# Black holes all over the Universe

**Remo Ruffini**
**in collaboration with**

C.L. Bianco, M. Della Valle, Liang. Li, T. Mirtorabi, R. Moradi, F. Rastegar Nia, J. A. Rueda, N. Sahakyan, C., C. Sigismondi, Y. Wang

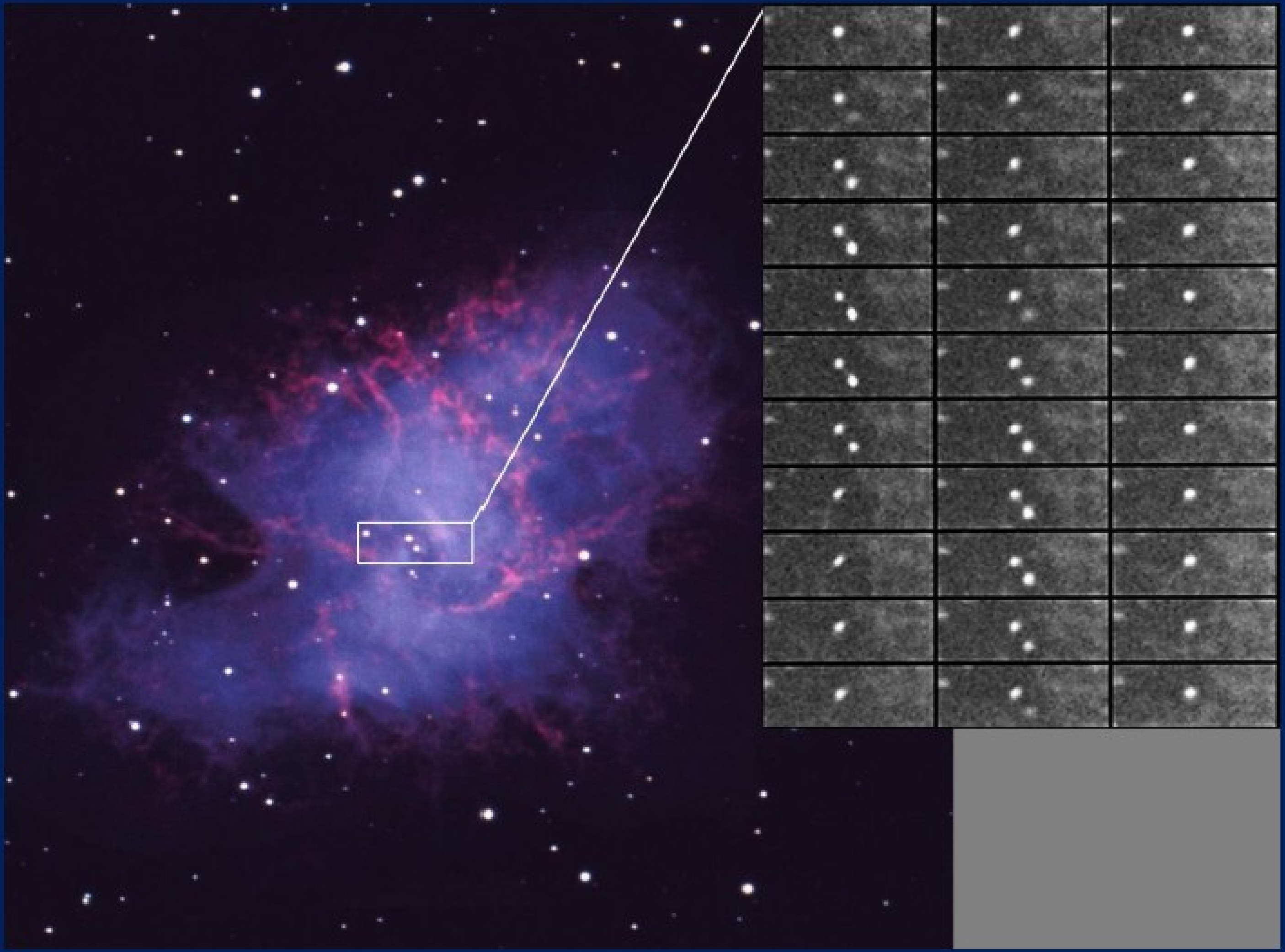
*With John A. Wheeler, we were quite fortunate introducing the concept of Black Hole (BH) and, more important, using the Kerr mathematical solution to find the BH mass energy formula with Demetrious Christodoulou and Stephen Hawking. This topic is still far from being concluded: the role of the irreducible mass is being scrutinized and new results are being established in the energy extraction processes from a Kerr BH, even in these hours. We have been equally fortunate in developing the Binary Driven Hypernova model, based on a simple CO core of 10* $M_{sun}$ *and a companion binary NS of 1.5* $M_{sun}$ *evolving, in seven Episodes, guiding the establishing of new physical laws made possible by the multywavelength observations in newly observed extra-galactic systems. Possibly, the greatest contribution is a novel paradigm to identify the birth of a SN and its evolution into an optical SN , the birth of a BH , the birth of a pulsar leading to the understanding of the earliest emission of the TeV radiation, the evolution of the SN remnant through the observation X ray afterglow. All these different processes previously uncorrelated are newly identified as originating in the time evolution of a single BDHN: so, unifying within the evolution of a single extragalactic system, the fragmented astrophysical knowledge traditionally acquired from observations in our own Galaxy. We extend the observations of the BDHN to the earliest phases of the Universe. We also call attention on how the BDHN can significantly modify the paradigms of differentiating long and short GRBs.*

*While all this rest on our traditional understanding of the standard model of particle physics, we are addressing the new physics encountered in the study of our galactic center pointing to the possible existence of a yet unidentified fermionic dark matter component.*

**October 8, 2024**
**High Energy Astrophysics and Cosmology in the era of all-sky surveys meeting (HEACOSS)**
**Yerevan, Armenia**

# The Crab Supernova Renmant
in 2005
Hubble space Telescope

# Crab Nebula Pulsar



***A. Hewish, S. J. Bell et. al., Nature, 1968.***

# Over 5000 references on Crab Nebula

AGILE - Astro-rivelatore Gamma a Immagini LEggero
ALMA - Atacama Large Millimeter/submillimeter Array
CFHT - Canada-France-Hawaii Telescope
Chandra - Chandra X-ray Observatory
Fermi - Fermi Gamma-ray Space Telescope
GBT - Green Bank Telescope
H.E.S.S. - High Energy Stereoscopic System
HSO - Herschel Space Observatory
HST - Hubble Space Telescope
Integral - INTErnational Gamma-Ray Astrophysics Laboratory
JCMT - James Clerk Maxwell Telescope
JVLA - Karl G. Jansky Very Large Array
Keck - Keck Observatory
LOFAR - Low-Frequency Array
MAGIC - Major Atmospheric Gamma Imaging Cherenkov Telescopes
NuSTAR - Nuclear Spectroscopic Telescope Array
ROSAT - Röntgensatellit
SOFIA - Stratospheric Observatory for Infrared Astronomy
Spitzer - Spitzer Space Telescope
Subaru - Subaru Telescope
Swift - Swift Gamma-Ray Burst Mission
VLA - Very Large Array
VLT - Very Large Telescope
VERITAS - Very Energetic Radiation Imaging Telescope Array System
XMM-Newton - X-ray Multi-Mirror Mission-Newton
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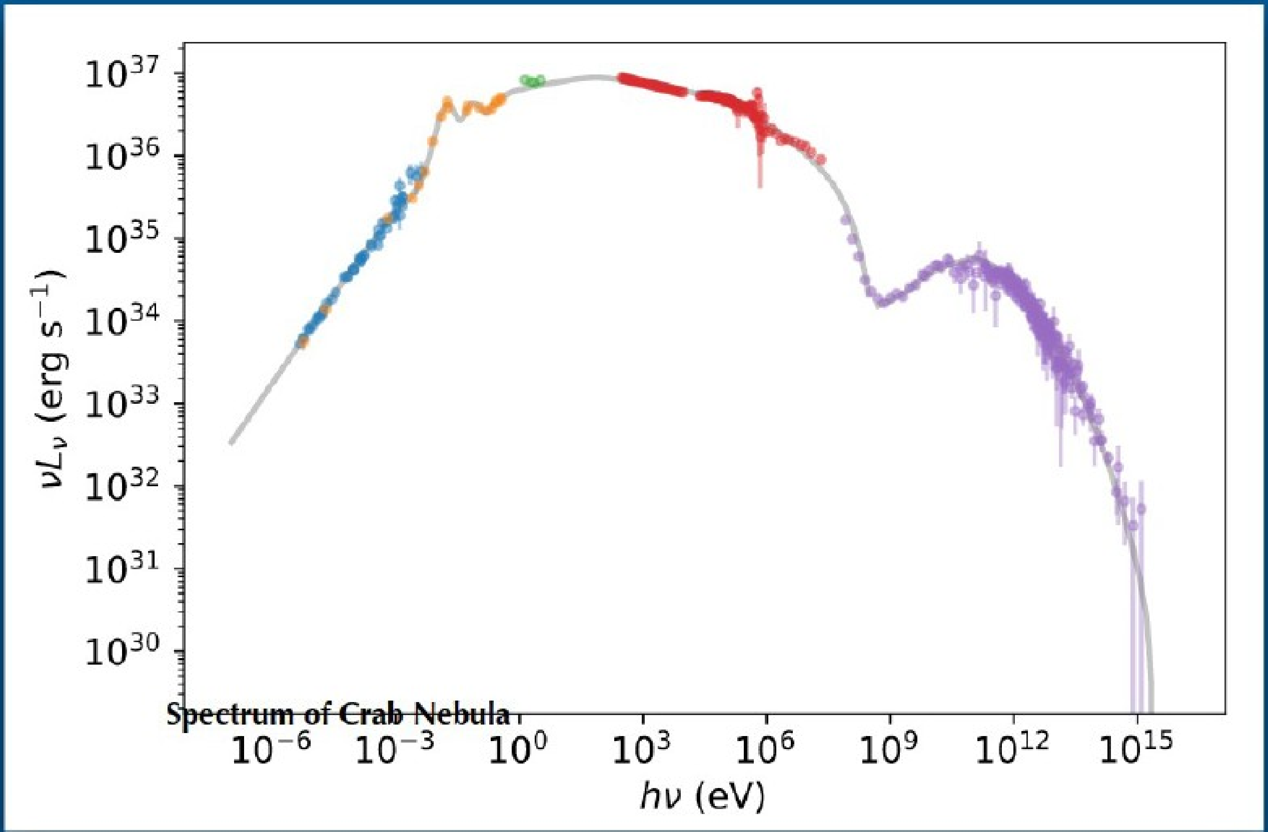
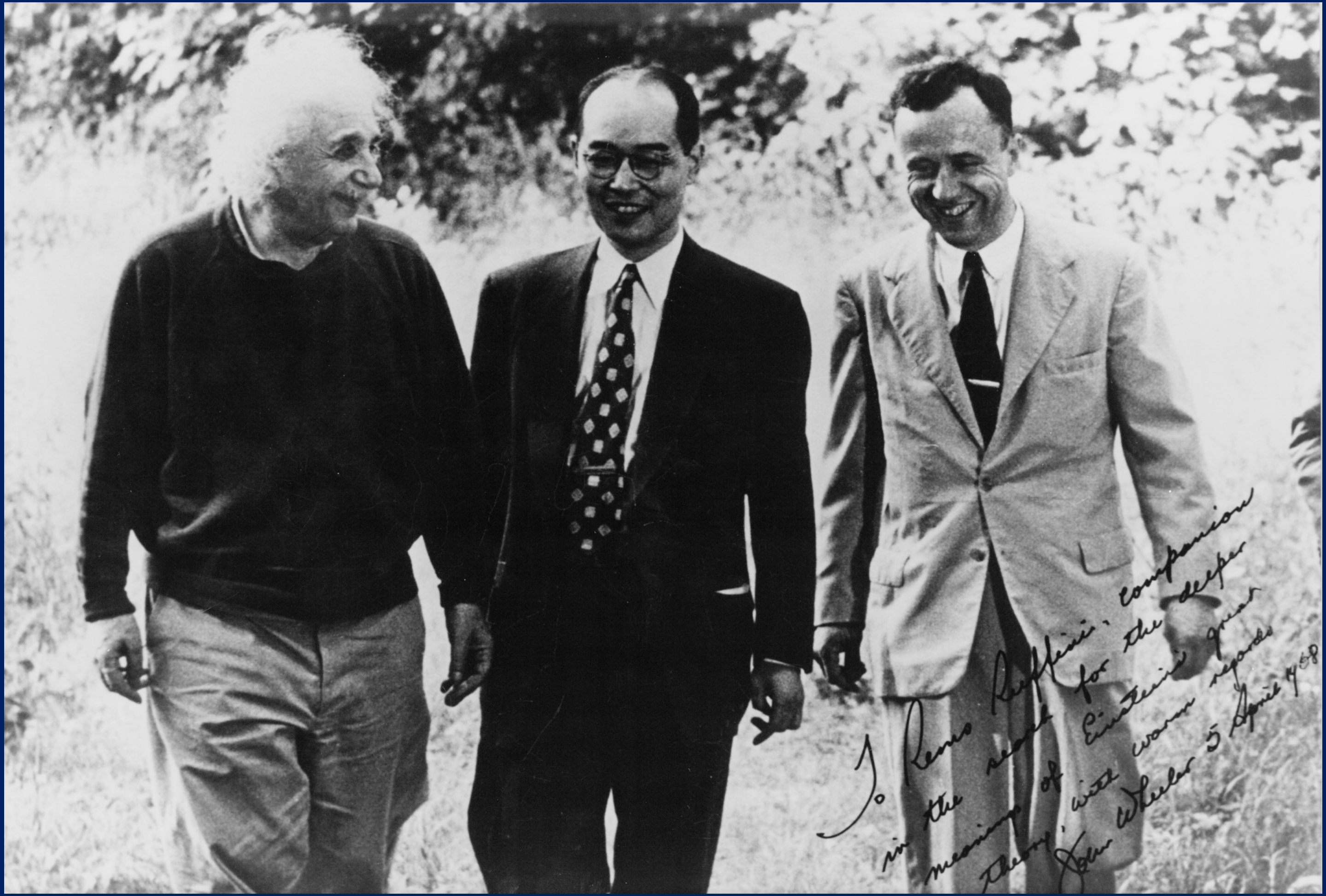


