SEAAN Meeting 2019

26 to 28 December 2019, Singapore

The Southeast Asia Astronomy Network (SEAAN) Meeting was first held in 2007 during the Thai National Astronomy Meeting in 2007, hosted by the National Astronomy Research Institute of Thailand (NARIT). Since then the SEAAN Meeting has rotated among Southeast Asian countries. Recent Meetings were held in Bandar Lampung (Indonesia, 2018), Mandalay (Myanmar, 2017) and Hanoi (Vietnam, 2016).

The purpose of the SEAAN Meeting is to bring together people working in the fields of astronomy and astrophysics from Southeast Asia. It aims to facilitate exchanges in both research findings and educational practices, as well as astronomy outreach efforts. The 2018 SEAAN Meeting consists of plenary talks and poster sessions over two days.

In conjunction with the meeting, there will also be an annular solar eclipse on 26 December 2019. This is an extremely rare event and a fitting occasion to celebrate astronomy in Southeast Asia.

Contents

Local Organizing Committee

Chair	Dr. Abel Yang
Co-Chair	Dr. Cindy Ng
Proceedings	Dr. Ng Wei Khim
Deputy Head, NUS Physics	Assoc. Prof. Phil Chan
Head, NUS Physics	Prof. Sow Chorng Haur
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Scientific Organizing Committee (SOC)

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Prof. Khin Swe Myint	Myanmar
Dr. Cynthia Celebre	Philippines
Dr. Pham Ngoc Diep	Vietnam
Dr. Abel Yang	Singapore

Program

Solar Eclipse Observation – Thursday 26 December 2019

Location: NUS Multipurpose Field

11:27 : First Contact

13:22 : Full Eclipse begins

13:23 : Maximum Eclipse

13:24 : Full Eclipse ends

15:18 : Last Contact

Day 1 – Friday 27 December 2019

08:00 – 09:30 : Breakfast and Registration
Breakfast at Physics Conference Room (S11-02-07)

09:30 – 09:40 : *Opening Address, Prof Sow Chorng Haur, NUS Head of Department*

Invited Talks

09:40 – 10:10 : Mr Alfred Tan (National Junior College, Singapore)
Title: *High-resolution solar imaging for citizen science*

10:10 – 10:40 : Mr Koh Joo Beng (Singapore)
Title: *Capturing a Total Solar Eclipse*

10:40 – 11:00 : Coffee Break

Session:	**Flash Talks (*strictly 5 mins each*)**
Time:	**11:00 am – 12:30 pm**
Chair:	**Dr Ng Wei Khim**

1. Mr Ang Han Wei (National University of Singapore)
   Title: *Properties of Modified Combinants in Multi-particle Production in the LHC*

2. Mr Gupta Arpit, Ms Cao Shangyu & Mr Seow Kit Hint (National Junior College-School of Science and Technology, Singapore)
   Title: *Development of a Solar Storm Radio Telescope*

3. Ms Izatul Hafizah & K. Vierdayanti (Institut Teknologi Bandung, Indonesia)
   Title: *Probing Supercritical Accretion in Ultraluminous X-ray Source M82 X-1 by means of X-ray Spectral Evolution Analysis*

4. Mr Lim Kian Hwee (National University of Singapore)
   Title: *Transverse energy density of Pb-Pb collisions at LHC (CERN) energies of TeV*

5. Ms Muthia Dewi & Aprilia (Institut Teknologi Bandung, Indonesia)
   Title: *A Study of Ethnoastronomy in Ciptagelar Civilizations, Sukabumi Regency, West Java, Indonesia: Relation of Full Moon Phase with Javanese Calendar and Hijriyah Calendar*

6. Ms Ni Made Kartika Wijayanti, M. I. Arifyanto, and N. Annisa (Institut Teknologi Bandung, Indonesia)
   Title: *Search for Stellar Streams in The Galactic Halo From Gaia DR2, GALAH DR2, RAVE DR5 and LAMOST DR4 Data*

7. Mr Oh Wei Shen (The Australian National University)
   Title: *Tracing the 3D structure of the Magellanic system*

8. Mr Ong Zongjin (National University of Singapore)
   Title: *Numerical solutions to Giovannini's parton branching processes*

9. Mr Pulkit Agarwal (National University of Singapore)
   Title: *Difference in multiparticle production from particle-particle and particle-antiparticle interactions*

10. Mr Quek Zhi Hao (National University of Singapore)
    Title: *Nonlinear Dirac Neutrino Oscillations in Matter*

11. Mr Rizchel M. Masong (De La Salle University)
    Title: *Optical property of white binary pulsar PSR J1713+0747*

12. Ms Rizky Maulana Nurhidayat, Mochamad Ikbal Arifyanto & Lucky Puspitarini (Institut Teknologi Bandung, Indonesia)
    Title: *Galactic warp from kinematics of O and B stars*

13. Ms Sneha Athreya & Mr Muhammad Adam Aqasha Bin Mohamed (National Junior College-School of Science and Technology, Singapore)
    Title: *Investigation of the Sudden Solar Ionosphieric Disturbance using Radiotelescopes*

14. Mr Wong Kan Jun, Mr Shrivastava Kushagra & Mr Keith Chia Wen Kai (National Junior College-School of Science and Technology, Singapore)
    Title: *Closing up onto our Sun: Solar imaging*

15. Mr Yuda Arif Hidayat, M. I. Arifyanto & Aprilia (Institut Teknologi Bandung, Indonesia)
    Title: *Analysis of tidal structure of NGC 6397*

12:30 – 14:00 : Buffet Lunch outside the Physics Conference Room (S11-02-07)
Poster Session

Session 1:	**Solar and Stellar Astrophysics**
Time:	**14:00 pm – 15:40 pm**
Chair:	**Dr Norhasliza Yusof**

14:00 – 14:25 : Dr David Mkrtichian (NARIT, Thailand)
Title : *Pulsations in Algols.*

14:25 – 14:50 : Dr Do Thi Hoai (Vietnam National Space Center, Vietnam)
Title : *On the winds of two nearby oxygen-rich AGB stars*

14:50 – 15:15 : Dr Evgenii Semenko (NARIT, Thailand)
Title : *Hot magnetic stars in exotic multiple systems*

15:15 – 15:40 : Ms Zety Sharizat Bt Hamidi (Universiti Teknologi MARA, Malaysia)
Title : *MARAAN Investigation On Pattern Of Unstable "Beta-Gamma(βγ)" Magnetic Classification Of Sunspot On Active Region*

Coffee Break, 15:40 pm - 16:10 pm

Session 2:	**Extragalactic Studies 1**
Time:	**16:10 pm – 17:50 pm**
Chair:	**Dr Pham Ngoc Diep**

