Все или не все гамма-всплески связаны с массивными сверхновыми?

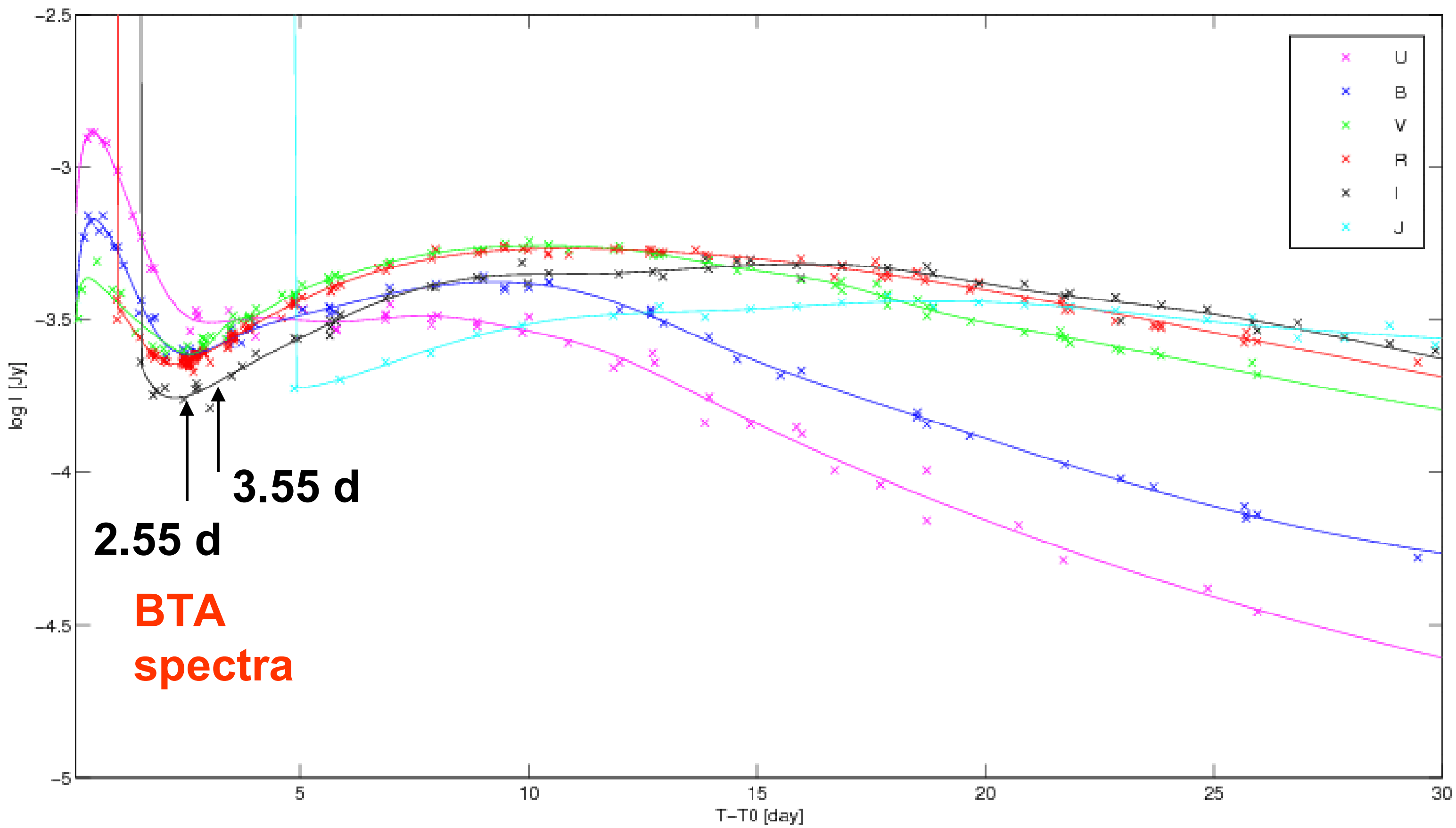
(отождествление гамма-всплесков продолжается)

В.В.Соколов

Finally, GRBs were identified with quite a definite class of supernovae – the core-collapse supernovae or massive supernovae.

A new era in the study of core-collapse supernovae.

Thanks to gamma-ray bursts, these supernovae can be observed from the very beginning.



Оптические и инфракрасная кривые блеска GRB/XRF060218/SN2006aj.
Первый максимум соответствует shock breakout эффекту.
Наши спектры относятся к переходной области около минимума.
T0(day) соответствует 2006 Feb. 18.149 UT.

Nature, 364, 507, 1993
K.Nomoto et al.

SN1993J

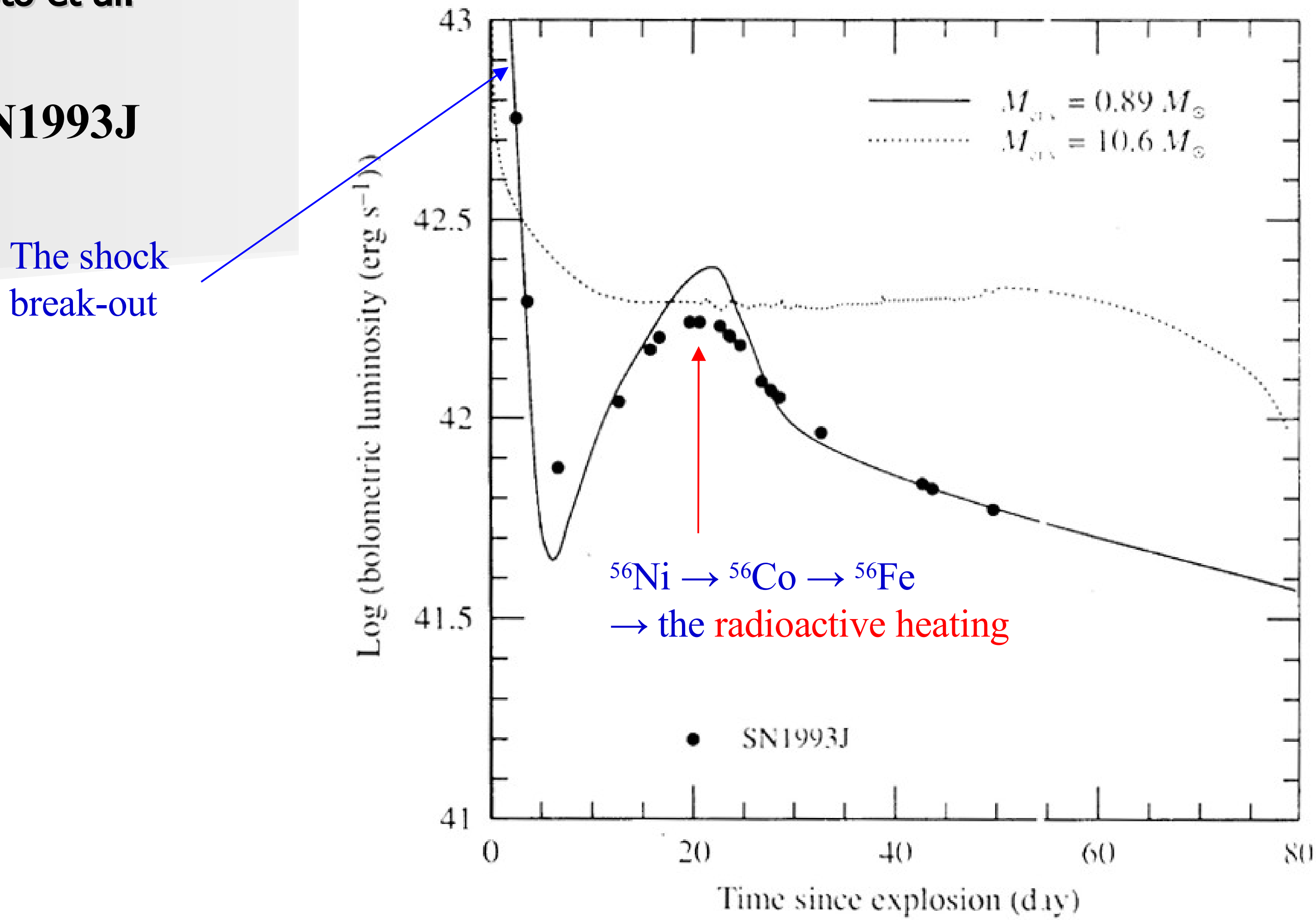
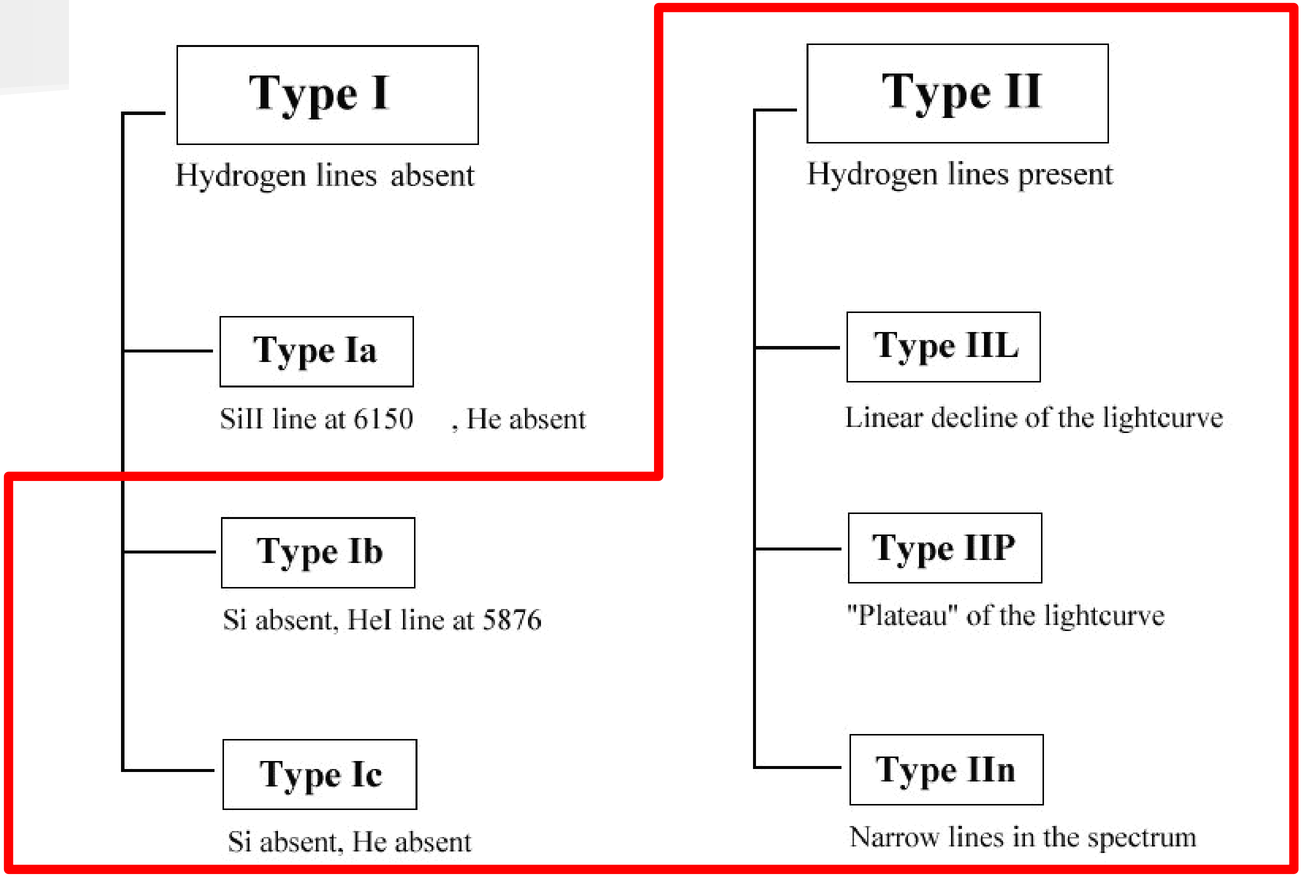


FIG. 2 The calculated bolometric light curves fo· two models, with envelopes of different masses M_{env} on top of the same 4 $M_{\odot}$ helium core. The solid and the dotted lines show the cases with $M_{env} = 0.89$ and 10.6 $M_{\odot}$, respectively. The bolometric light curve of SN1993J is shown by the filled circles[4].

Classification of Supernovae



The core-collapse or massive supernovae

The Core-collapse SNe:

SNe that have undetached hydrogen lines have obvious hydrogen lines and are classified as Type II.

SNe that have detached hydrogen lines are classified as Type Ib because the presence of hydrogen is not immediately obvious.

SNe Type IIb are those that have undetached hydrogen lines when they are first observed.

In some cases, whether an event is classified as Ib or IIb may depend on **how early the first spectrum is obtained!**

Type Ic supernovae (SNe Ic) are very similar to SNe Ib, but they lack conspicuous He I lines.

S.Valenti et al., "The Broad-lined Type Ic SN 2003jd"
arXiv:0710.5173v1 [astro-ph] 26 Oct 2007.

