BN Orionis (TYC 126-0781-1) Duplicity Discovery from an Asteroidal Occultation by (57) Mnemosyne

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Abstract: An occultation of BN Orionis (SAO 112952, HD 245465, TYC 126-0781-1) by the asteroid (57) Mnemosyne on March 11, 2012 showed this star to be a double star. The separation of the two components (Sep) is 0.0038 ± 0.0008 arcseconds at a position angle (PA) of 63.6 ± 15.2 degrees. The magnitude of the primary component is estimated to be 9.9 ± 0.1. The magnitude of the secondary component is estimated to be 10.8 ± 0.2.

Target Star

TYC 126-0781-1 is the star that was targeted for this observation. Unknown to the observers at the time of the occultation, TYC 126-0781-1 is also listed in the General Catalogue of Variable Stars as BN Ori, an INSB eruptive variable. The target star is not listed in either the Fourth Interferometric Catalog or the Washington Double Star catalog. See text box labeled Figure 8 for documentation of the known stellar properties and a condensed description of the FU Ori (FUOR) characteristics of BN Ori.

Observation and Analysis

On 2012 March 11, Brooks, Conard, D. Dunham, J. Dunham, Jones, Lipka, Thomas, Warren, Wasson, and Wisniewski observed the asteroid (57) Mnemosyne occult the star TYC 126-0781-1 at thirteen locations across the United States, from the mid-Atlantic

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Table 1: Observers, Site Locations, Telescopes and Observing Methods
Video+GPS time ins = NTSC CCD video with GPS time inserted on each frame
Video+GPS linked = NTSC CCD video with GPS time linked to each frame by calibrating GPS UT to digital video recorder clock time.

Observer	Location	Telescope Type	Telescope Diam (cm)	Observing Method
T. Lipka	Uniontown, MD	Newtonian	20	Video+GPS time ins
S. Conard	Gamber, MD	Schmidt-Cassegrain	36	Video+GPS time ins
R Wasson	Murrieta, CA	Newtonian (Dobson)	30	Video+GPS time ins
J. Brooks	Winchester, VA	Schmidt-Cassegrain	30	Video+GPS time ins
S. Conard	Dayton, MD	Schmidt-Cassegrain	13	Video+GPS time ins
W. Warren J. Dunham	Greenbelt, MD	Refractor	8	Video+GPS time ins
J. Wisniewski	The Plains, VA	Dobson Newtonian	30	Visual
R Jones	Salton City, CA	Schmidt Camera	20	Video+GPS time ins
D. Dunham	Hawthorne, MD	Refractor	8	Video+GPS linked
W. Thomas	Anza Borrego State Park, CA	Schmidt-Cassegrain	28	Video+GPS time ins
D. Dunham	Port Conway, VA	Refractor	8	Video+GPS linked
D. Dunham	Bowling Green, VA	Refractor	8	Video+GPS linked
D. Dunham	Doswell, VA	Refractor	8	Video+GPS time ins
D. Dunham	Doswell, VA	Refractor	12	Video+GPS time ins

