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Predicting Field Microlensing Rates in Wide-Field Surveys

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Poster ID
Missions 11

Motivation

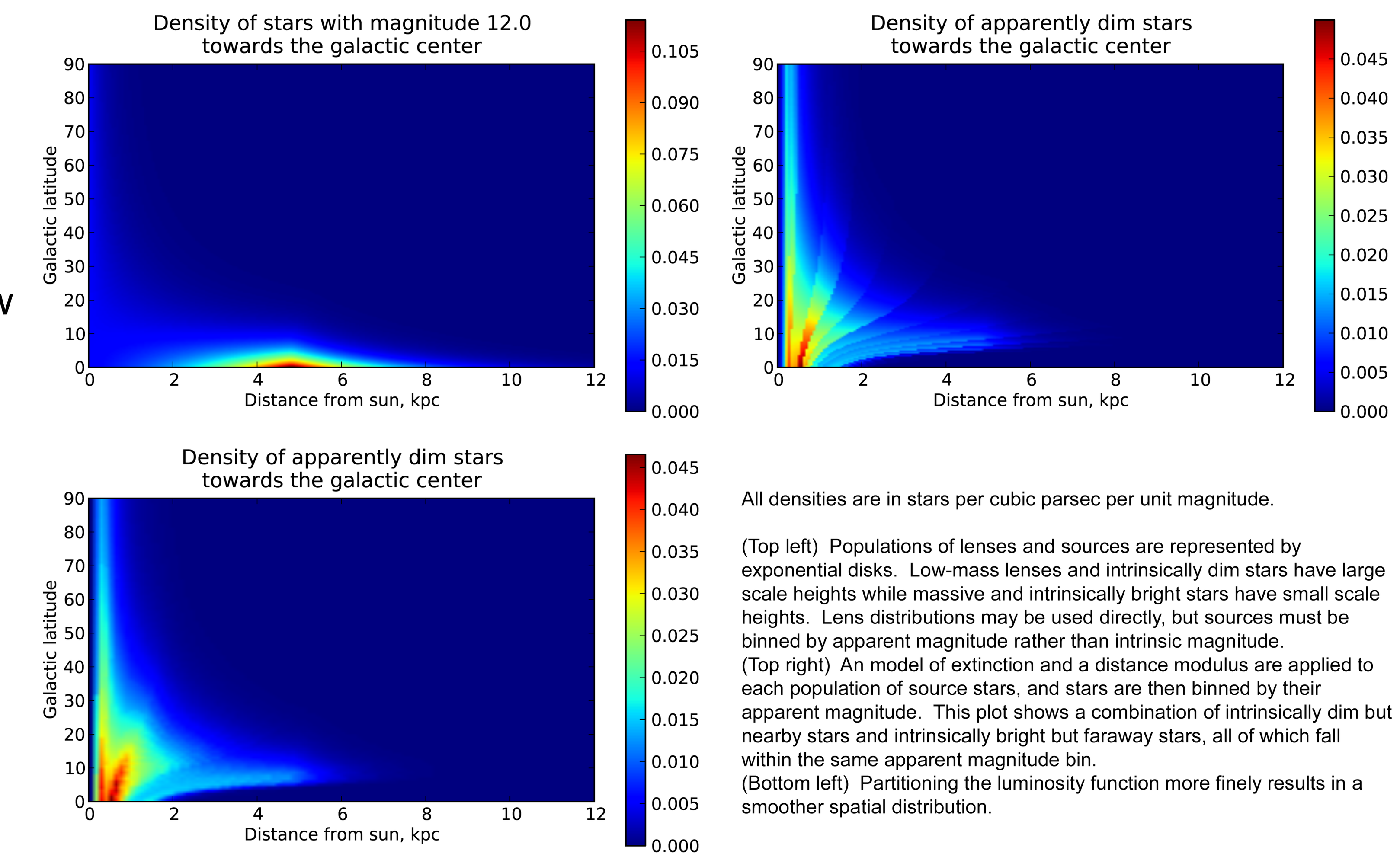
The advent of wide-angle, high-cadence surveys has created a wealth of data that can be used to find rare variable objects and transient events. Field microlensing events, in which a galactic disk star is gravitationally lensed by a massive object, are one such type of event. Because microlensing rates are highest towards the galactic center, past microlensing searches have focused almost exclusively on the bulge, but the rarer field microlensing events have additional scientific potential. Like all microlensing events, they are sensitive to dark objects, including planets. The average field microlensing event occurs much closer to the sun than a typical bulge microlensing event, and provides information about the distribution of compact masses in the solar neighborhood. The source and lens stars in nearby events separate more quickly, and the lower angular density of stars at high latitudes increases the likelihood that they can be resolved soon after the lensing event. Resolving the source and lens allows for more complete characterization of the event and of any planets detected.

