Death of Massive Stars: Supernovae and Gamma-Ray Bursts
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Measuring cosmological parameters with GRBs: status and perspectives

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Gamma-Ray Bursts (GRBs) are the brightest sources in the universe, emitting mostly in the hard X-ray energy band and have been detected at redshifts up to ∼9.4. Thus, they are in principle very powerful probes for cosmology. I briefly review the researches aimed at using GRBs for the measurement of cosmological parameters, which are mainly based on the correlation between spectral peak photon energy and total radiated energy or luminosity. In particular, based on an enriched sample of 130 GRBs, I will provide an update of the analysis by Amati *et al.* (2008) aimed at extracting information on Ω_{M} and, to a lesser extent, on Ω_{Λ}, from the $\mathrm{E_{p,i}}$-$\mathrm{E_{iso}}$ correlation. The results obtainable in the near future with next generation experiments will also be discussed.

New interpretation of the Amati relation

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We propose a physical interpretation of the $\mathrm{E_{peak}}$-$\mathrm{E_{iso}}$ correlation (Amati relation) of gamma-ray bursts (GRBs) in the framework of a new physical model. This model relates gamma-ray bursts (GRBs) to explosions of very massive stars (more than 130 solar masses) caused by pair-instability. Timescales of the prompt emission of gamma-rays and the fact that GRBs are cosmological objects shows that GRBs are the result of explosive processes with very high energy budgets. We propose that it could be explosions of very-massive stars that undergo pair-instability. Prompt emission in that case could be explained by total disruption of the star due to nuclear burning, which could open the core of the star. Afterglow emission could be the result of photon propagation through the hot corona, which was formed during the explosion of the star. We describe possible scenario of the final stage of evolution of massive stars and present results of the numerical simulations of pair-instability supernova.

The SED Machine - a dedicated transient spectrograph

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The SED Machine is a spectrograph designed from the bottom-up to classify transients. It is based on a low resolution (R∼100) IFU spectrograph, with a real time calibration system based on a 4-band imager. The SED Machine will give a higher rate of classified transients, and thus better exploit the immense amount of data available from on-going and future surveys. An efficient and fast way to classify objects will allow us much higher statistics for the more common type of transients, and a better ability to focus on the more exotic ones. The following work presents the science cases, optical design, and data reduction strategy of the SED Machine, as well as the current status of the instrument.

PTF10iue - evidence for an internal engine in a unique Type Ic SN

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PTF10iue is a Type Ic supernova discovered by the PTF collaboration on April 10 2010 UT. This supernova exhibits a plateau in its light curve extending over ∼150 days, as well as a nebular spectrum from an early epoch that evolves slowly in time. The light curve and spectral behavior of PTF10iue can not be explained by any of the typical SN scenarios. Photon diffusion, which is the typical explanation for plateaus observed in Type II-P SNe, requires an unrealistic ejected mass of more than 200 $M_{\odot}$. Nickel decay, which is the energy source in most Type Ic SN, is ruled out by the slow decline rate, and interaction with CSM is ruled out by the undeveloping spectra, constant velocity, constant temperature, and lack of narrow lines. The long plateaus and the unevolving spectrum clearly require some sort of an exotic solution. In this work, we describe different measurements, from ground-based, and space-borne telescopes, taken at different wavelengths over the past year and a half. We discuss different scenarios for an internal engine that might be powering PTF10iue with an emphasis on two scenarios. The first one is the generation of a Magnetar, instead of a regular neutron star, by the collapse of a fast rotating massive star. The Magnetar will radiate magnetic energy at the X-ray band, where some fraction of the energy will be converted to the optical band by the ejected material. The second scenario is the formation of a stellar black hole, either directly or through fall-back, as a result of the death of a massive star with an initial mass above $\sim 25\, M_{\odot}$. Accretion to the nascent black hole can inject enough energy to the expanding supernova envelope to explain the optical behavior we observe.

