Microlensing pulsars

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Outline

- Introduction:
  a) Gravitational microlensing
  b) Mass of isolated neutron stars
- Microlensing pulsars
  a) Lensing rate
  b) Survey
- Conclusion

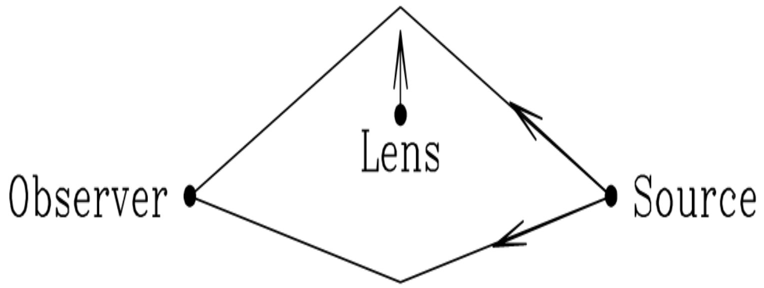
Gravitational microlensing

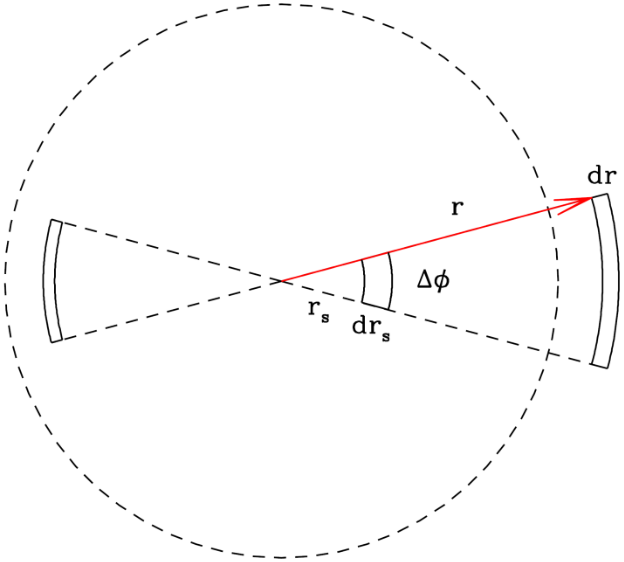
- Gravitational Microlensing:

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.

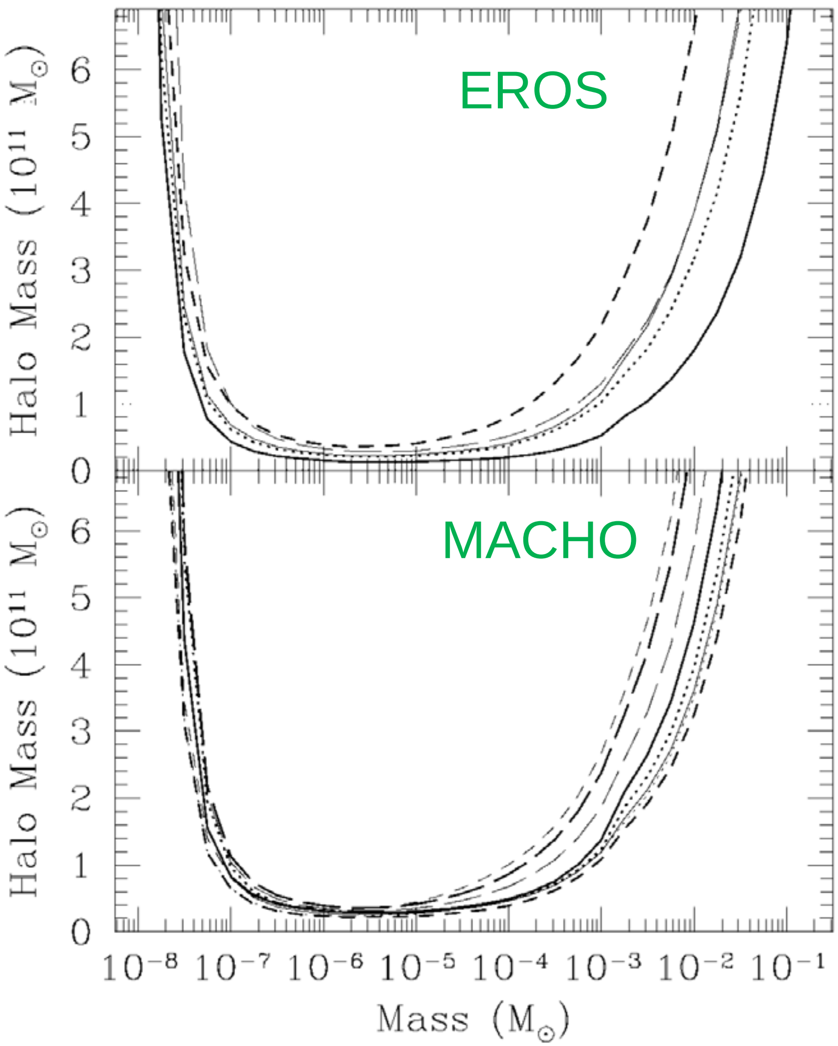
$$R_E = \sqrt{\frac{2R_S}{D} r(D-r)} \approx 1 mas$$



