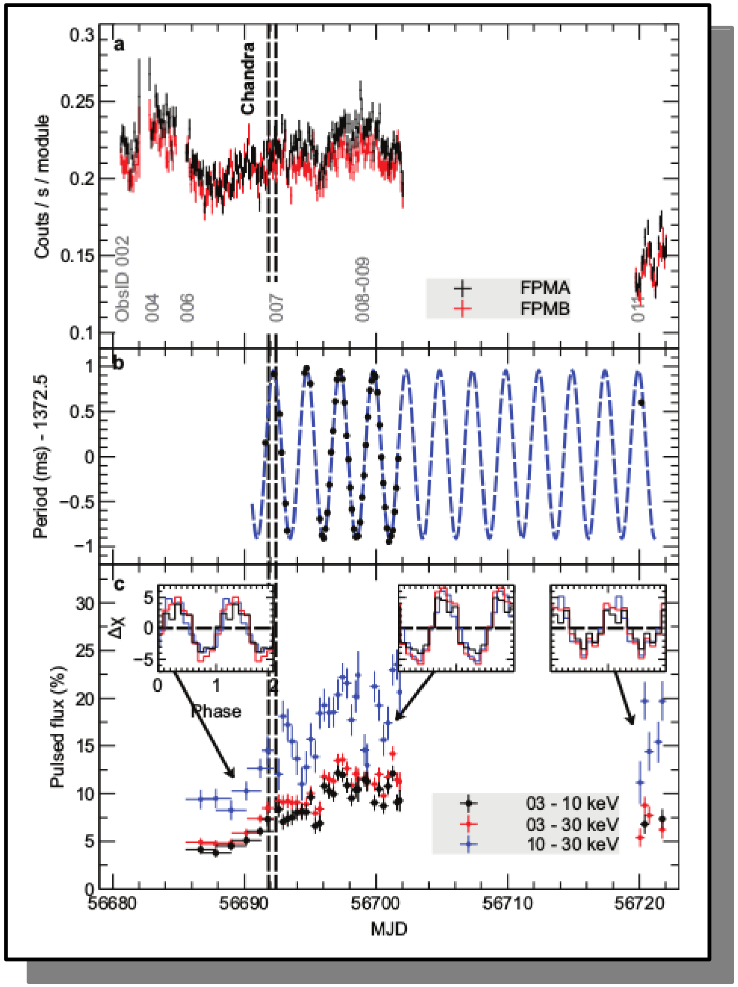
Mining the beat of ULXs

GianLuca Israel (INAF AO of Rome)

on behalf of the EXTraS team

Outline:

- EXTraS in a nutshell
- XMM timing analysis
- The results of the ULX timing survey
- Implications/The future



Bachetti+14

EXTraS in a nutshell

EXTraS = Exploring the Transient x-ray Sky (fp7 funded project; 3Yr 2014-2016; PI Andrea DeLuca - INAF).
Focused on the EPIC 3XMM catalog (~500,000 sources)

WP2: search and characterization of source aperiodic variability

EXTraS WP3: search and characterization for coherent signals

WP4: search for faint and/or short transients

WP5: long term variability (more pointings and/or slew data)

WP6: Multiwavelength characterization and classification

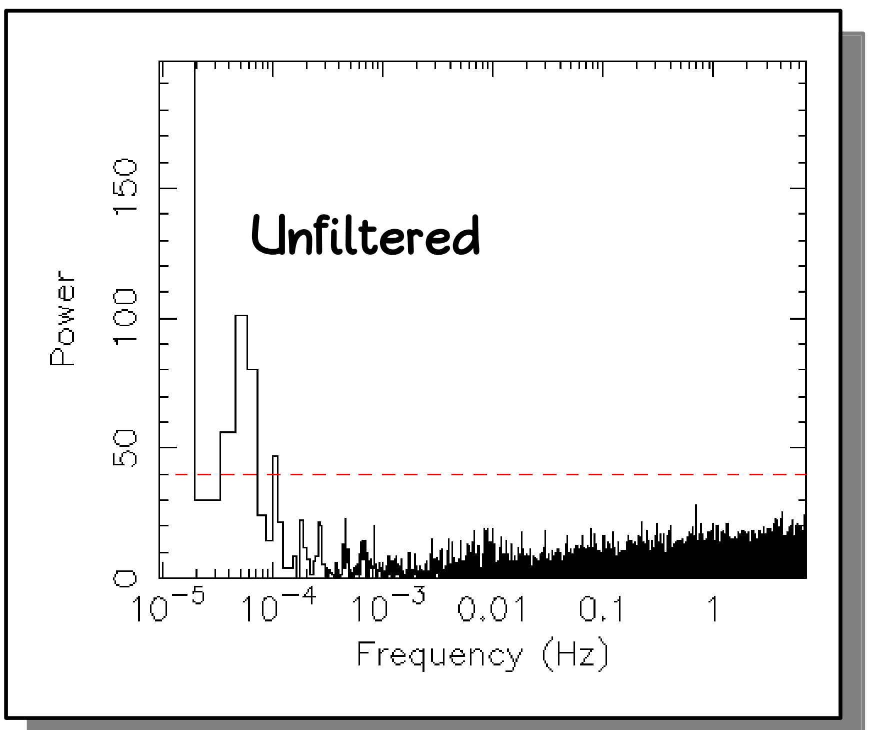
Results (catalogs/metadata) will be released to the community as part of the 3XMM catalog (sping 2017).

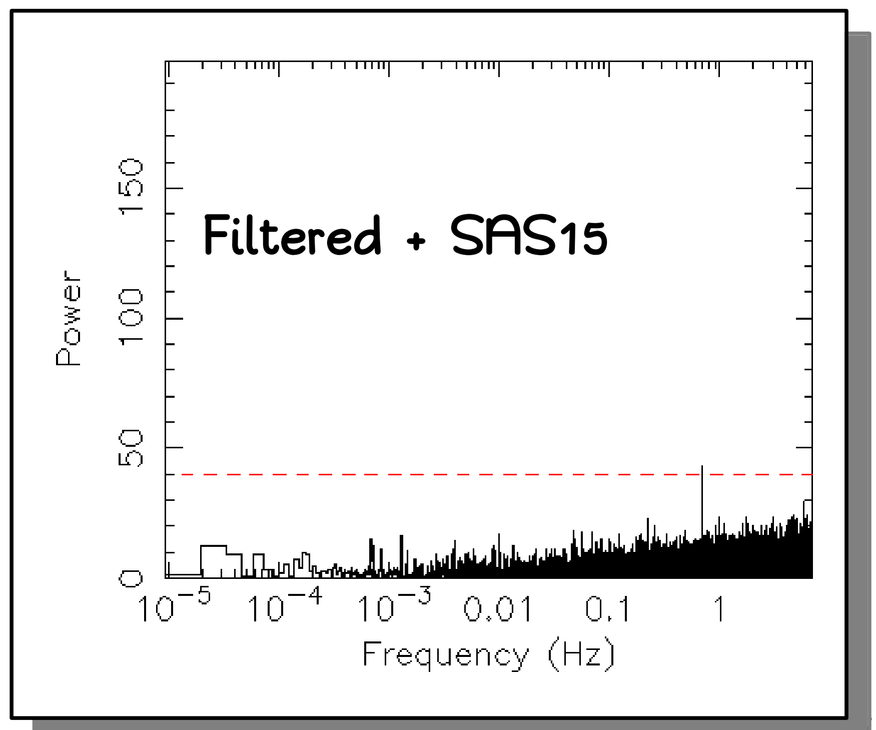
INAF IUSS imati University of Leicester MPE ECAP Erlangen Centre for Astroparticle Physics

and the search of signals

Timing analysis: Mainly based on FFTs with an ad hoc detection algorithm which takes into account additional non-Poissonian noise component in power spectra.

