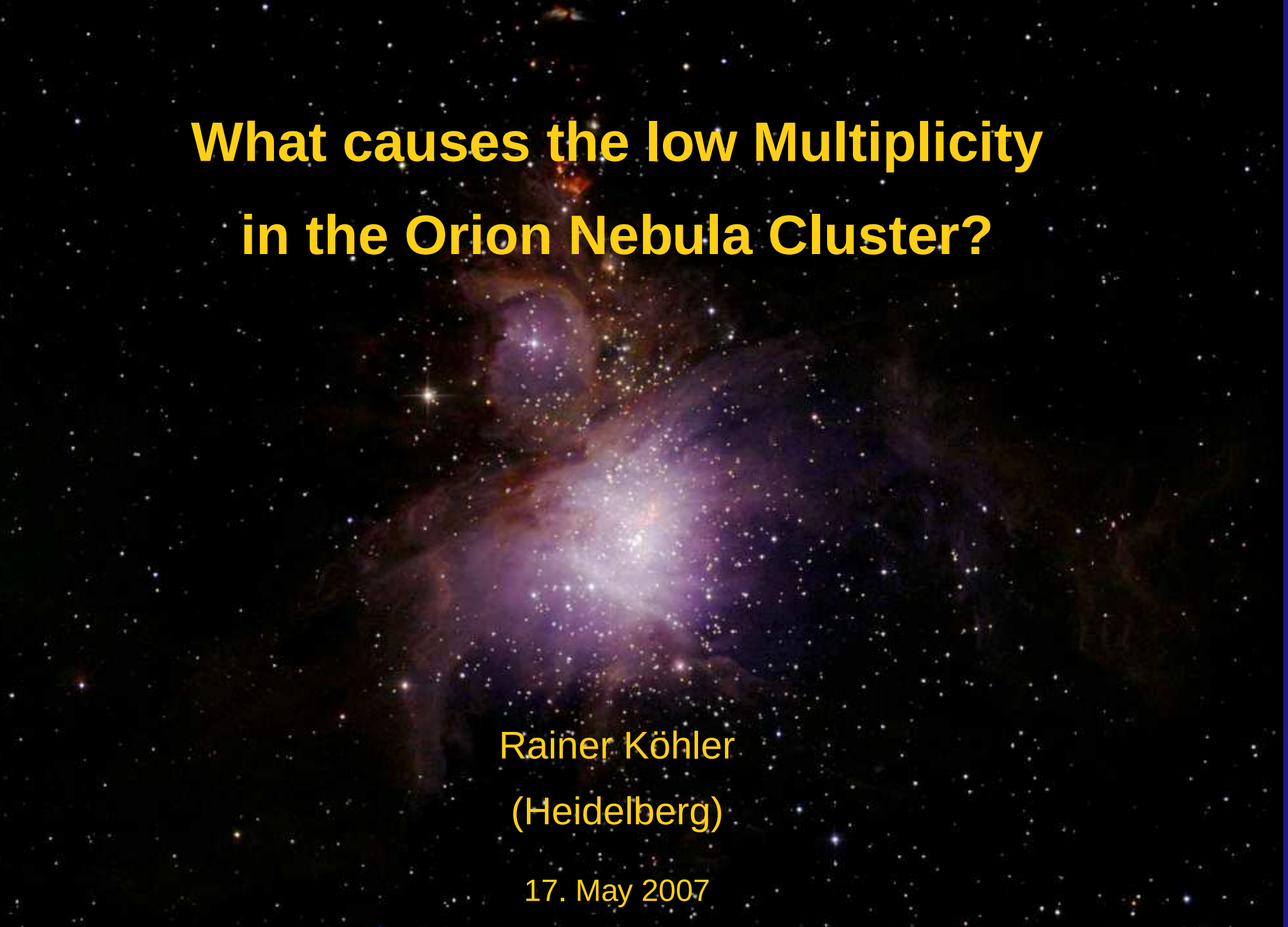
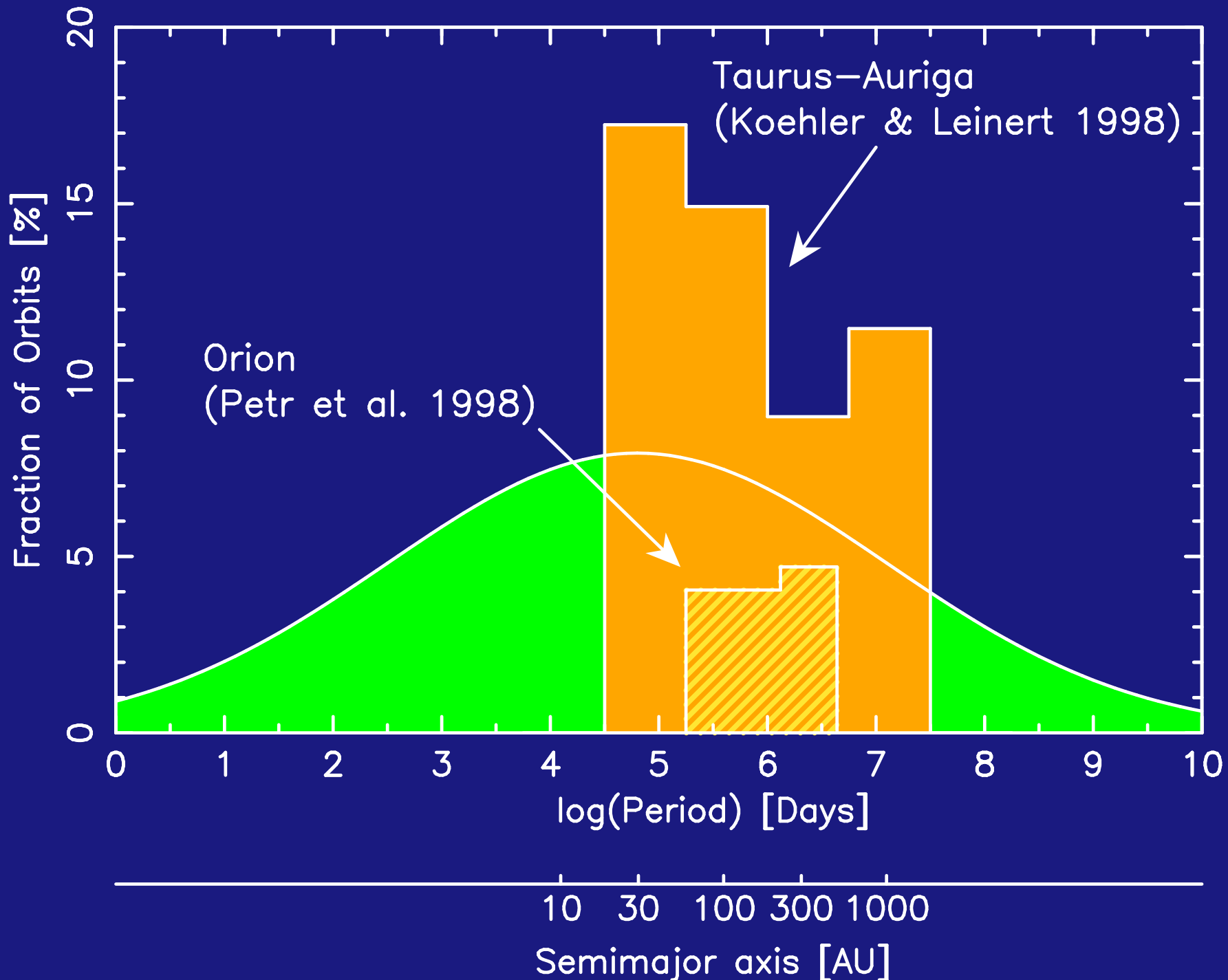


What causes the low Multiplicity in the Orion Nebula Cluster?

