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RESULTS OF OBSERVATIONS OF MAXIMA OF PULSATING STARS[1]

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ABSTRACT

The systematic study of some HADS stars, recognized as variables for decades, has allowed us to provide data on their secular variations through O-C analysis. However, some of the data have large gaps without observations. This is our motivation for continuously observing these stars as part of the research carried out by the "Grupo de Astronomía Observacional del Observatorio de Tonantzintla" (GAOOT). This article is our third compilation of times of maxima for pulsating stars. These observations have been carried out at the Observatorio Astronómico Nacional de Tonantzintla (TNT) and San Pedro Mártir (SPM), México and for the first time we also present data from the Complejo Astronómico de Cota Cota, Bolivia (Universidad Mayor de San Andrés) and the Observatorio Astronómico Centroamericano de Suyapa, Honduras (Universidad Nacional Autónoma de Honduras).

RESUMEN

El estudio sistemático de algunas estrellas pulsantes HADS ha permitido proporcionar datos sobre sus variaciones seculares mediante el analisis O-C. Sin embargo, en algunas de ellas los datos presentan grandes vacíos temporales sin observaciones. Esta es una motivación por la que hemos decidido observar continuamente estas estrellas como parte del trabajo que realiza el Grupo de Astronomía Observacional del Observatorio de Tonantzintla. Este grupo presenta esta tercera compilación de tiempos de máximo de estrellas pulsantes. Dichas observaciones se han llevado a cabo en los Observatorios Astronómicos Nacionales de Tonantzintla (TNT) y San Pedro Mártir (SPM), México a los que se han unido el Complejo Astronómico de Cota Cota, Bolivia (Universidad Mayor de San Andrés, Bolivia) y el Observatorio Astronómico Centroamericano de Suyapa (Universidad Nacional Autónoma de Honduras).

Key Words: ephemerides — stars: variables: Scuti

1. MOTIVATION

The study of δ Scuti stars has been carried out for many years since the pioneering works of Breger (1966) and Millis (1966). It was shortly after this that the monitoring of some of these stars was started in Mexico (Warman, Malacara and Breger, 1974, Warman, Peña and Arellano Ferro, 1979) and it has continued ever since.

More recently, with the acquisition of CCD detectors thirteen years ago, the observations of δ Scuti stars were retaken at the Observatorio Astronomico Nacional de Tonantzintla (TNT) with the participation of many students of the Observational Astronomy courses taught at the UNAM and later of the Escuela Latinoamericana de Astronomía Observacional (ESAOBELA). These students have provided us with motivation, and have supplied an eager workforce.

[1]Based on observations collected at the San Pedro Mártir and Tonantzintla Observatories, México, Tegucigalpa at Honduras and La Paz, Bolivia.

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TABLE 1

CHARACTERISTICS OF THE OBSERVED STARS

ID	RA	Dec	Magnitude	Spectral Type	Epoch (d)	P (d)
AD Ari	02 17 45	+18 27 18.00	7.43	F0	2453330.654	0.53972
RV Ari	02 15 07	+18 04 27.91	11.61	A0		0.09312808
BE Lyn	09 18 17	+46 09 11.31	8.80	A3		
BL Cam	03 47 19	+63 22 42.14	13.03			0.03909844
V367 Cam	04 40 55	+53 38 06.46	10.47			0.121596
KU Cen	11 51 51	-41 17 09.23	13.48			0.07996
AD Cmi	07 52 47	+01 35 50.47	9.38	F0IV/V	2453478.4714	0.1229746
AZ Cmi	07 44 07	+02 24 19.52	6.47	A5IV		0.095205
VZ Cnc	08 40 52	+09 49 27.15	7.18	A9III		0.178364
KZ Hya	10 50 54	-25 21 14.72	10.06	B9III/IV	2442516.15836	0.0595104212
AN Lyn	09 14 28	+42 46 38.36	10.64	A7IV/V		
BO Lyn	08 43 01	+40 59 51.77	11.49			
SZ Lyn	08 09 35	+44 28 17.61	9.08	F2	2438124.39824	0.120534920
TV Lyn	07 33 31	+47 48 09.83	11.54	A6	2440950.922	0.24065119
1 Mon	05 59 01	-09 22 56.00	6.16	F2/3IV	2441661.1668	0.13612600
V1162 Ori	05 32 01	-07 15 24.65	9.9			
RR Leo	10 07 43	+23 59 30.32	9.94	F0	2443295.402	0.4523933
V369 Sct	18 51 16	-06 21 11.16	9.35	F3/5II	2440393.709	0.223
AE Uma	09 36 53	+44 04 00.40	11.35	A9	2435604.338	0.086017055
EX Uma	08 45 12	+56 36 26.76	11.02			
GW Uma	10 44 11	+44 40 44.11	9.89	F3V		
YZ Boo	15 24 06	+36 52 00.60	10.36	F0	2448500.0030	0.1040920
EH Lib	14 58 55	-00 56 53.01	9.83	A5	2433438.6082	0.0884132445

