



GLOWSKA

German SKA Community Meeting 2016

KIT June 3, 2016

Understanding the Neutron Star population with SKA

Thomas Tauris & SKA collaborators
MPIfR / Universität Bonn

“Understanding the Neutron Star Population” SKA Science Book, AASKA14-039 PoS

**Thomas Tauris, Vicky Kaspi, Rene Breton, Adam Deller, Evan Keane,
Michael Kramer, Duncan Lorimer, Maura McLaughlin, Andrea Possenti,
Paul Ray, Ben Stappers & Patrick Weltevrede (2015)
arXiv:1501.00005**

NS population

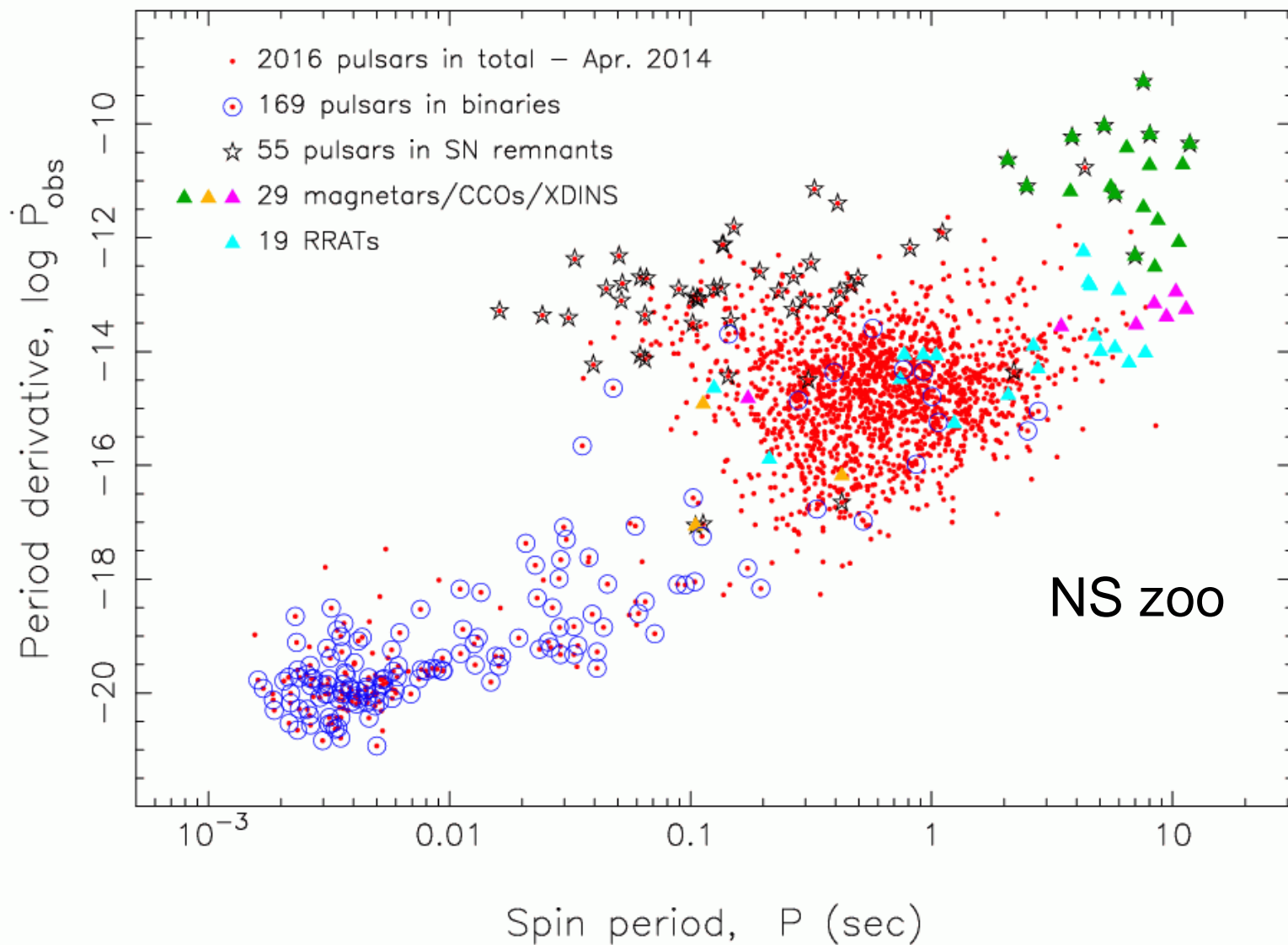
~100 million NSs in Milky Way



tip of the iceberg:

- strong B-fields
- rapid spin
- accreting
- hot (newborn)

NS population



Phase I @ 2023

Phase II @ 2030

Frequency range: 50 MHz to 14 GHz

- **SKA-low** array (50 – 350 MHz)
(dipole antennas)



- **SKA-mid** array (350 MHz – 14 GHz)
(15 m. dish antennas)



- **SKA-survey** array (350 MHz – 4 GHz)
(a compact array of parabolic dishes)



SKA will increase the number of known NSs by a factor ~10

Keane et al. (2015), AASKA14, arXiv:1501.00056

...and so what, we already know 2500 pulsars!