Rainer Köhler

(Heidelberg)

17. May 2007


Taurus–Auriga
(Koehler & Leinert 1998)
Orion
(Petr et al. 1998)
Fraction of Orbits [%]
0
5
10
15
20
0
1
2
3
4
5
6
7
8
9
10
log(Period) [Days]
10
30
100
300
1000
Semimajor axis [AU]

The Problem

The binary frequency in the Orion Nebula Cluster is

$\sim$ 2 – 3 times lower than in Taurus-Auriga

$\sim$ 1.5 times lower than among

solar-type main-sequence stars

Theories

- Bonnell & Kroupa (1998):
  Binaries are destroyed in
  close encounters with other stars

- Durisen & Sterzik (1994):
  The formation rate of binaries depends on the
  precollapse cloud conditions (e.g. temperature)

Interaction time as function of radius

Time between interactions: $\tau \propto (n\sigma S)^{-1}$

Stellar density: $n \propto r^{-2}$

Velocity dispersion: $\sigma \approx \text{constant}$

Binary cross section: $S = \text{constant}$

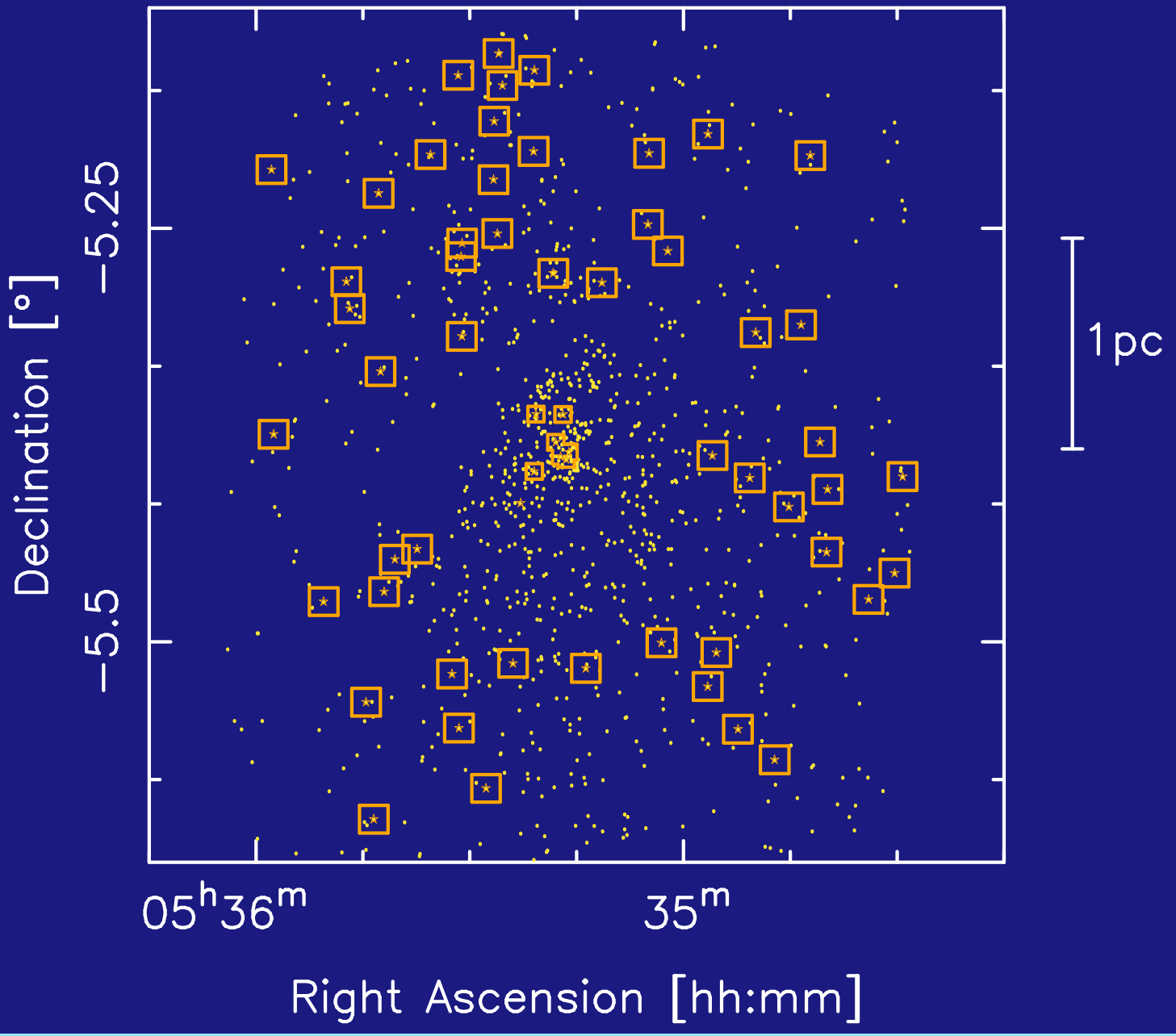
$$\Longrightarrow \quad \boldsymbol{\tau \propto r^2}$$

With typical numbers, for a 0.5 arcsec binary in Orion:

$\tau \approx$ 1 Myr in the center

$\tau \gtrsim$ 250 Myr at $r = 1$ pc

Observed Fields



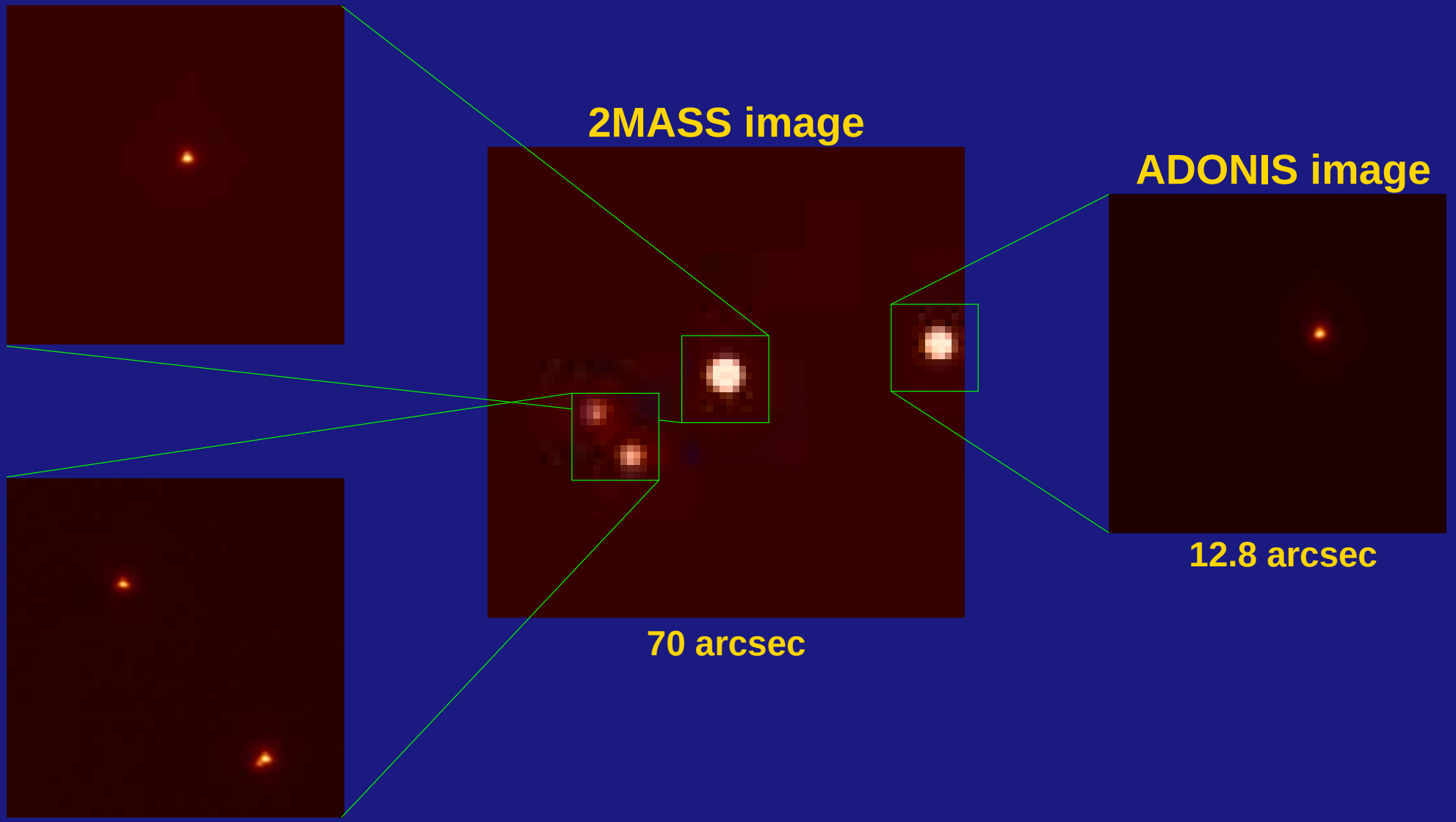
Observations in the Periphery of the ONC

- Adaptive Optics observations in K
  with ADONIS at the 3.6 m Telescope on La Silla
  and NIRC2 at the Keck Telescope on Mauna Kea
- select stars from Jones & Walker (1988)
  – brighter than I = 12.5 mag
  – at radii 5 – 15 arcmin (0.7 – 2 pc) from center

  $\Rightarrow$ **52 Fields**

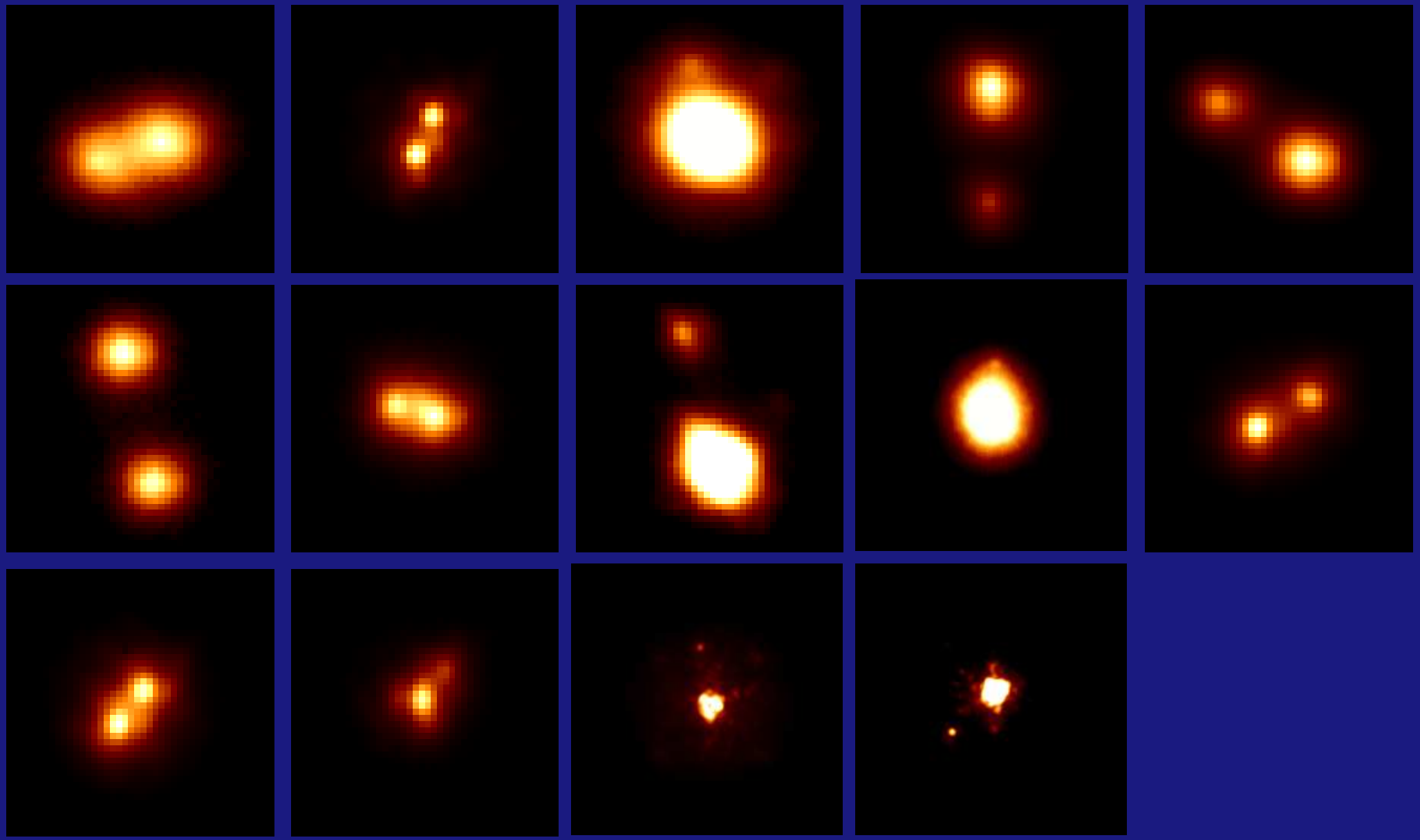
  (11 observed with Keck, the rest with ADONIS)

