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Multi-band Photometric Study of the Variable Star BN Tri

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Abstract: Using the 43.18 cm wide-field telescope at Xinjiang Astronomical Observatory, we carried out BVR three-band photometric observations of the variable star BN Tri. The data were reduced and the light curves were analyzed with the software MaxIm DL 6. The light curves in the g, r, and i bands were subjected to three-frequency sinusoidal fitting using the Period04 software, yielding residuals of 0.00848, 0.00700, and 0.00673, respectively, indicating a good fitting quality. The fundamental frequency F1 is measured to be about 13.47 d^{-1}, corresponding to a period of approximately 0.074 days, which is in good agreement with the period of 0.070 days given in the GCVS5 catalog. This consistency supports the reliability of our data and confirms that BN Tri is a short-period pulsating variable star of δ Scuti type. Meanwhile, the secondary frequencies F2 and F3 exhibit slight shifts between the r and i bands, with their amplitudes showing a decreasing trend from the r band to the i band, and significant phase differences are observed among the bands. These features reflect differences in the vertical propagation of distinct pulsation modes. The zero-point values in the g, r, and i bands are 0.268, −0.413, and −0.208, respectively, indicating an asymmetric band-to-band distribution of the mean spectral energy. In summary, the measured period is in good agreement with the GCVS5 value (0.070 days), with a relative deviation of about 5.7%, which is within the allowable range of observational errors, thus validating the effectiveness of the present observational data.

1. Introduction

1.1 Definition and categorization of variable stars

Variable stars are stars whose luminosity changes either due to drastic variations in their physical properties, composition, or shape, or due to eclipses during the orbital motion of close binary systems. Variable stars were formerly classified according to the morphology of their light curves or their spectra, and in 1964, at the IAU Symposium on Variable Stars, they were divided into three categories: eruptive variables, pulsating variables, and eclipsing variables.[1][6]

1.2 Definitions of major types of variable stars and the morphology of their light curves (with Figure 1, 2 and 3)

The main types of eruptive variables include supernovae (SN), novae, U Geminorum stars (UG), and Z Camelopardalis stars (Z). The main types of pulsating variables include long-period Cepheids (C), Population I Cepheids (Cδ), Population II Cepheids (W Virginis), and RR Lyrae stars (RR). The main types of eclipsing variables include Algol-type (EA), β Lyrae-type (EB), W Ursae Majoris-type (EW), and ellipsoidal variables (ELL), among others.[6]