16:10 – 16:35 : Dr Chelsea Sharon (Yale-NUS College)
Title : *The Evolutionary Connection Between Star Formation and AGN as Probed by Molecular Gas*

16:35 – 17:00 : Mr Chen-Fatt Lim (National Taiwan University (NTU) / Academia Sinica Institute of Astronomy & Astrophysics (ASIAA))
Title : *SCUBA-2 Ultra Deep Imaging EAO Survey (STUDIES)*

17:00 – 17:25 : Dr Hesti Retno T. Wulandari (Institut Teknologi Bandung, Indonesia)
Title : *Host Galaxy Properties of Ultraluminous X-ray Sources (ULXs) with Minimal Contamination*

17:25 – 17:50 : Dr John Soo Yue Han (Universiti Sains Malaysia, Malaysia)
Title : *Solving Missing Data Problems in Astrophysics Using Machine Learning*

17:50 : Dinner outside Physics Conference Room (S11-02-07)

18:30 : Business Meeting

22:00 : End of Business Meeting

Day 2 – Saturday 28 December 2019

08:00 – 09:00 : Breakfast at Physics Conference Room (S11-02-07)

Invited Talk

09:00 – 09:30 : Mr Remus Chua (Singapore)
Title: *Digital Astrophotography: Lessons From Bortle 1/2 Dark Skies*

Session 3:	**Other Topics**
Time:	**09:00 am – 10:45 am**
Chair:	**Prof Yee Yee Oo**

09:30 – 09:55 : Mrs Evaria Puspitaningrum (Xtremax Ltd., Singapore)
Title : *Photoionization Model of StWr4-10*

09:55 – 10:20 : Mr I Putu Wira Hadiputrawan (National Central University, Taiwan)
Title : *On The Dynamical Effects of Pluto-Sized Objects in the Priomordial Kuiper Belt*

10:20 – 10:45 : Mr Rizchel M. Masong (De La Salle University)
Title : *Predictive and Characterized Pulsar Behavior from Optical Pulsation*

10:45 – 11:10 : Coffee Break

Session 4:	**Education and History**
Time:	**11:10 am – 12:25 pm**
Chair:	**Prof Boonrucksar Soonthornthum**

11:10 – 11:35 : Dr Pham Ngoc Diep (Vietnam National Space Center, Vietnam)
Title : *Astrophysics research at the DAP*

11:35 – 12:00 : Mr Sze-leung Cheung (NARIT, Thailand)
Title : *Collaboration under the UNESCO International Training Center of Astronomy network*

12:00 – 12:25 : Prof Wayne Orchiston (NARIT, Thailand)
Title : *Telescopes, Temples, Eclipses and Ethnohistory: Exploring Southeast Asia's Exciting Astronomical History*

12:25 – 14:00 : Buffet Lunch outside the Physics Conference Room (S11-02-07)

Session 5:	**Cosmology**
Time:	**14:00 pm – 15:40 pm**
Chair:	**Dr Cindy Ng**

14:00 – 14:25 : Mr Fargiza A. M. Mulki (Institut Teknologi Bandung, Indonesia)
Title : *Matter Power Spectrum in Coupled Scalar Field Cosmology*

14:25 – 14:50 : Miss Lisa Goh Wan Khee (National University of Singapore)
Title : *Modified Statistical Analysis of Type 1a Supernovae Data*

14:50 – 15:15 : Mr Low Lerh Feng (University of Auckland, New Zealand)
Title : *The Distribution of Vacua in Random Landscape Potentials*

15:15 – 15:40 : Mr Lu Jianlong (National University of Singapore)
Title : *A Model of Effectively Oscillating Massless Neutrinos and Its Implications*

15:40 – 16:10 : Coffee Break

Session 6:	**Extragalactic Studies 2**
Time:	**16:10 pm – 17:50 pm**
Chair:	**Dr Chelsea Sharon**

16:10 – 16:35 : Dr Eddie Chua (Institute of High Performance Computing, A*STAR)
Title : *Effect of inelastic self-interacting dark matter on the structure of a Milky Way halo*

16:35 – 17:00 : Mr Fahmi Iman Alfarizki (Institut Teknologi Bandung, Indonesia)
Title : *Tracing Black Hole Signatures in Several Black Hole Candidates based on Their X-ray Spectral Evolution*

17:00 – 17:25 : Mr Mochammad Dafa Wardana (Institut Teknologi Bandung, Indonesia)
Title : *Determination of the Local Dark Matter Density Using K-dwarfs from Gaia DR2*

17:25 – 17:50 : Ms Putri Mutmainah Khoirul Anam (Institut Teknologi Bandung, Indonesia)
Title : *Exploring the Physical Properties of Blazar OJ 287 Inferred from the Multiwavelength Spectral Energy Distribution*

19:00 : Banquet at NUSS Kent Ridge Guild House (See Map)

22:00 : End of conference

Abstracts and Authors

Invited Talks

Alfred Tan
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Singapore

Title: High-resolution solar imaging for citizen science

Abstract: High-resolution solar imaging, essential for research into the Sun is usually limited to high-end expensive telescopes found in professional observatories using adaptive optics technology. However a Schmidt-Cassegrain Telescope equipped with a narrow-band energy rejection filter and a suitable etalon, employing appropriate data acquisition and post-processing techniques can provide an amateur astronomer a cost-effective means to high-resolution solar imaging with a spatial resolution of under 0.2 arcsec. SCT with apertures from 8 to 14 inches can produce results comparable with those from professional observatories.

Koh Joo Beng
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Singapore

Title: Capturing a Total Solar Eclipse

Abstract: Joo Beng is an avid solar eclipse observer and enjoys documenting total solar eclipses around the world. He has witnessed more than 10 solar eclipses to date at remote locations such as the Gobi Desert, Easter Island, Kenya, and the Faroe Islands. Joo Beng will delve into the oddities of eclipses, share some of his eclipse experiences as well as explain what it takes to document via photos and videos, one of the astronomical world's most awe-inspiring phenomena.

Remus Chua
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Singapore

Title: Digital Astrophotography: Lessons From Bortle 1/2 Dark Skies

Abstract: Be taken on a journey to one of the most pristine dark skies in the world, as well as understand how the fundamentals and principles of digital astrophotography are engaged to bring out the best in deep sky astrophotography.

Since the 1990s, the speaker has taken an avid interest in the various fields of astronomical imaging, ranging from early emulsion--based (film), CMOS, to CCD deep sky imaging, with the data acquisition of information including the wide--field panoramic expanse of the Milky Way to narrow-field record of galaxies and planetary nebulae. He has also taken a keen interest in the areas of planetary and solar system high -resolution imaging (from sunspots to assembling of lunar mosaics covering detailed lunar topographical surfaces), resulting in image publications in internationally renowned astronomy magazines like ASTRONOMY and SKY AND TELESCOPE, as well as numerous local media publications, journals, and even the cover of an orchestral score! The speaker was also awarded the distinguished Cadi Scientific Award by the Institute of Physics, for demonstrating outstanding inspiration, innovation and enthusiasm in promoting physics (or physical science) to the public, and has been to several key astrophotography conferences all around the world. On the astronomy outreach front, the speaker has also helped founded SINGASTRO, the only online astronomy forum for Singapore, and has been the main organizer for several nation-wide astronomy events.