Example: Field around JW0971



The Sample

- 52 fields containing some 230 stars
- + 134 stars in the core region (Petr 1998)
- Binaries with
  - separation $> 0''.13 =$ 60 AU (diffraction limit)
  - separation $< 1''.12 =$ 500 AU (chance alignment)

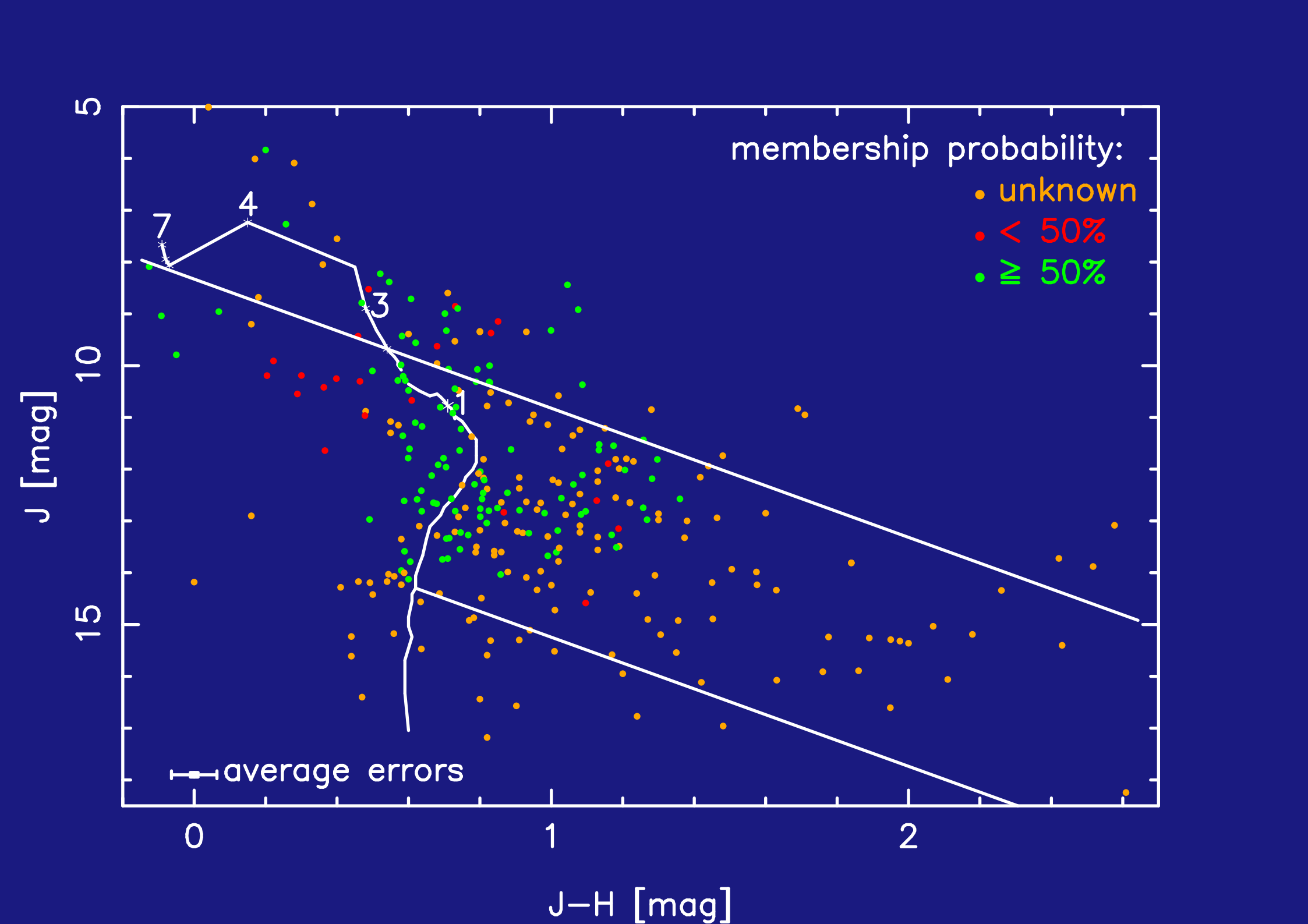


Corrections

- subtract chance alignments
  (= area $\times$ surface density)
- (in)completeness

Masses

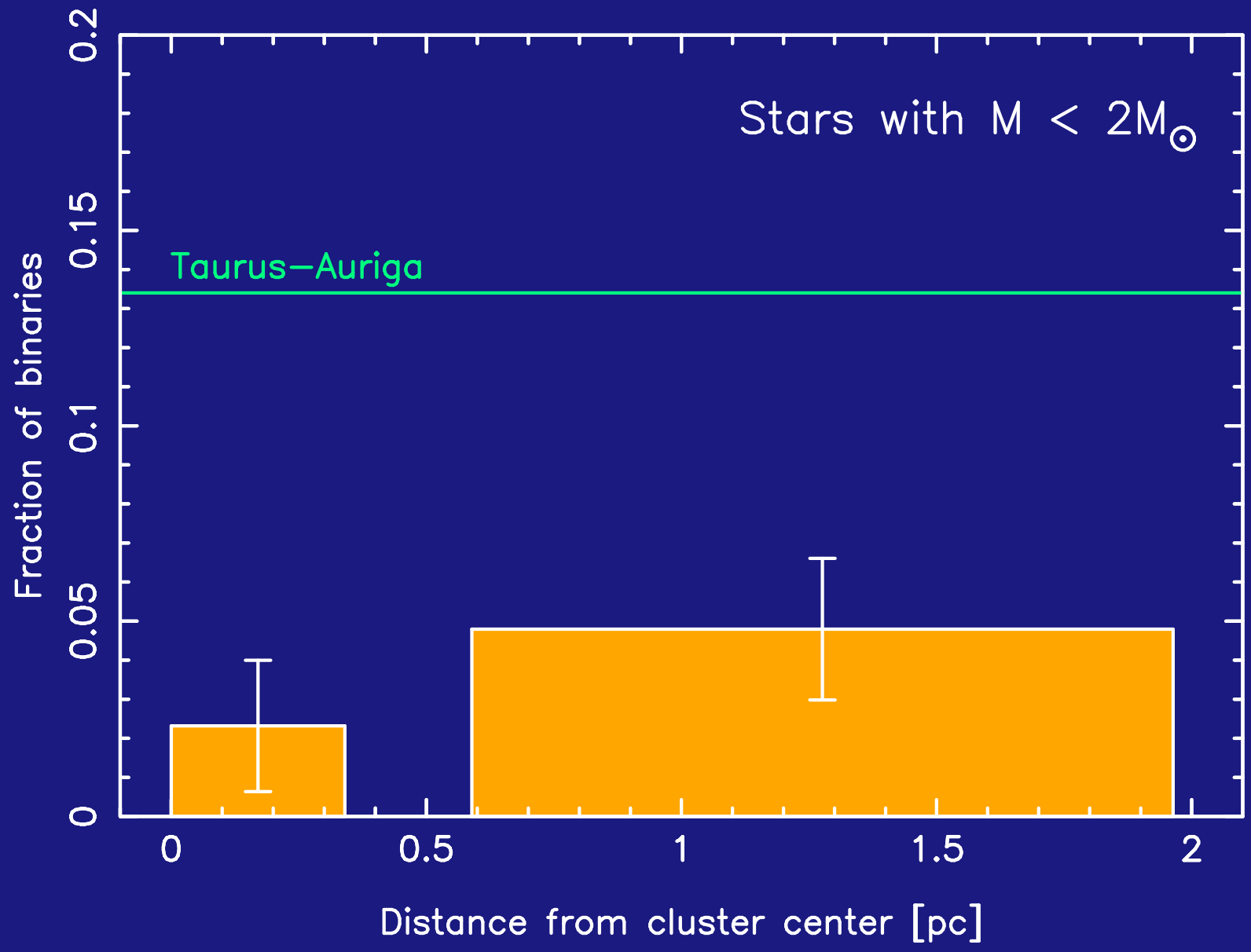
- 166 stars in Hillenbrand (1997)
  (masses from spectroscopy and photometry)
- 145 mass estimates from IR-photometry


