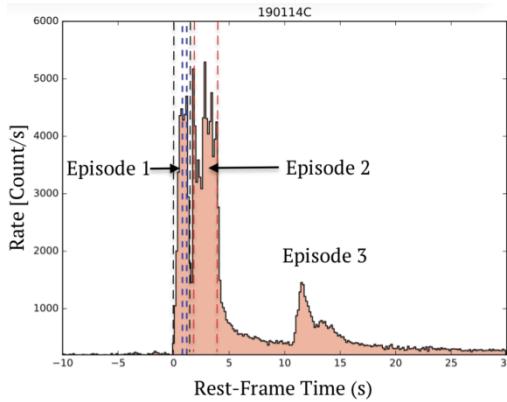


## “On the role of a cavity in the hypernova ejecta of GRB 190114C”

Since 2018, a new style of research has been introduced in Gamma-Ray-Bursts (GRBs) studies: it does not describe the prompt radiation phase observed by the Neil Gehrels Swift Observatory and the NASA Fermi Gamma-ray Space Telescope by a time-integrated spectral analysis, typically applied to long GRBs and obtaining a Band spectrum with various fitting parameters, this procedure, as recognized by David Band, does not permit a taxonomy of GRBs [1]. The approach followed by the ICRANet group, developing the Binary driven Hypernova (BdHN) model of long GRBs, focuses only on luminous GRBs with a large signal to noise ratio which allow to proceed to a time-resolved analysis. In doing so three main events in the prompt radiation phase have been identified [2]: 1) the supernova rise, 2) the moment of formation of a black hole coinciding with the onset of the GeV radiation and 3) the emission of a cavity, created by the explosion of electron-positron plasma in the expanding supernova ejecta, see Fig. 1. In addition to these results, the greatest novelty in this field has been so far the discovery of self-similarity and power laws in the data, following the black hole formation from 1.9 second to 3.9 seconds, see the accompanying article [2], leading to evidence of quantized versus continuous emission in the GeV radiation, see the accompanying article [3].

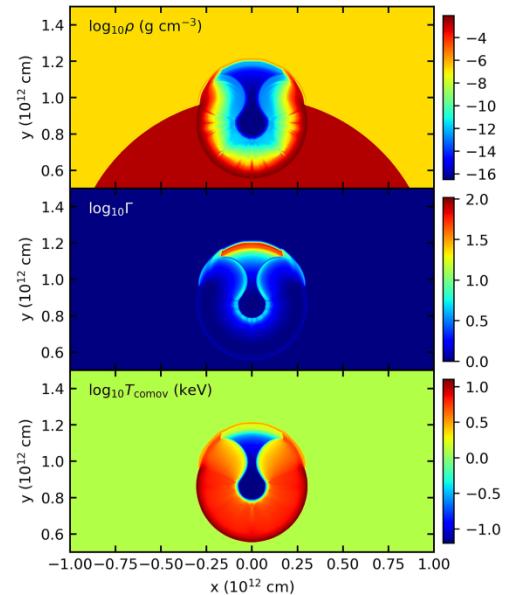


**Fig. 1. The light curve of GRB190114c in the rest frame of the source contains the precursor up to 1.9 s (Episode 1), then ultrarelativistic prompt emission (UPE) up to 3.9 s (Episode 2), then the residual emission following the UPE from 3.9 s up to 11 s. The emission from the cavity (Episode 3) occurs at 11 s and continues up to 20 s.**

within its horizon, and thus a cavity of approximately  $10^{11}$  cm is formed around it with initial density  $10^7$  g/cm<sup>3</sup>. A further depletion of baryons in the cavity originates from the expansion of the electron-positron-photon plasma formed at the moment of the collapse, reaching a density of  $10^{-14}$  g/cm<sup>3</sup> by the end of the interaction. It is demonstrated, using an analytical model complemented by a hydrodynamic numerical simulation, see Fig. 2, that part of the electron-positron-photon plasma is reflected off the walls of the cavity. The consequent outflow and its observed properties are shown to coincide with the featureless emission occurring in a time interval of duration, measured in the rest frame of the source, between 11 and 20 s of the GBM observation. Moreover, similar features of the GRB light curve were previously observed in GRB 090926A and GRB 130427A, all belonging to the BdHN I class. These results support the general framework presented in [2] and guarantees that a low baryon density is reached in the cavity, a necessary condition for the operation of the

The new study, co-authored by R. Ruffini, J. D. Melon Fuksman, G. V. Vereshchagin [4], has been accepted for publication by the Astrophysical Journal on August 19, 2019. It presents the evidence of the formation of a cavity in the source of gamma-ray burst GRB 190114C. It is proposed that this GRB originates in a binary system composed of a massive carbon-oxygen core, described within the binary-driven hypernova I (BdHN I) scenario. In this scenario, the carbon-oxygen core undergoes a supernova explosion with the creation of a new neutron star, hypercritical accretion occurs onto the companion binary neutron star until it exceeds the critical mass for gravitational collapse.

It is shown that the formation of a black hole captures  $10^{57}$  baryons by enclosing them



**Fig. 2. Spatial distributions of matter density (top), Lorentz factor (middle) and comoving temperature (bottom) at  $t = 11$  s, showing the mildly relativistic reflection wave propagating backward in the cavity, as well as the ultrarelativistic electron-positron plasma wave propagating outside the cavity. The shock wave is visible inside the ejecta.**

“inner engine” of the GRB, presented in the accompanying article [3].

The density of  $10^{-14}$  g/cm<sup>3</sup> here discovered points clearly to a completely different origin of the MeV and GeV emission hosted in the cavity: an electromagnetic machine, producing emission very close to the black hole horizon, and based on three components: 1) a Kerr black hole, 2) a uniform magnetic field following the Papapetrou theorem and 3) a low density plasma of  $10^{-14}$  g/cm<sup>3</sup> [4]. This contrasts with the traditional gravitational accretion of very high density matter onto a black hole. This result profoundly changes the traditional mechanism of emission of GRBs and can be extended to active galactic nuclei (AGNs) [5]. As a consequence, also the physics of GRBs afterglows has been modified avoiding the ultrarelativistic blast wave emission and utilizing the synchrotron process occurring around the new neutron star expected in the BdHN model [6].

## References:

1. D. Band, et al., “BATSE Observations of Gamma-Ray Burst Spectra. I. Spectral Diversity”, [ApJ v.413, p.281 \(1993\)](#).
2. Ruffini, R., Li, L., Moradi, R., Rueda, J. A., Wang, Y., Bianco, C., Melon Fuksman, J. D., Xue, S., Cherubini, C., Filippi, S., Karlica, M., & Sahakyan, N. (2019). “Self-similarity and power-laws in GRB 190114c”, [arXiv:1904.04162](#).
3. Ruffini, R. & Moradi, R., e. a. (2019). “On the determination of the mass and spin of the black hole in the inner engine of GRB 190114c”, submitted.
4. R. Ruffini, J.D. Melon Fuksman, G.V. Vereshchagin, “On the role of a cavity in the hypernova ejecta of GRB 190114C”, ApJ, 2019, in press; [arXiv:1904.03163](#).
5. J. A. Rueda, R. Ruffini, “The blackholic quantum”, [arXiv:1907.08066](#).
6. J. A. Rueda, R. Ruffini, M. Karlica, R. Moradi, Y. Wang, “Inferences from GRB 190114C: Magnetic Field and Afterglow of BdHN”, [arXiv:1905.11339](#).