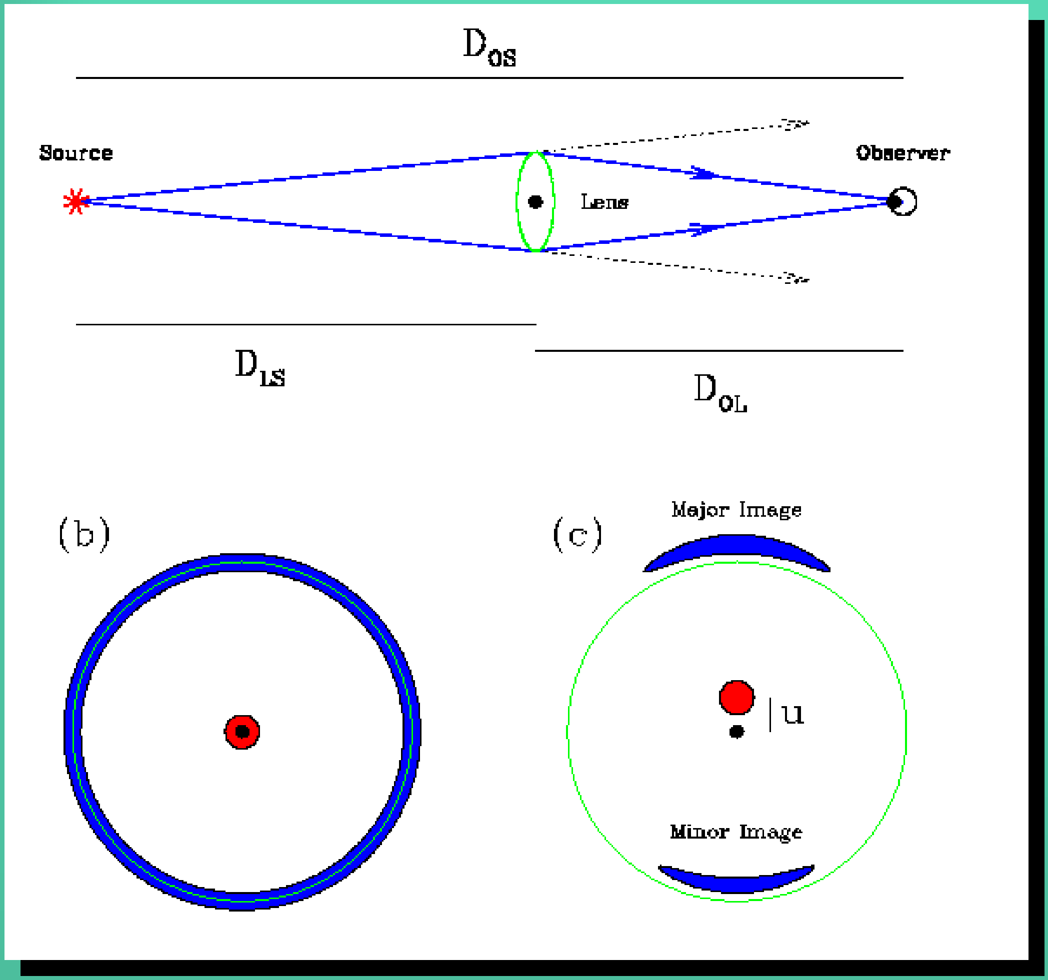
Microlensing Searches for Extrasolar Planets

Scientific Frontiers in Research on Extrasolar Planets, June 19, 2002

Microlensing and Planets



Lens Equation:

$$b = \theta - \theta_E^2/\theta$$

Angular Einstein Ring Radius

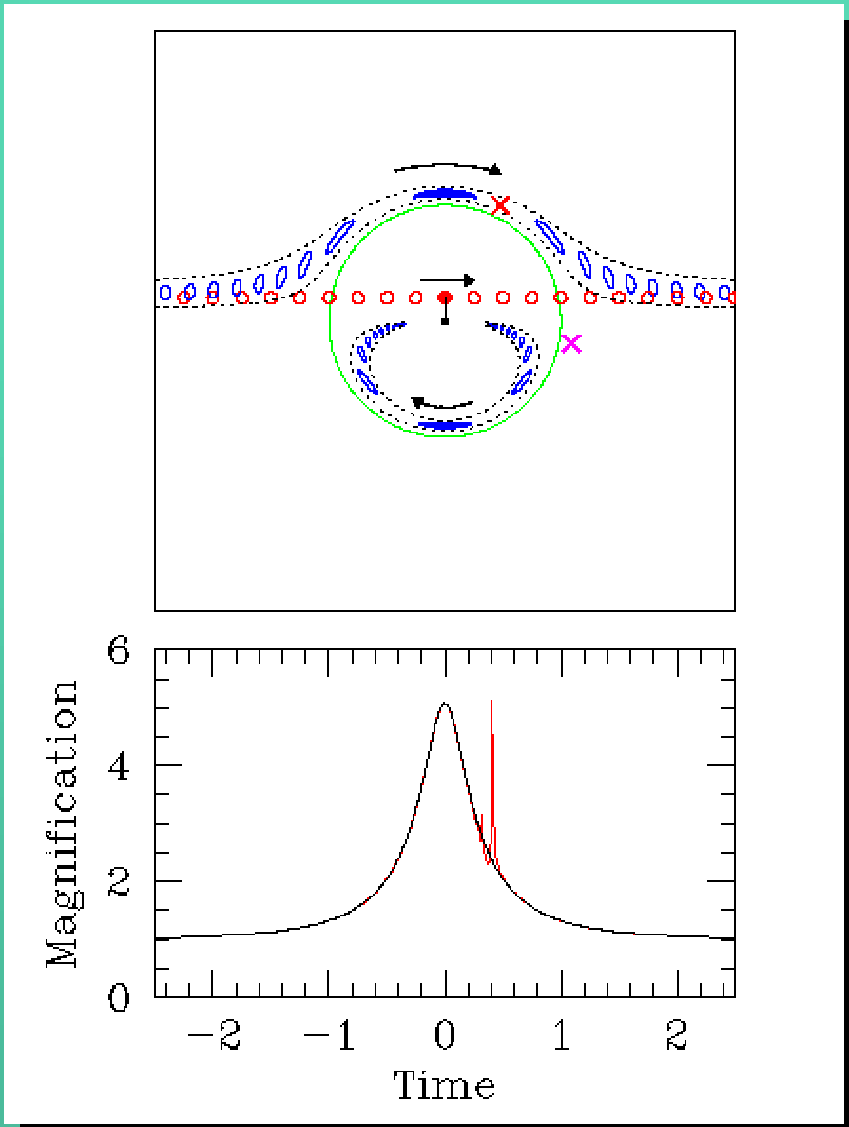
$$\theta_E = \sqrt{\frac{4GM}{c^2}\frac{D_{LS}}{D_{OL}D_{OS}}}$$

