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Survey for roAp stars in the northern sky from Naini Tal

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Abstract. Of the 31 known rapidly oscillating Ap (roAp) stars, 28 are in the southern sky and majority of them were discovered at SAAO indicating that a systematic survey also is needed in the northern sky. Therefore, a project has been initiated at the Uttar Pradesh State Observatory in Naini Tal with the objective to find and study new roAp stars in the northern sky. The test observing campaigns were made during 1997 and 1998 from UPSO at Naini Tal. A brief report of these efforts is presented here. The initial results were encouraging and qualified the site, the telescope and the instrument as the right combination needed for the success of the project. Though these preliminary observations did not yield new roAp stars, they did lead to the discovery of delta Scuti pulsations in two chemically peculiar stars, HD 13079 and HD 13038.

Key words : Stars: pulsations, stars: chemically peculiar, stars: individual: HD13038, HD13079

1. Introduction

The roAp (rapidly oscillating Ap) stars are cool, magnetic, chemically peculiar main sequence stars of spectral type A-F, IV-V (Kurtz 1990). They pulsate with periods ranging from 6 to 16 minutes having Johnson B amplitudes of less than 0.008. They are the only main sequence stars other than the sun which exhibit indisputable evidence of nonradial p modes of very high overtone. The light variations are caused by global nonradial acoustic pulsations similar to the well studied solar 5-minute oscillations. The pulsations are aligned with the magnetic axis, which is oblique to the rotation axis, causing the observed pulsation amplitude to vary with rotation as the nonradial pulsations are seen from variable aspect.

The roAp stars are ideal targets for the techniques of asteroseismology. Although they lack the rich spectrum of modes and disk resolved data available for the sun, by comparing the observed frequency spectrum to asymptotic pulsation theory and by applying the *oblique pulsator* model (Kurtz 1990), we can investigate a variety of properties of an roAp star such as its radius, rotation period, evolutionary status, pulsation modes, magnetic geometry, mean internal magnetic field strength and the temperature structure of the atmosphere (Matthews 1991).

In order to study the asteroseismology of roAp stars, they need to be found first. Of the 31 known roAp stars, 28 are southern objects and majority of them were discovered at the South African Astronomical Observatory (SAAO). This reflects the disparity in the number of known roAp stars in the two hemispheres demanding the need for a survey in the northern sky.

The roAp stars are all brighter than 11th mag and are thus accessible to 1-m class telescopes. However, since the amplitude of the oscillations is typically less than 1%. An excellent photometric site and high-quality, stable instrumentation are essential requirements for the discovery and study of these stars. Therefore, the Uttar Pradesh State Observatory (UPSO) at Naini Tal with proven photometric sky conditions was selected for this purpose and the survey was initiated jointly by the University of Cape Town (UCT) and the South African Astronomical Observatory (SAAO) in South Africa and UPSO and the ISRO satellite Applications Centre (ISAC) in India.

2. Observations

The observations were conducted at UPSO Naini Tal on the 1-m sampurnanand telescope. The instrument is a photometer built at ISAC. Time series photometric data for each candidate star were collected in a Johnson B filter with a sampling time of 10s for a typical duration of 1-2 hours. A photometric aperture of 25 arcsec was used. A single light curve is sufficient to reveal roAp star pulsation on a photometrically good night. However, a single null result is insufficient to exclude a candidate since beating between multiple pulsation periods and rotation of the star may both cause the star to appear constant for short periods. This demands that each candidate star be observed several times during the survey, to confirm variability as well as constancy.

3. Data reduction and sources of noise

The time series photometric data for each star were corrected for coincidence counting losses due to the dead time (~ 23 ns) of the photon counting electronics, sky background and atmospheric extinction. Fourier spectra of the light curves were then computed to search for coherent oscillations. The dominant sources of noise in the Fourier spectra are (1) sky transparency variations and (2) atmospheric scintillation. Sky transparency variations occur on a typical time scale of 20 min or longer. Therefore, these variations introduce peaks at low frequency ($\nu \leq 0.8$ mHz) in the Fourier transform of the data. On photometric nights, these sky transparency peaks are well resolved from the frequencies of interest ($\nu \geq 1.0$ mHz) and the roAp oscillations can be detected without difficulty. On marginal nights, the sky transparency noise can extend above 2.0 mHz making the detection of roAp oscillations impossible.

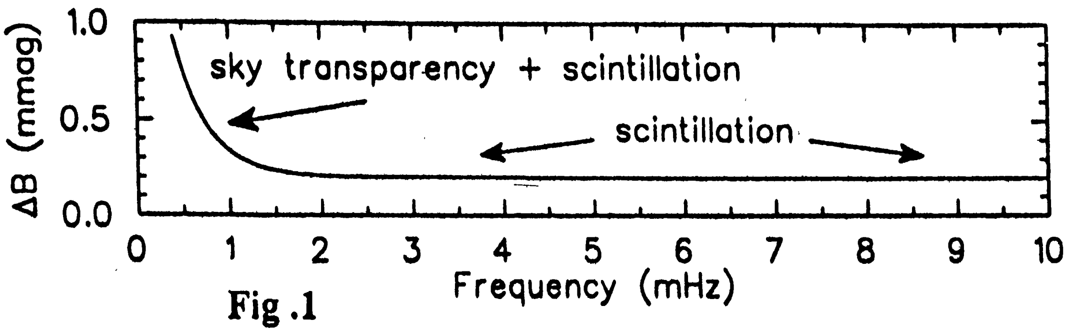

Figure 1.