Increased sensitivity search both at low and high frenquencies for PN in counting mode (BKG flares)

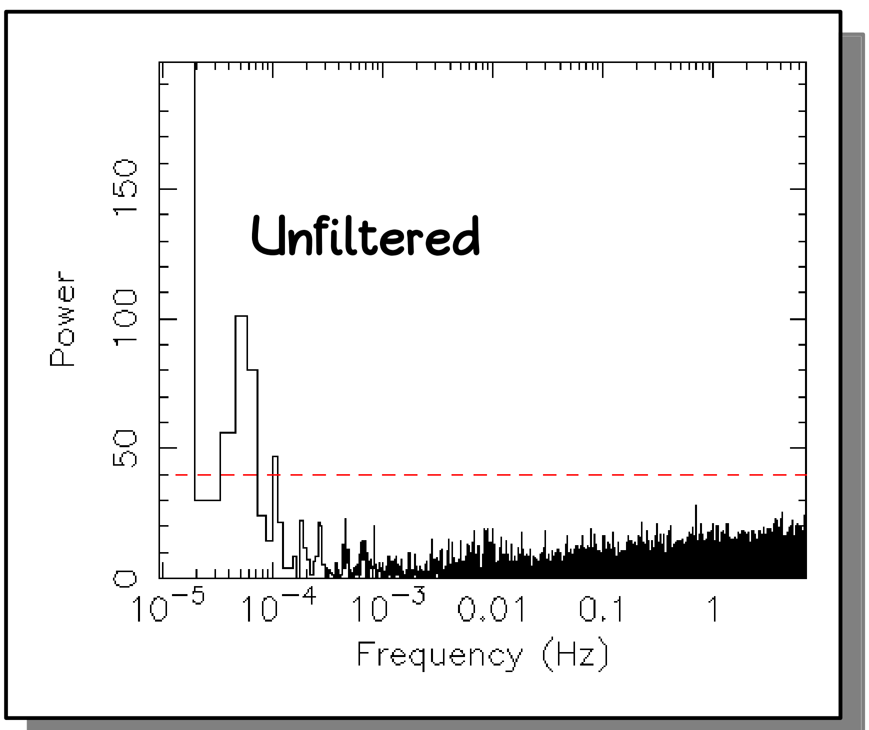


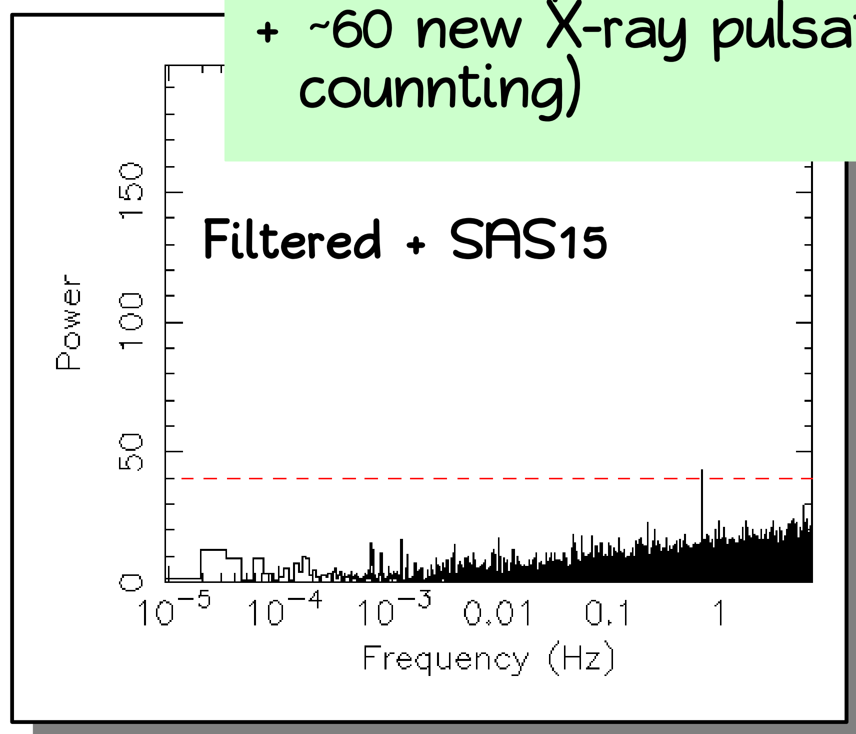


exTraS WP3 and the search of signals

Timing issue: PN data in counting mode (>30 ct/s in imaging in a CCD) due to background or source flares affected by wrong GTIs and event time shift. Approx 25% of total PN data affected. Solved in SAS15.

WP3 in numbers:
+ 15 years of public data
+ ~10,000 datasets
+ ~500,000 times series (TSs)
+ ~290,000 TSs with >50 photons searched for signals
+ >5 milions FFTs carried out (different searching modes)
+ ~100,000 peaks
+ ~60 new X-ray pulsators (still counnting)



