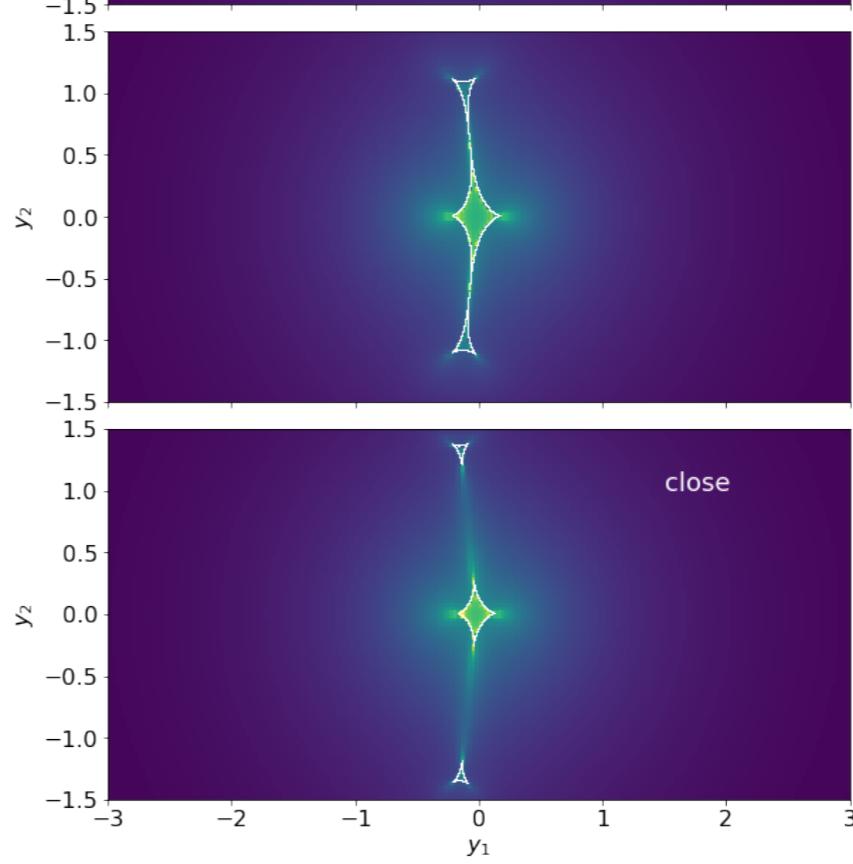
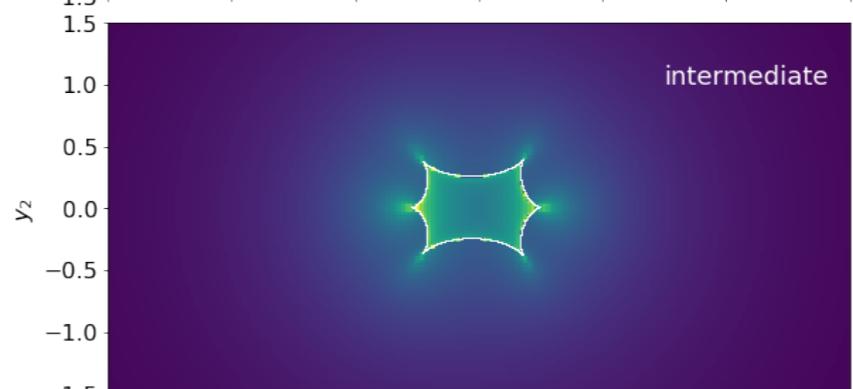
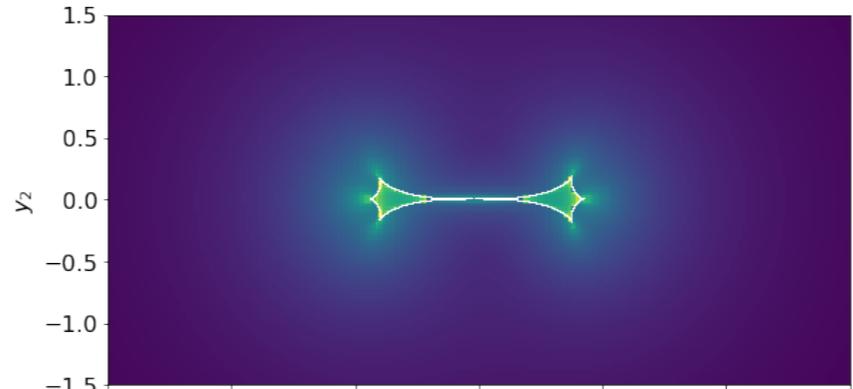
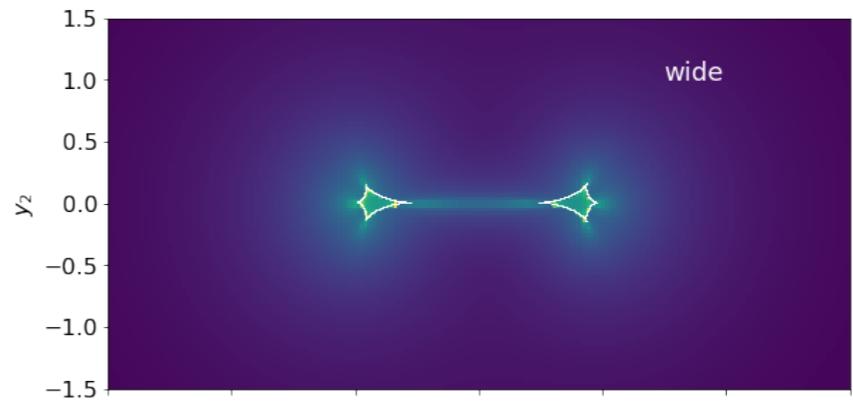
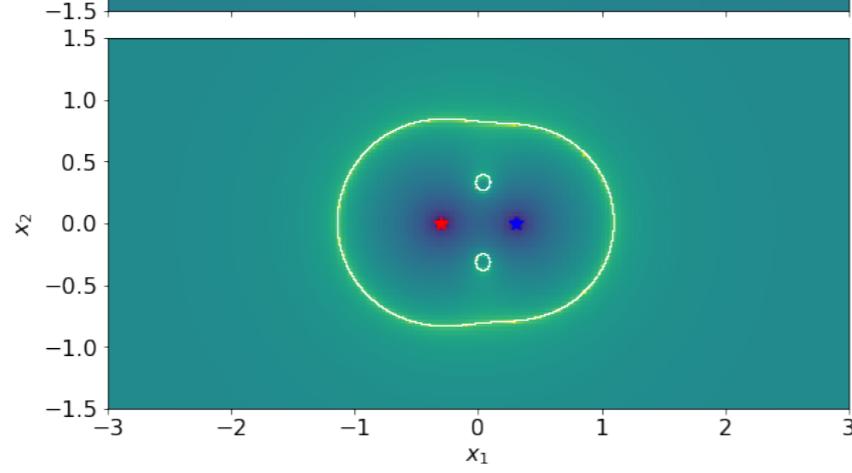
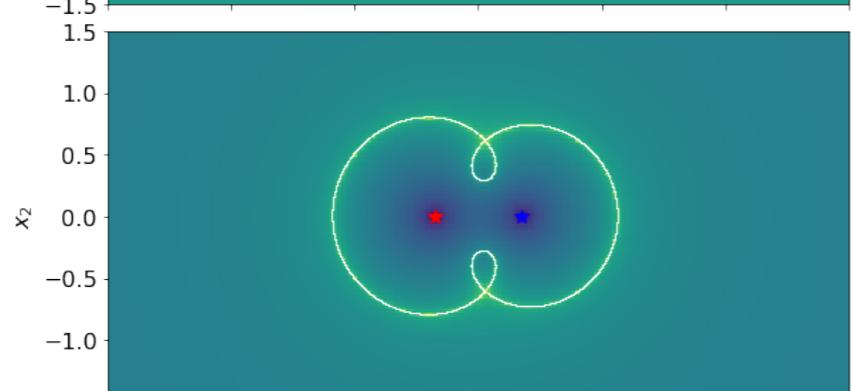
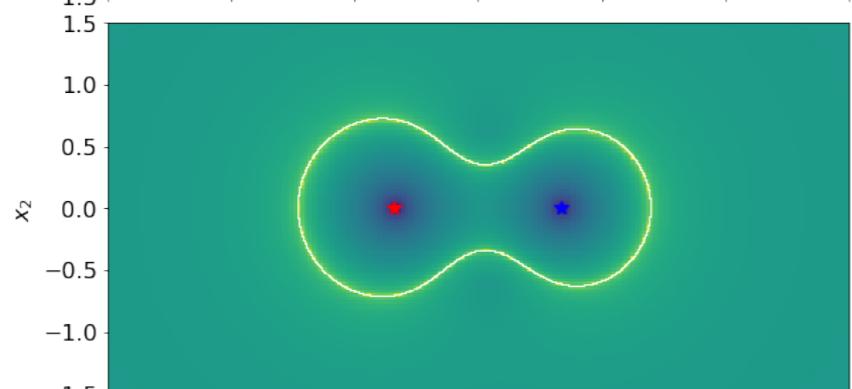
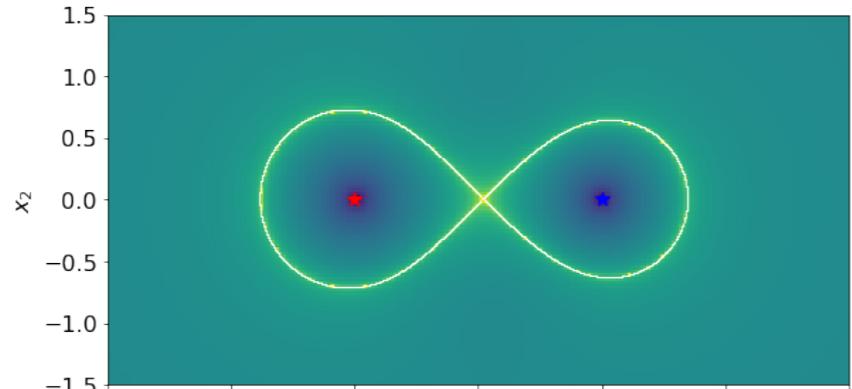
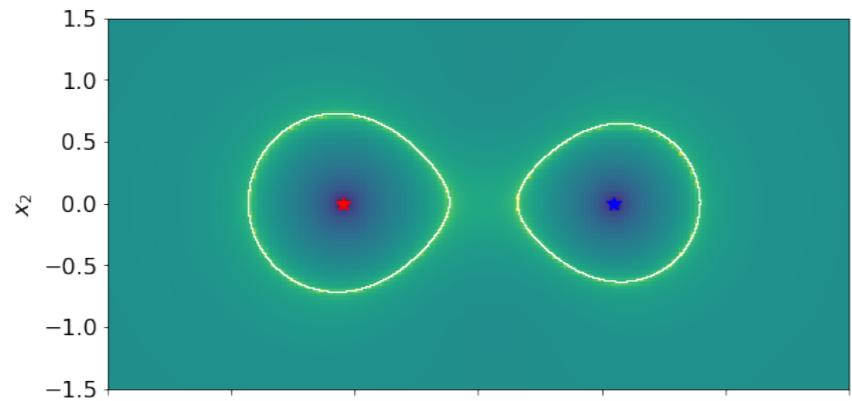