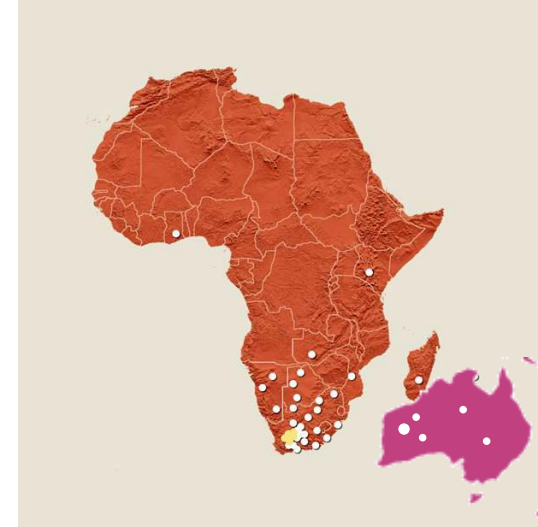
Numbers do matter!!



Much larger statistical sample



Discoveries of new exotic pulsars



- The spin period distribution
- The spin period derivative (B-field) distribution

➔ Evolution (young pulsars → old pulsars)
(e.g. normal pulsars → intermittent pulsars → RRATs)

- Birth properties from obs. of young pulsars

➔ Formation in SNe / progenitor stars
(radio pulsar – magnetar connection)

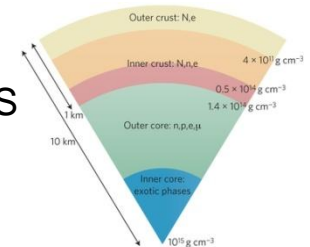


- Proper motions

➔ Formation in SNe (kick velocities, kick-spin relation)

- Mass distributions of NSs

➔ Stellar-, SN and accretion physics, EoS

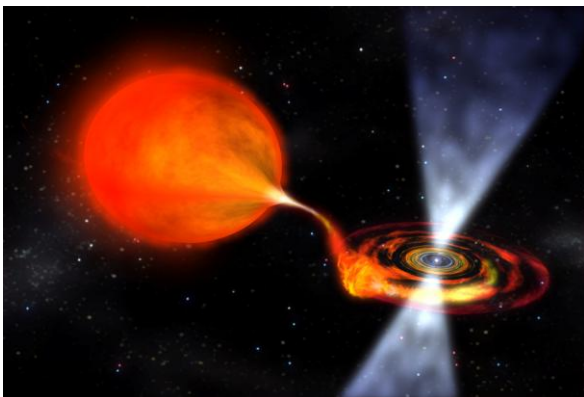
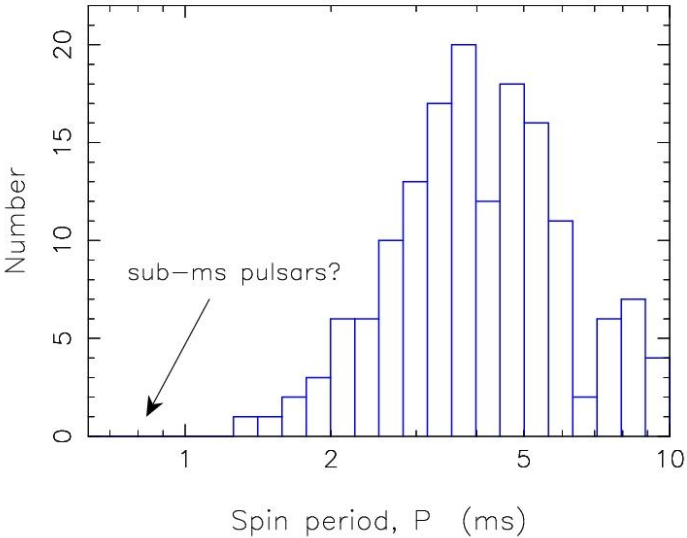
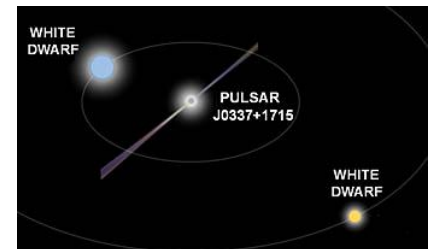


- Fastest spin periods

➔ Accretion physics, binary evolution, EoS

- Origin of exotic MSPs

➔ Binary evolution
(e.g. the eccentric MSPs)



1978: ~ 200 pulsars known

2016: ~ 2500 pulsars known

SKA 2030: ~ 20 000 pulsars?