membership probability:
unknown
< 50%
≧ 50%
7
4
3
1
average errors
J [mag]
J−H [mag]
5
10
15
0
1
2

Results

Mass range	Systems	Binaries	Fraction
$< 0.1\ M_\odot$	33	0	$0 \pm 0\%$
$0.1 – 2\ M_\odot$	227	11	$4 \pm 2\%$
$> 2\ M_\odot$	48	9	$17 \pm 6\%$

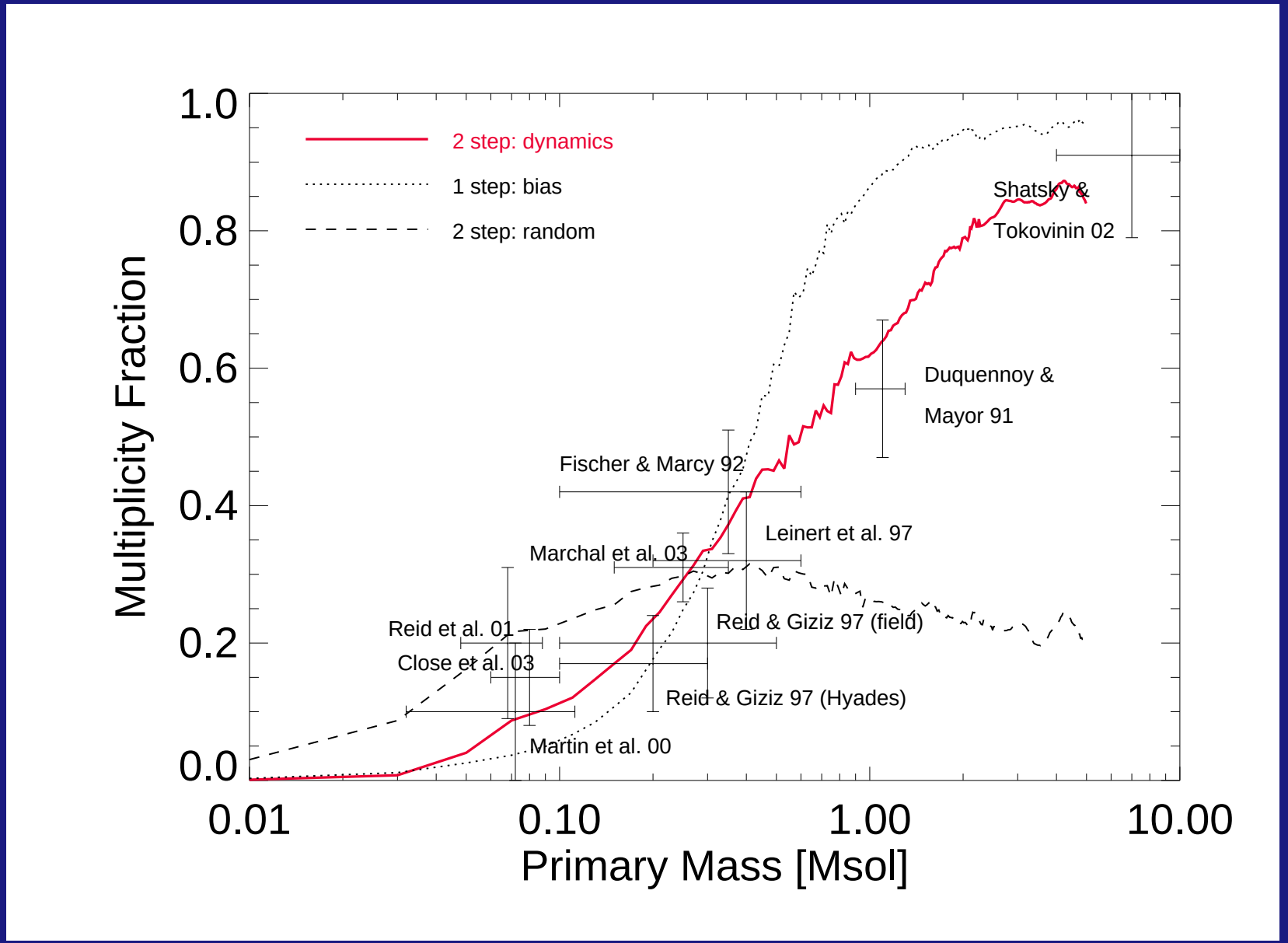
Binary Stars in the Orion Nebula Cluster



Conclusion so far:

This is not the effect we are looking for!

Köhler et al., A&A 458, 461 (2006)