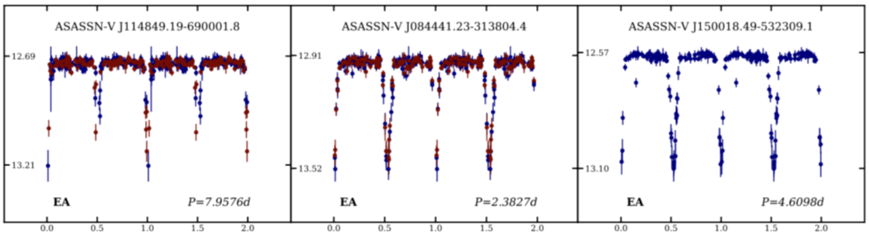

Figure 1 Light curves of eclipsing variables

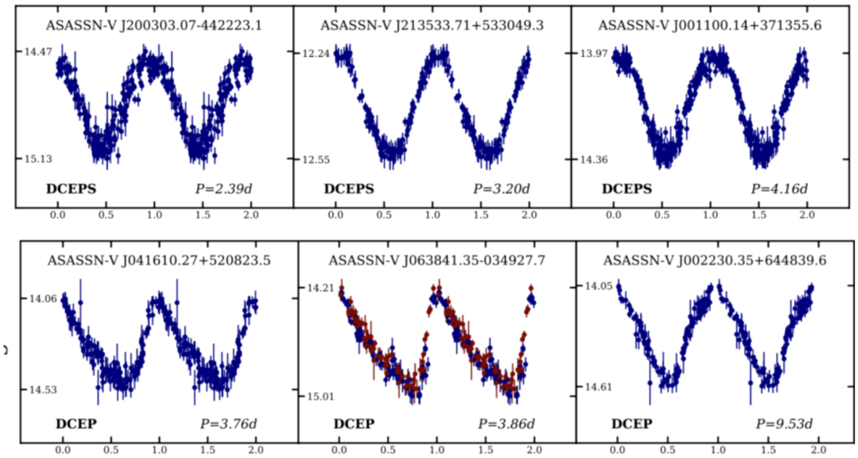

Figure 2 Light curves of pulsating variables

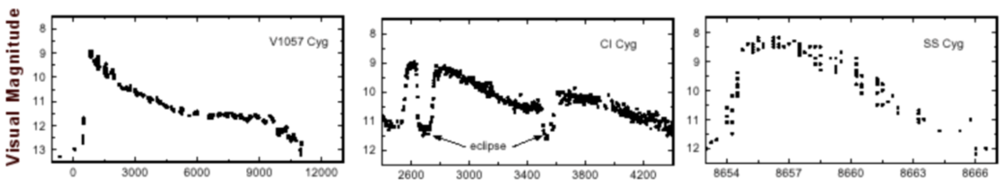

Figure 3 Light curves of eruptive variables

1.3 Regarding whether this variable star has been observed before, and the description of its properties (amplitude, period)

BN Tri is a Delta Scuti star. This type of variable star is a short-period Cepheid located in the pulsational instability strip, with spectral types A–F and pulsation periods shorter than 0.3 days. BN Tri has a pulsation period of 0.0668 days and a light amplitude of 0.38 mag.[2][8]

1.4 The structure of essay

In Section 2, the criteria for selecting observational targets are introduced, and the targets are determined to be V1513 and V2455. In Section 3, data reduction and analysis are carried out through the three-band BVR observations. In Section 4, the research results are obtained and discussed in comparison with previously known results.

2. Selection of target star

2.1 Introduction to the observational equipment

Figure 4 Actual photograph of an equatorial-mount telescope

As shown in Figure 4, the observational equipment selected is an equatorial-mount astronomical telescope with an aperture of 17 inches (43.18 cm). This telescope adopts an R-C Cassegrain double-reflection optical system, equipped with a five-position switchable filter wheel, an ASA equatorial mount, a PlaneWave optical tube (focal ratio F/D = 6.8), and a QHY4040 imaging camera (full resolution of 4096×4118 pixels, pixel size of $9.0\ \mu m \times 9.0\ \mu m$, plate scale of 0.624 arcsec/pixel, and a CMOS field of view corresponding to $43' \times 43'$ on the sky). The imaging can also be fed back to a computer for remote observation. The setup is additionally equipped with fan ports, counterweights, and a base to facilitate observations with a fully opening dome.

2.2 The principle of selection

The observation site of this study is the Nanshan Observation Station in Urumqi, Xinjiang, located at 87°10′24″ E, 43°28′18″ N, with an altitude of 2088 m. Due to the geographical location and observation time, the observable range and duration at this site must be strictly followed. The observational targets were selected based on amplitude, magnitude, finding charts, and altitude angle, with backup plans prepared to avoid excessive interfering stars around the selected variable stars in the sky. Given the limited availability of the observational equipment, the period was required to be 0.125 days or shorter ($24 \times 0.125 = 3$ hours), and the amplitude was required to be 0.4 mag or larger, so that the telescope would be suitable for the observed variable stars. The planned observation time was around July 12, with the local sidereal time at upper culmination corresponding to 19 hours at midnight, so the right ascension was chosen to be in the range of 19 ± 3 h, and the declination range was selected according to the geographic latitude of the Nanshan station (about 43°). Due to weather conditions, the observation date was changed to October 31, and the observational target was changed to BN Tri.[4]

2.3 Amplitude

Due to the aperture limitation, under all the conditions being satisfied, the selected target is BN Tri. Its amplitude ranges from about 12.15 mag to 12.35 mag, corresponding to 0.20 mag.

