"Time-Domain Astronomy in the Multi-Messenger Era"
Invited talk
11/21/2019, 9:00 - 9:40

Marcelle Soares-Santos
(Brandeis University)

Title: **Cosmology in the era of multi-messenger astronomy with gravitational waves**

Abstract: Motivated by the exciting prospect of a new wealth of information arising from the first observations of gravitational and electromagnetic radiation from the same astrophysical phenomena, the Dark Energy Survey (DES) has established a search and discovery program for the optical transients associated with LIGO/Virgo events (DESGW). Using the Dark Energy Camera (DECam), DESGW has contributed to the discovery of the optical transient associated with the neutron star merger GW170817, and produced the first cosmological measurements using gravitational wave events as standard sirens. We now pursue new results during the third, and ongoing, observing campaign. In this talk, I present an overview of our results, and discuss its implications for the emerging field of multi-messenger cosmology with gravitational waves and optical data.

“Time-Domain Astronomy in the Multi-Messenger Era”
Contribution talk
11/21/2019, 9:40 - 10:00

Masaomi Tanaka
(Tohoku University)

Title: **Optical/infrared counterparts of gravitational wave sources**

Abstract: The first gravitational wave (GW) observation from a neutron star merger was successfully performed in 2017 (GW170817). The detection triggered electromagnetic (EM) wave observations over the entire wavelength range, which enabled the first identification of an EM counterpart of a GW source. In optical and infrared wavelengths, the counterpart shows characteristic properties of "kilonova", EM emission powered by radioactive decays of newly synthesized r-process elements. I summarize current understanding of kilonova emission by focusing on recent progress in atomic opacity calculations, and discuss what we can learn from optical/infrared observations of kilonova. Then, I highlight open questions and future prospects toward understanding the origin of r-process elements in the Universe.

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11/21/2019, 10:00 - 10:20

Mahito Sasada
(Hiroshima University)

Title: **J-GEM Optical and NIR Follow-Up in Gravitational-Wave Third Observing Run**

Abstract: Gravitational-wave (GW) astronomy has been opened since detecting astronomical events of GW by LIGO in 2015. In August 2017, a merger of a binary neutron star (BNS) has been detected as GW170817, from which an electro-magnetic (EM) emission was detected by many telescopes and satellites from radio to gamma-ray regimes. The optical and near-infrared (NIR) lights were emitted from a kilonova, which was energized by radioactive decay through the rapid neutron-capture process (r-process). Optical and NIR observations can reveal a process of nuclear synthesis in a merger of BNS. J-GEM (Japanese collaboration for Gravitational-wave Electro-Magnetic follow-up) aims to firstly detect and observe a GW EM counterpart using Japanese optical and NIR telescopes including Subaru telescope.
Since April 2019, the 3rd observing run (O3) of LIGO/Virgo GW telescope has been carried out. LIGO/Virgo have detected over 10 GW events including several events having a neutron star. The EM surveyed observations were performed in entire wavelengths to find a EM candidate of the GW source, including Subaru and other Japanese optical and NIR telescopes in J-GEM. We also performed follow up observations for candidates of GW EM objects with imaging and spectroscopy. I would present our strategy and follow ups of detected GW events in O3.

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Takayuki Ohgami
(Konan University)

Title: **Subaru/Hyper Suprime-Cam survey for finding gravitational wave counterpart**

Abstract: Advanced LIGO and Advanced Virgo detected the gravitational wave from a binary neutron star on 17th August 2017. This gravitational wave event was named GW170817. J-GEM (Japanese collaboration for Gravitational wave Electro-Magnetic follow-up) has conducted the follow up survey using the Subaru/Hyper Suprime-Cam (HSC) that aimed to identify an optical counterpart to the gravitational wave source. As a result, we find 60 candidate extragalactic transients, including J-GEM17btc (also known as SSS17a/DLT17ck). Evaluating the probabilities that they are located within the 3D skymap, we conclude that J-GEM17btc is the most likely and distinguished candidate to be the optical counterpart of GW170817. The 3rd observing run called O3 started from 1st April 2019. Three of events including a neutron star are reported by 15th June.We have conducted the follow up survey using the HSC for one of them (GW190510). Moreover we plan for using the Thirty-Meter Telescope (TMT) which is the next generation large telescope in the future. In this talk, I will report the detail of our observations (for GW170817 and GW190510) and importance of Subaru and TMT for the follow-up observations of GW events.

