X-ray and Optical Observations of the Closest Isolated Radio Pulsar

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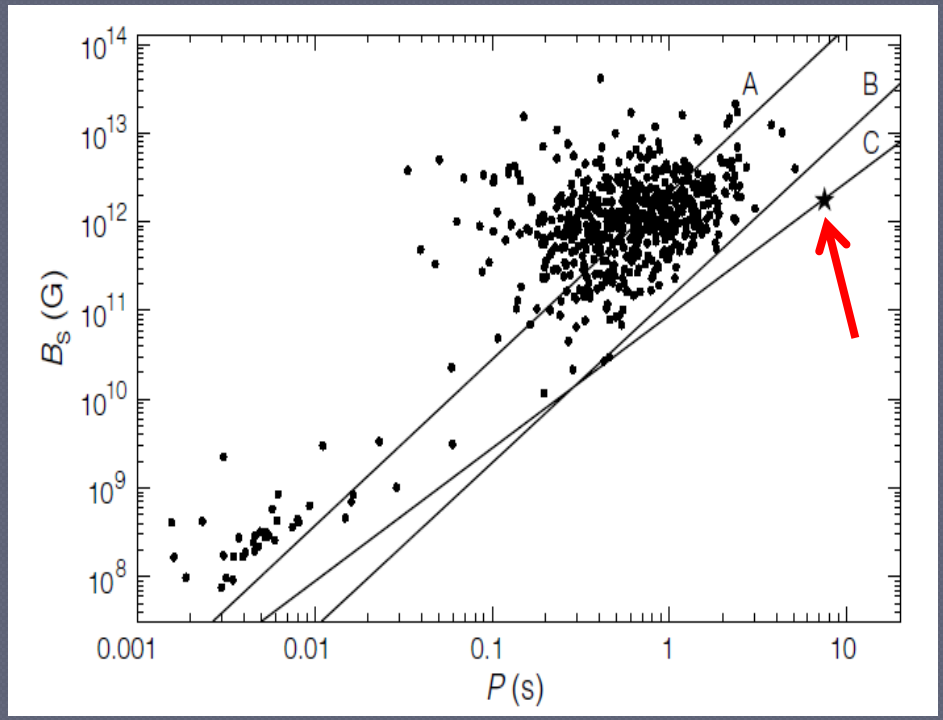
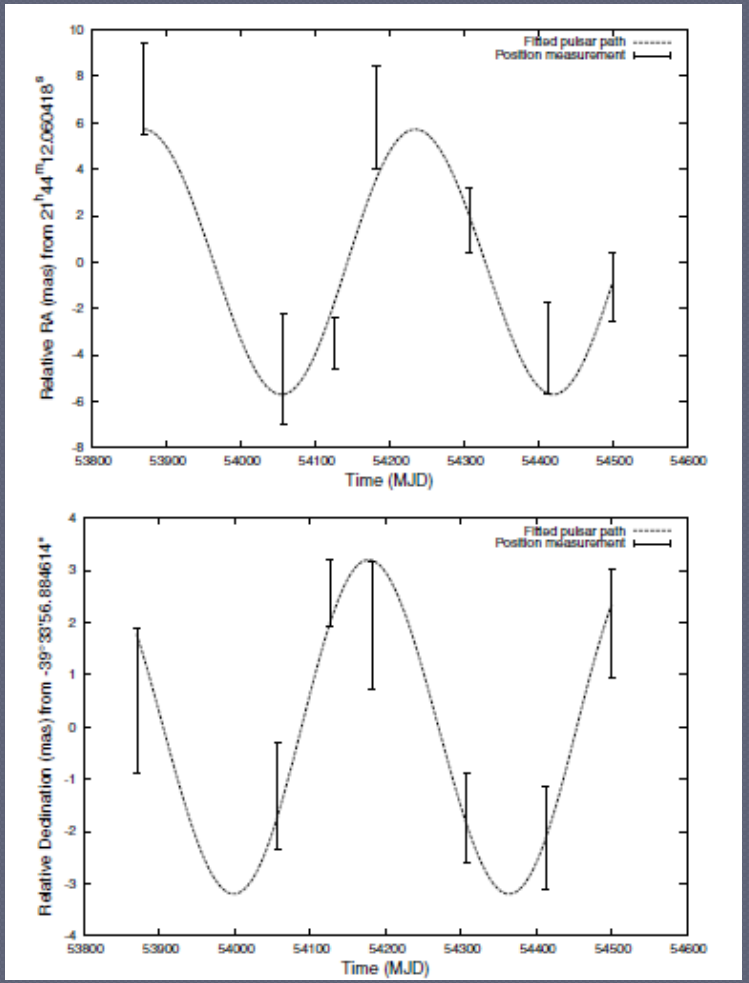
PSR J2144-3933
P=8.5 s → the slowest radio PSR

