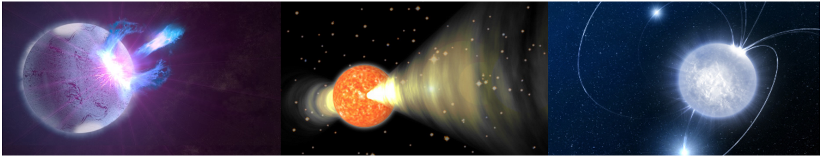

Isolated Neutron Stars in X-rays

Neutron Stars in Future Research

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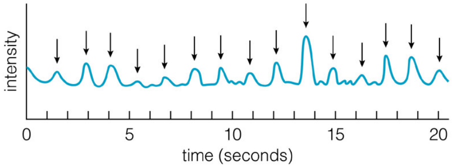
Leibniz Institute for Astrophysics Potsdam (AIP)

11^{th} Bonn Workshop on Neutron Stars, 12/12/2017

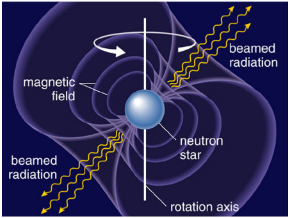
Outline

Isolated neutron stars in X-rays

The neutron star census today



"PULSAting source of Radio" (Bell, 1967)



Hewish et al., *Nature* 1968

Today: over 2600 catalogued pulsars, most seen in radio

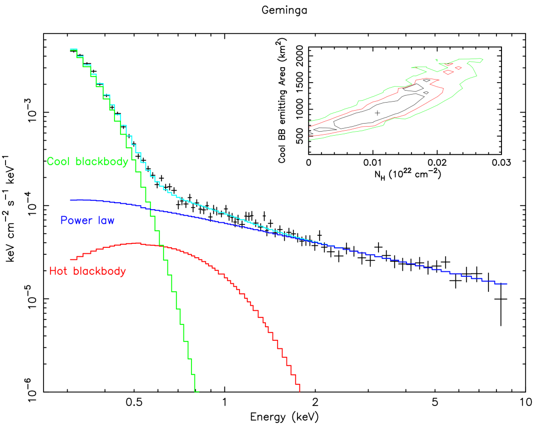
- rotation powered pulsars
- millisecond recycled pulsars (mostly binary)
- radio transients (RRATs, over 110)
- "Fermi Pulsar Revolution" (over 200 LAT detections)
- 2% 'peculiar' X-ray emitting

Neutron stars at high energies

Origin

- internal heat
- rotational energy
- magnetic energy
- accretion

Depends on age, birth properties, evolution



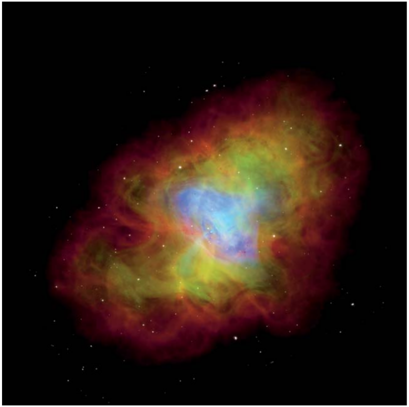
De Luca et al. 2005

Thermal and non-thermal components;
photospheric, magnetospheric, heated polar caps

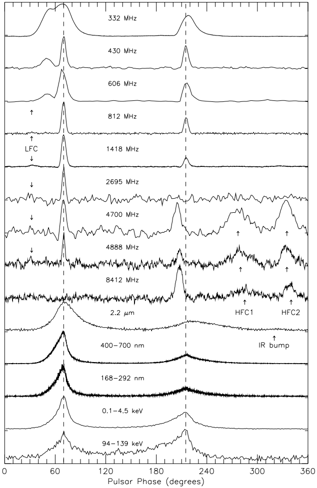
What’s a typical young neutron star?