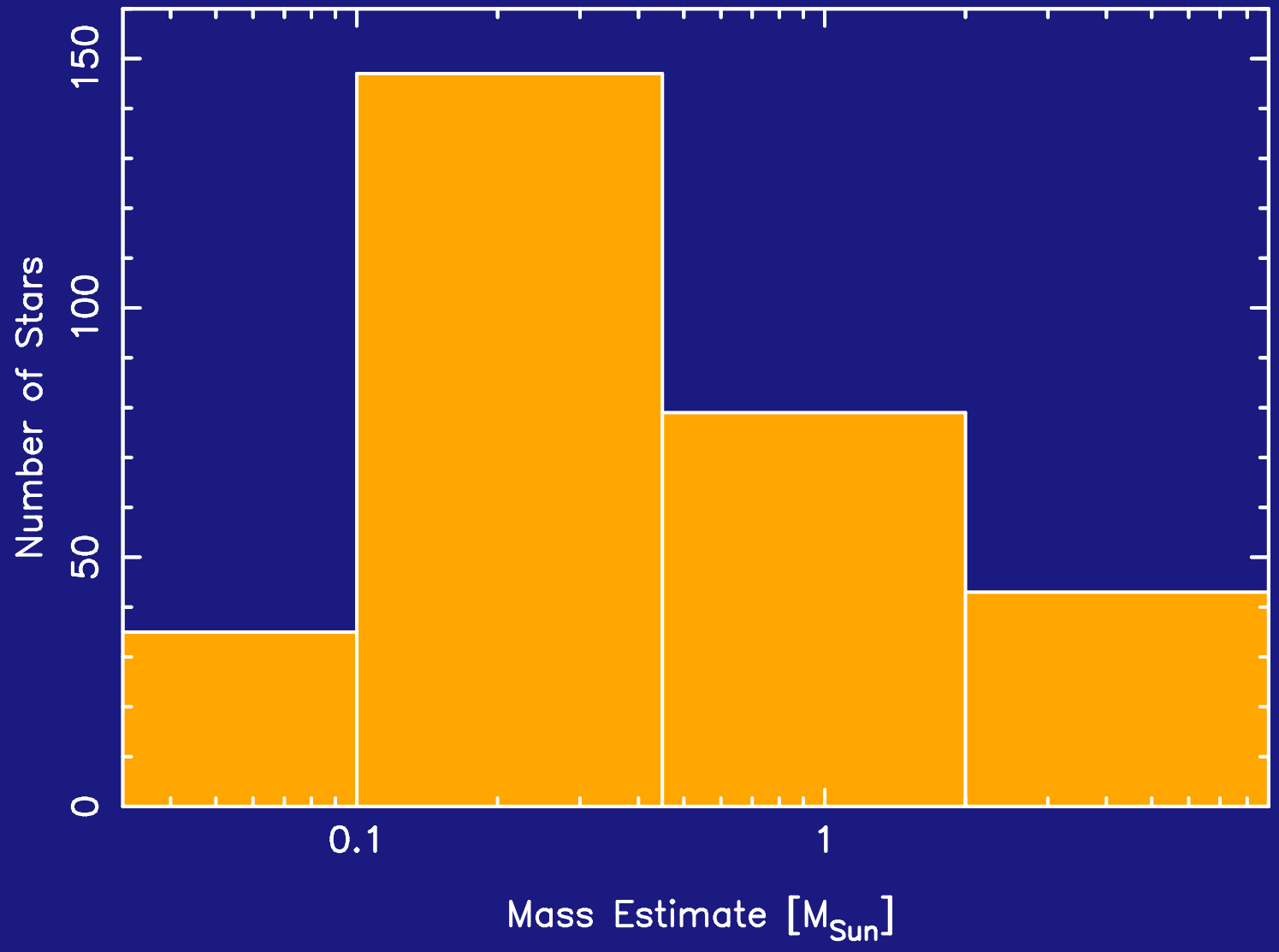
(from Sterzik & Durisen 2003, A&A 400, 1031)

Low-Mass Stars (0.1 – 2 $M_\odot$)

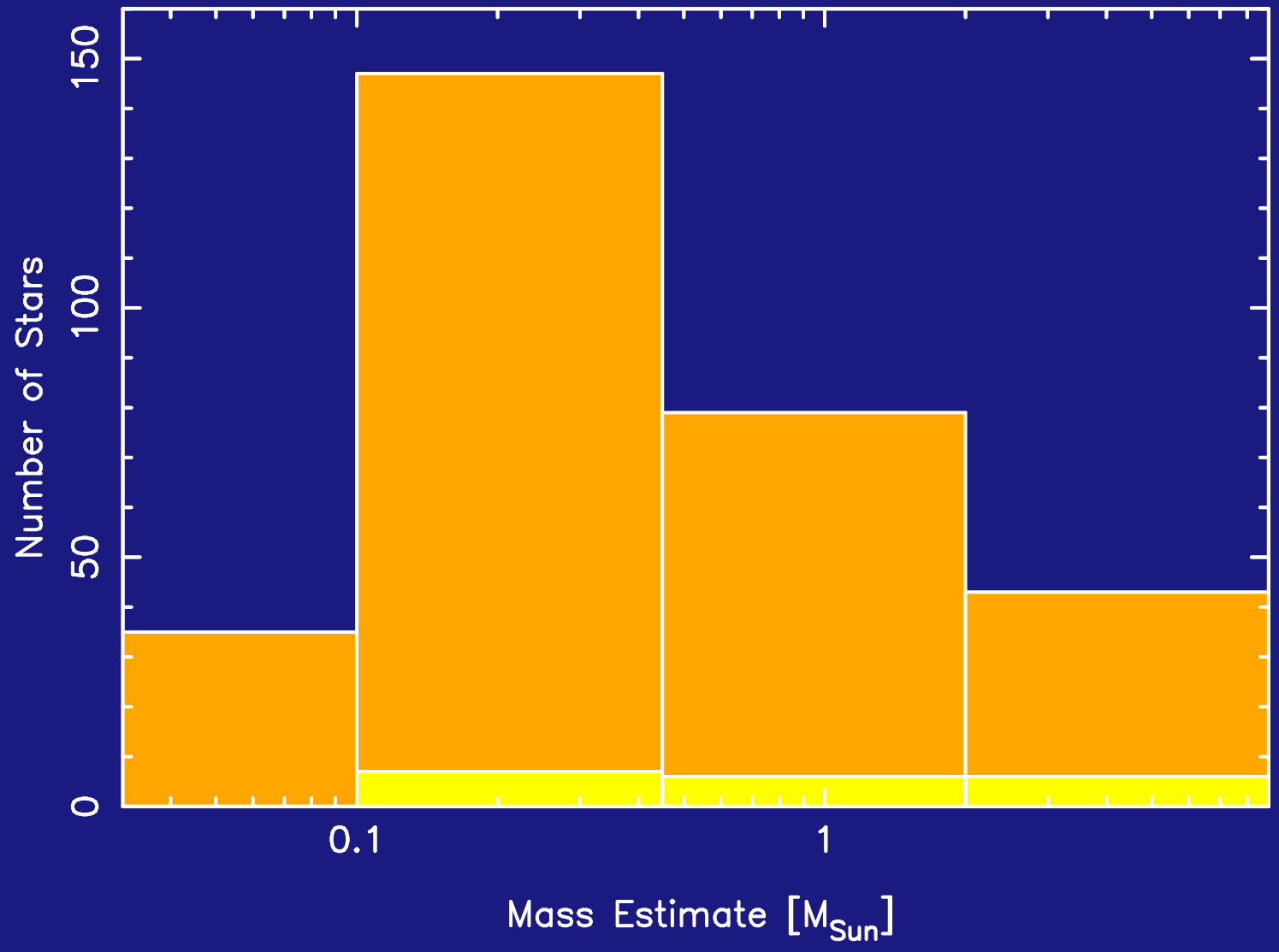
- Orion $3.4 \pm 1.5\,\%$
- Taurus-Auriga $14 \pm 3\,\%$ (Köhler & Leinert 98)
- Main-sequence stars
  - solar-type $9 \pm 2\,\%$ (Duqennoy & Mayor 91)
  - M-dwarfs $3 \pm 2\,\%$ (Reid & Gizis 97)

companion star frequency corrected for chance alignments and completeness

Mass Distribution of the Orion Sample



Mass Distribution of the Orion Sample



Low- and Lower-Mass Stars

- Orion

  $0.45 < M \leq 2$ $8 \pm 3\%$ (79 systems, 6 bin.)