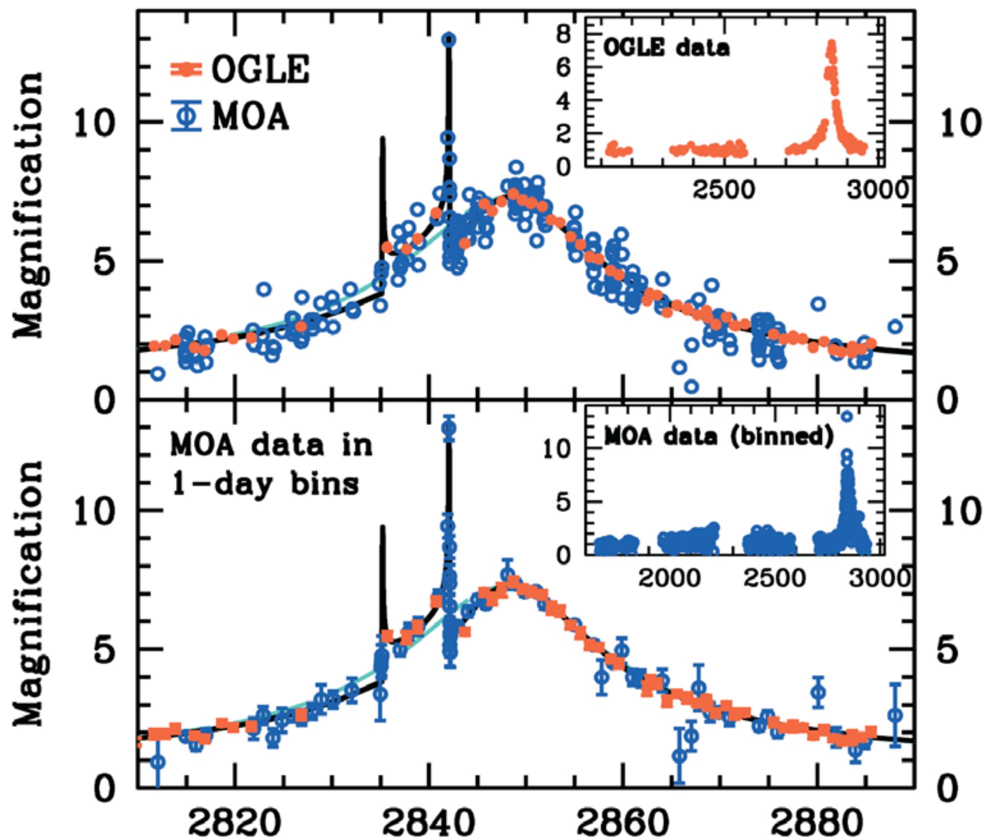


Mao, 2008

Gravitational microlensing



Alcock et al. 1998

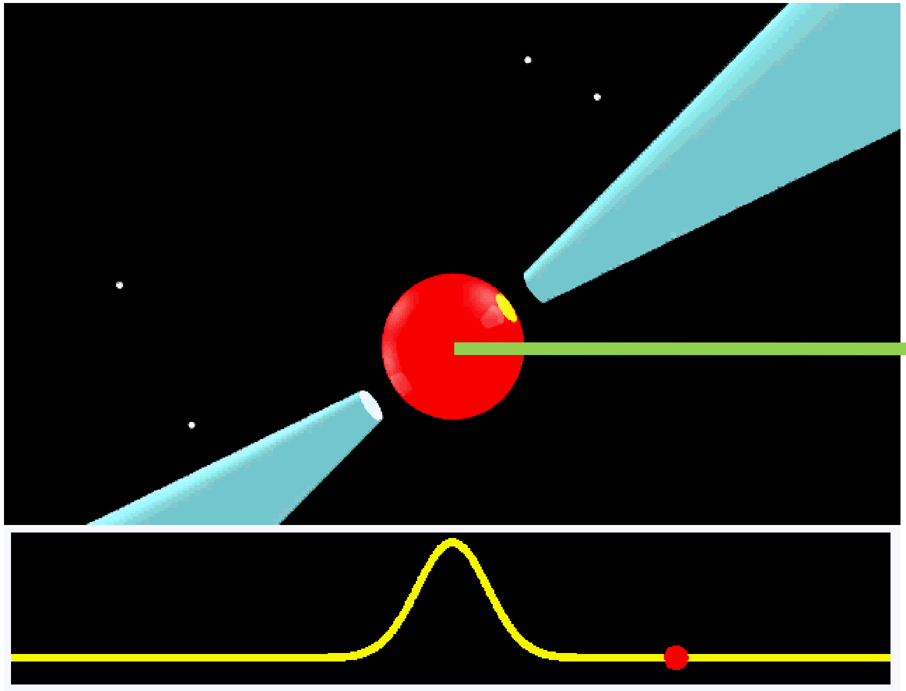


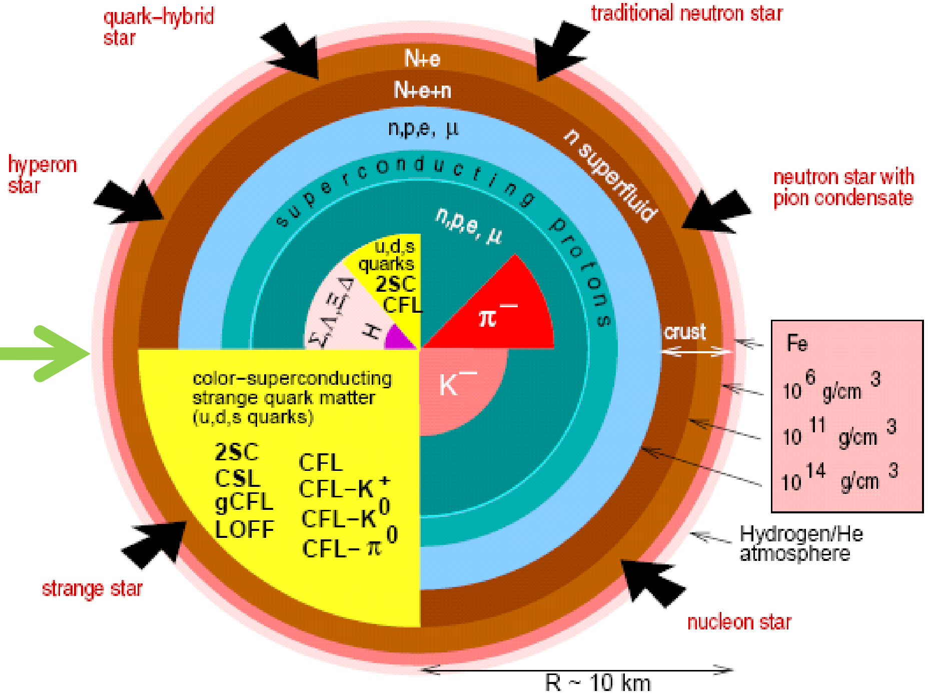
Bond et al. 2004

MACHO, OGLE ……

Pulsars