‘Crab-like’ pulsars powered by rotation

strong, multi-λ, non-thermal pulsed emission



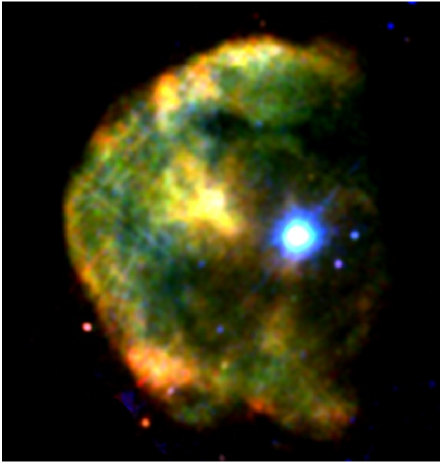
Becker, Haberl & Trümper 2009



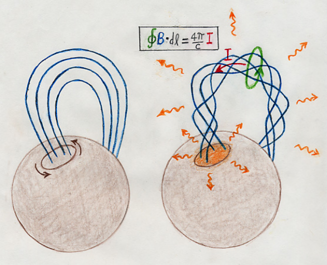
Moffatt & Hankins 1996

Atypical (?) young NSs: Magnetars

Violent bursts of high-energy emission, glitches, multi-λ variability



ⒸESA/M. Sasaki



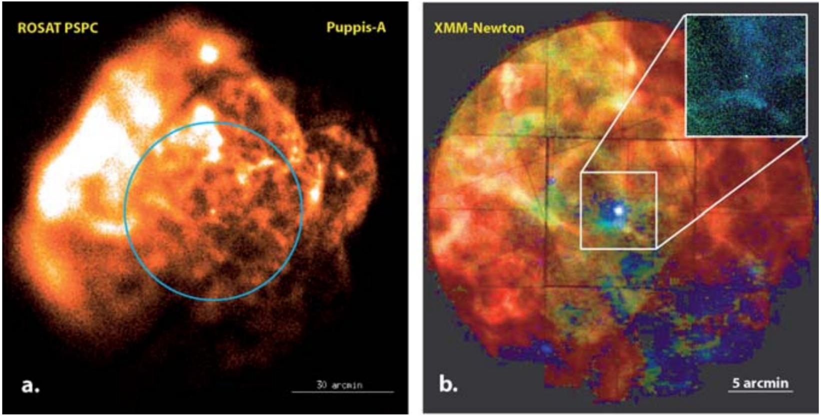
Ⓒ R. Duncan

phenomenology powered by decay or re-arrangement of super-strong *B*

Thompson & Duncan 1995

Atypical (?) young NSs: CCOs

No optical, radio, gamma counterparts; no pulsar-wind nebula

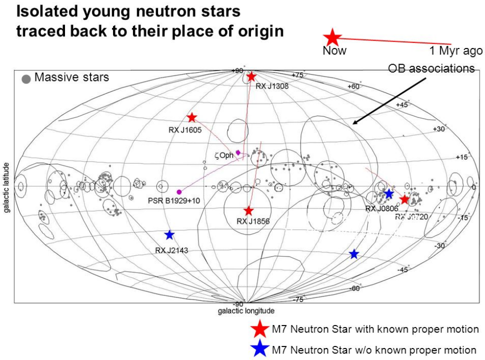


Hui & Becker 2006

anti-magnetars: is the low magnetic field intrinsic?

The Magnificent Seven

Local group discovered by ROSAT (origin in nearby OB associations)



Neuhäuser, Tetzlaff+ 2011

- low N_{H}, $d < 1\,\mathrm{kpc}$
- HST parallaxes
- proper motions: kinematic ages
- X-ray bright and purely thermal

Much effort to discover new members (outside solar vicinity)

eg Rutledge+08, Pires+09

Peculiar groups of neutron stars

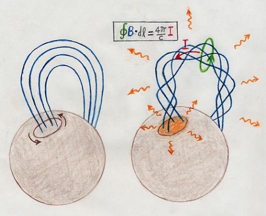
Unknown from radio surveys

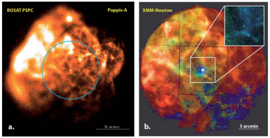
- magnetars
- magnificent seven
- CCOs (anti-magnetars)