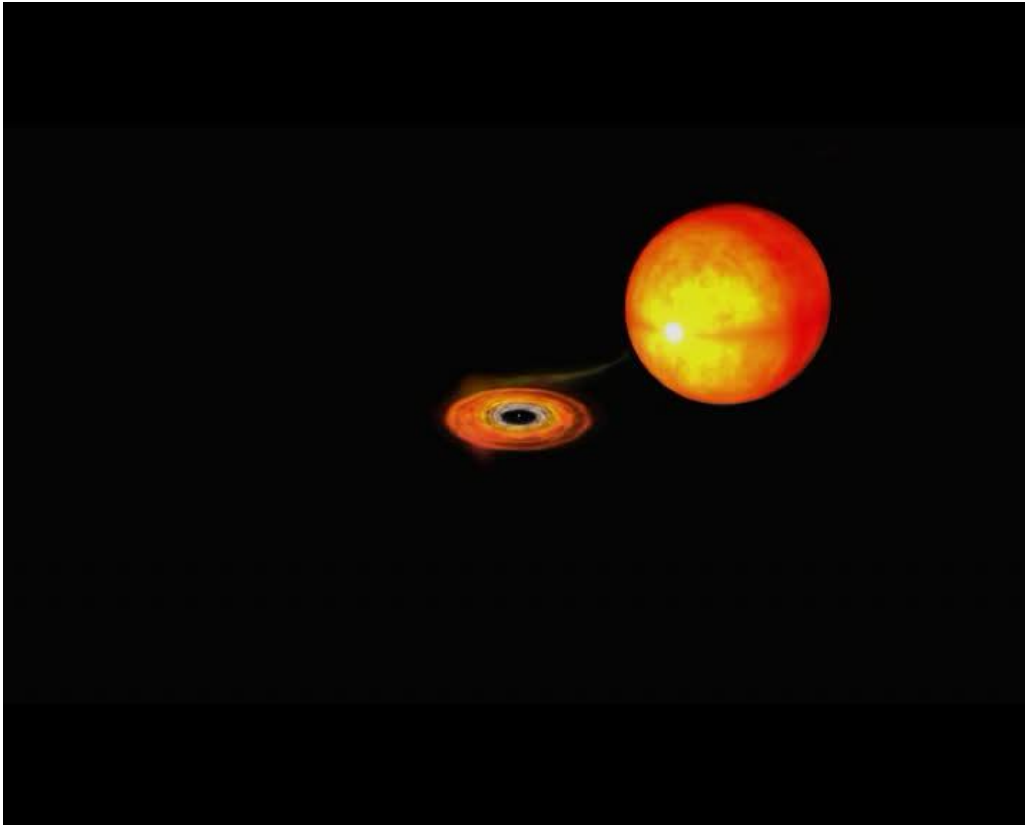
The following NSs were NOT known in 1978 *....



* Before the results from the Second Molonglo Pulsar Survey.

Millisecond pulsars (MSPs) Backer et al. (1982)

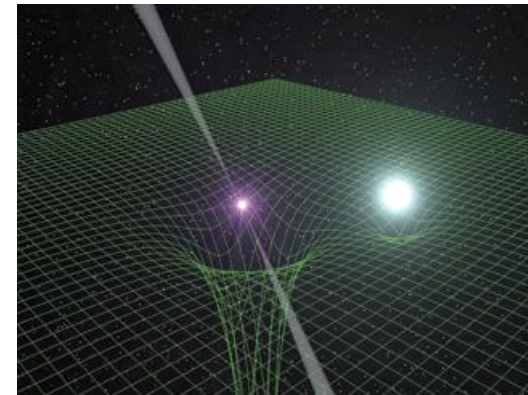
Not known
@ $N < 10\%$



Today: about 300 MSPs known.

Interesting for:

- Binary stellar evolution
- Accretion physics
- EoS
- Observed in radio, X- and γ -rays
- PTA gravitational wave detection
- Probes for tests of gravity