Session 1: Solar and Stellar Astrophysics

David Mkrtichian, Engelbrecht C., Gunsriwiwat K. et al.
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National Astronomical Research Institute of Thailand (NARIT)
Thailand

Title: Pulsations in Algols.

Abstract: We present the most recent results of ground-based spectroscopic and space photometric studies of non-radial pulsations in mass-accreting components of Algols (oEA stars). The ground-based observations have been obtained at 10-m South African Large Telescope (SALT) at Sutherland, South Africa, the high-precision photometric data have been acquired and with TESS space telescope. We found that the excitation of high-degree non-radial modes and co-existence with a wide spectrum of low-degree modes is a common phenomenon in oEA stars.

Do Thi Hoai
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Vietnam

Title: On the winds of two nearby oxygen-rich AGB stars

Abstract: Millimetre ALMA observations of the nascent winds of EP Aqr and R Dor, two similar oxygen-rich AGB stars, are presented and analysed. Emphasis is placed on the presence of high Doppler velocities close to the stars and their possible interpretations. We draw a global picture of the morphokinematics of the circumstellar envelopes, from a few au up to some 1000 au away from the central star. While EP Aqr is observed to display approximate axi-symmetry of the terminal wind, R Dor is dominated by strong inhomogeneity, both angular and radial.

Evgenii Semenko
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Thailand

Title: Hot magnetic stars in exotic multiple systems

Abstract: A strong and stable magnetic field covering the whole surface is a landmark of chemically peculiar or CP-stars. To explain the origin of magnetic stars several hypotheses were proposed, which depending on the mechanism and time of formation can be grouped into three main. The magnetic field may originate in the protostellar medium ('fossil field'), turbulent layers of a star ('dynamo' mechanism) or in the other environment. In either scenario, binary stars appear as a merit of its reliability. Recent advances in observational astrophysics uncovered a bunch of new binary magnetic stars that were considered as rare before. In this talk, we outline the new results of studies of exotic binary and multiple systems with magnetic CP components: HD 6757, HD 34736, and HD 40759. Two massive systems, HD 34736 and HD 40759, host at least one pulsating companion as it was established from new TESS data.

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Title: MARAAN Investigation On Pattern Of Unstable "Beta-Gamma(βγ)" Magnetic Classification Of Sunspot On Active Region

Abstract: The pattern of unstable "Beta-Gamma (βγ)" magnetic classification of sunspot on active region has been investigated. From previous study, it has reported Delta (δ) sunspot correlates well with flares productivity thus lead to major flares. However, based on data collected, it shows that βγ sunspot has tendency to produce major flares as it seen to be the highest formation compared to the other types of magnetic classification of sunspot included Delta (δ) sunspot. From this study, the pattern of the unstable βγ sunspot occurred within 5 years, from 2012 till 2016 shows different pattern for each type of magnetic classification. Furthermore, the frequency formation of unstable βγ sunspot on active region were analysed and proved the highest frequency of βγ sunspot to occur was in 2014, which is 120 days (34.38%) and the lowest was 14 days (4.01%) in 2016. The Sun was at solar maximum phase during 2012 to 2014 where the activity of the Sun is active leads increased of sunspot number thus solar flares and CMEs high possibility to occur. It reached minimum phase of Solar Cycle 24 during 2015 to 2016 and activity of the Sun less active thus decreased the sunspot number and decreased the possibility of solar flares and CMEs occurred. Active Sun will be increased in sunspot number and has higher tendency to produce solar flares and CMEs. When compared with other type of sunspot classifications, βγ sunspot shows the highest formation, 349 days (62.77%) compared to δ sunspot, 39 days (7.01%). The correlation between βγ sunspot with Sun's parameter shows βγ sunspot has ranges of solar wind speed (248.6-744.1 km/s),proton density (0-52.4 proton/cm3), sunspot number (25-296), radio flux (83-188sfu) and magnetic field (0.9-23.8 nT) presented in all ranges of other types of magnetic classification of sunspot. βγ sunspot might be the initial stage magnetic classification of sunspot before the sunspot becomes complex and formed other types of magnetic classification. In this study, βγ sunspot possible to trigger the production of solar flares (Type III burst) or Coronal Mass Ejections (CMEs) (Type II burst). Data were collected from Space Weather Network and e-CALLISTO network.

Session 2: Extragalactic Studies 1

Chelsea Sharon
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Singapore

Title: The Evolutionary Connection Between Star Formation and AGN as Probed by Molecular Gas

Abstract: Theoretical work has suggested that AGN play an important role in quenching star formation in massive galaxies. However, direct observational evidence of AGN affecting molecular gas (the fuel for star formation) via outflows is challenging to obtain, requiring long integration times, stacking, or poorly-calibrated molecular mass tracers. Indirect evidence for AGN's impact on their host galaxies' cold gas phase may be provided by measurements of the gas excitation. I will present recent work using both low- and high-excitation CO lines from the VLA and ALMA for samples of z~2-6 dusty star-forming galaxies (SMGs) and AGN. We find that the average CO spectral line energy distributions differ between these two populations, even at low excitation, suggesting that AGN affect the bulk of the molecular ISM. However, there is significant scatter even in the highest-excitation lines. The similarities between these two populations, both in terms of excitation and for relations like the Schmidt-Kennicutt law, suggests that future attempts to identify their evolutionary connection require better tools for disentangling the effects of intense star formation vs. AGN.

