Neutron Stars and Pulsars: Challenges and Opportunities after 80 years
Proceedings IAU Symposium No. 291, 2012
J. van Leeuwen, ed.

doi:10.1017/S174392131202409X

A new low-B magnetar: Swift J1822.3–1606

A. Camero-Arranz[1], N. Rea[1], G. L. Israel[2], P. Esposito[3], J. A. Pons[4], R. P. Mignani[5,6], R. Turolla[7,5], S. Zane[5], M. Burgay[3], A. Possenti[3], S. Campana[8], T. Enoto[9], N. Gehrels[10], E. Göğüş[11], D. Götz[12], C. Kouveliotou[13], K. Makishima[14,15], S. Mereghetti[16] and S. R. Oates[5]

[1]Institut de Ciències de l'Espai (CSIC-IEEC), Campus UAB, Facultat de Ciències, Torre C5-parell, E-08193 Barcelona, Spain
email: camero@ice.cat

[2]INAF, Osservatorio Astronomico di Roma, via Frascati 22, 00040, Monteporzio Catone, Italy

[3]INAF, Osservatorio Astronomico di Cagliari, Poggio dei Pini, I-09012 Capoterra, Italy

[4]Departament de Fisica Aplicada, Univ. d'Alacant, Ap. Correus 99, 03080 Alacant, Spain

[5]Mullard Space Science Laboratory, Univ. College London, Dorking, Surrey RH5 6NT, UK

[6]Institute of Astronomy, University of Zielona Góra, Lubuska 2, 65-265, Zielona Góra, Poland

[7]Università di Padova, Dipart. di Fisica e Astronomia, via F. Marzolo 8, I-35131 Padova, Italy

[8]INAF – Osservatorio Astronomico di Brera, via E. Bianchi 46, I-23807 Merate, Italy

[9]Kavli Institute for Particle Astrophysics & Cosmology (KIPAC), SLAC/Stanford University, PO Box 20450, MS 29, Stanford, CA 94309, USA

[10]NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA

[11]Sabancı University, Orhanlı-Tuzla, 34956 İstanbul, Turkey

[12]AIM (CEA/DSM-CNRS-Université Paris Diderot), Irfu/Service d'Astrophysique, Saclay, F-91191 Gif-sur-Yvette, France

[13]NASA Marshall Space Flight Center, Huntsville, AL 35812, USA

[14]High Energy Astrophysics Laboratory, Institute of Physical and Chemical Research (RIKEN), Wako, Saitama 351-0198, Japan

[15]Department of Physics, Univ. of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan

[16]INAF – IASF Milano, via E. Bassini 15, I-20133 Milano, Italy

Abstract. We report on the long term X-ray monitoring with *Swift*, *RXTE*, *Suzaku*, *Chandra*, and *XMM–Newton* of the outburst of the newly discovered magnetar Swift J1822.3–1606 (SGR 1822-1606), from the first observations soon after the detection of the short X-ray bursts which led to its discovery (July 2011), through the first stages of its outburst decay (April 2012). Our X-ray timing analysis finds the source rotating with a period of $P = 8.43772016(2)$ s and a period derivative $\dot{P} = 8.3(2) \times 10^{-14}$ s s^{-1}, which entails an inferred dipolar surface magnetic field of $B \simeq 2.7 \times 10^{13}$ G at the equator. This measurement makes Swift J1822.3–1606 the second lowest magnetic field magnetar (after SGR 0418+5729; Rea *et al.* 2010). Following the flux and spectral evolution from the beginning of the outburst, we find that the flux decreased by about an order of magnitude, with a subtle softening of the spectrum, both typical of the outburst decay of magnetars. By modeling the secular thermal evolution of Swift J1822.3–1606, we find that the observed timing properties of the source, as well as its quiescent X-ray luminosity, can be reproduced if it was born with a poloidal and crustal toroidal fields of $B_p \sim 1.5 \times 10^{14}$ G and $B_{tor} \sim 7 \times 10^{14}$ G, respectively, and if its current age is ∼550 kyr (Rea *et al.* 2012).