2.4 Magnitude

In order to ensure a high density of observational data points, a variable star with a magnitude of around 12 was selected to guarantee observation quality and exposure. BN Tri has a magnitude of approximately 12.35 mag (in the V band).

2.5 Finding chart (interfering stars)

Figure 5 BN Tri Finding chart,the cross is the target star

To ensure that no interfering stars in the vicinity affect the observations, it is necessary to examine the finding chart to confirm the absence of interfering stars around the target. As shown in Figure 5, it can be seen that there are no interfering stars that would affect the observations.[7]

2.6 Altitude angle (right ascension and declination)

The right ascension of BN Tri is 01h 54m 58.04s, and its declination is +29° 47′ 37.1″. Based on the latitude of the observation site and the observation time window, the altitude angle of this target is relatively favorable when it is near the meridian. This observation time can reduce the effect of atmospheric extinction and ensure photometric accuracy.

3. Data reduction

Photometry uses aperture photometry to calculate the flux of the target. Aperture photometry refers to, for a target on a detector image, drawing a circle with a selected aperture as the radius, summing the stellar flux contained within that circle, then subtracting the background value to obtain the net flux of the target, from which the instrumental magnitude of the target is then calculated. As shown in the figure 6, R1 is the photometric aperture. Starting from R2, the annular region with a thickness of Width is used to calculate the sky background: the median average of all pixels within this annulus is taken to obtain the sky background per pixel, denoted as I_{sky}. If the total number of pixels enclosed within the circle of radius R1 is Area, and the sum of the detector counts (ADU) within it is Sum, then the net flux is:Flux=Sum-Area×I_{sky}

The instrumental magnitude is defined as: $\mathrm{Mag} = \mathrm{Z_{mag}} - 2.5 \times \log(\frac{\mathrm{Flux}}{\mathrm{I_{time}}})$

Among, Z_{mag} is the custom photometric zero point., I_{time} is the exposure time.

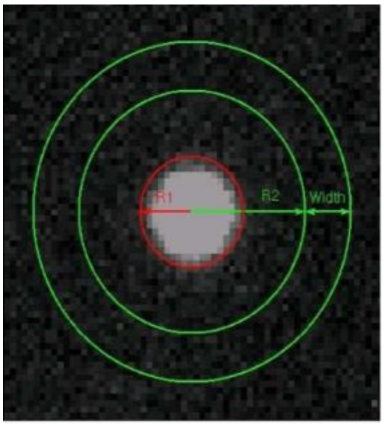

Figure 6 Schematic diagram of aperture photometry

4. Results and discussions

With a clear indication and overview from Figure 7 and Figure8, it can be seen that the magnitudes of the target star in the g, r, and i bands show no significant variation with time, as the data of Figure 9, Figure 10 and Figure 11, respectively, has shown. In the g band, the magnitude is around 0.8 with extremely small fluctuations; in the r band, it is around −0.14 with extremely small fluctuations; and in the i band, it is around −0.06 with extremely small fluctuations.

