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แบบขออนุมัติหัวข้อและโครงร่างฯ
Request Form for Dissertation/Thesis/I.S. Title and Proposal Approval

บัณฑิตวิทยาลัย มหาวิทยาลัยเชียงใหม่
The Graduate School, Chiang Mai University

วันที่ 11 เดือน พ.ย. พ.ศ. 2562
Date Month Year (BE)

ข้าพเจ้า (นาย/นาง/นางสาว) นงลักษณ์ ทองนพรัตน์ รหัสนักศึกษา 610551009
I am (Mr/Mrs/Ms) (Name in English) NONGLUK TONGNOPPARAT Student Code

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Program: Regular International Other

สาขาวิชา ดาราศาสตร์ แบบ/แผน 2.1 คณะ วิทยาศาสตร์ มีความประสงค์
Major/Field of Specialization Type/Plan Faculty of would like to request for

ขอเสนอหัวข้อและโครงร่างเพื่อทำ ☐ วิทยานิพนธ์ ☐ การค้นคว้าแบบอิสระ ในหัวข้อเรื่อง
approval of the Title and Proposal for doing Dissertation/Thesis Independent Study with the Title shown below

(Title in Thai) การวิเคราะห์สมบัติทางกายภาพของระบบดาวคู่แบบแตะกันชนิดดวงอาทิตย์ที่มีคาบการโคจรสั้นกว่า 0.3 วัน

(Title in English) Analysis of Physical Properties of Solar-type Contact Binaries with Orbital Period Shorter than 0.3 Days

โดยได้ ☑ ผ่านเงื่อนไขภาษาต่างประเทศ CMU-eTEGS คะแนน 71 และ การสอบวัดคุณสมบัติ เมื่อ 7/11/2562
has passed Foreign Language Test (TOEFL/IELTS/TEGS, etc - Specify with Score) and Qualifying Examination on DD/MM/YYYY (BE)

และขอให้ 1. รศ.ดร. วิเชียร ไกรวัฒนวงศ์ เป็น ☑ อาจารย์ที่ปรึกษา ☑ ประธานกรรมการฯ
Under the advice of as the Advisor Advisory Committee Chair

และ 2. ผศ.ดร. ศิวกร วิมลแจ่ม 3. ผศ.ดร. จตุพร ศรีสุข เป็นกรรมการฯ
and as Committee Members/Co-advisors

ตามข้อเสนอโครงร่างฯ ที่แนบ จึงเรียนมาเพื่อโปรดอนุมัติและแต่งตั้งคณะอาจารย์ที่ปรึกษาต่อไป
Details shown in the attached proposal and please appoint the proposed Advisor/Advisory Committee

(ลงนาม) [signature] นักศึกษา
(Signature) Student

เห็นชอบด้วย (ลงนาม) [signature] อาจารย์ที่ปรึกษา (Signature) Dissertation/Thesis/I.S. Advisor (รศ.ดร. วิเชียร ไกรวัฒนวงศ์) 11 / พ.ย. / 2562	☑ เห็นชอบโดย กก. สาขาฯ ในการประชุม 8/2562 เมื่อ Consented by Academic Program Committee on 13/พ.ย./62 ความเห็นอื่น .... Other comments (ลงนาม) [signature] ประธานฯ หลักสูตร/สาขา (Signature) Academic Program Chair (ผศ.ดร. ศิวกร วิมลแจ่ม) .... / ธ.ค. / 62
☑ เห็นชอบโดย กก. ประจำฯ ในการประชุม 13/2562 เมื่อ Consented by Executive Program Committee on 12/ธค/2562 ความเห็นอื่น .... Other comments (ลงนาม) จิรัฏฐ์ แสนทน ประธานฯ บ.ศ. คณะ/บว. (Signature) Executive Program Chair (ผู้ช่วยศาสตราจารย์ ดร.จิรัฏฐ์ แสนทน) รองคณบดีฝ่ายวิชาการ ปฏิบัติการแทน	☐ ทราบ Acknowledged (ลงนาม) .... คณบดีบัณฑิตวิทยาลัย (Signature) Dean of the Graduate School (........) ..... / ..... / .....