Pulsars: Rotating magnetized compact neutron stars.



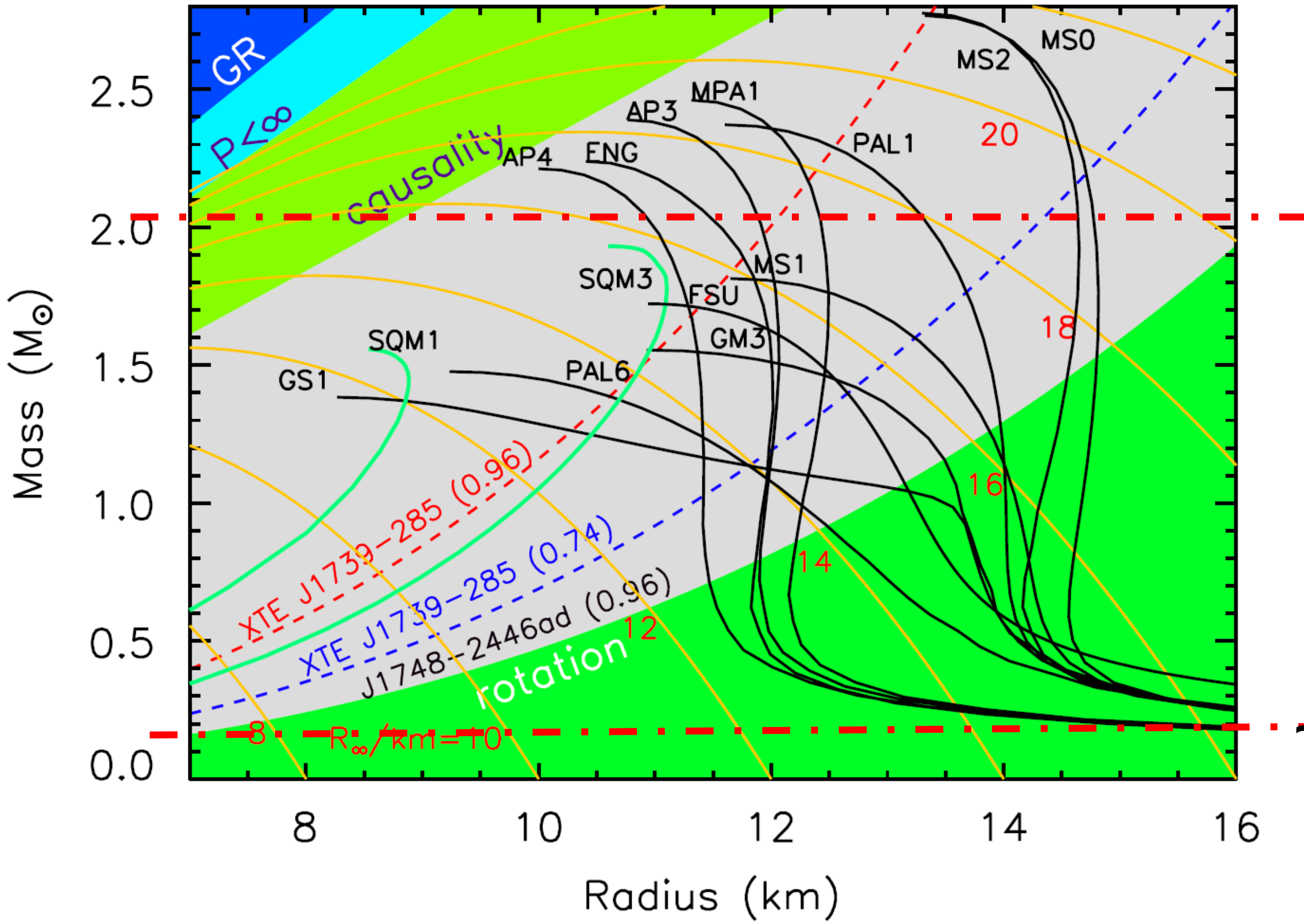


(Weber, 2005)

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

Pulsars

Lattimer & Prakash, 2006



~ 2 $M_\odot$?

~ 0.1 $M_\odot$?

