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PMS stars as COROT additional targets

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Abstract

The importance of pre-Main Sequence (PMS) δ Scuti studies is discussed and recent developments both from the theoretical and observational point of view are reviewed. The open problems in the current status of knowledge of these young pulsators are mainly connected to the limitations of short time baseline ground observations. COROT could definitely help to solve these problems by allowing accurate and continuous observations. A list of possible PMS δ Scuti candidates for a COROT additional program has been identified and exploratory ground-based observations are planned.

Introduction

PMS stars with masses $M \geq 1.5 M_{\odot}$, called Herbig Ae/Be stars, cross the pulsation instability strip during their contraction toward the main sequence. The estimated crossing times range from $\sim 0.05\ \tau_{KH}$ ($1.5 M_{\odot}$) to $\sim 0.1\ \tau_{KH}$ ($4 M_{\odot}$), where τ_{KH} is the Kelvin-Helmholtz timescale. In spite of the relatively short crossing time, a number of Herbig stars have the appropriate values of colors to fall within the instability strip boundaries of the well known evolved variable stars.

The existence of pulsating stars among intermediate Herbig stars was originally suggested by Breger (1972) who discovered two PMS pulsator candidates in the young open cluster NGC 2264. This initial finding was confirmed by subsequent observations of a δ Scuti-like pulsation in the Herbig Ae stars HR5999 (Kurtz & Marang 1995) and HD104237 (Donati et al. 1997).

This evidence stimulated the first theoretical investigation of the PMS instability strip, based on nonlinear convective hydrodynamical models (Marconi

& Palla 1998). As a result, the topology of the PMS instability strip for the first three radial modes was identified and a list of possible PMS pulsating candidates was provided on the basis of spectral types.

New observational studies were then devoted to the search for δ Scuti-type photometric variations with periods of minutes to several hours and amplitudes less then few tenth of magnitudes among Herbig stars inside or close to the theoretical instability boundaries.

Kurtz & Muller (1999) reobserved HD104237 and confirmed its photometric variability; Marconi et al. (2000) identified two new PMS pulsating stars, namely HD35929 and V351 Ori; Pigulski et al. (2000) discovered the pulsating nature of two members (BL50 and HP57) of NGC 6823; Kurtz & Catala (2001) confirmed the δ Scuti pulsation and periodicity of HR5999; Kurtz & Muller (2001) identified the PMS δ Scuti star HD142666; Marconi et al. (2001) provided new observations and frequency information on V351Ori; finally, Pinheiro et al. (2001) observed the pulsational variation of the luminosity of V346 Ori.

In order to properly understand the nature and intrinsic properties of PMS δ Scuti stars, an extensive comparison of the observed pulsation properties with theoretical predictions is required (e.g. Marconi et al. 2000, 2001). In particular, the comparison between empirical and theoretical periods and period-ratios is expected to provide important constraints on stellar mass, whereas the comparison of the position in the color-magnitude diagram suggested by observations and/or the pulsational analysis with PMS and post-MS tracks may allow to constrain the evolutionary state.

Position of PMS δ Scuti stars in the HR diagram

The main characteristics, including the observed frequencies, of the ten known or suspected δ Scuti stars are reported in Table 1. For most of these objects, the reported periodicities are affected by the uncertainty due to the 1 day alias, so that they may not represent the actual periods. Moreover, for some objects the observations are too scarce and the errors too large to allow accurate frequency determinations.

However, let's assume that the published frequencies are indeed correct and compare them with the predictions of linear non adiabatic pulsation models (see Marconi et al. 2000, 2001 and references therein). Such a comparison allows us to constrain the position of observed stars in the HR diagram, as shown in Fig. 1. In fact, at fixed solar composition, the mass, luminosity, and effective temperature are varied in order to simultaneously satisfy the observed periodicities and the PMS evolutionary constraint.

It is worth noting that the solution of such a fitting procedure is unique

Table 1: Known or suspected PMS δ Scuti stars.