Figure 7 g-band observation image

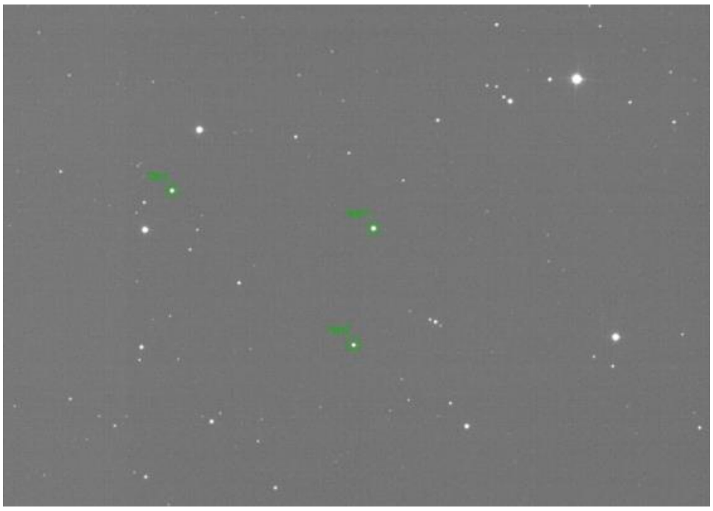

Figure 8 Schematic diagram of target star and reference stars

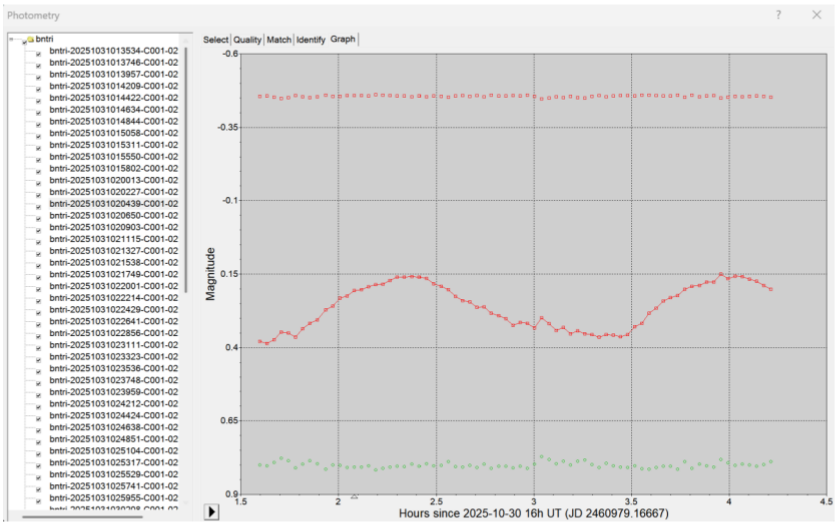

Figure 9 g-band data images (target star and reference stars)

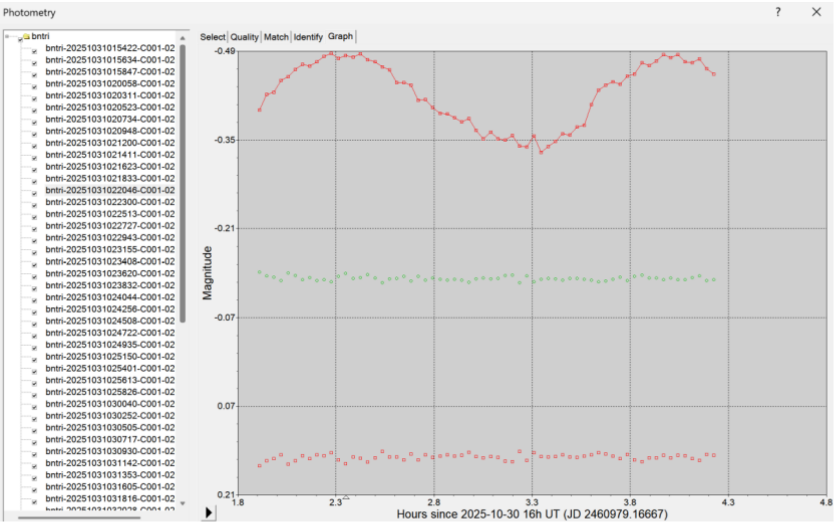

Figure 10 r-band data images (target star and reference stars)

