



# The neutron star in the Carina Nebula

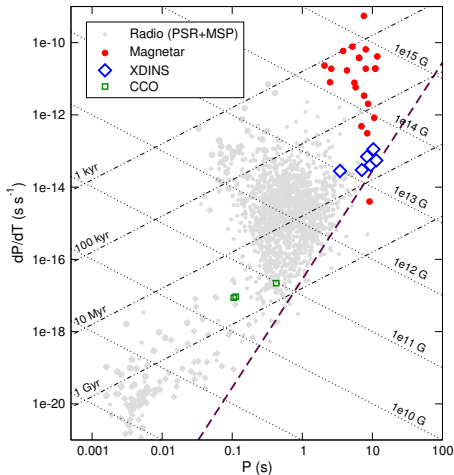
*New XMM-Newton observation of 2XMM J104608.7-594306*

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# X-ray dim INSs (aka the Mag 7)



Local group of INSs sharing peculiar properties

- ▶ purely thermal spectrum
- ▶ slow rotators,  $P \sim 3 - 10$  s
- ▶ high  $B \sim 10^{13} - 10^{14}$  G
- ▶  $L_X \gg \dot{E}$

Additional heating of NS crust by means of field decay

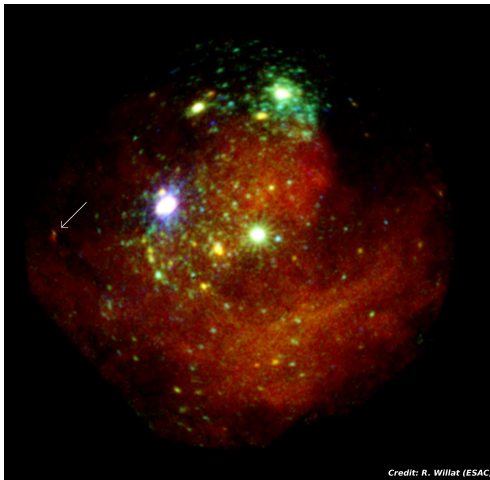
- ▶ different  $B$ - $P$  evolution
- ▶ cooling rate
- ▶ detection in X-rays

# Is there any XDINS beyond the Gould Belt?

- ▶ Why so many XDINS in the Solar vicinity?
- ▶ How numerous are they in the Galaxy?

New candidates to be searched at faint fluxes

- ▶ J1046: discovered in the direction of Carina
- ▶ Overall properties: younger and more distant XDINS?

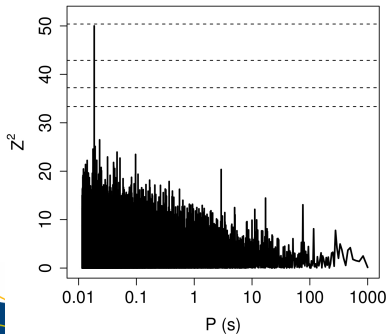


Credit: R. Willat (ESAC)

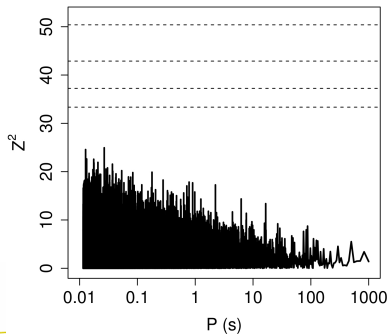
# Results of AO9 observation (1)

- ▶ Goal: better characterize the spectrum; look for pulsations
- ▶ Blind search, broad frequency range  $P = 0.011 - 1000$  s (90 ks in AO9)
- ▶  $Z^2$  tests: different energy bands, sizes of extraction region

(over source photons; 5260 counts)



(over background events; 5322 counts)

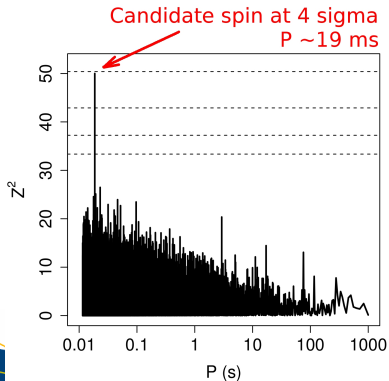




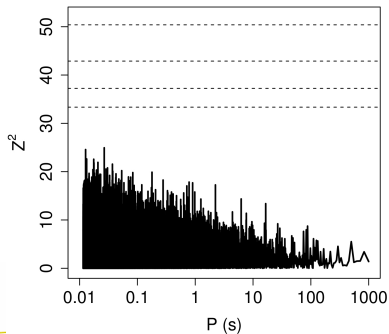
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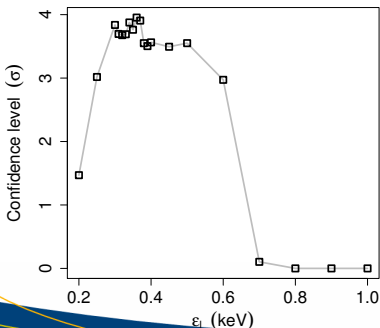
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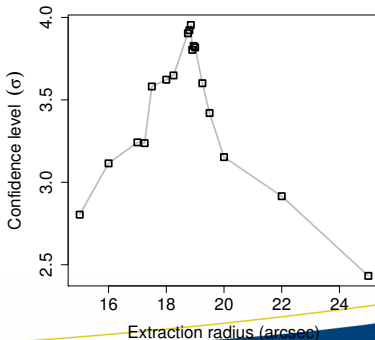
# Results of AO9 observation (2)

- ▶ Significance of detection sensitive to the choice of search parameters
- ▶ Power affected even by randomization in energy (*standard processing of event file*)
- ▶ Is the source signal easily “lost” in the background?

