

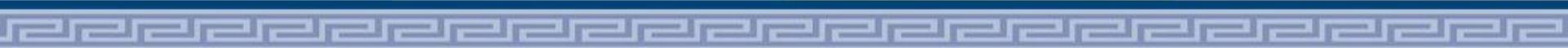


Time-scale distributions and event rates of microlensing pulsar events

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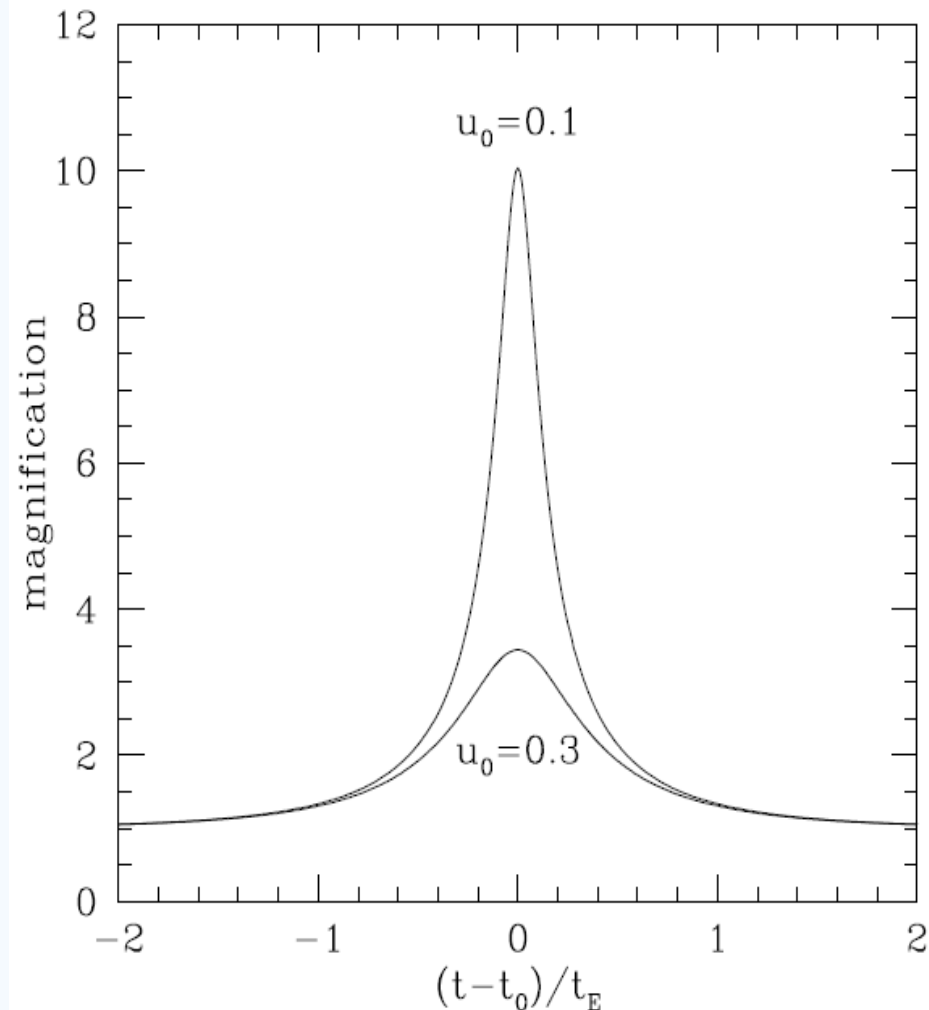
Martin Smith(KIAA), Youling Yue(NAOC),

Renxin Xu(PKU)

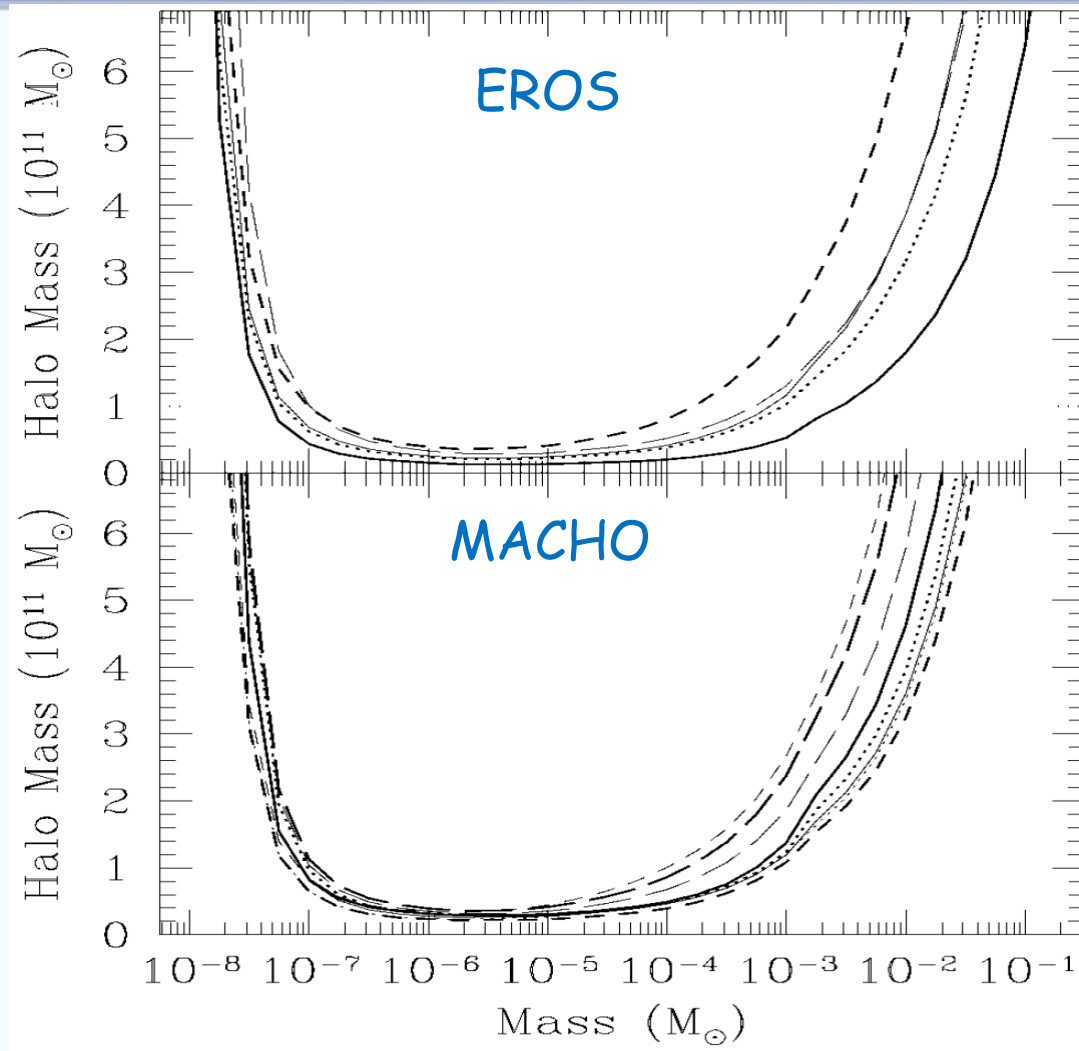


What is microlensing?