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Francisco Forster
(University of Chile)

Title: **High cadence surveys and the future ecosystem of time domain astronomy**

Abstract: A new generation of high etendue telescopes is allowing us to explore large volumes of the Universe with fast cadences. This has led to the discovery of new populations of events or the new phases of evolution of known populations of events. In order to take advantage of these new discoveries several new tools are required. Among them are high performance image processing tools, fast machine learning aided discovery and classification algorithms, interoperable tools that allow an effective communication between the different astronomical infrastructure, new models which allows interpreting new regions of the parameter space, and new tools to extract the most physical knowledge from these observations. In this talk I will review some examples of high cadence surveys, their tools and scientific results, in particular concerning our experience with the High cadence Transient Survey (HiTS). I will also discuss the future ecosystem of time domain astronomy in the era of high cadence observations, where a new layer of astronomical alert brokers and target and observation managers will be required to connect survey and follow-up telescopes. In particular, I will discuss the challenges and opportunities found while developing the ALeRCE astronomical broker and its implications for the future of multi messenger astronomy.

"Time-Domain Astronomy in the Multi-Messenger Era"
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11/22/2019, 9:00 - 9:40

Takashi Moriya
(NAOJ)

Title: **High-redshift supernova surveys with Subaru**

Abstract: I will introduce high-redshift supernova surveys with Subaru/HSC and discuss their discoveries, focusing on high-redshift superluminous supernovae.

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Ji-an Jiang
(Kavli IPMU)

Title: **Unveiling the Nature of Type Ia Supernovae with Early-phase Information Obtained from Subaru Deep Imaging Surveys**

Abstract: Type Ia supernovae (SNe Ia) have been used as "standard candles" to demonstrate the accelerating expansion of the Universe though their progenitor systems and explosion physics are still under debate. Photometric information of SNe Ia within a few days of their explosions (early-phase SNe Ia) plays an irreplaceable role in solving such long-standing issues of SNe Ia, and the systematical study of early-phase SNe Ia is now carrying out with the Subaru Hyper Suprime-Cam (HSC). In this talk, I will introduce an abnormal early-phase SN Ia, MUSSES1604D (SN 2016jhr) discovered in the first observing run of the "MUltiband Subaru Survey for Early-phase SNe Ia" (MUSSES) that robustly supports the so-called He-shell detonation scenario and the multiple origins of peculiar early light-curve behavior of SNe Ia for the first time. Then, I will present new findings by investigating early-phase SNe Ia discovered by the ongoing HSC SSP transient survey.

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Sei Saito
(Tohoku University)

Title: **Spectropolarimetry of Superluminous Supernova**

Abstract: In recent years, many superluminous supernovae which are ten to hundred times more luminous than normal supernovae have been discovered. However, their explosion mechanism is not yet clear. Because in the case of some models of mechanisms, it is expected that the shape of the explosion considerably deviates from spherical symmetry, it is important to study the multi-dimensional shapes of superluminous supernova. Since all extragalactic supernovae cannot be spatially resolved, polarimetric observation is one of the most powerful tool to study their morphology.

We performed spectropolarimetric observation of a superluminous supernova, SN 2017egm (Type I SLSN) about 200 days after the maximum light, using FOCAS of Subaru Telescope. The degree of interstellar polarization estimated in this study is consistent with that of polarization that is supposed to originate from the supernova in a previous study. In other words, SN 2017egm does not have a large intrinsic polarization in the early epoch. It shows that the outer layer of the supernova is almost spherical. Whereas, in the late epoch, it shows polarization originating from the supernova and it indicates that the inner part of the supernova is aspherical. Hence, we conclude that the inner ejecta of superluminous supernovae are more aspherical.

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Masahiro Matsuda
(Tohoku university)

Title: **Luminous Supernovae from Subaru HSC**

Abstract: Core-collapse supernovae (CCSNe) have a wide variety in the peak luminosity.While CCSNe have only -16 ~ -18 mag at peak, superluminous supernovae (SLSNe) reach -21 ~ -23 mag. There maybe a gap between SNe and SLSNe in the luminosity distribution, but the intrinsic luminosity distribution is not yet clear.We carried out a transient survey with Hyper Suprime-Cam Subaru Strategic Program (HSC-SSP) from April 2016 to November 2017. This survey covered the COSMOS field (Ultra-Deep layer 1.77 deg2, Deep layer 5.78 deg2) for about half a year with a depth of about 26 mag. The data are suitable to unbiasedly study the luminosity distribution of SNe. We identified SNe more luminous than -19.5 mag with reliable redshifts and studied properties of their light curves. Using this sample, we present the event rate and luminosity distribution of luminous SNe.

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Ichiro Takahashi
(Kavli IPMU)

Title: **Photometric Classification of the HSC Transients through Machine Learning**

Abstract: The progress of observation technology in recent years has brought the rapid increase in the number of discovered supernovae. More than 1,800 supernova candidates were discovered in transient survey of the COSMOS field with the Subaru Hyper Suprime-Cam (HSC) (Yasuda et al. 2019), and it is estimated that tens of thousands of supernovae will be discovered each year in the Large Synoptic Survey Telescope (LSST) era. In order to select follow-up candidates efficiently among these numerous supernovae, we study type classification of supernovae using machine learning technologies. Our classifier using Deep Neural Network enables classification in a short time after observation by learning with simulated data before observation and directly inputting photometric information. We tried this classifier to select candidates for the follow-up observations together with conventional template fitting in the HSC transient survey from 2016 to 2018. We present the performance of the classifier and how we classified supernovae type using machine in actual supernova survey.