- Pdot = 4 10^{-16} s/s
  (corrected for Shklovskii effect)
- Below the Death Lines
  "challenges emission models" (Young, Manchester, Johnston 1999, Nature)



PSR J2144-3933
The closest radio PSR

- VLBI parallax and proper motion
  (Deller et al. 2009)
- D = 170 +/- 20 pc
  (corrected for Lutz-Kelker bias)
- PM=166 +/-1 mas/yr
  (V_T =130 km/s)



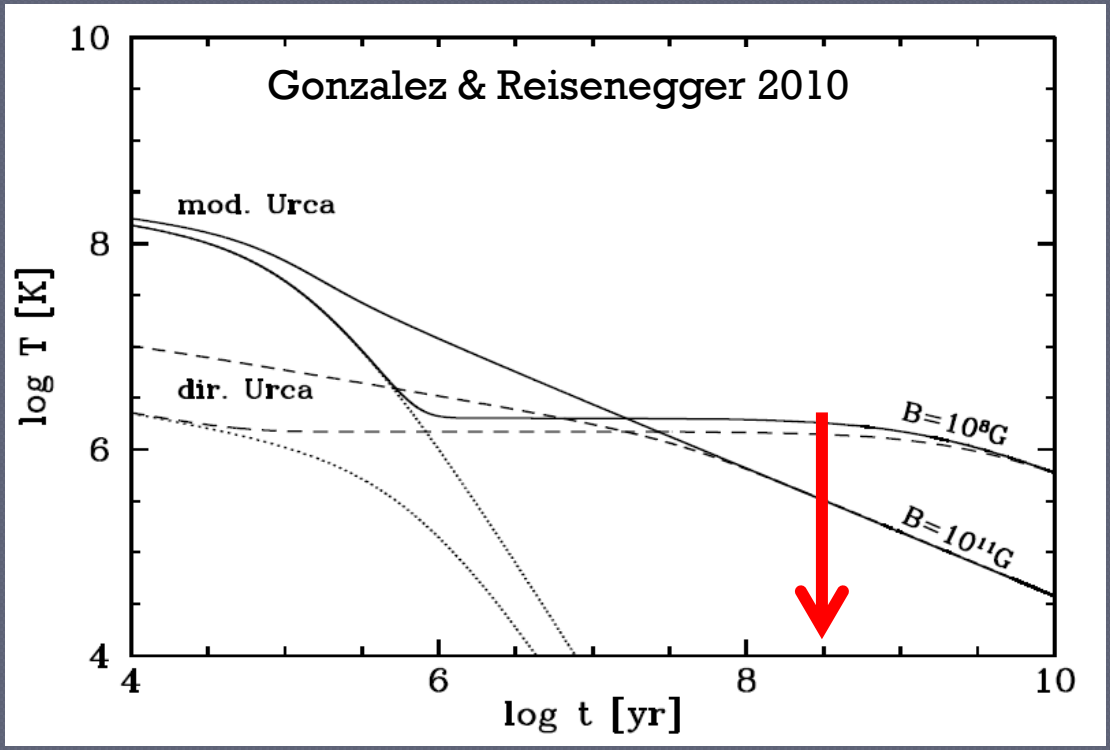
PSR J2144-3933 Parameters

- P = 8.51 s
- Pdot = 4 10^{-16} s/s
- L_{SD} = 2.6 10^{28} erg/s
  - Lowest of any radio pulsar
- τ=340 Myr
  - Among the oldest non-recycled radio PSRs
- B=2 10^{12} G Typical pulsar field

