Abstracts of the Workshop

"Gamma-Ray Bursts: New Missions to New Science"

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Extreme Universe Laboratory
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Contents

Measuring cosmological parameters with Gamma-Ray Bursts

Lorenzo Amati

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Abstract

Given their huge isotropic-equivalent radiated energies, up to more than 10^{54} erg released in a few tens of seconds, and their redshift distribution extending up to more than z = 8, Gamma-Ray Bursts (GRB) are in principle a powerful tool for measuring the geometry and expansion rate of the Universe. However, they are not standard candles given that their luminosities span several orders of magnitude, even when considering possible collimation angles. In the recent years, several attempts to exploit the correlation between the photon energy at which the νF_ν spectrum peaks ("peak energy") and the radiated energy (or luminosity) for using GRBs as tools (complementary to other probes like SN Ia, BAO and the CMB) for the estimate of cosmological parameters have been made. These studies show that already with the present data set GRBs can provide a significant and independent confirmation of $\Omega_M \sim$ 0.3 for a flat LambdaCDM universe and that the measurements expected from present and next GRB experiments (e.g. Swift, Fermi/GBM, SVOM, CALET/GBM, UFFO) will allow us to constrain Ω_M, Ω_Λ, and, in particular, to get clues on dark energy properties and evolution.

Rapid TeV and GeV variability in AGNs as result of Jet-Star interaction

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Abstract

We propose a new model for the description of ultra-short and short flares from TeV and GeV AGNs by compact magnetized condensations (blobs), produced when red giant stars or gas clouds cross the jet close to the central black hole. Our study includes a simple dynamical model as 2D relativistic HD for the evolution of the envelope lost by the star in the jet, and its high energy non-thermal emission through different leptonic and hadronic radiation mechanisms. We show that the fragmented envelope of the star can be accelerated to Lorentz factors up to 100 and radiate effectively the available energy in gamma-rays predominantly through proton, electron synchrotron radiation or external inverse Compton scattering of electrons or proton-proton collisions. The model readily explains the day-long and variable on timescales of hours GeV gamma-ray flare observed from 3C454.3 on top of the weeks-long plateau observed during November 2010. The model can also explain the minute-scale TeV flares from the blazar PKS 2155-304 and day-scale TeV flares from M87.

Galaxy clusters with dark energy

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Abstract

Dark energy can produce a significant change in the structure of outer parts of large galaxy clusters. Hot gas could flow from galaxy clusters with increasing speed due to antigtavity action of the dark energy.

Spectral evolution in GRBs: confronting the predictions of the internal shock model to observations in the Fermi era

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Abstract

Several general trends are identified in the prompt GRB emission: e.g. hard-to-soft evolution, pulse width evolution with energy, time lags, hardness-intensity and hardness-fluence correlation. Recently Fermi has significantly extended the spectral coverage of the GRB prompt emission and improved the characterisation of the spectral evolution. We examined how the internal shock model can reproduce these observations. We present a comprehensive set of simulations of a single pulse and investigate the impact of the model parameters, related to the shock microphysics (energy redistribution in particles and magnetic field), and to the initial conditions in the ejecta (kinetic energy, Lorentz factor). We find a general qualitative agreement between the model and the various observations used for the comparison. The best quantitative agreement is obtained for (i) steep electron slopes ($p > 2.7$), (ii) microphysics parameters varying with shock conditions so that more electrons are accelerated in stronger shocks, (iii) steep variations of the initial Lorentz factor in the ejecta.

Jet propagation within the Collapsar model

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Abstract

A necessary condition for the formation of a GRB within the framework of the Collapsar model is the successful breakout of the jet from the star. This breakout leaves a distinctive imprint on the distribution of GRB durations: a plateau in the distribution at times shorter than the typical breakout time.

In this talk I will show that this plateau exists in the duration distributions of GRBs observed by all major GRB satellites. I will discuss the implications of this plateau on low luminosity GRBs and present a new classification method for Collapsar GRBs. Finally I will discuss the different physical models for Collapsar jets and the difference in their propagation within the star. I will show how we can distinguish between the jet models according to the breakout times obtained from observations.

Radiation mechanisms for relativistic jets in Gamma-Ray Bursts

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Abstract

We present a review of most efficient radiation mechanisms for relativistic jets, keeping in mind their application to Gamma-Ray Bursts. We also discuss possible pathways for generating non-thermal energetic particles, which are responsible for the observed GRB emission. A special emphasis is put on the problems faced by the existing models, as well as on the latest developments in the field.

Small, faster, better rapid-Optical/IR instruments for new GRB science

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Abstract

In the current budget era, new, large dedicated GRB missions seem unlikely. Opportunities to put new science instruments into space exist, but they are highly constrained. There are some GRB missions planned, but uncertain, such as SVOM, and these have limited new capabilities. Without the opportunity for multi-ton instruments on precision-pointed spacecraft, is there a future for multi-band GRB studies after SWIFT?