TABLE 2

TIMES OF MAXIMUM LIGHT OF THE VARIABLE STARS CONSIDERED

ID	Date	N	Δt(d)	Nmax	Tmax +2450000	Telescope	Filters	Detector	Observatory	Observers/ Reducers
AD Ari	19120607	368	0.2119	1	8824.6543	Me	V	1001	TNT	JGT,HHC/JGT
RV Ari	19112930	81	0.1294	1	8817.7421	Me	V	1001	TNT	FS,DSP/DSP
	19113031	113	0.1841	2	8818.7621	Me	V	1001	TNT	FS,DSP/DSP
	19113031				8818.8606					
BE Lyn	17032223	420	0.1173	1	7835.6745	M8	G	402	OACS	AA/ARL,GIEP
BL Cam	20011112	122	0.0960	3	8860.7052	M2	wo	andor	TNT	E20/HHC
					8860.7448					
					8860.7842					
	20011213	162	0.1396	3	8861.7247	M2	wo	andor	TNT	E20/HHC
					8861.7641					
					8861.8022					
	20011314	116	0.0880	3	8862.7415	M2	wo	andor	TNT	E20/HHC
					8862.7804					
					8862.8204					
	20011415	151	0.1230	3	8863.7182	M2	wo	andor	TNT	E20/HHC
					8863.7599					
					8863.7959					
	20011617	117	0.0906	2	8865.7510	M2	wo	andor	TNT	E20/HHC
					8865.7905					
	20011718	146	0.1187	2	8866.7287	M2	wo	andor	TNT	E20/HHC
					8866.7684					
	20022425	40	0.0819	2	8904.6927	84	$uvby-\beta$	danish	SPM	DSP/DSP
					8904.7318					

