Neutron star metamorphosis

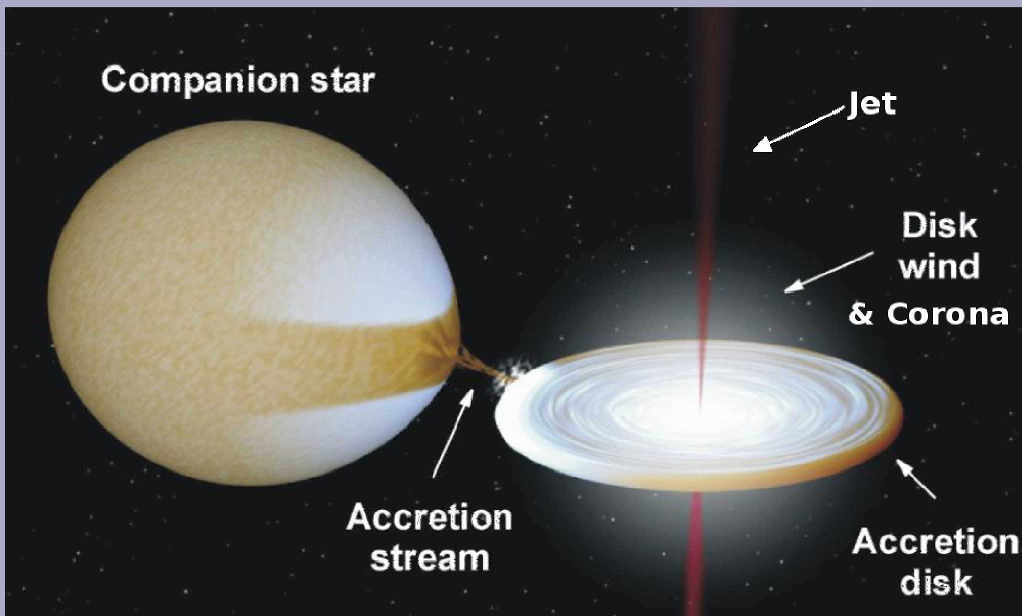
from sub-luminous accretion to rotation-powered quiescence

