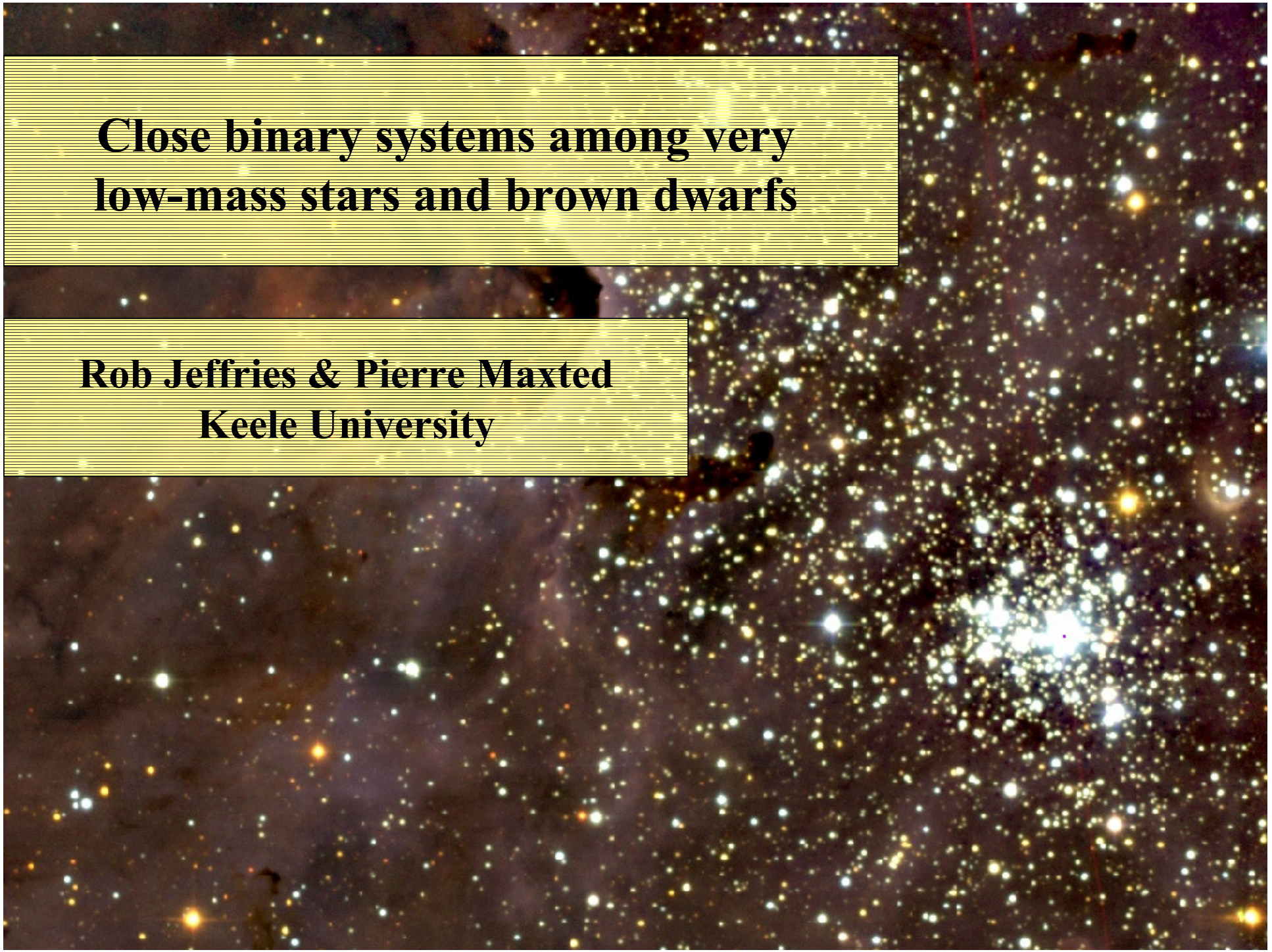


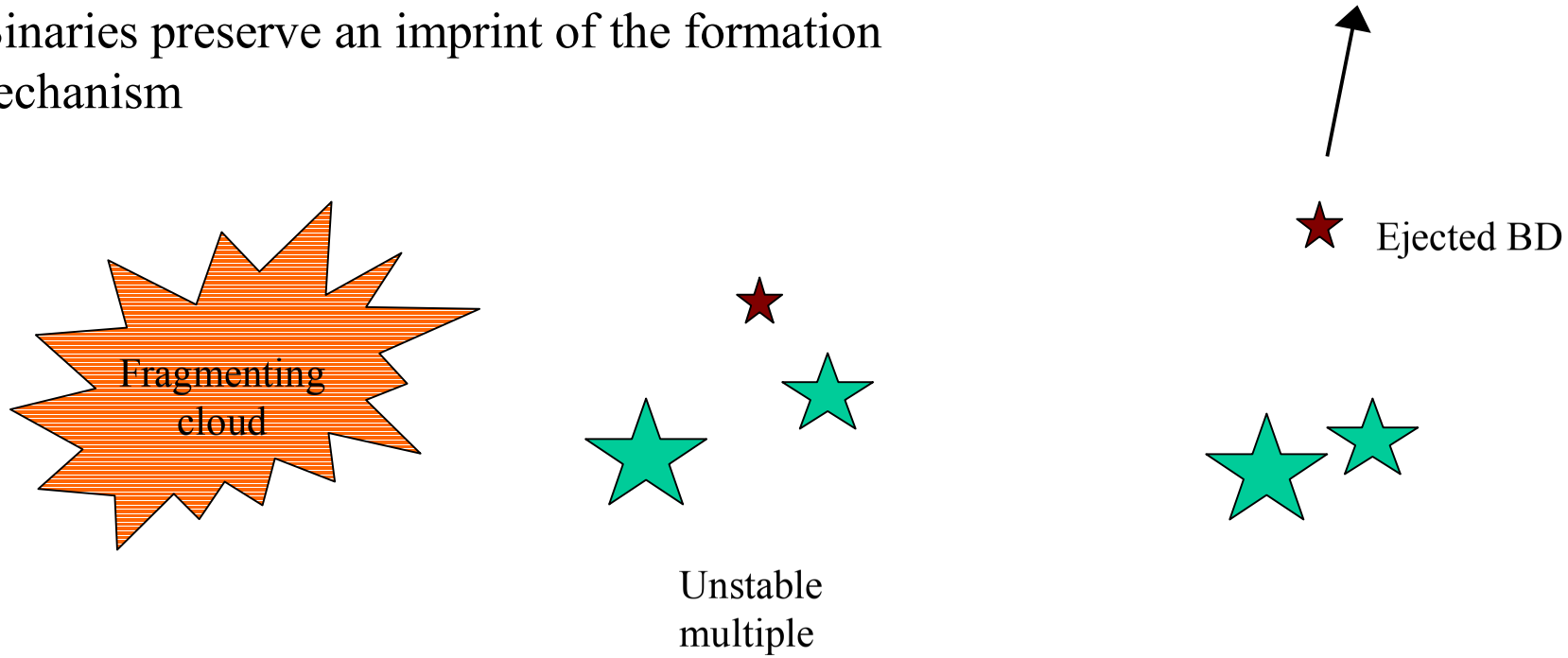
Close binary systems among very low-mass stars and brown dwarfs

