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A Cosmological Fireball with Sixteen-Percent Gamma-Ray Radiative Efficiency

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Gamma-ray bursts (GRBs) are the most powerful explosions in the universe. How efficiently the jet converts its energy to radiation is a long-standing problem and it is poorly constrained. The standard model invokes a relativistic fireball with a bright photosphere emission component. A definitive diagnosis of GRB radiation components and measurement of GRB radiative efficiency require prompt emission and afterglow data with high-resolution and wide-band coverage in time and energy. Here we report a comprehensive temporal and spectral analysis of the TeV-emitting bright GRB 190114C. Its fluence is one of the highest of all GRBs detected so far, which allows us to perform a high-resolution study of the prompt emission spectral properties and their temporal evolution down to a timescale of about 0.1 s. We observe that each of the initial pulses has a thermal component contributing $\sim 20\%$ of the total energy, the corresponding temperature and the inferred Lorentz factor of the photosphere evolve following broken power-law shapes. From the observation of the non-thermal spectra and the light-curve, the onset of afterglow corresponding to the deceleration of the fireball is considered at ~ 6~s. By incorporating the thermal and the non-thermal observations, as well as the photosphere and the synchrotron radiative mechanisms, we can directly derive the fireball energy budget with little dependence on hypothetical parameters and to measure a $\sim 16\%$ radiative efficiency for this GRB. With the fireball energy budget derived, the afterglow microphysics parameters can also be constrained directly from the data.

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