A CATALOG OF 1022 BRIGHT CONTACT BINARY STARS

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ABSTRACT

In this work we describe a large new sample of contact binary stars extracted in a uniform manner from sky patrol data taken by the ROTSE-I telescope. Extensive ROTSE-I light-curve data are combined with J, H, and K-band near-infrared data taken from the Two Micron All Sky Survey to add color information. Contact binary candidates are selected using the observed period-color relation. Candidates are confirmed by visual examination of the light curves. To enhance the utility of this catalog, we derive a new J − H period-color-luminosity relation and use this to estimate distances for the entire catalog. From these distance estimates we derive an estimated contact binary space density of \((1.7 \pm 0.6) \times 10^{-5} \text{ pc}^{-3}\).

Key words: binaries: close — catalogs — stars: variables: other

Online material: FITS file

1. INTRODUCTION

W UMa–type contact binaries are eclipsing systems in which both stars overflow their Roche lobes, forming a common envelope of material (Lucy 1968). They are formed from nearly normal main-sequence stars with spectral types usually between F and K. Typical mass ratios are between \(q \approx 0.2\) and 0.5, but reported values are almost as high as unity and as low as 0.066 (Rucinski et al. 2001). Their periods range from 0.22 to 1.5 days, with most systems having periods between 0.25 and 0.5 days. Because of their close proximity, they produce continuously varying light curves, making them detectable at a large range of inclinations.

Due to the common atmosphere, both stars have essentially the same surface temperature. Through a combination of Kepler’s third law and the radius-color relationship for main-sequence stars, this common temperature leads to a period-color-luminosity relation (Rucinski 1994; Rucinski & Duerbeck 1997). This relation, along with their ease of detection, makes contact binaries useful tracers of distance and Galactic structure, especially on small scales (Rucinski 2004).

Contact binaries are known to be quite common among variable stars, although their space density is still debated. Early estimates range from \(10^{-6}\) pc\(^{-3}\) (Kraft 1967) to \(10^{-4}\) pc\(^{-3}\) (van’t Veer 1975). More recent estimates include those of Rucinski (2002), who found a density of \(1.0 \times 10^{-5}\) pc\(^{-3}\), or 1 out of 500 main-sequence stars, in the solar neighborhood. This conflict with a previous estimate of 1 out of 130 main-sequence stars made using OGLE-I data in the Galactic disk (Rucinski 1998) and may be an indication of significant variability in the contact binary fraction through the Galaxy.

Currently, the General Catalog of Variable Stars (GCVS)\(^2\) labels 845 stars as EW-type variables: W UMa variables with periods less than 1 day and nearly equal minima. However, GCVS classifications are not entirely secure. Other contact binary catalogs include that of Pribulla et al. (2003), which contains 361 Galactic EW- and EB-type variables, each previously identified by another catalog such as the GCVS. Contact binaries included had either light-curve or good spectroscopic data available. Also, analysis of the ROTSE-I variability test fields (Akerlof et al. 2000) found 382 contact binary candidates within about 2000 deg\(^2\), identified by their light-curve shape and period. Periods and light-curve data were provided for all these ROTSE-I objects.

We present here a catalog of 1022 contact binary stars, 836 of which are not found in the GCVS, SIMBAD database, Pribulla catalog, or ROTSE-I test fields. Light-curve data, periods, and distance estimates are presented for each object. These objects passed a rather stringent selection process and have high-quality light curves, so their classification is relatively secure. The completeness of this catalog for the regions surveyed is estimated to be about 34%, with the remaining objects lost to data quality cuts. Near-infrared observations of these objects drawn from the Two Micron All Sky Survey (2MASS) allow us to create a near-infrared period-color-luminosity relation and to estimate distances to each object. Finally, an estimate of the space density of these objects is made.

Section 2 contains an overview of the data and selection methods and is followed by a description of the method used to obtain distance estimates in §3. The space density derived from this catalog is discussed in §4. Section 5 contains a summary of the results.

2. ASSEMBLING THE CONTACT binary CATALOG

In this section we describe how we assemble a catalog of bright contact binary stars for study. We begin with a short description of the ROTSE-I instrument, which obtained the data, and the Northern Sky Variability Survey (NSVS) database on which this project is based. This is followed by a description of the variable selection, identification of short-period variables, phasing of these variables, combination of ROTSE-I optical data with 2MASS near-infrared data, and finally, the selection of contact binaries from this catalog.