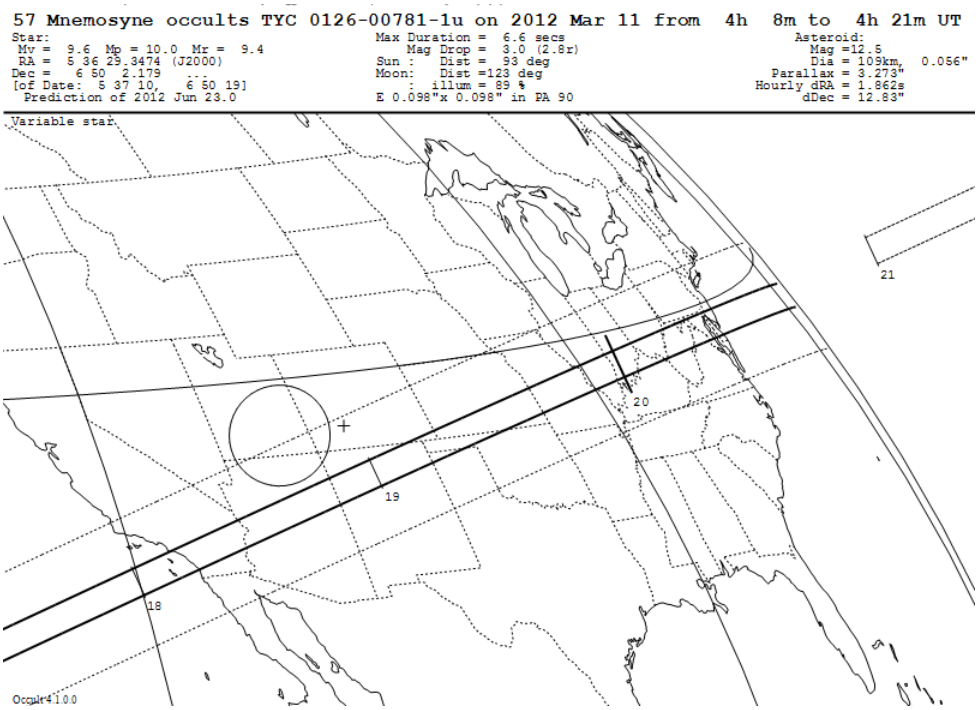

Figure 1: Occultation Path (Occult4)

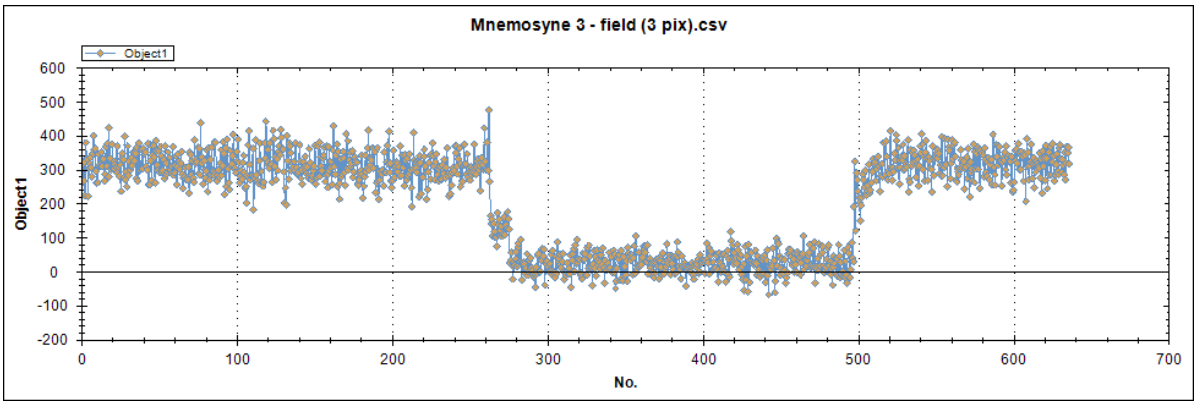

Figure 2 : Jones occultation light curve

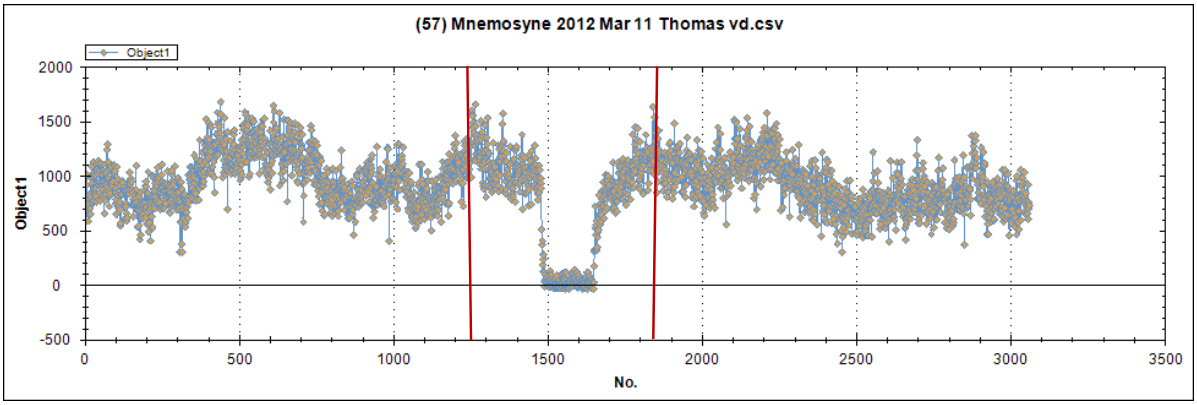

Figure 3: Thomas total raw-data light curve showing variable baseline due to clouds - data in the area between red lines were normalized and used in the final analysis of the double star solution.

