INAF – TIME ALLOCATION COMMITTEE

Application for observing time **Category: D**

Period AOT39 (April 2019 – September 2019) **Submit using: www.tng.iac.es/submit.html**

1. Title

Following-up Gaia newly discovered Cepheid variables

2. Abstract

Classical Cepheids are the most important primary indicators for the extragalactic distance scale. Establishing the precise zero points of their Period-Luminosity and Period-Wesenheit (PL/PW) relations has profound consequences on the estimate of H_0. The recent Data Release 2 (DR2) of the *Gaia* Spacecraft includes photometry and parallaxes for thousands of classical Cepheids. However follow up observations to obtain Near-Infrared (NIR) photometry as well as spectroscopic data are needed to fully exploit *Gaia* results. With the present proposal we aim at observing 12 Cepheids possessing precise *Gaia* parallaxes (better than 10%). A companion proposal presents the part of the project to obtain NIR observations for these 12 objects (and many more) with REM.

3a. Number of requested hours per telescope and instrument

TNG					REM	
DOLORES	DOLOR.+MOS	NICS	HARPS-N	GIANO-B	ROSS	REMIR
			18			

3b. Observing modes

TNG:		Visitor	X	Service		ToO
REM:		Rapid Response		Queuing		ToO

4a. Preferred months

first choice: Jun second choice: July

4b. Other scheduling constraints (use also box 14)

5a. Past and future of the project

a) Hours already awarded to the project:

b) Hours foreseen to complete the project: 18
(not including this request)

6. Principal investigator

Name V. Ripepi

Institute INAF-Osservatorio astronomico di Capodimonte

Address Via Moiariello 16 80131, Naples, Italy

e-mail vincenzo.ripepi@inaf.it

Phone +390815575416

7. Co-investigators (name and institution)

G. Catanzaro, INAF-OACatania
V. Testa, INAF-OAMontePorzio
G. De Somma, INAF-OACapodimonte
S. Leccia, INAF-OACapodimonte
R. Molinaro, INAF-OACapodimonte
M. Marconi, INAF-OACapodimonte
I. Musella, INAF-OACapodimonte

8. Status of the project

Telescope	Instrument	Date	Hours	Notes

Description

Publications

9a. If this proposal is a part of a PhD thesis, write here the name of the student, the thesis title and briefly describe the relevance of these observations for the thesis goals.

G. De Somma, *The theoretical calibration of the H_0 from Classical Cepheids.* The proposed observations will be crucial to test theoretical predictions concerning the use of multi-filter Period-Luminosity and Period-Wesenheit relations and their dependence on chemical composition.

9b. Is this, or a similar application submitted to other time allocation committees (e.g. ESO, TNG-CAT, ITP)? If yes, please specify which and explain if and why the proposals should be considered complementary.