Heating in old pulsars
Frictional motion of superfluid n vortices

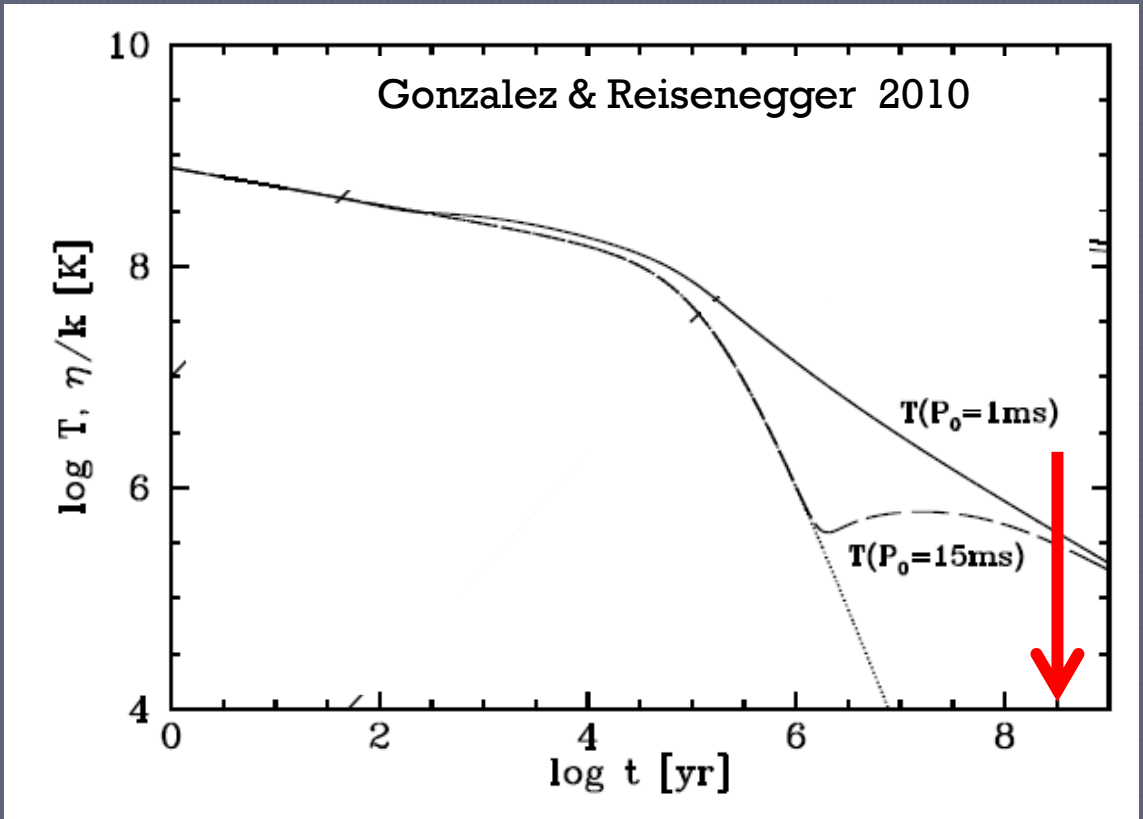
- Alpar et al. 1984, Shibazaki & Lamb 1989

$$L = I_P \, <(\Omega_S - \Omega_C)> \, \dot{\Omega}$$



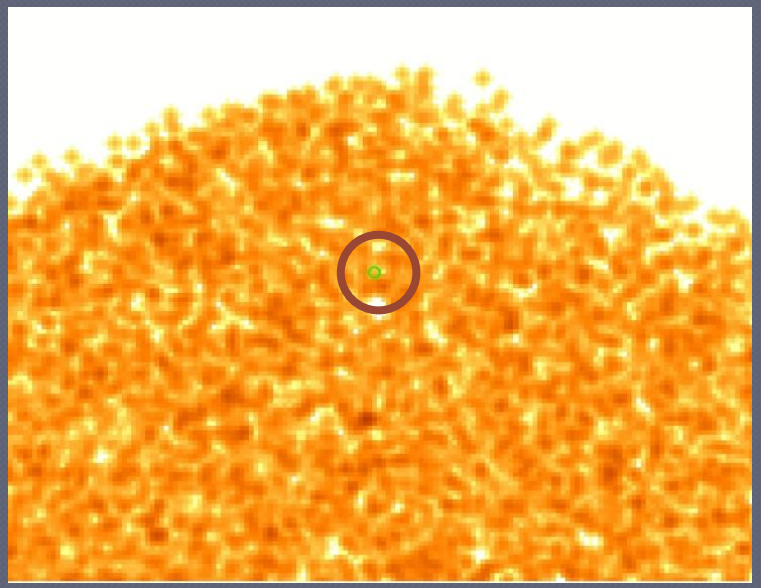
Heating in old pulsars
Rotochemichal heating

