An Extremely Luminous Panchromatic Outburst from the Nucleus of a Distant Galaxy

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Variable x-ray and γ-ray emission is characteristic of the most extreme physical processes in the universe. We present multiwavelength observations of a unique γ-ray–selected transient detected by the Swift satellite, accompanied by bright emission across the electromagnetic spectrum, and whose properties are unlike any previously observed source. We pinpoint the event to the center of a small, star-forming galaxy at redshift $z = 0.3534$. Its high-energy emission has lasted much longer than any γ-ray burst, whereas its peak luminosity was ~100 times higher than bright active galactic nuclei. The association of the outburst with the center of its host galaxy suggests that this phenomenon has its origin in a rare mechanism involving the massive black hole in the nucleus of that galaxy.

Surveys of the sky at short wavelengths (x-ray and γ-ray) reveal a much more dynamic universe than is seen in the optical wavelengths. Many sources vary substantially; the most extreme can go from invisibility to being the brightest objects in the sky, sometimes on time scales of seconds. The sources of such bursts of high-energy radiation have proven difficult to trace, but dedicated observational programs have shown that some fraction originate in the Milky Way, either from isolated neutron stars with intense magnetic fields (*1*) or from binary systems containing neutron stars and black holes (*2*). Some long-lived but variable x-ray and γ-ray emissions originate in active galaxies (*3*), whereas the brightest are the long-duration γ-ray bursts (long-GRBs), which are detected at a rate of approximately two per week by current missions such as the Swift satellite (*4*) and are now thought to originate from the collapse of massive stars in the distant universe (*5*, *6*).

GRB 110328A/Swift J164449.3+573451 (hereafter Sw 1644+57) was detected with the Swift Burst Alert Telescope (BAT) at 12:57:45 UT on 28 March 2011 (*7*). It required an unusually long integration, in excess of 1000 s, to trigger the instrument because of its slow variability time scale. Follow-up observations with the Ultraviolet and Optical Telescope (UVOT) and X-Ray Telescope (XRT) onboard the Swift satellite began 1475 s after the initial outburst. No source was seen in the UVOT observations, but a bright point source was found with the XRT (*7*). Unlike any previously observed long-GRBs (which typically decline substantially on a time scale of minutes), Sw 1644+57 remained bright and highly variable for a prolonged period and went on to retrigger the BAT on three further occasions over the next 48 hours (*8*). Reexamination of previous γ-ray observations of this region showed that the source appears to have been present a few days before the initial trigger but not at earlier times (*9*). Equally unlike any normal long-GRB, the source remained bright in the x-rays for more than 2 weeks (Fig. 1). The early x-ray behavior showed the same dramatic flaring seen with BAT, with flares having time scales of hours and with broadly similar shapes. After the first 48 hours, the x-rays maintained a more constant level, albeit with episodic brightening and fading spanning more than an order of magnitude in flux.

Our first ground-based observations of Sw 1644+57 began approximately 2 hours after the burst trigger, with the Gemini-North Telescope in Hawaii. Unfortunately, poor weather conditions meant that only shallow observations were possible, and these did not yield any candidate optical counterpart to a limit of $r \sim 22.1$ magnitude. At 13 hours after the trigger, we obtained imaging with the Nordic Optical Telescope (NOT) on La Palma, which revealed a $R \approx 22.5$ magnitude source that was consistent with the x-ray position (*10*). Examination of archival images obtained with the Palomar Transient Factory (PTF) revealed this source to be present at approximately the same brightness more than a year before the outburst. Our subsequent optical monitoring (below) confirms that the optical flux is dominated by the host galaxy. Early analysis of the x-ray/γ-ray data was used to argue that the transient was most likely a source within the Milky Way (*11*). However, our spectroscopy of the optical counterpart with Gemini-North (*12*), the Gran Telescopio Canarias (GTC) in La Palma (*13*), and the Keck Telescope in Hawaii (*14*) [supplementary online material (SOM) text] showed strong emission lines of hydrogen and oxygen (as well as absorption lines from a moderate age stellar population), which is consistent with a star-forming galaxy at a systemic redshift of $z = 0.3534 \pm 0.0002$ (Fig. 2). Thus, Sw 1644+57 is a source at cosmological distance with extremely unusual properties.