Manu Linares – IAC, Spain

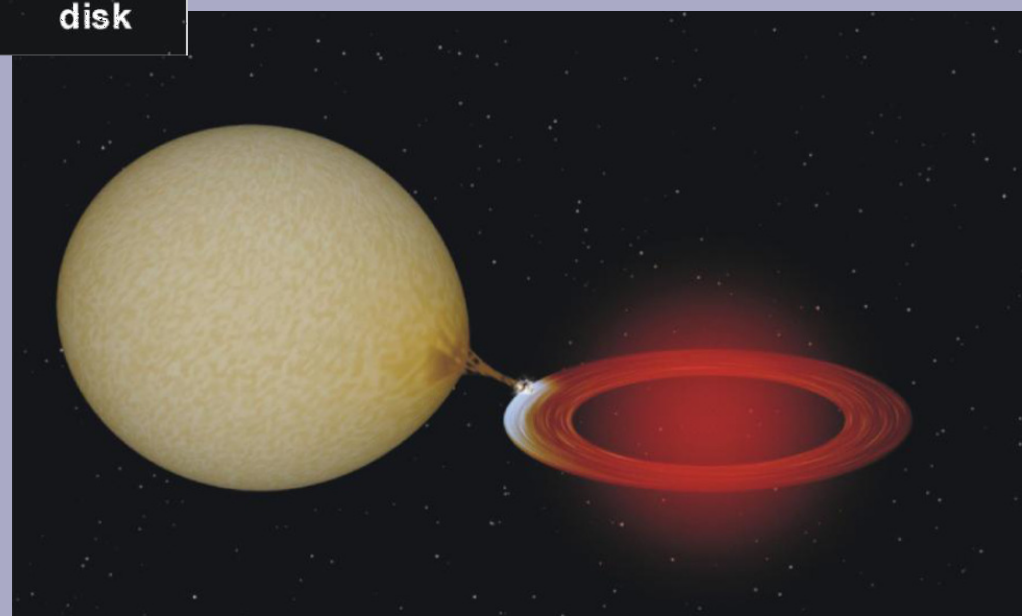
Firenze NS-2014, March 25

With: Bahramian, Heinke, Wijnands, Patruno, Altamirano, Homan, Bogdanov, Pooley

Low-Mass X-ray Binaries

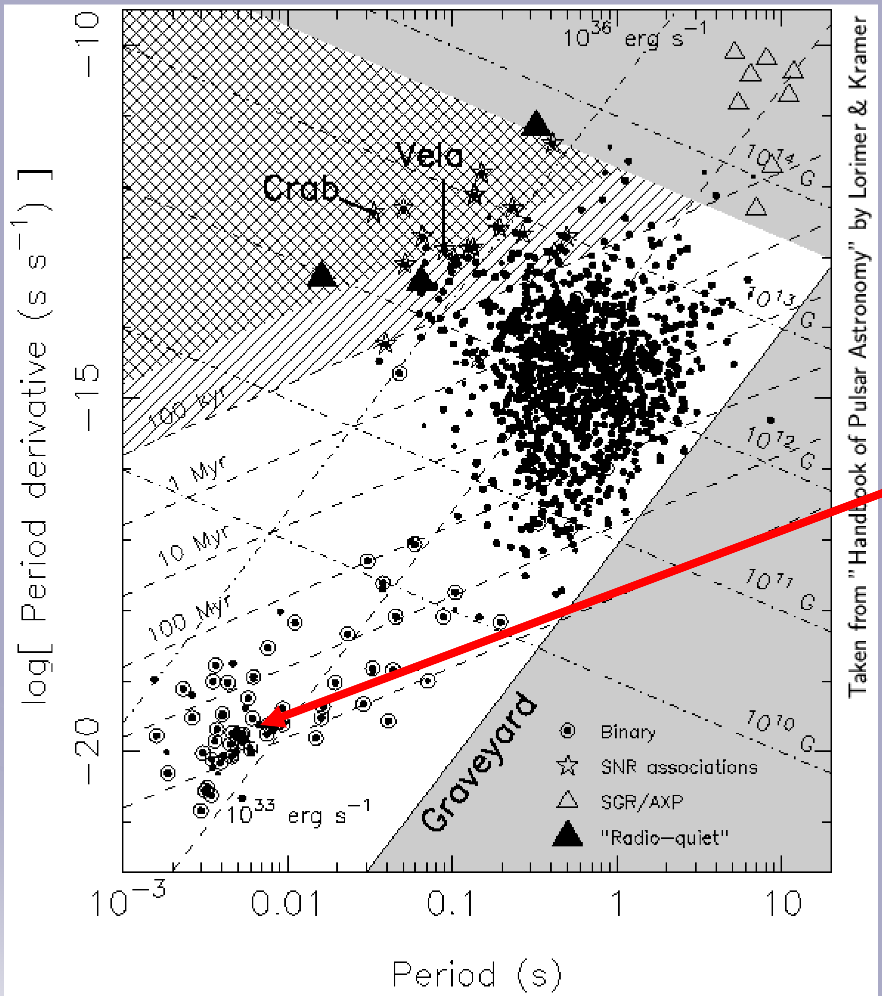


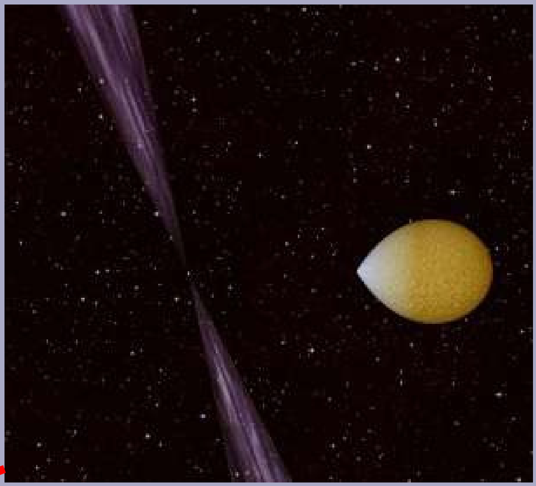
ON (outburst):
$L_X \sim 10^{36}$ - 10^{38} erg/s



OFF (quiescence):
$L_X \sim 10^{30}$ - 10^{33} erg/s

Millisecond radio pulsars





$L_X \sim 10^{29}$ - 10^{32} erg/s

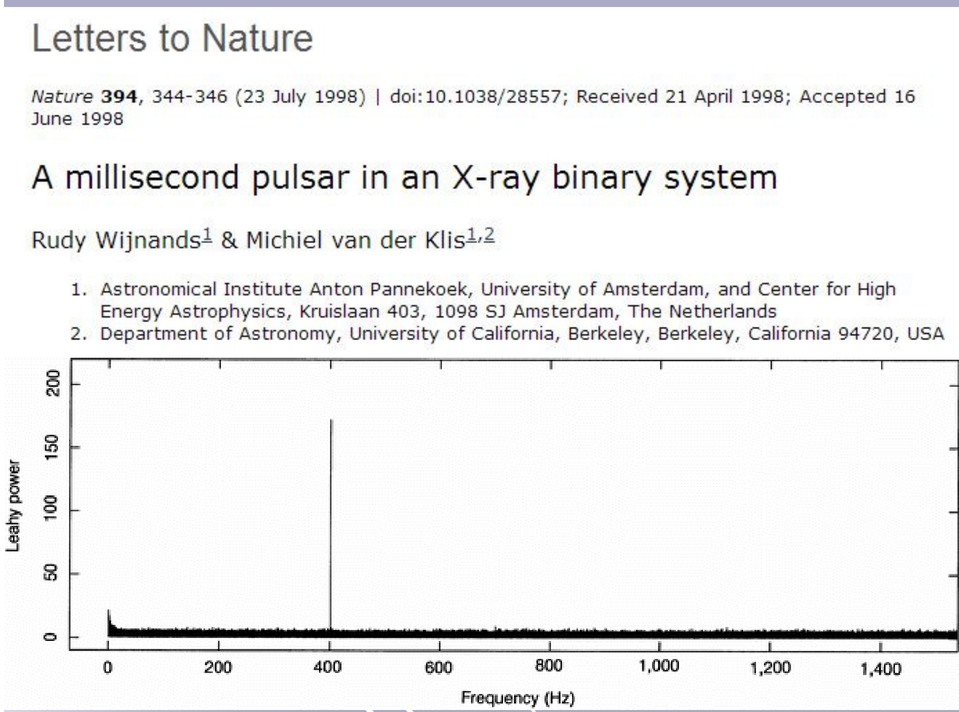
Soon after MRPs were discovered (Backer+82) it was proposed that NS are spun up through accretion in LMXBs: "the recycling scenario" (Alpar+82)

Are NS-LMXBs progenitors of MRPs?

LMXB-MRP "missing links"

In 1998: SAX J1808.4-3658
Wijnands & van der Klis

In 2009: PSR J1023+0038
Archibald et al.