  $0.1 < M \leq 0.45$ $5 \pm 2\%$ (147 systems, 7 bin.)

- Main-sequence stars

  solar-type $9 \pm 2\%$ (Duqennoy & Mayor 91)

  M-dwarfs $3 \pm 2\%$ (Reid & Gizis 97)

No corrections!

Conclusions so far

- Multiplicity in Orion is not exceptionally low

  $\approx$ main-sequence stars of comparable mass

  ($\Longrightarrow$ make sure you know what you observe!)

- much lower than in Taurus-Auriga
- not (strongly) dependent on radius

Köhler et al., A&A 458, 461 (2006)

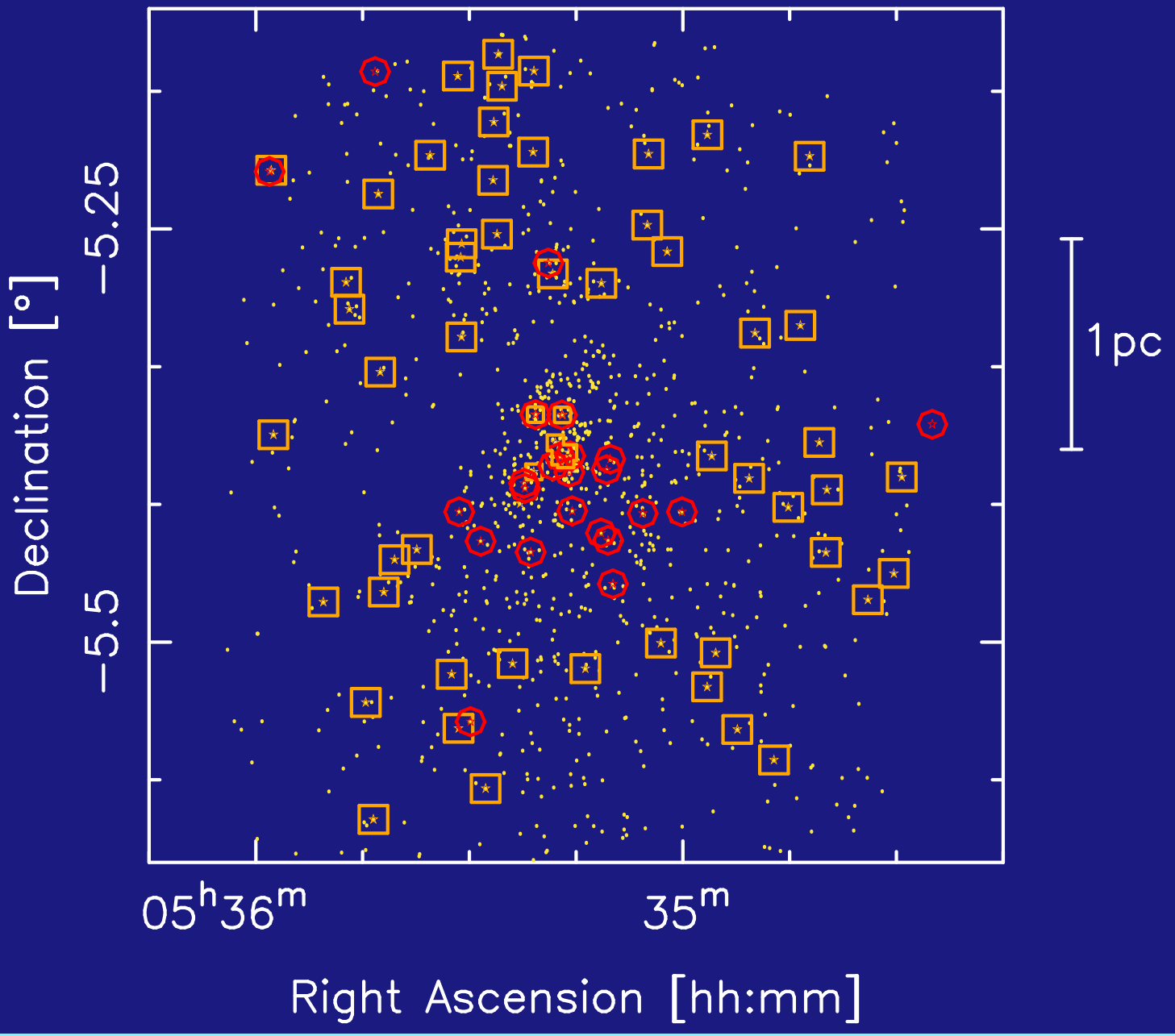
Observations with NACO/VLT

- Adaptive Optics observations in J, H, K
- include cluster center
- 3 nights in December 2004
- 27 fields,

