INTERNATIONAL COOPERATION ON TRANSIENT OBJECT OBSERVATIONS: IMPORTANCE AND RECENT RESULTS

D. Nogami[1], T. Kato[2], H. Yamaoka[3], and M. Uemura[2]

[1] *Universtäts-Sternwarte, Geismarlandstr. 11, D-37083 Göttingen, Germany*
e-mail: daisaku@uni-sw.gwdg.de/nogami@kusastro.kyoto-u.ac.jp

[2] *Department of Astronomy, Kyoto University, Sakyo-ku, Kyoto 606-8502, Japan*

[3] *Department of Physics, Kyushu University, Ropponmatsu, Fukuoka 810-8560, Japan*

We are living in a very exciting era when the nature of the universe is dramatically being revealed. Transient objects are a group, research of which will promisingly become more active in astronomy. We review some topics currently urged to be solved by international cooperations, concentrating gamma-ray bursts, dwarf novae, X-ray transients, and supernovae among such transient objects. We then argue importance of the telescope distribution for covering whole the sky and of the international network for exchanging information and opinions.

1. INTRODUCTION

A variety of transient objects with quite short timescales has recently been discovered, giving unprecedented insights of the Universe. The study of these objects has been rapidly progressing. Most of the observations carried out so far, however, are too fragmentary and insufficient to reveal the whole nature of such phenomena. Then, it is the time that we must consider to establish the system to smoothly organize a coordinated international observation soon after a burst detection by various methods and to continue the observation until deducing all the physics which appear only in the active state. Significance of these observations will increase in the future. Since the Ukraine is located in a quite important place, we would appeal to the Ukrainian astronomical society for positive contributions to observations of transient objects.

We put focus mainly on optical observations, unless otherwise stated. Spotting gamma-ray bursts (GRBs), dwarf novae, X-ray transients (XRTs), and supernovae (SNe), we will outline some points which are desired to be observationally clarified, in the next section. Note that discoveries other than what we mention here is, of course, expected, because we can not explain all in this short contribution and this paper is based on our *current* knowledge. Because the progress of the science in this field is currently quite rapid, the contents of this paper may be already a little obsolete when this proceedings are published. We will describe some respects on the coordinated observations in the section 3. Then, the concluding remark is placed at the end.

2. OBSERVATIONS OF TRANSIENT OBJECTS

Here we pick up some types of transient objects, for which international cooperative observations will yield great improvement on our understanding. They are gamma-ray bursts, dwarf novae, X-ray transients, and supernovae. The study of the transient object physics has been quite rapidly progressing recently. Readers should keep in mind that some topics reviewed in this contribution may be a little *obsolete*, especially in the GRB field, even when the proceedings are published.

2.1 Gamma-Ray Bursts

Gamma-ray bursts are one of the most catastrophic and energetic events in the Universe. The duration of GRBs is quite short, from 0.01 to 1000 seconds, but some of their total radiated energies are believed to reach the order of 10^{53} erg.

The first GRB was discovered in 1969 [21]. During 23 years since then, the nature of GRB had been mystery, although thousands of burst events had been caught during this interval. The GRB burst study, then, had two great turning points. The first one is the advent of BATSE in 1992 [12]. This detector revealed the isotropic distribution of GRB in the sky, suggesting GRBs to occur at the cosmological distance, *e.g.*, [11]. The second is the discovery of the X-ray and optical afterglow of GRB970402 in 1997 [39]. Following this discovery, afterglows of many GRBs have been found successively, which have made rapid progress of the GRB study in these 3 years.

In the gamma ray region, the event shows violent variability in many cases, while the afterglow in X-ray to radio shows rather smooth power-law decay, where the power-law index α is of about 1.0 (see Greiner's personal collection of light curves, URL: *http://www.aip.de/~jcg/grb.html*). The optical flux of afterglows does not seem to be scaled directly by the GRB strength, *e.g.*, [1]. These two facts suggest that different radiation mechanisms work for the GRB and for the afterglow. The current standard GRB model, namely, the fireball+blast wave model ([43] for a review) depicts an image: a certain mechanism drives an expansion of a fireball, then, the internal shock in the relativistic ejecta causes gamma-ray radiation. After the ejecta collides with the ambient matter, the afterglow from X-ray to radio is generated in the forward external shock by synchrotron radiation. The radiation due to the forward shock in the late stage does not clearly reflect what the central engine is. This is why the early observations are needed.