Star	F_1	F_2	$V(mag)$	Sp. Type
V351Ori	15.49±0.23	11.89±0.24	8.9	A7
V346Ori	34.2±4.9	21.2±3.8	10.1	A5
HD104237	33.0±0.2		8.1	A5
HR5999	4.81±0.01		7.0	A7
HP57	12.7256±0.0002	15.5244±0.0003	14.6	
BL50	13.9175±0.0005	9.8878±0.0009	14.5	
V588 Mon	9.09±0.82		9.75	A7
V599 Mon	8.06±0.39		10.3	F2
HD142666	21.43±3.00		8.8	A8
HD35929	5.10±0.13		8.1	A5

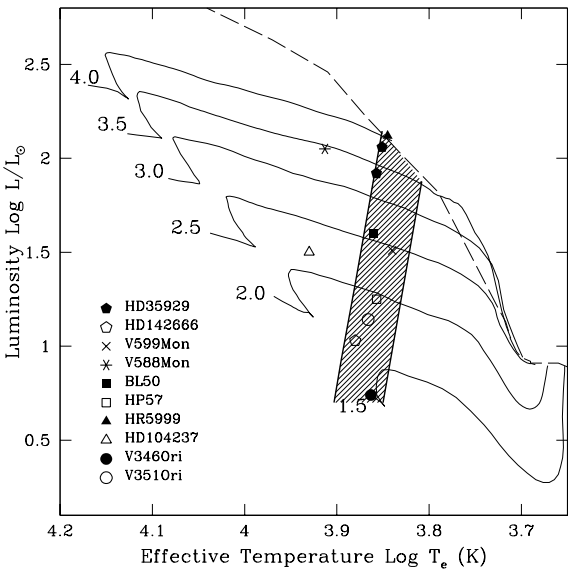

Figure 1: Position in the HR diagram of observed PMS δ Scuti stars, as predicted on the basis of linear nonadiabatic computations. The PMS evolutionary tracks by Palla & Stahler 1993 and the nonlinear instability strip by Marconi & Palla (1998), for the three lowest radial modes, are shown for comparison.

only for candidates for which several periodicities are available from observations (V351 Ori, V346Ori, HP57, BL50). In fact, two relations are needed to

Table 2: The position in the HR diagram and the pulsation mode(s) of PMS δ Scuti stars. The modes are indicated with F (Fundamental), FO (First Overtone), SO (Second Overtone), TO (Third Overtone), FoO (Fourth Overtone), FiO (Fifth Overtone).

Star	$M/M_\odot$	log $L/L_\odot$	$\log T_e$	Source	mode(s)
V351Ori	1.8	1.142	3.866	Marconi et al. 2001	F,FO
V346Ori	1.5	0.74	3.863	Pinheiro et al. 2001	F,SO
HD104237	2.2	1.5	3.93	van den Ancker 1998	FiO
HR5999	4.0	2.12	3.845	Marconi & Palla 1998	SO
HP57	2.0	1.25	3.857	this paper	FO/SO
BL50	2.5	1.6	3.86	this paper	SO/FoO
V588 Mon	3.5	2.05	3.913	this paper	TO
V599 Mon	2.5	1.51	3.84	this paper	FO
HD142666	1.7	1.03	3.88	Natta et al. 1997	FO
HD35929	3.4	1.92	3.857	Marconi et al. 2000	FO
HD35929	3.8	2.06	3.851	Marconi et al. 2000	SO

properly disentangle the luminosity and effective temperature contributions to periods, the mass being determined via comparison with the evolutionary tracks. In case of a single observed periodicity, the comparison with the nonlinear instability strip (e.g. for HR5999, see Marconi & Palla 1998) and/or independent information on the intrinsic parameters (e.g. for HD104237 and HD142666) are taken into account and used to remove degeneracies. The predicted pulsation modes for all the selected candidates are reported in Table 2 together with references for the luminosity and effective temperature values. For HD35929, the solutions found by Marconi et al. (2000) are reported (see also Fig. 1).

We also notice that a certain ambiguity on the evolutionary state holds for stars close to the MS (e.g. V351 Ori). In this region of the HR diagram the PMS and post-MS tracks are not well separated at fixed stellar masses. In such cases a nonradial pulsation analysis could help solve the problem, as nicely discussed by Suran et al. (2001).

As a final comment on Fig. 1, it is interesting to note that only two stars (V588 Mon and HD104237) bluer than the second overtone blue edge of the theoretical instability strip are actually predicted to pulsate in overtones higher than the second one.

How COROT could help

The 1 day alias problem affecting most of the observed PMS δ Scuti stars could be easily removed with *continuous* observations. If these observations are made from space, the additional uncertainty due to weather conditions is

Table 3: PMS δ Scuti candidates for COROT observations.

