Central Engine from Early Multimessanger GRB observations

Vladimir Lipunov

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GRB Energy

$E \sim 10^{51-53} \text{ erg}$

This energy is typical for collapse

$E \sim 0.1 \text{ Mc}^2, M \sim 1-100 \text{ M}_{\text{solar}}$

Firstly pointed out by Blinnikov et al., 1984; Pachinsky, 1986 (!), Astrophys. J. 308, L43-L46
SPECTRUM

\begin{itemize}
  \item $E_{\text{peak}} \sim 1 \text{ Mev}$
  \item Typical energy for relativistic collapse
  \item $E \sim m_e C^2$
\end{itemize}
DURATION

\[ \Delta t_{obs} \sim 0.1 - 100 \text{s} \]

Typical collapse time scale:

\[ \Delta t \sim \frac{R_g}{c} \sim 10^{-5} \text{s} \ll \Delta t_{obs} \]

The MAIN Paradox

Vladimir Lipunov, Central Engine from Early Multimessanger GRB observations, KW25
2 SOLUTIONs

1. Back fall rotating envelope
   
   *Woosly et cetera*

   \[ V_{env} = HR < \left( \frac{2GM}{R} \right)^{\frac{1}{2}} \]

   \[ \Delta t \sim R^2/2D \quad \text{diffusion massive disk accretion} \]

2. Magneto-rotational collapse (Spinar paradigm)

   \[ \Delta t \sim I_{core} \Omega / K \]

   Where $K$ – dissipation force moment
   Of the Viscosity + Magnetic Field

Vladimir Lipunov, Central Engine from Early Multimessanger GRB observations, KW25, St.Petersburg, Russia, 12 sep 2019
• Usual Collapse - Super Novae

• Magneto-Rotational Collapse – GRB

• Rate (SN) / Rate (GRB) ~ 100
SN & GRB in Spinar Paradigma

After 17 Aug 2017

Short GRB
NS+NS merging
And NS+BH …
Long GRB
core collapse rotating massive star

Vladimir Lipunov, Central Engine from Early Multimessanger GRB observations, KW25, St.Petersburg, Russia, 12 sep 2019
IS THERE THE NEW PHYSICS IN GRB?

• Kardashev limit

\[ \frac{B^2}{8\pi R^3} = Mc^2, \quad R = R_g = \frac{2GM}{c^2} \]

• Max. Energy = eER \sim eBR \sim \left(\frac{1}{137}\right)^{1/2} E_{pl}

\[ 10^{27} \text{eV} \]
Prolongated GRB activity features

1. early Precursors (up to 200сек)

2. follow-up X-ray Flares (up to 10000s)
Precursors

The Importance of the magnetic rotational effect was pointed firstly with connecting to energetic and evolution of the quasars (Hoyle & Fauler, 1963; Kardashev, 1964; Ozernoy, 1966; Morison, 1969; Ozernoy & Usov, 1973).


The formation of the quasi equilibrium object was noted - Spinar. (Lipunov (1983) proposed of the idea Spinar with stellar mass).

Spin-up and spin-down was considered by in the frame the magnetorotator (Lipunov, 1987).

The relativistic Spinar was considered by, where was a first model GRB as the Spinar (Lipunova G.V., 1997).
Prolongated GRB activity was predicted

Spinar Paradigma


\[ a_0 \equiv \frac{I\omega_0 c}{GM_{\text{core}}^2} \quad \alpha_m \equiv \frac{U_m}{GM_{\text{core}}^2 / R_A} \]

\[ E_B \approx GM^2 / 2R_{\text{spinar}} = (1 / 2a_0^2)M_{\text{core}}c^2 \]

\[ \omega R_B^2 = GM_{\text{core}}^2 / R_B \]

\[ \frac{dI\omega}{dt} = -U_m \]

\[ L = -\omega dI\omega / dt = U_m \omega \propto R^{-5/2} \]

\[ L = \frac{\alpha_m c^5}{a_0^5 G} \left(1 - t/t_C\right)^{-3/5} \]
SN & GRB in Spinar Paradigma