ประธานกรรมการบัณฑิตศึกษาประจำคณะวิทยาศาสตร์

THESIS TITLE AND RESEARCH OUTLINE

1. Student Name and Surname / Code

(Thai) นางนงลักษณ์ ทองนพรัตน์

(English) Mrs Nongluk Tongnopparat
Student Code 610551009

2. Thesis Title

(Thai) การวิเคราะห์สมบัติทางกายภาพของระบบดาวคู่แบบแตะกันชนิดดวงอาทิตย์ที่มีคาบการโคจรสั้นกว่า 0.3 วัน

(English) Analysis of Physical Properties of Solar-type Contact Binaries with Orbital Period Shorter than 0.3 Days

3. Advisory Committee/Thesis Advisor

Assoc. Prof. Dr. Wichean Kriwattanawong	Advisor
Asst. Prof. Dr. Sakhorn Rimjaem	Co-advisor
Asst. Prof. Dr. Jatuporn Saisut	Co-advisor

4. Principles, Theory, Rationale and/or Hypotheses

4.1 Binary star system

A binary system consists of two gravitationally bound stars orbiting around their common center of mass. The more massive star is typically called the primary, while its companion is called the secondary. The period, P, of the orbital motion of the binary system is given by Kepler's Third Law,

$$\left(\frac{P}{2\pi}\right)^2 = \frac{a^3}{G(m_1+m_2)} \quad , \tag{1}$$

where G is the gravitational constant, m_1 and m_2 are masses of each star, and a is the semi-major axis describing the full separation between the two stars.

An eclipsing binary is a binary star system in which the orbital plane of the two stars lies nearly in the line of sight of the observer that the components undergo mutual eclipses. Eclipsing binaries are variable stars, not because the light of the individual components vary but because of the eclipses (due to their geometrical configuration). The light curve of a detached eclipsing binary is characterized by periods of practically constant light, with periodic drops of intensity. In total eclipse, the smaller component must be obscured for whole intensity while the other will be obscured some part, allowing intensity from an annular surface. The orbital period of an eclipsing binary can be determined from a study of the light curve, and the relative sizes of the individual stars can be determined in terms of the radius of the orbit by observing how quickly the brightness changes during eclipse. If it is also a spectroscopic binary the orbital elements can also be determined, while mass, radius and luminosity of the stars can also be calculated. Therefore, the study of eclipsing binaries provides a very important tool for the field of stellar astrophysics.

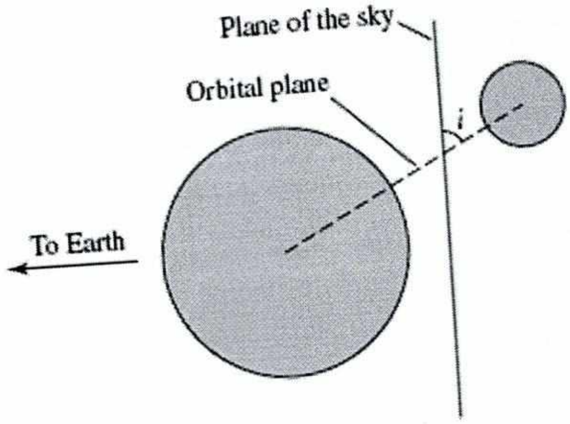

Fig.4.1 The geometric of an eclipsing binary (Bradley W. and Dale A.2014)

4.2 Contact binary system

Binary systems can also be classified according to their properties, based on the orbital separation of the components. Using the designations from the Prsa et. al (2011) catalog, these types are denoted detached (D), semi-detached (SD) and contact (C) binaries.

A contact binary has stellar components which both fill or slightly overfill their Roche lobes. As a result, the components of the binary are surrounded by a low-density common envelope (Wilson 1994). The properties of the shared convective envelope and the mass and energy transfer between the components within this envelope have been investigated by numerous authors (Kahler 2002; Webbink 2003; Kahler 2004; Csizmadia & Klagyivik 2004; Li et al. 2004; Yakut & Eggleton 2005; Stepien' & Gazeas 2012).