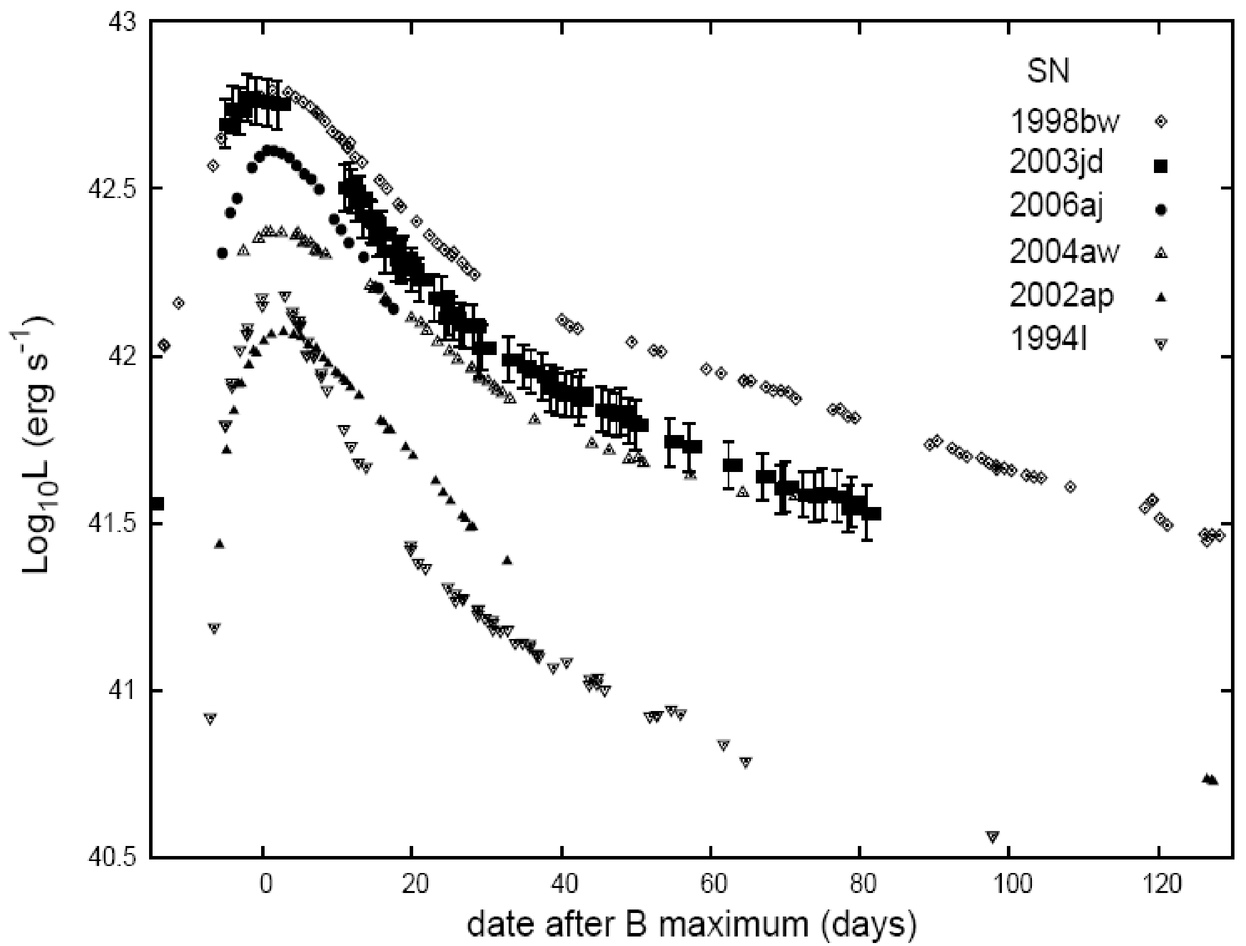


Figure 13. Quasi-bolometric (BVRI) light curves of SN 2003jd and other SNe Ic. We assume H_0 = 72 kms^{-1} Mpc^{-1}. Extinctions and distance moduli are given in Tab. 6.

ApJ, 536, 778-787, 2000 June 20

BeppoSAX OBSERVATIONS OF GRB 980425: DETECTION OF THE PROMPT EVENT AND MONITORING OF THE ERROR BOX

E. PIAN, L. AMATI, L. A. ANTONELLI, R. C. BUTLER, E. COSTA, G. CUSUMANO, J. DANZIGER, M. FEROCI, F. FIORE, F. FRONTERA, P. GIOMMI, N. MASETTI, J. M. MULLER, L. NICASTRO, T. OOSTERBROEK, M. ORLANDINI, A. OWENS, E. PALAZZI, A. PARMAR, L. PIRO, J. J. M. IN ´T ZAND, A. CASTRO-TIRADO, A. COLETTA, D. DAL FIUME, S. DEL SORDO, J. HEISE, P. SOFFITTA, AND V. TORRONI

Received 1999 October 12; accepted 2000 January 31

ABSTRACT

We present BeppoSAX follow-up observations of GRB 980425 obtained with the Narrow Field Instruments (NFI) in 1998 April, May, and November. The first NFI observation has detected within the 8′ radius error box of the gamma-ray burst (GRB) an X-ray source positionally consistent with the supernova 1998bw, which exploded within a day of GRB 980425, and a fainter X-ray source, not consistent with the position of the supernova. The former source is detected in the following NFI pointings and exhibits a decline of a factor of 2 in six months. If it is associated with SN 1998bw, this is the first detection of X-ray emission from a Type I supernova above 2 keV. The latter source exhibits only marginally significant variability. The X-ray spectra and variability of the supernova are compared with thermal and nonthermal models of supernova high-energy emission. Based on the BeppoSAX data, it is not possible to establish firmly which of the two detected sources is the GRB X-ray counterpart, although probability considerations favor the supernova.

S.Valenti et al., “The Broad-lined Type Ic SN 2003jd”
arXiv:0710.5173v1 [astro-ph] 26 Oct 2007.

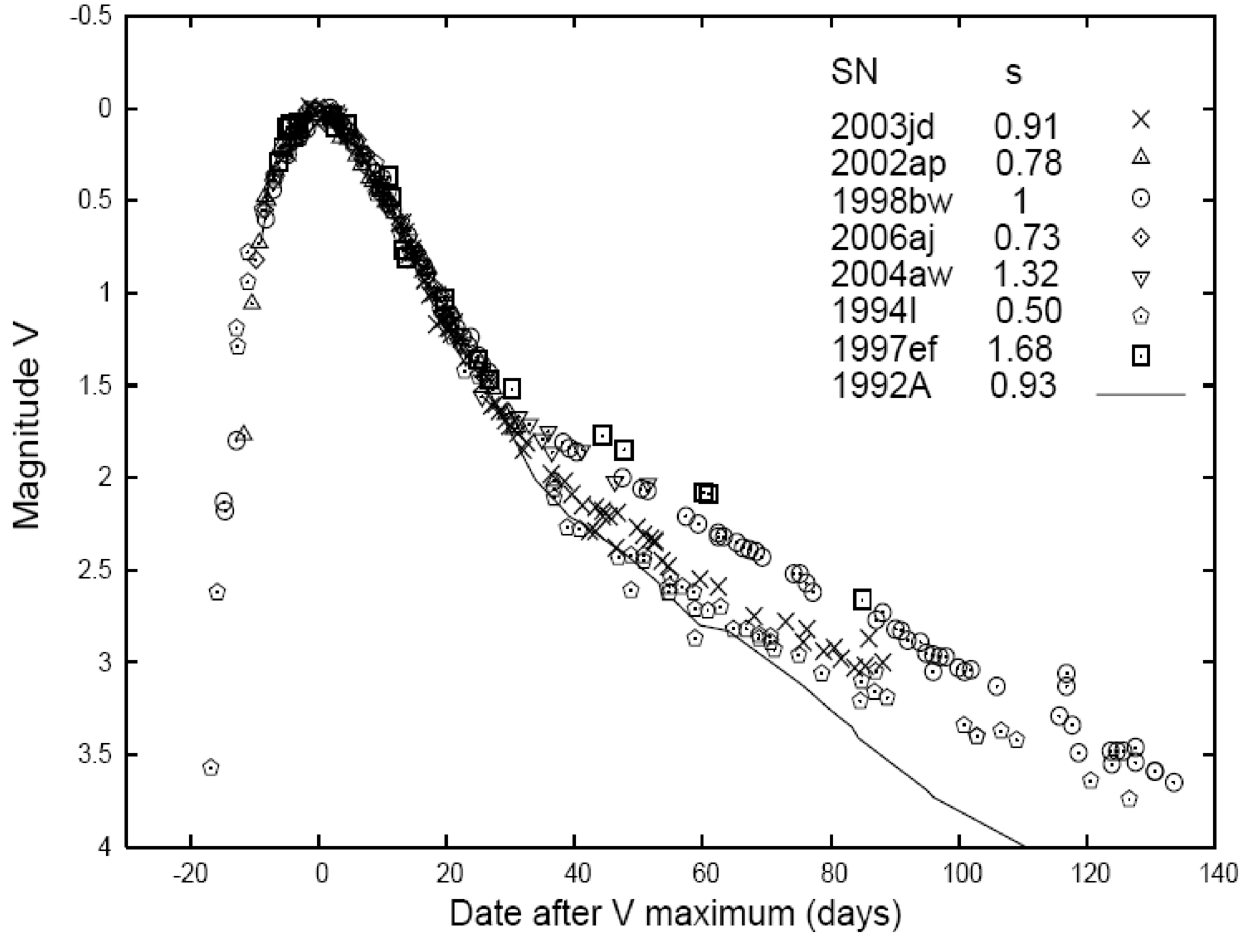


Figure 12. Comparison of V-band light curves of different SNe Ic corrected for stretch factor. SN 1998bw is the reference object with stretch factor defined to equal 1. The light curves are scaled in magnitude and phase to the V maximum

S.Valenti et al., “The Broad-lined Type Ic SN 2003jd”
arXiv:0710.5173v1 [astro-ph] 26 Oct 2007.