Using real spacecraft data, I show that a remarkable number of GRBs can be located with a much smaller instrument than Swift. With the additional capability of very rapid optical follow-up via a beam-steering mirror system, numerous topics in new GRB science are possible with small spacecraft, without special pointing stabilization. Emphasizing the use of existing optical and X-ray data, I give hard rate predictions for X-ray, optical and IR detections as a function of instrument collecting area. This work significantly extends my previous work in this area, using larger samples with better optical coverage for more definitive results. I also discuss the new science possible with rapid ($\leq$ 10 s) optical-IR response and time resolution ($\leq$10 s), which includes: identifying internal shock and reverse shock mechanisms and magnetically dominated jet structure; independently testing for high bulk Lorentz factors from optical measurements (for comparison with high Lorentz factors from Fermi); measuring the evolution of the IR/optical emission ratio to measure dust evaporation and dust properties in the immediate vicinity of the host, one of the few measurements of dust associated with a single star outside our galaxy.

New Results on the Gamma-Ray Burst Supernova Connection

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Abstract

A conclusive link between GRBs and broad-lined Type Ic SNe has been shown. The sample of well-studied events has now grown large enough to do statistics on larger samples. What is the luminosity distribution? How spectrally similar are GRB-SNe to the prototype SN 1998bw? I will present the results of several new studies on GRB-SNe that have been detected over the last years.

Recent advances in our understanding of GRB emission mechanism

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Abstract

After a brief summary of key observational properties of gamma-ray prompt emission I will describe recent advances to our understanding of the emission mechanism. I will describe the strength and weaknesses of the internal shock and Poynting jet models. The high energy gamma-ray radiation detected by the Fermi satellite from GRBs and their origin will also be discussed. A brief summary of the successes and limitations of the photospheric radiation model, and neutron-proton collision model will also be provided.

Photospheric emission from radiation mediated shocks in GRBs

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Abstract

A shock that forms below the photosphere of a gamma-ray burst outflow is mediated by Compton scattering of radiation advected into the shock by the upstream fluid. The characteristic scale of such a shock, a few Thomson depths, is larger than any kinetic scale involved by several orders of magnitude. Hence, unlike collisionless shocks, radiation-mediated shocks cannot accelerate particles to nonthermal energies. The spectrum emitted by a shock that emerges from the photosphere of a GRB jet reflects the temperature profile downstream of the shock, with a possible contribution at the highest energies from the shock transition layer itself. In this talk, I will discuss the properties of radiation-mediated shocks that form during the prompt phase of GRBs, and will present results of computations of the time-integrated spectrum emitted by the shocked fluid following shock breakout. I'll show that the time-integrated emission from a single shock exhibits a prominent thermal peak, with the location of the peak depending on the shock velocity profile, and that multiple shock emission can produce a spectrum that mimics a Band spectrum.

Numerous optical transients discovery by MASTER-Net.

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Abstract

The Global MASTER-Net developed as the universal system which simultaneously presents fast reactive follow-up color and polarization system and fast synoptic survey up to 19-20 mag. About 400 bright optical transients have been discovered during synoptic survey: supernovae (neutron stars and black holes formation and search of dark energy), dwarf novae, novae (thermonuclear burning on white dwarfs in binary systems and accretion process), quasar and blazar activities (luminous of relativistic plasma near super massive black holes) and other short-time living objects available for optical observations.

High-redshift GRB hosts as cosmological tool

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Abstract

Detailed self-consistent calculations to address the process of cosmic star formation in the early Universe will be presented and results from N-body, hydrodynamical, chemistry simulations following stellar evolution and metal pollution for different star formation (Population III and PopulationII-I) regimes will be shown. Implications of the different parameters and feedback mechanisms on the formation of primordial galaxies will be introduced, with particular emphasis on the observable and physical features of those star forming objects that might host the first GRB events in the cosmological landscape. Consequences for primordial GRB hosts as tracers of different star formation regimes and as possible cosmological tools will be discussed, as well.

GRB spectral evolution: from complex profile to basic structure

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Abstract

We investigated the dependence of a spectral lag on energy band based on 28 bright GRBs detected by the SPI and IBIS/ISGRI instruments on the INTEGRAL observatory. It was found that for simple structure bursts or well separated pulses of multi-pulse bursts the spectral lag can be approximated by the relation $t \sim Alog(E)$, where A is a positive parameter, which correlates with pulse duration. We did not found any negative lag in simple structure bursts or in well separated pulses. While investigating the time profile of the whole burst the negative lag may appear due to different spectral parameters of the overlapping pulses.

Low luminosity GRBs as a different class and shock breakout events

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Abstract

Low-luminosity GRBs are central to the understanding of the connection between GRBs and SNe. But, while all the SNe observed in connection with GRBs are rather similar, the properties of low-luminosity GRBs are fundamentally different than those of their cosmological relatives. Their luminosity is lower by about four orders of magnitude; their volumetric rate is higher by at least an order of magnitude and their prompt emission light curves are unusually smooth. Moreover, we have recently showed that unlike regular long GRBs, the gamma-ray emission of low-luminosity GRBs is most likely not generated by relativistic jets that penetrate the progenitor's envelope. It is therefore of key importance to identify the mechanism that produces the gamma-ray emission of low-luminosity GRBs. I will present the theory of relativistic shock breakouts and its predictions for gamma and X-ray emission. I will then compare these predictions to the observations of low-luminosity GRBs and discuss the possibility that all low-luminosity GRBs are relativistic shock breakouts.