There are two kinds of contact binaries: one group is extensively low-temperature contact binaries (LTCBs) whose components share a common convective envelope, while the other group consists of high-temperature contact binaries (HTCBs) with common radiative envelopes. Contact binaries have been divided into two subgroups of A- and W-type by Binnendijk (1970). If the more massive and hotter component is eclipsed during the deeper (primary) minimum, we are dealing with an A-type system. On the other hand if the less massive star is the hotter one, the system is called W-type. The spectral types of A-type and W-type systems range from A to G and F to K, respectively. Most of low-mass contact binaries have orbital periods shorter than 0.3 d, the total mass lower than about 1.4 $M_{\odot}$ (Stepien and Gazeas 2012).

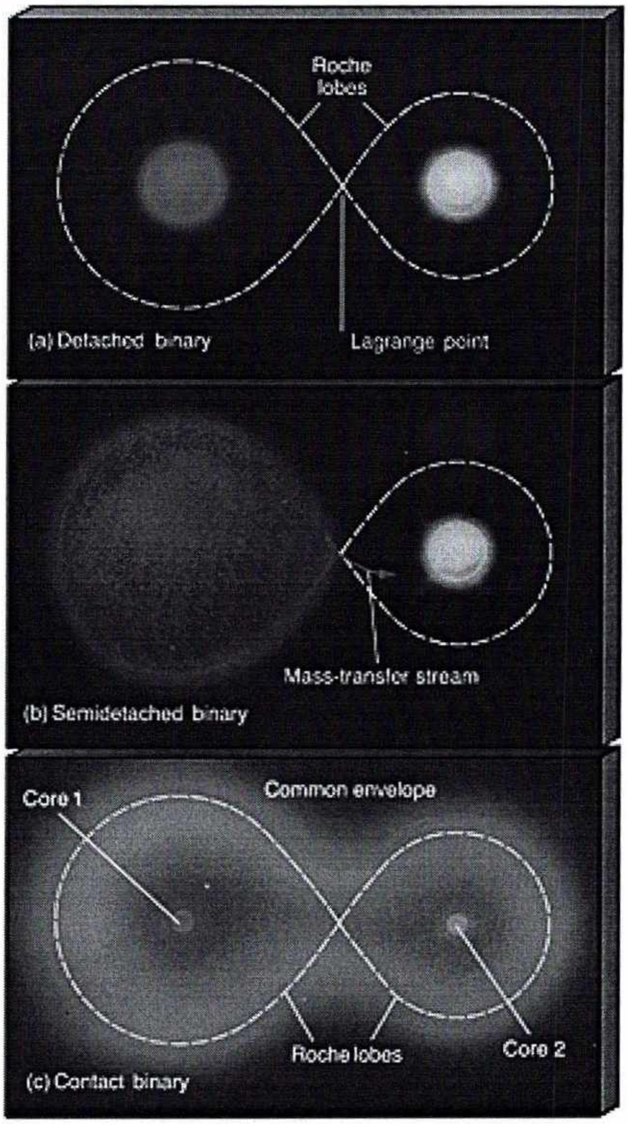

Fig.4.2 (a) detached binary, (b) semi-detached binary and (c) contact binary.(Darling)

In shallow contact binaries, which have components with different temperatures, their light curves typically show different eclipse depths between the primary and secondary minimum. This type of close binaries is also essential for studying the initial stages of the contact phase since the evolutionary stage contains many unknowns (Yildirim 2018).