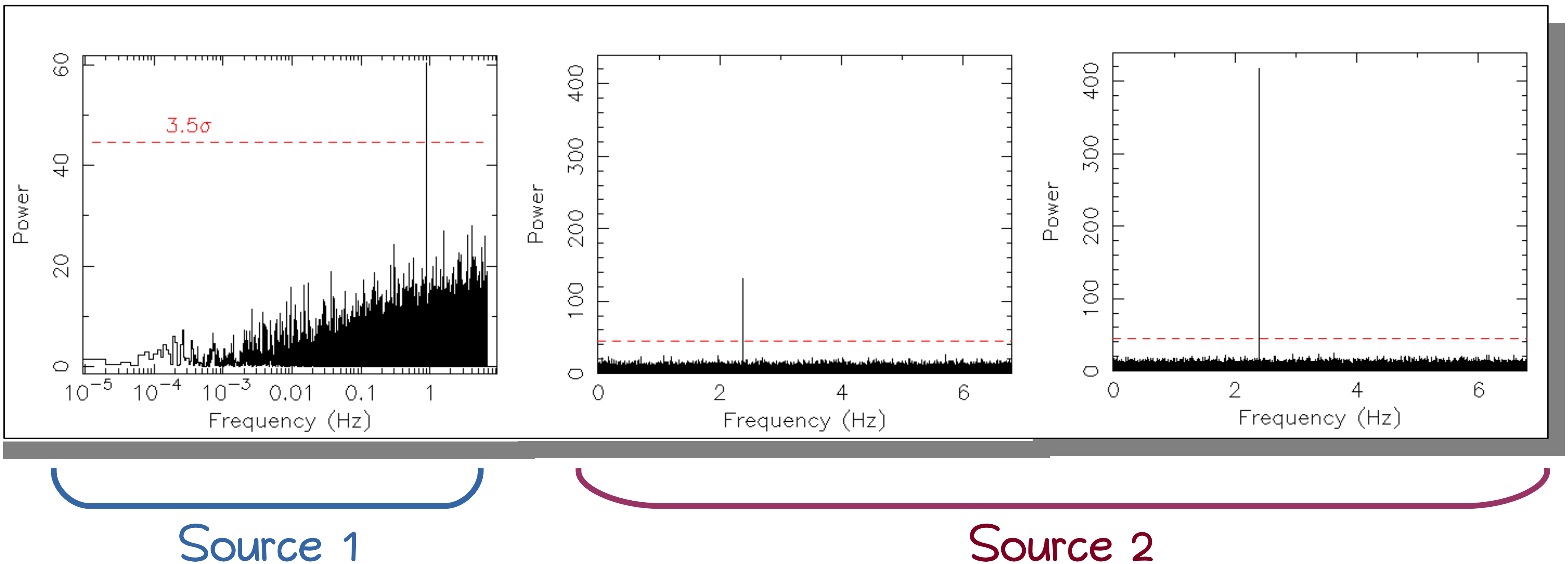


and the ULXs

About 500 XMM datasets including the position of cataloged or suspected ULX.

We simply checked all the peaks detected by our pipeline in the ~500 datasets

We found 3 significant peaks from two different sources (both known ULXs).



