Draft version April 5, 2017
Preprint typeset using LaTeX style emulateapj v. 04/21/05

AN INFRARED COUNTERPART OF SGR 1935+2154 FROM THE *HUBBLE SPACE TELESCOPE*

Andrew Levan[1], Chryssa Kouveliotou[2], Andrew Fruchter[3]

Draft version April 5, 2017

ABSTRACT

We present deep *Hubble Space Telescope* observations of the soft gamma-repeater SGR 1935+2154, recently discovered by *Swift*. Three epochs of observations have been obtained, while the source was active in March 2015, during a quiescent period in August 2015, and during a further active phase in May 2016. Close to the centre of the X-ray error region identified by *Swift* and *Chandra* we find a faint ($F140W(AB) = 25.3$) source which fades by a factor of ~ 2 over the course of 5 months between first two epochs of observations before rebrightening during the second active period. If this source is the counterpart to SGR 1935+2154 then it is amongst the faintest yet located for a magnetar. This offers further support for rapid optical/nIR observations of SGRs while they are active, in order to maximise the probability of counterpart discovery, and the ability of later observations to constrain their dynamics. In the case of SGR 1935+2154, our observations 1.3 years apart place limits on the space velocity of $\mu = (60 \pm 40)$ km s^{-1} kpc^{-1}; observations on timescales of a decade can hence probe proper motion limits smaller than the velocities observed for the majority of pulsars. In the case of SGR 1935+2154, the combination of faintness and crowding are such that a detection would not have been possible without the capabilities of *HST*, and suggests that future observations with *HST* and *JWST* will be a valuable route to probing the intrinsic properties of this unique population of neutron stars.

Subject headings: stars: neutron — supernovae: general

1. INTRODUCTION

Soft gamma-repeaters (SGRs) are one of the physical manifestations of magnetars, neutron stars with surface magnetic fields in excess of 10^{14} G (e.g. Kouveliotou et al. 1998). Although initially thought to be extremely rare, perhaps originating only from the most massive stars (e.g. Gaensler et al. 2005), increasing numbers of SGRs have been found in recent years (e.g. Olausen & Kaspi 2014; Collazzi et al. 2015), thanks to sensitive wide field monitors such as the *Swift* Burst Alert Telescope (BAT) and *Fermi* Gamma-ray Burst Monitor (GBM). The total number of magnetars is now approaching 30, and they appear as both Anomolous X-ray Pulsars (AXPs) and SGRs[4]. Most magnetars appear young (characteristic spin down ages $t_c = P/2\dot{P} \sim 10^3 - 10^4$ years) suggesting they can only be readily identified for a short-time after their formation. Since they are often uncovered by bursting activity and may have long quiescent periods in between it also seems likely that we are still some way from a complete census of young magnetars in the Milky Way. The combination of youth and incompleteness implies that a significant fraction of SNe must create a magnetar. Magnetar lifetimes ($\sim 10^4$ years) combined with the known Galactic core collapse SN rate of one per century would require that $\sim$30% of the Milky Way SNe have created the observed magnetar population. Most likely the rate is even higher, as many more remain to be found. While this is a very crude estimate, such rates indicate that magnetar progenitors must be drawn from much further down the stellar mass function in order to explain the observed rate, something that has observational support in some cases (e.g. Davies et al. 2009).

The astrophysical insights from magnetars are potentially many. They are natural laboratories for the behaviour of matter under extreme magnetic fields, with their bursts and persistent emission providing insights into particle acceleration and emission mechanisms (Kouveliotou et al. 1999; Thompson et al. 2000). The very rare magnetar Giant Flares (only three detected in the last 37 years; two from our MW and one from the Large Magellanic Cloud) have initial short spikes very similar to short Gamma Ray Bursts(Hurley et al. 2005) and may manifest as such in nearby galaxies (e.g. Tanvir et al. 2005). The recent identification of a repeating fast radio burst (Spitler et al. 2016) may originate from magnetars from greater distances. The creation of a magnetar clearly requires somewhat special conditions within their progenitor stars, and so the properties of the magnetar must in some way reflect the nature of the stars that create them. Understanding which stars create magnetars, either from detailed studies of magnetars themselves, or from their environments can therefore provide unique constraints on the diversity of the final stages of stellar evolution. Indeed, rare, rapidly rotating magnetars are increasingly invoked to explain many of the most energetic events in nature, including both long- and short-duration gamma-ray bursts and super luminous supernovae (e.g. Metzger et al. 2015; Rowlinson et al. 2013). While it is apparent that these events are far too rare to be linked to the numerous young magnetars observed in the Milky Way (see Rea et al. (2015)), studying both the magnetars themselves, and their likely progenitors may

