The largest impact in the Cosmos. A Gamma-Ray Burst impacting on an infant Supernova.

Prof. Remo Ruffini announces a new publication of ICRANet scientists: "On the induced gravitational collapse scenario of gamma-ray bursts associated with supernovae", posted online on October 16 (http://lanl.arxiv.org/abs/1606.02523) and currently in press in the Astrophysical Journal.

This follows the previous publications "On the classification of GRBs and their occurrence rates", posted online on September 9 (https://arxiv.org/abs/1602.02732) *in press in the Astrophysical Journal, and "GRB 090510: a genuine short-GRB from a binary neutron star coalescing into a Kerr-Newman black hole", posted online on September 6 (https://arxiv.org/abs/1607.02400) and currently also in press in the Astrophysical Journal.*

GRBs, traditionally classified as "short" and "long" have been often assumed, till recently, to originate from a single Black Hole with an ultrarelativistic jetted emission. There is today clear evidence that both short and long GRBs have as progenitors merging and/or accreting binary systems, each composed by a different combination of iron-carbon-oxygen (FeCO) core, Neutron Stars (NSs) Black Holes (BHs) and white dwarfs in different combinations [1].

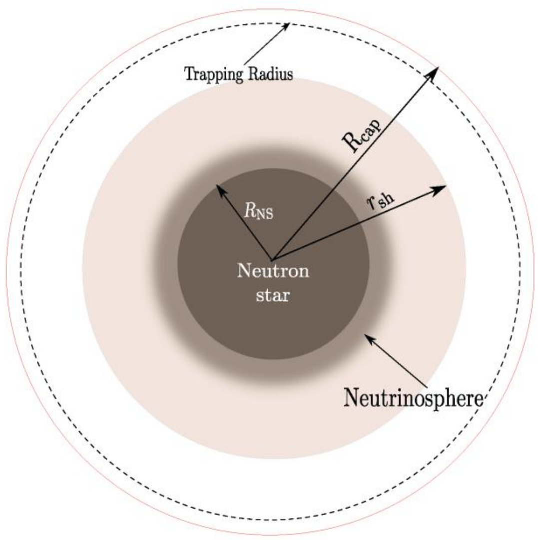

Fig. 1. Structure of the NS hypercritical-accretion region above the NS radius R_{NS}.

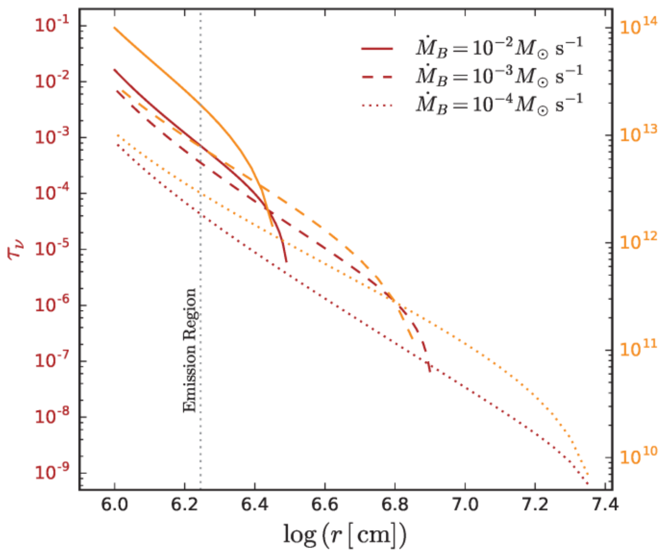

Fig. 2. Neutrino τ_ν and photon optical depths τ_γ in the NS hypercritical-accretion region above the neutrinosphere τ_ν=1, with selected mass accretion rates.

This paper sheds new light on the process of hypercritical accretion, which is at the heart of the induced gravitational collapse (IGC) paradigm for gamma-ray bursts (GRBs), proposed by prof. Ruffini [2,3] and ICRANet scientists. The IGC paradigm, originally proposed in 2001, has been developed further in 2012 to explain the GRB-SN connection [4]. Within this paradigm a long GRB originates in a binary systems composed of a FeCO core and a NS, where the orbital period measures minutes [4]. In such systems the explosion of FeCO core as a supernova leads to hypercritical accretion onto the NS companion, which

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reaches the critical mass, hence inducing its gravitational collapse to a BH with consequent emission of the GRB. The IGC paradigm was first successfully applied to GRB 090618 [5,6]. Based on this paradigm the new concept of binary-driven hypernovae (BdHN), characterized by four different episodes of emission with precise spectral and luminosity features, has been proposed by prof. Ruffini with ICRANet scientists for long GRBs [7].