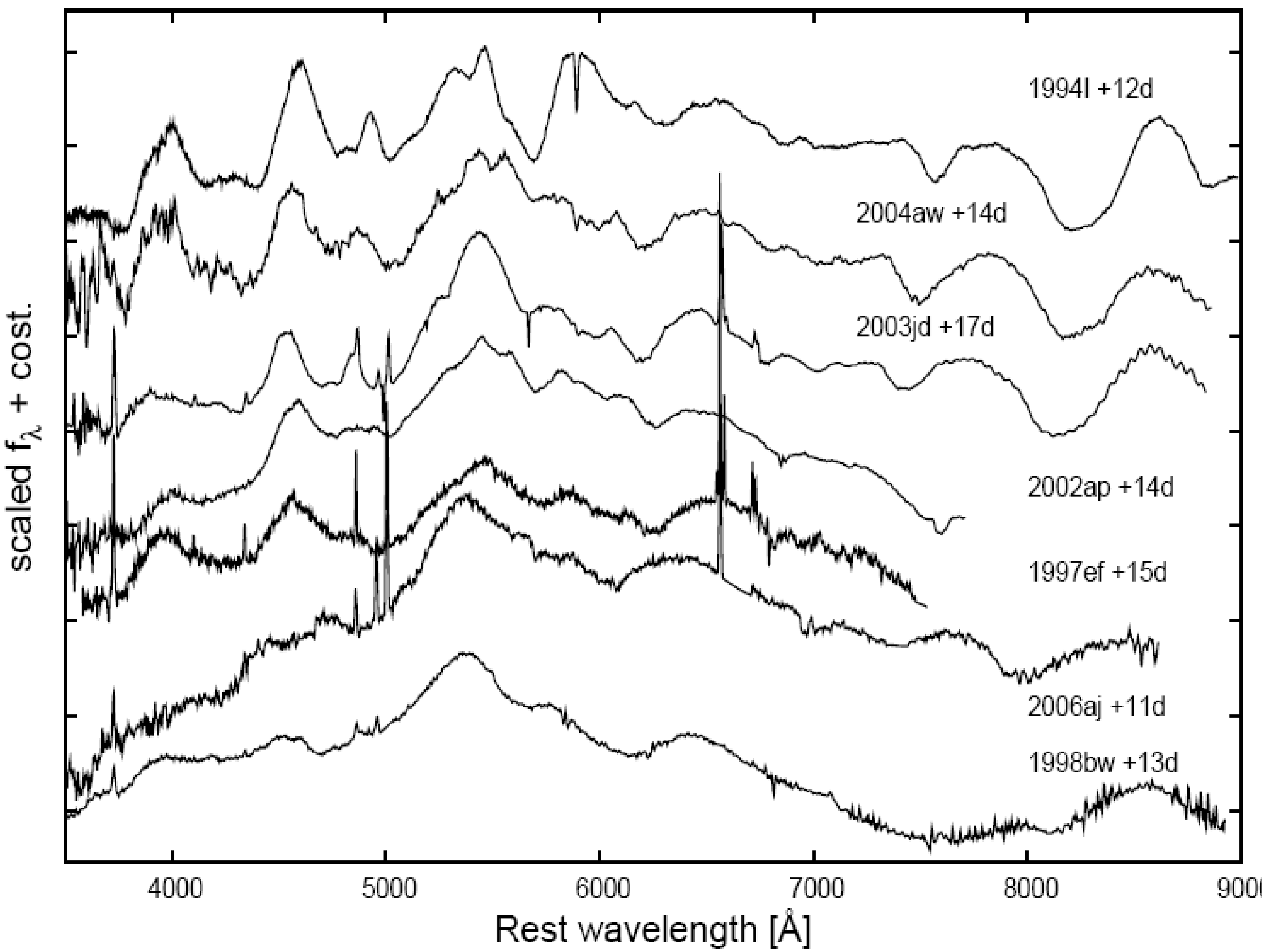


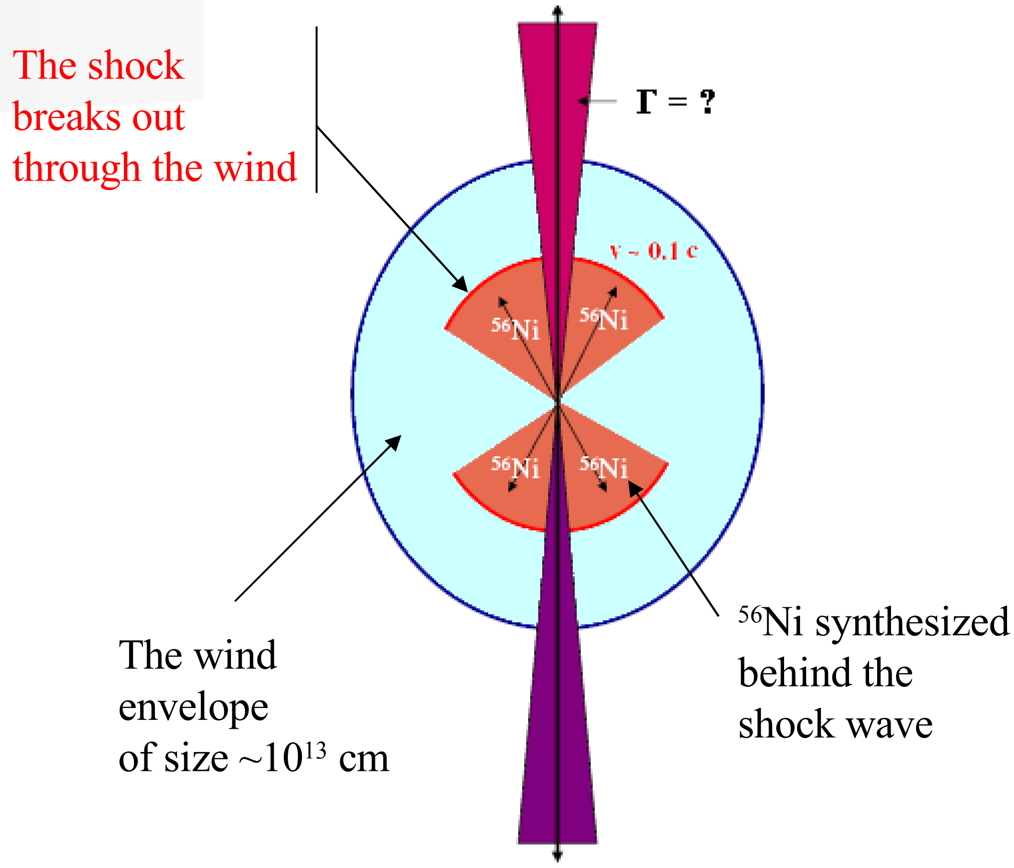
Figure 6. Comparison spectra of SNe Ic at 2 weeks past B maximum.

Shematic model of asymmetric explosion of a GRB/SN progenitor

…a strongly non-spherical explosion may be a generic feature of core-collapse supernovae of all types.

…Though while it is not clear that the same mechanism that generates the GRB is also responsible for exploding the star.

astro-ph/0603297
Leonard, Filippenko et al.



Though the phenomenon (GRB) is unusual, but the object-source (SN) is not too unique.

The closer a GRB is, the more features of a SN.

On asymmetry
of explosions
# of core-collapse SNe

Рим-2000, наши

Рим-2000, японцы+

arXiv:0801.1100v3 [astro-ph] 19 Mar 2008

Asphericity in Supernova Explosions from Late-Time Spectroscopy

Keiichi Maeda, Koji Kawabata, Paolo A. Mazzali, Masaomi Tanaka, Stefano Valenti, Ken'ichi Nomoto, Takashi Hattori , Jinsong Deng, Elena Pian, Stefan Taubenberger, Masanori Iye, Thomas Matheson, Alexei V. Filippenko, Kentaro Aoki, George Kosugi, Youichi Ohyama, Toshiyuki Sasaki,

and Tadafumi Takata

Abstract. Core-collapse supernovae (CC-SNe) are the explosions that announce the death of massive stars. Some CC-SNe are linked to long-duration gamma-ray bursts (GRBs) and are highly aspherical. One important question is to what extent asphericity is common to all CC-SNe. Here we present late-time spectra for a number of CC-SNe from stripped-envelope stars, and use them to explore any asphericity generated in the inner part of the exploding star, near the site of collapse. A range of oxygen emission-line profiles is observed, including a high incidence of double-peaked profiles, a distinct signature of an aspherical explosion. Our results suggest that all CC-SNe from stripped-envelope stars are aspherical explosions and that SNe accompanied by GRBs exhibit the highest degree of asphericity

P.Mazzali et al., arXiv:astro-ph/0505199v1 10 May 2005
"An Asymmetric, Energetic Type Ic Supernova Viewed Off-Axis, and a Link to Gamma-Ray Bursts"

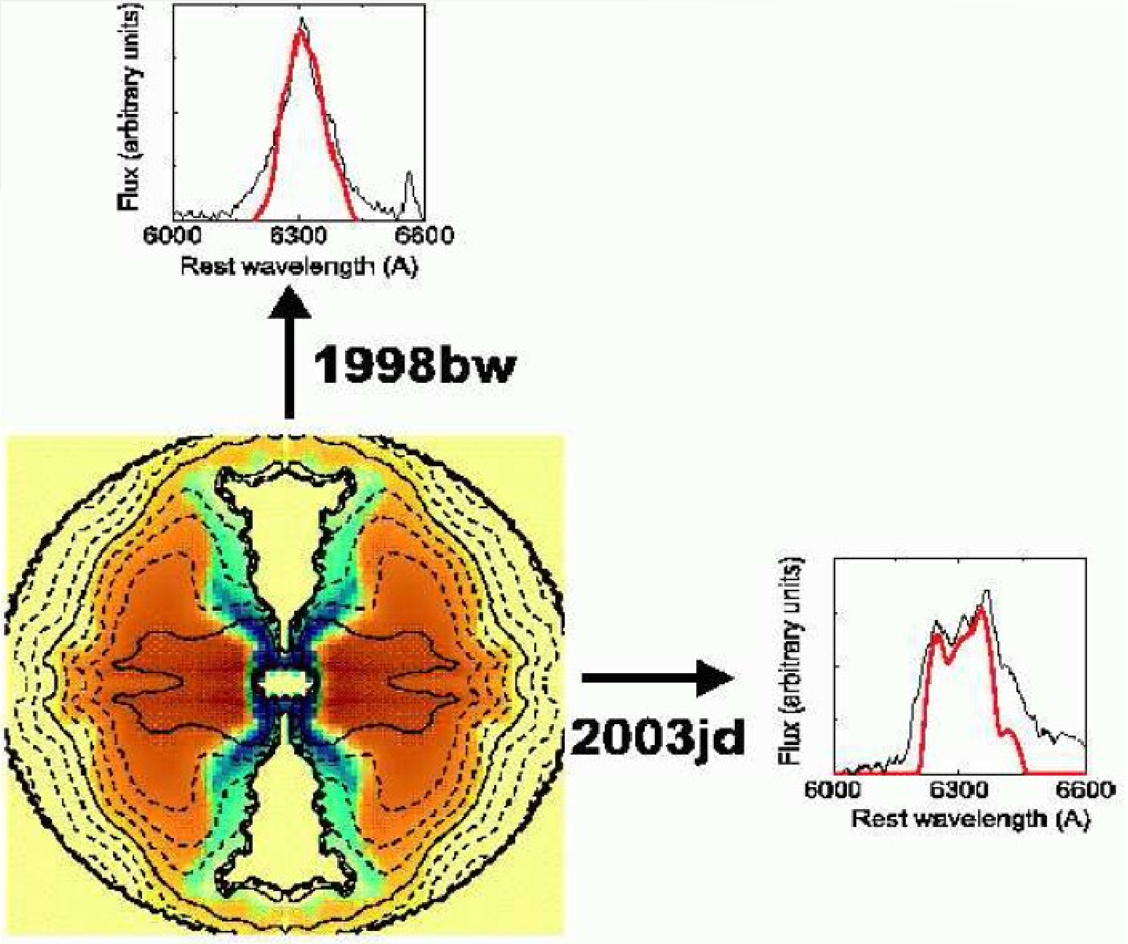


Figure 3: Nebular line profiles observed from an aspherical explosion model depend onthe orientation. The figure shows the properties of the explosion model computed in 2D (11): Fe (colored in blue) is ejected near the jet direction and oxygen (brown) in a disc-like structure on and near the equatorial plane. Density contours (covering 2 orders of magnitude and divided into 10 equal intervals in log scale) reflect the dense disc-like structure. Synthetic [O i] 6300, 6363 Å lines (red lines) computed in 2D are compared with the spectra of SN 1998bw and SN 2003jd (black lines).

S.Valenti et al., “The Broad-lined Type Ic SN 2003jd”
arXiv:0710.5173v1 [astro-ph] 26 Oct 2007.

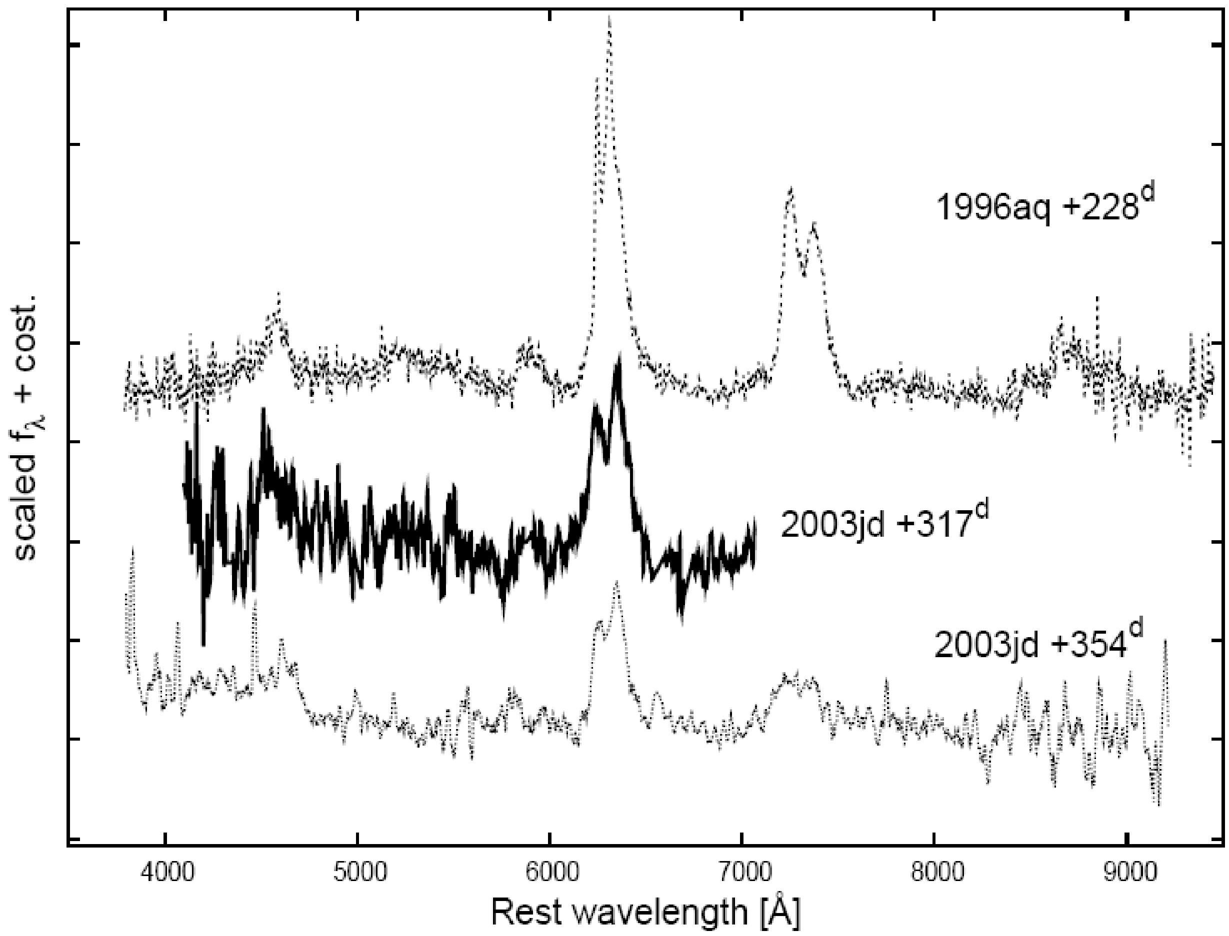


Figure 9. Nebular spectra of SN 2003jd (317 d, 354 d) and SN 1996aq (228 d).

