The Strongly Relativistic Double Pulsar and LISA

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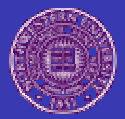


NORTHWESTERN
UNIVERSITY

with
Chunglee Kim (NU)
Duncan Lorimer (Manchester)

PSR J0737-3039 A and B in motion!

QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.

animation credit: John Rowe

$P_{spin\text{-}A}$ = 22.7ms

$P_{spin\text{-}B}$ = 2.7s

P_{orb} = 2.4 hr

e = 0.09

M_A = 1.25M_o

M_B = 1.35M_o

D = 0.6kpc

(or ~1kpc?)

Burgay et al. 2003

Lyne et al. 2004

Implications for GW detectors of PSR J0737-3039 discovery

Ground-Based:

VK, Kim, Lorimer, Burgay et al. 2004

> event rates boosted by a factor of 7 !

> Initial LIGO rate could possibly be as high as 1/3yr (comparable to optimistic estimates for BH-BH inspirals)

LISA:

> good calibration source @ 2×10^{-4} Hz with S/N ~ 2

Could LISA discover more relativistic binaries like the double pulsar ?

why would we care ?

> astrophysics …

increase observed sample of relativistic NS-NS:

- **NS-NS masses**
- **NS formation and recycling**
- **PSR beaming and precession**
- **PSR space distribution**

Q: How many such binaries are at close enough distances ?

Plan: Use empirical calculations of NS-NS inspiral rates

Radio Pulsars in NS-NS binaries → (Phinney 1991; Narayan et al. 1991) → **NS-NS Merger Rate Estimates**

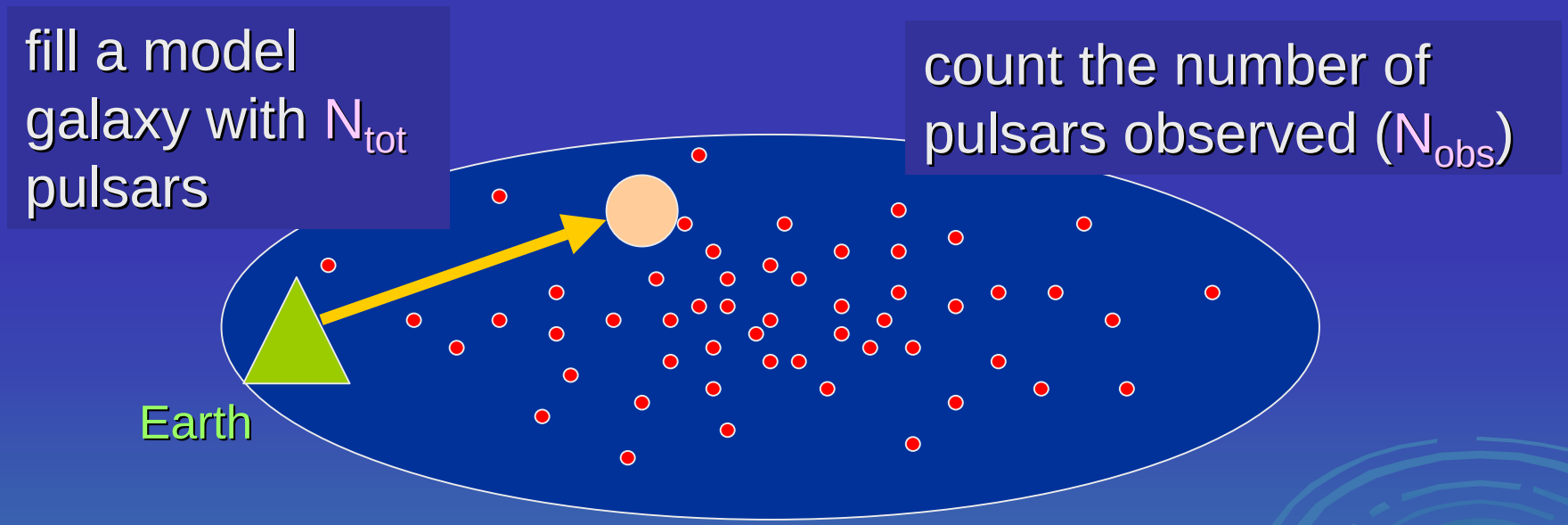
Kim et al. 2003

Bayesian analysis developed to derive the probability density of NS-NS inspiral rate

Small number bias and selection effects for faint pulsars are implicitly included.

Statistical Method

- Generate model PSR populations in the Galaxy for chosen luminosity and space distributions
- Simulate selection effects of all pulsar surveys and generate ``observed'' samples



- Derive ***probability distribution $P(N_{tot})$*** of total number of systems similar to PSR J0337-3039

