Instituto de Astrofísica de Andalucía, CSIC
Propuesta de Investigación-Solicitud de tiempo de Observación

1. 1. DATOS DE LA SOLICITUD

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OBSERVATION MODE:

In-Situ: X **Remota: X** **De servicio:**

PROGRAM TITLE(S): (one line per program)
A. Simultaneous multicolour photometric observations with BRITE satellite of fast-rotating A-type pulsating stars
B.
C.
D.
E.

ABSTRACT(S) (one single abstract or one abstract per program)
The objective of this proposal is to collect multilcolour photometric timeseries (lightcurves) of a sample of bright, rapidly-rotating-A-type stars (delta Scuti/gamma Doradus/hybrid pulsators), in order to combine them with ultraprecise photometry obtained with the BRITE Constellation space mission, and with high-resolution spectroscopy from SONG, SOPHIE, and ELODIE instrument. The combined multilcolour photometry from OSN with BRITE white light data will allow us to enhance the frequency analysis (i.e. obtain better precision in the frequency detection) in the high-frequency domain, for which the BRITE satellite is less sensitive. As a result, we will have an enhanced full coverage from low to high frequency domain for those stars, which is required for asteroseismic analysis. In particular we want to determine periodic patterns in the oscillation spectrum of those stars, which are nowadays one of the most useful asteroseismic parameters to constrain the mean density and evolutionary stage of delta Scuti stars. In addition, thanks to multilocour lightcurves, we will be able to constrain the mode identification, which is key in asteroseismic studies. All this information will be then compared with theoretical 1D-perturbative and 2D non-perturbative oscillation models, in order to better understand the pulsation content of these stars.

TELESCOPE TIME REQUESTED

Run	Program (A,B,C,D,E)	Telescope	Nasmyth (E/W)	Instrument	Nights	Lunar phase	Observers's initials
1	*A*	*90cm*	*E*	*Strömgren*	*90?*	*N,CR,DECr*	*JCS, SM, JP, AGH, MLM*
2							
3							
4							
5							
6							

Run	Optimum dates	Acceptable dates	Unacceptable dates (give reasons)
1	Noches de Luna nueva desde Enero a Junio	Noches de Luna Cre o Dec desde Enero a Junio	Las noches de Luna LLena
2			
3			
4			
5			
6			
7			
8			
9			

COLABORATORS

Name	Institution	E-mail	Program(s) (A,B,C,D,E)
Dr. Susana Martin Ruiz	IAA-CSIC		
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Dr. Rafael Garrido	IAA-CSIC		
Mariel Lares Martiz	IAA-CSIC		
Dr. Eloy Rodríguez	IAA-CSIC / UGR		

TELESCOPE TIME AWARDED TO PI IN THE LAST 2 YEARS

List the time assigned for observing campaigns at the OSN, including upcoming awarded time. Give date number of nights, telescope, instrument, program title, and briefly list status, results and publications. Use an additional page if necessary.

¿Is this proposal part of an approved thesis program?. If so, list ALL telescope time awarded for the thesis above, and summarize the total amount of time here:

CIENTIFIC JUSTIFICATION(S)

On the following pages, give the scientific justification for your program(s). Use any format you choose (e.g. an integrated discussion of closelya related programs, separate discussions for each program, or a general indrtoduction with separate detailded discussions). The scientific justification has a total limit of 5 pages of text, 2 pages of figures and tables, plus references (no limit). Use no less than an 11-point fotn and half-inch margins. Proposals that exceed these limits wil be returned to the submitter.

Context

The analysis of δ Scuti stars revealed the presence of periodic patterns in their p-mode frequency spectra [1–4]. These patterns were found to be compatible with the expected large separation ($\Delta\nu$) for these stars. A solid confirmation came from the scaling relation found between the observed $\Delta\nu$ and the mean density computed for a sample of well-known stars (including binary stars) at different rotation rates [5]. As predicted by oscillation models [6–8] these results demonstrate that $\Delta\nu$ can be detected in δ Scuti stars and that it scales with the star's mean density independently of its rotation rate. Being able to detect $\Delta\nu$ is crucial: first it provides an accurate constraint on the position of the star in the HR diagram, second it is a fundamental parameter of the p-mode spectrum. A systematic search for this new observable among δ Scuti stars will be a key part of our strategy. For hybrid δ Scuti - γ Doradus pulsators, we will be able to probe the deep interior (g-modes), in addition to the envelope. The pulsation modes of γ Dor stars are in the asymptotic regime, which means that, for slow rotation rates, their pulsation modes are evenly spaced in period. However, A and early F type stars can be moderate to fast rotators: V sin i values range from 40 to 130 km/s depending on the spectral type [9]. In that case, the period spacing is no longer constant, but varies linearly with the pulsation period[10]. Such a feature has been found in dozens of Kepler[11] stars, thereby paving the way for γ Dor seismology [12,13], and enabling us to establish a new seismic diagnostic of rotation for these stars[14]. Combining seismic diagnostics based on both g- and p-modes will bring valuable constraints on the whole interior of our hybrid target stars.