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Direct evidence for the collapsar model of long gamma-ray bursts

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According the collapsar model long gamma-ray bursts (LGRBs) involve relativistic jets that puncture the envelope of a collapsing star, and produce the γ-rays after they break out. This model provides a theoretical framework for the well known association between LGRBs and dying massive stars. However although a wealth of observations support the LGRB-SN association, to this date there is no direct observational evidence for the actual emergence of the jet from the star. In other words there is no direct conformation of the collapsar model. Here we show that a distinct signature of the collapsar model is the appearance of a plateau in the duration distribution of the prompt GRB emission at times much shorter than the typical breakout time of the jet. This plateau is evident in the data of all major GRB satellites, and provides direct evidence supporting the collapsar model. It also enables us to place limits on the sizes and masses of LGRB progenitors; suggests the existence of a large population of choked (failed) GRBs; and indicates that the 2 s duration commonly used to separate collapsars from non-collapsars holds for BATSE and possibly *Fermi* GRBs, but it is inconsistent with the duration distributions of *Swift* GRBs.

On pair instability supernovae and gamma-ray bursts

Pascal Chardonnet
University of Savoie

We present a model of a gamma-ray burst (GRB) related to very massive stars. In the framework of our model, the GRB phenomenon is a result of explosive nuclear burning in very massive star ($130\,M_{\odot}$). In our scenario the GRB observable prompt fast rise and decay part can be a result of photon propagation through the hot corona of the star. On the other hand, the GRB afterglow is a cooling phase of the expanding and outflowing envelope. Presumably, the X-ray part of the GRB emergent spectrum is formed due to upscattering of soft photons of outer layers of the star off hot coronal electrons, and thus it should have a specific shape of the Comptonization spectrum. The Amati relation is a natural consequence of this phenomenon. We will present interesting predictions.

Pan-STARRS1 observations of ultraluminous SNe

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We will present observations of several ultraluminous supernovae discovered at high redshifts by the Harvard/Johns Hopkins team in imaging data from the Medium Deep Survey of Pan-STARRS1. These objects have been found at redshifts in the range

0.9–1.4, with peak absolute magnitudes up to M = −23. We will present photometric and spectroscopic observations which exhibit a diversity of behaviors. While some objects appear to resemble the unusual SCP06F6-like transients, others have novel spectra and spectral energy distributions. We will evaluate several proposed explanations for the unusual luminosities of these exotic objects, which are the most optically luminous deaths of massive stars yet discovered.

The influence of rotation on the critical neutrino luminosity in core-collapse supernovae

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Numerical simulations of core-collapse supernovae (CCSNe) suggest that the critical neutrino luminosity (CNL) necessary to cause explosions is dependent on dimensionality. The lower threshold for explosion in 2D versus 1D has been well-documented, but recently Nordhaus *et al.* (2010) have found that going to 3D simulations further reduces the CNL by around 20% as compared with 2D simulations. This result may reflect the fundamental difference in the development of turbulence between 2D and 3D simulations and may indicate that 3D simulations are critically necessary to study CCSNe. The conclusion that the CNL is reduced in 3D simulations is not yet well-established, however. Hanke *et al.* (2011) conducted a study similar to that of Nordhaus *et al.* and find that, while the critical luminosity in 2D is lower than in 1D, going to 3D does not result in a significantly lowered CNL for explosion. This leaves open the question of the importance of 3D simulations and what physical mechanisms reduce the CNL in simulations of CCSNe. I will discuss our recent effort to examine the dependence of the CNL on dimensionality. Our approach is similar to those of Nordhaus *et al.* and Hanke *et al.*, implemented in the FLASH code. We examine the dependence of our results on the equation of state used. We also study the influence of rotation on the critical luminosity in 2D and 3D. Rotation provides additional large-scale, non-radial motion of the sort Hanke *et al.* suggest is critical to increasing dwell times in the gain region and, hence, increasing the neutrino heating efficiency.