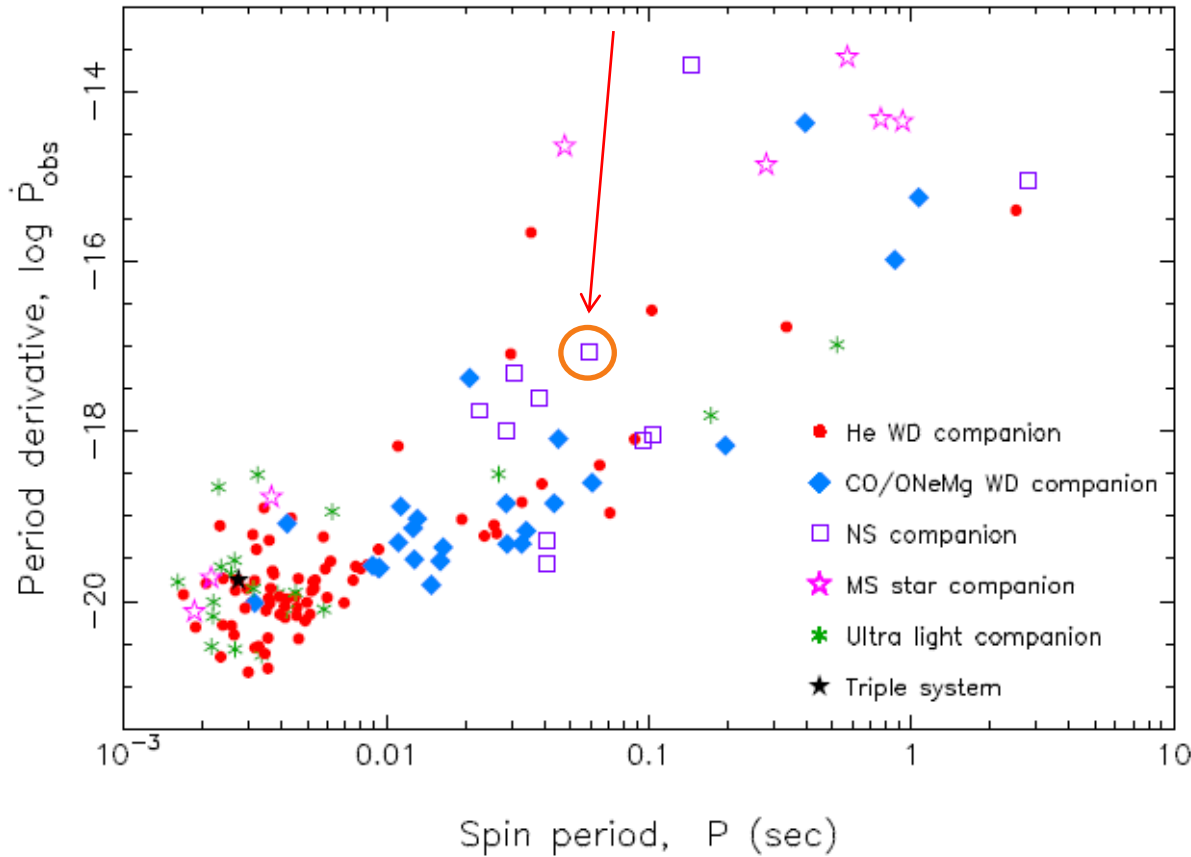


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Binary pulsars

>250 binary pulsars are known today.
Only 1 binary known in 1974

Not known
@ $N < 10\%$



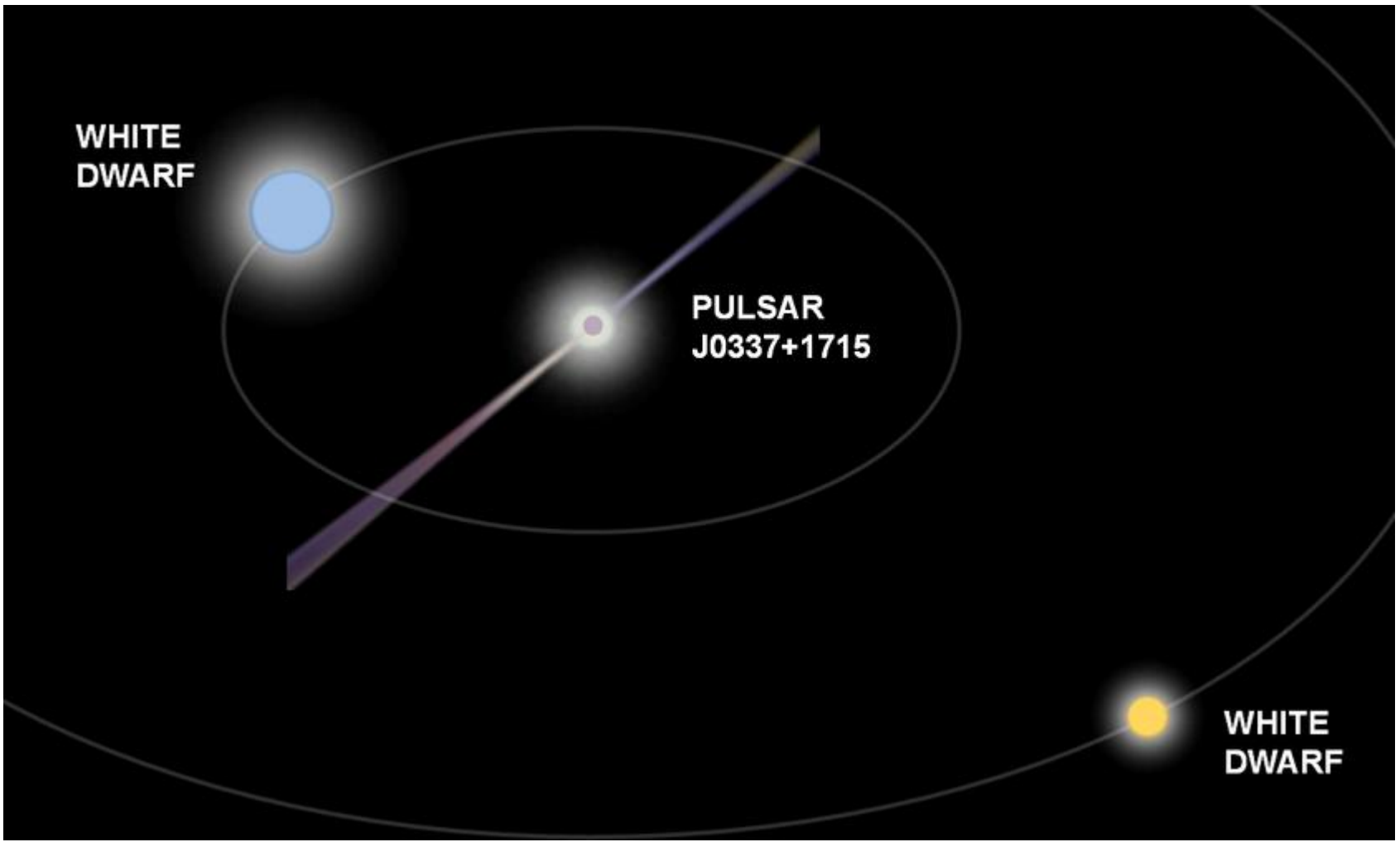
Companion types:

- White dwarf (He, CO, ONeMg)
- Neutron star (double pulsar)
- Main-sequence star (black-widow, redback)
- Ultra-light star
- Planets
- Triple system....



A triple MSP Ransom et al. (2014)

