DRM1 & Exoplanet Microlensing

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IDRM -> DRM1 changes

- Details from most recent SDT meeting
- Telescope aperture: 1.275m -> 1.2m
  - Changes image FWHM from 0.265” to 0.280” for a typical exoplanet microlensing survey star
- Telescope throughput increased by 14% (cancels with aperture reduction
- Imager goes from 4×7 to 4×9 => 29% increase in detector area
- Detectors have 2.5μm long wave cutoff instead of 2.1μm

New Detection Rate Calculations

- Assumes the same passbands as before
- $N_{\oplus}$: 127.3 -> 143.8
  - # of Earth-mass planets in 2 year orbits found if every star has one
  - 12.9% increase
- Predictions based on an input exoplanet mass function:
  - Total number of planets: 3850 -> 4342 - 12.8% increase
  - sub-Earth planets: 317 -> 358 – 12.8% increase
  - sub-10-Earth planets: 1483 -> 1674 – 12.9% increase
- Solar system analogs:
  - terrestrial: 277 -> 313 – 13.0% increase
  - gas giants: 3200 -> 3599 – 12.5% increase
  - ice giants: 84.4 -> 95.4 – 13.0% increase
- Habitable planets: N_{HZ} : 27.2 -> 30.7 – 12.7% increase

WFIRST Microlensing Figure of Merit

- FOM1 - # of planets detected for a particular mass and separation range
  - Cannot be calculated analytically – must be simulated
    - Analytic models of the galaxy (particularly the dust distribution) are insufficient
  - Should not encompass a large range of detection sensitivities.
  - Should be focused on the region of interest and novel capabilities.
  - Should be easily understood and interpreted by non-microlensing experts
    - (an obscure FOM understood only be experts may be ok for the DE programs, but there are too few microlensing experts)
- FOM2 – habitable planets - sensitive to Galactic model parameters
- FOM3 – free-floating planets – probably guaranteed by FOM1
- FOM4 – number of planets with measured masses
    - Current calculations are too crude

Figure of Merit

$$FOM \equiv (N_{\oplus} N_{HZ} N_{ff} N_{20\%})^{3/8} \propto T^{3/2}$$

1. $N_{\oplus}$: Number of planets detected (at $\Delta\chi^2$=160) with a M=$M_{\oplus}$ and P = 2 yr, assuming every MS star has one such planet.
   - Region of parameter space difficult to access from the ground.
   - Uses period rather than semimajor axis as P/R_E is a weaker function of primary mass than a/R_E.
   - Designed to be diagnostic of the science yield for the experiment. If mission can detect these planets, guaranteed to detect more distant planets
2. N_{HZ}: Number of habitable planets detected assuming every MS star has one, where habitable means 0.5-10M_{Earth}, and [0.72-2.0 AU]$(L/L_{sun})^{1/2}$
3. N_{ff}: The number of free-floating 1M_{Earth} planets detected, assuming one free floating planet per star.
4. $N_{20\%}$: The number of planets detected with a $M=M_{Earth}$ and P=2 yr for which the primary mass can be determined to 20%.