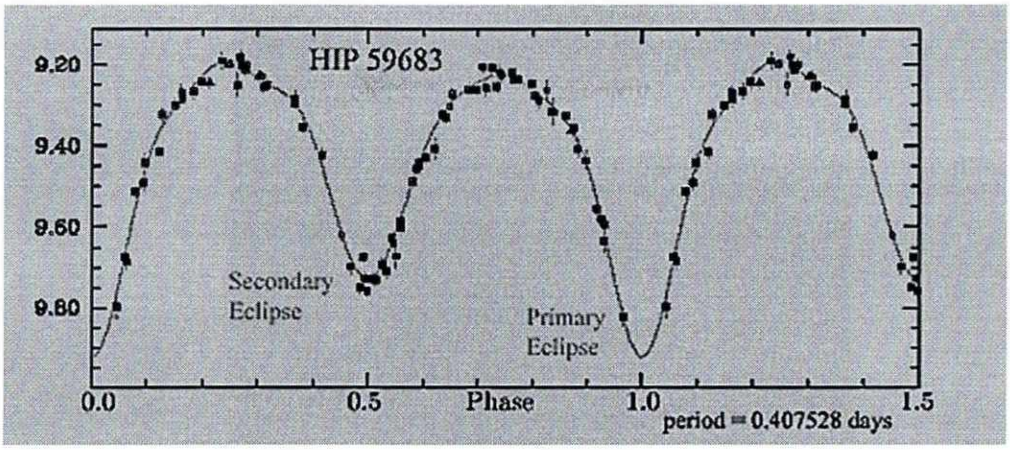

Fig.4.3 Light curve for HIP 59683, a contact binary system, shows different depths between the primary and secondary minimum.(ESA)

4.3 O - C curves

A very useful tool for analyzing these systems of eclipsing binaries are "observed minus calculated" $(O-C)$ curves. Such curves show the delay in the observed times of eclipses compared to the expected, or calculated, time, based on an assumed constant orbital period. The shape of the $O-C$ curve can reveal a number of features. For example, a straight line indicates that the assumed orbital period used to calculate the curve is accurate. If the assumed orbital period is slightly off from the actual value, the $O-C$ curve will have a varied slope either increase or decrease. A plot with a parabolic shape or gradually changing slope illustrates that the orbital period is changing over time. A possible physical explanation for such behavior is the decay or expansion of the orbit of the binary system. In addition, $O-C$ curves can exhibit sinusoidal variations that suggest periodic deviations to the orbital period of the binary. A possible explanation for such apparent or real changes in the binary period is the presence of a third star in the system. The Roemer delay, an effect due to the finite speed of light, may be the cause of apparent deviations to the orbital period (Roemer 1676). The presence of a third star can also cause Newtonian perturbations to the binary orbit, producing actual, physical changes to the binary period. Numerous analytic expressions have been developed for the case of a third body perturbing the orbit of a circular binary (Brown 1936; Harrington 1968, 1969; Soderhjelm 1975, 1982, 1984; Borkovits et al. 2003, 2011; Agol et al. 2005).

4.4 Evolution of contact binary

An evolution model has been suggested by Stepien (2006, 2009; Gazeas and Stepien 2008).The main features of this model are:

1. Cool contact binaries evolve from detached binaries with initial periods close to 2 days.
2. Both components are magnetically active, at the highest level.
3. Strong magnetized winds blow from both components leading to mass and angular momentum loss (AML). With the full spin-orbit synchronization, the orbital Angular momentum is ultimately reduced.
4. Evolutionary expansion of the more massive component, together with orbit shrinkage, results in Roche-lobe overflow (RLOF) followed by the rapid mass transfer to the less massive component.
5. The rapid mass exchange proceeds until the mass ratio reversal.
6. Depending on the detailed values of the orbital parameters, either a contact binary is formed directly from the rapid mass exchange phase, or a near-contact binary is formed, which reaches contact after some AML is added.
7. Further evolution of the binary in contact proceeds under the influence of AML and slow mass transfer from the present, evolutionary advanced, low mass component (donor) to the present massive component (receiver).
8. At the end, both components merge together forming a single, rapidly rotating star.

Thus the evolution of low-mass contact binary can explain final-stage evolution of binary systems. Solar-type contact binaries with orbital period shorter than 0.3 days are typically low-mass contact systems. This work aims to find evidence of the existence of the third body in the systems and physical parameters of the detected third body and magnetic activity cycles of these contact binaries. The evolutionary status of the binaries' components of the solar-type contact binaries will be examined to clearly understand about evolution of low-mass contact binary

5. Literature Review

Using data from the Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST) survey of China, Qian et al. (2017) found statistically that the majority of solar-type contact system are contact binaries, in comparison to other types. Moreover, most of these systems have orbital period shorter than 0.3 days. The solar-type contact binaries typically have magnetic activities with frequently occurrence. Some systems has a single star similar to our own sun, showing starspots, stellar activity cycles and flares. However, those activities in contact binary systems are not much investigated and there are no clear explanations on what mechanisms driving those phenomena in the contact binaries. Thus the study on the solar-type contact binaries can support understanding in magnetic activities and starspot evolution in contact binary systems. Therefore the solar-type contact system is target in this work and can represent most population of the contact binaries.