Nonstationary Relativistic Pseudo-Newtonian Spinar Model

\[ \frac{d^2 R}{dt^2} = F_{gr} + F_c + F_{\text{nuclear}} + F_{\text{diss}} \]

\[ F_{gr} = -\frac{GM}{x^3} \frac{(x^2 - 2ax + a^2)^2}{(\sqrt{x(x - 2)} + a)^2} \quad x = \frac{2R}{R_g} \]

\[ F_{\text{nuclear}} = \frac{1}{\rho} \frac{dP}{dr} = \frac{P}{\rho R} \]

\[ P = \rho\left(\sqrt{c^4 + b\rho^{2/3} + \left(\frac{Q}{M}\right)^2} - c^2\right) \quad b = \left(\frac{4\pi}{3}\right)^{2/3} G^2 M_{\text{Class}}^{4/3} \]

\[ F_{\text{diss}} = -\frac{1}{\tau} \frac{dR}{dt} \quad \tau = \frac{2\pi\chi}{\omega} \quad \chi = 0.04. \]

\[ K = \int_{R_{\text{min}}}^{\infty} \frac{B_z B_\phi dS}{4\pi} = \frac{1}{2} \int_{R_{\text{min}}}^{\infty} B_z B_\phi RdR \quad K = \kappa_t \frac{\mu^2}{R_c^3} \quad R = R_c = \left(\frac{GM}{\omega^2}\right)^{1/3} \quad \text{see Lipunov, 1987} \]

\[ \frac{dI\omega}{dt} = \frac{\mu^2}{R_c^3} = -\frac{\kappa_t \mu^2}{GM\omega^2} \]
Magnetic Field Evolution and Central Engine Power

\[ \mu \sim BR^3 \sim BR^2 R \sim R \]

\[ \mu = \mu_0 \left( \frac{R \xi(x)}{R_0 \xi(x_0)} \right)^2 \]

\[ \xi(x) = \frac{1}{x} + \frac{1}{2x^2} + \ln(1 - 1/x) \]

Ginsburg & Ozernoy (1963):

\[ L_0 = \frac{1}{\tau} kM \frac{dR}{dt} \]

\[ L_0 = \frac{\mu^2}{R_{\text{min}}^3} \omega \]

\[ L_\infty = \alpha^2 L_0 \]

\[ \alpha = \sqrt{\frac{x^2 + a^2 - 2x}{x^2 + a^2}} \]

Thorne et al., 1986
Spinar Collapse Video

Vladimir Lipunov, Central Engine from Early Multimessanger GRB observations, KW25
Among several hundred gamma-ray bursts, two GRB070110 and GRB050904 do not fit into the usual picture of the formation of X-Ray afterglow. Both bursts revealed an extensive plateau lasting up to 6000-7000 seconds in their own frame of reference. Troja et al. (2007) suggested that such a long manifestation of activity was associated with the features of the central engine and specifically with the formation of a neutron star after the collapse of a small mass nucleus (less than the Oppenheimer-Volkov limit).
Massive Core Collapse (M > MOV).

7 Solar Mass Core Collapse

Up to down: energy release, Spinar radius, Kerr parameter and Magnetic Field for far observer frame

Vladimir Lipunov, Central Engine from Early Multimessanger GRB observations, KW25
7 Solar Mass Core Collapse Luminosity for different Kerr parameters

Vladimir Lipunov, Central Engine from Early Multimessenger GRB observations, KW25, St. Petersburg, Russia, 12 sep 2019
Low mass collapse
$M < M_{\text{OV}}$
Low Mass Core Collapse.
(\textit{Neutron Stars Formated})
5 UNSOLVED OBSERVATIONAL GRB PROBLEMS

I. The discovery of the most distant objects in the Universe. +/-

II. Prompt optical Short GRB emission detection. -

III. Optical emission Precursor detection. -

IV. Polarization measurement of the prompt optical, X-ray and Gamma GRB emission. +

V. High time resolution observations of the prompt optical/UV/IR emission. --
Global MASTER Robotic Net
MASTER Net Detected 10 types of the OTs from NEO to redshift $z \sim 5$. 

