g cm-2)

480 yr

200 AU

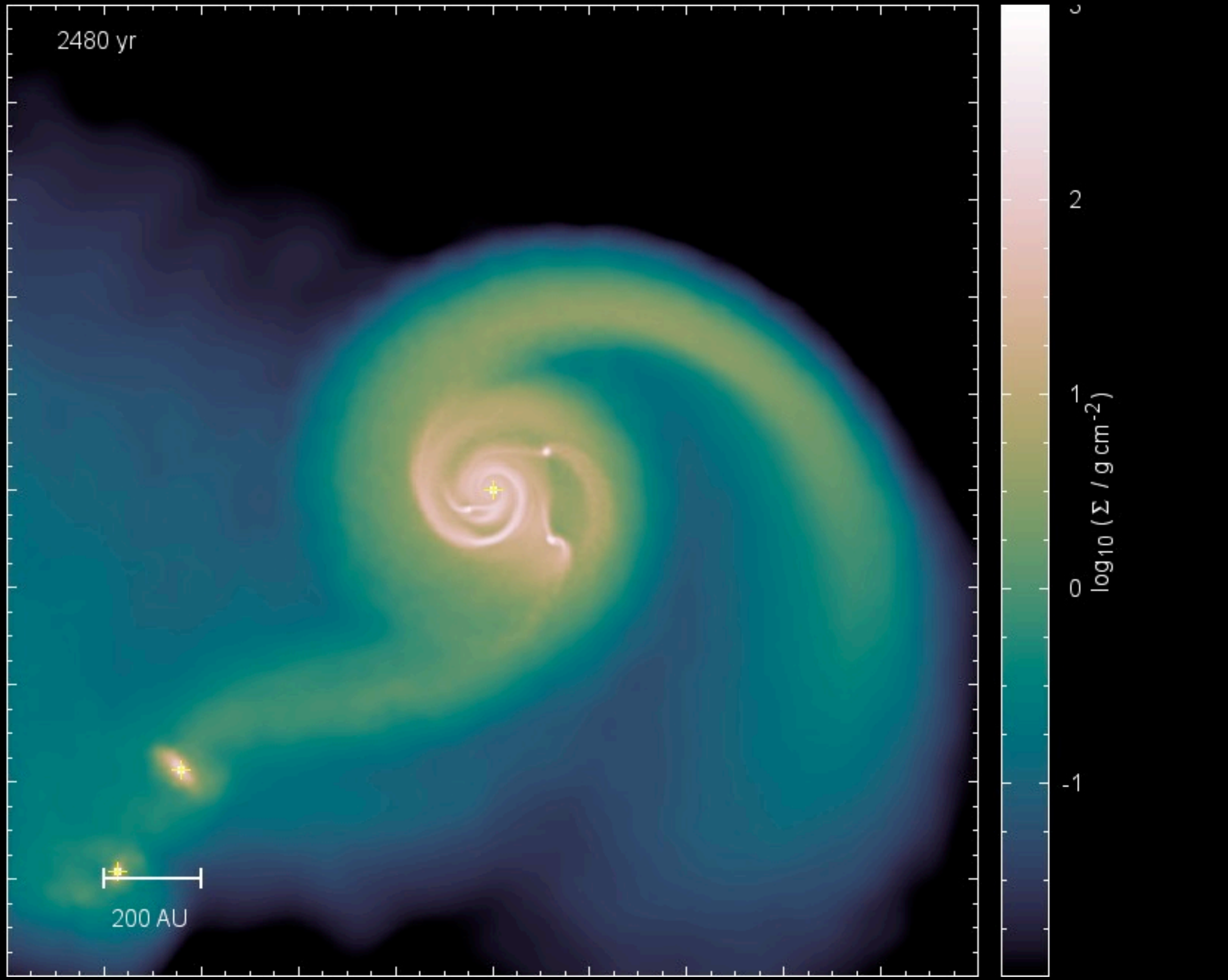
2

1

0

-1

$\log_{10}(\Sigma$ / g cm^{-2})


2480 yr
200 AU
2
1
0
-1
log10 (Σ / g cm-2)

7320 yr

Binary BD by capture

200 AU

3

2

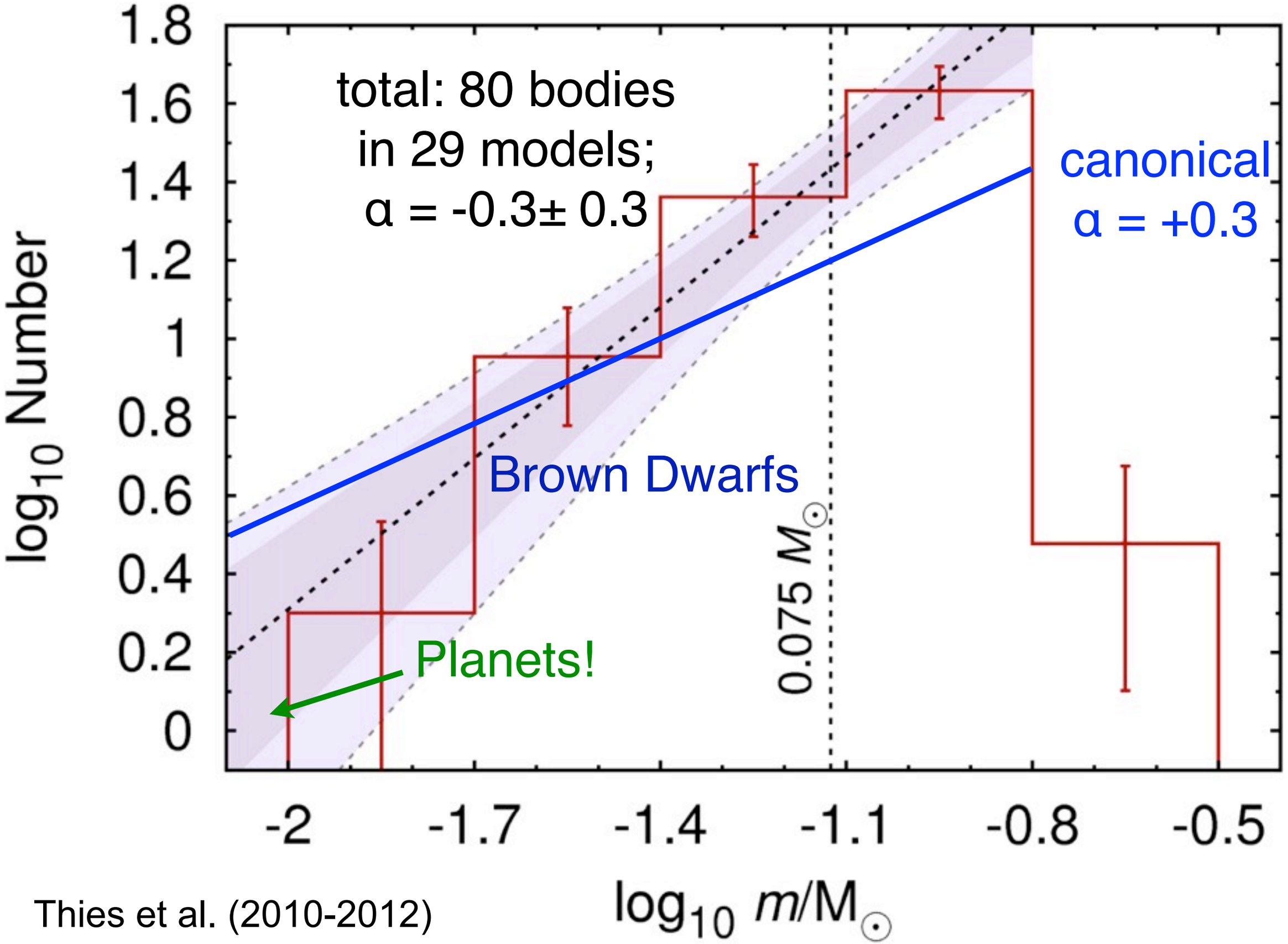
1

0

-1

$\log_{10}$ (Σ / g cm^{-2})