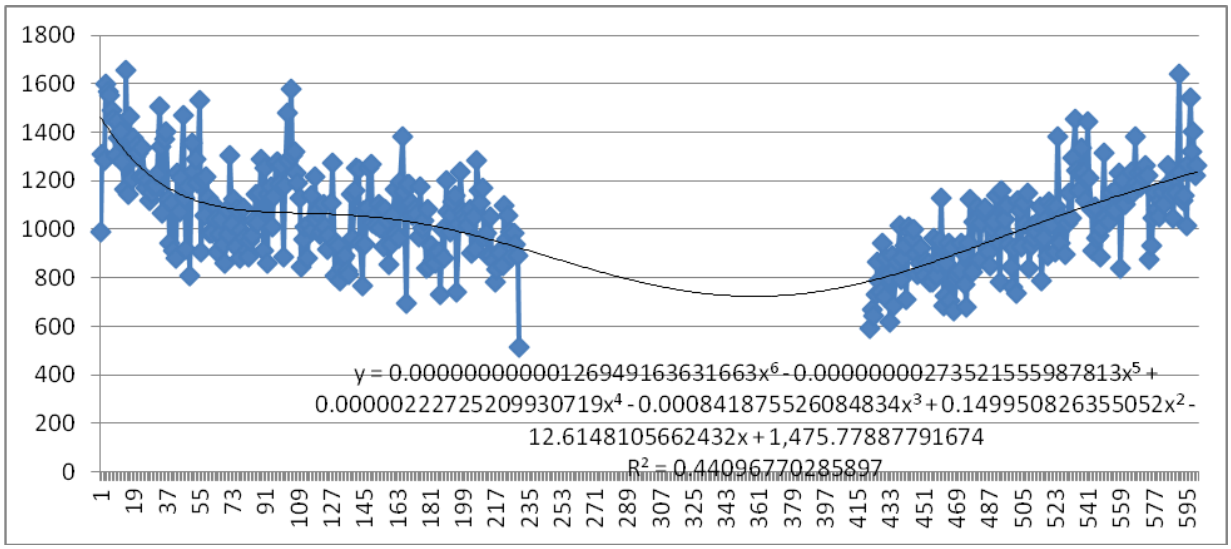

Figure 4: Thomas sixth order polynomial correction light curve between frames 1250 and 1850