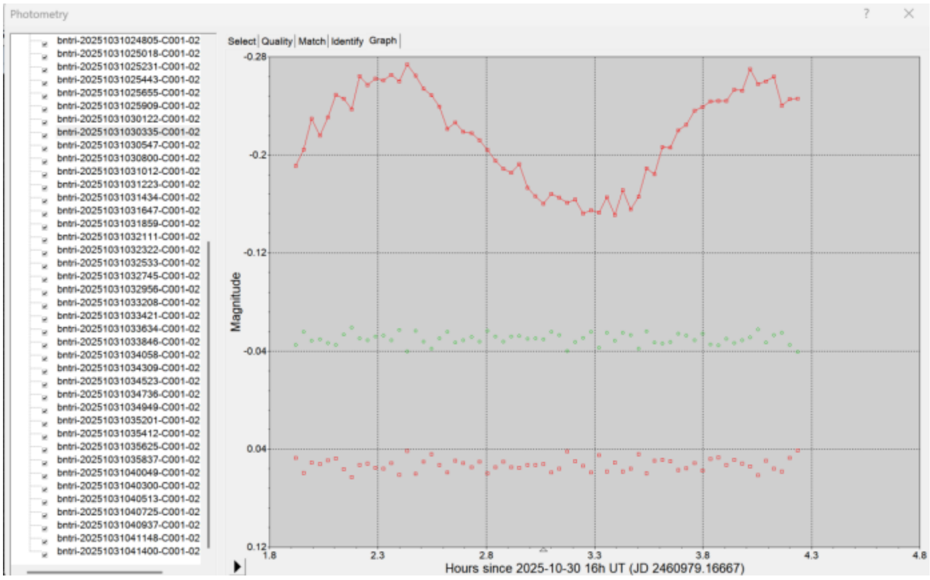

Figure 11 i-band data images (target star and reference stars)

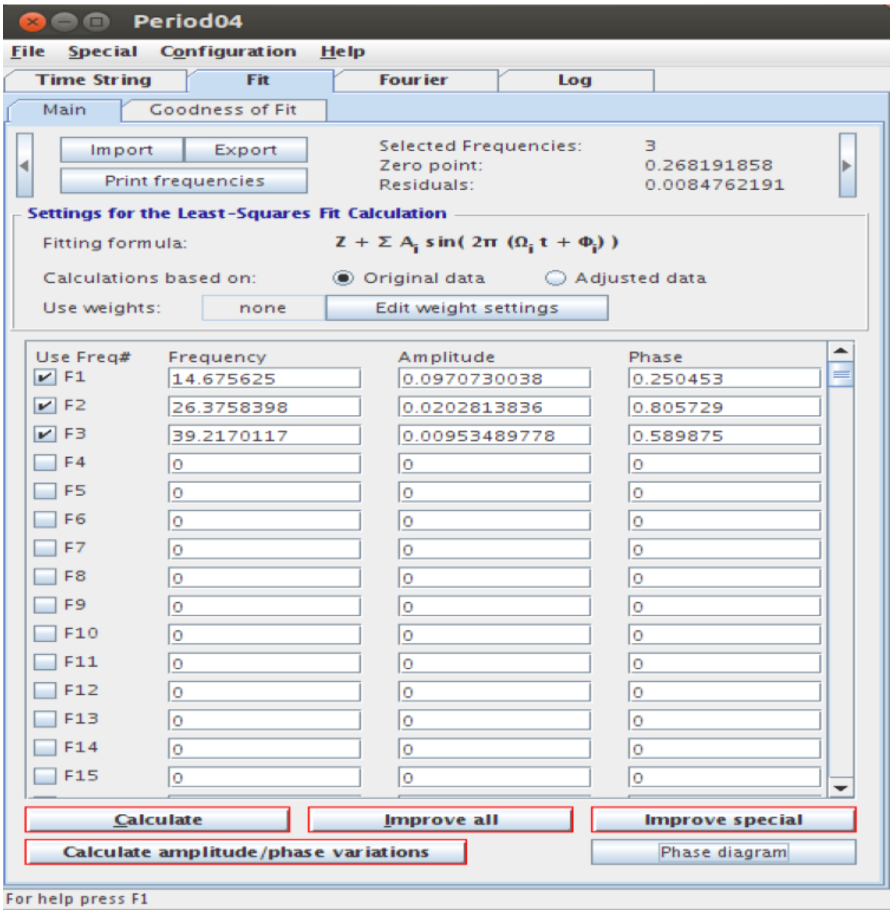

Figure 12 g-band data table (target star and reference stars)

