Mem. S.A.It. Suppl. Vol. 9, 200

Memorie della
Supplementi

δ Scuti pulsation among pre-main sequence intermediate-mass stars.

V. Ripepi[1], M. Marconi[1], F. Palla[2], and S. Bernabei[3,4]

[1] Istituto Nazionale di Astrofisica – Osservatorio Astronomico di Napoli, Via Moiariello 16, I-80131 Napoli, Italy e-mail: ripepi@na.astro.it
[2] Istituto Nazionale di Astrofisica – Osservatorio Astronomico di Arcetri, Largo E. Fermi 5, I-50125 Firenze, Italy e-mail: palla@arcetri.astro.it
[3] Istituto Nazionale di Astrofisica – Osservatorio Astronomico di Bologna, Via Ranzani 1, 40127 Bologna, Italy

[4] Departimento de Astrofísica, Universidad de La Laguna, Avda. Astrofisico F. Sánchez sn, 30071 La Laguna, Spain
e-mail: stefano.bernabei@bo.astro.it

Abstract. Intermediate mass Pre-main sequence stars (1.5 to 4 $M_{\odot}$) cross the instability strip on their way to the main sequence. They are therefore expected to be pulsating in a similar way as the delta Scuti stars. In this contribution we present the status of the observational and theoretical studies of pulsations in these stars and discuss the prospects for future investigations of these objects from the ground and from space.

Key words. Stars: variables – Stars: Pre-Main-Sequence – Stars: δ Scuti

1. Introduction

Intermediate mass (1.5 $M_{\odot} \leq M \leq 4$ $M_{\odot}$) Pre-Main-Sequence (PMS) stars are known as Herbig Ae/Be stars (Herbig 1960). This class of stars is characterized by spectral type A or B with emission lines, an infrared excess due to hot or cool circumstellar dust or both, and luminosity class III to V (Waters & Waelkens 1998). Herbig Ae/Be are also well known for their photometric and spectroscopic variability on time scales of minutes to years mainly due to photospheric activity and interaction with the circumstellar environment (see e.g. Catala 2003). However, the fact that these young stars during their contraction towards the Main-Sequence (MS) move across the pulsation instability region of more evolved stars has prompted the suggestion that at least part of the activity could be due to stellar pulsation (see Baade & Stahl 1989; Kurtz & Marang 1995).

The possible presence of pulsators among Herbig Ae/Be stars is particularly attractive since the precise observables which can be measured, i.e. the pulsation frequencies can, in principle, allow us to test evolutionary models by constraining the internal structure using asteroseismological techniques.

The existence of pulsating Herbig stars was suggested about 30 years ago with the discovery of two candidates in the young open cluster NGC 2264 (Breger 1972). This initial

Send offprint requests to: V. Ripepi

finding was confirmed by subsequent observations of δ Scuti-like pulsations in the Herbig Ae stars HR5999 (Kurtz & Marang 1995) and HD104237 (Donati et al. 1997).

This empirical evidence stimulated the first theoretical investigation of the PMS instability strip based on non-linear convective hydrodynamical models (Marconi & Palla 1998). As a result, the topology of the PMS instability strip for the first three radial modes was identified. These authors also pointed out that the interior structure of PMS stars entering the instability strip differs significantly from that of more evolved Main Sequence stars (with the same mass and temperature), even though the envelopes structures are similar. This property was subsequently confirmed by Suran et al. (2001) who made a comparative study of the seismology of a 1.8 $M_{\odot}$ PMS and post-MS star. Suran et al. found that the unstable frequency range is roughly the same for PMS and post-MS stars, but that some non-radial modes are very sensitive to the deep internal structure of the star. In particular, it is possible to discriminate between the PMS and post-MS stage, using differences in the oscillation frequency distribution in the low frequency range (g modes, see also Templeton & Basu 2003)).

It is also worth noticing that it has recently suggested (Breger & Pamyatnykh 1998; Catala 2003) that PMS stars could in principle be used to search for mode frequency changes due to evolution of the stellar inner structure. In fact, PMS evolutionary time scales are short enough to give relative variations of pulsation periods of the order of $\dot{P}/P$=10^{-6}, corresponding to about 0.4 h in 10 years for the epoch of maxima.