Total number of binary pulsars similar to J0737-3039

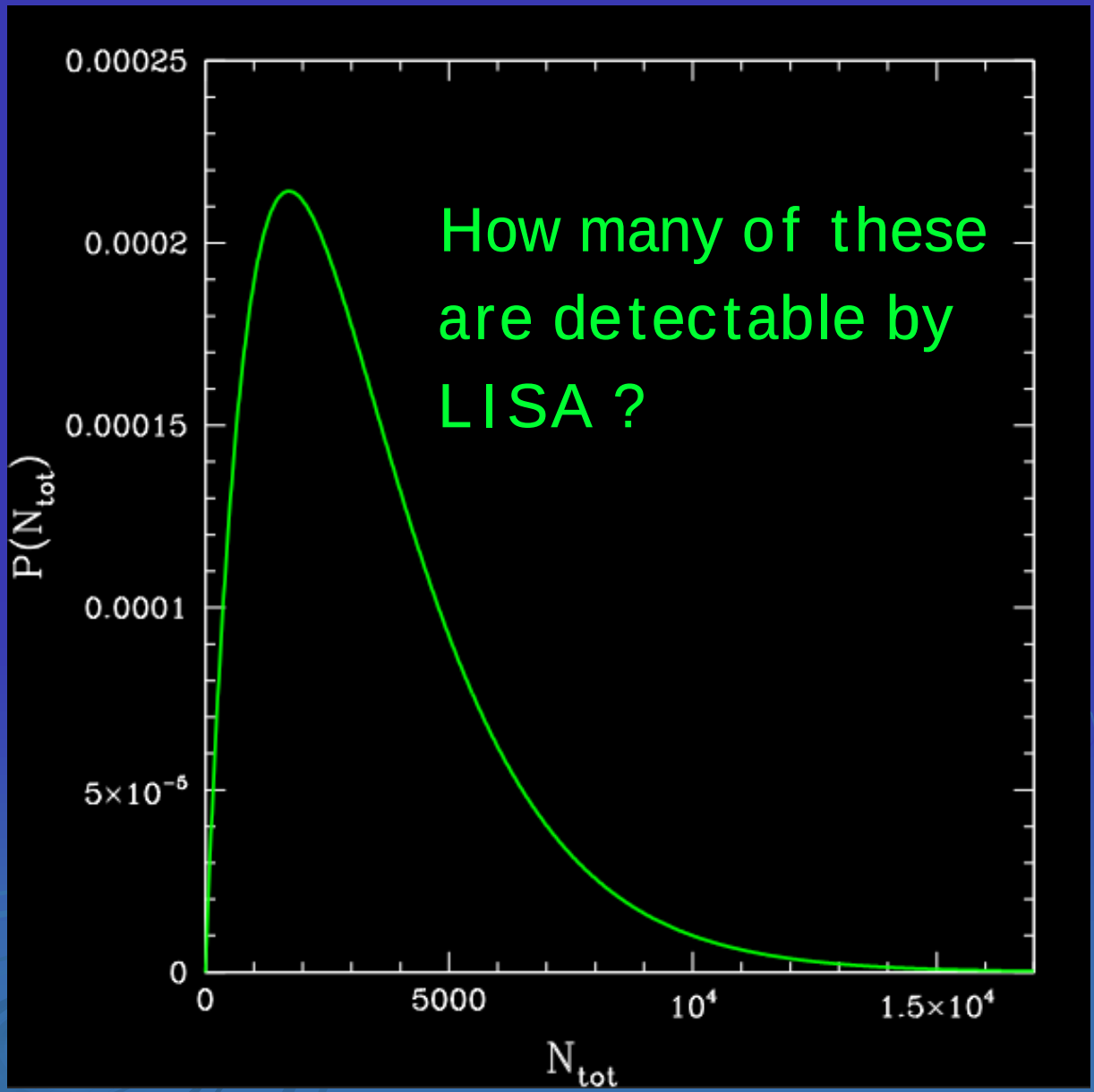
for our reference model:

L_{min}=0.3 mJy

$f(L) \sim L^{-2}$

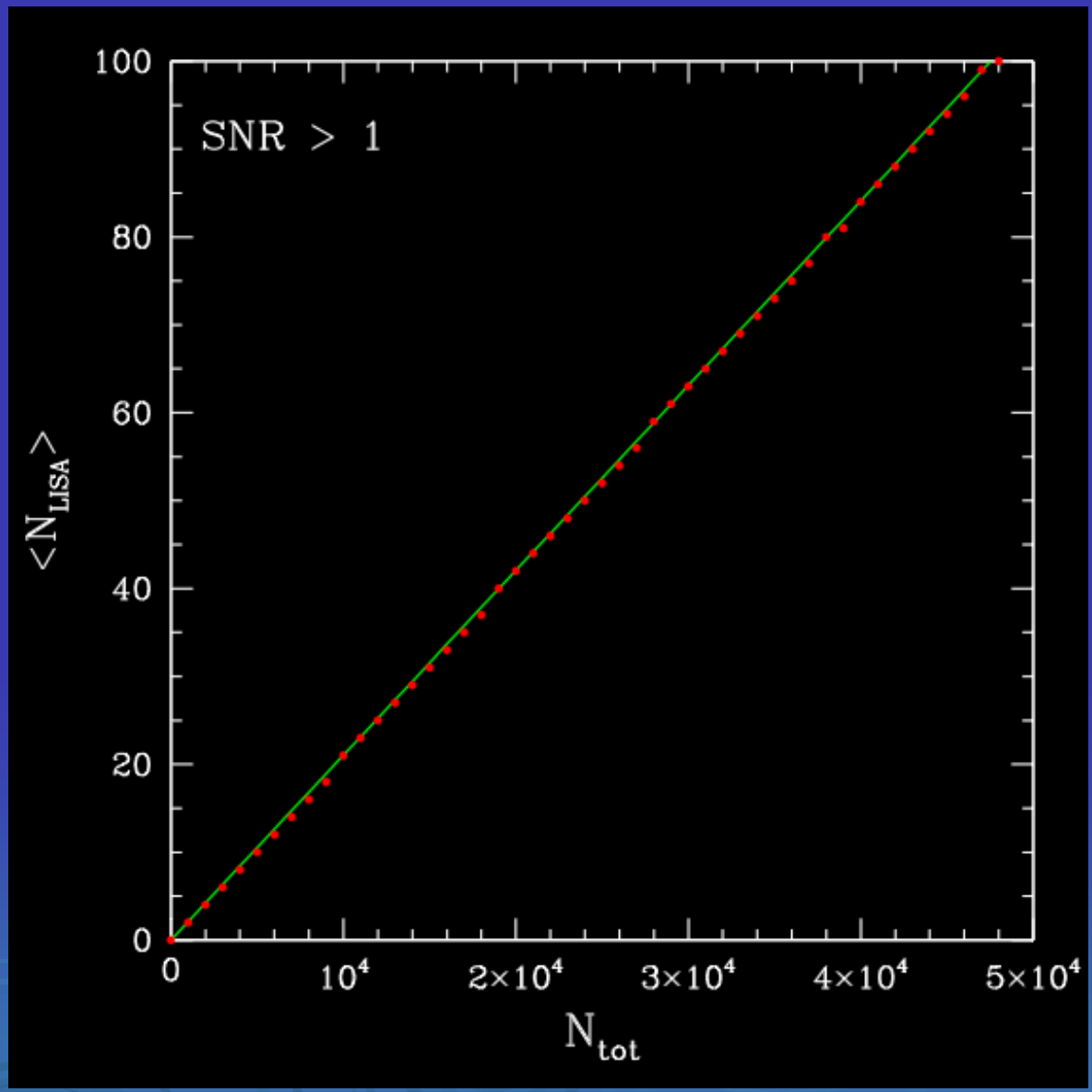
most probable N_{tot}~2,000

We assume T=1yr and e=0



Monte Carlo simulations of space distribution at each N_{tot}

- **Mean number of binaries with LISA S/N above a threshold linearly correlate with Galactic N_{tot}**