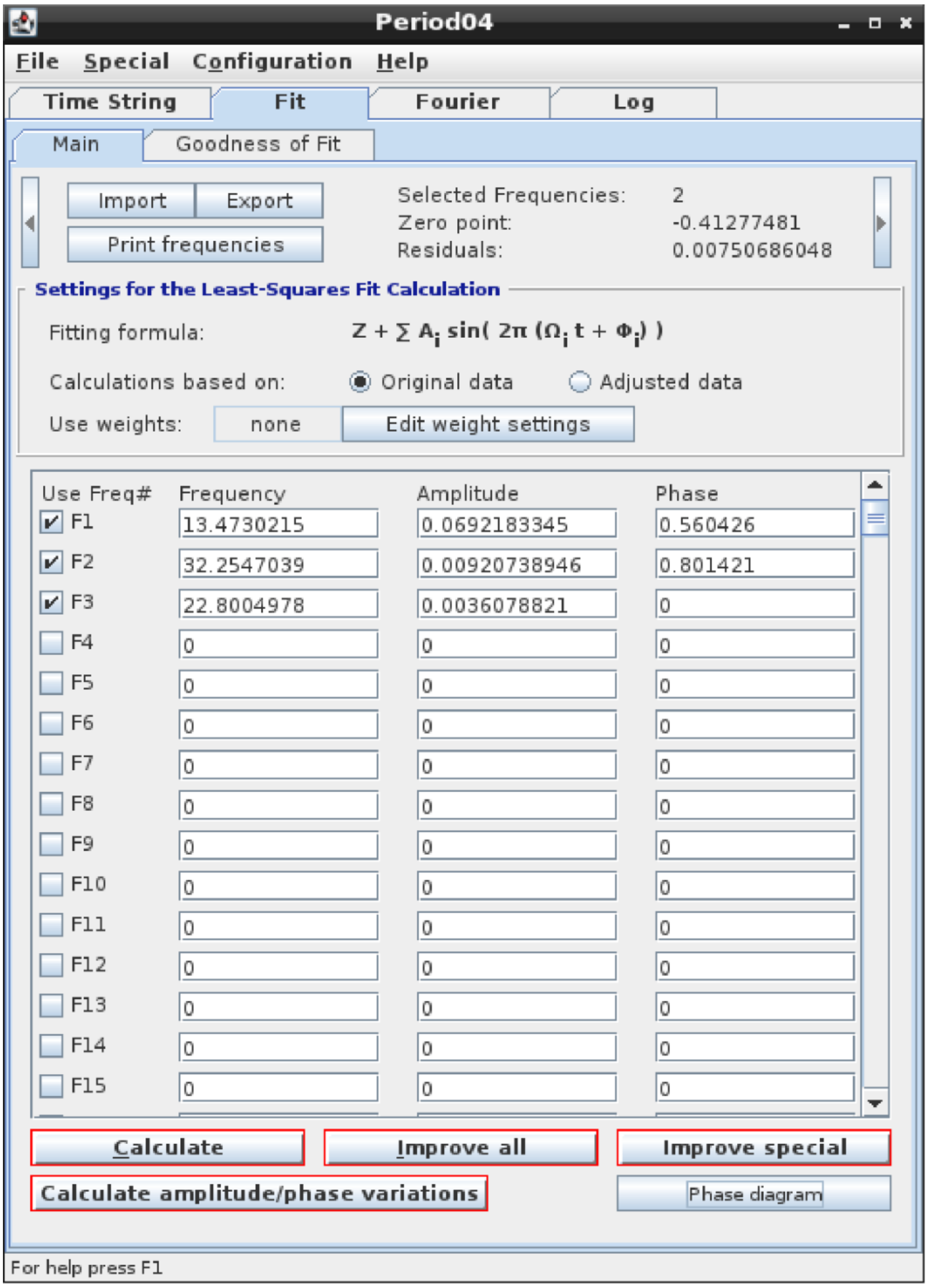

Figure 13 r-band data table (target star and reference stars)