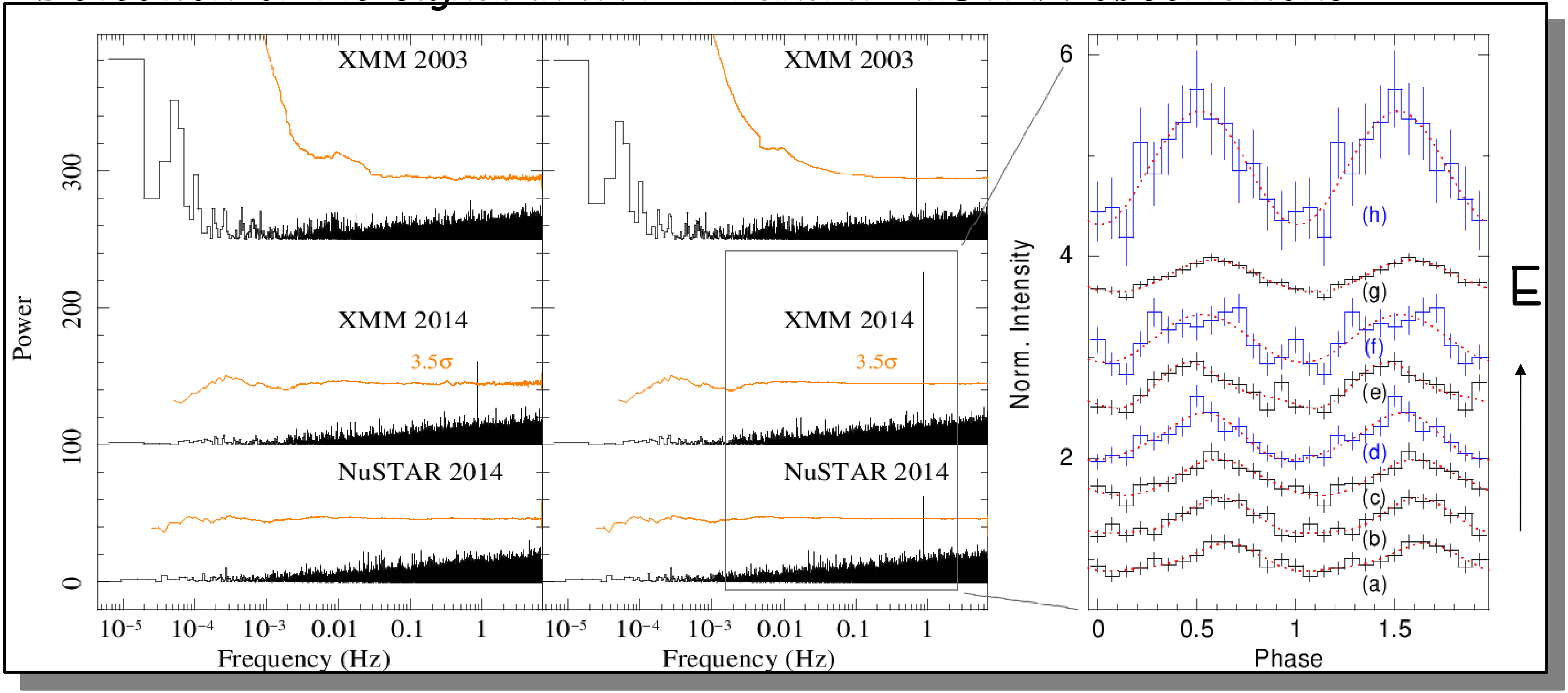
Source 1

7 XMM pointings (6 source detection)+5 NuSTAR pointings (3 detection)

XMM data reveals a rather large Pdot of several -10^{-9} s/s

We applied an accelerated search on the 12 XMM+NuSTAR pointings

Detection of the signal in 2 XMM and 2 NuSTAR observations



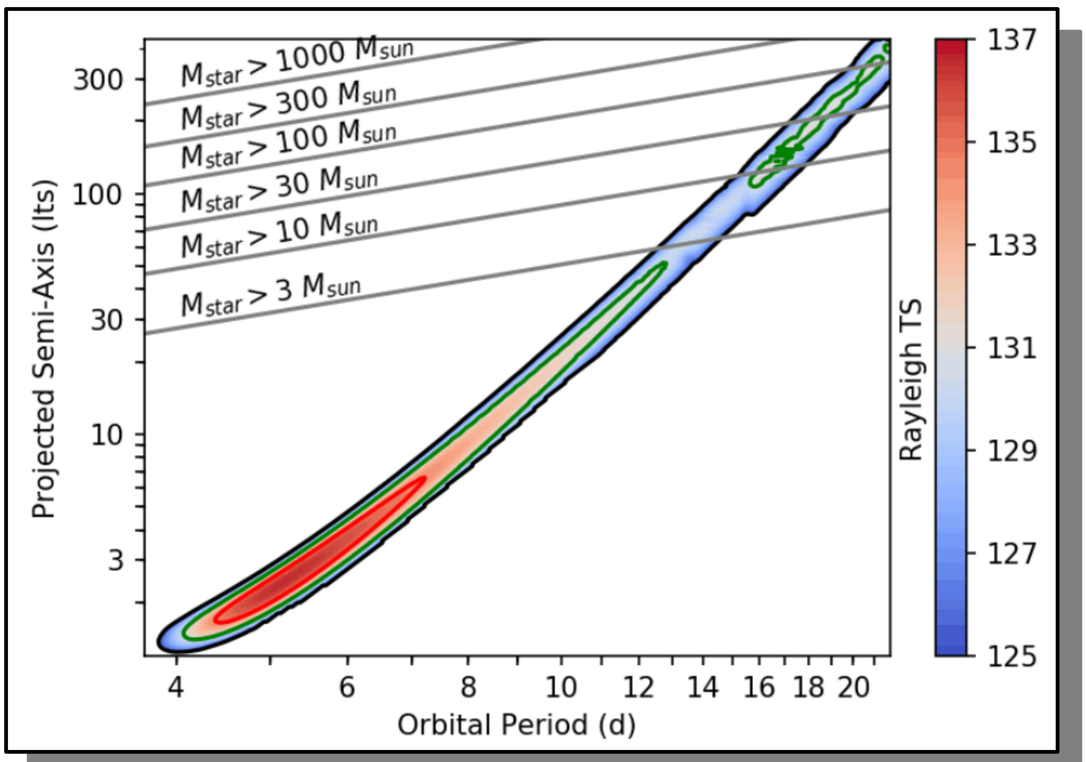
Israel+16a

Source 1: Parameters

Start Date	2003 Feb. 28	2014 Jul. 09	2014 Jul. 09	2014 Jul. 12
Mission	*XMM–Newton*	*NuSTAR*	*XMM–Newton*	*NuSTAR*
Epoch (MJD)	52690.9	56848.0	56848.2	56851.5
P (s)	1.427579(3)	1.137403(1)	1.137316(2)	1.136041(1)
$\dot{P}$ (s s^{-1})^a $\times 10^{-9}$	-9.6(7)	-5.2(1)	-5.0(4)	-4.7(1)

