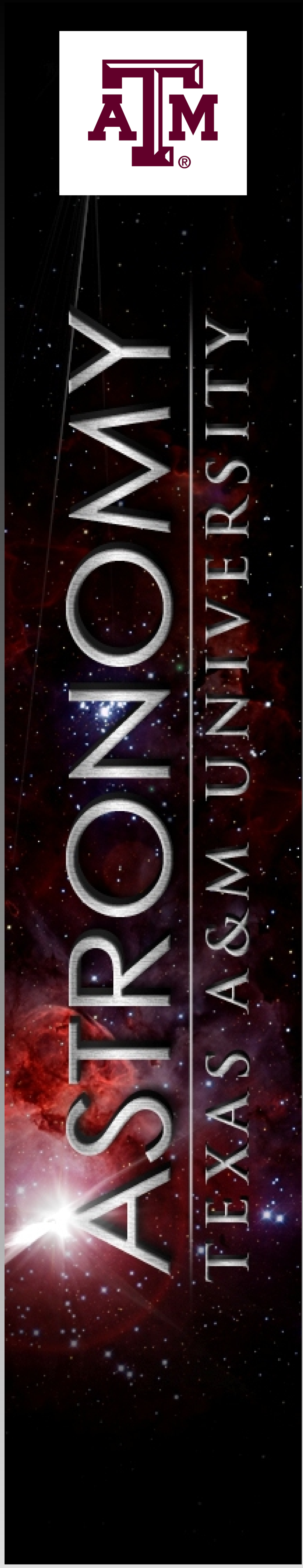

Contamination Rate of Red Giant Stars From 2MASS Photometric Error

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I. Introduction

Red dwarf stars can be mistaken for red giant stars because of errors in photometry. A color cut is often the most useful tool to distinguish between the two. Three filters are chosen (here, it is the J, H, and Ks filters, all in the near-infrared region) and the difference between magnitudes of all observed stars are plotted with the J - H magnitude on one axis and the J - Ks magnitude on the other. As J - Ks gets larger, there are less dwarfs, allowing one to select giants easily out of the various stars observed.

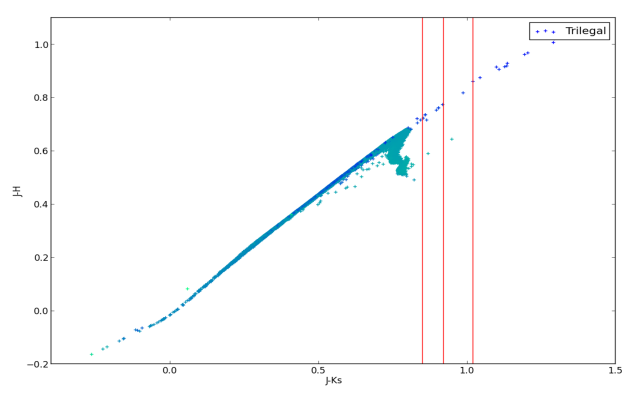


Figure 1: Color-color diagram (J-Ks filter on the x-axis, J-H filter on the y-axis) using data collected from Trilegal (results from Galaxia are nearly identical). Measured at b = 30, l = 164. Red vertical lines show possible cutoff points for identifying red giant candidates.

The red lines in Figure 1 are different suggested cutoff values for J - Ks. Three proposed values for this cutoff point are 0.85 (Majewski et al. 2003), 0.97 (Sharma et al. 2010), and 1.02 (Bochaski et al. 2014). The higher the cutoff value, the fewer dwarfs are included in the selection. The following results are a study of what the effects are of varying the cutoff value, the magnitude of the stars studied, and the latitude at which the data are collected.

II. Simulation Programs

The simulations used to generate mock catalogues of stars are Trilegal and Galaxia. Each takes different input parameters such as magnitude range, filter system used to observe the stars, and latitude and longitude for the sample. Each outputs a catalogue of stars and their properties, such as metallicity, age, magnitude, etc.

Trilegal and Galaxia show several key differences. One discrepancy is the star count produced by each program. For low latitudes (ie, b <= 10), Trilegal returns fewer stars than Galaxia does, a problem acknowledged by the Trilegal program. Unexplained, however, is the difference between thick disk populations that spans all latitudes (see Figure 2).