Mass function from SPH

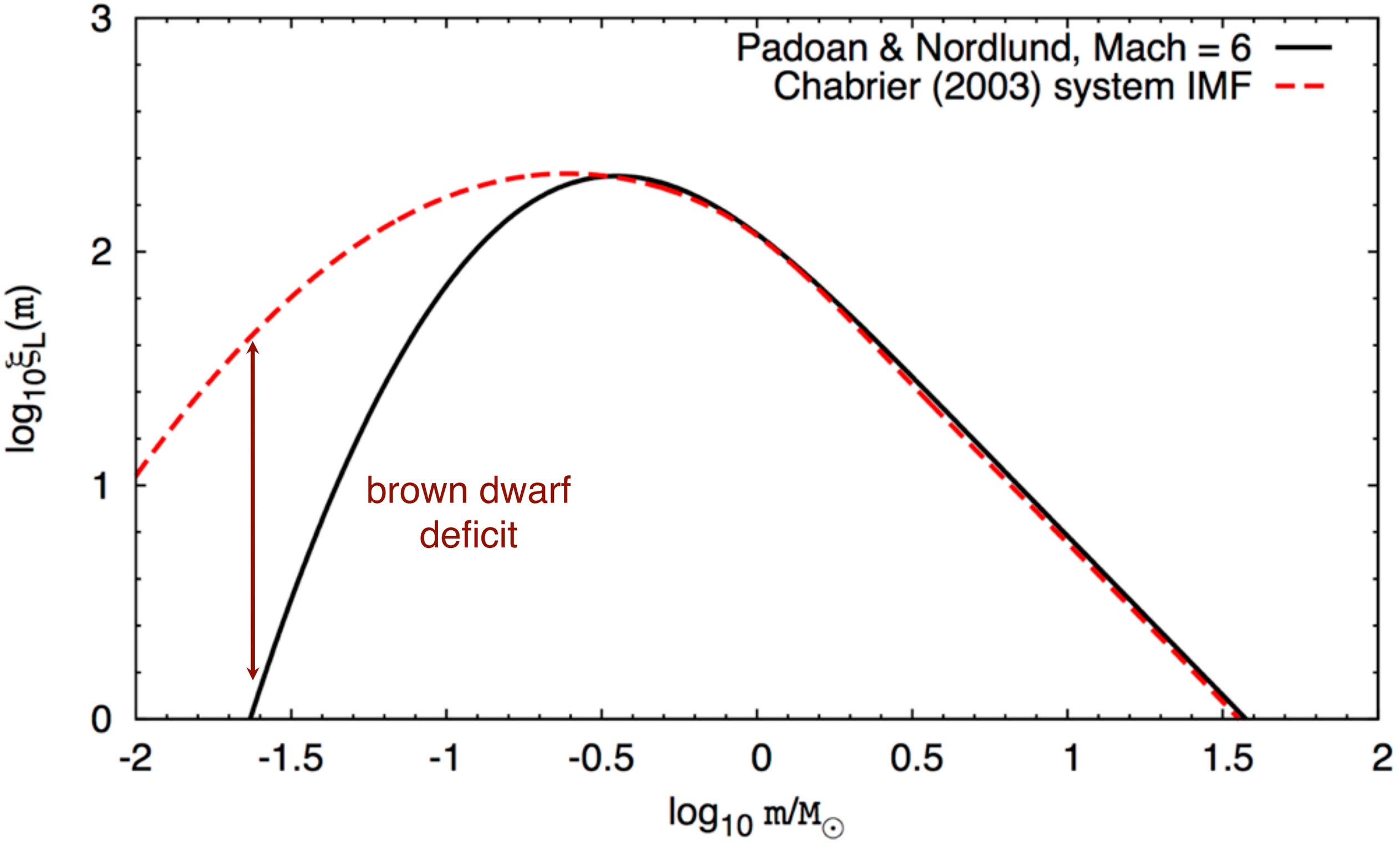


Thies et al. (2010-2012)

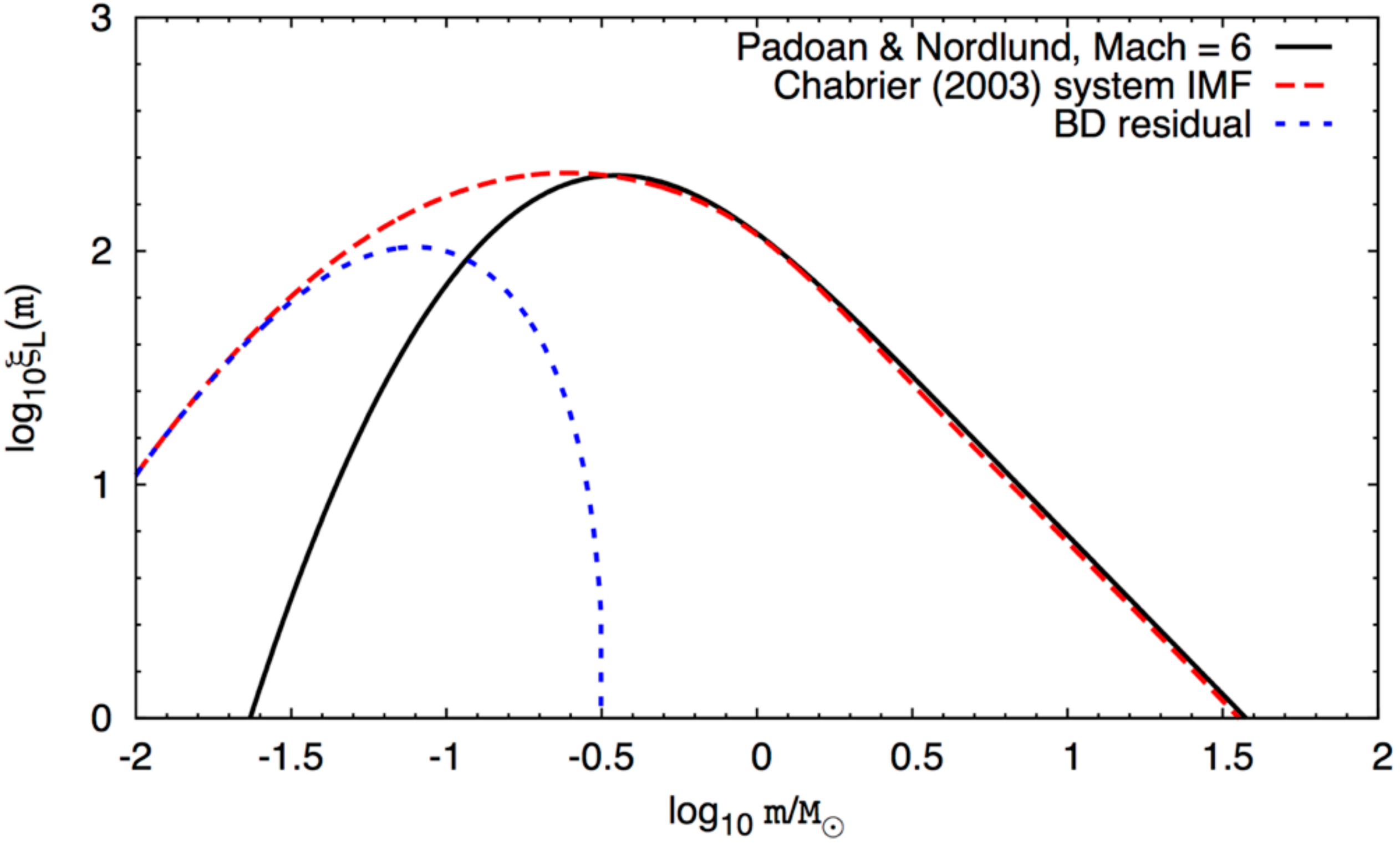
Analytical star-formation models

- Consider models by Padoan & Nordlund (2002) and Hennebelle & Chabrier (2008)
- Ansatz from initial random inhomogenities and Jeans instability
- → Pre-main-sequence clump mass function
- Method suitable for stars but not for brown dwarfs