- Gravitational Microlensing:
 - a) **Photometric**: the temporal brightening of a background star due to intervening objects.
 - b) **Astrometric**: the shift of the centroid of the combined images of the light source (cross-section 100 times larger).



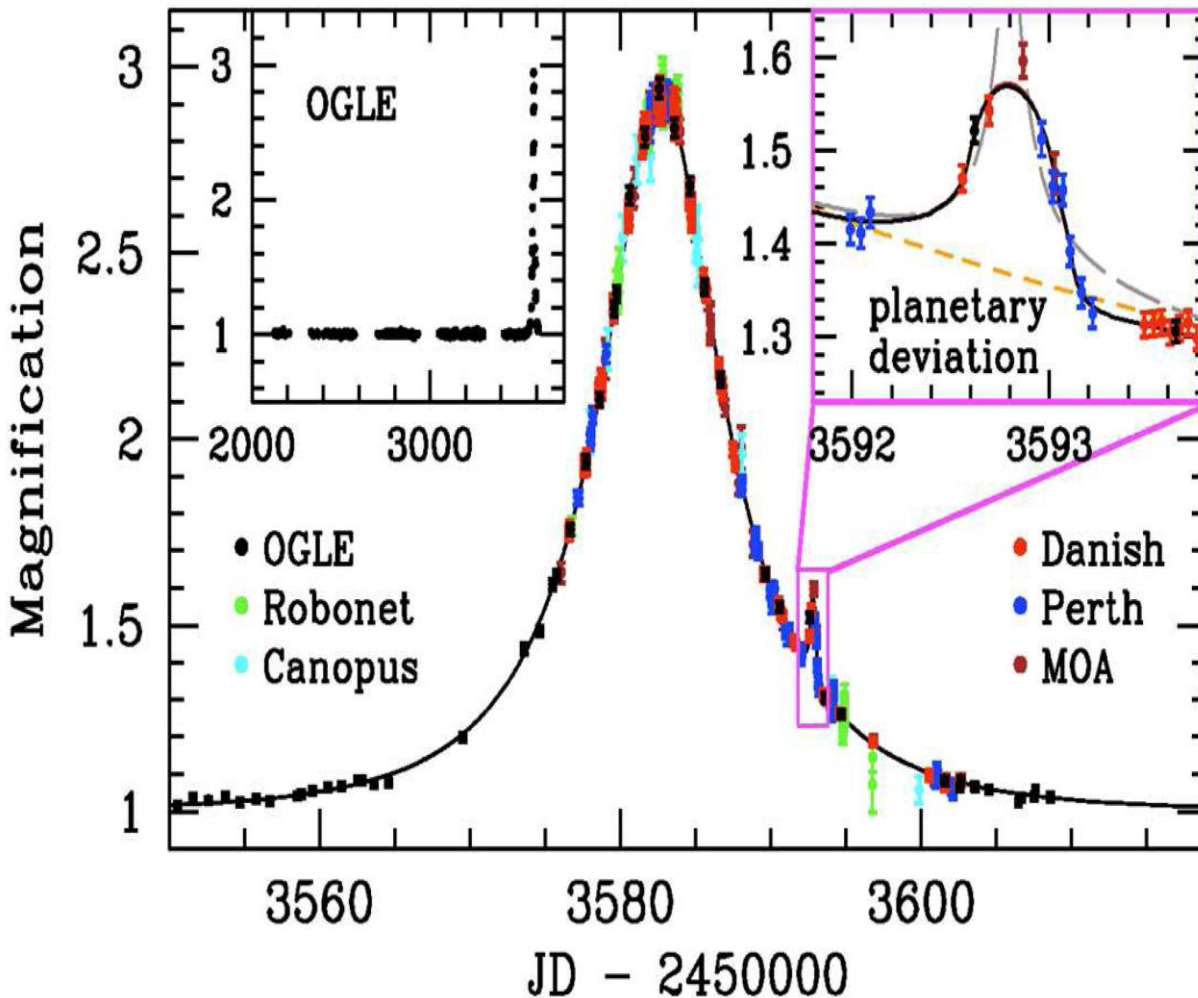
What is microlensing?



Less than **2%** of the halo could be in MACHOs.