This model generally explains observations of GRBs well, but still have some problems. One of the most important is the optical flash and the radio bump of GRB990123. Observations of this GRB by the Robotic Optical Transient Search Experiment (ROTSE) caught an optical peak of $m_V = 8.95$ about 30 sec after the BeppoSAX trigger [22]. This flash seemed to decay with $\alpha \sim 2.0$ for ~ 15 min, followed by a usual power-law decay $\alpha \sim 1.1$. The radio bump was seen about 1 day after the GRB event [13]. Such an optical flash and a radio bump may be explained by a reverse external shock, *e.g.*, [48]. Akerlof *et al.* [1], however, reported that their ROTSE follow-up observations of six GRBs with localization errors of 1 deg^2 or better produced no detection of the optical flash. It is needed to carry out as many follow-up observations as possible, as soon after the GRB trigger as possible, in order to make constraints on the mechanism and on the criteria for emergence of such exceptional behavior.

What is the central engine of the fireball? This is also a big problem. The currently strong hypotheses are 1) mergers of neutron star-neutron star or neutron star-black hole binaries [30], 2) collapsars of massive rapidly rotating stars with strong magnetic fields, so-called hypernovae, *e.g.*, [40], and 3) collapsars of supermassive neutron stars in low mass X-ray binaries, so-called Supranovae [55].

The GRB distribution in the host galaxies is predicted in the neutron-star binary model [3]: $\sim 15\%$ of all burst progenitors may be able to escape from their parent galaxy, and $\sim 50\%$ will be located more than 8 kpc from their original site. Clarification of the GRB locations may be a key to the progenitor problem.

Vietri [54] showed that the delay time (t_d) of the afterglow onset after the end of the GRB is a good indicator of the ambient matter density, which corresponds to the interstellar matter if $t_d \sim 15$ sec, to galactic halo if $t_d \sim 5$ min, and to the intergalactic matter if $t_d \sim 4$ hr. The measurement of the delay time in many GRBs by the prompt follow-up multi-wave length observation will make constraints on the progenitor, for example, collapsars of massive stars should occur in a dense medium and cause an afterglow immediately after the GRB.

In the case of GRB980425, the type-Ic supernova 1998bw was almost simultaneously discovered in the error box of the GRB position [13]. This association of a supernova and a GRB is explainable by the hypernova model [18, 29]. The redshift of SN 1998bw was measured to be z ~ 0.0085, meaning that γ-ray energy is about an order of 5 smaller than those of usual GRBs. There is a possibility that many such supernovae has been missed in the γ-ray region.

Taking advantage of the brightness of GRBs, there has been proposed a movement to make use of GRBs for investigation of the high-z universe. Using 7 GRBs with well-determined redshifts, Fenimore & Ramirez-Ruiz [9] found a relationship between the temporal variability of GRBs and the absolute luminosity: smooth bursts are intrinsically less luminous (see also [44]). This relation and reasonable assumptions concerning the star formation rate and the GRB rate will bring us information on the star formation history in the high-z region (*cf.* [24]). Confirmation of this relation by determining z in many GRBs is needed.

The BATSE and BeppoSAX projects have achieved a great success, but the large error box of, for instance, a few degree, at the early phase of GRB observations is one of the reasons why it is difficult to carry out follow-up observations. However, the next generation missions of HETE-2 (High Energy Transient Explorer, see *http://space.mit.edu/HETE/*) and *Swift* (see *http://swift.sonoma.edu*) will amazingly improve the situation. The latter is planed to have an ability to yield the GRB position of a few arcmin accuracy within ~ 15 sec after the burst and a set of information of the $\sim$ arcsec position, a finding chart, and the redshift of the source within ~ 200 sec. Coordinated observations of GRB afterglows promptly after catching GRBs will continue to renew our view of GRBs and the Universe.