Pulsars

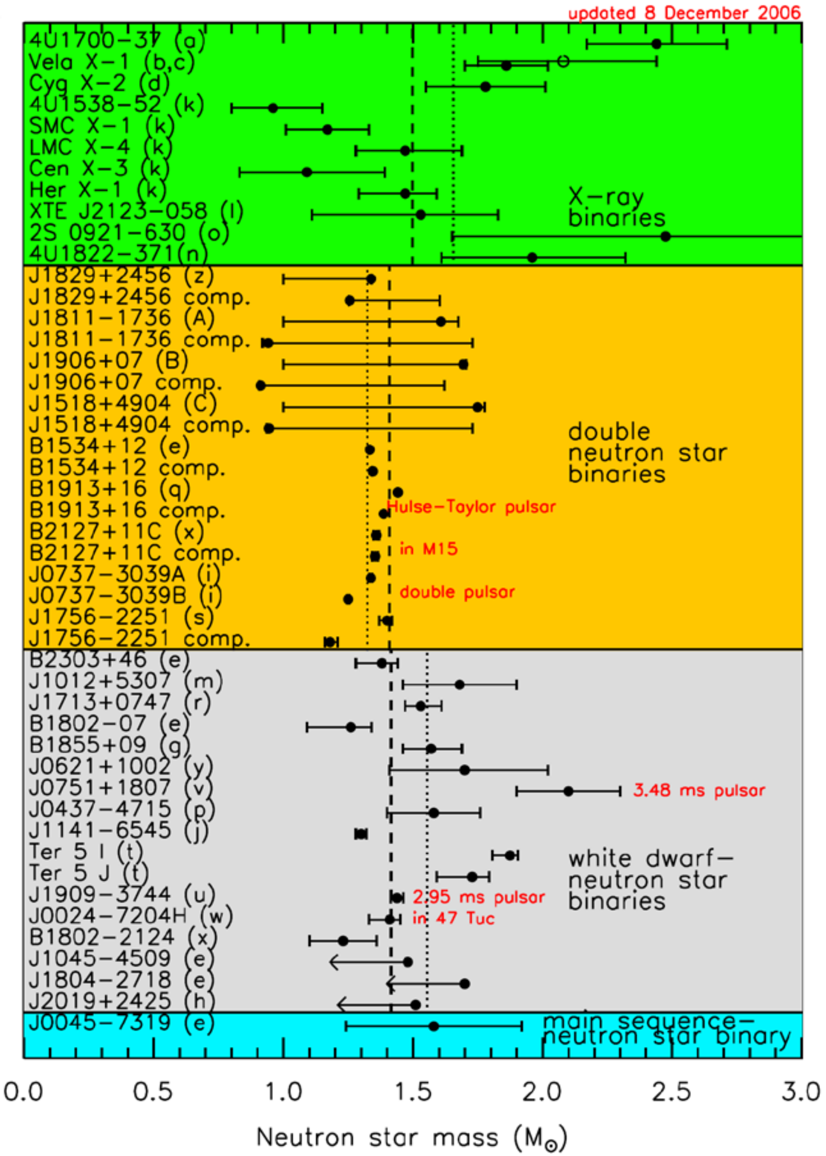
- Mass: a straight forward way

$m \geq 2M_{sun}$ → Strong constrains on equation of state.

$m \leq 0.1M_{sun}$ → Quark star

How to measure the masses of isolated pulsars?

Lattimer, 2007



Microlensing pulsars

- Horvath, 1996, MNRAS.
- Schwarz & Seidel, 2002, A&A.
- Dai, Xu and A. Esamdin, 2010, MNRAS.