arXiv:0801.1100v3 [astro-ph] 19 Mar 2008

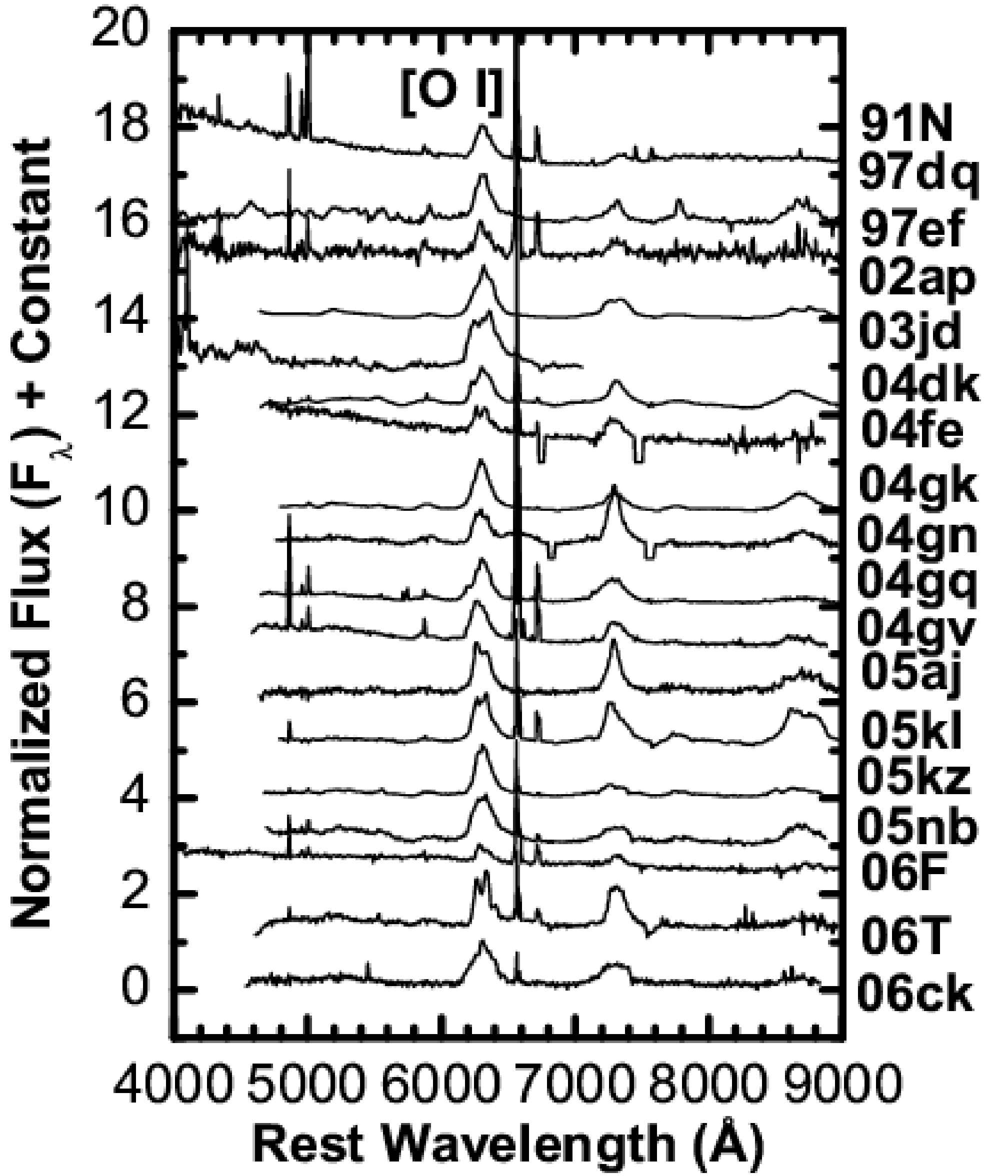


Figure 2: Nebular spectra of the supernovae in the sample used in this study. Narrow lines (e.g., Hα at 6563Å) originate from a diffuse superposed H II region, not from a SN. The spectra of SNe 1991N, 1997dq, 1997ef are from (21). The other spectra were obtained with the Subaru telescope, except for SN 2006F which was taken by the VLT (22). Spectra were deredshifted using the redshift obtained from the observed wavelength of the narrow Hα emission if possible; otherwise, the redshift of the nucleus of the host galaxy was adopted. For presentation, the is arbitrarily scaled and shifted vertically. The strongest emission line (dashed line) is [O I] λλ6300, 6363. The feature at ~7,300 Å is [Ca II] λλ7291, 7324 contaminated by several emission lines: [O II], [Fe II], and [Ni II].

Fig.1. – Selection of nebular spectra of SN IIb, SN Ib and SN Ic in their respective rest frames. SN name, type and phase of spectrum (with respect to maximum light, except for GRB 060218/SN 2006aj which is referenced to time of GRB burst) are marked. Also, the main nebular emission lines of [Mg I] λ4571, [O I] λλ6300,6363, [Ca II] λλ7291,7324 and O I λ7774 are marked at the very top.

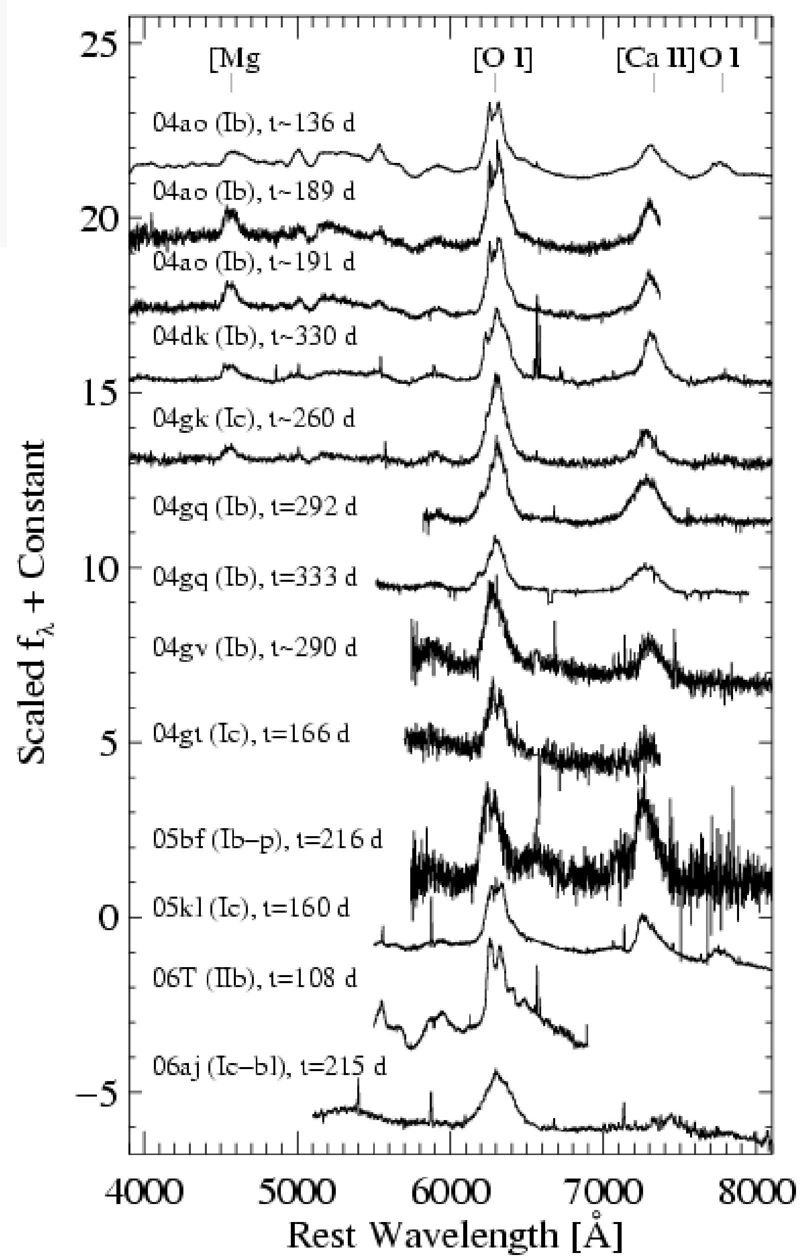
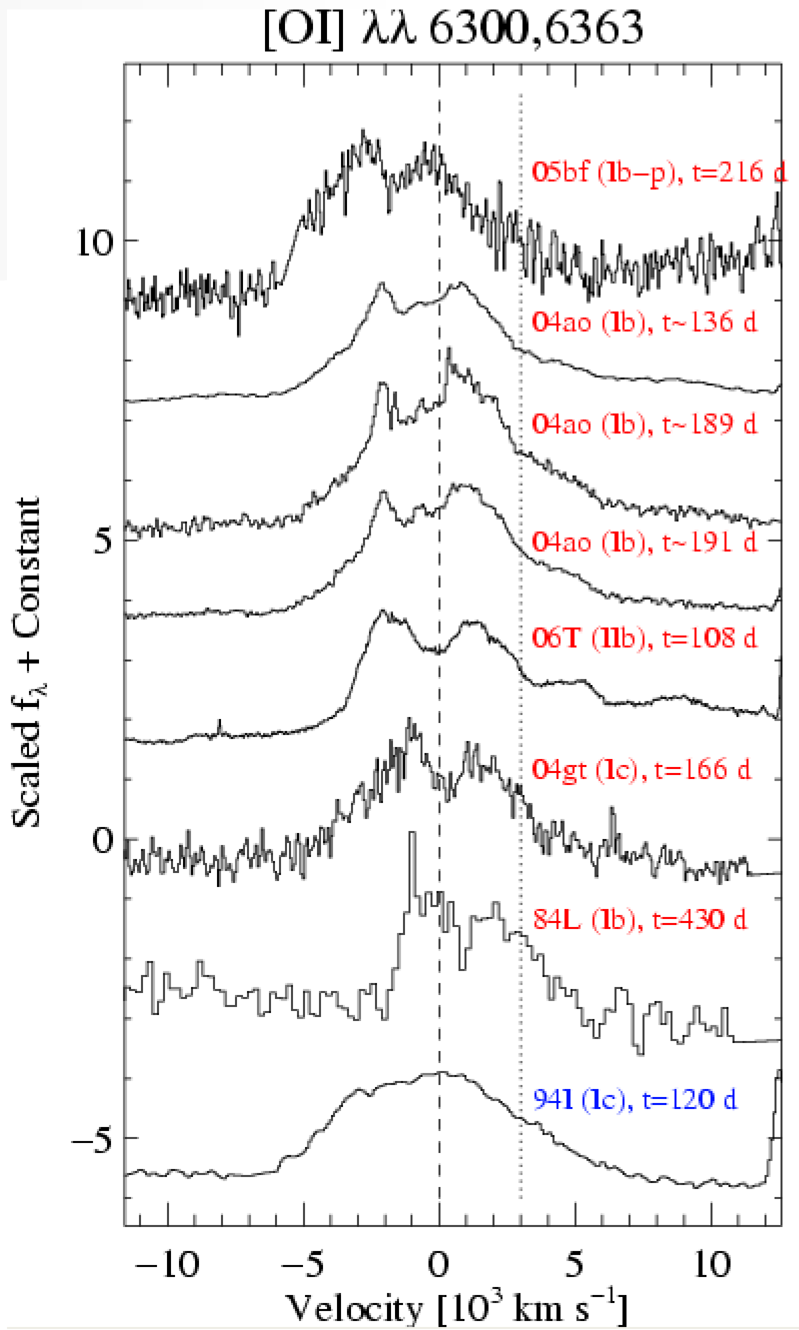


Fig. 2. – Montage of SN with double-peaked oxygen profile in velocity space. SN name, type and phase of spectrum (with respect to maximum light). SN 1984L, SN Ib is from Schlegel & Kirshner (1989). SN 1994I (Filippenko et al. 1995) that exhibits a simple parabolic oxygen line profile is plotted for comparison at the bottom. The dashed line marks zero velocity with respect to 6300 Å while the dotted line corresponds to [O I] λ6363. Clearly the two horns cannot be due to the doublet nature of [O I] λλ6300, 6363. Note the blueshift in SN 2005bf compared to the other SN.



arXiv:0801.0221v1 [astro-ph] 31 Dec 2007

DOUBLE-PEAKED OXYGEN LINES ARE NOT RARE IN NEBULAR SPECTRA OF CORE-COLLAPSE SUPERNOVAE

M. Modjaz, R. P. Kirshner, P. Challis

ABSTRACT

Double-peaked oxygen lines in the nebular spectra of two peculiar Type Ib/c Supernovae (SN Ib/c) have been interpreted as off-axis GRB-jet or unipolar blob ejections. Here we present late-time spectra of 10 SN IIb, Ib and Ic that show that this phenomenon is common and probably should not be linked to extraordinary events in the explosion physics. We show that this type of line profile is probably not caused by optical depth effects, but might well be due to ejecta expanding with a torus- or disk-like geometry. Double-peaked oxygen profiles are not necessarily the indicator of a mis-directed GRB jet.