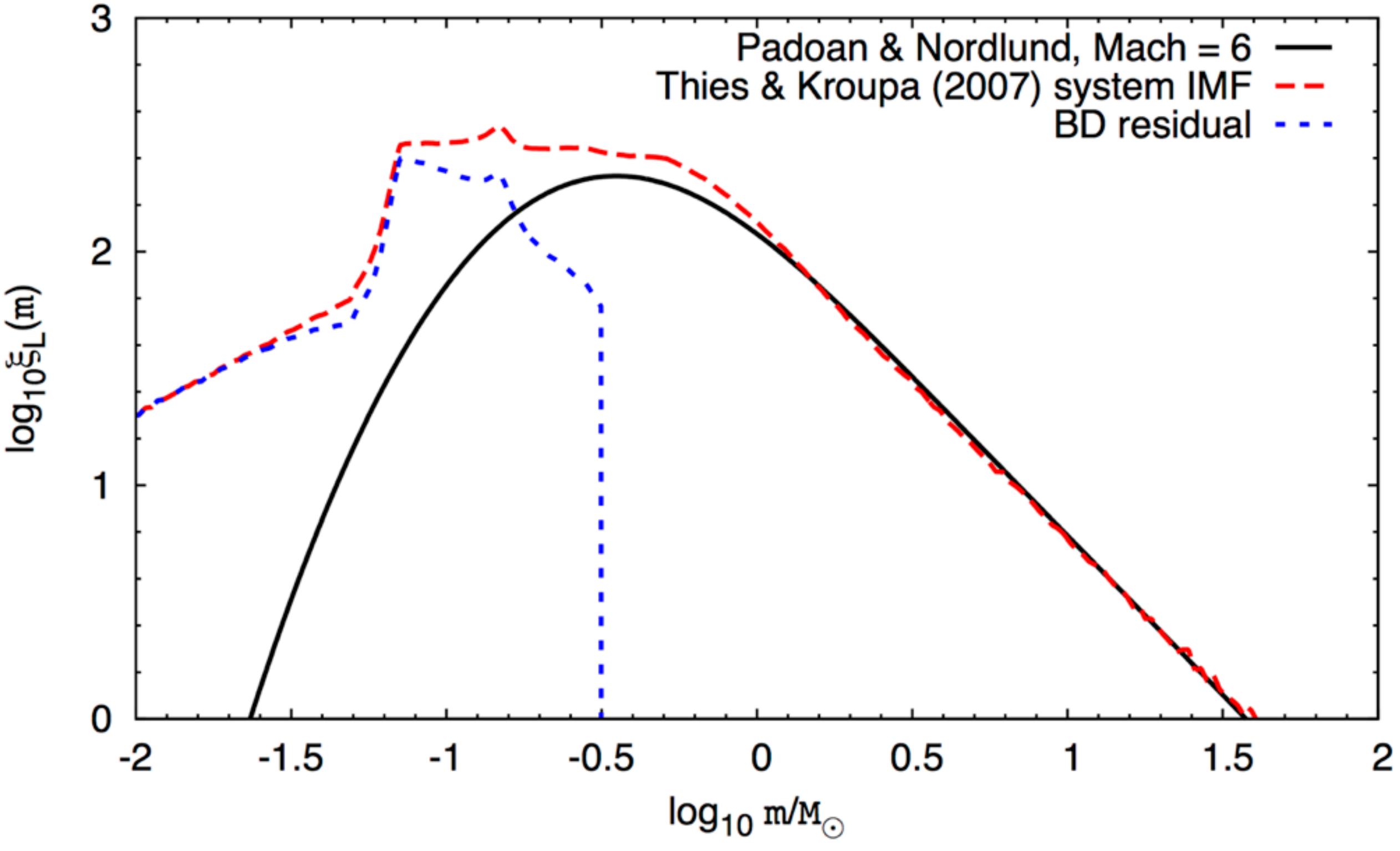
Model vs. empirical IMF



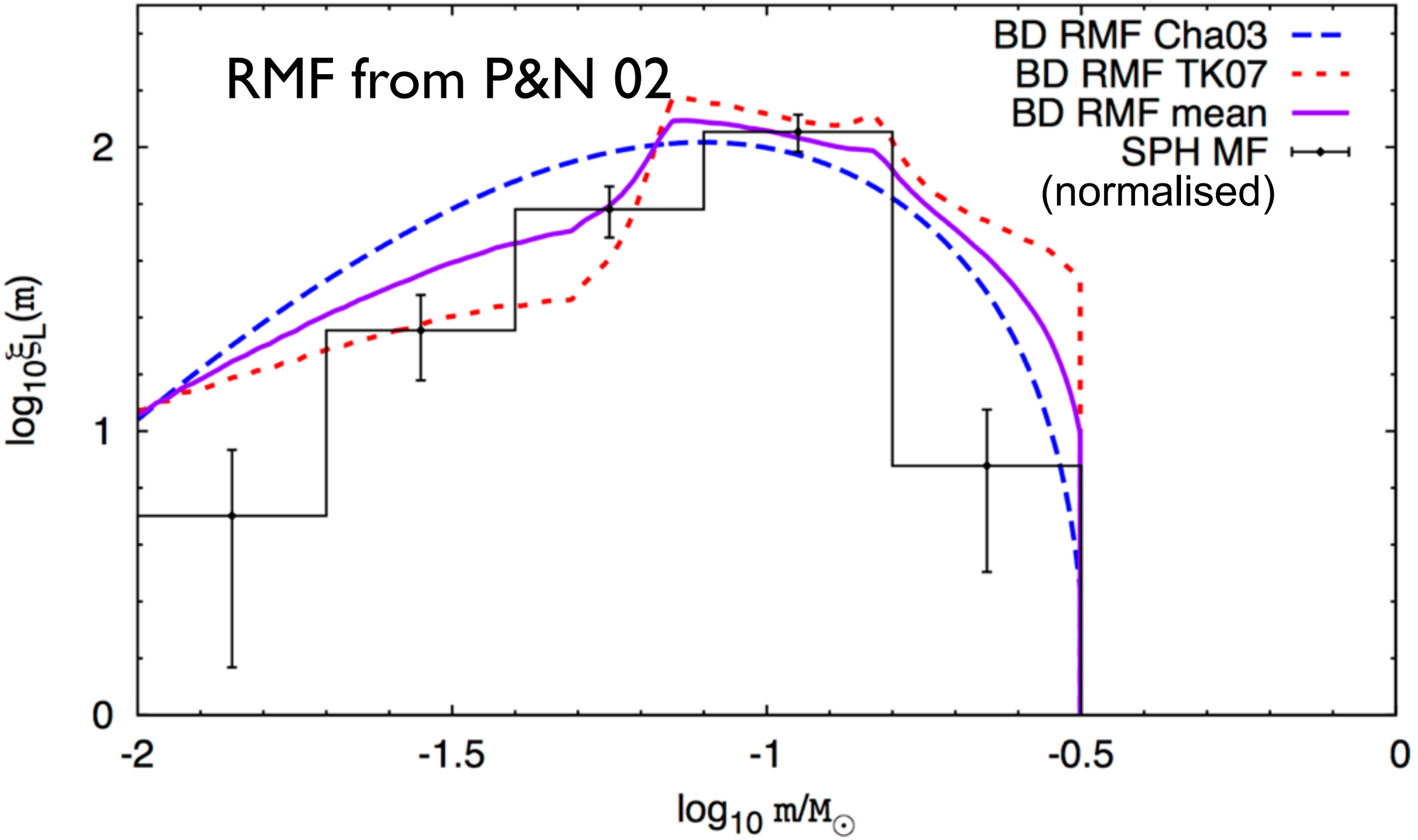
Residual Mass Function



RMF from composite IMF

