LOMONOSOV MOSCOW STATE UNIVERSITY

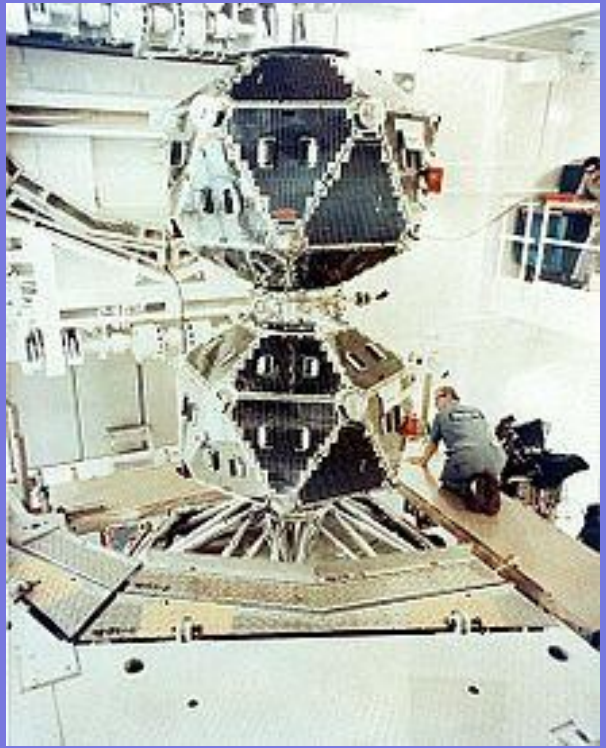
SAI MSU, Space Monitoring Laboratory, Extreme Universe Laboratory

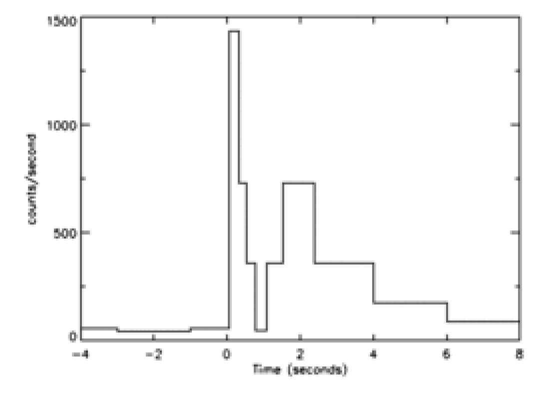
MASTER and unsolved GRB observational and theoretical problems

V.M. Lipunov

Discovery

Klebesadel R W, Strong I B, Olson R A *Astrophys. J. Lett.* **182** L85 (1973)





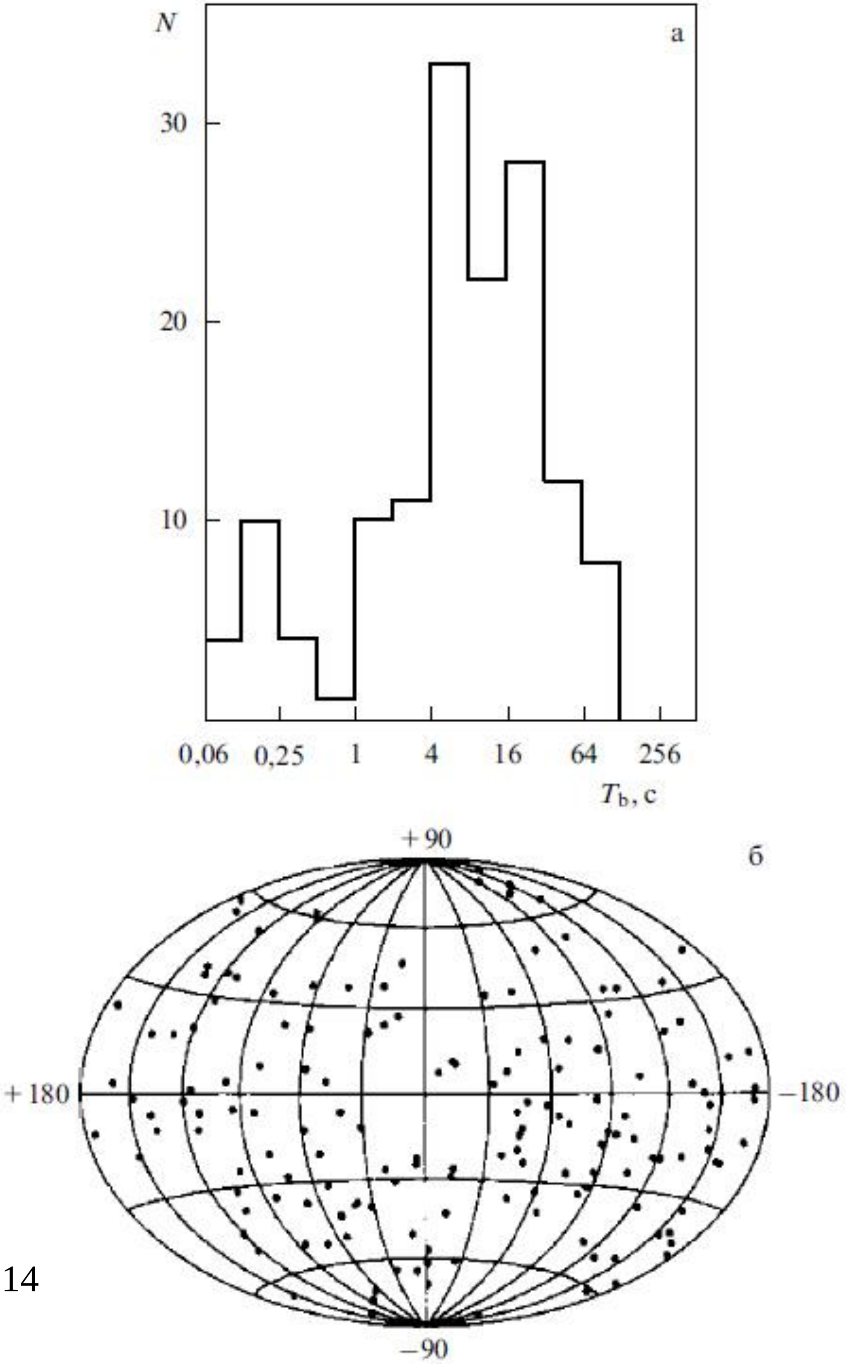
First GRB670702

Outburst of cosmic gamma-radiation according to observations aboard the artificial earth satellite Cosmos 461., Mazets E P, Golenetskii S V, Il'inskii V NJETP Lett. V. 19, 77 (1973)

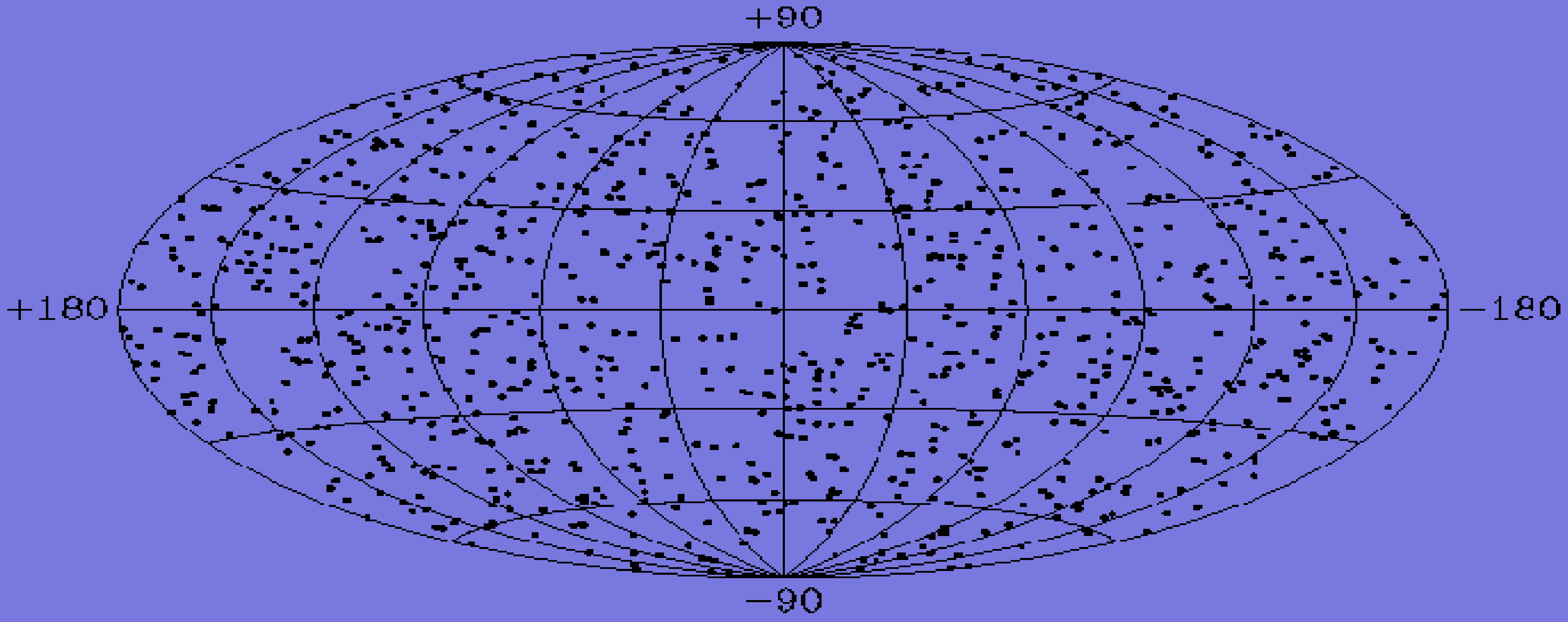
Bimodal + Isotropy

Mazets E P, Golenetskii S V, in Soviet Scientific Reviews, Sec. E,
Astrophysics and Space Physics Reviews Vol. 1 (Ed. R A Syunyaev)
(Chur: Harwood Acad. Publl., 1981) p. 205
+ ASPR Vo.6 1988 (Pt.3) p.283

Venus 11-14



1000 BATSE Gamma-Ray Bursts



Galactic Coordinates

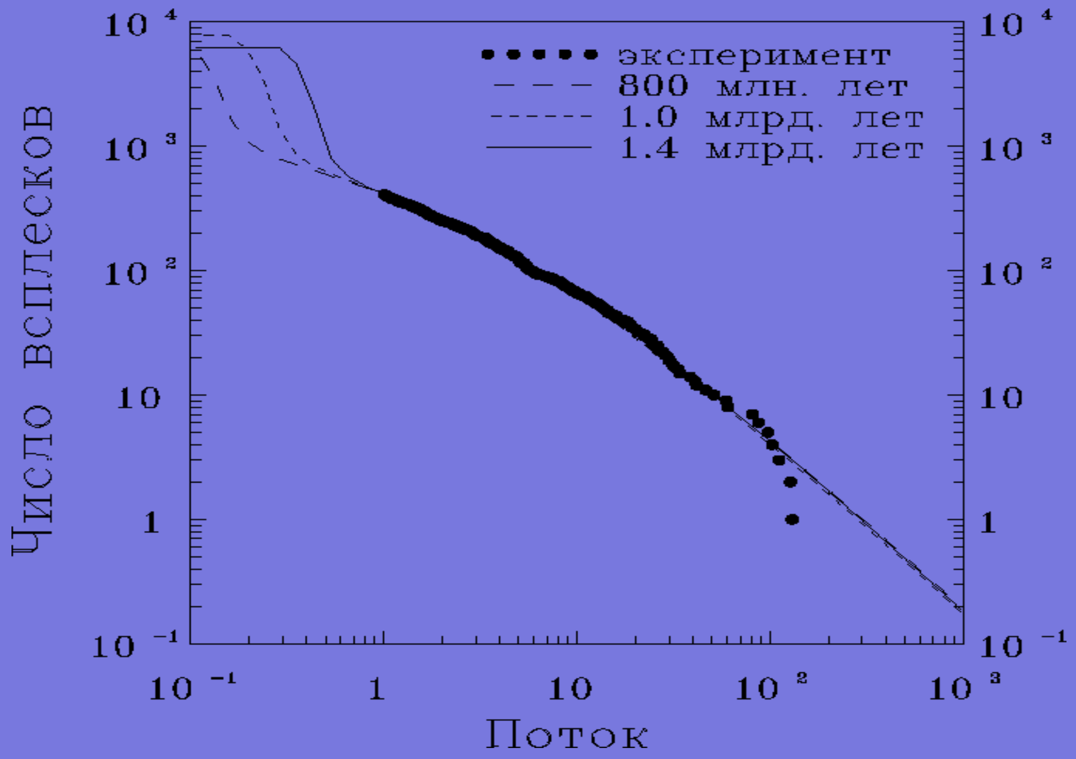
V.Lipunov, St.Pb.,09.22.14, GRB2014

SPACE DISTRIBUTION:

Mazetz et al., . 1980s

Evolution of the Double Neutron Star Merging Rate and the Cosmological Origin of Gamma-Ray Burst Sources

Lipunov et al., 1995, Astrophysical Journal v.454, p.593



$$F = \frac{L}{4\pi R^2}\,, \qquad (1)$$

$$N(>F) \sim \frac{4}{3}\pi R^3 \sim F^{-3/2}\,.$$

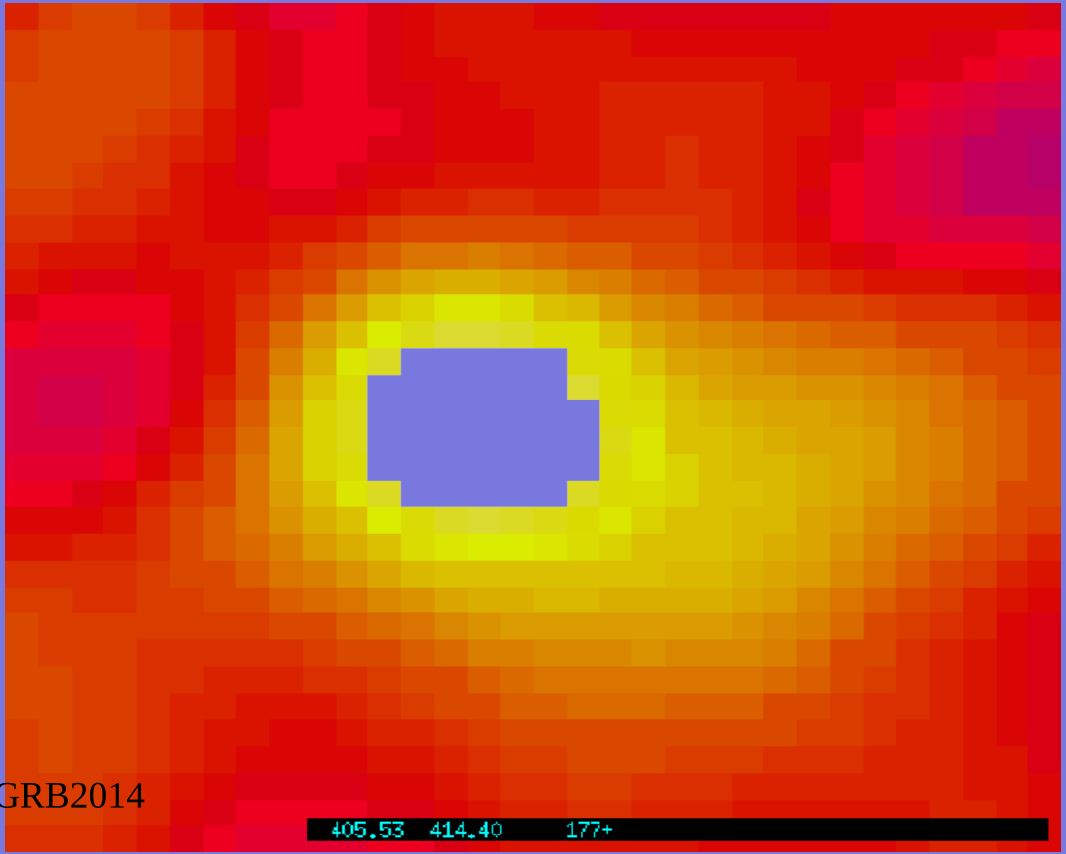
$$\mathrm{Log}\,N \sim -\frac{3}{2}\,\mathrm{Log}\,F\,.$$

BeppoSAX experiment

SAX – abbreviation of the Italian satellite Satelito di Astronomica X

Afterglow
GRB970228

Image of GRB (February 1997) from Hubble space telescope



1997:
Spectral line discovery

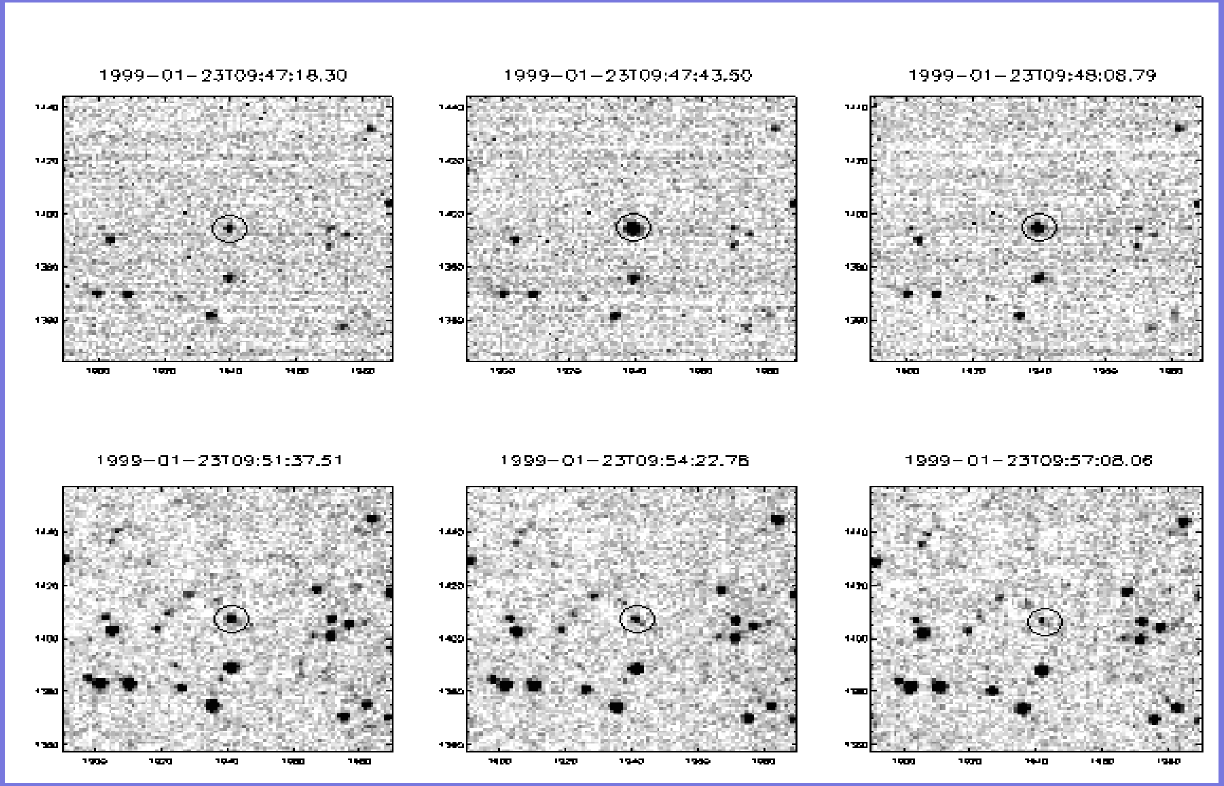
GRB970508

GRBs – cosmological!

Prompt Optical Very Bright Emission Discovery

GRB 990123

ROTSE I Akerlof et al. 1999



Energy

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

Typical collapse

$$E \sim 0.1\ Mc^2,\ M \sim 1\text{-}10\ M_{solar}$$

NS merging (Blinnikov et al., 1983)

Collapse (Paczynski, 1986, Astrophys. J. 308, L43-L46)

Spectrum

Epeak ~ 1 Mev

Typical collapse temperature

$T \sim 2m_e C^2 \sim 10^{10}$ K ~ 1Mev

DURATION

$\Delta t_{obs} \sim 0.1 - 100$ s

Typical collapse time

$\Delta t \sim R_g/c \sim 10^{-5}$ s $\ll \Delta t_{obs}$

Solution

Magneto-Rotational Collapse

$$\Delta t \sim I \omega / K$$

Where K – dissipation magnetic force moment

$$\Delta t \sim R^2 / D$$

D ~ Viscosity

Two scenarios for long GRB

Woosley Scenario

(Gamma-ray bursts from stellar mass accretion disks around black holes, ApJ, 405,273, 1993)

Core collapse mean massive star

1. Formation Black Hole
2. Formation Massive Accretion Disk
3. GRB is result of accretion in Massive Disk (BZ-mechanism)

Spinar Scenario

e+e- high massive fast rotating star collapse

1. Formation Spinar (precursor)
2. Formation limiting Kerr Black Hole (GRB)

Scenario for short GRB

Woosley Scenario

Core collapse mean massive star

Does not work

Spinar Scenario

NS+NS merging

1. Formation Spinar (precursor)
2. Formation limiting Kerr Black Hole (GRB)

Spinar history

The Importance of the magnetic rotational effect was pointed firstly with connecting to energetic and evolution of the quasars (Hoyle & Fauler, 1963; Ozernoy, 1966; Morison, 1969; Ozernoy & Usov,1973) and SN explosion (Bisnovatiy-Kogan; 1971, LeBlance & Wilson 1970).