[1] Department of Physics, University of Warwick, Coventry, CV4 7AL, UK
[2] Department of Physics, The George Washington University, Staughton Hall 707 22nd St NW, Washington, DC 20052, USA
[3] Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218, USA
Electronic address: A.J.Levan@warwick.ac.uk

[4] Although magnetars are typically defined as neutron stars with strong magnetic fields, there is no widely agreed definition, see (Rea & Esposito 2011), some low field bursting events are also included (Rea et al. 2010)

non-the-less provide valuable insights into the nature of these extreme explosions.

However, studies of magnetars are extremely challenging. Their flares are fleeting, with typical durations of ∼100 ms and are sometimes very infrequent. While bursting activity is often associated with an increase in X-ray luminosity on longer timescales (days) follow-up must still be rapid to be effective. While X-ray counterparts have been readily identified in the majority of cases, multi wavelength observations are needed to pinpoint the source and constrain the origins of the emission and the source dynamics via proper motion (e.g. Tendulkar et al. 2012, 2013). Such observations are often plagued by faint counterparts, crowded fields and significant line of sight extinction. Indeed, while optical counterparts have now been found to a number of sources ((see e.g. Olausen & Kaspi 2014; Rea & Esposito 2011, for a review of optical/IR observations)), these are all exclusively faint, and the majority are hard to study without intensive adaptive optics work, or with the *Hubble Space Telescope (HST)*, an approach we use here for observations of SGR 1935+2154.

2. OBSERVATIONS

2.1. *Discovery of SGR 1935+2154*

SGR 1935+2154 was discovered by *Swift* on 2014 July 5 (Lien et al. 2014). As with many new SGRs it was initially identified via a short, magnetar-like, burst of gamma-rays (duration 0.1s), but the subsequent detection of multiple bursts from the same direction on the Galactic plane identified it as an SGR. *Swift* also identified an X-ray counterpart, and observations with *Chandra* enabled the period (P=3.24729 s) to be determined (Israel et al. 2014); further observations with *NuSTAR* and *XMM-Newton* confirmed the period and allowed an estimate of the period derivative ($\dot{P} = 1.43 \times 10^{-11}$ s s^{-1}), from which it was possible to derive a dipole field of $B = 7 \times 10^{14}$G and a characteristic age $\tau_c = P/2\dot{P} =$ 3598 years (Younes et al. 2015; Israel et al. 2016). Following this initial detection a further period of activity was observed with the *Fermi* GBM, beginning on 22 Feb 2015 (Burns & Younes 2015), suggesting the source had entered a new active phase. The latter stages of this phase included an intermediate flare on 12 April 2015 (Kozlova et al. 2016). Following a short period of quiescence the source re-activated again in May 2016 (Younes 2016; Kozlova 2016). Detailed γ-ray and X-ray observations of SGR 1935+2154 are presented in Israel et al. (2016) and Younes et al. 2016 (in prep).

2.2. *Hubble Space Telescope*

We obtained three epochs of observations of SGR 1935+2154 with *HST*. Observations consisted of a single orbit with the IR channel and the F140W filter to maximise throughput, while the orients were set at 90 or 180 degrees relative to previous epochs so that diffraction spikes from bright stars overlay each other. At each epoch, we took 4x600 s of observation were taken. Individual exposures were aligned eachother (across both epochs) utilising point sources in common to each image, via the `tweakreg` task; finally the images were drizzled (Fruchter & Hook 2002) onto a common frame with an output scale of 0.07″. The RMS of `tweakreg` was tested by a direct map between ∼ 100 point sources in the drizzled images and found to be ∼ 7 mas, and this sets the level of relative astrometry that can be obtained. Finally, we refine the world co-ordinate system using ∼ 100 2MASS stars that fall within the field of view of WFC3, providing an absolute position accurate to 0.2″.