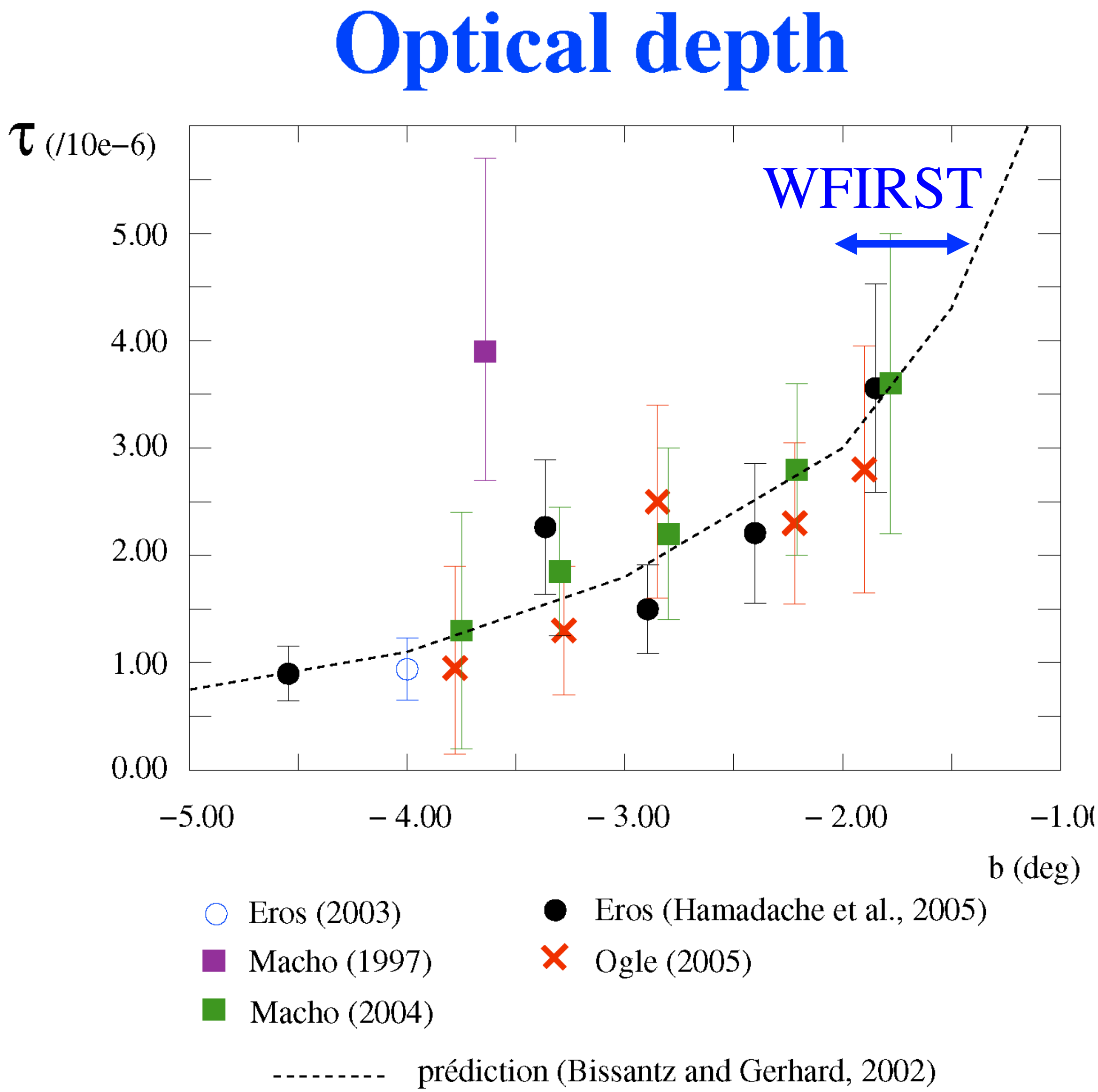
Why Doesn't Rate Scale with $(FOV)^1$?

- Microlensing rate ~ $(FOV)^{0.48}$
- Rate ~ $(\text{star density})^2$
- according to our model, only lower rate fields are available after the 1st 2 deg^2
- It is unclear to what extent this is an artifact of my assumptions
  - M. Penny has a different
  - perhaps rate ~ $(FOV)^{0.75}$