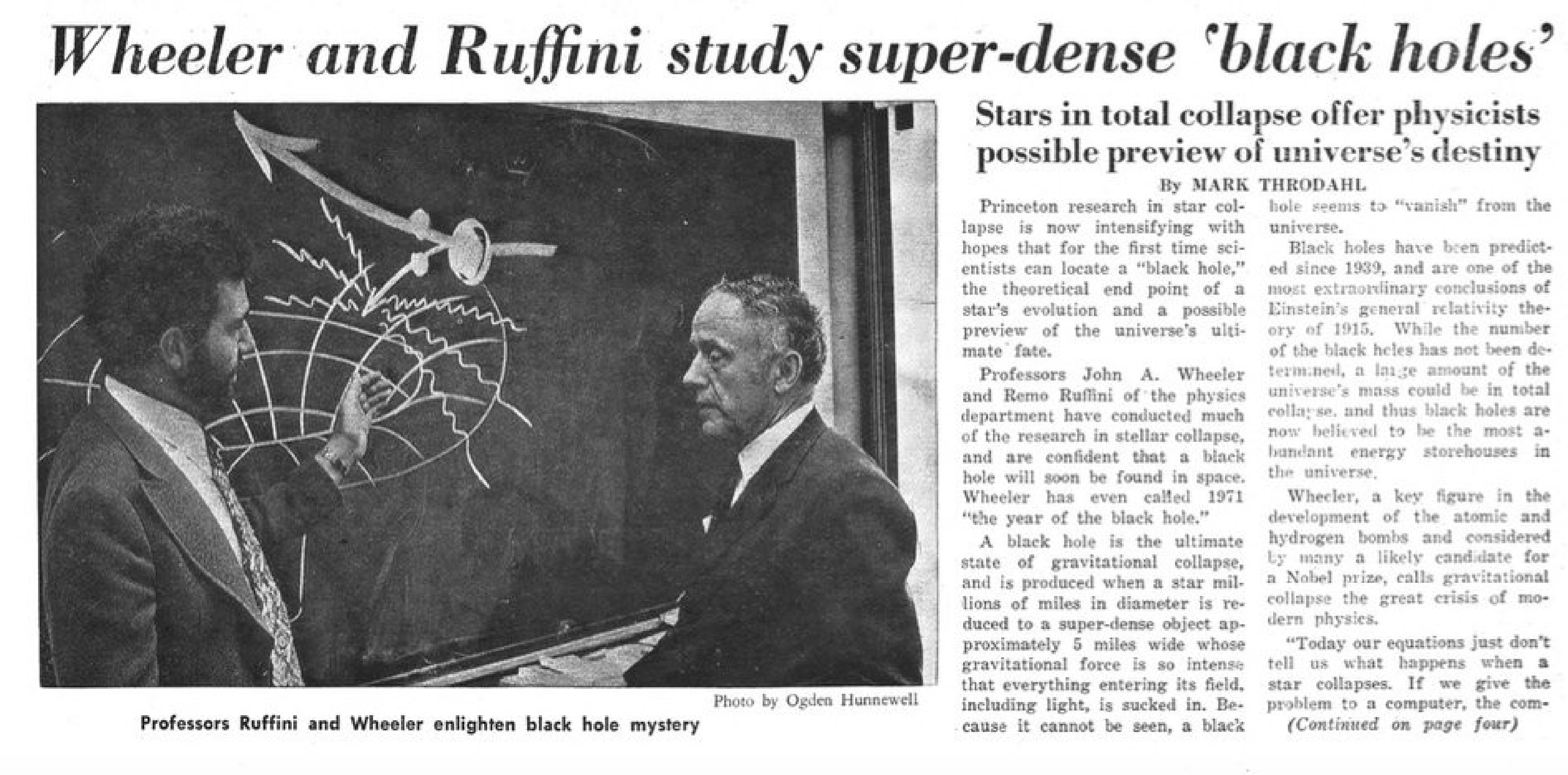
Spectrum of Crab Nebula

*Ruffini, R.; Sigismondi, C, Universe 2024, 10(7), 275, published on June 25, 2024*



To Remo Ruffini, companion
in the search for the deeper
meaning of Einstein's great
theory, with warm regards
John Wheeler 5 April 1958

Albert Einstein, Hideki Yukawa and John. A. Wheeler



# Wheeler and Ruffini study super-dense 'black holes'

Photo by Ogden Hunnewell

**Professors Ruffini and Wheeler enlighten black hole mystery**

## Stars in total collapse offer physicists possible preview of universe's destiny

By MARK THRODAHL

Princeton research in star collapse is now intensifying with hopes that for the first time scientists can locate a "black hole," the theoretical end point of a star's evolution and a possible preview of the universe's ultimate fate.

Professors John A. Wheeler and Remo Ruffini of the physics department have conducted much of the research in stellar collapse, and are confident that a black hole will soon be found in space. Wheeler has even called 1971 "the year of the black hole."

A black hole is the ultimate state of gravitational collapse, and is produced when a star millions of miles in diameter is reduced to a super-dense object approximately 5 miles wide whose gravitational force is so intense that everything entering its field, including light, is sucked in. Because it cannot be seen, a black hole seems to "vanish" from the universe.

Black holes have been predicted since 1939, and are one of the most extraordinary conclusions of Einstein's general relativity theory of 1915. While the number of the black holes has not been determined, a large amount of the universe's mass could be in total collapse, and thus black holes are now believed to be the most abundant energy storehouses in the universe.

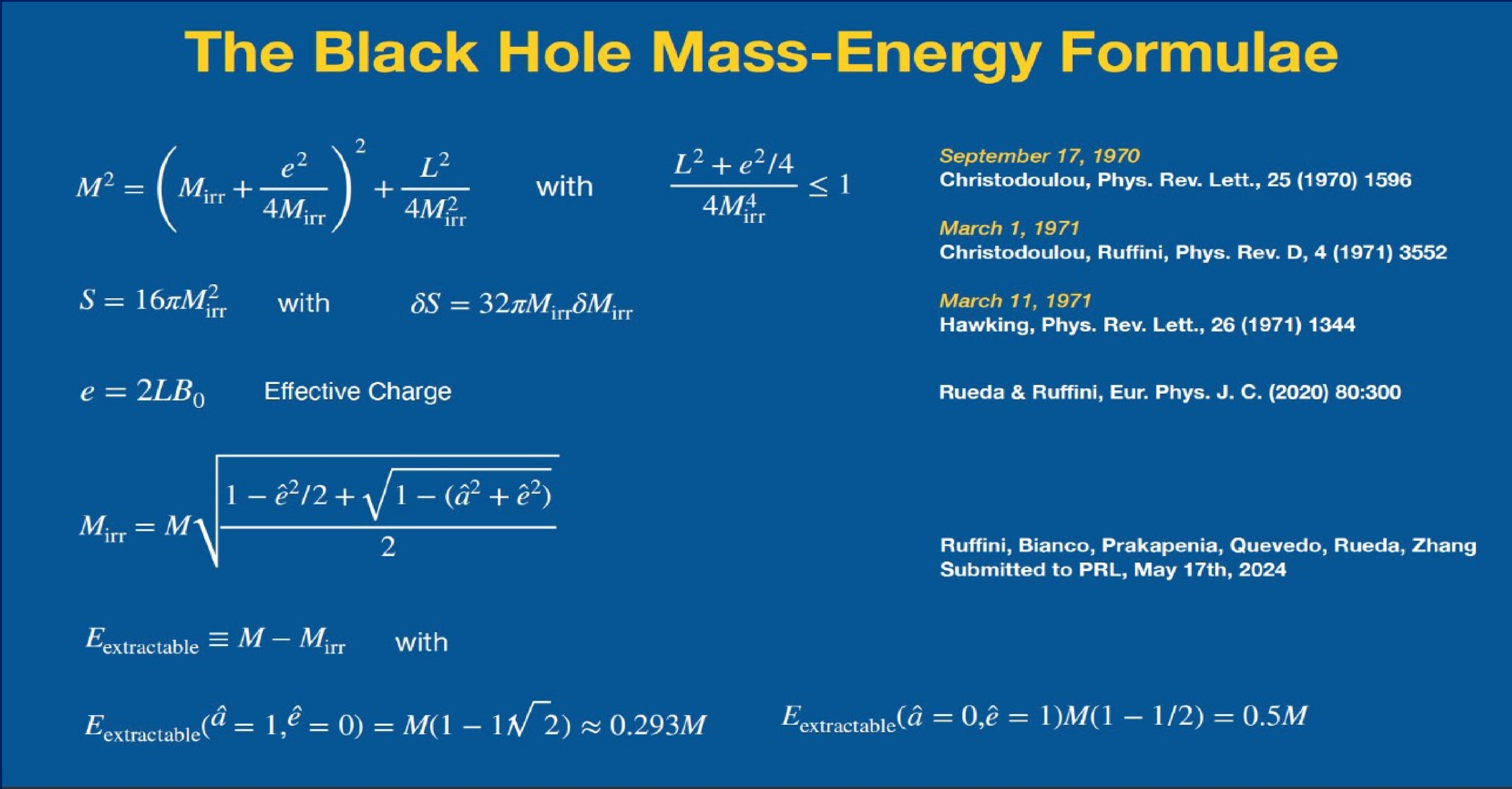
Wheeler, a key figure in the development of the atomic and hydrogen bombs and considered by many a likely candidate for a Nobel prize, calls gravitational collapse the great crisis of modern physics.

"Today our equations just don't tell us what happens when a star collapses. If we give the problem to a computer, the com-

(Continued on page four)

# Prof. Remo Ruffini and Prof. Roy Kerr at Prof. Stephen Hawking's home in Cambridge for dinner on June 20th, 2017

# Recent progress



## The Black Hole Mass-Energy Formulae

$$M^2 = \left(M_{\text{irr}} + \frac{e^2}{4M_{\text{irr}}}\right)^2 + \frac{L^2}{4M_{\text{irr}}^2} \quad \text{with} \quad \frac{L^2 + e^2/4}{4M_{\text{irr}}^4} \leq 1$$

*September 17, 1970*
**Christodoulou, Phys. Rev. Lett., 25 (1970) 1596**

*March 1, 1971*
**Christodoulou, Ruffini, Phys. Rev. D, 4 (1971) 3552**

$$S = 16\pi M_{\text{irr}}^2 \quad \text{with} \quad \delta S = 32\pi M_{\text{irr}} \delta M_{\text{irr}}$$

*March 11, 1971*
**Hawking, Phys. Rev. Lett., 26 (1971) 1344**

$$e = 2LB_0$$

Effective Charge

**Rueda & Ruffini, Eur. Phys. J. C. (2020) 80:300**

$$M_{\text{irr}} = M\sqrt{\frac{1 - \hat{e}^2/2 + \sqrt{1 - (\hat{a}^2 + \hat{e}^2)}}{2}}$$

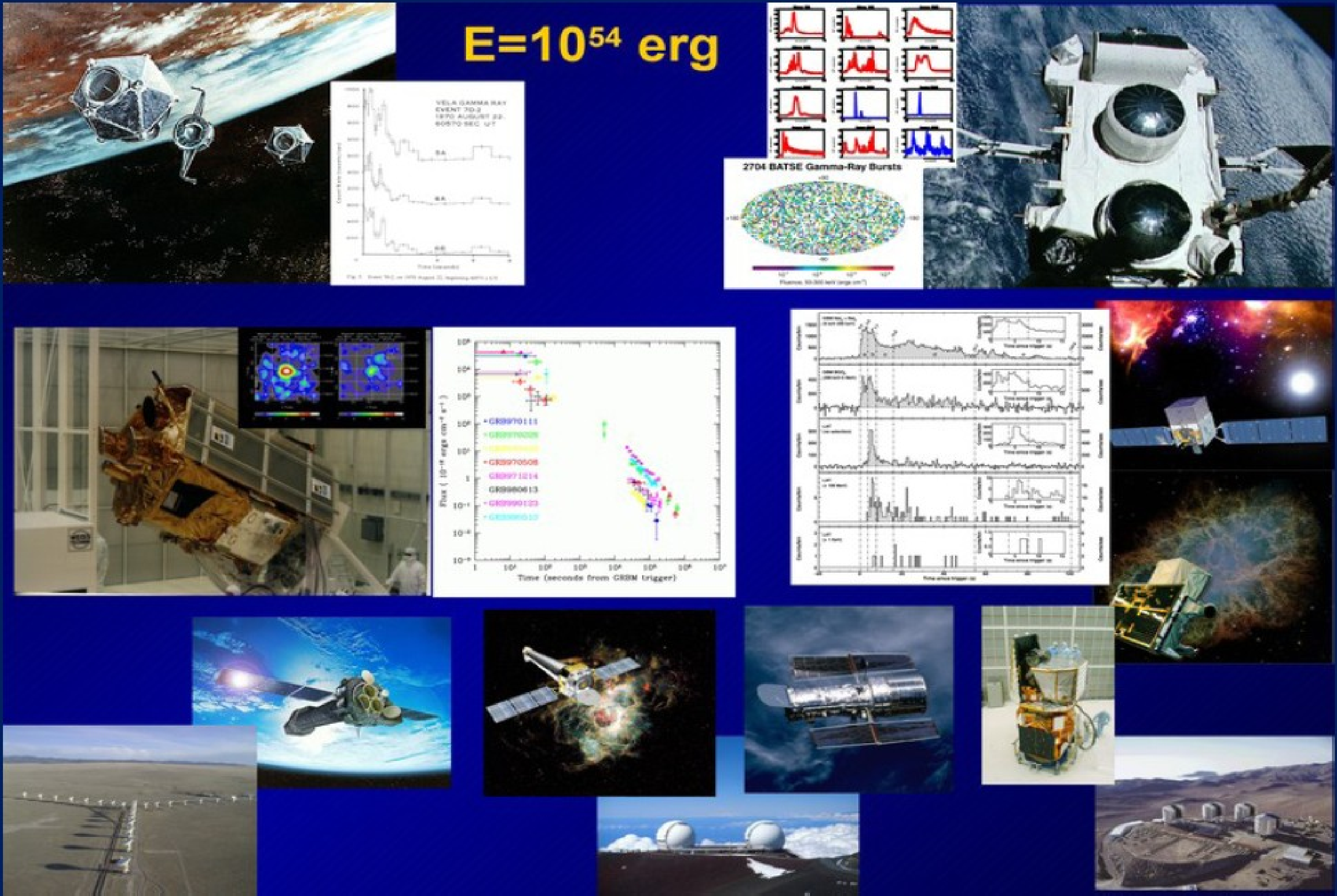
**Ruffini, Bianco, Prakapenia, Quevedo, Rueda, Zhang**
**Submitted to PRL, May 17th, 2024**

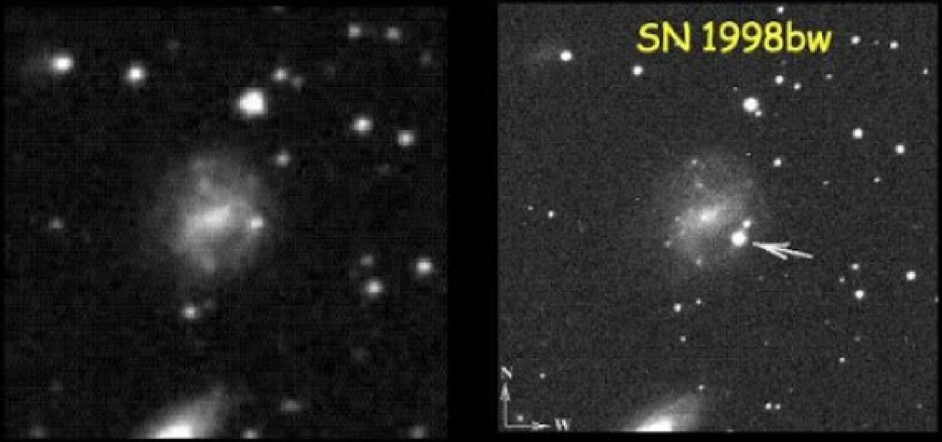
$$E_{\text{extractable}} \equiv M - M_{\text{irr}} \quad \text{with}$$

$$E_{\text{extractable}}(\hat{a} = 1, \hat{e} = 0) = M(1 - 1/\sqrt{2}) \approx 0.293M \qquad E_{\text{extractable}}(\hat{a} = 0, \hat{e} = 1) M(1 - 1/2) = 0.5M$$

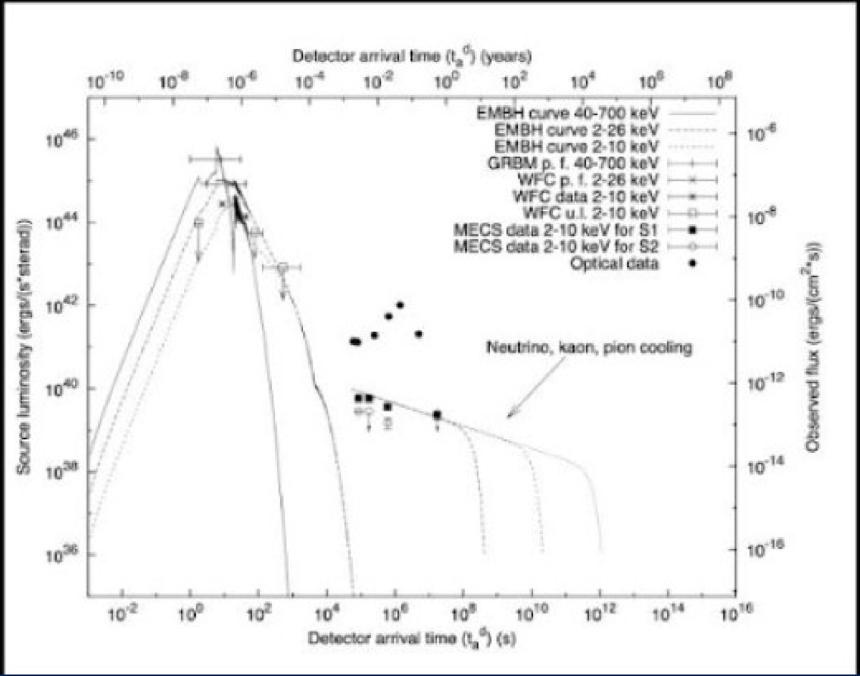
# *The new era: the launch of Beppo Sax on April 30, 1996*