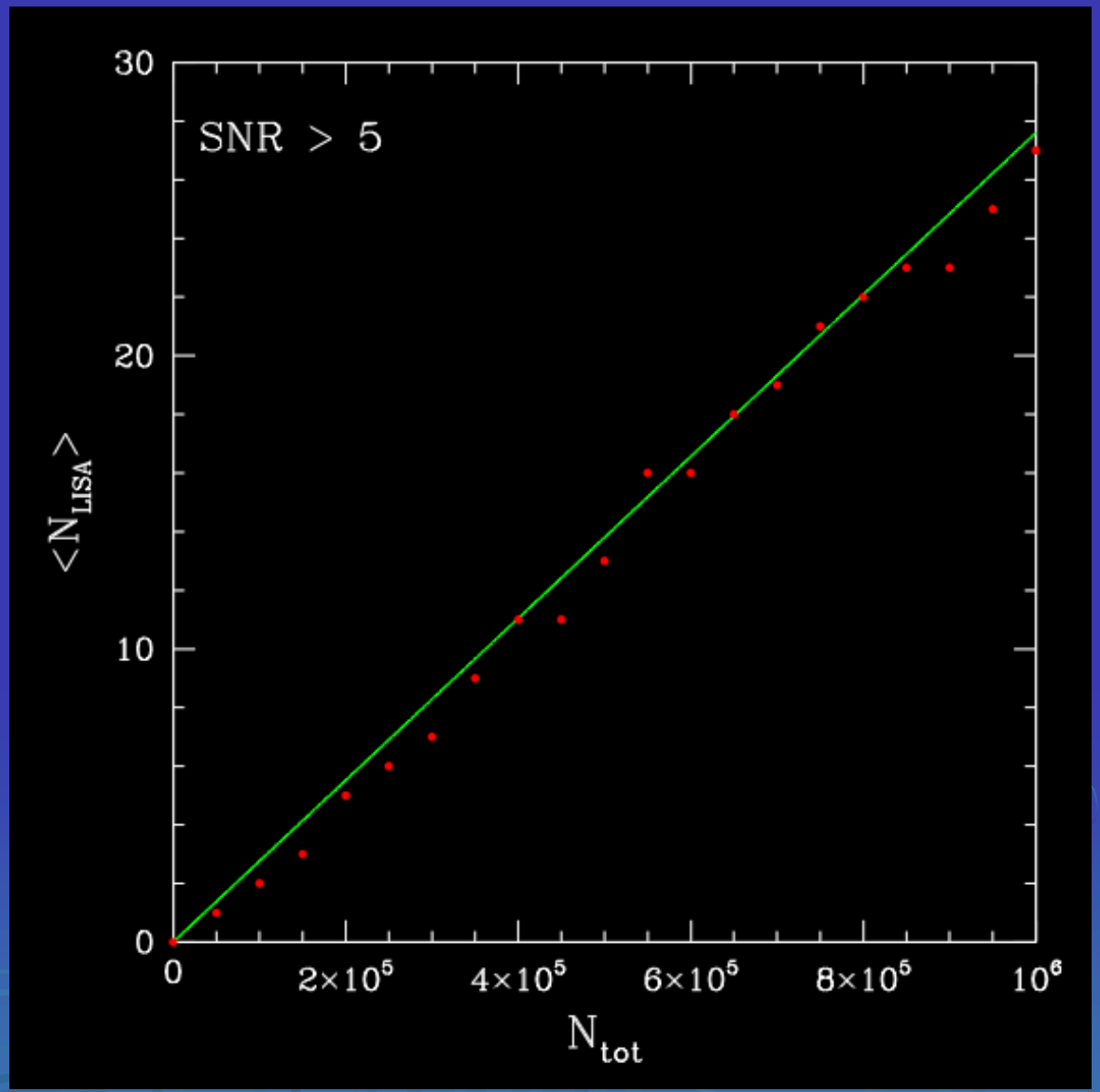


Monte Carlo simulations of space distribution at each N_{tot}

- Mean number of binaries with LISA S/N above a threshold **linearly correlate** with Galactic N_{tot}

- Use this linear correlation to transform:

$P(N_{tot}) \rightarrow P(\langle N_{LISA} \rangle)$

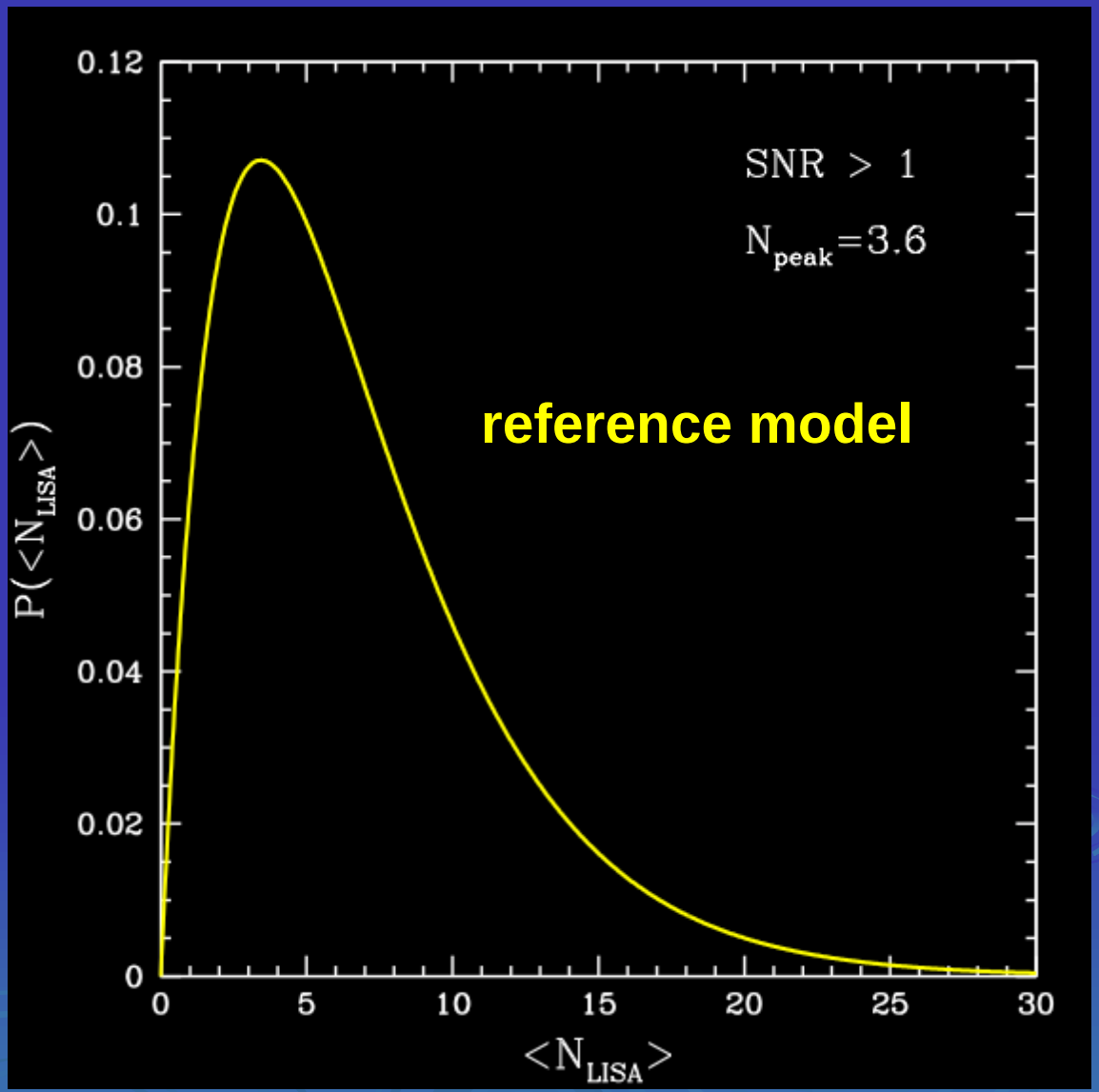


Probability distribution for $\langle N_{LISA} \rangle$

S/N > 1

$\langle N_{LISA} \rangle$ at peak probability density: 3.5

$\langle N_{LISA} \rangle$ distribution mean: 7



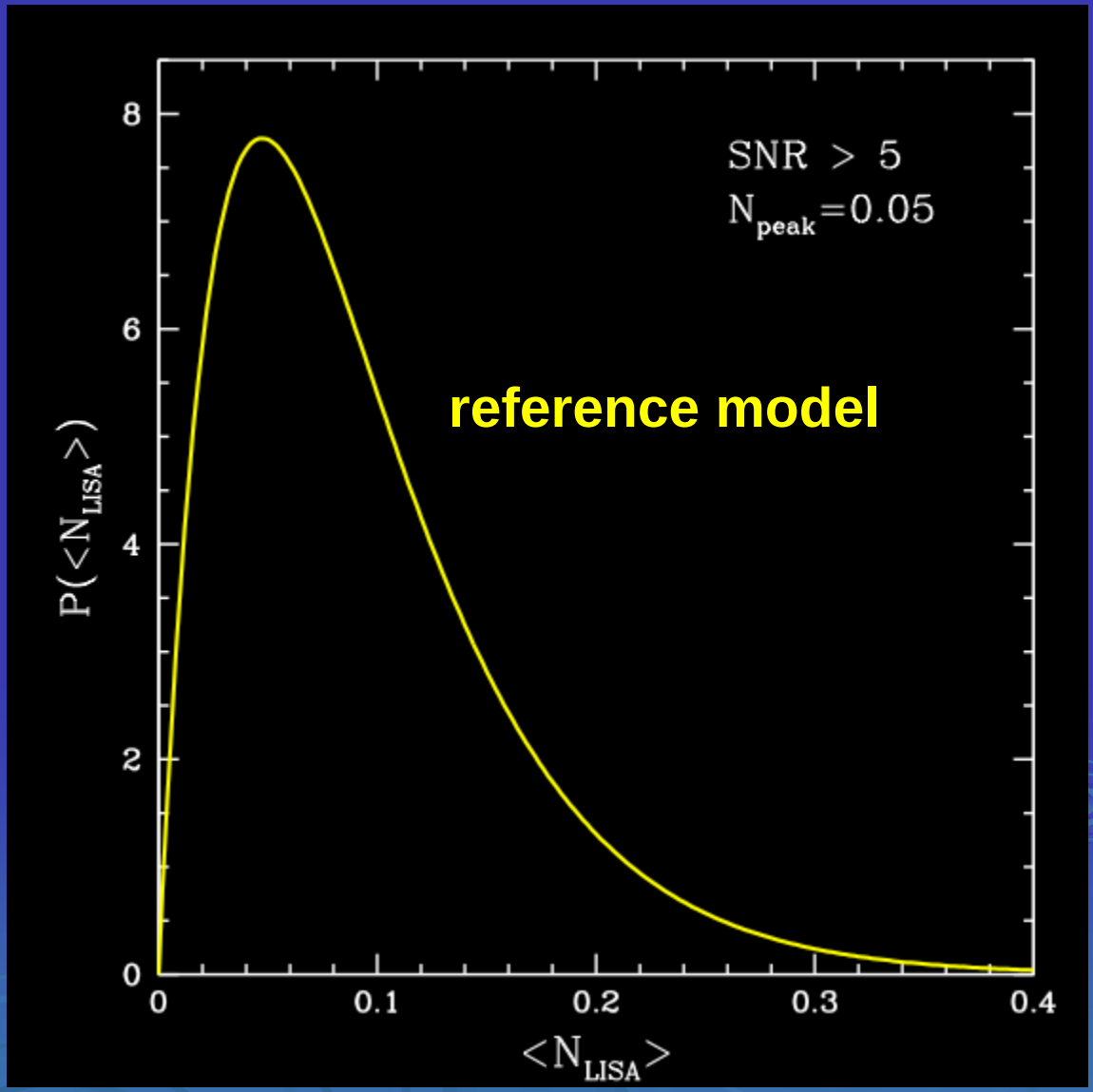
Mean number with LISA S/N > 1

Probability distribution for $\langle N_{LISA} \rangle$