Star	RA(J2000)	Dec(J2000)	V	Sp. Type
RNO63	06 07 52.41	-05 16 04.4	13.3	F6e
LKH338	06 10 47.05	-06 12 47.9	15.1	F2e
LKH339	06 10 54.43	-06 14 39.4	13.6	F2e
V588Mon	06 39 05.90	09 41 03.4	9.75	A7
V589Mon	06 39 28.45	06 42 04.8	10.3	F2
VSB2	06 39 41.55	09 34 40.2	13.33	F7
W121	06 40 56.50	09 54 10.4	10.8	F8e
V360Mon	06 41 06.18	09 36 22.9	13.29	F8e
VV Ser	18 28 47.96	00 08 39.7	11.87	B,Ae
Par21	19 29 00.81	09 38 38.7	14.16	A5

also removed. In the case of COROT, a high photometric precision is also foreseen, such that accurate period measurements and the identification of low amplitude pulsations will be possible.

PMS δ Scuti candidates for COROT observations

According to the adopted Scenario 4 of the COROT (Center=102.5 deg, i.e. RA=6h 50min, see Minutes of the 6th Scientific Committee) mission, the two possible fields in the Galactic anticenter and center directions are those reported in Figs. 2 and 3. On the basis of these fields, we have identified a list of PMS candidates (open circles in Figs. 2 and 3) by searching in the Herbig catalogue (Thé, Winter & Perez 1994). The coordinates, V-magnitudes, and spectral types of the selected candidates are listed in Table 3.

Unfortunately, none of the PMS candidates is located close to the main targets of the asteroseismological project (filled circles in Figs. 2 and 3). For this reason, we propose these objects as the targets of a COROT additional program. The first three objects of the list (RNO63, LKH338, LKH339) are so close to each other that they can be observed within a single COROT field. The fourth and the fifth stars are the two PMS δ Scuti stars already discovered by Breger (1972) in NGC2264 (also shown in the figure). We notice that these two stars are the brightest ones in the list. The three following objects (VSB2, W121, V360 Mon) are again observable within a single field. Most of these candidates are too faint (V>9 mag) to be observed in the Astroseismology program configuration and too bright (V<16.5 mag) for the Exoplanet program setup. However, fainter magnitudes than V=9 mag are probably measurable in the Astroseismological configuration even by loosing a bit in precision (1 part over 10,000 is enough for our goals).

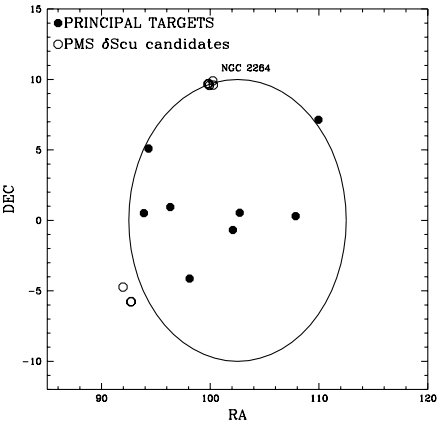

Figure 2: Position of PMS δ Scuti candidates (open circles) in the anticenter direction COROT field. The main targets of the asteroseismological project (filled circles) are shown for comparison.

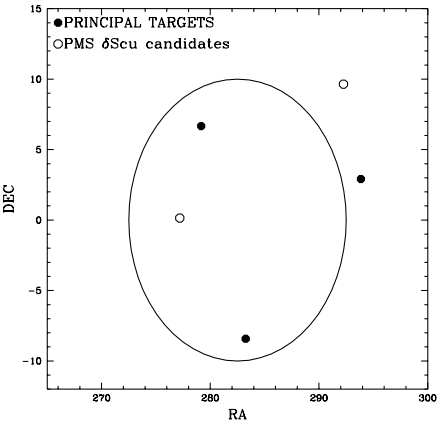

Figure 3: As in Fig. 2 but in the Galactic center direction

Up to now, only V588 Mon and V589 Mon are known to be δ Scuti-like variable stars, but the search for variability in the other candidates by means of ground based observations is planned.

Conclusions

With the recent development of both observational and theoretical studies, PMS δ Scuti stars have become an important tool for understanding the structure and the evolutionary properties of young intermediate-mass stars. The number of known or suspected pulsating PMS objects has significantly increased during the last few years, but for most of them the detected periodicities are quite uncertain due to alias problems and/or poor data number. Continuous and accurate observations from space, as those expected with the advent of the COROT mission, would definitely overcome these problems. In this paper, we have proposed PMS δ Scuti stars as the targets of a COROT additional program and provided a list of suitable candidates.

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