**E=$10^{54}$ erg**





3.54m - NTT, ESO La Silla



Light curves in the 2-10 keV band compared with theoretical models of neutron star cooling (Ruffini et. al. Adv.Sp.Res. 2004)

# The binary driven Hypernova model BDHN

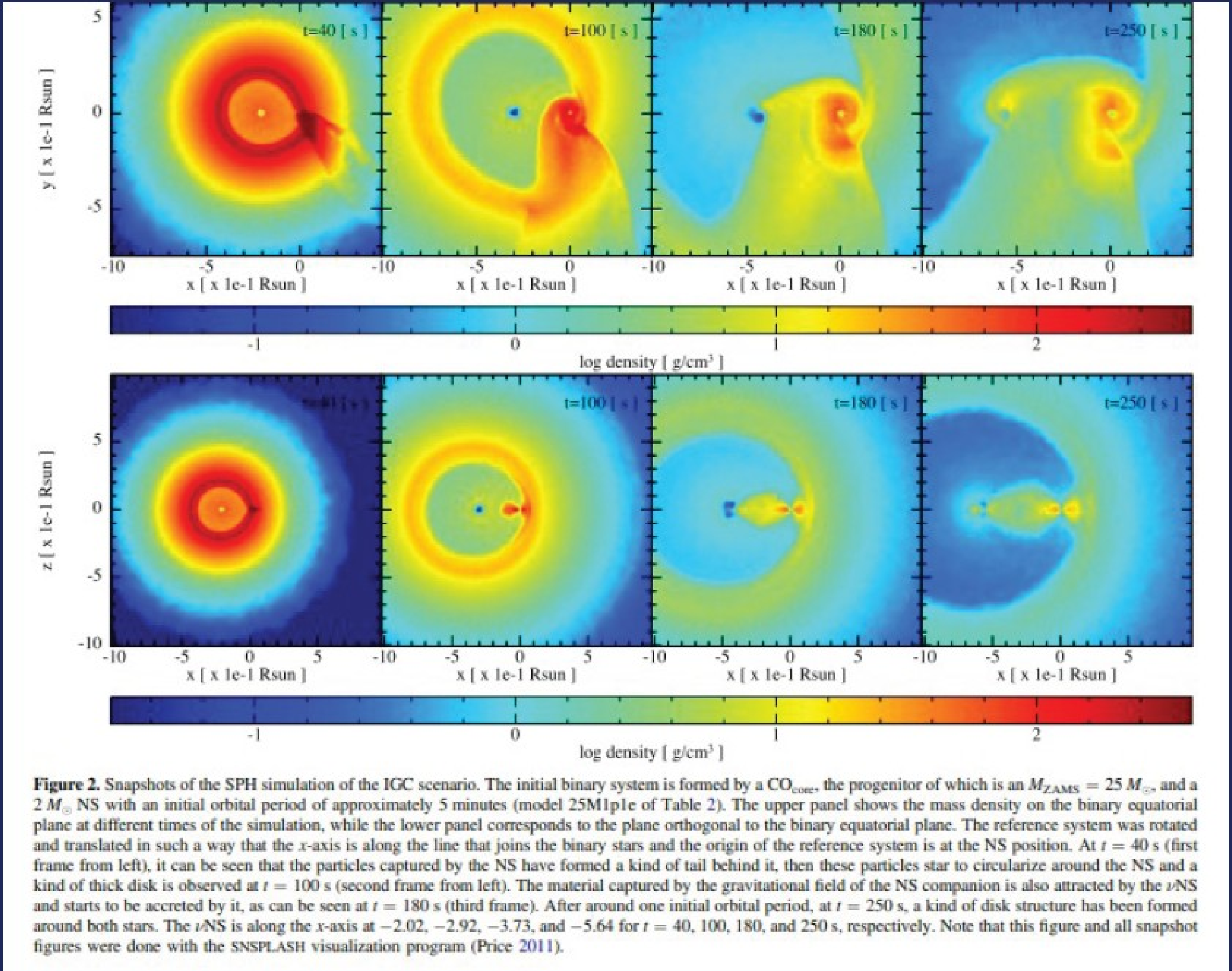
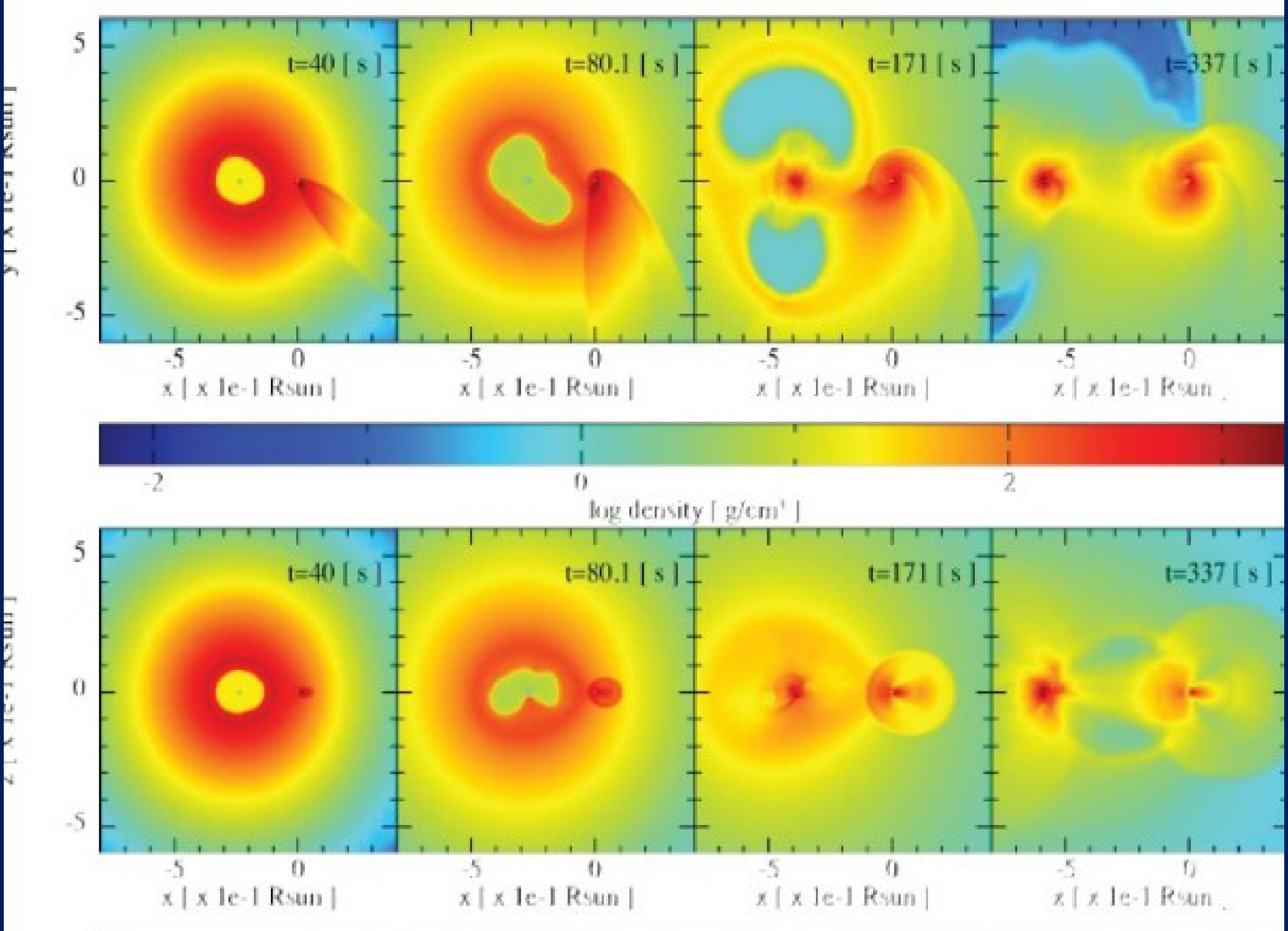


**Figure 2.** Snapshots of the SPH simulation of the IGC scenario. The initial binary system is formed by a $\mathrm{CO_{core}}$, the progenitor of which is an $M_{\mathrm{ZAMS}} = 25\,M_{\odot}$, and a $2\,M_{\odot}$ NS with an initial orbital period of approximately 5 minutes (model 25M1p1e of Table 2). The upper panel shows the mass density on the binary equatorial plane at different times of the simulation, while the lower panel corresponds to the plane orthogonal to the binary equatorial plane. The reference system was rotated and translated in such a way that the $x$-axis is along the line that joins the binary stars and the origin of the reference system is at the NS position. At $t = 40$ s (first frame from left), it can be seen that the particles captured by the NS have formed a kind of tail behind it, then these particles star to circularize around the NS and a kind of thick disk is observed at $t = 100$ s (second frame from left). The material captured by the gravitational field of the NS companion is also attracted by the $\nu$NS and starts to be accreted by it, as can be seen at $t = 180$ s (third frame). After around one initial orbital period, at $t = 250$ s, a kind of disk structure has been formed around both stars. The $\nu$NS is along the $x$-axis at −2.02, −2.92, −3.73, and −5.64 for $t = 40$, 100, 180, and 250 s, respectively. Note that this figure and all snapshot figures were done with the SNSPLASH visualization program (Price 2011).

*Fig. 1: Becerra et Al., ApJ, 871:14 (29pp), 2019*

# The formation of the Black Hole in the BdHN



From Becerra et al. PRD 2023; astro-ph.HE 4788532, March 15, 2023

# A (not complete) list of articles on BdHN model

*Rueda et al. ApJ 2022 → Synchrotron afterglow of GRB 180720B*
*Wang Yu et al. ApJ 2022 → BdHN analysis of GRB 171205A*
*Rueda et al., PRD 2022 → GWs from NS triaxial-biaxial transition*
*Becerra et al. PRD 2022 → The first minutes of BdHN evolution*
*Rueda, et al., ApJ 2022 → Inner engine, full GR*
*Ruffini, et al., MNRAS 2021 → BdHN I, statistics, GeV emission*
*Moradi, et al., A&A 2021 → Inner engine GRB 190114C and M87**
*Rueda, et al., ApJ 2020 → X-ray afterglow, magnetic field in BdHN*
*Rueda & Ruffini, EPJC 2020 → Inner engine, blackholic quantum*
*Ruffini, et al., ApJ 2019 → Inner engine model, first estimates*
*Becerra, et al., ApJ 2019 → First 3D SPH simulation*
*Ruffini, et al., ApJ 2018 → X-ray afterglow, synchrotron newNS*
*Becerra, et al., ApJ 2018 → Neutrino flavour oscillations*
*Ruffini, et al., ApJ 2018 → e+e expansion in matter around BH*
*Cipolletta, et al., PRD 2017 → NS spacetime properties*
*Becerra, et al., ApJ 2016 → First 3D simulation*
*Fryer, et al., PRL 2015 → Binary stability*
*Becerra, et al., ApJ 2015 → First 2D simulation*
*Fryer, et al., APJL 2014 → First 1D simulation*
*Rueda & Ruffini, APJL 2012 → Idea and first estimate of IGC*

# Inner Engine Components

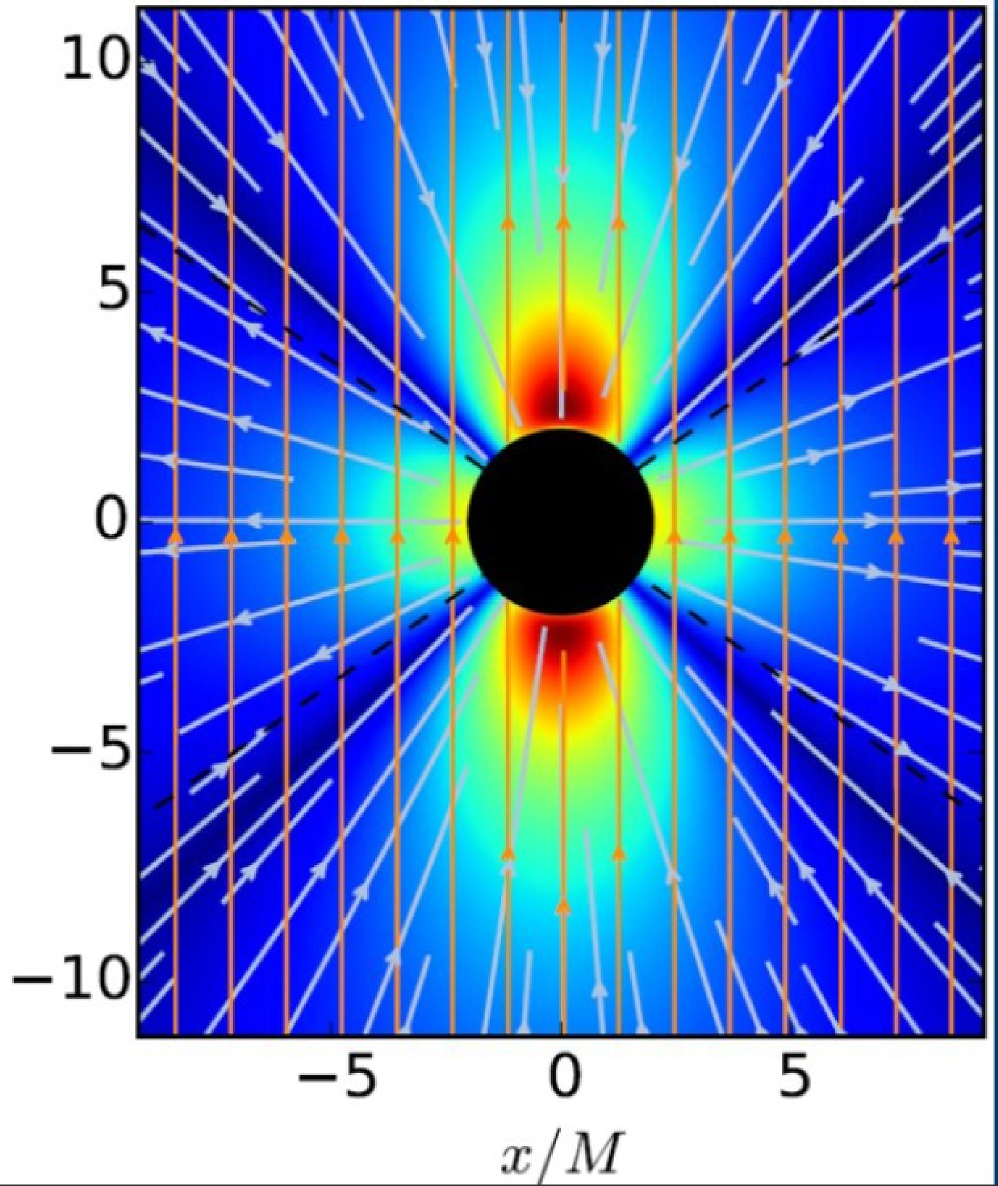
The Kerr metric describing the rotating BH.

An asymptotically uniform magnetic field around the Kerr BH.