The formation of the quasi eqvilibrium object was noted - Spinar. Lipunov (1983) proposed of the idea Spinar with stellar mass (see Ostriker, 1973). Spin-up and spin-down was considered by Lipunov, 1987 in the frame the magnetorotator.

The relativistic Spinar was considered by Lipunova G.V. (1997), first model GRB as the Spinar.

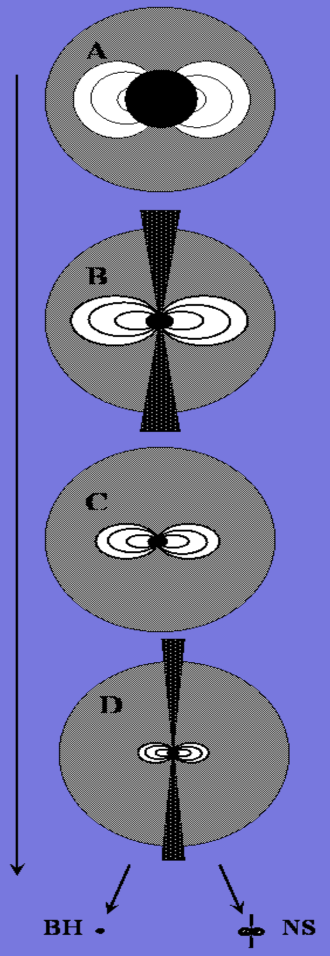
Prolongated GRB activity was predicted

Lipunova, G.V. A burst of electromagnetic radiation from a collapsing magnetized star. *Astronomy Letters* 23, 84-92 (1997).

Lipunova, G.V. & Lipunov, V.M. Formation of a gravitationally bound object after binary neutron star merging and GRB phenomena. *Astron. Astrophys*. 329, L29-L32 (1998).

Spinar Paradigma

(Lipunov & Gorbovskoy, 2007, ApJLetters, v.665, 97L)



$$a_0 \equiv \frac{I\omega_0 c}{GM^2_{core}} \qquad \alpha_m \equiv \frac{U_m}{GM^2_{core}/R_A}$$

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

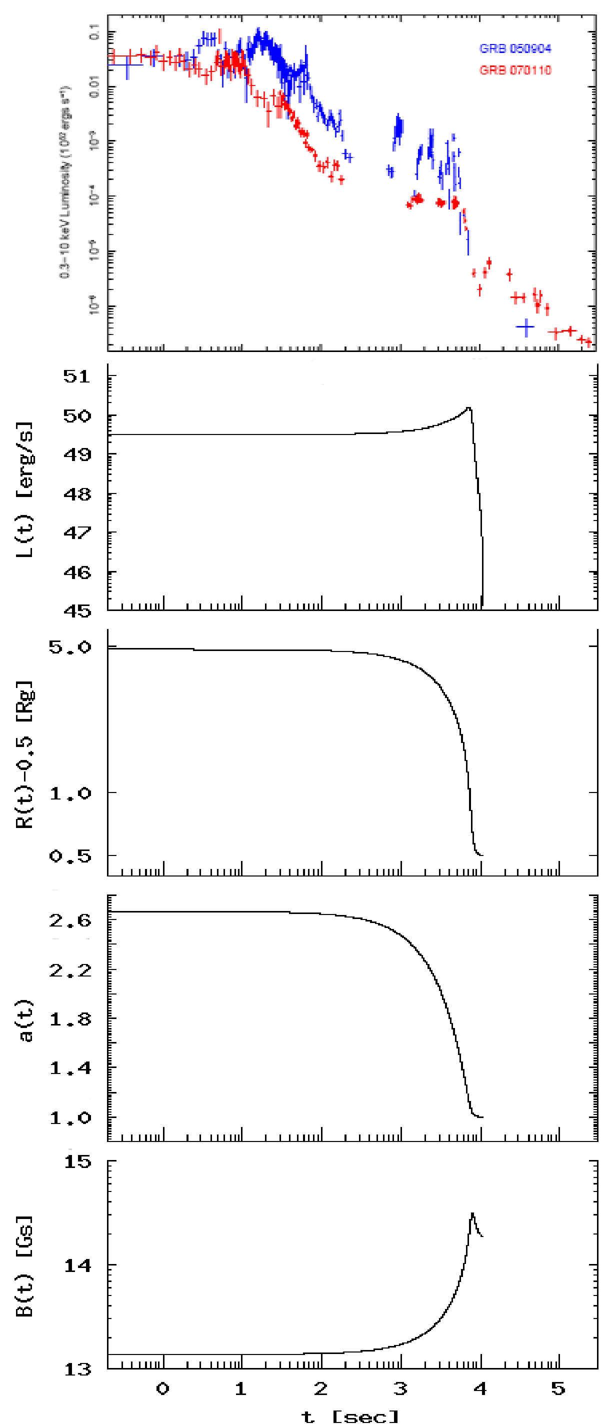
$$\omega R_B^2 = GM^2_{core}/R_B$$

$$dI\omega/dt = -U_m$$

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

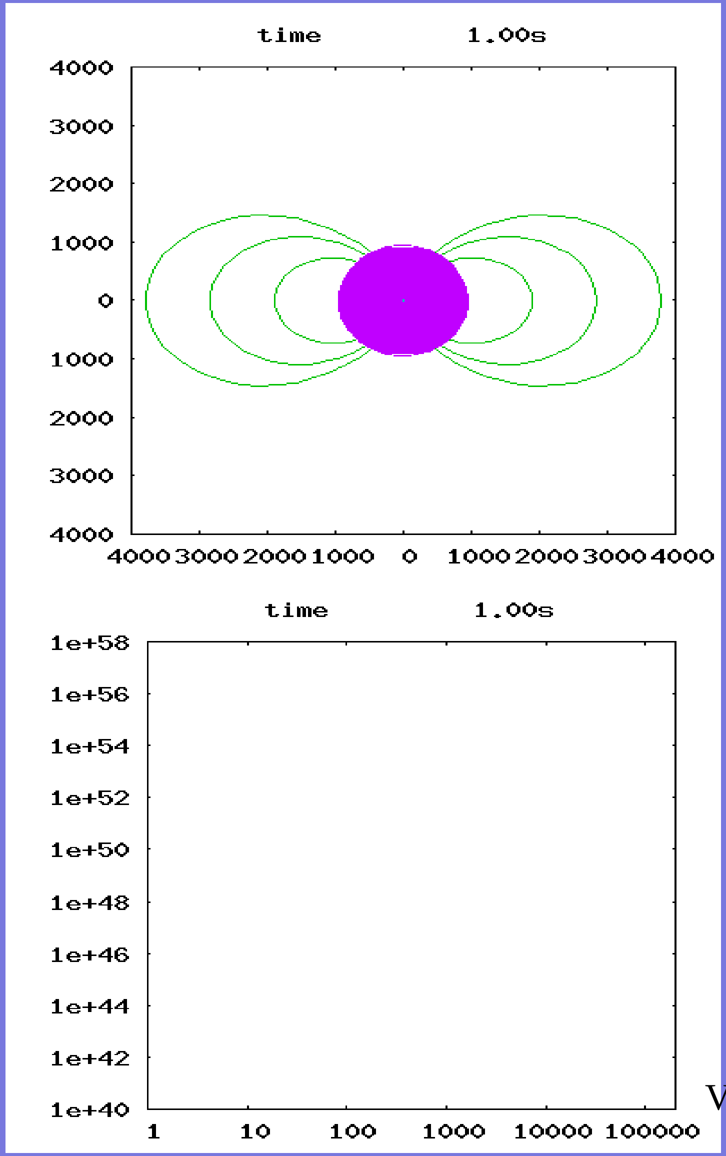
$$L = \frac{\alpha_m}{a_0^5}\frac{c^5}{G}(1-t/t_C)^{-3/5}$$

Extralong X-ray Plato



Among the several hundreds of gamma-ray bursts - GRB070110 and GRB050904 don’t fit into the usual picture of the X-Ray afterglow formation. Both bursts have a long plateau lasting up to 6000-7000 seconds in the rest frame. Troja et al. (2007) suggested that such a long display of activity is associated with features of the central engine and specifically with the formation of a neutron star after the collapse of the core of low-mass (less Oppenheimer-Volkoff limit).

Spinar Collapse Video



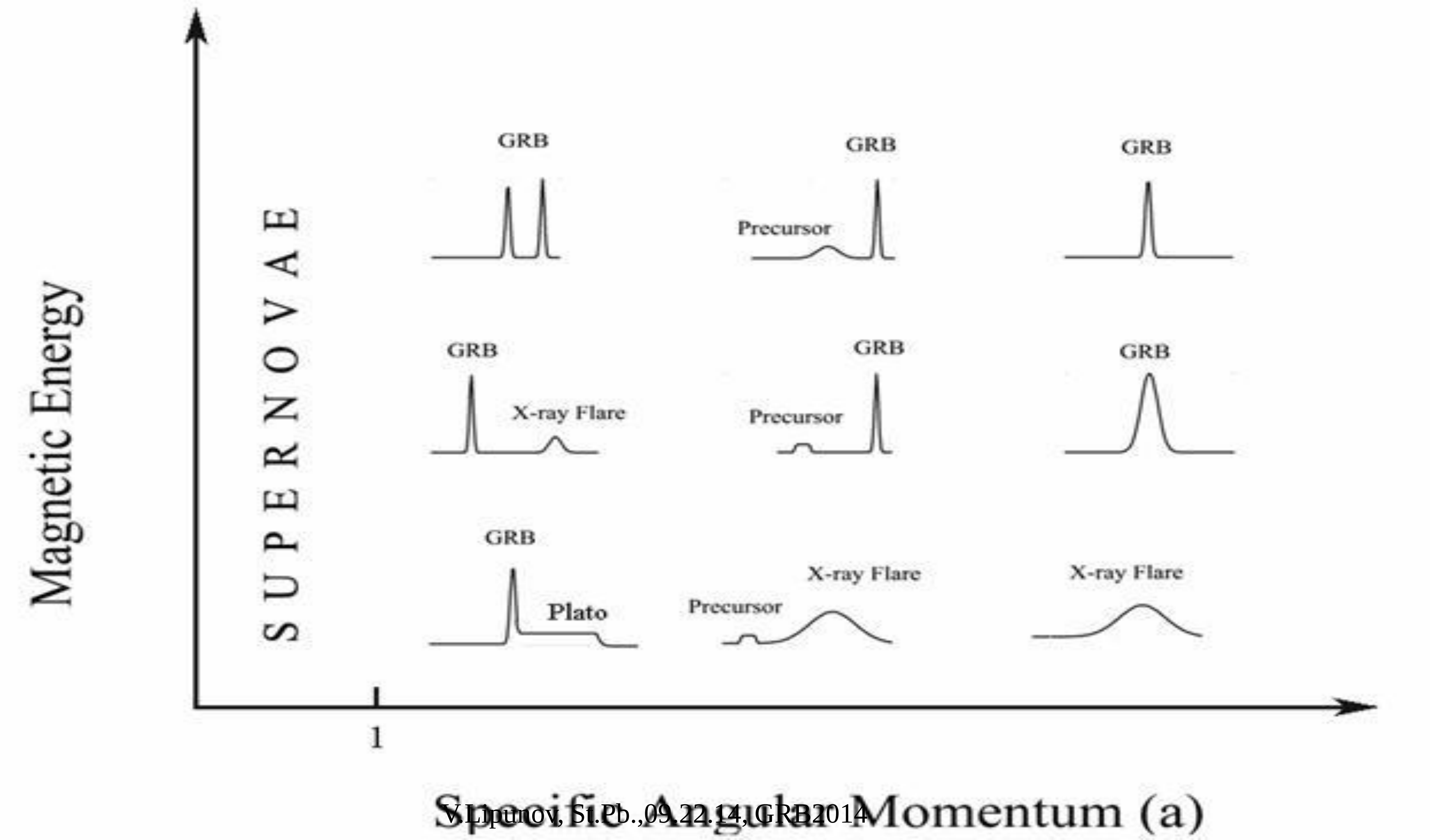
Nonstationary Relativistic Psevdoneutonian Spinar Model (Lipunov & Gorbovskoy, 2007, MNRAS)

-Drag frame effect
-Gravitational redshift
-Nuclear matter pressure
-Relativistic magnetic field disappearance (BHs have no hair)
-Magnetic spindown

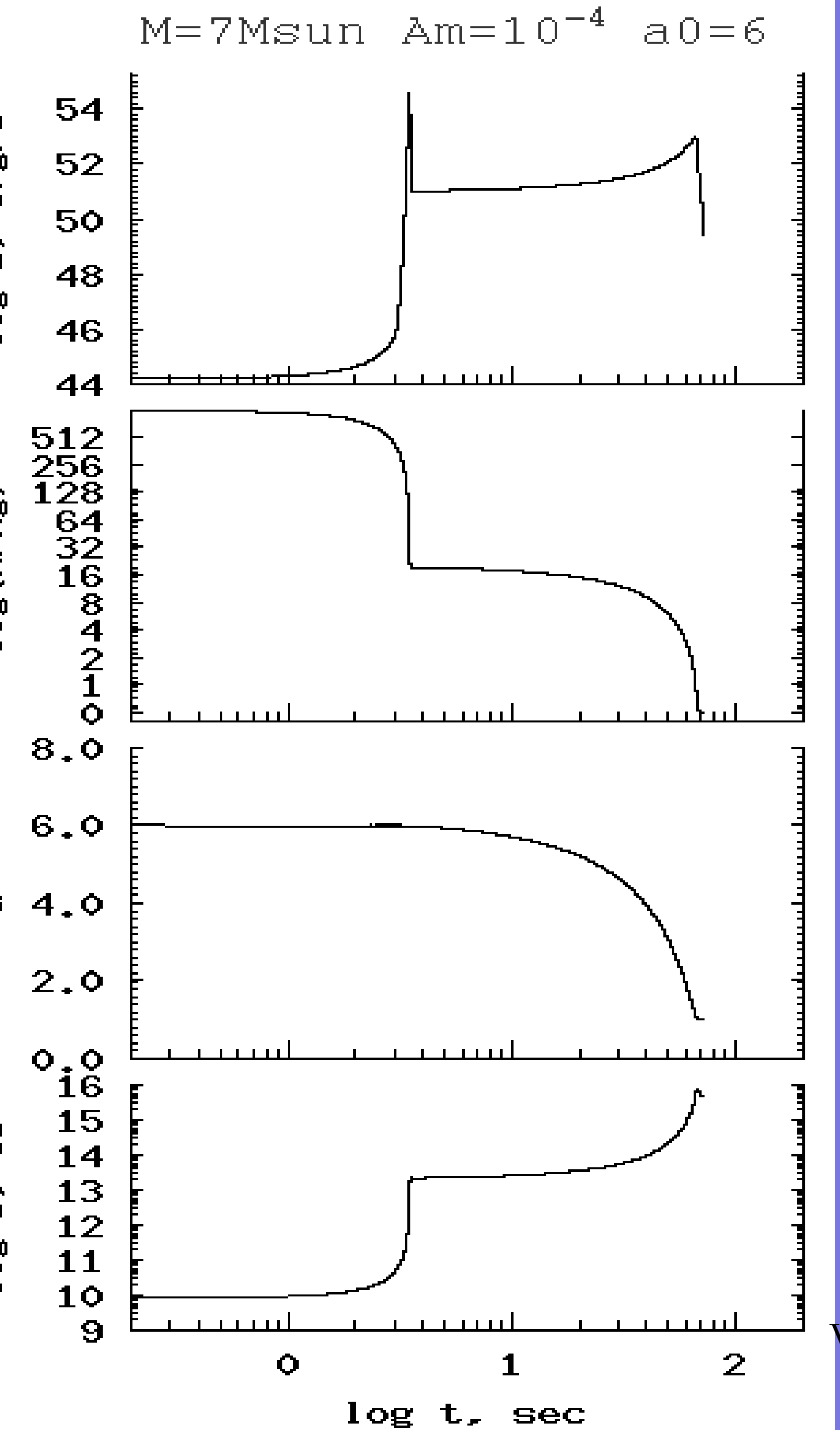
-All Included

SN & GRB in Spinar Paradigma

(*Lipunov & Gorbovskoy, ApJlett, 665, p.97L, 2007*)



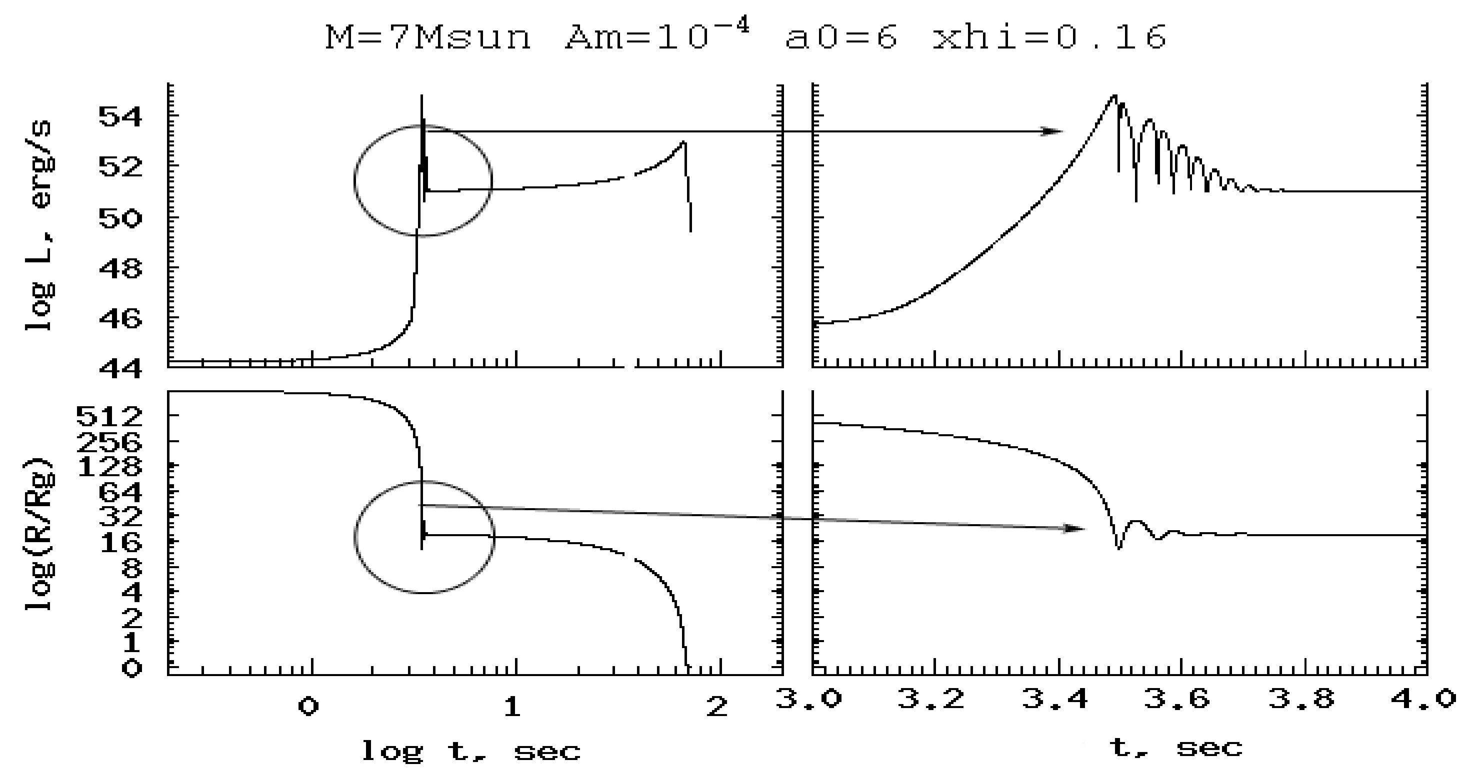
Massive Core Collapse (M > MOV).