$$\approx 300\mu as\sqrt{\frac{M}{0.3M_\odot}}$$

Physical Radius

$$r_E = \theta_E D_{OL} \approx 2AU$$

Microlensing and Planets

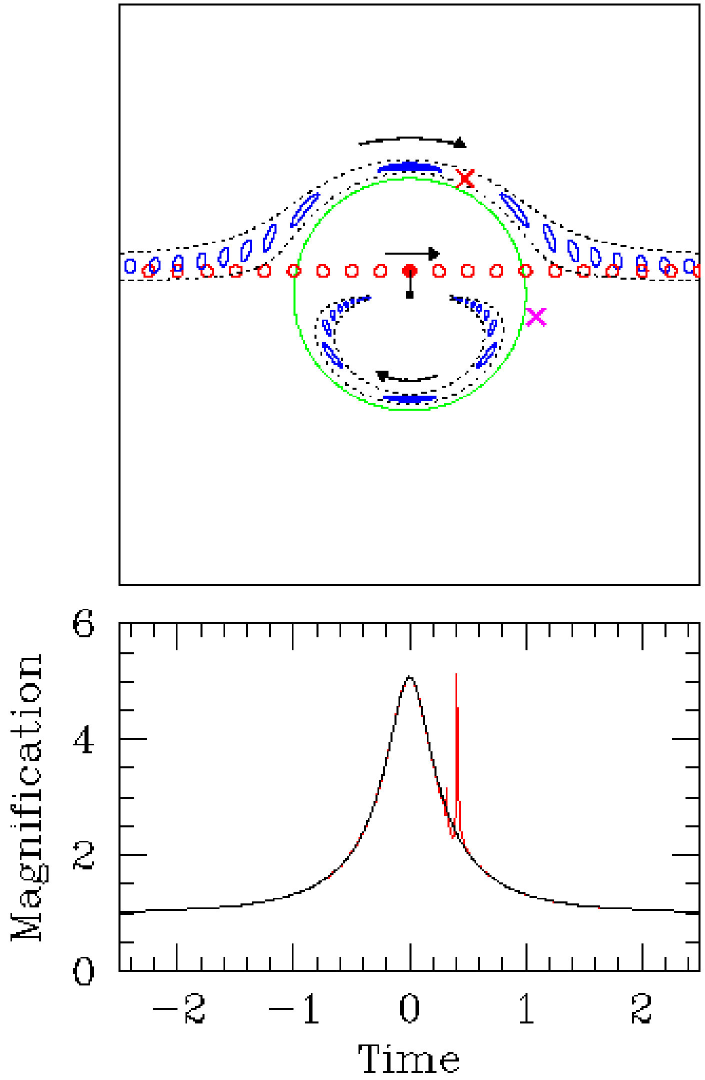


Single Lens Parameters:

- Impact parameter
- Time of Maximum Mag.
- Timescale

$$t_E = \frac{q_E}{\mu} \approx 20\text{days}\sqrt{\frac{M}{0.3M_\odot}}$$

Microlensing and Planets



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- •Timescale

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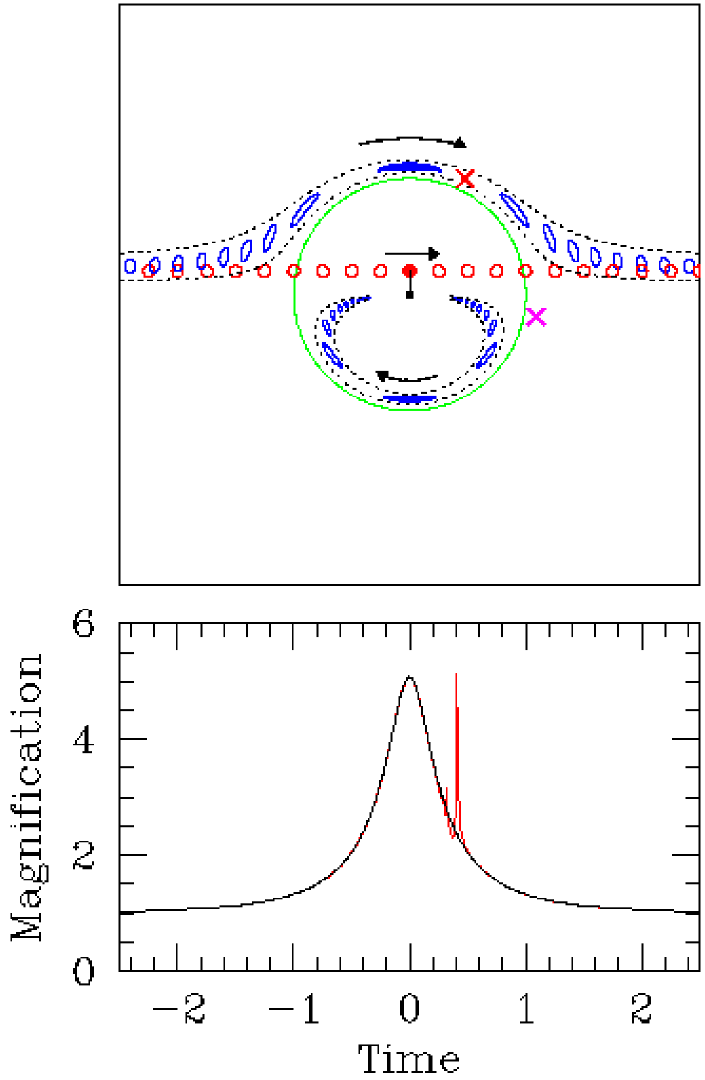
Planet Parameters:

- •Angle wrt Binary Axis
- •Projected Separation
- •Mass Ratio - q

$$t_p = \sqrt{q}\,t_E \approx 1\text{day}\sqrt{\frac{M_p}{M_J}}$$

Microlensing and Planets



Detection Efficiency:

Naïve Estimate:

$$\approx \frac{q_p}{q_E} \approx 3\% \sqrt{\frac{q}{10^{-3}}}$$

Enhanced Probability:

$$\approx A\frac{q_p}{q_E} \approx 15\% \sqrt{\frac{q}{10^{-3}}}$$

High-Magnification Events

➡ Higher Efficiencies

Maximized at $a \approx r_E$

Mao & Paczynski 1991,
Gould & Loeb 1992,
Griest & Safizadeh 1998

Microlensing and Planets

Advantages:

Sensitive to Jupiters at 1-10 AU.
No Flux Needed.
Extend Sensitivity to Lower Masses.

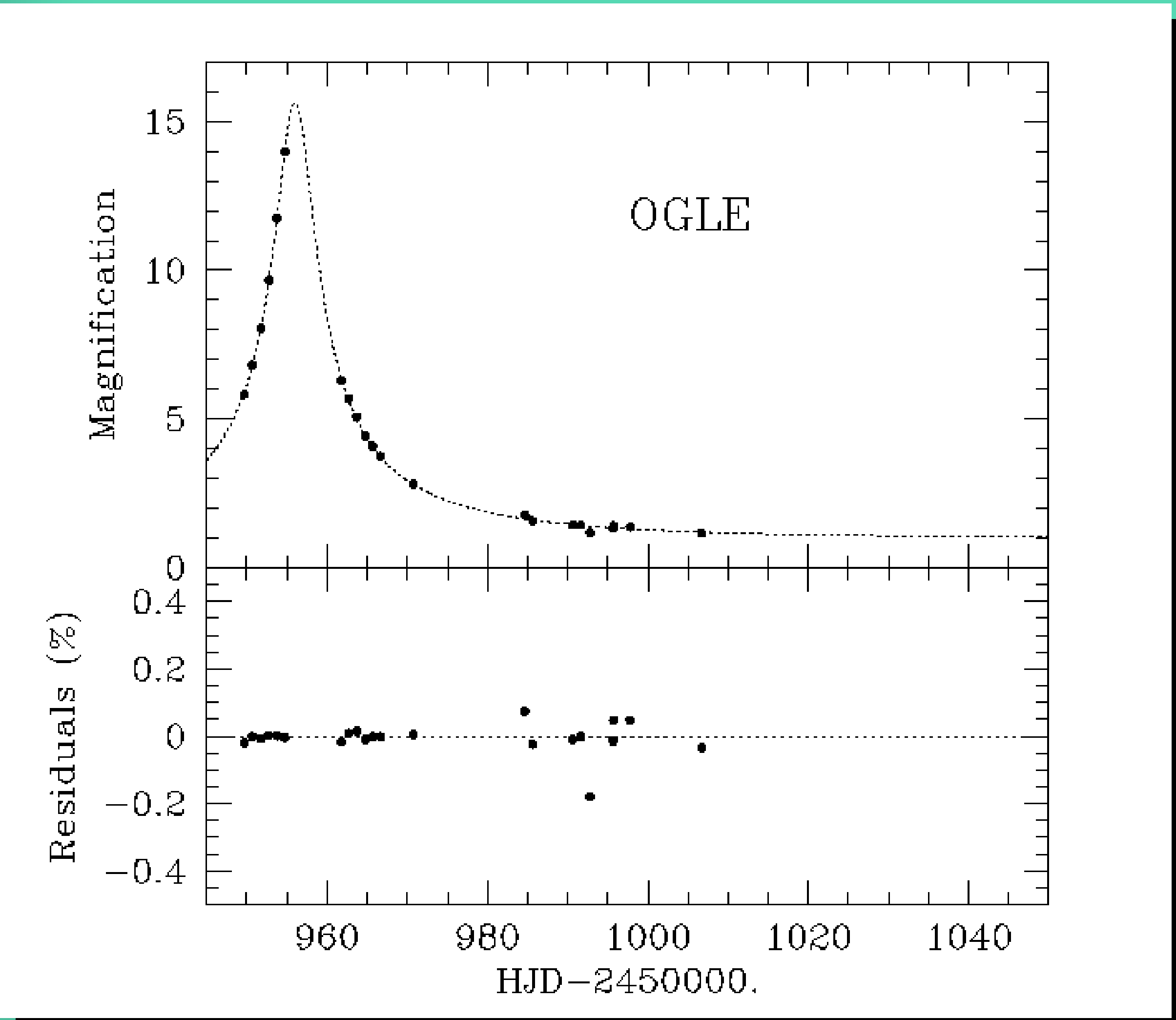
Disadvantages:

Follow-up Difficult.
Non-repeatable.
Short Timescale Perturbations.

Basic Requirements:

Nearly Continuous Sampling.
Good Photometry for Detection.