Gamma-Ray Bursts with the mission of UFFO/Lomonosov

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Abstract

The rise phase of the optical light curve, one of the least known aspects of GRBs, could be addressed by UFFO(Ultra-Fast Flash Observatory)-pathfinder onboard Lomonosov spacecraft. It is equipped with a fast-response Slewing Mirror Telescope that uses a rapidly moving mirror to redirect the optical beam rather than slewing the entire spacecraft to aim the optical instrument at the GRB position. The UFFO-pathfinder will open a completely new frontier in transient studies by probing the early optical rise of GRBs with seconds response, for the first time. The status will be reported together with our next planned mission.

Macronova and Short GRBs

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Abstract

Observations on the HST (Tanvir et al 2013, Berger et al 2013) revealed a weak IR signal nine days following the short GRB 130603B. It has been suggested that this IR signal is a Macronova – a weak supernova-like signal that arises from radioactive decay of matter ejected during a NS binary merger. I describe the evidence that short GRBs indeed arise from neutron star mergers and the theoretical macronova model. I examine the observations and confront them with the theoretical predictions. Finally, I discuss the implications of this interpretation, if correct, to r-process nucleoshynthesis and the production of heavy elements in the Universe.

Testing a two-jet model of short Gamma-Ray Bursts

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Abstract

We discuss a two-jet model of short duration Gamma-Ray Bursts with an Extended Emission (EE). Among the observational tests which could support the model there are investigations of the decaying part of the EE, the light curve of the afterglow, and the number density of the ratio of the peak flux of EE and the peak flux of Initial Pulse Complex (IPC). Based on the parameters investigated we can restrict the parameters of the two-jet model. We also review a possible dichotomy in a population of short GRBs and other models of the extended emission.

Polarization observations with the MASTER Global Robotic Net

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Abstract

We present the results of polarization observations performed with the MASTER Global Robotic Net [22, 23, 18] for one supernova and two blazars. Photometry in polarizers is presented for Type Ia Supernova 2012bh, starting on March 27. We find that linear polarization of SN 2012bh at the early stage of the envelope expansion was less than 3%. Polarization measurements for blazars OC 457, 3C 454.3 are presented. Blazars OC 457 and 3C 454.3 were observed in polarizers during their periods of activity. We infer the degree of linear polarization and polarization angle. The results show that the MASTER is able to measure substantially polarized light; at the same time it is not suitable for determining weak polarization (less than 5%) of dim objects (fainter than 16^m). Polarimetric observations of early optical emission from gamma-ray bursts and supernovae are necessary to get insights into the nature of these transient objects.

1 Introduction

Polarimetry plays an important role in modern astrophysics. Polarization measurements provide information about the nature of radiation sources, about geometrical properties of the emitting regions, spatial distribution of matter around sources, and about magnetic fields.

In the last two decades polarimetry, especially spectropolarimetry, has greatly advanced. Different polarization techniques and devices are developed. Fast CCD cameras and new polarizing materials made possible polarimetric observations for a rising number of optical telescopes. In particular polarization measurements are important for short-living or/and fast variable objects such as gamma-ray bursts (GRBs) and supernovae.

More than 100 alert pointings at GRBs (in most cases, being the first ground telescopes to point at the GRBs) were made by MASTER. The MASTER net holds first place in the world in terms of the total number of first pointings, and currently more than half of first pointings at GRBs by ground telescopes are made by the MASTER network. More than 400 optical transients have been discovered. Among them are cataclysmic variables, supernovae, blazars, potentially hazardous asteroids, transients of unknown nature. Photometry of 387 supernovae has been carried out. Polarization measurements was one of the motivations for us to design and construct the MASTER II robotic telescopes [22, 23, 18, 15]. The main idea of linear polarization measurements consists in simultaneous observations of an object by four telescopes equipped with cross linear polarizers. Since each telescope of the net has two wide-FOV astronomical tubes, we have to point at least two telescopes [1] to the object simultaneously in order to determine Stokes parameters.

The unique design of MASTER II makes it the only wide-FOV instrument in the world able to measure polarization. In this work we report the results of its accuracy examination and analyze its capability to measure polarization of supernovae and blazars.

2 MASTER instruments and reduction of observations

Each MASTER II broadband telescope contains a two-tube aperture system with a total field of view of eight square degrees, equipped with a 4000 pix x 4000 pix CCD camera with a scale of $1.85''$/pixel, an identical photometer with B, V, R, and I filters realizing the Johnson-Cousins system, and polarizing filters. Both optical tubes are installed on a high-speed mount with position feedback, which does not require additional guide instruments for exposures not exceeding three to ten minutes. The setup also has an additional degree of freedom – the variable angle between the optical axes of the two tubes. This allows us to double the field of view during survey observations if the tubes are deflected from each other, or to conduct synchronous multi-color photometry with parallel tubes. A single telescope of the MASTER II net provides a survey speed of 128 square degrees per hour with a limiting magnitude of 20^m on dark (moonless) nights.

Astrometric and photometric calibration is made by a common method for all MASTER observatories [14, 18]. Bias and dark subtraction, flat field correction, and astrometry processing were made automatically. Bias and dark images obtained before the beginning of observations and the closest in time flat field images obtained on the twilight sky were used.

The first MASTER polarizers were high contrast Linear Polarizing Films combined with usual

[1] The photometer in Kislovodsk contains 4 differently oriented polarizers, which allows us to measure linear polarization

glass (in 2011, January–July, they were combined with R filter instead).