- Reisenegger 1995, 1997, Petrovich & Reisenegger 2010

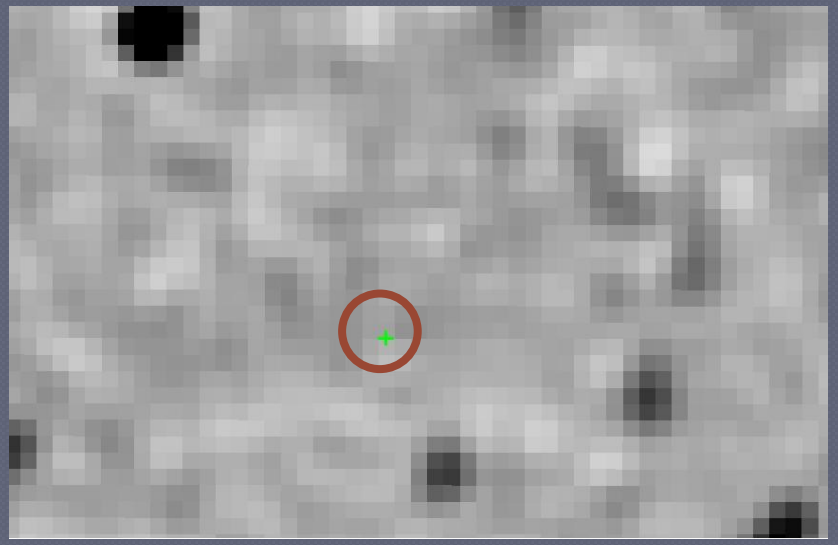


PSR J2144-3933
Previous X-ray/opt. observations

- ROSAT HRI (1997)
- 5 ks @ 15' off-axis
- No detection



- No pointed optical observations
- DSS (POSS-II), B filter



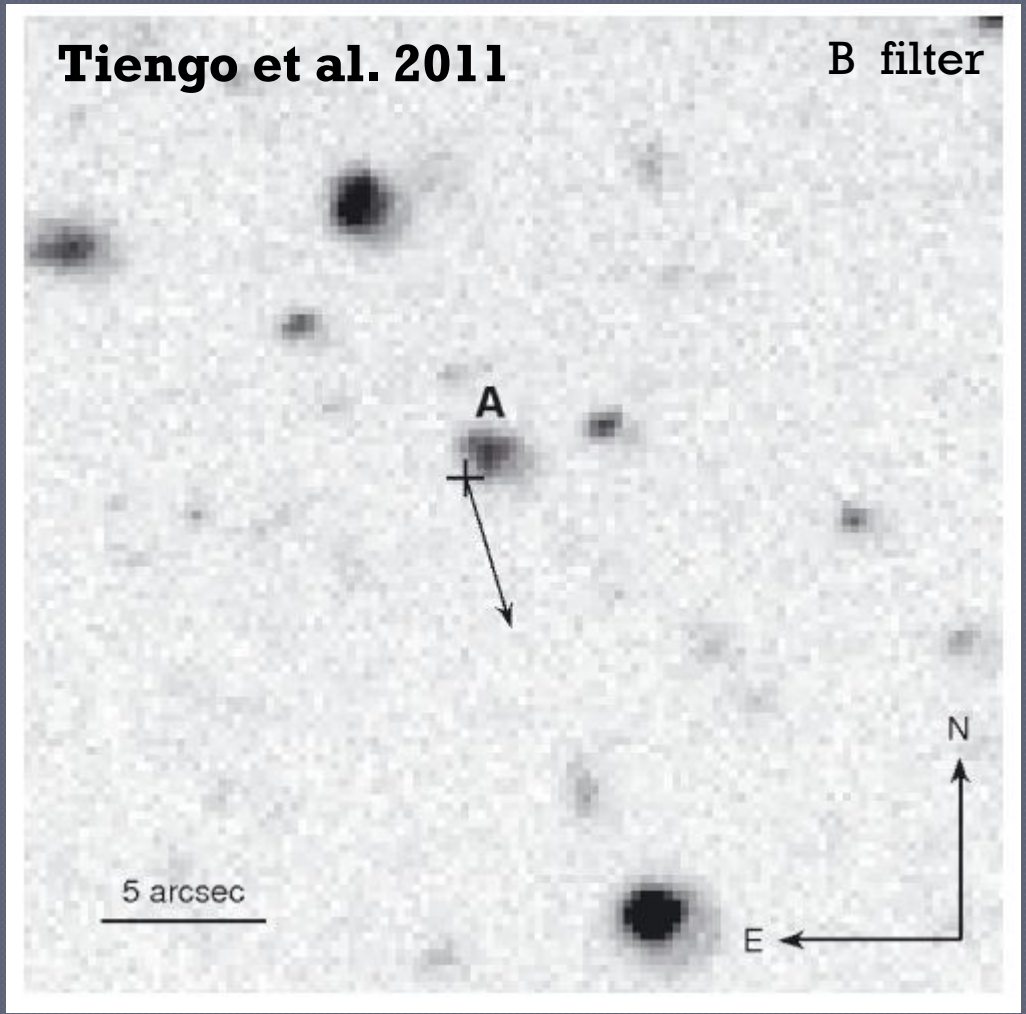
PSR J2144-3933
Optical observations at ESO VLT