Appears that asphericities are prevalent in normal core-collapse SNe.

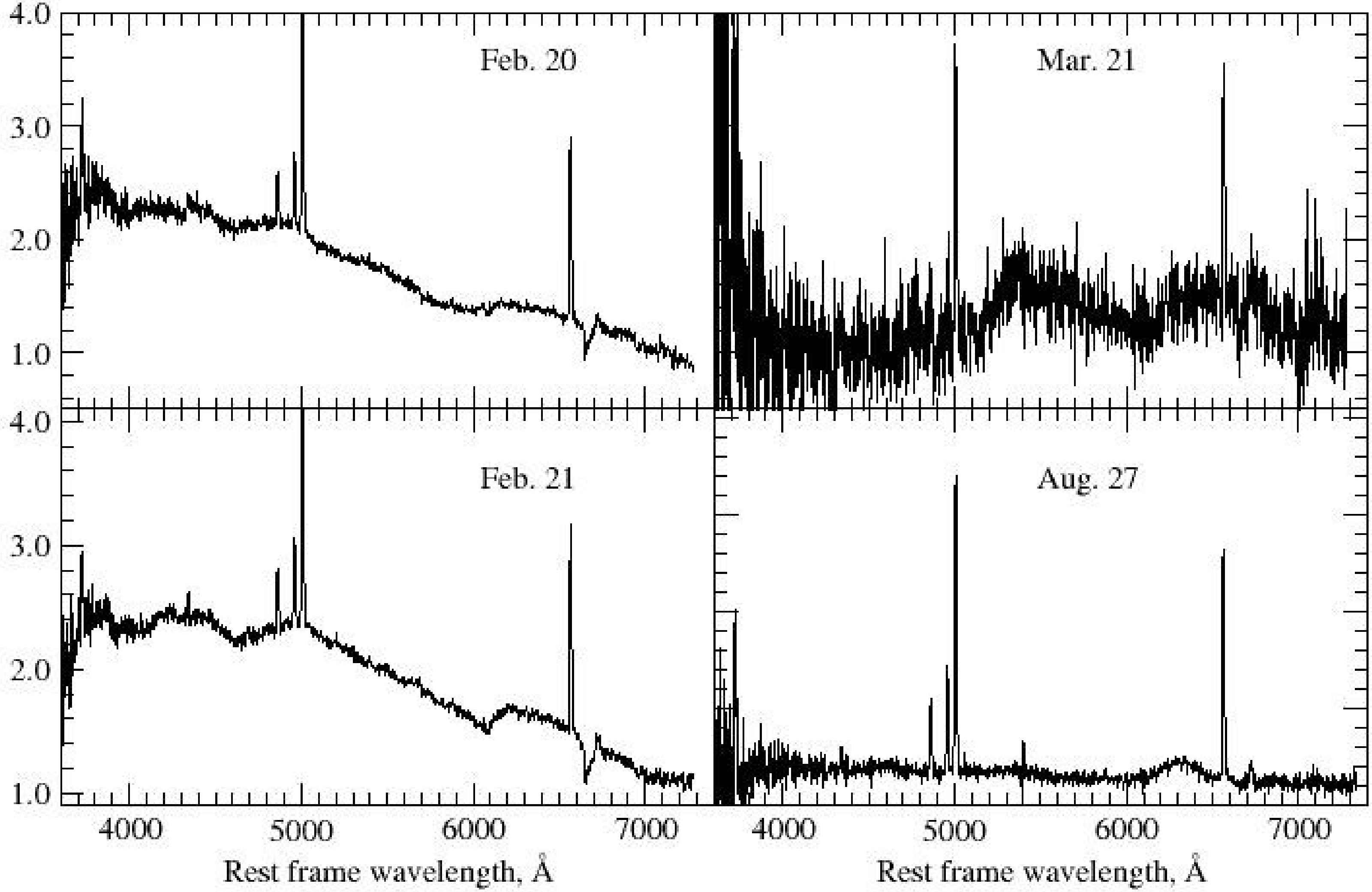
Monitoring of the optical transient of the closest GRB

The program “physics of GRBs in the SWIFT era».

A. Castro-Tirado (IAA-CSIC, Spain), V.Sokolov, T.Fatkhullin (SAO)

The spectral *monitoring* of the optical afterglow of the closest GRB060218 with the red shift z = 0.033 was carried out with the BTA (and with the swears).
Broad spectral details typical for massive supernovae of type Ib-c were detected in early (February, 20, 21) spectra of the optical transient. Absorption at ~4600A (February, 21) can be a result of the blend of iron lines (Fe II), as, for example, in the case of Ic type supernovae SN 1997ef and SN 2002ap.
The main result of the joint monitoring (the BTA + other telescopes): ”long” GRBs are *the beginning of explosion* of massive supernovae, and, the most probably, the burst that we observe is *the relativistic collapse* of the star nucleus and the burst of a very dense object – the compact remnant of supernova explosion.

The last spectrum obtained on August, 27, clearly shows a wide blend [OI] 6300, 6364 A typical for the nebular stage of supernovae. This is already the spectrum of the host galaxy almost without contribution of the supernova SN 2006aj related to the GRB 060218 (SN 2006aj/GRB 060218).



Feb. 20
Mar. 21
Feb. 21
Aug. 27
4.0
3.0
2.0
1.0
4000
5000
6000
7000
Rest frame wavelength, Å
Rest frame wavelength, Å

Второй результат отождествления GRB:

теперь длинные GRB отождествляются с обычными(?) массивными (core-collapse) сверхновыми

Первый результат оптического отождествления γ-всплесков (2001-2002): длинные всплески отождествляются с обычными, часто встречаемыми при таких *z* (непекулярными) галактиками до ≈ 26 зв. вел. Это дает возможность, используя подсчеты галактик (ярче 26 зв.вел.) с учетом результатов прямых оптических отождествлений γ-всплесков (регистрируемых до уровня ~/> 10^{-7} эрг $см^{-2}$), оценить среднюю годовую частоту γ-всплесков, приходящихся на галактику. Она оказывается равной $N_{GRB} \sim 10^{-8}$ в год в среднем на каждую галактику со вспышкой звездообразования.

GRBs as cosmological probes—cosmic chemical evolution

S. Savaglio
Max-Planck-Institut für Extraterrestrische Physik,
New Journal of Physics 8 (2006)

Abstract. Long-duration gamma-ray bursts (GRBs) are associated with the death of metal-poor massive stars. Even though they are highly transient events very hard to localize, they are so bright that they can be detected in the most difficult environments. GRB observations are unveiling a surprising view of the chemical state of the distant universe (redshifts $z > 2$). Contrary to what is expected for a high-z metal-poor star, the neutral interstellar medium (ISM) around GRBs is not metal poor (metallicities vary from ~1/10 solar at $z = 6.3$ to about solar at $z = 2$) and is enriched with dust (90–99% of iron is in solid form). If these metallicities are combined with those measured in the warm ISM of GRB host galaxies at $z < 1$, a redshift evolution is observed. Such an evolution predicts that the stellar masses of the hosts are in the range $M_* = 10^{8.6-9.8} M_\odot$. This prediction makes use of the mass-metallicity relation (and its redshift evolution) observed in normal star-forming galaxies. Independent measurements coming from the optical–NIR (near-infrared) photometry of GRBhosts indicate the same range of stellar masses, with a typical value similar to that of the Large Magellanic Cloud (LMC). This newly detected population of intermediate-mass galaxies is very hard to find at high redshift using conventional astronomy. However, it offers a compelling and relatively inexpensive opportunity to explore galaxy formation and cosmic chemical evolution beyond known borders, from the primordial universe to the present.

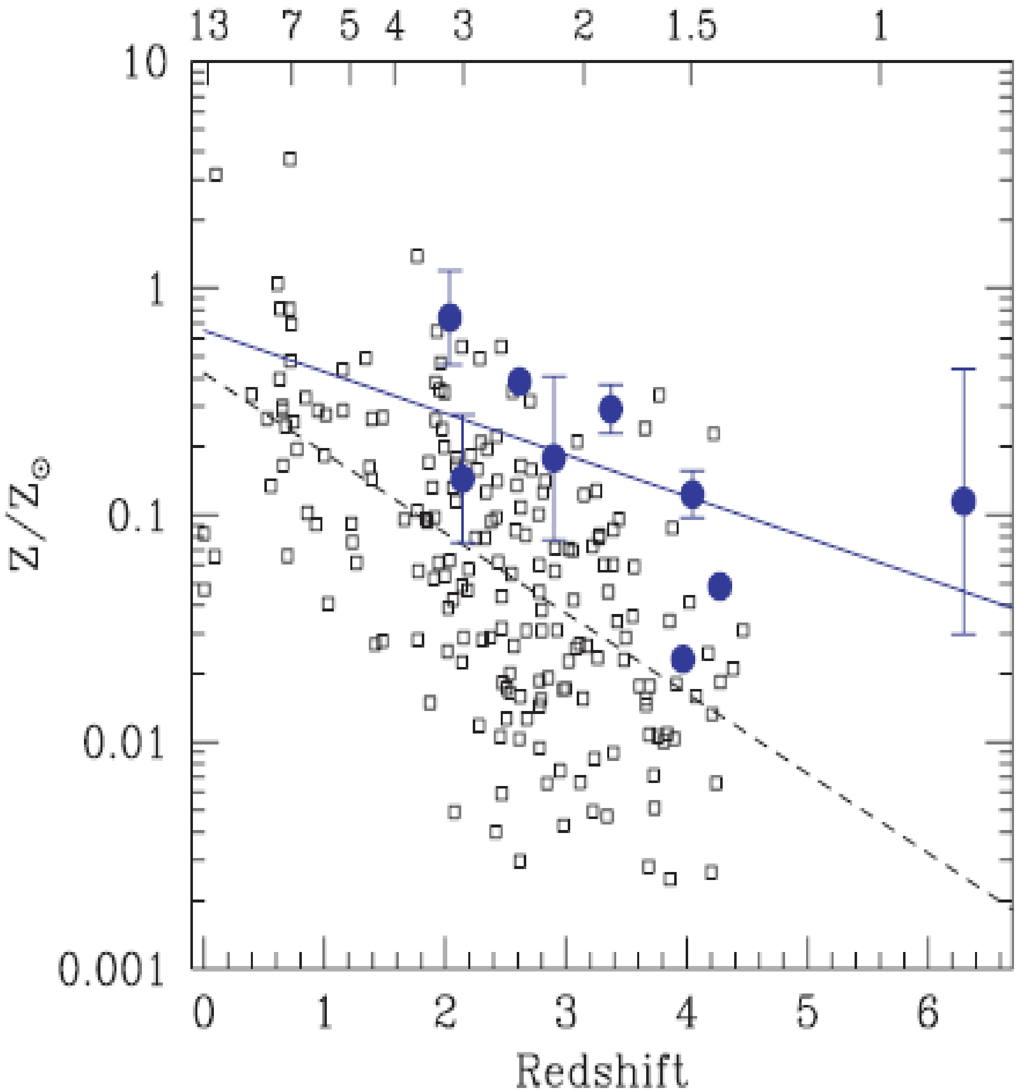


Figure 5. Redshift evolution of the metallicity relative to solar values, for nine GRB-DLAs (•) and 197 QSO-DLAs (□). Error bars are not available for three GRB-DLAs. Errors for QSO-DLAs (measured from the element column density uncertainties) are generally smaller than 0.2 dex. The solid and dashed lines indicate the best-fit linear correlation for GRB-DLAs and QSO-DLAs, respectively. The GRB-DLAs metallicity is on average ~ 5 times larger than in QSO-DLAs. The upper horizontal *x*-axis indicates the age of the Universe (Hubble time).

Astro-ph/0609489. S.Savglio. GRBs as cosmological probes—cosmic chemical evolution

The low stellar masses are not surprising because low-mass galaxies are the most numerous in the universe at any redshift. GRB hosts are not special, but just normal, faint, generally starforming galaxies, detected at any redshift just because a GRB event has occurred. Such a statement does not support the conclusion accordingto which GRB hosts tend to be more metal-poor than normal galaxies with similar masses

Второй этап отождествления длинных гамма-всплесков:

поиск наблюдательных признаков массивных SN у всех GRB, теперь

с учетом эффектов асимметрии взрывов таких SN

'22nd Texas Symposium on Relativistic Astrophysics', Palo Alto (USA), December 13-17, 2004

Evidence for Supernova light in all Gamma-Ray Burst afterglows

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D. H. Hartmann
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!

