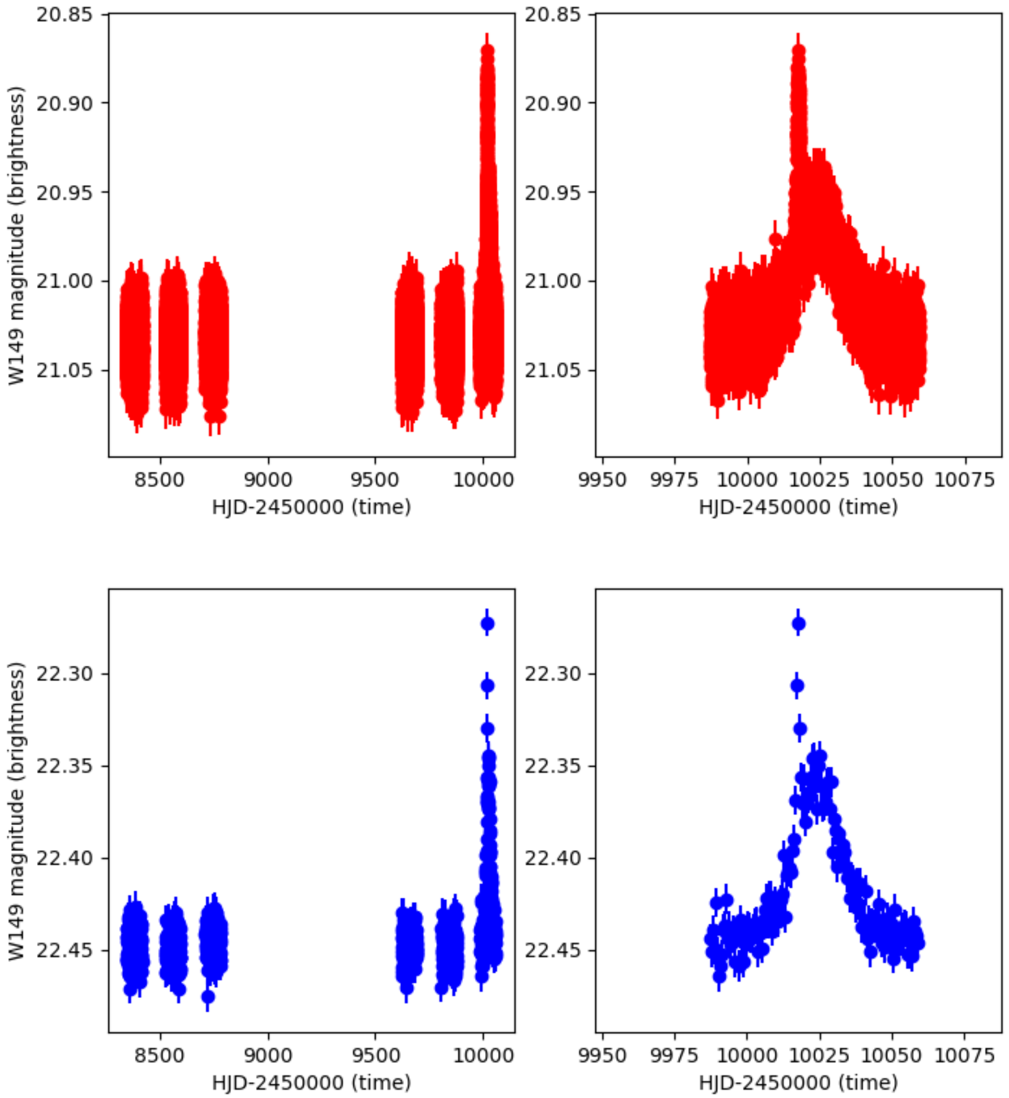
Harvard-Smithsonian Center for Astrophysics