- Сверхновые
- Антивспышки
- Короткие гамма-всплески
- Длинные гамма-всплески
- Новые
- Микроквазары
- Квазары
- Кометы
- Опасные астероиды

Vladimir Lipunov, Central Engine from Early Multimessenger GRB observations, KW25, St.Petersburg, Russia, 12 Sep 2019
MASTER and Huge Physical Experiment

ANTARES

Ice-Cube (Antarctica)

10-м GTC

LIGO/VIRGO

FGST

Gravitационно-волной
Alain Klotz\textsuperscript{\textregistered} Talk "TAROT: follow-up of LIGO, GRB, IceCube, ANTARES" 
International Conference is devoted to the 15 th Anniversary MASTER project 
"Bursting Universe by Robots Eyes" SAI MSU 14-18 Aug. 2017
GRB 160725B
Troja et al.,
*Nature*, 2017, 547, 425-427

Vladimir Lipunov, Central Engine from Early Multimessanger GRB observations, KW25, St.Petersburg, Russia, 12 sep 2019
Figure 1 | Prompt $\gamma$-ray and optical light curves of GRB 160625B. The $\gamma$-ray light curve (black; 10–250 keV) consists of three main episodes: a short precursor (G1), a bright main burst (G2), and a fainter and longer-lasting tail (G3). Optical data from the MASTER Net telescopes and other ground-based facilities\(^9\) are overlaid for comparison. Error bars represent 1$\sigma$; upper limits are 3$\sigma$. The red box marks the time interval over which polarimetric measurements were taken. Within the sample of nearly 2,000 bursts detected by the GBM, only six other events have a comparable duration (https://heasarc.gsfc.nasa.gov/W3Browse/fermi/fermigbrst.html). Most GRBs end before the start of polarimetric observations.

Vladimir Lipunov, Central Engine from Early Multimessenger GRB observations, KW25, St.Petersburg, Russia, 12 sep 2019
"The optical identification of events with poorly defined locations: the case of the Fermi GBM GRB 140801A


Figure 1. MASTER OT discovery of GRB 140801A in the Fermi GBM error-box. The left panel illustrates the final GRB localizations [red circle: 3σ of statistical error (3-σ) and 3σ of systematic error GBM; blue lines: 3-σ IPN]. Grey squares are fields covered by MASTER. The black square is the location of the MASTER OT. The right panels show MASTER images of the OT position: discovery image (bottom), reference image (top). The IPN localization was published after the MASTER discovery circular (Gorbovskoy et al. 2014; Hurley et al. 2014).

Vladimir Lipunov, Central Engine from Early Multimessanger GRB observations, KW25.
St. Petersburg, Russia. 12 sep 2019"
One more FERMI GRB 170209A

OT detected inside 600 sq. Degree error box
At MASTER-OAFA

Vladimir Lipunov, Central Engine from Early Multimessenger GRB observations, KW25, St.Petersburg, Russia, 12 sep 2019
Первый снимок аргентинский МАСТЕР сделал в 22:54:18 UT то есть через 10.22 часа после столкновения и как выяснилось позже, телескопы МАСТЕРа прошли мимо галактики NGC 4993.
Independ optical Localization GW

V. Lipunov, The Discovery of gravitational waves: prediction & observation, The Third Zeldovich meeting, April 23-27, 2018, Minsk, Belarus
First pointing in Argentina
MASTER Wide field cameras started at 22:54:18 UT, 10:22 hours after merging in NGC 4993.

The MASTER-OAFA with two MASTER-VWF cameras, began imaging the new BAYESTAR-HLV (Singer, Price 2016, Singer et al. 2016) localization map of LIGO/Virgo G298048 (LIGO Scientific Collaboration and Virgo Collaboration 2017a, b, c) at 2017-08-17 22:54:18 UT, immediately after sunset. Observations started for the first field at RA, DEC = 12h 59m 00.00s -19d 59m 38.00s.
First image host galaxy NGC 4993 after NSs Merging at 10.22 hours UT 2017-08-17. Upper OT limit 15.2 V.