➢ Microlensing: radio + optical

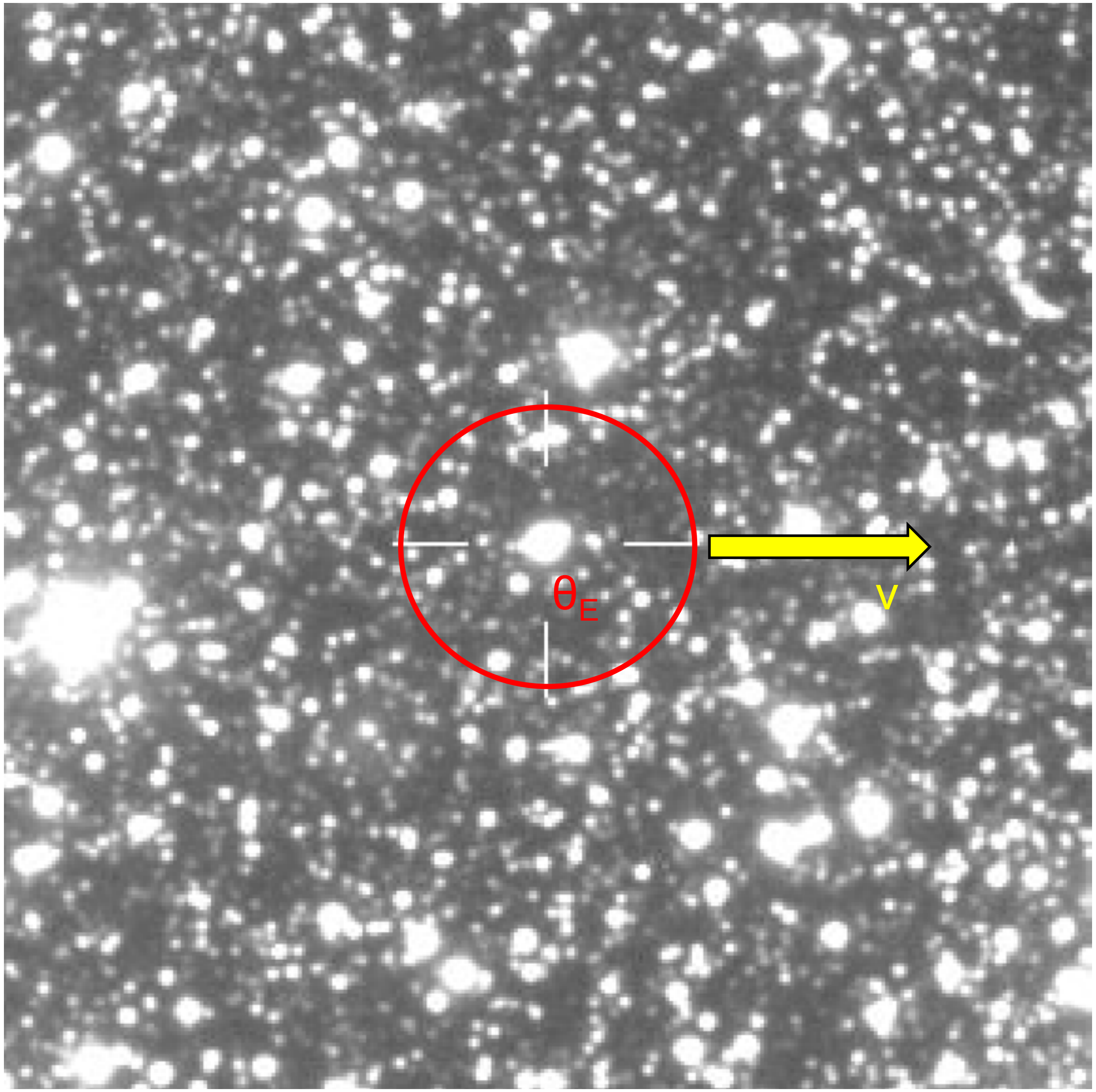
Position, distance, proper motion

➡ Pulsars: dark objects not so dark.

➢ Future advanced facilities

FAST, SKA, TMT, Gaia… …

Microlensing pulsars



$$R_E = \sqrt{\frac{2R_S}{D} r(D-r)}$$

$$S_N\left(M, \nu, r, D\right) = \theta_E \frac{\nu t}{r}$$

$$p = \frac{\sum_N S_N}{S} N_{star}$$

Microlensing pulsars

OGLE observation ⟶ $N_{star} \approx 10^9$

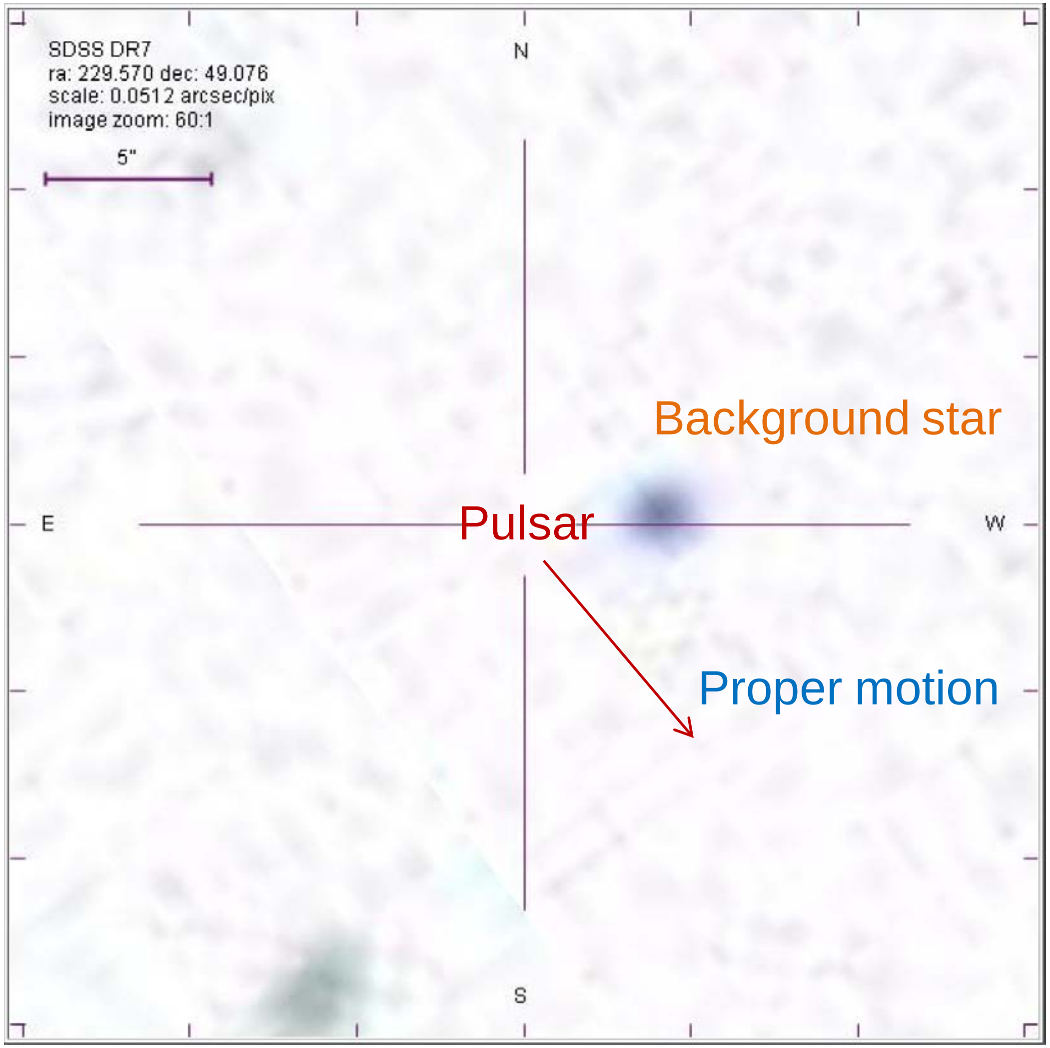
Simulation results for FAST and SKA ⟶ $N \approx 15000$

	Detectable pulsars	FAST[c]		SKA[d]	
	All Sky	$20° < l < 90°$ $\lvert b\rvert \leqslant 10°$	$20° < l < 90°$ $\lvert b\rvert \leqslant 10°$	$0° < l < 85°$ & $155° < l < 360°$ $\lvert b\rvert \leqslant 5°$	Dec $< 50°$
Normal pulsar	$\sim 30000^a$	$\sim 5700(352)$	$\sim 7000(418)$	~ 11000	~ 14000
Millisecond pulsar	$\sim 30000^b$	$\sim 550(14)$	$\sim 770(20)$	~ 4000	~ 6000

Note. – The results are from "*a*": Lorimer (2006), "*b*": Lyne et al. (1998), "*c*": Smits (2009b), "*d*": Smits (2009a).