Only ultraprecise photometry combined with high-resolution spectroscopy is able to give us a complete picture of stellar interiors, including rotation. In moderate and fast rotators, spectral resolution translates into spatial resolution by enabling us to disentangle different longitudes of the stellar surface. As a result, non-radial modes will perturb line profiles by introducing "moving bumps". A detailed analysis of these line-profile variations allows us to identify corresponding modes, because the shape and the behaviour of the variations depend on the properties of the modes. In addition, high-resolution spectroscopy may also provide an estimate of the inclination of fast rotators with low-to moderate Vsini. Indeed, determining the actual V and i is crucial to properly understand oscillation power-spectra[15,16]. These are determined by analysing the spectral lines affected by gravity darkening and observed with a very high S/N ratio, i.e. for very bright stars[17]. Although the CoRoT [18] and Kepler missions have provided us with ultra-high precision photometric data, most of their targets are too faint to have their inclination determined through the aforementioned spectral analysis. Currently, only the BRITE constellation covers such a gap, as will the forthcoming CHEOPS mission[19].

Global objectives

The joint analysis of photometric (OSN+BRITE) and spectroscopic (SONG, ELODIE, HERMES, SOPHIE) data has the following global objectives:

Objective 1. Provide observed oscillation spectra for a sample of stars with accurate global stellar parameters. Such a sample will be constructed from space photometric data (BRITE), seismic indices (at least the large separation) and complementary constraints (from spectroscopy/binarity). This sample of stars with accurate fundamental parameters will also be crucial for testing new seismic diagnostics and conducting a more detailed analysis of internal transport processes. This sample will enable us to establish a guideline for properly analyzing and interpreting rotating stars. This will be particularly important for preparing and maximizing the scientific return of the PLATO 2.0 mission20, for which accurate stellar density (obtained from large separations) and ages is of key importance for the characterization of planetary systems.

Objective 2. Develop seismic diagnostics. We will use the observed data to test seismic diagnostics that we develop from theoretical pulsation spectra of rapidly rotating stars. In particular, we will search for patterns related to the rotational splittings of p-modes (predicted but not detected yet) and the period spacings of gravito-inertial modes. Line profile variation21 and multicolour photometry diagnostics have been also developed and will be tested on the stellar sample. Constraints on mode amplitudes are now becoming available thanks to new non-adiabatic calculations of the mode-excitation mechanisms. Our theoretical models are produced by current 1D and 2D stellar evolution codes (e.g. CESTAM22, MESA23 for 1D, STAROX24 and ESTER25 for 2D, respectively) and the oscillation codes like GraCo26, FILOU27, ACOR28 and TOP29,30.

Objective 3. Derive constraints on internal transport processes in massive and intermediate-mass stars. Detections of rotational splittings or oscillatory components in the large frequency separation and the period spacing will provide us with constraints on angular momentum and chemical element transport processes. Identification of individual modes (for example from the analysis of line profile variations) would also constrain these processes especially if some mixed mode can be identified.

Specific objectives for this proposal

Objetive 1. To improve the precision and coverage of the photometric timeseries: As explained above, the BRITE observing mode with 20s sampling allows to study high-frequency variable phenomena, in particular oscillation modes in that regime. Space missions have shown that some A-F stars show frequencies in the high-frequency domain, sometimes reaching a kind of non-explained (yet) asymptotic regime over the instrumental noise. On the other hand, since observations present large gaps between samplings, low-frequency domain is undersampled, which results in a global low duty cycle. OSN observations will cover this, allowing to better detect frequencies in that regime.