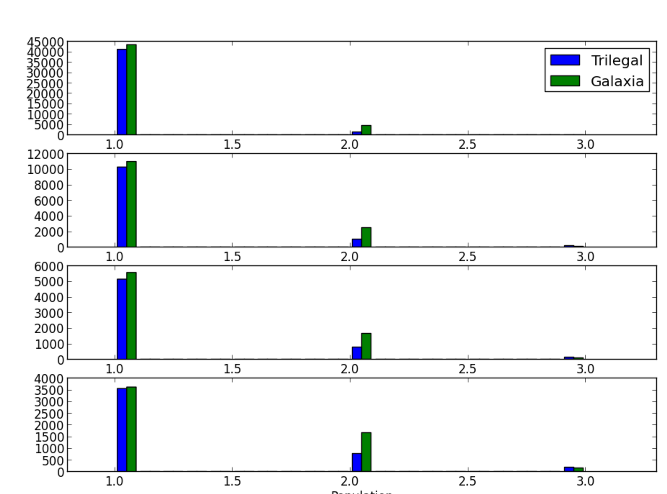


Figure 2: Population for Trilegal and Galaxia generated star populations [Trilegal in blue on the left of each bin, Galaxia on the right in green]. Top row has latitude of b = 10; second from the top has a latitude of b = 30; third from the top has a latitude of b = 50; bottom row has latitude of b = 90. A value of 1.0 for the population measurement means the star is labeled as a thin disk star. A value of 2.0 is a thick disk star. A value of 3.0 is a star in the bulge. A value of 4.0 is a star in the halo (no halo stars were identified in this model).

III. Photometric Error

The output of both Trilegal and Galaxia does not take into account the photometric error that is involved in taking real data from a telescope - therefore, to simulate real data collected from a telescope, a magnitude error was added from information about the 2MASS survey (the source of the catalogues of stars that both Trilegal and Galaxia drew from).

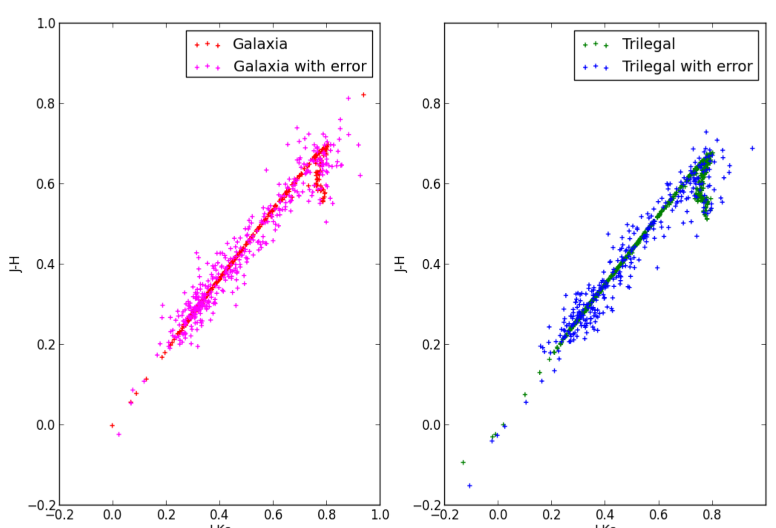


Figure 3: Illustration of the error in photometry added. *Left*: Galaxia original data (in red) and the data after error was added (pink). *Right:* Trilegal original data (in green) and the data after error was added (blue).

The 2MASS survey released their error estimates based on band and magnitude; in Figure 4, error magnitude is plotted vs. a parameter that defines the sigma of a Gaussian that describes the error probability curve for that particular magnitude. For example, if a measurement of 13.5 was taken in the H-band, then this sigma value would be approximately 0.035, and the error value would be chosen randomly from a Gaussian centered on zero, with a standard deviation of 0.035 magnitudes. These Gaussians are generated in Python; examples can be found in Figure 5.