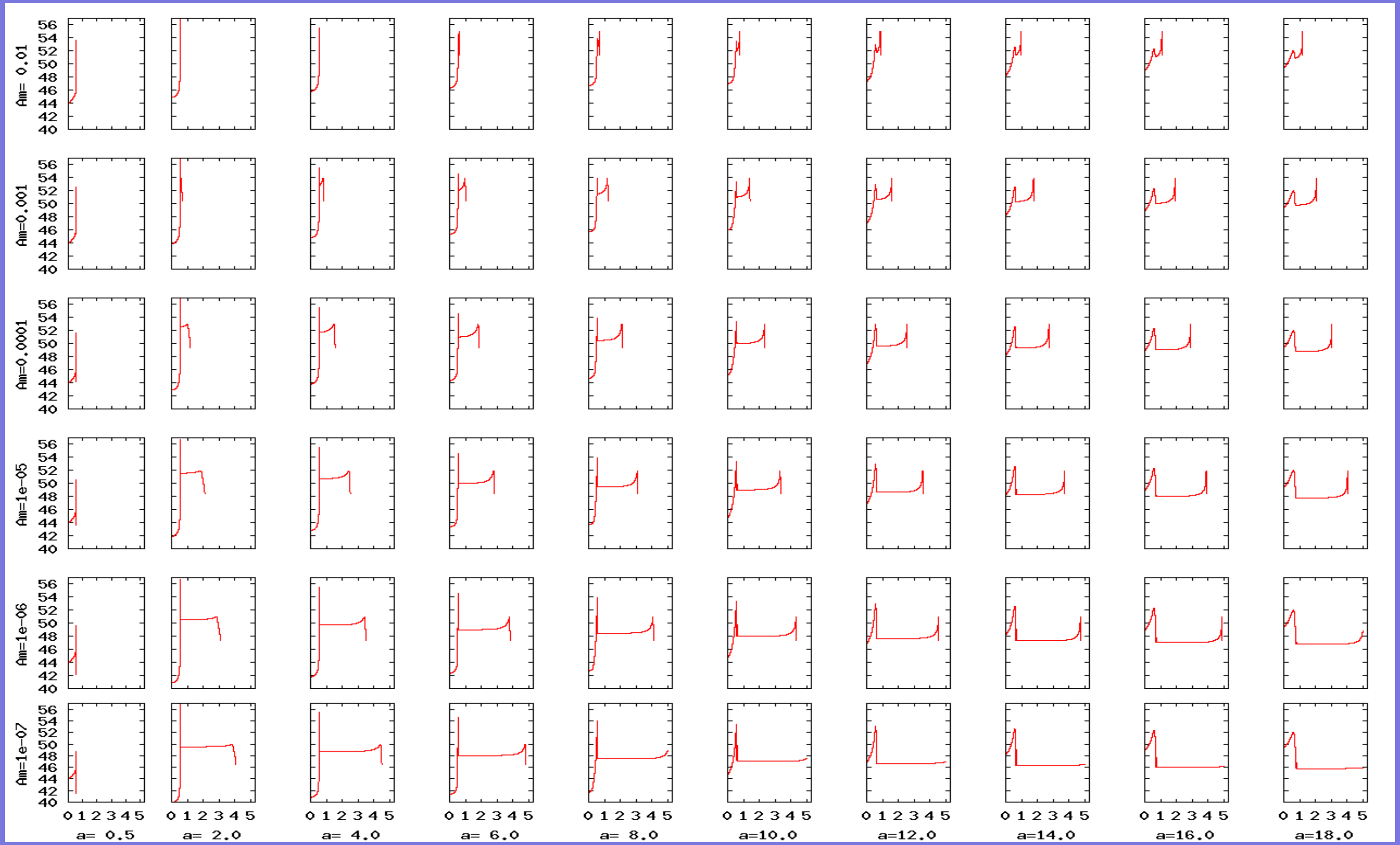
7 Solar Mass Core Collapse

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

Microstructure

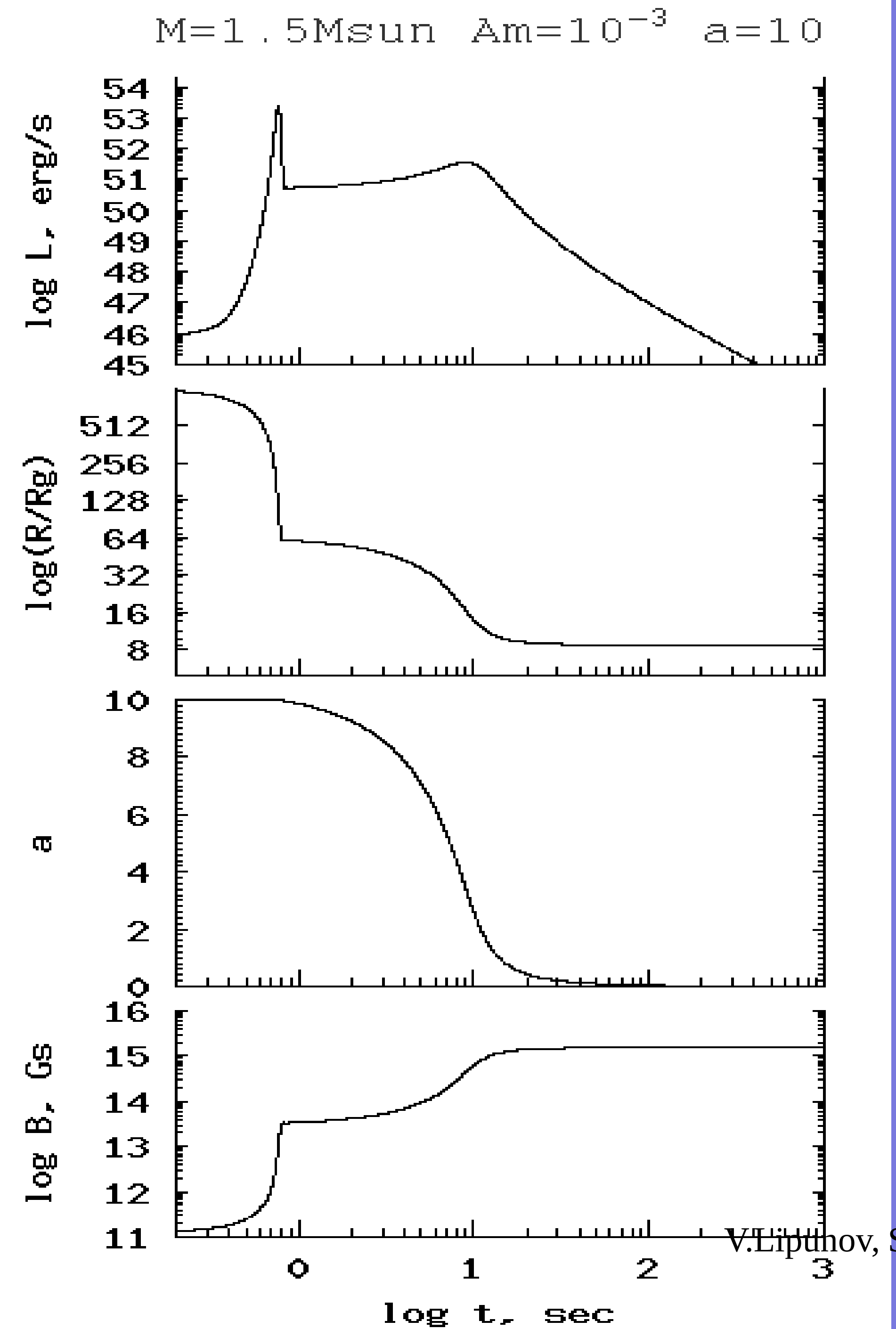


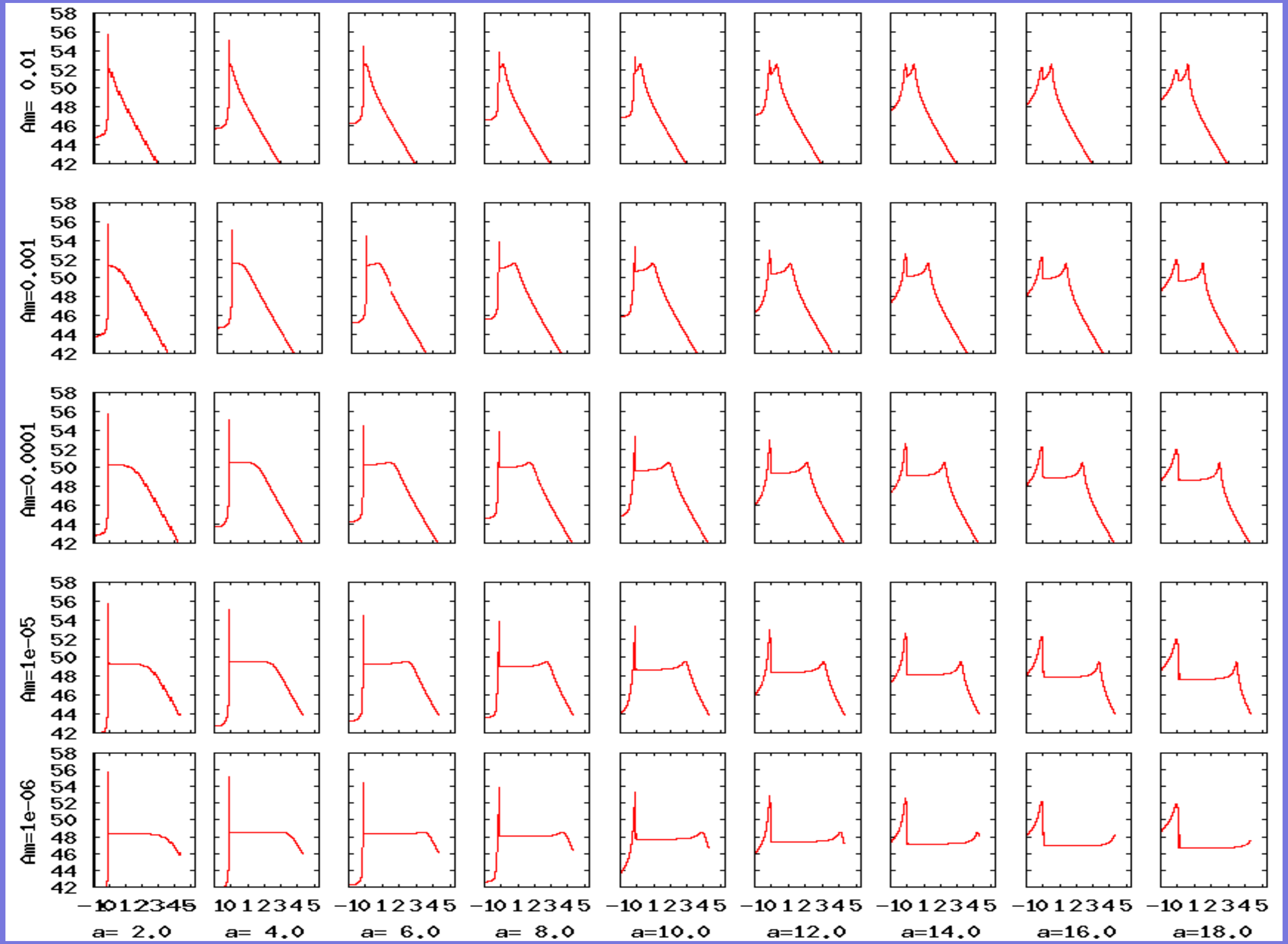
7 Solar Mass Core Collapse Luminosity for different Kerr parametyers



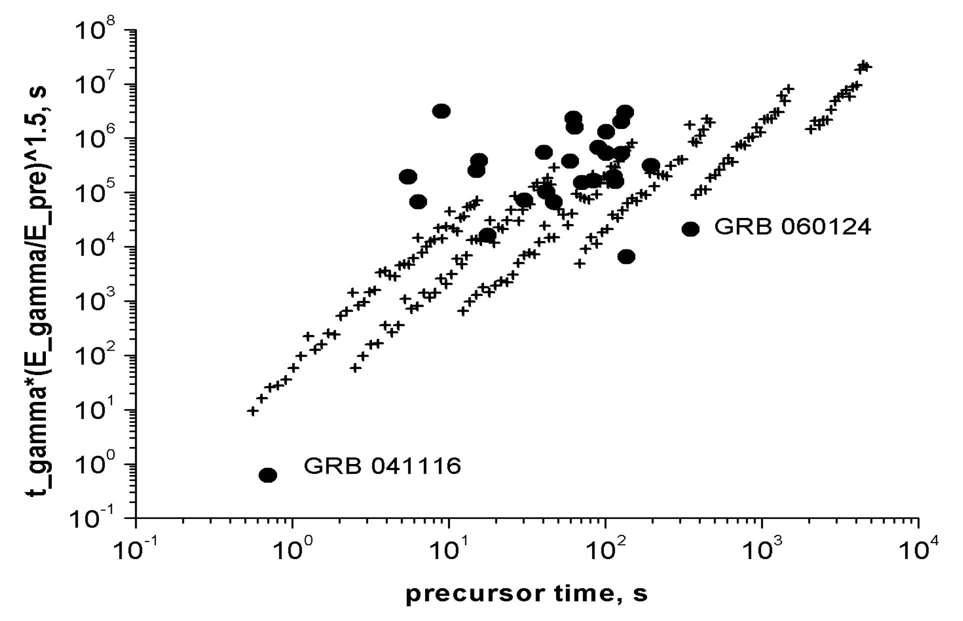
V.Lipunov, St.Pb.,09.22.14, GRB2014

Low mass collapse $M<M_{OV}$





Low Mass Core Collapse . *(Neitron Stars Formated)*



Зависимость комбинации времени гамма-всплеска помноженной на отнощщение энергии гамма-всплеска к энергии прекурсора от времени прекрсора. Заполненными кружками показаны наблюдения по данным BATSE (Lazzati, 2002) и двух аутсендинг вспелсков: короткого (GRB041116) и длинного (GRB 060124). Использованы данные по флюинсам, а отношение углов раскрытия прекурсора и гамма-всплеска приняты одинаковми. Крестиками показаны симулированные гамма-всплески с прекурсорами для ядра с массой 7 масс солнца. При этом эффективный параметр Керра менялся от 7 и до 20 , а магнитное поле в пределах: *10-2---10-6*.

Event Rates

Rate (SN) / Rate (GRB) ~ 100

Including jet angle ~1 degree

Scenario Machine – Population Synthesis Binary Stars

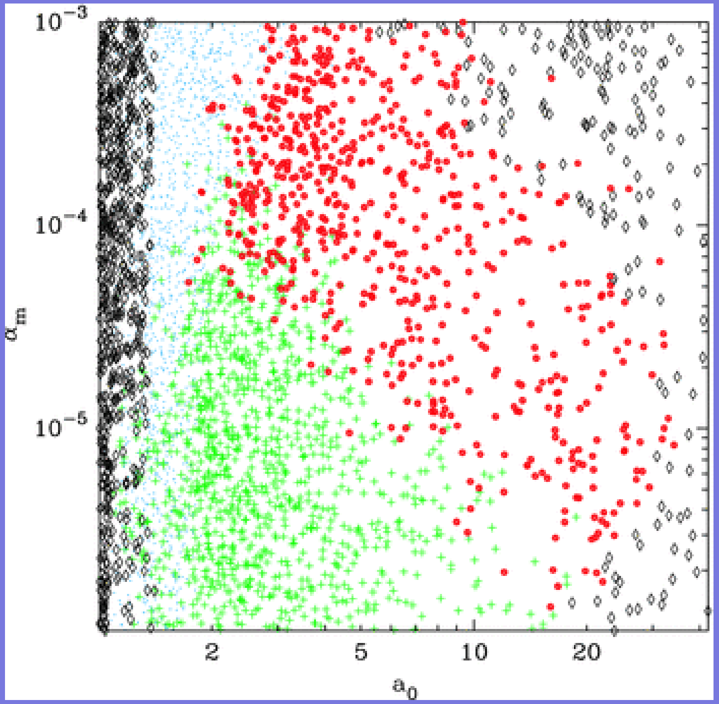
Bogomazov, Lipunov & Tutukov, 2007, Astronomy Reports, Volume 51, pp.308-317

The origin of the large angular momentum collapsing core is tidal synchronizations in binary high massive stars with period less 0.5 days. We are talking about pair annihilation CO core collapse.

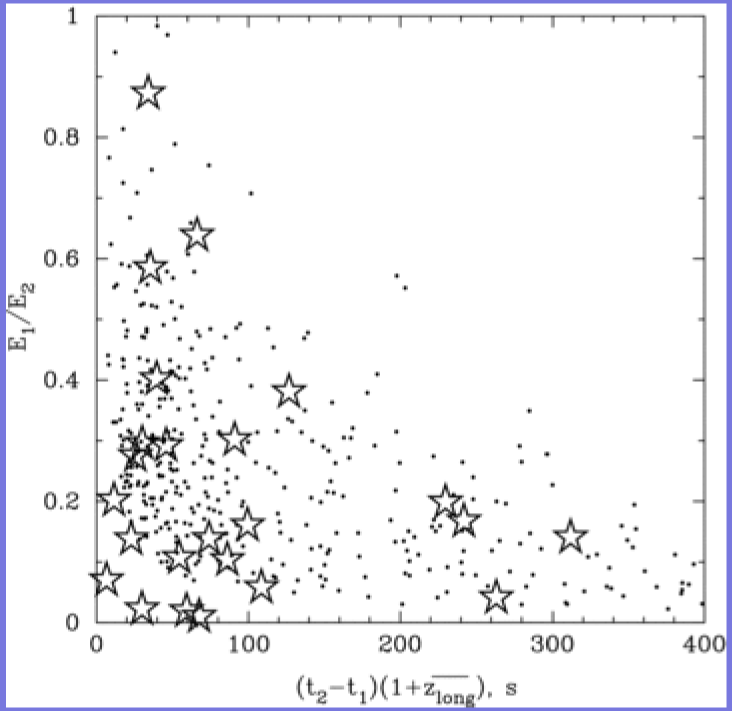
The formation rate of this binaries 1/100 per all SN type Ib or II.

Scenario Machine – Population Synthesis Binary Stars

Bogomazov, Lipunov & Tutukov, 2007Astronomy Reports, Volume 51, pp.308-317
Lipunova et al., 2009Monthly Notices of the Royal Astronomical Society, Volume 397, Issue 3, pp. 1695-1704



Magnetic parameter versus initial effective Kerr parameter for different classes of GRBs: with precursor (big red dots), with the stronger first peak (green pluses), with single peak (black diamonds) and merged peaks (small blue dots).



Ratio of the energy released during the precursor and the main peak versus separation time multiplied by the constant factor. Dots represent model results for GRBs with precursor for population ‘1’. The average value of the redshift for long GRBs . Stars are adopted from fig. 13 of Koshut et al. (1995)

Common (more or less) opinion

Short GRB

NS+NS, NS+BH merging

Long GRB

Massive star collapse

Is the any new physics near GRB?