Since July 2011 all polarizers were replaced by new broadband polarizers manufactured using linear conducting nanostructure technology [18, 2]. Magnitudes obtained from broadband photometry correspond to $0.2B + 0.8R$ where B, R are standard Johnson filters [14]. Each tube is equipped by one polarizer, the polarization directions of two tubes in a single assembly being perpendicular to one another. Polarizers' axes are set in two ways with respect to celestial sphere: in MASTER Kislovodsk and MASTER Tunka sites the axes are directed at positional angle 0° and 90° to the celestial equator (polarizers oriented at 45° and 135° were added in Kislovodsk in April 2012), in MASTER Blagoveshchensk and MASTER Ural, at angles 45° and 135°. Thereby, using several MASTER telescopes one can perform observations with different orientation of polarizers. Such a construction is very effective for fast events with significant intrinsic polarization. These events are mostly of extragalactic origin. In spite of the fact that all MASTER telescopes have the similar construction, optical scheme, and polarizers, there are some uncertainties in channel responses. They limit the precision of polarization measurements. Also, the calibration using known polarized Galactic sources is not possible, as any measurement of polarization involves subtraction of nearby field stars between at least three images, obtained with tubes with differently oriented polarizers. Thus, any polarization measured would be relative to the field stars around. They are usually chosen from the area (closer than 10 arcmin) around a target source and bound to have the same polarization due to the similar ISM properties toward them. The goals of MASTER polarimetric analysis, when observing highly-polarized extragalactic events, are: to 1) find polarization of an event in excess of the average polarization of Galactic field stars in that direction, 2) remove additional systematic polarization introduced by the instruments, 3) estimate the uncertainty of polarimetric measurements by MASTER.

Stars with zero polarization are required for the channel calibration. We assume that the polarization of light from stars in the field of view is small, and that the orientation of the polarization plane is random. The difference in magnitudes between two polarizers orientations averaged for all reference stars gives the correction that takes into account different channel responses. The original stellar radiation is not polarized, polarization appears when light passes through the interstellar dust. Interstellar polarization can reach high values and strongly depends on the Galactic direction and wavelength [35].

3 Supernovae polarization observations

As precise standardizable candles, Type Ia supernovae have been used to trace the expansion of the Universe as a function of redshift, leading to the discovery of the accelerated expansion [27, 28]. However, several questions related to the physics of the explosion mechanisms are still open. It is generally believed that there are two main mechanisms of Type Ia supernovae explosions: the merger of two white dwarfs [17, 40] and the Shatsman mechanism, according to which a burst is the result of matter accretion on a white dwarf from the companion-star in binary systems [41]. In the first case, which is more often realized in elliptical galaxies [24], the specific angular momentum of matter is higher than in the second case. This could lead to an anisotropy of the explosion and asymmetrical loss of envelope and, consequently, a significant polarization of the optical radiation of the supernova is expected. Thereby, the registration of significant (more than 2%) polarization can be an independent argument for a model of merging white dwarfs. It should be noted that continuum polarization depends on the geometry of the explosion but line polarization is associated with the distribution of matter around supernovae [39].

Previous observations of Type Ia supernovae display close to zero continuum polarization and modest line polarization $\sim 1\%$. Even if continuum polarization is observed, its value is small: for example, continuum polarization for SN 1999by (prototype of which is SN 1991bg) was $0.3 - 0.8\%$ [16], for SN 2005hk $\sim 0.4\%$ [8].

SN 1996X was the first SN Ia with spectropolarimetry prior to optical maximum. The broadband polarimetry showed that continuum polarization is zero. The spectropolarimetry demonstrated spectral features with a rather low polarization $\sim 0.3\%$ [36].

It is very important to measure polarization before optical maximum while an envelope is not expanded substantially. Polarization at the latest phase of any supernova is low. For example, [21] report spectropolarimetric observations of SN 1997dt 21 days after optical maximum. Polarization was not detected but inessential line polarization in FeII and SiII was found. Another example is SN 2001el [37]. Before optical maximum the linear polarization in the continuum was $\sim 0.2 - 0.3\%$. During the next 10 days the degree of continuum and line polarization decreased and disappeared entirely ~ 19 days after the optical maximum. Spectropolarimetry of SN 2004S 9 days after the maximum light displayed very low polarization [9]. The absence of polarization in the later stages stresses the importance of early polarimetric observations.

A significant line polarization was found for SN 2004dt, for which there are data approximately 7 days before [38] and 4 days after the maximum light 2[21]. During this period polarization of the SiII line varied within the range $\sim 2\%$. Measurements of polarization of the SN 2002bf at approximately the similar time interval as for the SN 2004dt showed CaII line polarization $\sim 2\%$ [21]. SN 1997bp and SN 2002bo also showed $(1-2)\%$ line polarization [38].

Interstellar polarization (ISP) in our Galaxy or in host galaxies of supernovae complicates the determination of intrinsic supernova polarization. ISP is calculated using the empirical Serkowski law [32]. This law was obtained based on observations in our Galaxy, thus we cannot be certain that distribution and structure of dust in host galaxies of supernovae are the same. Host-galaxy ISP can be high enough. For example, in SN 2006X polarization uncorrected for ISP declines from 8% at 4000Å to $\sim 2\%$ at 8000Å [26]. In particular, polarization of the CaII IR line was $\sim 1.5\%$ and the SiII line was $\sim 0.5\%$ (10 days before the maximum light).