Chen-Fatt Lim
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Title: SCUBA-2 Ultra Deep Imaging EAO Survey (STUDIES)

Abstract: Multi-wavelength properties and luminosity functions of 450-µm selected galaxies. The majority of star formation in the Universe is obscured by dust and produces strong infrared and sub-millimeter radiation. Far-infrared or sub-millimeter observations are therefore required to fully understand the formation history of galaxies. Sub-millimeter surveys have revealed a population of dusty galaxies (sub-millimeter galaxies, SMGs) at z ~ 1-3.5, occupying the same epoch as the peak of quasar activities. SMGs dominate the massive end of star-formation with star formation rates of >100 $M_{\odot}$yr^-1 and reside in massive dark matter halos (10^12 to 10^13h^-1$M_{\odot}$), suggesting that SMGs may be the progenitors of elliptical galaxies in the local Universe. In this talk, I will present the results of the SCUBA-2 Ultra Deep Imaging EAO Survey (STUDIES) project. STUDIES is a James Clerk Maxwell Telescope Large Project aiming at obtaining confusion limited 450-µm images in the COSMOS and SXDS regions, to detect the majority of the dusty galaxy population. By the end of 2019, the STUDIES project leads to a very deep 450-µm image with an area of ~300 arcmin^2 and a noise level of ~0.56 mJy in the COSMOS field. I will also present some physical properties of our sources with multi-wavelength counterparts, including infrared luminosities, star formation rates, dust temperatures, stellar masses, and dust attenuations. Because of the unprecedented depth of the STUDIES image, these analyses reached a star formation rate of ~30 $M_{\odot}$yr^-1 dusty population at z ~ 2. Our data provide new measurements of obscured SFR densities at z = 0-4, without any assumptions in the faint-end slopes of the infrared luminosity function. We also build a machine-learning algorithm to identify the 450-µm-based SMG candidates in the entire COSMOS region. There are roughly 6000 such machine-learning candidates and all of them will be used for clustering analyses and halo mass estimations for faint SMGs. All the above will advance our understanding of the typical members of the high-redshift dusty galaxy population.

Hesti Retno T. Wulandari
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Title: Host Galaxy Properties of Ultraluminous X-ray Sources (ULXs) with Minimal Contamination

Abstract: Ultraluminous X-ray sources (ULXs) are off-nuclear point-source objects, whose luminosities exceeding the Eddington luminosity of stellar mass black holes. We explore the host galaxy properties of a sample of ULXs with minimal contamination. The sample of ULXs was selected from an available catalog of ULX candidates from Chandra observations within 40 Mpc distance. We calculated background contamination for each galaxy in the sample and chose a limit for background probability to ensure that only galaxies with a 4 sigma confidence level as not being a background are included. We furthermore applied another criterion which stricken our goal to minimize the chance of being a background source, by performing inclination and position angle corrections, and considered only ULXs within the corrected R25 of each galaxy. Our final sample consists of 195 ULX candidates (45%) in 73 galaxies (41%). Most well-known ULXs can also be found in our final sample. The dominant morphology in our final sample is spiral (73%). Only 23% are normal galaxies, while the rest are classified as peculiar or interacting or starburst or AGN or combination of them. More than half (63%) galaxies have stellar mass between 10 <log(M/Msun)<11 and the range of star formation rate between -3.3<log(SFR)<1.2.

John Soo Yue Han
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Title: Solving Missing Data Problems in Astrophysics Using Machine Learning

Abstract: In the effort to produce photometric redshift (photo-z) catalogues for galaxies, one major disadvantage machine learning methods face compared to template-based methods is the problem of missing data. While template-based methods could essentially obtain photo-z's for galaxies with missing bands (e.g. SDSS ugriz with missing u and z, or etc) with lower quality, machine learning methods require some method to replace missing bands with numbers that would help the training and testing process. The most common method used at the moment is to discard galaxies with missing bands, however this reduces the number of useful objects in the final catalogue. In this work in process, I will show how some of the simple methods fare, and how it will be useful especially for multi-narrowbands surveys like the Physics of the Accelerating Universe (PAU).

Session 3: Other Topics

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Title: Photoionization Model of StWr4-10

Abstract: StWr4-10 is a compact planetary nebulae (PN) with dimensions of ~2.36" × 2.90", classified as elliptical PNe, has inner structure and halo. This PN is located in the southern sky and classified as early-type emission line star previously but then recognized as PN. Its low temperature effective (26600 ± 1100 K) and size indicates that it is relatively young. But, its position in H-R diagram based on its Teff and luminosity showed that this object does not follow any theoretical post-AGB evolutionary track. It is suggested that might be this PN have experienced an LTP, however, this scenario should be supported by observational data from time to time. Another explanation is this PN might be not located in the galactic disc but it might be located in galactic halo. We investigated properties of the central star and the nebula based on unique data set from optical to far-IR wavelength (~3 - 160 micron) and constructed the spectral energy distribution (SED) model by using photoionization code Cloudy. We compare the observed elemental abundances and dust features with the model result and from other PNe in order to verify the possible explanation for StWr4-10

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Title: On The Dynamical Effects Of Pluto-Sized Objects In The Priomordial Kuiper Belt

Abstract: A key feature of the architucture of the Kuiper belt oustide the orbit of Neptune has to do with the presence of objects trapped in different mean-motion resonances with Neptune. The dwarf planet, Pluto, in 3:2 resonance with Neptune is the most outstanding representative. Accompanying Pluto, there are many KBOs, called Plutinos, also have the same orbital relation with Neptune. According to the theory of planetary orbital migrations, Pluto and Plutinos and other groups were captured into the 3:2, 4:3, 5:3, 2:1, and 5:2 resonances by the outward orbital drift of Neptune. In this study, we explored the possibility of the existence of multiple Pluto-sized (or bigger) objects in the 3:2 resonance and the corresponding dynamical effects on the structure of the Kuiper belt. Besides serving as a probe to the chaotic evolutionary history of the early solar system, this scenario is also of interest to the emerging topic of scattering process of dwarf plaents in the debris disk.

Rizchel M. Masong
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Title: Predictive And Characterized Pulsar Behavior From Optical Pulsation

Abstract: Here we present the measured and predicted variables of pulsar PSR B1937+21. Among with its unique characteristics is the changing spectrum and temperature over several years. A number of models of light and temperature curves from pulsation were statistically analyzed using power spectrum and related it with other observable. Within the extended area of optical pulsation, the photons were calculated by folding the data statistically through time series and temporal analysis. The results were verified through optical profiling of optical pulse and cross validation. The phase-folded light curves in different energy bands will predict the varying spectral evolution, temperature evolution, pulse arrival times, mass transfer, and spin down power respectively,

Session 4: Education and History

Pham Ngoc Diep
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Vietnam

Title: Astrophysics research at the DAP

Abstract: DAP stands for Department of Astrophysics which is part of the Vietnam National Space Center. Our Department had been founded some twenty years ago. Currently, we have ten members and we do research on stellar physics and high-redshift galaxies using mm/sub-mm radio data observed by the most modern radio interferometers such as ALMA and NOEMA. During the last five years we have published about 20 articles in ISI journals (many of them are Q1) and kept training master and PhD students. To be scientifically efficient in an environment which is not favoured for astrophysics research development is difficult: there is little support for fundamental research, astronomy and astrophysics is not included in Vietnamese curriculum. We can keep working at the frontiers of science greatly thanks to the generous policy of observatories such as ALMA to release their data to public one year after the observation is made. In this talk, I will present generally about our research activities putting emphasis on the use of archival data which is an opportunity for researchers from developing countries.

