European Organisation for Astronomical Research in the Southern Hemisphere

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APPLICATION FOR OBSERVING TIME

PERIOD: **98A**

Important Notice:

By submitting this proposal, the PI takes full responsibility for the content of the proposal, in particular with regard to the names of CoIs and the agreement to act according to the ESO policy and regulations, should observing time be granted.

1. Title — Category: **D–11**

OGLE-LMC-ECL-01350: a possible orbital precessing compact triple near stability limit

2. Abstract / Total Time Requested

Total Amount of Time:

The system OGLE-LMC-ECL-01350 is one of only very few systems with the orbital precession on the sky. Being a 17-th magnitude star, located in the LMC, having the predicted orbital period of the third component of about 6 days, close to the stability limit - all of these makes this star an ideal target for the UVES/UT2. Our preliminary solution of the third body orbit shows that this system is probably one of the most compact triples with shortest inner and outer periods and relatively fast orbital precession. Moreover, there is a lack of such systems known nowadays, despite the fact that there is no known theoretical reason for this deficit. Studying this system should also help us to test the stellar evolution models (different metallicity in LMC), and also to test our new approach for discovering the triple systems via the detection of binaries with orbital precession only on the basis of photometric data (and later confirmed via spectroscopy) out of our Galaxy.

3.

Run	Period	Instrument	Time	Month	Moon	Seeing	Sky	Mode	Type
A	98	UVES	20h	any	n	n	CLR	s	

4. Number of nights/hours — Telescope(s) — Amount of time

a) already awarded to this project:

b) still required to complete this project:

5. Special remarks:

6. Principal Investigator: JURYSEK

6a. Co-investigators:

P. Zasche 1207

7. Description of the proposed programme

A – Scientific Rationale:

Multiple stellar systems with the eclipsing binary (EB) on inner orbit are excellent physical laboratories allowing us to study the mechanisms of formation of the stellar systems and even stars itself (e.g. Goodwin & Kroupa, 2005). Despite the fact a lot of work has been done during recent years, the problem of multiple systems formation still remains open. The reason why we do not fully understand it well yet is poor statistics of multiple systems because of difficulty of detection and observational biases (Tokovinin, 2008).

Multiplicity is the most promising mechanism to explain the existence of close binaries with orbital periods $P \lesssim 1$ day. Third star on highly inclined outer orbit may cause so called Kozai cycles which means oscillation of eccentricity and inclination of both inner and outer orbits. Tidal friction between binary components causes orbital shrinkage and circularization (Kozai 1962; Eggleton & Kiseleva-Eggleton 2001). However, there are several more mechanisms which can be responsible for orbital shrinkage and formation of the hierarchical systems as accretion of gas from surrounding nebula (or circumstellar disc at later stage of evolution) or cascade fragmentation of the nebula with subsequent orbital evolution (Tokovinin, 2008). Numerical simulations including only particular mechanisms are capable to explain only several statistical properties of multiple systems, but fails in attempts to explain others. That is matter of intensive investigation of recent years and each newly discovered multiple system helps us to improve statistical properties of our sample and provide new limits on theory.

If the inner binary of a multiple system shows eclipses the so called Eclipse Timing Variations (ETVs) may emerge. ETVs are combination of classical Rømer's delay (so called *light time effect (LTE)*) and dynamical effects, both caused by presence of third body. Recently, *Kepler* team took advantage of ETVs to found several dozens new compact triple systems with short outer period (Rappaport et al. 2013; Borkovits et al. 2015; 2016). That was impossible before *Kepler* era because of insufficient cadency and precission of earth-based observations. Other useful way to detect the third body is orbital precession, which occurs when orbits are not coplanar (Söderhjelm 1975). Orbital precession is reflected as minima depth changes, which can easily be detected by photometry. Unfortunately, at the most cases a timescale of orbital precession is very long $\tau \sim P_{\rm out}^2/P_{\rm in}$ and that is the reason why we still know only a few these systems.

Recently found compact triples with short outer period (upper left Figure, for further details see (Borkovits et al. 2016)) show relatively fast orbital precession on the timescale of $\tau \simeq 10^1 - 10^2$ years and fast LTE. Such systems should also display the radial velocity variations as the bodies revolve around a barycenter. Rather interesting finding was that there is a lack of such systems with the shortest inner and outer periods, despite the fact that these systems would have passed all theoretical and observational restrictions and there is no known reason for this deficit (Borkovits et al., 2016).