Dai, Xu and A. Esamdin, 2010

Microlensing pulsars



$p \geq 1$ event/decade

An observation strategy

↓ FAST, SKA

New pulsars

↓ predict

Microlensing candidates

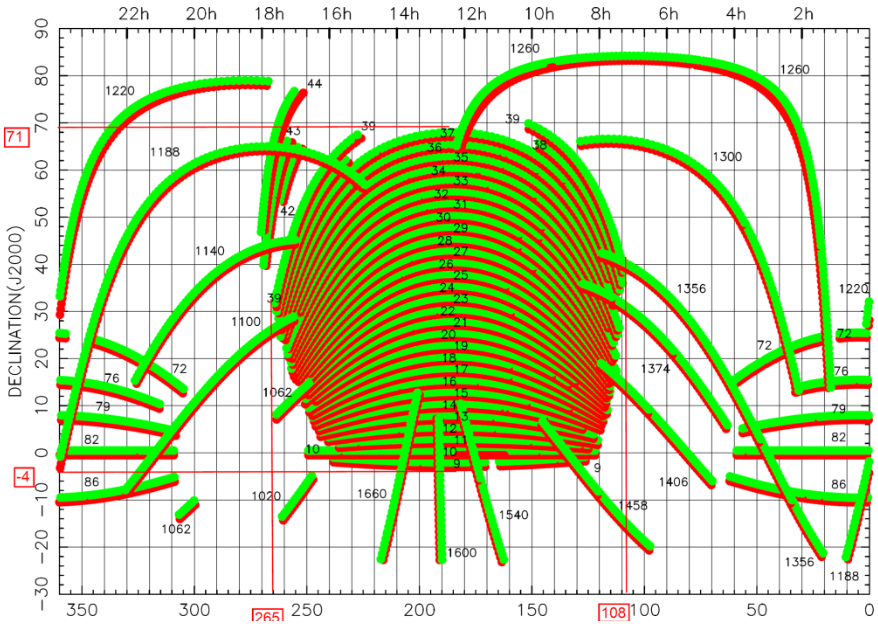
↓ Gaia, JWST

Microlensing pulsars

Survey

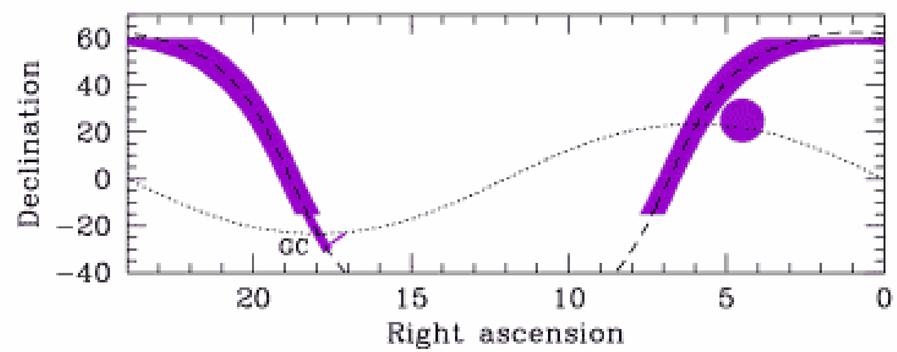
- The ATNF Pulsar Database
  192 pulsars with measured proper motion.