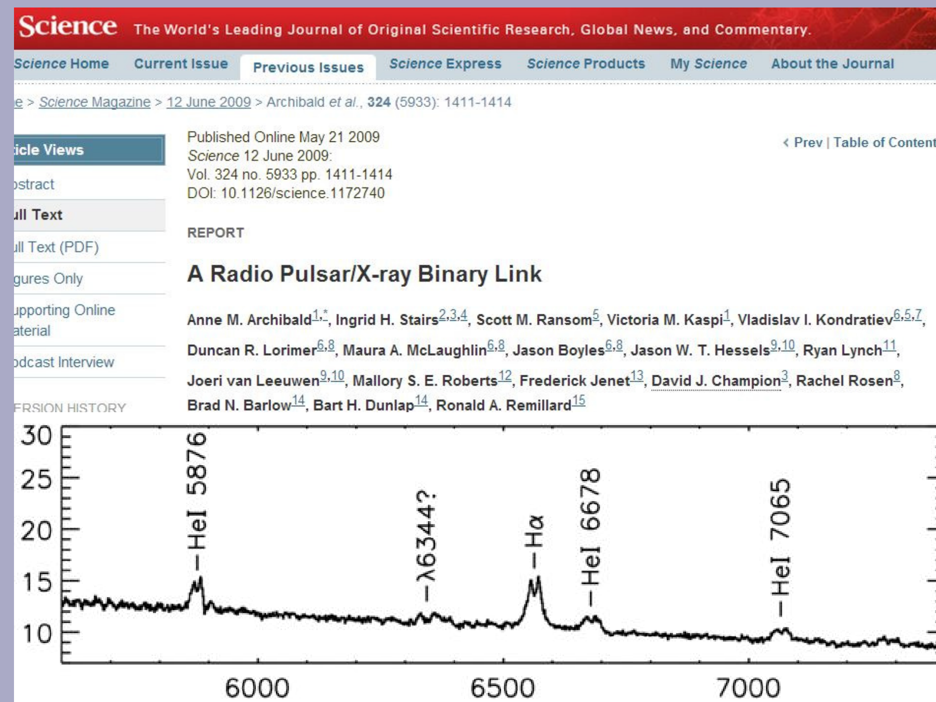

Letters to Nature

Nature **394**, 344-346 (23 July 1998) | doi:10.1038/28557; Received 21 April 1998; Accepted 16 June 1998

A millisecond pulsar in an X-ray binary system

Rudy Wijnands[1] & Michiel van der Klis[1,2]

1. Astronomical Institute Anton Pannekoek, University of Amsterdam, and Center for High Energy Astrophysics, Kruislaan 403, 1098 SJ Amsterdam, The Netherlands
2. Department of Astronomy, University of California, Berkeley, Berkeley, California 94720, USA


Science The World's Leading Journal of Original Scientific Research, Global News, and Commentary.

Science Home | Current Issue | Previous Issues | Science Express | Science Products | My Science | About the Journal

e > Science Magazine > 12 June 2009 > Archibald et al., 324 (5933): 1411-1414

icle Views
ostract
ull Text
ull Text (PDF)
gures Only
upporting Online aterial
odcast Interview
ERSION HISTORY

Published Online May 21 2009
Science 12 June 2009:
Vol. 324 no. 5933 pp. 1411-1414
DOI: 10.1126/science.1172740

‹ Prev | Table of Contents

REPORT

A Radio Pulsar/X-ray Binary Link

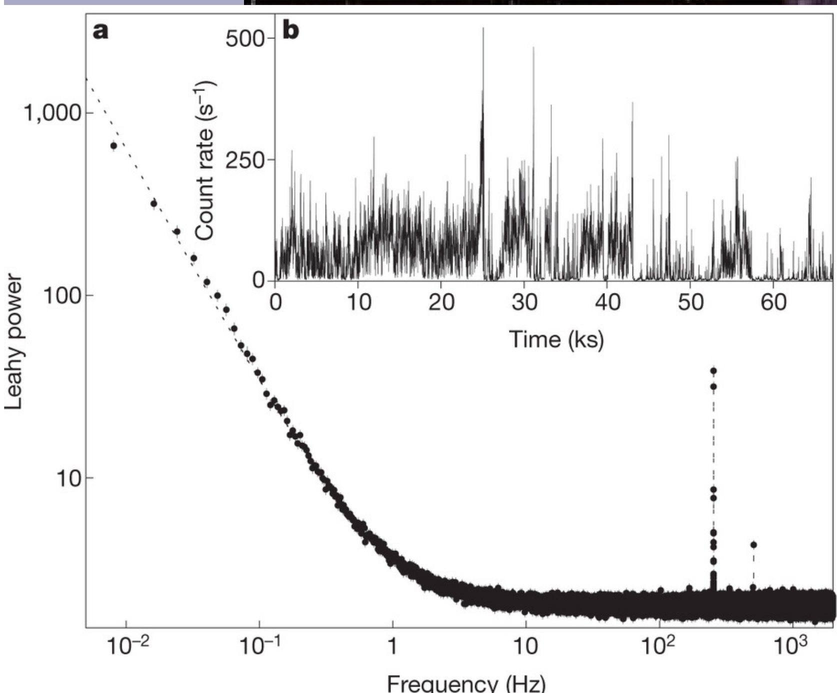
Anne M. Archibald[1,*], Ingrid H. Stairs[2,3,4], Scott M. Ransom[5], Victoria M. Kaspi[1], Vladislav I. Kondratiev[6,5,7], Duncan R. Lorimer[6,8], Maura A. McLaughlin[6,8], Jason Boyles[6,8], Jason W. T. Hessels[9,10], Ryan Lynch[11], Joeri van Leeuwen[9,10], Mallory S. E. Roberts[12], Frederick Jenet[13], David J. Champion[3], Rachel Rosen[8], Brad N. Barlow[14], Bart H. Dunlap[14], Ronald A. Remillard[15]

Yes, most NSs in LMXBs have ms spins! (Chakrabarty+03)

An MRP with an accretion disk back in 2001, and as we speak!
(Wang+09, Stappers+13, Patruno+13)