Psec =-8.1(1)x10-10 s/s   P/Pdot ~ 40 yr !!!

A factor of 10 lower than the local Pdot, suggesting an orbital contribution



Based on the 2014 NuSTAR obs. and a likelihood analysis a most probable Porb is inferred (circular orbit assumed)

Porb=5.3[+2.0,-0.9] days (1σ)

Longer orbits are NOT excluded though a 100Msun companion implies Porb<20days

Israel+16a

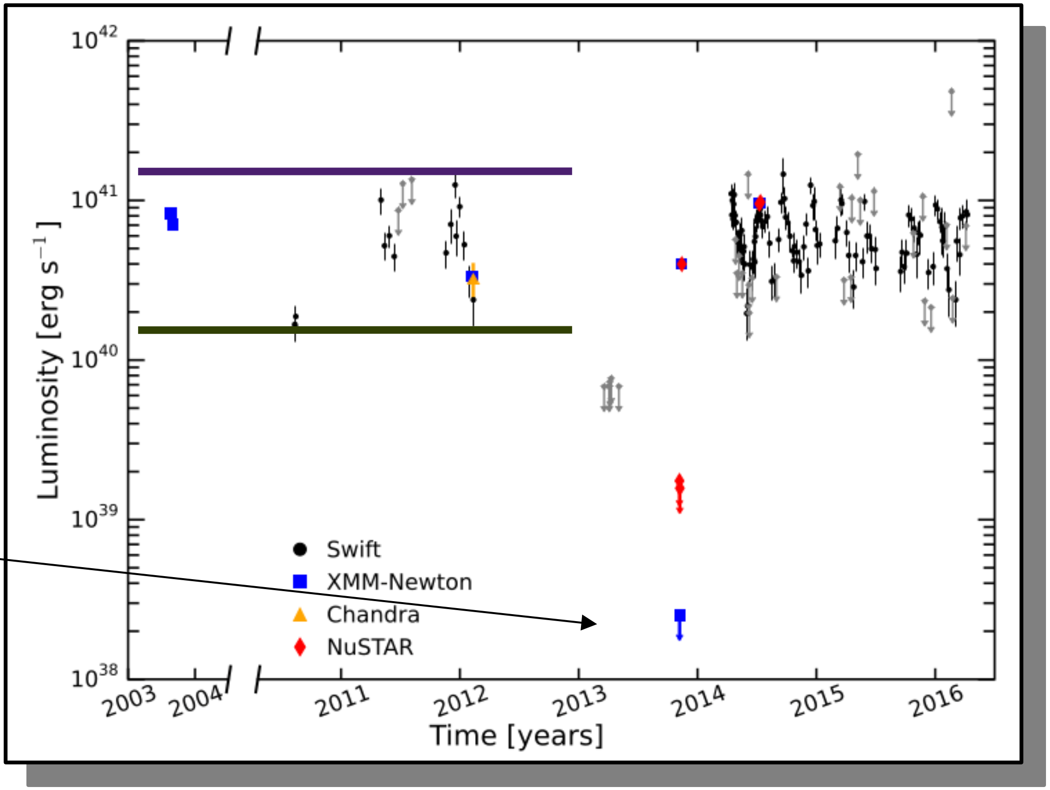
Source 1= NGC 5907 X-1

For a distance of 17.1Mpc the (isotropic) luminosity range is

Lx ~ 1.5×10^{40} and ~1.6×10^{41} erg/s

With an upper limit of

3×10^{38} erg/s



Israel+16a

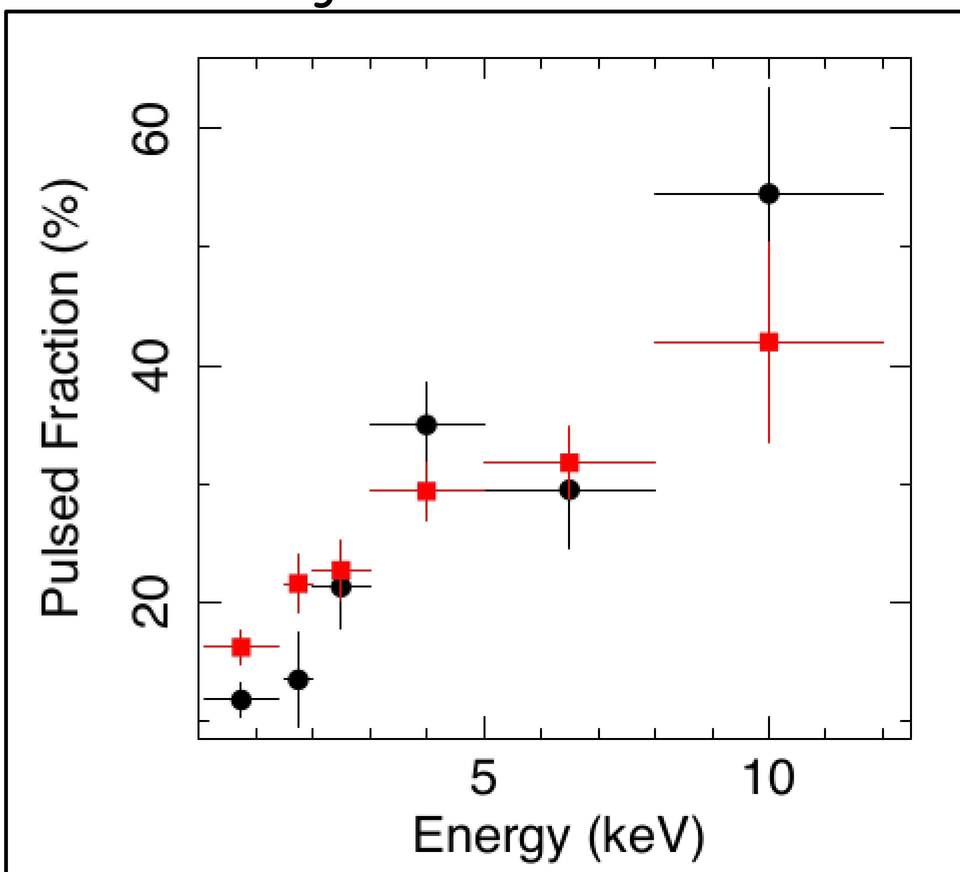
NGC5907 X-1 is therefore the most luminous and distant X-ray pulsar ever detected.