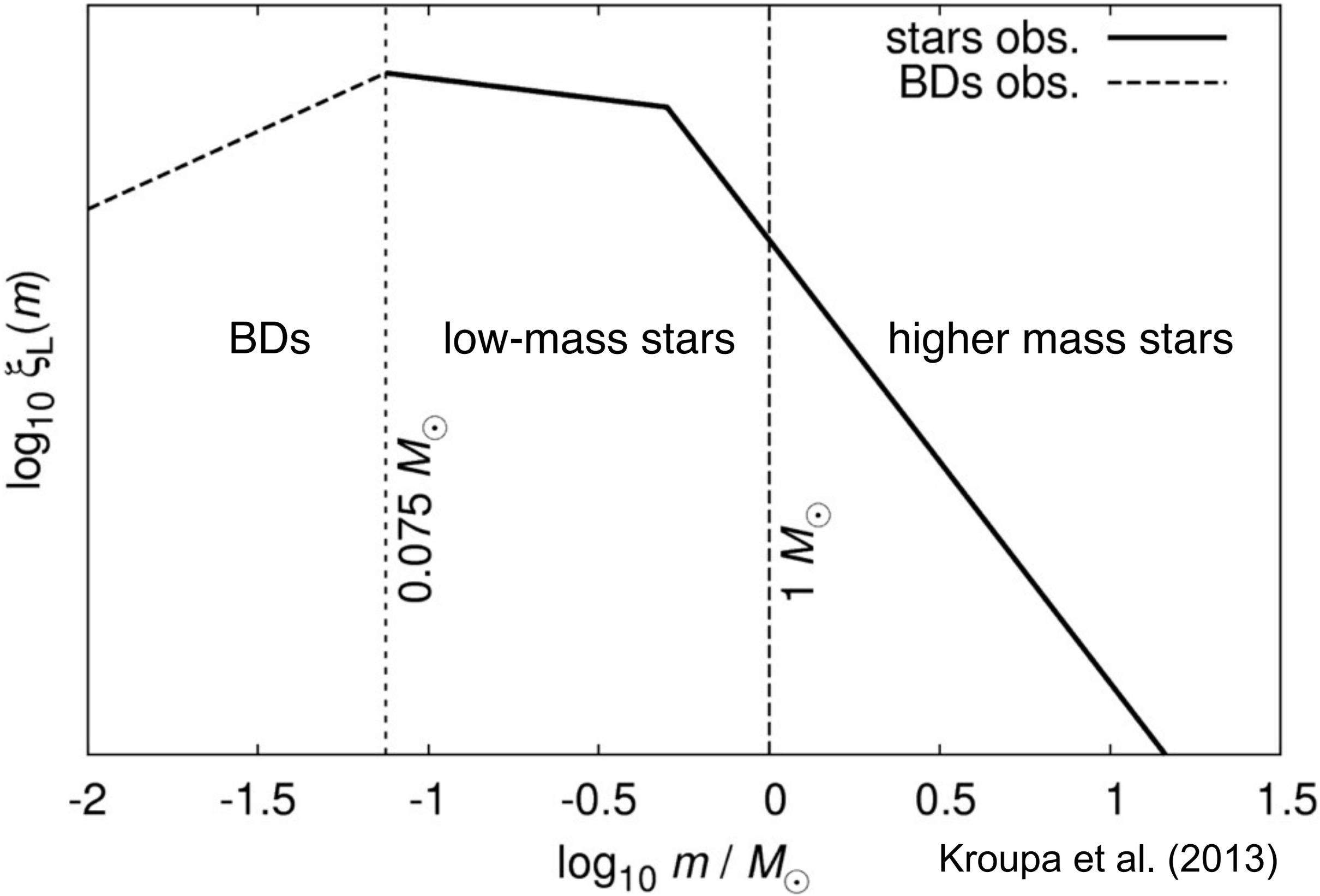


Residual MF vs. SPH MF



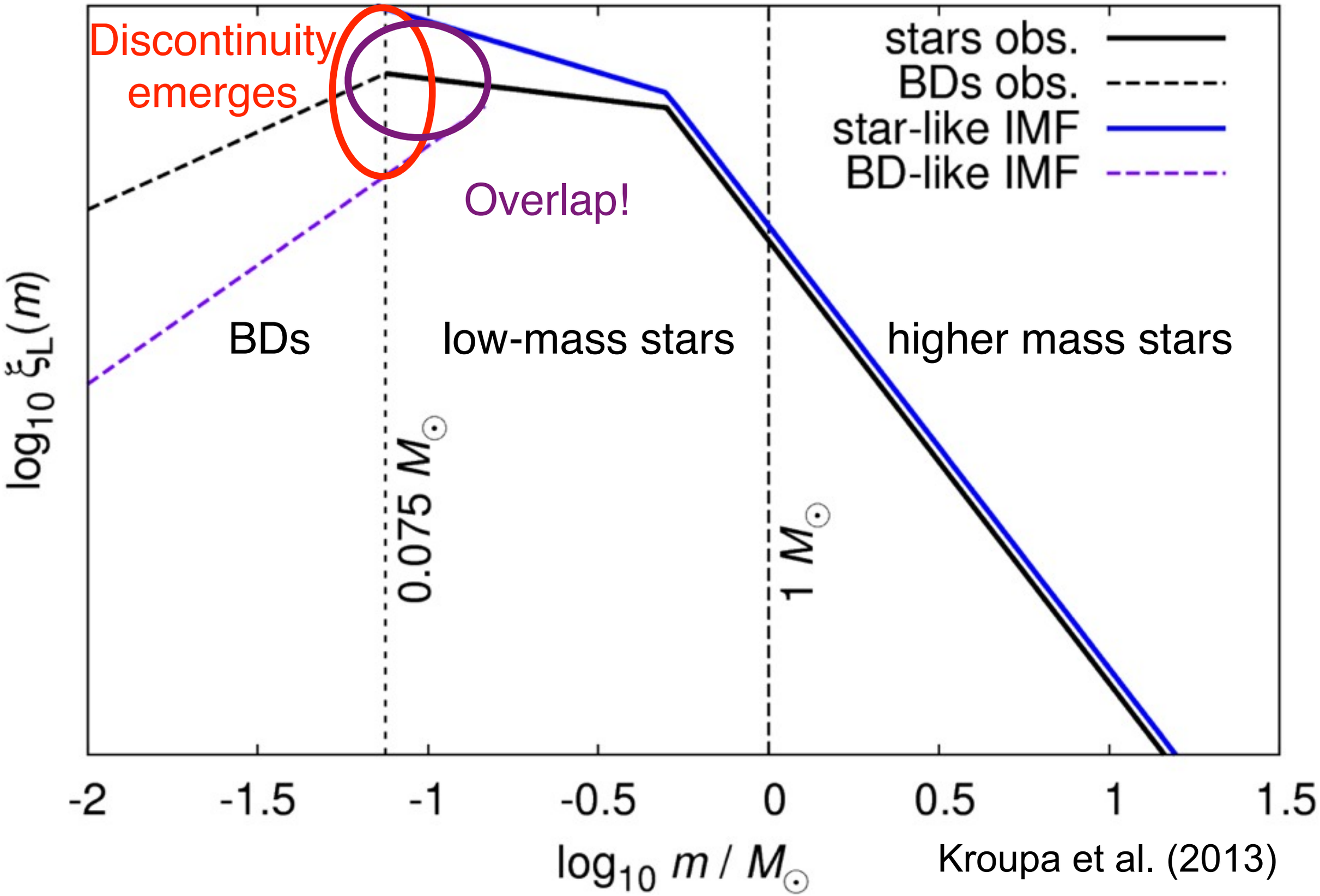
Monte-Carlo study on stellar and BD binary statistics