The number of Type Ia supernovae detected before maximum light is small, but the number of those for which spectropolarimetric and/or polarimetric data were obtained is much smaller. SN 2012bh is a good example of Type Ia supernova that was discovered before maximum light. SN 2012bh, exploded in the Sb galaxy UGC 7228, it was first detected by the Pan-STARRS1 Medium Deep Survey on 2012 March 11.50 UT [10, 13, 11]. The supernova coordinates are $R.A. = 12^h13^m37^s.309, Decl. = +46°29'00''.48$ (J2000.0). The object was discovered with an approximate brightness of $z_{P1} = 22.8(AB)$ mag and brightened to $i_{P1} = 16.99$ mag by 2012 March 21.47 UT [10]. The spectrum in the range 480-940 nm obtained on March 15 with the Grand Telescope Canaries identified the object as a young normal SN Ia. Another spectrum in the range 350-740 nm was obtained on March 23 with the 1.5-m telescope at the Fred L. Whipple Observatory on Mount Hopkins, Arizona. Joint processing of these two spectra showed that the supernova was detected three weeks prior to the maximum light. The first polarization observations of SN 2012bh on the MASTER global robotic net was on March 27, 2012.

The observations of SN 2012bh were made by MASTER global robotic net in Tunka, Kislovodsk, and Blagoveshchensk in polarizers. MASTER observed the supernova before and after the maximum light, from March 27 to April 15. The image of the supernova obtained by MASTER Tunka is presented in Fig. 1.

From SDSS-DR7 catalog [1] 43 comparison stars were selected with the help of the Aladin application [6]. All stars are less than 10′ away from the supernova location and brighter than 18 mag.

The photometry was made in the IRAF/apphot [34]. The nearest galaxy is far enough (40′ or 22 pixels) to affect the accuracy of the photometry. The robust algorithm "centroid" was used for the background value calculation. The algorithm allows one to exclude the influence of the nearby objects. The data were reduced for the fluctuations of atmospheric opacity using the "Astrokit" program[2] that implements a slightly modified algorithm described in [12]. This program conducts differential photometry using an ensemble of stars that are close to an object.

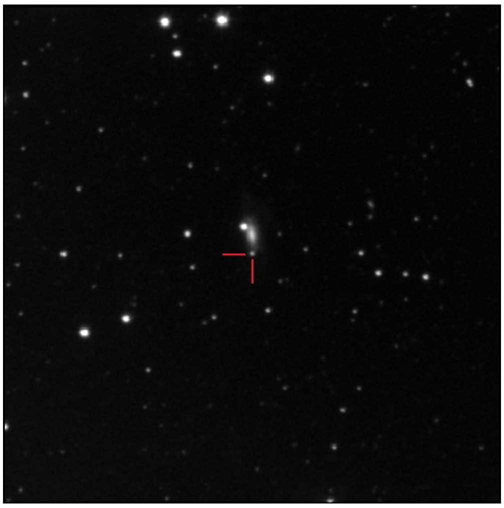

Figure 1: Supernova 2012bh observed by MASTER Tunka on April 1, 2012.

The combined light curve is presented in Fig. 2. For comparison the light curve of a "standard" Type Ia SN 1994D is shown. The light curve of SN 1994D is obtained from its light curves in B and R bands [4] using the relation $0.2B + 0.8R$. Assuming that SN 2012bh is a "standard" Type Ia supernova, its light curve can be approximated by light curve of SN 1994D with parameters: $T_{max} = 2456017.865$ (March 31), $m_{max} = 15.75$.

There is no information about the polarization of stars near SN 2012bh. The standard analysis described in Section 2 is applied. The assumption of small interstellar polarization seems justified. The supernova is located 70 degrees above the galactic equator and absorption in this direction is very small [29, 7]. Based on the data of [25] we conclude that ISP does not exceed 1%. Moreover, according to the Serkowski law, the value of galactic interstellar extinction indicates that the ISP in this direction is very small $P_{ISP} \leq 9E(B-V) = 0.12\%$ [33, 30].

[2]developed by V.V. Krushinsky and A.Yu.Burdanov (President Yeltsin Ural Federal University).

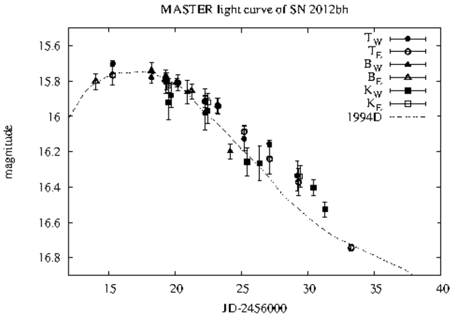

Figure 2: Light curve of SN 2012bh by MASTER. Tunka data are shown by circles; Blagoveshchensk, triangles; Kislovodsk, squares. Solid and empty signs correspond to different tubes with mutually perpendicular polarizers (W – west, E – east). The dashed curve is a fit by the light curve of SN 1994D.

We derived the polarization degree on different days for two pairs of polarizers: Blagoveshchensk-Tunka and Blagoveshchensk-Kislovodsk. In both cases for every day the polarization was near zero. We averaged the polarization degree over all days for each pair of polarizers, then two values obtained were averaged too. The resulting 1-σ upper limit on linear polarization degree of SN 2012bh is 3% (to be published in New Astronomy).