Furthermore, there are several researches (e.g., Eggleton & Kiseleva-Eggleton 2006, Qian et al. 2007, 2013) suggested that the third companion in a contact binary with the orbital period of 0.3 days plays role on the evolution of the binary for decreasing angular momentum of the system and transforming the system into a low angular momentum binary with a short orbital period. Statistically, the third body in the system can explain the destiny of the contact binary in the sense that a detached binary system with an orbital period shorter than 1 days typically has the third companion supporting in a process of angular momentum transfer out of the system, resulting the orbital period to decrease. Associating with magnetic stellar wind, a large amount of angular momentum will be lost, lead the orbital period to decrease rapidly and finally transform into a contact binary system. The process is the so-called angular momentum loss (AML) that has been discussed widely during a few decades to explain possibility of evolution of the contact binary (Bradstreet & Guinan 1994; Yakut & Eggleton 2005; Stepien 2006; Jiang et al. 2014; Qian et al. 2017; Qian et al.2018).

Not only magnetic activities but the third companion in a contact binary is also crucial to encourage understanding evolution of the contact systems. The third companion may be a low-mass stars or brown dwarfs (Qian et al. 2009; Yang et al. 2009; Wang et al. 2017) or planets (Qian et al. 2010) or even high-mass stars, such as neutron stars (Liao & Qian 2009) or black holes (Qian, Liao & Fernandez 2008). Besides there are several systems composite of two binaries orbit around each other or multiple systems (Pribulla & Rucinski 2006; D'Angelo et al. 2006; Rucinski et al. 2007).

6. Research Objectives

6.1. To provide fundamental physical parameters of the solar-type contact binaries with orbital period shorter than 0.3 days, i.e., semi-major axis of the binaries and masses, radii, temperatures and relative luminosities of both components.

6.2. To indicate current evolutionary status of the binaries' components.

6.3. To provide evidence of the existence of the third body in the systems and physical parameters of the detected third body.

6.4. To study magnetic activity cycles of the binaries.

7. Usefulness of the Research (Theoretical and/or Applied)

7.1. Obtain fundamental physical parameters of the selected solar-type contact binaries with orbital period shorter than 0.3 days.

7.2. Obtain current evolutionary status of the binaries' components.

7.3. Obtain evidence of the existence of the third body in the systems and physical parameters of the detected third body.

7.4. Obtain understanding magnetic activity cycles and evolution of the binaries.

8. Methodology, Scope and Research Plan

8.1. **Methodology**

Generally, the photometric BVR imaging data of the target binaries are measured using standard astronomical image processing software, i.e. IRAF, StarLink, etc. Target's brightness is measured in the term of differential magnitudes, which always vary with time, contributing light curves. The observed minimum light times, combining with data from literature can be used to estimate the revised orbital period, using the linear ephemeris method (Kreiner et al. 2001) as following equation:

$$Min\,I = HJD + (P \times E) \qquad , \qquad (2)$$

where $Min\,I$ is integrated observed minimum light, and HJD (Heliocentric Julian Day) is initial minimum light time. P is the orbital period and E is the epoch of the light minimum. Then,C, the calculated times of minimum light can be estimated, using the revised orbital period to obtain the $(O - C)$ curve, where O is the observed times of minimum light. The non-linear least-squares method will be used to fit the $(O - C)$ curve as following equation:

$$O - C = a_0 + (a_1 \times E) + (a_2 \times E^2) \qquad (3)$$

Typically, the $O - C$ curve of the newly discovered system has a trend as parabolic line, with a_0 , a_1 and a_2 coefficients. Thus, the long-term orbital period change dp/dt can be derived from the a_2 coefficient (Marino et al. 2007; Yang et al. 2009).

A standard method to derive photometric solutions of binary systems, the Wilson-Devinney (W-D) method (Wilson and Devinney 1971; Wilson and van Hamme 2003) will then be used in analysis. For contact binaries, the parameters can be fitted with the observed light curves.

Typically, the orbital period were found as a cyclic variation whether there exists the long-term orbital period change or not. The cyclic period change could be explained by using two mechanisms: the light time effect due to the third body in the system (Irwin, 1952; Pribulla and Rucinski, 2006) or magnetic activity cycle (Applegate, 1992).