We continued to monitor the field from the ground in the optical and near-infrared (near-IR) with Gemini-North, the UK Infrared Telescope (UKIRT), the NOT, the William Herschel Telescope (WHT), PAIRITEL, the Telescopio Nazionale Galileo (TNG), and GTC, obtaining observations

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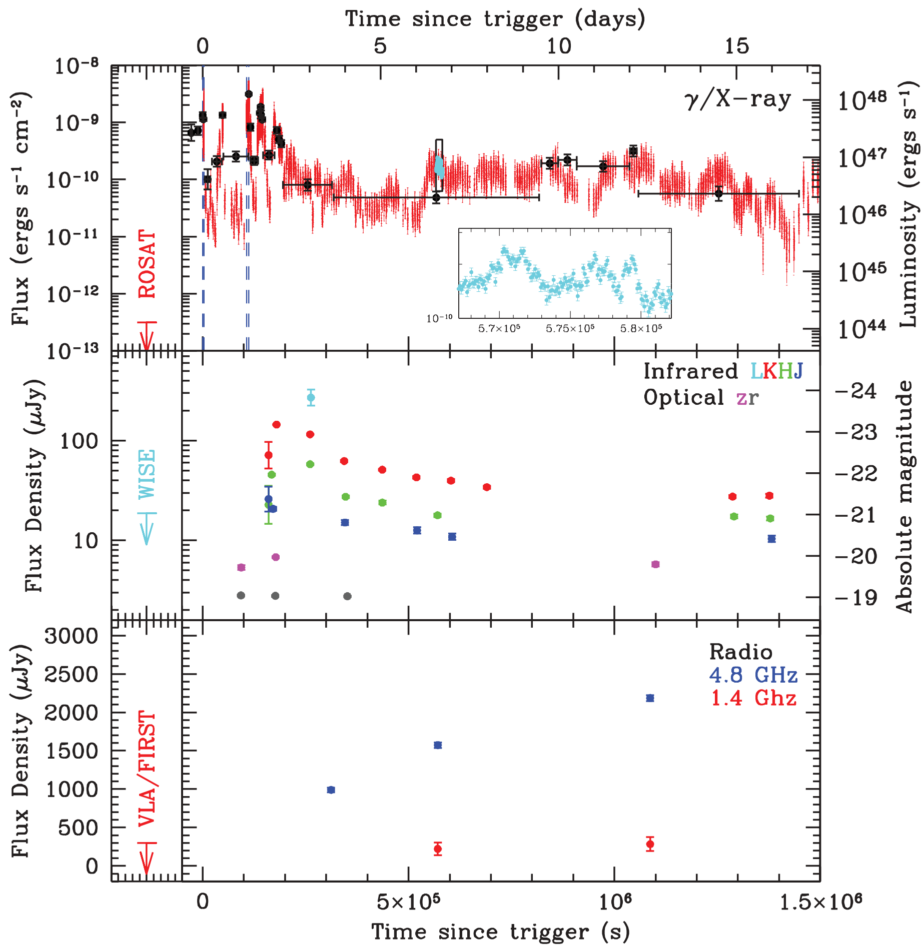

Fig. 1. The x-ray, IR, and radio lightcurves of Sw 1644+57. (**Top**) The XRT (0.3 to 10 keV; red) and BAT (15 to 50 keV; black) flux against observed time since the initial outburst trigger time; the right hand axis indicates the luminosity of the event. (Inset) The dense sampling of our Chandra observation. The dashed blue vertical lines indicate the times of subsequent triggers of the BAT. (**Middle**) Our near-IR lightcurve of this event (host flux not subtracted). (**Bottom**) Our 4.8- and 1.4-GHz lightcurve's obtained from the WSRT show a rising radio flux. The left-hand panels represent pre-outburst observations of the location of Sw 1644+57 and the limits on transient emission at this time (*24*), in the x-ray (ROSAT, 1991), IR (WISE, Jan 2010), and radio (VLA FIRST, 1998). They clearly demonstrate the large amplitude of this outburst in the x-ray and IR.

from the *B* band (435 nm) to the *L* band (3780 nm). In contrast to the non-varying behavior in the optical, these data showed that at near-IR wavelengths the source fluctuated by more than a factor of 3 in flux over several days, indicating that the γ-ray transient was also producing considerable longer-wavelength emission. Our detection in the *L* band [270 ± 50 microjansky (μJy)], compared with quiescent limits from the WISE satellite, implies that the transient is at least an order of magnitude brighter than its host galaxy at these wavelengths. The IR variations roughly track those of the x-ray (Fig. 1) but are certainly not perfectly correlated, suggesting multiple emission components.