General relativistic magnetospheres of slowly rotating and oscillating neutron stars

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Magnetosphere of a slowly rotating magnetized neutron star subject to toroidal oscillations is studied in the relativistic regime. This research is motivated by the detection of quasi-periodic stellar oscillations both in the initially rising spike and in the decaying tail of the giant flares of soft gamma-ray repeater neutron stars that exhibit sporadic burst activities most prominently in soft gamma-rays. Under the assumption of a zero inclination angle between the magnetic moment and the angular momentum of the star,

we analyze the Goldreich-Julian charge density and derive a second-order differential equation for the electrostatic potential. The analytical solution of this equation in the polar cap region of the magnetosphere shows the modification induced by stellar toroidal oscillations on the accelerating electric field and on the charge density. The results clarify the extent to which stellar oscillations are reflected in the time variation of the physical properties at the surface of the rotating neutron star, mainly by showing the existence of a relation between $P\dot{P}$ and the oscillation amplitude. Based on obtained results a qualitative model for the explanation of the phenomenology of intermittent pulsars is proposed. The idea is that stellar oscillations, periodically excited by star glitches, can create relativistic winds of charged particles because of the additional electric field. When the stellar oscillations dampen, the pulsar shifts below the death line in the PB-diagram, thus entering the OFF invisible state of intermittent pulsars.

Host galaxies of short GRBs

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Thueringer Landessternwarte Tautenburg

GROND, the Gamma-Ray Burst Optical Near-Infrared Detector mounted at the 2.2-m telescope on La Silla, Chile, has observed a complete sample of short burst host galaxies from 2007 to 2012, supplemented by observations with the VLT. Here we present the main properties of those particular galaxies and compare them with what is known about the long burst host galaxy population.

GRB 100418A: a bridge between GRB-associated hypernovae and SNe

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Long gamma-ray bursts (GRBs) are now considered to be the death of massive stars. The most convincing observational evidences have been associations with supernovae. We present the result of a search for a supernova component associated with GRB 100418A at a redshift of 0.624. The field of GRB 100418A was observed with FOCAS on the Subaru 8.2 m telescope under photometric conditions (seeing 0.3–0.4 arcseconds) on 2010 May 14 (UT). This date corresponds to 25.6 days after the burst trigger. We have done imaging observations in V, R_c, and I_c bands, and two hours of spectrophotometric observations. We resolved the host galaxy which is elongated 1.6 arcseconds (11 kpc) from north to south. No point source was detected on the host galaxy. We found that no time variation of the R_c-band magnitude between 17.7 days and 26.0 days after the burst when we compared our measurement to the reports in the GCN circulars. We could not identify any supernova feature such as broad emission-lines and bumps in our spectra. The continuum of the galaxy is very similar to that of the nearby blue compact dwarf galaxy NGC 1140. We also could not find any difference between the SDSS pre-burst magnitudes and post-burst magnitudes calculated from our spectrophotometric observations. We thus estimate

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the upper limit of the supernova absolute magnitude to be $M_V = 17.5$ (no correction of intrinsic extinction). This magnitude corresponds to a typical brightness of Type Ib/c supernova. Our upper limit provides the upper mass limit of radioactive ^{56}Ni produced in the relativistic jet, thus providing an useful constraint on the jet formation mechanism. The metallicity of the host is estimated to be 12+log(O/H)=8.8 by using emission-line diagnostics. This value is slightly higher than the recently reported mass-metallicity relation of GRB host galaxies. The progenitor of GRB 100418A may be an intermediate population between GRB-associated hypernovae and other core collapse SNe.

Two super-luminous SNe at $z \sim 1.5$ from the SNLS

Andrew Howell
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We show spectra and lightcurves from two members of the emerging class of superluminous supernovae similar to SCP 06F6 and the PTF objects from Quimby *et al.* These SNe are at the highest redshifts known for the class, $z \sim 1.5$, and were discovered by the Supernova Legacy Survey. SNLS-06D4eu is the highest redshift supernova with a spectrum, at $z = 1.588$, and at $M_U = 22.7$ and 3.4×10^{44} erg s^{-1} is one of the brightest supernovae known. SNLS-07D2bv is at a similar redshift, but host galaxy spectroscopy is not available. The observer-frame *griz* lightcurves are the most complete of this new class of supernova, and correspond to the restframe ultraviolet. They show agreement with a blackbody starting near 16,000 K. Comparison to simple models shows the spectra show lines of CII, CIII, MgII and FeIII. We discuss possible explanations, including the core-collapse of a massive star, interacting shells cast off from previous episodes of mass loss, and the creation of a magnetar.