2.3. *Chandra and Swift*

The field of SGR 1935+2154 was observed with the *Chandra X-ray Observatory* on 2014 July 15 utilising ACIS-S for a duration of 10 ks. From this we determine a position for the SGR of RA=19:34:55.593, DEC=21:53:47.75. The observations used a small window, resulting to a small number of sources, insufficient to perform an astrometric solution with a small error circle. However, our experience of other CXO observations in which a wider window has been used suggests it will be in the region of 0.4-0.6″, and we adopt the larger number as a conservative approach. *Swift* observations of SGR 1935+2154 have also been obtained. The UVOT enhanced position is RA=19:34:55.61, DEC=21:53:48.0, consistent with the *Chandra* localisation above, although with a 1.5″ error (90% containment)

3. THE INFRARED COUNTERPART OF SGR 1935+2154

At the depth of our *HST* observations the available X-ray locations do not allow us to identify a single source, and even in the *Chandra* error circle there are multiple IR detections. However, our multiple epochs of observations allow us to conduct a variability search (see Figure 1). A direct subtraction reveals a single variable source close to the centre of the *Chandra* error region; no other variables are detected, and the photometry of nearby stars is consistent between the images (in particular the source on the north-western edge of the error circle varies by 0.007 mag). Furthermore, none of the brighter sources show any evidence of variability between the individual exposures within orbits, either in each 600s exposure, on the the multiple non-destructive reads that make up each exposure (there is insufficient signal to noise for such an approach to be practical for our proposed counterpart). The source apparently lies on a background, either of faint point sources or diffuse emission. Because of the crowded field, we perform photometry in a 0.1″ radius aperture, and then correct using the published encircled energy curves. Background estimation is achieved by placing apertures of the same size through the image away from obvious bright sources, although the field is sufficiently crowded that some background from faint stellar or diffuse objects may be included. The resulting photometry is shown in Table 1. It is clear the source is variable, and we identify it as the counterpart of SGR 1935+2154. Its location is RA=19:34:55.606 DEC=21:53:47.45 (±0.2″, see above). We note that the photometry of the source in progressively larger apertures provides a brighter source even after correcting for the encircled energy, suggesting that there is a diffuse component under the source, and implies that even with the resolution of *HST* precise photometry may be difficult. However, we also note that the confidence of fading is not strongly dependent on the aperture size for aperture sizes $< 0.3''$; beyond this the increased background contribution and contamination from nearby stars begin to be significant. There is no significant motion of the