MASTER-OAFA VWF camera NGC 4993 first image, 2017-08-17 22:54:18. Upper limit 15.5 m. 5 x 225 exposure.
MASTER-OAFA inspection.
Kilonova started imaging at 2017-Aug-17 11:59:56 UT (02:59:56 Moscow Time)


V. Lipunov, The Discovery of gravitational waves: prediction & observation, The Third Zeldovich meeting, April 23-27, 2018, Minsk, Belarus
MASTER OT J OTJ130948.10-232253.3/SSS17a detection in NGC4993 by MASTER-OAFA

Lipunov, V., Gorbovskoy, E., Kornilov V., et al., 2017c, GCN, 21546, 1

V.Lipunov, The Discovery of gravitational waves: prediction & observation, The Third Zeldovich meeting, April 23-27, 2018, Minsk, Belarus
Color composed Kilonova image by W, B, V, R, I MASTER-SAAO+OAFA.

Composed MASTER image

MASTER-net full frame image 2 x 2 deg.
NGC 4993 and GW170817 optical counterpart

Zoom 32x
4 x 4 arcmin

Zoom 8x
15 x 15 arcmin
MASTER-OAFA
One year – one superdiscovery

V. Lipunov, The Discovery of gravitational waves: prediction & observation, The Third Zeldovich meeting, April 23-27, 2018, Minsk, Belarus
At 17:52:17 UT on 17 Sep 2016, the Lomonosov BDRG Gamma-ray Burst Monitor triggered GRB 161017A (E. Troja et al., GCN 20064). GRB 161017A has several peaks LC, total duration ~100s, the energy range 70-300 keV.

MASTER-Amur, robotic telescope (MASTER-Net: http://observ.pereplet.ru) located in Blagoveschensk was pointed to the GRB161017A 21 sec after notice time and 47 sec after Swift trigger time at 2016-10-17 17:52:38 UT in two polarizations. On our first (10s exposure) set we marginally found optical transient at Yurkov et al. (GCN 20063) and Troja et al. (GCN 20064) position. The 5-sigma upper limit has been about 14.5 mag. The OT was became brighter up to maximum at 3-4 set.

MASTER-Tunka robotic telescope (MASTER-Net: http://observ.pereplet.ru) located in Tunka (Baykal lake) was pointed to the GRB161017A 74 75 sec after notice time and 103 sec after trigger time at 2016-10-17 17:53:34 UT. We imaged OT late.

MASTER-IAC robotic telescope located at Teide Observatory (Tenerife, Canary, Spain) was pointed to the GRB161017A 32942 sec after trigger time at 2016-10-18 03:00:53 UT. We found optical transient on coadded images.
GRB 180728A: MASTER-SAAO observations:

Detected by SWIFT BAT  Starling et al GCN 23046

OT discovered by MASTER Lipunov et al GCN 23048

MASTER-SAAO robotic telescope located in South Africa (South African Astronomical Observatory) was pointed to the GRB180728A 22 sec after notice time and 38 sec after trigger time on 2018-07-28 17:29:38 UT in two polarizations. On our first (10s exposure) set we found new optical object (transient) within SWIFT error-box MASTER OT J165415.75 -540239.27  RA, DEC = 16h 54m 15.75s , -54d 02m 39.27s  m ~ 14.5

V. Lipunov et. Al GCN 23048

Vladimir Lipunov, Central Design & Planning, Multimessanger GRB observations, KW25, St.Petersburg, Russia. 12 sep 2019
GRB 180728A: MASTER-SAAO observations:

Detected by SWIFT BAT
Starling et al GCN 23046

Z = 0.117 ESO VLT
(Rossi et. al GCN 23055)

Very close GRB

Gal. latitude: -7.0 d
Gal. longitude: 334.2 d

Supernova SN 2018fip discovered 12 days after trigger by X-shooter instrument on the ESO/VLT (Izzo et al. GCN 23142)
GRB 180728A: MASTER-SAAO observations:

Detected by SWIFT BAT  Starling et al GCN 23046

OT discovered by MASTER Lipunov et al GCN 23048

$T_{90} = 8.68 \pm 0.3 \text{ s}$

Second point polarization low limit

$P > 12.5\% \pm 1.8\%$

Vladimir Lipunov, Central Engine from Early Multimessanger GRB observations, KW25, St.Petersburg, Russia, 12 sep 2019
Detected by Swift BAT Gropp et al GCN 23688

V. Tyurina et al GCN 23690
MASTER-IAC robotic telescope (Global MASTER-Net: http://observ.pereplet.ru, Lipunov et al., 2010, Advances in Astronomy, vol. 2010, 30L) located in Spain (IAC Teide Observatory) was pointed to the GRB190114.87 25 sec after notice time and 47 sec after trigger time at 2019-01-14 20:57:51 UT. On our first (10s exposure) set we found 1 optical transient within SWIFT error-box brighter than 16.54.

Vladimir Lipunov, Central Engine from Early Multimessanger GRB observations, KW25, St. Petersburg, Russia, 12 sep 2019
Vladimir Lipunov, Central Engine from Early Multimessenger GRB observations, KW25, St.Petersburg, Russia, 17 sep 2019
Swift, GRB190829A
GCN 25552 (19/08/29 20:25:37)
Ttrig = 19:56:44.60 UT

Swift/XRT data of GRB 190829A

MASTER Robotic net observations of GRB190829A

Vladimir Lipunov, Central Engine from Early Multimessanger GRB observations, KW25, St.Petersburg, Russia, 12 sep 2019
Fermi / Swift GRB190829A

Fermi 588801358 GCN 25551 (19/08/29 20:06:10 UT)

Swift BAT,XRT (UVOT-) GCN 25552 (19/08/29 20:25:37)
Ttrig= 19:56:44.60 UT

MASTER GCN 25553 (19/08/29 21:31:14)
MASTER-Kislovodsk 1259 sec after notice time (1290 from trigger)

Dabancheng-0.5m optical afterglow detection (GCN 25555 19/08/29 21:36:30,
started at 20:49:03 UT (52.3 min after the burst), x150s OT
MASTER bright and decay OT detection (GCN 25558 19/08/29 22:35:55

GROWTH India detection of afterglow GCN 25550 19/08/29 22:55:45 g + r, starting 51 min after, 16.9

NOT optical afterglow detection and spectroscopy GCN 25563 19/08/30 03:42:22,
r-band 19/08/30 02:03:52 18.9
10.4m GTC GCN 25565 19/08/30 06:40:25 i = 18.42 19/08/30 3:00UT, z =0.0785

VHE gamma-ray emission with H.E.S.S. GCN 19/08/30 07:08:37 T0 + 4h20, >5sigma
gamma-ray excess compatible with the direction of GRB190829A
Fermi / Swift GRB190829A

25651 GRB190829A: GROND detection of the accompanying SN MPG/ESO 2.2-metre Gamma-ray Burst Optical/Near-infrared Detector, La Silla, Chile

25652 GRB 190829A: MASTER confirmation of GROND SN

25657 GRB 190829A: Liverpool Telescope observations of a slow supernova rise

25660 Konus-Wind observation of GRB 190829A

25664 GRB190829A: Keck LRIS spectroscopic confirmation of the accompanying supernova

Low Resolution Imaging Spectrograph (LRIS)

Vladimir Lipunov, Central Engine from Early Multimessanger GRB observations, KW25, St.Petersburg, Russia, 12 sep 2019

25667 GRB 190829A optical observation
Рабочая LVC

Грав. Волновые детекторы

Vladimir Lipunov, Central Engine from Early Multimessanger GRB observations, KW25, St.Petersburg, Russia. 12 sep 2019
Чувствительность LVC
Чувствительность LVC в момент гамма-всплеска по нейтронным звездам