We obtained an observation with the Chandra X-ray Observatory, which took place about 6.5 days after the initial outburst (Fig. 1). This showed that the x-ray emission continued to exhibit a factor of ~2 changes in flux on time scales as short as ~100 s even at this comparatively late time after the early flaring. However, our photometry of individual optical and near-IR images (with a time resolution of 20 to 60 s) does not reveal rapid variability in the near-IR light. In the optical *r* band, little variability was seen (<10%) on all time scales, indicating that the host galaxy dominates the optical emission. The tran-

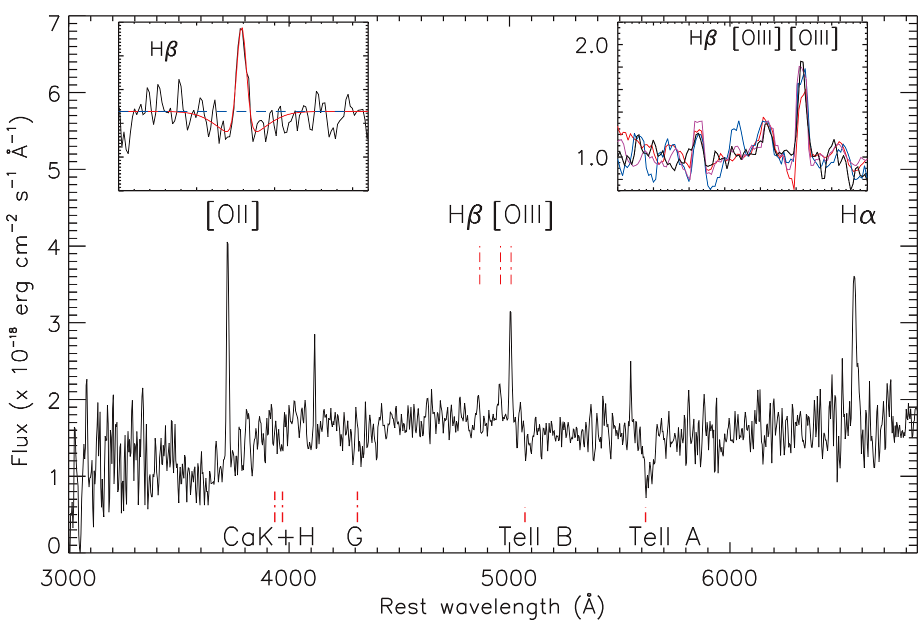

Fig. 2. Spectrum of the host galaxy of Sw 1644+57, obtained at the GTC. (**Left inset**) the Hβ line as seen in the first Gemini Multi Object Spectograph spectrum. Prominent stellar atmosphere absorption is visible. (**Right inset**) The first Gemini spectrum (red), the second Gemini spectrum (blue), the Keck spectrum (purple), and the GTC spectrum (black) covering the Hβ and [O III] doublet, all rebinned to the lower resolution of the GTC spectra. No emission line variability is apparent over the 3-day span of these observations.

