Multisite Observations of the Pre-Main-Sequence δ Scuti IP Per

V. Ripepi (1), S. Bernabei (2,3), M. Marconi (1), F. Palla (4), A. Arellano Ferro (5), A. Bonanno (6), P. Ferrara (1), A. Frasca (6), X.J. Jiang (7), S.L. Kim (8), S. Marinoni (2), G. Mignemi (6), M.J.P.F.G. Monteiro (9), T.D. Oswalt (10), P. Reegen (11), E. Rodriguez (12), A. Rolland (12), A. Ruoppo (1,13), L. Terranegra (1), K. Zwintz (11)

Abstract

We present preliminary results of a photometric multisite campaign on the δ Scuti Pre-Main-Sequence star IP Per.
Nine telescopes have been involved in the observations, with a total of about 173 hour of observations over around 40 nights. Present data allowed us to confirm the multiperiodic nature of this star and to determine at least 9 pulsational frequencies. A preliminary non-radial theoretical analysis seems to show that the star pulsates in a mixture of l=0,1,2 modes.

Introduction

Stellar pulsation is in principle a very useful tool to investigate the internal structure and evolution of stars. This kind of analysis has been adopted for many MS and post-MS stars. In the last few years new evidences came out (see the review by Ripepi & Marconi (2004) that intermediate mass Pre-Main-Sequence stars (Herbig Ae/Be) do pulsate when crossing the instability strip for δ Scuti stars.
For more details on the pulsation among PMS stars, see the talks by M. Marconi and K. Zwintz, and the poster by Bernabei et al. (this meeting).
In the following we will concentrate on the detailed photometric study of IP Per.

IP Per

IP Per is a Herbig Ae star with: V=10.34, sp. type A7V, $\log L/L_\odot \simeq 1.0 \pm 0.05$, $T_{eff} \simeq 8000 \pm 200$ K (Miroshinichenko et al. 2001). By using this physical parameters in the HR diagram, IP Per falls in the instability strip for δ Scuti pulsation by Marconi & Palla (1998). An exploratory observing run in 2002, shown in the following (2002 B data) revealed that IP Per actually pulsates as expected and shows a multiperiodic behaviour (6 significative frequencies are found). In order to overcome the well known 1d alias problem, we decided to organize a multisite photometric campaign for fall-winter 2003.
Preliminary results of this campaign are presented in the following.

Observations and data reduction

The observations have been carried out during two periods:

- Sept.-Dec, 2002 B filter, single site (Loiano)
- Nov.-Dec., 2003 BV filters, multisite campaign.

Observations in 2003 have been carried out by means of 9 telescopes and a variety of instruments (see table below:)

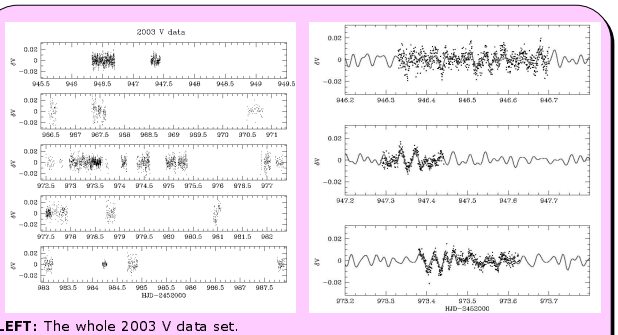
Table 1: Telescopes and instruments involved in the multisite campaign.

Observatory	Telescope	Instrument
BAO (China)	0.85m	Three Channel Photometer
Loiano (Italy)	1.5m	CCD - 2002 data
Loiano (Italy)	1.5m	Three Channel Photometer (TTCP) - 2003 data
Sac Peiro Martir - SPM (Mexico)	1.5m	Danish (sofsj) Photometer
Kitt Peak National Observatory (USA)	0.9m SARA	512x512 CCD
Teide (Spain)	1.0m OGS	1024x1024 CCD
Fairborn (USA)	0.75m APT	PMT
Sierra Nevada (Spain)	0.9m	(sofsj) Photometer
Serra la Nave (Italy)	0.8m	PMT
SOAO (Korea)	0.6m	CCD

We used one main comparison star: TYC 2359-802-1 (V=11.3).

Due to the inhomogeinity of the data (different filters, zero points etc.), we decided to reduce all the measurements to a common value (zero). This procedure, of course, does not allow us to investigate low frequencies (roughly < 3 c/d).

The final data set for 2003 V is shown below



LEFT: The whole 2003 V data set.

RIGHT: Detail of the 2003 V data, i.e. the data collected in **Loiano** with the Three Channel Photometer, which represent our best data. The red line shows the fit calculated with the 9 frequencies derived by means of the Fourier analysis discussed in the next slides.

Data analysis

Data analysis have been performed by means of Period98 (Sperl, 1998).
The three dataset, i.e.: 2002 B data, 2003 B data and 2003 V data have been analysed separately as shown in the figure.
Without entering into details, we note that the frequencies reported in the three tables below are in substantial agreement (taking into account aliases, errors on the frequencies, etc...).
The **figures** below show the spectral window for the three datasets, as well as the Fourier transform. Each panel shows the periodogram after prewithening for the labeled frequency. The solid, dashed and dotted lines show the 99.9%, 99% and 90% confidence levels (see e.g. Breger et al. 1993 and Kuschnig et al. 1997).
Note that due to the better time coverage we decided to use the 2003 V data for the comparison with the theory.