2.2 Dwarf Novae

Dwarf novae are a class of cataclysmic variable stars, which are binary stars of a white dwarf and a late-type main-sequence star, and they show many kinds of variability mostly due to the accretion disk around the white dwarf (for a thorough review, [57]). Among dwarf novae, SU UMa-type stars are characterized by the two types of outburst, namely, normal outburst and superoutburst. The former typically lasts 3–5 days and the amplitude is of about 3–4 magnitude. The superoutburst lasts about 3 times longer than the normal outburst and reaches of about by 0.5–1 magnitude brighter than the normal outburst. Superhumps only observed during superoutbursts are modulations with ~ 0.1–0.3 mag. The superhump period ($P_{\rm sh}$) is 1–3% longer than the orbital period ($P_{\rm orb}$), and very gradually decreases as the superoutburst proceeds. These characteristics are basically understood in the frame of the thermal-tidal disk instability theory (for a review, *e.g.*, [38]).

Some stars out of such a standard scheme, however, recently have been reported. Several extreme stars in SU UMa-type dwarf novae, called WZ Sge stars, *e.g.*, [37], have been proven to show peculiar evolution of the superhump (see N99). For instance, in AL Com, modulations with a period equal to its orbital period were observed within 2 days from the onset of the 1995 superoutburst, then gradually declined (see [33]). Usual superhumps with a period 1.0% longer than $P_{\rm orb}$ were seen 10 days after. Interestingly, this superhump period became longer as time went, which may suggest extension of the accretion disk. The $P_{\rm sh}$-elongation phenomenon was also observed in other WZ Sge-related stars, HV Vir [20], SW UMa [32, 49] and V1028 Cyg [2].

Another interesting, recent topic concerning superhumps is the transition from the 'negative' superhump to the usual superhump during a superoutburst. This was observed around a maximum of a superoutburst in ER UMa [15], the prototype of another group of extreme SU UMa stars (for a review, [19]), and possibly during the 2000 superoutburst in BC UMa [53].

These phenomena would challenge the standard disk instability model, but the observations are still not enough to construct a new detailed model. It is needed to clarify the evolution of superhumps by continuous observations from soon after the superoutburst detection in many SU UMa-type dwarf novae.

2.3 Soft X-ray Transients

Soft X-ray transients, also called X-ray novae, are low-mass X-ray binaries of a neutron star or a black hole and a main-sequence, or a subgiant secondary star of typically less than 1 $M_\odot$ (for a review of SXTs, [52]). The outburst shape of SXTs have been pointed out to be similar to that of dwarf novae, especially for the fast-rise-exponential-decay-type outburst, *e.g.*, [23], and the trial to explain the SXT outbursts using the disk instability theory has been carried out since 1982 [6]. This challenge is still continuing, taking into account X-ray irradiation of the accretion disk and the secondary star, evaporation, and so on, *e.g.*, [5, 7, 8], which requires observers to reveal the evolution of the accretion disk during the outburst by continuous multiwavelength monitoring.

The superhumps are also seen in SXTs in outburst, *e.g.*, [36]. It is, however, difficult to recognize superhumps in SXTs, because of contamination of orbital modulations due to irradiation of the secondary star and long orbital periods ($\geq$ several hours). How the superhump in SXTs evolve is an interesting subject to test whether the disk instability theory works in SXTs in the same way in dwarf novae. In addition, one can make constrains on the binary parameters including the primary mass from the superhump observations [28]. This method is quite useful to roughly judge if the primary star is a black hole or not, because most of SXTs are quite faint in quiescence and it is difficult to make the radial velocity study, or even to find its optical counterpart.

In March 2000, an outburst of the SXT, XTE J1118+480 was detected by the RXTE All Sky Monitor [45]. Soon after the detection report to VSNET (vsnet-alert 4501), a VSNET campaign of the international coordinated observation of this star started (before the IAU Circular was published!) (see *http://www.kusastro.kyoto-u.ac.jp/vsnet/Xray/xtej1118.html*). Then, this campaign was extended to a multiwavelength one with the X-ray satellite ASCA (see *http://www.kusastro.kyoto-u.ac.jp/vsnet/Xray/xtej1118-camp.html*).