Aug. 21, 2009

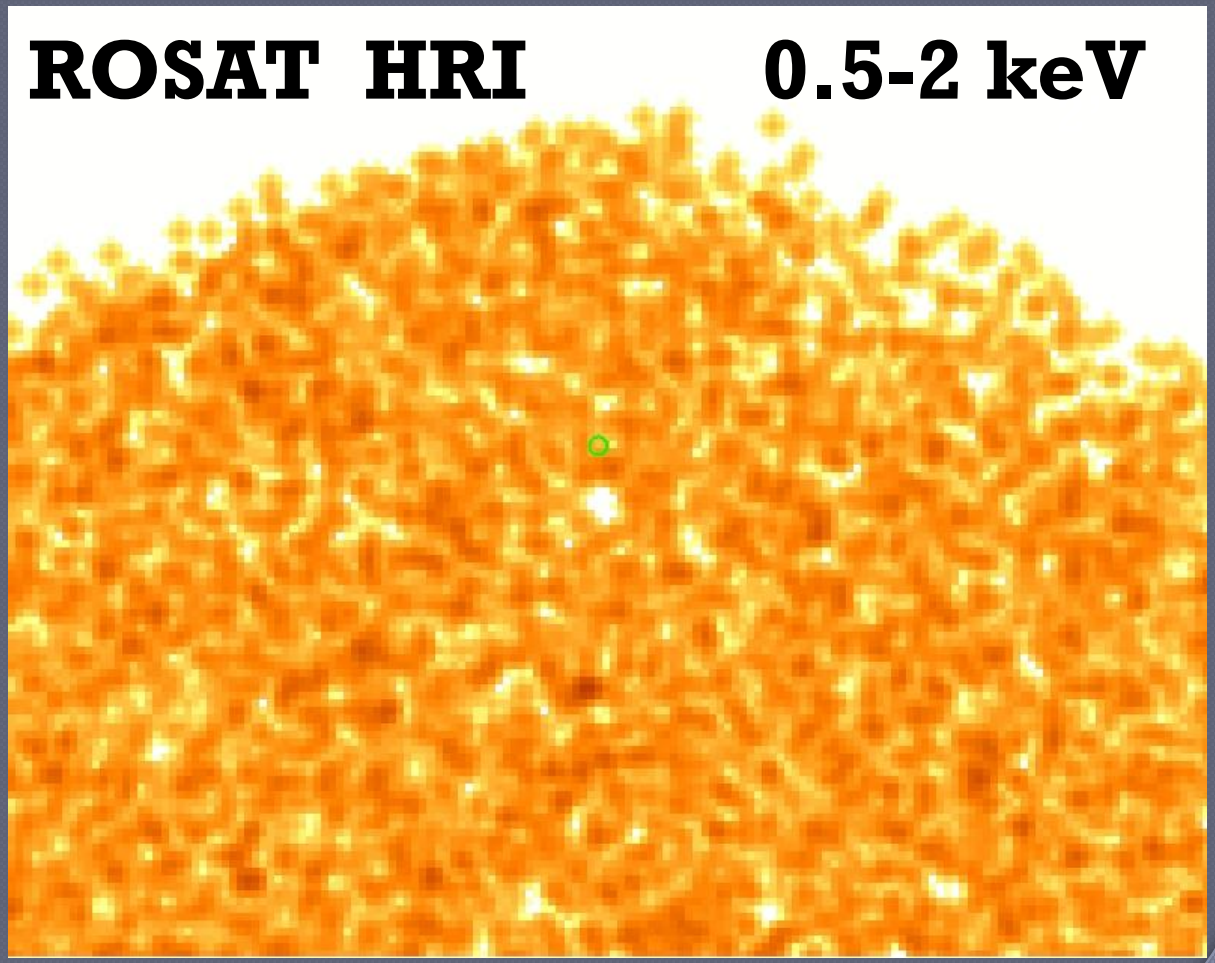
- U filter 9 ks
- B filter 9 ks
- V filter 3 ks
- IQ ~ 0.8”