# WFIRST Data Analysis Challenge

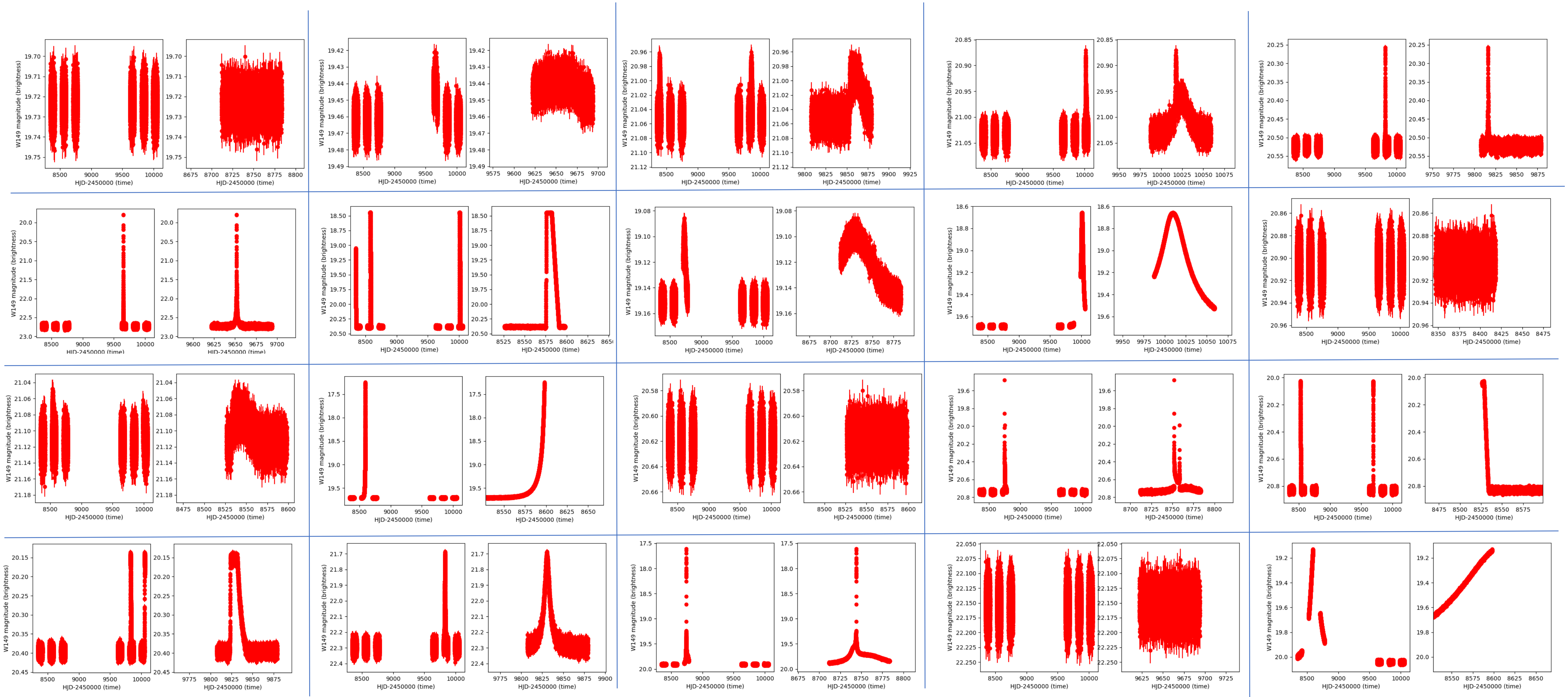
Jennifer C. Yee

# A Data Challenge Light Curve




- Magnitude (brightness) vs. Time
- 2 wavelengths → 2 light curves

# Data Challenge: “Solve” 293 light curves

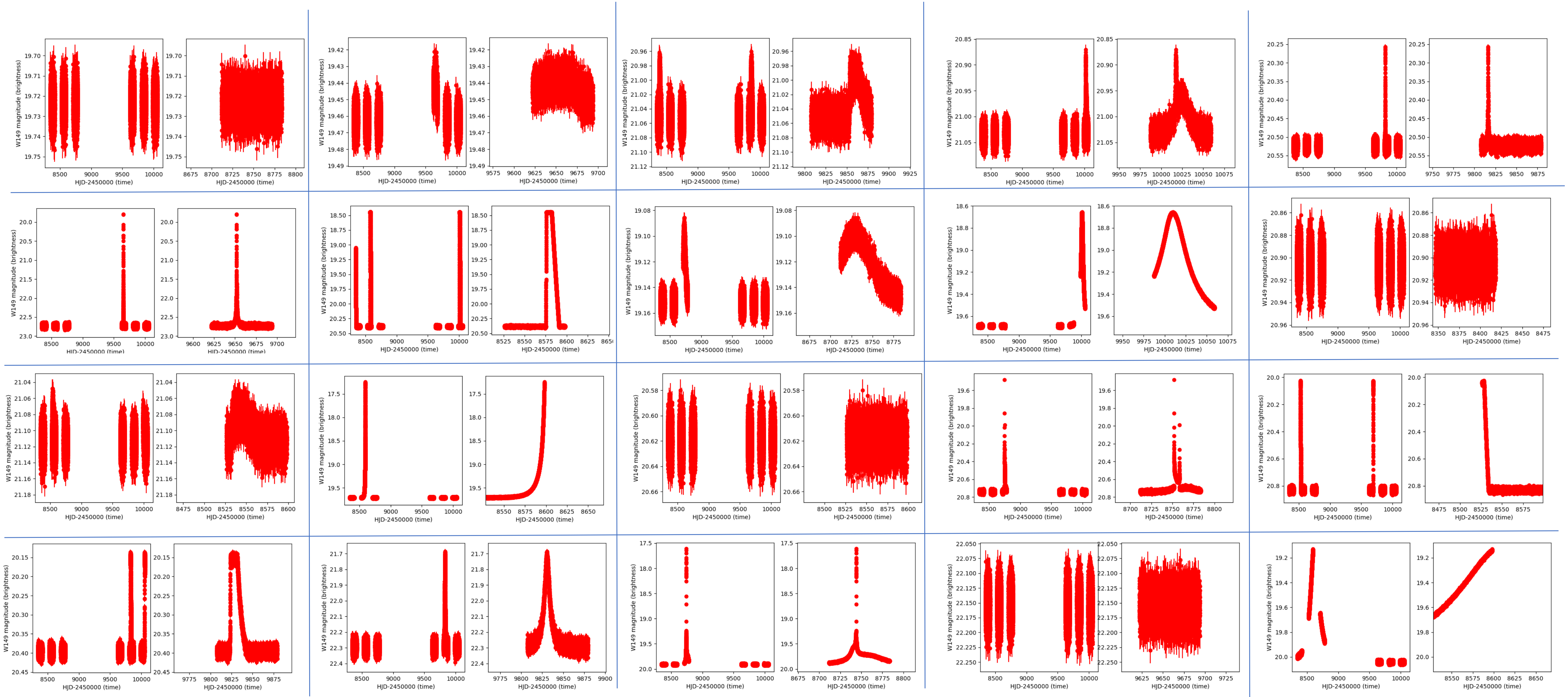


# Astronomer’s Question: Which ones have planets and what are their properties?

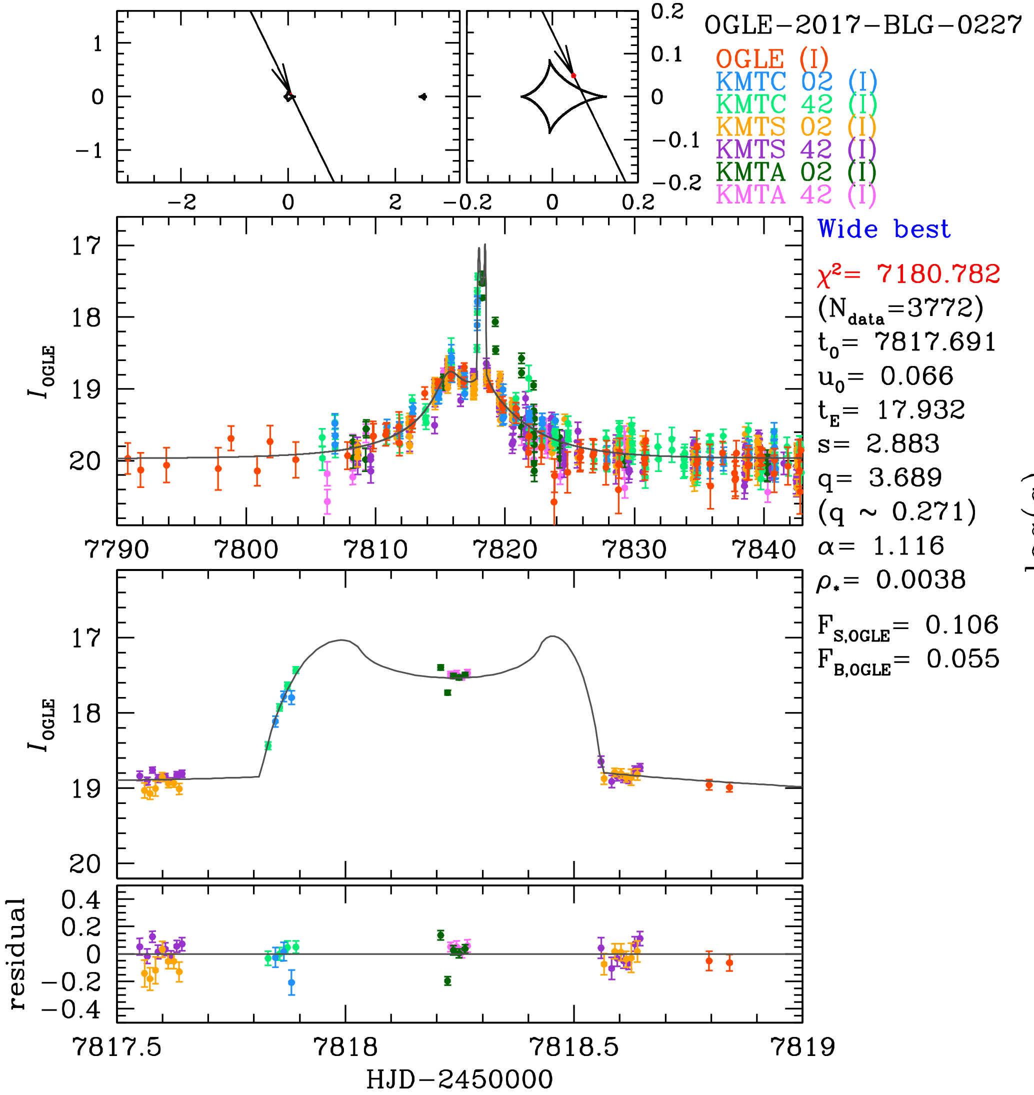
# More General Questions:

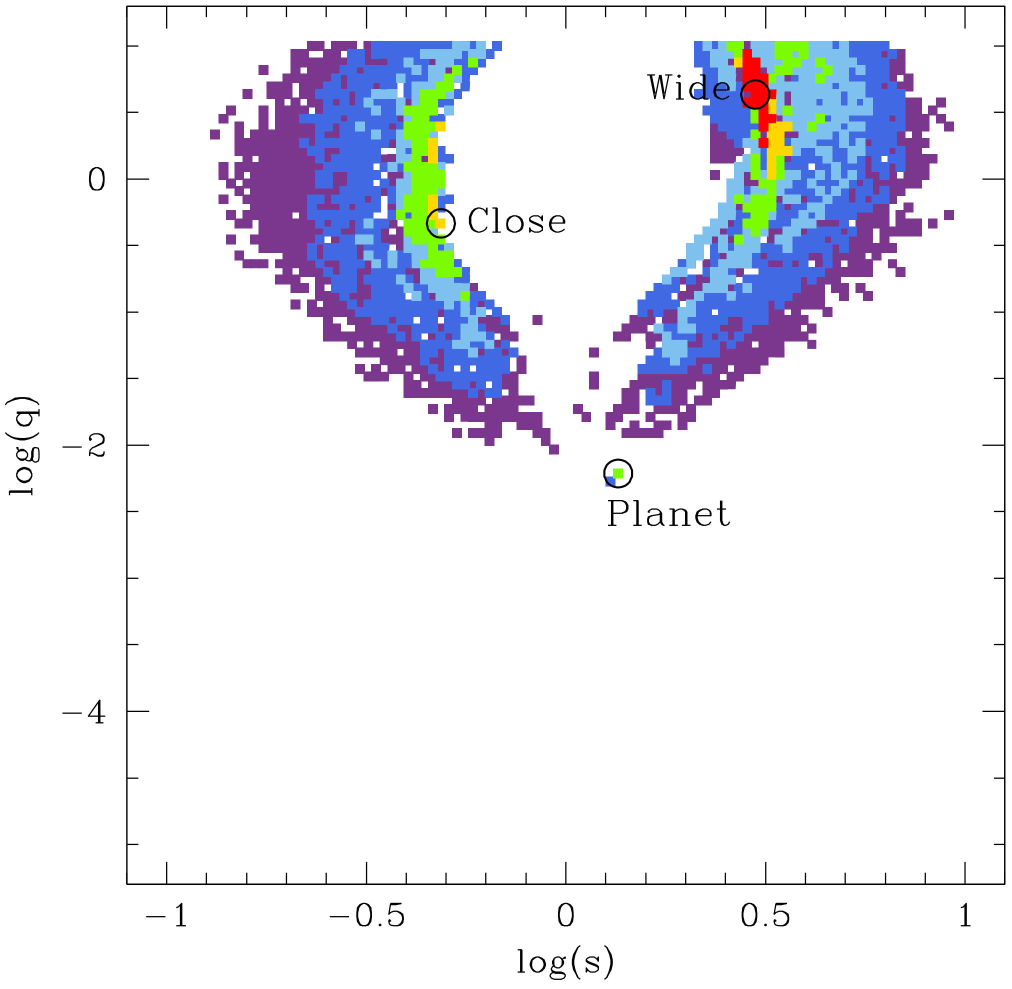
- Microlensing or Not Microlensing?
- 1-body or 2-bodies?
- What are the parameters?