Alcock et al. 1998

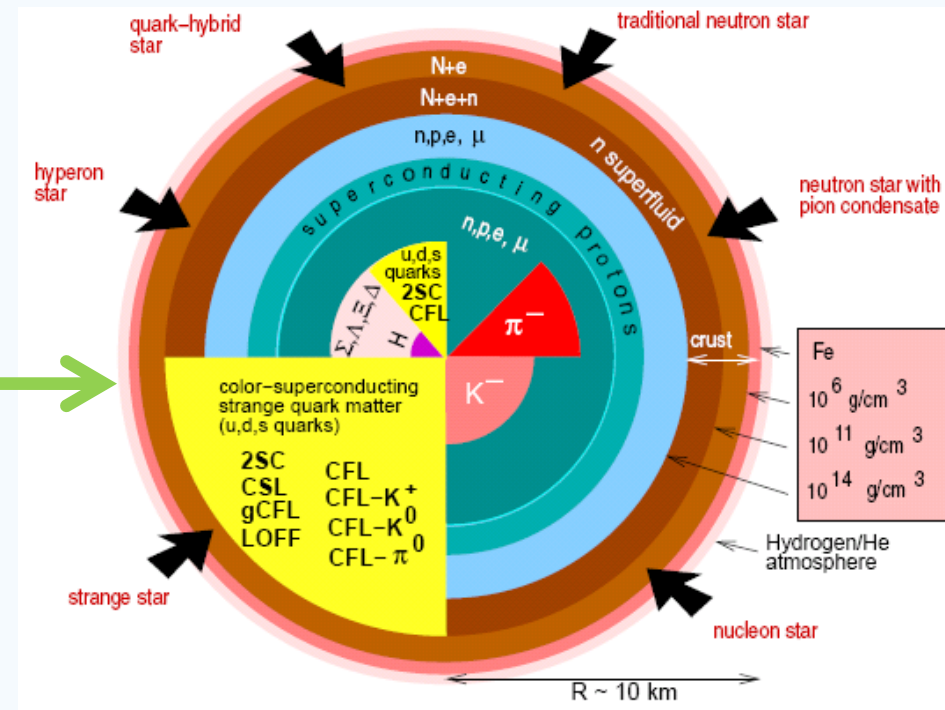
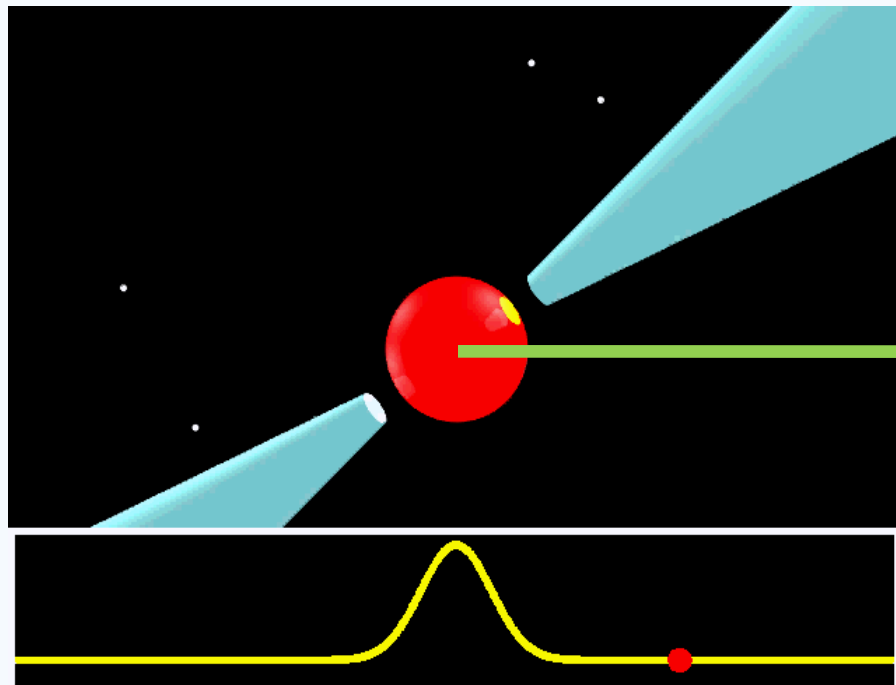
What is microlensing?



A super-Earth ($\approx 5.5M_{\oplus}$) discovered by microlensing.

What is pulsar?

Pulsars: Rotating magnetized compact neutron stars.



(Weber 2005)

A Challenge: What's the real nature of pulsars?

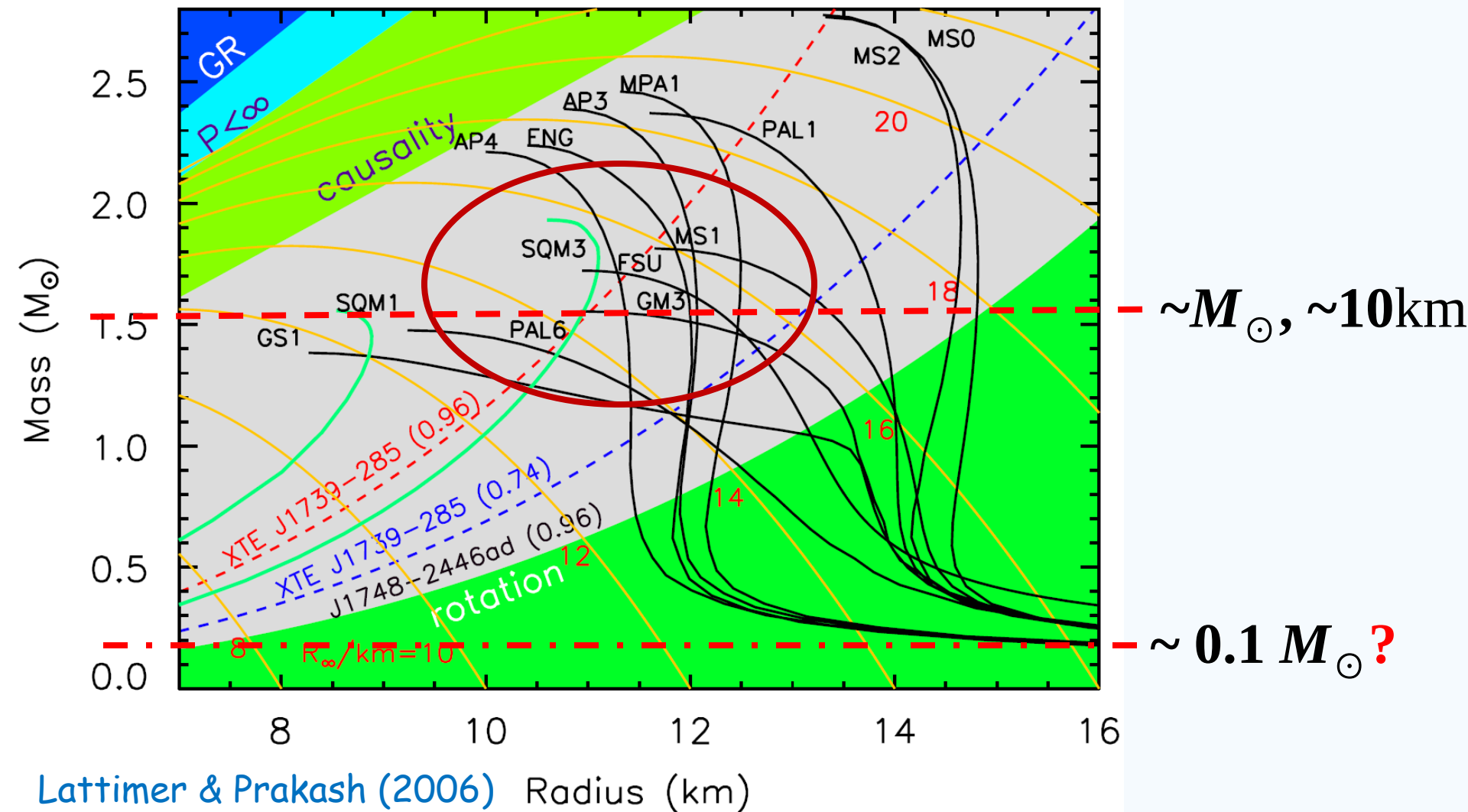
What is pulsar?