2.1. NSVS Data

Optical variability data were obtained by the ROTSE-I telescope.\(^3\) ROTSE-I was a fourfold array of Canon 200 mm f/8 lenses, each equipped with an unfiltered 2048 × 2048 pixel Thompson TH7899M CCD. At this f-number, the 14 μm pixels of the CCD subtended 14”.4 on the sky. The combined array imaged a continuous \(16’’ \times 16’’\) field of view. ROTSE-I, designed to pursue real-time observations of gamma-ray bursts, spent most of the time from 1998 March until 2001 December patrolling the sky. The very large ROTSE-I field of view allowed it to image the entire available sky twice each night, taking a pair of 80 s images during each visit. Typical limiting magnitudes ranged from

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\(^{2}\) VizieR Online Data Catalog, 2250 (N. N. Samus et al., 2004).

\(^{3}\) For more information about ROTSE, see http://www.rotse.net.
\[ m_v = 14.5 \text{ to } 15.5, \] depending on sky conditions. During its operating life, ROTSE-I amassed a 7 Tbyte time domain survey of the night sky. Since being disassembled in 2002, the ROTSE-I lens and camera assemblies have been reborn as elements of the Hungarian Automated Telescope Network (Bakos et al. 2004). Initial studies of ROTSE-I sky patrols were reported in Akerlof et al. (2000). Although this work examined only 3 months of observations covering just 5% of the sky patrol area, it revealed nearly 1800 bright variable objects, most of which were previously unknown. More recently, light-curve data from a full year of all ROTSE-I sky patrols have been released publicly by Wozniak et al. (2004) as the NSVS, which is available through the SKYDOT Web site at Los Alamos National Laboratory. This work includes the entire region north of \(-30^\circ\) declination, although coverage is neither perfectly uniform nor absolutely complete. Many more light-curve points are available for sources at high declination than at low. Completeness is reduced in regions of very high stellar density.

All optical light curves used in this paper are drawn from the NSVS. Details of the SExtractor-based (Bertin & Arnouts 1996) reductions and relative photometry corrections of ROTSE-I data for inclusion in the NSVS catalog, along with maps of source density and the number of good light-curve data points, are presented in Wozniak et al. (2004).

2.2. Selection and Phasing of Variable Objects with Short Periods

Selection of variable objects from the NSVS light-curve database follows the methods outlined in Akerlof et al. (2000). For each object, available data are examined for all good coincident pairs of observations. For this purpose, “good” points are defined at two levels, one more tolerant than the other. Cuts are made by examining the measurement flags described in Wozniak et al. (2004). Our tight cuts require no processing flags except for the SExtractor “blended” flag, indicating that an object is the result of a deblending procedure. In addition to the “blended” flag, our second set of loose cuts allows the inclusion of points that have “nocorr” and “patch” flags, indicating that the relative photometry correction of an object could not be estimated or that the map of corrections was patched to obtain the value for that object. Both sets of cuts are quite restrictive and leave us with a set of very well measured light curves.

For each object with at least 20 pairs of observations passing the tolerant cuts, we calculate the modified Welch-Stetson (Welch & Stetson 1993) variability index \( I_{\text{val}} \) described in Akerlof et al. (2000). The distribution of variability indices seen in a representative sample of the data is shown in Figure 1. This distribution is roughly Gaussian with a mean value of 0.227 and a width \( \sigma = 0.11 \). Every object with \( I_{\text{val}} \) greater than 1, about 7 \( \sigma \) from the mean, is accepted as a variable. From a list of \( 1.43 \times 10^7 \) input light curves, 63,665 are selected as variable by these criteria, a variability fraction of 0.45%. The total number of detectable variables, as can be seen from the \( I_{\text{val}} \) distribution plot, is substantially larger.