PSR not detected

- U > 25.3
- B > 26.6
- V > 25.5

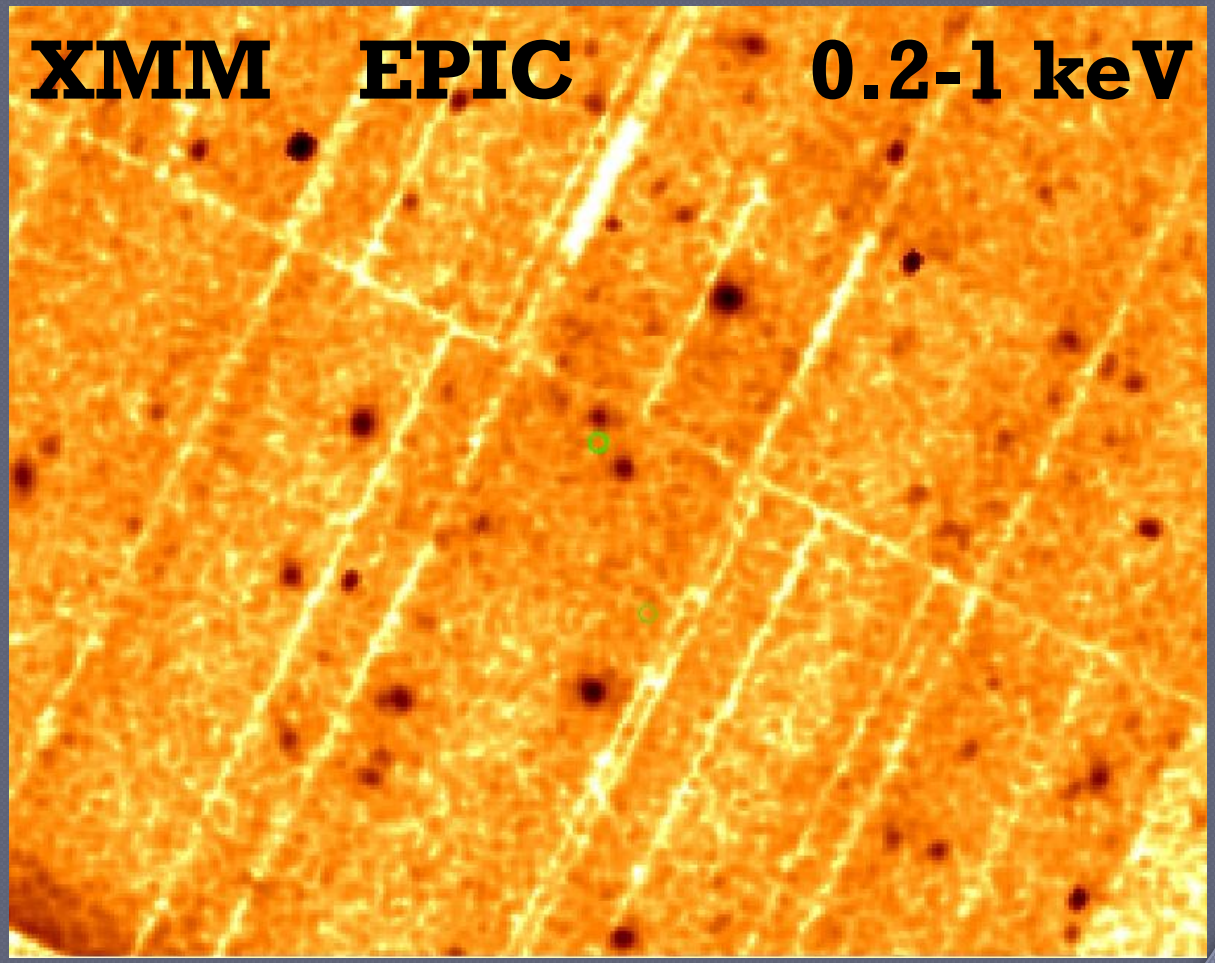


PSR J2144-3933
Our XMM-Newton observation



PSR J2144-3933
Our XMM-Newton observation

- Oct. 24, 2009
- 40 ks (25 ks with low BKG)
- PSR not detected

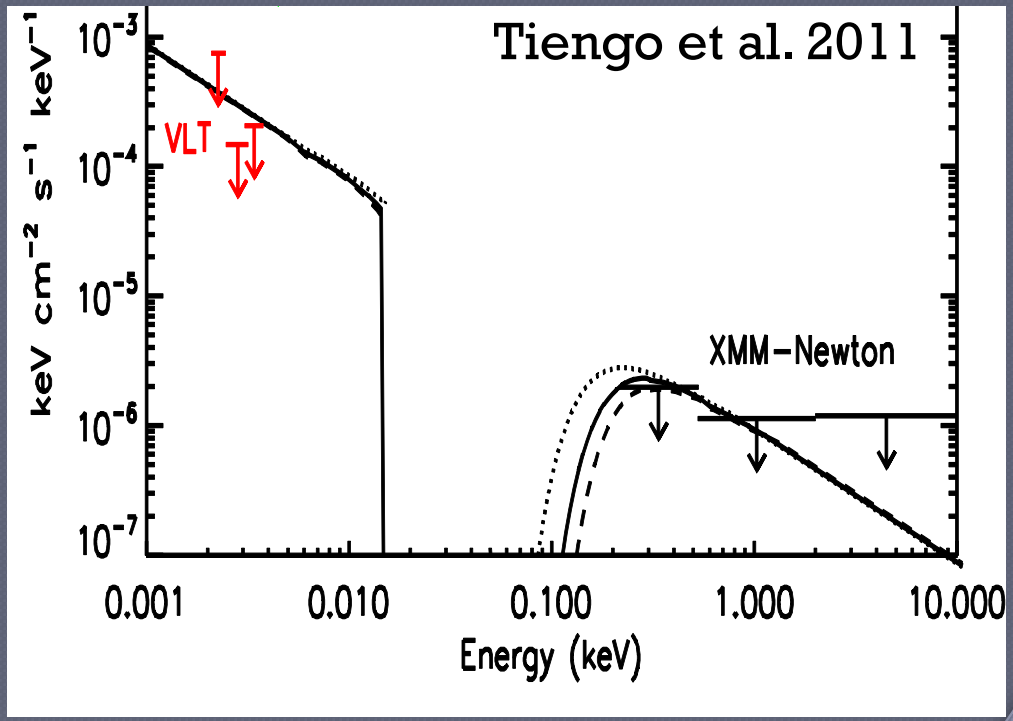


PSR J2144-3933
X-ray upper limits (3σ)

- 0.2-0.5 keV 4.9 10^{-4} PN cts/s
- 2-10 keV 1.1 10^{-3} MOS cts/s