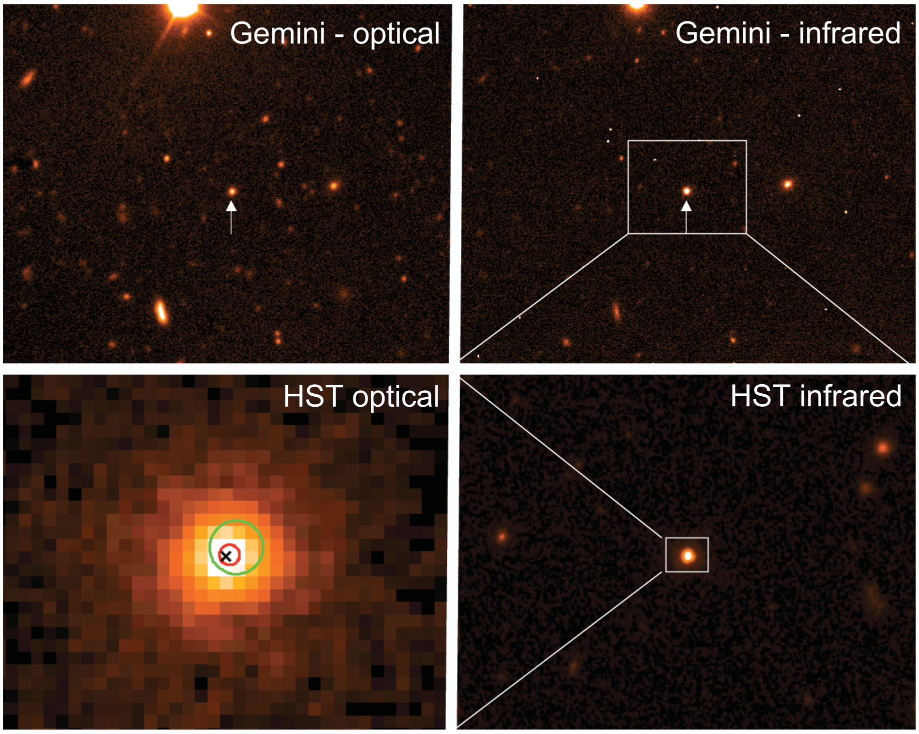

Fig. 3. Discovery images of Sw 1644+57-and its host galaxy. (**Top**) Our ground-based imaging in the optical *r* band (top left) and IR *K*-band (top right). The images are oriented north, up; east, left and are approximately 1 arc min in height. The location of Sw 1644+57 is indicated with arrows. (**Bottom**) Zoomed-in regions of our later time observations with HST in the IR (bottom right) and optical (bottom left). The crosshair indicates the optically derived centroid of the host galaxy. The red circle shows the location of the IR source inferred from our first epoch WFC IR observations, whereas the larger green circle shows the offset (due to the systematic uncertainty in tying coordinate frames) from our very long baseline interferometry position.

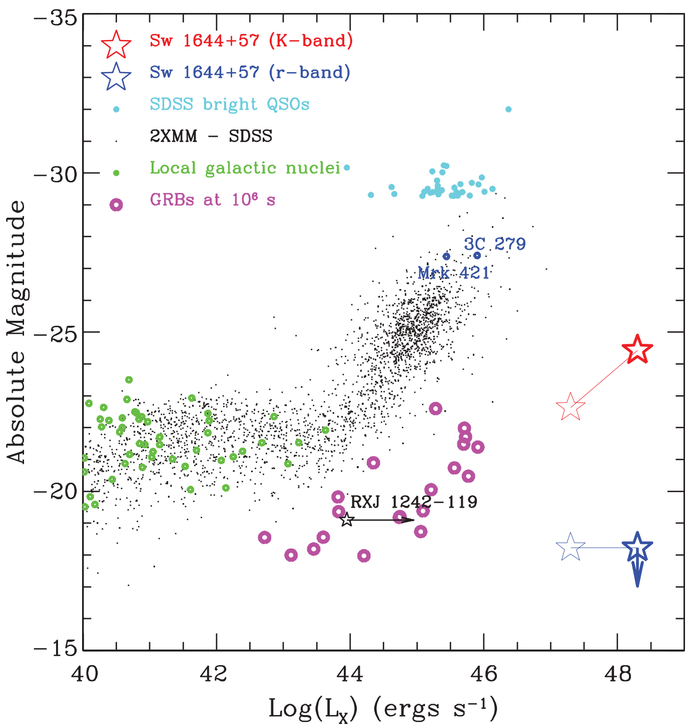

Fig. 4. The x-ray luminosity and optical/near-IR absolute magnitude of Sw 1644+57, at peak (bold stars) and at 10^6 s after the trigger. For comparison, we show the properties of the most luminous quasars and blazars (3C 279 and Mrk 421); a sample of all objects within the 2XMM survey with high confidence (>2 σ) association with objects in the Sloan Digital Sky Survey of known redshift $z < 3$ (*25*); and a sample of more local galaxies [from (*26*); optical magnitudes include contribution from the host galaxy]. We also plot the late-time luminosities of a sample of bright GRB afterglows [extrapolated from (*27*, *28*)], which are relevant because Sw 1644+57 stays within an order of magnitude of its brightest peak, even 10^6 s after the outburst began. We also plot the location of the candidate tidal disruption event in RXJ 1242-119 (*29*).

sient has a very red optical near-IR color, probably because of a high dust column along the line of sight. The dust hypothesis would be consistent with the high hydrogen column density inferred from the x-ray spectrum (10^{22} cm^{-2}), which implies host extinction of $A_V \sim 6$ (*15*), reducing the optical luminosity by a factor of $\gtrsim$100. Together, these findings suggest that the source is situated in a dense and dusty region, such as a galactic nucleus (SOM text).

