OPEN EUROPEAN JOURNAL ON VARIABLE STARS
September 2007 http://var.astro.cz/oejv ISSN 1801-5964

TWO BRIGHT ECLIPSING BINARIES SOLVED WITH THE HELP OF VISUAL OBSERVATIONS

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Abstract:
Visual observations of V975 Cen and NSV 15737 were combined with photometric data from the Hipparcos and ASAS databases to determine the elements for these eclipsing binaries. V975 Cen is an Am+F binary in an extremely eccentric orbit with elements HJD 2454217.582 (±0.080) + 135.9255 (±0.0015) x E. NSV 15737 is an EA-system made up of very different components with elements HJD 2454329.479 (±0.001) + 8.161235 (±0.000001) x E.

Introduction

The Hipparcos Space Astrometry Mission **(ESA)** carried out between 1989 and 1993 became a gold mine for variable star research. The Hipparcos satellite discovered more than 8,000 variable stars. They were included in the Hipparcos Variability Annex of the Hipparcos Catalogue **(Perryman et al., 1997)**. Among these new variable stars, some have been analyzed and their periods found by the Hipparcos team (they are flagged as "P" in the catalogue) but a large number of them could not be classified with the available data and have been published as "unsolved" (U). Among the unsolved variables, there are hundreds of new eclipsing binaries showing an insufficient number of eclipses to allow a period determination. A subset of them were automatically classified as such due to their light curve shape but the small amplitude ones and those showing too few observations were given the U flag with no variability type. NSV 15737 and V975 Centauri belong to the latter group. However, V975 Cen was given an official name and type by the GCVS team **(Kholopov et al., 2006)**. There was only one eclipse recorded but due to its very long period, the seven data points present in the Hipparcos database clearly showed a descending branch of an eclipsing binary so the star was classified as an EA-type eclipser.
Even though there were three eclipses recorded, the number of faint observations of NSV 15737 was only five and they were spread over the years so NSV 15737 was not classified and only included in the supplement to the New Catalogue of Suspected Variables **(Kazarovets et al., 1998)**.
Since 2003, an extensive research of these and other unsolved eclipsing binaries has been made (see **Otero, 2003**, for the first paper of the series) using the publicly available ASAS-3 **(Pojmanski, 2005)** and NSVS **(Wozniak et al., 2004)** databases. Combination of Hipparcos data with the new data from those surveys made possible to determine periods for hundreds of eclipsing binaries but many of the longer period ones (with not enough time coverage) and the brighter stars (with saturated or not available data from the surveys) have remained unsolved. In this scenario, visual observations become very important since they offer the time coverage needed for the detection of elusive eclipses.
Among the stars published in the past years in the framework of this project, six of them could only be solved due to the visual detection of several eclipses, namely V438 Pup (V= 6.0, per= 4.935 d., **Otero, 2003**); V353 Hya (V= 7.4, per= 7.56 d., **Otero and Stephan, 2004**); KV CMa (V= 7.2, per= 68.4 d., **Otero and Dubovsky, 2004**); GSC 3612-1565 (V= 11.1, per= 5.86 d., **Otero et al., 2006**); GSC 4257-0906 (V= 10.0, per= 12.92 d., **Otero et al., 2006**) and VZ PsA (V= 5.7, per= 5.76 d., **Otero et al., 2006**).

Results

Since V975 Cen and NSV 15737 were ideal targets for visual observations due to their brightness (7th magnitude) and amplitude (at least half a magnitude), they were included in the observing plan of the authors and were observed as often as possible.
Once enough eclipses were detected the observations were analyzed using a Microsoft Excel period search utility kindly provided by Patrick Wils **(Wils, 2003)**. Periods and epochs were then improved by light curve fitting of all the datasets. The uncertainties are those for when the folded light curve began to show systematic differences.

The time span of the observations is 18 years, since the early Hipparcos measurements up to the 2007 visual data, which allows an accurate period determination. Hipparcos observations have been transformed to V using a table by the author published electronically in IBVS No. 5482 **(Otero, 2003b)**.

V975 Centauri - *13 38 54.13 -55 01 28.2 (2000.0)*

HIP 66580 = HD 118548 = SAO 241032 = CPD-54 5680 = CD-54 5334 = PPM 342113 = GSC 8667-0764.