Kardashev limit (maximal energy accelerated particles):

$(B^2 / 8 \pi)R^3 = Mc^2$, $R = R_g = 2GM/c^2$

Max. Energy = e E R ~ e B R ~1/137 E_{pl}

10^{26}ev

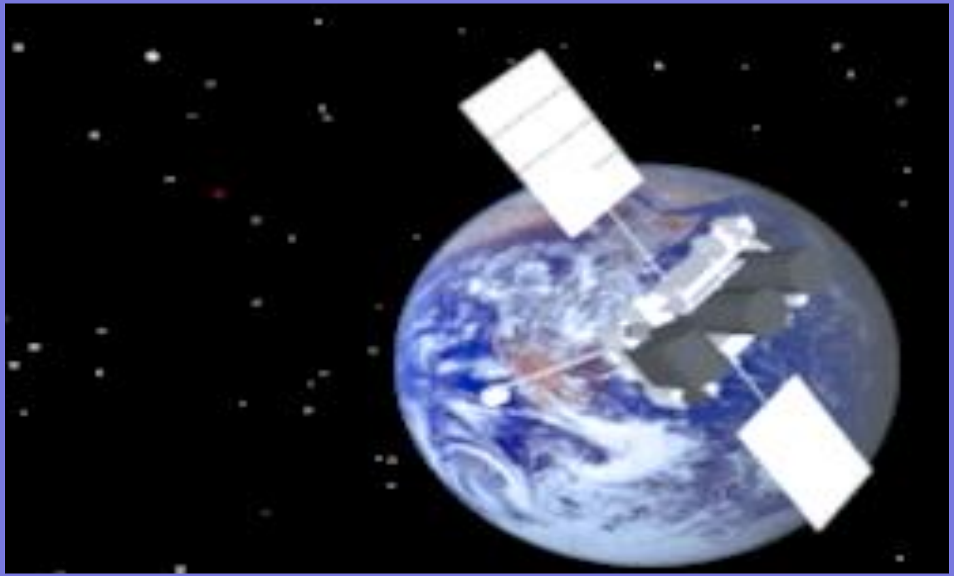
Prediction of the Spinar Paradigma

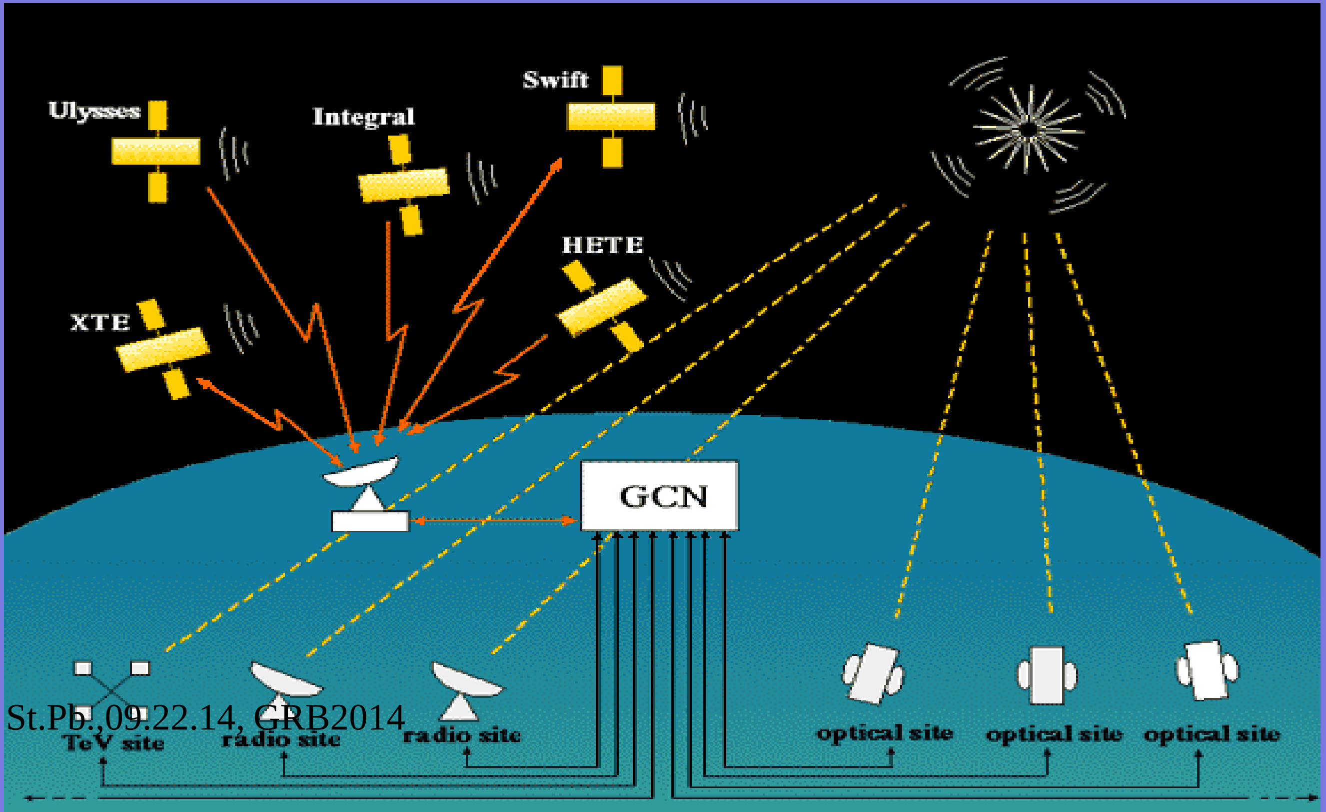
1. The existence precursors with more 1000 sec before GRB
2. The existence extra long GRB or XRAY flare.
3. We need high wave length electromagnetic prompt observations from Radio, IR, Optical to X-Ray, Gamma, UHE diapason for Understanding of the Central Engine.

5 unsolved GRB optical observational problems

1. **Discovery most distant gravitationaly bounded objects Z >10-12.**
2. **Discovery of the Prompt Optical Emission from Short GRB.**
3. **Optical Precursors Detection**
4. **Prompt optical polarizations doscovery.**
5. **High time resolution optical observations.**

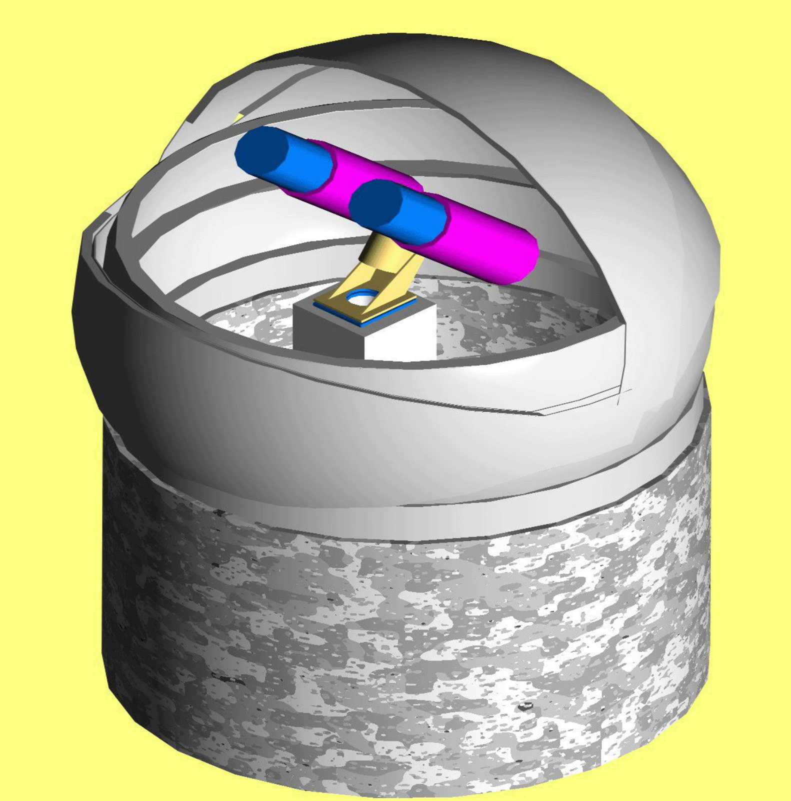
GCN global physical expirement





Second Generation Robotic Telescope MASTER II

Colors, Polarization



- Very Wide Field Cameras

MACTEP VWF

•FOV=400 square degrees up to 12 mag per 1 s.

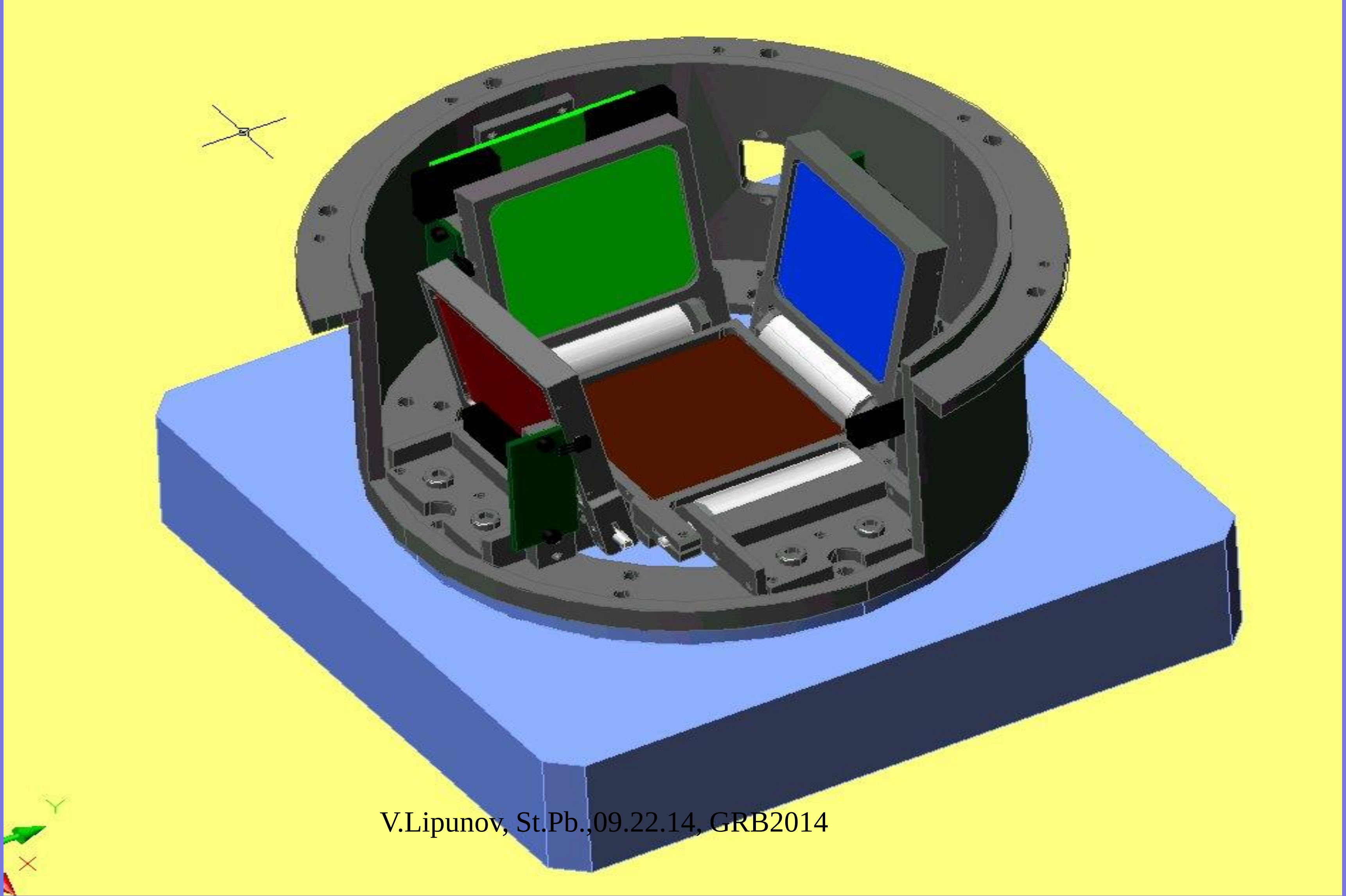
•Time Resolution 150 ms

MASTER II (D=400mm)

- FOV= 2x4 = 8 square degrees up to 20-21 up.

V.Lipunov, St.Pb.,09.22.14, GRB2014

MASTER Photometer

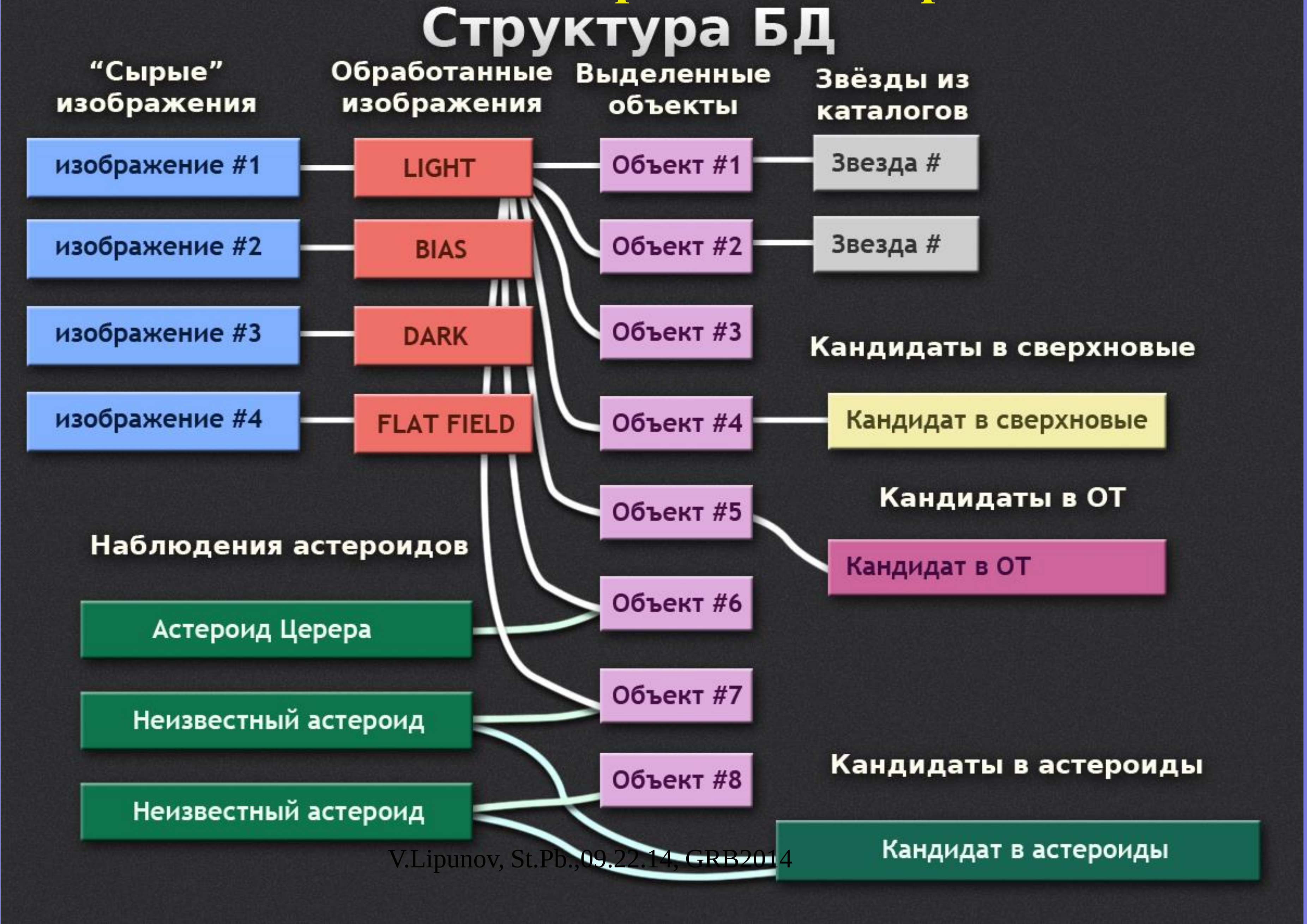


V.Lipunov, St.Pb.,09.22.14, GRB2014

MASTER-Net (2008-2011)

МАСТЕР ГАИШ МГУ , Кисловодск

Автоматическая обработка изображений



Структура БД

“Сырые” изображения

- изображение #1
- изображение #2
- изображение #3
- изображение #4

Обработанные изображения

- LIGHT
- BIAS
- DARK
- FLAT FIELD

Выделенные объекты

- Объект #1
- Объект #2
- Объект #3
- Объект #4
- Объект #5
- Объект #6
- Объект #7
- Объект #8

Звёзды из каталогов

- Звезда #
- Звезда #

Кандидаты в сверхновые

- Кандидат в сверхновые

Кандидаты в ОТ

- Кандидат в ОТ

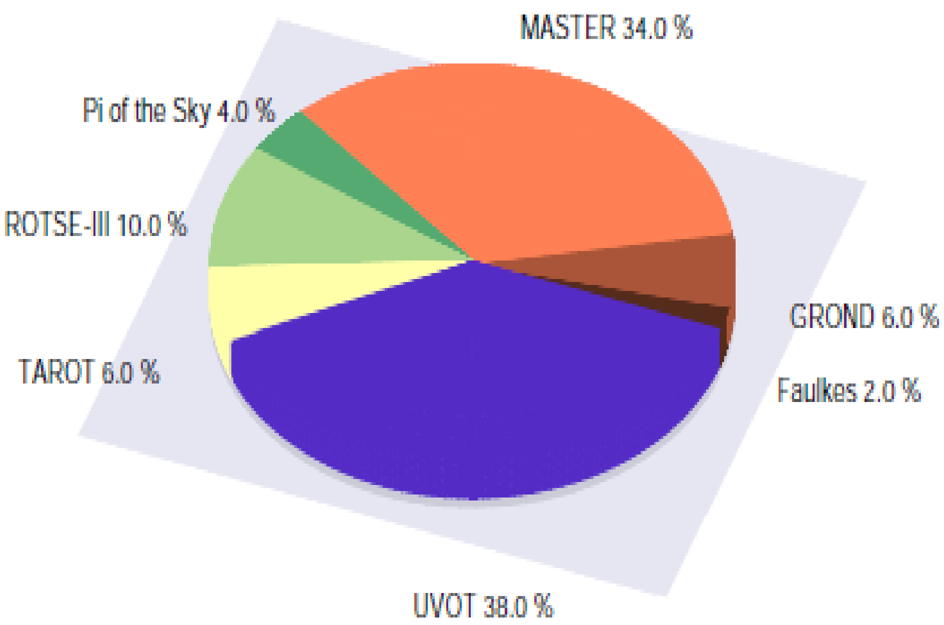
Наблюдения астероидов

- Астероид Церера
- Неизвестный астероид
- Неизвестный астероид

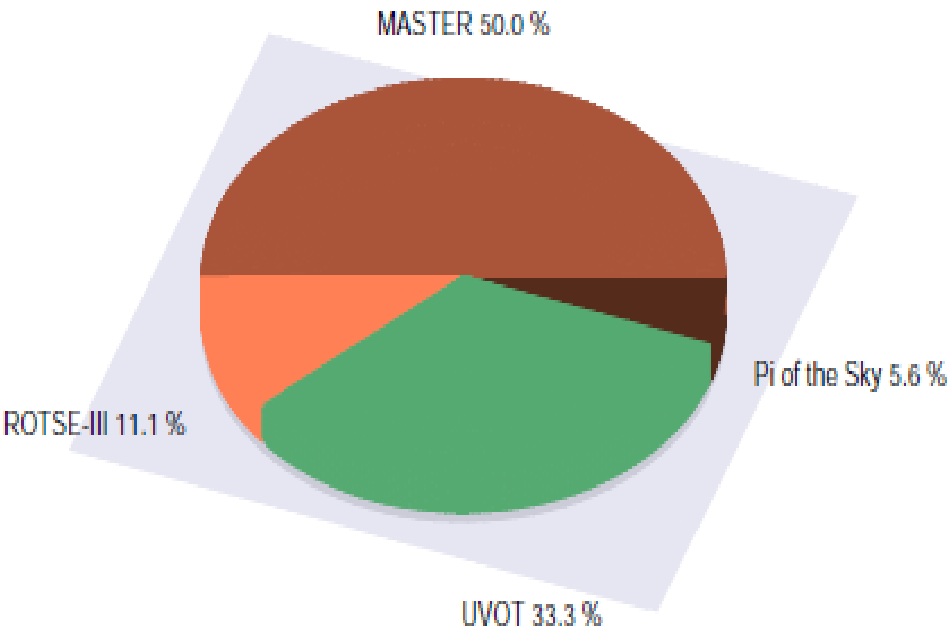
Кандидаты в астероиды

- Кандидат в астероиды

Статистика наблюдений гамма-всплесков сетью МАСТЕР
66 наблюдений гамма всплесков



Доля первых наведений



Доля prompt наведений

Рис. 5: Относительная доля первых и prompt наведений на гамма-всплески после введения в строй всех телескопов сети МАСТЕР с 01 сентября 2010 г по настоящее время (июнь 2011)

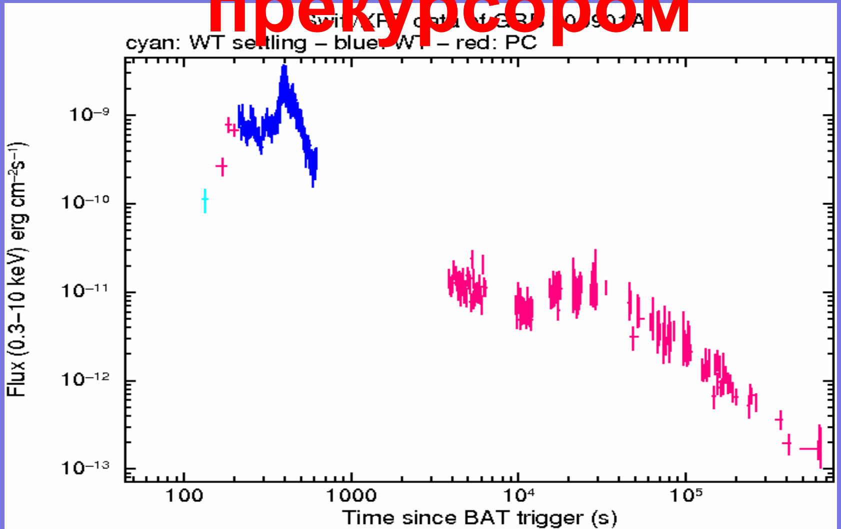
Наблюдение 2-х подряд гамма-всплесков сетью телескопов МАСТЕР: Gorbovskoy, E. S. et al.,MN RAS, V. p. 2580, 2012