Goals

In this project, we aim to estimate the rates of detectable microlensing events in existing wide-angle surveys. Previous works (notably Han 2008) have estimated the all-sky lensing rate with a constant source apparent magnitude and magnification cutoff. To estimate the full detection rate for a particular observational setup, we intend to account for numerous other effects, such as photometric precision, cadence, sky coverage, and angular resolution. Additional adjustments may apply where supporting target-of-opportunity or followup observations are available. In particular, we hope to apply our simulation to estimate the rates of detectable and fully characterizable events in the SuperWASP (Wide-Angle Search for Planets) and PTF (Palomar Transient Factory) surveys, with supporting observations from the LCOGT telescope network.

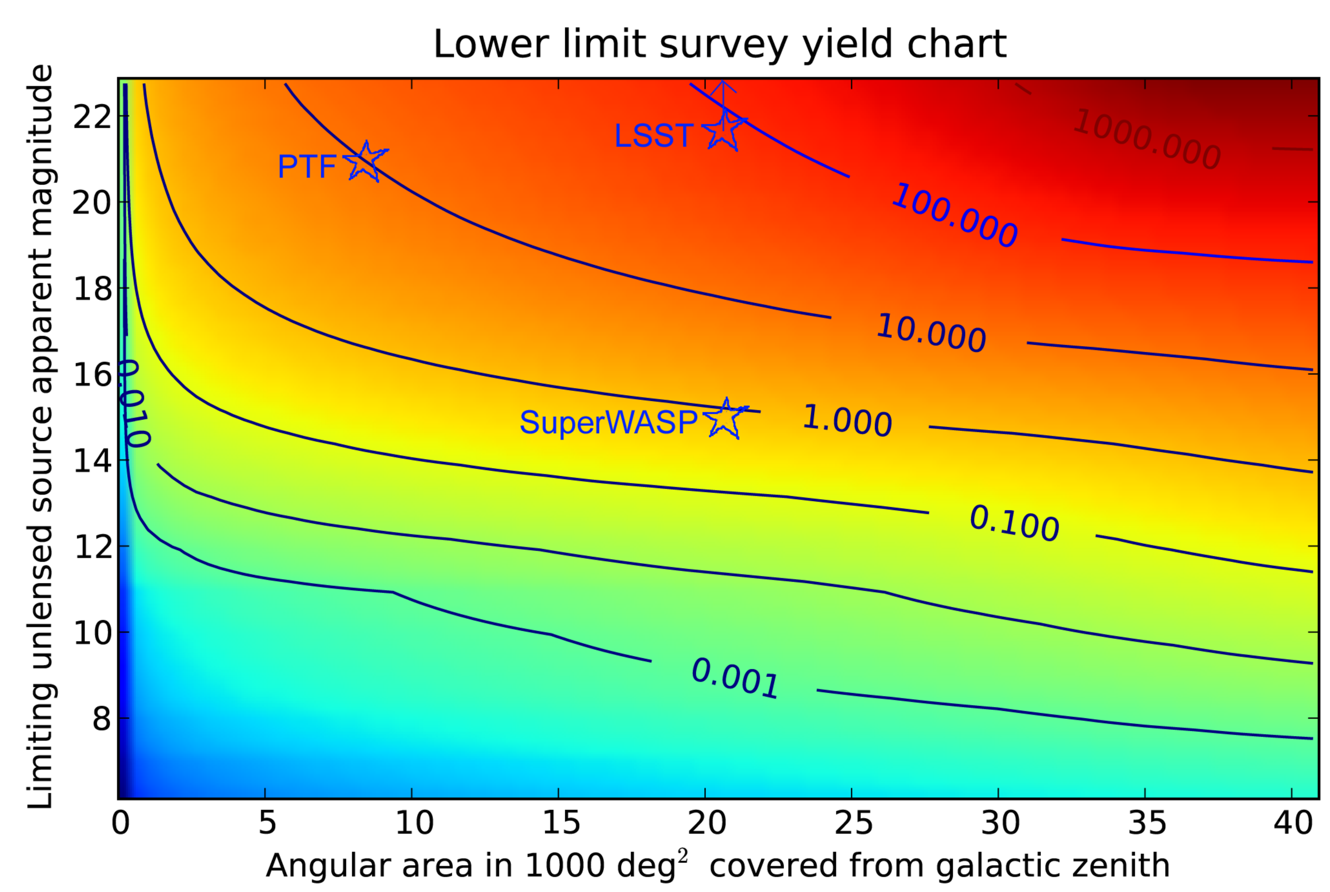
Method

We follow the method of Han 2008 in estimating microlensing rates for wide-field surveys. This method accounts only for stars located in the disk, not the bulge; this is appropriate as wide-field surveys typically have low angular resolution and cannot resolve stars at low galactic latitudes, especially those in the bulge. Populations of lenses and sources are assembled as described in the figure to the right. A velocity distribution consisting of a three-dimensional dispersion plus a uniform rotation is used. The Einstein radius is used as a representative cross section, and the lensing rate is calculated by analogy to a two-dimensional collision rate.