It is good to highlight that all known compact triples, including new *Kepler* sample, are placed inside our Galaxy and it is challenging to study the triple or multiple systems also in the close galaxies and test our detection capabilities. Good candidate is Large Magellanic cloud, photometricaly covered by several automatic surveys like OGLE and MACHO. Our automatic pipeline reveals several dynamicaly interesting eclipsing binaries with high probability of orbital precession manifesting by a changing of observed inclination. One of them – OGLE-LMC-ECL-01350 – thanks to its sufficient brightness 17 mag and absence of any close bright star within $4''$ vicinity, seems to be a great candidate for spectroscopic follow-up observation with UVES which can confirm its triplicity.

Analysis of available photometric data combined together with our own observations restricted the parameters of third body in the system. Time dependency of inclination (down left Figure) gives us constrains on the third body mass and the orbital period (grey area in the down right Figure). Additionally, there are a couple more restrictions on the allowed area in the $m_2 - P_2$ plot. Light curve solution gives us a limit on third body maximum mass, LTE amplitude gives us upper limit on mass–period relation and LTE period (upper right Figure) allows us to estimate orbital period of third body $P_{\rm out} \in (5.5, 8.0)$ days. In the right down Figure is clearly seen that the period of the third star have to be smaller than $P_{\rm out} \lesssim 70$ days. That makes our system to be excellent candidate to fit in the gap of compact triples (upper left Figure). Note that the possible third component seems to be close or even slightly behind the stability limit what makes this system even more interesting. But there is a strong need for the quality high-dispersion spectra because the estimated third-body parameters are still only poorly constrained and careful analysis of the gamma velocity of the inner binary or the third component itself, together with spectral disentangling will give us opportunity for precise determination of system parameters. System is still being monitored photometrically with our telescope in Chile, and simultaneous photometric and spectroscopic observations would be of great benefit.

B – Immediate Objective:

Our aim is to obtain high-resolution (≈ 40000 ??) optical spectra over the orbital period of predicted outer component of the triple system. The data will then be processed and analyzed as follows: i) basic reduction and wavelength calibration with the ?? package; ii) spectral disentangling to obtain spectra of individual components (KOREL, Hadrava 1995; 2009), derivation of the radial velocities and the solution of the orbit,

7. Description of the proposed programme and attachments

Description of the proposed programme (continued)

combined together with the inner orbital solution from the Phoebe code (Prša & Zwitter 2006) will give us a complete physical parameters of the system.

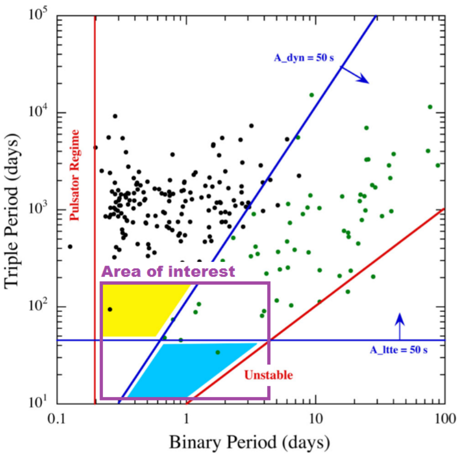
The proposed observations would enable us to answer the following questions: i) How close to the stability limit of the system the outer period is? ii) Does the system fit in the gap of the compact triples? iii) What about a long-term stability of the orbits and the future of such a tight triple - will it remain or will it dissolve into a more stable binary plus an expelled single star? iv) Are the light curve amplitude variations really caused by orbital precession driven by third body on the outer orbit?

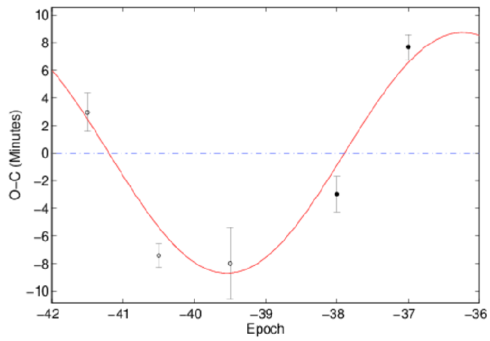
For a complete analysis we have own unpublished photometric data, together with long-term photometry from surveys of this system, but precisse spectroscopic observations are missing. Suficient coverage of the outer orbit of this system at airmass below 1.6 requires a few nights (depending on conditions). We assume exposure time about 3600 s and 20 observations of radial velocities would be enought for spectral disentangling and reveal the nature of the third body.