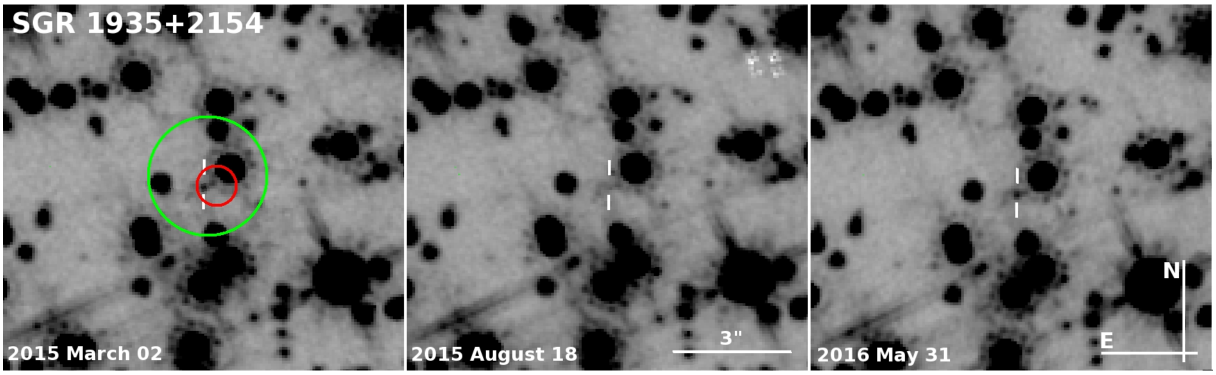

Fig. 1.— Our *Hubble Space Telescope* observations of SGR 1935+2154. The *Chandra* location is marked with a green circle, and an estimated uncertainty of 0.6″radius. Close to the centre of the error box is an apparently transient source, fading by ∼ 0.7 magnitudes between the two observations. It is the only transient of this significance within ∼ 20″of this location, and we identify it as the counterpart of SGR 1935+2154.

source between the first and final images taken 1.3 years apart, with the formal motion measured as $\mu = 13 \pm 9$ mas yr^{-1}, including the contribution from the astrometric tie (7 mas per axis) and centroiding (4 mas per axis).

TABLE 1
HST observations of SGR 1935+2154

Date	MJD	AB-mag
2015-03-02:23:04:06	57083.96118	25.26 ± 0.04
2015-08-18:08:11:06	57252.34104	26.09 ± 0.11
2016-05-31:22:13:51	57555.92685	25.22 ± 0.04

Note. — Photometry has been obtained in 0.″1 apertures centred on the location of the counterpart and corrected for encircled energy. Each observation is an identical 4 × 600s exposures.

Numerous deep searches have been conducted for the optical counterparts of other SGRs and magnetars. To date there are optical/IR detections of ∼ 8/29 magnetars and ∼ 3/12 SGRs[5]. Most of these detections have been made in ground based K-band observations and have magnitudes in the range 18-22 (e.g. Olausen & Kaspi 2014). The counterpart of SGR 1935+2154 has a discovery magnitude of F140W(AB) ∼ 25.3, this is approximately H(Vega)=24.0, making the counterpart of SGR 1935+2154 the faintest discovered to date. However, there are some observations made with *HST* that place deeper limits on a handful of SGRs, most notably SGR 0418+5729 (Durant et al. 2011), in a region with relatively little crowding, where deep J-band observations place a limit of F110W<27.4. This depth is significantly fainter than our detection of SGR 1935+2154, while the location of SGR 0418+5729 is also likely in the Perseus arm at a distance of only ∼ 2kpc, closer than the likely distance of SGR 1935+2154 (see section 4). However, SGR 0418+5729 is also unusual for a magnetar, since its slow spin down rate renders an unusually low field (Rea et al. 2010), and observations were taken long after the active period.

In Figure 2 we compare the X-ray and IR light curves of SGR 1935+2154. It is clear that our first observations did take place during a period of enhanced activity, but not at its peak. In total 11 triggers were recorded between 2015 Feb 22 and 2015 March 05 by *Swift*-BAT and *Fermi*-GBM (**XXX - NOTE This is based on GCN info, could be incorrect if others are there**. The majority of these were observed in a cluster between Feb 22 - Feb 24, but one more burst was detected after the *HST* observations. Rapid slews to the target were only obtained by *Swift* for the first triggers (which were obtained by *Swift*-BAT, and so the X-ray flux level following the *Fermi*-GBM triggers has not been monitored). However, the overall X-ray flux level appears to return to a near quiescent level rapidly after the initial cluster of triggers, and is consistent with a constant source from ∼ 4 days after the first detection. The source is relatively faint, and so associated photon noise is significant. In particular, it is apparent that relatively slow fading, comparable to that seen in the *HST* observations would have been difficult to discern. The data taken from 2 days after the first *Swift* trigger are consistent with a constant source (χ^2/dof = 34.83/38), although fitting a power-law slope ($F_\nu \propto (t/t_0)^{-\alpha}$) with $t_0(MJD) = 57075.51141$, the time of the first *Swift* trigger) yields an X-ray decay of $\alpha = 0.06 \pm 0.04$, only marginally consistent with the $\alpha = 0.25 \pm 0.06$ determined from the *HST* observations. The final epoch of *HST* observations was accompanied by simultaneous observations with the *Swift*, allowing us to construct a direct X-ray to IR measurement. The νF_ν IR flux at this point is $\sim 6 \times 10^{-16}$ ergs s^{-1} cm^{-2} (or XXX corrected for extinction through the entire Galactic column). $F_X =$, (XXX unabsorbed) based on a $\Gamma = 3.6, N_H = 4.2 \times 10^{22}$ model fitted to the entire *Swift* XRT PC mode data. This means the X-ray to optical flux ratio is ∼ 3000, comparable to that seen in other magnetars (Israel et al. 2005; Durant et al. 2011).

