nature International weekly journal of science
LETTER
doi:10.1038/nature23289

Substantial and variable linear polarization during the prompt optical flash of GRB 160625B

E. Troja[1,2], V. M. Lipunov[3,4], C. G. Mundell[5], N. R. Butler[6], A. M. Watson[7], S. Kobayashi[8], S. B. Cenko[1,2], F. E. Marshall[2], R. Ricci[9], A. Fruchter[10], M. H. Wieringa[11], E. S. Gorbovskoy[3,4], V. Kornilov[3,4], A. Kutyrev[1,2], W. H. Lee[7], V. Toy[1], N. V. Tyurina[3,4], N. M. Budnev[12], D. A. H. Buckley[13], J. González[7], O. Gress[12], A. Horesh[14], M. I. Panasyuk[15], J. X. Prochaska[16], E. Ramirez-Ruiz[16], R. Rebolo Lopez[17], M. G. Richer[18], C. Román-Zúñiga[18], M. Serra-Ricart[17], V. Yurkov[19] & N. Gehrels[2]

Newly formed black holes of stellar mass launch collimated outflows (jets) of ionized matter that approach the speed of light. These outflows power prompt, brief and intense flashes of γ-rays known as γ-ray bursts (GRBs), followed by longer-lived afterglow radiation that is detected across the electromagnetic spectrum. Measuring the polarization of the observed GRB radiation provides a direct probe of the magnetic fields in the collimated jets. Rapid-response polarimetric observations of newly discovered bursts have probed the initial afterglow phase[1–3], and show that, minutes after the prompt emission has ended, the degree of linear polarization can be as high as 30 per cent—consistent with the idea that a stable, globally ordered magnetic field permeates the jet at large distances from the central source[3]. By contrast, optical[4–6] and γ-ray[7–9] observations during the prompt phase have led to discordant and often controversial[10–12] results, and no definitive conclusions have been reached regarding the origin of the prompt radiation or the configuration of the magnetic field. Here we report the detection of substantial (around eight per cent), variable linear polarization of a prompt optical flash that accompanied the extremely energetic and long-lived prompt γ-ray emission from GRB 160625B. Our measurements probe the structure of the magnetic field at an early stage of the jet, closer to its central black hole, and show that the prompt phase is produced via fast-cooling synchrotron radiation in a large-scale magnetic field that is advected from the black hole and distorted by dissipation processes within the jet.

On 25 June 2016 at 22:40:16.28 Universal Time (UT), the γ-ray burst monitor (GBM) aboard NASA's Fermi Gamma-ray Space Telescope discovered GRB 160625B as a short-lived pulse (lasting about 1 second) of γ-ray radiation (G1 in Fig. 1). An automatic localization was published rapidly by the spacecraft, allowing wide-field optical facilities to start follow-up observations. Three minutes after the first

counterpart in two orthogonal polaroids simultaneously, starting at $T_0 + 95$ seconds and ending at $T_0 + 360$ seconds. The detection of a polarized signal with this instrumental configuration provides a lower bound ($\Pi_{L,min}$) to the true degree of linear polarization, thus $\Pi_{L,min} = (I_2 - I_1)/(I_1 + I_2)$, where I_1 and I_2 refer to the source intensity in each polaroid. Substantial levels of linear polarization, up to $\Pi_{L,min} = 8.0 \pm 0.5\%$, were thereby detected (Fig. 2; by comparison, values of less than 2% have been detected for other nearby objects of similar brightness). Over this time interval a weak tail of γ-ray emission was visible, until the onset of a third, longer-lived episode of