Alerts and Follow-up



"Survey" Collaborations

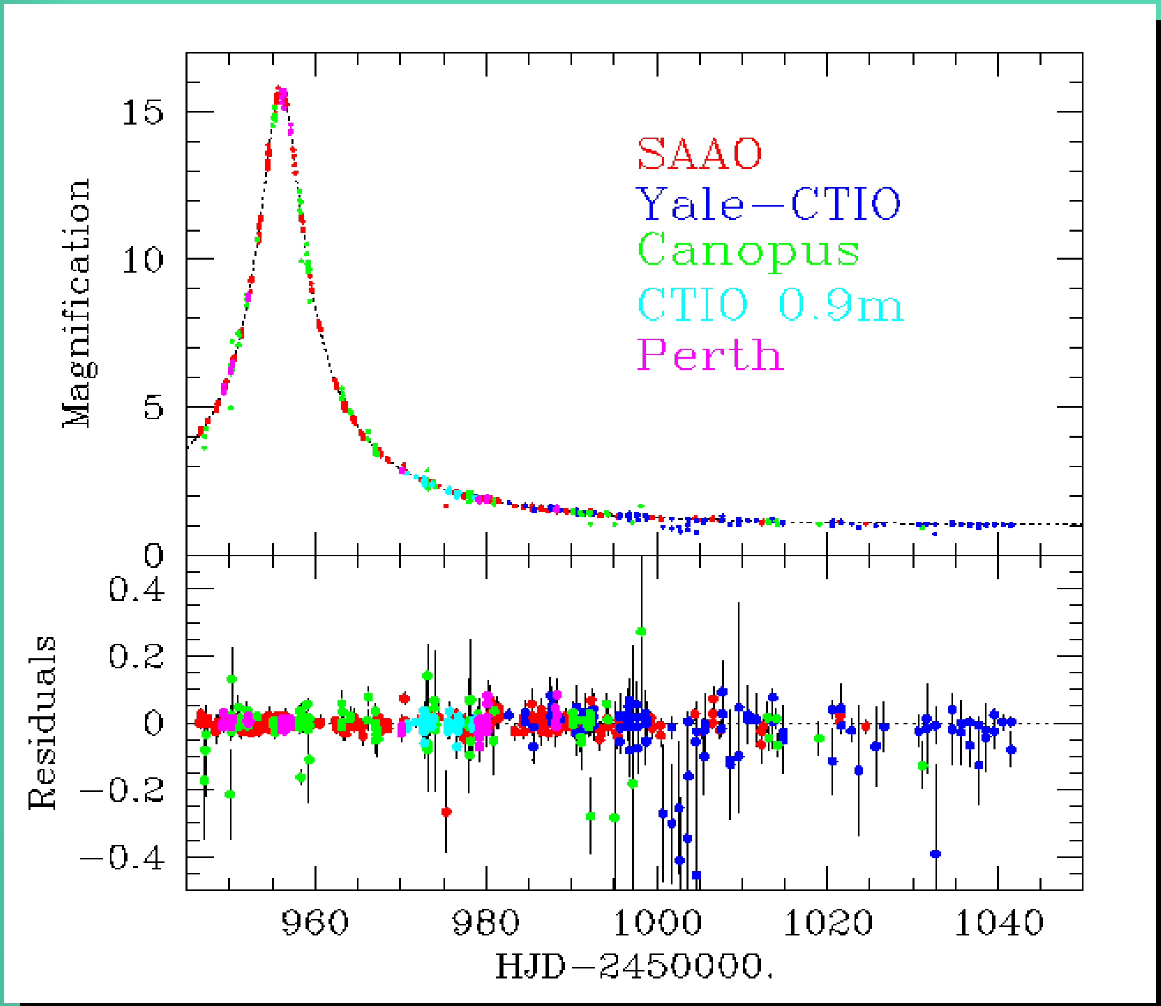
- Insufficient Sampling
- Real-time Alerts

Current and Past Alerts

- EROS
- MACHO*
- MOA
- OGLE III

(500 per year?)