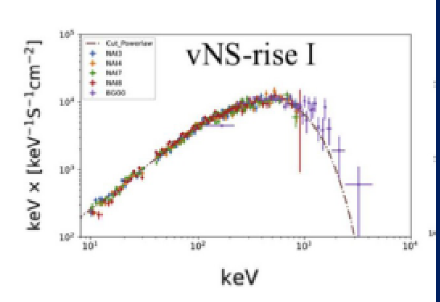
A very low density ionized plasma $10^{-14}$ - $10^{-6}$ g cm$^{-3}$.

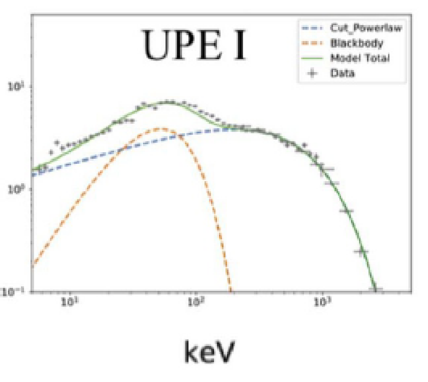
*References:*

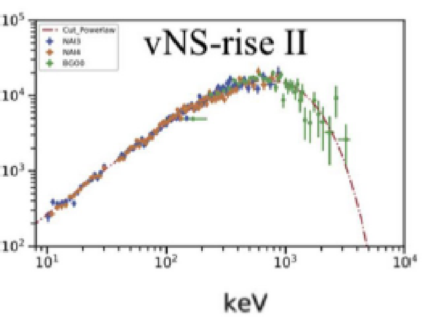
1. *Moradi, Rueda, Ruffini, Wang, A&A 2021*
2. *R. Moradi, J.A. Rueda, R. Ruffini, Liang Li, C.L. Bianco, S. Campion, C. Cherubini, S. Filippi, Y. Wang, and S.S. Xue. PRD 2021*
3. *Rueda, Ruffini, Kerr, ApJ 2022*
4. *Rueda & Ruffini, EPJC 2023*

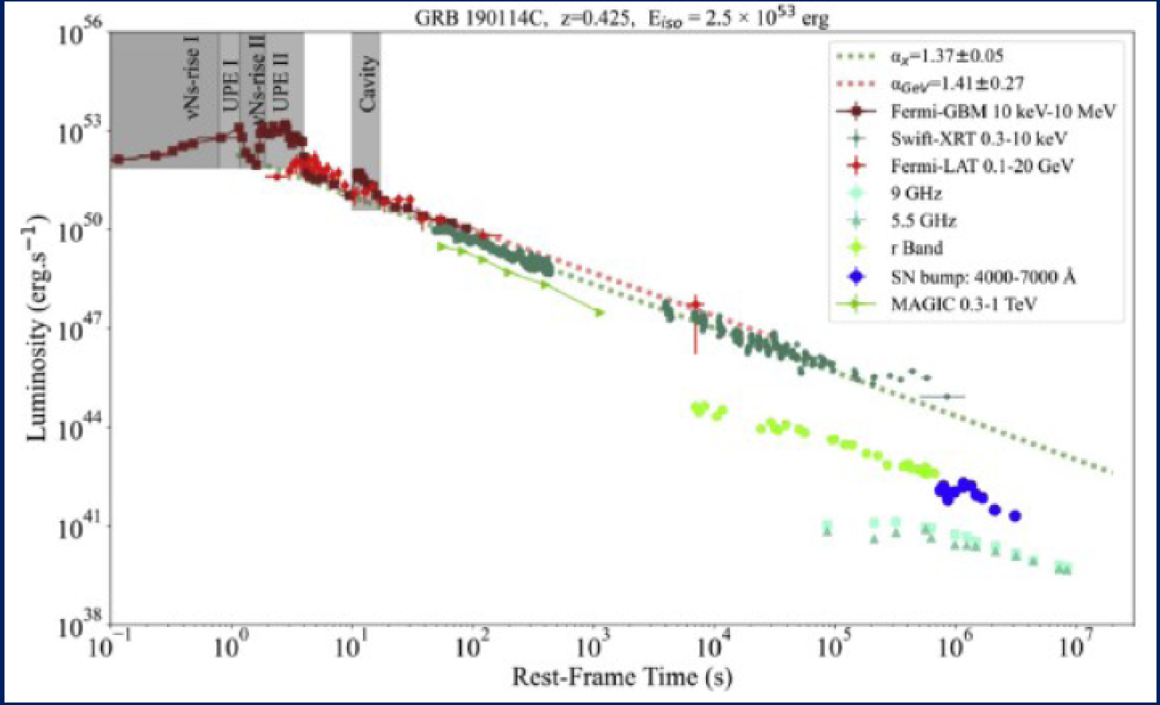


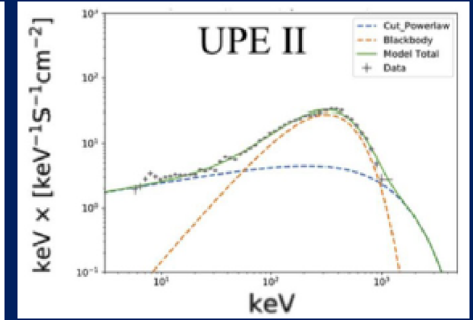
# The seven episodes GRB 190114C

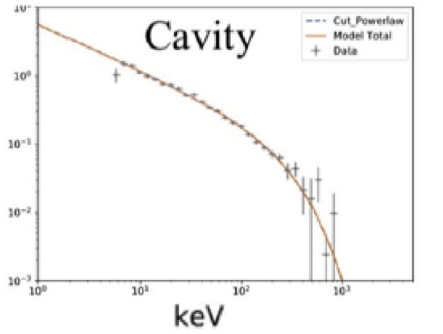










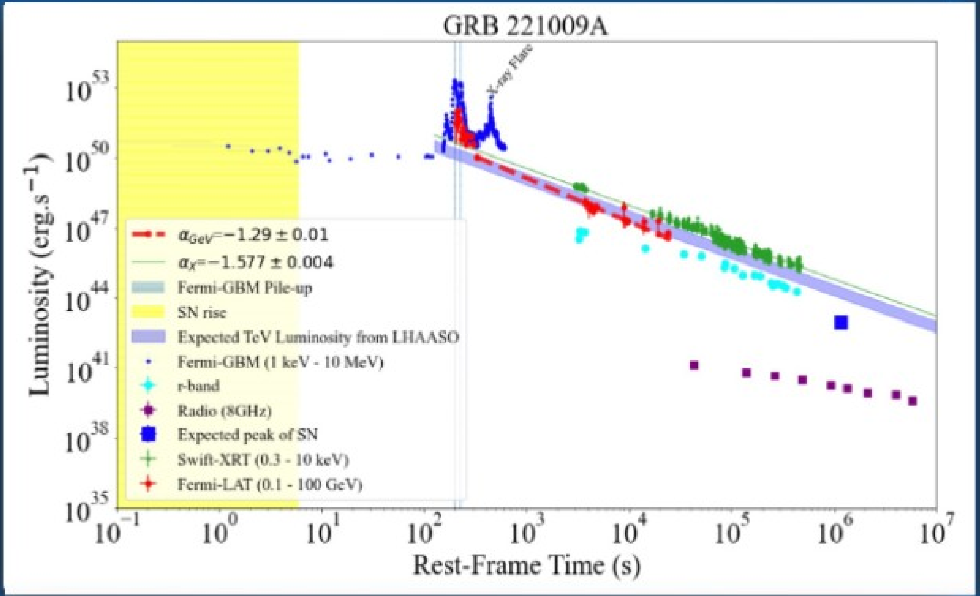


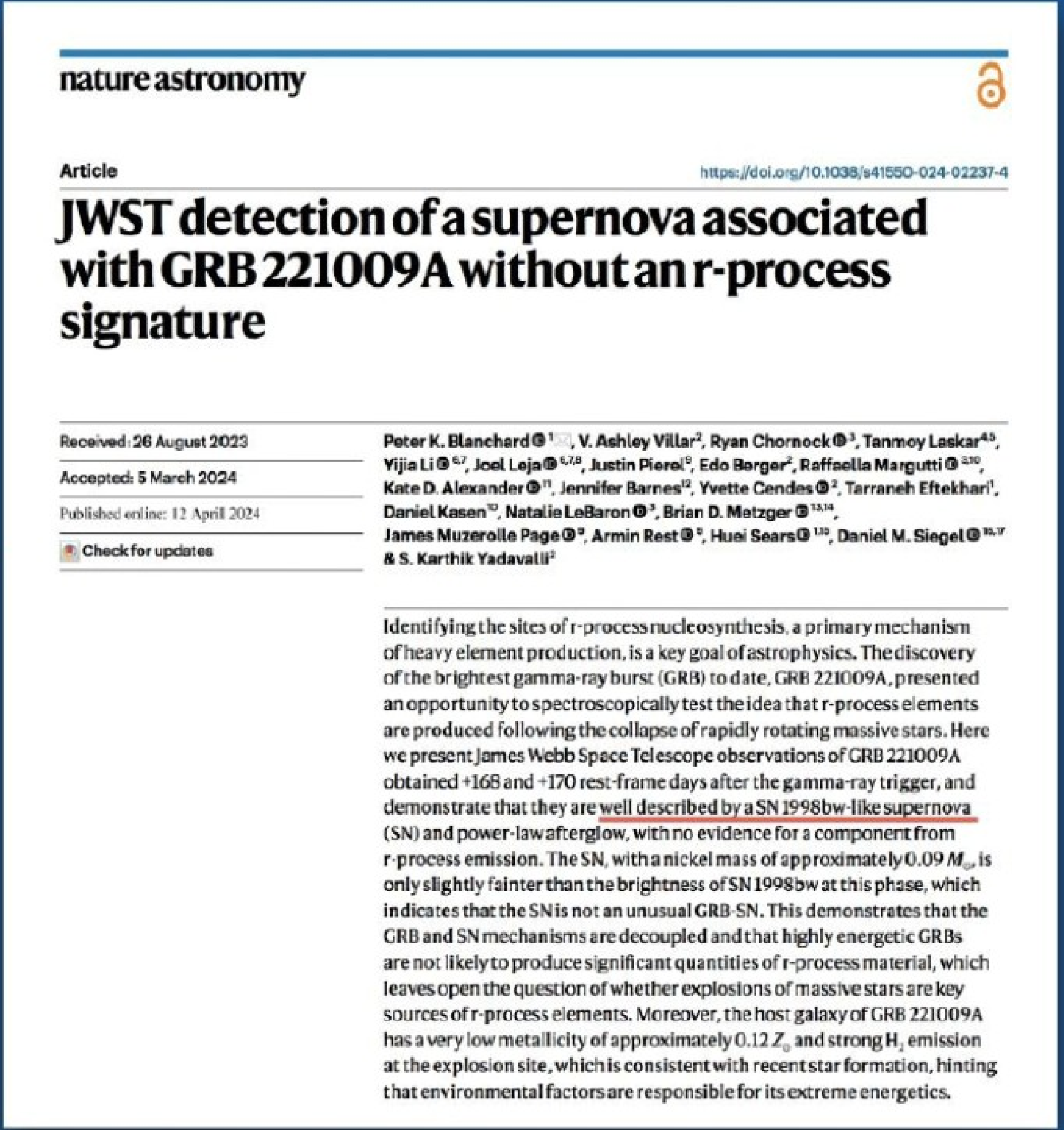
Aimuratov et al 2023 ApJ 955, 93

**GCN Circular #32808**

*Y. Aimuratov, L. Becerra, C.L. Bianco, C. Cherubini, S. Filippi, M. Karlica, Liang Li, R. Moradi, F. Rastegar Nia, J.A. Rueda, R. Ruffini, N. Sahakyan, Y. Wang, S.S. Xue, on behalf of the ICRANet team, report:*

GRB 221009A appears to be a rare example (Jean-Luc Atteia et al. 2022, GCN 32793) of a particularly energetic and close GRB (de Ugarte Postigo et al. 2022, GCN 32648 and Lesage et al. 2022, GCN 32642 and N.P.M. Kuin et al. 2022, GCN 32656). Within the BdHN model, we have followed the X-ray, optical, and radio afterglows originating from synchrotron emission powered by fast spinning newborn neutron stars (νNS) with initial periods of fraction of a millisecond, accreting the supernova ejecta, created by the collapse of a carbon-oxygen core (Rueda et al. 2022, arXiv:2204.00579). Figures 1, 2 and 3 show the afterglows of three type I BdHNe, namely GRB 180720B (Ruffini et al. 2018, GCN 23019), GRB 190114C (Ruffini et al. 2019, GCN 23715), and GRB 211023A (Aimuratov et al. 2021, GCN 31056), and the prediction of their associated supernova. We have indicated the expected time of the occurrence of the supernova in GRB 221009A (Aimuratov et al. 2022, GCN 32780). The ongoing observations in optical, radio, and X-ray bands are strongly recommended for allowing the determination of the spin and magnetic field of the νNS. This will probe as well if the optical synchrotron emission, at ~ 10^6 s from the Fermi-GBM trigger, impedes the observations of the optical emission of the supernova originating from nickel decay (Aimuratov et al. in preparation, see also data from Ilfan Bikmaev et al. 2022, GCN 32752, and Jia. Ren et al. 2022, arXiv:2210.10673, reproduced in Fig. 4). Fig1: http://www.icranet.org/docs/Fig1.pdf Fig2: http://www.icranet.org/docs/Fig2.pdf Fig3: http://www.icranet.org/docs/Fig3.pdf Fig4: http://www.icranet.org/docs/Fig4.pdf




nature astronomy

Article

https://doi.org/10.1038/s41550-024-02237-4

# JWST detection of a supernova associated with GRB 221009A without an r-process signature

Received: 26 August 2023

Accepted: 5 March 2024

Peter K. Blanchard[1], V. Ashley Villar[2], Ryan Chornock[3], Tanmoy Laskar[4,5], Yijia Li[6,7], Joel Leja[6,7,8], Justin Pierel[9], Edo Berger[2], Raffaella Margutti[3,10], Kate D. Alexander[11], Jennifer Barnes[12], Yvette Cendes[2], Tarraneh Eftekhari[1], Daniel Kasen[10], Natalie LeBaron[3], Brian D. Metzger[13,14], James Muzerolle Page[9], Armin Rest[9], Huei Sears[1,10], Daniel M. Siegel[15,17] & S. Karthik Yadavalli[2]

Identifying the sites of r-process nucleosynthesis, a primary mechanism of heavy element production, is a key goal of astrophysics. The discovery of the brightest gamma-ray burst (GRB) to date, GRB 221009A, presented an opportunity to spectroscopically test the idea that r-process elements are produced following the collapse of rapidly rotating massive stars. Here we present James Webb Space Telescope observations of GRB 221009A obtained +168 and +170 rest-frame days after the gamma-ray trigger, and demonstrate that they are well described by a SN 1998bw-like supernova (SN) and power-law afterglow, with no evidence for a component from r-process emission. The SN, with a nickel mass of approximately 0.09 $M_{\odot}$, is only slightly fainter than the brightness of SN 1998bw at this phase, which indicates that the SN is not an unusual GRB-SN. This demonstrates that the GRB and SN mechanisms are decoupled and that highly energetic GRBs are not likely to produce significant quantities of r-process material, which leaves open the question of whether explosions of massive stars are key sources of r-process elements. Moreover, the host galaxy of GRB 221009A has a very low metallicity of approximately 0.12 $Z_{\odot}$ and strong $H_2$ emission at the explosion site, which is consistent with recent star formation, hinting that environmental factors are responsible for its extreme energetics.