10. Description of the programme (max. 3 pages, including references, tables, and figures.)

A) Scientific rationale Classical Cepheids (DCEPs) are young (50-500 Myrs) Population I stars commonly found in disks of late-type galaxies as well as in the irregular ones. DCEPs are the most important primary distance indicators for the cosmic distance scale (Riess+2016,Riess+2018a), due to their characteristic Period-Luminosity (PL) and Period-Wesenheit (PW - reddening-free) relations (Leavitt 1912,Madore 1982,Caputo+2000). In conjunction with secondary distance indicators such as SNIa, the DCEPs provide an estimate of $\mathrm{H}_0 \sim 73.48 \pm 1.66$ km/sec/Mpc with 2.3% of claimed uncertainty (Riess+2018b). However, there is a tension at 3.4-3.7 σ with $\mathrm{H}_0 \sim 66.93 \pm 0.62$ km/sec/Mpc obtained from the analysis of the cosmic microwave background plus ΛCDM model (Planck Collaboration+2016,Riess+2018a,Riess+2018b).
To reconcile the inconsistency between these values, we need more accurate calibrations of the different steps of the cosmic distance ladder. In first place we have to check locally (in the Milky Way) the calibration of slopes/zero points of the PL/PW relations used for DCEPs that at moment rely on a handful of objects with accurate Hubble Space Telescope (HST) parallaxes (Riess+2018a).
In this context a great help can be given by the measures of the astrometric spacecraft *Gaia* (Gaia Collaboration, Prusti+2016). Indeed, the recent Data Release 2 (Gaia Collaboration Brown+ 2018) includes accurate photometry and astrometry (including parallaxes) for more than 1000 DCEPs (Holl+2018,Clementini+2018). In a recent paper (Ripepi+2018) we have re-analised the sample of *Gaia* DCEPs, removing the existing contaminants, remaining with about 800 DCEPs, among which 143 are new discoveries. Gaia parallaxes are crucial to calibrate PL and PW relations. The slope and the zero points of these relations depend on a number of systematic effects. As the combination of the period-mean density relation, the Stefan-Boltzmann law and the evolutionary mass-luminosity relation lead to Period-Luminosity-Color (PLC) relations, the commonly adopted PL relations result from an averaging operation of the finite color width of the instability strip. Since the intrinsic dispersion of the PL relation, due to the strip topology, strongly decreases as the adopted filter wavelength increases, Near-Infrared (NIR; JHK_S bands) PL are commonly used for the distance scale. NIR bands are also much less affected by reddening with respect to the optical, even if Cepheids especially towards the Galactic center, can show large extinctions also in the NIR. On the other hand, both in the optical and NIR, the use of PW relations has many advantages, indeed they are reddening free by definition and the color term included in their definition take partially into account the width of the instability strip, thus reducing significantly the intrinsic dispersion of these relations. However, both PL and PW relations show a dependence on metallicity that is smaller at NIR but has to be taken into account to avoid systematic effects in the determination of the distances (e.g. Romaniello+2008, Bono+2010, Gieren+2018 and references therein). An additional issue in the determination of PL/PW relations for DCEPs is the presence of companions. Indeed, it is estimated that at least half of the DCEPs are part of binary systems (e.g. Anderson & Riess 2018). This occurrence can alter significantly both the photometry (wrong average magnitudes, especially in the optical) and the astrometry (wrong distances) of DCEPs and it needs to be taken into account in the determination of PL/PW relations.
Therefore, to safely use DCEPs for the distance scale, we need NIR photometry and information about their reddening, metallicities and possible duplicity. Accurate estimates for these quantities are already present in the literature (e.g. Genovali+2015) for a subsample of about 1/3 of the DCEPs observed by *Gaia*. Hence, to fully exploit the *Gaia* astrometry for the DCEP pulsators it is crucial to carry out follow-up observations, to obtain accurate: i) light curves in the JHK_s bands and ii) high resolution spectra
In this context, the instruments available to our community are perfect for our purposes. Indeed, the target DCEPs are bright enough to obtain high-resolution spectra with HARPS-N@TNG. In this proposal we concentrate on the spectroscopic observations, whereas a parallel proposal is devoted to the photometry with REM.
B) Scientific aim We aim at collecting three epochs high-resolution spectra with HARPS-N@TNG for a sample of 12 bright DCEPs possessing precise *Gaia* parallaxes (better than 10%). The proposed observations will allow us to obtain: i) very accurate abundance analysis. This not only means a measure of the [Fe/H] value but also of the other important chemical species such as the α-, iron-peak, s-, r- elements; ii) extremely accurate radial velocities. The three epochs will allow us to devise with absolute certainty the presence of companions.
The availability of these information will be important to: i) decide to use or not (in case of duplicity) these high weight objects in the derivation of DCEPs PL/PW (small error on distance implies great weight in the PL/PW regression procedures). In case of use, they will contribute to the determination of the metallicity term in these relations; ii) contribute to the study of the Galactic gradient and chemical enrichment of young disk stars.
It is important to note that chosen targets are all with declination±20 deg, allowing these objects to be observed with REM, so that we will have a complete characterisation from the photometric point of view (see the companion proposal), too.
We foresee to apply for additional 12 objects with the same characteristics for the next semester.
Finally, we underline that our team gathers the different expertises needed to carry out successfully the present project as well as the parallel one on REM devoted to the NIR photometry. In particular, G. Catanzaro, V. Ripepi and S. Leccia will take care of the HARPS-N spectra (abundances and radial velocities); V. Testa, V. Ripepi, I. Musella, S. Leccia and R. Molinaro will analyse the REM data (optical/NIR light curve production); G. De Somma and M. Marconi will provide theoretical predictions based on the most up-to-date pulsational code. All the team will collaborate in exploiting the results.