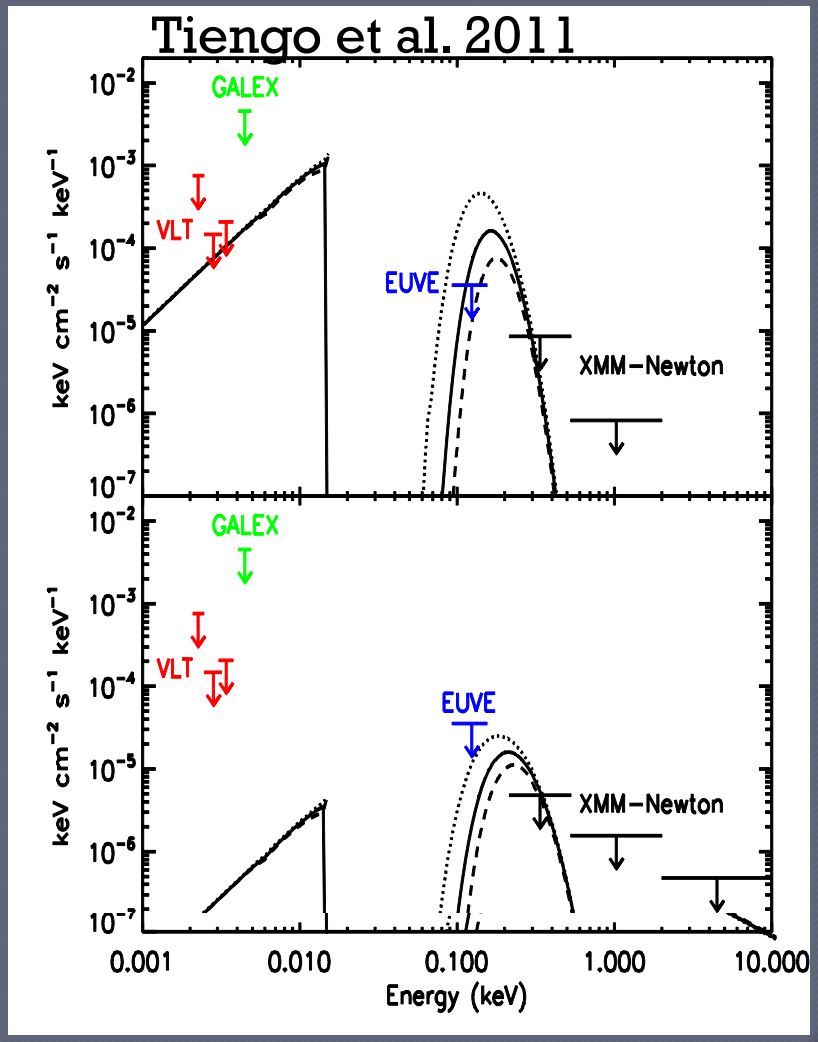
- For a power law with photon index = 2

→ $L_{0.5\text{-}2\ keV} < 7\ 10^{27}$ erg/s = 30% L_{SD}



PSR J2144-3933
Upper limits on temperature

- $N_H = 10^{20}$ cm^{-2}
  E(B-V) = 0.02
- Depend on assumed emission radius, e.g.:
  - R_∞ =13 km
    → $T < 2.3\ 10^5$ K
  - R_∞ = 500 m
    → $T < 4.4\ 10^5$ K
    ($L_{bol} < 7\ 10^{28}$ erg/s)