Most recently, two curious X-ray transients has been discovered successively. They are CI Cam [27, 50] and V4641 Sgr [17, 26, 51]. The peculiarities of these stars are their quite short durations of the ourbutst (a few days), and their bright quiescent magnitudes, a little fainter than 13 mag. Because of the short timescale of the outburst, such X-ray transients may have been missed many times so far. Considering their brightness, which means that they are close to us, say within 1.0 kpc [16], there possibly exist much more black holes in our vicinity than our expectation. We can see how important quick operations in response to a discovery of a transient object are.

2.4 Supernovae

The greatest topic in the recent supernova research is the utility of type Ia supernovae (SNeIa) as cosmological standard candles. The most impressive result would be that Einstein's cosmological constant was proved to exist in 1998 from the comparison of the recession velocities and the maximum visual magnitude of supernovae detected in the deep images, whose images have galaxies at the redshift of $\sim$ 0.3 to $\sim$ 0.8 [46, 41].

The progenitor of SNeIa is considered as a white dwarf in a binary system which explodes when exceeding the Chandrasekhar mass, *e.g.*, [34]. This scheme suggests the maximum brightness to be constant for all SNeIa. However, this constancy has been recently doubted from the observations, for instance, the discoveries SN 1991T and SN 1991bg. The former was $\geq$ 0.6 mag brighter than the average SNIa (*e.g.*, [10]) and the latter was over 1.0 mag fainter than the average SNIa (*e.g.*, [25]).

A statistical analysis of light curves of many type Ia supernovae gave an empirical relation between the light curve and the decline rate in the sense that an SNIa more rapidly declining is less luminous [42]. There is a correlation between the spectrum and the maximum brightness [35]. It was also reported that the SNIa brightness may be depend on the color of the host galaxy [4]. The characteristics of SNIa seem to have a correlation with the distance from the galaxy core [56]. Then, it was reported that the light curve before the maximum is different in type Ia supernovae in nearby galaxies and in far galaxies, even after corrected with the decline-rate correlation [47]. There has not yet existed a theoretical model which can explain all these features well. It is urgent to discover many type Ia supernovae as at an early phase as possible and to clarify the nature by dense follow-up observations.

The observation of line γ-rays emitted by the decay of radioactive elements will give us precious information on the nature of SNeIa, especially the distribution of those elements which are the energy source of supernovae. In this observation, it is crucial to inform γ-ray observers of the discovery of a supernova and its type in a quite early phase, because the line γ-ray reaches its maximum intensity earlier than the optical light. It is only in SN 1987A in the Large Magellanic Cloud and in 1991T that the γ-ray lines have been detected so far.

The relationship between peculiar supernovae and GRBs is as we have already mentioned.

Conclusively, of importance are discovery of many SNe and reveal of its nature by 1) detection of supernovae in an early phase by systematic observations, 2) follow-up observations to confirm the existence, to carry out astrometry, and to clarify the type, and 3) long-term monitoring to draw a detailed light curve and chase the spectrum variation.

3. INTERNATIONAL COOPERATION

As we have reviewed so far, there are many topics about which we can deduce fruitful information only by international cooperative observations of transient objects from soon after onsets of *bursts*. Because of short timescales of the phenomena and need of continuous coverage as long as possible, we must consider two critical infrastructure to realize those observations. One is by the telescope network, and the other is by the method of information exchange.

3.1 Telescope Network

The ideal situation is that telescopes usable for those observations are distributed all over the world, and whole the sky is observable anytime by several, or more, telescopes (at least one is for photometry/imaging, at least one is for spectroscopy, one is for spectropolarimetry if possible) in each wavelength. The current situation is, unfortunately of course, far from it.