We present an update of our systematic analysis of all Gamma-Ray Burst (GRB) afterglow data, now published through the end of 2004, in an attempt to detect the predicted supernova light component. We fit the observed photometric light curves as the sum of an afterglow, an underlying host galaxy, and a supernova component. The latter is modeled using published *UBVRI* light curves of SN 1998bw as a template. The total sample of afterglows with established redshifts contains now 29 bursts (GRB 970228 - GRB 041006). For 13 of them a weak supernova excess (scaled to SN 1998bw) was found. In agreement with our earlier result [47] we find that also in the updated sample all bursts with redshift $\lesssim 0.7$ show a supernova excess in their afterglow light curves. The general lack of a detection of a supernova component at larger redshifts can be explained with selection effects. These results strongly support our previous conclusion based on all afterglow data of the years 1997 to 2002 [47] that in fact *all* afterglows of long-duration GRBs contain light from an associated supernova.

This is a dangerous conclusion!

Astro-ph/0603530 v1 20 March 2006

Gamma-Ray Burst associated Supernovae: Outliers become Mainstream

E. Pian,[1,2] P. A. Mazzali,[1,2,3] N. Masetti,[4] P. Ferrero,[5] S. Klose,[5] E. Palazzi,[4] E. Ramirez-Ruiz,[6,7] S. E. Woosley,[7] C. Kouveliotou,[8] J. Deng,[2,9] A.V. Filippenko,[10] R. Foley,[10] J.P.U. Fynbo,[11] A. Kann,[5] J. Hjorth,[11] K. Nomoto,[2,12,13] F. Patat,[14] J. Sollerman,[11] P. M. Vreeswijk,[15] E.W. Guenther,[5] A. Levan,[2,16] P. O'Brien,[17] N. Tanvir,[16] R. Wijers,[18] C. Dumas,[15] O. Hainaut,[15] L. Amati,[4] E. Cappellaro,[19,20] A.J. Castro-Tirado,[21] F. Frontera,[4,22] J. Greiner,[23] K. Kawabata,[24] K. Maeda,[2,25] P. Møller,[14] L. Nicastro,[4] E. Rol[17]

Astro-ph/0603495

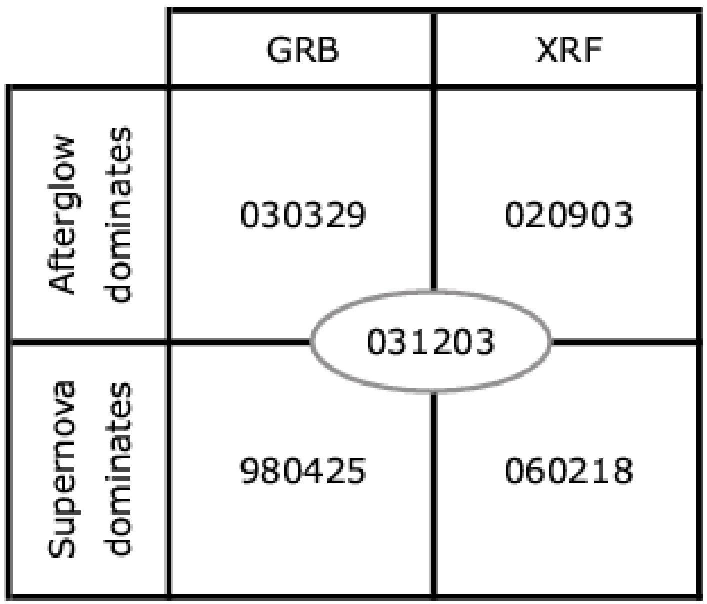

Fig. 6.—
Four-field diagram representing different varieties of Supernova-GRBs. There are differences in high-energy properties defining the peak energy of the burst, as well as in the optical afterglow appearance. SN 2006aj fills in the lower right of this diagram, as an XRF with supernova light dominating the transient.

Astro-ph/0403399 Ph. Podsiadlowski

Table 1. Rates in an average galaxy

	Rate (yr^{-1})
Core-collapse supernovae	7×10^{-3}
Radio pulsars (Galactic)	4×10^{-2}
SNe Ib/c	1×10^{-3}
Hypernovae	$\sim 10^{-5}$
GRBs (for different effective beaming angles θ)	
$\theta = 1°$	6×10^{-4}
$\theta = 5°$	3×10^{-5}
$\theta = 15°$	3×10^{-6}
Massive stars	
$> 20 M_\odot$	2×10^{-3}
$> 40 M_\odot$	6×10^{-4}
$> 80 M_\odot$	2×10^{-4}

GRBs for $\theta \sim 0.1°$ **7×10^{-3}**

Основной результат *оптического отождествления* GRB с объектами уже известной природы (галактиками со звездообразованием):

$$N_{GRB} \sim 10^{-8}\, yr^{-1} galaxy^{-1}.$$

Учитывая годовой темп взрывов массивных сверхновых

$N_{SN} \sim 10^{-3} – 10^{-2}\, yr^{-1} galaxy^{-1}$ и тот факт, что

все длинные GRBs связаны с взрывами массивных сверхновых,

отношение N_{GRB}/N_{SN} можно интерпретировать как сильную коллимацию квантов, *достигающих наблюдателя*, когда излучение источника GRB или какая-то его часть распространяется на очень далекое расстояние внутри маленького телесного угла

$$\Omega_{beam} = N_{GRB}/N_{SN} \sim (10^{-5} – 10^{-6}) \cdot 4\pi \;\; sr$$

Если GRB коллимированы так сильно, освещая только малую часть неба, тогда энергию каждого события нужно уменьшить на несколько порядков по сравнению с так называемым «изотропным эквивалентом» E_{iso} ($E_{iso} \sim 10^{51}$ - 10^{52} ergs и до 10^{53} ergs). Таким образом, полный выход энергии GRB может быть равен

$$E_{beam} = E_{iso}\, \Omega_{beam} / 4\pi \sim 10^{45} - 10^{47} \text{ ergs}.$$

Если энергия γ-лучей, распространяющихся в виде узкого пучка, достигающего наблюдателя на Земле, является всего лишь частью полной энергии, излученной источником GRB (от ~10^{47} до ~ 10^{49} ergs), тогда *остальная часть* энергии может быть излучается *изотропно* (или почти изотропно).

ИТОГО:

Существуют прямые и косвенные наблюдательные свидетельства в пользу физической связи массивных SN и длинных GRB. Эта связь была сначала обоснована тем, что все родительские галактики GRB оказались обычными (star-burst) галактиками с высокими темпами массивного звездообразования (Djorgovski et al., 2001; Frail et al., 2002; Sokolov et al., 2001; Savaglio 2006).

Но если бы в большом количестве случаев были получены ясные/бесспорные спектральные и фотометрические признаки ассоциации обычных массивных SN Ib/c (и других типов) и GRB, то кроме того, что это было бы прямым доказательством связи GRB с массивными звездами, мы могли бы иметь еще и сильные наблюдательные ограничения на угол коллимации гамма-лучей (GRB-beaming) и, тем самым, имели бы НАБЛЮДАТЕЛЬНУЮ оценку истинной полной энергетики источников GRB.

GRB – самые далекие взрывы SN. До каких Z могут наблюдаться гамма-всплески?

При каких Z взрывов массивных сверхновых уже нет?

J.Bloom et al. "Observations of the Naked-Eye GRB 080319B: Implications of Nature's Brightest Explosion" arXiv:0803.3215v1 [astro-ph]

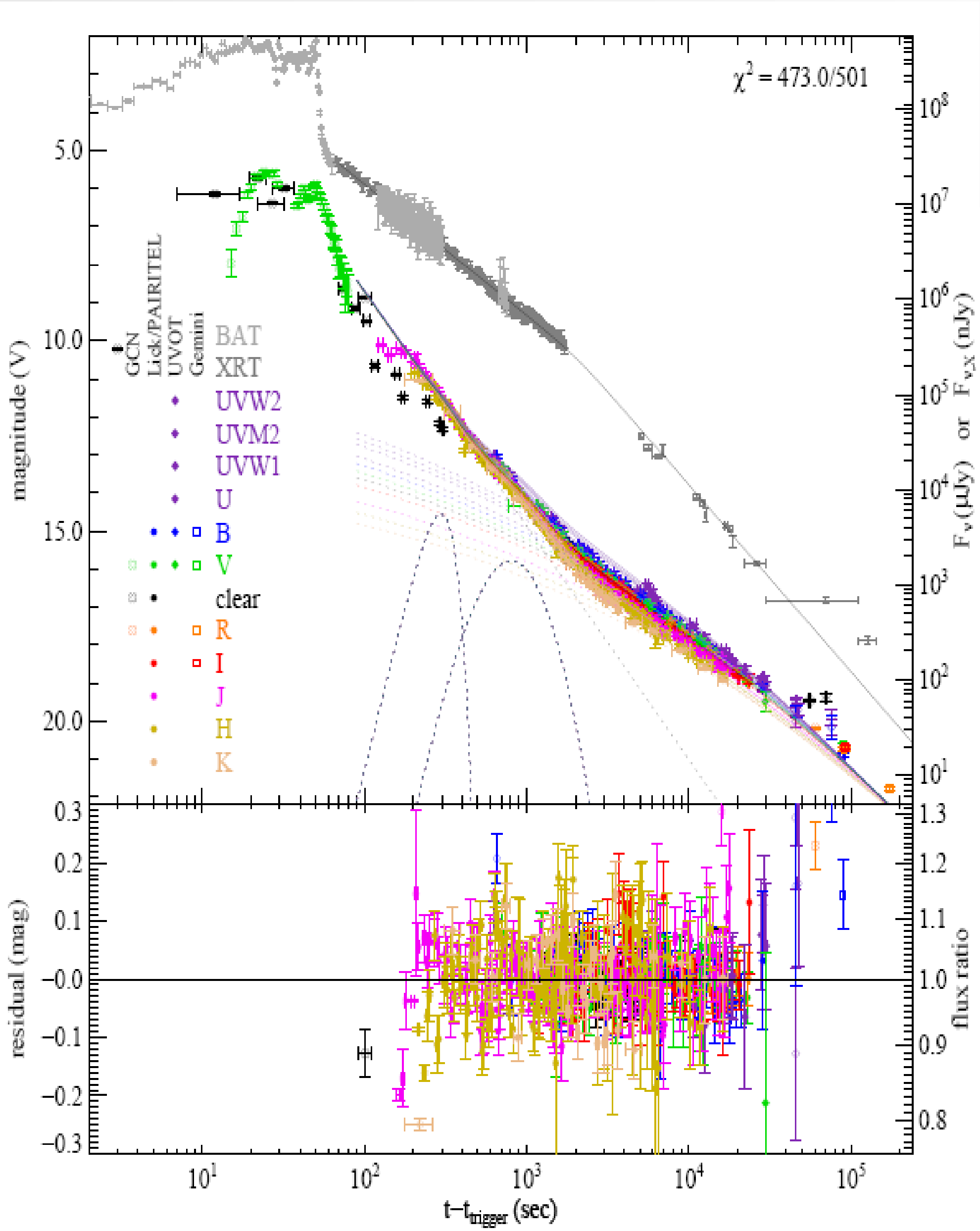

Fig. 1.— Light curves of the GRB080319B long-wavelength afterglow, fit by our empirical model, which allows (and in this case prefers) color change. This is a combination of data from the GCN Circulars (× symbols, including the prompt light curve as plotted by Karpov et al. 2008, in green), our observations from various ground-based instruments (KAIT, the Lick Nickel 1m, and PAIRITEL) and our re-reductions of the SwiftUVOT, XRT, and BAT data. The afterglow decays extremely rapidly, dropping from 5th to 21st magnitude in less than one day. For clarity, UV/O/IR data are corrected to V [Vega] mag using the model. Empty points were not used in the fitting in §3.2.