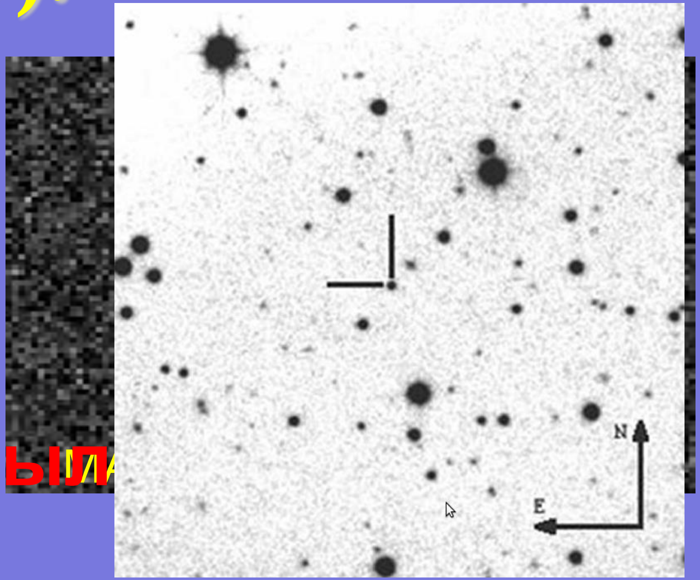
GRB100901A

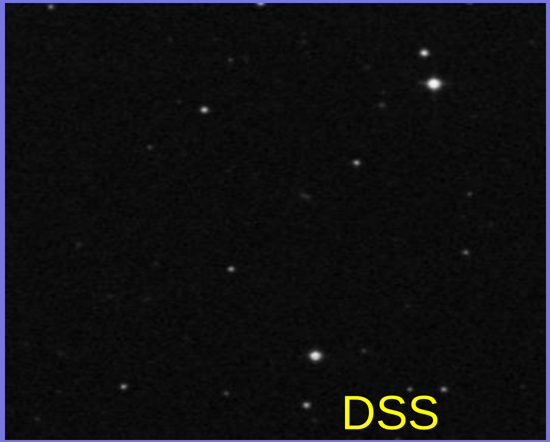
Итого: Более 11 часов непрерывных наблюдений собственного излучения и послесвечения гамма-всплеска, начиная с 101 сек на 4-х единообразных обсерваториях

GRB100901A (gcn11159):

Первая вспышка был
скорее всего
прекурсором







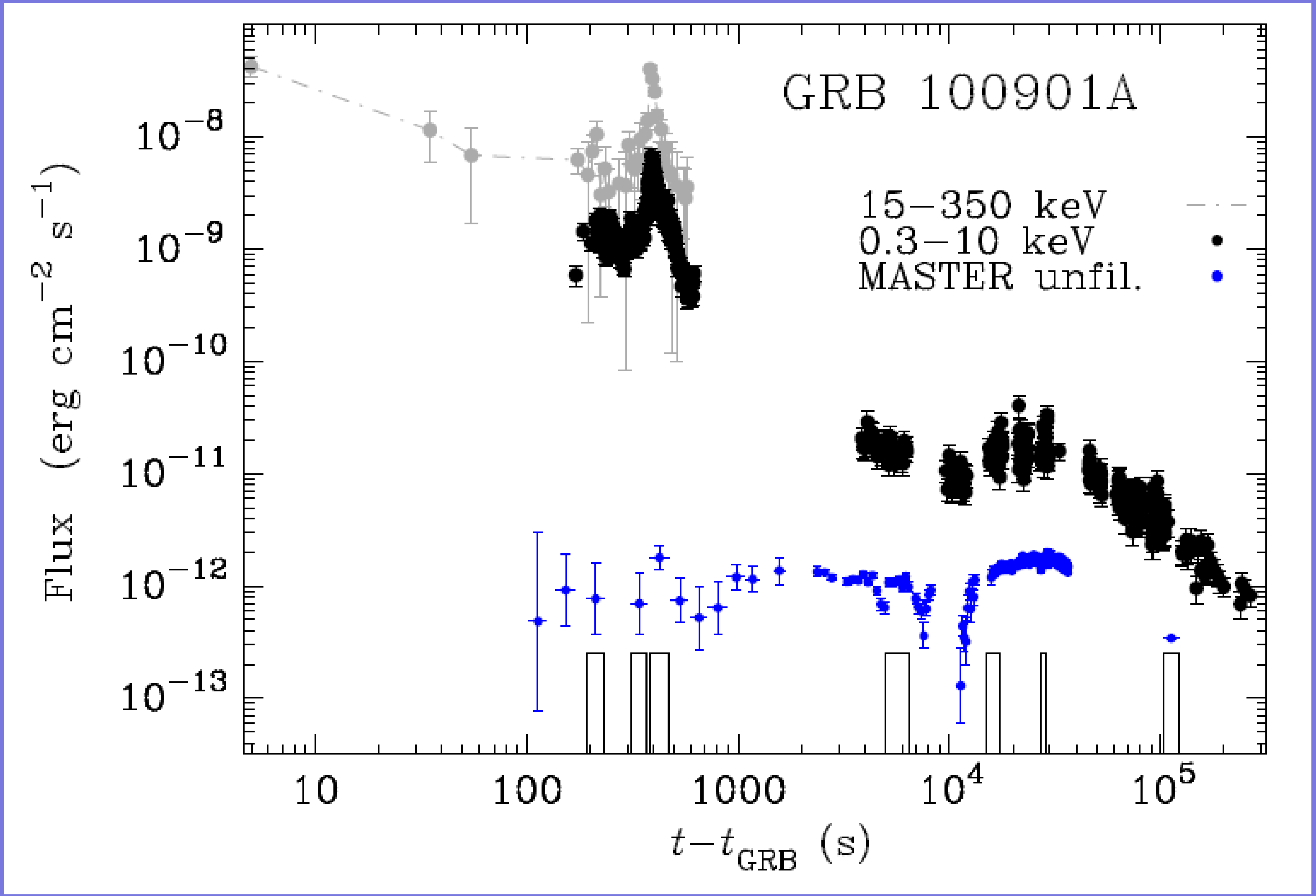
ы RA(J2000) = 01h 49m 00.5s
Dec(J2000) = +22d 45' 02.9"

Высота в Тунке на момент начала наблюдений ~12 градусов.

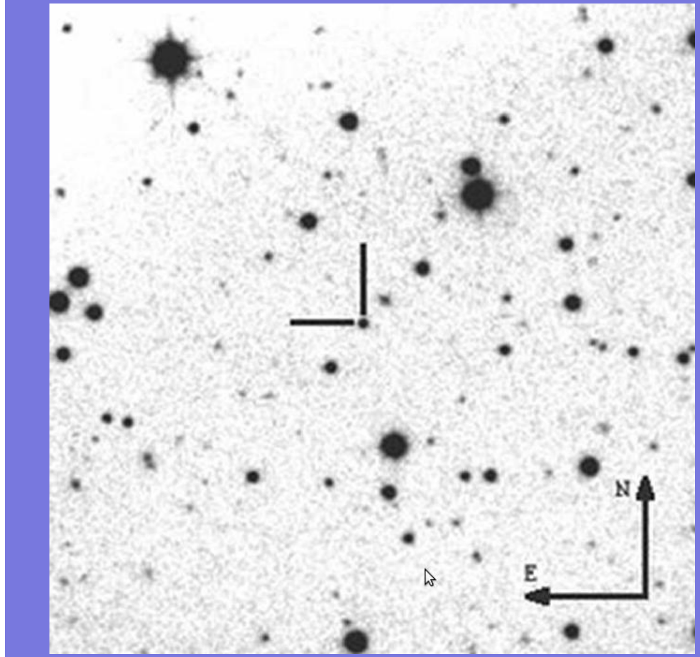
T90 (15-350 keV) is 439 +- 33 sec

Наблюдения в Тунке стартоали через 103 сек.

GRB100901A: Gorbovskoy, E. S. et al.,MN RAS, V. p. 2580, 2012



gcn11178



arXiv e-print (arXiv:1111.3625)

GRB100901A: Спектральная эволюция

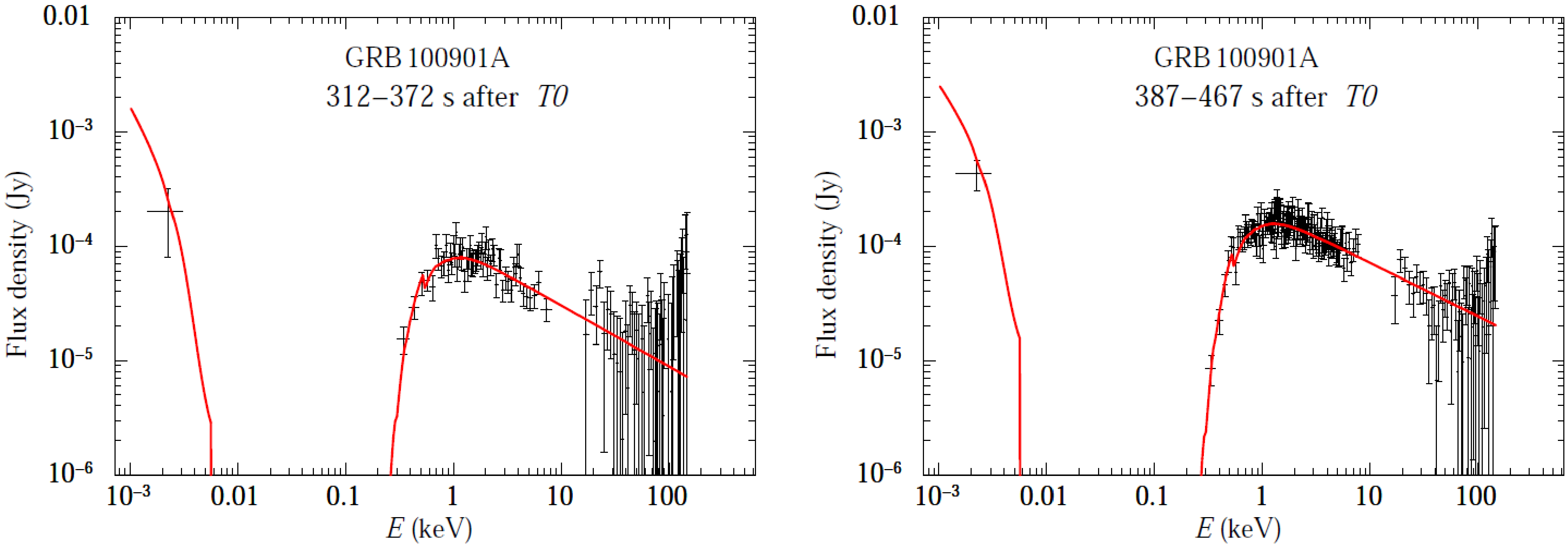


Figure 7. Spectrum of GRB 100901A for two time intervals at $t \lesssim T_{90}$. Optical flux density obtained by MASTER, corrected for the Galactic extinction $A_V = 0.327$ (NED; Schlegel, Finkbeiner & Davis 1998), is shown by the single left point, whose horizontal bar corresponds to the MASTER unfiltered effective frequency interval. Spectra in 0.3–10 and 15–150 keV are made with the *Swift* BAT and XRT data. Best-fitting absorbed power laws are shown by the red lines. Their spectral parameters are described in Table 10 as Fit 100901.2 for 312 – 372 s and Fit 100901.3, for 387 – 467 s).

arXiv e-print (arXiv:1111.3625)

GRB100901A: Spinar Paradigma Parameters

Gorbovskoy, E. S. et al.,MN RAS, V. p. 2580, 2012

Z=1.408 [1], $D_L \approx 10^{10}$ pc

Fluence(tot,15-350 keV)=3.56 10^{-6} erg/cm^2
before 460 s [2]

→ Eiso (15-350 keV) =1.8 10^{52} erg

$\Delta\tau = 400$ s/(1+z)≈170 s

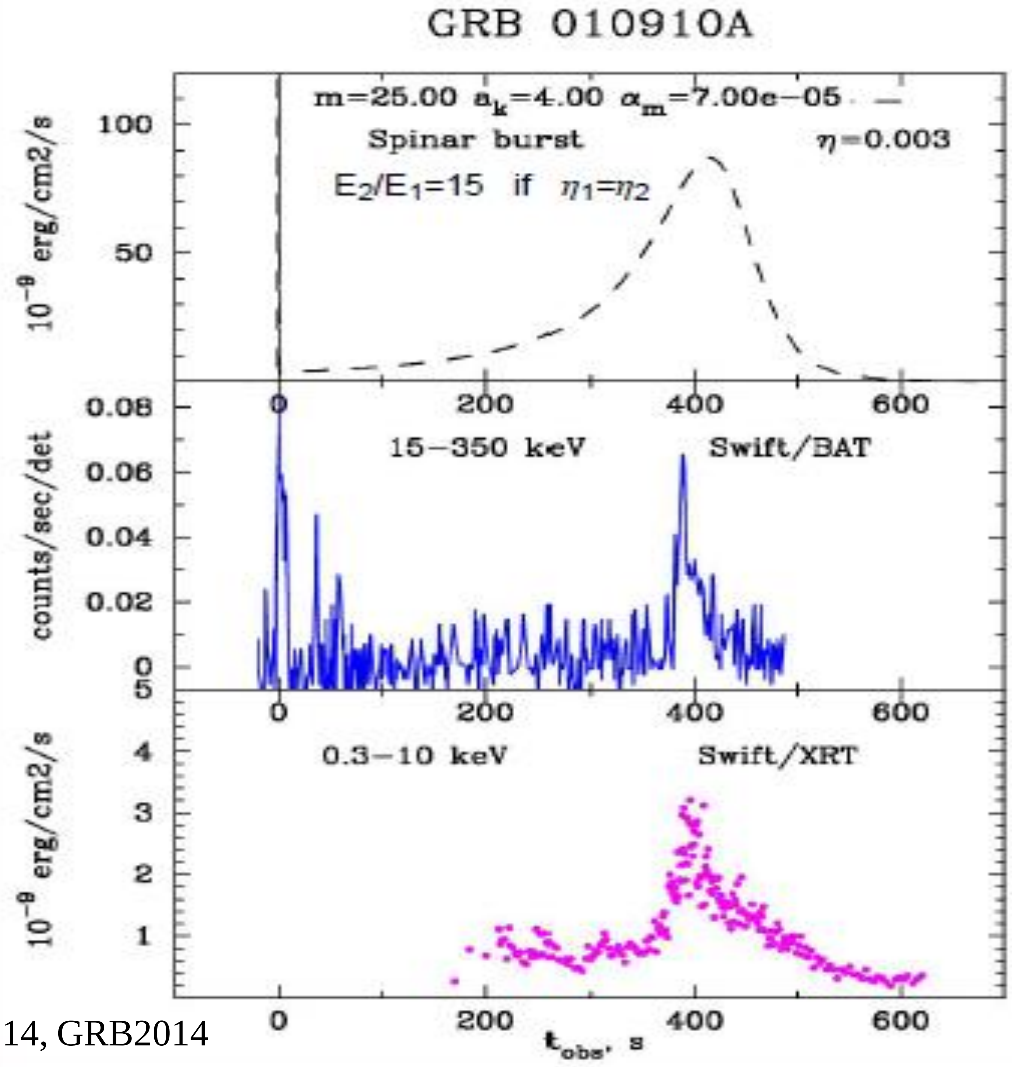
$\Delta t_1 \sim 7$s,
Fluence(1,15-350 keV) = 5.3 10^{-7} erg/cm^2

→ Fluence$_2$/Fluence$_1$ ~6

$\eta E_{burst} = E_{iso} = 4 \pi D_L^2$ Fluence / (1+z)

$E_{burst} = 6.2e+54$ erg

[1] Chornock et al., GCN Circ 11164
[2] Results of the *batgrbproduct* analysis,
http://gcn.gsfc.nasa.gov/notices_s/433065/BA/



Наблюдение 4-х гамма-всплесков сеть телескопов МАСТЕР

GRB100906A

(gcn11214)

23 s after notice time

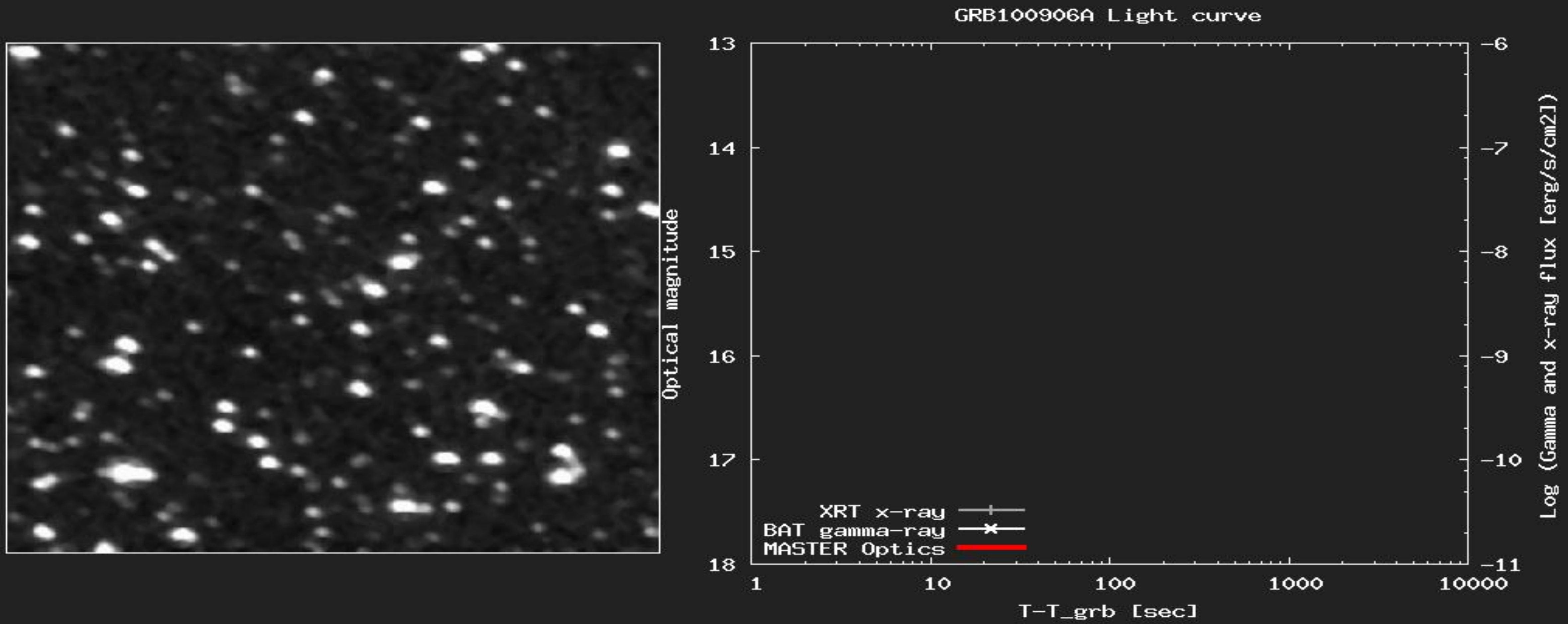
38 s after trigger time

gcn 11228

Итог:

Впервые в мире получены поляризационные изображения собственного излучения гамма-всплеска

Первые в мире синхронные поляризационные наблюдения гамма-всплеска (6 сентября 2010 года, роботизированная сеть МАСТЕР)



Слева – оптическая вспышка – расстояние около 10 млрд.св.лет.