# GRAVITATIONAL LENSING

## 14 - PLANETARY MICROLENSING

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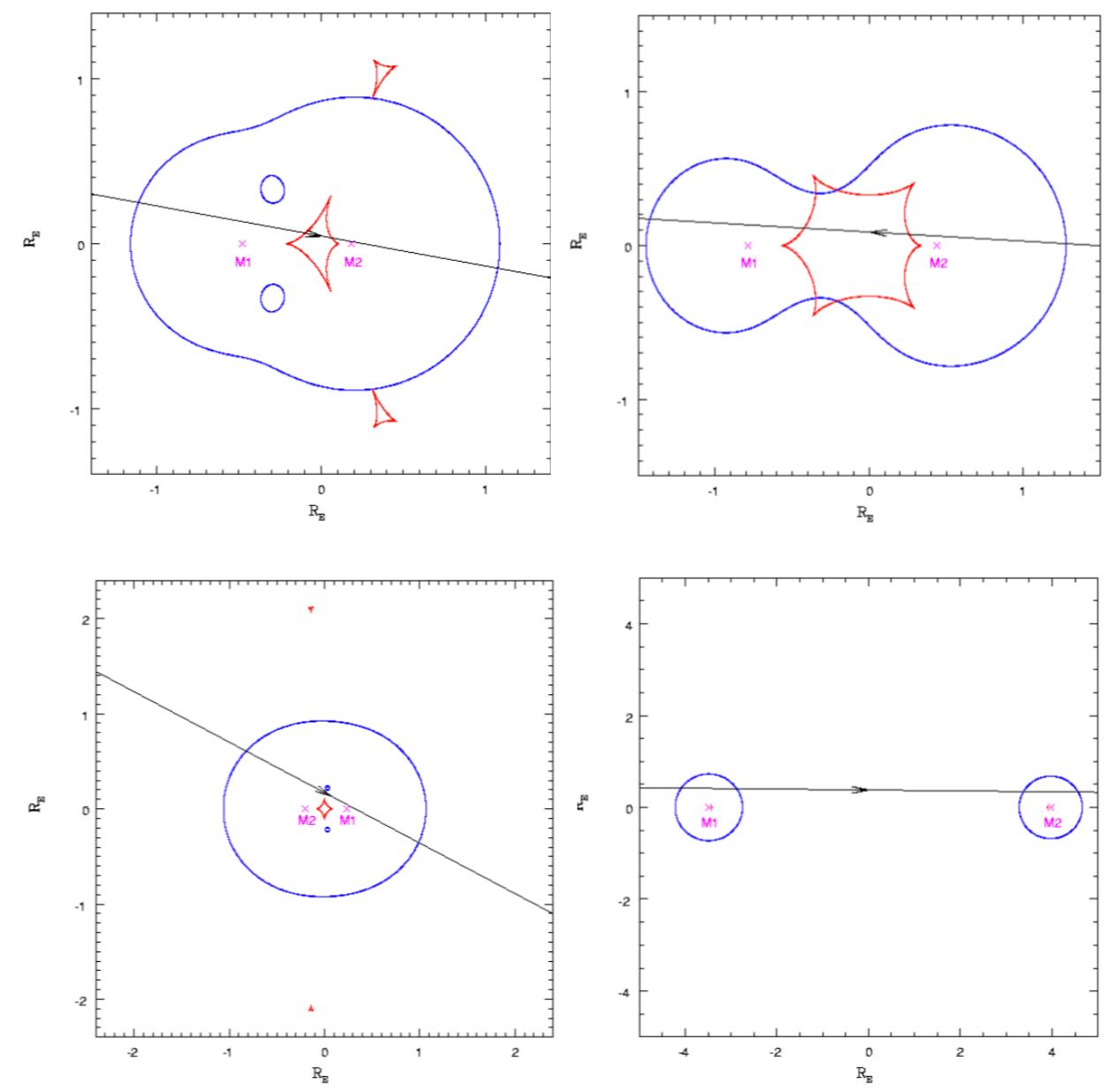
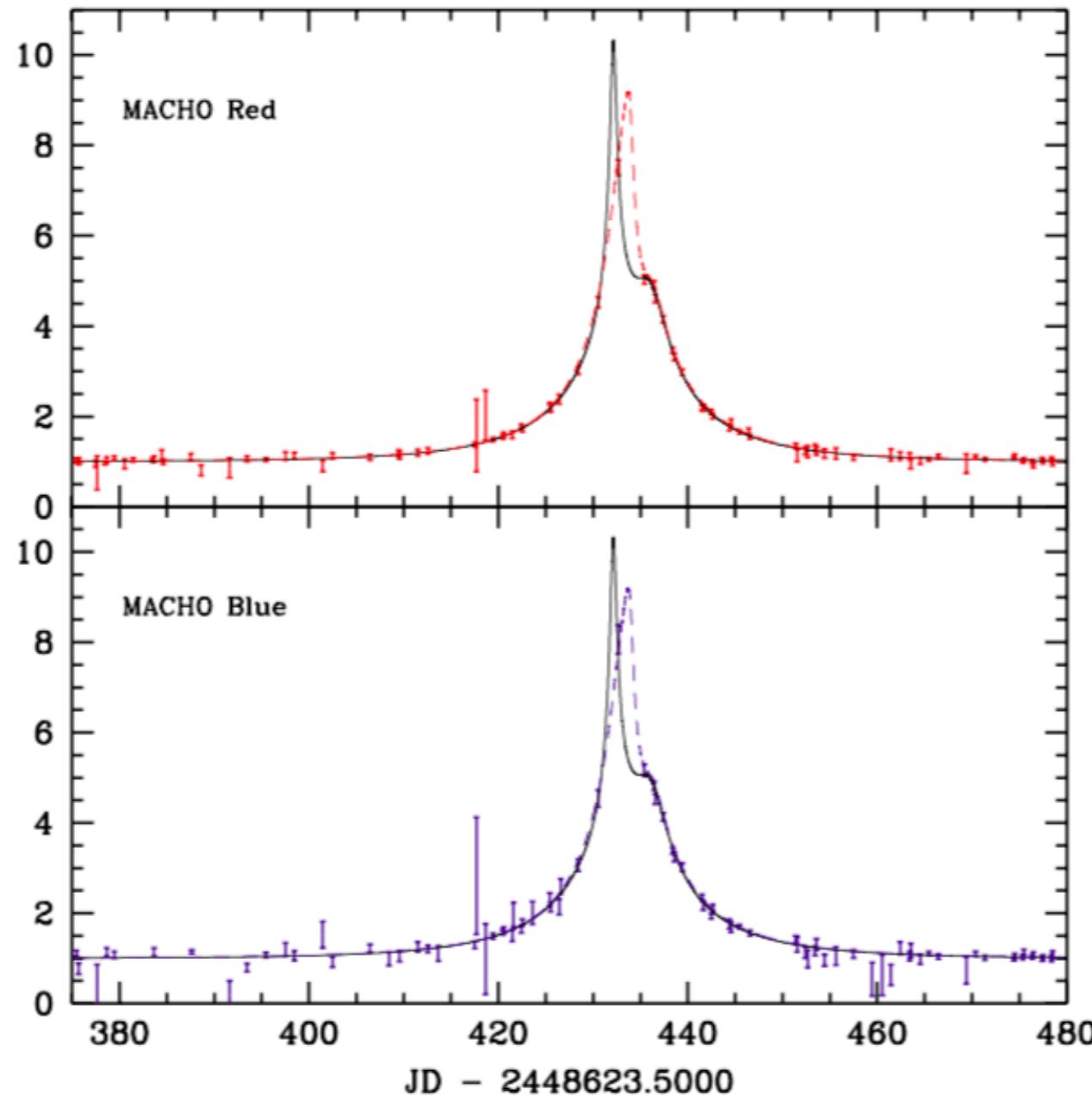
*Massimo Meneghetti*  
AA 2017-2018