Rob Jeffries & Pierre Maxted
Keele University

Very low-mass stars and brown dwarfs in binary systems

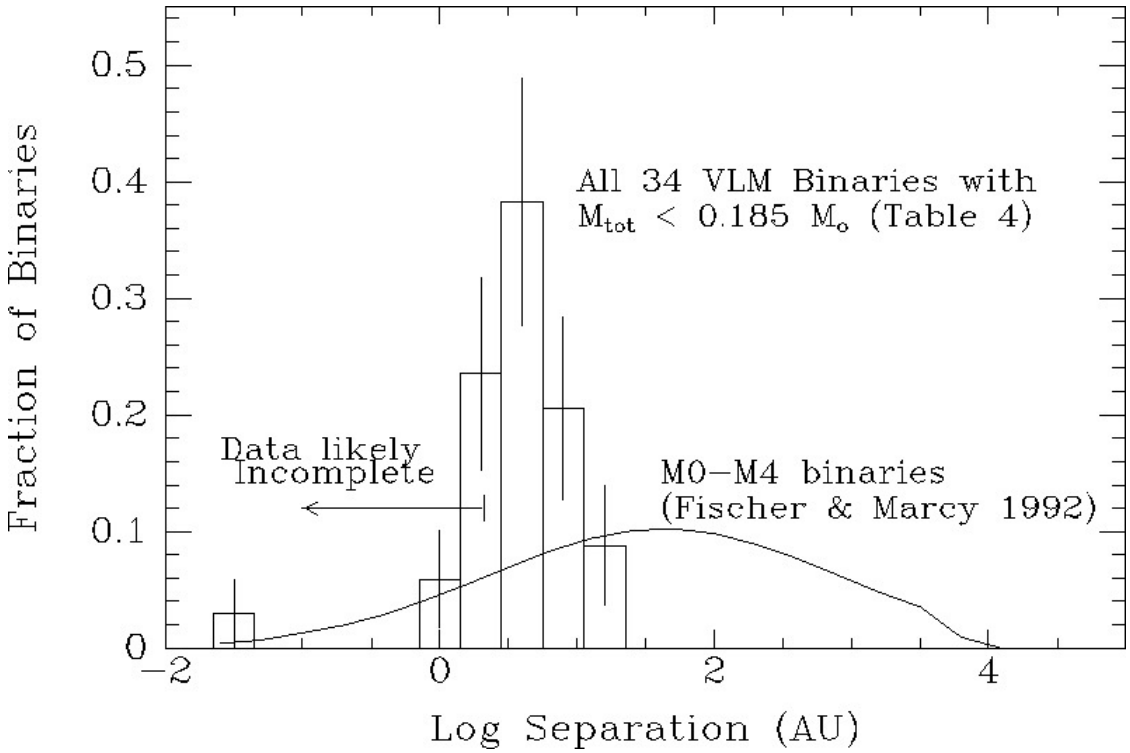
•Formation mechanism for lowest mass objects controversial - typical Jeans mass is too large!