The GRB flashes, *i.e.*, simultaneous optical flashes with the γ-ray like as observed with GRB 990123, cannot be observed everywhere on the Earth. The maps of the Earth viewed from the direction of GRBs at the moment of GRB detections (*http://www.rc.kyushu-u.ac.jp/~yamaoka/GRB/grb.html*, cooperated with A. Nomura) show the "observable hemisphere" of the GRB flashes. Of course, the GRB flashes cannot be observed from the sunlit portion of this map even if they existed. The observable region is quite restricted. For example, Ukrainian people might be able to carry out the search of the GRB970828 afterglow from the evening. The early afterglow of GRB990506 could be caught only from the east area of Asia, Australia, and New Zealand. After the observation in these region, the results would have been relayed to following observers in the central Asia and Europe.

In making a plan of an international multi-longitudinal campaign at this time, it should be emphasized that Ukraine is located in a quite important point. In the north hemisphere, there are relatively many telescopes from Europe to North America. We can expect relatively dense coverage in this region. The region from North America to Europe, however, has fewer eyes to the sky. Especially, only a few large telescopes with an aperture > 2 m exist in this region (see *http://www.seds.org/billa/bigeyes.html*). If we consider only over-2.5-m telescope, the Crimean Astrophysical Observatory has the very *next* telescope to the large telescopes in Hawaii. It is, therefore, expected that the Crimean Observatory plays a quite important role in future international campaigns of transient object observations by spectroscopy. To fill the gap from Hawaii to Ukraine, it is also expected that 3-m, or larger, telescopes are constructed in Japan or in the Asian continent.

As for photometry, more observatories can join international campaigns. Recently, as the CCD camera has very rapidly become a popular device even for amateur observers, the chances of collaboration between professionals and amateurs has been increasing. It is, hence, easier to organize a photometric campaign than a spectroscopic one. Even in this case, the coverage in the hemisphere from North America to Europe is sparser than in the hemisphere from Europe to North America. Contributions from Ukraine does not decrease their importance even in this field.

It will become more important for observatories to accept Target-of-Opportunity observations more flexibly. The telescopes and detector systems to be constructed in future should be designed to be able to change the observation mode in a short time in response to a burst alert.

3.2 Method of Information Exchange

The information should be easily, rapidly, and smoothly exchanged between the discoverer(s) of a burst and other observers and between preceding observers to following observers. This leads to effective calls for observation from whole the world, sharing the current state of the target, and discussion of the observation strategy which will vary in time according to various factors, for instance, the target state and the status of other observers.

Such an information network is now being developed, such as The GRB Coordinates Network (GCN; *http://gcn.gsfc.nasa.gov/gcn/*), the Variable Star Network (VSNET; *http://www.kusastro.kyoto-u.ac.jp/vsnet/*), and so on. The VSNET is basically an aggregation of mailing lists concerning variable stars, especially transient objects described here. Subscribers live in over 100 countries and exceed 500 persons. An article posted to a sub-list of VSNET is distributed to all subscribers of the list within one hour. Making use of VSNET, many international coordinated campaigns have been organized, and yielded splendid results. One most recent example is the simultaneous multi-wavelength observations of the X-ray transient, XTE J1118+460 in outburst from X-ray by ASCA to near-IR (see *http://www.kusastro.kyoto-u.ac.jp/vsnet/Xray/xtej1118-camp.html*).

The GCN is a network specialized to GRB, as the name indicates. Although GCN has a mailing list for follow-up observers, the unique point is that the dedicated phone line (but currently only in US) and the internet socket connection are available. The latter two enable the GCN computer to distribute the coordinates and the time obtained by the BATSE and other detectors in space to the computers at observatories within a few second. The combination of this system and automated robotic telescopes, like ROTSE, surely bears fruitful results. If a new object is discovered by prompt comparison of the images given by the telescope with old images or plate archives and spectra of the new object can be obtained also by a robotic telescope within a short timescale, the study of transient objects will make a great progress[1].

Consolidation of the network is indispensable for further progress of the transient object observations, and we are on the way of the development. This should be a topic to be discussed by all astronomers in the related field.

REFERENCES

[1] *Akerlof C., Balsano R., Barthelmy S., et al.* // Astrophys. J. Lett.–2000.–**532**.–P. L25–L28.