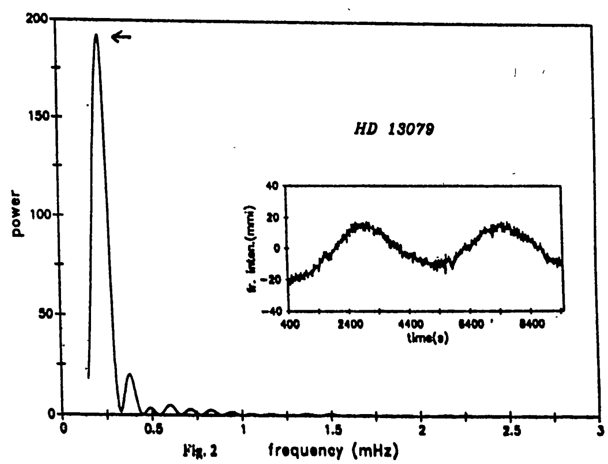

Figure 2.

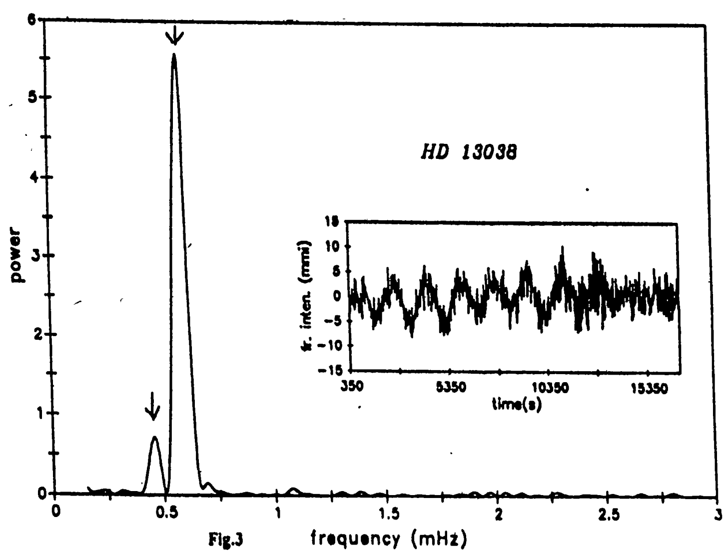

Figure 3.

The noise at the higher frequency is dominated by atmospheric scintillation. For the relatively bright roAp stars, it is the level of scintillation noise, not the photon noise, that sets the lower limit of delectability of oscillation amplitudes. The scintillation noise is white noise where as the sky transparency noise is frequency dependent and dominant towards lower frequencies. The combined noise starts increasing below a critical frequency for example < 1 m Hz as shown in Fig. 1 If the sky conditions are poor or for a non photometric site, the critical frequency shifts towards higher frequency side and thus reduce the range of detectable frequencies in roAp stars. Therefore, the level at which the sky transparency noise reaches the scintillation noise sets the lower frequency limit at which oscillations can be detected and studied. Since the photometric noise due to scintillation scales as the -2/3 power of telescope aperture, a bigger telescope is an advantage for the detection and study of roAp star pulsations.

4. Preliminary results

To date, around 30 targets were observed during 5 nights in November 1997 and 9 nights in November / December 1998 (The journal of observations will be published in a detailed survey paper which is under preparation). The amplitude spectrum of the atmospheric photometric noise attainable with 5 hrs of observations on a good night at Naini Tal on the 1.0 m telescope is shown in Fig. 1. On photometric nights, the level of the transparency noise drops down to the scintillation noise somewhere between 1-2 mHz. Naini Tal is thus proved to be an excellent site to conduct a northern-hemisphere roAp star survey.

Although, no new roAp stars were found in these preliminary observations, two new delta Scuti stars were discovered. The chemically peculiar star HD 13079 was discovered to be pulsating with a 73-min period and a Johnson B amplitude of 0.015 mag. (Martinez 1998) Strömgren photometry and the pulsations together suggest that HD 13079 is an Am star near ZAMS and that it is a fundamental mode pulsator on the red edge of the instability strip. Pulsation in cool main-sequence Am stars is a rare phenomenon observed in a few marginal Am stars and only in one classical Am star. The chemically peculiar star HD 13038 was discovered to be pulsating in two modes with periods of 28 and 34 min with Johnson B amplitudes of 1.61 and 1.33 m mag, respectively (Martinez 1999). Sample light curves and power spectra of HD 13079 and HD 13038 are shown in Fig. 2 & 3. More detailed analyses on these two stars will be published elsewhere.

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