Accretion meets rotation in M28

Spectacular link between radio and X-ray millisecond pulsars



NATURE | LETTER

日本語要約

Swings between rotation and accretion power in a binary millisecond pulsar

A. Papitto, C. Ferrigno, E. Bozzo, N. Rea, L. Pavan, L. Burderi, M. Burgay, S. Campana, T. Di Salvo, M. Falanga, M. D. Filipović, P. C. C. Freire, J. W. T. Hessels, A. Possenti, S. M. Ransom, A. Riggio, P. Romano, J. M. Sarkissian, I. H. Stairs, L. Stella, D. F. Torres, M. H. Wieringa & G. F. Wong

PSR J1824-2452I (2006): = M28-I = IGR J18245–2452 (April 2013):

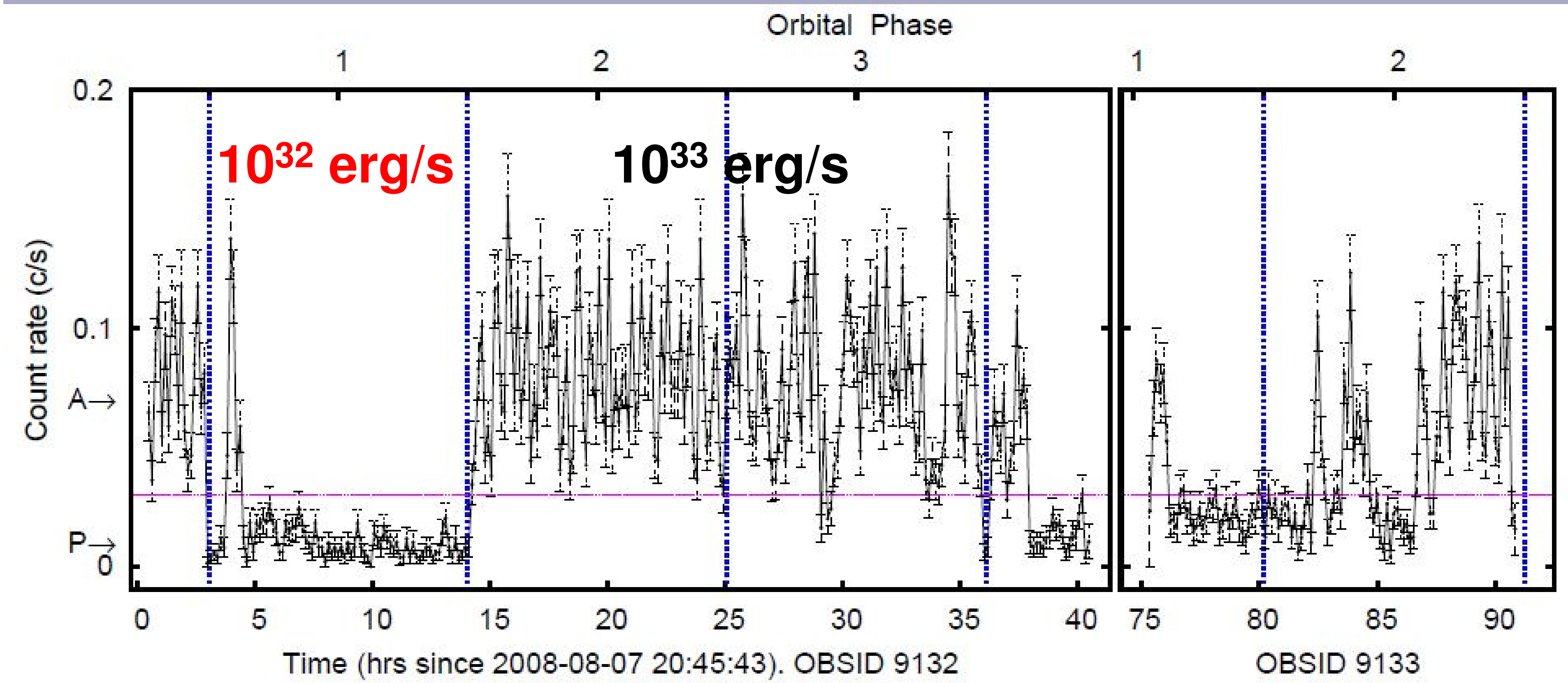
A 3.93185 ms *radio* pulsar in a 11.0258 hr orbit (Begin 2006).

A 3.93185 ms *X-ray* pulsar in a 11.0258 hr orbit (Papitto+2013).

→The same object and the first neutron star seen to "swing" between rotation- & accretion-powered pulsations!