- SDSS + UKIDSS



SDSS: DR7

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



UKIDSS: **Galactic Plane Survey—5plus**

$$|b| \leq 5^{\circ}$$

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

Survey

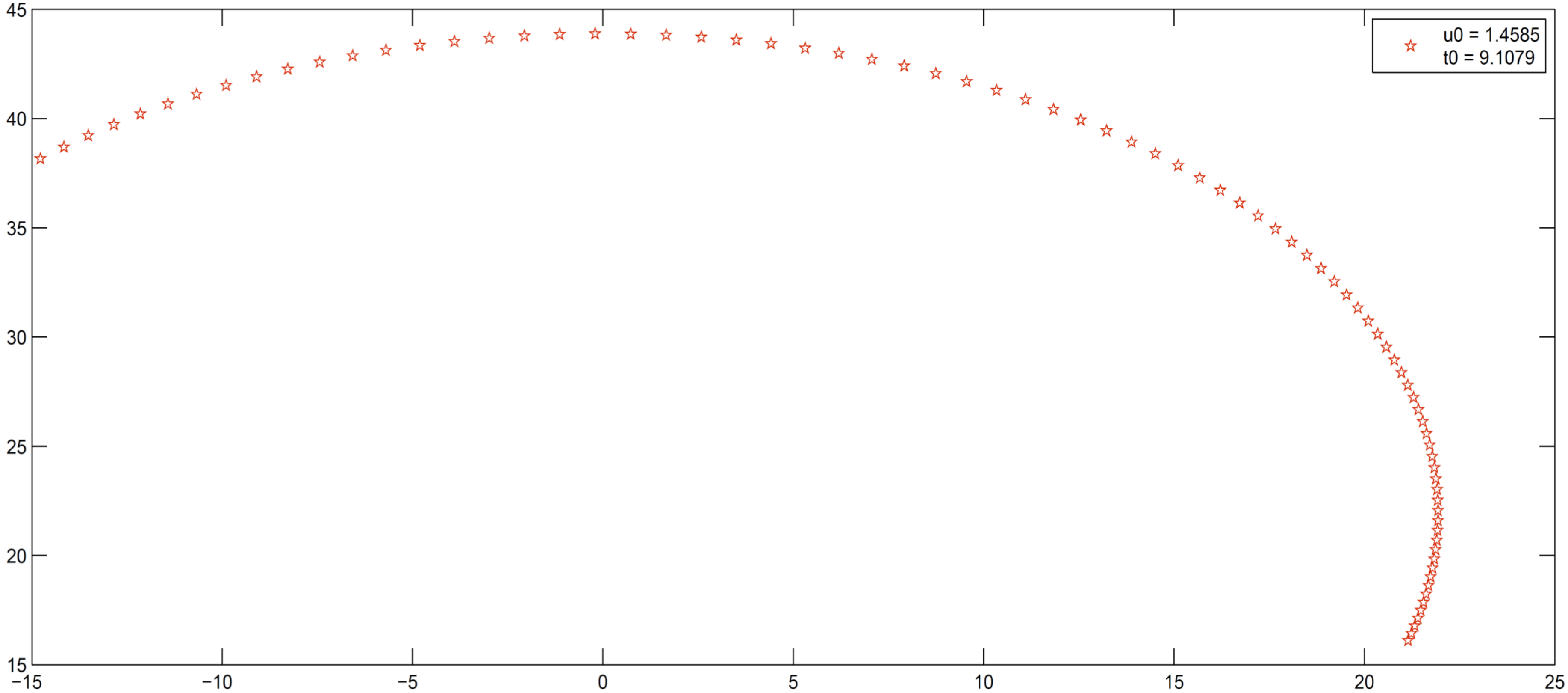
- Considering the resolution of Gaia, we restrict that

$$\Delta\varphi \leq 6''$$

- SDSS: 6 candidates, most high proper motion; one double neutron stars system.
- UKIDSS: 16 candidates, on the disk(only up to 5plus; 8plus now).

name	distance/kpc	pmra/mas/yr	pmdec/mar/ys	u0/arcsec	t0/yr	distance
B1933+16	4.55	1.13	-16.09	1.8119	-11.7199	
B1834-10	5.39	18	12	2.2019	6.1246	>10kpc
B1823-13	4.12	23	-3.9	3.8128	24.0041	
B1952+29	0.42	25	-36	0.2231	42.1517	>800pc
J1835-1106	3.08	27	56	1.4585	9.1079	>10kpc
B2011+38	13.07	-32.1	-25	5.2887	0.1221	
J1518+4904/double NS	0.7	-0.67	-8.53	5.6811	4.5591	>>1kpc
B2045-16	0.95	113.16	-4.6	3.0354	10.9964	>10kpc