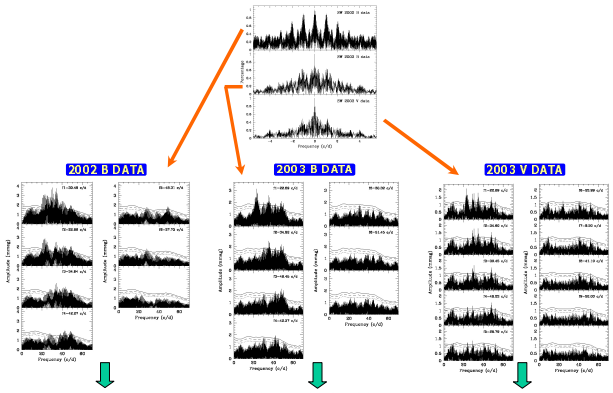


Table 1: Frequencies, amplitudes and confidence levels for the 2002 data in the B filter (Loiano etc etc).
The uncertainty on the frequencies is ~0.35 c/d.

	Frequency (c/d)	Amplitude (mmag)	confidence (%)
f_1	30.45	3.2	99.9
f_2	22.88	3.3	99.9
f_3	34.64	3.3	99.9
f_4	42.27	2.3	99.9
f_5	48.31	1.9	99.9
f_6	27.73	1.9	99.9

Table 1: Frequencies, amplitudes and confidence levels for the 2003 data in the B filter. The uncertainty on the frequencies is ~0.31 c/d.

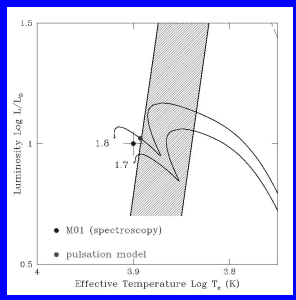
	Frequency (c/d)	Amplitude (mmag)	confidence (%)
f_1	22.89	3.1	99.9
f_2	34.82	2.4	99.9
f_3	48.45	2.3	99.9
f_4	42.37	1.9	99.9
f_5	30.32	1.7	90.0
f_6	51.45	1.3	90.0

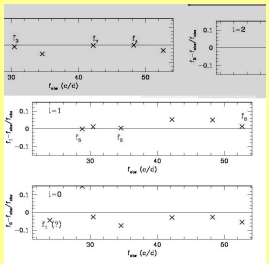
Table 1: Frequencies, amplitudes and confidence levels for the 2003 data in the V filter. The uncertainty on the frequencies is ~0.11 c/d.

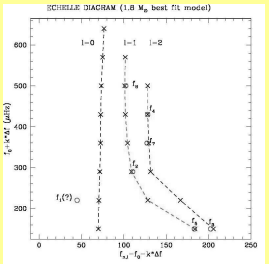
	Frequency (c/d)	Amplitude (mmag)	confidence (%)
f_1	22.89	1.9	99.9
f_2	34.60	1.5	99.9
f_3	30.45	1.8	99.9
f_4	48.23	1.6	99.9
f_5	28.79	1.5	99.9
f_6	23.99	1.3	99.9
f_7	9.30	1.3	99.9
f_8	41.11	1.2	99.9
f_9	52.00	1.1	99.9

Comparison with the theory

Position in the HR diagram of variable IP Per according to the spectroscopic measurements by Microschenko et al. (2001, blue symbol). The dashed region is the predicted instability strip for the first three radial modes by Marconi & Palla (1998), whereas the black lines are the PMS evolutionary tracks computed with the FRANEC code (see Chieffi & Straniero 1989) for the labeled masses. The red symbol is the selected PMS evolutionary model which was been perturbed for nonradial pulsation with **Christensen Dalsgaard's** code (see below). Note the substantial agreement between spectroscopic and pulsation approachs.







LEFT: Percentual difference between predicted and observed frequencies as a function of the observed values. From top to bottom model results refer to l=2, l=1 and l=0 and are all computed with **Christensen Dalsgard's** code applied to the evolutionary PMS model shown above. A tentative identification of frequencies is labeled.
RIGHT: Predicted echelle diagram for the above model (crosses), by adopting a frequency large separation of 6.05 c/d and a reference frequency f0=12.96 c/d. The observed periodicities are overplotted (red circles).

(1) INAF-Osservatorio Astronomico di Capodimonte, Via Moiariello 16, 80131, Napoli, Italy
(2) INAF-Osservatorio Astronomico di Bologna, Via Ranzani 1, 40127 Bologna, Italy
(3) Universidad de La Laguna, Avda. Astrofisico F. Sanchez sn, 30071 La Laguna, Spain
(4) INAF-Osservatorio Astrofisico di Arcetri, Largo E. Fermi, 5, I-50125, Firenze, Italy
(5) Instituto de Astronomia, UNAM, Apdo. Postal 70-264, México D.F., CP 04510, México
(6) INAF-Osservatorio Astrofisico di Catania, Città Universitaria, 95125 Catania, Italy
(7) National Astronomical Observatories, Chinese Academy of Sciences, Beijing, 100012, China
(8) Korea Astronomy Observatory, Daejeon 305-348, Korea
(9) Centro de Astrofisica da Universidade do Porto, Rua das Estrelas, 4150-762 Porto, Portugal
(10) Florida Inst. Technology, 150 W Univ. Blvd., Melbourne, FL 32901-6988, USA
(11) Institute for Astronomy (IfA), University of Vienna, Türkenschanzstrasse 17, A-1180 Vienna, Austria
(12) Instituto de Astrofisica de Andalucia, CSIC, Apdo. 3004, 18080 Granada, Spain
(13) Dipartimento di Scienze Fisiche, Università Federico II, Complesso Monte S. Angelo, 80126, Napoli, Italy

BIBLIOGRAFY:

Breger et al. 1993, A&A, 271, 482
Kuschnig et al. 1997, A&A, 328, 544
Marconi, M. & Palla, F. 1998, ApJ, 507, L141
Sperl, M. 1998, CoAstr, 111, 1