How Likely are Wide Pairs to be Physically Connected?

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Abstract: There are numerous binary pairs that are not in the Washington Double Star Catalog (WDS)[1] that appear to be physical binaries. We show in this study that such pairs are often optical using Monte Carlo simulations of the sky.

A casual glance at the photos in the DSS[2] with Aladin[3] or WikiSky[4] will reveal pairs of stars that seem to be isolated from other stars in the field. These wide (> 4") pairs, whose components are within a visual magnitude of each other, are sometimes not in the WDS. If they also have similar blue magnitudes, this would imply that their spectral types are also similar, which further suggests they are at similar distances, and probably orbiting one another.

To test the idea that two stars within 60 arc seconds of one another are physically connected, all stars brighter than 15mv and within 20 degrees of the north galactic pole (NGP) were selected from the UCAC4[5] CCD astrograph catalog. The NGP was selected as the stellar density there is less than in other regions of the sky, thereby increasing the probability that pairs in that region are physically connected.

To be included in the study, the stars had to be:

- Within 20 degrees of the NGP.
- Brighter than 15.0mv.
- Each star's proper motion had to be greater than twice its proper motion error.

There were 129,762 stars found within 20 degrees of the NGP that met these criteria for the study.

A program was used to create an artificial sky, randomly assigning the stars to different positions within 20 degrees of the NGP. The magnitudes and proper motions of the stars themselves were unchanged.

A program to locate binaries was created to search the data, both real and simulated, for binary pairs using the following rules:

- Components of a pair of stars needed to be closer than 60" of one another.
- The magnitudes of the stars needed to be within 2mv of each other.
- Once a star was identified as a member of a pair, it was removed from the list, preventing it from being chosen as a member of another pair.
- The proper motions of the stars had to be greater than 2 milliarcseconds per year, and the directions of their motion needed to be within 2 radians (~115 degrees) of one another, and finally not differ in magnitude by more than +/- 50% of each other's proper motion.
- The proper motion of each star in the pair needed to exceed the error in it's proper motion by a factor of two or more.

The pairs that were found were divided into 5 zones, based on their separations (ρ).

The results from the stars of the UCAC4 yielded 1271 possible pairs, with the following distribution of separations:

- 32 pairs less than 4".
- 57 pairs between 4 and 8".
- 123 pairs between 8 and 15".
- 275 pairs between 15 and 30".
- 784 pairs between 30 and 60".

The artificial sky was simulated 100 times, and the results shown are the averages of these runs. There were 893 possible pairs found with the following distribution of separations:

- 2 pairs less than 4".
- 10 pairs between 4 and 8".

- 35 pairs between 8 and 15".
- 158 pairs between 15 and 30".
- 688 pairs between 30 and 60".

These results are graphed in Figure 1. The X axis value of each datum reflects the minimum value of a zone, e.g. 0 = zone 0" - 4". This can be shown more clearly if the number of simulated pairs for a given bin is shown as a percentage of UCAC4 for that bin, Figure 2. The UCAC4 data are set to 100, in a line across the top of Figure 2.

Note that for the simulated pairs, the wider the pair zone, the closer its numbers get to those found in the UCAC4 survey. This indicates that many wide pairs, which at first glance appear to be mutually orbiting one another, are actually optical pairs or that their orbit is so large as to be easily disrupted when the pair interacts with the other stars, clusters, and spiral arms of the rest of the galaxy.

For details on the computing required to conduct this study, please see the appendix below.

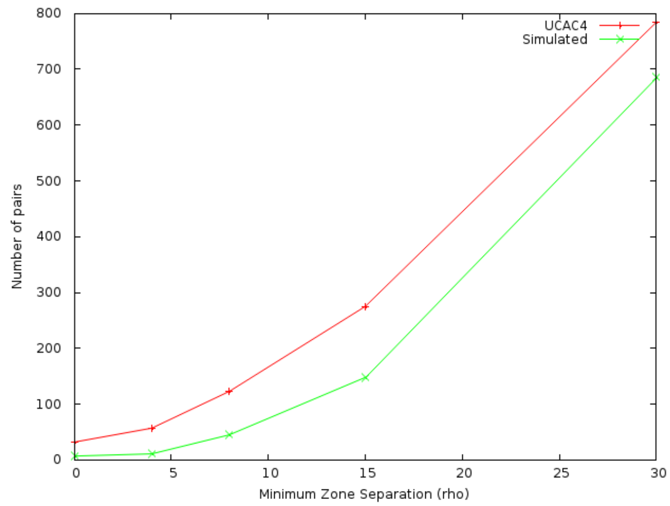

Figure 1. Distribution of separation of double stars for the artificial sky (green line) and from UCAC4 (red line).