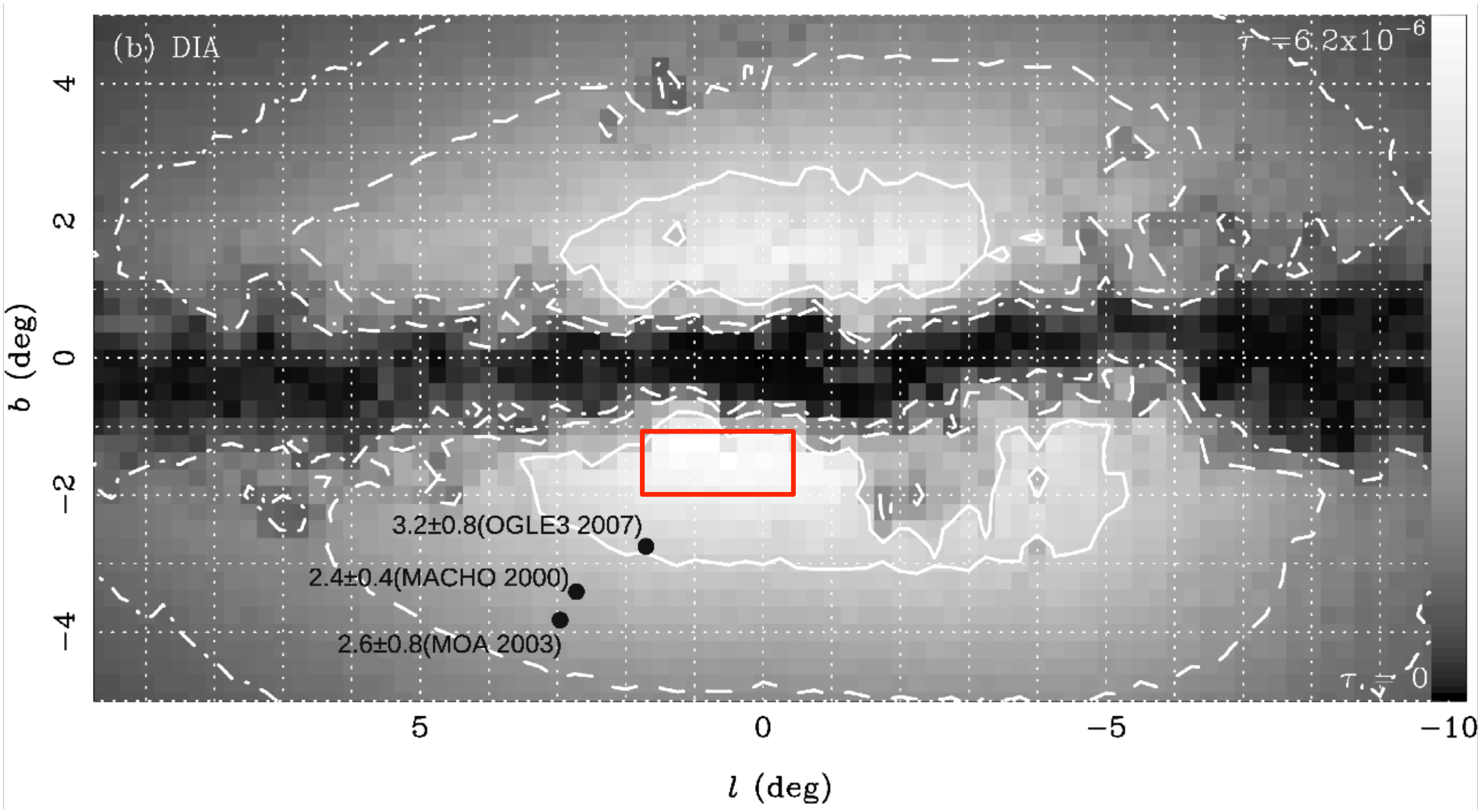
Microlensing Optical Depth & Rate

- Bissantz & Gerhard (2002) τ value that fits the EROS, MACHO & OGLE clump giant measurements
- Revised OGLE value is ~20% larger than shown in the plot.

- Star density scales with optical depth!



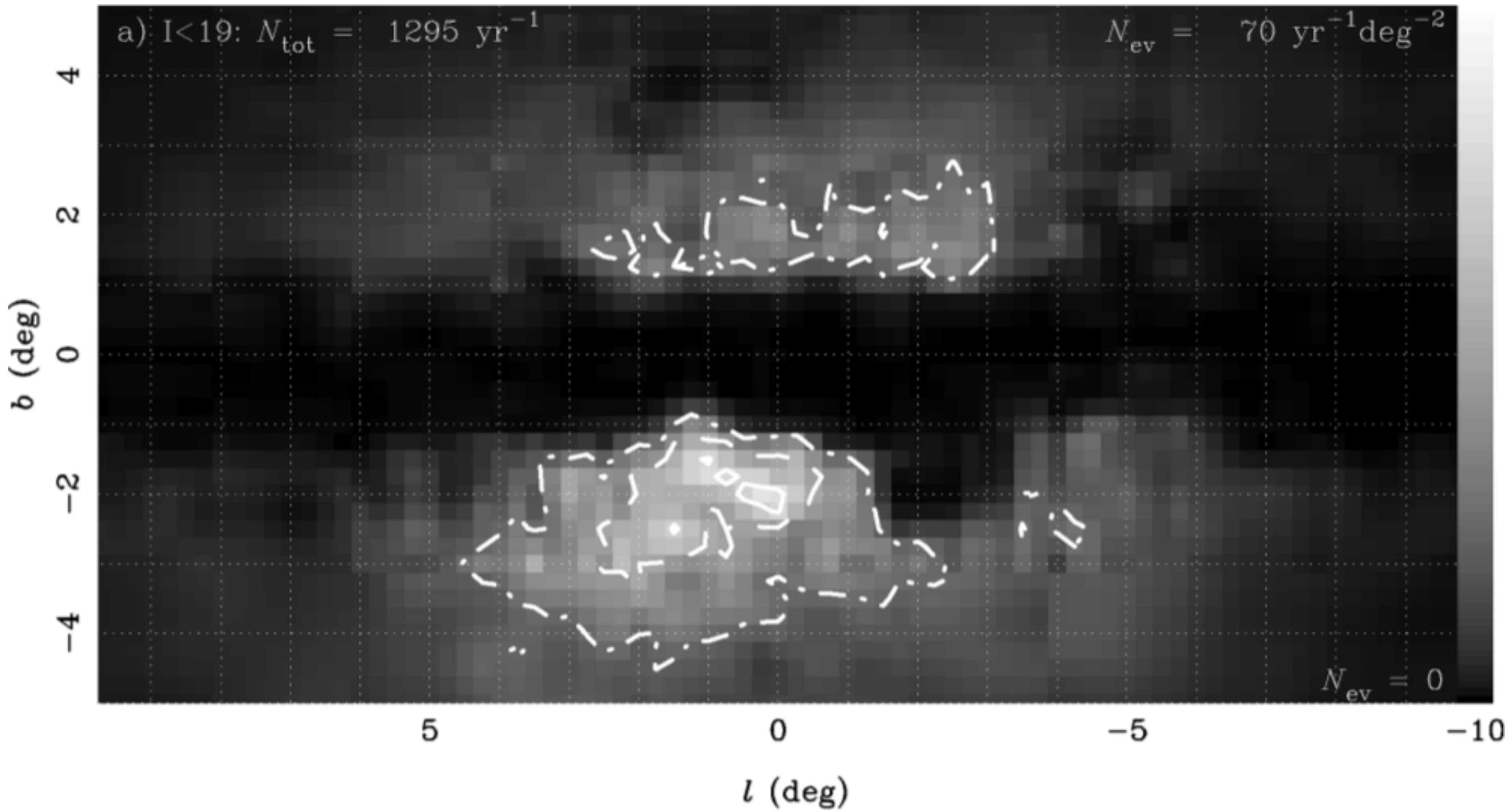
Select Fields from Microlensing Optical Depth Map (including extinction)



