Table 1.1: Basic parameters for BN Cnc and BV Cnc

| Star | R.A(2000) | DEC(2000) | $m_V$ | Sp. | $b-y$ | $V \sin i$ (km/s) |
|---|---|---|---|---|---|---|
| BN Cnc | 8 40 39.33 | 19 13 42.7 | 7.80 | A9V | .130 | 130 |
| BV Cnc | 8 40 33.02 | 19 11 40.5 | 8.65 | F0V | .181 | 100 |

# The STACC 1998 campaign on BN Cnc

## The Praesepe cluster

S. Frandsen, H. Kjeldsen and M. Breger

## 1.1 Stellar Evolution: the new cluster approach

Stellar modelling has developed a lot in recent years thanks to the attempts to model the Sun well enough to remove discrepancies with helioseismic data and to explain a few outstanding problems in variable star research (double mode Cepheids, the instability of $\beta$ Cephei stars). We want to meet this theoretical challenge in terms of observations of a quality that equal the improved quality of stellar modelling. The target is the nearby open cluster Praesepe, which has a rich population of $\delta$ Scuti stars that have been extensively observed. As target we prefer BN Cnc, which has bright star BV Cnc (see later) nearby that serves as a good reference. The other $\delta$ Scuti variables with rich sets of pulsation modes in this cluster do not offer as nice a field of view for CCD photometry. The parameters for the two stars are listed in Table 1.1

The test of stellar models in this cluster, however, still suffers from the problem of mode identification. Progress has been made recently by (Belmonte et al. 1996; Hernández et al. 1996) using the possibility of a simultaneous analysis of several stars.

The key point is, that if a mode identification succeeds for one star, then it is much easier to identify modes for all the other stars. We therefore want

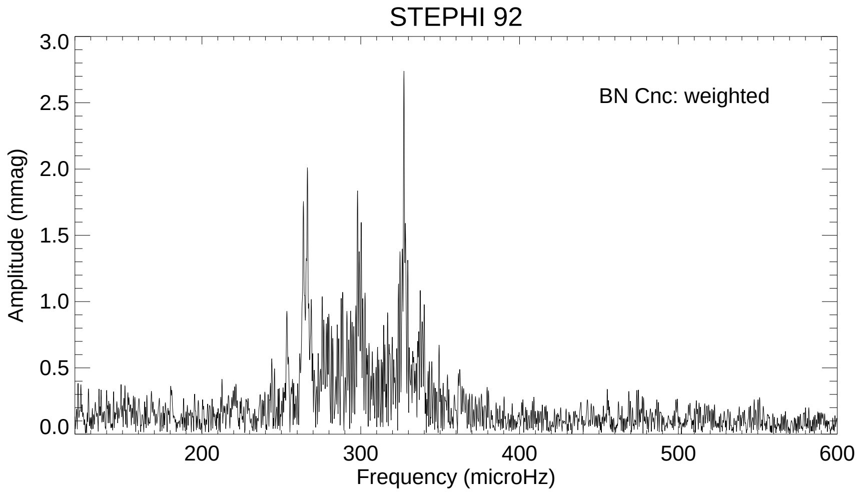


Figure 1.1: Amplitude spectrum based on the new reduction of the STEPHI data

to concentrate on a good target star and try to solve the problem for this star. The first step in this process is to get very high quality photometric data for the star. That is the purpose of our current campaign. BN Cnc has a rich pulsation spectrum (Table 1.2 with references to all observations and Fig. 1.1) and is an ideal target. We have re-analysed the STEPHI data (Belmonte et al. 1994) kindly put at our disposal by the STEPHI team and been able to reduce the noise level in the power spectrum considerably. We have also made a re-analysis of the DSN data on BU Cnc (Breger et al. 1993). In addition we have obtained CCD photometry for a limited period of time, but with low noise levels, from Tenerife. This has led to a revised list of frequencies for BN Cnc presented below. The data presented are the new values, that we have redetermined. References are given, if this frequency has been seen before or one close enough that we believe it's the same. Frequencies not in the list are not detected at a significant level in the STEPHI or the CCD data sets.

The references have been coded this way

- BR72 Breger (1972)
- KO81 Kovacs (1981)

Table 1.2: Observed frequencies (see text)

| f(c/d) | f($\mu$Hz) | A(mmag) | Signal/noise | References |
|---|---|---|---|---|
| 22.783 | 263.69 | 1.2 | 7.8 | ST94, KO81, IFA96 |
| 23.019 | 266.42 | 2.1 | 13.8 | ST94, IFA96 |
| 24.181 | 279.87 | 0.7 | 4.8 | ST94, KO81, IFA96 |
| 25.748 | 298.01 | 2.0 | 13.5 | ST94, KO81, BR72, IFA96 |
| 25.941 | 300.24 | 0.9 | 6.5 | ST94, IFA96 |
| 26.526 | 307.01 | 0.5 | 3.2 | IFA96 |
| 27.956 | 323.56 | 0.5 | 3.6 | IFA96 |
| 28.267 | 327.16 | 2.7 | 19.4 | ST94, IFA96 |

- ST94 Belmonte et al. (1994)
- IFA96 Kjeldsen et al. (1996)

The noise level in the revised spectrum from the STEPHI data set can be described quite well by the equation

$$a(\nu)^2 = (20\mu mag)^2(1 + \frac{14000\mu Hz}{\nu} + (\frac{630\mu Hz}{\nu})^2) \tag{1.1}$$

For relative CCD photometry one can use the star BV Cnc as a reference. There are several fainter stars that can be used as a combined reference as well to check whether BV Cnc is constant. Although it is classified as a slowly pulsating (0.55 c/d) $\delta$ Scuti star (Belmonte et al. 1996), our recent CCD measurements do not show any variability above 2 mmag (Kjeldsen et al. 1996). To check the stability of this star, and to verify the noise level we predict from a large campaign, a new, larger set of CCD measurements has recently been obtained at the Konkoly Observatory through a collaboration between Aarhus and Budapest. This data set is large enough to confirm the stability of BV Cnc at a much lower level, and to enable a precise extrapolation of the noise level from the CCD measurements to a large, multisite campaign.