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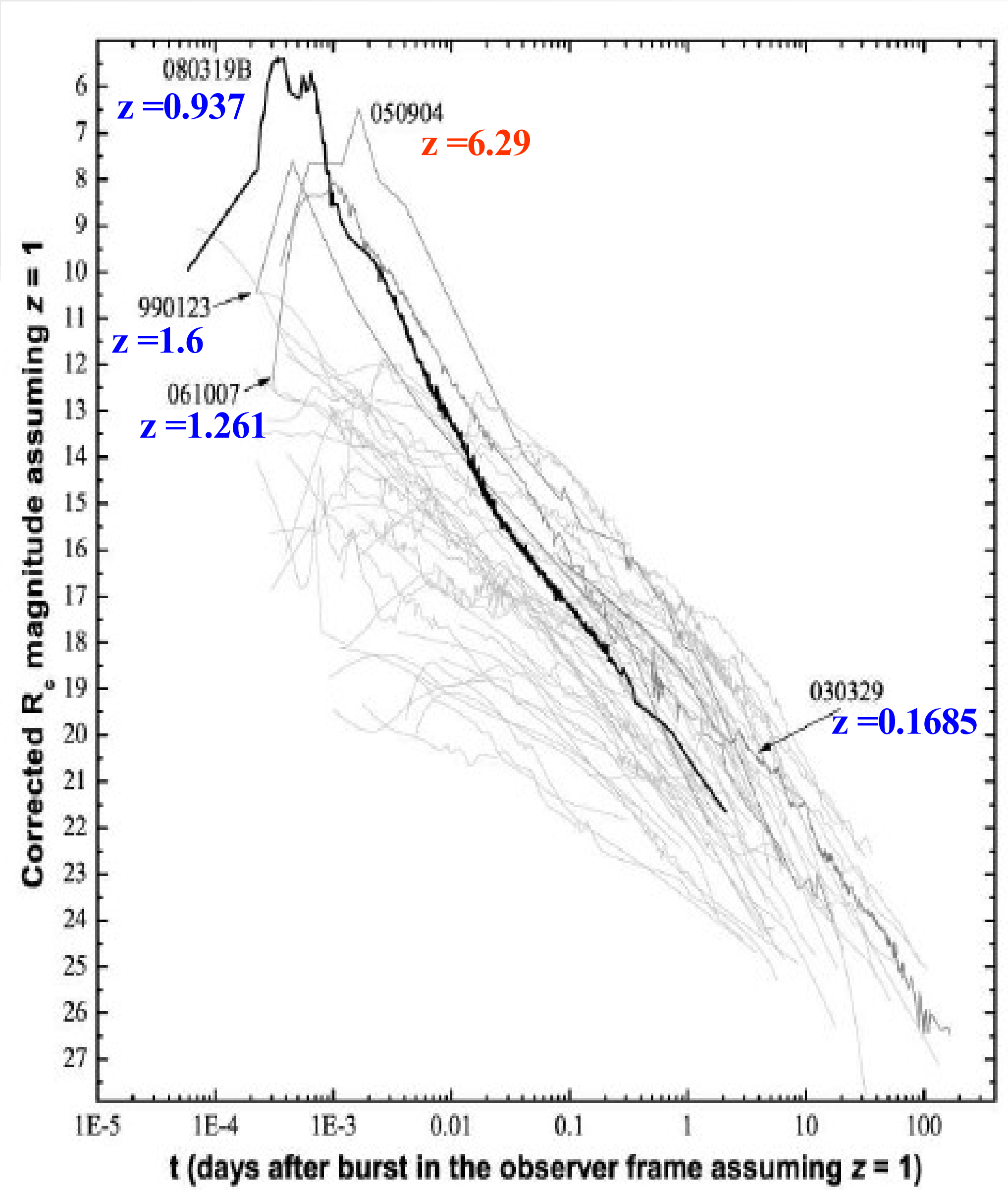

Fig. 4.— Comparison between the observed light curve of GRB080319B (z=0.937) and those of other GRB afterglows, both from the pre-Swift as well as the Swift era, shifted to a common redshift of z = 1 with the method of Kann et al. (2006). The prompt flash of GRB080319B is clearly shown to be the most luminous optical transient ever observed with a high degree of confidence. In spite of this, because of its rapid early decay the afterglow at late times is quite unremarkable, and is similar in this regard to the three other "ultra-luminous" gamma-ray bursts to date, GRB 990123 (z=1.6), GRB 061007 (z=1.261), and GRB 050904 (z=6.29). In contrast, the bursts that remain the brightest tend to be those with late plateaus and slow decays.

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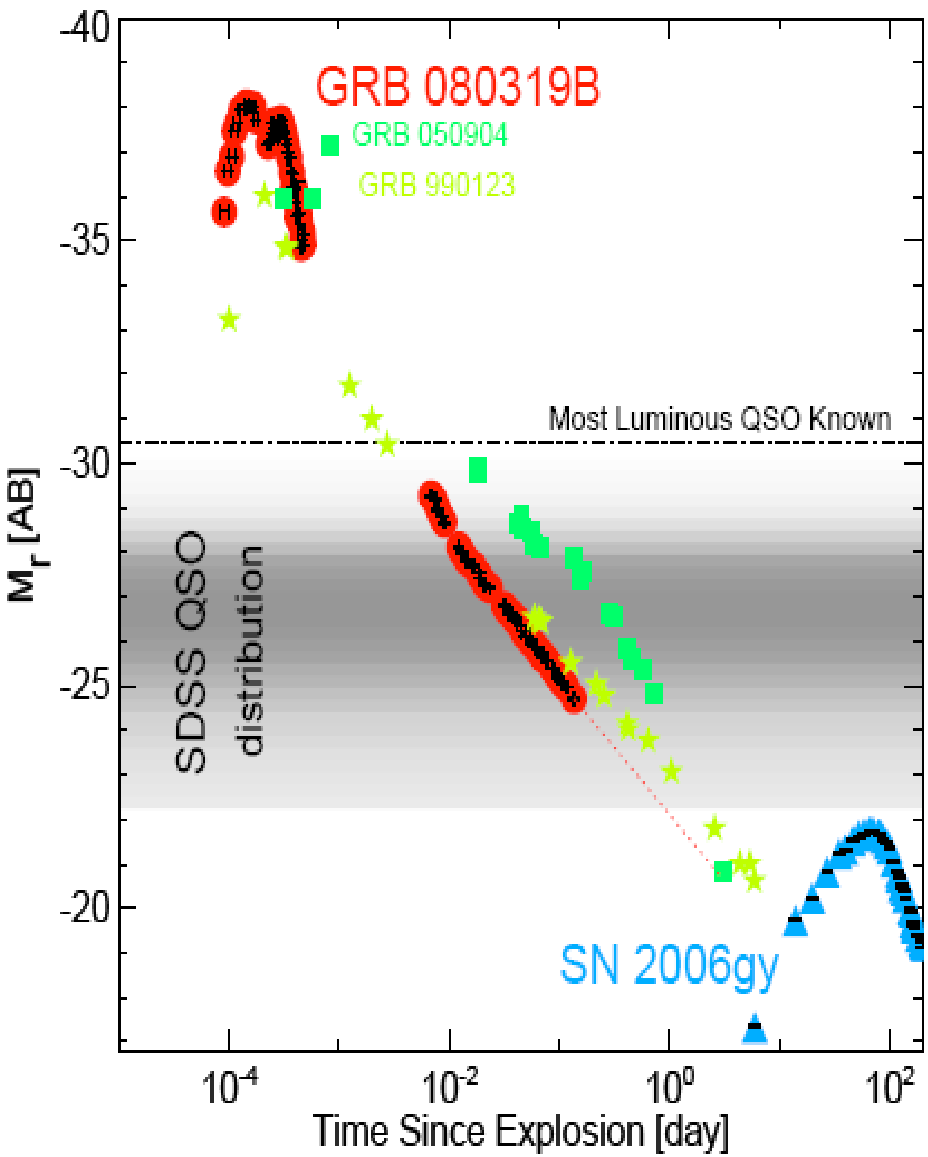

Fig. 5.—Rest-frame comparison of the most luminous optical/IR probes of the distant universe, showing the absolute magnitude (Mr, in AB magnitudes as defined by Oke & Gunn 1982) versus time of GRB080319B (red circles) and SN2006gy (blue triangles; Smith et al. 2007). Transformed light curves of GRB990123 (yellow stars; adapted from Galama et al. 1999) and GRB050904 (green squares; adapted from Kann et al. 2007a) are also shown. For reference, the most luminous known QSO (Schneider et al. 2007) is shown with a dashed horizontal line; the distribution of SDSS QSO magnitudes, adapted from Fig. 6 of Schneider et al., is shown as horizontal banding (darker indicates higher density of sources per unit magnitude). The afterglow of GRB080319B was the brightest GRB afterglow ever recorded and was at early times 103 times more luminous than the most luminous QSO; for 1 hr (in the rest frame) it was more luminous than the typical SDSS QSO.

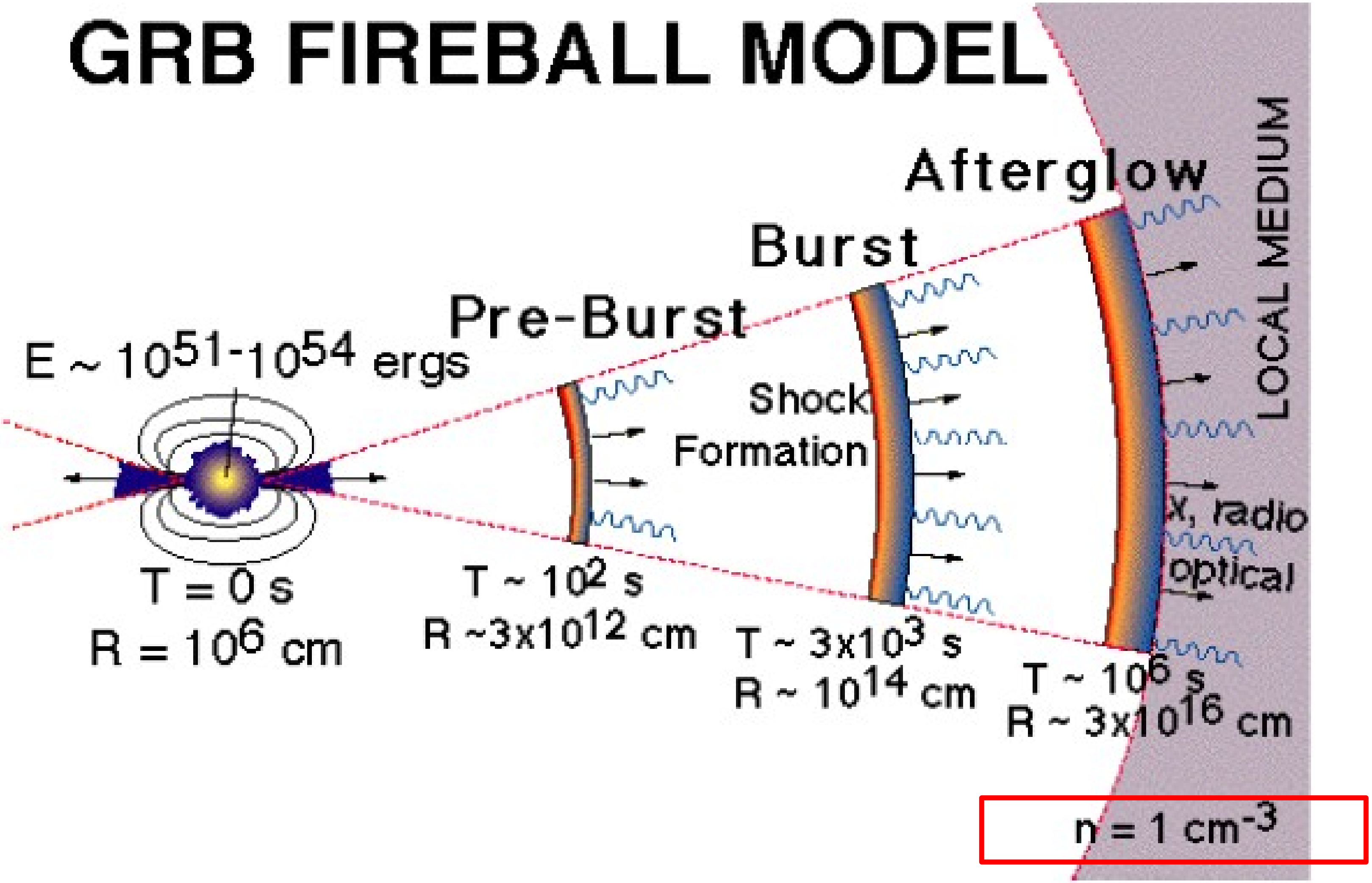

Fig. 1 Illustration of the FB model and its internal/external shock scenario, adapted from Ghisellini 2001.

В.И.Даль. Толковый словарь живого великорусского языка.

ПРЕДРАССУЖДЕНИЕ или *предрассудок* – предубежденье, твердое понятие, мнение, убежденье о деле, которое не довольно знаешь; мнение превратное или одностороннее, ложное; || поверье, суеверие. … … *Мы невольники общественных предрассудков.*

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Например, твердое убеждение большинства людей о том, что черные дыры уже открыты…

An interesting remark from astro-ph/0604047 (Branch et al.), concerning the classification of the core-collapse SNe:
SN 2005bf (Type Ib, or Ib/c, or Type Ibc) showed evidence for high velocity polar ejection, reminiscent of SN 1998bw-like explosions of massive stars, some of which produce GRBs. In view of the high ejected mass and the polar ejection, Folatelli et al. (2006) suggested that SN 2005bf may have been a transition event between ordinary SNe Ib/c and "hypernovae".

Therefore if SN 2005bf ejected hydrogen we should consider the possibility that SN 1998bw-like SNe Ic also do.

But the it is not forbidden to think that the point is in an asymmetric explosion of these core-collapse SNe and to do without introduction of a special class "hypernovae".

On asymmetry of explosions of core-collapse SNe (astro-ph/0701198)

F06 discussed models for SN 2005bf. Although the numerical results they presented were based on spherical symmetry, they envisaged **a grossly asymmetric explosion** having many features in common with the SNe that are associated with GRBs, for which *the most popular model* is the collapsar model (Woosley & Bloom 2006). In SN 2005bf, according to F06, a collapsar launched relativistic jets that drove a small fraction of the ejected matter into high-velocity ($v > 14{,}000$ km s^{-1}) bipolar flows...