Accretion is a familiar process in astrophysics, and it is known to power such objects as X-ray binaries [8,9]. There the gravitational energy is converted into heat, so that accretion disk emits X-rays. In contrast, according to the BdHN model [7], the gravitational energy of hypercritically accreting matter is released primarily in the form of neutrinos, see Fig. 1 and 2. The accretion process is so violent, with mass accretion rate up to one solar mass per second, that photons remain trapped within the accreting flow. With such huge accretion rates the temperature near the surface of the NS reaches 10 billion of degrees. Actually, this phenomenon was pioneered independently by Zeldovich [10] and Ruffini [11] in 1973, before the discovery of GRBs was announced.

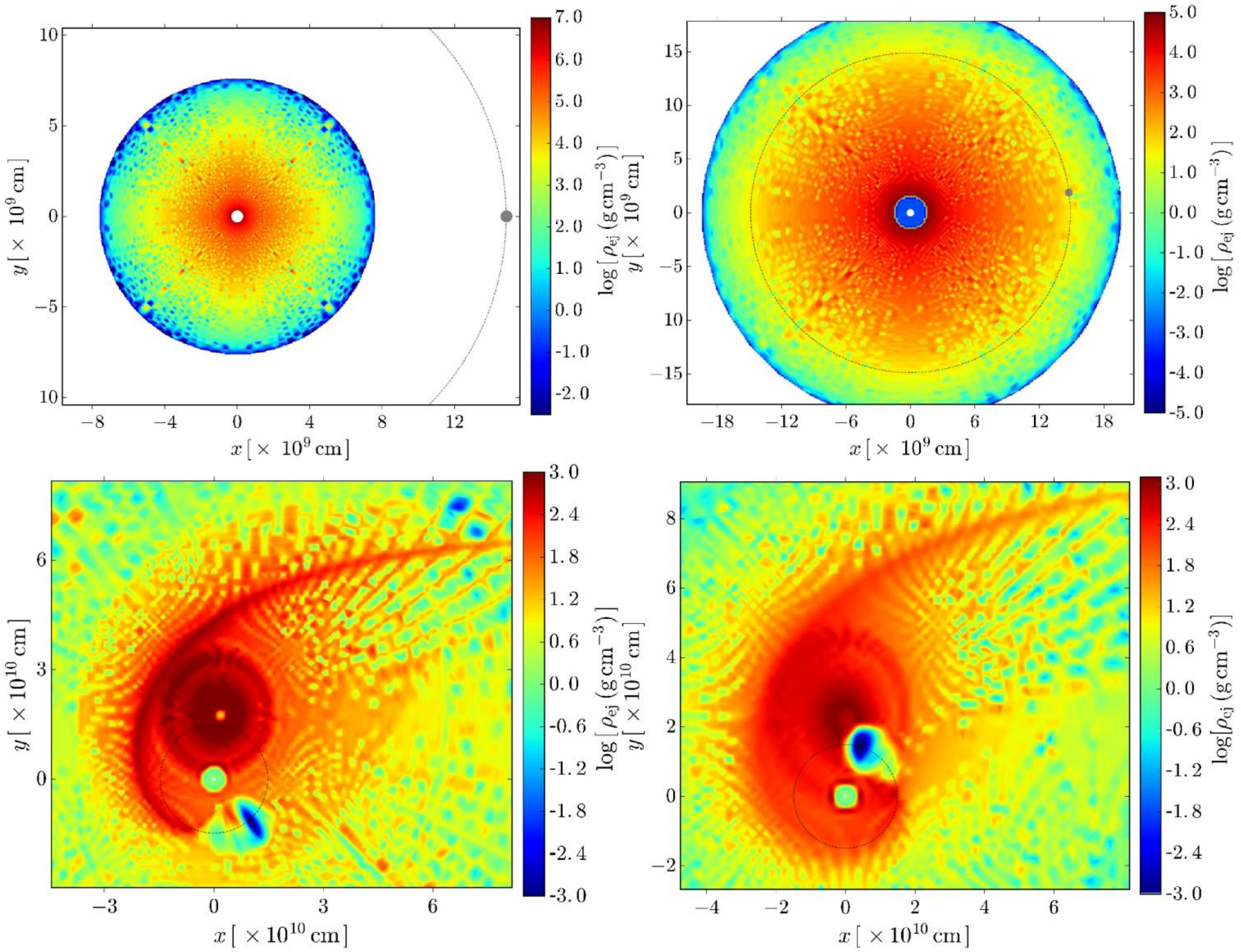

Fig. 3. Snapshots of the expanding supernova ejecta which interacts with the companion neutron star. The white dot in the origin is the newly formed neutron star.