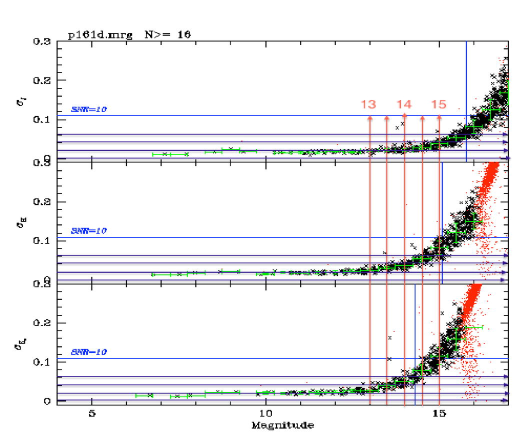


Figure 4: Sigma of error probability distribution vs. magnitude for J-band (top), H-band (middle), and Ks-band (bottom).

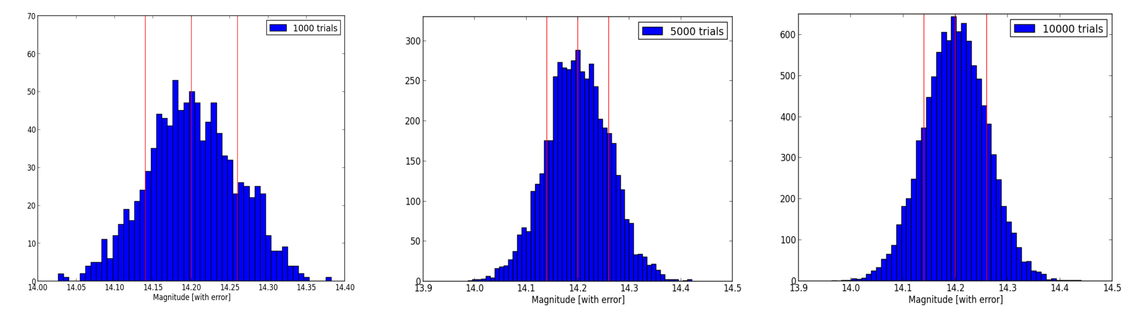
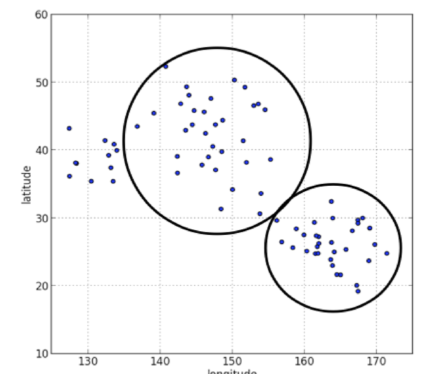


Figure 5: Histogram of magnitudes generated with error added. Errors were calculated for a measured magnitude of 14.2 in the Ks-band. The distribution of 1,000 (*left*), 5,000 (*center*), or 10,000 (*right*) trials is roughly Gaussian, indicating that the probability distribution for the error chosen is Gaussian as well.

IV. Comparison Regions

The rate of false positives among red giant stars is important because observational followup to a predicted cluster of red giants found that over 90% of these predicted giants were, in fact, red dwarf stars. This discrepancy could be explained by the photometric errors of the 2MASS survey. Figures 6 and 7 are longitude/latitude plots of the two pertinent areas, called A11 and A13.



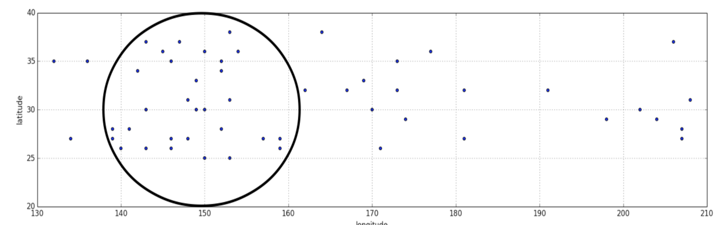


Figure 6: A13 region [clipped slightly for this figure]. Red giant candidates, with magnitude predominantly between 10 and 11. The encircled region was reproduced partially with Galaxia and Trilegal to compare false giant rates. The region had an area of 452 square degrees, with 30 giant candidates in the circle.

Figure 7: A11 region [clipped slightly for this figure]. Red giant candidates, with magnitude predominantly between 13.5 and 14. Each encircled region was reproduced partially with Galaxia and Trilegal to compare false giant rates. The upper region had an area of 593 square degrees, with 33 giant candidates inside the circle. The lower region had an area of 314 square degrees, with 32 giant candidates inside the circle.