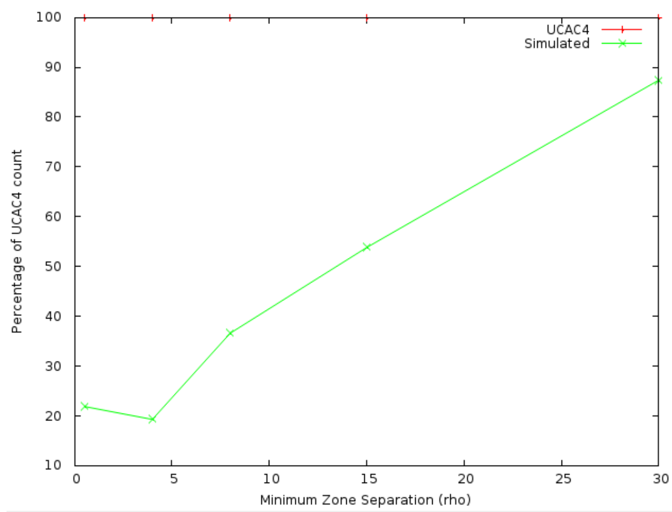

Figure 2. Number of simulated pairs as a percentage of UCAC4 pairs.

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References

1) The Washington Double Star Catalog. Brian D. Mason, Gary L. Wycoff, William I. Hartkopf, Geoffrey G. Douglass, and Charles E. Worley, 2001, http://ad.usno.navy.mil.wds.

2) The Sloan Digital Sky Survey web site, http://www.sdss.org.

3) Aladin web site, http://aladin.u-strasbg.fr.

4) The WikiSky web site, http://www.wikisky.org.

5) The Fourth US Naval Observatory CCD Astrographic Catalog (UCAC4). Zacharias, et al, 2012, http://www.usno.navy.mil/USNO/astrometry/optical-IR-prod/ucac.

Appendix

The programs used to generate this study are available on SourceForge: https://sourceforge.net/projects/are-wide-binaries-optical/files/AreWideBinaries/OpticalSource.

You'll also need the gcc compiler and perl on your machine, as well as about 100GB of disk space for the data to reproduce this study. Windows users can run them under cygwin.

The UCAC4 catalog is available on line (see its on line site in the above references) in binary format.

The catalog data are placed in a data directory. On the author's system, for example, it is /work/astro/data/.

The UCAC4 data are first parsed with readUcac4.c, and then ucac4TextToNA_Format.pl and splitUCAC4intoDecZoneFiles.pl create the data read by getDataFromCatalogs.c.

The format of the transformed UCAC4 data are then rendered into a "standard" format:

```
ra|dec|R|G|B|Visual Magnitude|Catalog|Name|pmRa|pmDec|ePmRa|ePmDec
1   2  3 4 5        6             7     8     9   10     11    12
```

Definition of each field is as follows:

1. ra: Right ascension in radians.
2. dec: Declination in radians.
3. Red color estimate for the star. Not used in this study.
4. Green color estimate for the star. Not used in this study.
5. Blue color estimate for the star. Not used in this study.
6. Visual magnitude. Usually the Johnson V band magnitude.
7. Catalog: A single character identifier for the catalog the data was from.
8. Name: The star's identifier in the catalog.
9. pmRa: Proper motion in right ascension. In milliarcseconds / year.
10. pmDec: Proper motion in declination. In milliarcseconds / year.
11. ePmRa: Error in proper motion in right ascension. In milliarcseconds / year.
12. ePmDec: Error in proper motion in declination. In milliarcseconds / year.

The data itself is split into 180 different files, one for each degree of declination, and placed in directories named naFormatData which are placed in a sub directory, e.g. /work/astro/data/UCAC4/naFormatData.

From these files, the stars within 20° of the NGP are found and placed in their own file.

We are now ready to create a simulation of the NGP stars. SimulateNGP.c does this by assigning a randomly chosen position for each of the stars in NGPstars. The magnitude and proper motion data for the stars are left intact.

Binaries are then found by findBinaries.c

Note that the following command will compile the C programs, where programName.c is the C source code and executableName is the executable the compiler creates:

gcc -std=gnu99 -O2 -o executableName -Wunused programName.c -lm

The graphs were made using gnuplot.