SWIFT J195509+261406: Dramatic flaring activity from a new Galactic magnetar

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Abstract

Most of the transient sources that are detected in the gamma-ray sky are produced by extragalactic gamma-ray bursts (GRBs). However, it is known that there are some other astronomical objects that can produce high-energy bursts within the Milky Way. SWIFT J195509+261406, just one degree off the Galactic plane, is one of them. It was discovered on the 10th July 2007 by the *Swift* satellite and was since then observable for a period of a fortnight. During this time SWIFT J195509+261406 experimented dramatic flaring activity that could be observed in near infrared, optical and X-rays.

We gathered multi-wavelength observations of SWIFT J195509+261406 including optical, near infrared, millimeter and radio observations. Our dataset covers the time from 1 minute after the burst onset to more than 4 months later. Following the initial burst in the gamma-ray band, we recorded more than 40 flaring episodes in the optical bands (reaching up to $I_c \sim 15$) over a time span of three days, plus a faint infrared flare that was observed at late times. After this time, the source slowly faded away until it became undetectable.

Using the observations compiled in this work we propose that this source is part of the magnetar family, linking soft gamma-ray repeaters and anomalous X-ray pulsars to dim isolated neutron stars.

1 Introduction

At 20:52:26 UT of the the 10^{th} of June 2007, *Swift*/BAT detected what seemed to be a gamma-ray burst (GRB) with a FRED (Fast Rise Exponential Decay) profile and a duration of ∼4.6 seconds, generating an alert for the GRB community [1, 2]. Follow-up observations in the optical bands showed an optical source at the location of the burst [3, 4] which had strong flaring activity. This flaring persisted in time, a very unusual behavior for a GRB; a fact that led Kann et al. [5] to propose that this source was most probably not a GRB but a rare Galactic source. Indeed, the location of the burst in the plane of the Milky Way (a Galactic latitude of just 1 deg) favored this hypothesis. From this moment, the source was not only identified as GRB 070610 but also as SWIFT J185509+261406, according to the nomenclature that is used for the high-energy sources in our Galaxy discovered by *Swift*.

2 Observations

Following the discovery of SWIFT J185509+261406 we triggered an observing campaign that included radio limits from RATAN-600, millimiter limits from Plateau de Bure, near infrared observations from Paranal and optical observations from WATCHER, BOOTES, Sierra Nevada, Tautenburg, Izaña, Roque de los Muchachos, Paranal and Special Astrophysical Observatory. In order to compile a complete dataset we combined these data with the publicly available *Swift*/XRT X-ray data. A late-time observation by XMM-Newton 173 days after the burst failed to detect the source, imposing an upper limit (3) to any underlying X-ray flux of $< 3.1 \times 10^{-14}$ erg cm^{-2} s^{-1} (0.2-10 keV). See Fig. 1 for the optical and X-ray light curves.

In order to obtain an estimate of the distance scale we carried out CO (J = 1-0) millimeter observations at the 30m milimeter telescope on Pico Veleta in order to search for molecular clouds towards the line of sight and 21 cm radio observations at Effelsberg radio telescope.

Our earliest observations began, with the WATCHER robotic telescope, just one minute after the burst detection in gamma-rays. During the first four nights we obtained an intensive coverage of the light curve, mostly in I_c-band. During the first 60 hours there is very intense activity that reached a maximum around one day after the burst, when the brightest flares were seen in optical (see Fig. 2) and X-rays. In both