Most of the variable objects we identify are long-period variables, with periods of 10 days or more. To identify short-period variables within this set, we calculate a simple light-curve roughness parameter similar in spirit to the Welch-Stetson variability parameter. For this calculation we consider triplets of consecutive pairs of observations spaced by no more than 5 days. For each of

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\[ \text{Fig. 1.—Top:} \text{ Distribution of modified Welch-Stetson variability indices for a representative subset of NSVS data. The dotted line shows a Gaussian fit to this distribution, and the solid line shows the variability cut (about 7 \( \sigma \)) applied in forming this catalog.} \]

\[ \text{Bottom:} \text{ Distribution of the roughness parameter \( R \) described in the text for the 63,665 variables extracted from the NSVS light-curve database. The dotted line shows a Gaussian fit to this distribution, and the solid line shows the cut applied to identify short-period variables.} \]
the outer pairs in a triplet we calculate the mean magnitude. Using these, we predict by linear interpolation the mean magnitude for the middle pair. We then compare the residual between actual and predicted magnitude for each observation in the central pair to the error in its magnitude:

\[ \delta_1 = \frac{m_1 - m_{\text{predicted}}}{\sqrt{\sigma_1^2 + 0.04^2}}, \]

\[ \delta_2 = \frac{m_2 - m_{\text{predicted}}}{\sqrt{\sigma_2^2 + 0.04^2}}. \]

An additional uncertainty of 0.04 mag is added in quadrature to the measurement errors to reduce the sensitivity of this parameter to small non-Gaussian errors. We then sum the absolute values of the products of these scaled residuals, divided by the number of predicted points, to construct our roughness parameter:

\[ R = \frac{1}{\sqrt{N_{\text{triplets}}(N_{\text{triplets}} - 1)}} \sum_{\text{triplets}} |\delta_1 \delta_2|. \]

The distribution of this roughness parameter for all 63,665 variables is shown in Figure 1. For variables with periods longer than a few days, this roughness parameter is distributed in an approximately Gaussian manner, with a mean of 0.4 and a width \( \sigma = 0.22 \). To construct a list of candidate short-period variables we select those with \( R > 1.0 \). The total number of such candidates is 17,508.

Each of these candidate short-period variables is then passed to the cubic spline phasing code described in detail in Akerlof et al. (1994). This code provides best-fit periods, period error estimates, and spline fit approximations for light-curve shapes. For each variable, we test the quality of this phasing by measuring an analogous roughness parameter for the phased light curve. For most eclipsing systems the period identified is actually half the real period. If the light curve is symmetric (as is the case for full contact binaries), the phased light curve is very smooth with this period. If the minima are not symmetric, the light curve will appear "rough" with this period but smooth when tested at twice the period. As a result we measure light-curve smoothness for both the identified period and twice the period and accept as well phased those light curves that have acceptably small roughness with either period. Examples of this are shown in Figure 2. Comparison of this folded roughness to the original roughness allows us to define a sample that is well phased. Of the 17,508 short-period candidates, 16,548 have a phased roughness parameter less than 1.5 when phased at either the derived period or twice the derived period. These objects are deemed to be confidently phased.

2.3. Combination of NSVS and 2MASS Data

ROTSE-I data are unfiltered, so although we have excellent light-curve information, we have no color information. To ameliorate this, we combine the ROTSE-I light-curve information with \( J \)-, \( H \)-, and \( K \)-band near-infrared data drawn from 2MASS.
This combination is especially apt because 2MASS data are significantly deeper than ROTSE-I data. As a result, 2MASS measurements for all ROTSE-I objects are rather precise. 2MASS observations are taken simultaneously in all three bands and are reported for a single epoch. Combining these data with ROTSE information provides three colors, $m_{\text{ROTSE}}/C_0$, $J/C_0$, and $H/C_0$, where $m_{\text{ROTSE}}$ is the mean apparent magnitude in the unfiltered ROTSE-I band. The 2MASS observations correspond to random phases of the ROTSE light curves, generating uncertainty in each value of $m_{\text{ROTSE}}/C_0$ and causing the horizontal spread in the $m_{\text{ROTSE}}/C_0$ versus $J/C_0$ plots. The $J/C_0$, $H/C_0$ color measurements do not suffer this dispersion, and the measured $J$, $H$, and $K$ magnitudes can be simply compared to determine single-epoch object colors.

To identify the proper 2MASS counterparts we pass the positions of all NSVS variables to the 2MASS database query tool at IPAC. Since ROTSE-I pixels are relatively large, there can be minor ambiguity in the identification of the correct corresponding 2MASS source. This problem is limited by the fact that ROTSE-I variables are all rather bright, and hence, their sky density is not especially high. When there is more than one match, the chosen 2MASS matching object is the nearest object with $m_{\text{ROTSE}}/C_0 > 0$.