Keywords. stars: magnetic fields — stars: neutron — X-rays: Swift J1822.3–1606

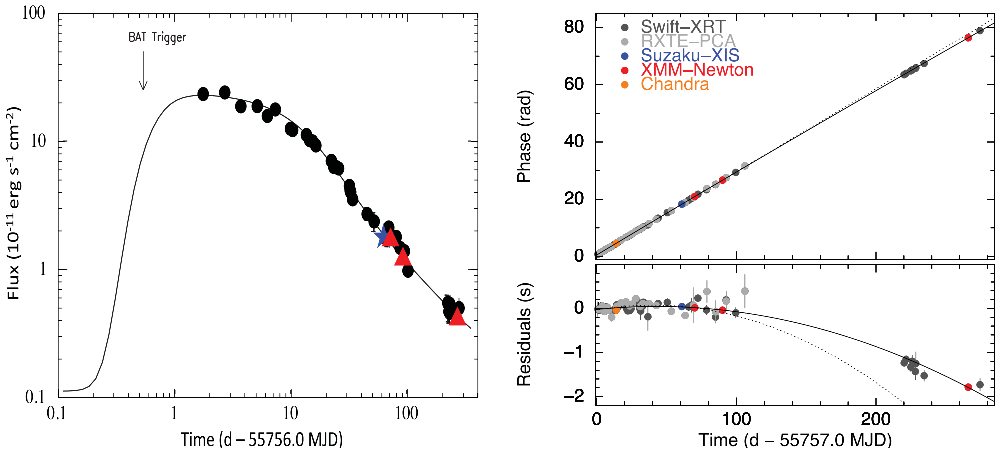

Figure 1. *Left:* Outburst model from Pons & Rea (2012) superimposed to the 1-10 keV flux decay of Swift J1822.3–1606 . Black circles denote *Swift*/XRT data, red triangles correspond to *XMM-Newton* and blue stars to *Suzaku*/XIS03 data. *Right:* Pulse phase evolution as a function of time, together with the time residuals (lower panel) after having corrected for the linear component (correction to the P value). The solid lines in the two panels mark the inferred P–$\dot{P}$ coherent solution based on the whole dataset, while the dotted lines represent the P–$\dot{P}$ coherent solution based on the data collected during the first 90 days only.

1. X-ray spectral modeling

In this study, we used all available data obtained from different space-based satellites, covering a time-span from July 2011 until end of April 2012. Spectra were extracted for all the *RXTE*/PCA, *Swift*/XRT, *Suzaku*/XIS03, and *XMM–Newton*/pn data, using standard software provided by the different team missions, and modeled using XSPEC version 12.7.0. Best fits were found using a blackbody plus power-law (BB+PL; χ^2_ν/dof =1.05/2522) and a 2 blackbodies (2BBs; χ^2_ν/dof =1.06/2522) model, all corrected for the photoelectric absorption. Figure 1 (left) shows how the flux decreased by about an order of magnitude, typical of the outburst decay of magnetars.

The aggressive monitoring campaign we present here allowed us not only to study in detail the flux decay of Swift J1822.3–1606, but also to give an estimate of its typical timescale. We have compared the observed outburst decay with the more physical theoretical model presented in Pons & Rea (2012). In addition, we have performed numerical simulations with a 2D code designed to model the magneto-thermal evolution of neutron stars. In Figure 1 (left), super-imposed, we show our best representative model that reproduce the observed properties of the decay of Swift J1822.3–1606 outburst. This model corresponds to an injection of 4×10^{25} erg cm^{-3} in the outer crust, in the narrow layer with density between 6×10^8 and 6×10^{10} g cm^{-3}, and in an angular region of 35 degrees (0.6 rad) around the pole. The total injected energy was then 1.3×10^{42} erg.