# By-eye Identification



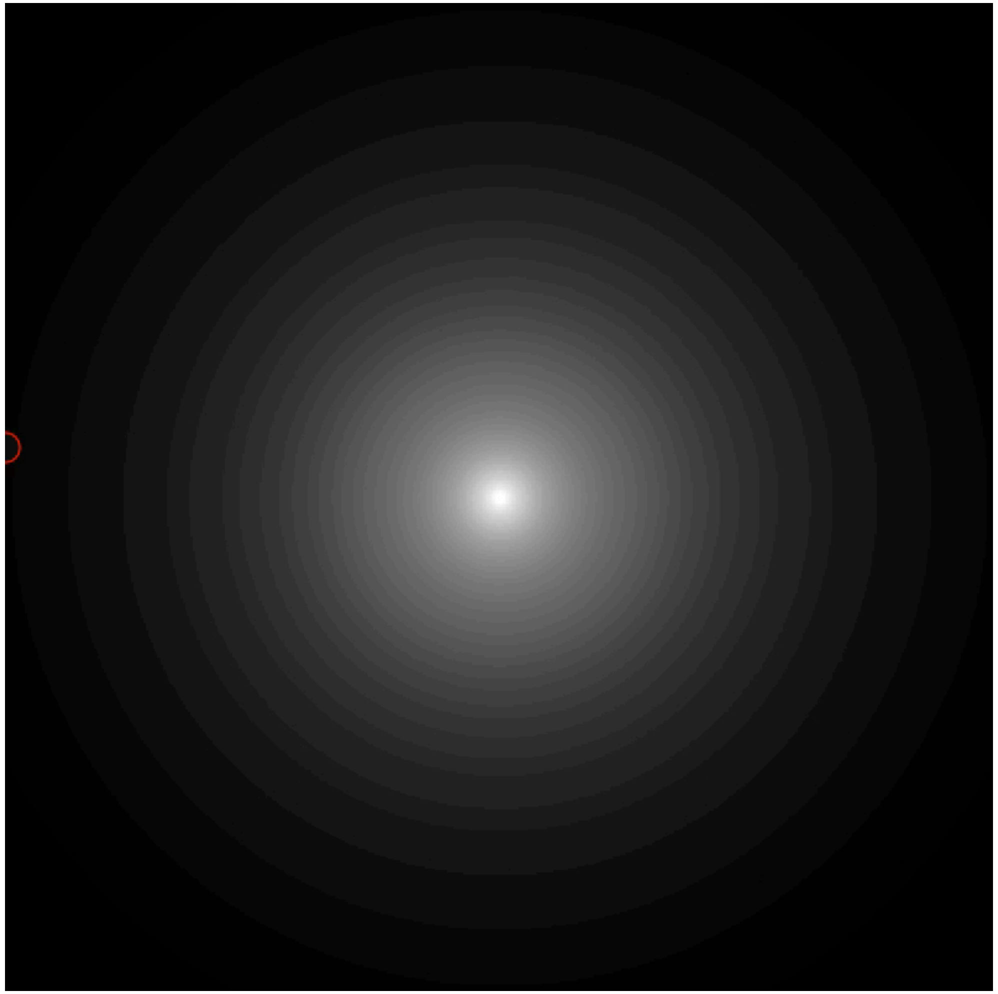
# Grid Search for Best Model




Modelling by In-Gu Shin

# Microlensing with 1-body: $t_0$, $u_0$, $t_E$

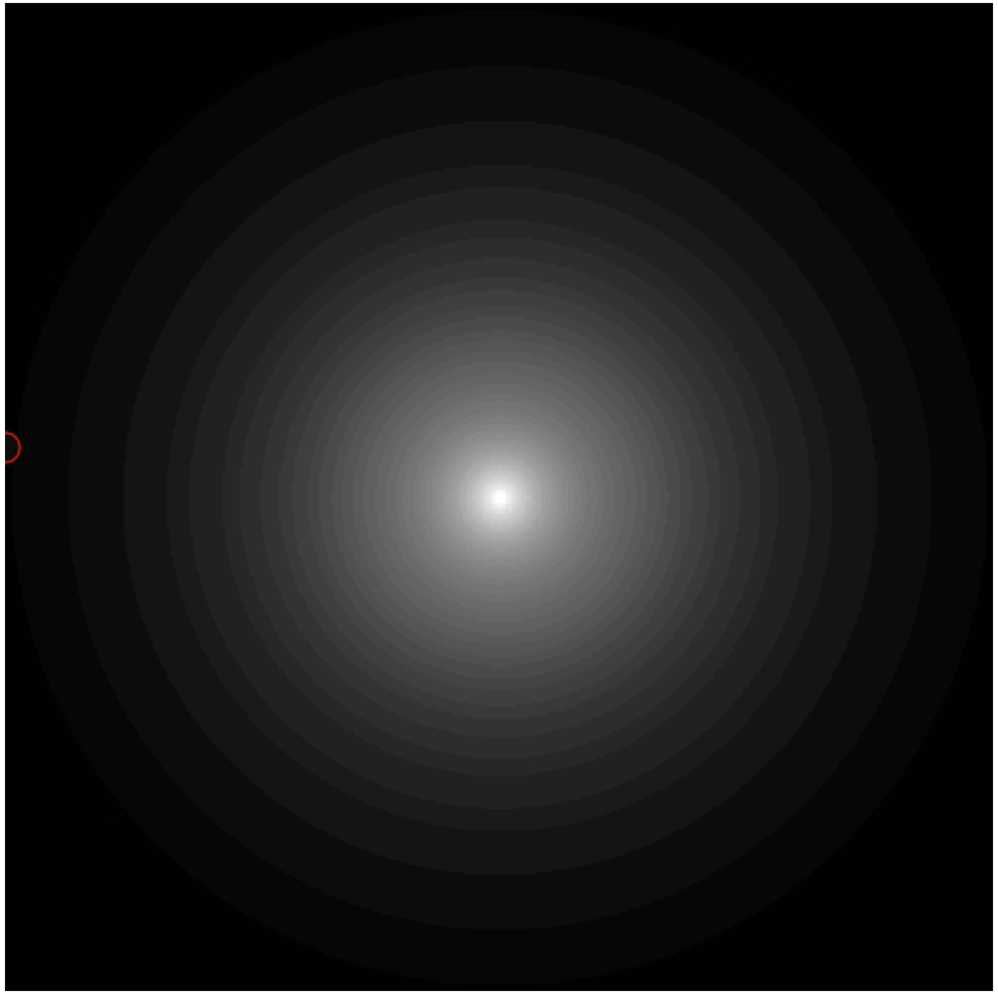


magnification =

$$A(u) = \frac{u^2 + 2}{u\sqrt{u^2 + 4}}$$

$$u = \sqrt{{u_0}^2 + \frac{(t - t_0)^2}{t_E}}$$

# Larger $t_E$ = Slower

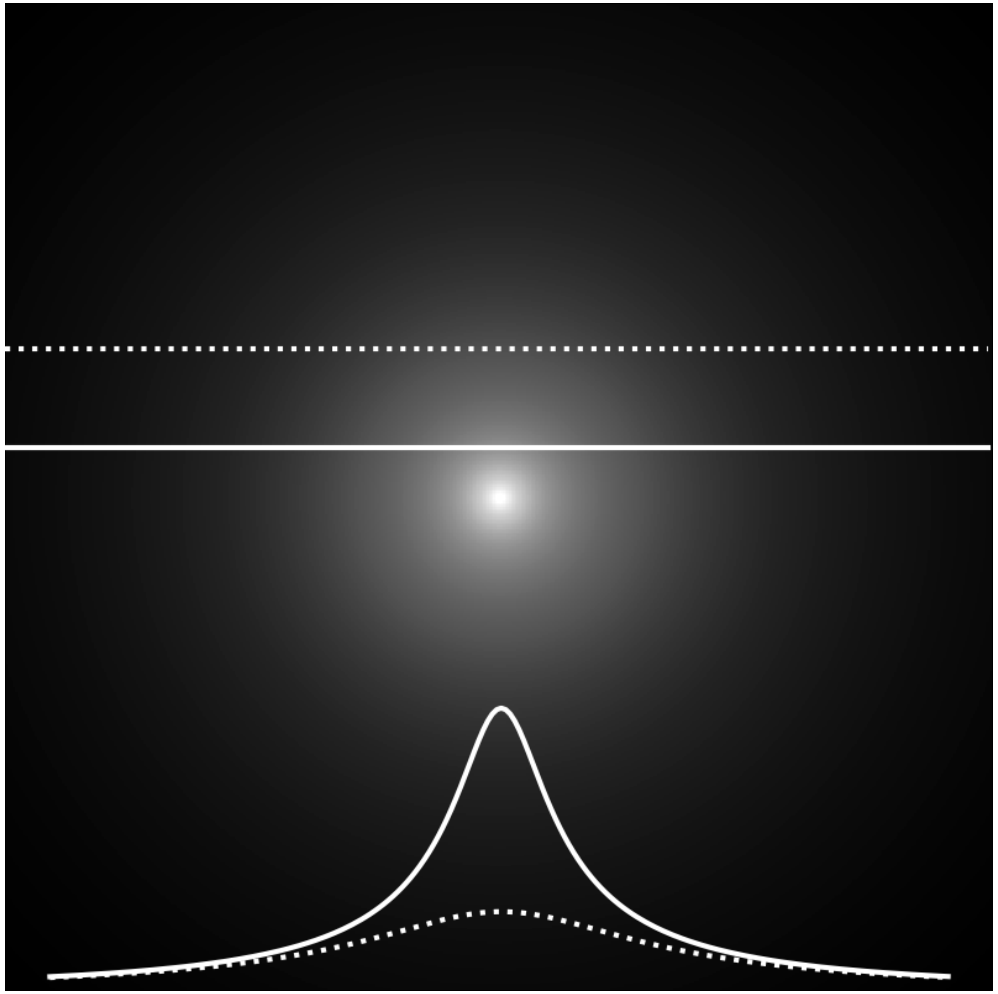


magnification =

$$A(u) = \frac{u^2 + 2}{u\sqrt{u^2 + 4}}$$