- Is there any exotic matter in neutron stars?
- Do quark stars exist?



Nuclear & particle Physics
Condensed matter Physics
(e.g., QCD)

Mass of isolated neutron stars?



What is pulsar?

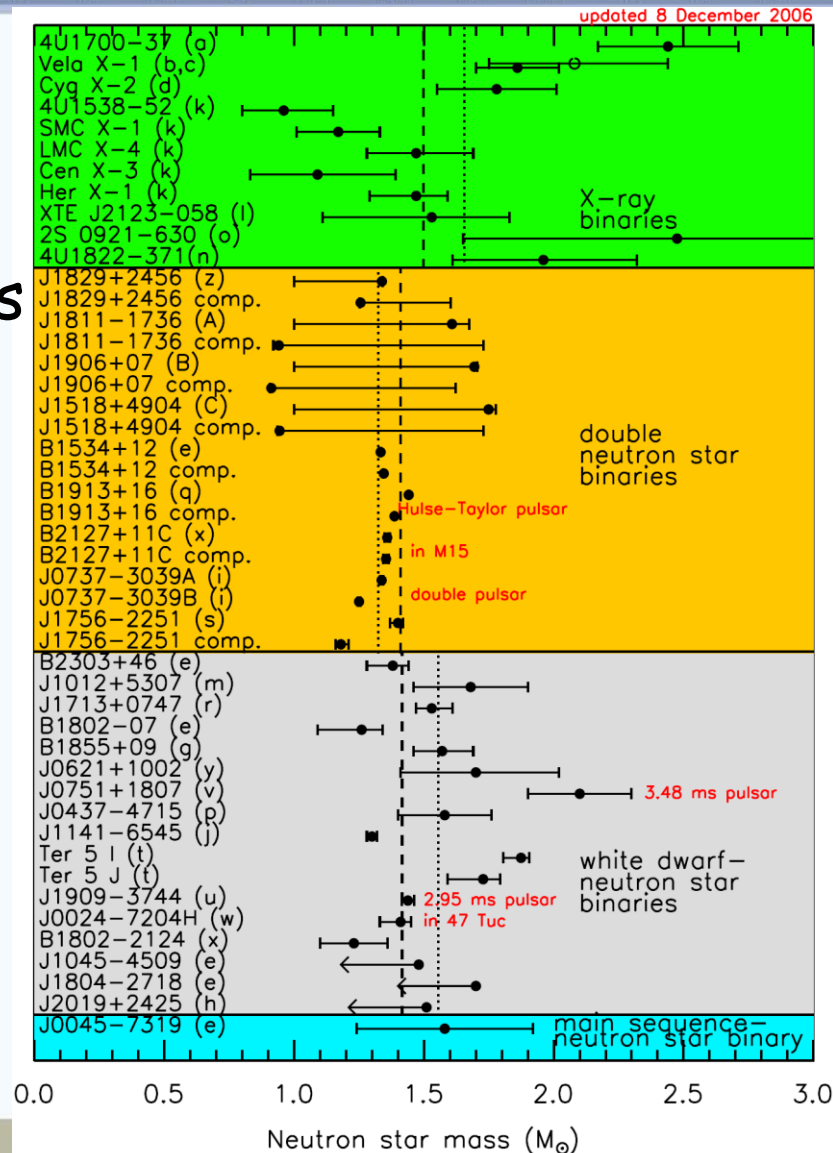
- Mass: a straight forward way

$m \geq 2M_{\odot}$ $\longrightarrow$ Strong constraints on EOS

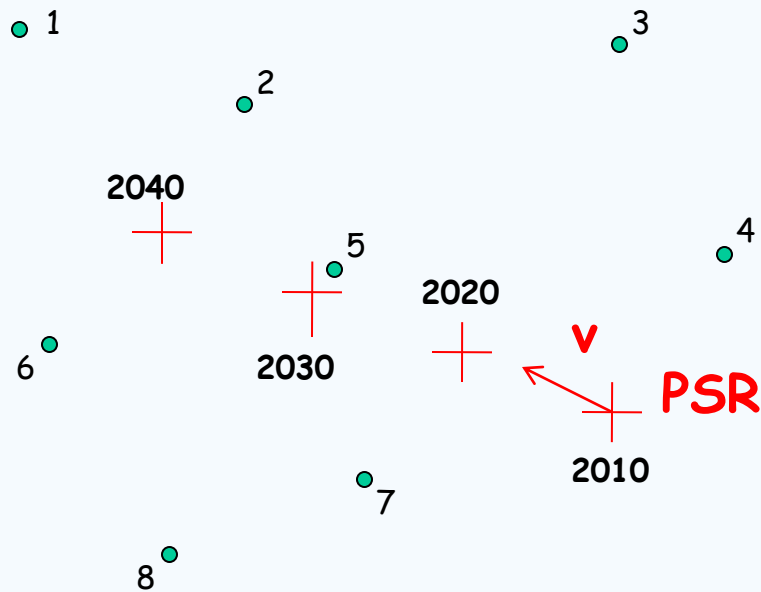
$m \leq 0.1M_{\odot}$ $\longrightarrow$ Quark star

How to measure the masses of **isolated** pulsars?