Observations at still longer wavelengths showed a bright radio (*16*) and millimeter source (*17*) at the same location. Our millimeter observations from the Institut de Radioastronomie Millimétrique (IRAM) confirm this, and radio (1.4. and 4.8 GHz) observations from Westerbork Synthesis Radio Telescope (WSRT) show a bright source, which in contrast to the optical and IR light brightened over the first week after the outburst (Fig. 1, bottom). These observations demonstrate that Sw 1644+57 emitted strong radiation across the electromagnetic spectrum, whereas the differing behavior in each waveband may be due to either strong spectral evolution or distinct emission components.

The character of the host galaxy and the position of the transient within it are potentially important clues to the nature of Sw 1644+57, and to this end, we obtained observations with the Hubble Space Telescope (HST) on 4 April and 20 April 2011. In the near-IR, the image remains unresolved, fading between the two epochs of observation, and consistent with emission from the transient still dominating. In the optical wavebands, we clearly detected the light of the host galaxy. The Wide Field Camera 3 (WFC3) IR position of the transient falls within 0.03 arc sec (1 σ, < 150 pc at z = 0.3534) of the center of the host galaxy (Fig. 3). We also obtained Very Long Baseline Array (VLBA) observations of Sw 1644+57 on 1 April 2011. These provided another precise astrometric position, with an offset from the center of the host of 0.04 ± 0.07 arc sec, further strengthening the association with the nucleus of the host (*18*).

The host galaxy itself appears compact and noninteracting, with a half-light radius in the optical of r_h = 1.04 kpc and an absolute magnitude of M_V = −18.19 (comparable in luminosity with the Large Magellanic Cloud). Subtraction of a point source from the HST F606W image suggests an upper limit to the transient magnitude in that band of 30% of the host light, or a magnitude of 24.1 (AB). The measured ratios of emission lines are consistent with an origin in a normal star-forming galaxy that has not, at least until now, contained an active nucleus. The inferred star formation rate of the host is 0.5 solar mass ($M_\odot$) yr^{-1}.

Our observations clearly show that the transient originates from the center of a galaxy at cosmological distances. At this redshift, the brightest x-ray flare reached a luminosity of $L_X \sim 3 \times 10^{48}$ erg s^{-1} (isotropic equivalent) for ~1000 s. The total energy output in the first ~10^6 s after the outburst of ~10^{53} erg is equivalent to ~10% of the rest energy of the Sun. Although these numbers are not abnormal for long-GRBs, the properties of this outburst are clearly distinct from the long-GRB population. First, the repetition of the γ-ray trigger four times in 48 hours is unheard of for long-GRBs, which are destructive and non-repeating events. Further, the duration of bright x-ray emission is much longer than has ever been seen for any long-GRB (*19*, *20*), persisting at $L_X \sim 10^{47}$ erg s^{-1} 2 weeks after the initial event. This, together with the origin in the core of its host galaxy, implies that Sw 1644+57 most likely originates from the central massive black hole. However, the x-ray luminosity of Sw 1644+57 is well beyond the bright end of the quasar luminosity function (*21*) and is more luminous (by a factor of ~100) than flares from the brightest blazars (*3*). However, its optical luminosity is a factor of $\sim 10^4$ fainter than a bright quasar (*22*), implying either different emission processes or (as seems to be the case, owing to the red color) a particularly high dust column within the host. The overall energetics and long duration, together with the order-of-magnitude variations in flux over 100 s time scales, make it clear that we are observing an unprecedented astrophysical object (Fig. 4).

The peak luminosity corresponds to the Eddington luminosity of a $\sim 10^{10}\,M_\odot$ black hole. It is highly unlikely that a moderate-sized galaxy such as the host of Sw 1644+57 could contain such a massive black hole; our spectral energy distribution fitting of the host galaxy implies that its total stellar mass is less than this value (SOM text and fig. S6), and for a typical stellar mass–black hole mass relation (*23*), its black hole mass is unlikely to be greater than $\sim 10^7\,M_\odot$. Hence, Sw 1644+57 is either accreting at a super-Eddington rate or has its total energy modified by relativistic beaming (or both). Bloom *et al*. (*24*) consider the possibility that the source of this event is the tidal disruption of a star around the central black hole.