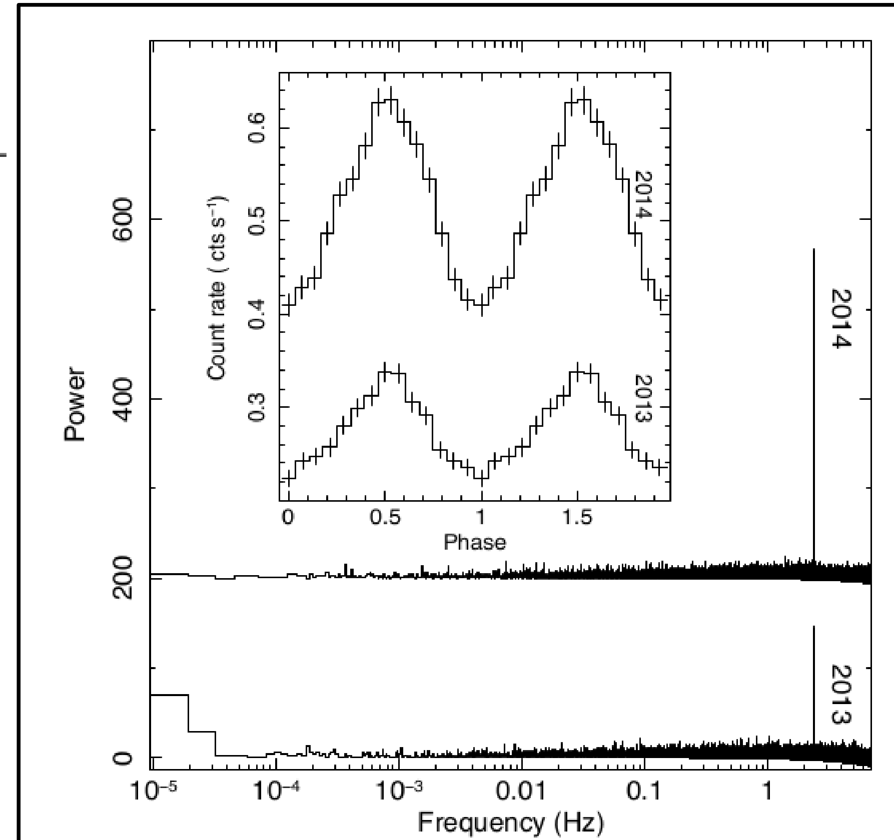
The peak luminosity is ~500 times the Eddington luminosity

Source 2= Parameters

Epoch (MJD TDB)	56621.0	57001.0
P (s)	0.4197119(2)	0.4183891(1)
ν (Hz)	2.382586(1)	2.3901207(6)
$\lvert\dot{P}\rvert$ (10^{-11} s s^{-1})	<10	<5
$\dot{P}_{sec}$ (10^{-11} s s^{-1})	−4.031(4)	
Pulsed fraction (%)[a]	18(1)	22(1)

P/Pdot~320 yr





Almost sinusoidal pulse shape with energy-dependent pulsed fraction: 10-50%

Israel+16b

Source 2= NGC 7793 P13

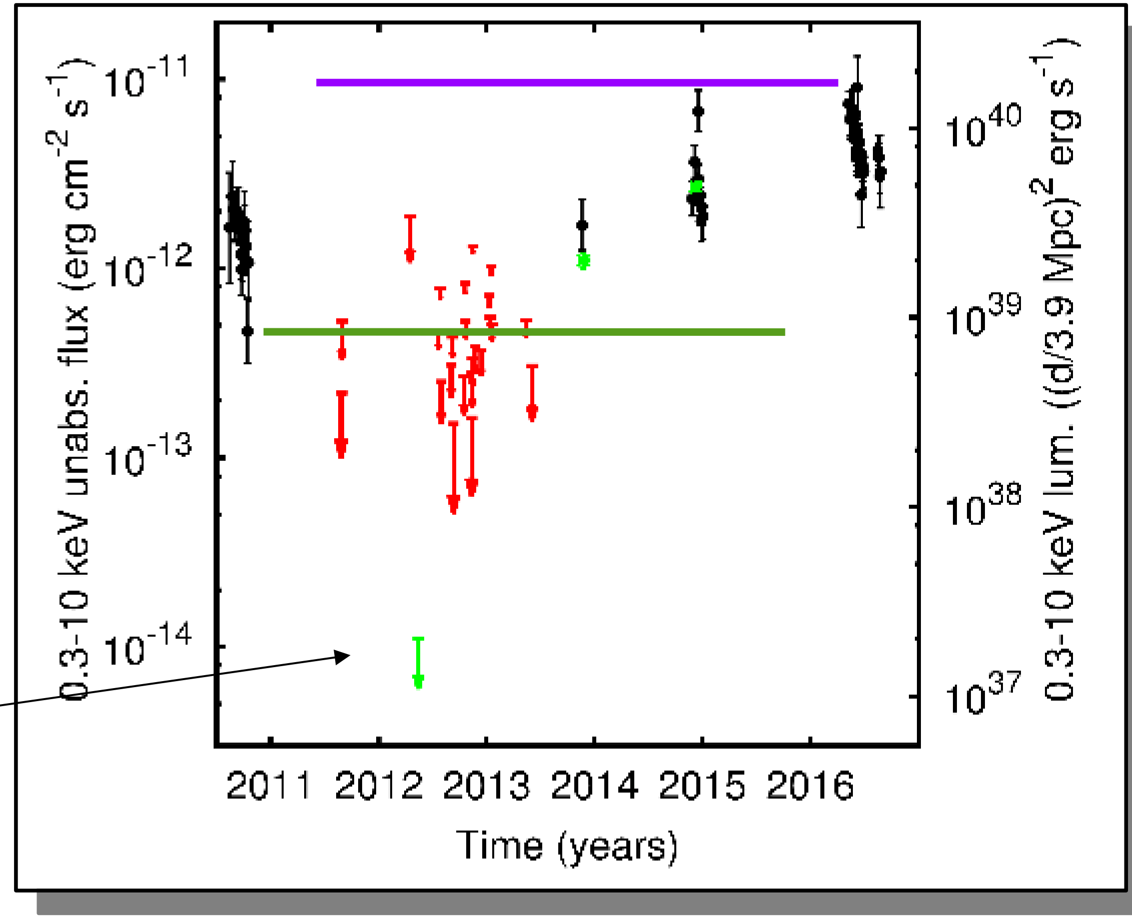
Known Porb: 64 days (Motch et al. 2014)
~20Msun B9Ia companion