$$u = \sqrt{{u_0}^2 + \frac{(t - t_0)^2}{t_E}}$$

# Larger $u_0$ = Smaller Magnification

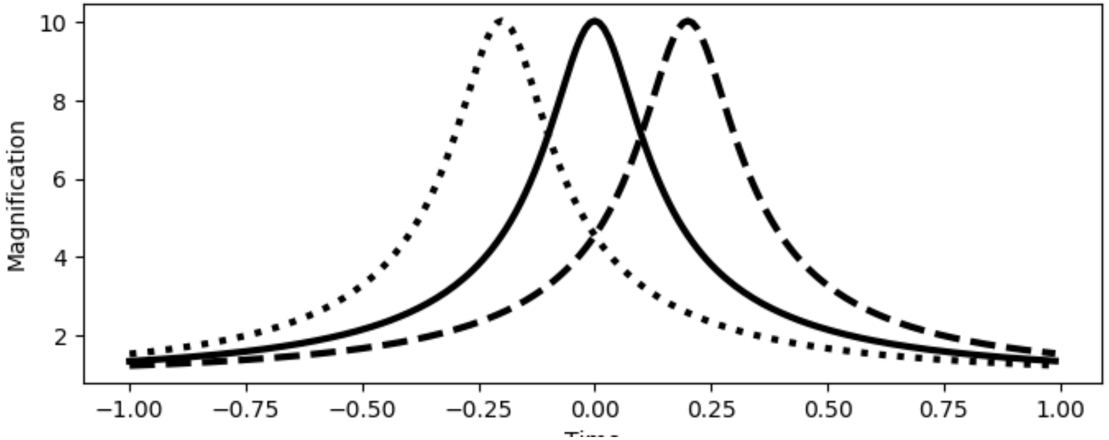


magnification =

$$A(u) = \frac{u^2 + 2}{u\sqrt{u^2 + 4}}$$

$$u = \sqrt{{u_0}^2 + \frac{(t - t_0)^2}{t_E}}$$

# $t_0$ shifts the light curve in time

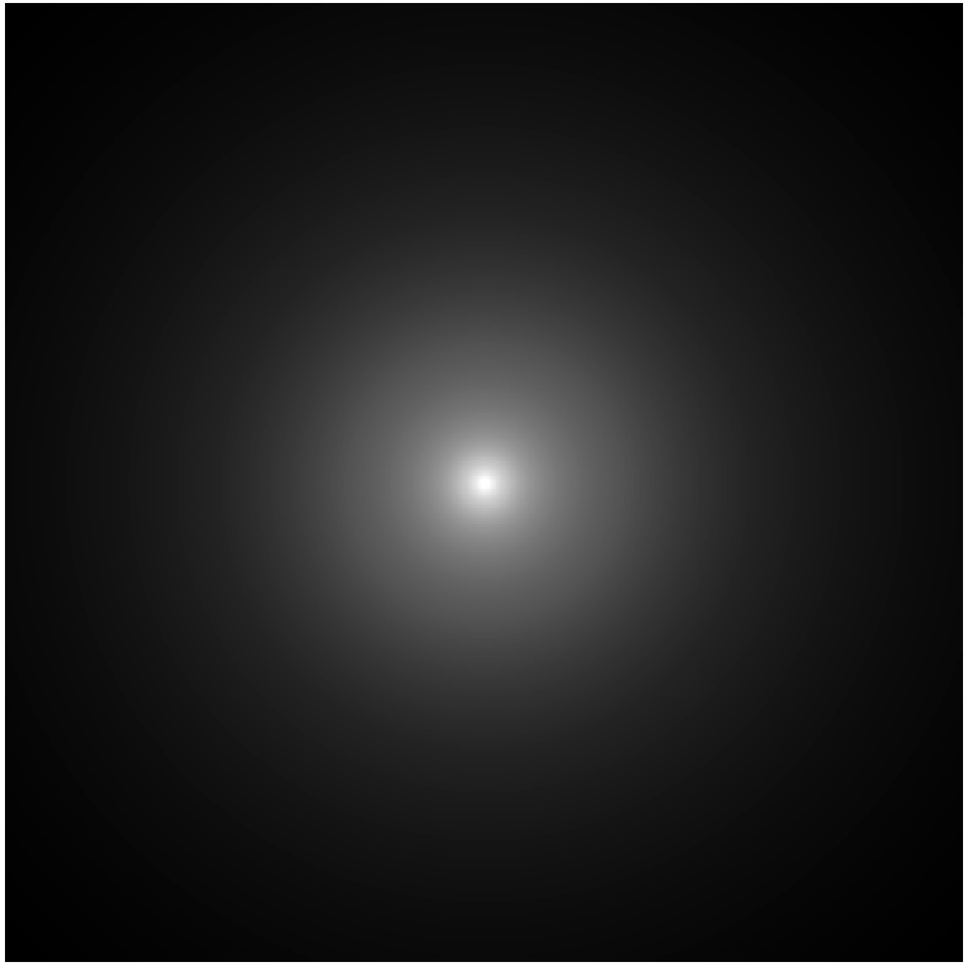



magnification =

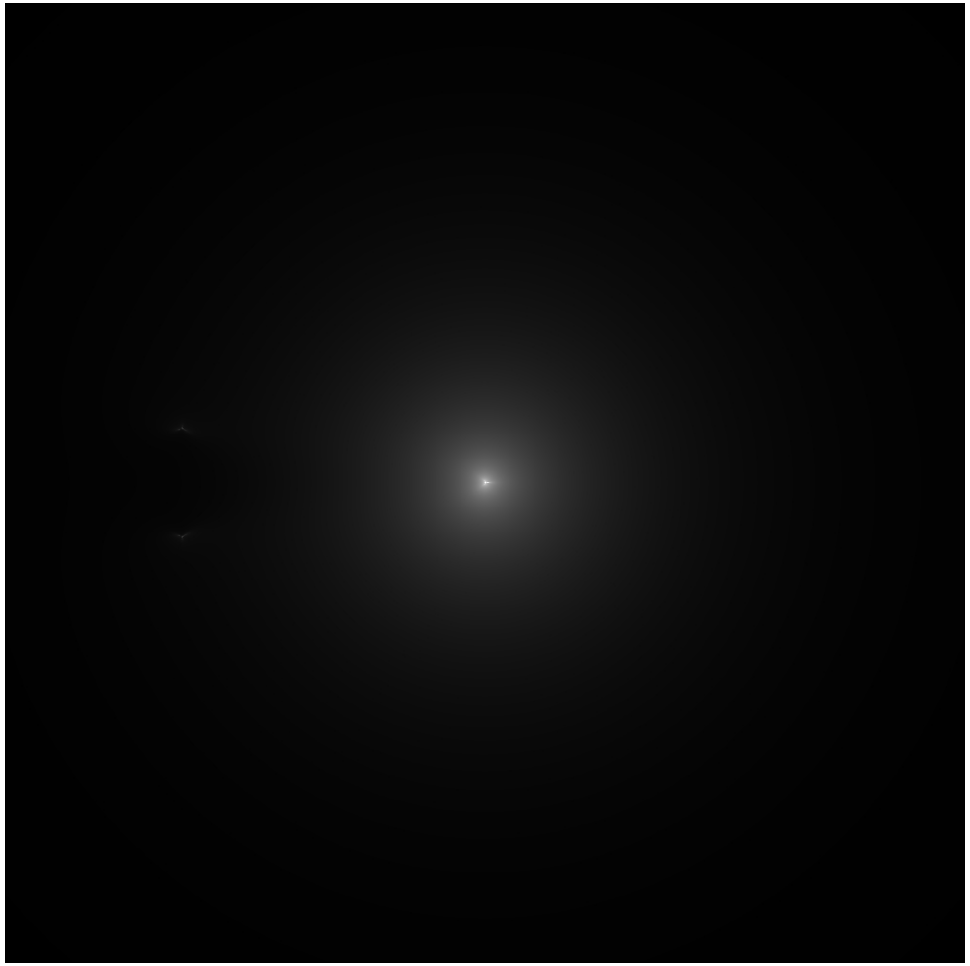
$$A(u) = \frac{u^2 + 2}{u\sqrt{u^2 + 4}}$$