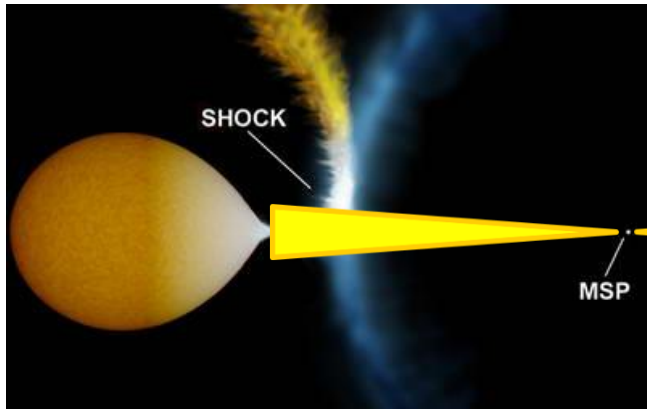
Not known
@ $N < 10\%$



© Tauris & van den Heuvel

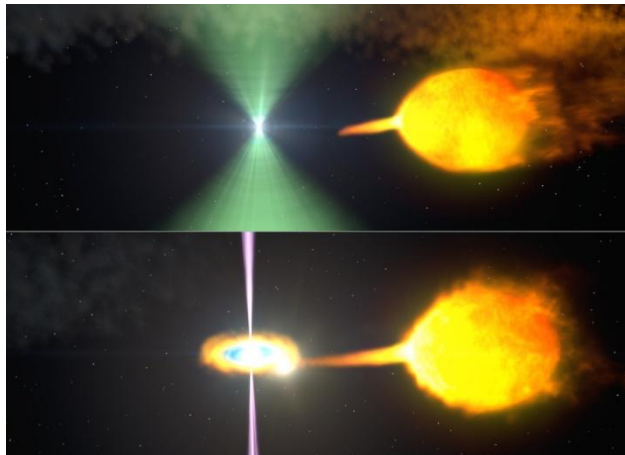
Not known
@ N < 10%

Eclipsing MSPs (30 systems known)



Evaporation of pulsar companion star
→ formation of isolated MSPs

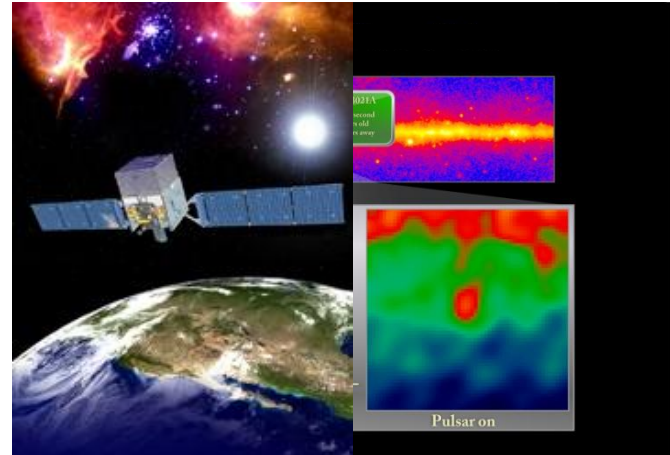
Transitional MSPs (4 systems known)



Radio

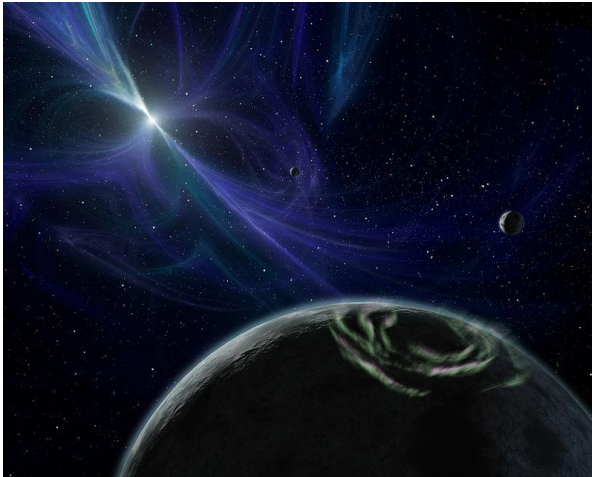
X-rays

X-ray and γ -ray MSPs (100 known)



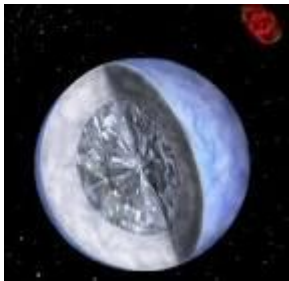
Pulsar planets (first exoplanets ever detected in 1992)