J. Lattimer, 2007



Microlensing pulsars



- : background stars
- + : pulsars

Dai, Xu and Esamdin 2010

Photometric: $p \approx 1$
Astrometric: $p \approx 100$ /decade

An observation strategy



An ambitious program

Using HST to Detect Isolated Black Holes and Neutron Stars through Astrometric Microlensing

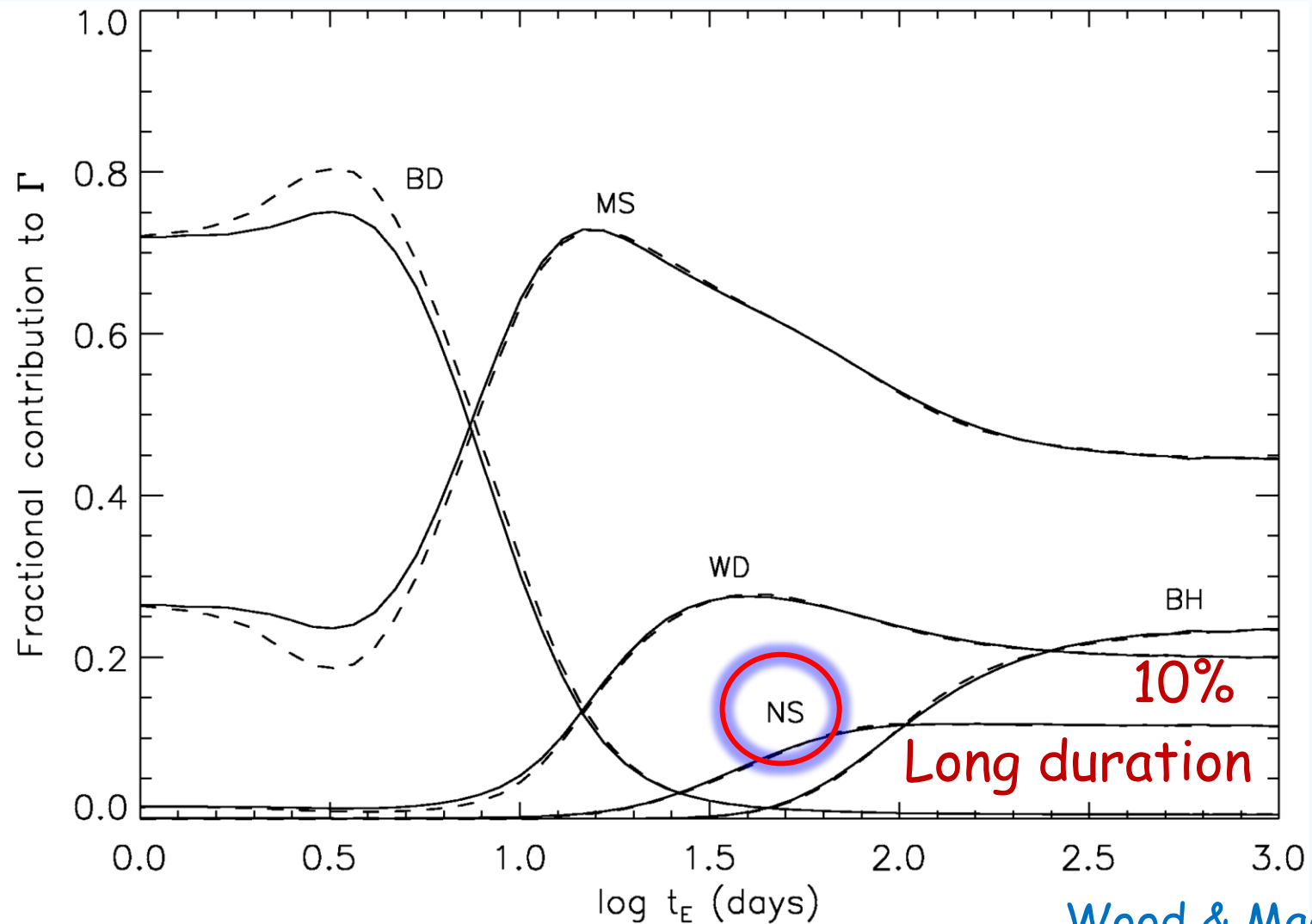
Sahu, K. C.; Albrow, M.; Anderson, J.; Bond, H. E.;
Bond, I.; Brown, T. M.; Casertano, S.; Dominik, M.;
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Perrott, Y.; Udalski, A.; Yock, P.