TABLE 2. CONTINUED

ID	Date	N	Δt(d)	Nmax	Tmax +2450000	Telescope	Filters	Detector	Observatory	Observers/ Reducers
V367 Cam	20011314	91	0.1442	1	8862.8298	M1	V	ST-8300	TNT	E20/JGT
KU Cen	20011213	97	0.0818	1	8861.9195	M2	wo	andor	TNT	E20/HHC
	20011314	100	0.0724	1	8862.8795	M2	wo	andor	TNT	E20/HHC
	20011415	120	0.0934	1	8863.9195	M2	wo	andor	TNT	E20/HHC
	20011617	137	0.1232	2	8865.9165	M2	wo	andor	TNT	E20/HHC
					8865.9965					
AD CMi	16021112	130	0.1400	1	7430.7541	M2	V	1001	TNT	DSP/DSP
	16031112	167	0.1500	1	7459.6543	M1	V	1001	TNT	AOA16/DSP
	17011415	144	0.1200	1	7768.8131	M1	V	1001	TNT	E17/DSP
	17120607	40	0.1000	1	8095.0522	84	$uvby-\beta$	danish	SPM	JCC,DSP/DSP
	18030203	142	0.1600	1	8180.7831	M1	V	1001	TNT	AOA18/DSP
	18030304	157	0.1500	1	8181.7596	M1	V	1001	TNT	AOA18/DSP
	18031718	129	0.1300	1	8195.7759	M1	V	1001	TNT	AOA18/DSP
	19011415	84	0.1500	1	8498.8915	M2	G	ST-800	TNT	E19/HHC
	19011516	97	0.1500	1	8499.8951	M2	G	ST-800	TNT	E19/HHC
	19011819	205	0.1600	1	8502.8419	M2	G	ST-800	TNT	E19/HHC
	19012122	141	0.1900	1	8505.9170	M2	G	ST-800	TNT	E19/HHC
	19012223	186	0.2100	2	8506.7780	M2	G	ST-800	TNT	E19/HHC
					8506.9044					
	19020102	228	0.2700	2	8516.7387	M2	wo	ST-8300	TNT	JGT/JGT
					8516.8638					
	19031617	187	0.1400	1	8559.7805	Me	V	1001	TNT	AOA19/ARL
AZ CMi	20021920	51	0.1151	1	8899.8223	84	$uvby-\beta$	danish	SPM	DSP/DSP
VZ Cnc	18031718	267	0.2107	1	8195.7696	M1	G	ST-800	TNT	JGT,HHC/JGT
	19012122	211	0.1873	1	8505.9443	M1	G	ST-800	TNT	E19/JGT
	19012223	372	0.2447	1	8506.8515	M1	G	ST-800	TNT	E19/JGT
	19121011	383	0.1198	1	8828.9646	Me	V	ST-8300	TNT	JGT/JGT
	20022526	36	0.2352	1	8905.8573	84	$uvby-\beta$	danish	SPM	DSP/DSP
	20022627	49	0.0969	1	8906.9136	84	$uvby-\beta$	danish	SPM	DSP/DSP
	20032829	150	0.1304	1	8937.7654	M1	V	ST-8300	TNT	JGT/JGT
KZ Hya	17032223	270	0.7285	1	7835.7613	M8	G	402	OACS	AA/ARL,GIEP
	18021617	87	0.0919	2	8166.7547	Me	V	1001	TNT	SBJ,ALZ/HHC
					8166.8144					
	19020102	6	0.0678	1	8516.9686	M2	G	ST-800	TNT	Bo19/JGT
	19030102	50	0.0409	1	8544.8786	M1	V	1001	TNT	AOA19/HHC
	19040506	1393	0.2109	3	8579.6324	M8	G	402	OACS	Ho19/ARL,GIEP
					8579.6918					
					8579.7512					
	19042021	110	0.0930	2	8594.6884	Me	V	1001	TNT	DSP/DSP
					8594.7480					
	20012021	87	0.0892	1	8869.9210	Me	V	1001	TNT	E20/DSP,HHC
	20031314	64	0.0565	1	8922.8845	Me	V	1001	TNT	AOA20/HHC
	20031314	40	0.0309	1	8922.8847	M1	V	ST-8300	TNT	AOA20,JGT/HHC,JGT
AN Lyn	20010910	394	0.0966	1	8859.9659	M2	wo	andor	TNT	E20/HHC
BO Lyn	19011516	176	0.1419	2	8499.7999	Me	V	1001	TNT	E18/JGT
					8499.8890					
SZ Lyn	18011213	90	0.0702	1	8131.8979	M1	V	ST-8300	TNT	E18/HHC
	18011516	165	0.1672	1	8134.9104	M1	V	ST-8300	TNT	E18/HHC
	18011617	176	0.0873	2	8135.7517	M1	V	ST-8300	TNT	E18/HHC
					8135.8755					
	18012021	121	0.1053	1	8139.8537	M1	V	ST-8300	TNT	E18/HHC
	19020203	115	0.1106	1	8517.8584	M2	G	ST-800	TNT	Bo19/JGT
TV Lyn	19011617	300	0.0208	1	8135.8526	M2	G	ST-800	TNT	E18/HHC
	19020405	304	0.2884	1	8519.7864	M2	G	ST-800	TNT	Bo19/JGT