Anderson, R. I.; Riess, A. 2018, ApJ, 861, 36
Bono et al. 2010, ApJ, 715, 277
Caputo et al. 2000, A&A, 354, 610
Clementini et al. 2018, arXiv:1805.02079
Gaia Collaboration et al. 2016 2016, A&A, 595, A1
Gaia Collaboration et al. 2018, A&A, 616, A1
Genovali et al. 2015, A&A, 580, A17
Gieren et al. 2018, arXiv:1809.04073
Holl et al. 201818, arXiv:1804.09373
Leavitt & Pickering 1912, Harvard College Observatory Circular, 173, 1
Madore 1982, ApJ, 253, 575
Riess et al. 2016, ApJ, 826, 56
Riess et al. 2018a, ApJ, 855, 136
Riess et al. 2018b, ApJ, 861, 126
Ripepi et al. 2018, arXiv181010486R
Romaniello et al. 2008, A&A, 488, 731

11. List of targets (note that the absence of a proper object list and information may weaken the proposal)

Name	α	δ	Epoch	Mag.	Time	Additional Information
431901873...	19 20 06.95	+12 47 43.0	J2000	G9.38	1200s	Target also for REM
410485778...	18 31 19.75	-13 06 29.5	J2000	G9.48	1200s	Target also for REM
406988778...	18 03 41.74	-22 10 58.7	J2000	G9.54	1200s	Target also for REM
434461141...	16 23 26.40	-09 40 59.5	J2000	G9.57	1200s	Target also for REM
409634104...	18 21 05.54	-18 27 19.7	J2000	G9.80	1200s	Target also for REM
415475802...	18 39 04.03	-10 49 21.3	J2000	G9.97	1200s	Target also for REM
425646446...	18 33 46.85	-04 48 32.9	J2000	G10.07	1800s	Target also for REM
427857059...	18 48 16.32	+00 49 03.5	J2000	G10.21	1800s	Target also for REM
409578265...	18 09 46.69	-18 22 38.3	J2000	G10.31	1800s	Target also for REM
182519033...	19 35 44.75	+18 56 42.5	J2000	G10.60	1800s	Target also for REM
415555094...	18 36 52.36	-09 07 04.8	J2000	G10.62	1800s	Target also for REM
414569787...	18 11 30.60	-15 55 33.5	J2000	G10.73	1800s	Target also for REM

12. Observational strategy and justification of requested time, including overheads.

The proposed targets have all *Gaia* G<10.7 mag that corresponds to V<11 mag at the temperature of the DCEPs. Using the latest HARPS-N exposure time calculator, with templates F0/G0, airmass=1.5, seeing=1.2 arcsec, moon=14 days, we obtain that for the 6 stars with V<10 mag exposure time of 1200s allows us to get SNR~55-60 in the wavelenght range $\lambda \sim 4700 - 7000\AA$, where most of the relevant lines for the chemical abundance lies. Similarly, for the 6 stars with V<11 an exposure time of 1800s permits to reach SNR~45-47 in the same wavelength interval. Allowing 300s (5m) overhead for each spectrum, we have that on average we obtain 1 spectrum every 30m, i.e. 6h to observe all the objects. Since we wish to obtain three epochs for each objects, the total time requested is 3x6h=18h. Obviously, the three epochs should not be consecutive, but executed over different nights, given that the periods of the target DCEPs span a wide range of periods, from about 1.3 to 42 days. This is the reason why we ask for service observing.

13. Requested instrument(s) setup

Id	Instrument	Binning	Filter(s)	Slit	Grism	Time	Additional Information
1	HARPS-N					18h	HARP-N is offered with one set-up only

14a. Moonlight constraints

Max. # of days from new moon

14b. Scheduling constraints, special requirements and other remarks
(please include justification of constraints in 14a)

No constraints on moon
Given that we need to obtain three epochs for each target in different nights, our proposal can be best carried out in service mode (see also box 12).
Note that the names of the targets are truncated because the *Gaia* IDs are too long.

15. Observational background of the applicants

Name of the observer(s) at TNG:

Experience of the observer(s) with the requested TNG instrument(s)

Experience of the observer(s) with other telescopes/instruments