Five visual eclipses were combined with another one from Hipparcos and four from ASAS (one of them also detected visually) and the following elements were found:

$$HJD\ Min\ I = 2454217.582 + 135.9255 \times E$$
$$(\pm 0.080) \quad (\pm 0.0015)$$
$$HJD\ Min\ II = 2454227.551 + 135.9255 \times E$$
$$(\pm 0.050) \quad (\pm 0.0015)$$

Epochs have large uncertainties because only visual data are available and the time coverage for individual minima is poor due to the extremely long period. The system has an extremely eccentric orbit, with a secondary eclipse at phase 0.073. The visual data suggest the eclipses are total so the stars should be slightly different in size. From a maximum V-magnitude of 7.37 (±0.01), the system drops to 7.76 (±0.03) during min I and to 7.54 (±0.02) during min II. Also Min I lasts longer than Min II (0.0070 and 0.0058 phase units respectively) which is not surprising given the extremely high eccentricity.
From the combined magnitude at Min II mid-eclipse we find that the A-component's V-magnitude is 7.54 and B is 9.4. Spectral type from **Houk (1975)** is A2mA5-A7. Assuming a dwarf companion, this must be of spectral type F.
Data-mining of the all-sky databases have led to the discovery of 16 Am eclipsing binaries in the last 4 years. V975 Cen is the longest period Am-type eclipser known among 47 such systems in the GCVS, Hipparcos and sky survey data. The nature of Am stars seems to be explained by the presence of a similar mass companion leading to tidal breaking **(Mayer and Hakkila, 1994)**. The discovery of more eclipsing binaries among Am stars supports this binary scenario. However, the components may be very different as in the case of V339 Gem **(Otero and Dubovsky, 2004)** where the secondary minimum is barely visible.
The complete light curve of V975 Cen is shown in Figure 1 and Figure 2 shows details of each of the eclipses.

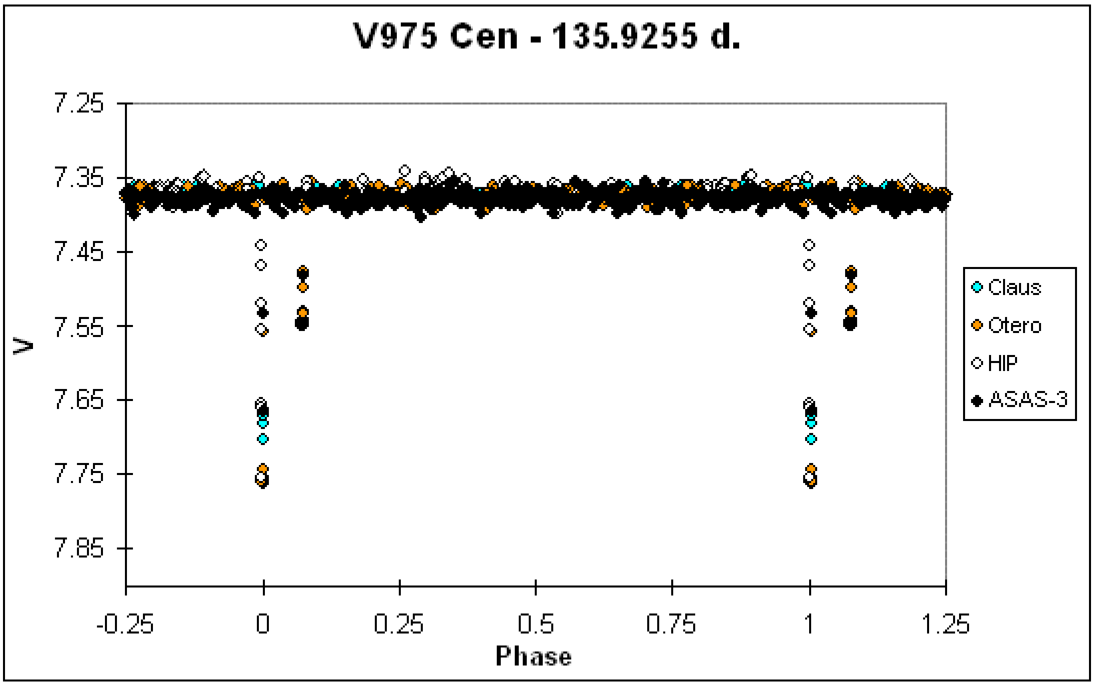

Figure 1: Light curve of V975 Centauri folded with a period of 135.9255 days including photometry by ASAS and Hipparcos (HIP) and visual observations by Claus and Otero.