Color-color plots for all the variables and those identified as short period by the methods described above are shown in Figures 3 and 4. It is clear by comparison that the short-period candidates are a special, predominantly blue subset. Visual examination of the few red ($m_{\text{ROTSE}} - J > 3.0$) short-period candidates shows them to all be long-period variables with relatively large light-curve roughness. As a result, we further refine our short-period variable candidate list by requiring $m_{\text{ROTSE}} - J \leq 3.0$ and $H - K \leq 0.35$. These cuts leave a total of 16,046 phased short-period variable candidates.

### 2.4. Selection of Contact Binary Stars

Contact binary stars are known to exhibit a period-color relation. As shown in Figure 5, there is a dense patch of short-period variables that displays a period-color dependence. Comparison to the location in period-color space of known contact binaries suggests that this excess is largely due to these stars. To generate a list of potential contact binaries, cuts were made defining the region

$$0.26 < \Gamma < 0.6,$$

$$0.71 - 1.45 \Gamma < J - H < 0.96 - 1.45 \Gamma,$$

selecting a total of 5179 objects. Here, the period ($\Gamma$) is twice the value returned by the phasing procedure and so represents the true period for contact binaries.

Interspersed throughout the region of period-color dependence is a background of variables that are not contact binaries. On scanning the light curves, many of the 5179 candidates were found to be other types of variables. In addition, many of the candidates with lower $I_{\text{val}}$ parameters had small-amplitude light curves and large photometry errors, making classification difficult.

To ensure an essentially pure sample of contact binaries, further data quality cuts were made to select only the very well measured light curves. A cut at $I_{\text{val}} > 2$ eliminated 62% of the candidates, many of which had relatively indistinct light curves.

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5 See http://www.ipac.caltech.edu/2mass.
An additional cut was placed on the roughness of the light curve when phased at the true period, requiring this to fall in a range from 0.25 to 0.75. This removed an additional 14% of the candidates, mostly variables that were clearly not contact binaries and so had light curves characterized by a different phased roughness value. The remaining 1238 candidates were individually scanned, and 66 objects that did not appear to be contact binaries were removed. Nine of these appeared to be RR Lyrae stars, and three appeared to be ordinary eclipsing binaries. The other removed light curves were not sufficiently well measured to be easily identified, and many appeared to have asymmetric brightening and dimming phases. After these cuts, a sample of 1172 contact binaries remained.

Finally, due to the overlap in the fields, some of the objects appeared two or more times in the catalog. In these cases we kept in the catalog data from the field that provided the greatest number of good observations. After discarding the duplicate objects, we were left with a catalog of 1022 contact binaries. Based on visual inspection and comparison to existing catalogs we expect this sample to be rather pure, with perhaps 5% contamination of pulsating variables such as RRc stars. A sample of this catalog is given in Table 1. The full catalog is available in the online version of the journal as a FITS file.

2.5. Tests of Selection Efficiency

In this section we describe efforts to determine the selection efficiency for contact binaries. We test the catalog of Pribulla et al. (2003) for inclusion in our catalog. Due to the data quality cuts, it is expected that our catalog will be most complete for nearby objects, but it is not possible to use a volume-limited sample, as their catalog does not contain distance estimates. Instead, we use a magnitude-limited sample, restricting our analysis of completeness to objects brighter than 12.5 mag. This corresponds roughly to the objects whose distance estimates place them within...
In this section we describe the calibration of a near-infrared period-color-luminosity relation for contact binaries. We also discuss applying this relation to estimate distances to all of our contact binaries.

### 3.1. Determining $V_{\text{max}}$

For contact binaries, the maximum magnitude $V_{\text{max}}$ is independent of inclination and hence is an appropriate measure of apparent magnitude for distance estimation. The $V_{\text{max}}$ of each object was determined from its light curve. First the light curves were phased, then the observations dimmer than the mean magnitude were removed, and a parabola was fitted to the remaining points. The vertex of the parabola was taken to be the maximum magnitude. If the fit failed, $V_{\text{max}}$ was taken to be the average magnitude of the brightest observations. Figure 6 shows the parabola fit used in obtaining $V_{\text{max}}$ for eight random objects in the catalog.

To obtain the error on $V_{\text{max}}$, this fit was bootstrap resampled 10,000 times. Of the $N$ data points for each star, a random sample of size $N$ was selected, creating numerous slightly different fits from a single light curve. The resulting distribution of $V_{\text{max}}$ values was histogramed using the optimal bin size and then fitted to a Gaussian. The mean of the Gaussian was taken to be $V_{\text{max}}$, and its standard deviation was taken to be the error on $V_{\text{max}}$. Examples of the Gaussian fit to the histogram are given in Figure 7.