To compare the properties of the counterpart of SGR 1935+2154 with those of other magnetars, we compare the brightest optical/IR detections available for each magnetar in Figure 3. In doing so we look both at the observed distribution of magnitudes, in which the counterpart of SGR 1935+2154 is by some way the faintest detected, and at the distributions taking into account uncertainties relating to foreground extinction and likely distance. Doing so suggests that while the counterpart to SGR 1935+2154 is likely towards the fainter end of the distribution, it is not distinct from those of other magnetar counterparts. The X-ray flux for SGR 1935+2154 is

[5] based on the McGill Magnetar database, and references therin. Note the numbers are approximate as there are some cases in which plausible candidates have been observed, based on X-ray locations, or unusual colours, but for which a secure identification has yet to be made

relatively faint for other magnetars, whose median quiescent X-ray flux is XXX. This suggests that for similar ratios *HST* observations will be a powerful route to identifying counterparts. This may be straightforward in the case of outbursting systems, but given that many magnetars are significantly brighter than SGR 1935+2154 in X-ray's multicolour observations that can disentangle stellar and non-stellar sources within $\sim 1''$error boxes may also be productive. With *JWST* the combination of larger aperture and redder filter system (less affected by foreground extinction) should make snapshot colour identification of the counterparts of the majority of magnetars relatively routine. Indeed, with the advent of *JWST* it will be possible to obtain high resolution mid-IR observations for the first time, these may be particularly sensitive to the presence of any disc emission around magnetars, as has been suggested in the case of 4U...... For SGR 1935+2154 the luminosity of the source in our three epochs varies between (), the faint end of which is broadly consistent with the extrapolation of the disc model of **?** to 10 kpc and allowing for the (uncertain) Galactic extinction.

4. THE WIDER ENVIRONMENT AND BIRTHPLACE

As with the majority of SGRs, the galactic location of SGR 1935+2154 is $l = 57.25$, $b = 0.82$ is close to the Galactic plane. The direction lies approximately along the Orion Spur (where the Sun lies), and crosses the Perseus Arm at 8-9 kpc distance. The significant over densities of stars in this direction lie in these two regions, with most stars in the Perseus arm. The X-ray N_H measured for SGR 1935+2154 for either a power-law, or thermal model is modestly in excess of the Galactic value with N_H=(3.8 $\pm$ 0.4)x10^{22} cm^{-2} (powerlaw) or N_H=(1.6 $\pm$ 0.2)x10^{22} (thermal) (Israel et al. 2016), compared to N_H(gal) = 1.23 $\times 10^{22}$ cm^{-2} (Willingale et al. 2013), consistent with the source lying behind the bulk of the Galactic column, and more likely in the Perseus-arm. The IR extinction in this direction is E(B-V) = 4.31 (Schlafly & Finkbeiner 2011), corresponding to $A_V = 13.4$, $A_{F140} = 2.99$ if integrated across the entire Galactic column. Optical observations suggest the typical extinction in this direction is $A_V > 6.5$ to 6.5 kpc (Sale et al. 2014), and so the likely true extinction is in the range $1.5 < A_{F140W} < 3$.