$$u = \sqrt{{u_0}^2 + \frac{(t - t_0)^2}{t_E}}$$

# Microlensing with 2-bodies: s, q, alpha

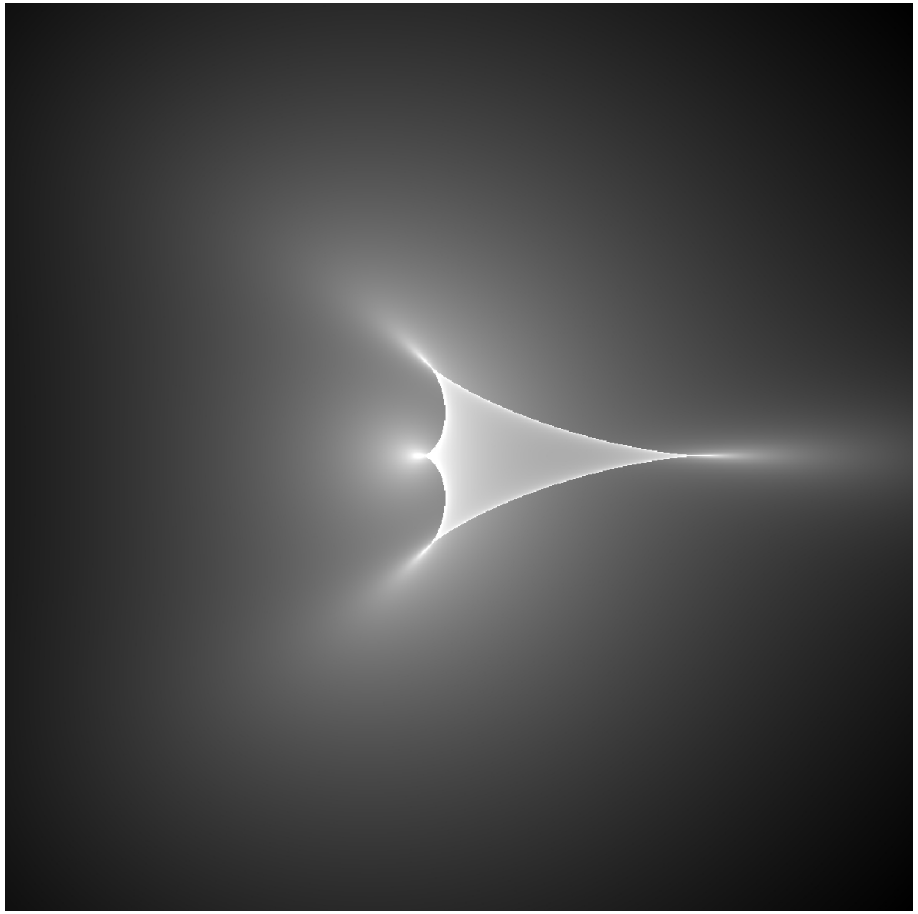


1-body



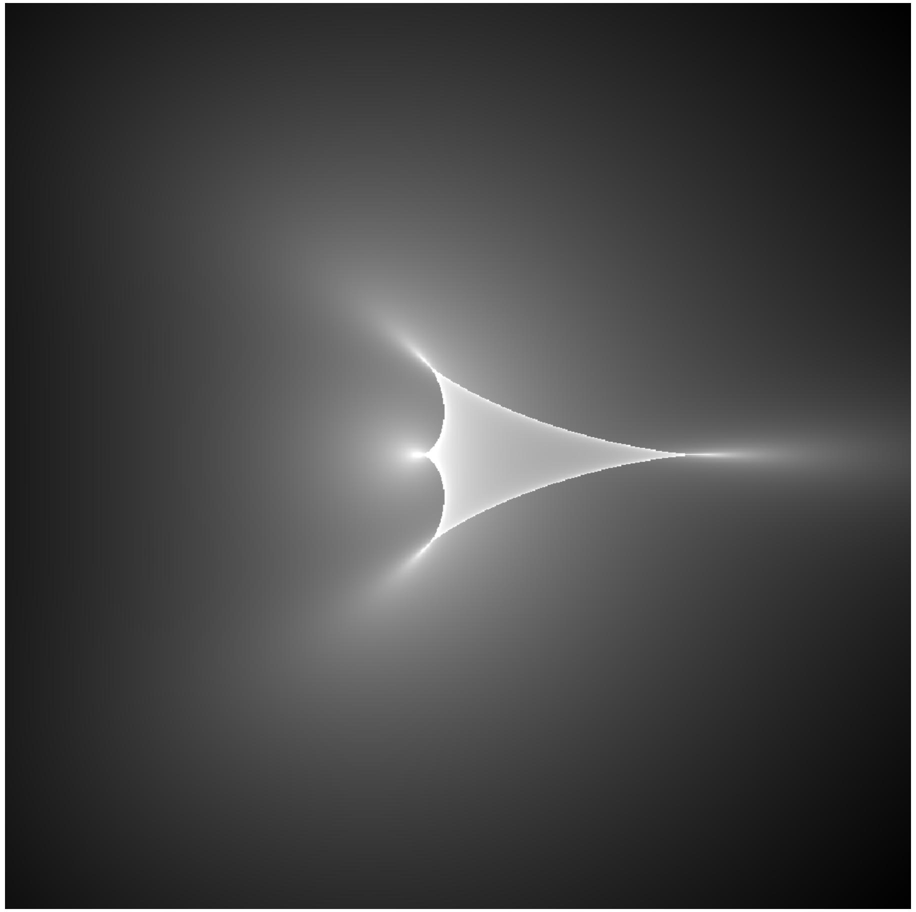
2-bodies

# Microlensing with 2-bodies: Caustics



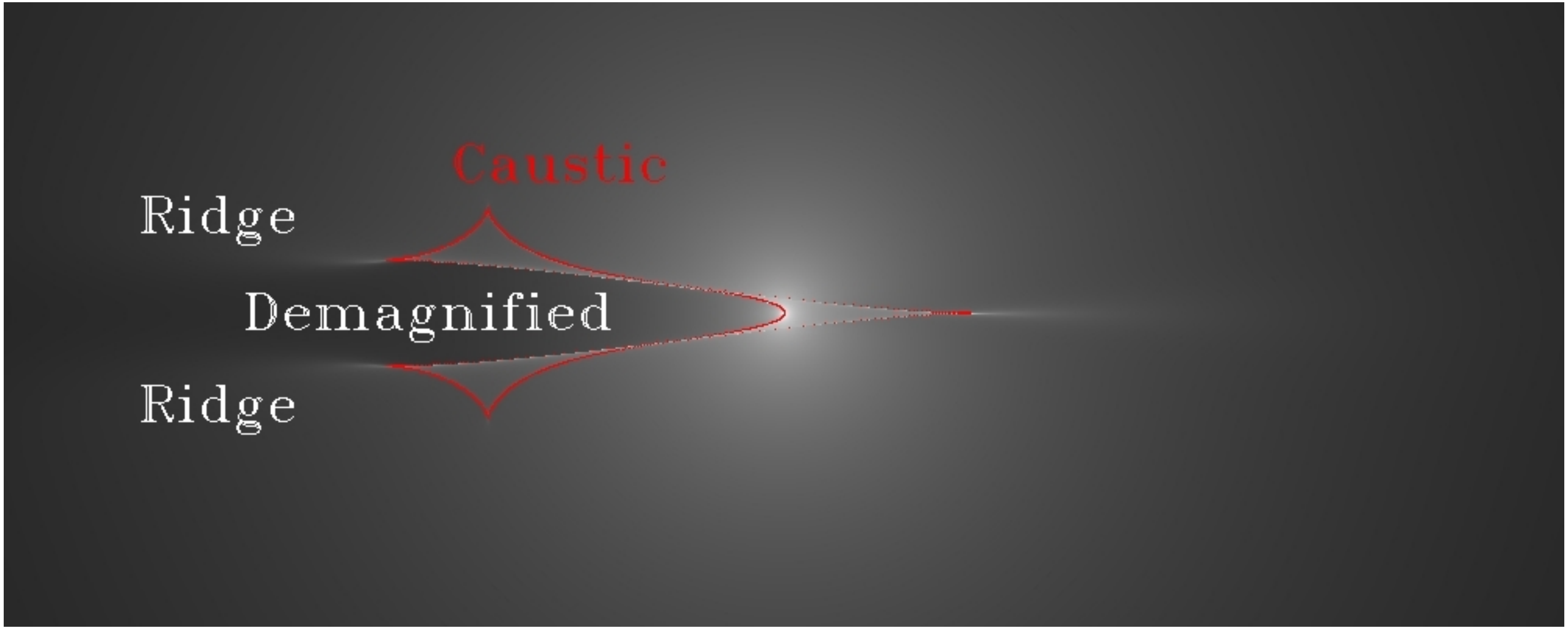
$$\text{magnification} = A(\boldsymbol{u}) = \frac{1}{|\det J|}$$