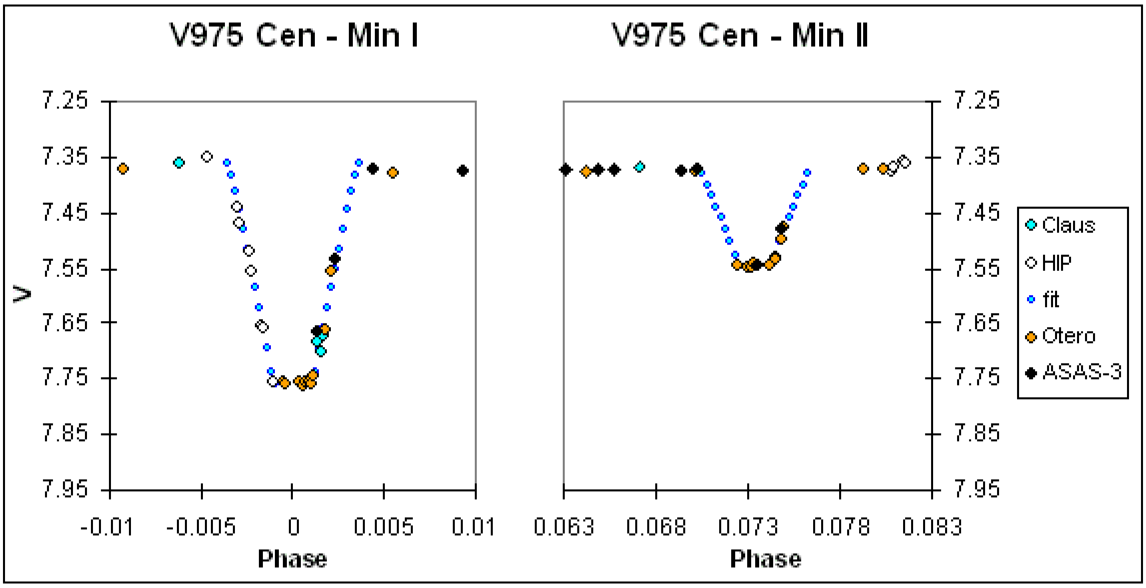

Figure 2: Detail of V975 Cen's eclipses. A symmetric synthetic light curve was plotted to show the fit of the observations. Visual observations of both eclipses suggest they are total.

NSV 15737 in Taurus - *03 40 38.77 +28 46 24.0 (2000.0)*

HIP 17168 = HD 22766 = SAO 76071 = BD+28 0562 = PPM 400053 = CCDM 03406+2846 A = STF 427 = GSC 1811-2054

Two visual eclipses were observed and a preliminary ephemeris was determined after combining those observations with Hipparcos data. Subsequent CCD observations were carried out by Michal Vadila from Astronomical observatory at Kolonicke sedlo and a primary eclipse was recorded. Observations were made with a Meade DSI Pro CCD with a Zeiss 180/2.8 photolens and a Johnson V-filter. Exposure time was 10 seconds. The comparison star used was HD 22860 (V= 6.88, B-V= -0.01) and the check star HD 22964 (V= 8.06, B-V= 1.02). The instrumental V-magnitudes of the target were shifted to match the standard V value of the star.
Elements:

$$HJD\ Min\ I = 2454329.479 + 8.161235 \times E$$
$$(\pm 0.001)\ (\pm 0.000010)$$

The eclipsing system is part of a visual binary where A= 7.46 (spectral type A1V) and B= 7.92 Hp. (A2V) Separation is 6".99 **(Perryman et al., 1997)**. At this separation Hipparcos photometry generally suffers from problems that could lead to wrong results **(Otero, in preparation)** but fortunately this is not the case with this entry, where the observations show a maximum scatter of 0.03 mag. only. The primary component was visually confirmed at the eyepiece to be the eclipsing binary. The combined variation in V is 6.86 (±0.01) - 7.42 (±0.05). Subtracting the third light we get a range of 7.42 - 8.62. Eclipses are partial. Min I lasts 0.05 phase units. No secondary eclipse was observed but phase coverage is not complete. The amplitude of the primary minimum indicates the secondary eclipse –if present- is small. Light curves of NSV 15737 can be seen in Figures 3 and 4.