2. Observational Status

Since the seminal work by Marconi & Palla (1998) our group has started a systematic photometric monitoring program of Herbig Ae stars with spectral types from A to F2-3 with the following aims: 1) to identify the largest number of pulsating objects in order to observationally determine the boundaries of the instability strip for PMS δ Scuti pulsation; 2) to study in detail through multisite campaigns selected objects showing multiperiodicity (see Marconi et al. 2001; Ripepi et al. 2002; Pinheiro et al. 2003; Ripepi et al. 2003; Bernabei et al. 2004). The multiperiodic pulsators are potential candidates for future asteroseismological analysis.

Similar observational programs have been carried out by various groups. As a results the current number of known or suspected candidates amounts to about 34 stars (see the updated list at http://ams.astro.univie.ac.at/pms_corot.php, and the reviews by Zwintz et al. 2004; Marconi & Palla 2004; Marconi et al. 2004). In particular over 34 candidates, 29 have been studied photometrically, but most of them have insufficient data due both to the short duration of the observations and/or to the poor duty cycle. Therefore most of the periodograms are affected by aliasing problems and are not useful for asteroseismology.

Only 5 stars have been observed by means of multisite campaigns: V588 and V589 Mon (12 and 19 frequencies respectively, Zwintz et al. 2004), V351 Ori (5 frequencies, Ripepi et al. 2003), IP Per (9 frequencies, Ripepi et al. 2005), and HD 34282 (9 frequencies, Amado et al. 2005).

Concerning spectroscopic studies, radial velocities and line profile analysis (the latter being sensible to high degree modes, very useful for asteroseismology) have been carried out only for few stars: V351 Ori (5 frequencies, Balona et al. 2002), β Pic (19 frequencies, Koen et al. 2003), HD 104237 (5 frequencies, Böhm et al. 2004), and the binary star RS Cha (Alecian et al. 2005). This last object is very interesting because it is an eclipsing double-lined spectroscopic binary. Preliminary results based on high resolution spectroscopy (Alecian et al. 2005) seem to show that both components are pulsating. This star therefore will offer the unique opportunity to obtain stringent constraints on pulsating models.

As for asteroseismology from space, two satellites have the possibility to observe PMS stars: MOST and COROT: MOST (Microvariability and Oscillations of STars) is equipped with a 15 cm telescope and a CCD camera. MOST already observed the two pro-

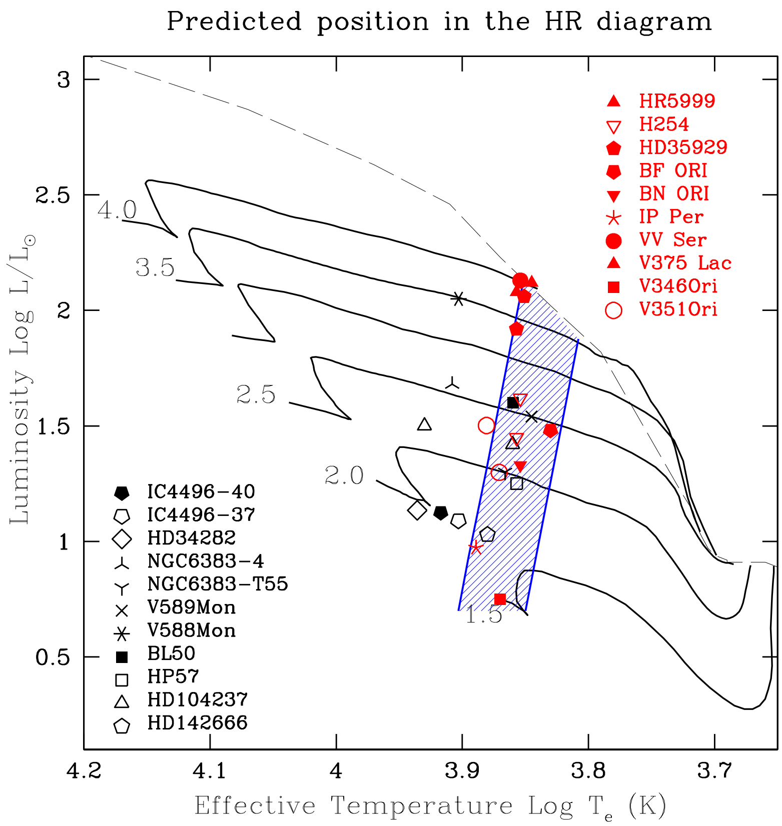

Fig. 1. The position of PMS δ Scuti stars in the HR diagram as predicted on the basis of the comparison between the observed periodicities and linear nonadiabatic radial pulsation models. The dashed region is the theoretical instability strip for the first three radial modes (Marconi & Palla 1998), that is the region between the second overtone blue edge and the fundamental red edge.

totypes of the class: V588 and V589 Mon. The results will be available in the near future.