Sze-leung Cheung
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National Astronomical Research Institute of Thailand
Thailand

Title: Collaboration under the UNESCO International Training Center of Astronomy network

Abstract: The speaker will provide an overview of the educational activities of NARIT and the opportunities arise from South East Asia collaborations of education and outreach project under the framework of the UNESCO International Training Center of Astronomy.

Wayne Orchiston[1] & Darunee Lingling Orchiston[2]
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[1]National Astronomical Research Institute of Thailand
[2]Independent Researcher
Thailand

Title: Telescopes, Temples, Eclipses and Ethnohistory: Exploring Southeast Asia's Exciting Astronomical History

Abstract: In this review paper we will briefly discuss the first introduction of the telescope into Southeast Asia in the seventeenth century, and the historically significant telescopes at Manila and Bosscha Observatories. We will then look at the orientations of Hindu and Buddhist temples and the special role of the Hindu Sun temples before examining the total solar eclipses of 1868, 1871, 1875 and 1929 and the key roles they played in the development of solar physics. Finally, we turn to the special potential that SE Asia offers ethnoastronomers, and focus on just two exciting projects. One involves the orang asli (= original inhabitants) of the Andaman-Nicobar Islands, southern Thailand, peninsula Malaysia and the Philippines, and the other is about the Chinese ethnic minorities (the co-called 'hill tribes") of Myanmar, Thailand, Laos, Vietnam and southern China.

Session 5: Cosmology

Fargiza A. M. Mulki & Hesti Wulandari
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Institut Teknologi Bandung
Indonesia

Title: Matter Power Spectrum in Coupled Scalar Field Cosmology

Abstract: In this paper we reconstructed matter power spectrum of a cosmological model in which coupled scalar field acts as dark energy. The so-called coupled scalar field (CSF) dark energy is a generalized model of quintessence, k-essence or phantom coupled to general matter (baryonic and non-baryonic dark matter) via a coupling constant. The existence of coupling between dark energy and matter allows energy to transfer between them that may give rise to different observational signatures, especially at perturbation level, including matter perturbation. In this work, through analytical exploration we studied that possible signature in matter power spectrum that may be induced by this model.

Lisa Goh Wan Khee
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National University of Singapore
Singapore

Title: Modified Statistical Analysis of Type 1a Supernovae Data

Abstract: In this thesis, we review an improved maximum likelihood analysis of the Type 1a Supernova (SN1a) data. We calculate the profile likelihood in the Ω_m - Ω_Λ parameter space by conducting a parameter sweep across the 8 SN1a parameters, using a Markov Chain Monte Carlo optimization algorithm. This improved analysis, which does not assume arbitrary values for the uncertainties, has the advantage of being bias-free as compared to the original analysis. We use the Joint Lightcurve Analysis (JLA) dataset containing 740 SN1a data samples for our study, and compare among 5 different models: the LambdaCDM model, the flat wCDM model, its non-flat generalization, as well as two dynamical w(z) parametrizations. We find that the LambdaCDM model is favoured over the other models, and the best fit values based on this model are Ω_m=0.40 and Ω_Λ=0.55. Interestingly, in most of the contour plots we obtain, the line of no acceleration is crossed at 2 -3sigma confidence levels, which is similar to the results published by Nielsen et al, the original authors who introduced the improved maximum likelihood analysis. When we generalize the wCDM model to the dynamical w(z) parametrizations, the evidence for cosmic acceleration becomes even weaker. This raises the question of how secure we can be of an accelerating expansion of the universe.

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Title: The Distribution of Vacua in Random Landscape Potentials

Abstract: Landscape cosmology posits the existence of a convoluted, multidimensional, scalar potential – the eponymous “landscape” – with vast numbers of metastable minima. The huge number of minima supported by landscape potentials suggest a potential explanation to the small but non-zero vacuum energy observed in our universe. We use the properties of random matrices and random functions in many dimensions to investigate the landscape. We explore the distribution of minima as a function of vacuum energy in an N-dimensional Gaussian random potential and derive a “likelihood” function for the density of minima in N dimensions, showing that after rescalings its properties are fully defined by the dimensionality and a single free parameter. We present a mix of analytical and numerical results at low N and extrapolate these to larger values of N, extracting estimates for P(Λ), the distribution function of vacuum energies in these scenarios.

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Title: A Model of Effectively Oscillating Massless Neutrinos and Its Implications

Abstract: In this paper, I consider the possibility of effectively oscillating massless neutrinos. In order to reconcile the zero masses and the observed flavor-changing phenomena, new particles are introduced. Besides being responsible for the flavor-changing phenomena of neutrinos, these particles can also act as candidates of dark matters. Some cosmological implications of this model are discussed. In this model, several important problems can become trivial, or at least easier to tackle, such as the smallness of neutrino mass, the mass hierarchy and the Dirac/Majorana nature of neutrinos.

Session 6: Extragalactic Studies 2

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Title: Effect of inelastic self-interacting dark matter on the structure of a Milky Way halo

Abstract: Self-interacting dark matter (SIDM) is an alternative to collisionless cold dark matter which can be useful for solving the problems encountered with cold dark matter (CDM) on sub-galactic scales. Although previous SIDM simulations have mainly considered elastic collisions, theoretical considerations motivate the existence of multi-state dark matter. In the simplest two-state model, excited to ground state transitions are exothermic and impart velocity kicks related to the mass splitting between the states. Here we present an analysis of inelastic self-interactions on the structure of a Milky Way-size dark matter halo, which we simulate using the Arepo code where a two-state inelastic dark matter model has been implemented. Our work is based on a comparative analysis between CDM, an elastic SIDM and an inelastic SIDM model. We find that the energy injection resulting from inelastic self-interactions lead to the formation of a larger core, and reduce the central densities at an earlier redshift compared to elastic SIDM. Inelastic collisions also isotropize the orbits, resulting in lower velocity anisotropy than the elastic SIDM counterpart. In the inner halo, the inelastic SIDM halo (minor-to-major axis ratio $s \equiv c/a \approx 0.65$) is more spherical than the CDM model ($s \approx 0.4$), but less spherical than for elastic SIDM ($s \approx 0.75$). The speed distribution f(v) at the location of the Sun in the inelastic SIDM model shows a significant departure from the CDM model, with f(v) falling more steeply at high speeds. In addition, the velocity kicks imparted during inelastic collisions produce unbound high-speed particles with velocities up to 500~km/s throughout the halo. These effects imply that inelastic self-interacting dark matter models could be distinguished from CDM or elastic self-interacting models through direct detection experiments.