TABLE 2. CONTINUED

ID	Date	N	Δt(d)	Nmax	Tmax +2450000	Telescope	Filters	Detector	Observatory	Observers/ Reducers
	19020708	190	0.2903	1	8522.7723	M2	G	ST-800	TNT	Bo19/JGT
1 Mon	19020506	187	0.1481	1	8520.7220	M2	G	ST-800	TNT	Bo19/JGT
V1162 Ori	20011213	151	0.1118	1	8861.8051	Me	V	1001	TNT	E20/DSP
	20011718	185	0.1533	2	8866.7603	Me	V	1001	TNT	E20/DSP
					8866.8368					
	20022324	41	0.0940	1	8903.7422	84	$uvby-\beta$	danish	SPM	DSP/DSP
RR Leo	19011314	90	0.0881	1	8497.8039	Me	V	1001	TNT	Bo19/DSP
	19012122	260	0.2516	1	8505.9479	Me	V	1001	TNT	Bo19/DSP
	19012223	310	0.2804	1	8506.8542	Me	V	1001	TNT	Bo19/DSP
	19013101	390	0.3257	1	8515.9003	Me	V	1001	TNT	Bo19/DSP
	19020102	390	0.3589	1	8516.8054	Me	V	1001	TNT	Bo19/DSP
	19020203	363	0.3211	1	8517.7120	Me	V	1001	TNT	Bo19/DSP
	20022425	72	0.1883	1	8904.9676	84	$uvby-\beta$	danish	SMP	DSP/DSP
	20022526	36	0.2635	1	8905.8787	84	$uvby-\beta$	danish	SPM	DSP/DSP
	20033031	375	0.3155	1	8939.8071	M1	V	ST-8300	TNT	JGT/JGT
V369 Sct	19082930	471	0.1785	1	8817.7421	C16	v	1001	CotaCota	JMD/DSP
AE Uma	18011617	162	0.0545	2	8135.8224	Me	V	1001	TNT	E18
					8135.9041	Me	V	1001	TNT	
	18021617	90	0.0746	1	8166.8715	Me	V	1001	TNT	SBJ,ALZ/HHC
	18032526	100	0.0842	1	8203.8565	M1	G	ST-800	TNT	JGT/JGT
	19011415	69	0.1120	1	8498.8116	Me	V	1001	TNT	E19/JGT,DSP
	19020304	273	0.1925	2	8518.7688	Me	V	1001	TNT	Bo19/JGT
					8518.8482					
EX Uma	20011617	135	0.2232	1	8865.9608	M1	G	ST-8300	TNT	E20/JGT
GW Uma	19020102	218	0.1738	1	8516.9623	M1	V	1001	TNT	Bo19/JGT
	19020203	267	0.2392	1	8517.7795	M1	V	1001	TNT	Bo19/JGT
	19022122	220	0.1721	1	8536.8787	M1	G	ST-800	TNT	JGT
	19022324	124	0.1085	1	8538.9137	1M	V	ST-8300	TNT	JGT,APC/JGT
	20011415	101	0.1310	1	8864.0182	M1	G	ST-8300	TNT	E20/JGT
YZ Boo	18032829	120	0.1123	1	8206.8536	M1	G	ST-800	TNT	JGT,DSP/JGT
	18030304	90	0.0800	1	8181.8708	me	V	1001	TNT	AOA18/HHC
	18031617	76	0.8148	1	8194.8829	me	V	1001	TNT	AOA18/HHC
	19042021	130	0.1172	1	8594.8027	Me	V	1001	TNT	DSP/DSP
	20021920	30	0.0653	1	8899.9954	84	$uvby-\beta$	danish	SPM	DSP/DSP
	20022324	68	0.1622	2	8903.8477	84	$uvby-\beta$	danish	SPM	DSP/DSP
EH Lib	18031718	129	0.1114	2	8195.8240	me	V	1001	TNT	AOA18/HH
					8195.9122					

Remarks:

1. Telescope
1M - 1m telescope
ME - 10" Meade LX200 telescope Equatorial
M1 - 10" Meade LX200 telescope
M2 - 10" Meade LX200 telescope
C11 - 11" Celestron telescope
84 - 0.84m telescope
C16 - 16" Celestron Pacific telescope
M8 - Meade LX200 telescope

2. Detector
ST8 - CCD SBIG ST-8
1001 - CCD SBIG ST-1001
8300 - CCD SBIG ST-8300
danish - *uvby-β* Photometer
402 - CCD SBIG ST-402

3. Filter
V - V-filter in UBV system
G - Green in RGB set
V - y-filter in *uvby* system
wo - Without filter

Remarks (Continued). Observers.: AA: A. Artola (UNAH); ALZ: A. L. Zuñiga; ARL: A. Rentería; DSP: D. S. Piña; FS: F. Saldaña; JCC: J. Calderón; JGT: J. Guillen; JHP: J. H. Peña; SBJ: S. B. Juárez.

E17 (ESAOBELA 2017): Ramirez, Vanesa; Rodríguez, Mariana; Vargas, Stephany; Castellón, Cindy; Salgado, Ricardo; Mata, Joaquin; Santa Cruz, Raúl; Chipana, Karol; Gonzales, Lisseth; Rodríguez, Reina; De la Fuente, Diana.

E18 (ESAOBELA 2018): Calle, Carla; Huanca, Ever; Uchima, Juan Pablo; Ramírez, Raquel; Funes, Ricardo; Martinez, Juan José; Sarmiento, Karina; Cruz, Mauricio; Meza, Enith; Alvarado, Mayubell; Huaman, Victor; Ochoa, Gerson; Matamoros, Andrea.

