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Exploring Origin of Ultra-Long Gamma-ray Bursts: Lessons from GRB 221009A

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The brightest Gamma-ray burst (GRB) ever, GRB 221009A, displays ultra-long GRB (ULGRB) characteristics, with a prompt emission duration exceeding 1000 s. To constrain the origin and central engine of this unique burst, we analyse its prompt and afterglow characteristics and compare them to the established set of similar GRBs. To achieve this, we statistically examine a nearly complete sample of Swift-detected GRBs with measured redshifts. Categorizing the sample to Bronze, Silver, and Gold by fitting a Gaussian function to the log-normal of \tninty duration distribution and considering three sub-samples respectively to 1, 2, and 3 times of the standard deviation to the mean value. GRB 221009A falls into the Gold sub-sample. Our analysis of prompt emission and afterglow characteristics aims to identify trends between the three burst groups. Notably, the Gold sub-sample (a higher likelihood of being ULGRB candidates) suggests a collapsar scenario with a hyper-accreting black hole as a potential central engine, while a few GRBs (GRB 060218, GRB 091024A, and GRB 100316D) in our Gold sub-sample favour a magnetar. Late-time near-IR (NIR) observations from the 3.6 m Devasthal Optical Telescope (DOT) rule out the presence of any bright supernova associated with GRB 221009A in the Gold sub-sample. To further constrain the physical properties of ULGRB progenitors, we employ the tool MESA to simulate the evolution of low-metallicity massive stars with different initial rotations. The outcomes suggest that rotating (Omega > 0.2 Omega_{c) massive stars could potentially be the progenitors of ULGRBs within the considered parameters and initial inputs to MESA

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