Optical Depth map from Kerins et al. (2009) in *I*-band with peak *I* < 19

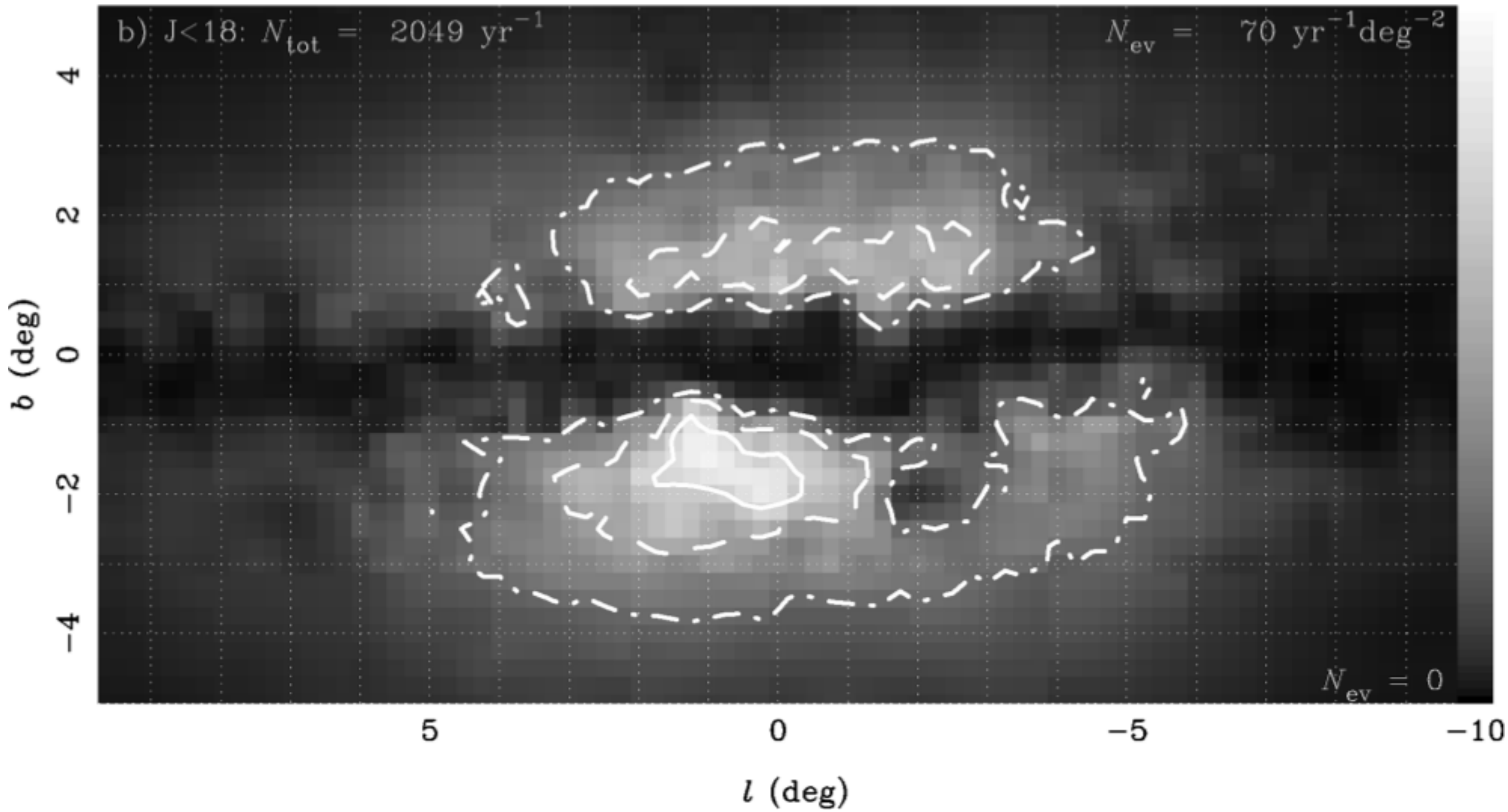
contours are 1, 2, & 4×10^{-6} (fraction of sky covered by Einstein rings)