•Binaries preserve an imprint of the formation mechanism



Wide VLM/BD binaries

- BF = (15±7) % (at >2.6au)
- Peak at 3-4 au
- No very wide systems

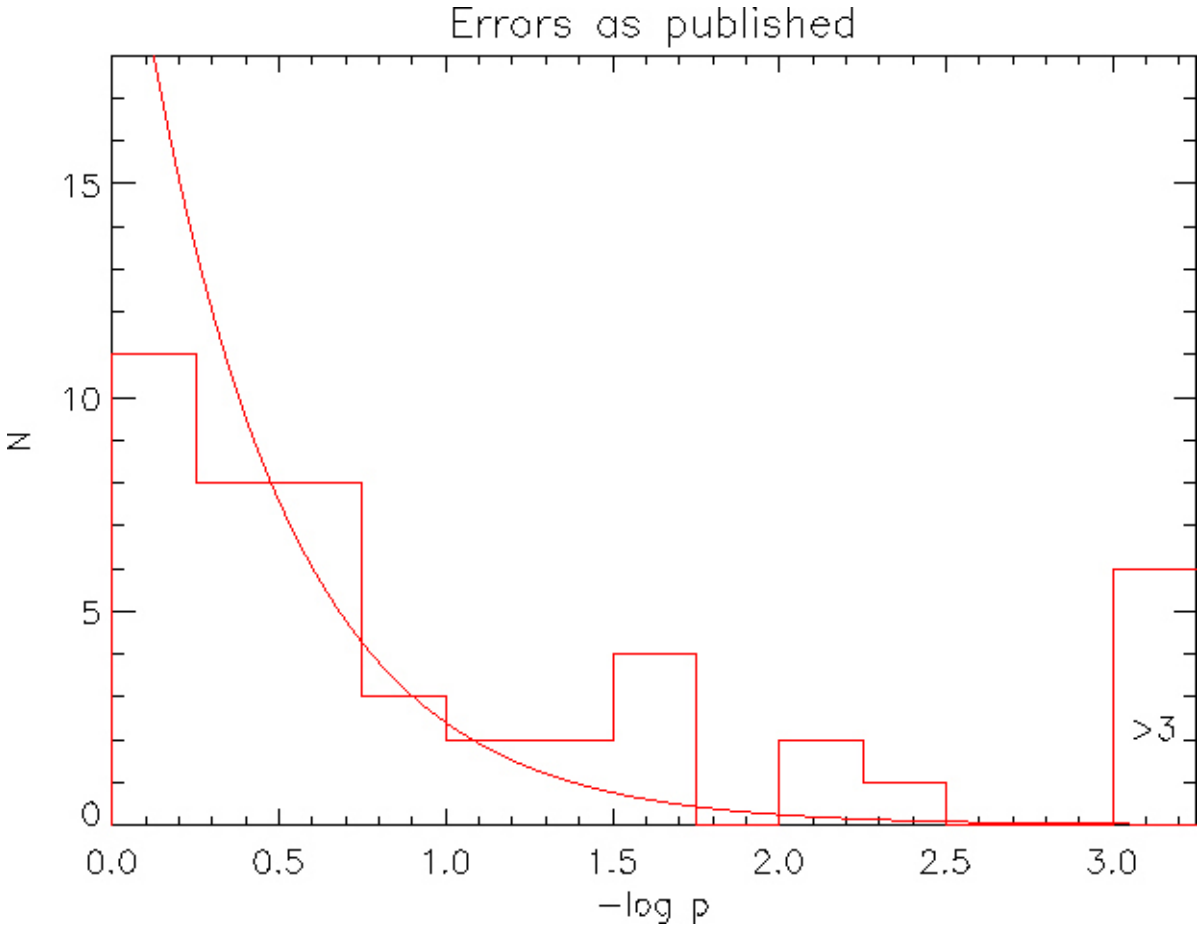


Close binaries

- Guenther & Wuchterl (2003) - 3 RV variables in 24 field VLMS/BDs
- Joergens (2005) - 2 RV variables in 11 Cha I VLMS/BDs
- Kenyon et al. (2005) - 4 close binaries in ~60 Sigma Ori VLMS/BDs

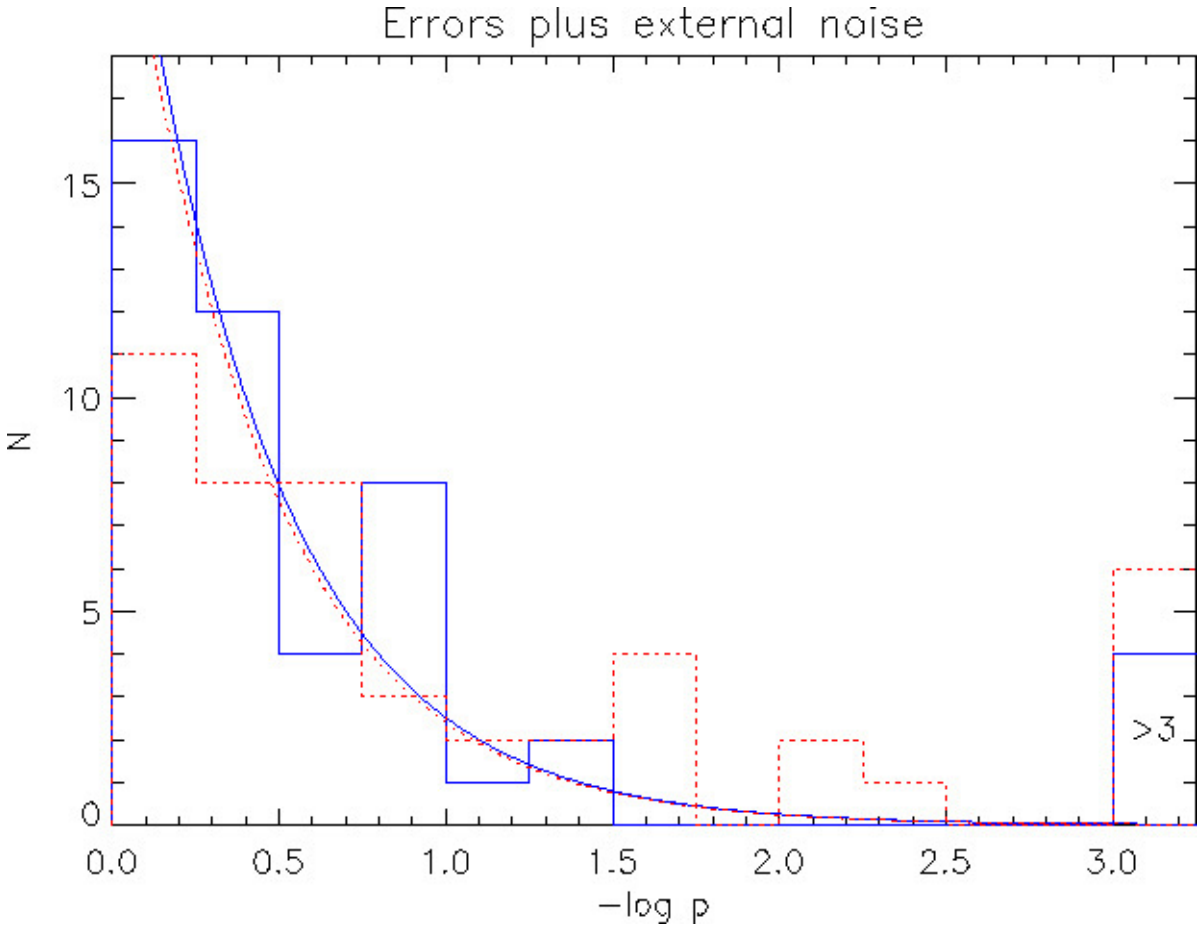
Close binary frequency of >10% ??

Data - 47 VLM/BD binaries with >1 RV measurement and 0.045<M<0.11 M_{sun}



Add external errors to match **log p** distribution?

Data - 47 VLM/BD binaries with >1 RV measurement and $0.045<M<0.11\ M_{sun}$



Add external errors to match **log p** distribution?

Monte Carlo Simulations

For each target, take error bars, masses and times of observation.
Generate $\mathbf{10^7}$ trials picking randomly from:

- a distribution of **log a**
- a distribution of $\mathbf{q=m_1/m_2}$
- a distribution of eccentricity, **e**
- phase, inclination, longitude of periastron