# QUIZ

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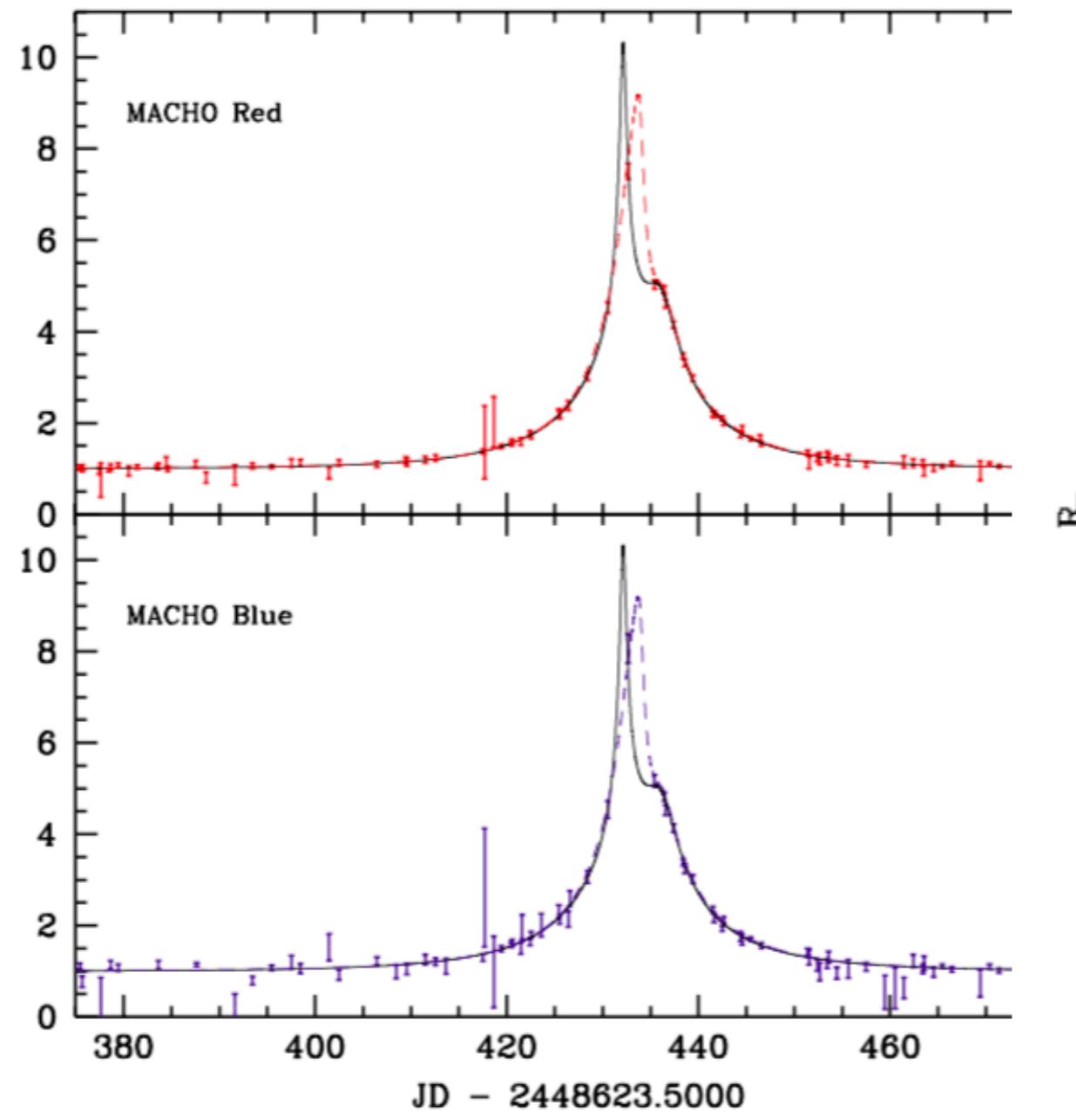
Source Magnification