The observed mass function



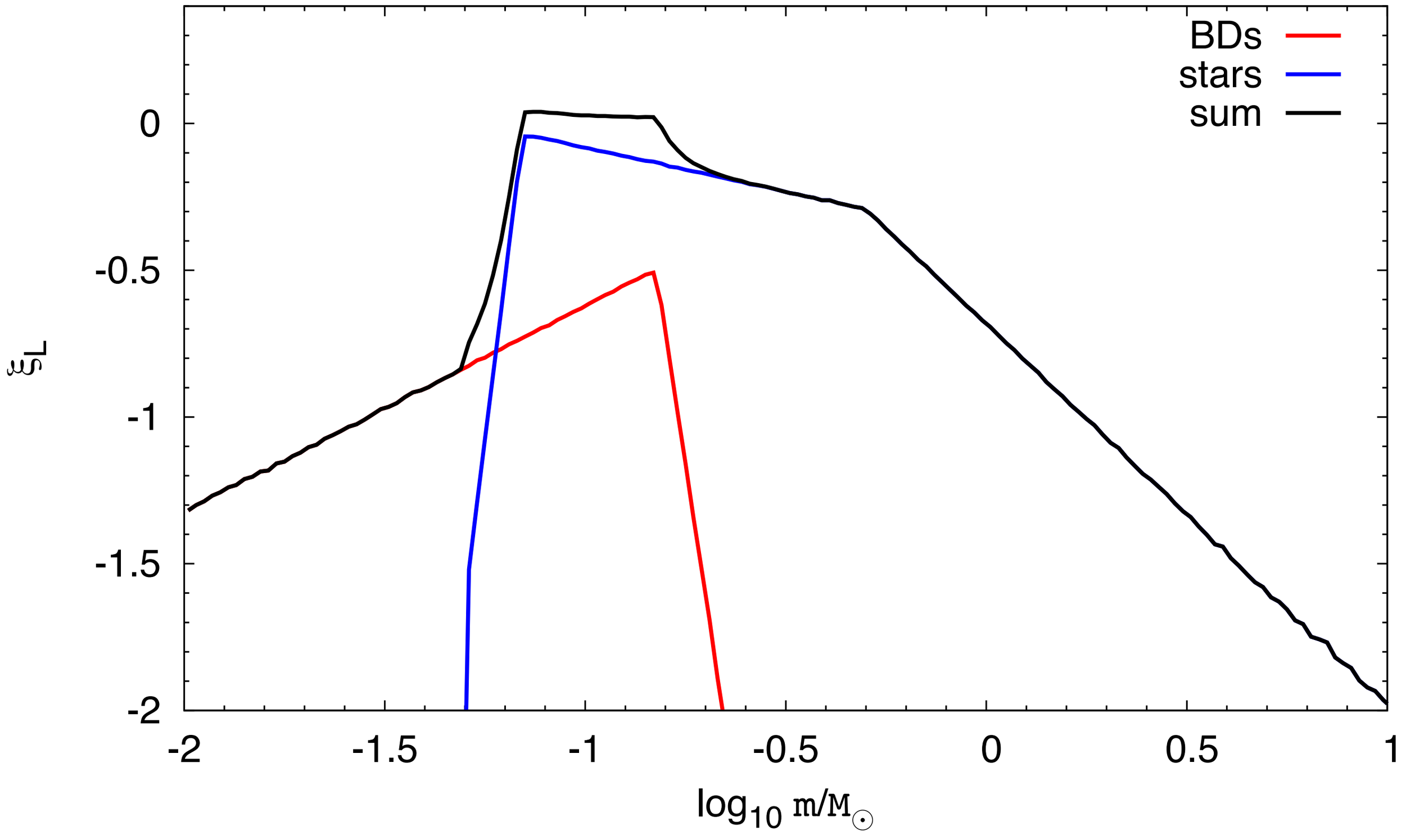
Kroupa et al. (2013)

The composite IMF

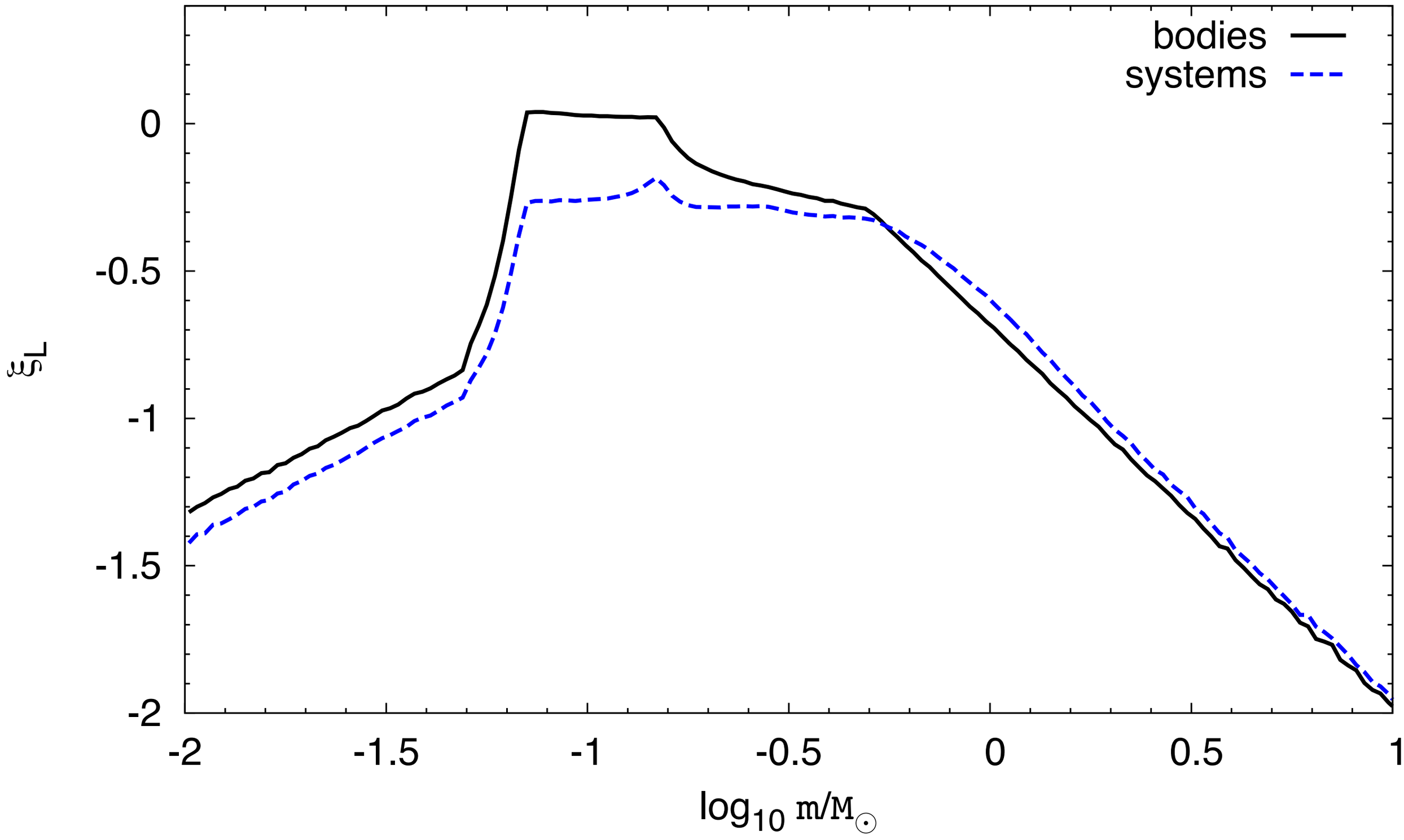


Kroupa et al. (2013)