Справа: белым – гамма-излучение, серым – рентгеновское излучение, красным – оптическое излучение

GRB100906A:

Поляризация менее 2%

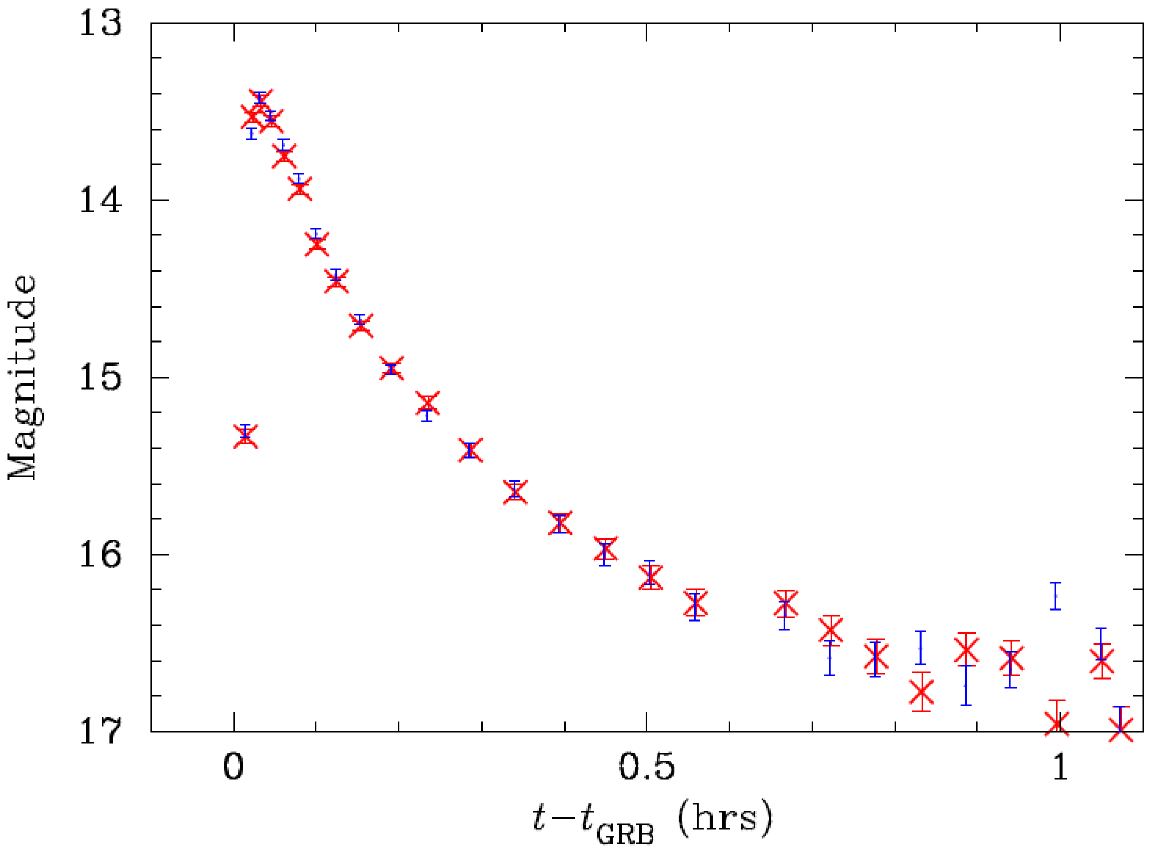


Figure 4. MASTER light curve of GRB 100901A in two polarizations, unfiltered band (blue dots and red crosses). Data are not corrected for the Galactic extinction.

GRB100906A: Спектральная эволюция

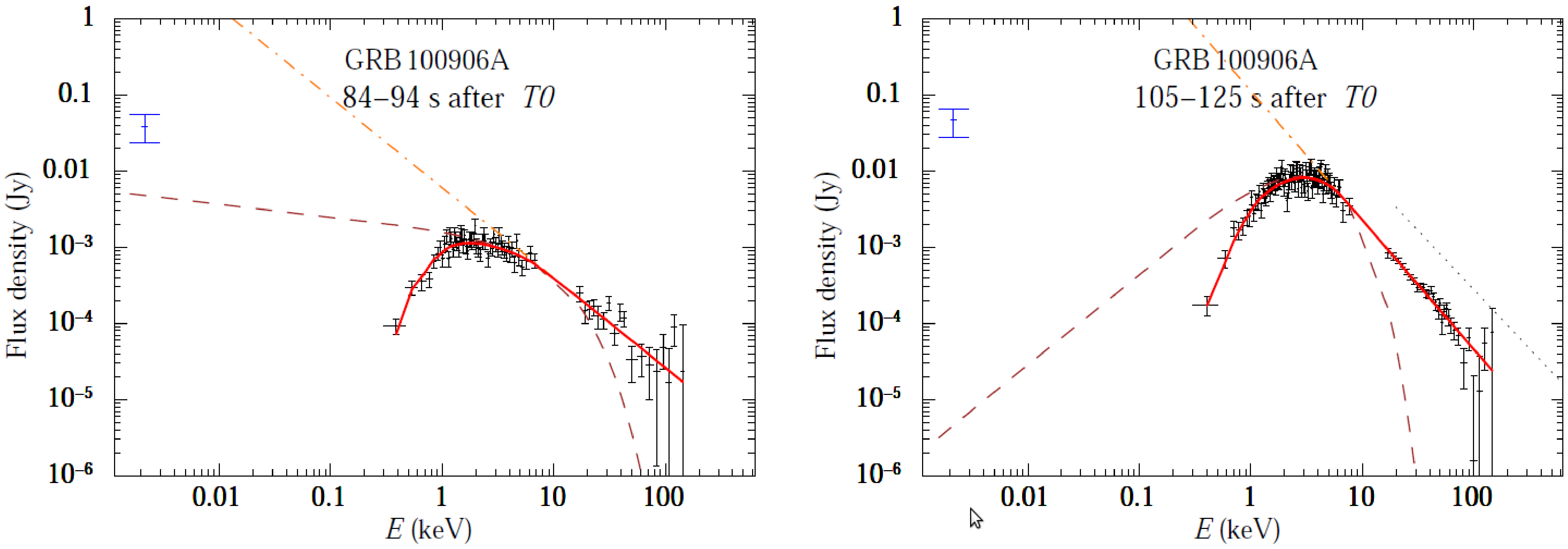


Figure 8. Spectrum of GRB 100906A for two time intervals at $t \lesssim T_{90}$. Optical points are corrected for the Galactic extinction $A_V = 1.194$ (NED; Schlegel, Finkbeiner & Davis 1998). In the left panel, we use the MASTER observation at 73.8–83.8 s. Best-fitting absorbed Band functions are shown by the red lines (Fit 100906.1 and 100906.2 in Table 10). No attempt has been made to estimate the optical extinction in the GRB host galaxy. The brown dashed line depicts the unabsorbed low-energy part, and the orange dot-dashed line, the unabsorbed high-energy part. Dotted power law represents observations of Konus–*Wind* from 98.304 to 122.880 s in 20 keV-2 MeV with a correct slope and a roughly estimated flux.

GRB100906A: Спектральная эволюция

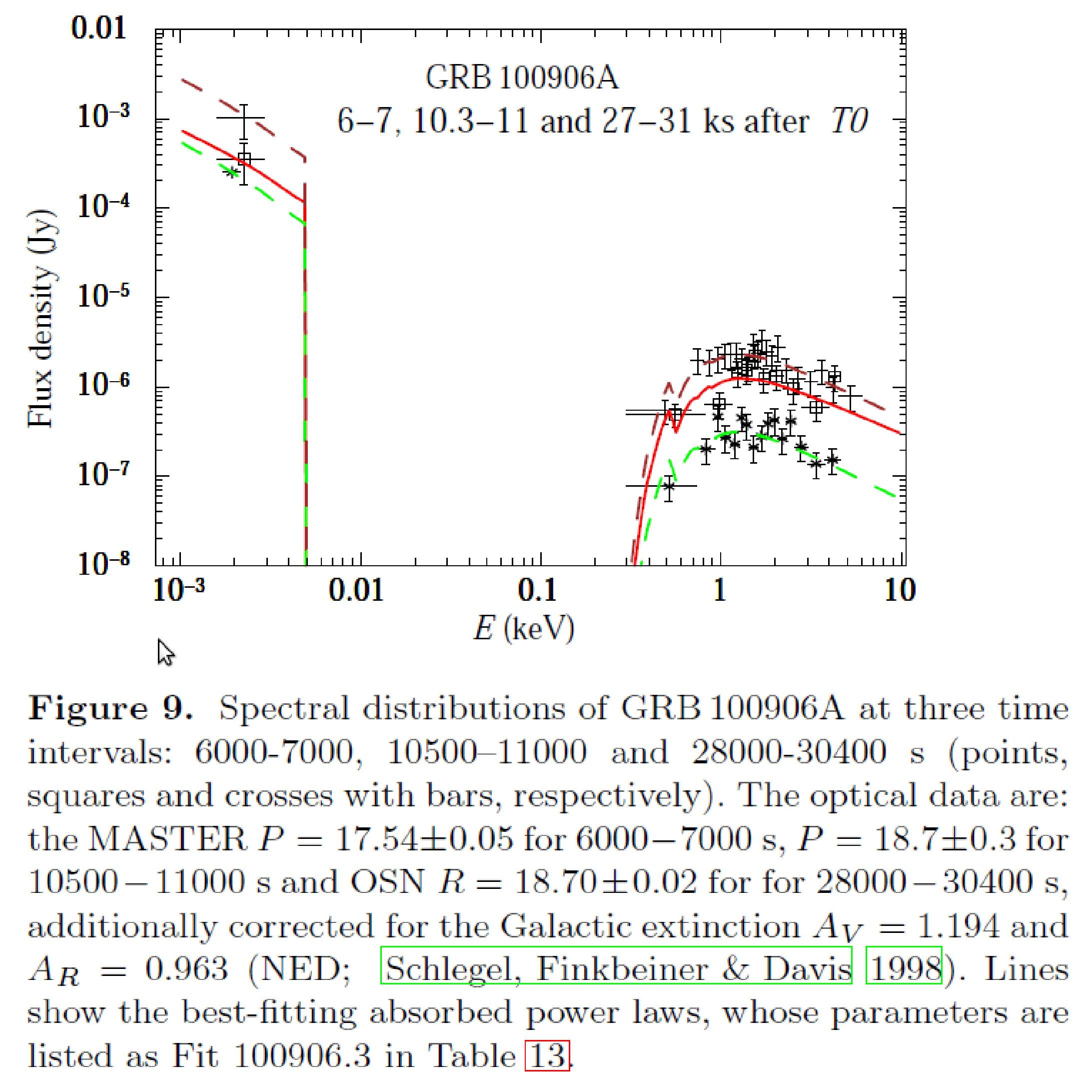


Figure 9. Spectral distributions of GRB 100906A at three time intervals: 6000-7000, 10500–11000 and 28000-30400 s (points, squares and crosses with bars, respectively). The optical data are: the MASTER $P = 17.54 \pm 0.05$ for 6000 – 7000 s, $P = 18.7 \pm 0.3$ for 10500 – 11000 s and OSN $R = 18.70 \pm 0.02$ for for 28000 – 30400 s, additionally corrected for the Galactic extinction $A_V = 1.194$ and $A_R = 0.963$ (NED; Schlegel, Finkbeiner & Davis 1998). Lines show the best-fitting absorbed power laws, whose parameters are listed as Fit 100906.3 in Table 13.

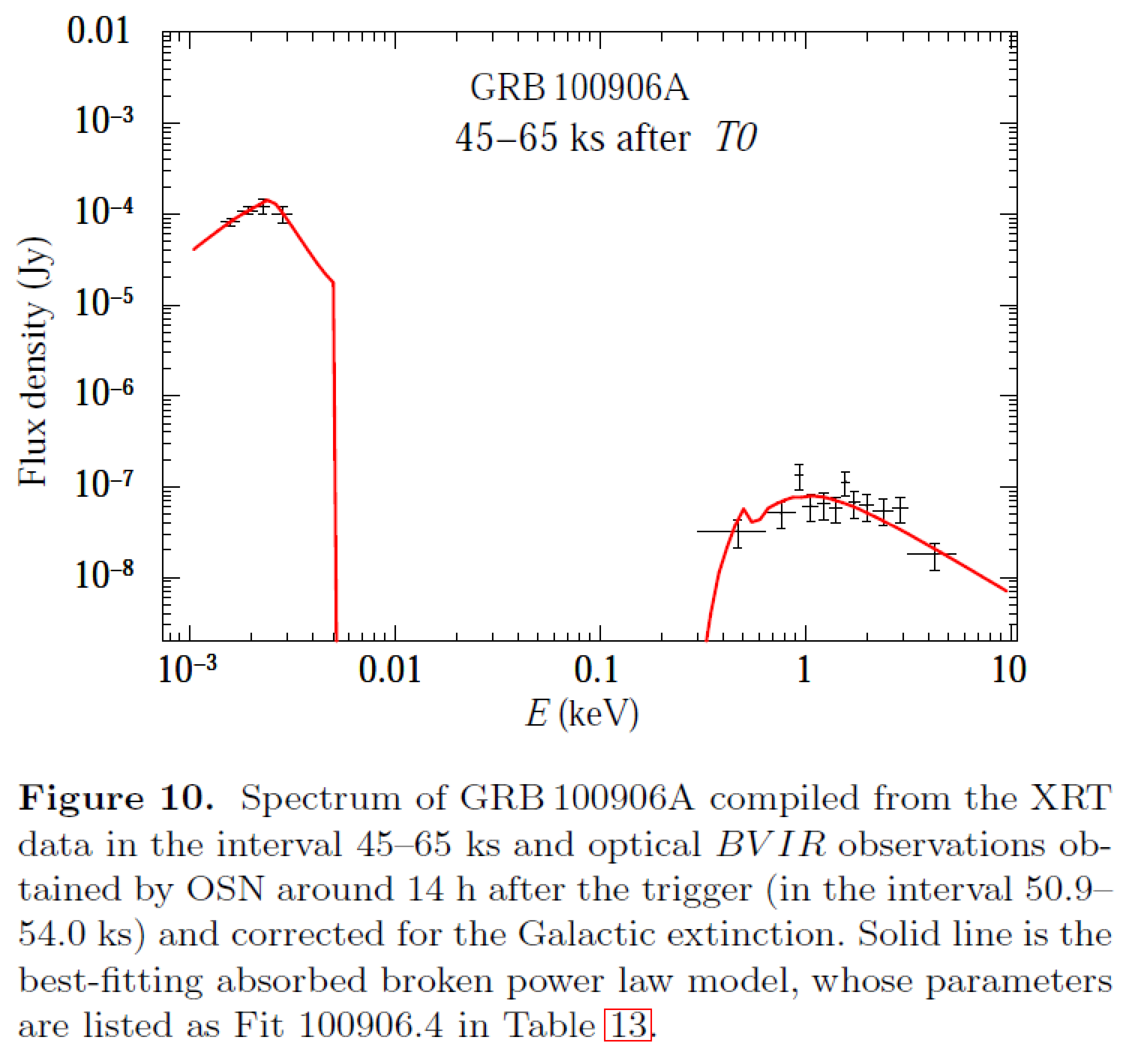


Figure 10. Spectrum of GRB 100906A compiled from the XRT data in the interval 45–65 ks and optical $BVIR$ observations obtained by OSN around 14 h after the trigger (in the interval 50.9–54.0 ks) and corrected for the Galactic extinction. Solid line is the best-fitting absorbed broken power law model, whose parameters are listed as Fit 100906.4 in Table 13.

GRB100906A: Спектральная эволюция

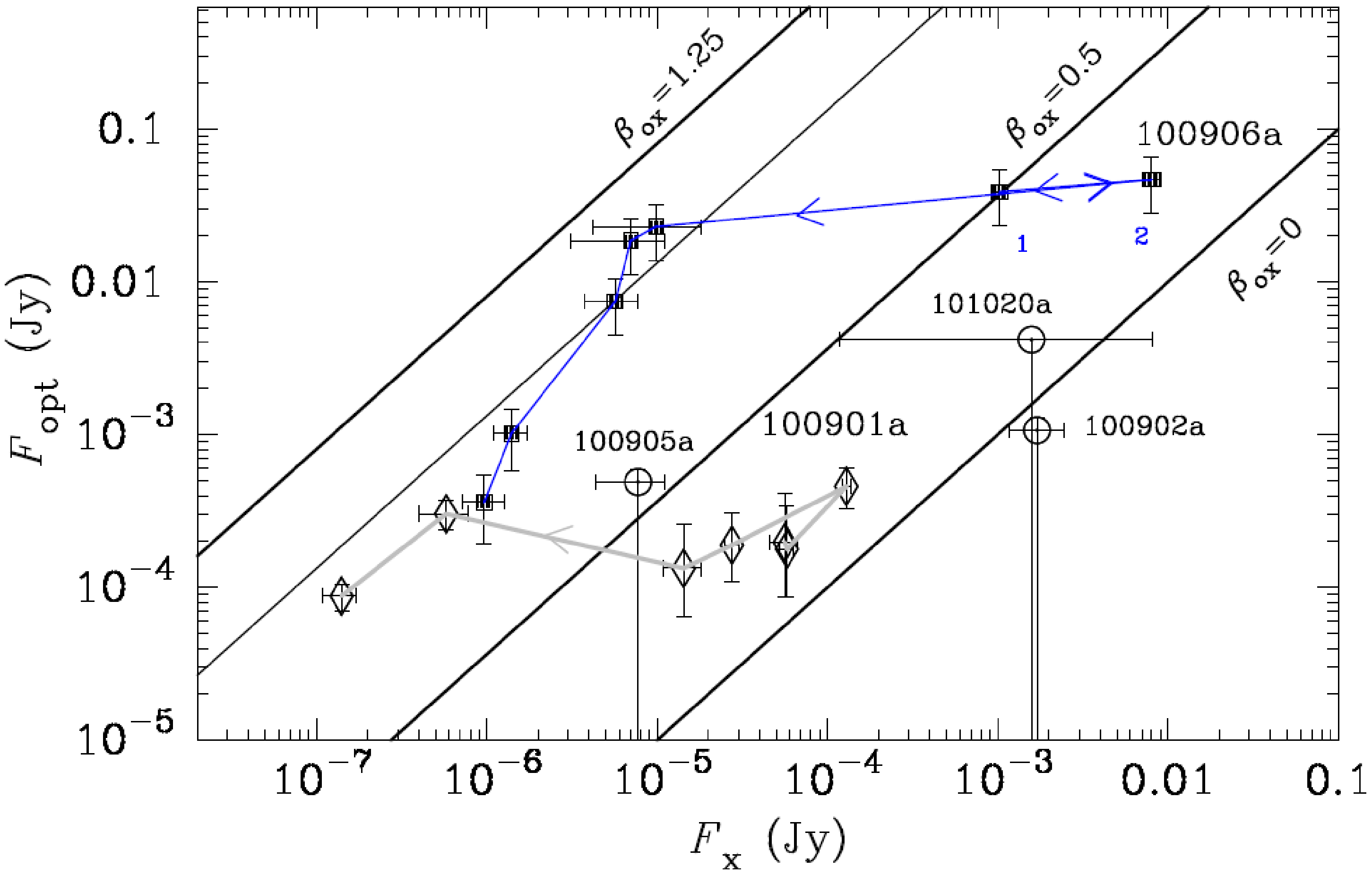
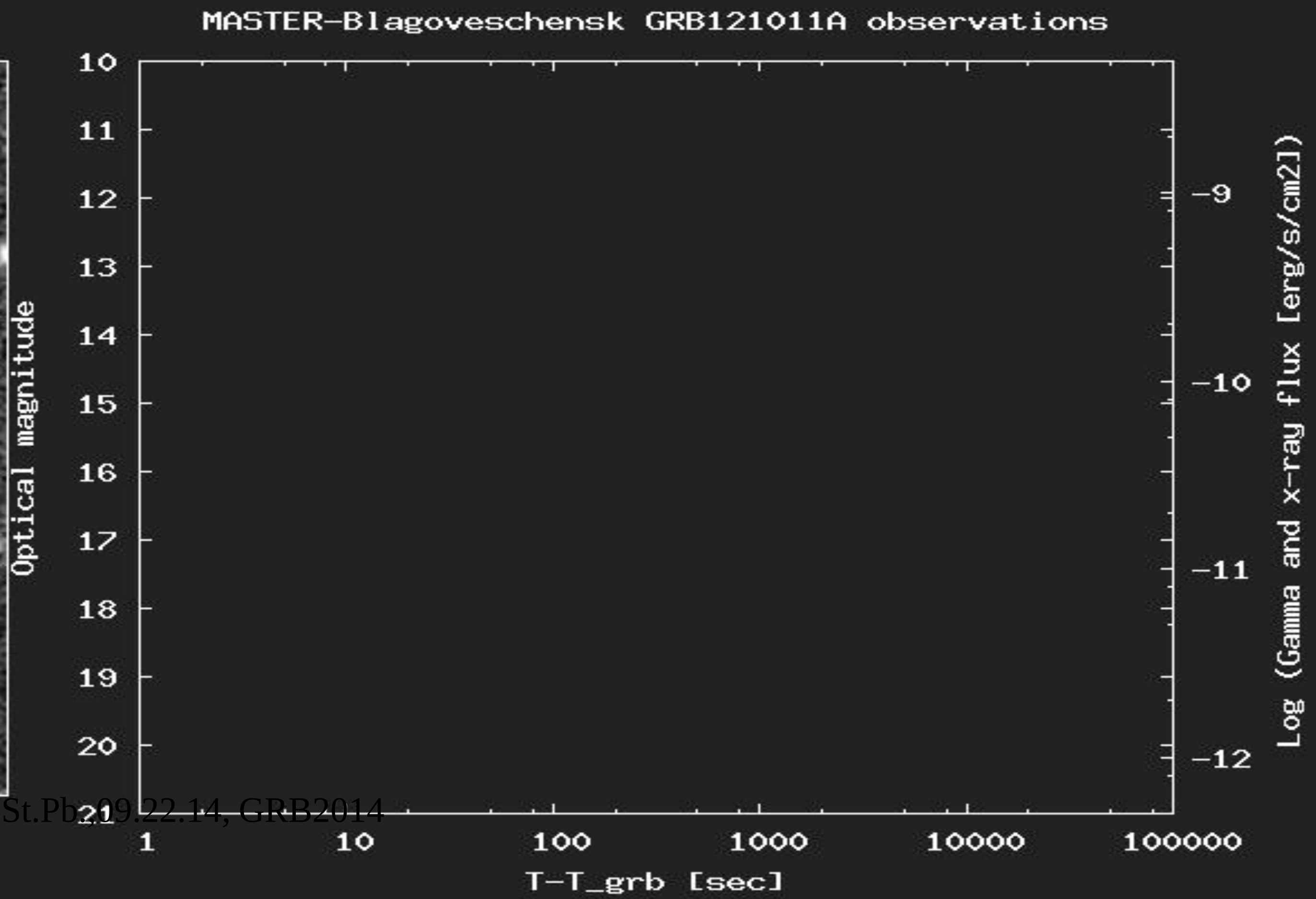


Figure 12. Diagram of the optical flux density versus X-ray flux density at 3 keV for five GRBs observed by MASTER in September and October 2010. Each point represents a simultaneous observation in the optical and by *Swift*/XRT. The optical flux densities have been corrected for the Galactic extinction. Diamonds connected with grey line show evolution of GRB 100901A (eight time intervals: 193–233, 312–372, 387–467, 481–581, 595–715, 3800–4150, 27000–28500, and 102800–121500 s); squares connected by blue lines, of GRB 100906A (seven time intervals: 84–94 (point 1), 105–125 (point 2), 330–390, 410–480, 942–1112, 6000–7000, and 10300–11000 s). For GRBs 100902A, 100905A, and 101020A, only upper limits on optical flux density are given at post-trigger times 132–162, 150–180, and 106–126 s, respectively. When tracks are parallel to β =const lines, the optical flux density is emphatically correlated with the 3 keV flux density. We adopt Galactic extinctions A_V = 1.037 for GRB 100902A, A_V = 0.191 for GRB 100905A, and A_V = 0.051 for GRB 101020A from the NED Extragalactic Calculator.