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Title: Tracing Black Hole Signatures in Several Black Hole Candidates based on Their X-ray Spectral Evolution

Abstract: We use Swift/XRT data to investigate spectral evolution of several black hole candidates by utilizing color-color diagram as well as spectral fitting. We focus on those candidates which are newly found and classified as low-mass X-ray binary system based on their transient nature. We compare their results to those of XTE J1752-223, a transient system which is a more convincing candidate of black hole binary whose mass has been determined from spectral-timing correlation scaling. In addition, we also compare them to Cygnus X-1, a well-known black hole binary, despite its persistent nature. We found that the range of innermost disk temperature from disk blackbody model for all candidates is $0.11\ \text{keV} < T_{in} < 4.15\ \text{keV}$, a significantly wider range compared to that of black hole binary system in thermal state. We also found a wider range of spectral index for all objects, $-0.85 < \Gamma < 7.5$, based on power-law model. However, we found that all candidates occupy similar region of color-color diagram as XTE J1752-223 and Cygnus X-1, in which cannot be occupied by neutron star system. We also investigate data which occupy the range of soft color between 0.2 and 0.6 in color-color diagram, which correspond to $0.7\ \text{keV} < T_{in} < 1.5\ \text{keV}$. We found that inside this range of soft color, most spectra has comparable thermal and non-thermal components, which resembles the steep power-law state commonly found in black hole binary system. This statement is confirmed by the majority of Rin values for each candidates which are less than Rs, assuming 10 $M_{\odot}$ black hole. This indicates high mass accretion rate, except for MAXI J1535-571 and MAXI J1828-249, whose values of Rin resemble the hard state. Based on our findings, we suspect that the candidates are highly likely to be a black hole rather than a neutron star.

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Title: Determination of the Local Dark Matter Density Using K-dwarfs from Gaia DR2

Abstract: Local dark matter density is one of the crucial astrophysical inputs for the calculation of detection rates in dark matter direct searches experiments. Knowing the value also helps us to investigate the shape of the dark matter halo, which is of importance for indirect dark matter searches, as well as for various studies in astrophysics and cosmology. In this work, we performed kinematical study of stars in the solar neighborhood to determine the local dark matter density. We use 95,543 K-dwarfs from Gaia DR2 inside a heliocentric cylinder with a radius of 150 pc and z up to 200 pc from the Galactic midplane as tracers. Their positions and motions were analyzed, assuming that the Galaxy is axisymmetric and the tracers are in dynamical equilibrium. We apply Jeans and Poisson equations to relate the observed quantities, i.e. vertical position and velocity, with the local dark matter density. Tilt term in the Jeans equation is considered to be small and is neglected. Galactic disk is modelled to consist of a single exponential stellar disk, a thin gas layer, and dark matter whose density is constant within the volume considered. Marginalization for the free parameters was performed with Bayesian theorem using Markov Chain Monte Carlo (MCMC) method. We obtain that the value of the local dark matter density is 0,0116±0,0012 solar mass per cubic parsec or 0,439±0,046 GeV per cubic cm, in agreement with the determinations by Garbari et al. (2012), Xia et al. (2016), Sivertsson et al. (2018), and Buch et al. (2018) within the range of uncertainty.

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Title: Exploring the Physical Properties of Blazar OJ 287 Inferred from the Multiwavelength Spectral Energy Distribution

Abstract: We generate and analyze Spectral Energy Distribution (SED) of blazar OJ 287 using Swift/UVOT, Swift/XRT, and Fermi/LAT data. We classified the spectra into non-outburst and outburst periods based on the observed flux of Swift/UVOT. Non-outburst data cover a wide range of observations from 2007 until 2016 while the outburst data correspond to the significant increase in Swift/UVOT flux in 2016/2017. Prior to the outburst period, Swift/UVOT also detected a smaller flux rise in 2015/2016. We found that in the non-outburst period, SED of OJ 287 shows two broad humps similar to those of blazars in general. However, we also found that the contribution of UV and soft X-ray flux in the SED increase during outburst about three times for UV and ten times for soft X-ray compared to those of non-outburst fluxes. The higher energy peak of the SED also appear broader compared to that of typical synchrotron self-compton model. We suspect that synchrotron radiation predominate the UV and soft X-ray spectra during outburst which provide additional source for synchrotron self-compton radiation in the gamma ray band.

Keywords: blazar, OJ 287, SED, multiwavelength

Posters

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Title: Properties of Modified Combinants in Multi-particle Production in the LHC

Abstract: It has been shown recently that additional information can be obtained from charged particle multiplicity distribution by investigating their modified combinants Cj , which has been shown to exhibit periodic oscillatory behaviour. The modified combinants obtained from experimental data can be expressed in a recurrent form involving the probability of obtaining N charged particles P (N) scaled by the void probability P (0). In this talk, the properties of Cj as a function of various experimental observables such as $|\eta|$, pT and type of incoming particles (pp vs $p\bar{p}$) will be discussed. The connection between Cj to the factorial moment Fq and cumulant factorial moment Kq will be introduced.

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Title: Development of a Solar Storm Radio Telescope

Abstract: Sudden Ionospheric Disturbances (SID) are transient changes in the ionosphere caused by enhancement in X-ray and EUV fluxes during solar flare events. The Solar Storm Radio Telescope is developed to detect SID via VLF remote sensing. The system, which consists of loop antenna, preamplifier and a computer, is able to detect VLF signals with frequency between 3-30 kHz transmitted from various VLF stations around the Globe. The participants will also be investigating different methods to reduce the background noise in the data collection. This will help to ensure an accurate hit when there is a Sudden Ionospheric Disturbance.

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Title: Probing Supercritical Accretion in Ultraluminous X-ray Source M82 X-1 by means of X-ray Spectral Evolution Analysis

Abstract: We analyze spectral evolution of ultraluminous X-ray source (ULX) M82 X-1 by means of spectral fitting. We use selected Swift/XRT data in 2014 and 2015. The flux of M82 X-1 increased by a factor of 2-3 from 2014 to 2015. Most of the data in 2015 show greater dominance of hard component than those of 2014. Due to moderate signal-to-noise ratio, we only fit each spectrum with power-law and disk blackbody model separately. The data in 2014 are better fitted with power-law model based on the value of reduced-chi squared. On the other hand, both power-law and diskbb models showed comparable reduced chi-squared value for the data in 2015. We found that the range of spectral index for 2014 data is 1.65 - 2.08 and for 2015 data is 1.02 - 1.95 from the power-law model, resembling the range for that of black hole binary system at low mass accretion rate. We obtained higher innermost disk temperature from the disk blackbody model, 1.2 keV <Tin<3.63 keV, compared to that of black hole binary system in the thermal state. The calculated innermost radius of the disk Rin varies between 0.99 to 4.89 Rs assuming 10 $M_{\odot}$ black hole which indicates that the spectral state is not in thermal dominant state but rather we suspect that M82 X-1 exhibit greater mass accretion rate than that of the thermal dominant state. Keywords: M82 X-1, black hole accretion, spectral evolution.