For a distance of 3.9 Mpc the Isotropic Lx range is

Lx ~ 9×10^{39} and ~1.6×10^{40} erg/s

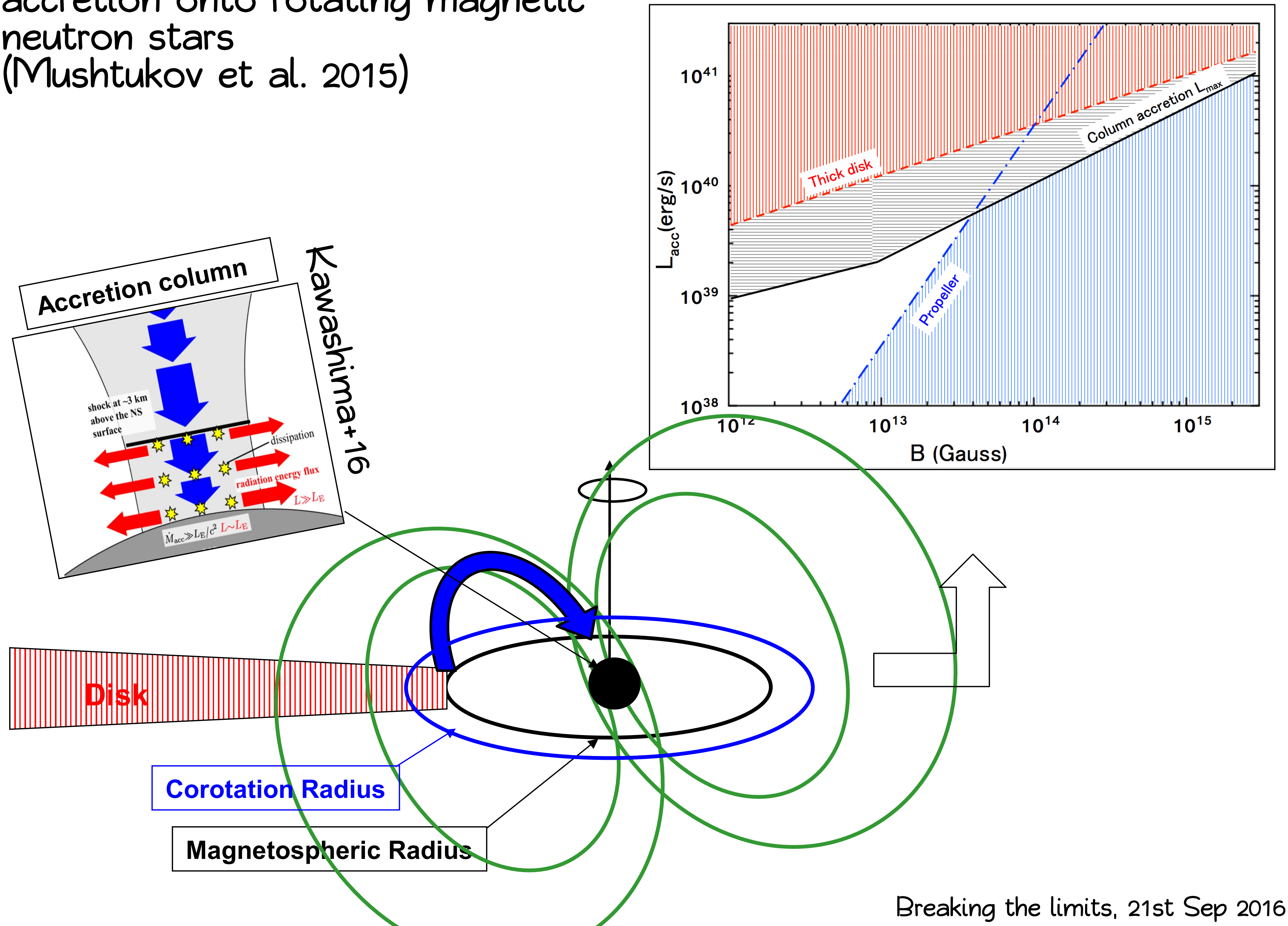
With an upper limit of

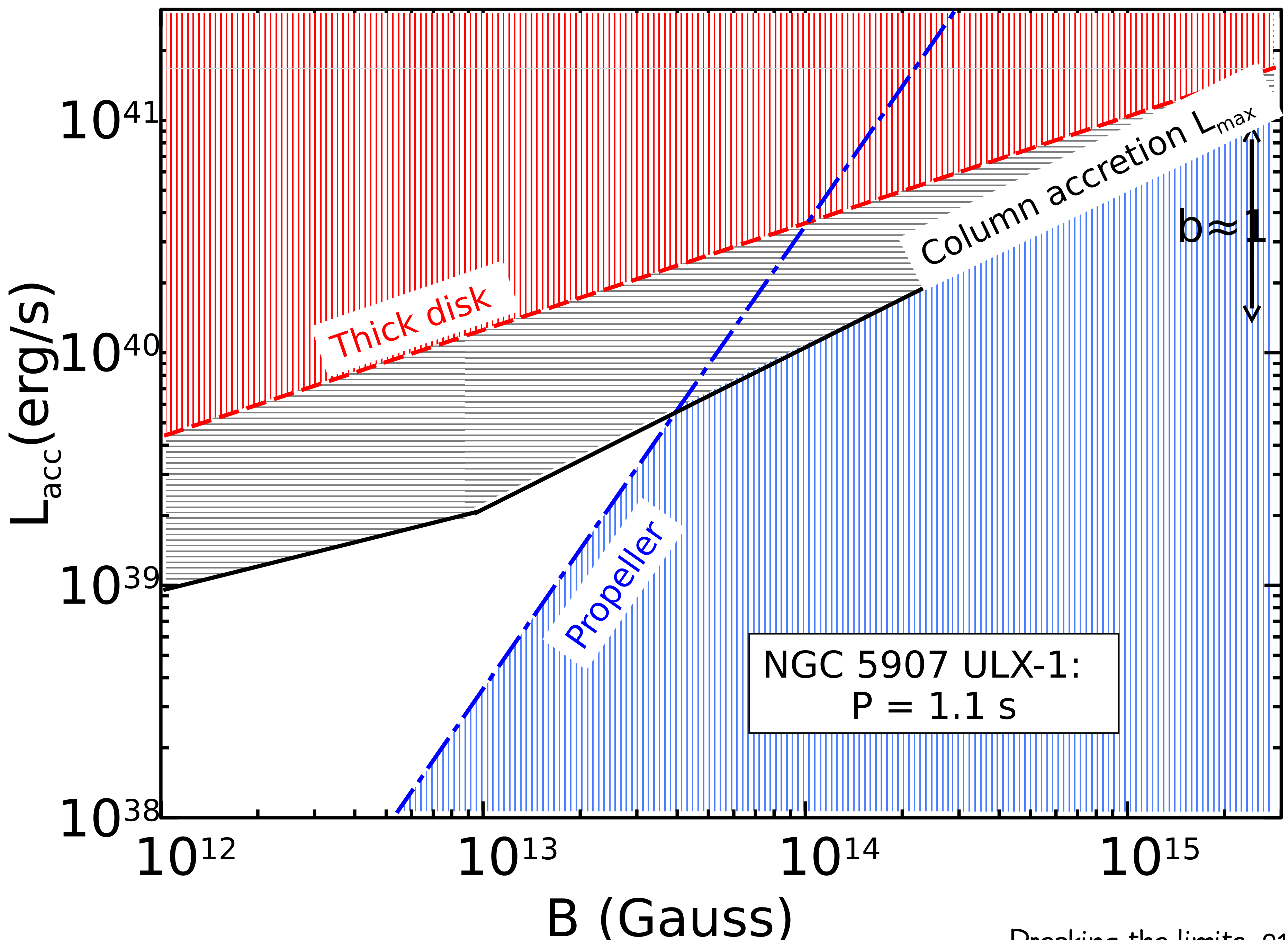
3×10^{37} erg/s



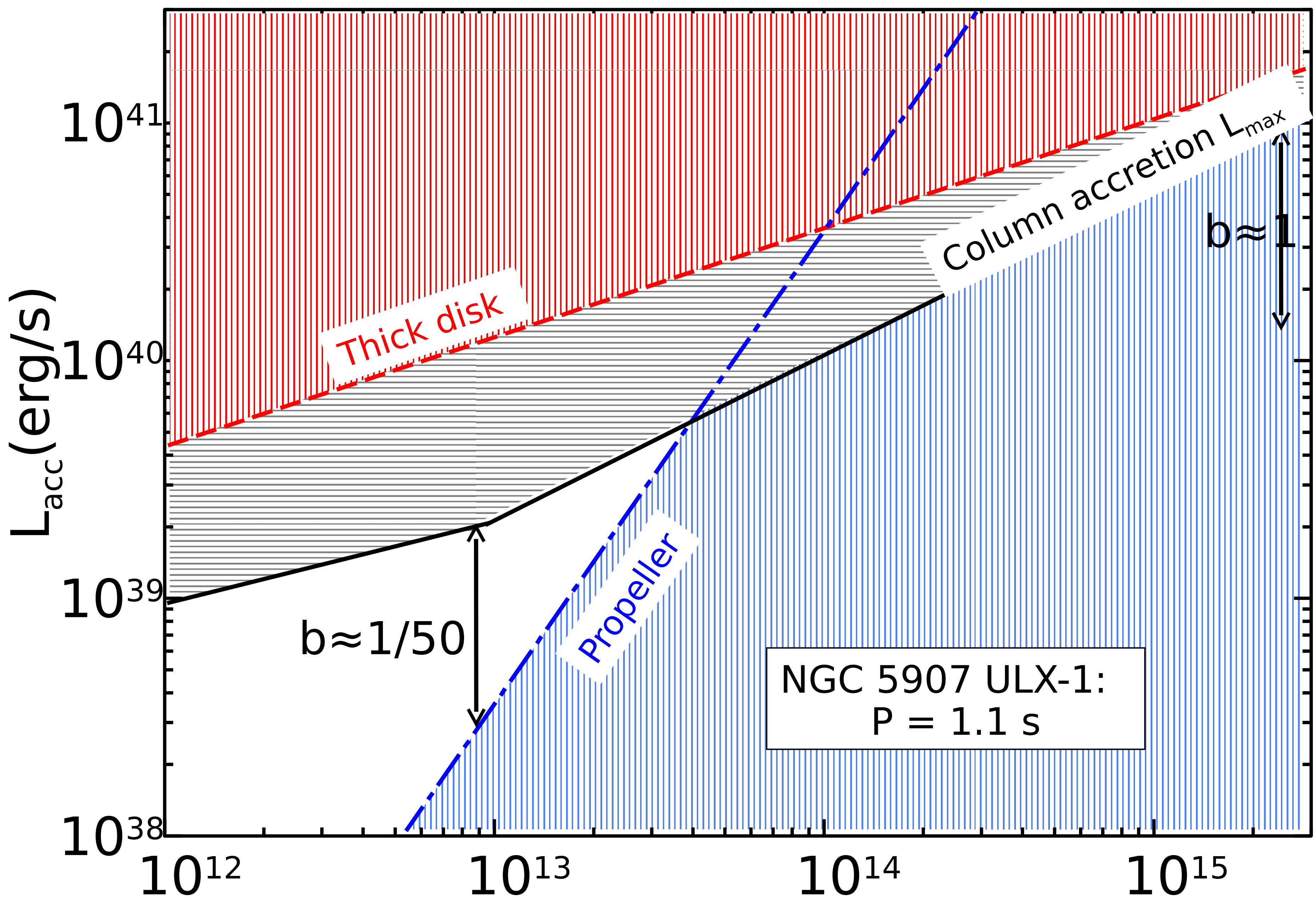
Israel+16b

Conditions for superEddington accretion onto rotating magnetic neutron stars (Mushtukov et al. 2015)