$Z_{\max}^2$  as a function of energy band...

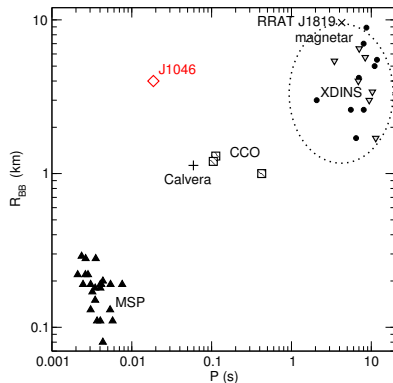
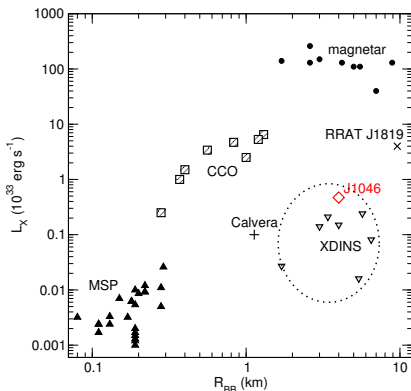


...and of extraction radii



# Spin too fast for a XDINS

## Spectro-rotational properties of thermally emitting INSs

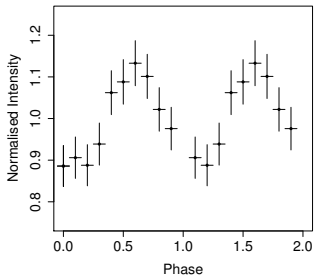


J1046: similar spectral properties to XDINS, how to explain the fast spin?  
Recycling in a binary? Very low spin down? Relation with old CCO/Calvera?

# New XMM-Newton observation (AO11)

Goal: confirm candidate period and constrain the INS spin down

Folded light curve at  $P=19$  ms



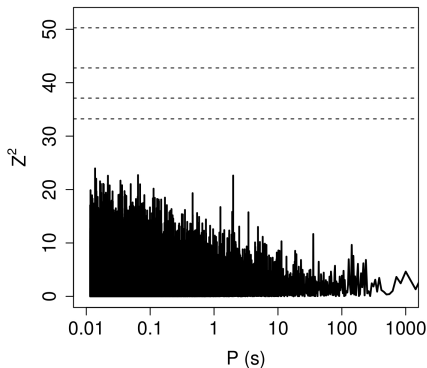
- ▶  $t_{\text{exp}} \sim 85$  ks
- ▶ 5000 to 6000 counts  
(optimal energy band, extraction region etc)
- ▶ pulsed fraction of 14% ( $Z^2 \sim 50$ )
- ▶ expected detection at  $5\sigma$   
(no blind search)
- ▶ fine-tuning to increase S/N
- ▶ second observation 2 yr apart

$$\dot{P} > 2.5 \times 10^{-16} \text{ s s}^{-1}; B_{\text{dip}} > 6-7 \times 10^{10} \text{ G } (2\sigma)$$

# Results of timing analysis

**P = 19 ms not confirmed – no significant signal**

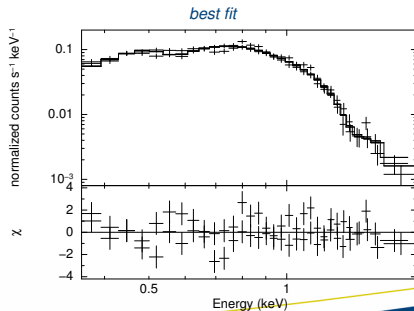
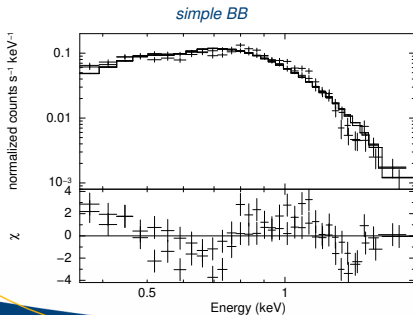
- ❶ New data with similar S/N ratio as in AO9
- ❷ Extensive searches 2 Hz around the detected periodicity
- ❸ Blind search (full frequency range) with best parameters as found for AO9 data



Upper limit:  $p_f \sim 12\% (2\sigma)$ ;  $P = 0.0114 - 10000$  s

# Spectrum of a faint XDINS

- 1 Soft and thermal spectrum; features around 0.6–0.7 keV and 1.35 keV
- 2 Power law tail below 1% of source luminosity
- 3 Best model with  $kT \sim 130$  eV + Gaussian absorption at 1.35 keV  
(first feature likely related to local oxygen overabundance in Carina)



## Fast spin not confirmed in AO11 data

- ▶ spurious/statistical artifact?
- ▶ transient phenomenon? change in pulsed fraction?

## Spectrally consistent with a more distant XDINS

- ▶ thermal spectrum with absorption feature(s)
- ▶ no magnetospheric emission
- ▶ true spin of few seconds, as for the M7?
- ▶ pulsed fraction below the sensitivity of our data?

## Presence in Carina constrains the neutron star age

- ▶ evidence for past supernova (e.g. Townsley et al. 2011)
- ▶ association with runaway star (Ngoumou et al. 2013)

# Thank you!

## *Acknowledgments to my collaborators*

Christian Motch, Roberto Turolla, Axel Schwope,  
Sergei Popov and Aldo Treves