If we get a successful observing run and identify many new pulsation frequencies, the next step is to make spectroscopy to identify the well detected

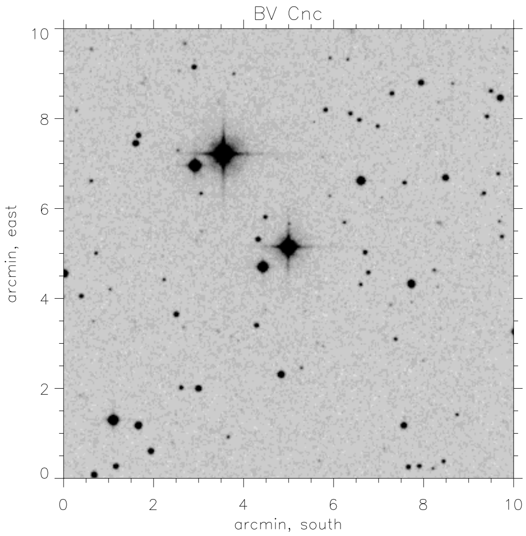


Figure 1.2: The field in Praesepe with BV CnC (center) and BN Cnc

pulsation frequencies with specific eigenmodes. We will then have an almost unique test case for stellar evolution.

Assuming a large campaign is organized, we will initiate the calculation of state of the art models and the eigenfrequencies belonging to each model. The Praesepe variables are all fast rotators so that rotation has to be taken into account during the modellization.

## 1.2 The observing plan

Our analysis of the previous photometric measurements show that CCD measurements can give a major improvement in the signal/noise in the power spectrum compared to previous data. Aperture photometry is very difficult in a cluster with fainter stars moving in and out of the aperture due to telescope tracking problems. The spectrum is obviously very dense and a long campaign is needed to separate the close set of frequencies. In the STEPHI data we see indications of a pair of frequencies at 266.20 and 266.42 $\mu$Hz.

T. Arentoft and M. Viskum have observed the field of interest (Fig. 1.2) with the IAC 80cm telescope at Tenerife for a total period of 11 hours. From their measurements we get a noise level of about 1.4 mmag per minute (r.m.s.

of time series). An exposure time of 110s and a readout time of 20s was used. The noise in the power spectrum is around 100 ppm, but the window function pretty awful.

Extrapolating from these measurements, we set out to get an order of magnitude improvement in terms of noise and a much cleaner window function. In order to get this we need a three week, multisite CCD campaign with three week extensions on both sides giving a total observing period of 2 months. This will ensure a frequency resolution that permit the detection of very close frequencies. We expect modes with high l values to be visible (l=3 to 5) with the low detection level we will reach (50 ppm?).

Further prestudies are planned for February 1997, where CCD measurements will be done from the Konkoly Observatory to check the noise levels we should achieve and the non-variability of BV Cnc.

The campaign is planned to take place in the first quarter of 1998. We need to find 4-6 sites for the main period and 1-3 sites for the extended periods. 1m class telescopes with 1Kx1K chips are typically what we would like to see, but as long as the telescope is not too small and the field large enough to cover BN Cnc and BV Cnc this is not an important demand. Almost any telescope will be scintillation limited anyway. An important information that influences the total number of sites involved is the expected number of clear nights. Some sites will not have the clear skies of La Silla or other high quality locations. This must be taken into account when the observing strategy is laid out. Very important is a careful observing procedure, which must be followed to reach the scintillation limit without adding noise from the measuring process. This is described in the next session.

This will be the most precise photometry ever done on a $\delta$ Scuti star and only surpassed in photometric precision by the M67 campaign, which was carried out with 4m class telescopes. The project will demonstrate how far one can get with modest size telescopes and prove, we think, that large telescopes are not necessarily better than small telescopes.

## 1.3 Observing procedures

In order to ensure the high quality of the data a series of calibrations are needed. Later on a detailed description will be distributed, but a short list of the observing procedure is given here:

- Before the observations (or after) low level and high level linearity tests are needed.

- For each night we need to make a series of bias frames, flat field frames (preferably sky flats, but dome flats can be used). We are presently working on a precise definition of the requirements for calibrations.

- Science frames. Good guiding is necessary keeping the stars fixed within a few pixels of the starting position on the CCD. Moderate defocusing is recommended to increase the duty cycle and to make the measurements less sensitive to guiding errors. The main contribution to 'instrumental' errors, on top of photon statistics and scintillation, is the combination of guiding deficiencies and flat field imperfections. The results deteriorate dramatically with the increase of pointing errors. To check that the observing parameters (defocus, integration time etc.) are optimal, monitor the frames at regular intervals.

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