[2] *Baba H., Kato T., Nogami D., et al.* // Publs Astron. Soc. Jap.–2000.–**52**.–P. 429–436.

[3] *Bloom J. S., Sigurdsson S., Pols O. R.* // Mon. Notic. Roy. Astron. Soc.–1999.–**305**.–P. 763–769.

[4] *Branch D., Romanishin W., Baron E.* // Astrophys. J.–1996.–**465**.–P. 73–78.

[5] *Cannizzo J. F.* // Astrophys. J.–2000.–**534**.–P. L35–L38.

[6] *Cannizzo J. F., Wheeler J. C., Ghosh P.* // Pulsations in Classical and Cataclysmic Variable Stars / Eds J. P. Cox, C. J. Hansen.–Univ. of Colorado Press, Boulder, 1982.–P. 13.

[7] *Esin A. A., Kuulkers E., McClintock J. E., et al.* // Astrophys. J.–2000.–**532**.–P. 1069–1077.

[8] *Esin A. A., Lasota J. -P., Hynes R. I.* // Astron. and Astrophys.–2000.–**354**.–P. 987–994.

[9] *Fenimore E. E., Ramirez-Ruiz E.* // Astrophys. J.–2000.–submitted (astro-ph/0004176).

[10] *Filippenko A. V., Richmond M. W., Matheson T. et al.* // Astrophys. J. Lett.–1992.–**384**.–P. L15–L18.

[11] *Fishman G. J., Meegan C. A.* // Annu. Rev. Astron. and Astrophys.–1995.–**33**.–P. 415–458.

[12] *Fishman G. J., Meegan C. A., Wilson R. B., et al.* // Astrophys. J. Suppl. Ser.–1994.–bf 92.–P. 229–283.

[13] *Galama T. J., Briggs M. S., Wijers R. A., et al.* // Nature.–1999.–**398**.–P. 394–399.

[14] *Galama T. J., Vreeswijk P. M., van Paradijs J., et al.* // Nature.–1998.–**395**.–P. 670–672.

[15] *Gao W., Li Z., Wu X., et al.* // Astrophys. J. Lett.–1999.–**52**.–P. L55–L58.

[16] *Hjellming R. M.* // Astrophys. J. Lett.–2000.–submitted.

[17] *in't Zand J., Heise J., Bazzano A., et al.* // IAU Circ.–1999.–N 7119.

[18] *Iwamoto K., Mazzali P. A., Nomoto K., et al.* // Nature.–1998.–**395**.–P. 672–674.

[19] *Kato T., Nogami D., Baba H., et al.* // Disk Instabilities in Close Binary Systems / Eds S. Mineshige, J. C. Wheeler.–Tokyo: Universal Academy Press, 1999.–P. 45–52.

[20] *Kato T., Nogami D., Baba H., et al.* // Wild Stars in the Old West: Proc. 13th North American Workshop on Cataclysmic Variables and Related Objects / Eds S. B. Howell, E. Kuulkers, C. Woodward.–San Francisco: ASP, 1998.–P. 9–17.

[1]This is very one of the aims of the *Swift* project.

[21] *Klebesadel R. W., Strong I. B., Olson R. A.* // Astrophys. J. Lett.–1973.–**182**.–P. L85–L88.

[22] *Kulkarni S. R., Djorgovski S. G., Odewahn S. C., et al.* // Nature.–1999.–**398**.–P. 389–394.

[23] *Kuulkers E.* // Disk Instabilities in Close Binary Systems / Eds S. Mineshige, J. C. Wheeler.–Tokyo: Universal Academy Press, 1999.–P. 169–176.

[24] *Lamb D. Q., Reichart D. E.* // Astrophys. J.–2000.–**536**.–P. 1–18.

[25] *Leibundgut B., Kirshner R. P., Phillips M. M., et al.* // Astron. J.–1993.–**105**.–P. 301–313.

[26] *Markwardt C. B., Swank J. H., Marshall F. E.* // IAU Circ.–1999.–N 7120.

[27] *Marshall F. E., Strohmayer T. E., Lewin W. H. G.* // IAU Circ.–1998.–N 6857.