S/N > 5

$\langle N_{LISA} \rangle$ at peak probability density: 0.05

$\langle N_{LISA} \rangle$ distribution mean: 0.1



Mean number with LISA S/N > 1

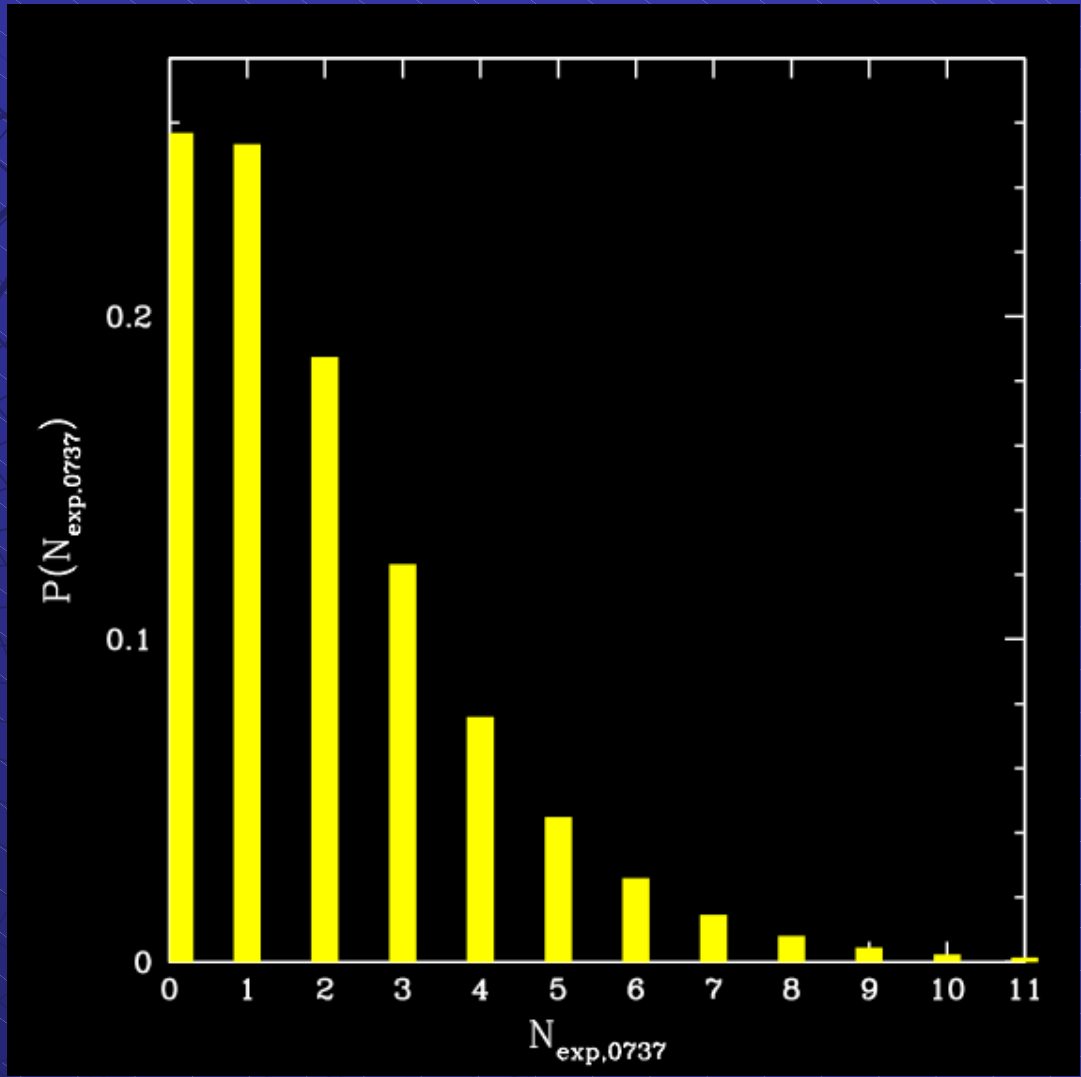
How many relativistic pulsars could the Parkes Multibeam Survey discover when acceleration searches are completed ?

at peak probability density:

PMB N = 0-1

distribution mean:

PMB N = 2



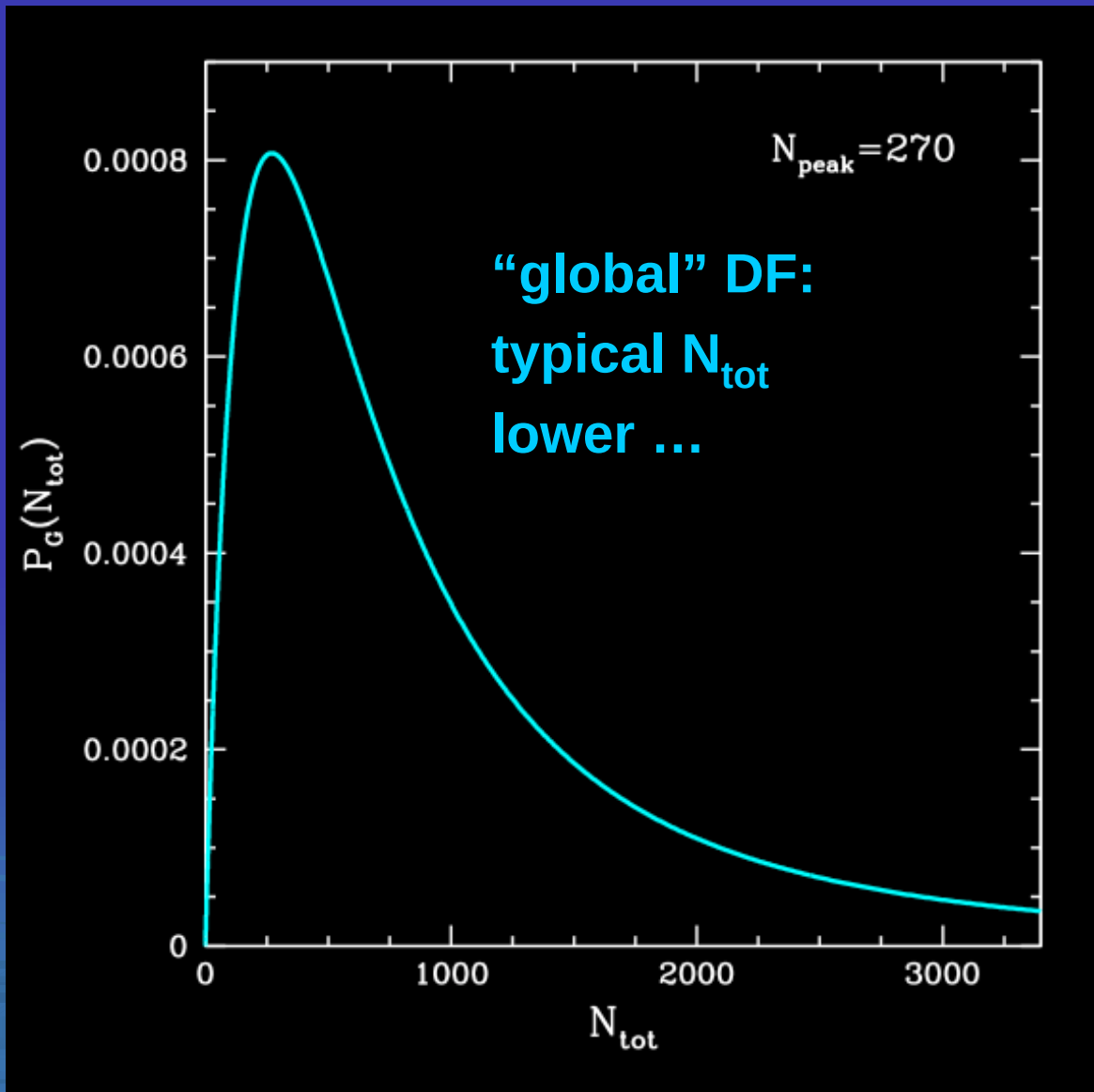
Results depend on the assumed PSR luminosity function:

$f(L) \sim L^{-p}$ for $L > L_{min}$

BUT L_{min} and p are not precisely known …

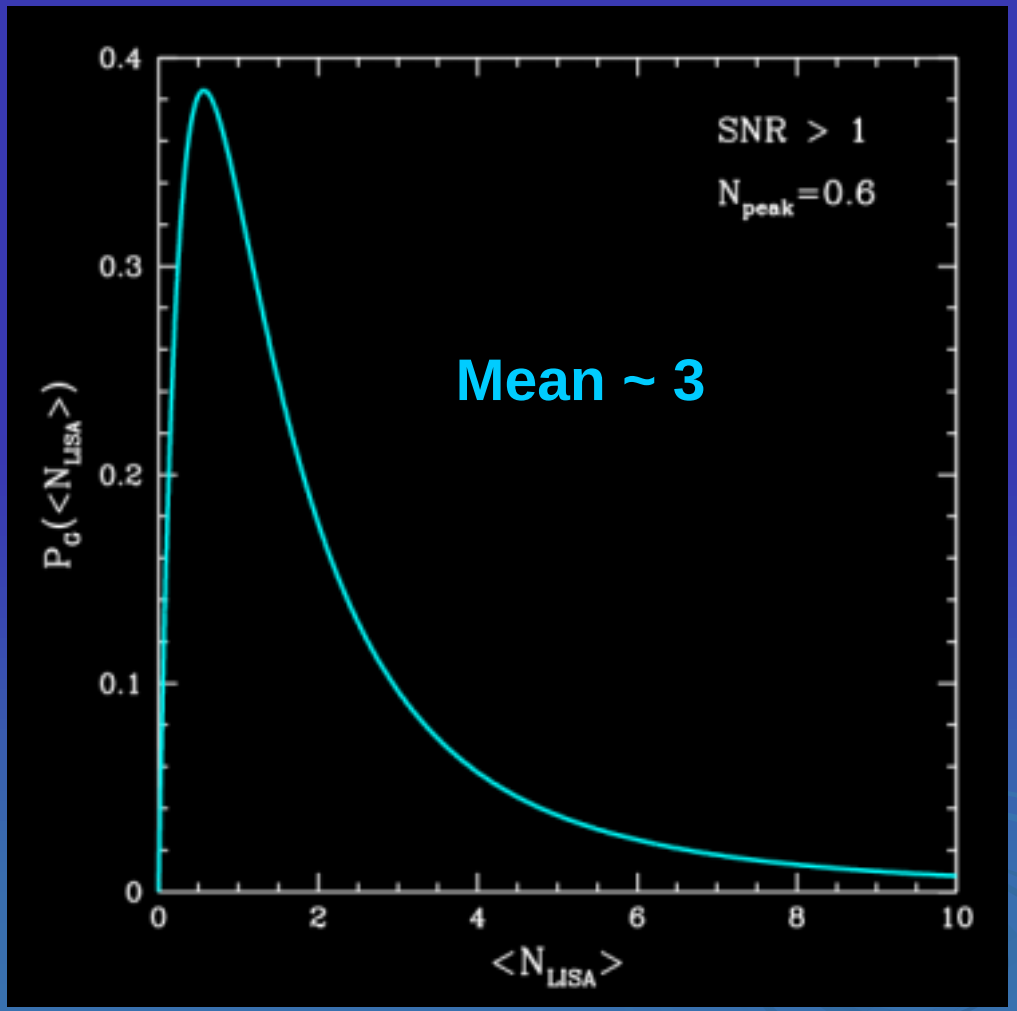
Analysis of PSR population characteristics can provide us with distribution functions of L_{min} and p