Objetive 2. To provide precise colour information: the study of patterns in the oscillation spectra as explained in the global objectives is the first step to seismically constrain the asteroseismic models representative of the observed stars. Indeed, the combined information of large separations pave the way of modal identification, which might be significantly helped by constraints on the identification of individual modes. This can be performed with the help of diagnostics based on amplitude rations and frequency differences using multicolour information. See the example of 29 Cyg (one of the stars of the sample) studied by Casas et al. 2009.

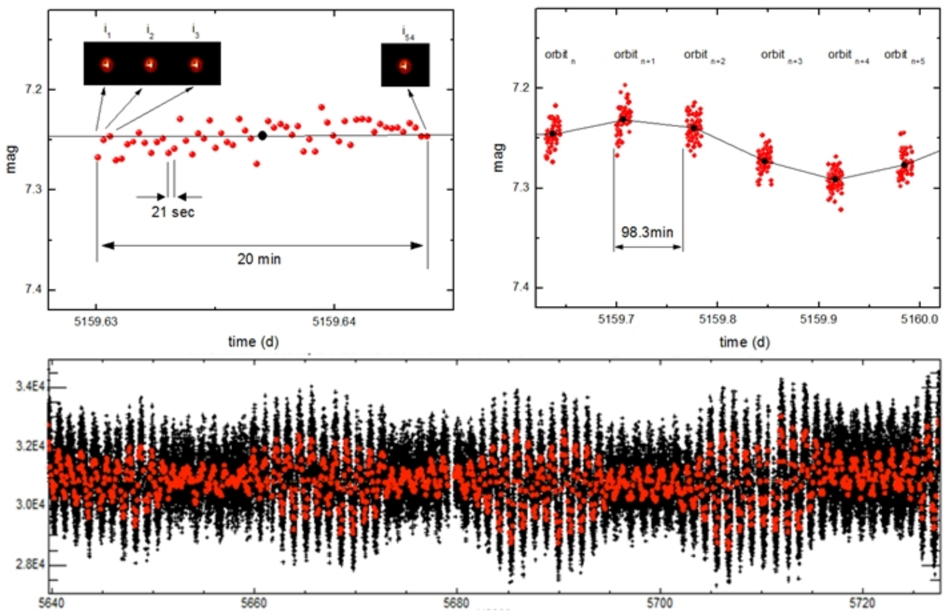
Procedure

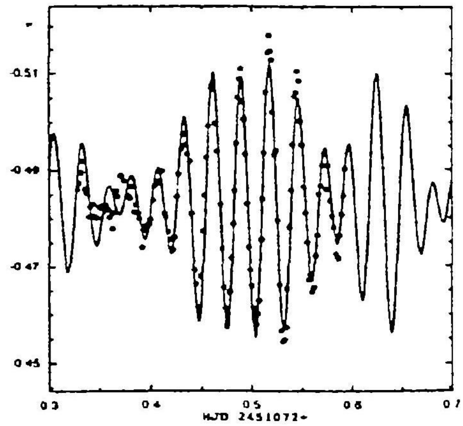
The BRITE Constellation observes each star field during ~15 minutes per satellite orbit for up to 6 months. Each satellite has a CCD detector sensitive to two passbands: red (550-700nm) and blue (390-460nm). The exposure time of the camera is 1-5 secs collected about 3-4 times per minute (i.e. ~20 secs of sampling). Figure 1 shows the typical features of BRITE time series.

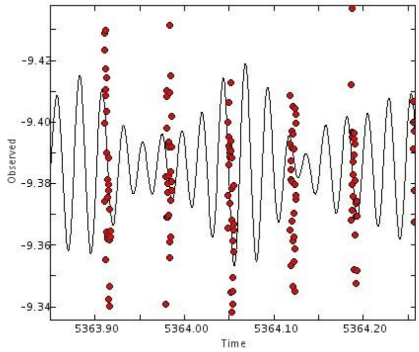
The primary science goal is to study the variability of hot stars. The observing strategy is: the longer the time base of observations, the more information on stellar variability can be obtained [37]. The long time base observation of BRITE provides a ver high frequency resolution but, as can be seen in Fig. 1, periodic gaps appear in their time series spanning about 80-90% of the nominal time. In this sense measurements from Sierra Nevada Observatory might help to reduce the effects of the spectral window considerably.