Only X-ray bright neutron stars are known (or when in outburst)

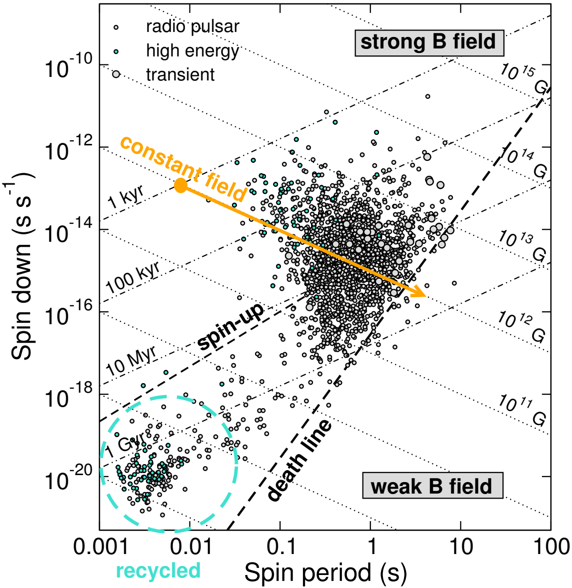
Challenge understanding of emissivity and evolution

Do “normal” pulsars tell the whole story?





Evolution in the $P - \dot{P}$ diagram



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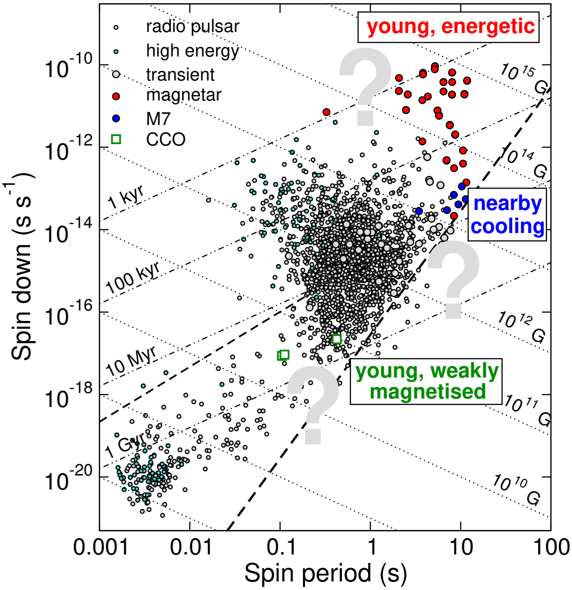
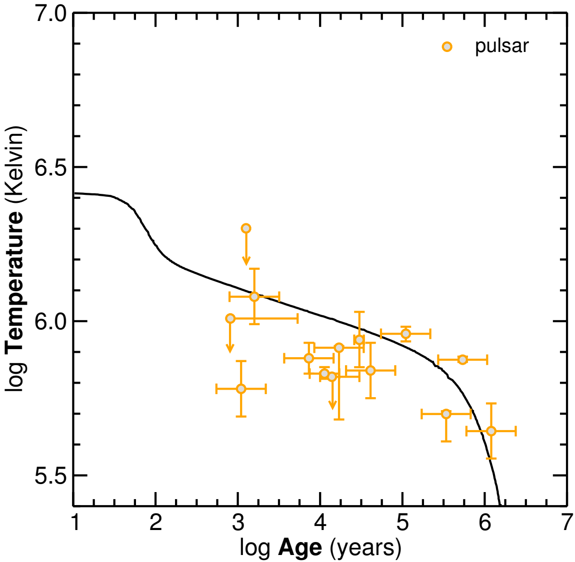
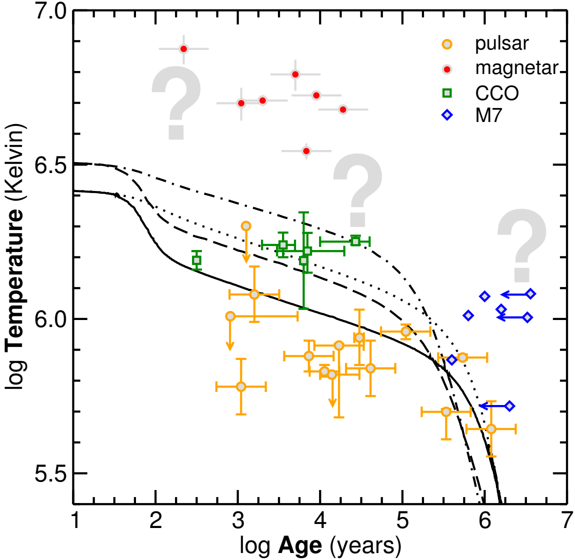