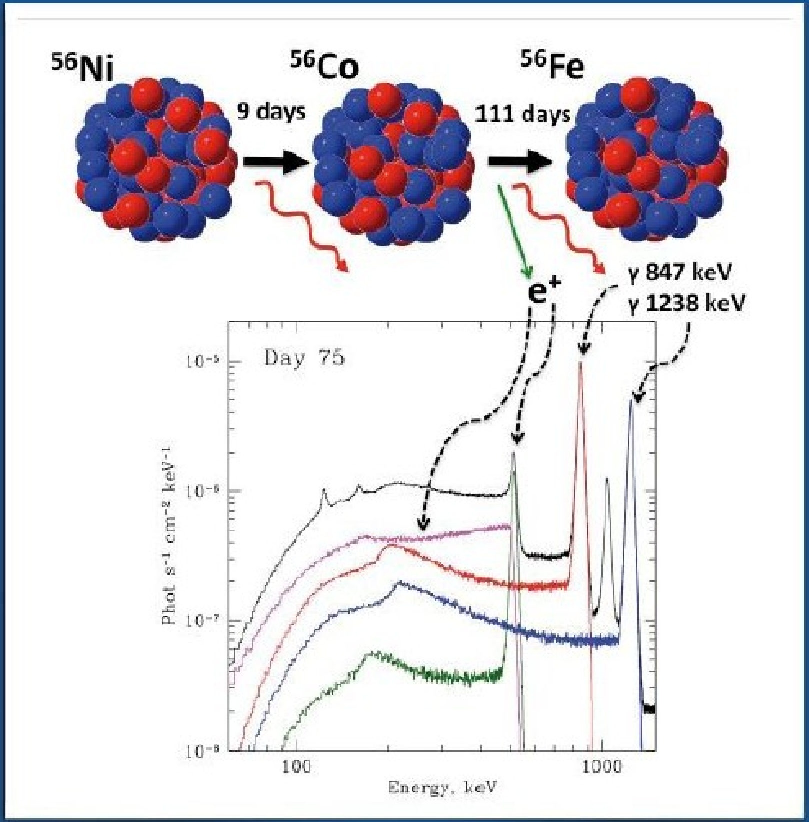
## ~ 0.5 $M_\odot$ Nickel per Supernova

*Outer part:* Nickel brass

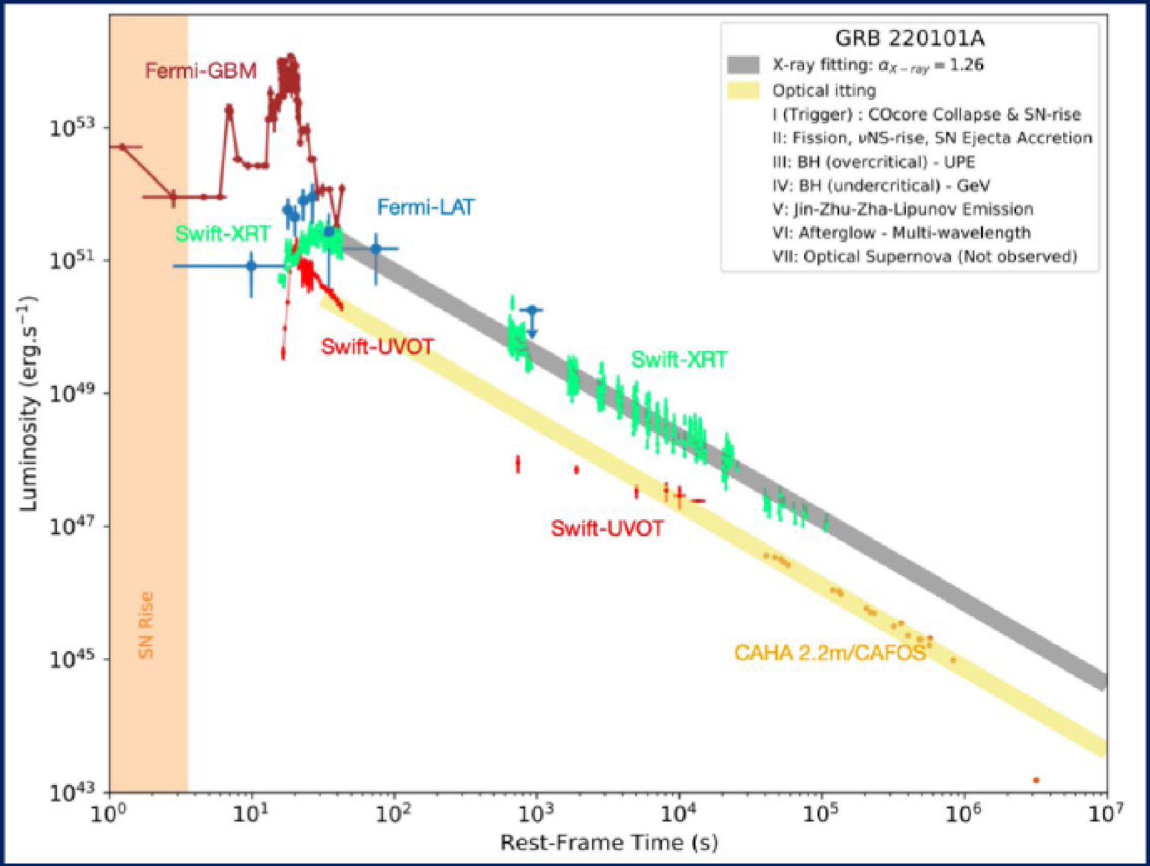
*Inner part:* Layers of copper-nickel, nickel, copper-nickel

*Outer part:* Copper-nickel

*Inner part:* Layers of nickel brass, nickel, nickel brass.



# GRB 220101A

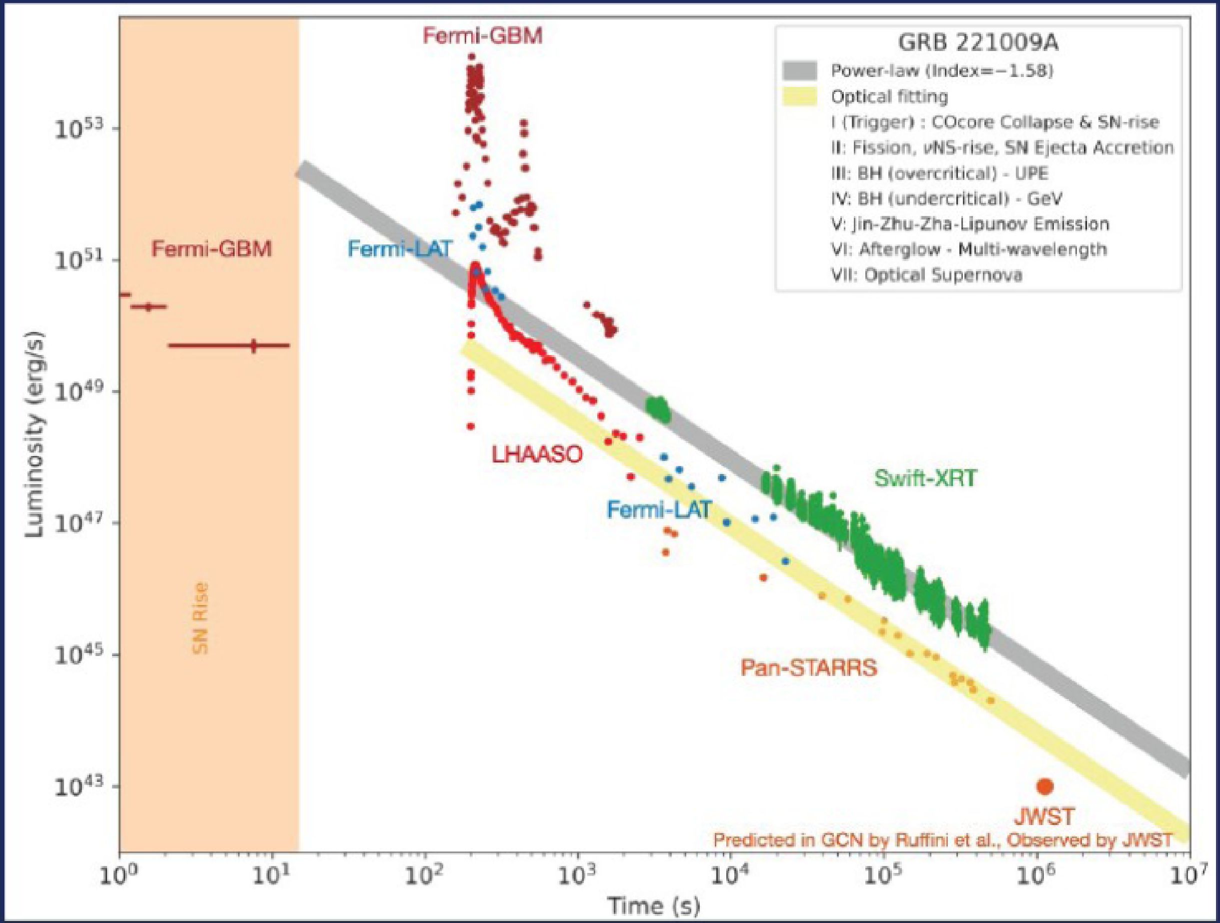


$E_{iso} = 3.5 \times 10^{54}$ erg

Z= 4.615

**The astrophysical components :Co core NS binary, and fission of VNS, SN rise and ejecta accretion on vNS, leading to $m_{sec}$ Pulsar, accretion on NS leading to BH, accretion on SN remnant X ray afterglow**