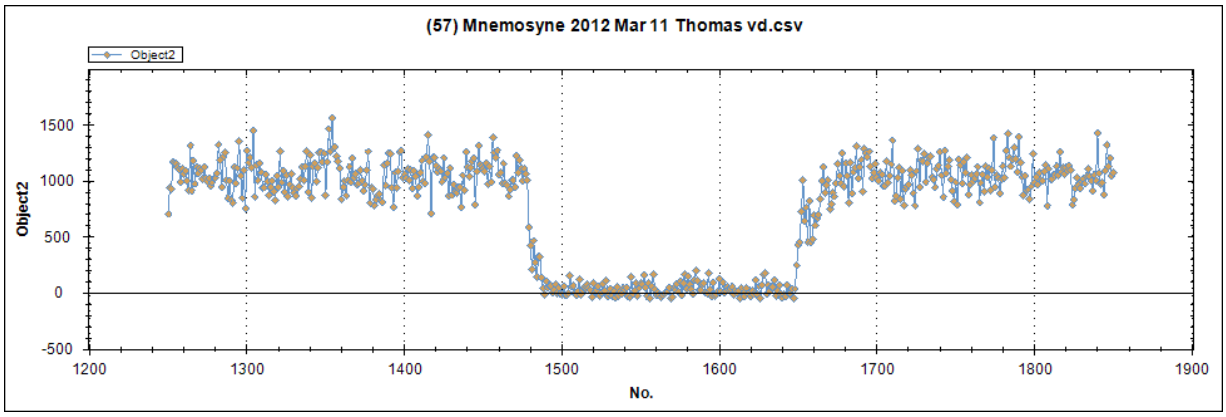

Figure 5: Thomas normalized occultation light curve

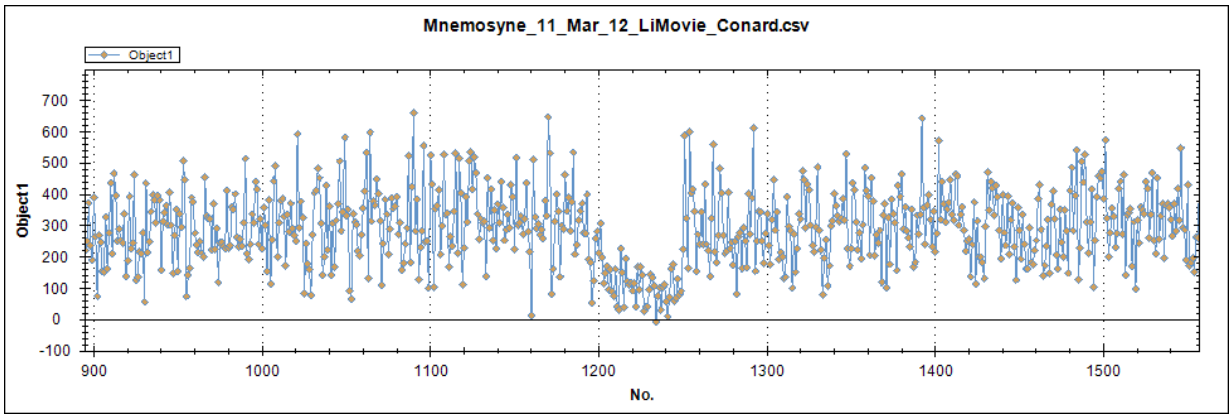

Figure 6: Conard single-step single star event

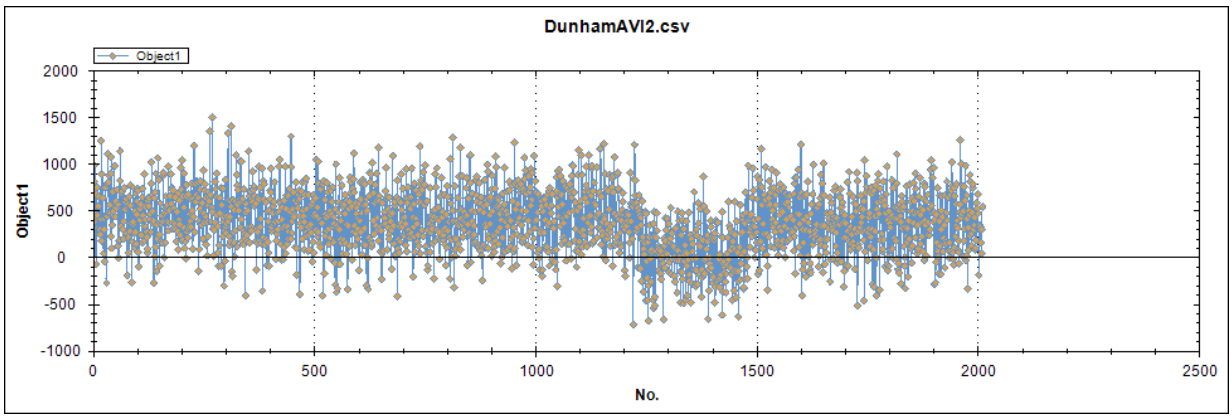

Figure 7: D. Dunham event

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states to California (see Figure 1). The observations were made at the locations and with the equipment listed in Table 1. This is the second recorded occultation of a star by (57) Mnemosyne.

Jones and Thomas both observed two step-event observations. The Jones event is shown in Figure 2. The Jones event disappeared in two steps of 0.95 magnitude drop and 1.78 magnitude drop, and reappeared in two steps of 2.44 magnitude increase and 0.31 magnitude increase.

The Thomas event raw-data light curve is shown in Figure 3. It appears to have been affected by clouds. In order to correct the Thomas light curve, we analyzed the portion of the curve nearest the event (red bars shown in Figure 3) and developed a normalization curve to correct the baseline values. The sixth-order polynomial trend-line solution is shown in Figure 4. Once the trend-line solution was used to normalize the data, the Thomas light curve had step events very similar to Jones as seen in Figure 5. The normalized disappearance (D) and reappearance (R) times were used in the calculation of the asteroid profile and double star PA and Sep.