How fast does a neutron star cool down?



How fast does a neutron star cool down?



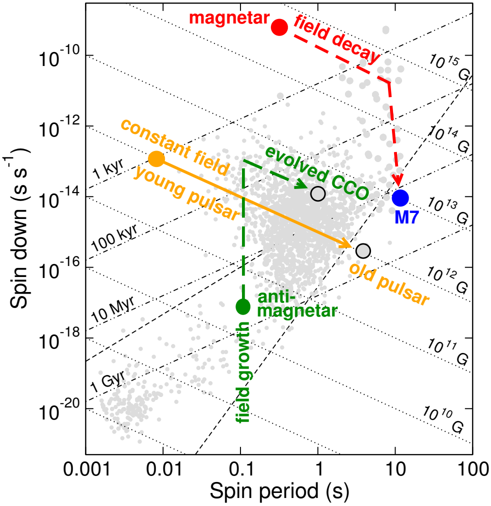
Alternative evolutionary channels

Strong fields at birth produce hot and long-P NSs due to **B-field decay**

c.f. Pons, Viganò, Popov, Rea, Aguilera et al.

If there's lots of fallback accretion after supernova: **hidden B-field scenario**

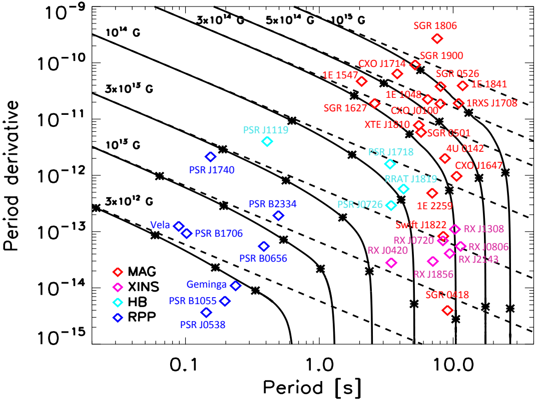
Chevalier, Geppert, Ho, Bernal, Viganò...



Evolutionary channels (1): Field decay

What happens when a magnetar ages?

Coupled evolution: according to initial field (Viganò, Rea, Pons+)



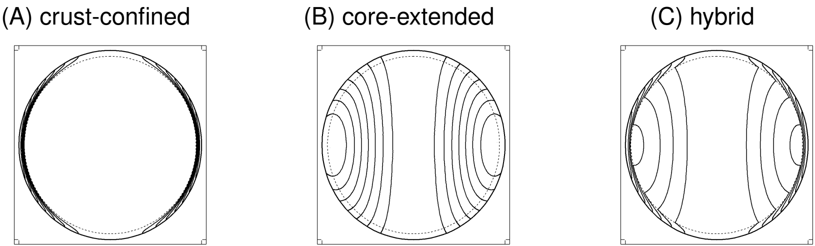
Viganò et al. 2013

- torque brakes spin to asymptotic value
- field dissipates and heats the crust
- neutron star is hot and spins slowly
- magnetar-M7 connection