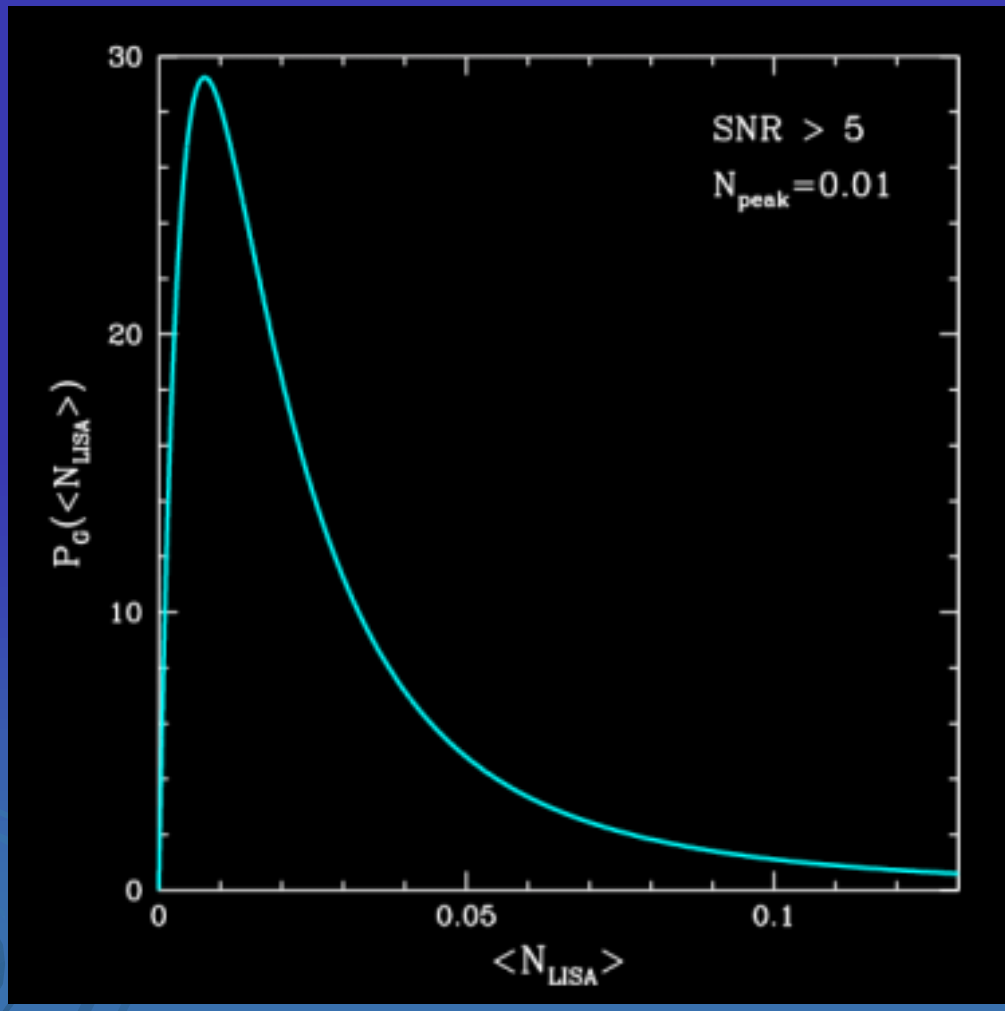
BUT currently out-of-date!
STILL if used …



Expectations for LISA detections drop drastically if we adopt the currently available constraints on the DF of L_{min} and p.