Alerts and Follow-up



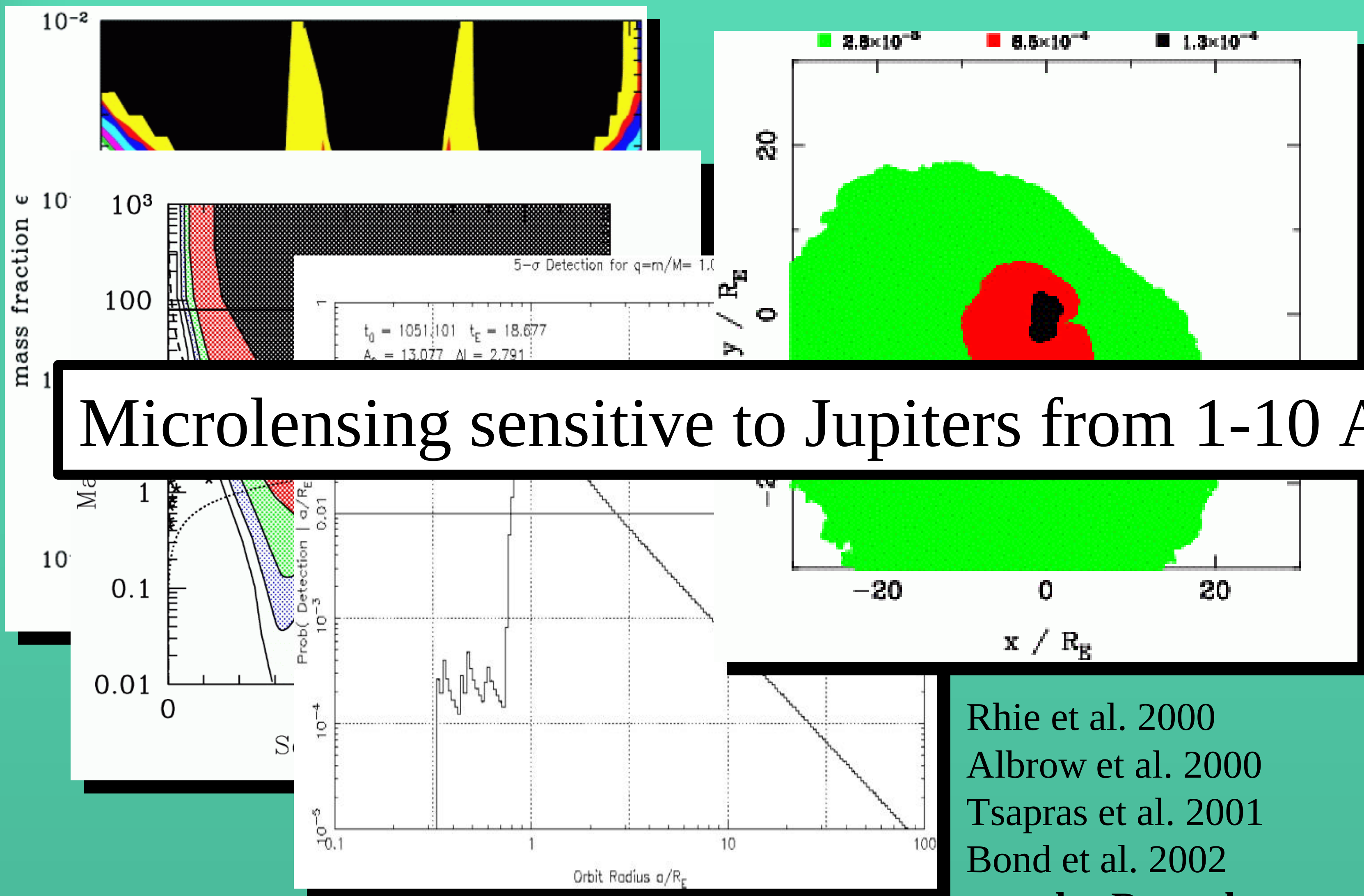
Follow-up Collaborations

- High Temporal Sampling
- Good Photometry

Current Collaborations

- EXPORT
  (Tsapras et al. 2001)
- μFUN
  (new collaboration)
- MOA
  (Bond et al 2002)
- MPS
  (Rhie et al. 2000)
- PLANET
  (Albrow et al. 1998)

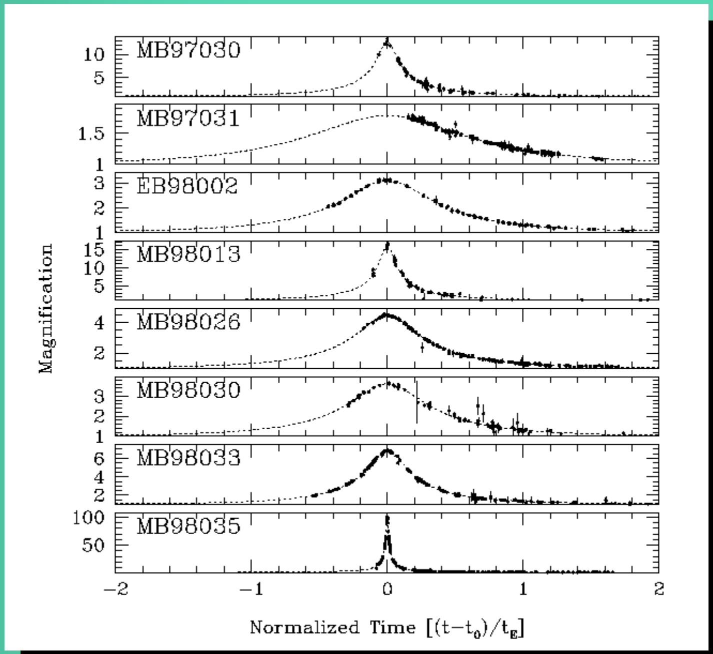
Detection and Efficiency



Microlensing sensitive to Jupiters from 1-10 AU

Rhie et al. 2000
Albrow et al. 2000
Tsapras et al. 2001
Bond et al. 2002
see also Rattenbury et al poster