2012, American Astronomical Society Meeting Abstracts, 220, #307.03

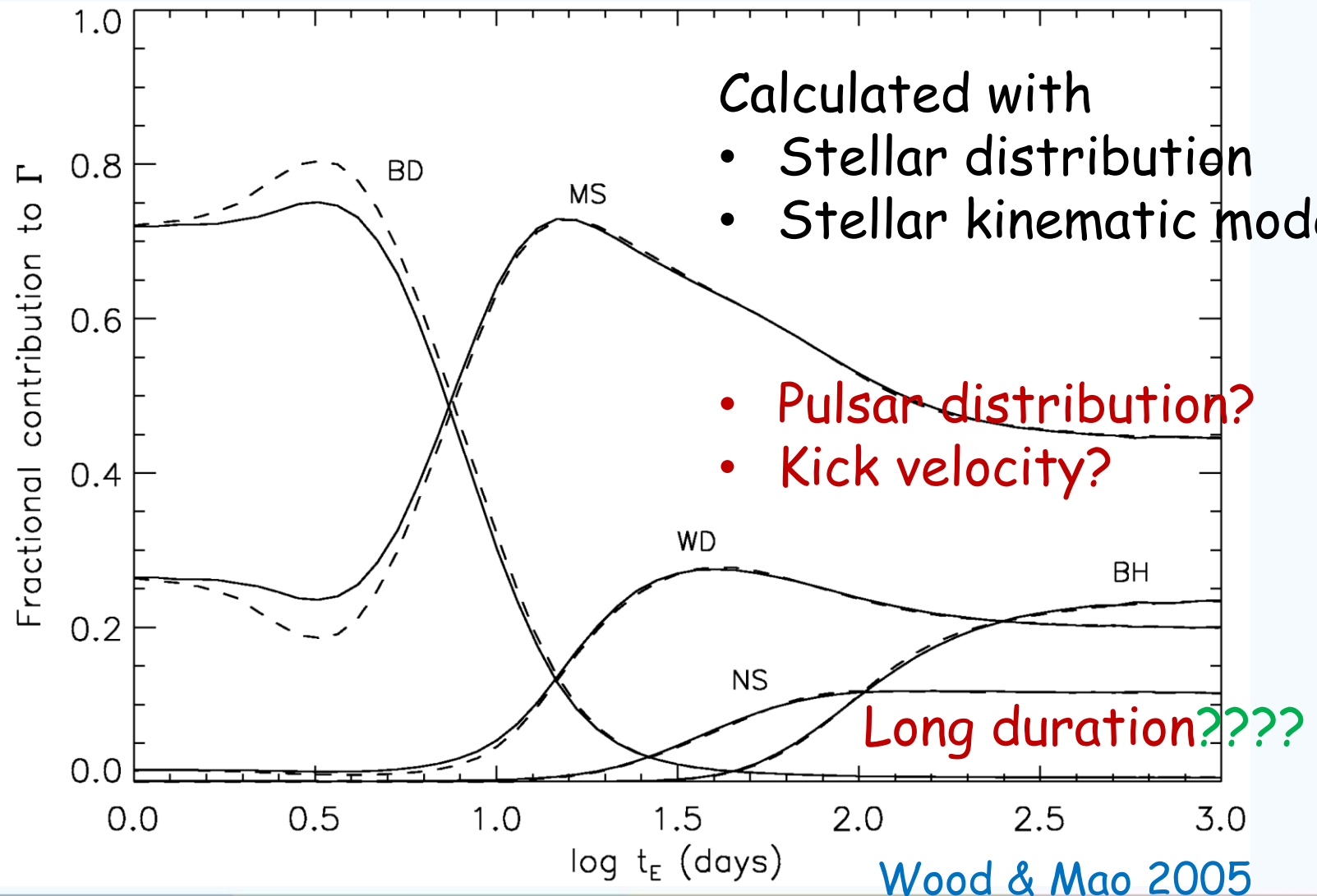
An ambitious program

To date, Black Hole (BH) and Neutron Star (NS) masses have been directly measured only in binaries; no isolated stellar-mass BH has been detected unambiguously within our Galaxy. We have underway a large, 3-year HST program (192 orbits) designed to detect microlensing events caused by non-luminous isolated BHs and NSs in the direction of the Galactic bulge.....Our program is optimized to detect **long-duration** events, which are more likely to be caused by massive lenses.....

An ambitious program



An ambitious program



Time-scale distributions

Considering the velocity and spatial distribution of neutron stars, we recalculate the time-scale distribution.

Pulsar distribution:

$$\rho(R) = A \left(\frac{R}{R_{\odot}} \right)^B \exp \left[-C \left(\frac{R - R_{\odot}}{R_{\odot}} \right) \right]$$

$$N = D \exp \left(\frac{-|z|}{E} \right)$$

Lorimer, et al. 2006

Time-scale distributions

- Disk model: Zhang et al. 2001

$$\rho(R, z) = \frac{\rho_0}{\eta} \exp \left(-\frac{R - R_0}{H} \right) \times \left[(1 - \beta) \operatorname{sech}^2 \frac{z}{\eta h_1} + \beta \exp \left(-\frac{|z|}{\eta h_2} \right) \right]$$

- Bulge model: Dwek et al. 1995

$$\rho_{G2}(x, y, z) = \rho_0 \exp(-0.5r_s^2) \quad r_s = \left\{ \left[\left(\frac{x}{x_0} \right)^2 + \left(\frac{y}{y_0} \right)^2 \right]^2 + \left(\frac{z}{z_0} \right)^4 \right\}^{1/4}$$

- Star counts from HST: towards the Baade's Window.

Time-scale distributions

Transverse velocity:

$$v_{l,b} = \left[(v_D - v_O) + (v_O - v_S) \frac{D_d}{D_s} \right]_{l,b}$$

Wood & Mao 2005

For pulsar:

$$f(v) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{v^2}{2\sigma^2}}, \quad \sigma = 290 \text{ km / s}$$

Faucher-Giguere & Kaspi 2006

Time-scale distributions

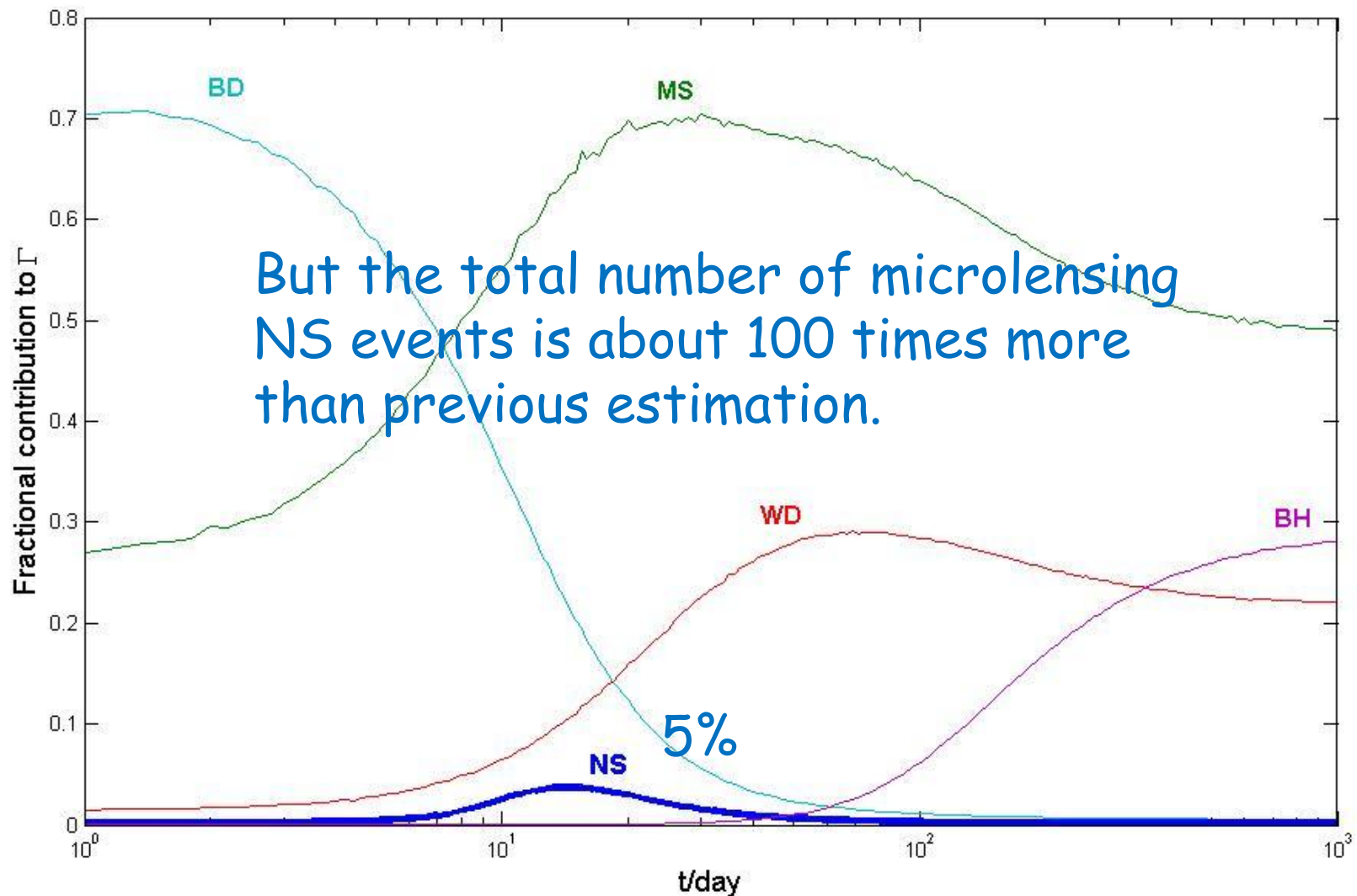
Event rate:

$$\Gamma = \frac{4G^{1/2}}{c} \iiint D_s^2 \sin \theta \rho_s(D_s, \theta, \varphi) dD_s d\theta d\varphi \\ \times \int_0^{D_s} \rho_d(D_d, \theta, \varphi) \cdot 2 \sqrt{\frac{MD_d(D_s - D_d)}{D_s}} \cdot v dt dD_d$$

Time-scale distribution:

$$t_E = \frac{R_E}{v}, \quad R_E = \sqrt{\frac{4GM}{c^2} \frac{D_d(D_s - D_d)}{D_s}} \quad \longrightarrow \quad \frac{d\Gamma}{d(\log t)}$$

Time-scale distribution

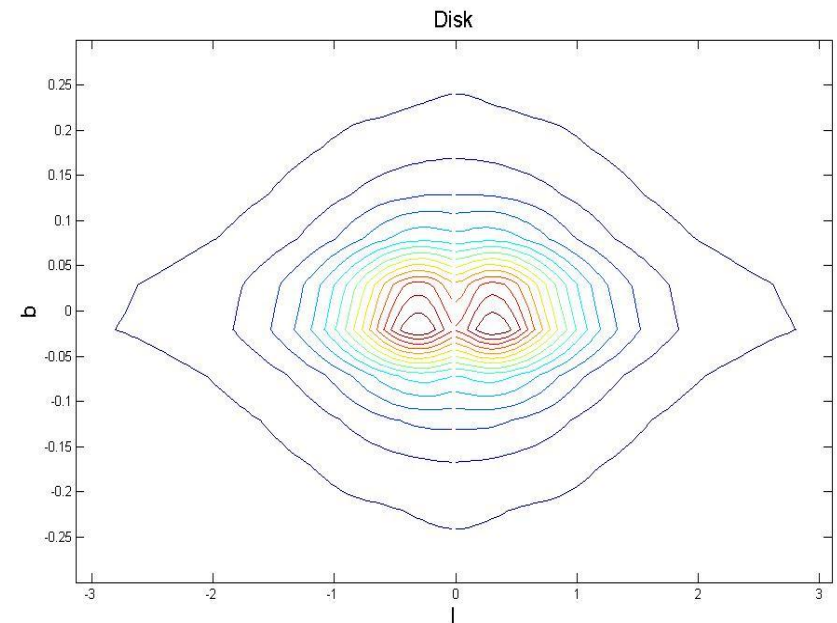
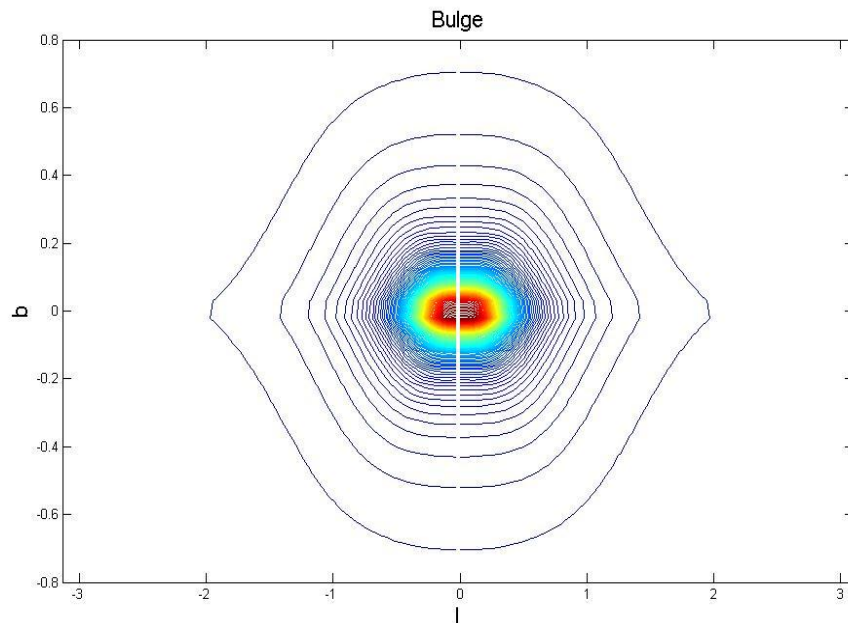


Event rates

Event rate:

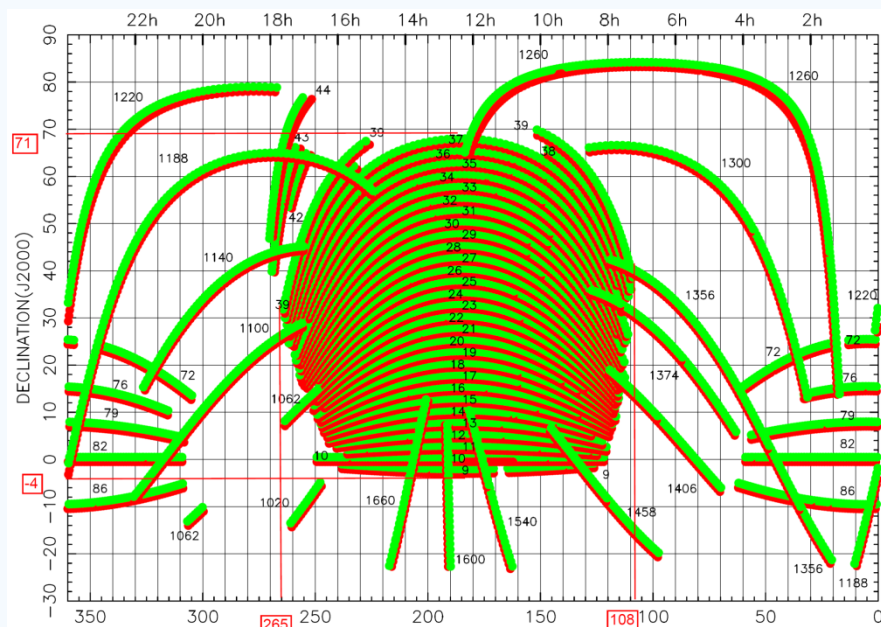
Photometric ~ 1.71 /decade

Astrometric ~ 200 /decade



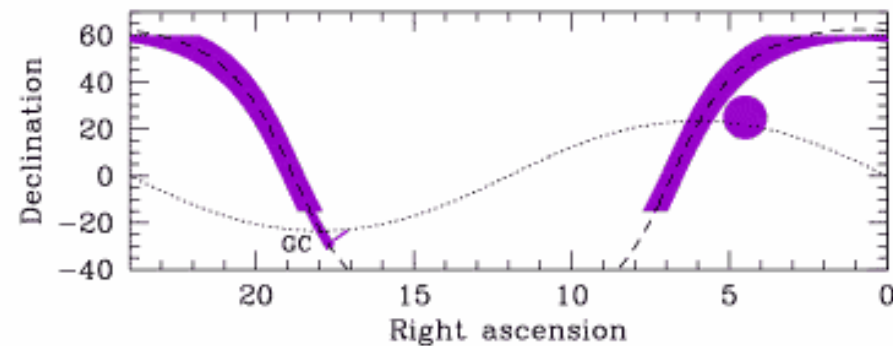
Catalogue comparison

- The ATNF Pulsar Database
192 pulsars with measured proper motion.
- SDSS + UKIDSS



SDSS: DR7

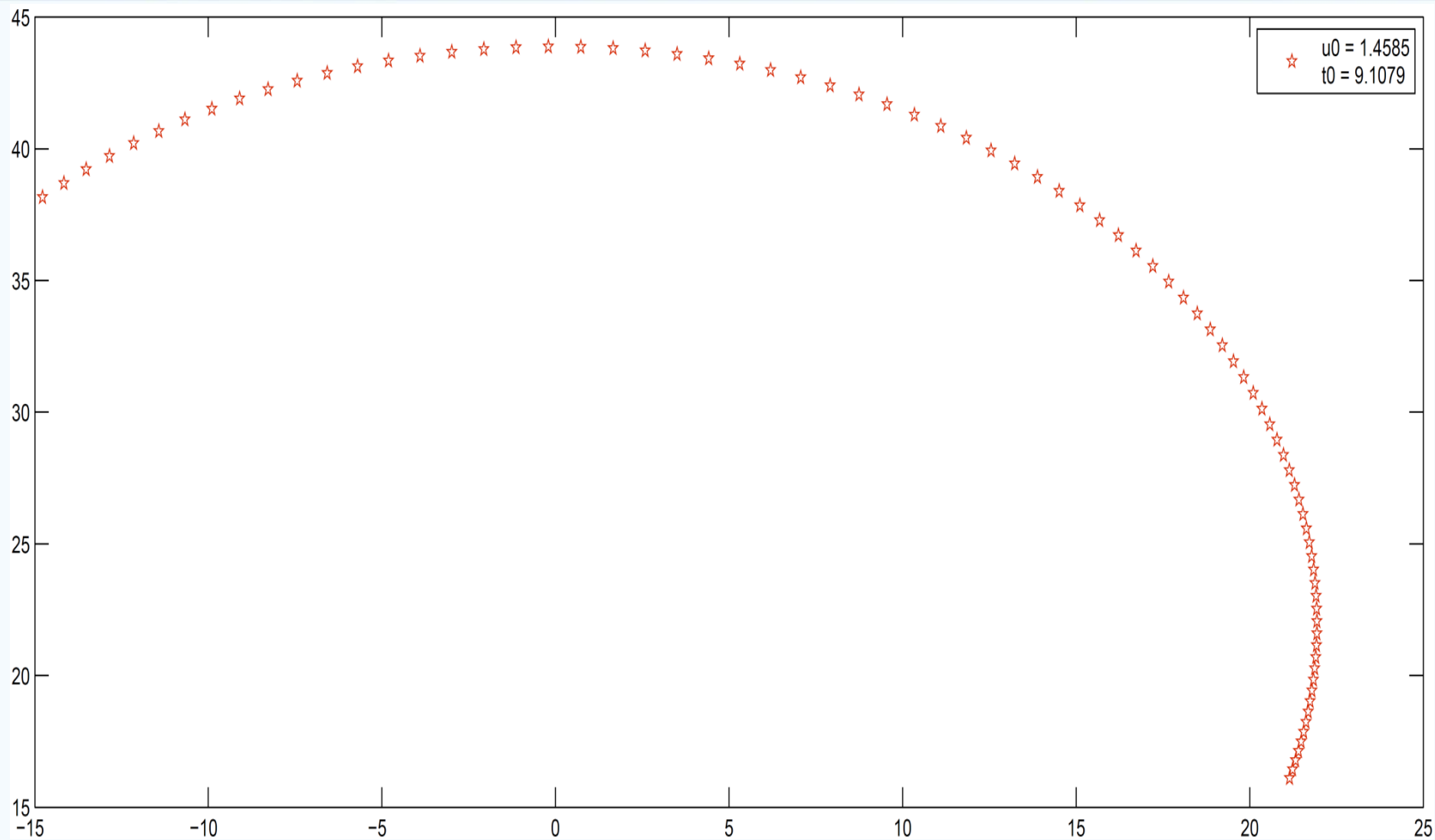
$$108^{\circ} \leq RA \leq 265^{\circ} \quad -4^{\circ} \leq DEC \leq 71^{\circ}$$



UKIDSS: Galactic Plane Survey—
5plus

$$15^{\circ} \leq l \leq 107^{\circ} \quad 142^{\circ} \leq l \leq 230^{\circ}$$

Catalogue comparison



Conclusions

- Microlensing pulsar events contribute about 5% to the Galactic microlensing at **short time-scale**.
- The event rate of photometric microlensing is about **1.7** per decade; the event rate of astrometric microlensing is about **200** per decade.
- Catalogue comparison found some promising astrometric microlensing candidates.