LIGO-Virgo binary neutron star inspiral range

GRB 190829A
trigger time

Hanford
Livingston
Virgo

Владимир Липунов, Центральный двигатель из ранней
Мультимессенджера. GRB наблюдения, KW25,
Санкт-Петербург, Россия, 12 сентября 2019
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<th>No.</th>
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<td>2019-05-24 04:52:02</td>
<td>LVC /master/data/ligo/db/S190524q/150</td>
<td>191.693 ± 101</td>
<td>BH</td>
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<td>S190521r</td>
<td>2019-05-21 07:43:50:66673</td>
<td>LVC /master/data/ligo/db/S190521r/152</td>
<td>1136.13 ± 279.258</td>
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<td>10439</td>
<td>S190521g</td>
<td>2019-05-21 03:02:29</td>
<td>LVC /master/data/ligo/db/S190521g/152</td>
<td>3931.42 ± 953.035</td>
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<td>10405</td>
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<td>LVC /master/data/ligo/db/S190519bj/151</td>
<td>3153.54 ± 790.989</td>
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<td>10403</td>
<td>S190518bb</td>
<td>2019-05-18 19:25:48</td>
<td>LVC /master/data/ligo/db/S190518bb/150</td>
<td>27.7601 ± 15.2671</td>
<td>BH</td>
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<td>10366</td>
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<td>2019-05-13 20:54:28</td>
<td>LVC /master/data/ligo/db/S190513bm/150</td>
<td>2955 ± 1037.65</td>
<td>BH</td>
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<td>10365</td>
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<td>LVC /master/data/ligo/db/S190512at/150</td>
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<td>2019-05-10 26:05:19</td>
<td>LVC /master/data/ligo/db/S190510g/150</td>
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<td>375.432 ± 108.174</td>
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<td>10198</td>
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<td>2019-04-25 18:08:15</td>
<td>LVC /master/data/ligo/db/S190425z/152</td>
<td>156.144 ± 413.734</td>
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<tr>
<td>10196</td>
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<td>BH</td>
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<td>2019-04-12 05:30:44</td>
<td>LVC /master/data/ligo/db/S190412m/150</td>
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<td>10183</td>
<td>S190408an</td>
<td>2019-04-08 18:08:02</td>
<td>LVC /master/data/ligo/db/S190408an/150</td>
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<td>BH</td>
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<td>10180</td>
<td>S190405ar</td>
<td>2019-04-05 16:01:30</td>
<td>LVC /master/data/ligo/db/S190405ar/150</td>
<td>268.106 ± 128.788</td>
<td>BH</td>
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<td>10066</td>
<td>G299232</td>
<td>2017-08-15 13:13:37</td>
<td>LVC /master/data/ligo/db/G299232/152</td>
<td>254.502 ± 86.5358</td>
<td>BH</td>
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<tr>
<td>10070</td>
<td>G299362</td>
<td>2017-08-23 13:53:58</td>
<td>LVC /master/data/ligo/db/G299362/152</td>
<td>1541 ± 415.434</td>
<td>BH</td>
<td>This</td>
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</table>
Very Bright GRB160625B

The black curve is the MASTER optical curve, red - Fermi LAT observations (> 1 MeV)
The black curve is the MASTER optical curve, red - Fermi LAT observations (> 1 MeV)
Model A: The gravitational impact of a companion star (NS) directly on the stellar wind. (Topolev et al., 2019)

The x, y axes show the distance in solar radii, the relative density of particles is shown in color (above)

Density distribution on the line of sight, x - distance in the radii of the Sun, y - relative density (right)

Параметры моделируемой системы:
1. $M_1 = 1.5 M_\odot$
2. $M_2 = 20 M_\odot$
3. $R_2 \approx 1.4 R_\odot$
4. $v_\infty \approx 1300$ км/с
5. $T \approx 5800$ с
Model B: a companion star (NS) is drawn in an ellipse relative to a collapsing star; passage through the pericenter of the orbit perturbs the main star. The stellar wind flux density increases, creating a density wave that is already accelerating according to the stellar wind acceleration law (Topolev et al., 2019):

\[ v = v_\infty \sqrt{1 - \frac{R_{\text{surf}}}{r}} \]

[Michals, D. “Stellar atmospheres”]

Zelenый - модельная кривая для параметров: радиус поверхности испускания – 1,4 R\( \odot \); Tsystem \( \approx \) 7200 с; \( v_\infty \approx 500 \text{км/с} \) (Сверху)

Движение волн плотности в радиальном направлении (Справа)

Vladimir Lipunov, Central Engine from Early Multimessanger GRB observations, KW25, St.Petersburg, Russia, 12 sep 2019
SPINAR COMEBACK!