At his Dayton, MD station, Conard had a chord near the edge of the asteroid. Careful analysis of the Conard light curve (Figure 6) did not show two steps in either the light curve D or R. Instead, there was a single (slightly grazing on disappearance) step with a magnitude drop of 1.07, which is consistent with the 0.97 magnitude drop recorded by Jones. Conard had a miss of the secondary star.

Other observations made by D. and J. Dunham, and Warren with smaller aperture telescopes were either unable to show the two-step light levels event due to high noise levels, or did not show the two-step light levels event. A representative light curve of the latter non-two-step observations is shown in Figure 7.

The altitude of the target star at the time of occultation may have also been a factor in being able to clearly see the steps in the light curve. Observers in California saw the star at an altitude above 45 degrees, while those in Maryland observed at an altitude of 17 degrees.

The original target star is listed as magnitude 9.60 (magnitude in Johnson V (T5)). However, since TYC 126-781-1 is listed as the variable star BN Ori in the GCVS, the actual brightness at the time of occultation may be different from predicted. The asteroid predicted magnitude was 12.5. The predicted combined magnitude of target star and asteroid was 9.53 magnitude. The expected magnitude drop at occultation was 2.97 magnitudes. (Occult4 predictions show slightly different magnitude estimates). Jones observed a total magnitude drop of 2.72, reasonably close to the predicted drop. The first disappearance drop of the two-step event was 0.95 magnitude, and the second drop was 1.78 magnitude. On reappearance, the magnitude increase was 2.44 and 0.31 magnitudes, respectively. These results are consistent with an ABAB occultation sequence, with A the brighter star at magnitude 9.92 and B the fainter star at magnitude 10.83.

See analysis done using the Magnitude calculator routine in Occult4 (Method 3 – Magnitudes from light curve values see Figure 9) and the MV from the TYC catalog.

In order to determine the position angle (PA) and separation (Sep) of the suspected double star, the observations were analyzed in the standard manner described by IOTA. See Figure 8 for a plot of the asteroid shape, size, PA and Sep derived from the data.

Based on the data presented in this report, the characteristics of the suspected double star are shown in Text Box 2.

Based on the calculated 0.0038 arcsecond angular separation for this double star system, assuming that the second star is actually a binary and not a background star, and assuming a 450 pc distance to BN Ori, the secondary star is calculated to be 1.7 AU from the primary star.[6]

Acknowledgements

The authors would like to acknowledge the contribution of Dave Herald, Hristo Pavlov, and Steve Preston to the observation and analysis of the BN Orionis occultation. Steve Preston provided the updated path predictions needed for the observers to get in the correct positions to observe the event. Hristo Pavlov provided the program OccultWatcher that observers used to coordinate site locations. Dave Herald provided the program Occult4 used for data reduction and analysis and comments on the solution of the asteroid profile, PA and Sep.

References

1. "Dunham, D.W., Herald, D., Frappa, E., Hayamizu, T., Talbot, J., and Timerson, B., Asteroid Occultations V10.0. EAR-A-3-RDR-OCCULTATIONS-V10.0. NASA Planetary Data System, 2012." The data is found at the URL:

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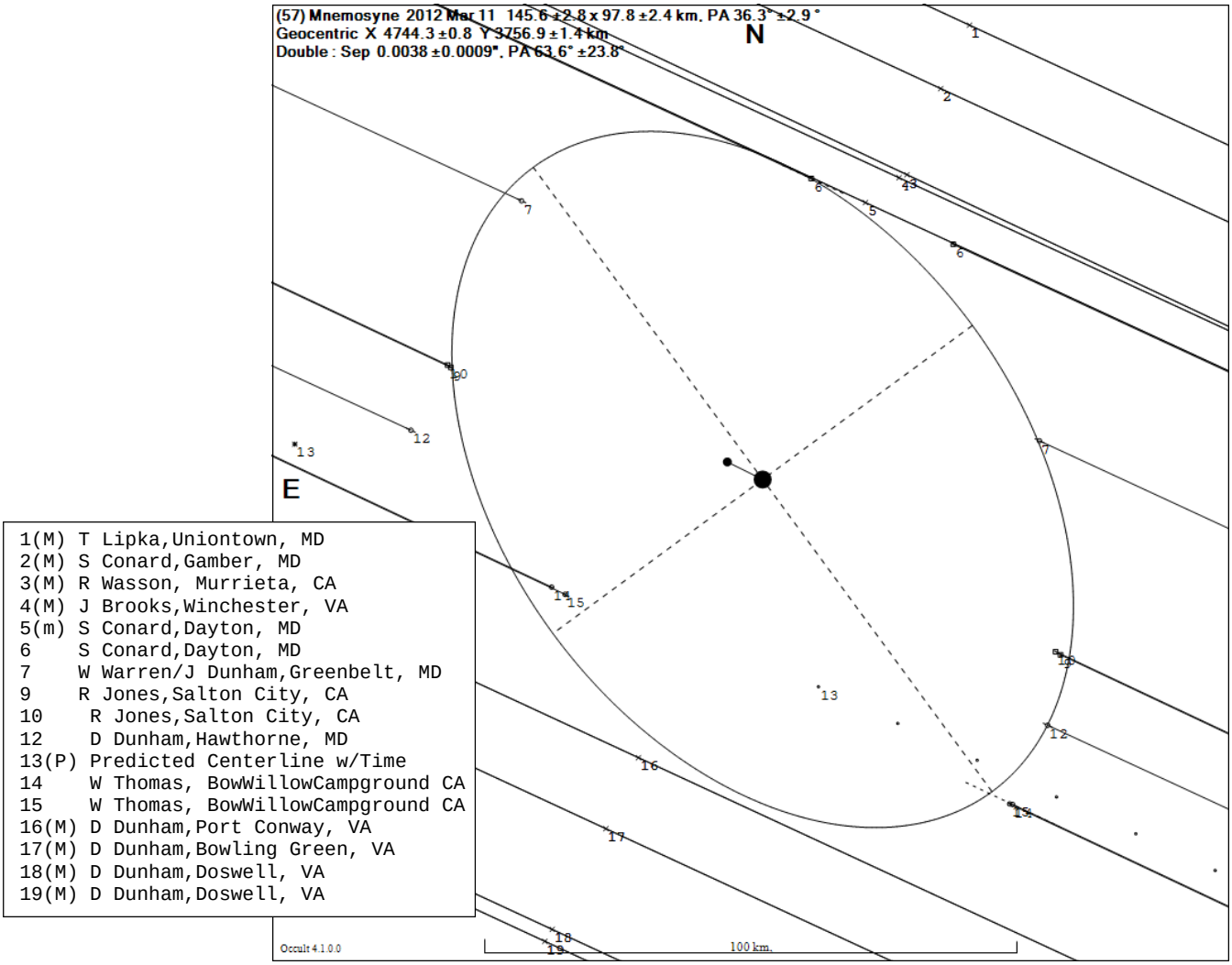

Figure 8: (57) Mnemosyne occultation of TYC 126-0781-1 – video CCD observations – ellipsoid of best fit and double star solution plot. Chord 8 was a visual observation and not used in the double star solution.

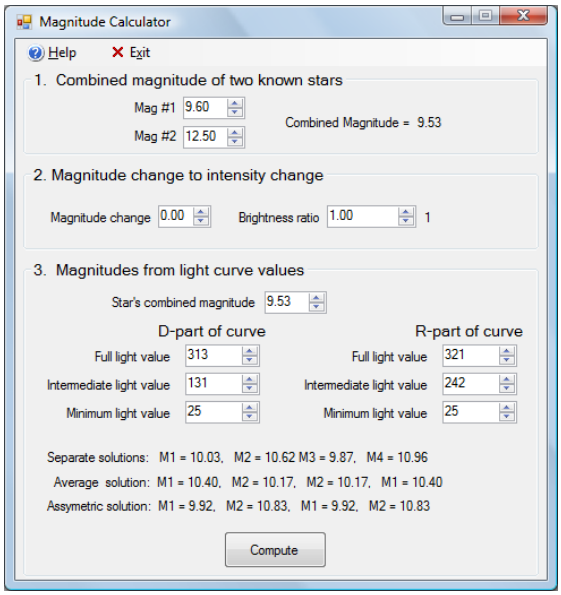

Figure 9 Calculation of component star magnitudes

Star Diameter
diameter = .0001" [Estimated]
= 0% of the asteroid's diameter
=> Fades caused by the star diameter are not expected.
Fresnel diffraction
diffraction for light drop of 2 mag (to 16%) = 0.0002"
fades of 0.02 secs might be expected
diffraction for light drop of 4 mag (to 2.5%) = 0.0005"
fades of 0.05 secs might be expected
AAVSO Variable star entry