M28-I: mode switching

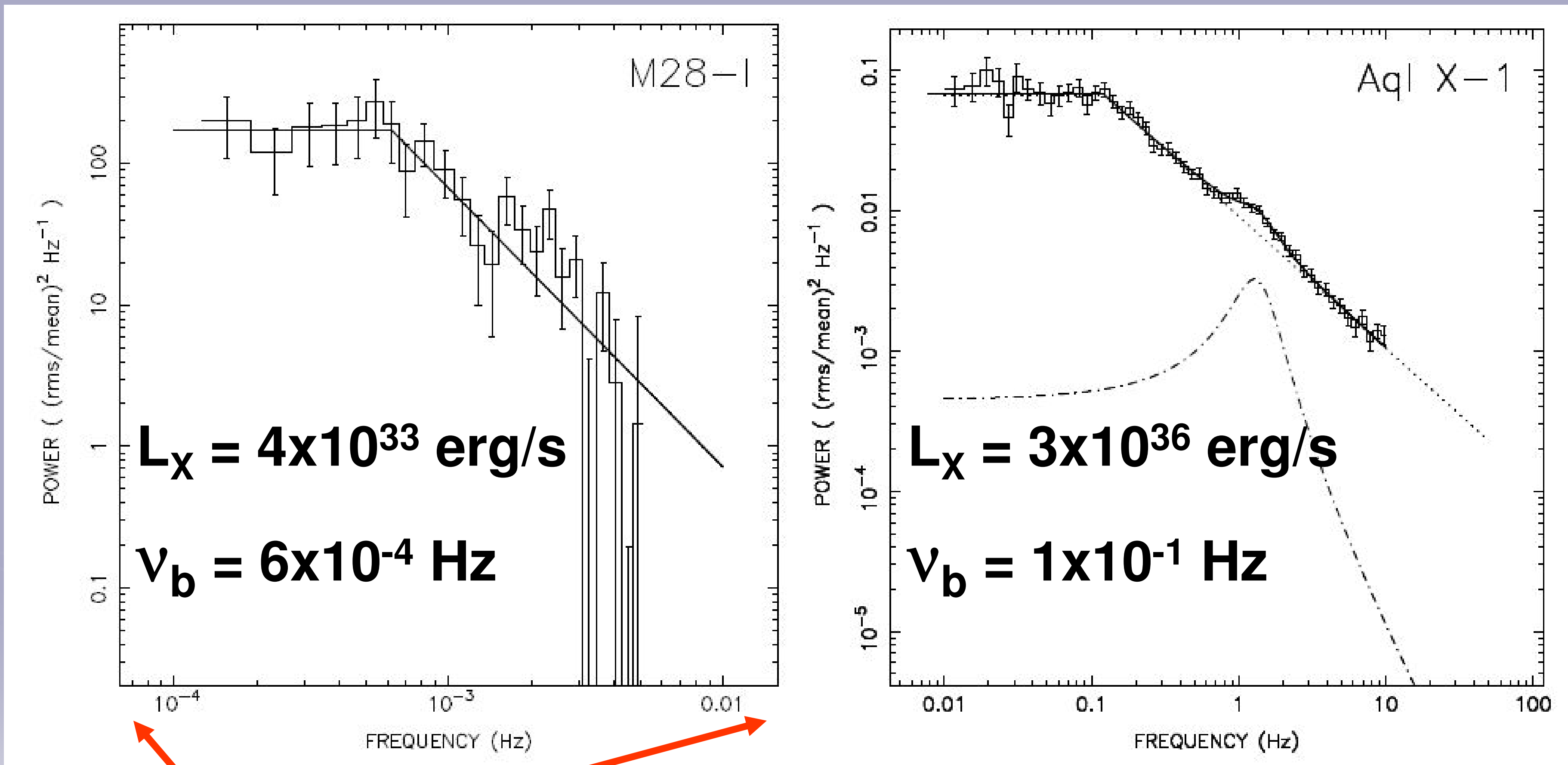
Variable quiescence

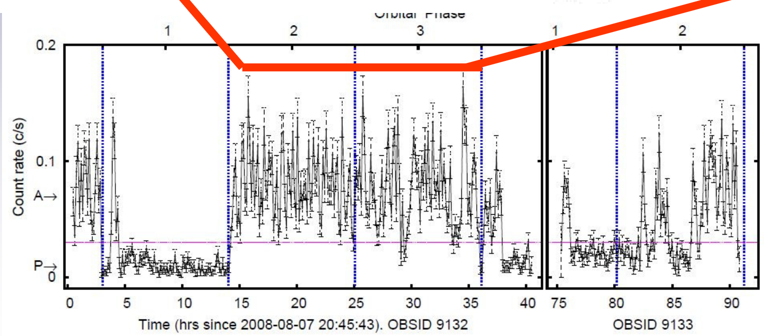


2008 Chandra observations of M28 show striking variability: fast (<500s) transitions between **disk-active** (L_X=3.9×10^{33} erg/s) and **disk-passive** (L_X=2.5×10^{32} erg/s) states, both non thermal (Γ=1.5)