2. X-ray timing analysis

For the X-ray timing analysis we used all available data after barycentering all the events. We started by obtaining an accurate period measurement by folding the data from the first two XRT pointings which were separated by less than 1 day, and studying the phase evolution within these observations by means of a phase-fitting technique (see Dall'Osso *et al.* 2003 for details). The resulting best-fit period (reduced χ^2 = 1.1 for 2 dof) is $P = 8.43966(2)$ s (all errors are given at 1σ c.l.) at the epoch MJD 55757.0. The above period accuracy of 20 μs is enough to phase-connect coherently the later *Swift*, *RXTE*, *Chandra*, *Suzaku*, and *XMM–Newton* pointings (see Figure 1).

We modeled the phase evolution with a linear plus quadratic term. The corresponding coherent solution (valid until November 2011) is $P = 8.43772007(9)$ s and period derivative $\dot{P} = 1.1(2) \times 10^{-13}$ s s^{-1} ($\chi^2 = 132$ for 57 dof; at epoch MJD 55757.0). The above solution accuracy allows us to unambiguously extrapolate the phase evolution until the beginning of the next *Swift* visibility window which started in February 2012. The final resulting phase-coherent solution, once the latest 2012 observations are included, returns a best-fit period of $P = 8.43772016(2)$ s and period derivative of $\dot{P} = 8.3(2) \times 10^{-14}$ s s^{-1} at MJD 55757.0 ($\chi^2 = 145$ for 67 dof). The above best-fit values imply a surface dipolar magnetic field of $B \simeq 2.7 \times 10^{13}$ G (at the equator), a characteristic age of $\tau_c = P/2\dot{P} \simeq 1.6$ Myr, and a spin-down power $L_{rot} = 4\pi I\dot{P}/P^3 \simeq 1.7 \times 10^{30}$ erg s^{-1}(assuming a neutron star radius of 10 km and a mass of $1.4M_\odot$). The final solution has a relatively high r.m.s. ($\sim$ 120 ms) resulting in a best-fit reduced $\chi^2_\nu = 2.1$. The 3σ upper limit of the second derivative of the period was $\ddot{P} < 5.8 \times 10^{-21}$s s^{-2} (but see also Livingstone *et al.* 2011 and Scholz *et al.* 2012).

3. Conclusions

We have reported on the outburst evolution of the new magnetar Swift J1822.3–1606, which, despite its relatively low magnetic field ($B = 2.7 \times 10^{13}$ G), is in line with the outbursts observed for other magnetars with higher dipolar magnetic fields.

We found that the current properties of the source can be reproduced if it has now an age of $\sim$ 550 kyr, and it was born with a toroidal crustal field of 7×10^{14} G, which has by now decayed by less than an order of magnitude.

The position of Swift J1822.3–1606 in the P–$\dot{P}$ diagram is close to that of the "low" field magnetar SGR 0418+5729 (Rea *et al.* 2010). As argued in more detail in Rea *et al.* (2012), we note that the discovery of a second magnetar-like source with a magnetic field in the radio-pulsar range strengthens the idea that magnetar-like behavior may be much more widespread than what believed in the past, and that it is related to the intensity and topology of the internal and surface toroidal components, rather than only to the surface dipolar field (Rea *et al.* 2010, Perna & Pons 2011, Turolla *et al.* 2011).

References

Dall'Osso, S., Israel, G. L., Stella, L., Possenti, A., & Perozzi, E. 2003, *ApJ*, 599, 485
Livingstone, M. A., Scholz, P., Kaspi, V. M., *et al.* 2011, *ApJ*, 743, L38
Perna, R. & Pons, J. A., 2011, *ApJ*, 727, L51
Pons, J. A. & Rea, N. 2012, *ApJ*, 750, L6
Rea, N., Esposito, P., Turolla, R., *et al.* 2010, *Science*, 330, 944
Rea, N., Israel, G. L., Esposito, P., *et al.* 2012, *ApJ*, 754, 27
Scholz, P., Ng, C.-Y., Livingstone, M. A., *et al.* 2012, arXiv:1204.1034
Turolla, R., Zane, S., Pons, J. A., *et al.* 2011, *ApJ*, 740, 105