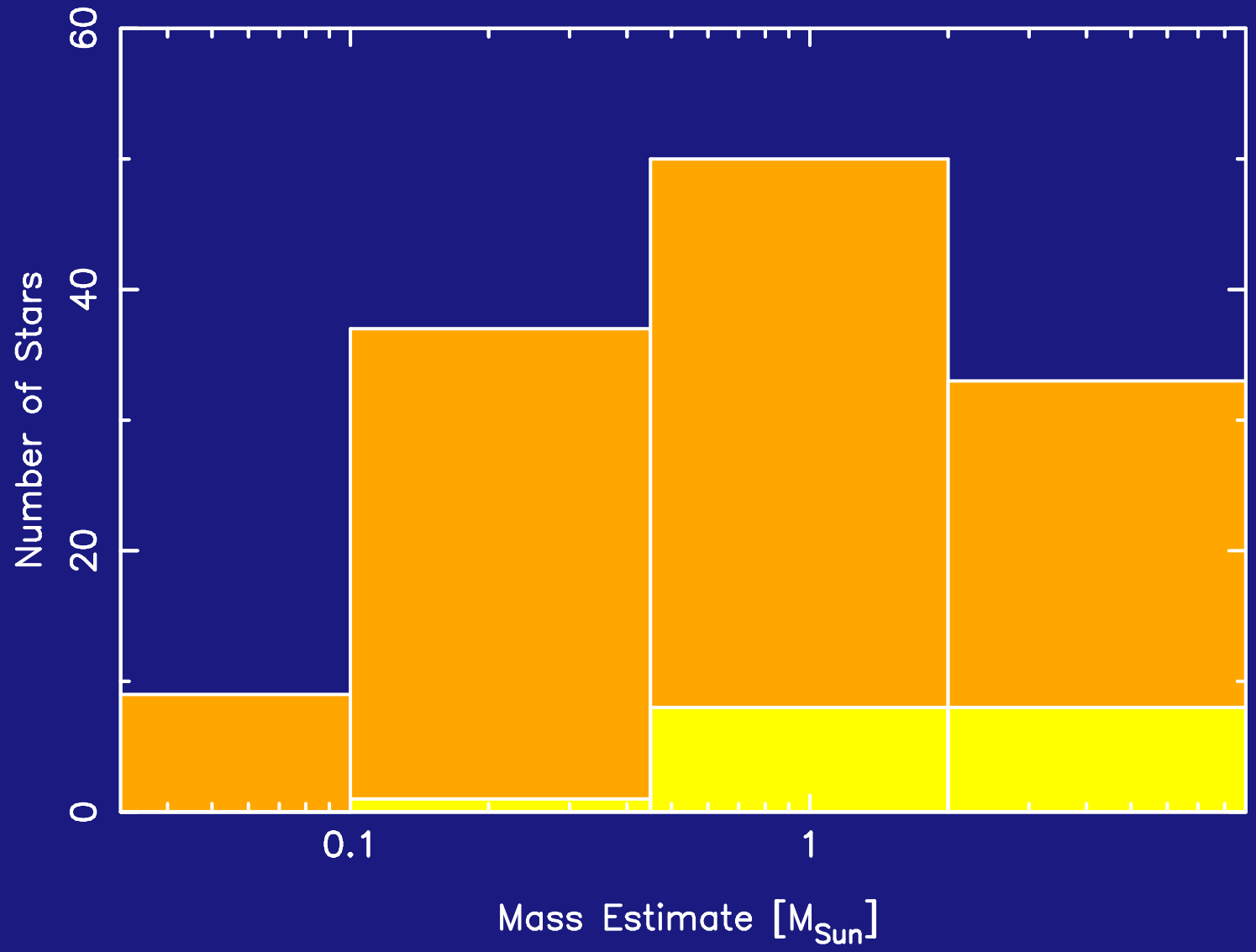
  $\sim$ 415 stars detected,

  $\sim$ 131 in 2MASS – 21 binaries (16 %)

Observed Fields



Mass Distribution of the NACO Sample



Low- and Lower-Mass Stars

(NACO + Periphery)

- Orion

  $0.45 < M \leq 2$ $11 \pm 3\,\%$ (100 systems, 11 bin.)

  $0.1 < M \leq 0.45$ $4 \pm 2\,\%$ (131 systems, 5 bin.)

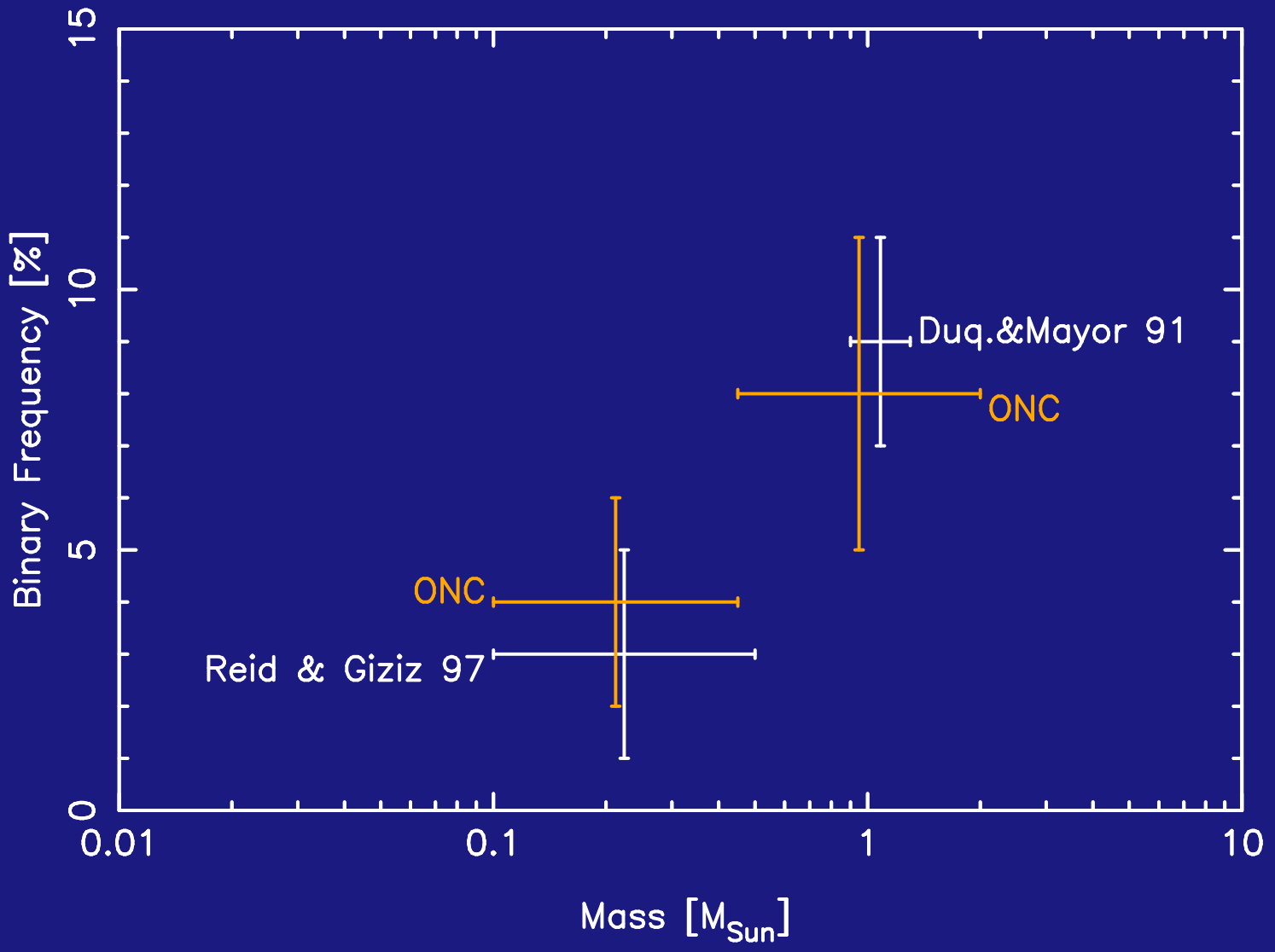
- Main-sequence stars

  solar-type $9 \pm 2\,\%$ (Duqennoy & Mayor 91)

  M-dwarfs $3 \pm 2\,\%$ (Reid & Gizis 97)

No corrections!

ONC compared to Main Sequence



To Do

- Photometric calibration
- Measure binary separations
- Corrections for completeness & chance alignments
- Study separation distribution
- Dependence on position in cluster?

Conclusions

- Multiplicity in Orion is not exceptionally low

  $\approx$ main-sequence stars of comparable mass

- much lower than in Taurus-Auriga
- not (strongly) dependent on radius