M28-I: Sub-luminous Accretion

Accretion at its lowest: 10^{-5} Eddington

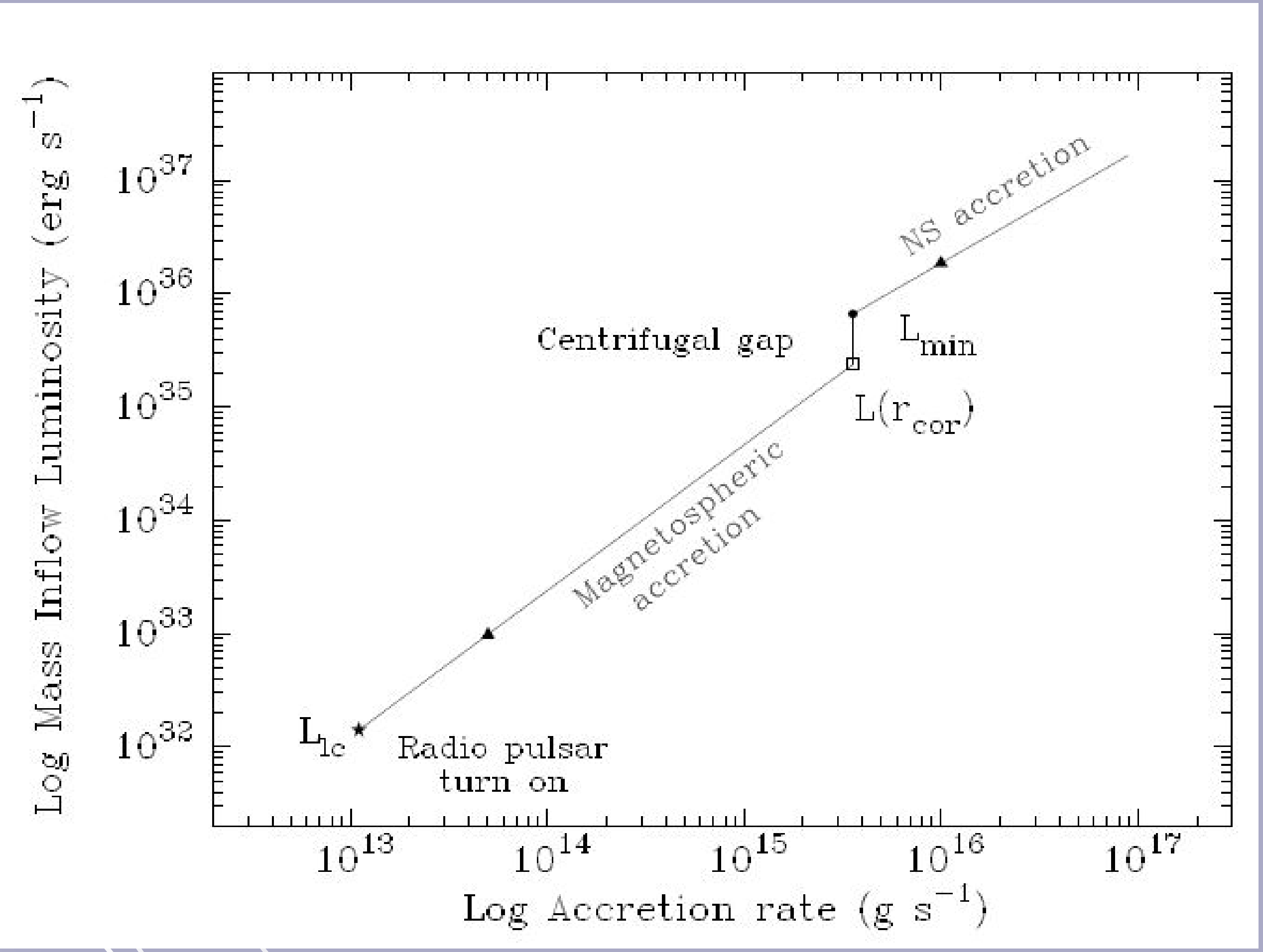




Disk-Active state has typical accretion variability: accretion rate fluctuations

Accretion vs. Rotation

Regimes of accretion onto a neutron star



(Campana et al. 1998; analytic estimates comparing pressures: ram/magnetic/radiation)

Different (non-thermal) emission regimes as mass accretion rate on the neutron star decreases (and the magnetospheric radius R_m increases)

Accretion vs. Rotation

When rotation power takes over

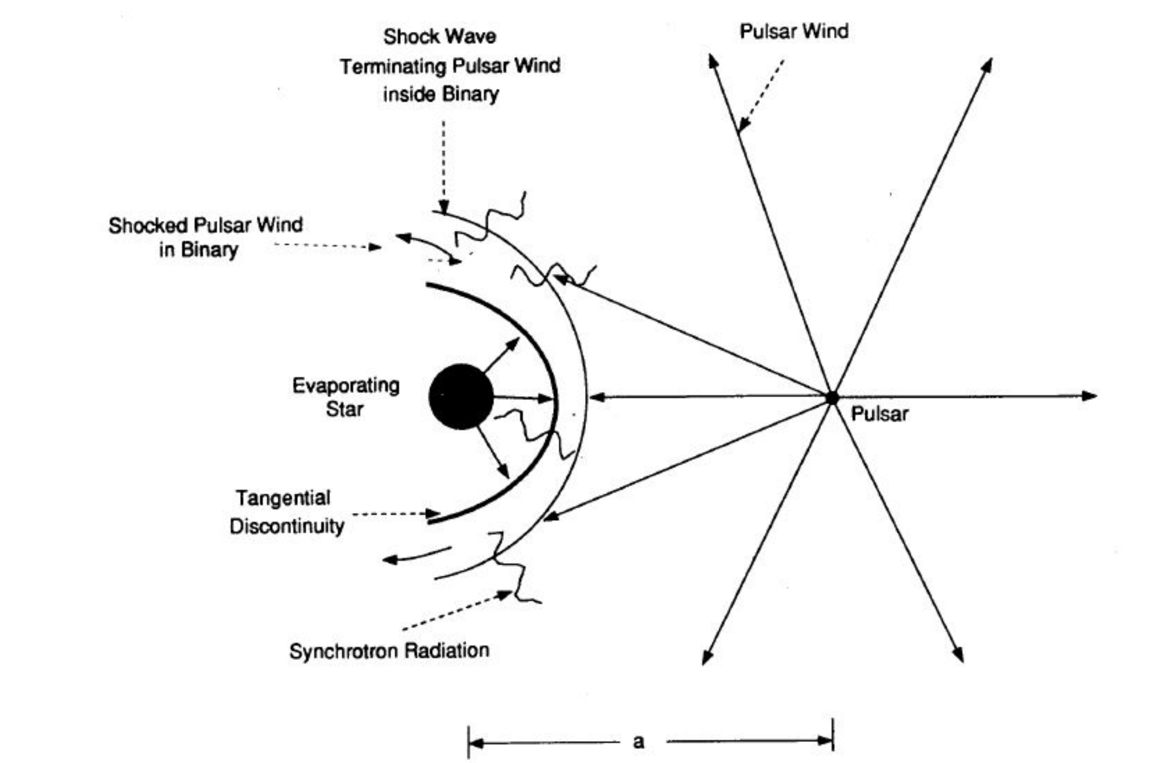
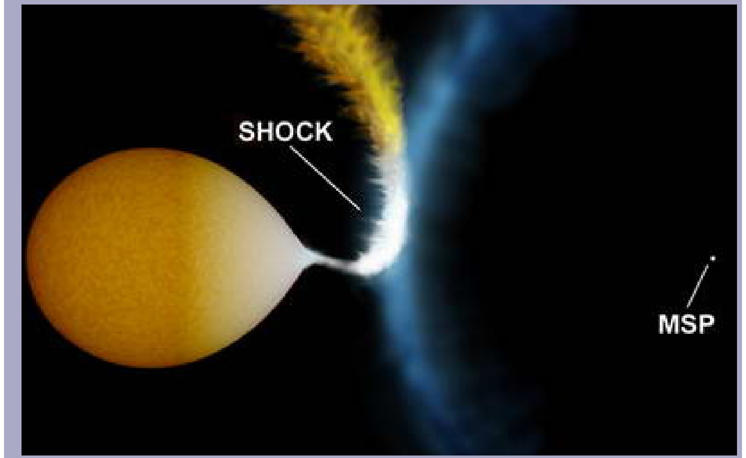


FIG. 2 Schematic representation of the shock geometry near the companion star.