Not known
@ $N < 10\%$



PSR B1257+12 has 3 planets

PSR J1719-1438 b is probably a diamond planet



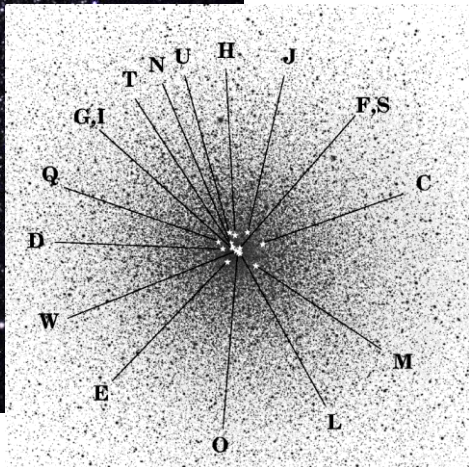
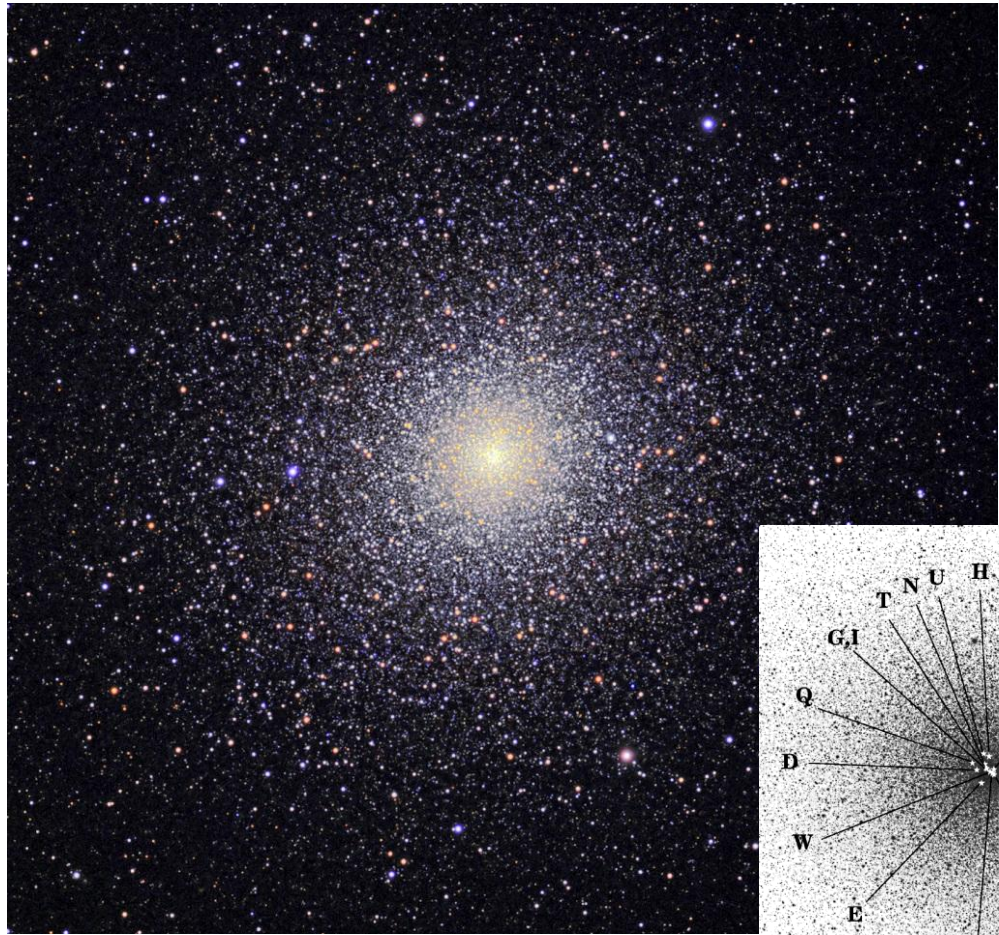
Magnetars (powered by B-field decay – 28 known today)

Not known
@ $N < 10\%$



Pulsars in globular clusters (146 known today)

Not known
@ $N < 10\%$

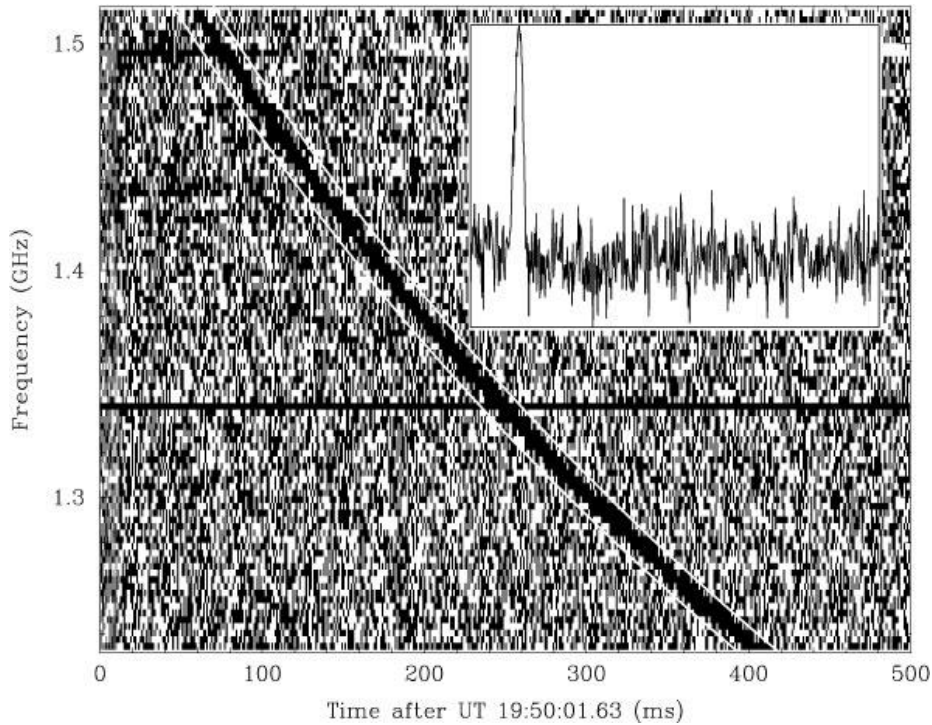


- Interesting for:
- Globular cluster potential
 - Globular cluster dynamics
 - Globular cluster gas content

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Fast Radio Bursts (FRBs) (possibly related to NSs)

Not known
@ $N < 10\%$



Recent news (2016)