# Microlensing with 2-bodies: Caustics

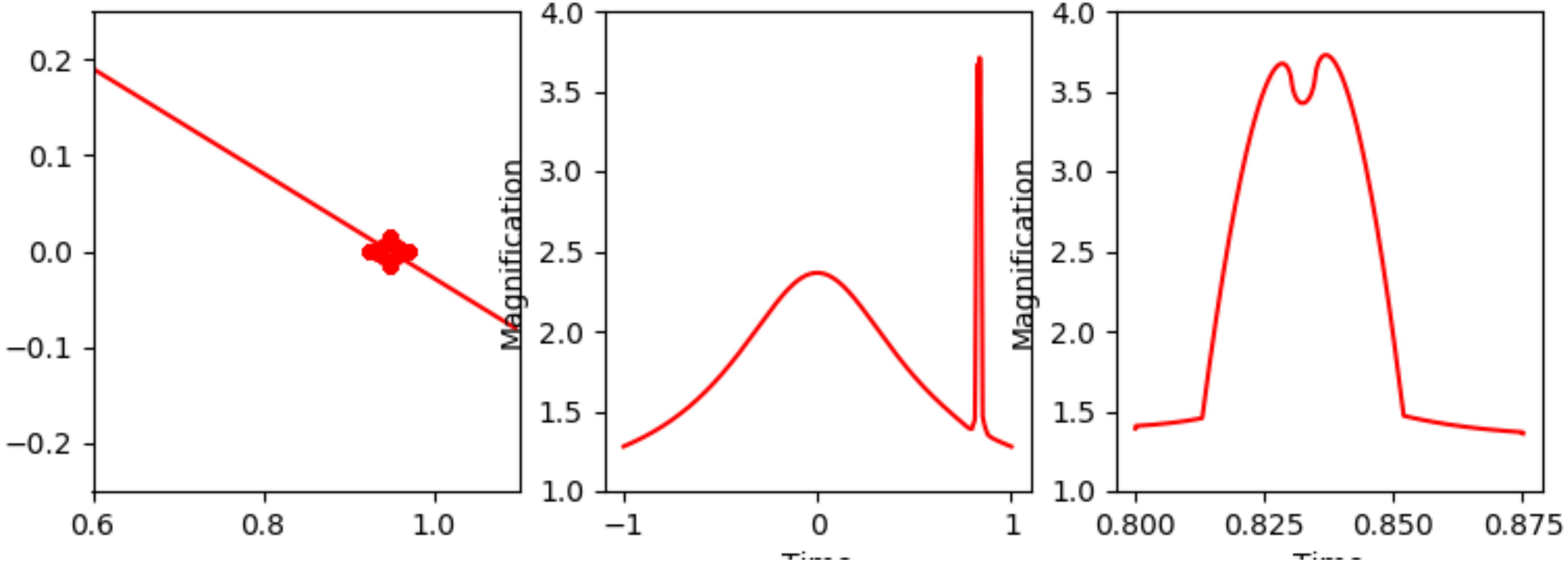


$$\text{magnification} = A(\boldsymbol{u}) = \frac{1}{|\det J|}$$

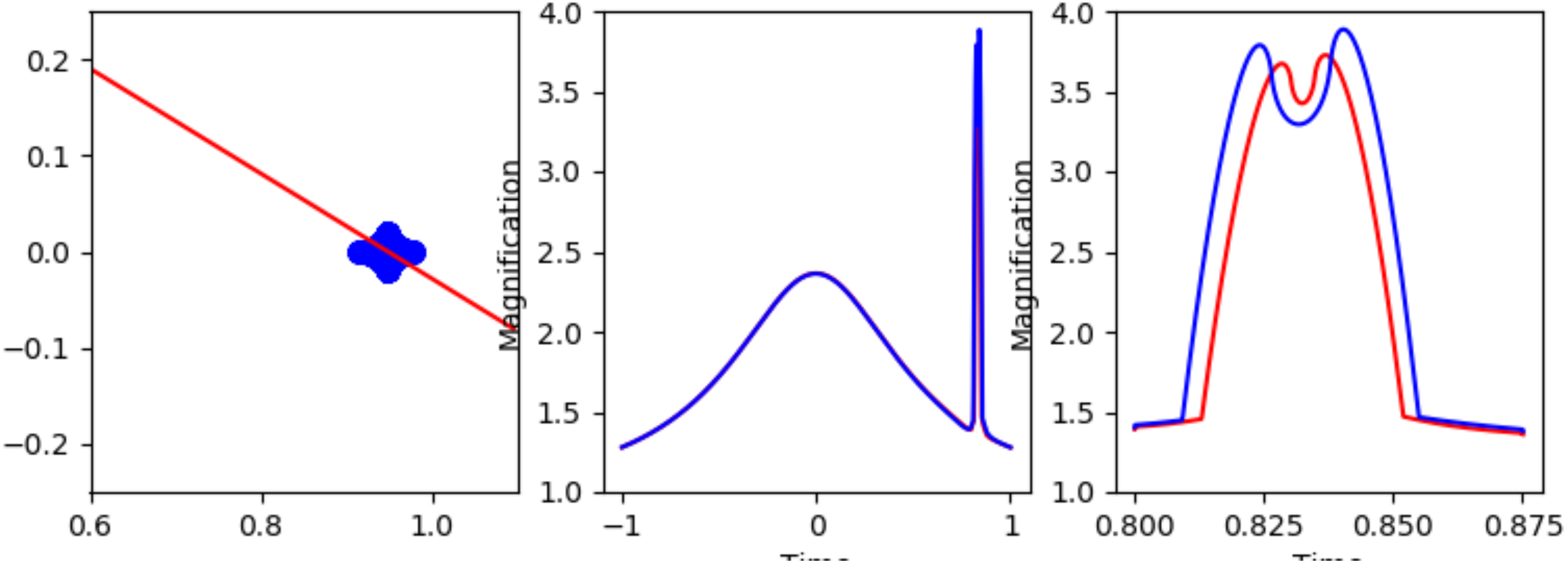
# s, q affect the topology of the caustic



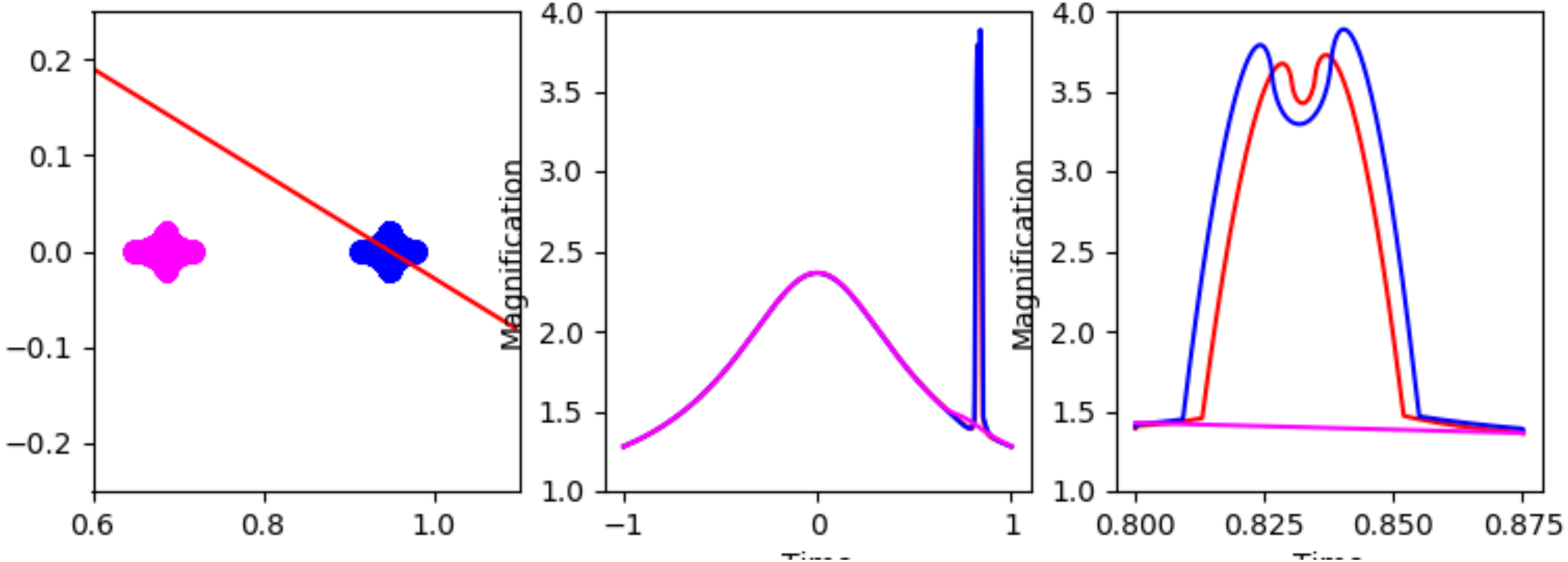
# How do (s, q, alpha) affect the light curve?



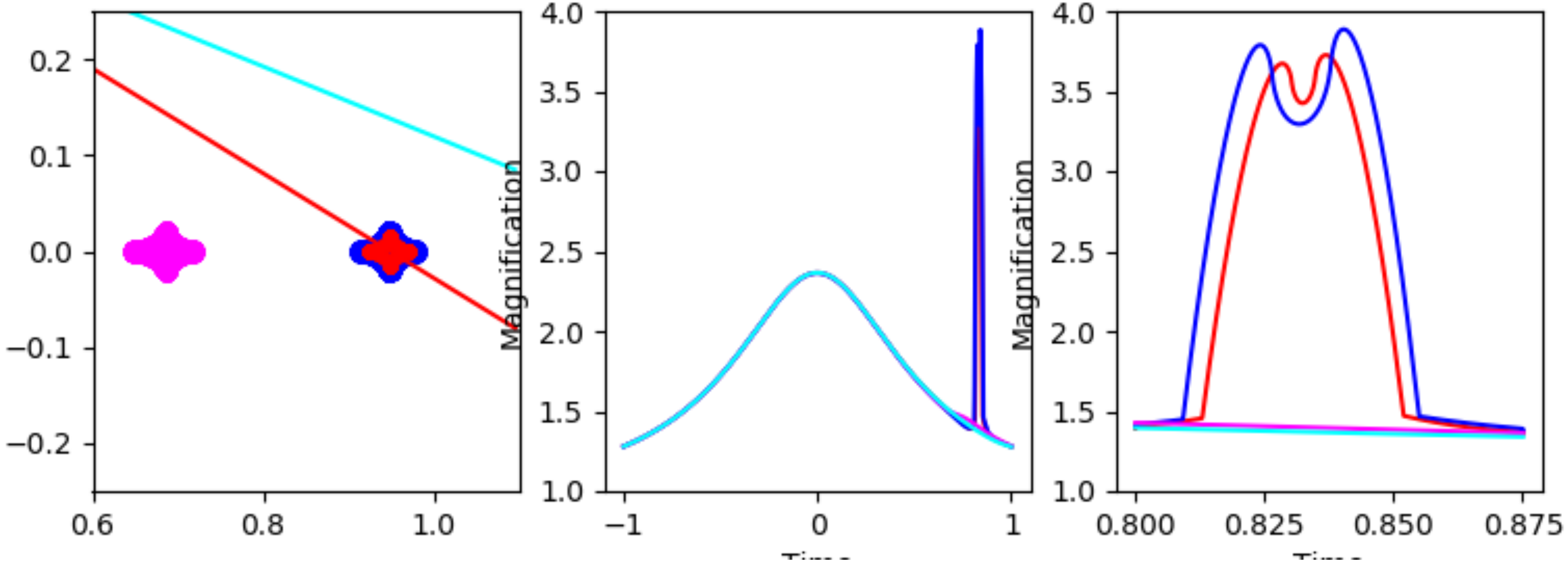
# Bigger q = bigger caustic = bigger signal