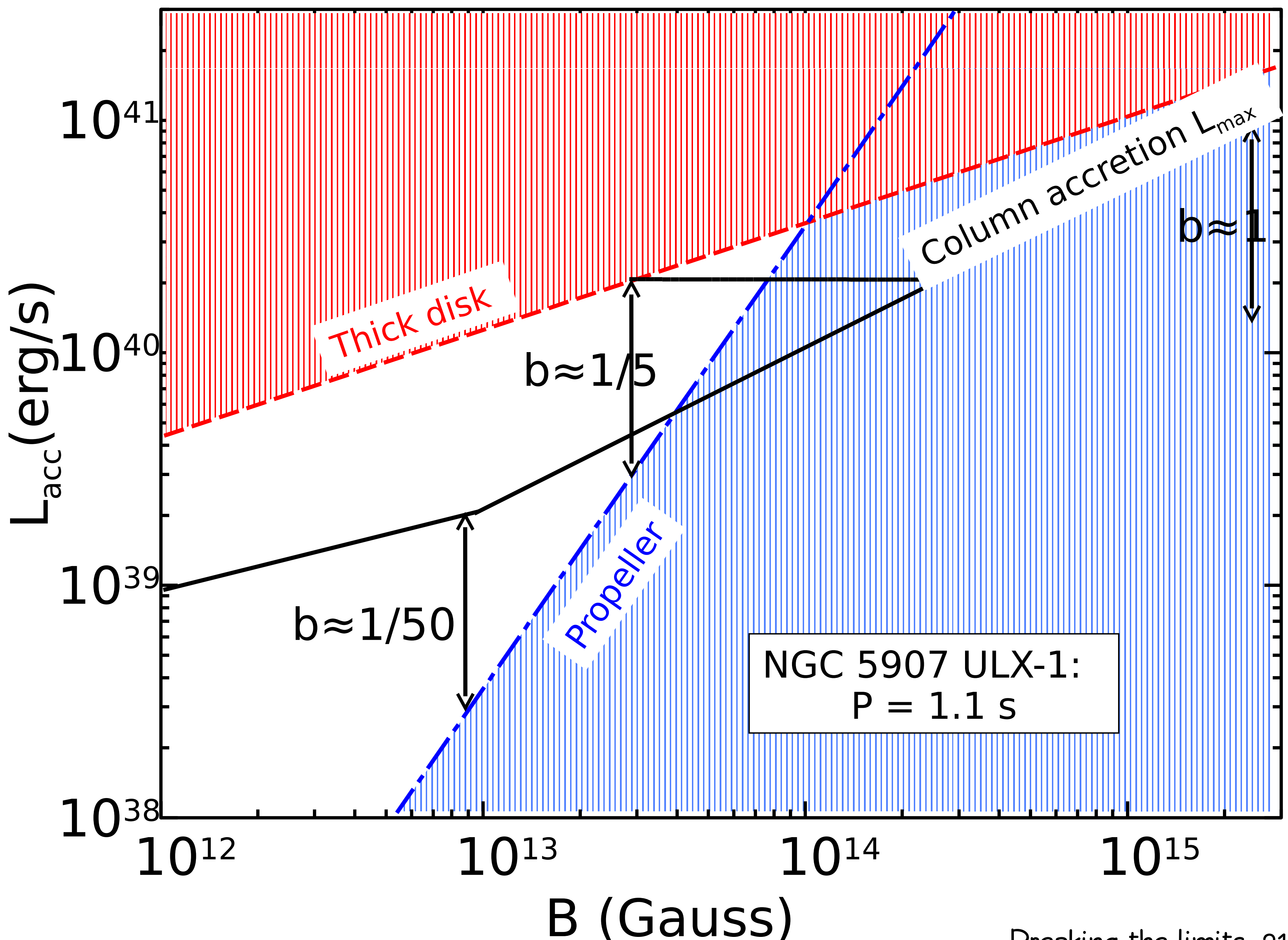




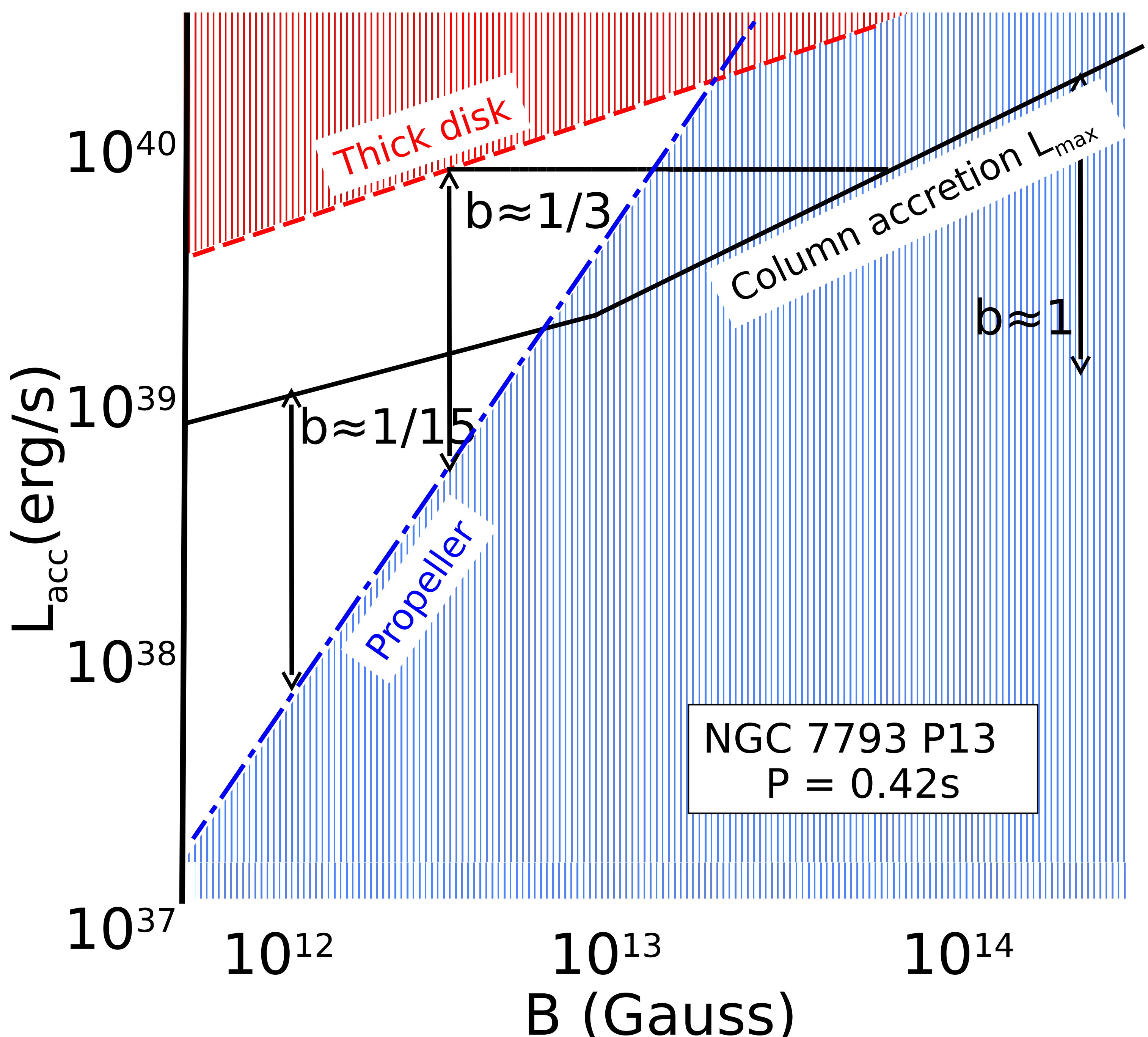
10^{41}
10^{40}
10^{39}
10^{38}
L_{acc}(erg/s)
10^{12}
10^{13}
10^{14}
10^{15}
B (Gauss)
Thick disk
Column accretion L_{max}
$b \approx 1$
Propeller
NGC 5907 ULX-1:
P = 1.1 s



Thick disk
Column accretion L_{max}
$b\approx1$
$b\approx1/50$
Propeller
NGC 5907 ULX-1:
P = 1.1 s
10^{41}
10^{40}
10^{39}
10^{38}
L_{acc}(erg/s)
10^{12}
10^{13}
10^{14}
10^{15}
B (Gauss)



Thick disk
Column accretion L_{max}
b≈1
b≈1/5
b≈1/50
Propeller
NGC 5907 ULX-1:
P = 1.1 s
L_{acc}(erg/s)
10^{41}
10^{40}
10^{39}
10^{38}
10^{12}
10^{13}
10^{14}
10^{15}
B (Gauss)



Thick disk
10^{40}
b≈1/3
Column accretion L_{max}
b≈1
L_{acc}(erg/s)
10^{39}
b≈1/15
Propeller
10^{38}
NGC 7793 P13
P = 0.42s
10^{37}
10^{12}
10^{13}
10^{14}
B (Gauss)

Some implications/Conclusions

- Even extreme ULXs, like NGC5907 X-1, can hosts accreting NS
- Spectral classification is not an unambiguous way to classify ULXs: both NGC 5907 X-1 and NGC7793 P13 have typical ULX spectra, especially NGC 5907 X-1.
- The large "local" Pdot, the orbital effects, the pulse intermittance make difficult the detection of these pulsars (check in your own data).
- Pulsed fractions increases with Energy making hard X-ray imaging an important tool
- Pulsars with luminosity of hundreds times the Eddington one implies we have problems with the current models of accretion on NS, even assuming beaming.