Prospects for very-high-energy gamma-ray bursts with the Cherenkov Telescope Array

Jun Kakuwa
Hiroshima University

We present the detection prospects of gamma-ray bursts (GRBs) with the Cherenkov Telescope Array (CTA), the next generation Imaging Atmospheric Cherenkov Telescopes (IACTs). Thanks to the very large effective area, CTA can detect a huge number of gamma-ray photons, up to $\sim 10^4$, once the prompt emission is detected, which revolutionizes our understanding of the GRB physics. On the other hand, the detection rate is reduced by their narrow field of view and various limitations by the ground observations. So far, no firm detection has been reported from the current-generation IACTs. Here, we model and simulate the follow-up observation of GRBs with CTA/LSTs, which will have a major role in GRB observations. For our fiducial parameter set, we found that LSTs can detect ~ 1 GRB per year per one array site for the alerts from both the *Fermi*/GBM and ECLAIRs onboard the French-Chinese SVOM satellite. In addition, we show the expected photon counts and redshift distributions, and also study how the detection rate

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depends on the delay time of the follow-up observation from a burst trigger and various intrinsic GRB properties. In particular, the low-energy sensitivity and the well-localized alert frequency are found to be important for the detection rate.

The dynamics and radiation of relativistic flows from massive stars

Andrew MacFadyen
New York University

I will discuss the propagation and observational signatures of relativistic flows as they are ejected from massive stars and interact with the circumstellar environment.

The search for light echoes from the supernova explosion of 1181 AD

Brittany McDonald
McMaster University

We continue our investigation of the Milky Ways historical supernovae with the search for scattered light echoes (LEs) from the supernova explosion of 1181 AD. If SN 1181 is associated with the 3C 58 pulsar and radio synchrotron nebula, a detection of LEs from this event would be the first LE discovery from a supernova which produced a pulsar. During the 2011B semester, we were awarded time to detect multiple light echoes from the original 830 year-old outburst using CFHT/MegaCam and KPNO/Mosaic. We expect that any LEs associated with SN 1181 should have an average apparent motion of 2.6 arcsec/month, easily allowing detection via difference imaging with pairs of epochs in the same observing semester. The results of our survey to date will be presented. Should LEs be detected, follow-up light echo spectroscopy in 2012A or 2012B will allow our group to type the 1181 explosion, as well as obtain a three-dimensional spectroscopic view of the original outburst.

The proto-magnetar model for gamma-ray bursts

Brian Metzger
Princeton University

Long duration gamma-ray bursts (GRBs) originate from the deaths of massive stars, but it remains unsettled whether the central engine is an accreting black hole or a rapidly spinning, highly magnetized neutron star (a ‘proto-magnetar’). This distinction has been brought into particular focus by recent MHD simulations of the core collapse of massive, rotating ‘collapsar progenitors,’ which suggest that powerful magneto-centrifugal outflows from the proto-neutron star may stave off black hole formation entirely. We present

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new detailed calculations of the spin-down evolution of proto-magnetars and use them to construct a self-consistent GRB model to compare with observations and phenomenology. Although the site and mechanism of the prompt emission are still debated, we calculate the GRB emission predicted by two models, magnetic dissipation and internal shocks. Heating from magnetic dissipation powers MeV photon emission near the photosphere. Internal shocks may occur at larger radii because the Lorentz factor of the jet increases with time as the magnetar cools. We examine the parameter space of proto-magnetar properties capable of explaining a wide range of high energy phenomena, ranging from sub-luminous GRBs to highly-energetic *Fermi* bursts. We argue that the proto-magnetar model provides a natural explanation for the energies, durations, and Lorentz factors of GRBs.

Stellar black holes at the dawn of the universe

I. Felix Mirabel
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Current theoretical models on the birth and death of massive stars, and the observations of stellar black holes in the Local Universe, suggest that stars more massive than 20 solar masses in the early epochs of the Universe end as black holes in high mass compact binaries. I will show that together with the first generations of massive stars this large population of black hole binaries (microquasars) determined the early thermal history of the intergalactic medium and maintained it ionized in low density regions over large volumes of space.