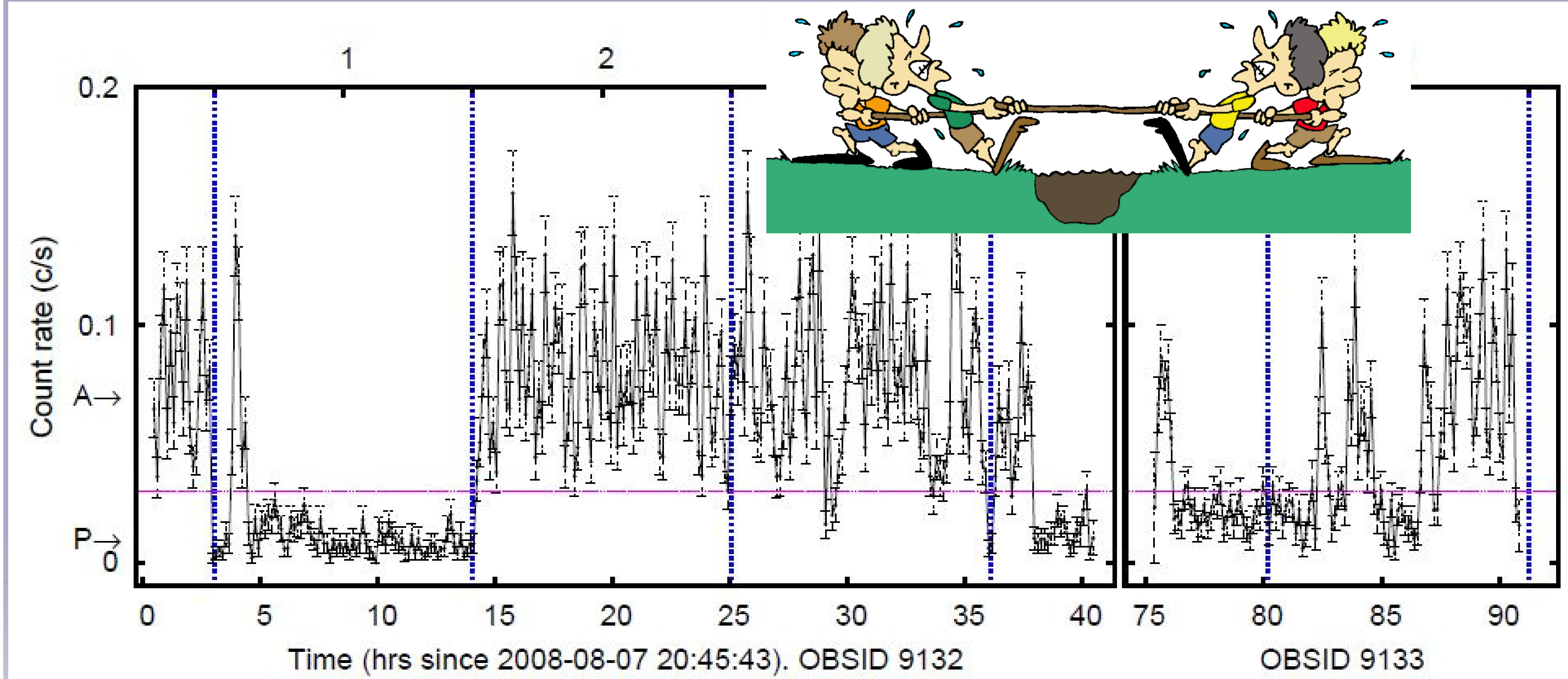


Arons & Tavani (1993)

At the lowest luminosities, when radio pulsar is ON (light cylinder empty), the pulsar wind is shocked by surrounding material (accretion flow / companion).

M28-I: Accretion vs. Rotation

At the boundary between accretion and rotation power



Balance (tug-of-war) between accretion flow and pulsar wind!

Light cylinder radius at **186 km**. For a 10^8 G magnetic field:

- Active states (L_{bol}=1.2×10^{34} erg/s → R_m~**130km**): magnetospheric accretion.
- Passive states (L_{bol}=1.7×10^{33} erg/s → R_m~**230 km**): pulsar wind shock.