Microlensing Rate vs. Passband: *I*



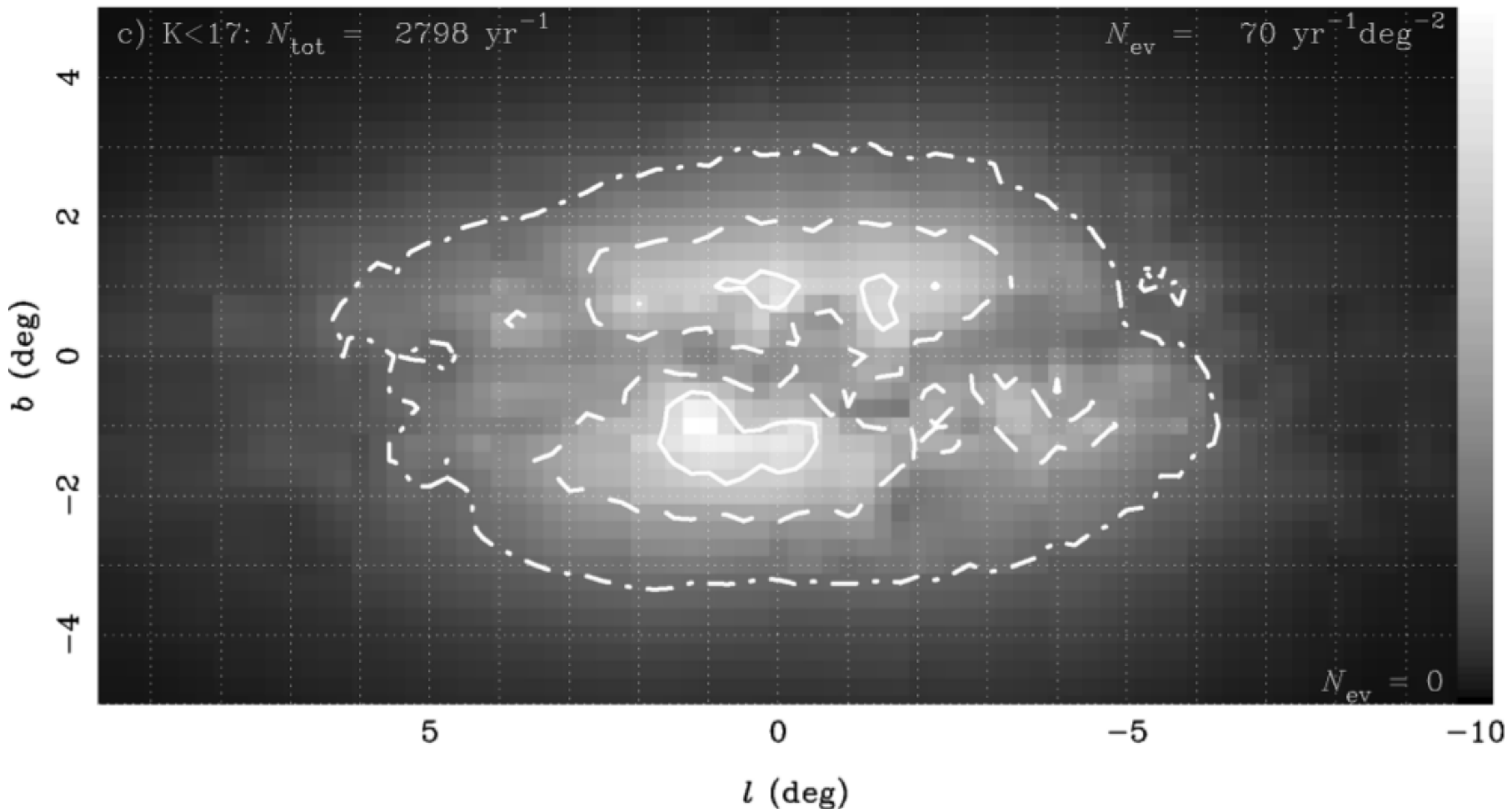
Microlensing simulations using the Besancon population synthesis Galactic model (Kerins, Robin & Marshall 2009) $I_s < 19$