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Title: Transverse energy density of Pb-Pb collisions at LHC (CERN) energies of TeV

Abstract: A well-known geometrical model is used to study the transverse energy distribution (E_T data for Pb-Pb collisions at LHC energies $\sqrt{s_{NN}} = 2.76$TeV obtained from the ATLAS collaboration. From the data, we determine the energy density ϵ during the collision, and compare it with the threshold energy density required to produce Quark Gluon Plasma as calculated by lattice QCD calculations.

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Title: A Study of Ethnoastronomy in Ciptagelar Civilizations, Sukabumi Regency, West Java, Indonesia: Relation of Full Moon Phase with Javanese Calendar and Hijriyah Calendar

Abstract: Astronomy has been practiced for as long as humans have been looking at the sky. Early civilizations used astronomy in many but still in simple ways. They used several celestial objects to do their daily activities, like doing a traditional ceremony. Ciptagelar Village, located at Sukabumi Regency, West Java, Indonesia is one of the traditional community which still uses this knowledge of astronomy in their lives for almost 650 years. Ciptagelar villagers consider that a full Moon phase is a special and sacred thing. They have a welcoming ceremony for a full Moon phase, named Mapag Purnama. We study this activity in the way of Ethnoastronomy. The method used are interviewing the villagers including the customary leader of the Ciptagelar Village and doing a literature study. Related to the full Moon phase, the ceremony of Mapag Purnama is held every 13rd to the night of 14th of the Moon Javanese Calendar. We use three references for choosing the date of full Moon phase, namely Fred Espenak, NASA, and Stellarium application. This date is then converted from Solar Calendar to Javanese and Hijriyah. Because the Javanese Calendar is adopted from the Hijriyah Calendar, both of two will have the same dates. We use 120-years correction for a difference cycle and number of leap years. However, after 2010 CE this correction is no longer valid. We find that the Javanese Calendar is one day slower than the Hijriyah Calendar.

Keywords: Ciptagelar Village, Full Moon, Mapag Purnama, Hijriyah Calendar, Javanese Calendar

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Title: Search for Stellar Streams in The Galactic Halo From Gaia DR2, GALAH DR2, RAVE DR5 and LAMOST DR4 Data

Abstract: Stellar streams are stars which are trapped in the same potential caused by dynamical resonance or tidal force. We aim to analyze kinematic substructures (streams) in the Galactic halo by V vs $\sqrt{U^2 + 2V^2}$ planes of Arifyanto & Fuchs (2006). We cross-matched data from Gaia DR2, GALAH DR2, RAVE DR5 and LAMOST DR4 based on positions. We have 3d kinematics and metallicity data of halo stars selected from kinematics criteria from ratio of probability of thick disk (TD) over halo (H) less than 0.01. Substructures are detected by using wavelet transformation and corrected using 15 Monte Carlo simulations. We obtained four kinematic structures on V vs $\sqrt{U^2 + 2V^2}$ plane which two of them are associated to BB17-1 and BB17-2 streams. All the streams had a high probability from the extragalactic origin.

Keywords: stellar stream, kinematic, Galactic halo.

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Title: Tracing the 3D structure of the Magellanic system

Abstract: The Large and Small Magellanic Clouds (LMC and SMC) are the largest satellites of the Milky Way. They provide a valuable example of a nearby interacting galaxy system, and are central to a variety of important problems in near-field cosmology. In this context, understanding the interaction history of the Clouds, and the total mass of the LMC, are critical unsolved issues. In this thesis, we utilised the latest data from two new panoramic surveys, the MagES project using the Dark Energy Camera, and the second data release from ESA's Gaia astrometric satellite, to explore the 3D properties of the Magellanic periphery. We used three different tracer populations (star clusters, red clump stars and RR Lyrae stars) to probe to a lower surface brightness, and over a wider area than, any previous study. The Magellanic periphery was chosen for our study as it is strongly sensitive to tidal stress, and the signatures of gravitational perturbations remain longer compared to the inner parts of the Clouds. This provides us with a clearer and longer record of interactions between the two galaxies. In the SMC, the evidence presented by the spatial and kinematic data of all three tracers paint a coherent picture of the system. Stellar populations on the Eastern side of the SMC (facing the LMC) are found at a closer distance as compared to the main body of the SMC, with a large line-of-sight distance spread (> 10 kpc) and significant residual proper motions (up to ~100 km/s) towards the LMC. In the LMC, the spatial distributions of the red clump stars and RR Lyrae stars mostly agree with the inclined disk model inferred from the inner parts of this galaxy, but this breaks down beyond ~10 degrees from the centre, with an apparent flattening of the inclination angle observed. Moreover, at larger radii, the position angle of the line-of-nodes appears to twist, and the inferred thickness of the disk increases, possibly indicating a flare. We observe no evidence for a substantial stellar halo component surrounding the LMC. All these observations are consistent with a picture in which the LMC and SMC have experienced a recent close interaction, as also evidenced by a variety of other features in the system. These include the overdensities and substructures in both the northern and southern outer disk of the LMC, as well as the prominent Magellanic Bridge and stream of HI gas. Altogether, this has helped us to trace faint Magellanic regions and understand the 3D nature of the Magellanic periphery better, which can subsequently be used in numerical models that aim to precisely reconstruct the recent interaction history of the Clouds.

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Title: Numerical solutions to Giovannini's parton branching processes

Abstract: In 1979, Giovannini [1] formulated multiparticle production as a manifestation of four QCD processes: A: $g \to gg$ (gluon bremsstrahlung), $\tilde{A}$: $q \to qg$ (quark bremsstrahlung), B: $g \to q\overline{q}$ (quark pair creation) and C: $g \to ggg$ (four-gluon vertex). At present, only approximate solutions exist, such as the Generalized Multiplicity Distribution (GMD) which excludes the *B* and *C* processes [2,3]. These approximate solutions have been very successful in describing charged particle multiplicities at lower energies, at least until the appearance of a "shoulder-like structure" (KNO-scaling violation) at $\sqrt{s} \approx 200$ and 900 GeV first reported by the UA5 collaboration [4]. Here, we extend the work of Sakai [5] and attempt a numerical solution that incorporates all four QCD processes, and see if the inclusion of the *B* and *C* processes can describe the KNO shoulder.

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Title: Difference in multiparticle production from particle-particle and particle-antiparticle interactions

Abstract: A simplified model of particle production and hadronization in high energy collisions is formulated using scalar fields and the resulting stochastic equation is solved numerically. Different initial conditions are used to compare particle-particle () and particle-antiparticle () interactions. It is shown that in this simplified view, there is a clear difference between the final multiplicity distributions resulting from the two initial conditions. To model the restricted phase space (limited pseudorapidity) measurements in experiment, a “loss” function is also proposed to account for the undetected particles close to the beam line.