For most objects, the mean of the Gaussian differed by less than 0.1 mag from the median of the bootstrap distribution. However, in a few the difference was much larger. These objects also had an atypically large standard deviation for their Gaussian fits. In this case, $V_{\text{max}}$ values at 4 $\sigma$ of the bootstrap distribution and beyond were thrown out, and the recalculated median and standard deviation were used as $V_{\text{max}}$ and its uncertainty, respectively.

### 3.2. Calibrating the Period-Color-Luminosity Relation

To obtain distance estimates, a sample of 38 previously known contact binaries was used. Each of these objects has parallax data from the *Hipparcos* catalog, in addition to 2MASS color data and a period derived from its light curve. Reference distances were
TABLE 1—Continued

| ID          | $V_{\text{max}}$ | $V_{\text{max}}$ err | Max     | Min     | Amp     | $M$     | $M$ err | D     | $D$ err | Field | Obs    | GCVS Name | Ref. |
|-------------|-------------------|-----------------------|---------|---------|---------|---------|---------|-------|---------|-------|---------|-----------|------|
| 8711652     | 12.5618           | 0.0055                | 12.523  | 13.459  | 0.937   | 4.4844  | 0.025072| 412   | 5       | 066a  | 319     | CE Leo*   | GC, PR |
| 7604549     | 11.9309           | 0.00524               | 11.907  | 12.716  | 0.809   | 5.40103 | 0.026801| 202   | 3       | 057b  | 213     | AW Vir*   | GC, PR |
| 13267072    | 11.0426           | 0.004465              | 11.029  | 11.754  | 0.724   | 4.17416 | 0.029237| 236   | 3       | 105d  | 213     | TU Boo*   | GC, PR, RT|
| 7726255     | 11.5106           | 0.003869              | 11.498  | 12.224  | 0.726   | 4.19645 | 0.031747| 290   | 4       | 059b  | 212     | GL Com*   | GC, PR, RT|
| 14850169    | 11.6192           | 0.007031              | 11.631  | 12.26   | 0.629   | 4.44737 | 0.029001| 272   | 4       | 120b  | 214     | GL Com*   | GC, PR, RT|

Fig. 6.—Examples of the automatic calculation of $V_{\text{max}}$ for a random set of eight contact binaries.
calculated from parallax, then three objects were removed due to poorly determined distance estimates. Absolute magnitude values were then determined from parallax.

Rucinski & Duerbeck (1997) established a relation between the period, $B/V$ color, and absolute magnitude of a contact binary system. Contact binaries are close to the main sequence and so have a mass-radius dependence. Because the stars are in contact, the period of the system depends on the radii of the component stars, so the color of the system depends on its period.

We derived a similar relation using the $J - H$ color obtained by 2MASS. A plane was fitted to the period, color, and luminosity

![Figure 7](image1.png)

**Fig. 7.** Examples of the Gaussian fit to the distribution of bootstrap resampled $V_{\text{max}}$ values for a sample of eight contact binaries.

![Figure 8](image2.png)

**Fig. 8.** Distances (parsecs) from parallax for the reference set of 35 contact binaries plotted against the distances obtained from the period-color-luminosity relation. Also included is a reference line of slope 1.

![Figure 9](image3.png)

**Fig. 9.** Distances (parsecs) obtained from our period-color-luminosity relation for the reference set contact binaries plotted against the distances from the relation in Rucinski & Duerbeck (1997), in $B - V$. Also included is a reference line of slope 1.
Residuals in distance from our period-color-luminosity relation. The included linear fits do not seem indicative of any real trend.
Fig. 11.—Residuals in absolute magnitude from our period-color-luminosity relation. The included linear fits do not seem indicative of any real trend.
data of the 35 calibration stars, which were weighted by distance uncertainty. The coefficients of this initial fit were sampled until a minimum value of $\chi^2$ was found, and these new coefficients were selected to be the proper fit. The uncertainty for these coefficients was derived from their pattern of variation with increasing $\chi^2$. The observed relation can be written as

$$M_{\text{ROTSE}} = (2.20 \pm 0.66) + (0.88 \pm 1.01) \log \Gamma$$

$$+ (7.99 \pm 2.33)(J - H).$$

(6)

Used in combination with the standard magnitude-distance formulae, we obtain the relation

$$\log D = 0.2V_{\text{max}} - 0.18 \log \Gamma - 1.60(J - H) + 0.56.$$  

(7)

where $D$ is the distance in parsecs and $\Gamma$ is the true period in days. When used to calculate distances for our sample, all but about 23% had values within 80 pc of their distances from parallax. The median difference was 36 pc, and the maximum was 273 pc. The comparison between the calculated distance and the distance from parallax is shown in Figure 8. This relation was then used to obtain distance estimates for the full set of contact binaries.