# GRB 221009A

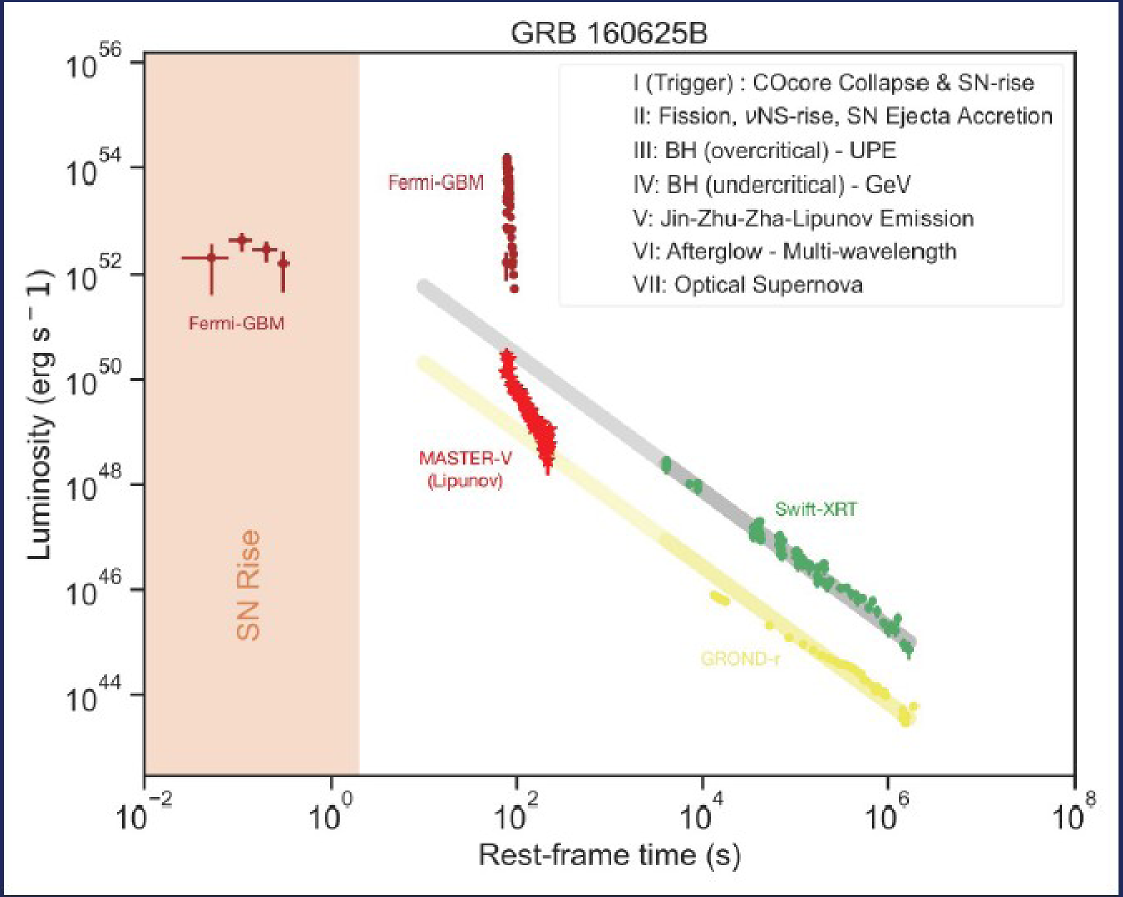


$E_{iso} = 1 \times 10^{55}$ erg

Z= 0.151

The coincidence of the TeV emission with the early phases of $m_{sec}$ v NS

# GRB 160625B

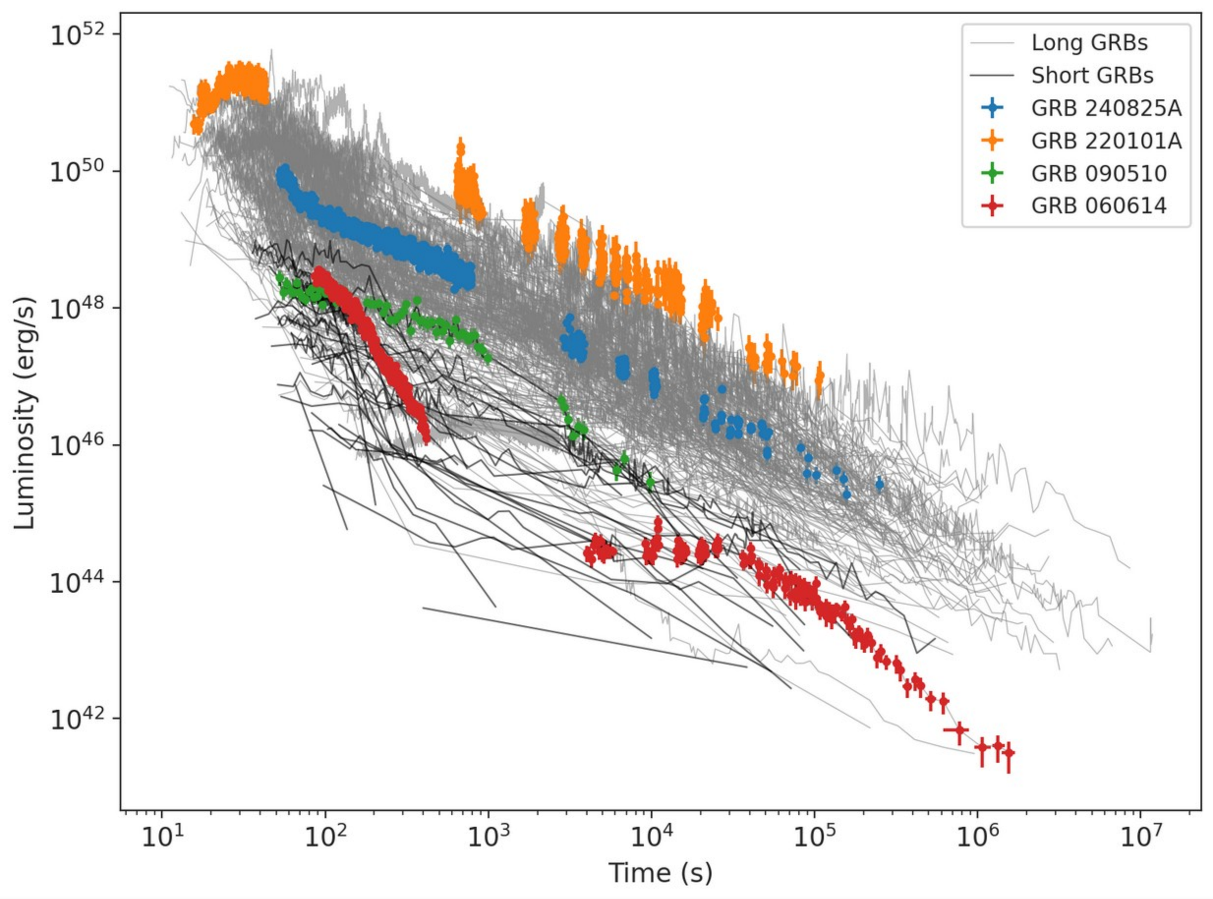


$E_{UPE} = 4.5 \times 10^{54}$ erg

Z= 1.406

**This source is very similar to GRB 221009A TeV could have been detected if the detectors would have been operative**

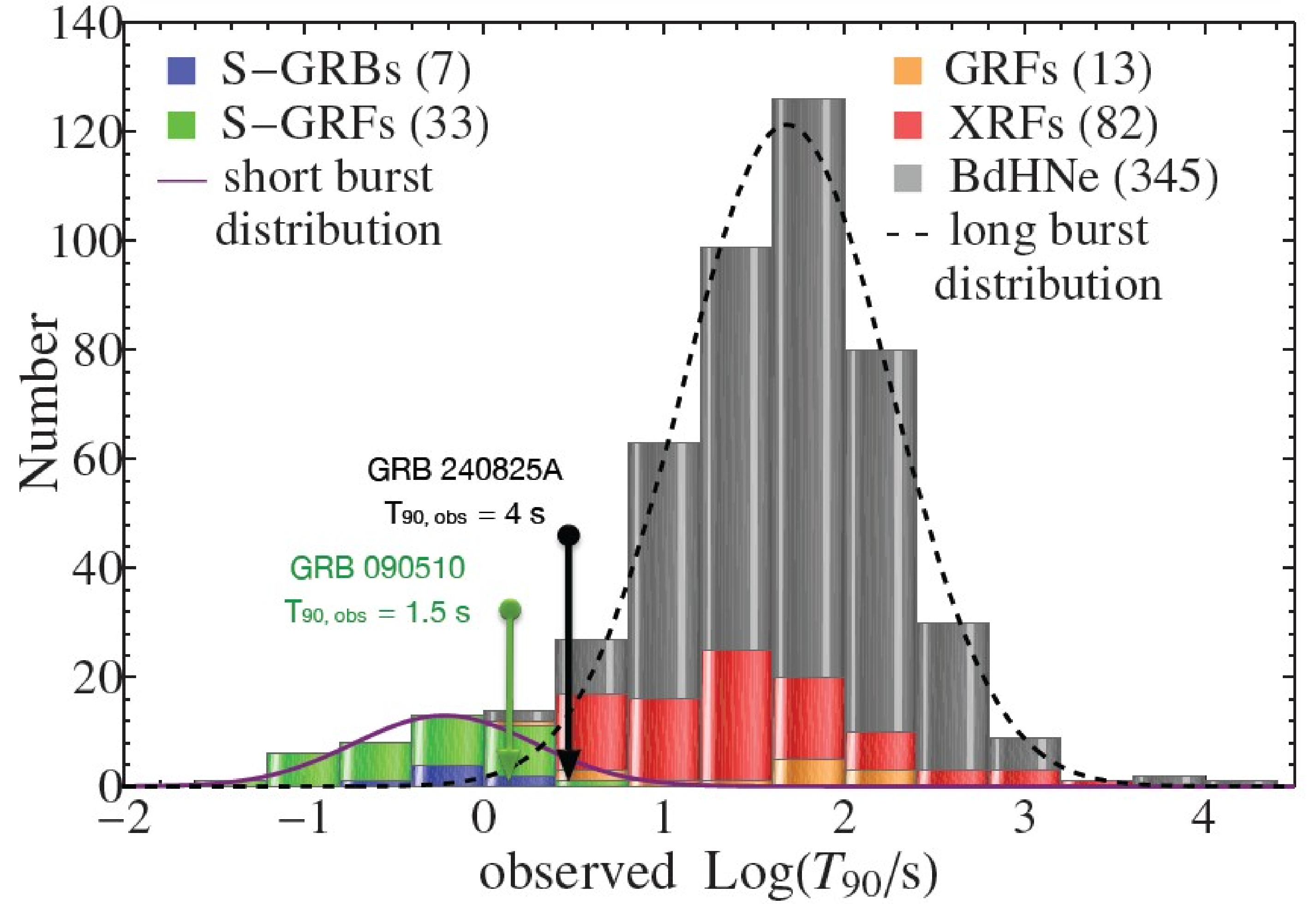
# GRB 240825A

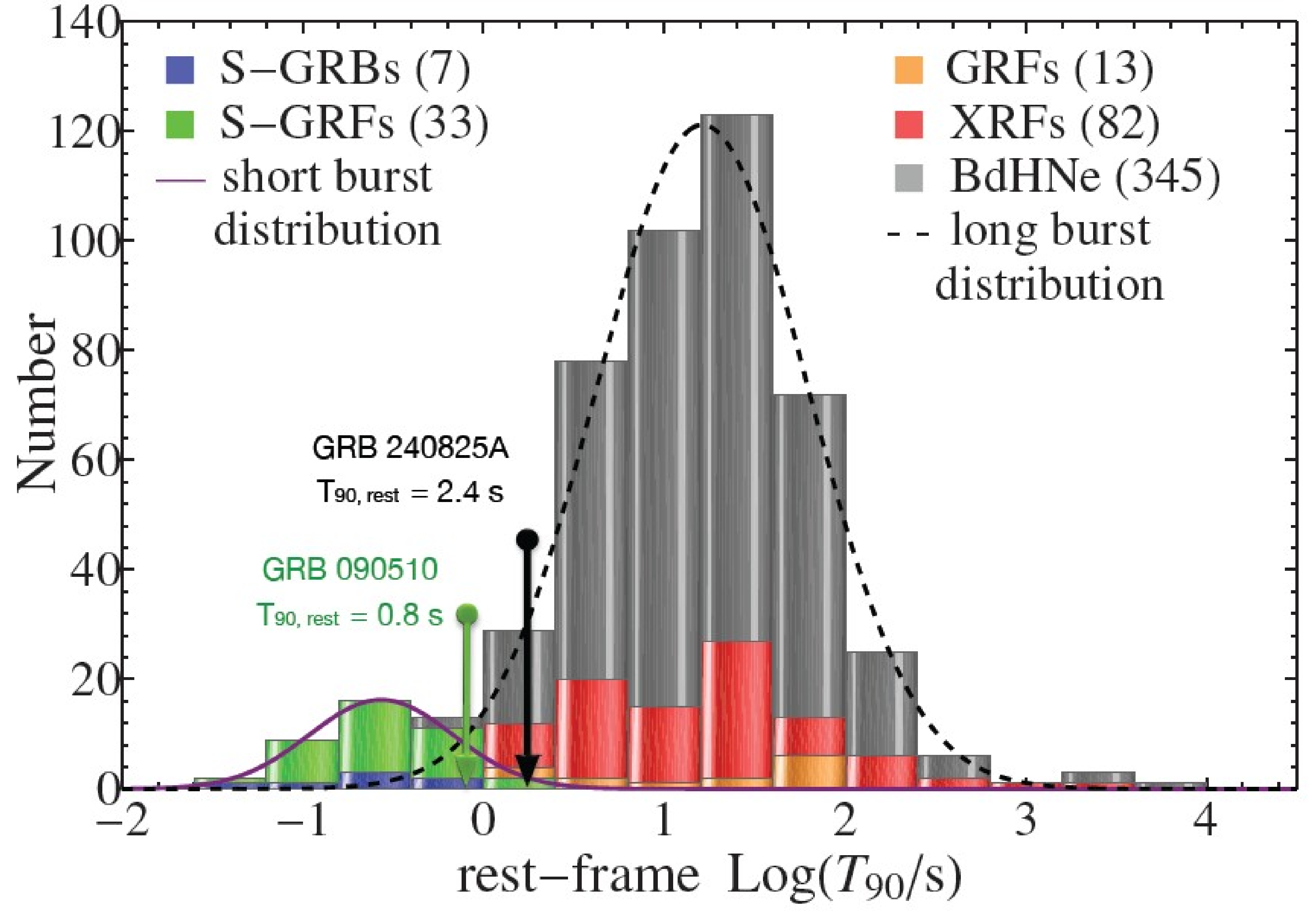


R. Ruffini, C.L. Bianco, M. Della Valle, Liang Li, M.T. Mirtorabi, R. Moradi, F. Rastegar Nia, J.A. Rueda, Y. Wang, on behalf of the ICRANet team, report:

The T90 of GRB 240825A is only 4 seconds (GCN 37301), and it is located at a relatively close distance (z=0.659, GCN 37293). The fluence reaches a high level of 10^{-4} erg/cm^2. Through spectral analysis, we find that peak energy Ep is about 400 keV and isotropic energy Eiso is about 2x10^{53} erg, consistent with the Amati relation for long-duration gamma-ray bursts. Comparing its X-ray afterglow (see figure attached below, blue dots), its luminosity falls within the range of other long-duration bursts which are associated with supernovae, higher than those of short-duration bursts which have merge origins. Based on these findings, we conclude that GRB 240825A is a long-duration burst (BdHN I; see, e.g., Bianco, et al., 2024, ApJ, 966, 219) and is associated with a SN. The supernova may reach its optical peak in the observer's rest-frame approximately one month after the trigger. Its peak brightness should be within the detection limits of both ground- and space-based telescopes. Therefore, we encourage further observations in the coming weeks.

## *The* shortest BDHN 1 ever observed differentiating long and short GRBs





🟦 S−GRBs (7)
🟩 S−GRFs (33)
short burst distribution
🟧 GRFs (13)
🟥 XRFs (82)
▨ BdHNe (345)
- - long burst distribution
GRB 240825A
$T_{90,\,rest} = 2.4$ s
GRB 090510
$T_{90,\,rest} = 0.8$ s
Number
0
20
40
60
80
100
120
140
−2
−1
0
1
2
3
4
rest−frame Log($T_{90}$/s)

# 27th September analysis of GRB 240825A

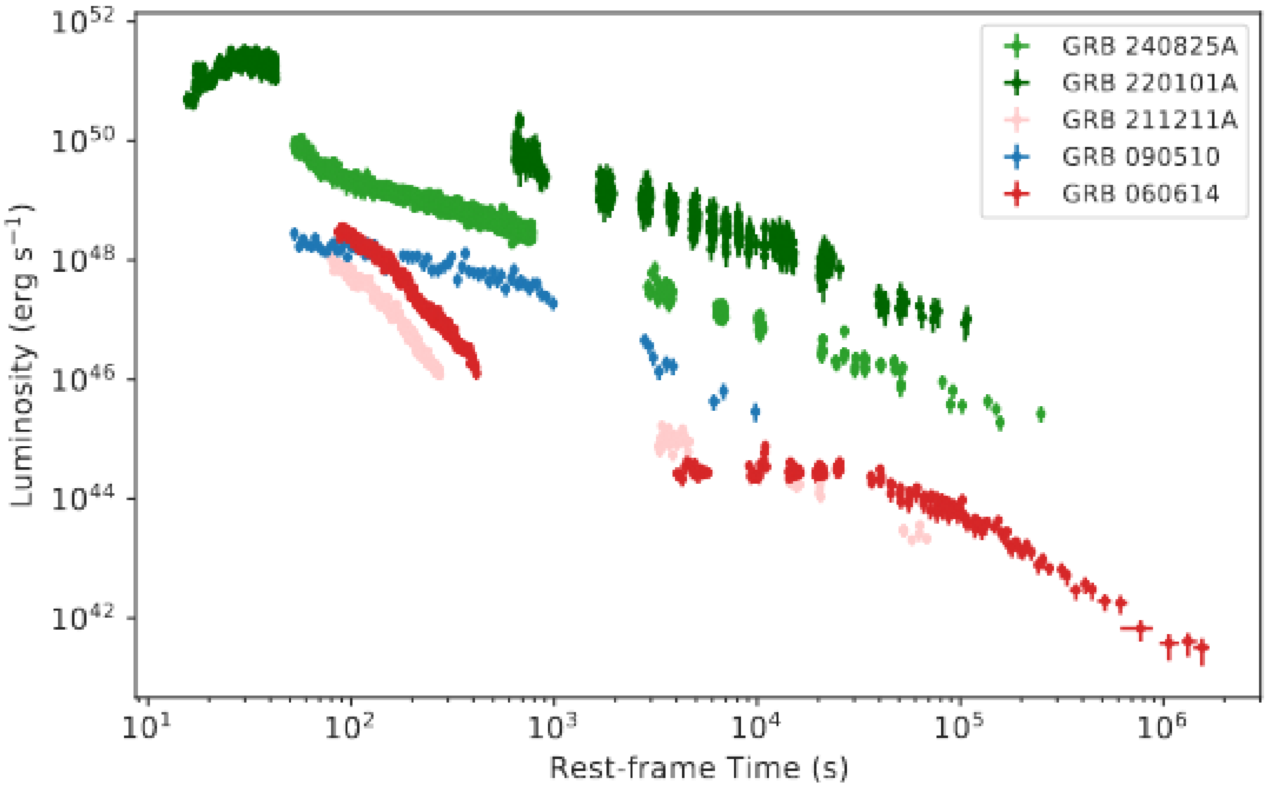


**Figure 4.** Comparing X-ray afterglows of GRB 240825A with typical long GRB (GRB 220101A, deep green), short GRB (GRB 090510, blue), and two long duration but merger origin GRBs (GRB 060614A and GRB 211211A, red).