COROT (COnvection and ROTation of stars) will be launched in June 2006 and will observe a few fields for 5 months continuously and a few others for 10-20 days. In the context of Additional Programs there are at least two projects having PMS δ Scuti stars as targets: 1) a short run on young open cluster NGC2264 which includes many low and intermediate mass PMS stars (P.I. F. Favata) 2) a long run for few selected stars in Dolidze 25, a distant young open cluster which fall in the continuous viewing zone of COROT (P.I. V. Ripepi).

3. Theoretical interpretation

The comparison between observed frequencies and those predicted by linear non-adiabatic pulsation analysis allows us to evaluate the position in the HR diagram and the mass for each pulsator (see Fig. 1). No object is predicted to be located to the right of the red boundary of the theoretical instability strip by Marconi & Palla (1998) Some objects are predicted to pulsate in higher overtones than the second one and then to be located to the left of the 2^{nd} overtone blue edge.

Most of the well observed candidates PMS δ Scuti stars show frequencies which cannot be reproduced by radial analysis only.

Clearly non-radial modes are present in this class of stars. A thorough interpretation of observed frequencies at the light of non-radial pulsation theory is still lacking for PMS δ Scuti stars. In recent times, we have attempted an asteroseismological interpretation of the data on IP Per (see Ripepi et al. 2005) using the Aarhus adiabatic non-radial pulsation code (http://astro.phys.au.dk/~jcd/adipack.n/). Of course much more work has to be done in this field.

4. Conclusions

Asteroseismology applied to PMS δ Scuti stars would allow us to test the evolutionary status and the internal structure of these objects. However more theoretical work is needed in order to interpret present observations.

Observationally we are still in an early phase: the empirical instability strip is not well known and only for few stars the derived frequency spectrum is accurate enough to use asteroseismological techniques.

We expect great improvements in the study of PMS δ Scuti stars from space observations with the satellites MOST and COROT.

References

Alecian, E., et al. 2006, Mem. Soc. Astron. Italiana, v.77, p93
Amado, P., et al. 2006, Mem. Soc. Astron. Italiana, v.77, p.97
Baade, D. & Stahl, O. 1989, A&A, 209, 255
Balona, L. A. et al. 2002, MNRAS, 333, 923
Bernabei, et al. 2004, in IAU symp.224, The A star puzzle, J. Zverko, J. Žižňovský, S.J. Adelman, W.W. Weiss eds, p. 812
Böhm, T., et al. 2004, A&A, 427, 907
Breger, M. 1972, ApJ, 171, 539
Breger, M. & Pamyatnykh, A. A., 1998, A&A, 332, 958
Catala, C. 2003, Ap&SS, 284, 53
Donati, J.-F., et al. 1997, MNRAS, 291, 658
Herbig, G.H. 1960, ApJS, 4, 337
Koen, C. 2003, MNRAS, 344, 1250
Kurtz, D. W., & Marang, F. 1995, MNRAS, 276, 191
Marconi, M.,& Palla, F. 1998, ApJ, 507, L141
Marconi, M. & Palla, F. 2004, in IAU symp.224, The A star puzzle, J. Zverko, J. Žižňovský, S.J. Adelman, W.W. Weiss eds, p. 69 (astro-ph/0410141)
Marconi, M. et al. 2001, A&A, 372, L21
Marconi, M., et al. 2004, CoAst, 145, 61
Pinheiro, F. J. G., et al. 2003, A&A, 399, 271
Ripepi, V., et al. 2002, A&A, 391, 587
Ripepi, V., et al. 2003, A&A, 408, 1047
Ripepi, V., et al. 2005, A&Asubmitted
Suran, M., et al. 2001, A&A, 372, 233
Templeton, M.R., Basu, S., 2003, in: Asteroseismology across the HR Diagram, M.J. Thompson, M.S. Cunha and M.J.P.F.G. Monteiro eds., Kluwer, 565
Waters, L. B. F. M.& Waelkens, C. 1998, ARA&A, 36, 233
Zwintz K., et al. 2004, in IAU symp.224, The A star puzzle, ed. J. Zverko, J. Žižňovský, S.J. Adelman, W., W. Weiss eds, p. 353