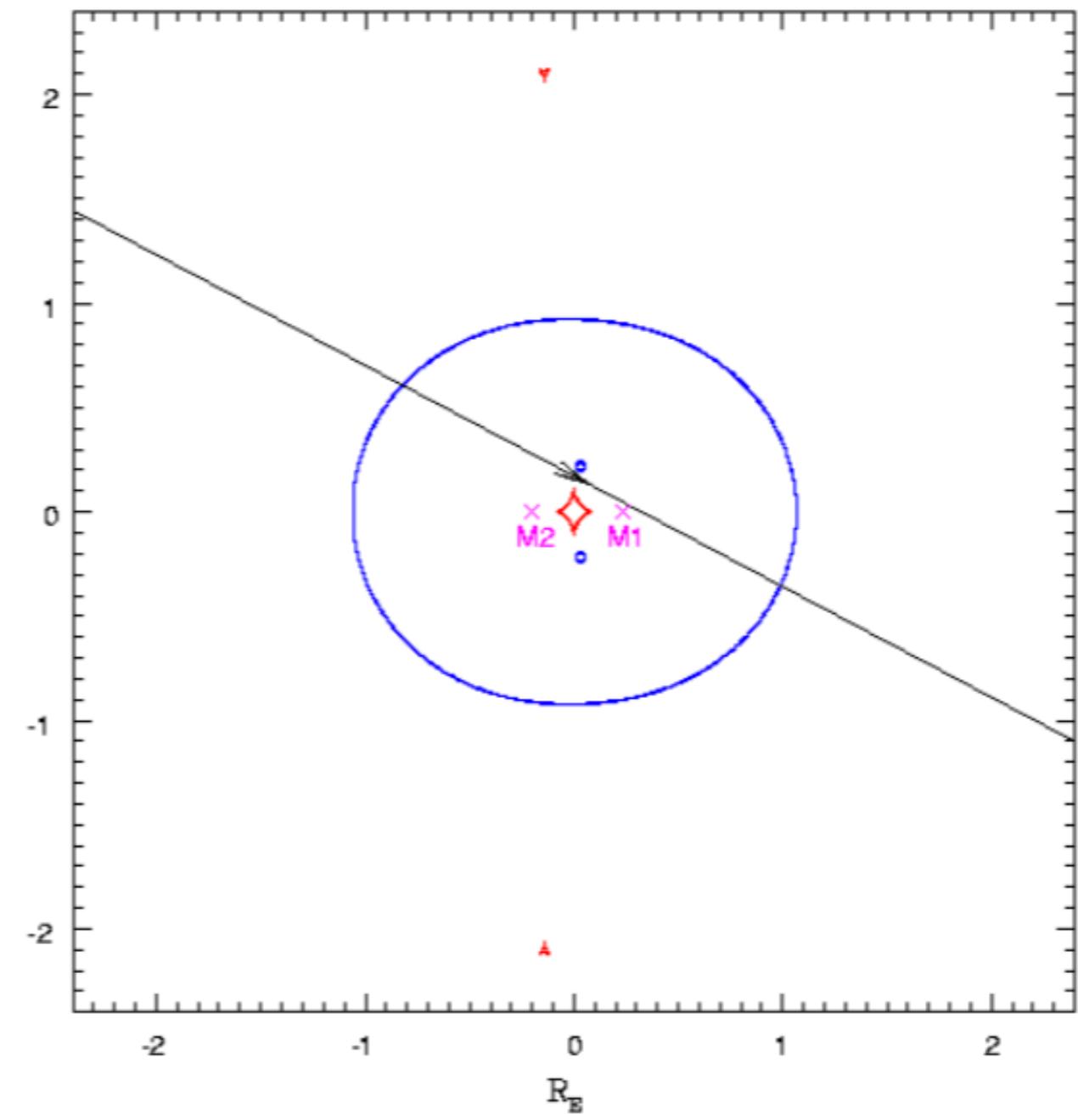
# QUIZ

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Source Magnification



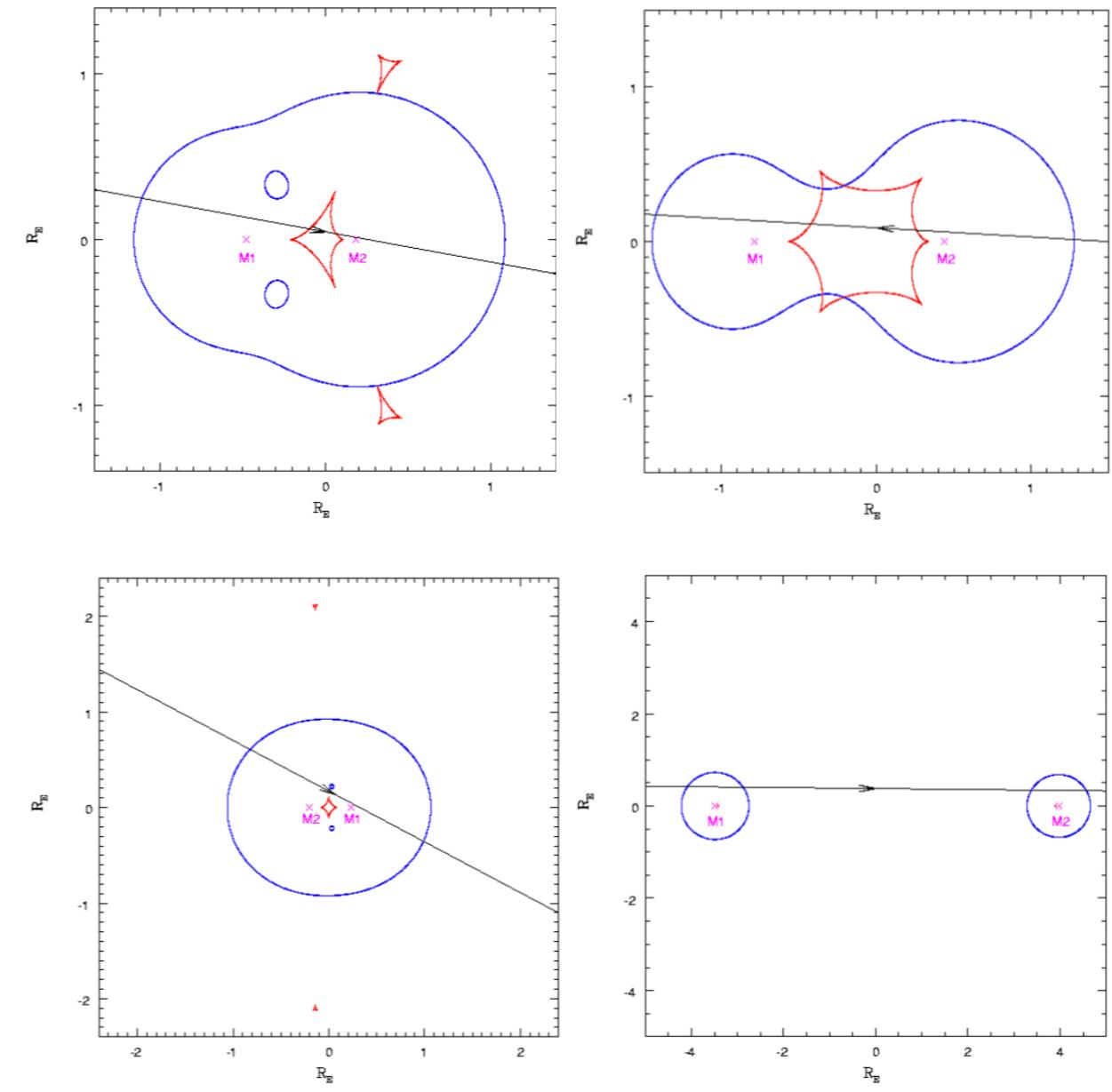
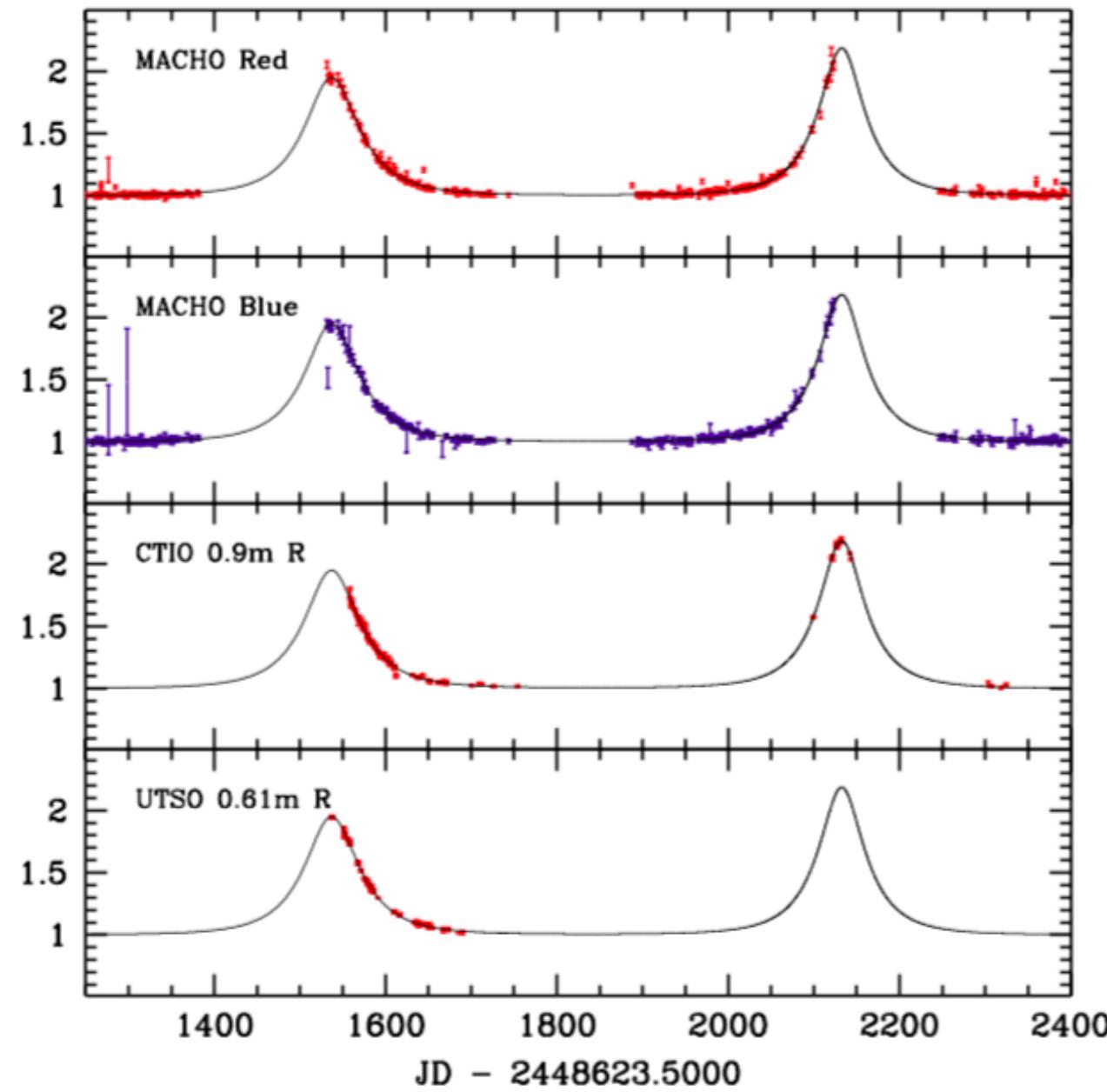
$R_E$



$R_E$

# QUIZ

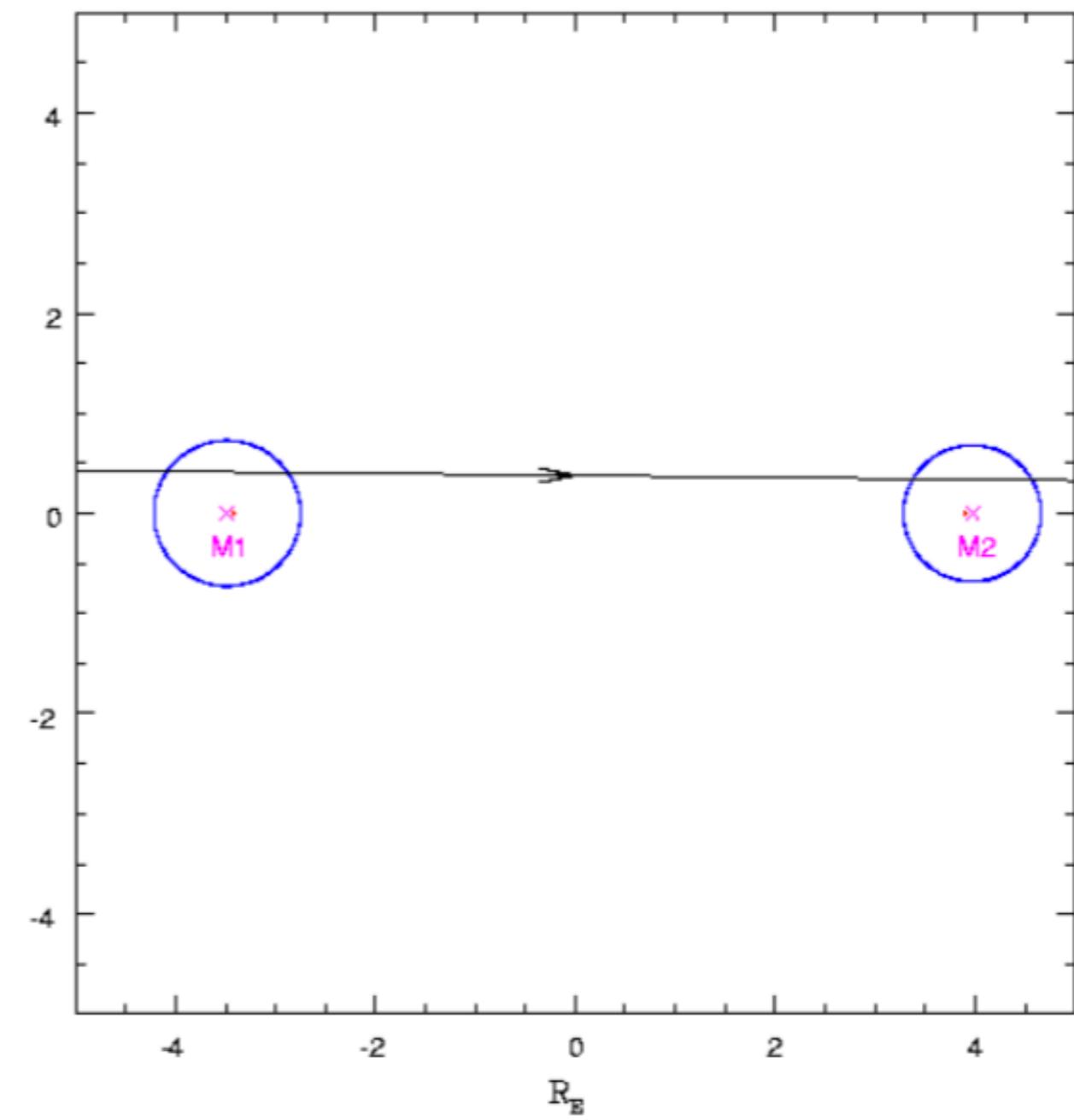
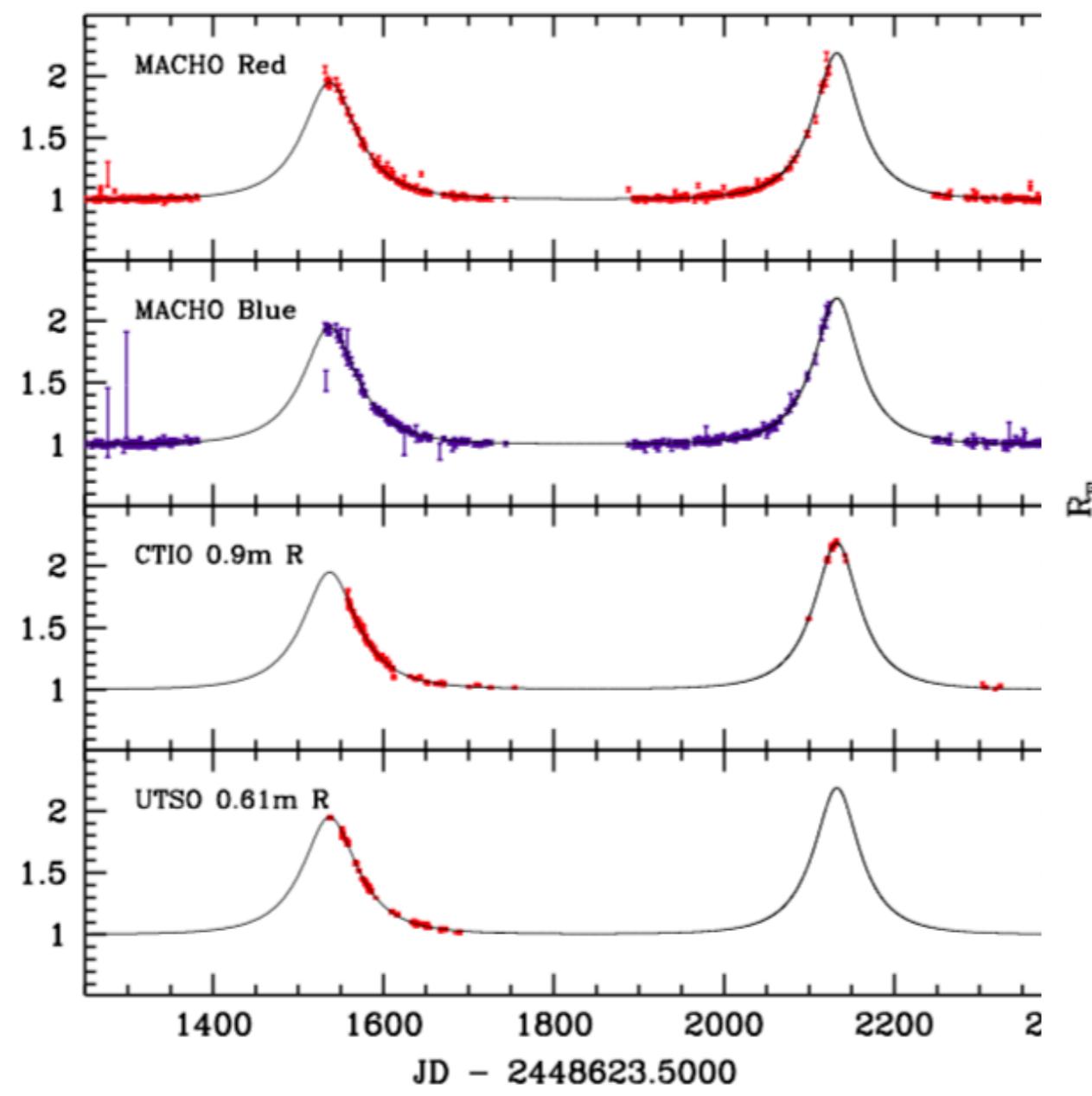
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# QUIZ