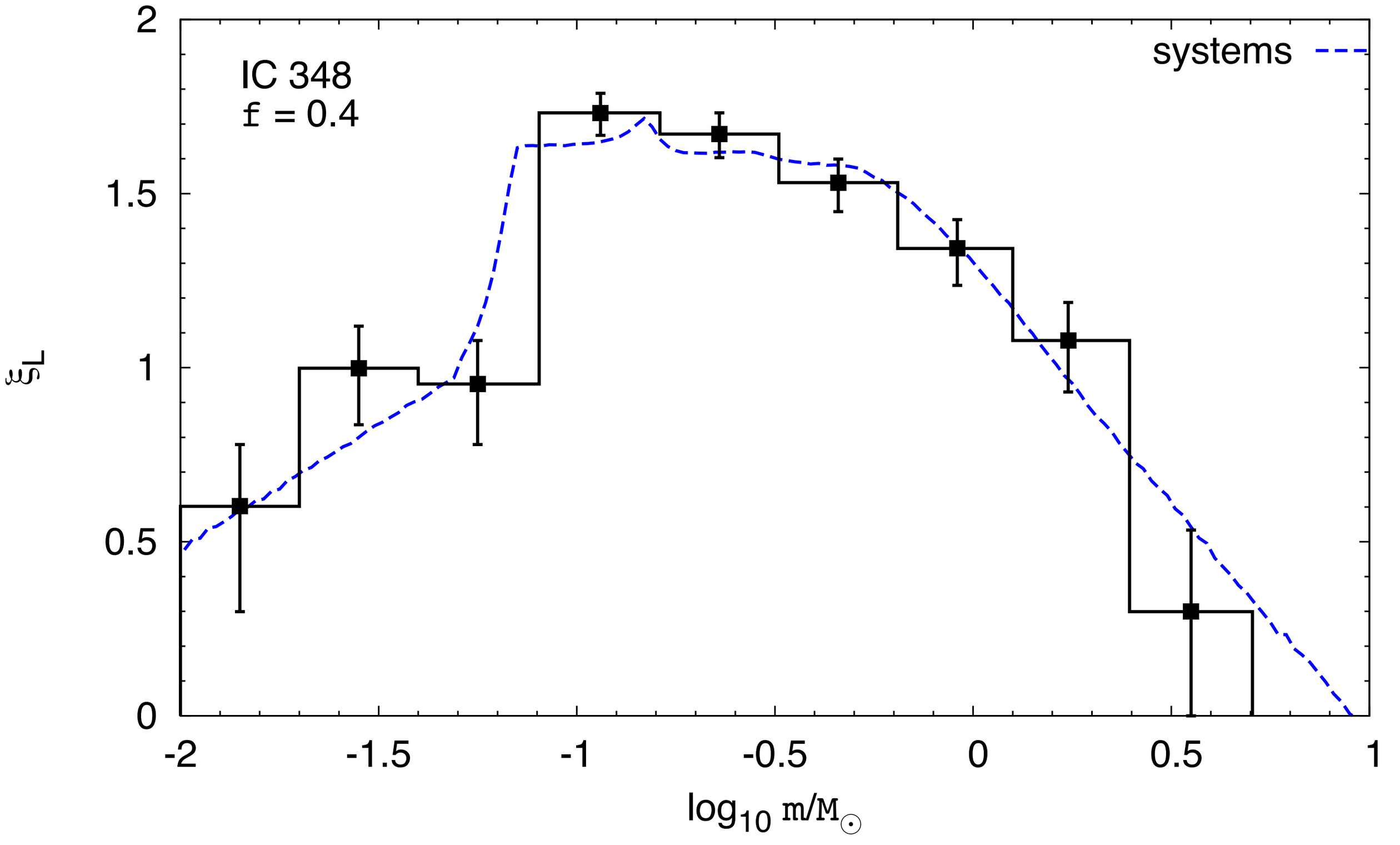
IMFs from Monte Carlo drawing



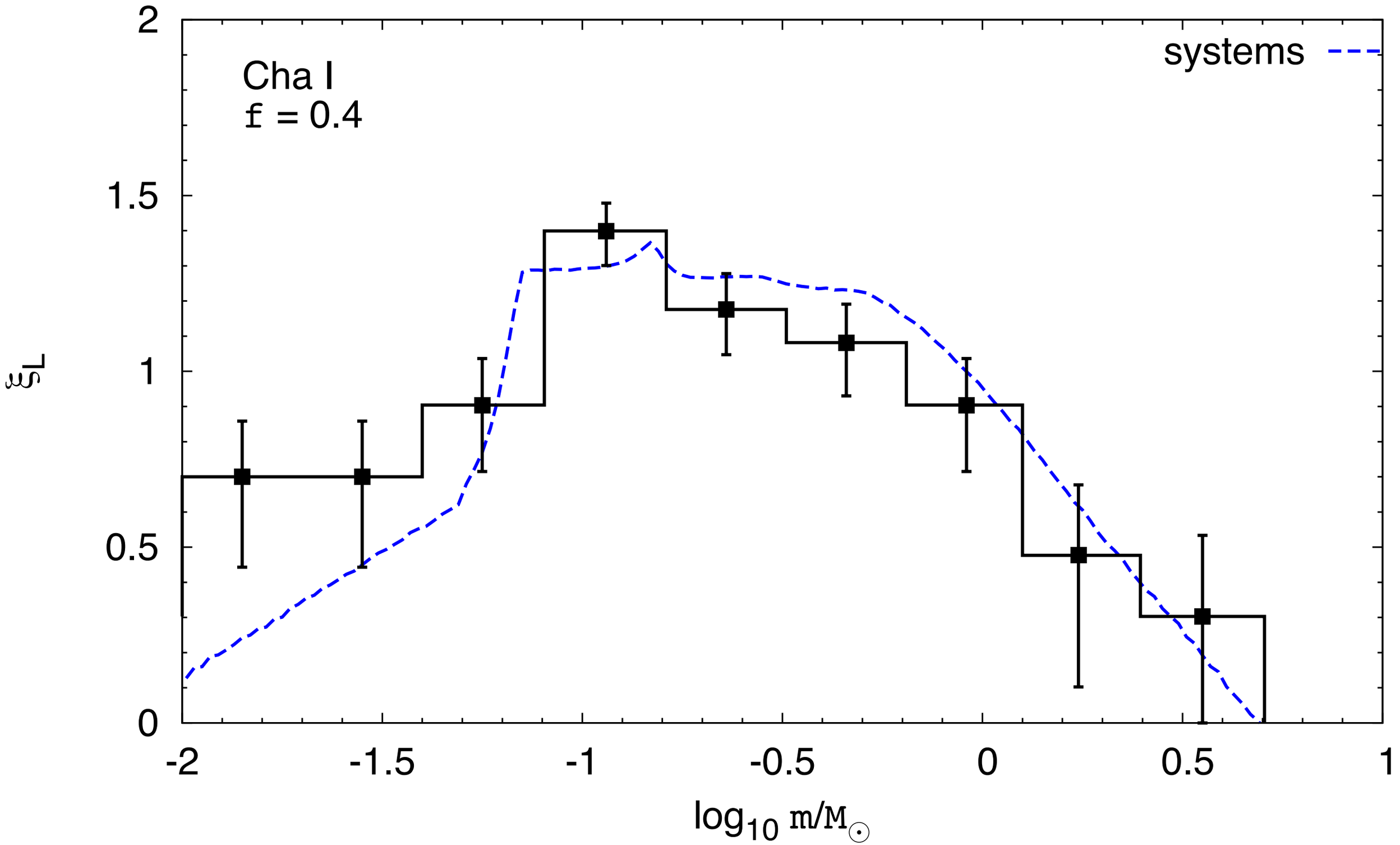
MC IMFs “observed”