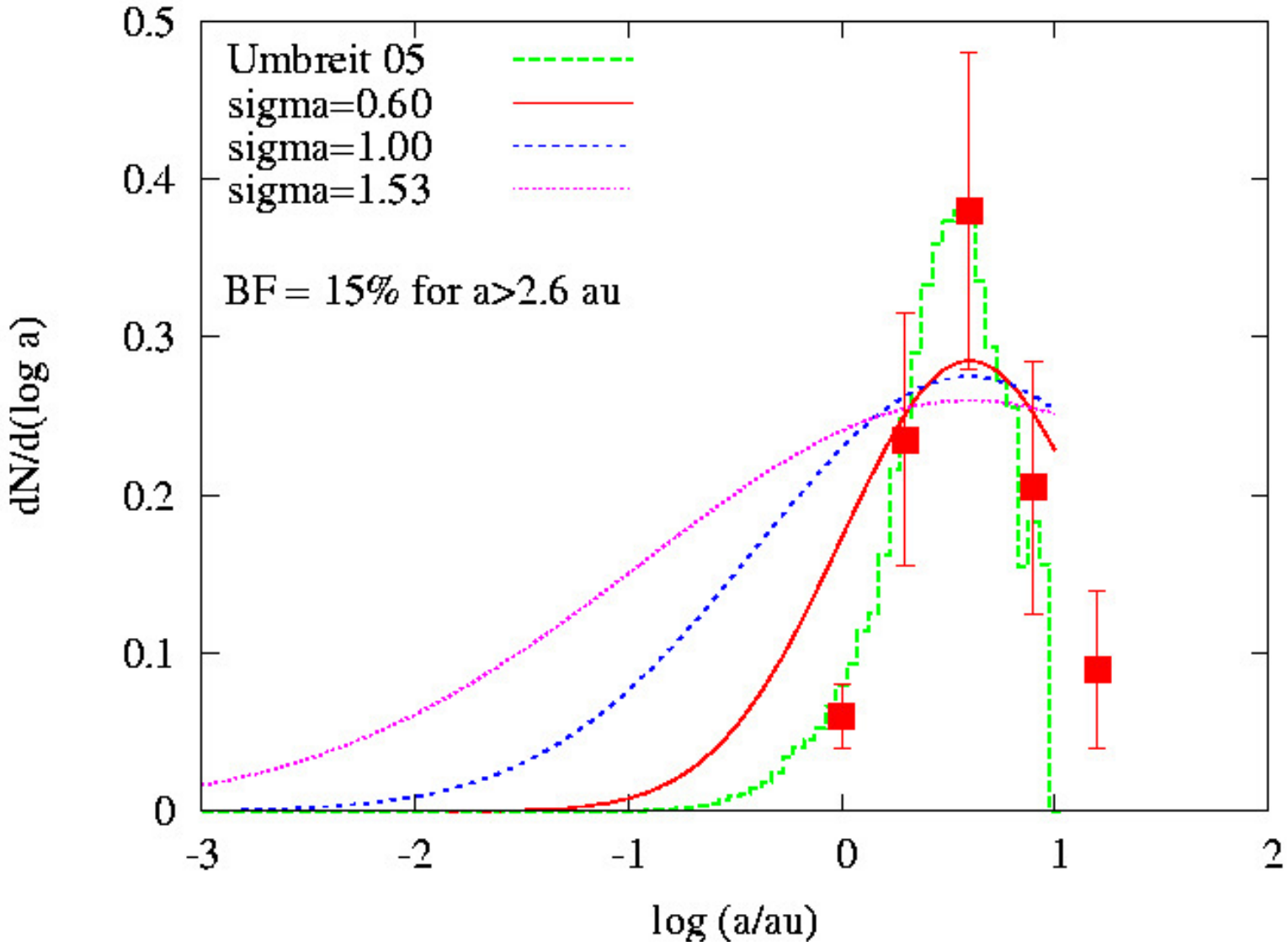
Hence calculate RV(t) and perturb according to error bar

Hence calculate χ^2 and **log p**

If **log p < -3** "binary" is detected

Get detection efficiency vs **log a** per star

Assumed a distributions



Assumptions

F(q)