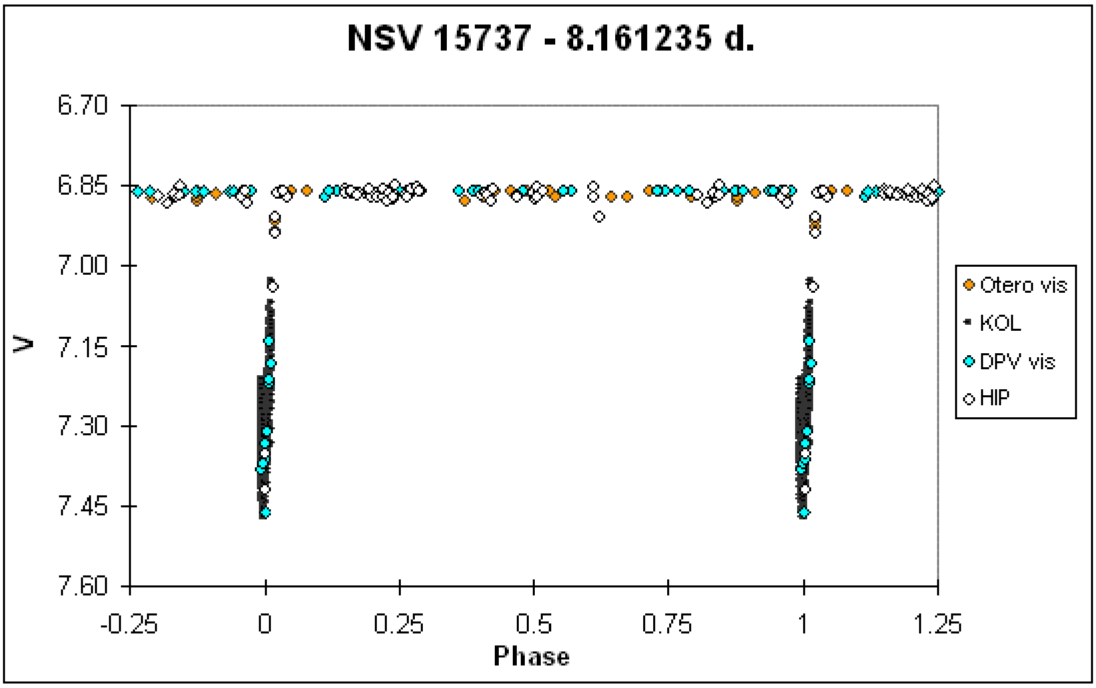

Figure 3: Light curve of NSV 15737 folded with a period of 8.161235 days including photometry by Hipparcos (HIP) and from Kolonicke sedlo (KOL) and visual observations by Dubovsky (DPV) and Otero.

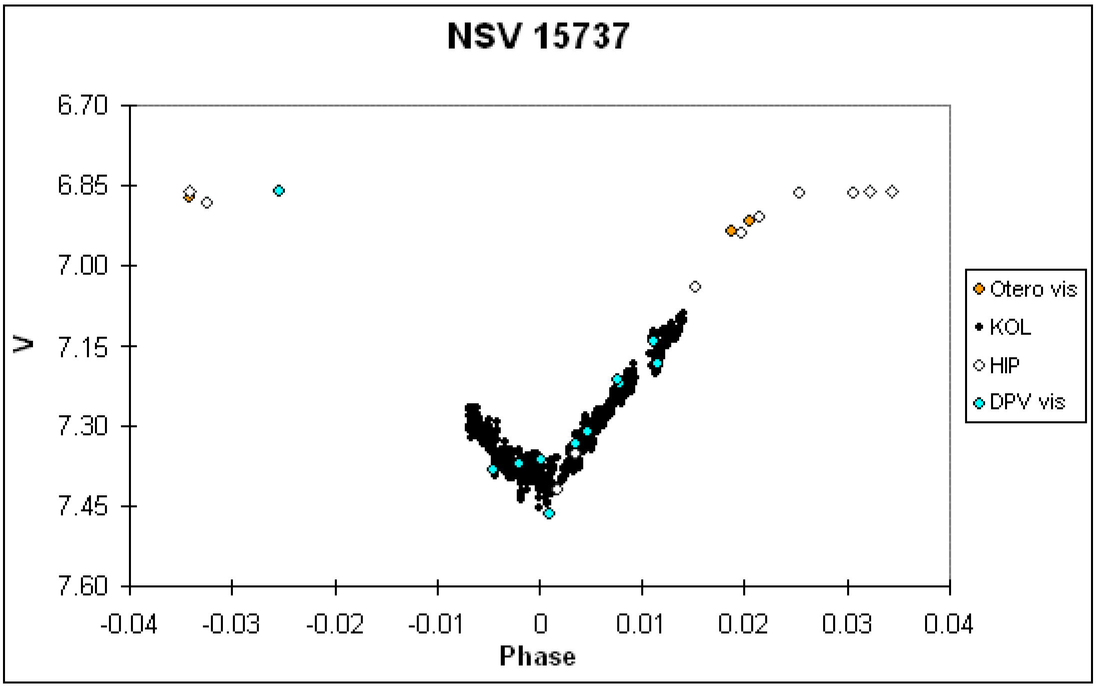

Figure 4: Primary minimum of NSV 15737 measured from Kolonicke sedlo (KOL) on August 16th, 2007. Visual observations by Dubovsky (DPV) and Otero and Hipparcos (HIP) data are also shown.

Acknowledgements: This research has made use of the SIMBAD and VizieR databases operated at the Centre de Données Astronomiques (Strasbourg). The authors thank Patrick Wils and John Greaves for useful discussions and Michal Vadila for the observations of NSV 15737.

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