PSR J2144-3933
Comparison with theory

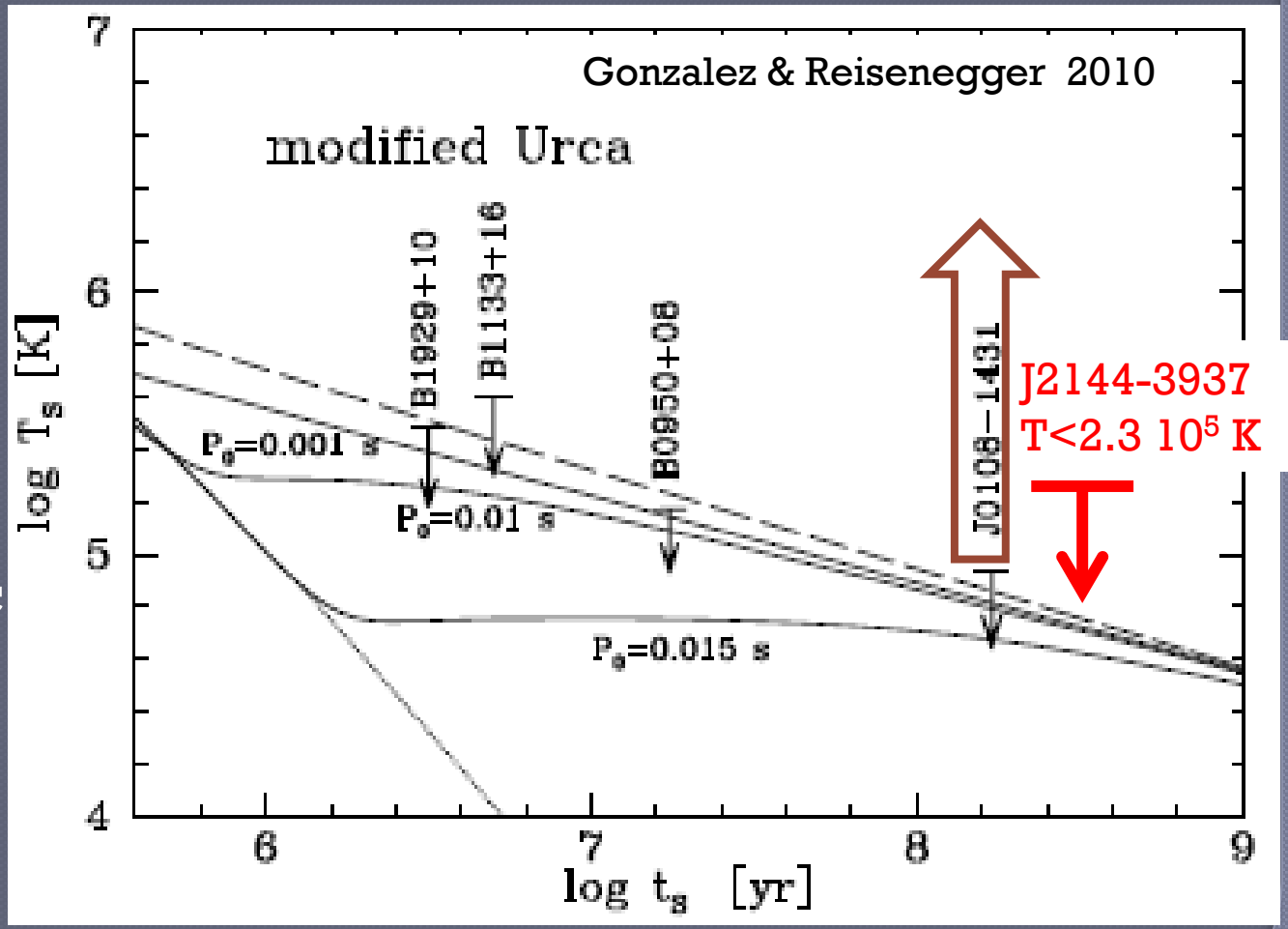
Cfr. uncertain distance of J0108-1431

DM → 130 pc
Taylor+Cordes 1993

DM → 184 pc
Cordes+Lazio 2002

VLBI → 240^{+124}_{-61} pc
Deller et al. 2009

Lutz-Kelker corr.
→ 625^{+375}_{-313} pc
Verbiest et al. 2010



PSR J2144-3933 Conclusions

- Closest radio PSR and well known distance
- Ideal target to study cooling of old NS
- Could be the descendent of a magnetar
- Our limits ($T<2.3\ 10^5$ K) are among the lowest for emission of whole surface of old NS and constrain parameters of some suggested re-heating models