Region	Magnitude Range	Giant Candidates	False Positives	False Positive Rate
A11, upper [Trilegal]	13.5-14	7	7	100%
A11, upper [Galaxia]	13.5-14	24	10	41.67%
A11, lower [Trilegal]	13.5-14	2	2	100%
A11, lower [Galaxia]	13.5-14	19	15	78.95%
A13 [Trilegal]	10-11	1	0	0%
A13 [Galaxia]	10-11	7	0	0%

Table 1: False positive rates for the A11 and A13 regions, with a magnitude limit of 13.5-14 and 10-11, respectively. The upper A11 region was centered on l = 147.5 and b = 41.25, with an area of 250 square degrees. The lower A11 region was centered on l = 163.75 and b = 26.25, with an area of 250 square degrees. The A13 region was centered on l = 150 and b = 32, with an area of 250 square degrees.

Region	Magnitude Range	Giant Candidates	False Positives	False Positive Rate
A11, upper [Trilegal]	10-11	2	0	0%
A11, upper [Galaxia]	10-11	7	0	0%
A11, lower [Trilegal]	10-11	0	0	0%
A11, lower [Galaxia]	10-11	3	0	0%

Table 2: False positive rates for the A11 region, with a magnitude limit of 10-11. The area considered for the Trilegal trials did not encompass the entire encircled areas from Figures 6 and 7, but was at least half in each case. False positives were more likely at higher magnitude ranges, corresponding to fainter stars and higher photometric error.

V. Results

The product of Galaxia's simulations better match the results of the survey on the A11 field, though neither Galaxia nor Trilegal perfectly reproduce the false positive rate. Galaxia's number of false positives is consistently close to the number of red dwarf stars found among the predicted red giant groups. However, the false positive rate is near 50% for the A11 region, which had true false positive rate of around 90%.

Five test areas were generated from both Trilegal and Galaxia, at four different latitudes (b = 10°, 30°, 50°, and 90°) at a longitude of 164° (to correspond roughly with the A11 region). Each test area had an area of 10° squared. Each data point plotted below in Figures 8, 9, &10 is the result of an average over the five test areas.

Figure 10 shows the rate of false positives for Galaxia (left) and Trilegal (right) for three cutoff values. The A11 giant candidates were identified with a 0.97 cutoff value, supported by the lower false positive rate for this cutoff value for both simulation programs. The high false positive rates for both Galaxia and Trilegal, over all cutoff values, supports the idea that photometric error was responsible for the high contamination rates in the A11 red giant search. The number of false positives drops dramatically once the cutoff rate is raised to over 0.91 for both Trilegal and Galaxia, as does the number of giant candidates.

The conclusion drawn from these simulations is that the cutoff value is rightly held to be 0.97, as it lowers the percent of false positives significantly. The simulations also illustrate the role that latitude plays in studying contamination; more giant candidates are found at low latitudes, which have higher star densities, although both have high contamination rates, according to Galaxia. The rate of false positives is also higher at low latitudes than at high latitudes, peaking at a latitude of 30 degrees. The A11 region is located between latitudes of 20° and 50°, which would explain the high contamination rate for the stars in that region.

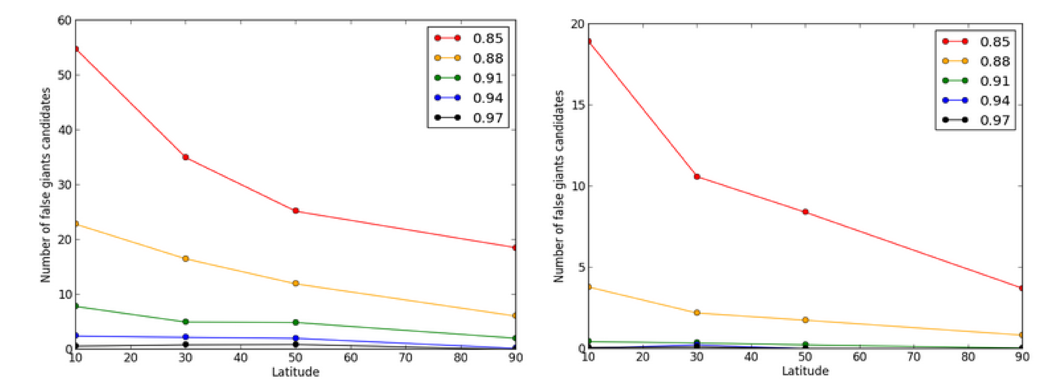


Figure 8: Number of giant candidates for Galaxia [left] and Trilegal [right] simulations. The number of giant candidates drops with latitude.