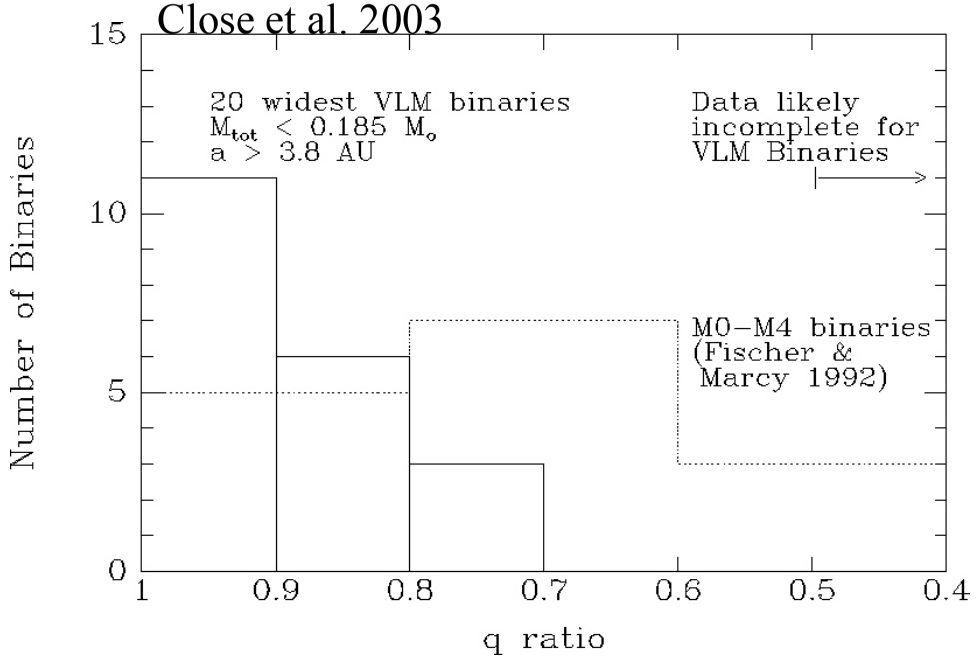
“flat” - uniform 0.2<q<1

(c.f. M-dwarf F(q)) --->

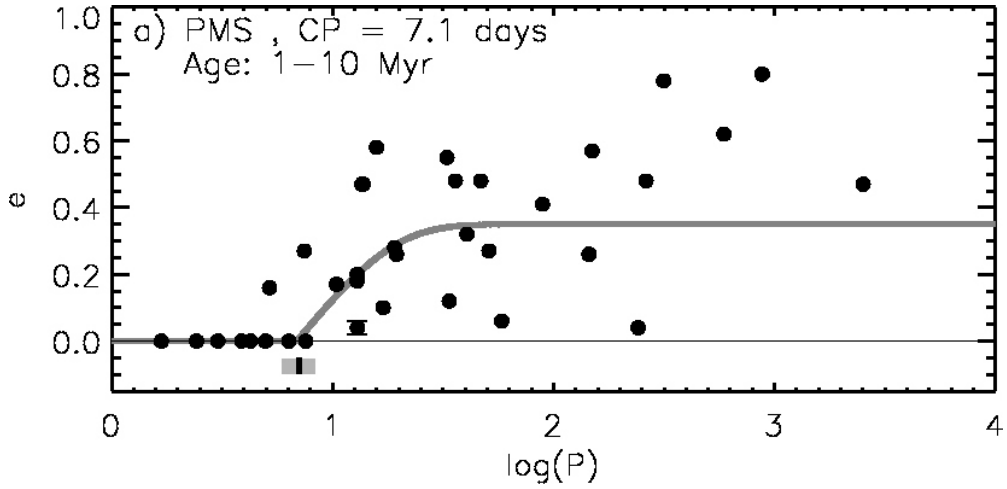
“peaked” - uniform 0.7<q<1

(c.f. VLM/BD F(q)) --->

Close et al. 2003



Meibom & Mathieu 2005



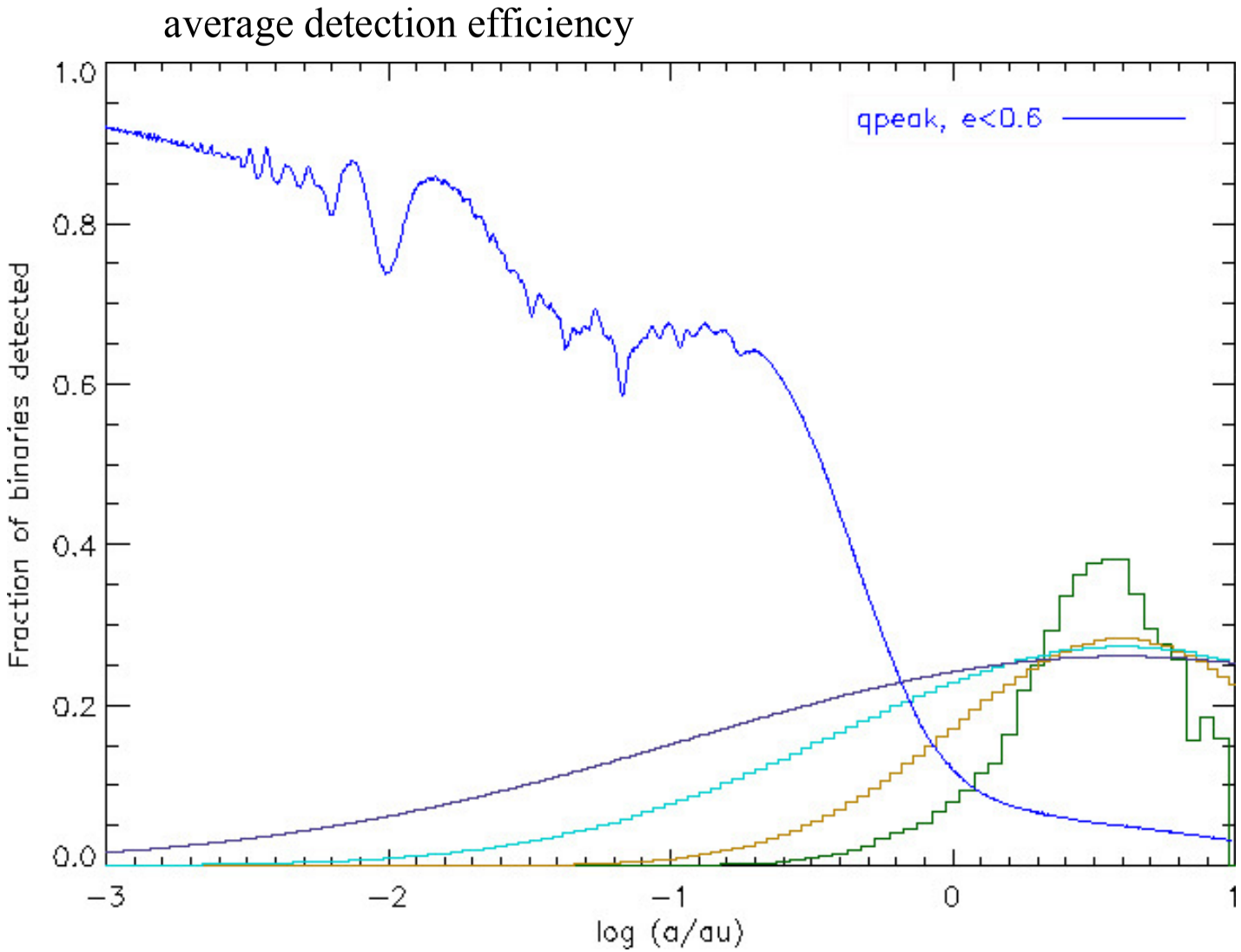
F(e)

e=0 for P<10 days, then

F(e)=uniform 0<e<e_{max}

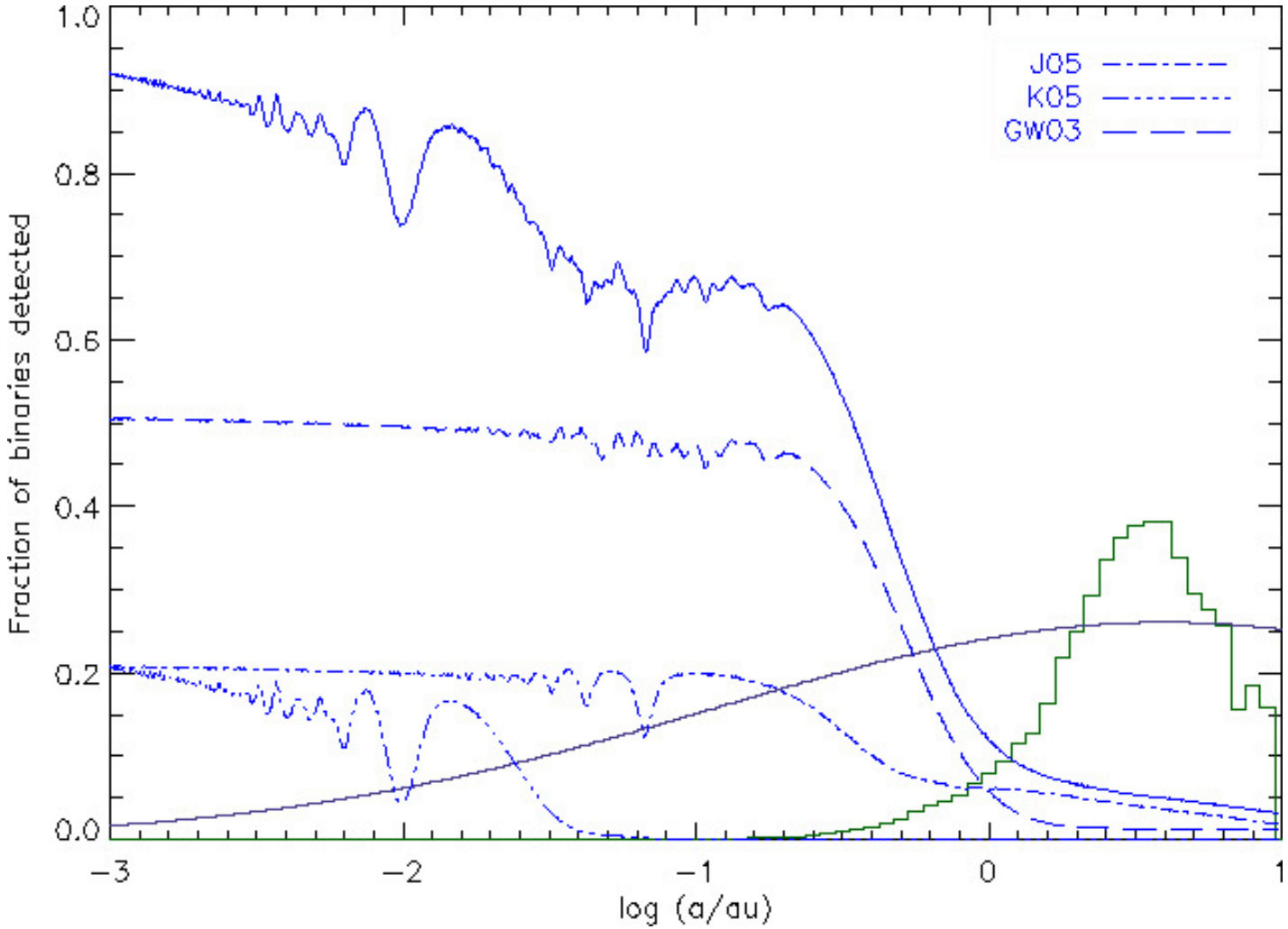
(with e_{max} 0.6 or 0.9)