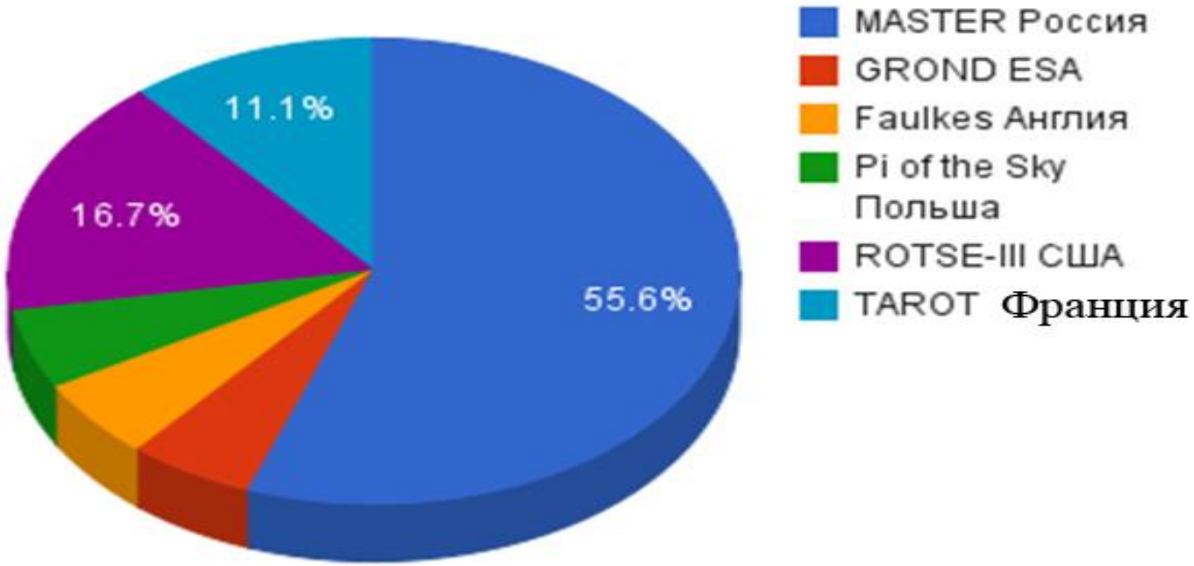
Уникальные поляризационные наблюдения гамма-всплеска GRB 121011A в Благовещенске

Горбовской (диссертация 2012)

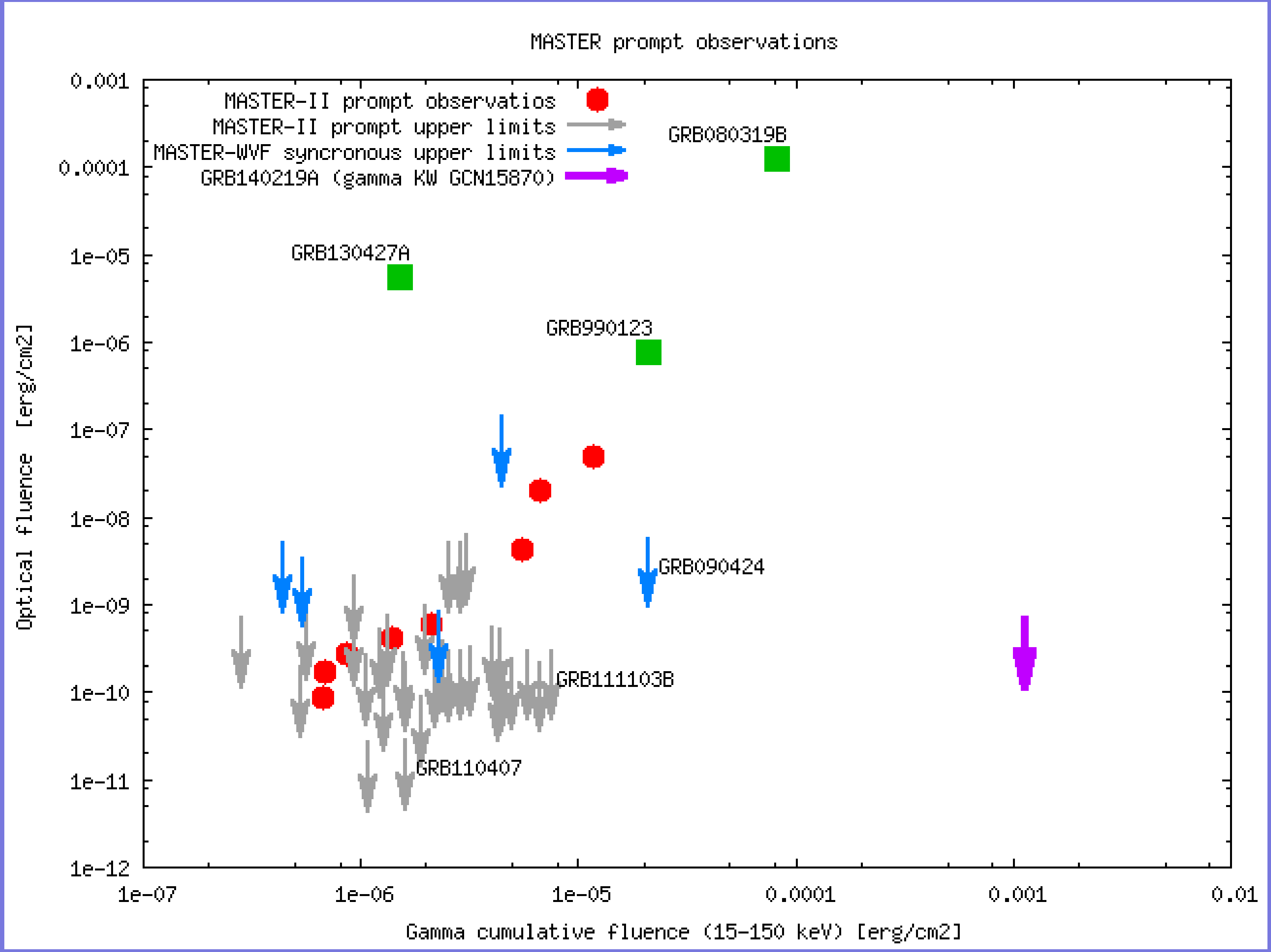
Pruzhinskaya et. al. New Astronomy v.29 , 2014