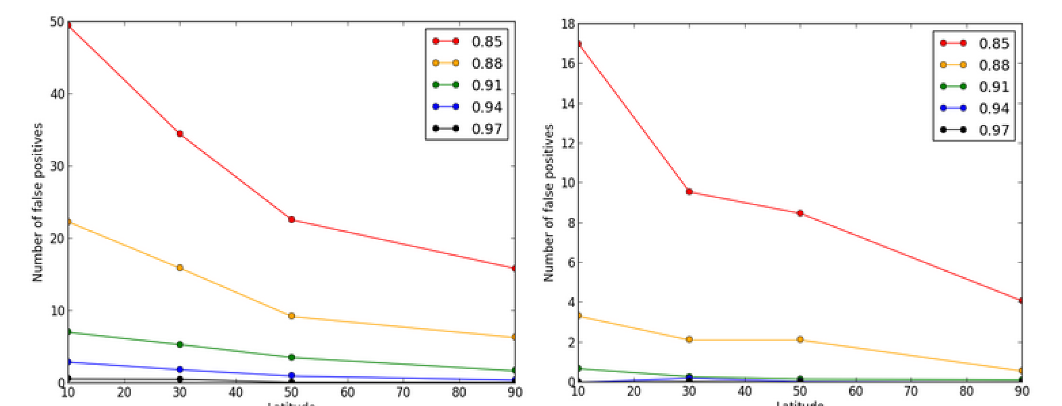


Figure 9: Number of false positives for Galaxia [left] and Trilegal [right] simulations. The number of false positives decreases with latitude.

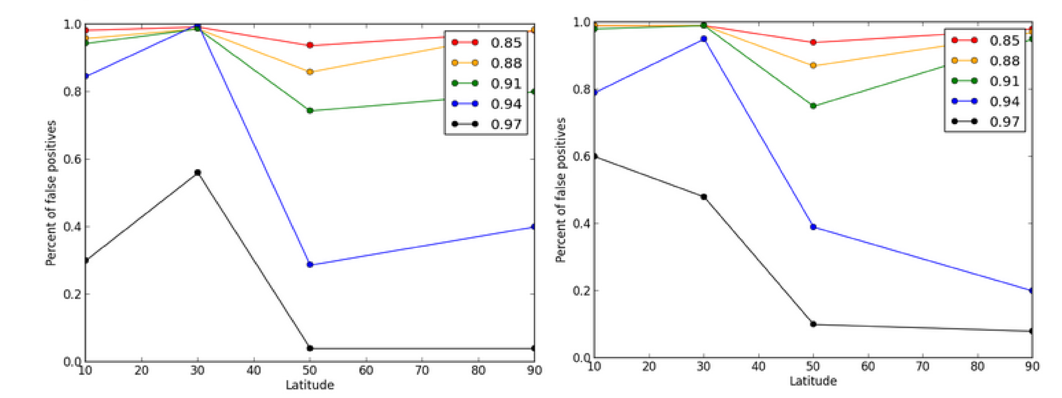


Figure 10: Percent of false positives for Galaxia [left] and Trilegal [right] simulations. The cutoff value of 0.97 delivers significant improvements in the contamination rate.

VI. References

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Skrutskie, M. F. et al. 2006, ApJ, 1163 - 1183

Texas A&M University Department of Physics and Astronomy is an institutional member of:

Munnerlyn Astronomical Instrumentation Lab, Texas A&M University — GMT — HETDEX: Illuminating the Darkness, Hobby-Eberly Telescope Dark Energy Experiment — LSST: Large Synoptic Survey Telescope — Dark Energy Survey

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