- Maurice H.P.M. van Putten and Massimo Della Valle, Mon. Not. R. Astron. Soc.000, 1–9, 4 September 2018 Observational evidence for Extended Emission to GW170817

Vladimir Lipunov, Central Engine from Early Multimessanger GRB observations, KW25, St.Petersburg, Russia, 12 sep 2019
MODERN CALCULATIONS and observations


• Maurice H.P.M. van Putten and Massimo Della Valle, Mon. Not. R. Astron. Soc. 000, 1–9, 4 September 2018 Observational evidence for Extended Emission to GW170817

Vladimir Lipunov, Central Engine from Early Multimessanger GRB observations, KW25, St.Petersburg, Russia, 12 sep 2019
New Spinar consideration:

(Posdnyakov et al. 2019, in preparation):

- Nuclear pressure
- Lense-Thirring effect
- Disappearance of the magnetic field during collapse
- Angular momentum losses
- New: Dynamo-mechanism
Before merger:

\[ L_g = \frac{32G^4 M_1^2 M_2^2 (M_1 + M_2)}{5c^5 A^5} \]

\[ L = \frac{\dddot{D}^2}{180c^5} \]
optical radiation

• We assume that the spinar spectrum corresponds to the Crab pulsar (B0531+21) spectrum.

Vladimir Lipunov, Central Engine from Early Multimessanger GRB observations, KW25, St.Petersburg, Russia, 12 sep 2019
$B = 10^{12} \, G$

$B = 10^{13} \, G$

$B = 10^{14} \, G$
Владимир Липунов, Центральный двигатель из наблюдений ГБР, KW25,
Pozdnyakov et al., in prep.
GW precursor

Vladimir Lipunov, Central Engine from Early Multimessanger GRB observations, KW25, St.Petersburg, Russia, 12 sep 2019
MASTER can see the optical transient:

![Graph showing a linear relationship between \( \lg R, \text{Mpc} \) and \( \lg B \).]
Summary

• The magnetic field strongly affects the electromagnetic luminosity
• For usual electromagnetic fields we can see the optical transient at a distance about 200-300 Mpc
• At these distances in the radio band can radiate about 20 Ya at a frequency of 178 MHz
Perspectives

• More detailed account of differential rotation
• Accounting of statistical data on magnetic fields of neutron stars
• More detailed account of the jet
5 UNSOLVED OBSERVATIONAL GRB PROBLEMS

I. The discovery of the most distant objects in the Universe.  
II. Prompt optical Short GRB emission detection.  
III. Optical emission Precursor detection for GRB.  
IV. High time resolution observations of the prompt optical/UV/IR emission.  
V. NS+BH localization

Vladimir Lipunov, Central Engine from Early Multimessanger GRB observations, KW25, St.Petersburg, Russia, 12 sep 2019
Thank you for attention
Extended Data Figure 1 | Multiwavelength light curves for GRB 160625B and its afterglow. Different emission components shape the temporal evolution of GRB 160625B. On timescales of seconds to minutes after the explosion, we observe bright prompt (solid lines) and reverse-shock (dotted lines) components. On timescales of hours to weeks after the burst, emission from the forward shock (dashed lines) becomes the dominant component from X-rays down to radio energies. After about 14 days, the afterglow emission falls off at all wavelengths. This phenomenon, known as jet-break, is caused by the beamed geometry of the outflow. Error bars denote 1σ limits; upper limits are 3σ. Times are given with reference to the LAT trigger time $T_0$. FS, forward shock; RS, reverse shock; a subscript ‘v’ refers to frequency; u, V, r, i, z, y, J and H denote specific optical filters.