Another issue is the distribution of hydrogen with respect to velocity. The progenitor star contained a surface layer of hydrogen. If the bipolar flows are of sufficiently wide opening angle, it may be that a pole-on observer sees only HV hydrogen in absorption, not PV hydrogen. But an equator-on observer would see PV hydrogen in absorption. Equator-on is statistically more likely than pole-on, yet it is not clear that any SN Ib/c has been seen to have PV, but not HV, hydrogen. Thus the F06 interpretation of SN 2005bf requires that SN 2005bf-like events are quite uncommon; otherwise, SNe Ib/c with PV but not HV hydrogen in absorption should be found.

Astro-ph/9909048   Bohdan Paczyński

5. Hypernova

While the term ‘hypernova’ became popular recently, it was been sporadically used in the past (e.g. Wilkinson & Bruyn 1990). It does not have a clear, universally accepted meaning. The following are several examples.

1. Hypernova is just a name. The optical light curve of GRB 970508 was several hundred times brighter than any SN ever discovered. The absolute luminosity of several other afterglows, e.g. 990123, 971214, 990510, was higher by another factor   100 (cf. Norris et al. 1999). So, rather than call it a super-super-nova, or a super-duper-nova, a term hypernova seems reasonable as a description of the phenomenon, with no implications for its nature.

2. …

The main result of *optical identification* of GRBs with objects of already known nature (star-forming galaxies) is $N_{GRB} \sim 10^{-8}\ yr^{-1} galaxy^{-1}$.

Allowing for the yearly rate of (massive) SN explosions $N_{SN} \sim 10^{-3} - 10^{-2}\ yr^{-1} galaxy^{-1}$ and the fact that *all* long-duration GRBs are related to explosions of massive SNe, the ratio N_{GRB}/N_{SN} should be interpreted as a strong collimation of quanta *reaching an observer*, when the radiation (a part of it) of the GRB source propagates to very long distances within a very small solid angle

$$\Omega_{beam} = N_{GRB} / N_{SN} \sim (10^{-5} - 10^{-6}) \cdot 4\pi \quad sr$$

If GRBs are so highly collimated, illuminating only a small fraction of the sky, then the energy of each event must be much reduced, by several orders of magnitude in comparison with a so called "isotropic equivalent" E_{iso} ($E_{iso} \sim 10^{51}$ - 10^{52} ergs and up to 10^{53} ergs). So, a total GRB energy release is

$$E_{beam} = E_{iso}\ \Omega_{beam} / 4\pi \sim 10^{45} - 10^{47}\ ergs\ .$$

If the energy of γ-rays propagating in the form of a narrow beam reaching an observer on the Earth is only a part of the total radiated energy of the GRB source (from ~10^{47} ergs to ~ 10^{49} ergs), then the *other part* of its energy can be radiated in *isotropic* (or almost isotropic) way indeed.

ApJ, 566, 1005-1017, 2002, D.Branch et al.

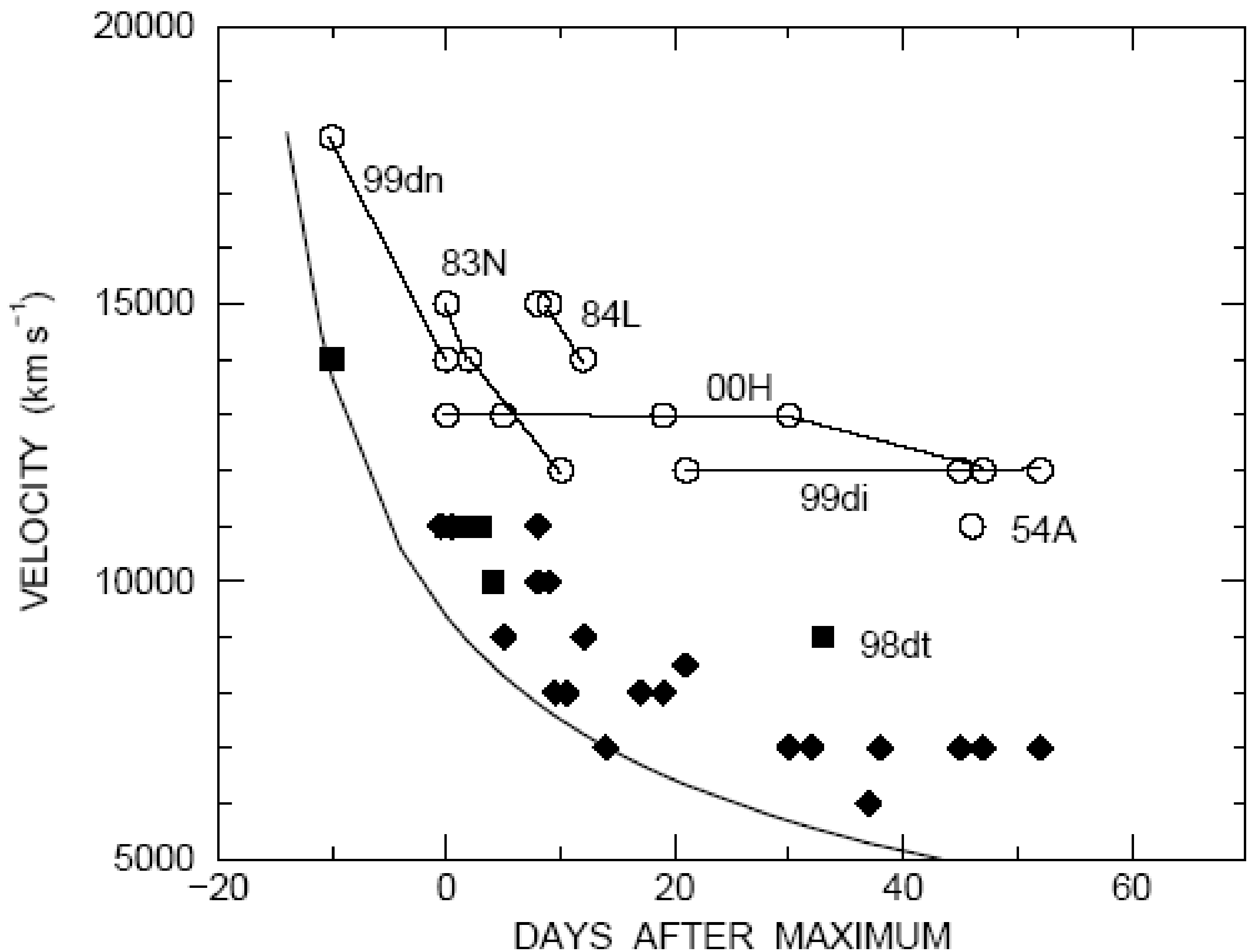

FIG. 23.—Minimum velocity of the He I lines (*filled squares when undetached, filled diamonds when detached*) and the minimum velocity of the hydrogen lines (*open circles; always detached*) are plotted against time after maximum light. The curve is the power-law fit to the velocity at the photosphere, from Fig. 22.

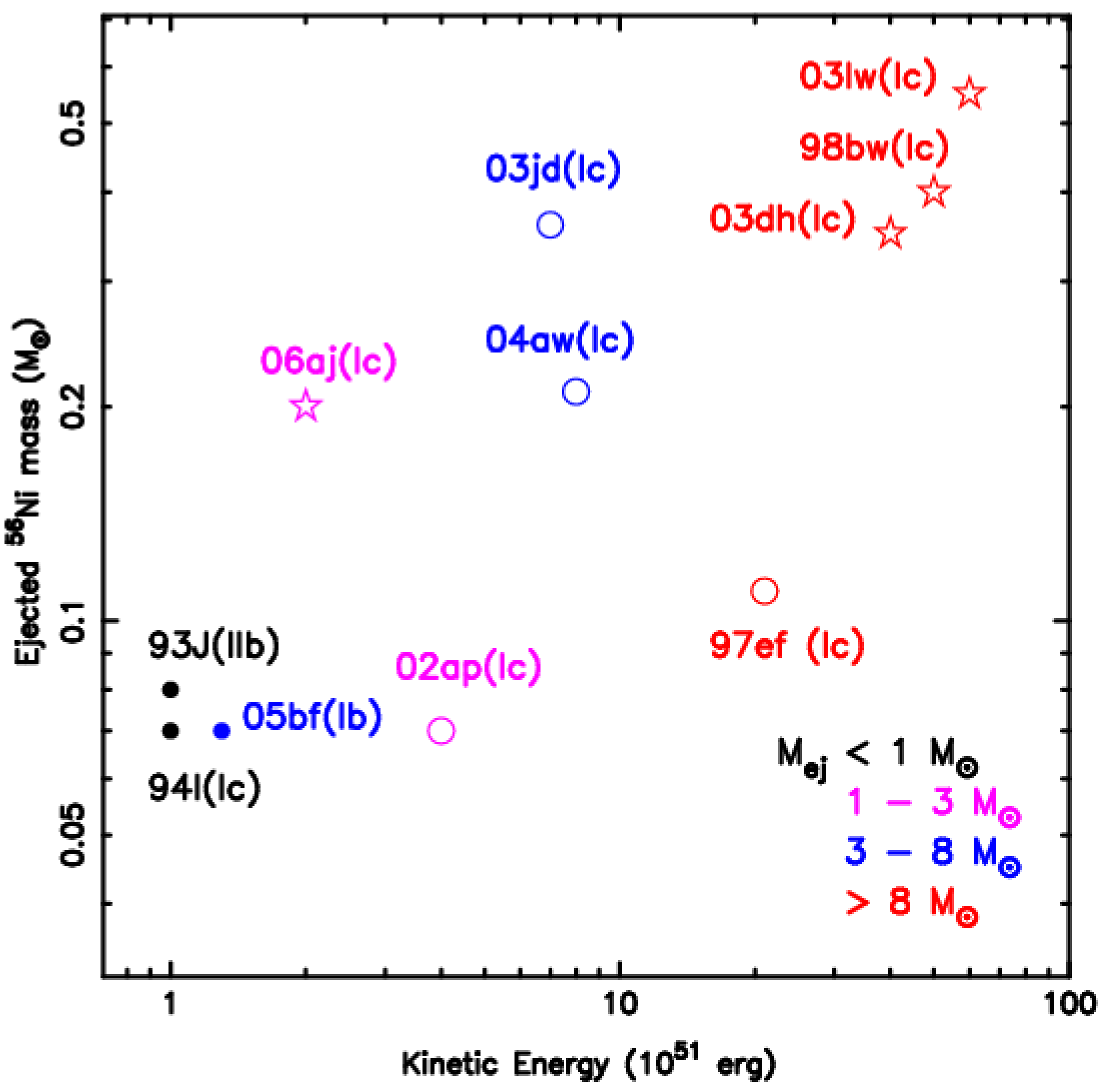

Figure 1: Relation between the kinetic energy of the explosion (E_K) and the mass of ejected ^{56}Ni [$M(^{56}Ni)$] of stripped CC-SNe (see supporting online text). Colors indicate the ejecta mass (M_{ej}). For SN IIb 1993J and SN Ib 2005bf, the ejecta mass after sub-tracting the He envelope mass is shown as M_{ej} , to compare with SNe Ic, which lack the He envelope. SNe associated with GRBs or an X-ray (XRF) are indicated by stars, and broad-lined SNe Ic without GRBs/XRFs by open circles. Other (normal) stripped CC-SNe are shown as dots.

Table S1: Supernova Samples

SN	Type	Observing Date	Days[1]	References	Figure[2]
1991N	Ic	1992-1-9	286	Lick (*S1*)	∘
1997dq	broad-Ic	1998-8-18	289	Lick (*S1*)	∘
1997ef	broad-Ic	1998-9-21	299	Lick (*S1*)	∘
2002ap	broad-Ic	2002-9-15	229	Subaru (*S12*)	∘
2003jd	broad-Ic	2004-9-12	323	Subaru (*S11*)	∘
2004dk	Ib	2005-7-6	342	Subaru	
		2005-8-26	392	Subaru	∘
2004fe	Ic	2005-7-6	250	Subaru	∘
		2005-8-26	300	Subaru	
2004gk	Ic	2005-7-6	224	Subaru	∘
2004gn	Ic	2005-7-6	218	Subaru	∘
2004gq	Ib	2005-8-26	258	Subaru	
		2005-10-25	318	Subaru	∘
		2005-12-27	381	Subaru	
2004gv	Ib/c	2005-7-6	206	Subaru	
		2005-8-26	256	Subaru	∘
2005aj	Ic	2005-8-26	189	Subaru	
		2005-10-25	249	Subaru	
		2005-12-27	312	Subaru	∘
2005kl	Ic	2006-6-30	220	Subaru	∘
		2006-12-25	398	Subaru	
2005kz	broad-Ic	2006-6-30	211	Subaru	∘
2005nb	broad-Ic	2006-6-30	195	Subaru	∘
		2007-1-24	403	Subaru	
2006F	Ib	2006-6-30	173	Subaru	
		2006-11-16	312	VLT	∘
2006T	IIb	2006-11-26	301	Subaru	
		2006-12-25	329	Subaru	∘
		2007-2-18	384	VLT	
2006ck	Ic	2007-1-24	249	Subaru	∘

[1]Days since the discovery.
[2]The spectra shown in Figures 1 and 2 in the main text are marked by circles.