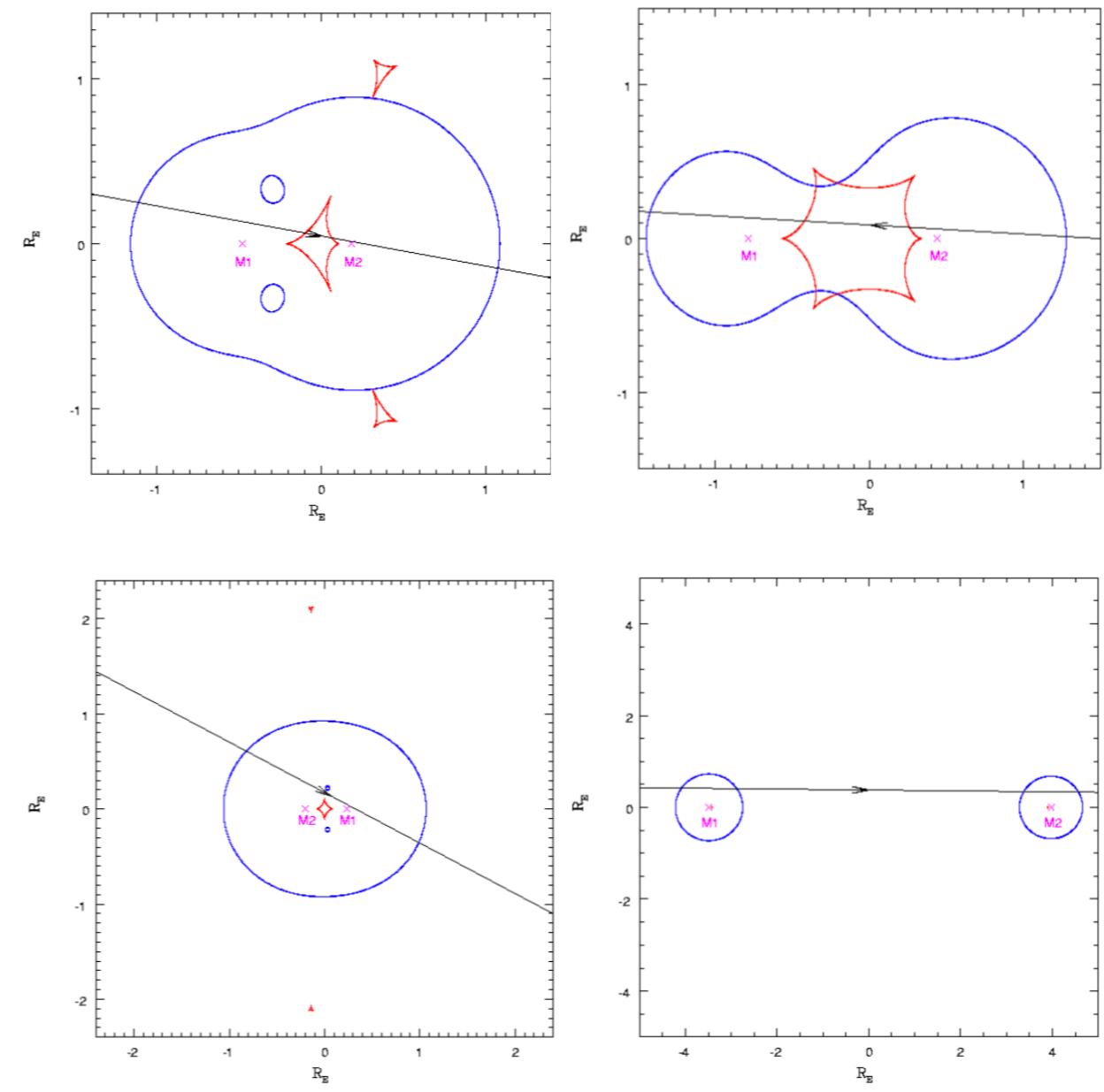
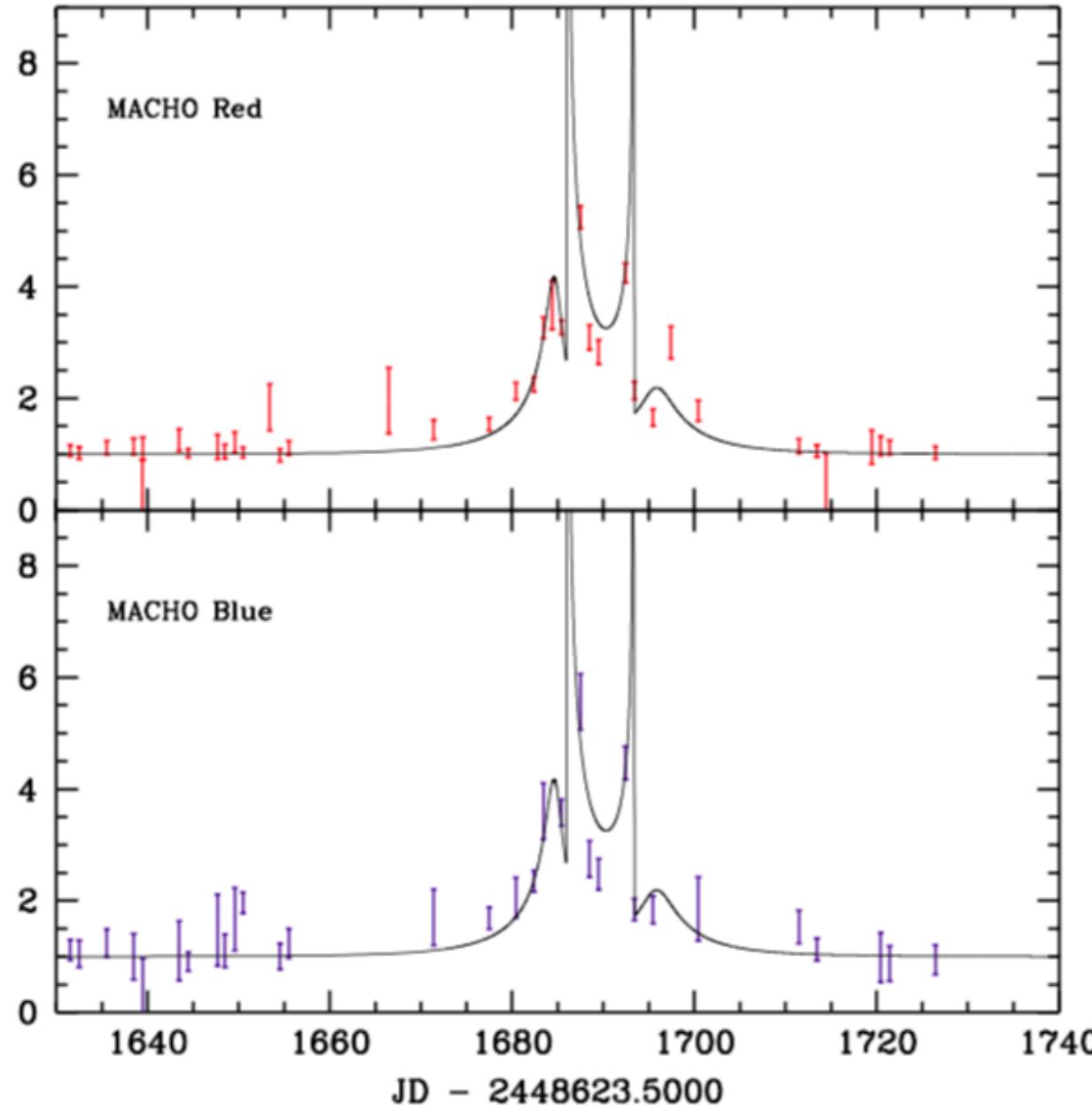
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Source Magnification