4 BL Lac objects polarization observations

For two blazars, OC 457 and 3C 454.3, observed by MASTER significant polarization was detected (to be published in New Astronomy). To account for the polarization bias in a case of low signal/noise, we used a traditional statistic correction $P_{real} = \sqrt{P^2 - (\sigma_P)^2}$ [31]. The errors of P_{real} and θ include the dispersions of corresponding values of field stars. Interstellar polarization P_{ISP} is calculated using the empirical law $P_{ISP} \leq 9E(B-V)$ [33, 30]. In all cases it is smaller than the dispersion of field stars polarization.

OC457 In the beginning of 2013 the activity of BL Lac object OC457 increased, in comparison with previous observations its brightness in R filter went up a fifty-fold [5]. Its redshift is $z = 0.859$ [3]. Polarization observations were carried out by MASTER from February 4 to February 7 in Kislovodsk and Blagoveshchensk. Then the average magnitude of the object was 15.5^m in white light $(0.2B+0.8R)$. The QU diagram and residual flux differences on February 7 are presented in Figs. 3, 4. There is a clear polarization present: $P = (21 \pm 2)\%$, $\theta = 87^\circ \pm 5^\circ$.

3C454.3 On the 24th of September [19] the start of activity of BL Lacertae object 3C 454.3 was reported. MASTER observed it on the night of the 25/26 September, in Kislovodsk with 4 polar-

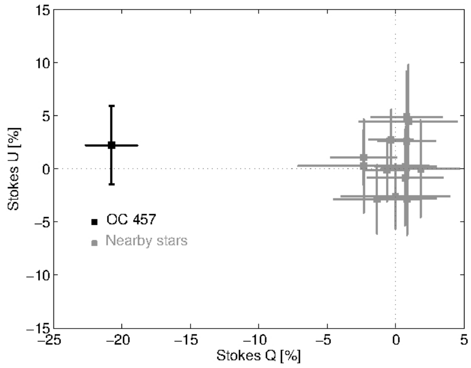

Figure 3: QU diagram of the blazar OC 457 (black point) and nearby stars (gray points) observed by MASTER Kislovodsk on February 7, 2013.

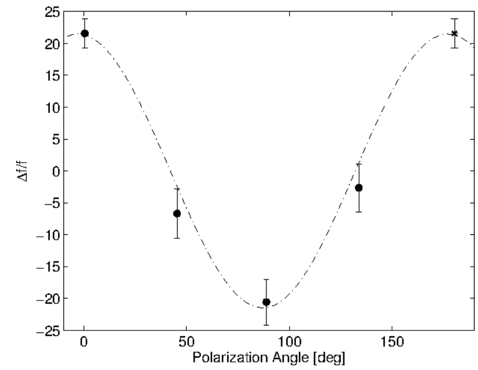

Figure 4: Residual flux differences as measured through the polarizers at MASTER Kislovodsk for OC 457. The point at $\theta = 0^\circ$ is a repetition of $\theta = 180^\circ$.

izers. The magnitude of the object was $\sim 14^m$ in white light. The polarization degree was very high $P = (34 \pm 2)\%$. The QU diagram and residual flux differences are presented in Figs. 5, 6.

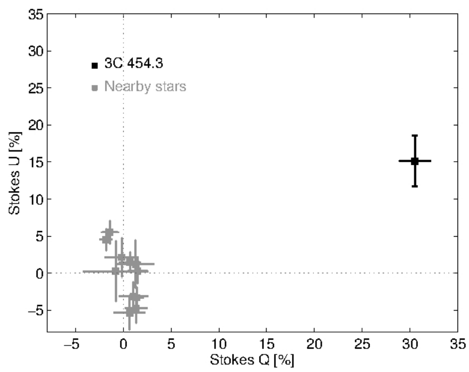

Figure 5: QU diagram of the blazar 3C 454.3 (black point) and nearby stars (gray points) observed by MASTER Kislovodsk.

The results emphasize once again that MAS-

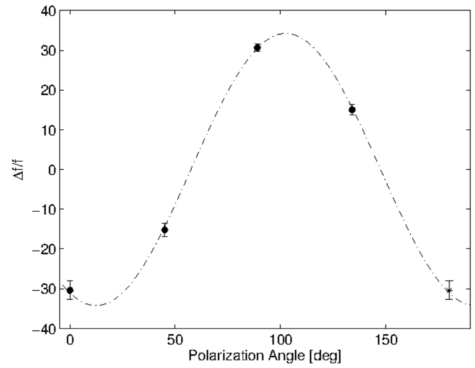

Figure 6: Residual flux differences as measured through the polarizers at MASTER Kislovodsk for OC 457. The point at $\theta = 0^\circ$ is a repetition of $\theta = 180^\circ$.

TER polarizers are able to measure high polarization of bright objects ($< 16^m$).

Due to the subtraction of nearby field stars between tubes with differently oriented polarizers MASTER cannot use standard galactic polarized and unpolarized objects for calibration. Blazars are good candidates for calibration of MASTER polarization degree and angle. The polarization degree of blazars can reach very high values during their period of activity as well as their brightness. On the other hand, blazars are strongly variable sources. For calibration we need to obtain polarimetric data synchronously with other telescopes.

The degree of linear polarization and position angle of blazars OC 457 and 3C 454.3 agree with the results obtained by [20] and the data of the virtual observatory of the Laboratory of Observational Astrophysics of Sobolev Astronomical Institute[3] at the same observational dates.