Big issues (1)

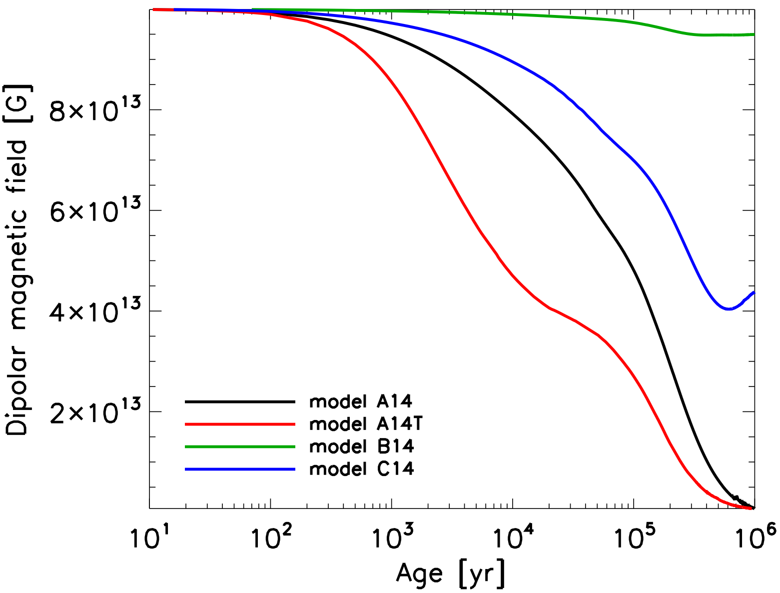
State-of-the-art models built over uncertain assumptions

from Viganò et al. 2013

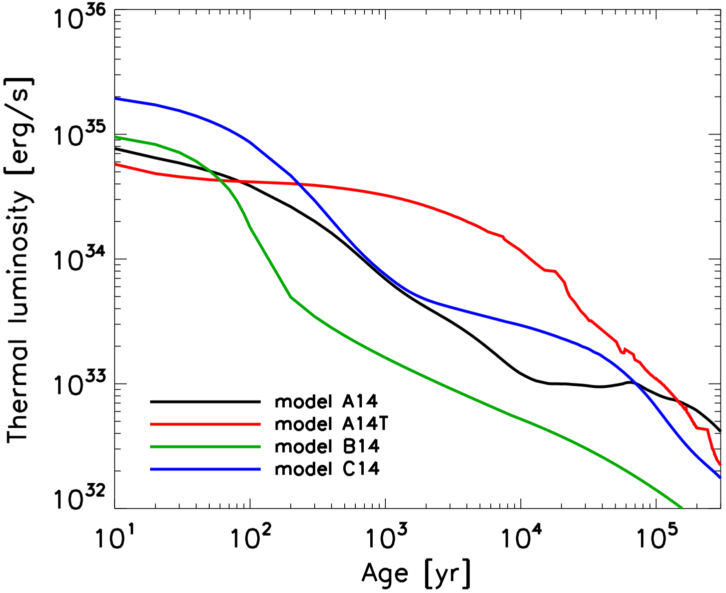


- initial field configuration
- field dissipation controled by ‘impurity’ of the crust

from Viganò et al. 2013



from Viganò et al. 2013



Evolutionary channels (2): the hidden-B scenario

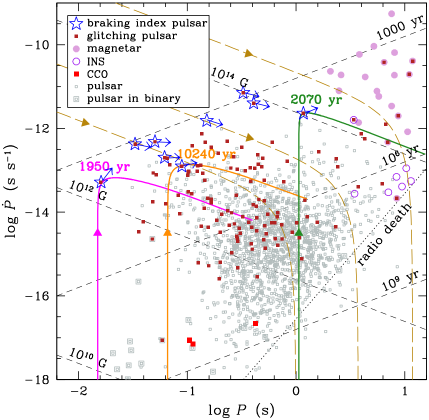
Evidence that some CCOs hide large crustal fields

(Gotthelf & Halpern, Rea, Lai, Luo, Bogdanov..)