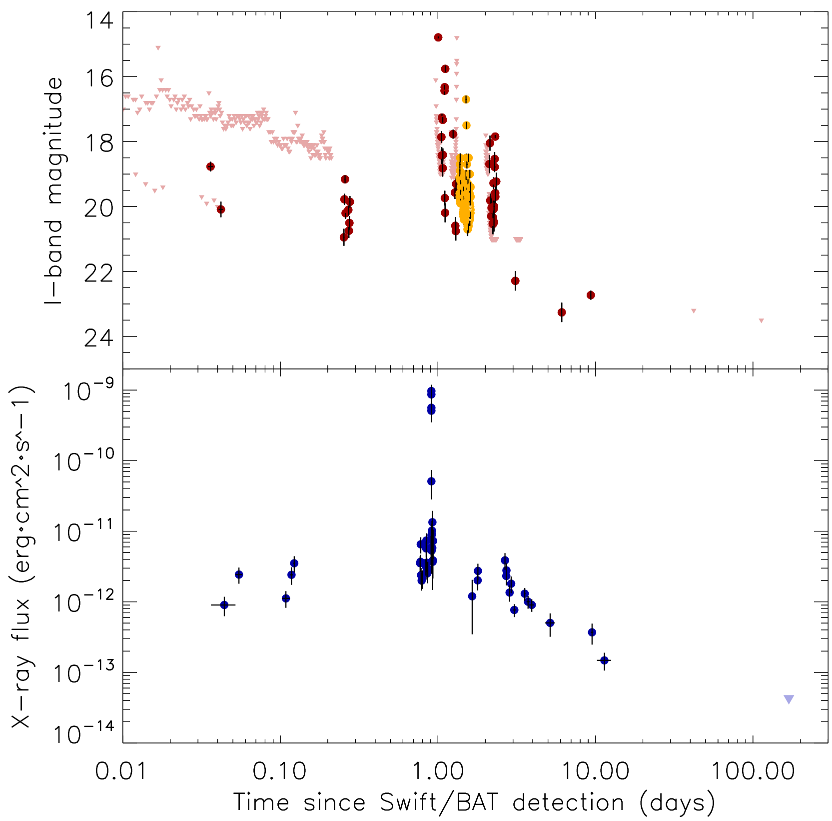

Fig. 1 Optical (top) and X-ray (bottom) light curves of SWIFT J195509+261406. Filled circles are detections while triangles are 3-sigma detection limits. The optical light curve includes in orange the observations of the flaring period presented in [6].

bands, the flux increase is of over 10^2 with flare duration between tens of seconds and a few minutes [3, 6, 7].

After the third day, the strong flaring activity stopped abruptly and only a dim, variable source could be detected. This source was observed for a couple of weeks and was no longer detectable in late observations. However, a last flare was observed, using 8.2m VLT (+NACO) 11 days after the burst, indicating that some activity was still ongoing at the time.

3 Discussion

Our CO (J = 1 - 0) spectrum towards the SWIFT J195509+261406 source reveals a molecular cloud in the range +25 km s-1 and +30 km s-1, with which we infer a a lower limit to the kinematic distance to the SWIFT source of 3.7 kpc. From the 21cm observations, we can also derive the equivalent H density, N(H) = N(H I) + 2N(H2) = (14.1 +/- 2.0) $\times 10^{21}$ cm^{-2} which should be compared with the X-ray absorption column derived from the *Swift*/XRT data: 10 (+4, -3) $\times$ 10^{21} cm^{-2} from [7], or [6] 7.2 (+3,-2) $\times$ 10^{21} cm^{-2} (all quoted errors here being 3-σ). Therefore we conclude that SWIFT J195509+261406 is located in the Galaxy and beyond this particular molecular cloud at a kinematic distance of 3.7 kpc from the Sun. This value is consistent with 4 kpc derived from the "red clump" method. A quite

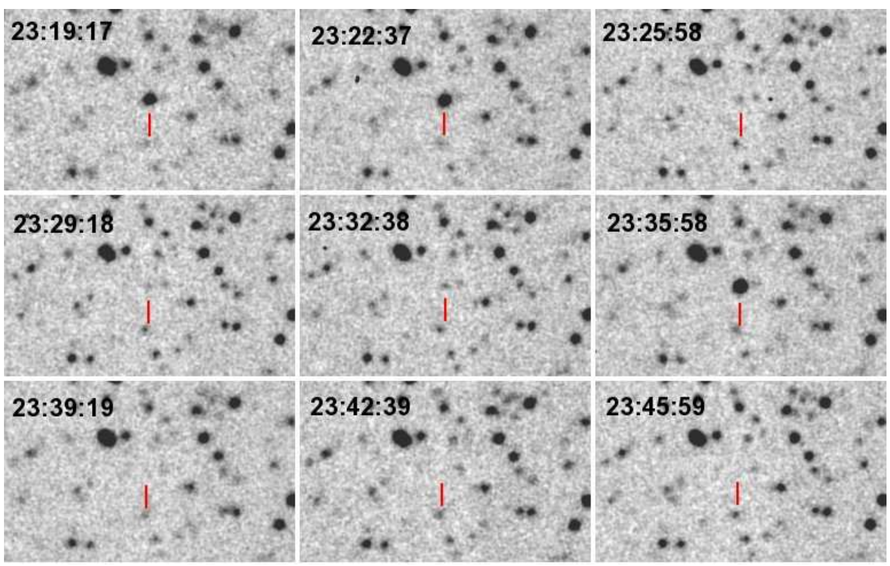

Fig. 2 Flares detected by the 0.8m IAC80 telescope at Izaña observatory (Tenerife, Spain) on the 11th June, aproximately one day after the onset of the gamma-ray burst, when the flaring activity was near maximum.

independent method by constructing the function of extinction versus distance based on field red giant stars. Hereafter, we consider a reference distance of 5 kpc.