Five Years of PLANET Data

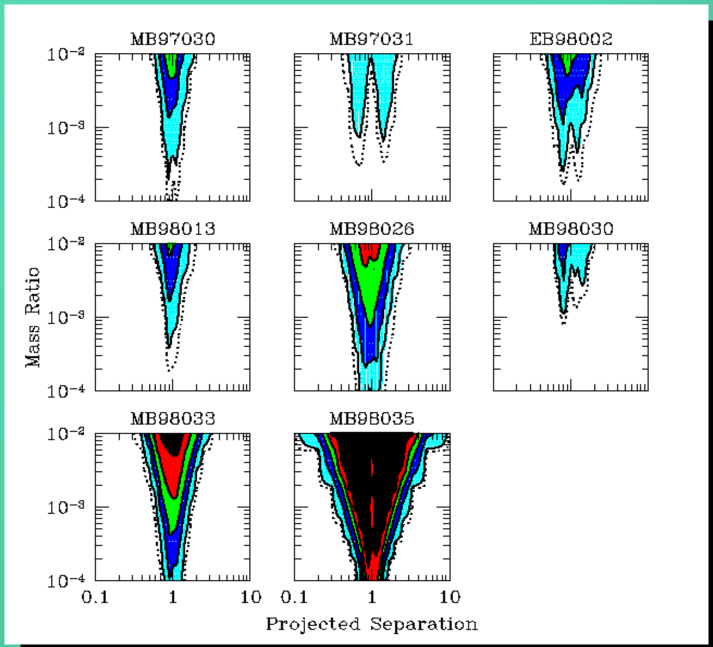


95-99 PLANET Sample

•43 Events

Albrow et al. 2001

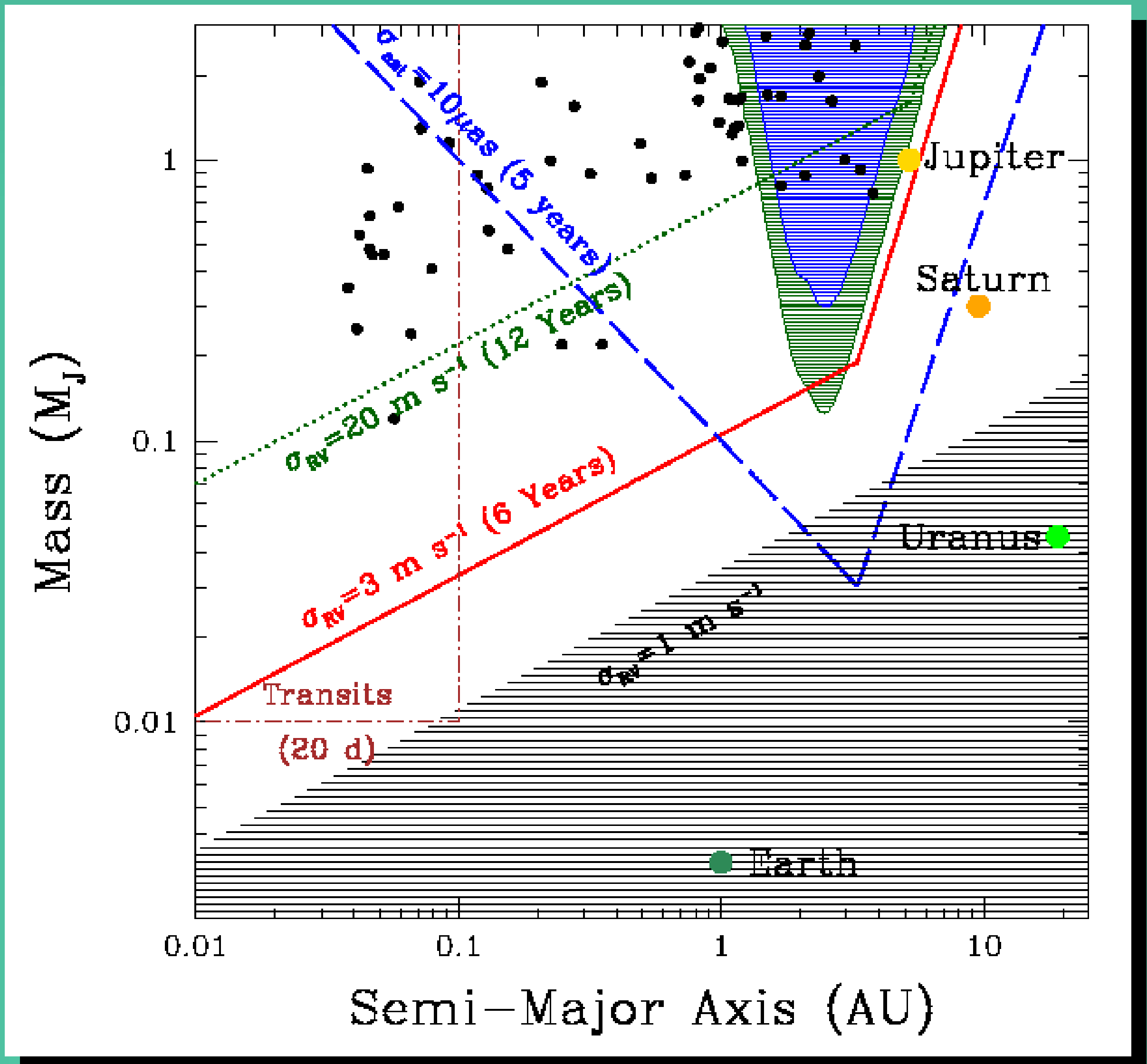
Gaudi et al. 2002



Search for Planets

- $-4 < \log(q) < -2$
- $-1 < \log(d) < 1$

No Viable Detections



<33% Have Jupiter-mass companions between 1.5-4 AU

<45% Have 3 x Jupiter-mass companions between 1-7 AU

Future Prospects - Ground

Pushing to Lower Fractions

- More Efficient Monitoring
- Image Subtraction Processing

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} Factor of 3 improvement
(Gaudi & DePoy in prep)

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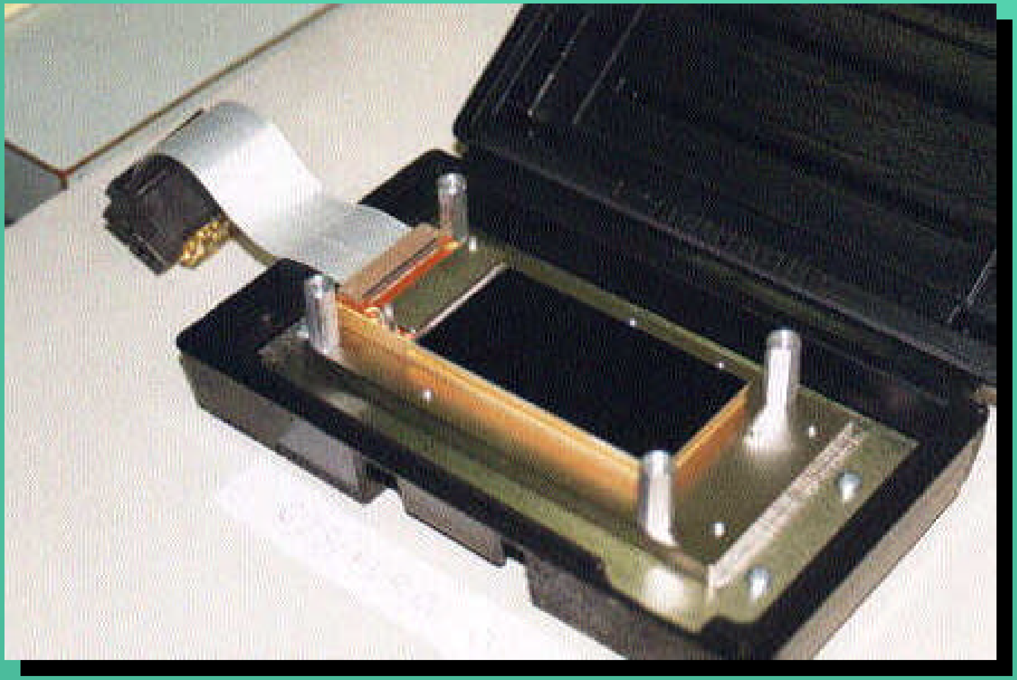
- Increasing the Number of Alerts (OGLE III)



OGLE-III Camera

- 8 2045x4096 CCDs
- 35' x 35' field-of-view
- ~500 alerts per year

$$R_{\exp} \approx 0.1\, f\, R_{\text{alert}}$$

$$\approx 1\,\text{yr}^{-1}\left(\frac{f}{2\%}\right)\left(\frac{R_{\text{alert}}}{500\text{yr}^{-1}}\right)$$