Probability of detecting a binary system at log p < -3



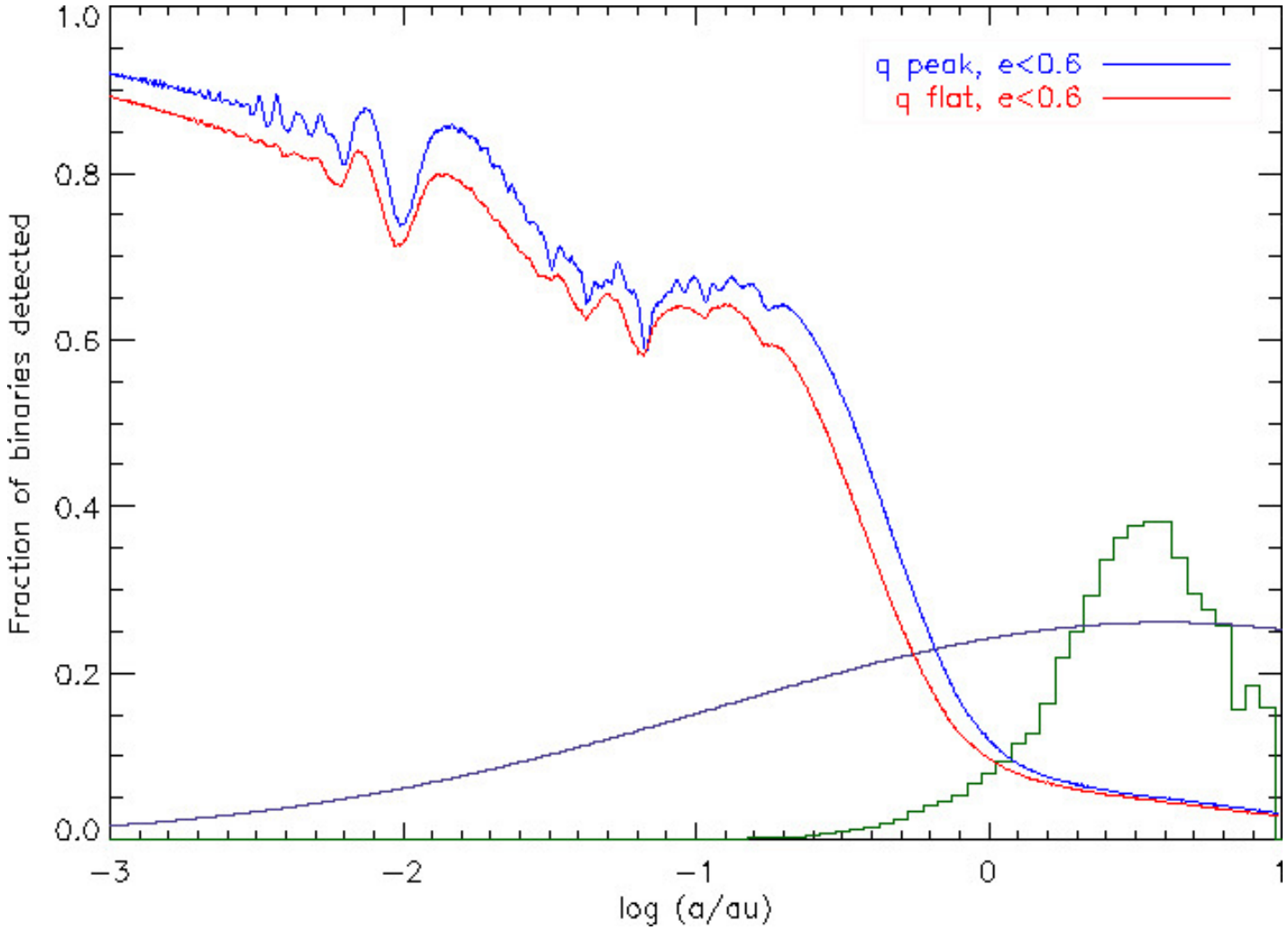
Probability of detecting a binary system at log p < -3