5 Conclusions

In this paper, we described the goals and methods of polarimetric observations made with the MASTER global robotic net. There is a number of different classes of astrophysical objects that manifest light polarization. Remarkably, most of them are the sites of high-energy phenomena. In the paper we present observations of one supernova and two highly polarized blazars.

The polarization observations of blazars show that MASTER's polarizers can be successfully used to measure linear polarization degree above 5-10% with position angle accuracy of 3–10 degrees depending on brightness. Observing blazars with MASTER also provides us with a source of calibration for MASTER polarization measurements.

MASTER telescopes can safely register linear polarization in excess of 10% and marginally detect polarization just above 5%. The level of 10% for the degree of linear polarization is predicted by some theoretical models of GRB emission.

The supernova phenomena can last several months. This allows us to obtain long data series including polarimetry. Discovery of significant polarizations from Type Ia supernovae will be an independent argument for the model of merging white dwarfs as one of the evolutionary path to such supernovae. Moreover, if some of SNe Ia are suspected to be asymmetric, it will raise a question about their suitability for cosmology as precise standardizable candles. Recent data show*s* modest continuum polarization (less than 1%) of SNe Ia but strong line polarization ($\sim 2\%$). Low continuum polarization of SNe Ia light could indicate that the explosion is nearly spherical. But theoretical predictions on polarization degree from asymmetric explosions are strongly model dependent. Furthermore, the observed polarization can be contaminated by interstellar polarization in our Galaxy and in the host galaxies. It is important to remind that the number of supernovae with good polarization measurements prior to maximum light is still too small to draw any conclusion about the explosion geometry in this class of supernovae.

We presented photometry in polarizers of Type Ia SN 2012bh (from March 27 to April 15). The light curve of SN 2012bh looks similar to the light curve of "standard" Type Ia SN 1994D. The analysis of the light curve shows that the maximum brightness was on March 31. The resulting 1-σ upper limit on the linear polarization degree of SN 2012bh is 3%. Further spectropolarimetric and polarimetric observations of SNe Ia are needed to investigate explosion geometry and matter distribution around supernovae and along the line of sight.

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[3]http://lacerta.astro.spbu.ru/program.html

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Timing properties of Gamma-Ray Bursts detected by SPI-ACS detector onboard of INTEGRAL

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Abstract

We study timing properties of a large sample of gamma-ray bursts (GRB) detected by the Anti-Coincidence Shield (ACS) of the SPI spectrometer of INTEGRAL telescope. First we identify GRB-like events in the SPI-ACS data. The data set under investigation is the history of count rate of the SPI-ACS detector recorded with a binning of 50 ms over the time span of 10 yr. In spite of the fact that SPI-ACS does not have imaging capability, it provides high statistics signal for each GRB event, because of its large effective area. We classify all isolated excesses in the SPI-ACS count rate into three types: short spikes produced by cosmic rays, GRBs and Solar flare induced events. We find some 1500 GRB-like events in the 10 yr exposure. A significant fraction of the GRB-like events identified in SPI-ACS occur in coincidence with triggers of other gamma-ray telescopes and could be considered as confirmed GRBs. We study the distribution of durations of the GRBs detected by SPI-ACS and find that the peak of the distribution of long GRBs is at 20s, i.e. somewhat shorter than for the long GRBs detected by BATSE. Contrary to the BATSE observation, the population of short GRBs does not have any characteristic time scale. Instead, the distribution of durations extends as a powerlaw to the shortest time scale accessible for SPI-ACS, 50 ms. We also find that a large fraction of long GRBs has a characteristic variability time scale of the order of 1 s. We discuss the possible origin of this time scale. Finally, we report recent SPI-ACS detection of unusual unexplained bursting activity, unlike any other observed by SPI-ACS in 10 years of operation. We discuss possible origin of this activity.

Relativistic explosions with Palomar Transient Factory

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Abstract

The Palomar Transient Factory (PTF) survey has discovered over 2000 supernovae and uncovered new classes of explosions with its wide field of view (7 square degrees), sensitivity (R 20.6 mag in 60 s), and real-time software pipeline guiding rapid panchromatic follow-up with an arsenal of telescopes. Recent GRB-related highlights include the afterglow-like optical transient PTF11agg, which lacking an accompanying GRB, may represent a new kind of relativistic explosion that is 4 times as common as long GRBs but produces no high energy emission. PTF is also ideally suited to finding the afterglows and host galaxies of Fermi Gamma-ray Burst Monitor (GBM) GRBs, which due to their coarse localizations have eluded the detection of optical counterparts until now. We have discovered the optical afterglow of GRB 130702A by searching 71 square degrees surrounding its Fermi GBM error circle. At z=0.145, it is among the lowest redshift GRBs detected to date and is attended by a supernova. However, its prompt gamma-ray emission and afterglow far exceed the luminosity of nearby sub-luminous events, bridging the gap to the cosmological GRB sample. Looking beyond, iPTF13bxl is also represents a crucial step in confronting the challenges in searching for faint optical counterparts to similarly poorly localized gravitational-wave transients in the Advanced LIGO and Virgo era. I will describe PTF itself, discuss these recent science highlights, and conclude with the way forward with its planned successor, the Zwicky Transient Facility.