When trying to explain the nature of this object, the most favoured model is that of an isolated compact object, i.e. a new magnetar in our Galaxy (see Fig. 3 for an artist's impression of such an object), displaying soft gamma-ray repeater like activity in the optical; and from which only one hard burst was recorded in gamma-rays, near the onset of its bursting activity. If this is the case, SWIFT J195509+261406 becomes the first SGR detected at optical wavelengths. This would be supported by the burst durations (Fig. 3 of [7]). The optical flares fluxes are lognormally distributed as seen in the high-energy flares of SGR 1806-20 and SGR 1900+14 [8], supporting the claim that SWIFT J195509+261406 is a new SGR, although this is not conclusive. In addition to this, we also want to point out that intermediate duration (1-30 s) bursts have been recorded in SGR 1627-41 and SGR 1900+14. In particular, two events arising from the latter source (at 7 kpc) and lasting about 1 s displayed unusual hard power-law spectra similar and comparable in energy, (6.5-11) $\times 10^{39}$ erg, to GRB 070610, the burst of gamma-rays associated with SWIFT J195509+261406 (1.9×10^{39} (D/ 5 kpc)^2 erg). Thus, both the gamma-ray burst duration and the lognormal distribution of the optical flares strengthen the association of the SWIFT source with a magnetar, although the lack of persistent X-ray pulses (i.e. which allow us to determine the spin period derivative P/t in order to yield the

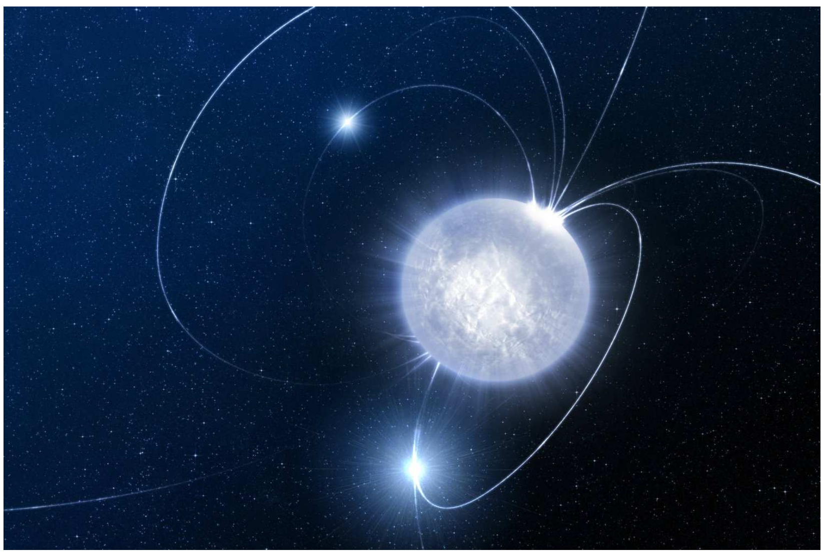

Fig. 3 Artist's impression of SWIFT J195509+261406. The twisting of magnetic field lines in magnetars, giving rise to crustquakes which will eventually led to an intense soft gamma-ray burst. In the case of the SWIFT source, the optical flares that reached the Earth were probably due to ions ripped out from the surface of the magnetar and gyrating around the field lines. As ions are much heavier than electrons, they gyrate slower and emit radiation at much lower frequencies. Courtesy L. Calcada (ESO).

magnetic field value) prevents us, for the time being, to prove the existence of extreme magnetic fields typical of magnetars (including both SGRs and anomalous X-ray pulsars, AXPs).

4 Conclussions

We have suggested that SWIFT J195509+261406 could be the first magnetar (either persistent or transient) that shows strong and protracted optical flaring activity in our Galaxy and for which the long-term X-ray emission is short-lived. A deeper X-ray observation together with a detailed study of future activity periods of SWIFT J195509+261406, including simultaneous X-ray/optical monitoring, can shed light onto its nature and discern whether the source is an ultra-compact low-mass X-ray binary or a NS displaying a new manifestation of magnetar activity. In this latter case, it would constitute the link between "persistent" SGRs/AXPs (with LX = (2-4) x 1035 erg s-1 and (0.2-5) x 1035 erg s-1 respectively) and dim isolated NS [9] (with LX = (2-20) x 1030 erg s-1), being one of a few hundred Galactic magnetars becoming active [10] in the last 104 yr. A complementary work can be found in the work by Castro-Tirado et al. [7].

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