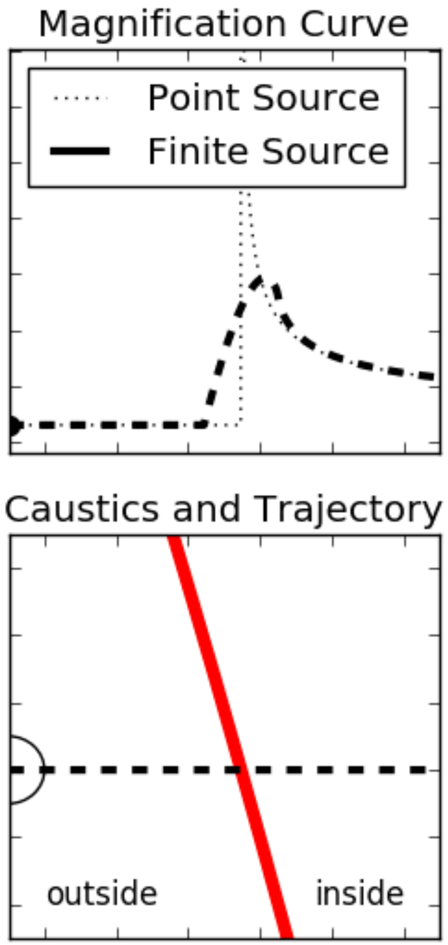
# Smaller s moves the caustic → no signal



# Larger alpha moves source path → no signal



# rho = source size → integrated magnification



$f_{\text{source}}$, $f_{\text{blend}}$ = The flux parameters

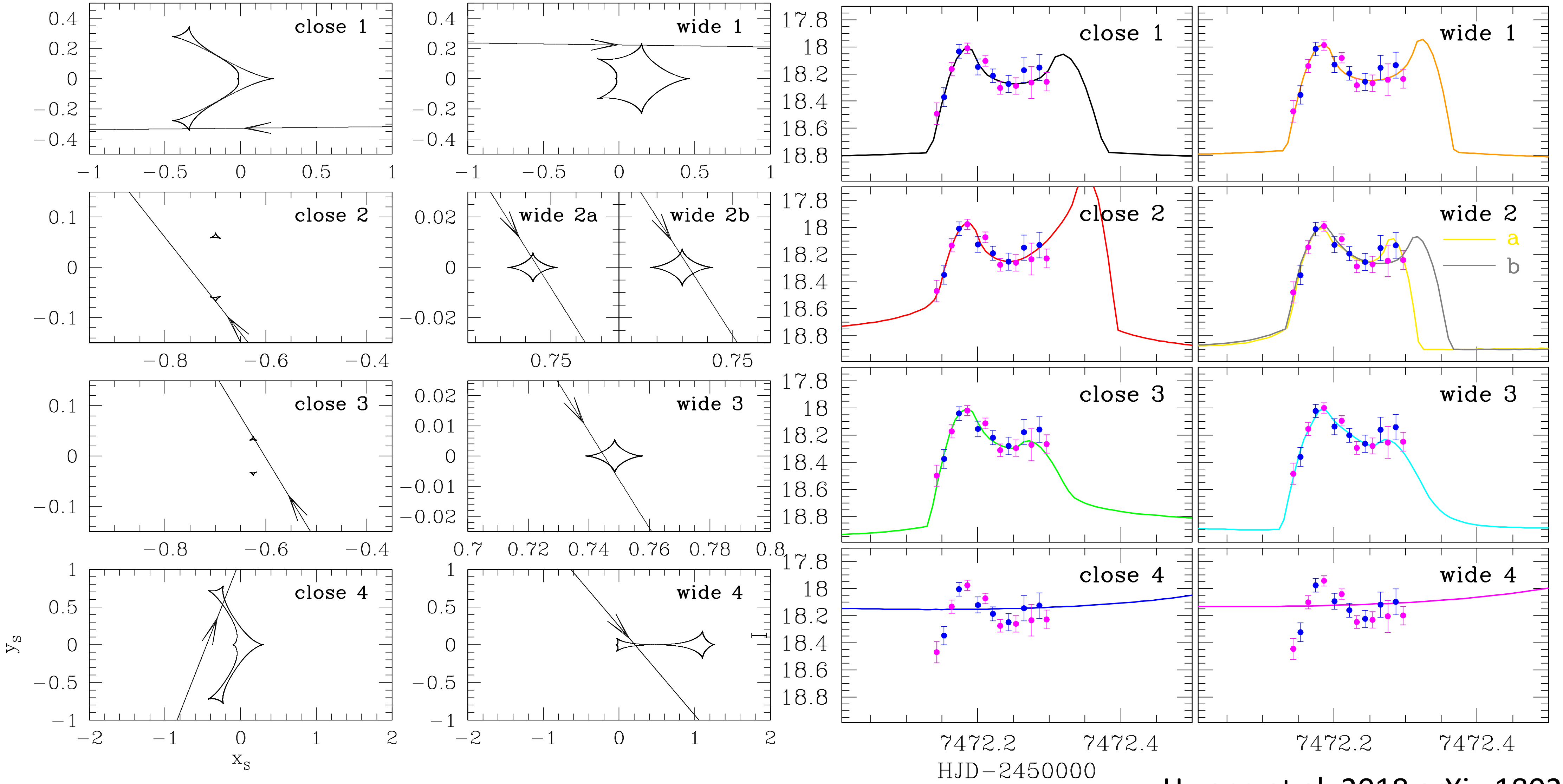
$$f_{\text{observed}} = f_{\text{source}}\, A(t) + f_{\text{blend}}$$

$$W149_{\text{observed}} = 18 - 2.5\ \log_{10}(f_{\text{observed}})$$

# Other Physics

- Parallax = non-inertial observer frame, e.g. the Earth accelerates (pi_E_N, pi_E_E)
- Lens motion = two gravitationally bound bodies orbit each other (ds_dt, dalpha_dt)
- Multiple source stars
  - 2 luminous sources
  - Orbital motion of the source

# Finding the Global Minimum: Multiple Minima




Hwang et al. 2018 arXiv:1802.10246

Given the complexity of the likelihood space, what are the best techniques for finding the global minimum?

# Resources

- Data Challenge Website: http://microlensing-source.org/data-challenge-guidelines/
- Codes for Generating Microlensing Models:
  - MulensModel: https://github.com/rpoleski/MulensModel
  - pyLIMA: https://github.com/ebachelet/pyLIMA
- Background on Microlensing:
  - Website: http://microlensing-source.org/
  - Review Articles:
    - Gaudi 2010 in Exoplanets edited by S. Seager
    - Gaudi 2012, ARA&A, 50, 411
    - Yee 2014 Section 7 of Exoplanet Detection Techniques in Protostars and Planets VI, ed. Beuther, Klessen, Dullemond, and Henning
  - Mathematics:
    - Schnieder & Weiss 1986, A&A, 164, 237
    - Dominik 1999, A&A, 349, 108