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11/22/2019, 11:20 - 11:40

Nozomu Tominaga
(Konan University)

Title: **High-cadence transient surveys with Subaru/Hyper Suprime-Cam**

Abstract: We perform high-cadence transient surveys with Subaru/Hyper Suprime-Cam (HSC) with time intervals of about one hour. We find five rapidly rising transients at z = 0.384-0.821 and a rapidly declining blue transient at z=0.4229 in the two-successive-nights observation with an image subtraction technique. Their absolute rates of brightness change are faster than 1 mag per day. The rapidly rising transients are consistent with early emission from core-collapse supernovae, e.g., the cooling envelope emission from the explosion of red supergiants or the shock breakout from a dense wind. On the other hand, the rapidly declining blue transient is consistent with none of the transients or variables observed so far. Comparisons with theoretical models demonstrate that a shock breakout at the stellar surface of an explosion of red supergiant star with the low-energy explosion energy of $< 0.4 \times 10^{51}$ erg reproduces its multicolor light curve. These discoveries show that the high-cadence multicolor optical transient survey with intervals of about one hour and continuous and immediate follow-up observations is important for studies of normal core-collapse supernovae at high redshifts.

"Time-Domain Astronomy in the Multi-Messenger Era"
Contribution talk
11/22/2019, 11:40 - 12:00

Nao Suzuki
(Kavli IPMU, Univ of Tokyo)

Title: **Progress Report on HSC SNIa Cosmology Program**

Abstract: We report the status of ongoing Type Ia Cosmology program in the framework of Subaru Hyper-Suprime Cam SSP. The second season of SSP Ultra Deep Field (SXDS) is being observed and supernovae are being discovered as we speak. Infrared photometric follow-up by Hubble Space Telescope is triggered on the best / highest redshift supernovae and followed by spectroscopic observations by Keck, VLT, Gemini, GTC and AAT. We aim to achieve the best constraint on dark energy and introduce live supernova as well as our challenges on calibration and systematic errors.

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Contribution Poster
Poster ID: P54

Yen-Chen Pan

(NAOJ)

Title: **Probing the Progenitor Metallicity of SNe Ia with Ultraviolet Spectra**

Abstract: Ultraviolet (UV) observations of Type Ia supernovae (SNe Ia) are useful tools for understanding progenitor systems and explosion physics. In particular, UV spectra of SNe Ia, which probe the outermost layers, are strongly affected by the progenitor metallicity. Theory suggests that SN Ia progenitor metallicity is correlated with its peak luminosity, but not its light-curve shape. This effect should lead to an increased Hubble scatter, reducing the precision with which we measure distances. If the mean progenitor metallicity changes with redshift, cosmological measurements could be biased. Models also indicate that changing progenitor metallicity will have little effect on the appearance of optical SN data, but significantly alter UV spectra. Here we use the largest UV spectroscopic sample of SNe Ia to date to study the metallicity effect. With this sample, we confirm theoretical predictions that SN Ia UV spectra are strong metallicity indicators. Our findings show that UV spectra are promising tools to further our understanding of SN Ia while directly improving the utility of SN Ia for cosmology.

"Time-Domain Astronomy in the Multi-Messenger Era"
Contribution Poster
Poster ID: P55

Kengo Takagi
(Hiroshima University)

Title: **Structure of circumstellar matter in helium nova V445 Puppis and its time evolution**

Abstract: V445 Pup (Nova Puppis 2000) is known as the first helium nova. Its stellar system would consist of a massive white dwarf and a helium star, and could be a strong candidate for a Type Ia supernova progenitor. To explore the structure of the stellar system and its evolutional stage, we performed optical and near-infrared observations, including one epoch Subaru/FOCAS photometry and spectroscopy.

Our spectropolarimetry during the outburst stage suggests that the bipolar outflow found by near-infrared AO imaging >4 years after the outburst already blew even at the outburst phase and that there were pre-existing scattering clouds along the circumstellar disk only the earliest stage of the outburst. The optical spectrum at 11 years is dominated by [O III], [O II] and He I lines, suggesting the hydrogen-poor circumstellar matter ionized by the nova remnant is seen and the possible helium star is obscured. At 18 years, the optical and near-infrared light is still about 3 mag fainter than that before explosion, but, in recent 3 years, the optical light is gradually brightening while the near-infrared light is almost stable or slightly faded, which cannot be explained by a simple clear up of the dusty circumstellar matter.