Contribution from each dataset illustrating differing sensitivities



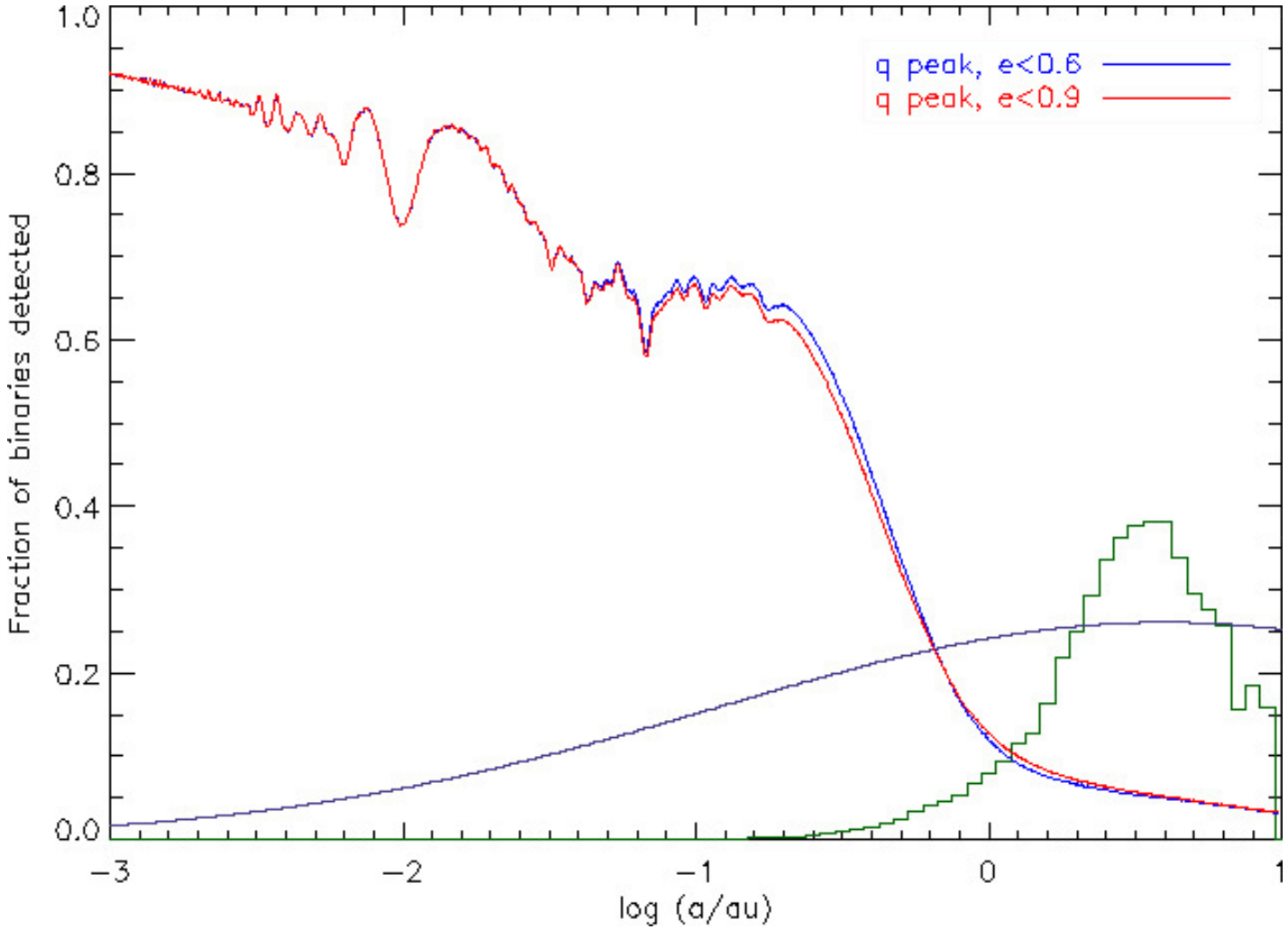
Probability of detecting a binary system at log p < -3