Статистика самых быстрых наведений на 66 Гамма-всплесков



Optcal SYNCHRONOUS observations of GRB

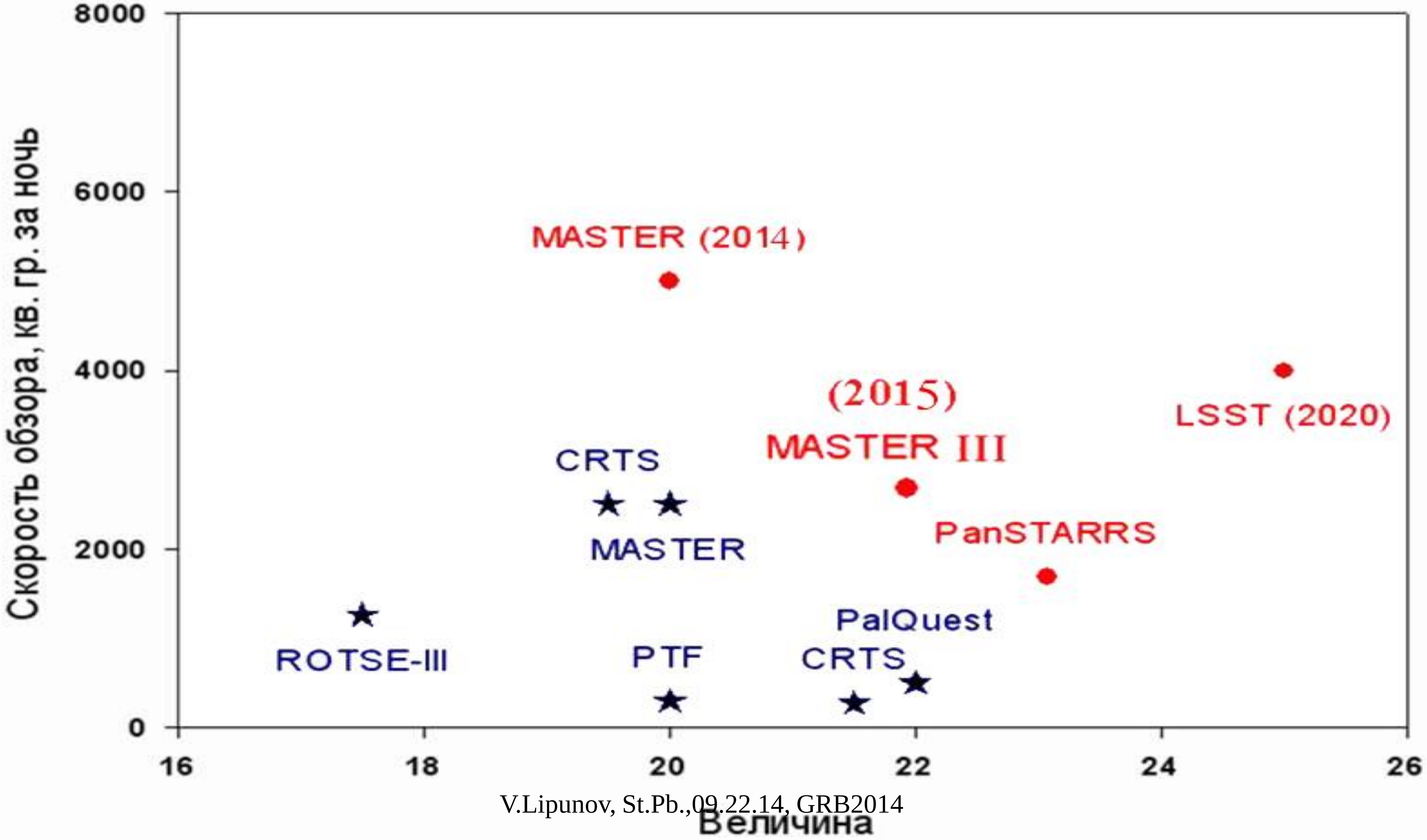


V.Lipunov, St.Pb.,09.22.14, GRB2014

2014

V.Lipunov, St.Pb.,09.22.14, GRB2014

Работающие и планируемые поисковые проекты



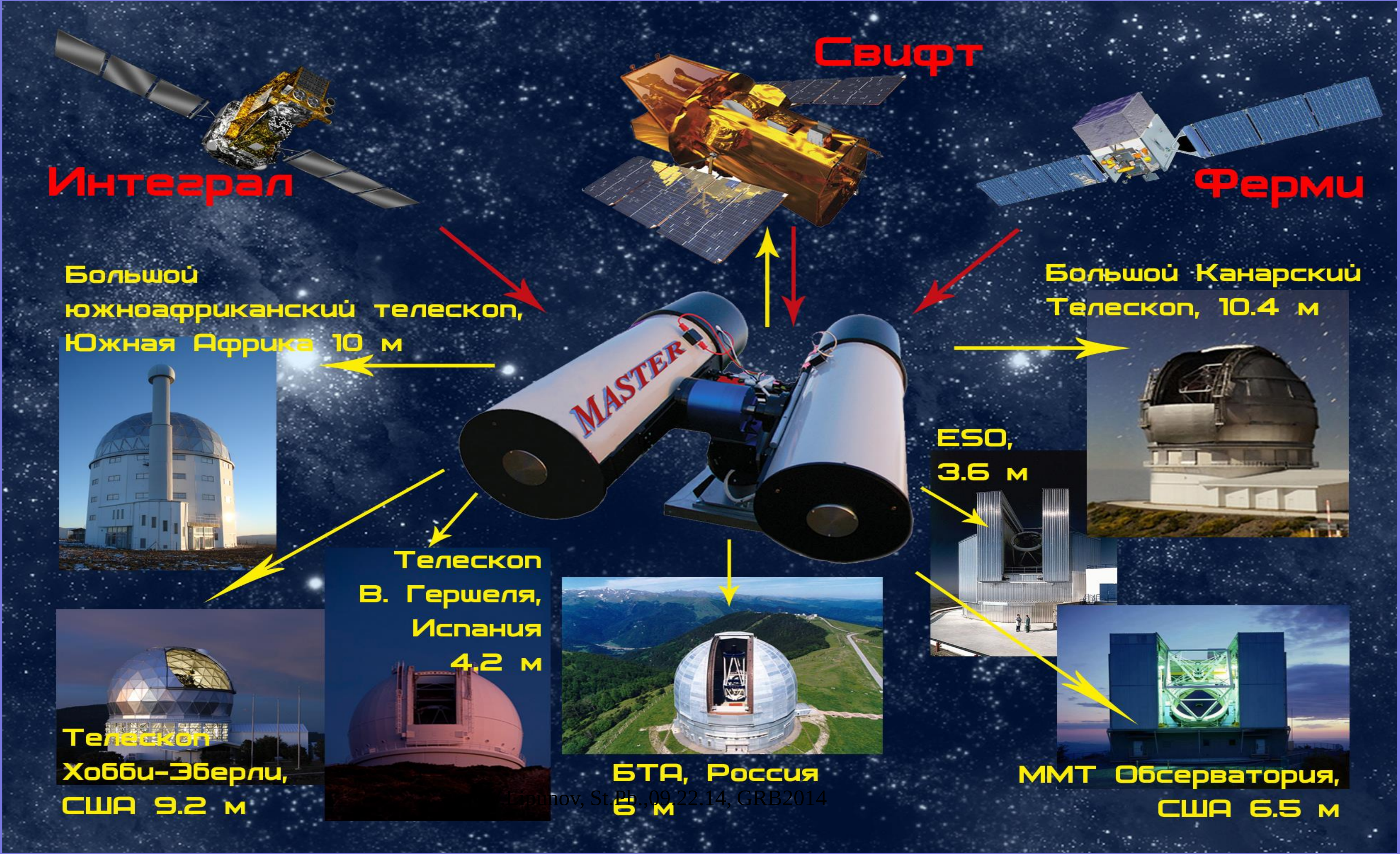
Information Flow

MASTER II 4x15Gb = 60Gb/night

MACTEP VWF

12 x950 Gb/night =10Tb/night

500 новых космических объектов, открытых телескопами МАСТЕР



Интеграл

Свифт

Ферми

Большой южноафриканский телескоп, Южная Африка 10 м

Большой Канарский Телескоп, 10.4 м

ESO, 3.6 м

Телескоп В. Гершеля, Испания 4.2 м

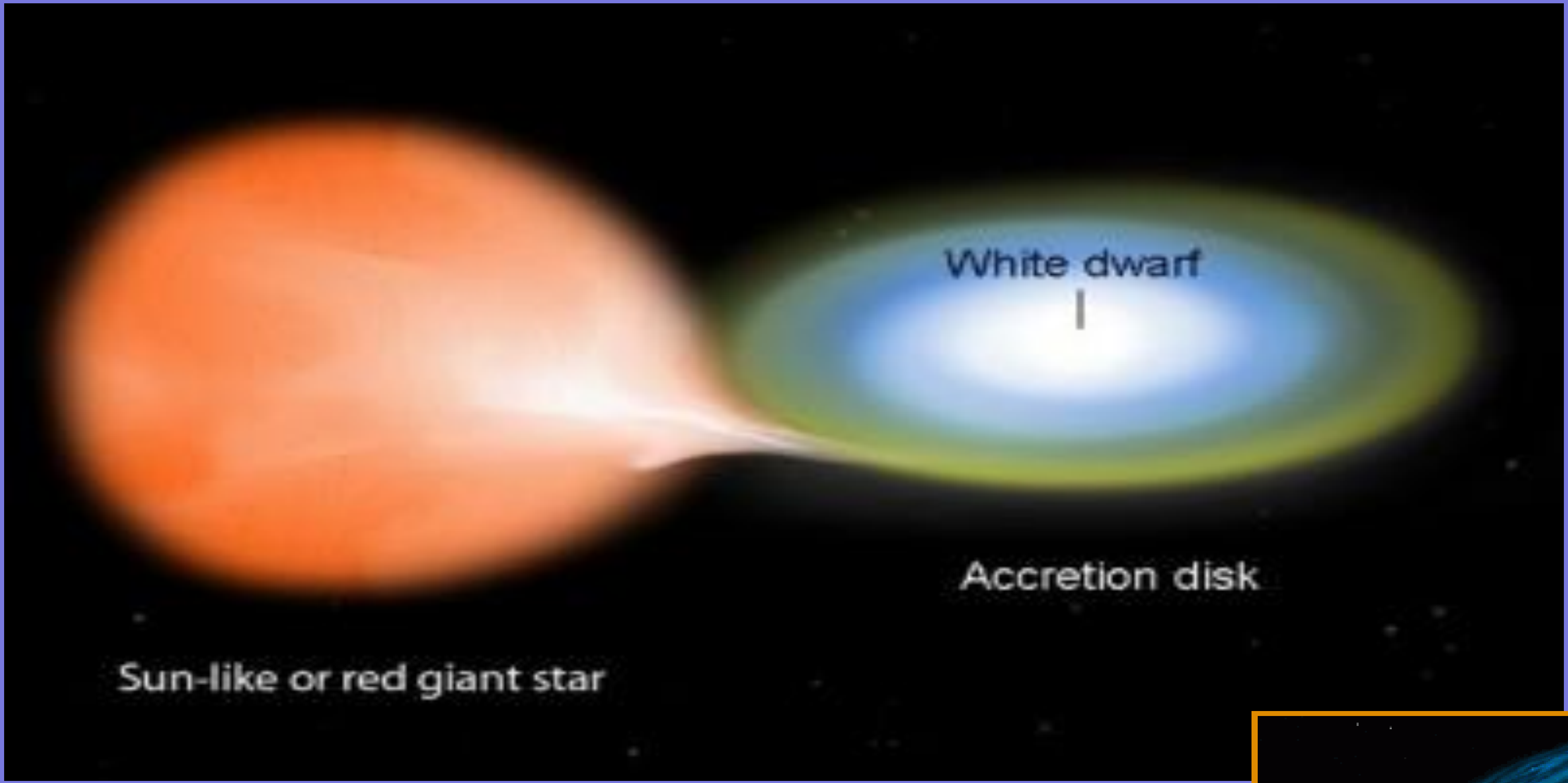
Телескоп Хобби-Эберли, США 9.2 м

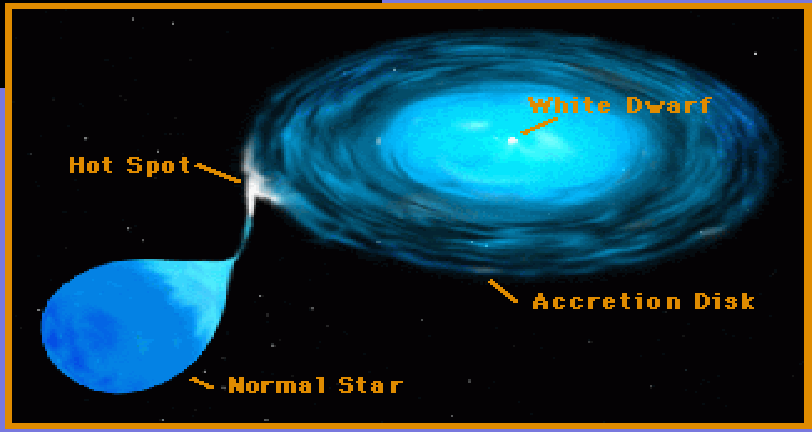
БТА, Россия 6 м

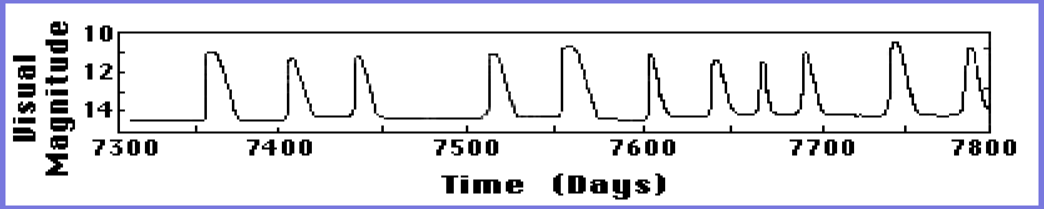
ММТ Обсерватория, США 6.5 м

2014

V.Lipunov, St.Pb.,09.22.14, GRB2014



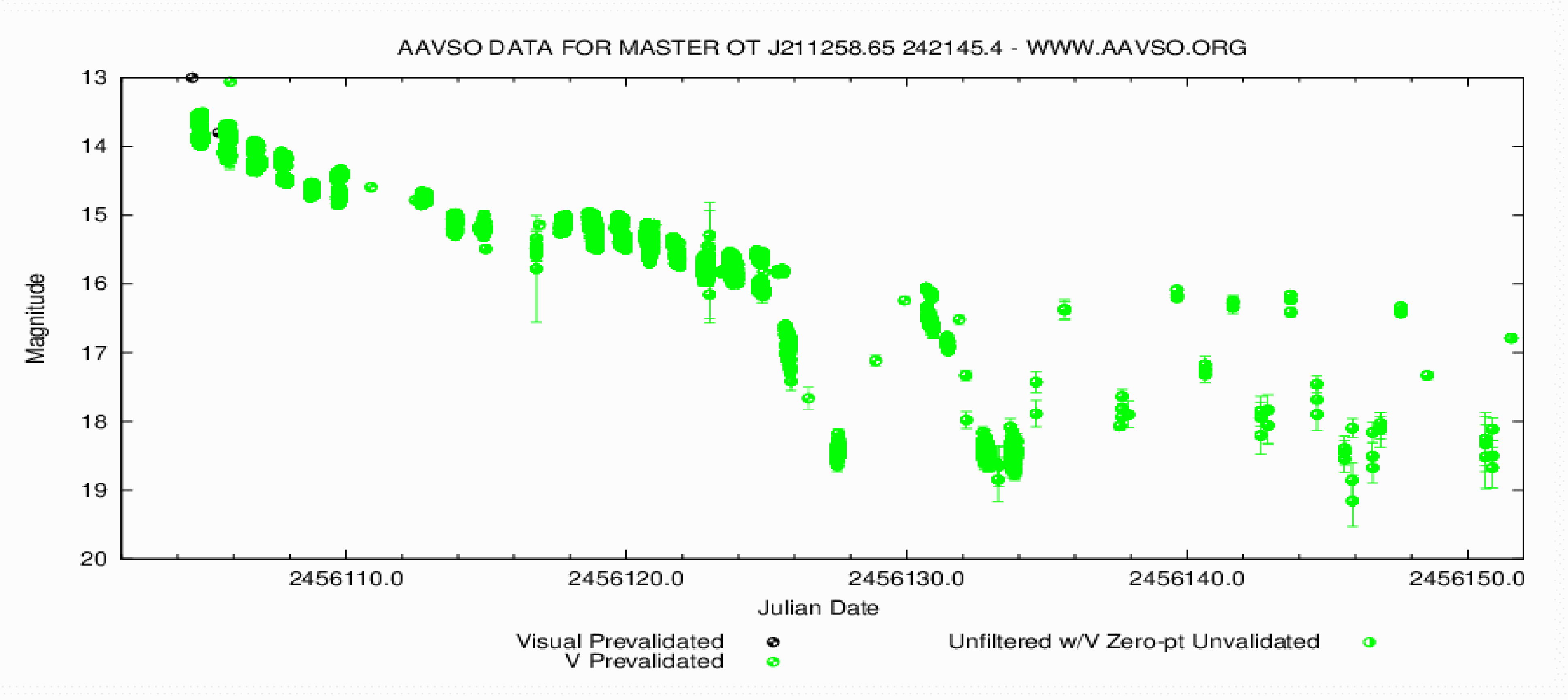




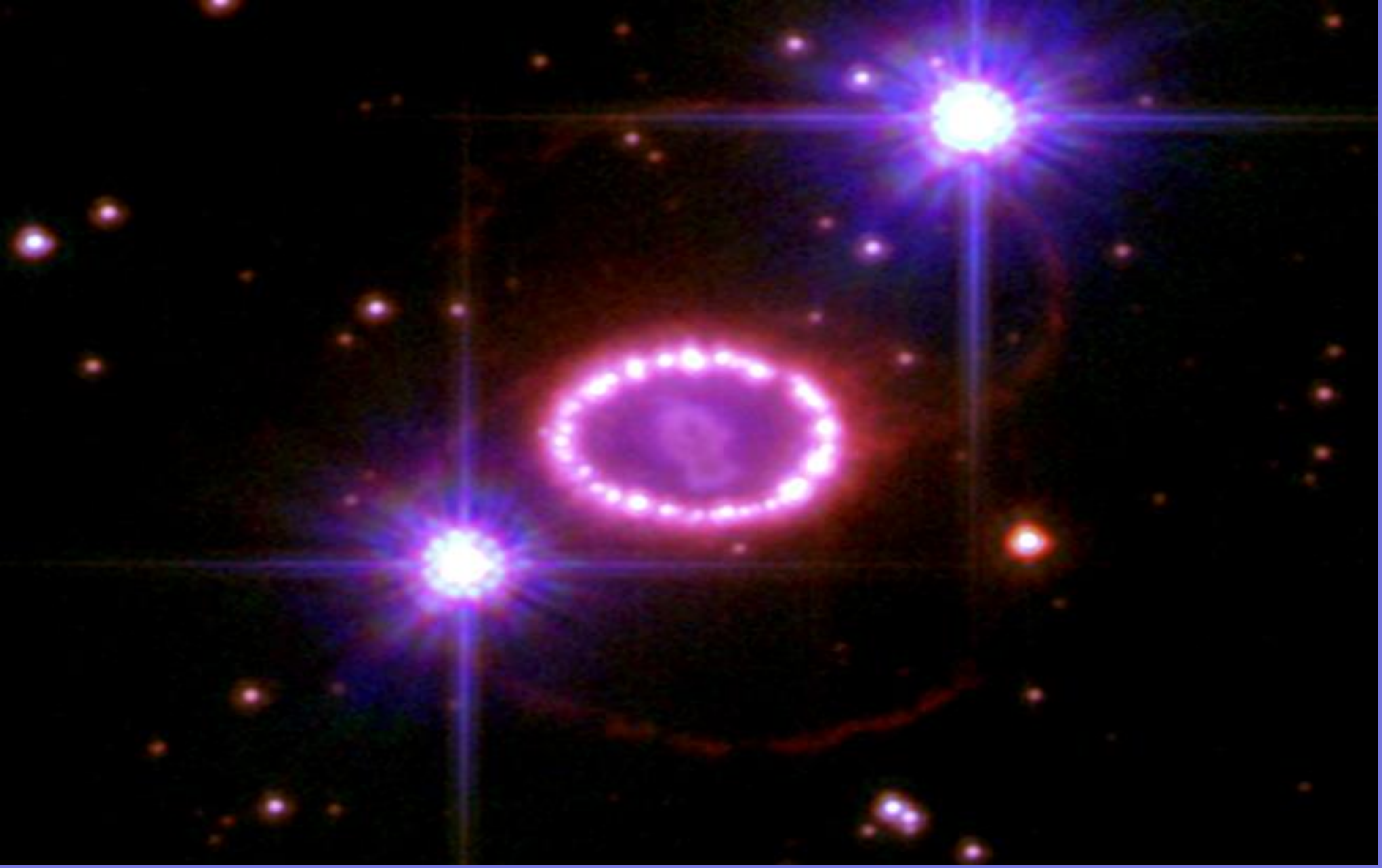
500 day light curve of the dwarf nova SS Aur.

Global MASTER Net 2013 by Vladimir Lipunov at Gravitational Wave Physics and Astronomy Workshop, December 17- 20, 2013

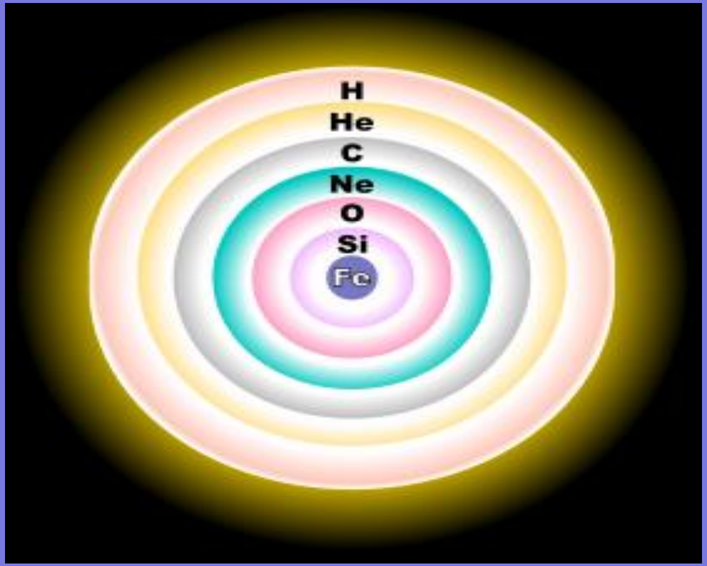
11000+ observations in 50 days after the discovery by MASTER, 7 rebrightenings



Global MASTER Net 2013 by
Vladimir Lipunov at Gravitational
Wave Physics and Astronomy



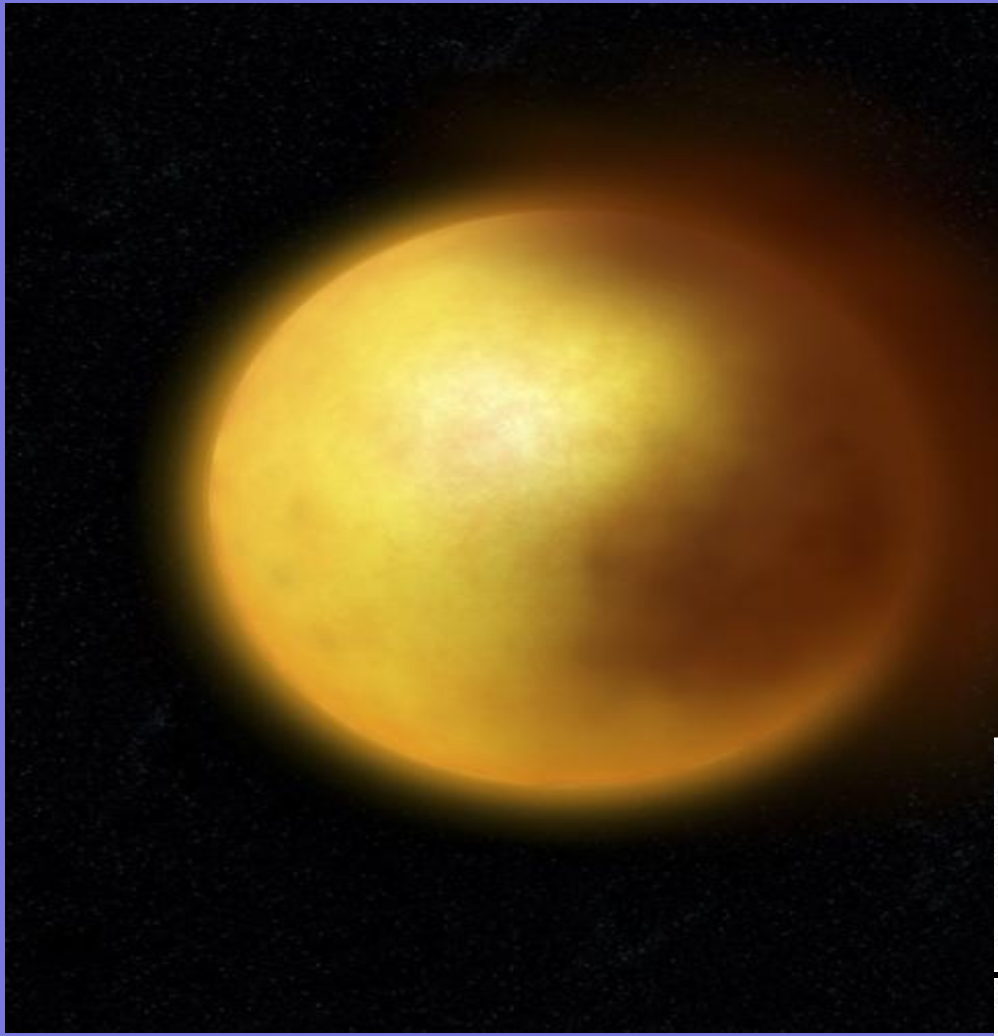
The expanding remnant of SN 1987A, a Type II-p supernova in the Large Magellanic Cloud. *NASA image*



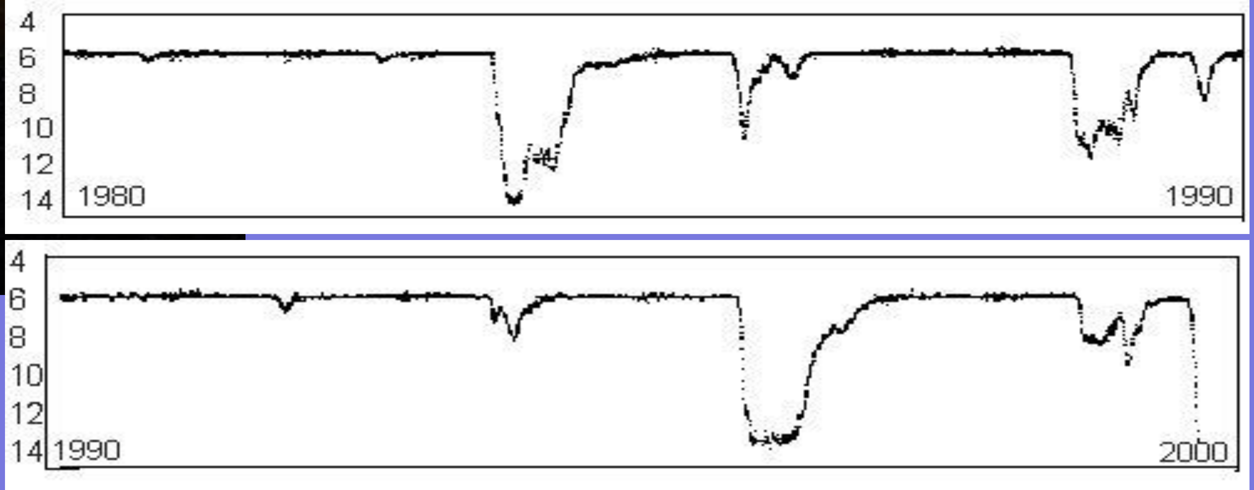
Active galaxies and the supermassive black holes they host remain mysterious to physicists

Blazar Markarian 421's flare-up is cosmic coincidence

Global MASTER Net 2013 by Vladimir Lipunov at Gravitational Wave Physics and Astronomy Workshop, December 17- 20, 2013

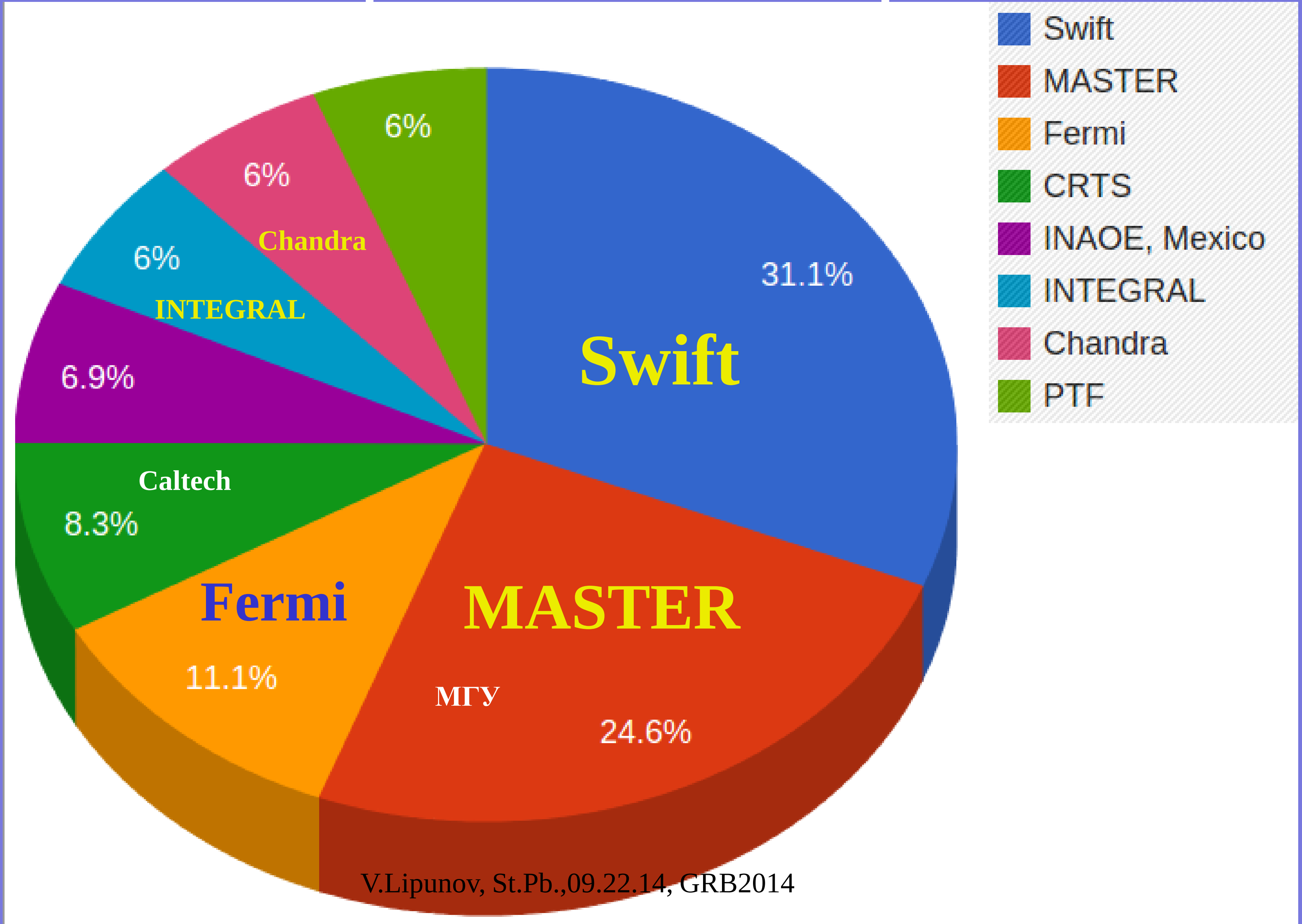


AAVSO light curve of R Coronae Borealis from 1980 to 1999



Global MASTER Net 2013 by Vladimir
Lipunov at Gravitational Wave Physics and
Astronomy Workshop, December 17- 20, 2013

Вклад МАСТЕРа в мировые публикации астрономических телеграмм



V.Lipunov, St.Pb.,09.22.14, GRB2014

2015

Global MASTER Net 2013 by Vladimir Lipunov at Gravitational Wave Physics and

МАСТЕР III
Противоастероидный космологический телескоп позволит открывать астероиды типа Челябинского за неделю до падения.

Диаметр = 1 м., Поле зрения = 4 кв.градуса. До 22-23 mag.

”Lomonosov”, SHOK, 2015 год

Prompt Optical High Time Resolution Observations

FOV = 2000 square degrees

Time Resolution =150ms

Спасибо ЯБ!