# QUIZ

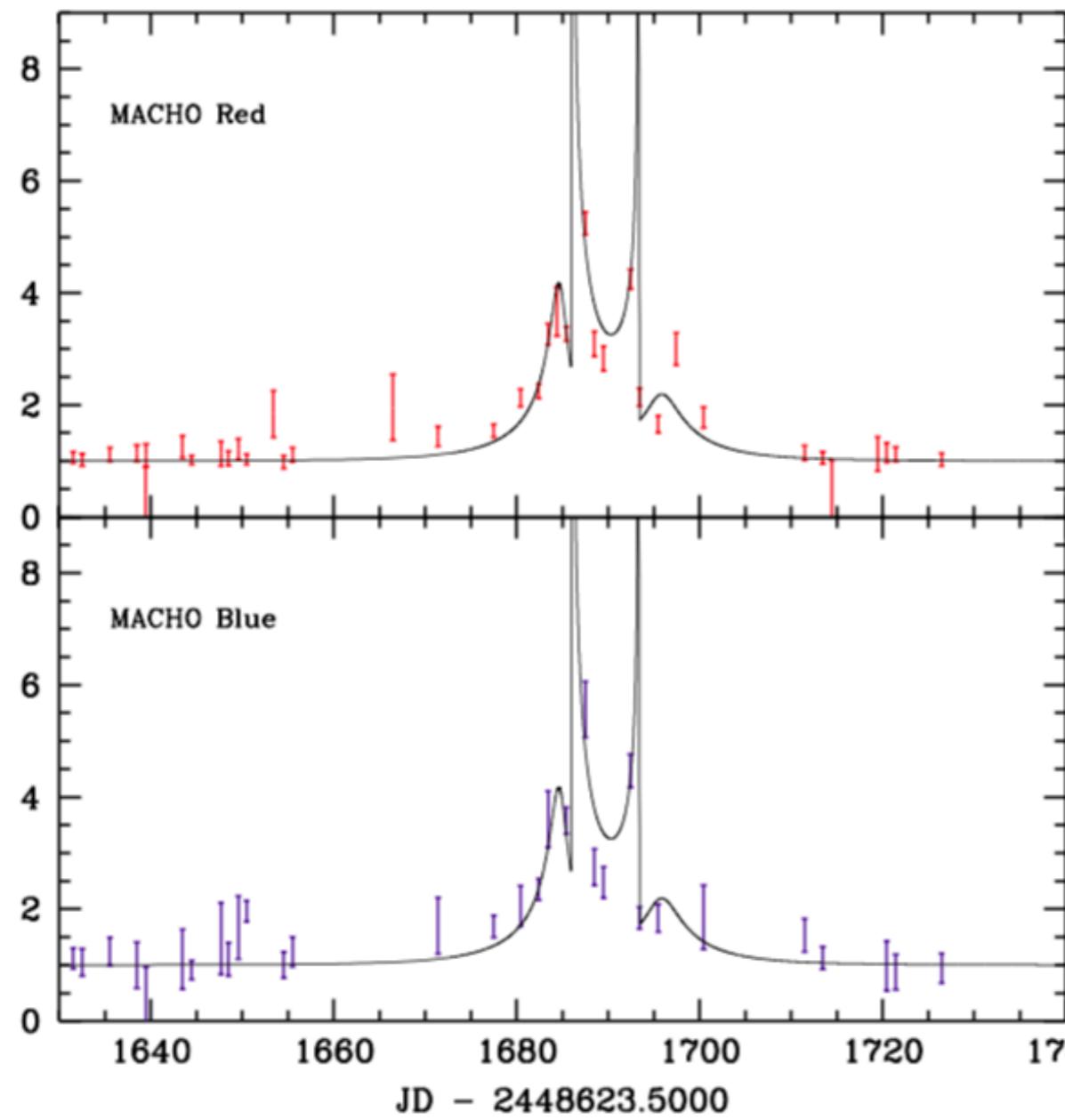
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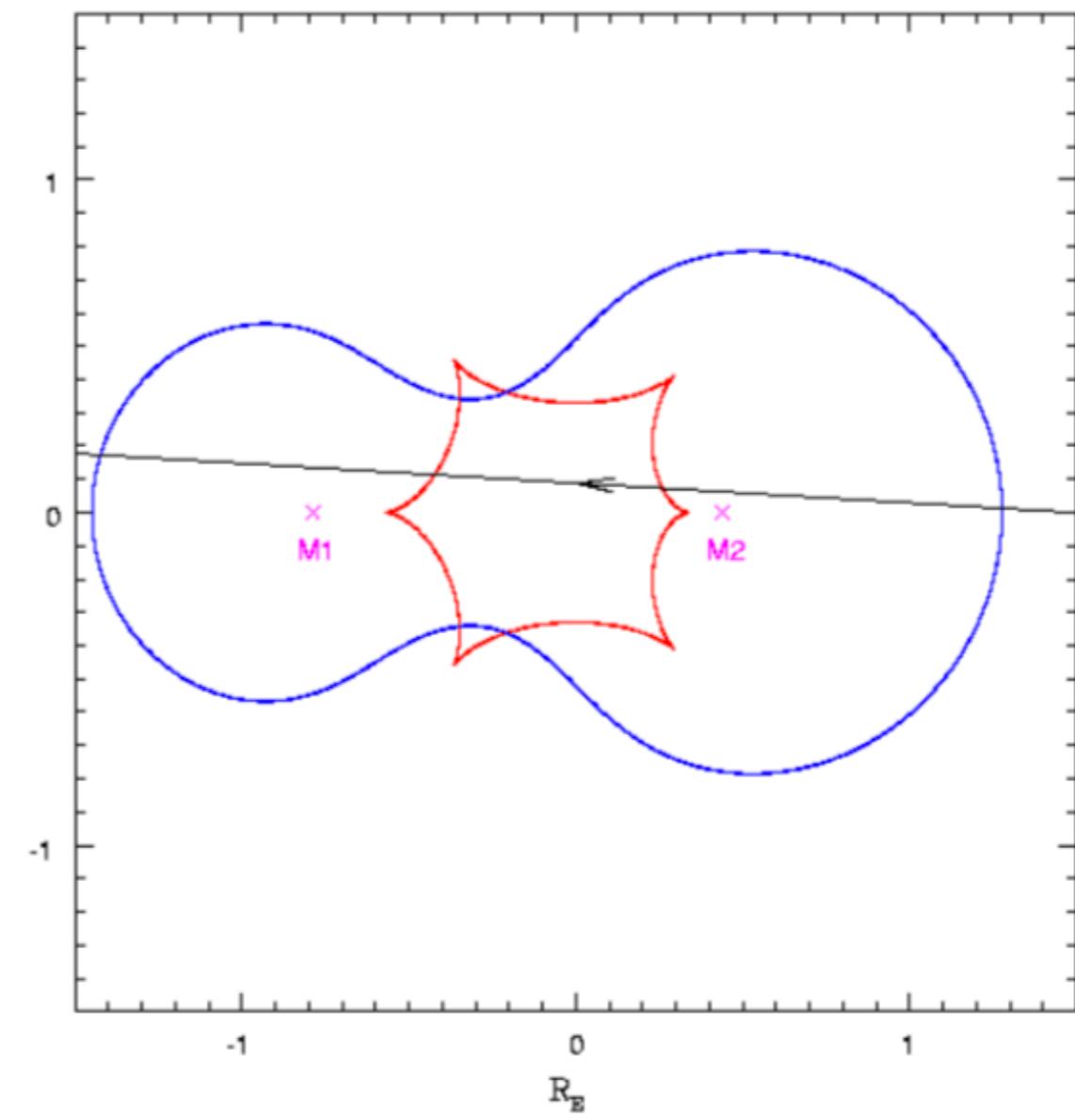
# QUIZ