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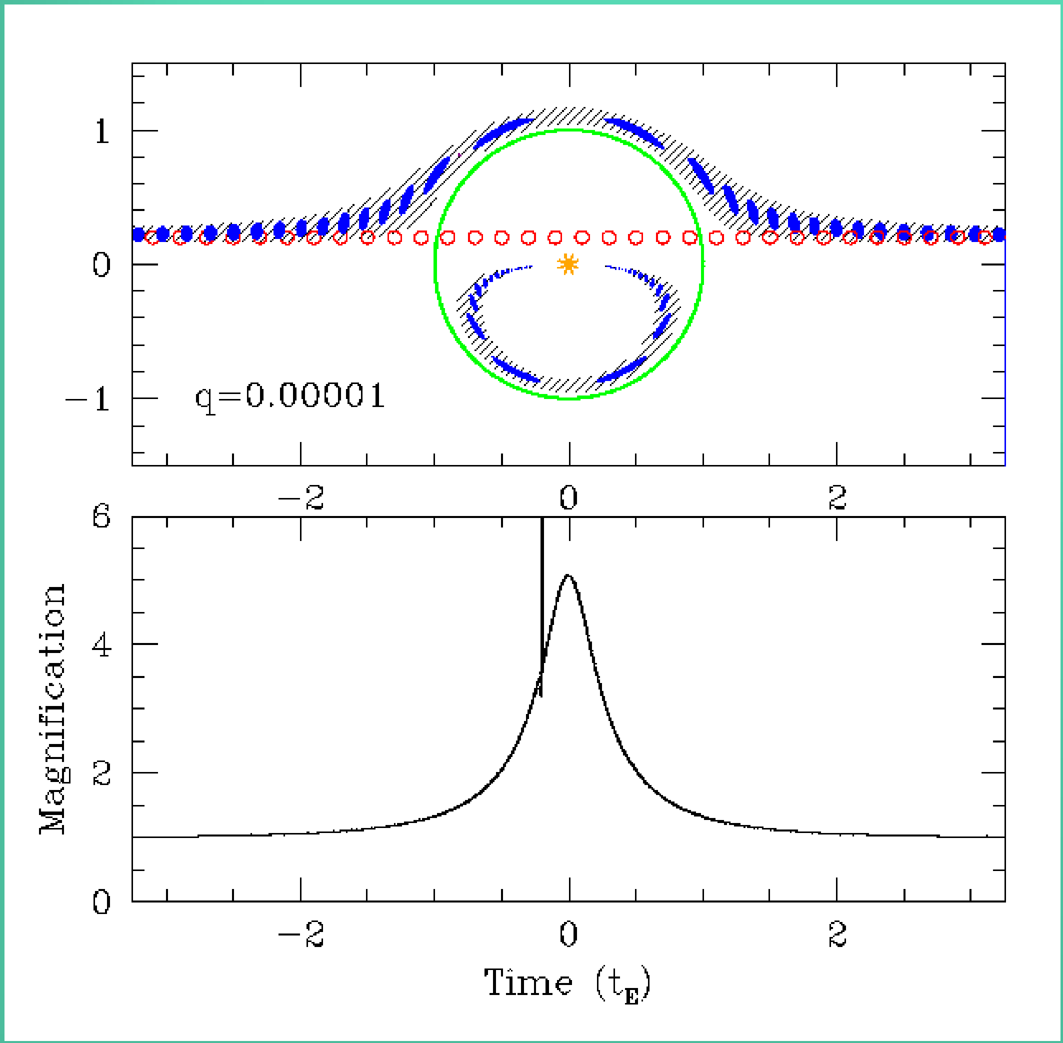
Pushing to Lower Masses