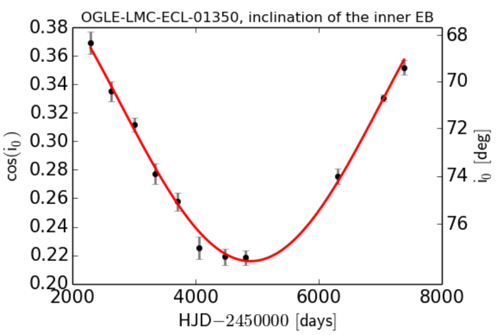
References:

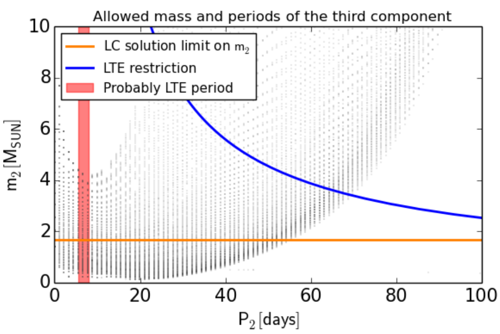
Borkovits et al. 2015, MNRAS,448,946
Borkovits et al. 2016, MNRAS, 455, 4136
Eggleton & Kiseleva-Eggleton 2001, ApJ, 562, 1012
Goodwin & Kroupa 2005, A&A, 439, 565
Hadrava 1995, A&AS, 114, 393
Hadrava 2009, A&A, 494, 399
Kozai 1962, AJ, 67, 591
Prša & Zwitter 2006, Ap&SS, 304, 347
Rappaport et al. 2013, ApJ, 768, 33
Söderhjelm 1975, A&A, 42, 229
Tokovinin et al. 2006, A&A, 450, 681
Tokovinin 2008, MNRAS, 389, 925

Attachments (Figures)









8. Justification of requested observing time and observing conditions

Lunar Phase Justification: No peculiar requirement for lunar phase.

Time Justification: (including seeing overhead) Using the ESO exposure time calculator, we estimated that a S/N ratio of minimum 18 for the selected object can be reached with an exposure time of 3600 s. (Sirka sterbiny 0.9arcsec, red arm 450-750, seeing 0.8, template B8.. nevim jestli to nenavolit jinak..) In total, about 20 hours of observing time are sufficient to fulfil the aims of our proposal. No special observing conditions are necessary for our target.

8a. Telescope Justification:

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8b. Observing Mode Justification (visitor or service):

...

8c. Calibration Request:

Standard Calibration

9. Report on the use of ESO facilities during the last 2 years

No data has been obtained from ESO facilities in recent 2 years.

9a. ESO Archive - Are the data requested by this proposal in the ESO Archive (http://archive.eso.org)? If so, explain the need for new data.

There are no data in the ESO archives.

9b. GTO/Public Survey Duplications:

Musim rucne prohlednout vsechny ty programy v tech odkazech, nebo se to da udelat nejak rychleji? :)
GTO programmes: http://www.eso.org/sci/observing/teles-alloc/gto.html
Public Survey programmes: http://www.eso.org/sci/observing/PublicSurveys/sciencePublicSurveys.html

10. Applicant's publications related to the subject of this application during the last 2 years

Zasche P., Wolf M., 2013, A&A, 559, 41: The first analysis of extragalactic binary-orbit precession

11. List of targets proposed in this programme

Run	Target/Field	α(J2000)	δ(J2000)	ToT	Mag.	Diam.	Additional info	Reference star
A	OGLE-LMC-ECL-01350	04 50 13.9	-68 23 07.6	20.0	17.1		1.099, 6.0	

Target Notes: An orbital period of the eclipsing pair and expected orbital period of third body (both in days) are given in the Additional info column.

12. Scheduling requirements

13. Instrument configuration

Period	Instrument	Run ID	Parameter	Value or list
98	UVES	A	RED	Standard setting: 580