- Host galaxy identified
- Repeating

2B

New discoveries

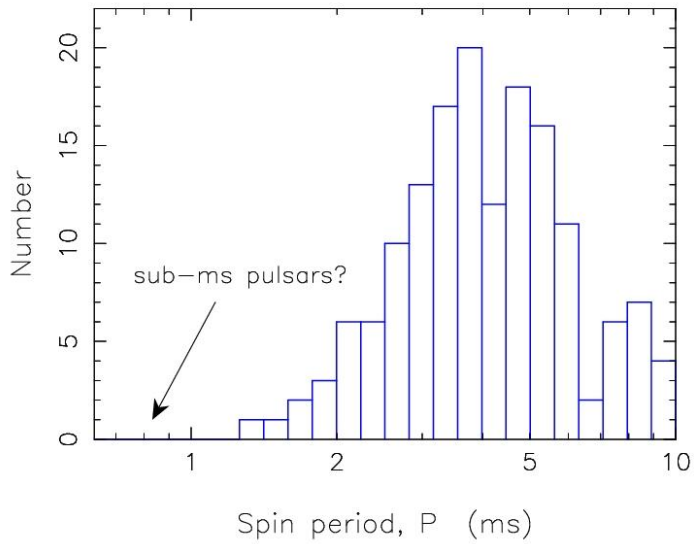
New discovery?
@ N = 1000%



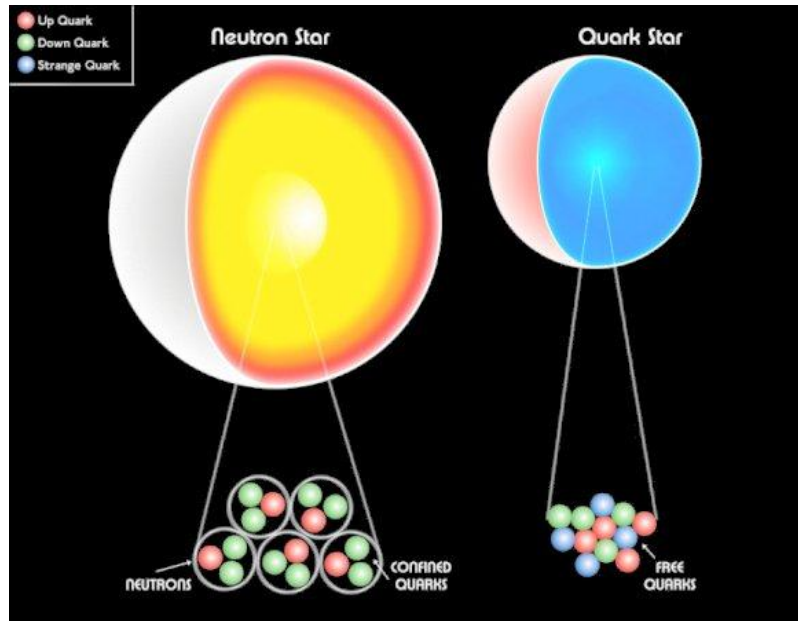
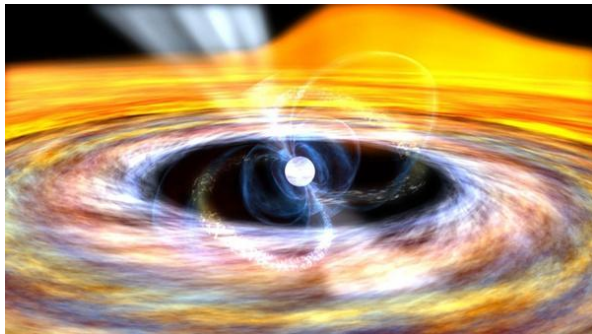
Key discoveries with SKA (should such NSs exist)....