All densities are in stars per cubic parsec per unit magnitude.

(Top left) Populations of lenses and sources are represented by exponential disks. Low-mass lenses and intrinsically dim stars have large scale heights while massive and intrinsically bright stars have small scale heights. Lens distributions may be used directly, but sources must be binned by apparent magnitude rather than intrinsic magnitude.
(Top right) An model of extinction and a distance modulus are applied to each population of source stars, and stars are then binned by their apparent magnitude. This plot shows a combination of intrinsically dim but nearby stars and intrinsically bright but faraway stars, all of which fall within the same apparent magnitude bin.
(Bottom left) Partitioning the luminosity function more finely results in a smoother spatial distribution.



Labelled contours represent lines of constant event rate in events per year.

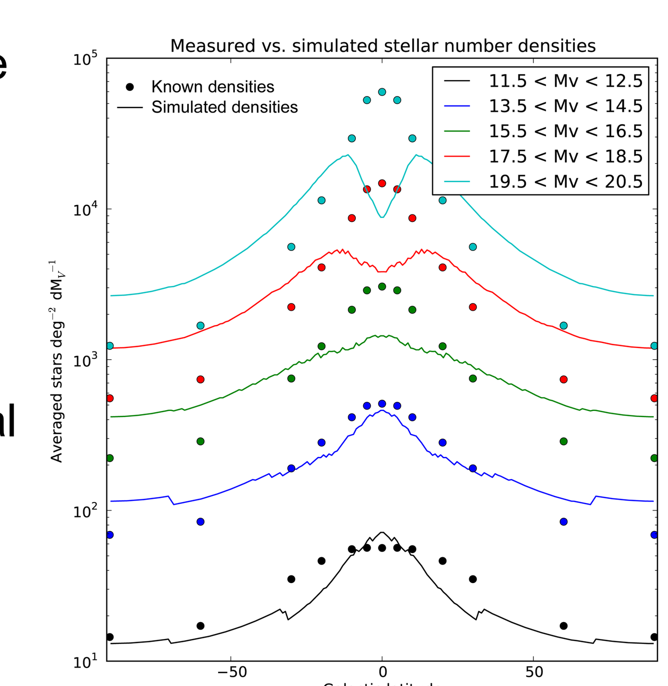
Preliminary Results

This graph, left, provides a lower-limit estimate of the field microlensing event rates detectable in a given survey. They show rates assuming (1) a flat event apparent magnitude cutoff, represented by the y axis; (2) an angular area of the sky covered at a sufficient cadence for detection, where it is assumed that this angular area is located as near to galactic zenith as possible, represented by the x axis; and (3) a flat magnification cutoff of 1.34, equivalent to an approach within the projected Einstein radius. If the survey covers regions near to the galactic plane rather than zenith, lensing rates will increase due to the higher angular density of both sources and lenses. Likewise, most survey telescopes can detect magnifications much more subtle than the cutoff shown here within most or all of their nominal operating range. Note that it is assumed that surveys have a dim cutoff but not a bright cutoff; the rate shown at a particular magnitude includes all contributions to the lensing rate from sources that bright or brighter. Should a survey have a bright magnitude limit, this will have a minimal effect on the lensing rate, as the lensing rate rises swiftly with the dim limiting magnitude.

Continuing work

Our calculated event rates are significantly higher than those in the literature and rise more swiftly with magnitude cutoff; see Han (2008). We believe that this stems from the stage in which density normalization and extinction are applied before stars are binned by apparent magnitude. We attempted to reproduce the known star counts in Allen's Astrophysical Quantities by simultaneously fitting the density normalization and extinction, giving greatest weight to high galactic latitudes. See the figure to the right, showing the angular density of stars as a function of galactic latitude.

We will continue to refine our code and will account for magnitude-dependent sensitivity as well as detailed spatial coverage and cadence for individual surveys. If the estimated yield justifies the effort, we will begin a search of the data. Archives of SuperWASP and PTF for serendipitously recorded lensing events. We will also build and put in place systems to detect microlensing events in these surveys as they occur, and to trigger supporting observations.



Compares directly to Han 2008 figure 1. Low galactic latitudes show underdensities because the galactic bulge was not modelled.

References

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