"Peaked" F(q) gives more detectable binaries

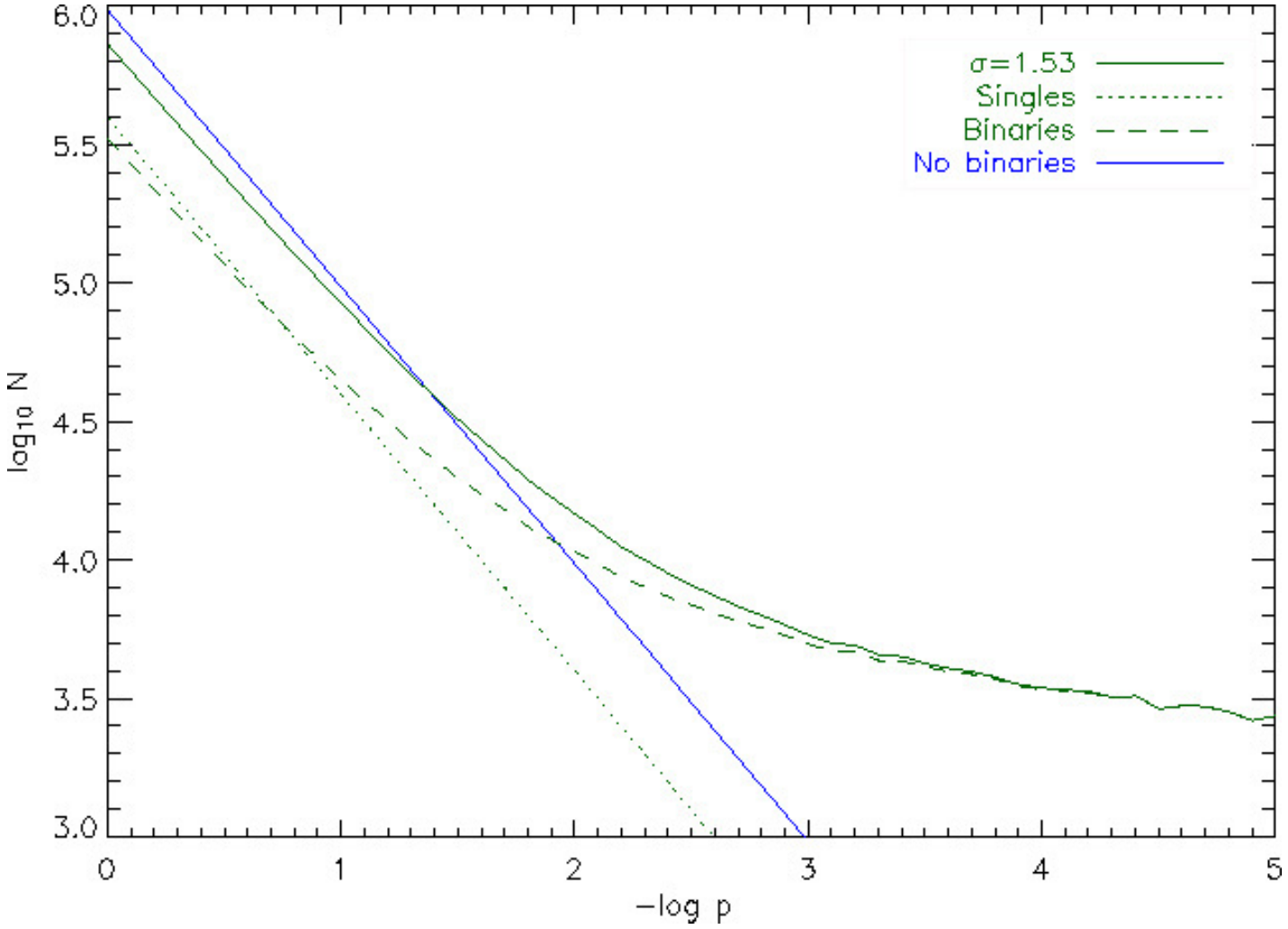


Probability of detecting a binary system at log p < -3

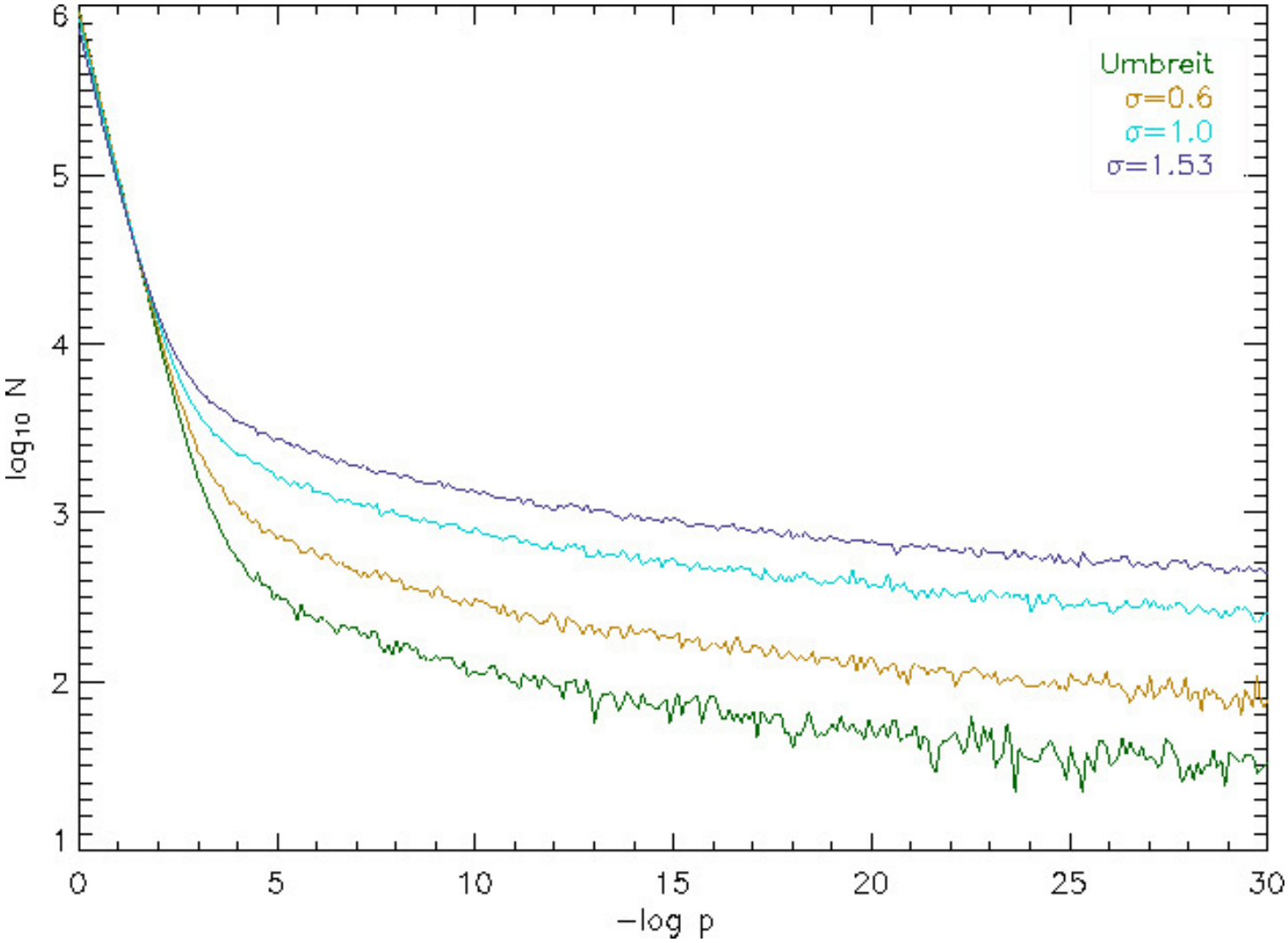
Changing F(e) makes little difference



Mix together singles and binaries in the appropriate proportion to simulate the expected log p distribution



Integrate beyond log p = -3 to calculate number of detected “binaries”



F(log a)	f_B	N_{BIN}	$P(N_{OBS} \geq 4)\%$	$P(N_{OBS} \leq 4)\%$
Umbreit	0.26	0.6 - 1.0	0.4 - 1.9	99.7 - 99.9
$\sigma = 0.60$	0.32	1.5 - 2.3	6.1 - 19.4	92.3 - 98.4
$\sigma = 1.00$	0.45	4.7 - 6.4	70.3 - 90.1	21.0 - 47.4
$\sigma = 1.53$	0.59	9.6 -12.1	99.3 - 99.9	0.3 - 2.4

N_{BIN} **is** corrected for "binary bias" in field star samples

Umbreit (N-body) produces **too few** binaries

σ =1.53 produces **too many** binaries

$0.6 < \sigma < 1.0$ favoured -- total BF=32-45% !

IMPLICATIONS

Fragmentation does not produce close (< few au) binaries – hardening mechanisms required.

1. N-body simulations produce few close binaries - so dynamical hardening probably ineffective

Ejection should produce few close VLMS/BD binaries as they are rarely the most massive objects in a protostellar aggregate

2. Hydrodynamical hardening processes must be effective. But current SPH simulations predict VLM/BD binary fractions of ~8% - mainly at 5-10 au.

CONCLUSIONS

- **Large close binary fraction 17-30% with a<2.6au**
- **Cannot be explained by N-body "ejection" models**
- **Neither can current SPH models produce these binaries**
- **Need a way of bringing VLMS/BDs together, without disrupting them**
- **Only caveat is small number (4) of identified close binaries - a larger survey is needed!**