For the first mechanism, Irwin (1952) suggested that existence of the unseen third body could be gravitationally affected the orbital period to have a cyclic variation with the period P_3 of the third companion orbiting around the mass center of the triple system. Thus, the formulae of Irwin (1952) were adapted to the $(O - C)$ fitting model (e.g. Irwin, 1952; Pribulla and Rucinski, 2006):

$$O - C = \Delta T + \Delta P \times E + Q \times E^2 + A\left[\frac{1-e^2}{1+e\cos\nu}\sin(\nu+\omega) + e\sin\omega\right], \quad (4)$$

where, ΔT is the difference of initial HJD, ΔP is the difference of orbital period, the quadratic parameter, $A = (a_{12}\, sin\, i)/c$ is the amplitude of the cyclic period change. The parameters a_{12}, i, e and ω are the orbital parameters, and ν is the true anomaly of the binary on orbit around the mass center of the system. E^* is the eccentric anomaly, used with the relation (Irwin, 1952):

$$\frac{2\pi(t-T)}{P_3} = \mathrm{M} = E^* - e\sin E^* \quad , \quad (5)$$

where M is the mean anomaly, t is the time of minimum light and T is the time of periastron passage.

In the other explanation for the cyclic period change, Applegate (1992) proposed that the magnetic activity in an active star can change its gravitational quadruple moment. For a binary containing at least one component as the active convective star, the variation of the quadruple moment can produce the period modulation. Thus, the equation of Applegate (1992) was adapted to the $(O - C)$ fitting model.

8.2. **Scope**

8.2.1. Observe the solar-type contact binaries with orbital period shorter than 0.3 days, using telescopes, operated by the National Astronomical Research Institute of Thailand (NARIT).

8.2.2. Determine magnitudes, light curve and times of light minimum.

8.2.3. Collect previous times of light minimum from literature for analysis of period change from the $O-C$ curve.

8.2.4. Determine physical parameters of the binaries.

8.2.5. Analyze current evolutionary status of the binaries' components.

8.2.6. Analyze the existence of the third body in the systems from the cyclic period change and determine physical parameters of the detected third body.

8.2.7. Analyze magnetic activity cycles of the binaries' components that have starspots from the cyclic period change.

8.2.8. Discussion and conclusions.

8.2.9. Write up thesis and full papers for participation in some international conferences and submission to international journals.

8.3. **Research Plan**

Activities	1st Year				2nd Year				3rd Year			
	1–3	4–6	7–9	10–12	1–3	4–6	7–9	10–12	1–3	4–6	7–9	10–12
Review literature												
Observe the solar-type contact binaries with orbital period shorter than 0.3 days												
Determine magnitudes, light curve and times of light minimum												
Analyze period change from the O - C curve												
Determine physical parameters of the binaries												

Activities	1st Year				2nd Year				3rd Year			
	1–3	4–6	7–9	10–12	1–3	4–6	7–9	10–12	1–3	4–6	7–9	10–12
Analyze the existence of the third body in the systems												
Analyze magnetic activity cycles												
Review literature, discussion and conclusions.												
Write up full papers for publications.												
Write up thesis												
Thesis defense Examination												

9. Research Location

9.1. Department of Physics and Materials Science, Faculty of Science, Chiang Mai University.

9.2. National Astronomical Research Institute of Thailand (NARIT)

10. Research Duration

3 years

11. References

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12. Thesis Advisors

The undersigned have read and approved this thesis proposal and have agreed to act as the Thesis Advisory Committee in the respective capacities mentioned below.

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Type/Plan

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ให้แก่มหาวิทยาลัยเชียงใหม่ตลอดอายุการคุ้มครองตามกฎหมายที่เกี่ยวข้องกับทรัพย์สินทางปัญญา
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Test Taker	:	Mrs. Nongluk Tongnopparat
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Registration Number	:	61040509
Test Date	:	April 19, 2018
Test Time	:	09:00-12:00 a.m.
Test Location	:	Language Institute, Chiang Mai University

(CMU-eTEGS) Test Result

Test Content	Maximum Score	Test Results
Section I : Listening	20 Points	16 points
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Section III : Vocabulary	20 Points	15 points
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(Associate Professor Rien Loveemongkol)
Director