Microlensing Rate vs. Passband: *J*



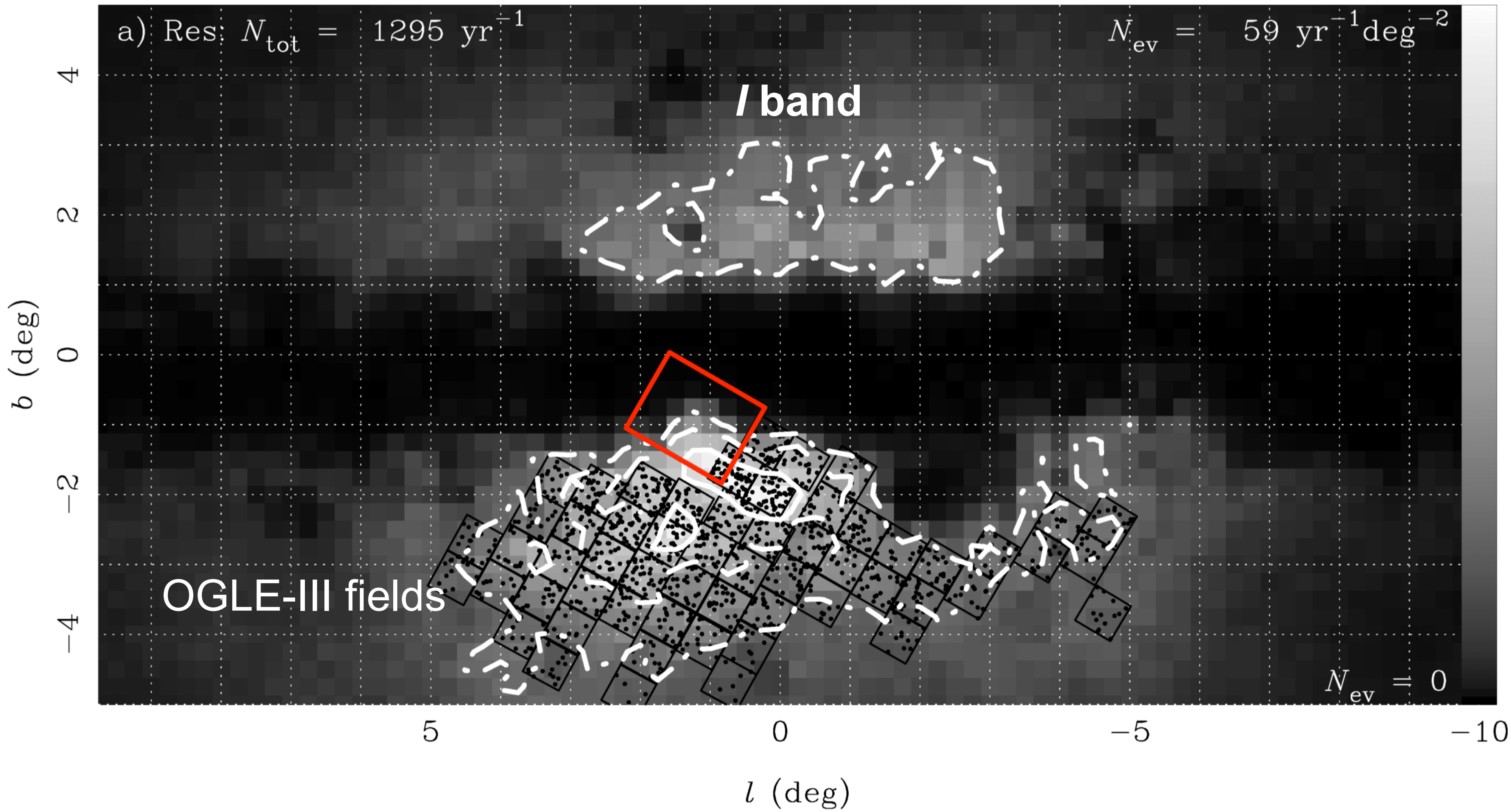
Microlensing simulations using the Besancon population synthesis Galactic model (Kerins, Robin & Marshall 2009) $J_s < 18$