Possibility of Electron tracking Compton camera for seeking deep Universe in MeV gamma-ray band

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Abstract

In order to explore MeV gamma-ray astronomy, we have developed an Electron Tracking Compton Camera (ETCC) consisting of a gas Time Projection Chamber and pixel array scintillators. By measuring the track of a recoil electron in the TPC event by event, ETCC measures the direction of each gamma-ray as a small arc (not circle), which also provides a good background rejection using the kinematical check for the angle between a recoil electron and a scattered gamma ray. We already carried out a balloon experiment with a small 10 cm cube ETCC (Sub-MeV gamma ray Imaging Loaded-on-balloon Experiment: SMILE-I) in 2006, and revealed the good background rejection ability. We have developed a 30 cm cube ETCC to detect gamma-rays from several celestial objects with a long duration balloon experiment (SMILE-II project). Recently, its performance has been measured on the ground, and its efficiency and angular resolution has been dramatically improved. This allows us to overcome both the serious issues of huge backgrounds and unclearness of imaging suffered by MeV gamma-ray observations so far. This performance indicates that a 40 cm cube ETCC onboard a satellite would provide a sensitivity near 10^{-12} erg cm^{-2}s^{-1} for 10^6 sec with good polarimetry, which enables us to detect most of the AGNs detected by Fermi and also high-z Gamma-Ray Bursts beyond z > 10.

Broad band chirp spectra in long GRBs

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Abstract

A chirp spectrum up to 1 kHz is found in long GRBs of the BeppoSax catalogue with a significant autocorrelation below 10 Hz. While their comoving Fourier spectra satisfy a power law with index $\alpha \simeq -0.82$ up to ~ 100 Hz, the comoving chirp spectra show broken power laws with $\alpha \simeq -0.65$ up $\simeq 10$ Hz, $\alpha \simeq -0.25$ up to $\simeq 300$ Hz and $\alpha \simeq 0$ beyond. At high frequency, we identify these chirps with modulations due to forced turbulence in matter about ISCO induced by relativistic frame dragging via an inner torus magnetosphere around rotating black holes. This model can account for the most energetic GRB-supernovae with accompanying broad-band gravitational wave emission.

Dark Gamma-Ray Bursts and their Host Galaxies

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Abstract

Despite the rapid GRB follow-up with robotic telescopes, 20-40% of long duration GRBs show a lack or even total absence of the optical afterglow. These events are called optically dark bursts. Only observations of X-ray afterglow and host galaxy of dark bursts allow us to study the main parameters of dark GRB sources and their environment and to determine the nature of the burst darkness. We provide a review of recent observations and statistical studies of optically dark gamma-ray bursts.

Radiative transfer and photospheric emission in gamma-ray burst jets

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Abstract

The low-energy spectral slopes of the prompt emission of most gamma-ray bursts are difficult to reconcile with optically thin emission models. Alternatively, one can invoke models in which the radiation near the peak of the spectrum originates from deep in a dissipative jet and is released once the flow becomes transparent. This so-called photospheric emission is shaped over a broad range of radii and carries important information about the jet expansion history. For example, the position of the spectral peak, which is directly related to the total number of photons carried by the outflow, probes the conditions deep below the photosphere where bulk of the observed photons are generated, and places strong constraints on the jet properties there. In contrast, the distortion of the spectrum into the observed non-thermal shape takes place much further out, in the vicinity of the Thomson photosphere. I will present the results of the first detailed simulations of global radiative transfer in GRB jets starting deep in the opaque zone and following the evolution of radiation in the expanding jet until it is released to distant observers. The new feature of our simulations is the self-consistent calculation of photon production and thermalization at large optical depths, which has a strong impact on the observed burst. I will discuss the effects of sub-photopsheric heating and bulk acceleration on the number of produced photons and the shape of the GRB spectrum, identify the heating histories that give spectra consistent with observations and discuss implications for the heating mechanism.

The Nuclear Compton Telescope

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Abstract

The Nuclear Compton Telescope (NCT) is a compact Compton telescope which consists of 12 high-purity Germanium detectors ($7.6 \times 7.6 \times 1.5$ cm^3) surrounded by a CsI shield. It is mounted on a platform for ultra-long-duration balloon flights at a floating altitude of $\sim$ 35 km. After the first successful flight of the full instrument in 2009, which resulted in the detection of the Crab with $\sim$ 6 sigma significance, we are currently building an improved version of NCT which consists of more detectors in an improved configuration, new shielding, cryo-cooling, and a light-weight gondola for ultra-long-duration balloon flights. Preparations have started for an anticipated test flight from Koruna, Sweden, in summer 2014 as well as several 100-day balloon flights from Wanaka, New Zealand, to observe the Galactic Center region.

NCT's wide field-of-view ($\sim$ 1/4 of the sky), broad energy range ($\sim$ 150 keV to $\sim$ 5 MeV), excellent energy ($\sim$ 2.5 keV) and position ($\sim$ 1.6 mm^3) resolution, as well as its good background suppression and good polarization sensitivity, make it an ideal instrument for nuclear-line science and polarization studies of pulsars, AGNs, and gamma-ray bursts. Therefore, its main science goals include the measurement of polarization from the Crab pulsar, improved mapping of 26-Al compared to COMPTEL, studies of 60-Fe and 44-Ti emissions, observations of the 511-keV annihilation line, as well as the measurement of polarization of several gamma-ray bursts ($\sim$ 7 per 100-day flight).

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