Here below 29 Cyg data from BRITE is shown along with Sierra Nevada Observatory campaign on 1996. The same time interval (0.4 d) is shown for comparison. Notice that BRITE data have a much higher cadence but the duty cycle is lower (~10%). The different time distribution of such measurements would eliminate the aliasing problem if both data sets are combined. The combination of high cadence in BRITE and higher duty-cycle in OSN might allow to obtain the full pulsational spectrum of this star without the influence of the spectral window.

Figures







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DETAILED OBSERVING PROGRAM IN SERVICE MODE

(Do not fill in if observing in remote or "in situ" modes). Describe, with as much detail as possible, the observing program, such as sky conditions (photometric, cirrus acceptable, seeing, etc) and moon, standard star measurements, number and type of calibration frames, instrument configuration (with filters to be used), signal to noise ratio, and all other considered necessary to carry out the observations.

TECHNICAL JUSTIFICATION
Discuss the feasibility of the observations and justify the amount of telescope time requested. The technical justification is limited to one-half page per run. Use and additional page for each run.

Run: A	Telescope: T90	Instrument: Strömgren

The stars accepted to be observed by BRITE, are bright stars between V = 4 and 7 mag, and therefore, not suitable for the CCD camera since they would saturate. Some of them have spectroscopic data obtained by SONG (Stellar Oscillations Network Group) or taken by SOPHIE (S) and ELODIE € (see column HRS). From this list we have labelled as priority 1 targets with visibility in the first quarter from the OSN for which SONG spectra are available:

GCVS name	HD number	V	(b-y)0	Period	Vsini	HRS
RC Ma	57167	5.70	0.209	0.0470	100	-
LM Hya	71297	5.60	0.112	0.0380	13	-
DP Uma	104513	5.22	0.170	0.0400	78	-
CN Boo	124953	5.98	0.162	0.0438	85	1 S
Iota Boo	125161	4.75	0.124	0.0265	130	11 E, 1 S
Lam Boo	125162	4.18	0.044	0.0230	110	5 E, 1 S
CL Dra	143466	4.96	0.175	0.0763	150	11 S
V1644 Cyg	192640	4.93	0.099	0.0267	80	11 E, 2 S

We labelled as Priority 2 those targets for which only SOPHIE and/or ELODIE spectra are available:

GCVS name	HD number	V	(b-y)0	Period	Vsini	HRS
-	64491	6.23	0.195	0.0490	15	1 E
Eps Cep	211386	4.18	0.171	0.0412	97	11 E, 1 S

And those with no spectra available are labelled with Priority 3:

GCVS name	HD number	V	(b-y)0	Period	Vsini	HRS
GG Vir	110377	6.22	0.120	0.0500	180	-
HR Lib	142703	6.11	0.182	0.0600	83	-

Targets will be observed in order of priority in addition to visibility; a minimun of 15 nights per object is required to attain the objectives of the proposal. The nights would be consecutives or divided into 8 + 7 or similar.

We know that BRITE will observe 29Cyg from April 30th to October 30th in 2019. We would like to simultenously observe the star with the T90 at least during 30 nights in the same period (withing the limits of the semester).

We will perform differential photometry, and therefore each target will be observed along with two reference (standard) stars. These reference stars are required to be as close as possible to the target, and have similar brightness and color. Reference stars must not be variable. For the brightest targets a half/neutral filter would be used to prevent the photometer to be damaged.

LIST OF MAIN OBJETS

Program	Objet	RA(h,m,s)	Dec (deg,min,sec)	Mag (give band)
A	RC Ma	07 19 28.18202	-16 23 42.877	5.70
A	HD71297	08 26 27.20825	+03 59 14.9199	5.60
A	DPUMa	12 02 06.78485	+43 02 44.169	5.22
A	CNBoo	14 16 04.1396	+18 54 42.457	5.98
A	iotaBoo	14 16 09.92995	+51 22 02.0267	4.75
A	lamBoo	14 16 23.01880	+46 05 17.9005	4.18
A	CLDra	15 57 47.44007	+54 44 59.1440	4.96
A	HD64491	07 55 40.82741	+35 24 45.6670	6.23
A	Eps Cep	22 13 58.40842	+69 53 51.1615	4.18
A	GGVir	12 41 34.39202	+10 25 34.5711	6.22
A	HRLib	15 56 33.37364	-14 49 45.9760	6.11
A	29 Cyg	20 14 32.03199	+36 48 22.6846	4.99