Estimates of the accretion rate and the possible fate of the accreting NS in the IGC binary were presented by ICRANet scientists already in 2012, see Refs. [4-6]. The new paper reports results of detailed numerical simulations of the explosion of a FeCO core as a supernova and hypercritical accretion of the supernova ejecta on the binary NS companion. These new simulations, performed by Laura Becerra as a part of her PhD thesis in the IRAP PhD program coordinated by ICRANet, involving more than a million of particles, see Fig. 3, include the effects of the finite size of the ejecta for different FeCO core progenitors and confirm the previous estimates, as well as identify the separatrix for such systems, which separate those where BH is formed, and examine the moment of its formation, from those where there is no BH formation. In addition, the expected luminosity of such systems undergoing hypercritical accretion is computed, and the results are shown to be in agreement with observations of the X-ray flash XRF 060218. This work also evidences the asymmetry of the supernova ejecta as induced by the presence of the companion, accreting NS as well as the formation of the new NS, see Fig. 3. The colorful snapshot of interaction between the supernova ejecta and the hypercritically accreting NS shown in Fig. 3 was selected for the poster of IRAP-PhD program for 2016 call.

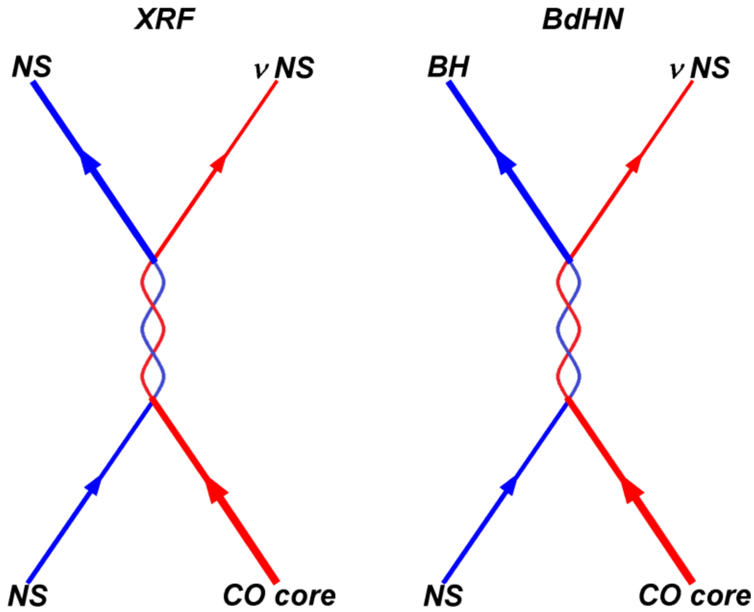

Fig. 4. Cosmic-matrix of XRFs and BdHNe as introduced in [12].

The new results obtained in this paper:

- show the moment of formation of the BH, as the result of hypercritical accretion of the supernova ejecta onto the companion NS, see Fig. 3;
- give the first treatment of neutrino emission in the process of hypercritical accretion and provide the determination of the neutrinosphere, see Fig. 1 and 2;
- give the first detailed model of a "Cosmic Matrix", see Fig. 4, which describes these systems as a four-body problem in analogy to the case of particle physics. The "in-state" is represented by the FeCO core and the NS companion. In the case of a BdHN the "out-state" is the a new NS, i.e. the neutron star left by the supernova explosion of the FeCO core, and a BH formed from the gravitational collapse of the NS companion of the FeCO core in the in-state. In XRFs the "out-state" is a new NS and another NS, more massive than the initial one present in the in-state.

These results are supported by numerical simulations done at Los Alamos National Laboratories by Chris Fryer and his group. Laura Becerra, who will receive the joint degree between the Universities of Bremen, Oldenburg, Savoie, Rome, Ferrara, Nice, will be spending six months at Los Alamos, starting 1 November, to foster the collaboration within ICRANet, including the ICRANet seat in Tucson, Arizona, and the Los Alamos National Laboratories.

References:

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