Where are the old CCOs?

After field re-emergence: neutron star spins down, joins the rest of the population

Braking index and thermal emission may keep signatures of past accretion episode



Ho 2015

Big issues (2)

Much theoretical work needed

Conditions determining / preventing fallback

- deviations from spherical symmetry
- neutrino-driven explosions
- convection in the accreting envelope
- rotation: ejector, propeller
- large kick velocity

Amount of accreted material

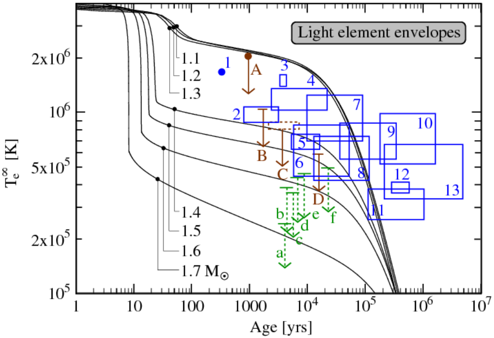
- determines the level of submergence
- timescale of re-emergence

More open questions

The “hollow supernova remnant” problem

Large fraction of known supernova remnants lack a detected compact remnant, despite radio/X-ray searches

(eg Kaspi, Kaplan, Kargaltsev; Samayra Straal’s talk)

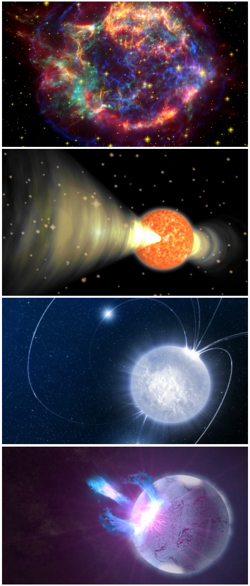


- SN Ia or black hole
- enhanced cooling?
- accreted envelope?

Real-time cooling in Cas A CCO?

(Heinke & Ho, Posselt)

Page et al. 2013



Radio + X-ray INSs cannot constrain models of *B*-decay (Gullòn+15)

Observability of old magnetars: deeper fluxes, quiescent level, transient behaviour

Fraction undergoing fallback?

Consequences to the birthrate?

NS-SNR connection: explosion mechanisms

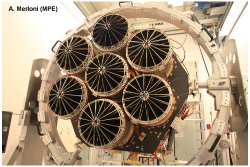
We need to: c.f. Pires+12,14,15

- obtain a better sampling of radio and gamma-ray quiet sources
- discover and characterise evolutionary missing links (especially in X-rays)
- evaluate alternative scenarios on evolution and observability

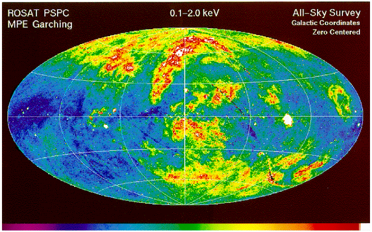
eROSITA is coming soon!

"Mapping the Structure of the Energetic Universe"; ROSAT's successor

New all-sky X-ray survey
mission on-board Spectrum-RG
(RU/DE collab.; launch: Autumn 2018)



- unprecedented sensitivity, angular/energy resolution
- millions of X-ray sources
- synergy with multi-λ surveys and facilities
  (E-ELT, LSST, Athena, SKA. . .)



Unique potential (for decades to come) to unveil faint radio-quiet neutron stars and probe the whole population

Pires+17

Outlook: the future is X-ray bright

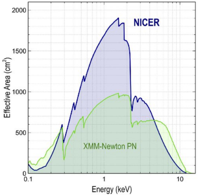
NICER ISS payload dedicated to neutron stars

eROSITA new X-ray survey mission

XIPE, IXPE X-ray polarimetry at last

XARM, eXTP high-resolution spectroscopy and timing

Athena, Lynx the new generation



Thank you!