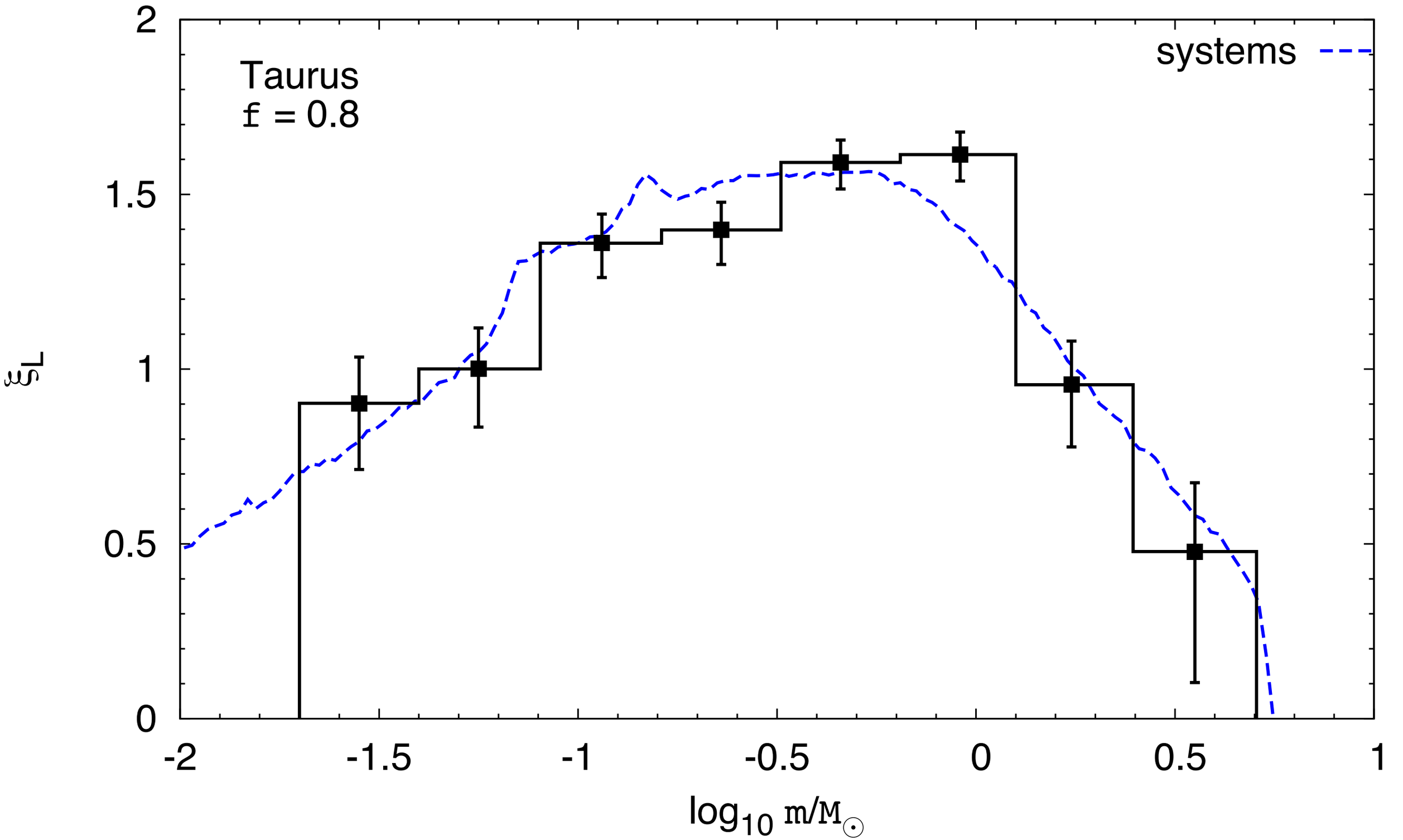
MC vs. IC 348



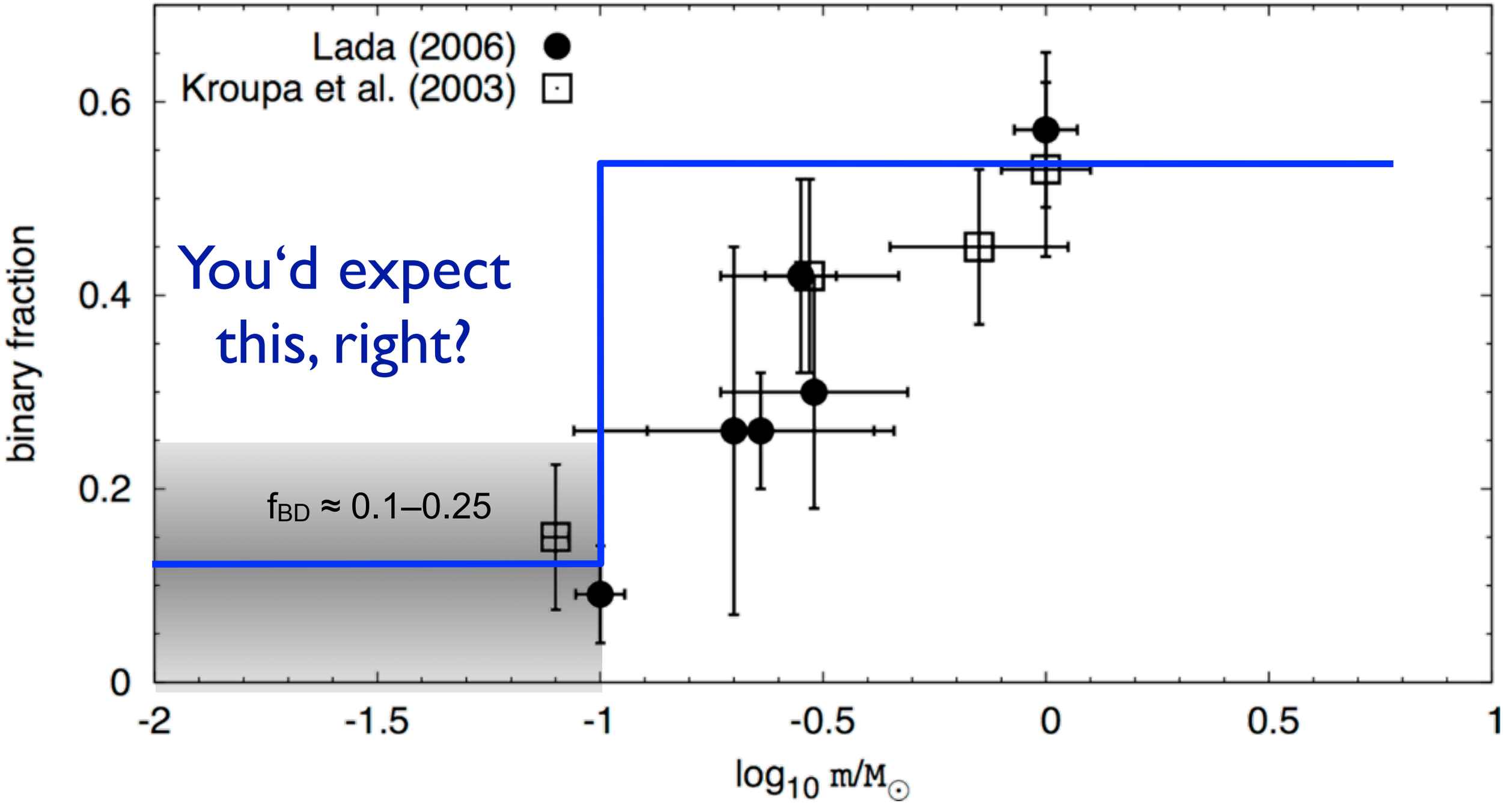
MC vs. Chamaeleon I



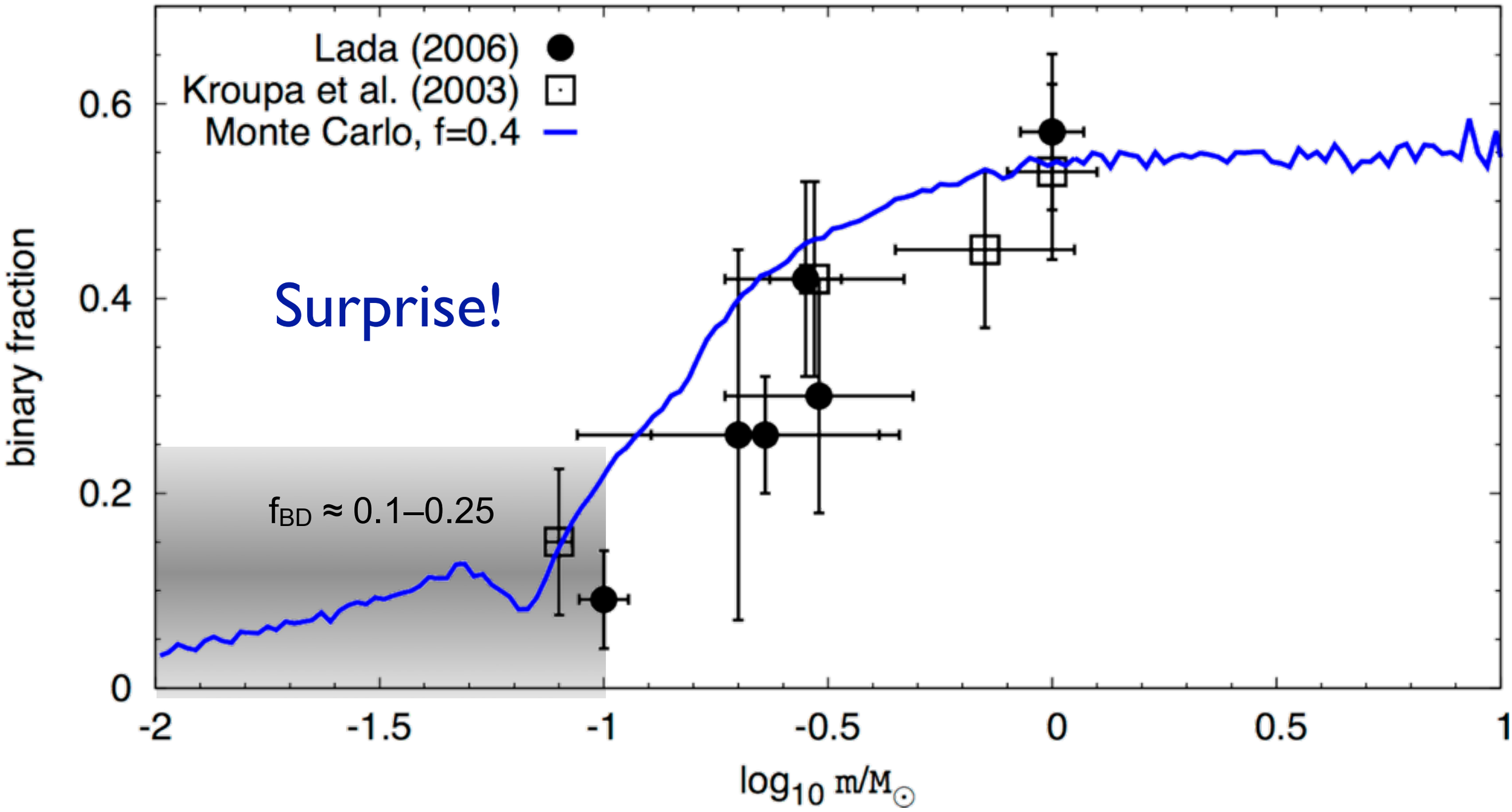
MC vs. Taurus-Auriga



Binarity fraction vs. mass



Binarity fraction vs. mass



Recap: BD Myths

✗ • BDs and stars form the same way,

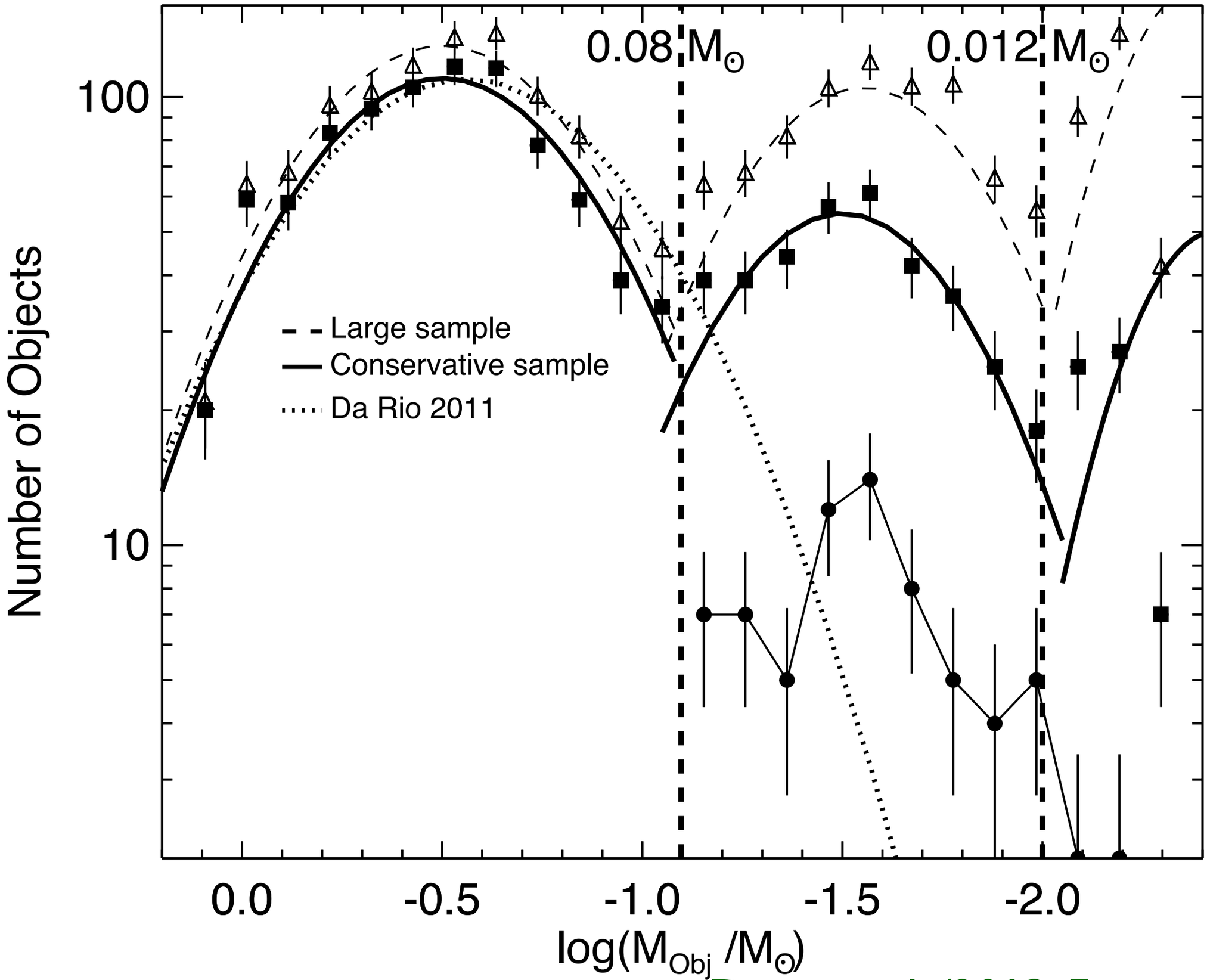
✓ • Binary statistics change smoothly from stars to BDs, (surprise!)

✗ • One IMF for all will do.

Things are more complex!

Maybe even more complex...

And then there were three...



Drass et al. (2013, Fuerteventura)

Summary

- Brown dwarfs preferably form from pre-processed material (e.g. discs)
- Separate population → composite IMF
- Monte Carlo results nicely fit the observed binarity function.
- Ejection kick → BDs wider spread – need more observational data!

Thank you!