Variable identifier	Type	Max	Min
BN Ori	INSB	8.8	13.9

From its discovery as a variable until 1947 the star behaved more like a Herbig Ae-type star with strong and irregular brightness variations. Then in 1947 the behaviour changed to FU-Ori object, or FUOR with a sharper large scale rise in brightness followed by a more gradual fading over 15 years and remained constant for 30 years thereafter. The current stellar classification is A7 (Pre Main Sequence) , 2-5 solar masses, with some surrounding gas and dust (faint emission nebula) and possessing an accretion disk, at a distance of some 400 pc but is rotating at speeds upward of 220 km/sec making it a faster than usual FUOR like object. The change in brightness since 1947 and steady output seems to indicate that a FUOR event blew away or at least for now cleared the dust shell and was triggered by thermal runaway in the inner accretion disk by a moderate increase in accretion rate. In 1991 there was a slight 0.5m drop in brightness that lasted for approximately 51 nights and this was attributed to infilling circumstellar dust.

Source: "The FUOR characteristics of the PMS star BN Orionis inferred from new spectroscopic and photometric observations"; Shevchenko, V. S.; Ezhkova, O.; Tjin A Djie, H. R. E.; van den Ancker, M. E.; Blondel, P. F. C.; de Winter, D. **Astronomy & Astrophysics Supplement** series, Vol. 124, July 1997, 33-54.

Text Box 1 – Documentation of miscellaneous star properties

Star Catalogue No.[3]	SAO 112952 BD +06° 971 HD 245465 AGK3 +06° 0599 TYC 126-0781-1 UCAC2 34055899 3UC 194-028123 NOMAD 0968-0002500 PPMXL n06d-0135833
Spectral Type	A7[4]
Coordinates (J2000)[5]	RA 05 36 29.365 Dec +06 50 02.11
Mag A	9.92 ±0.15
Mag B	10.83±0.15
Separation	0.0038 +/- 0.0008 arcseconds
Position Angle	63.6 +/- 15.2degrees

Text Box 2: Characteristics of the suspected double star

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http://sbn.psi.edu/pds/resource/occ.html. The most recent version of the database is always listed at the top. You may 'Browse' or 'Download' the database. If you 'Browse', there are six links. The first, "aareadme.txt", is a high -level summary. The asteroid occultation data is found by clicking on the "data" link. Under the "data" link. The file "occsummary.tab" contains information about all of the occultation solutions, ordered by asteroid number. The file "occlist.tab" lists all of the observed asteroidal occultations, in chronological order by "SEQ_NUM". The file "occlist.lbl" describes the format and information in the columns. The file "occtimings.tab" give the individual timings, in event chronological order, then in order of observers. The first column is the "SEQ_NUM" for the occultation, which is the same "SEQ_NUM" used in the "occlist.tab" file. All of these terms are defined in a format specific to the NASA PDS system. The details of reading the files are explained at: http://pdssbn.astro.umd.edu/howto/understand.shtml.

2. New Double Stars from Asteroidal Occultations, 1971 – 2008, Dave Herald, Canberra, Australia, Journal of Double Star Observations, Volume 6 Number 1 January 1, 2010

3. C2A (Computer Aided Astronomy), Philippe Deverchère, a Planetarium software that displays the following catalogues: SAO, GCVS, WDS and Hipparcos, Guide Star, Tycho-2, USNO-SA1.0, USNO-A2.0, USNO-B1.0, UCAC1, UCAC2, UCAC3, NOMAD and PPMXL.

4. Positions and Proper Motions - North (Roeser+, 1988)

5. The Hipparcos and Tycho Catalogues (ESA 1997), VizieR, Centre de Données astronomiques de Strasbourg

6. Personal communication: Dr. Mario van den Ancker, European Southern Observatory