The detection of a different class of extremely energetic γ-ray transient after many years of intensive monitoring of the γ-ray sky highlights the rarity of this phenomenon. Although the bright flares in Sw 1644+57 are of longer duration than typical GRBs, it is likely that Swift would have detected a similar event to at least $z \sim 0.7$. If we assume that galaxies within 1 magnitude of the Sw 1644+57 host will typically contain similar-mass black holes at their centers, then we can estimate a space density of $\sim 5 \times 10^7$ Gpc^{-3} potential hosts. Thus, a single example in 6.5 years of Swift operations would correspond to a rate per galaxy of 1 in $3 \times f_{\mathrm{beam}}$ gigayears, where we allow for the possibility that the radiation is beamed into a fraction f_{beam} of a sphere.

Although Sw 1644+57 was detected through its γ-ray emission, it is its behavior at x-ray and IR wavelengths, lasting at a bright flux level for days to weeks, that most strikingly demonstrates its difference from known classes of high-energy transient. This raises the possibility that similar events that are rather less variable or less luminous could be occurring but have so far evaded detection with existing satellites.

References and Notes

1. C. Kouveliotou *et al.*, *Nature* **393**, 235 (1998).
2. F. Aharonian *et al.*, *Science* **309**, 746 (2005).
3. I. Donnarumma *et al.*, *Astrophys. J.* **691**, L13 (2009).
4. N. Gehrels, E. Ramirez-Ruiz, D. B. Fox, *Annu. Rev. Astron. Astrophys.* **47**, 567 (2009).
5. J. Hjorth *et al.*, *Nature* **423**, 847 (2003).
6. S. E. Woosley, J. S. Bloom, *Annu. Rev. Astron. Astrophys.* **44**, 507 (2006).
7. J. C. Cummings *et al.*, *GRB Coord. Network* **11823**, 1 (2011).
8. T. Sakamoto *et al.*, *GRB Coord. Network* **11842**, 1 (2011).
9. H. Krimm, S. Barthelmy, *GRB Coord. Network* **11891**, 1 (2011).
10. G. Leloudas *et al.*, *GRB Coord. Network* **11830**, 1 (2011).
11. S. D. Barthelmy *et al.*, *GRB Coord. Network* **11824**, 1 (2011).
12. A. Levan, N. Tanvir, K. Wiersema, D. Perley, *GRB Coord. Network* **11833**, 1 (2011).
13. C. Thoene *et al.*, *GRB Coord. Network* **11834**, 1 (2011).
14. S. B. Cenko *et al.*, *GRB Coord. Network* **11874**, 1 (2011).
15. P. Predehl, J. H. M. M. Schmitt, *Astron. Astrophys.* **293**, 889 (1995).
16. A. Zauderer, E. Berger, D. A. Frail, A. Soderberg, *GRB Coord. Network* **11836**, 1 (2011).
17. A. Zauderer *et al.*, *GRB Coord. Network* **11841**, 1 (2011).
18. A. Brunthaler *et al.*, *GRB Coord. Network* **11911**, 1 (2011).
19. C. Kouveliotou *et al.*, *Astrophys. J.* **608**, 872 (2004).
20. J. A. Nousek *et al.*, *Astrophys. J.* **642**, 389 (2006).
21. Y. Ueda, M. Akiyama, K. Ohta, T. Miyaji, *Astrophys. J.* **598**, 886 (2003).
22. D. W. Just *et al.*, *Astrophys. J.* **665**, 1004 (2007).
23. V. N. Bennert, M. W. Auger, T. Treu, J.-H. Woo, M. A. Malkan, *Astrophys. J.* **726**, 59 (2011).
24. J. Bloom *et al.*, *Science* **333**, XXXX (2011).
25. F. Pineau *et al.*, *Astron. Astrophys.* **527**, A126 (2011).
26. L. C. Ho, *Astrophys. J.* **699**, 626 (2009).
27. D. A. Kann *et al.*, *Astrophys. J.* **720**, 1513 (2010).
28. P. A. Evans *et al.*, *Mon. Not. R. Astron. Soc.* **397**, 1177 (2009).
29. S. Komossa *et al.*, *Astrophys. J.* **603**, L17 (2004).

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Data used in this paper are presented in the SOM or taken from the literature as cited.

Supporting Online Material

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SOM Text
Figs. S1 to S12
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An Extremely Luminous Panchromatic Outburst from the Nucleus of a Distant Galaxy

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