Microlensing Rate vs. Passband: *K*



Microlensing simulations using the Besancon population synthesis Galactic model (Kerins, Robin & Marshall 2009) $K_s < 17$

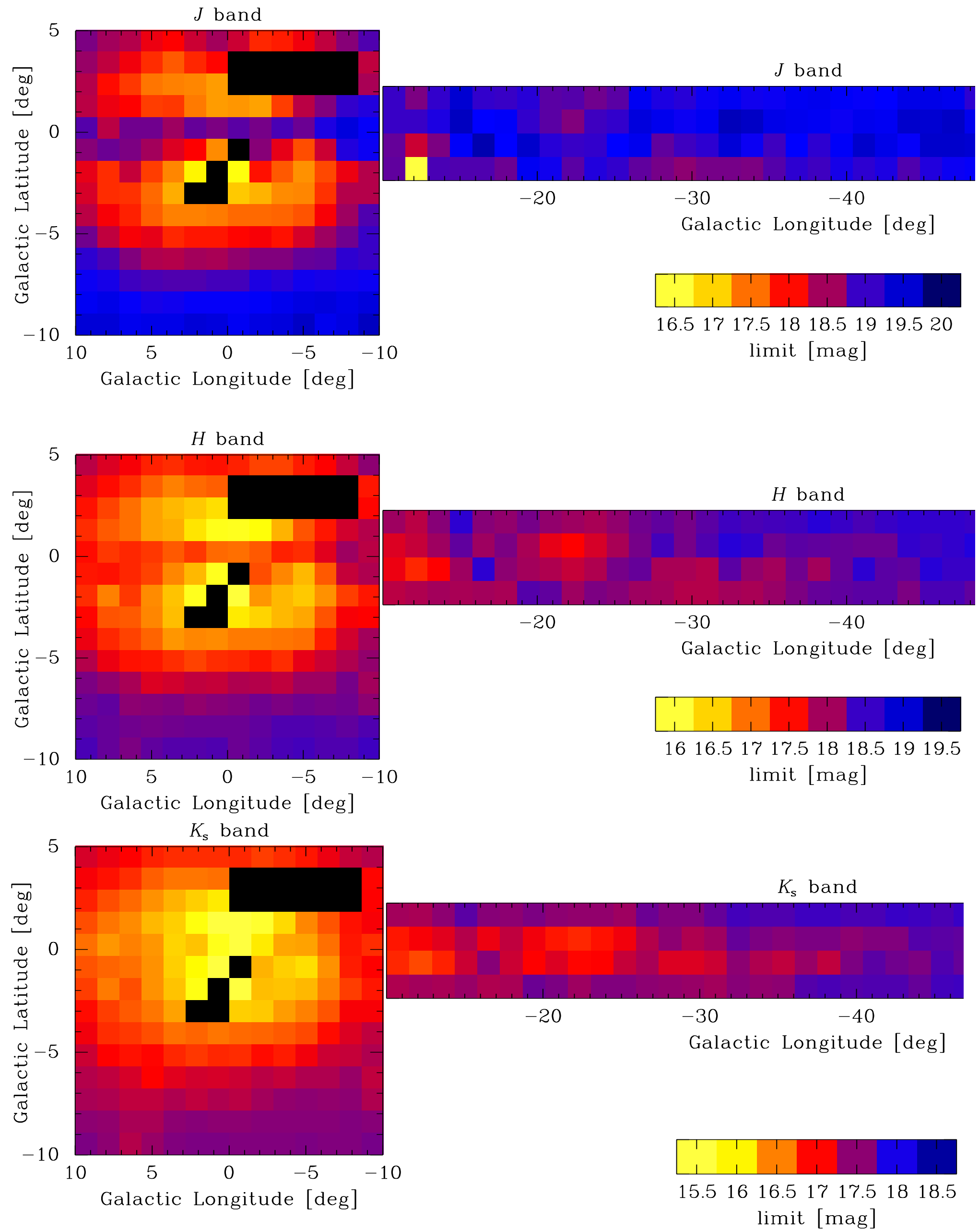
Comparison with OGLE-III



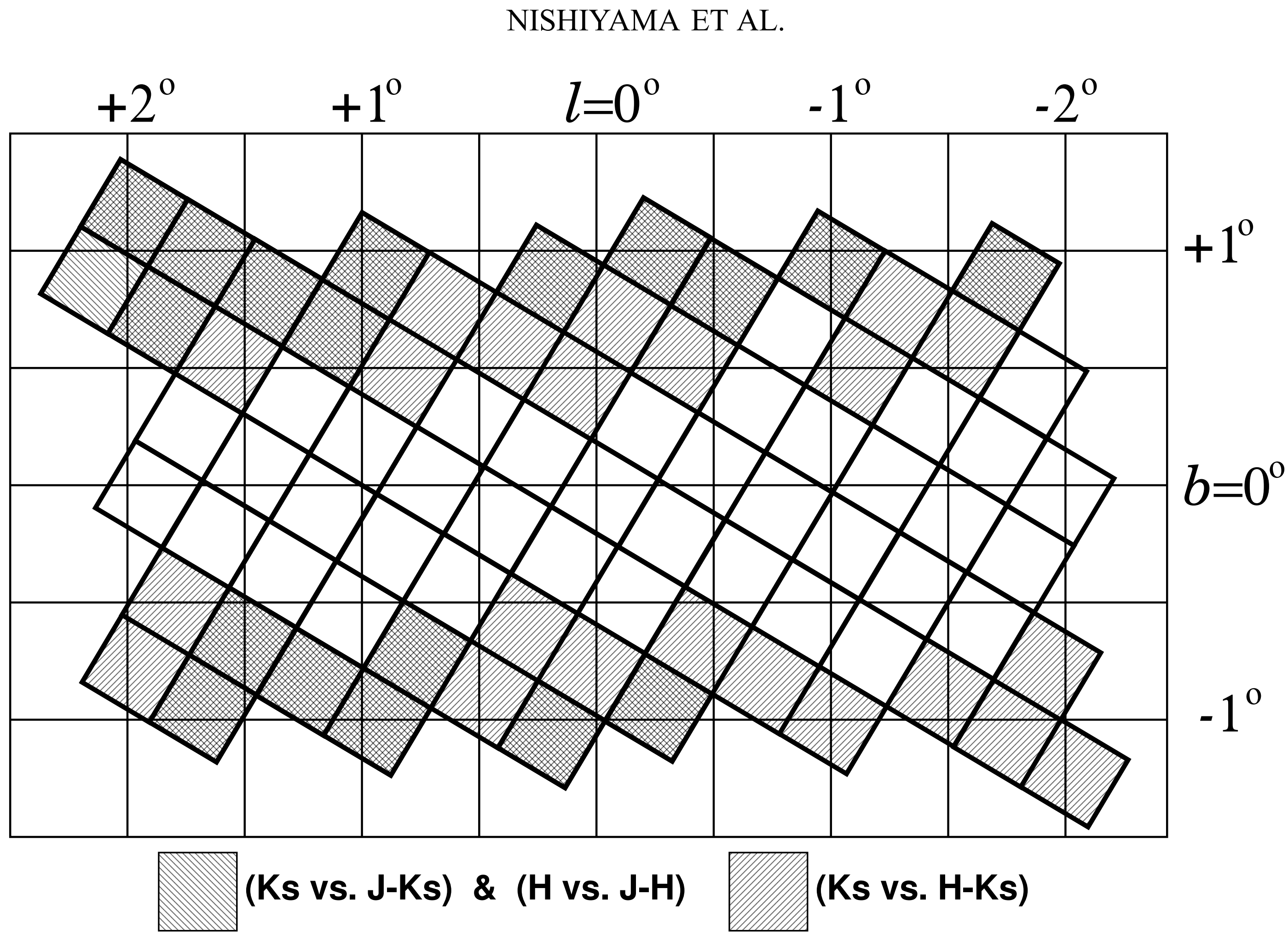
MOA-II field gb6 (in red) has a very small detection rate, so model isn't perfect.

More Data Needed

VVV survey not complete,
but more data this year



More Data Needed (2)



IRSF (2006) survey too small; Red Clump only identified in shaded region

WFIRST probably needs *J*-band colors