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Source Magnification

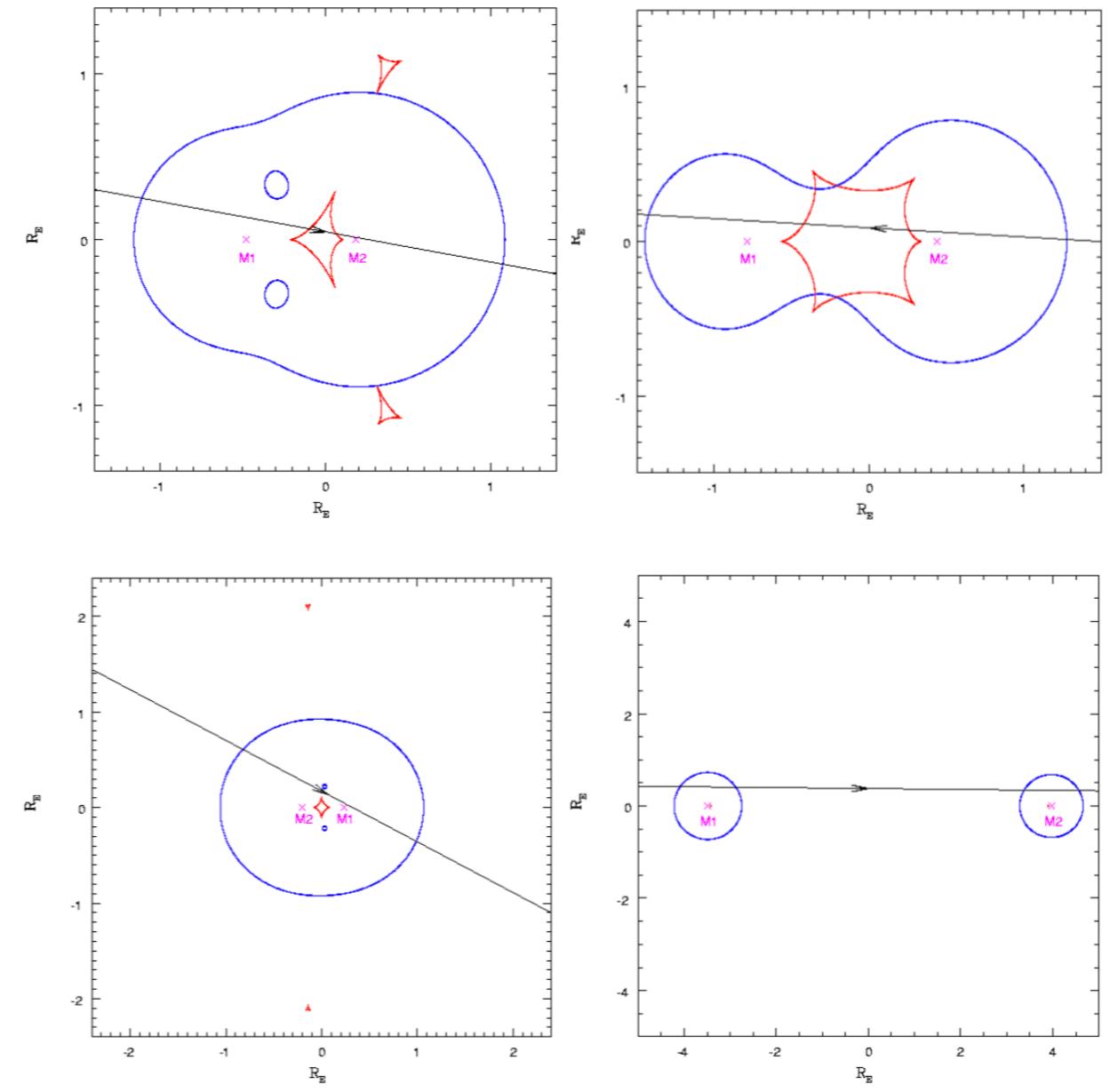
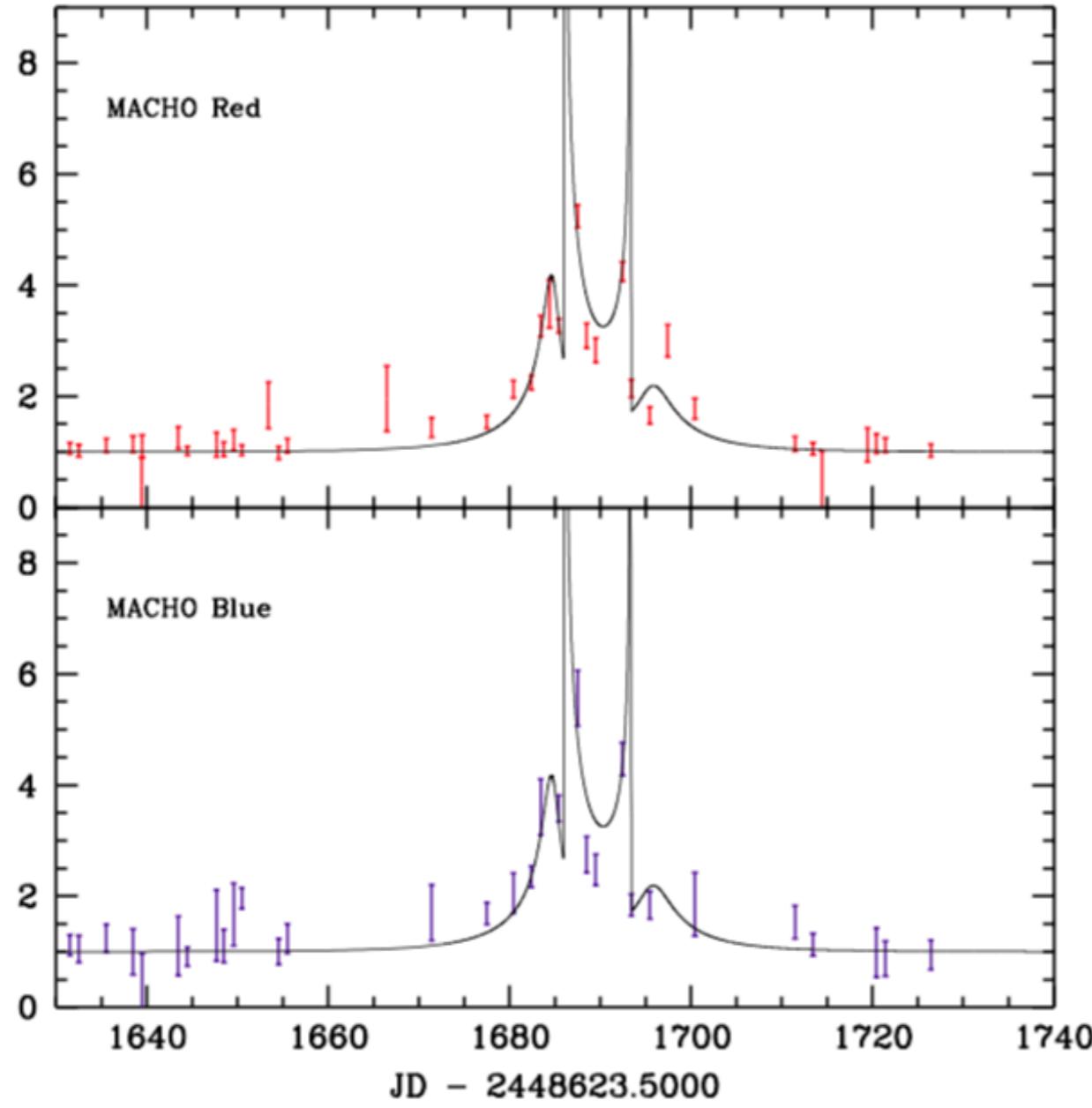