It has also been suggested that SGR 1935+2154 is associated with the supernova remnant G57.2+0.8 (Gaensler 2014), in which the SGR is approximately central. The SNR is approximately 0.1 degrees in radius, corresponding to $\sim$ 20pc at a favoured distance of 11.7$\pm$ 2.8 kpc (Surnis et al. 2016) somewhat beyond the bulk of the Perseus arm. The size is comparable to young (< 20-kyr) SNRs in the LMC (Badenes et al. 2010). We note that the size of the remnant would be inconsistent with the characteristic age of the magnetar were it located significantly closer (e.g. at 1 kpc within the Orion spur) and this offers further credence to the larger distance estimate. The position of SGR 1935+2154 within the SNR is approximately central. This would be indicative of a relatively low tangential velocity for the neutron star (or a low age). Our measured motion of $\mu = 13 \pm 8$ mas corresponds to a physical velocity of ($\mu \sim 60\pm$ 40) km s^{-1} kpc^{-1}. For a distance of 10 kpc our 2σ upper limit would be in the region of 800 km s^{-1}, something achieved by only the fastest $\sim 10-20\%$ of neutron stars (Arzoumanian et al. 2002; Hobbs et al. 2005). Given our intrinsic astrometric accuracy observations on a timescale of 5-10 years would place limits lower the those of a typical neutron star (80-160 km s^{-1}).

There is no obvious sign of an underlying cluster environment as might be expected for a massive progenitor. In particular, sources close to the SGR location have similar colours to those at larger radii, and there is no obvious spatial clustering of massive stars. The nearest bright star has colors that are stellar, and typical of others in the surroundings. The region does lie in the field of view of the IPHAS survey (Drew et al. 2005), but no Hα emission is seen near the SGR location, or at the location of bright radio emission. This may not be surprising given the high foreground extinction.

5. SUMMARY

The counterpart of SGR 1935+2154 is the faintest optical counterpart yet detected, although a handful of deeper limits have been obtained by late time *HST* observations of SGR fields (Durant et al. 2011). Given the very crowded nature of the fields it is clear that deep observations of X-ray locations will seldom allow for the unique identification of counterparts (e.g. **?**Durant & van Kerkwijk 2008) and so variability will be a necessary diagnostic (e.g. Israel et al. 2005). The magnitude of the counterpart of SGR 1935+2154 when discovered is sufficiently faint that it would have been extremely challenging from the ground, requiring several nights of integration with ground based AO for detection. For many SGRs the only route of counterpart identification with current technology may well be rapid response observations with *HST*. Such observations would not only provide counterpart identification, but ultimately enable light curve monitoring, the construction of spectral energy distributions and the measurements of proper motions.

ACKNOWLEDGEMENTS

We thank Kenneth Sembach, Claus Leitherer and the staff of STScI for the rapid scheduling and execution of these observations, and Neil Gehrels and the *Swift* team for their scheduling of *Swift* observations. AJL is supported by the Science and Technology Facilities council (grant #ST/L000733/1). Based on observations made with the NASA/ESA Hubble Space Telescope, obtained at the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS 5-26555. These observations are associated with programs 14055 and 14502.

REFERENCES

Arzoumanian, Z., Chernoff, D. F., & Cordes, J. M. 2002, ApJ, 568, 289

Badenes, C., Maoz, D., & Draine, B. T. 2010, MNRAS, 407, 1301

Burns, E., & Younes, G. 2015, GRB Coordinates Network, 17496

Collazzi, A. C., Kouveliotou, C., van der Horst, A. J., et al. 2015, ApJS, 218, 11