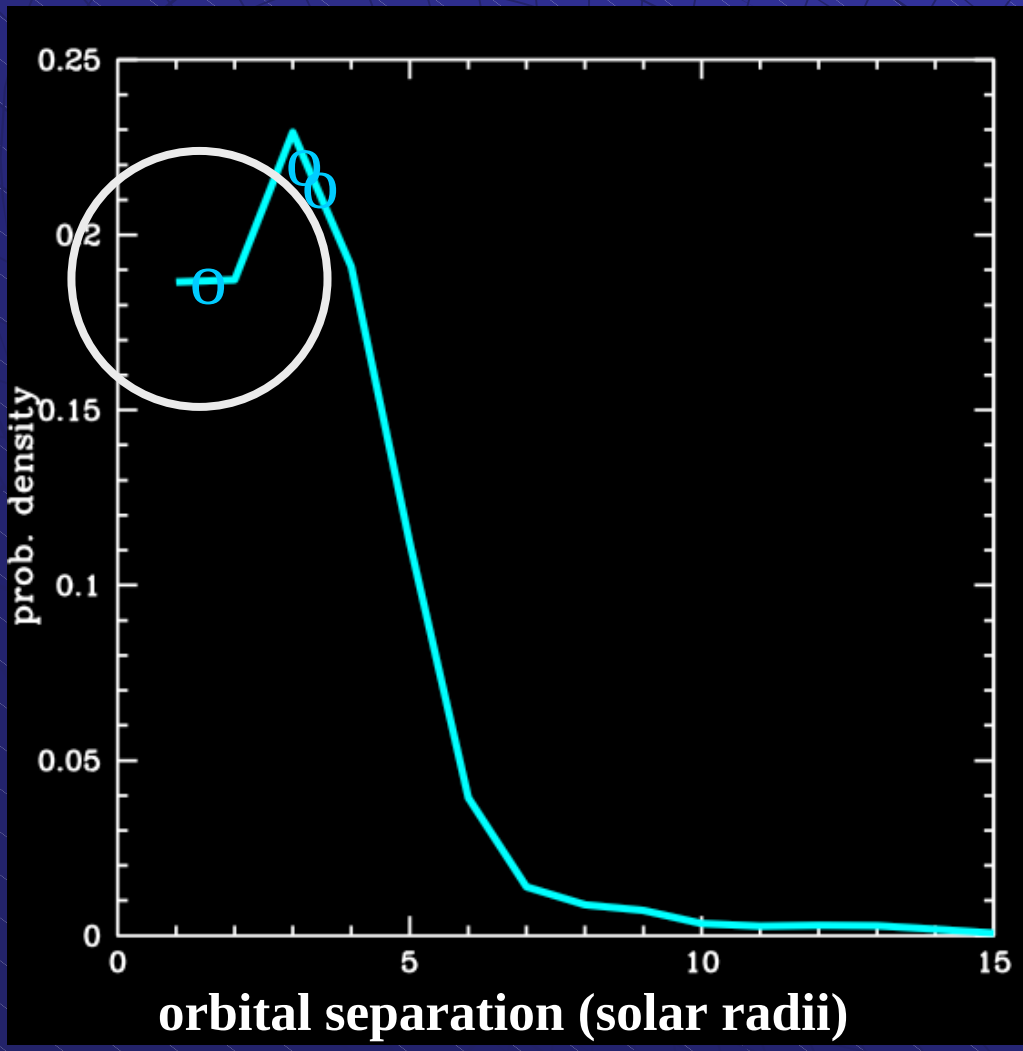
updated constraints are expected to favor higher numbers

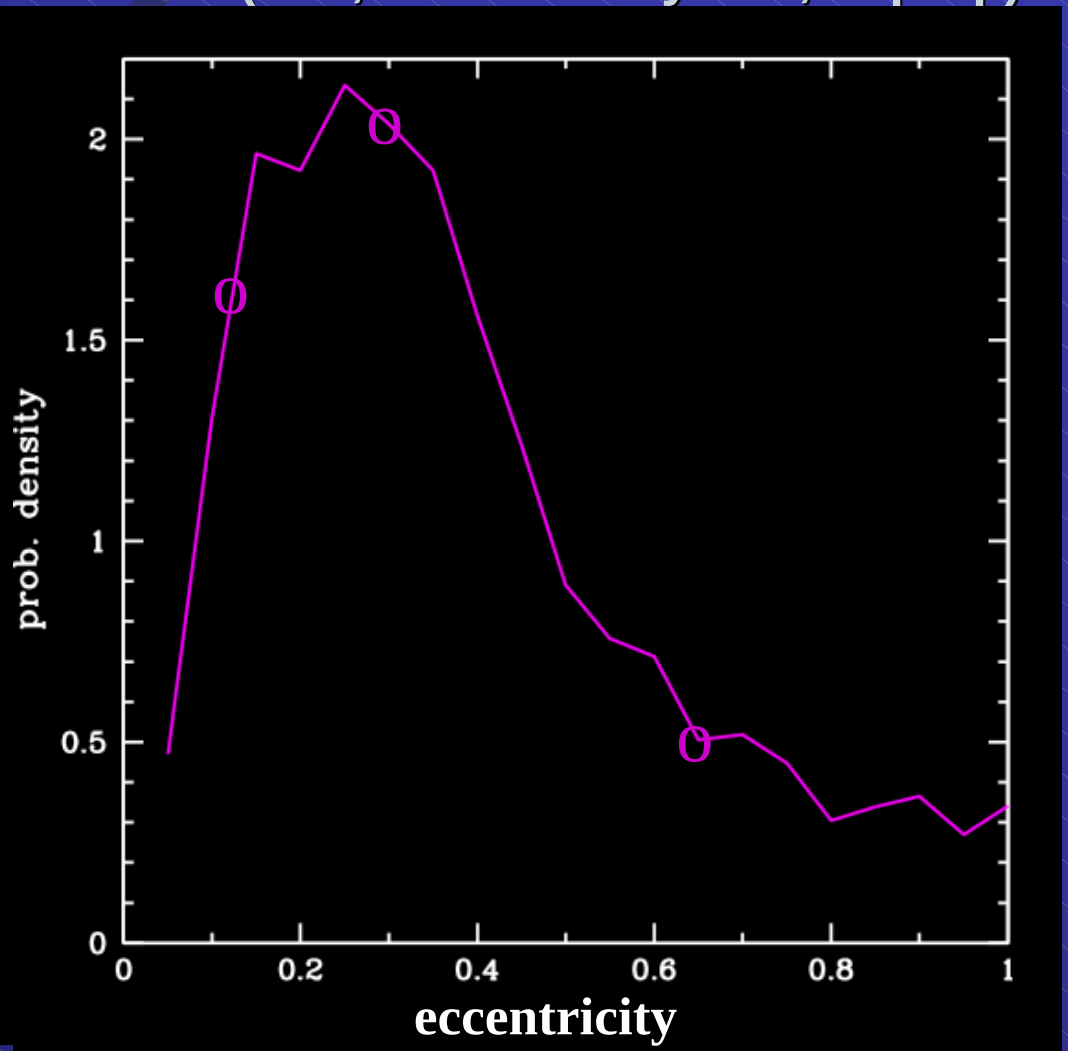




How likely is the formation of systems similar to PSR J0737-3039 ?

(Ihm, VK & Belczynski, in prep)





For the future …

- **Consider the extended population of strongly relativistic binary pulsars at other frequencies of interest and a range of pulsar spins**

- **Consider detection methods for such NS-NS at low S/N for LISA**