[28] *Mineshige S., Hirose M., Osaki Y.* // Publs Astron. Soc. Jap.–1992.–**44**.–P. L15–L18.

[29] *Nakamura T., Mazzali P. A., Nomoto K., et al.* // Astron. Nachr.–1999.–**320**.–P. 363.

[30] *Narayan R., Paczyński B., Piran T.* // Astrophys. J. Lett.–1992.–**395**.–P. L83–L86.

[31] *Nogami D.* // Disk Instabilities in Close Binary Systems / Eds S. Mineshige, J. C. Wheeler.–Tokyo: Universal Academy Press, 1999.–P. 13–20.

[32] *Nogami D., Baba H., Kato T., et al.* // Publs Astron. Soc. Jap.–1998.–**50**.–P. 297–302.

[33] *Nogami D., Kato T., Baba H., et al.* // Astrophys. J.–2000.–**490**.–P. 840–846.

[34] *Nomoto K., Iwamoto K., Kishimoto N.* // Science.–1997.–**276**.–P. 1378–1382.

[35] *Nugent P., Phillips M., Baron E., et al.* // Astrophys. J. Lett.–1995.–**455**.–P. L147–L150.

[36] *O'Donoghue D., Charles P. A.* // Mon. Notic. Roy. Astron. Soc.–1996.–**282**.–P. 191–205.

[37] *O'Donoghue D., Chen A., Marang J. P., et al.* // Mon. Notic. Roy. Astron. Soc.–1991.–**250**.–P. 363–372.

[38] *Osaki Y.* // Publs Astron. Soc. Pacif.–1996.–**108**.–P. 39–60.

[39] *Paczyński B., Wijers R.* // Nature.–1997.–**386**.–P. 650–651.

[40] *Paczyński B.* // Astrophys. J.–1998.–**494**.–P. L45–L48.

[41] *Perlmutter S., Aldering G., Goldhaber G., et al.* // Astrophys. J.–1999.–**517**.–P. 565–586.

[42] *Phillips M. M.* // Astrophys. J. Lett.–1993.–**413**.–P. L105–L108.

[43] *Piran T.* // Phys. Rep.–1999.–**314**.–P. 575–667.

[44] *Reichart D. E., Lamb D. Q., Fenimore E. E., et al.* // Astrophys. J.–2000.–submitted (astro-ph/0004302).

[45] *Remillard R., Morgan E., Smith D., et al.* // IAU Circ.–2000.–N 7389.

[46] *Riess A. G., Filippenko A. V., Challis P., et al.* // Astron. J.–1998.–**116**.–P. 1009–1038.

[47] *Riess A. G., Filippenko A. V., Li W., et al.* // Astron. J.–1999.–**118**.–P. 2668–2674.

[48] *Sari R., Piran T.* // Astrophys. J.–1999.–**520**.–P. 641–649.

[49] *Semeniuk I., Olech A., Kwast T., et al.* // Acta Astron.–1997.–**47**.–P. 201–209.

[50] *Smith D., Remillard R., Swank J., et al.* // IAU Circ.–1998.–N 6855.

[51] *Stubbings R., Pearce A.* // IAU Circ.–1999.–N 7253.

[52] *Tanaka Y., Shibazaki N.* // Annu. Rev. Astron. and Astrophys.–1996.–**34**.–P. 607–644.

[53] *Uemura M., Kato T., Shugarov S. Y., et al.* // 2000, vsnet-alert 4586 (*http://www.kusastro.kyoto-u.ac.jp/vsnet/Mail/vsnet-alert/msg*04586*.html*)

[54] *Vietri M.* // Astroparticle Phys.–in press (astro-ph/0003036).

[55] *Vietri M., Stella L.* // Astrophys. J. Lett.–1999.–**527**.–P. L43–L46.

[56] *Wang L., Hoflich P., Wheeler J. C.* // Astrophys J. Lett.–1997.–**483**.–P. L29–L32.

[57] *Warner B.* Cataclysmic Variable Stars.–Cambridge Academy Press, Cambridge, 1995.