Davies, B., Figer, D. F., Kudritzki, R.-P., et al. 2009, ApJ, 707, 844

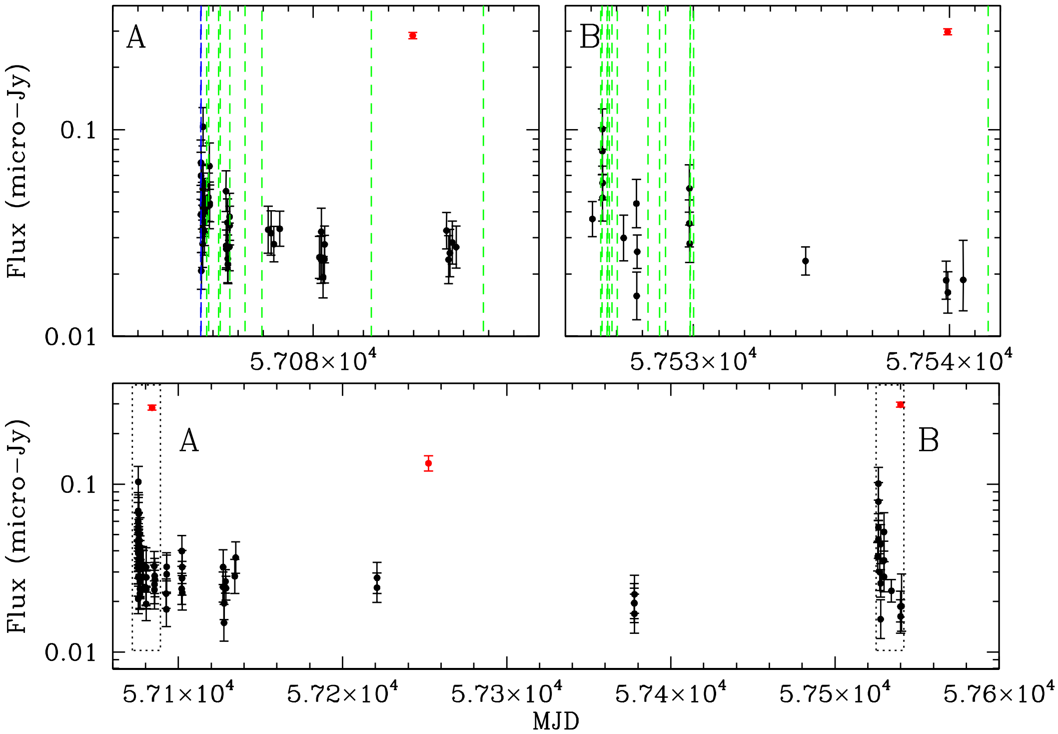

FIG. 2.— The X-ray (black) and infrared (red) light curve of SGR 1935+2154 from its activity period in Feb 2015. The lower panel shows a wide (1.5 year) time range, while the top panels are zoomed in around the periods of enhanced activity. In these panels the dashed vertical lines show the times of the bursts from *Swift*-BAT and *Fermi*-GBM. This shows that the *HST* observations were obtained during the active period, but not during its peak. The X-ray flux is broadly constant between all three *HST* epochs, and appears to rise rapidly around flares, before returning quickly to a quiescent level.