MAXI J0158-744: the discovery of a supersoft X-ray transient

Mikio Morii
Tokyo Institute of Technology

MAXI (Monitor of All-sky X-ray Image) discovered the supersoft X-ray transient MAXI J0158-744 near the outskirts of the Small Magellanic Cloud on 2011 Nov 11. This source is a new type of X-ray transient, because the X-ray spectrum was soft (below a few hundred eV) and the flare duration was less than a few hours. Using *Swift* follow-up observations, it was identified as a kind of the supersoft X-ray sources (SSS), where the X-ray emission come from the nuclear burning on the surface of a white dwarf. We will show the results of the observation by MAXI-GSC, MAXI-SSC and *Swift*-XRT. For example, we find the expansion of the photosphere. We also found the emission lines in the SSC spectrum at the initial phase of the eruption. We will discuss the nature of the source.

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Wide-band spectra of magnetar burst emission

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Gamma-ray bursts are suspected to produce magnetars which are highly magnetized neutron stars, with field strengths greater than the quantum critical level 4.4×10^{13} G (Thompson & Duncan 1995), as remnants (e.g., Toma *et al.* 2007). Soft gamma-ray repeaters (SGRs) and anomalous X-ray pulsars (AXPs) are phenomenologically defined to be magnetars showing persistent X-ray emission. SGRs and some AXPs also exhibit sporadic burst emission. The spectra of the persistent X-ray emission consists of a thermal component below 10 keV (e.g., a two blackbody function) and a hard X-ray component above 10 keV (a power-law model). The latter component was discovered by INTEGRAL (Kuiper *et al.* 2006) and was further studied by *Suzaku* (Enoto 2010). Using data from *Suzaku*, we discovered that spectra of weak bursts ($\sim 10^8 - 10^7$ erg cm^2 s^1) from SGR 0501+4516 (Nakagawa *et al.* 2011) and AXP 1E 1547.05408 (Enoto *et al.* to be submitted) also consists of the above two components. On the other hand, the hard X-ray component was not seen in bright bursts ($\sim 10^7 - 10^6$ erg cm^2 s^1). In order to examine the effects of the hard X-ray component on bright burst spectra, we re-analyzed 55 bright bursts from SGR 180620 and SGR 1900+14 detected by HETE-2. Consequently, some bright bursts are well fitted by the two blackbody function plus the power-law model. Bolometric luminosities of the thermal component are correlated with luminosities of the hard X-ray component over ∼5 orders of magnitude (Nakagawa *et al.* 2011). These results suggest a common radiation mechanism between the bursts and persistent X-ray emission, further leading to a possibility that the persistent X-ray emission may consist of numerous micro bursts (Nakagawa *et al.* 2009, 2011).

Dust formation and evolution in envelope-stripped core-collapse supernovae

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Core-collapse supernovae (CCSNe) are considered to be one of the important sources of interstellar dust. However, it has not yet been understood how the size and amount of dust grains formed in the ejecta depend on the envelope mass of SNe. We investigate the composition, size, and mass of dust formed in the ejecta of envelope-stripped Type Ib and Type IIb SNe, and compare to those in Type II-P SNe with massive hydrogen envelopes. We find that the total mass of dust formed in Type Ib/IIb SNe is 0.1–1.5 $M_\odot$ and is in good agreement with the estimates of dust mass formed in Type II-P SNe. However, the average radii of newly formed grains in Type Ib/IIb SNe are found to be less than 0.01 μm, which is about one order of magnitude smaller than those formed in Type II-P SNe. This indicates that the size of dust formed in the ejecta is heavily affected by the mass of the outer envelope. We also calculate the subsequent destruction of newly formed small grains by the reverse shocks penetrating into the ejecta of Type IIb SNe. We find that the dust grains formed in the ejecta are almost completely destroyed in the shocked hot gas before they are injected into the interstellar medium. This allows us to conclude

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that envelope-deficient SNe are not likely to be important sources of interstellar dust. We also discuss the evolution of dust in the Cassiopeia A supernova remnant by comparing the calculated infrared spectral energy distribution (SED) and the observed one.