Survey



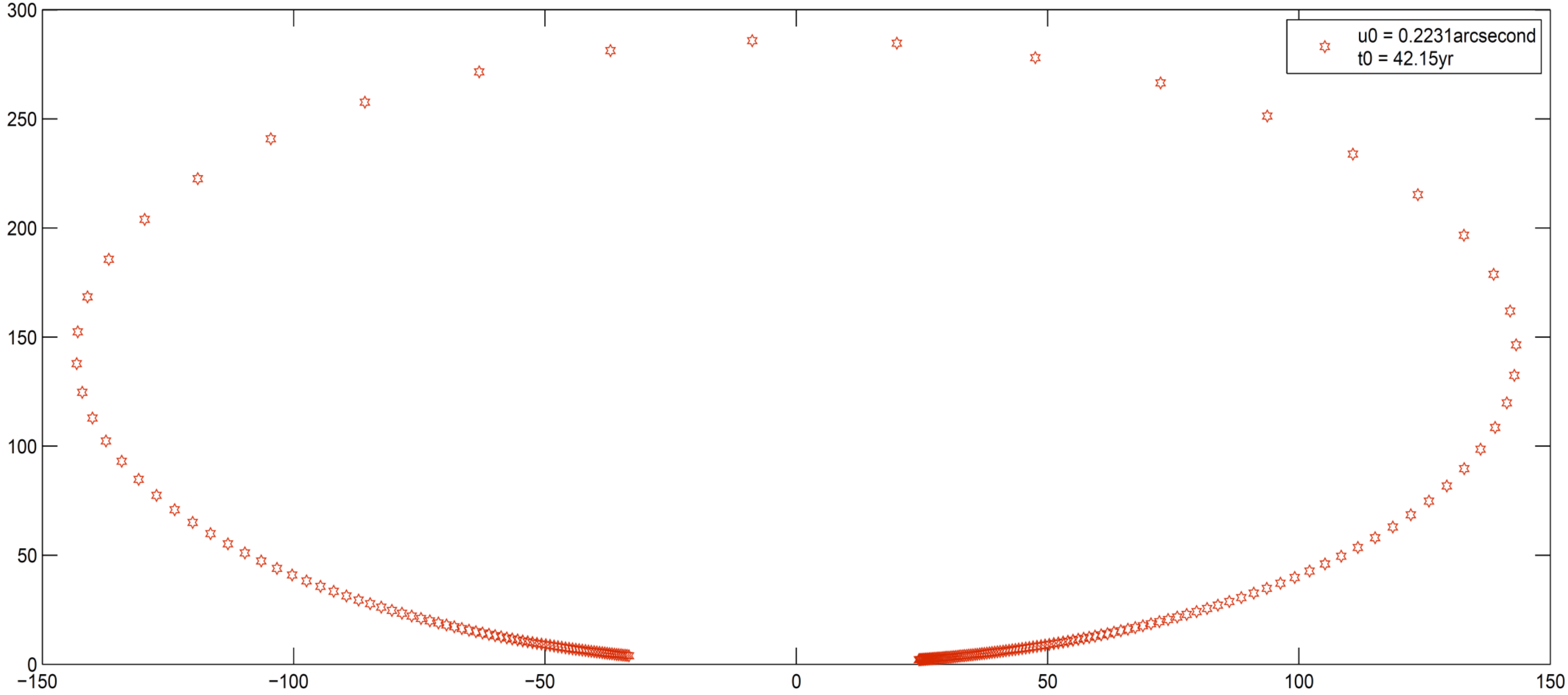
J1835-1106：

- Distance: 3.08kpc
- Proper motion: (27mas/yr, 56mas/yr)

Background source:

- $u_0 \approx 1.46''$
- Distance: >>10kpc

Survey



J1954+2923：

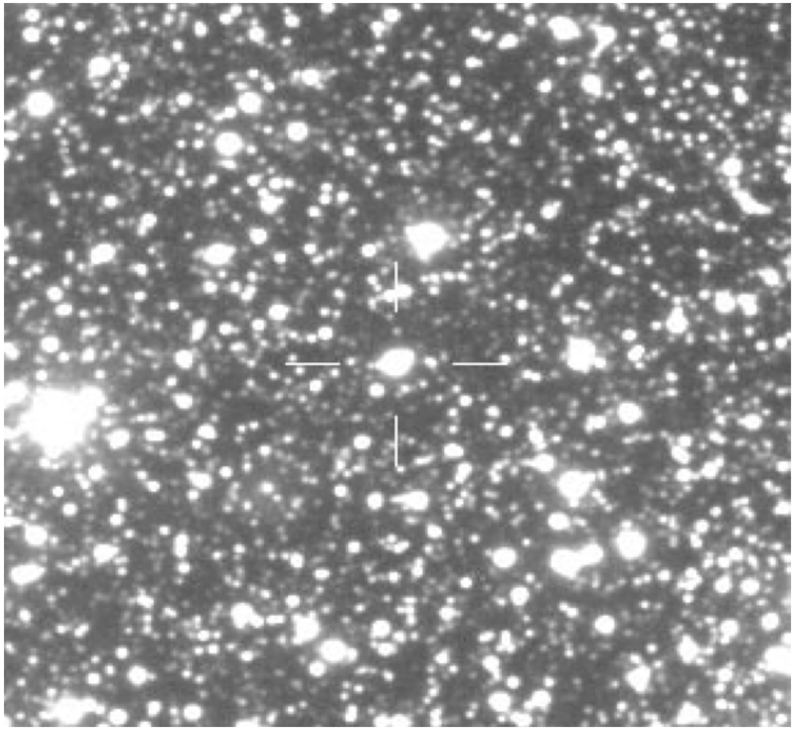
- Distance: 420pc
- Proper motion:

(25mas/yr, -36mas/yr)

Background source:

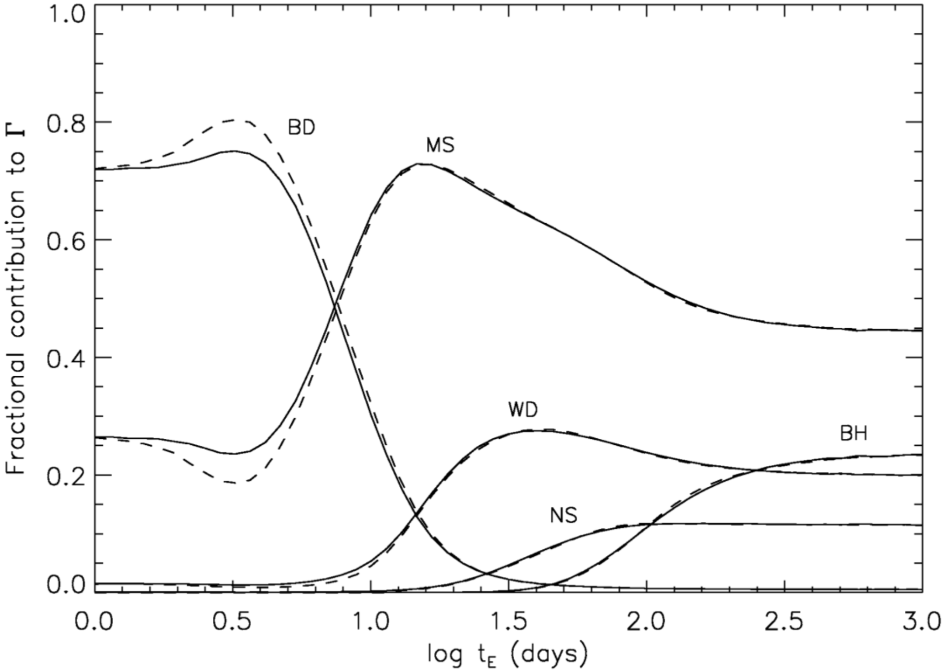
- $u_0 \approx 0.2231''$
- Distance: >1kpc

Survey



6000 microlensing events

Wood and Mao, 2005



3% due to NS

Conclusion

$p \geq 1$ event/decade

↓ FAST, SKA

Gaia, TMT, JWST

Microlensing pulsars

↓

Mass of isolated neutron stars

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Nature of pulsars and fundamental physics

Microlensing pulsar observation should be an important and hopeful way to measure the mass of isolated neutron stars.