Durant, M. 2005, ApJ, 632, 563
Durant, M., & van Kerkwijk, M. H. 2008, ApJ, 680, 1394-1397
Durant, M., Kargaltsev, O., & Pavlov, G. G. 2011, ApJ, 742, 77
Drew, J. E., Greimel, R., Irwin, M. J., et al. 2005, MNRAS, 362, 753
Fruchter, A. S., & Hook, R. N. 2002, PASP, 114, 144
Gaensler, B. M. 2014, GRB Coordinates Network, 16533
Gaensler, B. M., McClure-Griffiths, N. M., Oey, M. S., et al. 2005, ApJ, 620, L95
Hobbs, G., Lorimer, D. R., Lyne, A. G., & Kramer, M. 2005, MNRAS, 360, 974
Hurley, K., Boggs, S. E., Smith, D. M., et al. 2005, Nature, 434, 1098
Israel, G., Covino, S., Mignani, R., et al. 2005, A&A, 438, L1
Israel, G. L., Rea, N., Zelati, F. C., et al. 2014, The Astronomer's Telegram, 6370
Israel, G. L., Esposito, P., Rea, N., et al. 2016, MNRAS, 457, 3448
Kozlova, A. V., Israel, G. L., Svinkin, D. S., et al. 2016, MNRAS, 460, 2008
Kozlova, A. V. et al. 2016, GRB Coordinates Network, 19438
Kouveliotou, C., Dieters, S., Strohmayer, T., et al. 1998, Nature, 393, 235
Kouveliotou, C., Strohmayer, T., Hurley, K., et al. 1999, ApJ, 510, L115
Lien, A. Y., Barthelmy, S. D., Baumgartner, W. H., et al. 2014, GRB Coordinates Network, 16522
Lucas, P. W., Hoare, M. G., Longmore, A., et al. 2008, MNRAS, 391, 136
Metzger, B. D., Margalit, B., Kasen, D., & Quataert, E. 2015, MNRAS, 454, 3311
Olausen, S. A., & Kaspi, V. M. 2014, ApJS, 212, 6
Rea, N., & Esposito, P. 2011, Astrophysics and Space Science Proceedings, 21, 247
Rea, N., Gullón, M., Pons, J. A., et al. 2015, ApJ, 813, 92
Rea, N., Esposito, P., Turolla, R., et al. 2010, Science, 330, 944
Rowlinson, A., O'Brien, P. T., Metzger, B. D., Tanvir, N. R., & Levan, A. J. 2013, MNRAS, 430, 1061
Sale, S. E., Drew, J. E., Barentsen, G., et al. 2014, MNRAS, 443, 2907
Schlafly, E. F., & Finkbeiner, D. P. 2011, ApJ, 737, 103
Surnis, M., Joshi, B. C., Maan, Y., et al. 2016, arXiv:1605.08276
Spitler, L. G., Scholz, P., Hessels, J. W. T., et al. 2016, ArXiv e-prints
Tanvir, N. R., Chapman, R., Levan, A. J., & Priddey, R. S. 2005, Nature, 438, 991
Tendulkar, S. P., Cameron, P. B., & Kulkarni, S. R. 2012, ApJ, 761, 76
Tendulkar, S. P., Cameron, P. B., & Kulkarni, S. R. 2013, ApJ, 772, 31
Thompson, C., Duncan, R. C., Woods, P. M., et al. 2000, ApJ, 543, 340
Willingale, R., Starling, R. L. C., Beardmore, A. P., Tanvir, N. R., & O'Brien, P. T. 2013, MNRAS, 431, 394
Younes, G., Gogus, E., Kouveliotou, C., & van der Hors, A. J. 2015, The Astronomer's Telegram, 7213
Younes, G. 2016, GRB Coordinates Network, 19437

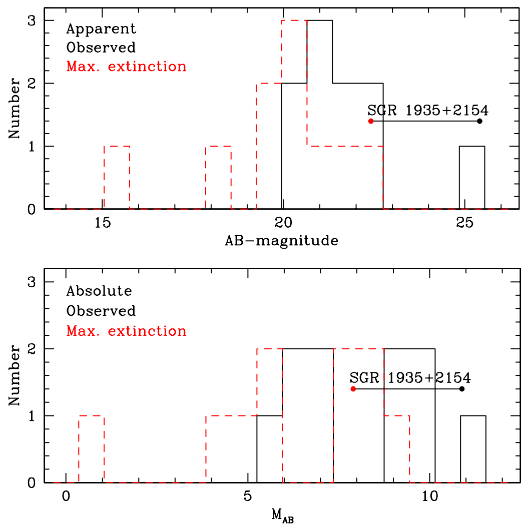

FIG. 3.— The comparative properties of the optical/IR counterparts of magnetars. **Top panel:** The distribution of apparent magnitudes of the brightest detections of magnetars for which a counterpart has been claimed as observed (solid line) and corrected for maximal extinction, defined as the entire Galactic extinction as measured by Schlafly & Finkbeiner (2011). **Bottom panel:** As for the top panel, but plotted for absolute magnitude, based on the best available estimates for the distances to magnetars (from Olausen & Kaspi 2014), and assuming 8kpc for SGR 1935+2154. The range for SGR 1935+2154 is show in each panel as a solid horizontal line. While there is significant uncertainty in determining the physical parameters of the optical/IR counterparts, it is apparent that while observationally faint, the counterpart of SGR 1935+2154 is broadly consistent with the properties of other counterparts.