The host galaxies of dark gamma-ray bursts

Daniel Perley
Caltech

GRBs are canonically believed to originate primarily from low-mass galaxies with little internal dust extinction, which as a result are exceedingly faint at infrared and longer wavelengths. However, pre-*Swift* studies underrepresented the contributions of 'dark' bursts, potentially introducing a significant selection effect. I will present the latest observations from our programs on the *Spitzer* Space Telescope, HST, *Keck*, and *Gemini*, targeting the hosts of over 20 *Swift* GRBs with highly dust-suppressed afterglows, as well as efforts to search for long-wavelength host emission using the EVLA, JCMT, and CSO. Many dark GRB host galaxies are extremely red and IR-luminous, suggesting that GRBs can indeed form in massive and metal-enriched systems, bolstering their utility as a cosmic SFR probe and imposing important constraints on the progenitor. However, radio/submillimeter observations indicate they are not super-starbursting galaxies like local ULIRGs. Many other dark GRB hosts are actually quite blue and have low stellar masses, confirming that even ordinary and seemingly dust-free systems can host significant obscured star formation.

Keck observations of 150 GRB host galaxies

Daniel Perley
Caltech

We present the first data release from our multi-year campaign at *Keck* Observatory to study the host galaxies of a large sample of *Swift*-era gamma-ray bursts (over 150 targets to date) via multi-color ground-based optical imaging and UV-to-NIR spectroscopy. While targeting was heterogeneous, the observations span the known diversity of GRBs including short bursts, long bursts, spectrally soft GRBs (XRFs), ultra-energetic GRBs, X-ray faint GRBs, dark GRBs, SN-GRBs, and other sub-classes. We present a complete catalog of calibrated multi-color photometry and spectroscopy of our targets, and discuss similarities and differences of each sub-group to each other and to field-selected populations of high-z galaxies. We also introduce an online interface for community access to all data taken during the course of the project.

Search for properties of GRBs at large redshift

Graziella Pizzichini
IASF/INAF

I shall try to find if GRBs at large redshifts show evidence of changes in their properties.

The early emission from SNe

Itay Rabinak
The Weizmann Institute of Science

We derive a simple approximate model describing the early, up to a few days, UV/optical supernova emission, which is produced by the expansion of the outer hundredth solar mass of the shock-heated envelope, following the shock breakout and preceding the optical emission driven by radioactive decay. Our model includes an approximate description of the time dependence of the opacity (due mainly to recombination), and of the deviation of the emitted spectrum from a black body spectrum. For He envelopes, neglecting the effect of recombination may lead to an underestimate of the luminosity by more than an order of magnitude. We also show that the relative extinction at different wavelengths may be inferred from the light-curves at these wavelengths, removing the uncertainty in the estimate of progenitor radius due to reddening (but not the uncertainty in E/M due to the uncertainty in absolute extinction). For core collapse SN, the characteristics of the early UV/O emission constrains the radius of the progenitor star, its envelope composition, and the ratio of the ejecta energy to its mass, E/M. For SN Ia, the characteristics of the emission may allow one to distinguish between a pure deflagration explosion and a delayed detonation (DDT) explosion, and to constrain the detonation and deflagration velocities for DDT explosions. The early UV/O observations of the Type Ib SN 2008D and of the Type IIp SNLS-04D2dc are consistent with our model predictions. For SN 2008D we find the progenitor radius to be $\sim 10^{11}$ cm, and an indication that the He envelope contains a significant C/O fraction.

Spectral properties of SN shock breakout

Nir Sapir
The Weizmann Institute of Science

The problem of a planar radiation mediated shock breaking out from a surface of a star during a supernova explosion is numerically solved in the diffusion approximation and the spectral properties of the resulting burst of radiation are described. Photon number density and temperature are solved assuming local Compton equilibrium, and bremsstrahlung emission as the dominant photon production mechanism, as a function of breakout velocity and density. Fitting functions are provided to describe the resulting surface temperature, with an error of up to 10% in peak value and an error of up to 40% at later times. The observed emitted spectrum, integrated over time, which is a robust

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estimate not sensitive to details of light travel time or moderately asymmetric explosions, is shown to have a universal shape. Temperature and spectral estimates provided in this paper are the same for pure hydrogen or pure helium fully ionized envelopes.

MAXI observation of GRBs and short X-ray transients

Motoko Serino
RIKEN

We present the results of analyses of the gamma-ray bursts (GRBs) and short X-ray transients observed by the Monitor of All-sky X-ray Image (MAXI) Gas Slit Camera (GSC) on the International Space Station. MAXI/GSC observed 20 bursts in two years and eight of them were confirmed by simultaneous detections by other satellites. The GSC has a sensitivity to photons of 2-20 keV, and can be an advantage in detecting bursts with soft spectra, such as X-ray flashes. From the analyses of hardness ratios, we found that about a half of the observed events may be classified as X-ray flashes or X-ray rich GRBs.