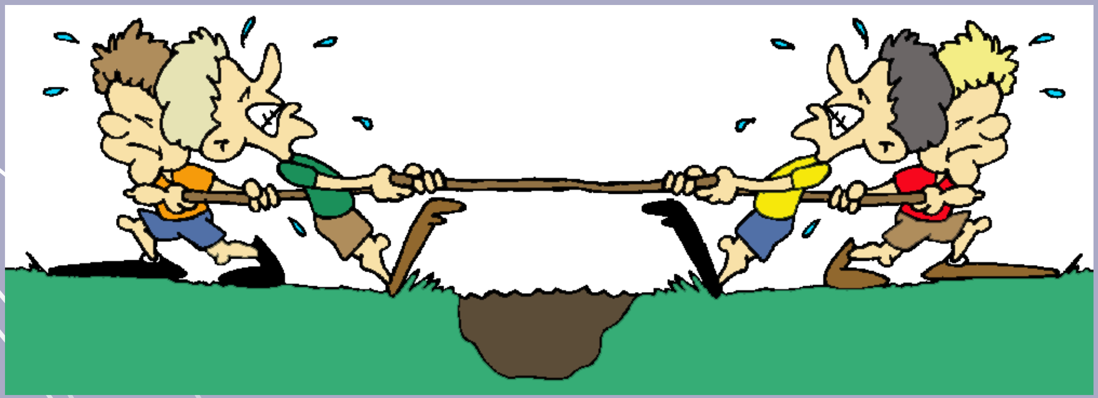
Summary & Conclusions

Grab & Go

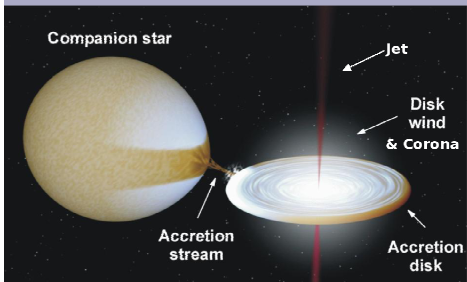
M28-I (but also J1023, J12270, +2come?)

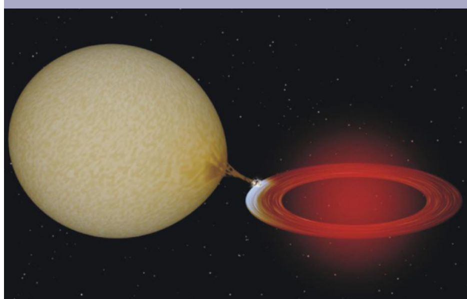
Rapid X-ray "mode switching" in quiescence.

Fast transitions at the boundary between accretion and rotation power !?!



Thanks! For more:





Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY
MNRAS **438**, 251–261 (2014) doi:10.1093/mnras/stt2167
Advance Access publication 2013 December 13

The neutron star transient and millisecond pulsar in M28: from sub-luminous accretion to rotation-powered quiescence

Manuel Linares,[1,2★] Arash Bahramian,[3] Craig Heinke,[3] Rudy Wijnands,[4] Alessandro Patruno,[5,6] Diego Altamirano,[4,7] Jeroen Homan,[8] Slavko Bogdanov[9] and David Pooley[10,11]

[1]*Instituto de Astrofísica de Canarias, c/ Vía Láctea s/n, E-38205 La Laguna, Tenerife, Spain*
[2]*Universidad de La Laguna, Departamento de Astrofísica, E-38206 La Laguna, Tenerife, Spain*
[3]*Department of Physics, University of Alberta, CCIS 4-183, Edmonton, AB T6G 2E1, Canada*
[4]*Astronomical Institute 'Anton Pannekoek', University of Amsterdam, Science Park 904, NL-1098XH Amsterdam, the Netherlands*
[5]*Leiden Observatory, Leiden University, PO Box 9513, NL-2300RA Leiden, the Netherlands*
[6]*ASTRON, The Netherlands Institute for Radio Astronomy, Postbus 2, NL-7990-AA Dwingeloo, the Netherlands*
[7]*Physics and Astronomy, University of Southampton, Southampton, Hampshire SO17 1BJ, UK*
[8]*Kavli Institute for Astrophysics and Space Research, Massachusetts Institute of Technology, 70 Vassar Street, Cambridge, MA 02139, USA*
[9]*Columbia Astrophysics Laboratory, Columbia University, 550 West 120th Street, New York, NY 10027, USA*
[10]*Department of Physics, Sam Houston State University, Huntsville, TX 77340, USA*
[11]*Eureka Scientific, Inc. 2452 Delmer Street Suite 100 Oakland, CA 94602, USA*

Accepted 2013 November 6. Received 2013 October 14; in original form 2013 September 4

ABSTRACT

The X-ray transient IGR J18245–2452 in the globular cluster M28 contains the first neutron star (NS) seen to switch between rotation-powered and accretion-powered pulsations. We analyse its 2013 March–April 25 d long outburst as observed by *Swift*, which had a peak bolometric luminosity of ∼6 per cent of the Eddington limit (L_{Edd}), and give detailed properties of the thermonuclear burst observed on 2013 April 7. We also present a detailed analysis of new and archival *Chandra* data, which we use to study quiescent emission from IGR J18245–2452 between 2002 and 2013. Together, these observations cover almost five orders of magnitude in X-ray luminosity (L_X, 0.5–10 keV). The *Swift* spectrum softens during the outburst decay (photon index Γ from 1.3 above $L_X/L_{Edd} = 10^{-2}$ to ∼2.5 at $L_X/L_{Edd} = 10^{-4}$), similar to other NS and black hole transients. At even lower luminosities, $L_X/L_{Edd} = [10^{-4}$–$10^{-6}]$, deep *Chandra* observations reveal hard (Γ = 1–1.5), purely non-thermal and highly variable X-ray emission in quiescence. We therefore find evidence for a spectral transition at $L_X/L_{Edd} \sim 10^{-4}$, where the X-ray spectral softening observed during the outburst decline turns into hardening as the source goes to quiescence. Furthermore, we find a striking variability pattern in the 2008 *Chandra* light curves: rapid switches between a high-luminosity 'active' state ($L_X \simeq 3.9 \times 10^{33}$ erg s^{-1}) and a low-luminosity 'passive' state ($L_X \simeq 5.6 \times 10^{32}$ erg s^{-1}), with no detectable spectral change. We put our results in the context of low-luminosity accretion flows around compact objects and X-ray emission from millisecond radio pulsars. Finally, we discuss possible origins for the observed mode switches in quiescence, and explore a scenario where they are caused by fast transitions between the magnetospheric accretion and pulsar wind shock emission regimes.

Key words: stars: neutron – pulsars: individual: PSR J1824–2452I – globular clusters: individual: M28 – X-rays: binaries – X-rays: bursts – X-rays: individual: IGR J18245–2452.

M