New discovery?
@ N = 1000%

sub-ms MSPs

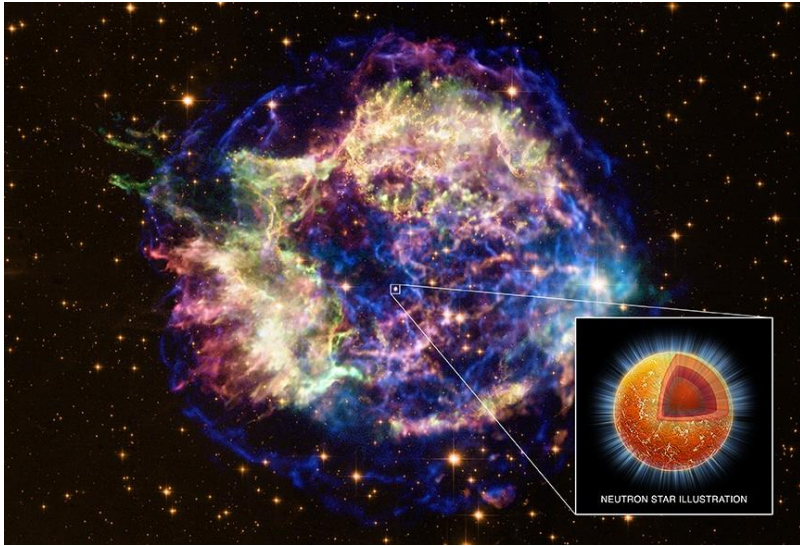


- Interesting for:
- EoS (quark stars?)
 - Accretion physics



NSs born as MSPs

New discovery?
@ N = 1000%

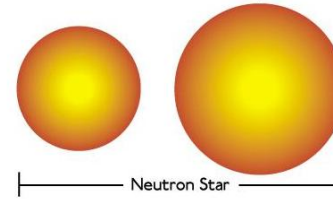
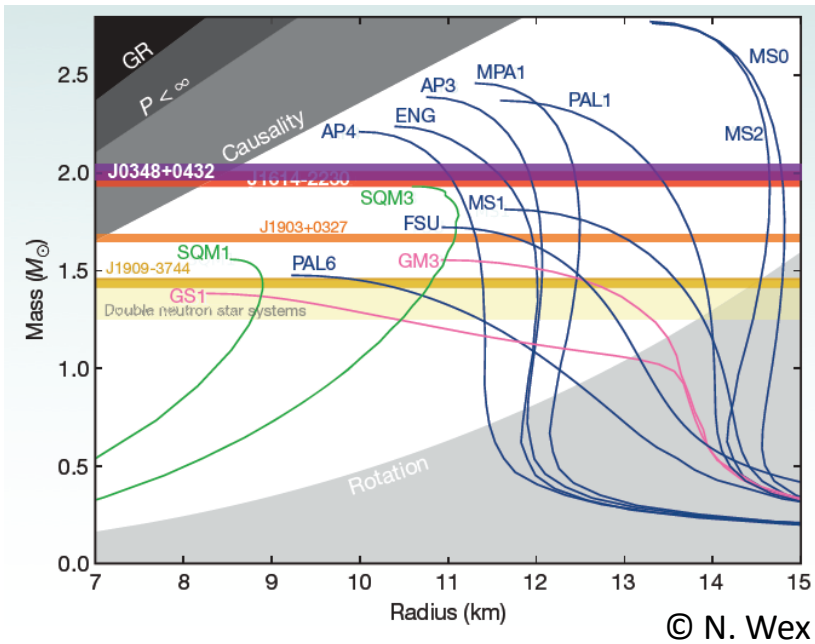


Interesting for:

- Progenitor evolution
- SN explosion physics

Extreme mass NSs ($< 1.0 M_{\text{sun}}$ or $> 2.5 M_{\text{sun}}$)

New discovery?
@ N = 1000%

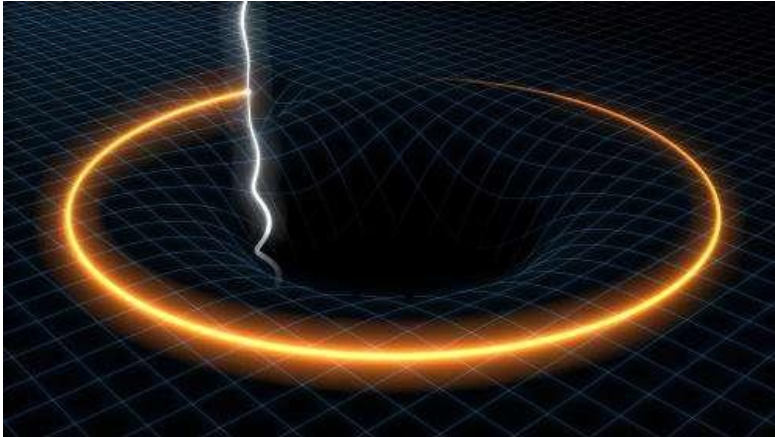


Interesting for:

- EoS
- Progenitor evolution
- SN explosion physics
- Binary evolution / accretion

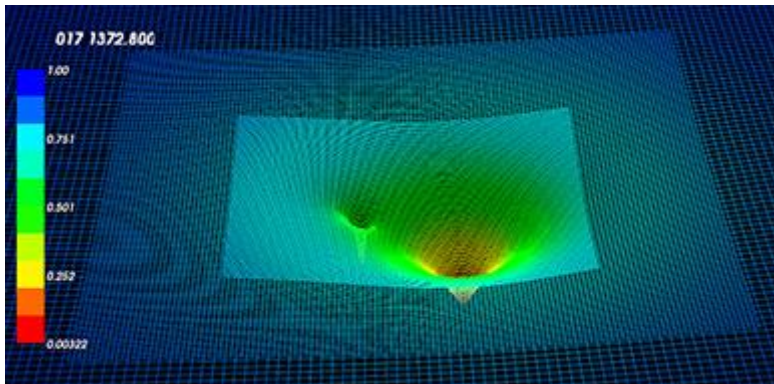
NS + black hole binary

New discovery?
@ N = 1000%



Interesting for:

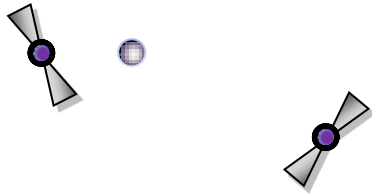
- Gravity tests / relativity
- Binary evolution



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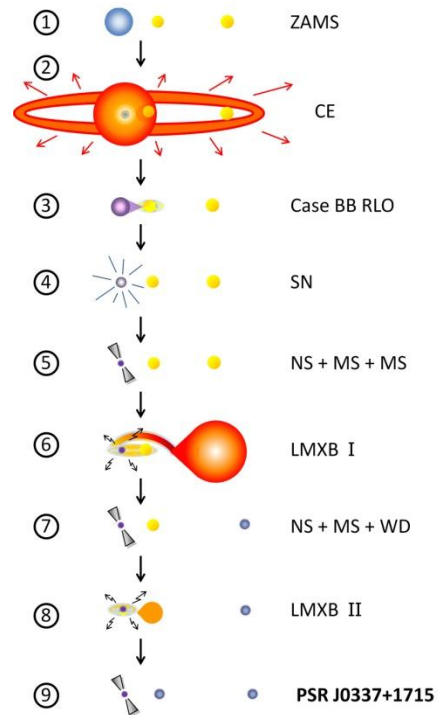
Triple MSP (NS,WD) + NS

New discovery?
@ N = 1000%



Interesting for:

- Gravity tests (Freire, Kramer & Wex 2012)
- Multiple star evolution



Surprises beyond wildest imagination...

New discovery?
@ $N = 1000\%$



- ★ It would have been an impossible task in the late 1970's (even for the wildest speculator) to foresee this diversity of upcoming NS discoveries.
- ★ Brings hope the SKA will reveal **new exotic objects** and surprises that will have a **huge scientific impact!**



With SKA the future looks very promising:

- 1 Much larger statistical sample of radio pulsars
- 2 Discoveries of new exotic pulsars