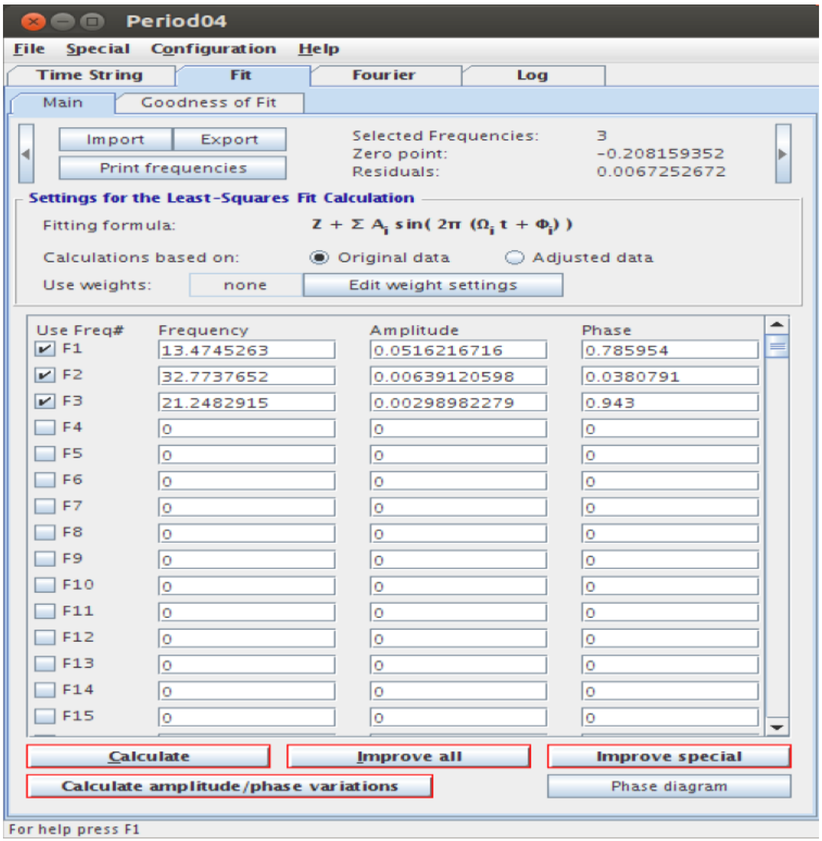

Figure 14 i-band data table (target star and reference stars)

5. Conclusion

We used the Period04 software to perform three-frequency sinusoidal fitting on the light curves of BN Tri in the g, r, and i bands. As shown in Figure 12, Figure 13 and Figure 14, the residuals are 0.00848, 0.00700, and 0.00673, respectively, indicating a good fitting quality. The fundamental frequencies F1 extracted from the three bands are nearly identical (about 13.47 d^{-1}), corresponding to a period of about 0.074 days (1.78 hours), which is also very close to the period of 0.070 days in the catalog.[3] This supports the credibility of the data, rules out the possibility of an eclipsing binary, and indicates that BN Tri is a short-period pulsating variable star, tentatively classified as a δ Scuti type. The secondary frequencies F2 and F3 exhibit slight shifts between the r and i bands (e.g., F2 changes from 32.25 d^{-1} to 32.77 d^{-1}), and the amplitudes show a decreasing trend from the r band to the i band, which exactly matches the characteristic that in pulsating stars, longer wavelengths correspond to smaller amplitudes. The phase differences among bands are relatively large (the phases in the r band are 0.562/0.790/0.187, and in the i band are 0.709/0.038/0.943), which precisely indicates the differences in the vertical propagation of different pulsation modes. The zero-point values in the g, r, and i bands are 0.268, −0.413, and −0.208, respectively, confirming the band-to-band asymmetry in the mean spectral energy distribution. In summary, BN Tri can be confirmed as a short-period pulsating star, and its three-frequency pulsation modes exhibit systematic variations in frequency, amplitude, phase, and zero point across multiple bands, providing key observational evidence for revealing its pulsation modes and atmospheric stratification structure.[5]

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