A three-dimensional view of SN 1987A using light echo spectroscopy

Brendan Sinnott
McMaster University

The light echo system of SN 1987A provides a unique opportunity for studying the original outburst spectroscopically from multiple viewing angles directly testing the degree of asymmetry in the explosion. Light echo spectroscopy allows astronomers to causally connect asymmetries in the outburst of a supernova to its now-observed remnant state. We present *Gemini* GMOS optical spectroscopy of five fields of the light echo system of SN 1987A. The 14 observed spectra probe six unique viewing angles of the original outburst while simultaneously providing a test-case for our theoretical interpretation of light echo spectra. We find variation in the Hα line profile as a function of echo azimuth, indicating an underlying azimuthal-dependent asymmetry in SN 1987A at a time near maximum light. These newly-reported observations of SN 1987A suggest early asymmetry in heavy-element mixing which we compare to recent observations of the remnant and current core-collapse simulations.

X-ray study of the southern extension of the SNR Puppis A

Michael Smith
ESAC/Vega Space

Puppis A is an extended SNR which shows clear signs of interaction with an inhomogeneous interstellar medium, and contains an associated neutron star. The SNR has been intensively studied in the radio continuum regime by Dubner *et al.* (1991) and in X-rays (Katsuda *et al.* 2010), while its environment was investigated in molecular and atomic lines by Dubner *et al.* (1988). The X-ray studies were up to now concentrated in the central and northern parts of the SNR. However, our investigation of data from the XMM-Newton Slew Survey shows that there is significant X-ray emission towards the as yet under-explored southern extent of the remnant, where the radio data suggest an interaction of the local shock front with a molecular cloud. The correlation between X-ray and radio emission is investigated.

All-sky survey of short X-ray transients by MAXI GSC

Takahiro Toizumi
Tokyo Institute of Technology

We searched for short X-ray transients in the all-sky survey data obtained with Monitor of All-sky X-ray Image (MAXI) in the 4.0-10.0 keV energy band between 2009 October 1 and 2010 December 31. MAXI is an all-sky X-ray monitor mounted on the International Space Station. The Gas Slit Camera (GSC) scans 85% of the entire sky every 92 minutes (i.e. orbital period of ISS). The transit time of the GSC over a source is about 40 seconds on the orbital plane, and longer towards the orbital poles. In this study we searched for transient sources that are detected in single scans, therefore the durations of the emission should be shorter than 92 minutes. The typical detection limit is about 50 mCrab (5σ). As a result of the transient survey, we found more than 500 transients with the significance above 5σ. These X-ray transients probably include various classes of events such as GRBs, X-ray bursts, flares from stars and AGN, and possibly tidal disruption events and nova/supernova shock breakouts. We present statistical properties of these events and discuss their spatial distribution and occurrence frequency.

Development of the CALET gamma-ray burst monitor (CGBM)

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The CALET Gamma-ray Burst Monitor (CGBM) is the secondary scientific instrument of the CALET mission to be attached to the ISS, sensitive to X- and gamma-rays from 7 keV to 20 MeV. The scientific goal of the CGBM is to search out a clue to the radiation

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mechanisms of gamma-ray bursts (GRBs) by obtaining very broadband spectra from optical to TeV gamma-rays together with the primary instrument, the calorimeter (CAL) sensitive to GeVTeV gamma-rays, and the star camera (ASC). The CGBM sensor consists of the hard X-ray monitor (HXM) sensitive to the 7–1000 keV range and the soft gamma-ray monitor (SGM) to 100 keV–20 MeV utilizing two $LaBr_3$ (Ce) and one BGO scintillators. The $LaBr_3$ crystals would be employed first for GRB observations in space. The electronics box (E-box) processing signals from the sensors, is equipped with analog circuits for a wide dynamic range, onboard GRB trigger system, and 10 Mbyte memory for GRB data accumulation. In this poster, we will describe the scientific performance and the development status of the CGBM.

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