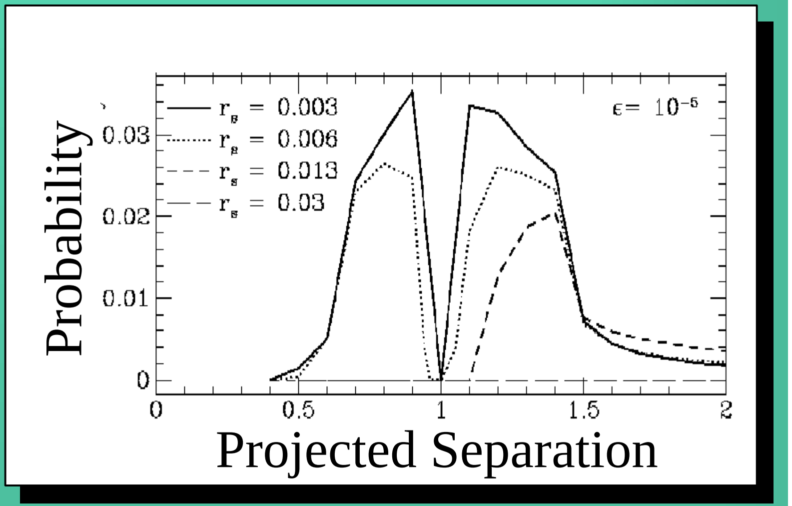
Future Prospects - Ground



Earth-mass Planets

$$q = 10^{-5}\sqrt{M_p / M_\oplus}$$

$$t_p = \sqrt{q}t_E \approx 1\mathrm{hr}\sqrt{M_p / M_\oplus}$$



Bennett & Rhie 1996

Detection Probability ~ few %

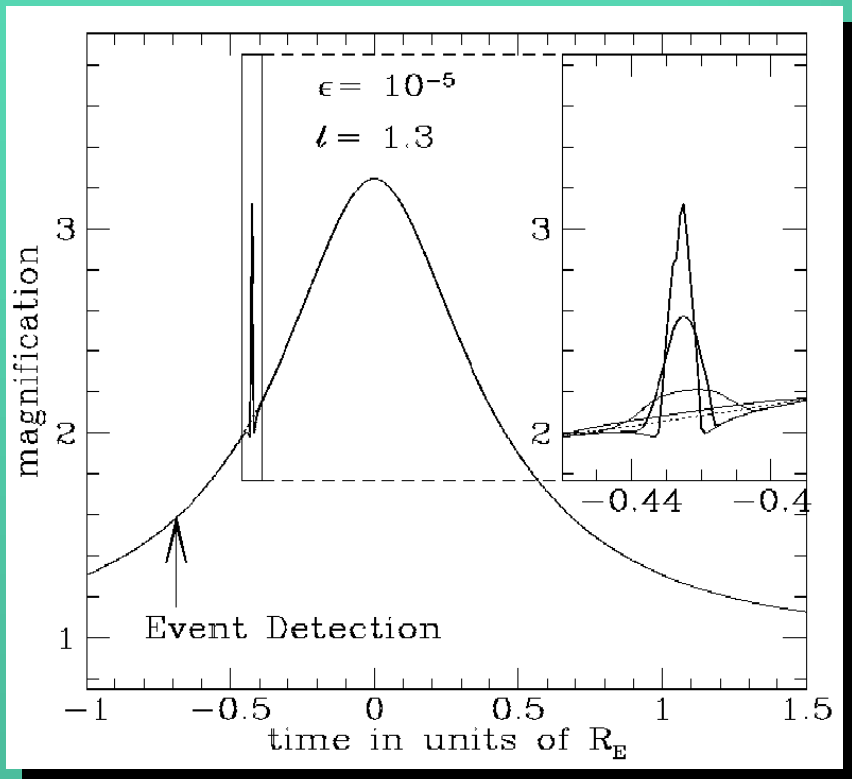
Future Prospects - Ground

Pushing to Lower Fractions

- Increasing the Number of Alerts (OGLE III)
- More Efficient Monitoring
- Image Subtraction Processing

Pushing to Lower Masses

- More Alerts
- Main Sequence Alerts
- Larger Apertures?



Bennett & Rhie 1996

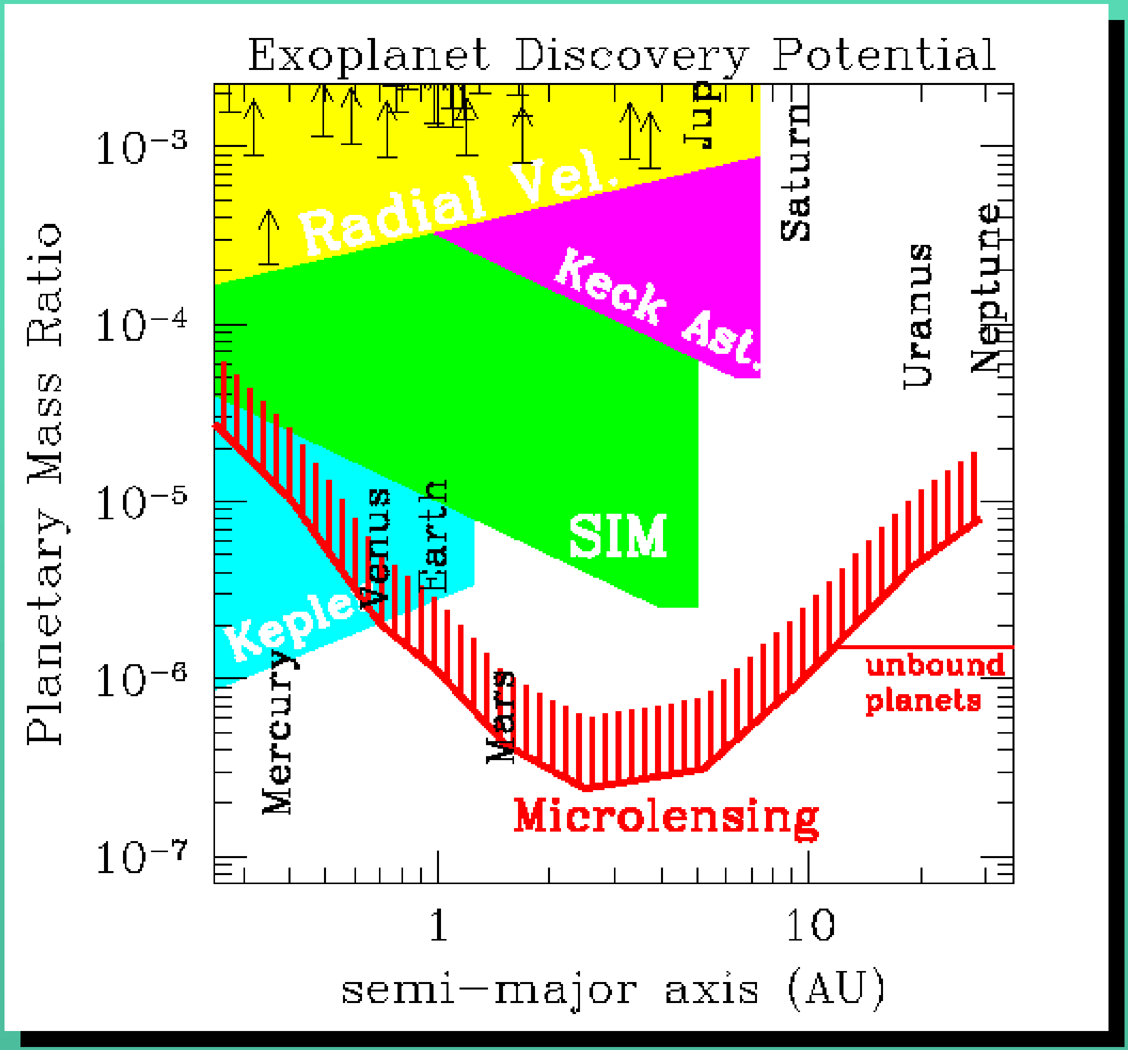
Require Main Sequence Sources

Future Prospects - Space

Galactic Exoplanet Survey Telescope (GEST)

- 1.5m aperture
- 2.1 square degree field-of-view
- Monitor 0.1 billion main sequence stars
- 100f Earth-mass planets at 1 AU

Future Prospects - Space



see Bennett poster

Conclusions

Microlensing offers a complementary way of searching for extrasolar planets.

Four collaborations obtaining useful data

- EXPORT, PLANET, MOA, MPS

Analysis of 95-99 PLANET database:

- No viable detections.
- <33% of M-dwafs in the Bulge have Jupiter-Mass Companions between 1.5-4 AU
- <45% have 3-Jupiter mass Companions between 1-7AU

Future Prospects

- Probe fractions of 1% in 5 Years with OGLE-III Alerts.
- Possible to push sensitivity to Earth-mass planets, but requires
  - Monitoring of many events.
  - Main-sequence sources.
- A space-based survey might be optimal for detecting Earths.