E19 (ESAOBELA 2019): Blanco, Agustina; Benadalid, Tania; Donaire, Johany; Salazar, Luis; Quirós-Rojas, Marianela; Portllo, Alejandro; Escobar, Pablo; Mejía, Raquel; Mireles, Monica; León, Antonis; Zelada, Cindy; Báez, Sol-haret; Ng,Jessica.

E20 (ESAOBELA 2020): Carrasco, Laura; Vargas, Camilo; Barba, Miguel; Martinez, Glenda; Castellanos, Mitsa; Mejia, Nicole; Buenfil, Guadalupe; Vásquez, Franklin; Martínez, Bexy; Beato, Manuel; Paredes, Jhonnayker; Muñoz, Fernanda; Salazar, Azalea.

AOA16: Juarez, Karen; Lozano, Karen; Padilla, Artemio; Velázquez, Roberto; Santillan, Priscila.

AOA18: Bustos, Sergio; Carrillo, José Luis; Chávez, Brian; Navez, David; Zuñiga, Ana.

AOA19: Briones, Joshua; Castro, Celeste; Martínez, Fernanda; Posadas, Hilde; Romero, Mitzi; Soberanes, Hilkar; Velasco, Alex.

AOA20: Blas, Karla; Madrigal, Norma; Perez, Alexis; Ramirez, José; Santiago, Beatríz.

Bo19 (Bolivia 19): Benadalid, Tania; Donaire, Johany; Muñoz, Ruber.

Ho19 (OACS Honduras 2019): Artola, Adán; Meza, Maria Renee; Mejia, Luis Fernando.

GIEP: Meza, María Renee; Argueta, Christian

HADS stars provided excellent targets since they have short periods of pulsation, large amplitudes and, most of them have been observed for large time spans providing a unique chance to study their secular variations. Surprisingly, most of the observed stars we studied show evidence of a light travel-time effect, suggesting the presence of another invisible companion star.

What we have found is that some of these stars have lacked continuous observations and that there are large gaps in which they were not observed. Conscious of the need for long continuous observations, we developed a systematic monitoring of HADS stars at Tonantzintla to pursue our study of HADS double systems.

Aware of this need we have previously presented two lists of times of maxima of pulsating stars (Peña et al. 2015 and Peña et al. 2017) and here we present the third list of results from our observations.

2. DATA COLLECTION

This is the third compilation of OAN results of 23 variable stars obtained from 2016 to March, 2020. These observations also include some maxima from the Observatorio Astronómico Centroamericano de Suyapa, Honduras and the Complejo Astronómico de Cota Cota, Bolivia. The results are presented for 23 stars, of which 114 maxima of pulsating stars were obtained.

The CCD reduction was done with AstroImageJ (Collins et al. 2017) whereas the photoelectric observations were reduced using a classical procedure (see Peña et al., 2016 for details). All times of maxima are heliocentric and were determined with a fifth grade polynomial fitting to the light curve.

The errors were determined from the RMS error of the residuals evaluated for the times of maxima, and are about 0.016 days. The accuracy of each point is given by the exposure time and varies between 3 min for the 1-meter telescope and 1 min

for the smaller telescopes. It may seem contradictory to use a longer integration time for the larger aperture telescope. However, this is done because the mounting of the smaller telescopes is of an altazimuth type, which does not allow long integration times. For the 1-meter telescope there were around 40,000 counts, and for the 10-inch telescope there were 11,000 counts, enough to secure the high precision desired. The photoelectric measurements and all the light curves can be requested for inspection. The procedure followed to reduce $uvby - \beta$ of the San Pedro Martir Observatory is presented in Peña et al. (2021).

In Table 1 we present the characteristics of the observed stars; that is, their IDs, coordinates (epoch 20009), V magnitude, spectral types and the observational epoch and periods in days when available from the web site of the General Catalog of Variable Stars (http://www.sai.msu.su/gcvs/cgi-bin/search.htm GCVS) as they are reported in that source. No errors are provided. All information about telescopes, photometers and filters is specified in the remarks of the table. In Table 2 the following quantities are listed: Column 1 is the ID, Column 2, date of observation, Column 3, N gives the number of data points in each run, Column 4, Δt is the time span in days of the run, Column 5, the number of Tmax of the run, Column 6, the time of maxima in HJD, Column 7, the telescope, Column 8, the filter used, Column 9, the detector, Column 10 the observatory, and finally, Column 11 gives the observers and reducers. Observers and reducers are specified in the remarks at the end of the table.

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