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Title: Nonlinear Dirac Neutrino Oscillations in Matter

Abstract: Neutrino oscillations are a possible way to probe beyond Standard Model physics. The propagation of Dirac neutrinos in a massive medium is governed by the Dirac equation modified with an effective Hamiltonian that depends on the number density of nearby matter fields. At the same time, quantum nonlinearities may contribute to neutrino oscillations by further modifying the Dirac equation and its associated dispersion relation. Such a nonlinear scenario is computationally studied using Mathematica. We find that… (placeholder – depends on simulation results).

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Title: Optical property of white binary pulsar PSR J1713+0747

Abstract: Here we report the interpretation of the characterized and predictive properties of pulsar PSR J1713+0747, a white dwarf binary neutron star. The optical pulsations observed were described from the result of the analysis of its pulse phase, frequency, polarization, and time arrival of photons. The optical pulse profile predicted and were analyzed from accretion disk that originated inside the magnetosphere or within a few hundreds of kilometres from it with its spin period. Synchrotron emission of electrons in this rotation-powered pulsar magnetosphere seems more likely.

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Title: Galactic warp from kinematics of O and B stars

Abstract: Warp is a common feature in spiral galaxy. It can be detected by analyzing the kinematics of HI gas as a tracer. Warp also can be detected by the kinematics of young stellar in the thin disk, such as O and B stars. Using a sample of about 25.000 O and B stars from Gaia Data Release 2, LAMOST, RAVE, GALAH, and radial velocity catalogue from Karchenko and Pulkovo, we confirm the kinematics signature of Milky Way's warp. The data showed the increase of mean vertical velocity as a function of azimuthal velocity. We detect warp started at a guiding center radius of 9,5 kpc that corresponding to 262 km/s of azimuthal velocity.

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Title: Investigation of the Sudden Solar Ionosphieric Disturbance using Radiotelescopes

Abstract: Low-frequency radio telescopes are cheap and useful devices for the investigation of terrestrial and extra-terrestrial emissions. These emissions come either from the Sun and the planet Jupiter to terrestrial emissions. We will deploy a few radios to investigate the VLF from mid-Sep to mid-December 2019. The radios used are Radiojove (20 MHz), INSPIRE (0-10 kHz) and SSID (3-30 kHz). The data collected will throw light on the atmospheric VLF conditions during that period.

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Title: Closing up onto our Sun: Solar imaging

Abstract: Solar activity research provides insight into the sun's past, future (Science Daily, 2018). The solar activity includes observations of large numbers of intense sunspots, flares, and other phenomena; and demands a wide range of techniques and measurements on the observations. This research needs long term data collection before critical analyses can occur, to generate meaningful learning and knowledge. In this project, we will use solar imaging to make observations of solar activity, and take our baby-steps to make contributions in citizen science. Observations will be made in 4 wavelengths to gain a more thorough analysis by looking at different perspectives of the Sun, namely H-Alpha, Calcium-K, G-band, and white light."

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Title: Analysis of tidal structure of NGC 6397

Abstract: The tidal stress exerted by the Milky Way on Galactic globular clusters (GCs) has a direct impact on their structure and evolution and varies in time as these systems move along their orbits. Therefore, We explore the possibility of searching for extratidal features around the Galactic globular cluster NGC 6397 using the Gaia DR2 data. We compute the Bayesian evidence to determine the tidal and core radius of the NGC 6397 by using family of King's profiles. We also estimated the total mass of the cluster from the posterior samples of the parameters returned by PyMultiNest. An estimate of the total mass from tidal interaction of the self-gravitating cluster with the galactic potential are $11.41^{+0.35}_{-0.67}$ pc, $17.62^{+8.47}_{-1.17}$ pc, and $6.35x10^5\ M_{\odot}$.

Keywords: Extratidal, Bayesian evidence, King's profile, PyMultiNest.

Maps

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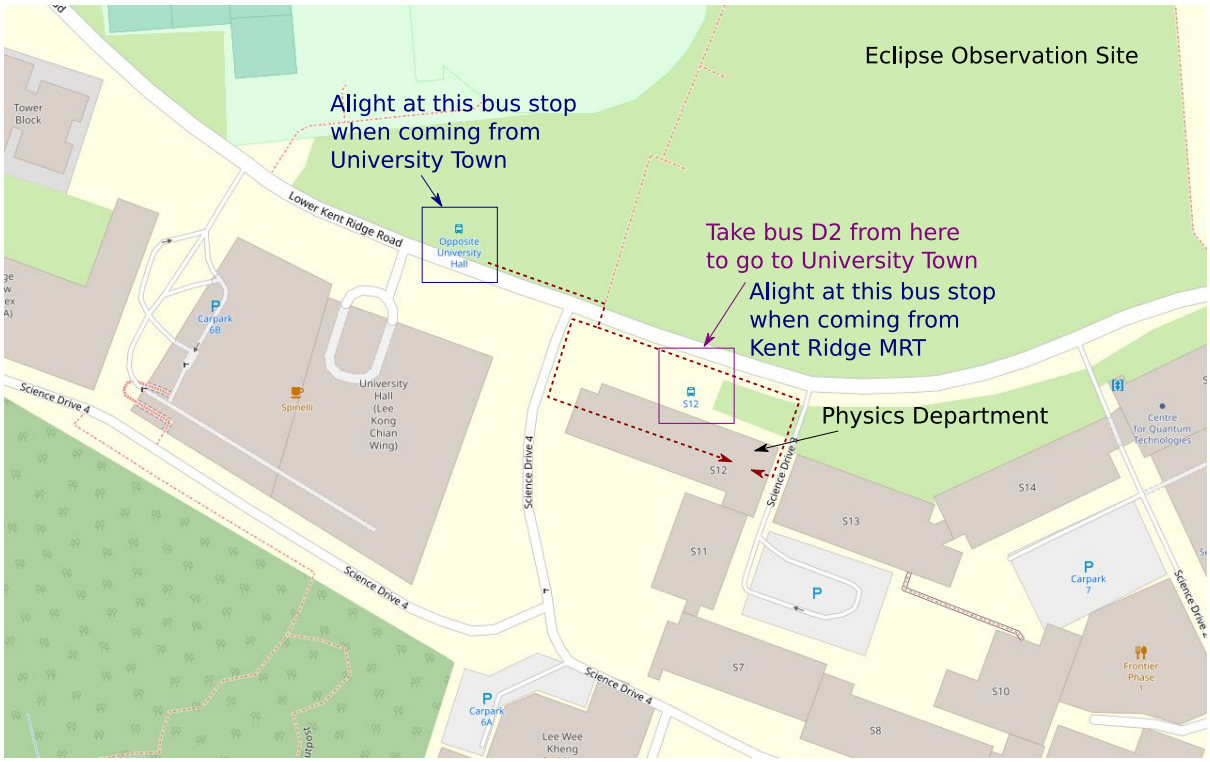
Map of the NUS Physics Department



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