# 27th September analysis of GRB 240825A

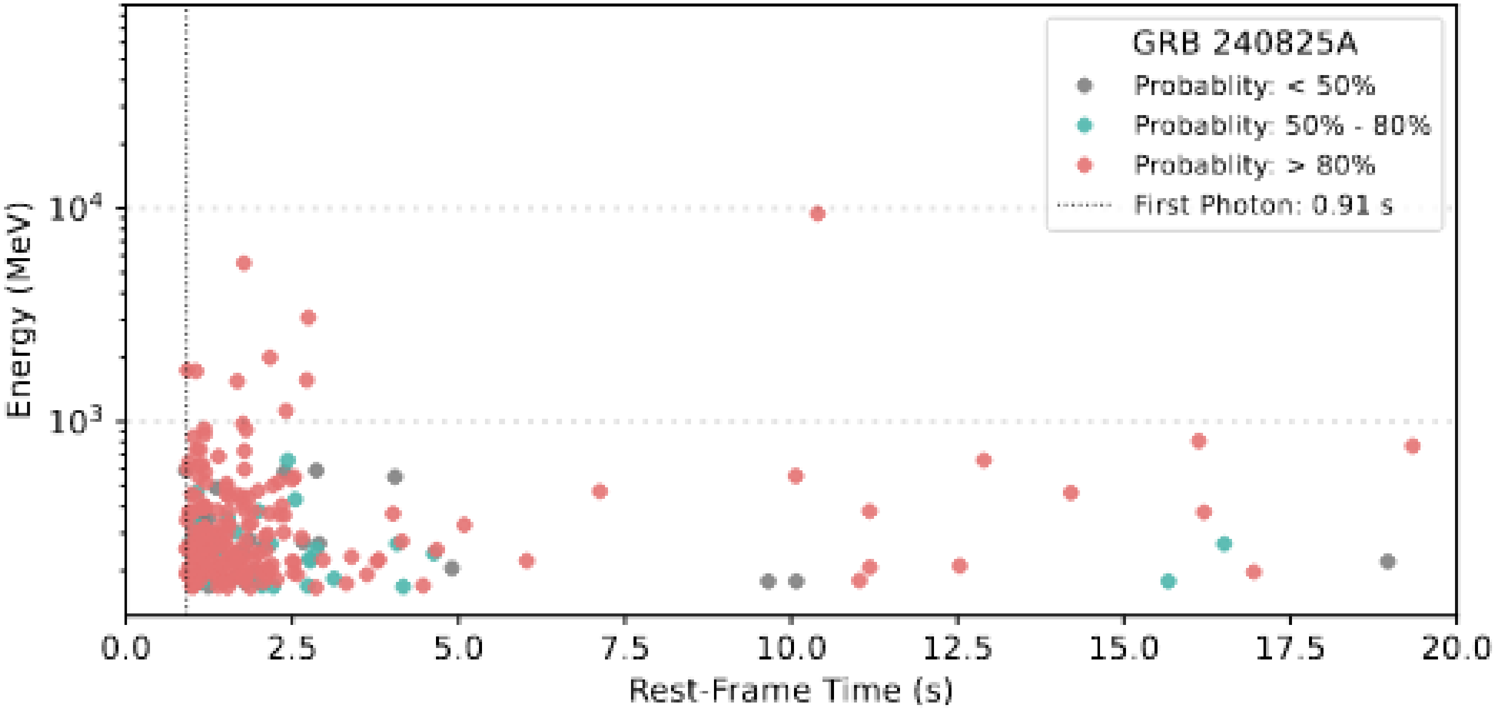


**Figure 3.** GeV Photons with probabilities more than 80% beonging to GRB 240825A (red points).

# 27th September analysis of GRB 240825A

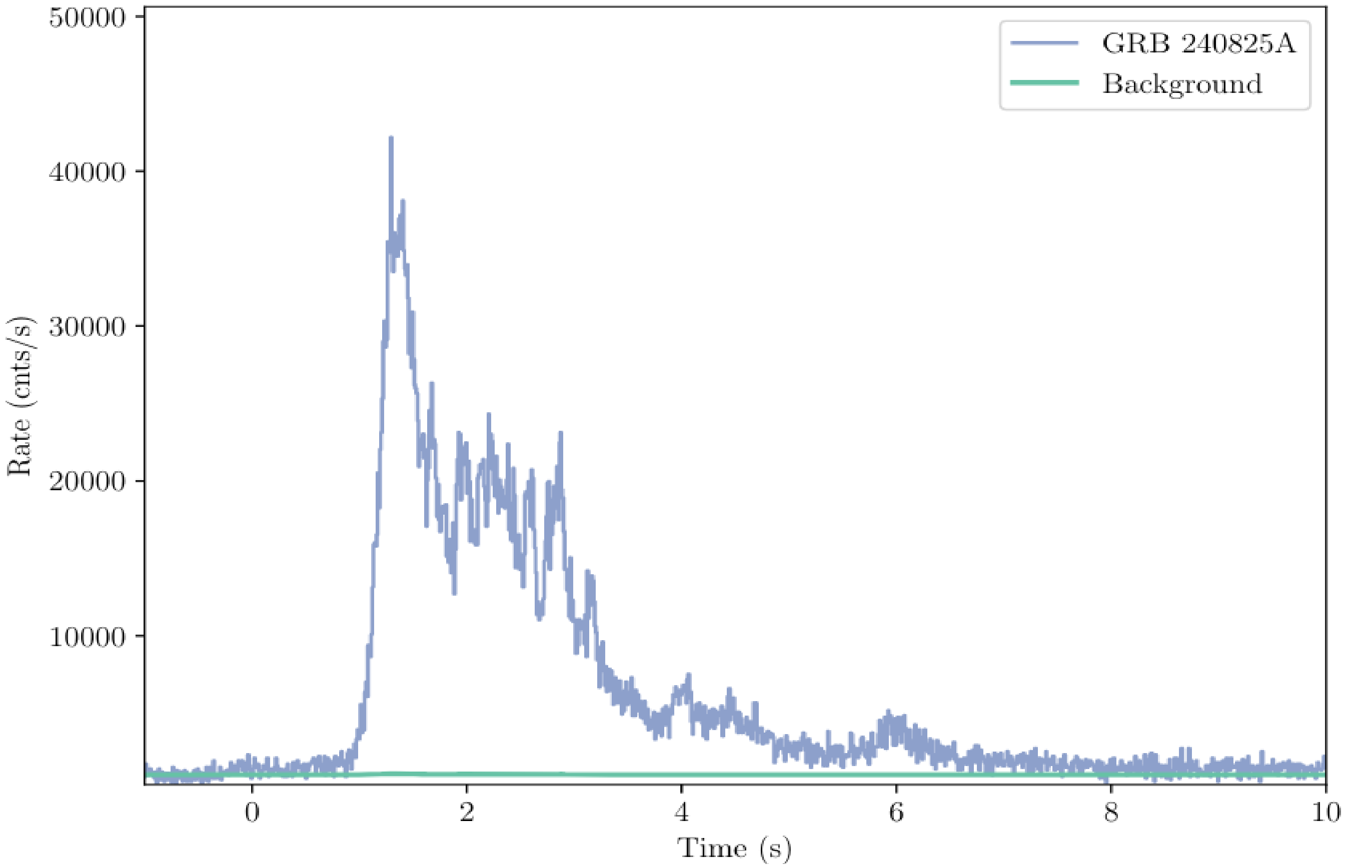


**Figure 1.** Count light curve of Fermi-GBM NAI6, showing the number of photon received by the satellite per second.

# 27th September analysis of GRB 240825A

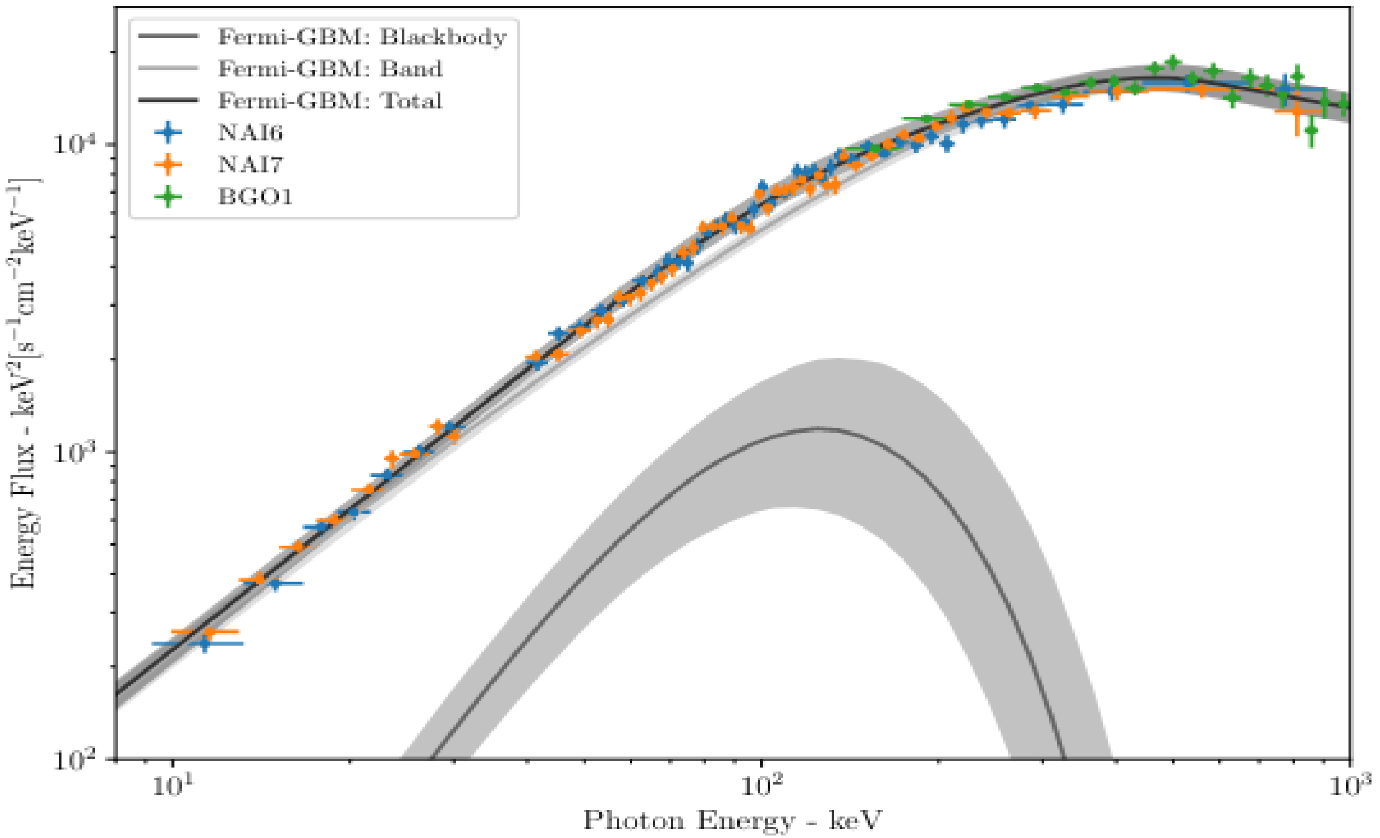


**Figure 5.** Spectrum of 1.1 - 1.8 s, showing a thermal component adhering on a band function. The thermal has temperature 32 keV.

# 27th September analysis of GRB 240825A

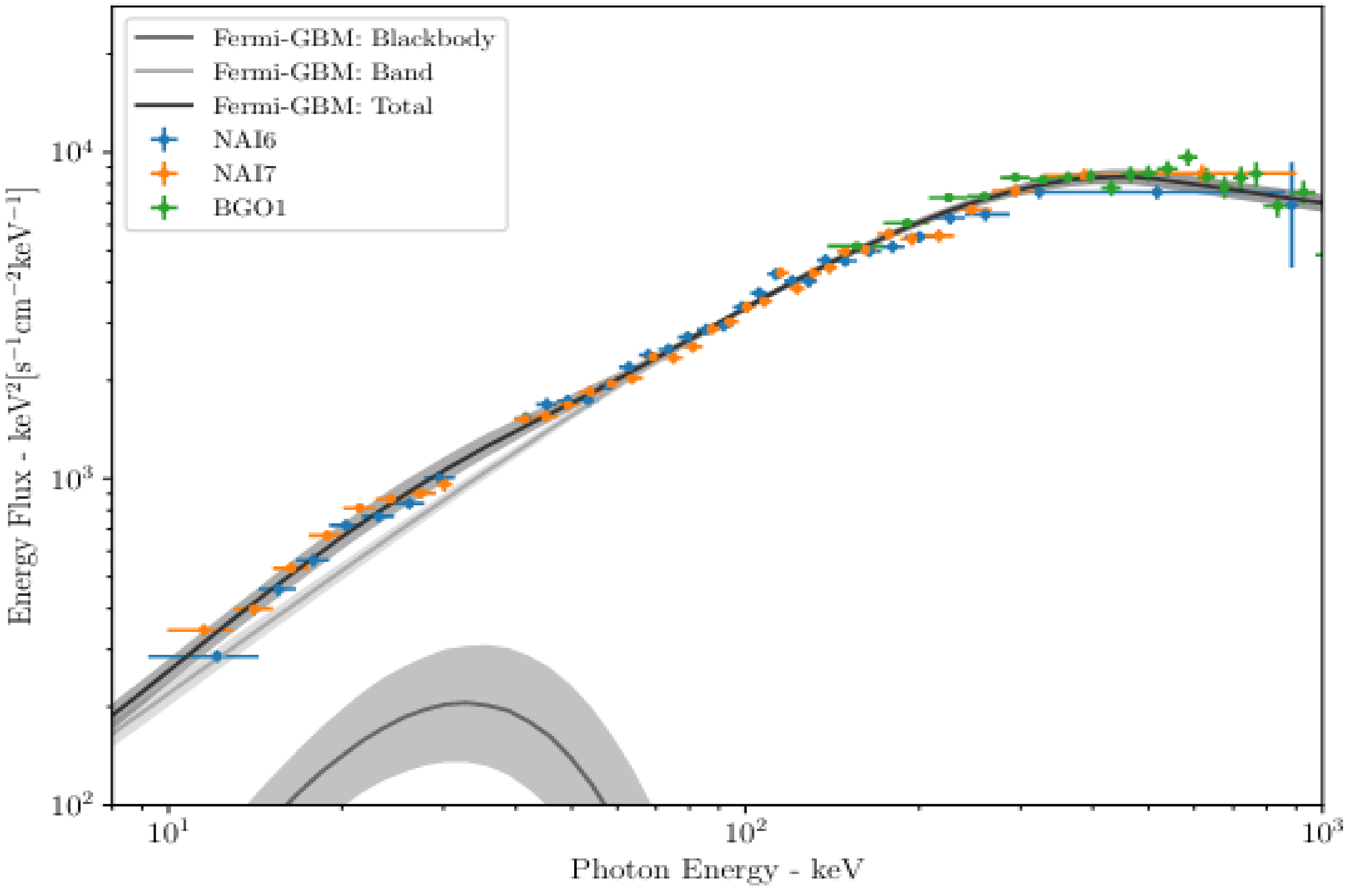
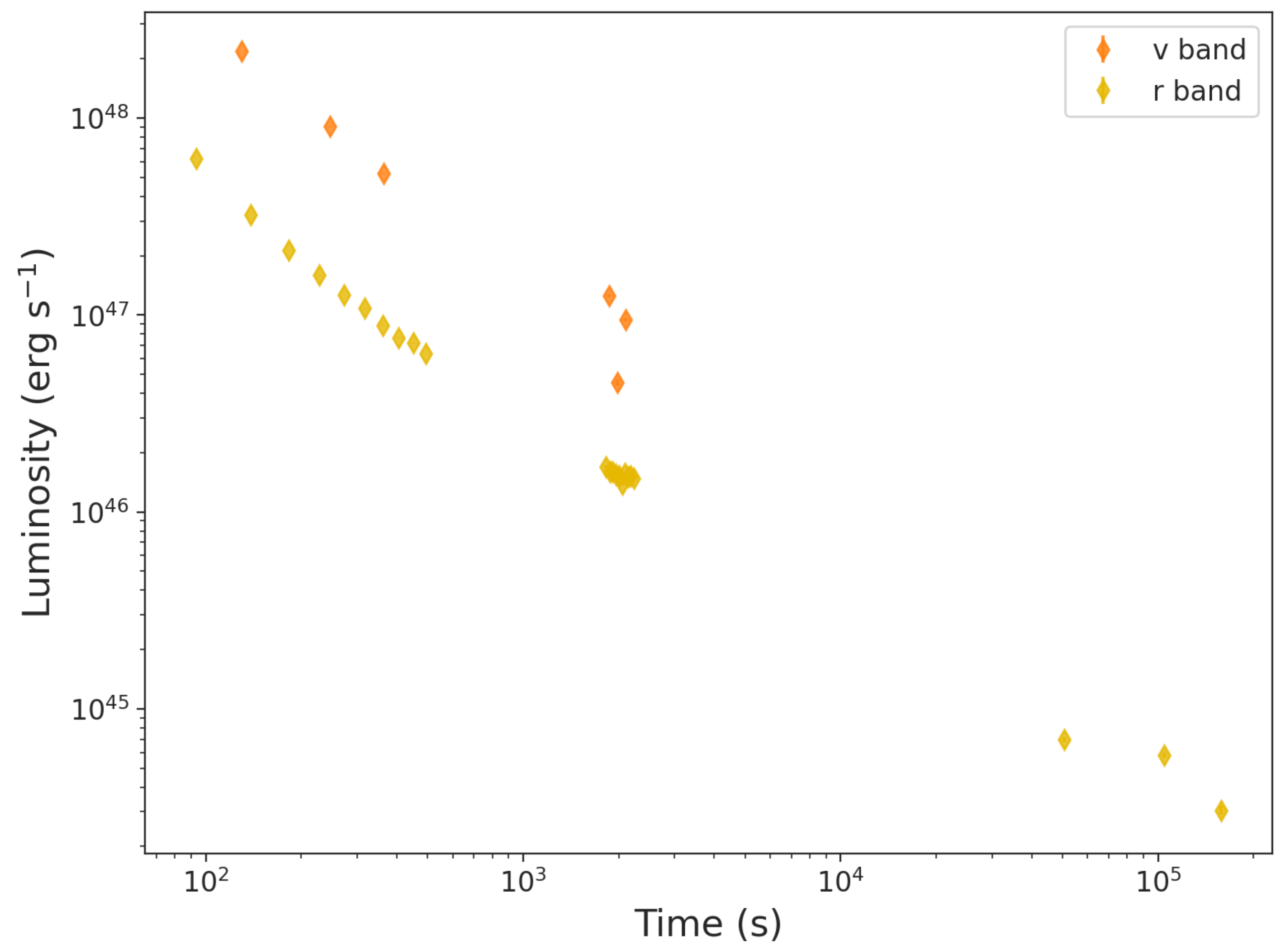
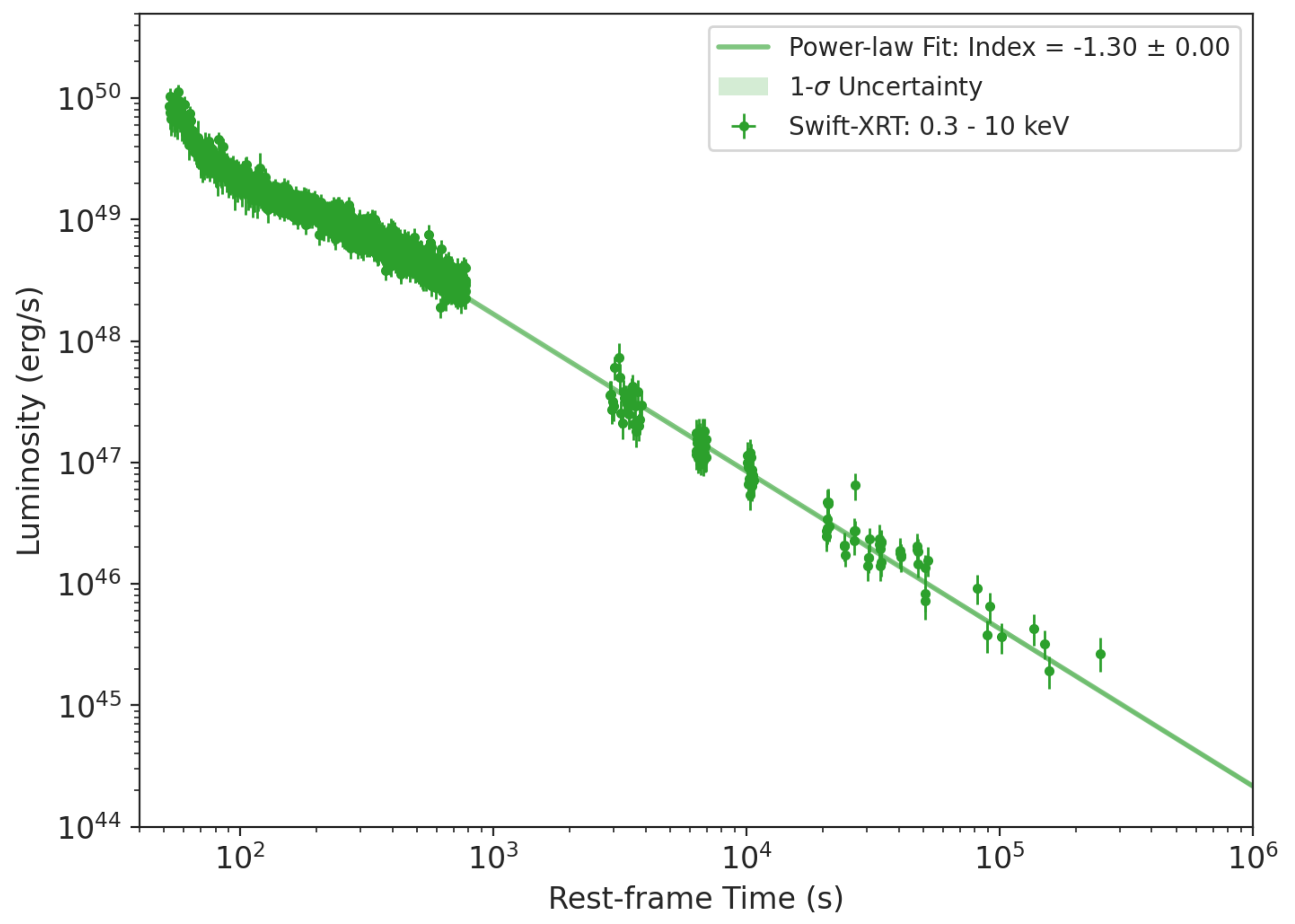