3.3. Comparison to Other Calibrations

Rucinski & Duerbeck’s (1997) original period-color-luminosity relation was then applied to our calibration sample. Their absolute magnitude estimates tended to be lower and their distance estimates slightly higher than ours (see Fig. 9). All but about 22% of their distance estimates were within 80 pc of the reference distances. The median difference was 39 pc, and the maximum was 400 pc, results that are comparable to those obtained here. Rucinski & Duerbeck used a calibration sample of 40 systems, only slightly larger than ours. However, those systems have a larger range of period, 0.24 days $< \Gamma < 1.15$ days versus 0.24 days $< \Gamma < 1.06$ days, and color, 0.26 $< B - V < 1.14$ versus 0.28 $< B - V < 0.87$, than do the 31 systems in our calibration set for which $B - V$ values are known. Therefore, their calibration set may be more representative of the entire class of contact binaries.

3.4. Tests for Third Parameters

Earlier absolute magnitude calibrations have included additional dependences, such as the metallicity and the orbital inclination of the system. To test for sources of dispersion in the period-color-luminosity relation, the distance residuals were plotted against all available colors, $m_{\text{ROTSE}} - J, J - H, H - K,$ and $B - V$, as well as $\Gamma, V_{\text{max}}, I_{\text{mag}}$, and the amplitude of the light curve. Any dependence on these last two parameters may be representative of a dependence on orbital inclination. Any relationship between the distance residuals and period or $J - H$ would indicate that absolute magnitude depends more strongly on those parameters than the calculated period-color-luminosity relation suggests. However, no significant dependencies were found (see Figs. 10 and 11).

4. ESTIMATING THE SPACE DENSITY

OF CONTACT BINARIES

The cumulative number of detections should increase with the distance to the sources cubed if contact binaries are homogeneously distributed. To calculate the space density of contact binaries, we must first estimate the sky coverage of the contact binary catalog. We limit our analysis to the sky north of 0° declination, which was more thoroughly observed. This yields an area of 17,458 deg², or about 42% of the sky. Therefore, we take the total volume studied to be approximately $0.55 \pi d^3$.

Using the distance estimates derived above and the method of Stepien et al. (2001), a curve was fitted to the cumulative number of contact binaries detected as a function of distance, using only objects from 150 to 300 pc. This is a distance range in which we expect uniform completeness. As can be seen in Figure 12, the curve $N = (9.9 \pm 3.7) \times 10^{-6} d^3$ systems pc⁻³ gives a good fit over this distance range. This implies a measured space density of about $(5.7 \pm 2.1) \times 10^{-6}$ pc⁻³. However, the catalog is only about 34% complete for objects brighter than 12.5 mag, which corresponds approximately to those objects that are closer than 300 pc and are thus used to determine the space density. Adjusting for this incompleteness, we obtain a space density of $(1.7 \pm 0.6) \times 10^{-5}$ pc⁻³. This agrees well with the recent estimate by Rucinski (2002), which was $(1.02 \pm 0.24) \times 10^{-5}$ pc⁻³.

5. CONCLUSION

In this work we present a new catalog of 1022 bright contact binary stars. All objects are selected from the extensive light-curve database assembled in the Northern Sky Variability Survey from data taken from ROTSE-I sky patrol observations. Period, amplitude, light-curve shape, and infrared colors are all used to identify contact binary candidates. We also present a period-color relation using $J - H$ and an estimate of the space density of contact binaries. The detection efficiency for contact binaries given the stringent set of cuts applied here was rather low, 34%. This suggests that as many as a few thousand more
contact binaries remain to be extracted from the NSVS data set. In addition, tens of thousands of additional variable stars of all kinds remain to be extracted from this powerful resource.

This publication makes use of the data from the Northern Sky Variability Survey created jointly by the Los Alamos National Laboratory and University of Michigan. The NSVS was funded by the Department of Energy, the National Aeronautics and Space Administration, and the National Science Foundation.

This publication also makes use of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center, California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation.

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