**Figure 6.** Spectrum of 1.8 - 3.4 s, showing a thermal component adhering on a band function. The thermal has temperature 18 keV.

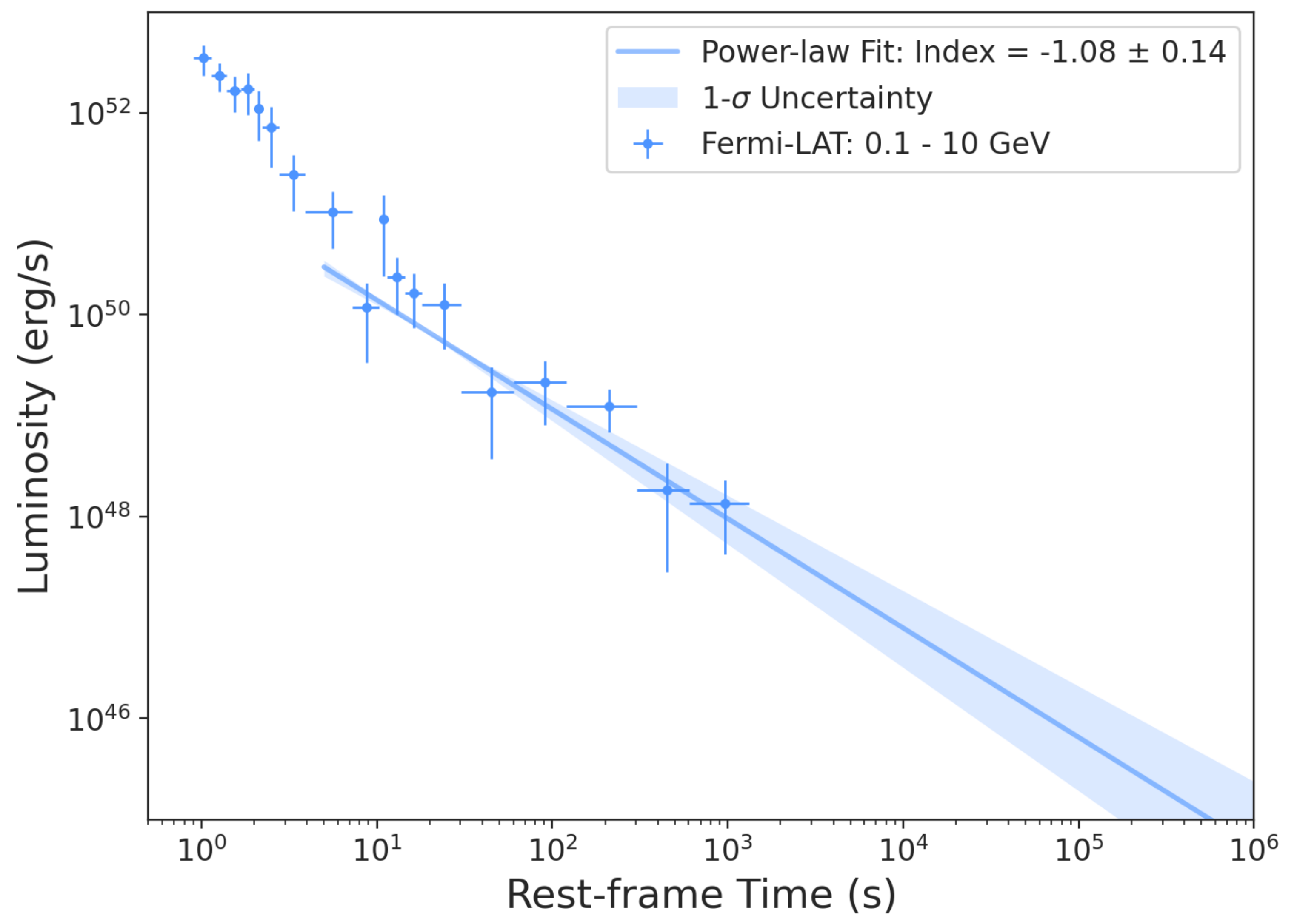
*The*
**optical emission**
*of*
**the $m_{sec}$ νNS**
**in GRB 240825B**



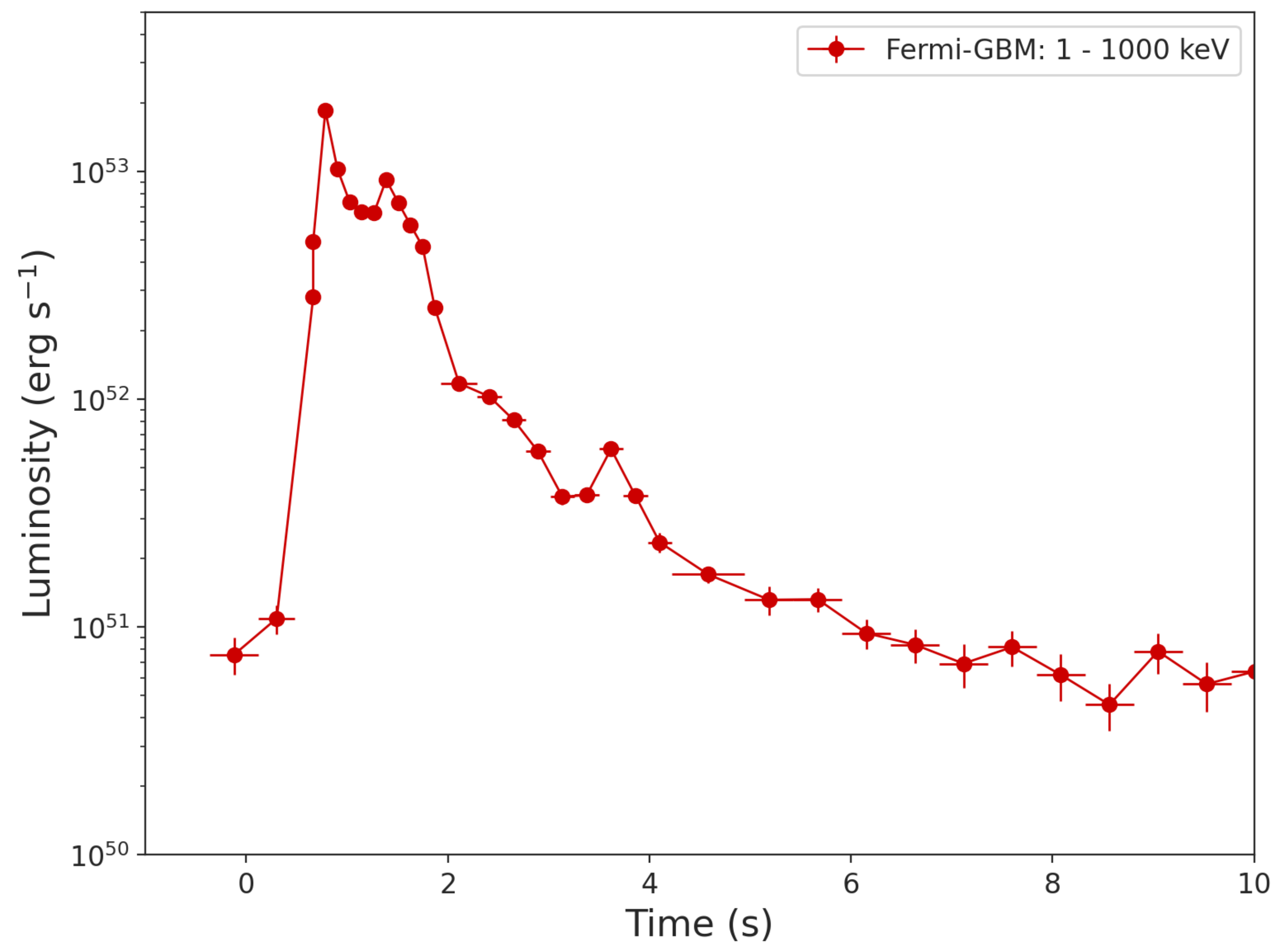
## *The*
## X-Ray afterglow emission
## *of*
## GRB240825B



# *The*
# GeV emission
# *of*
# GRB 240825B

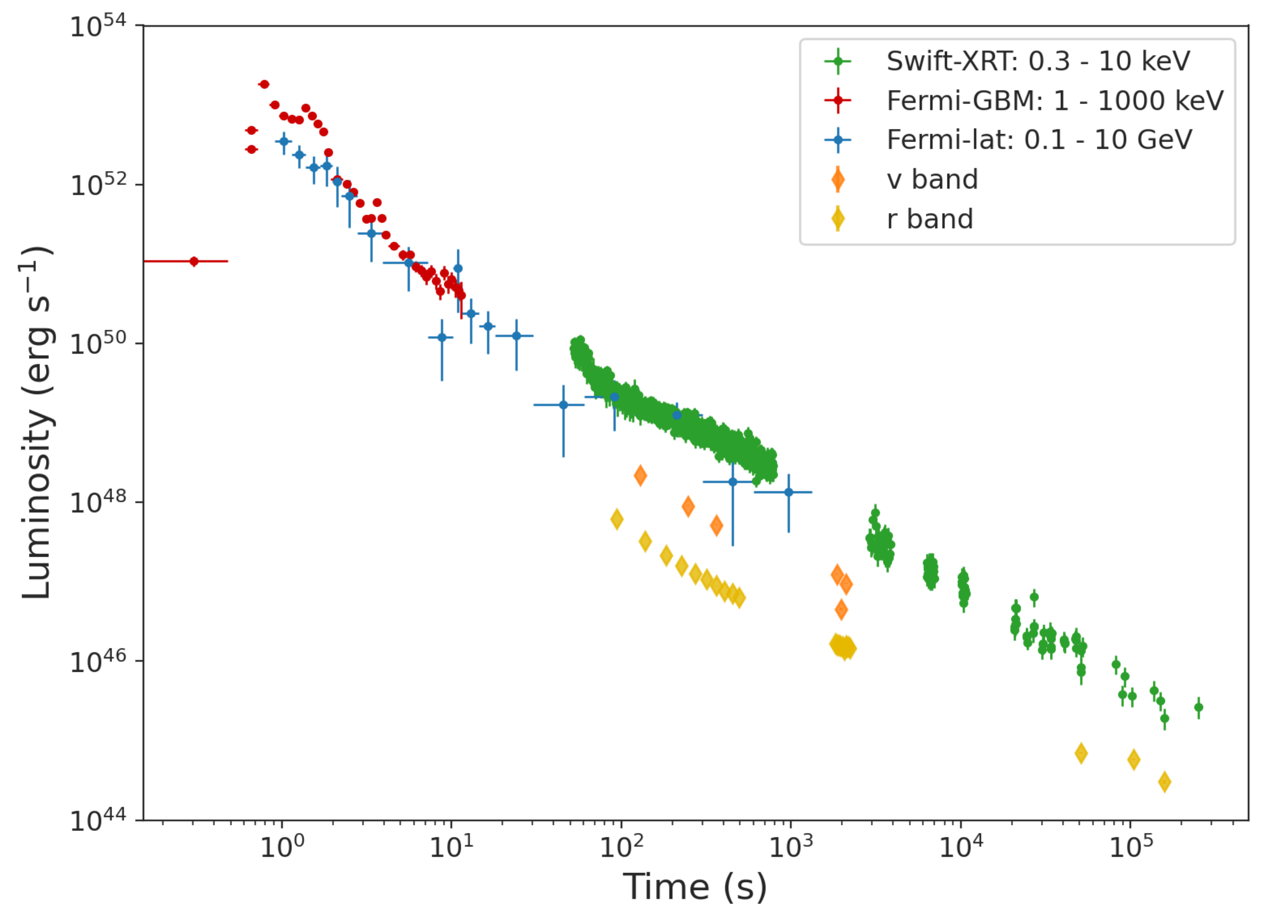


# *The*
# GBM emission
# *of*
# GRB 240825B



# The identified components of a BdHN I in GRB 240825BA (as of October 4, 2024)

**We expect
the observation
of
our predicted optical SN
by the observations
of
the James Webb Space Telescope
by the end of October 2024**



Albert Einstein, Hideki Yukawa,  John. A. Wheeler and Dr. Homi J. Bhabha