$R_E$



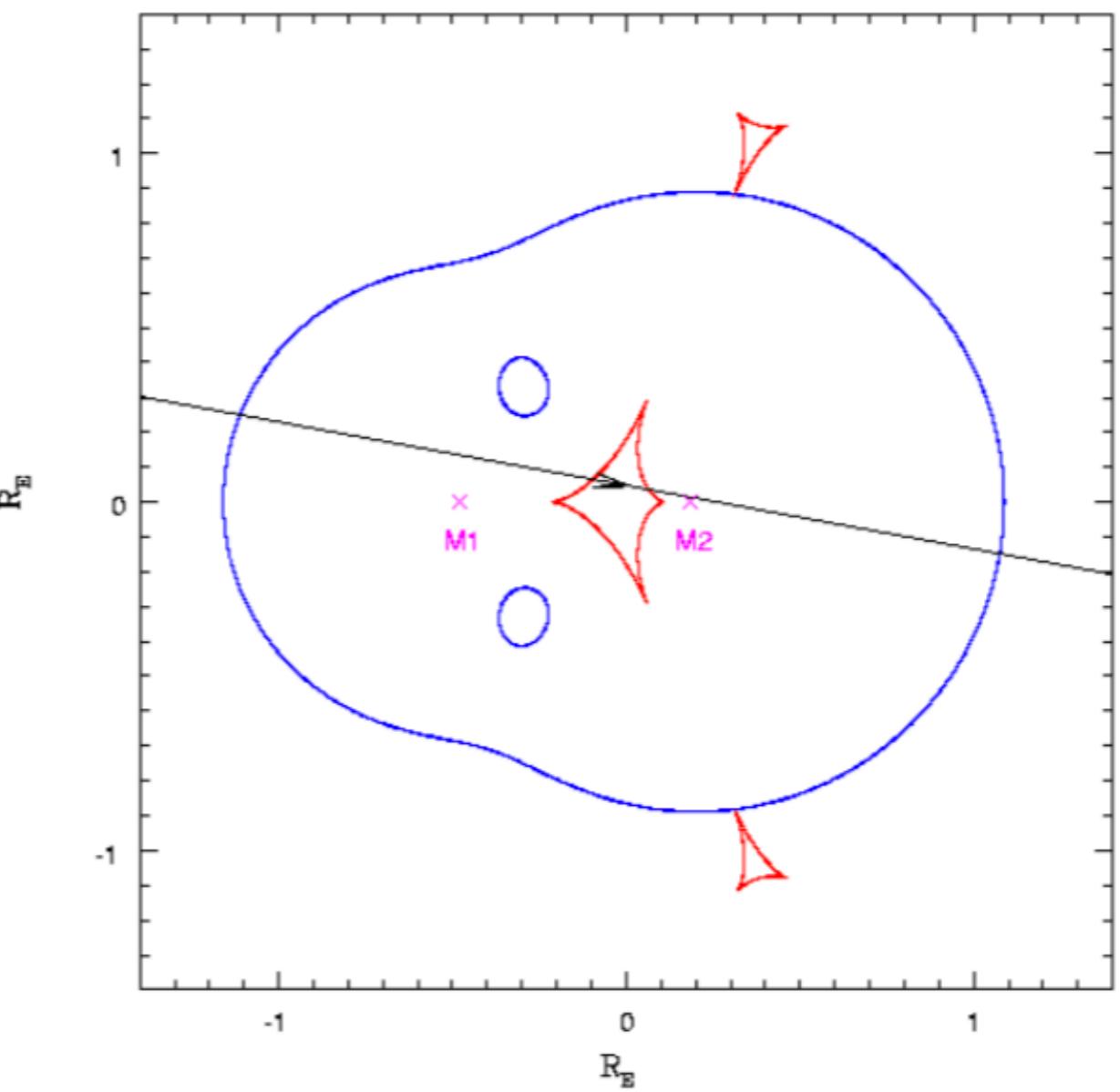
# QUIZ

Source Magnification



# QUIZ

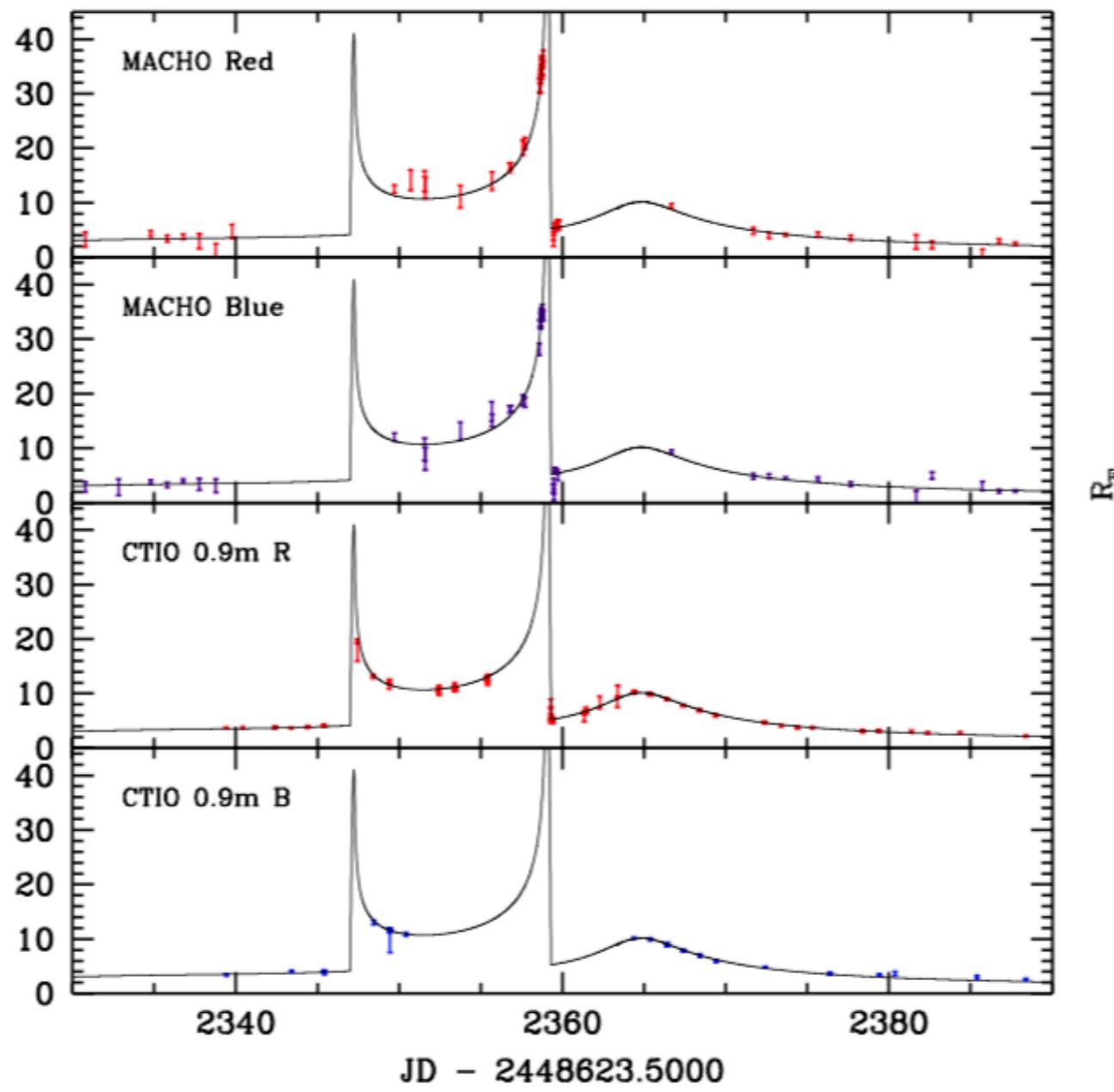
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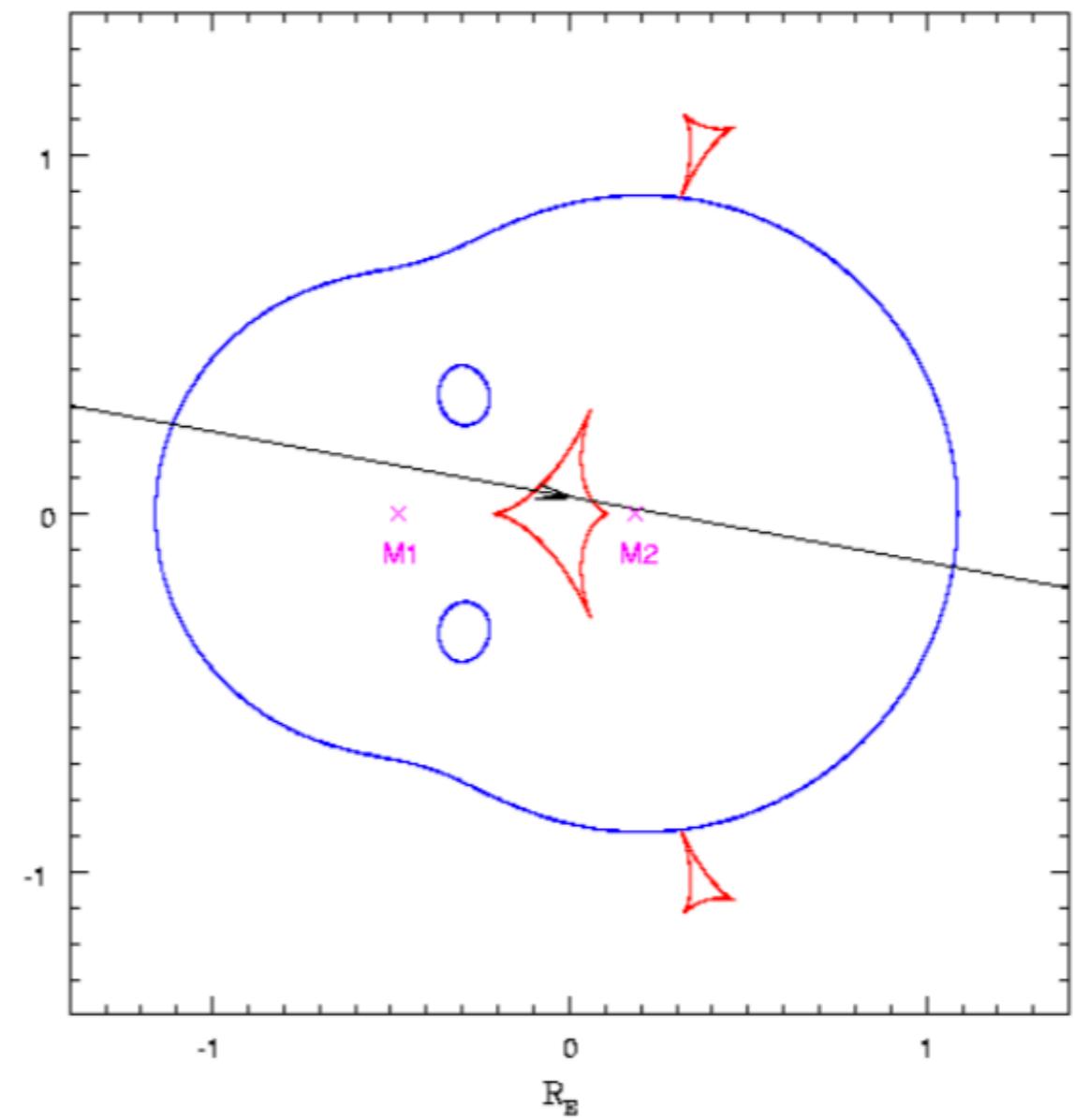
# QUIZ

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Source Magnification



$R_E$



# PLANETARY MICROLENSING

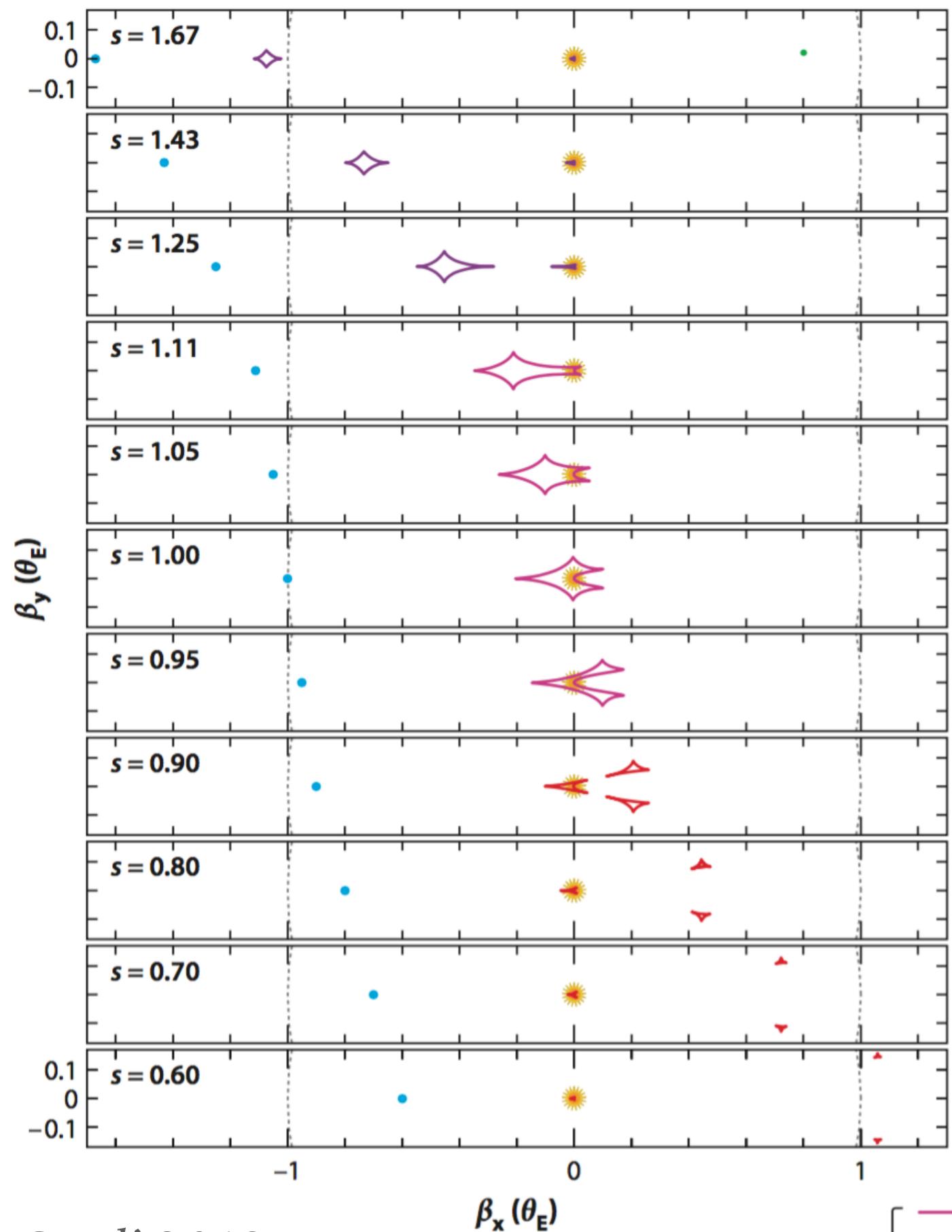
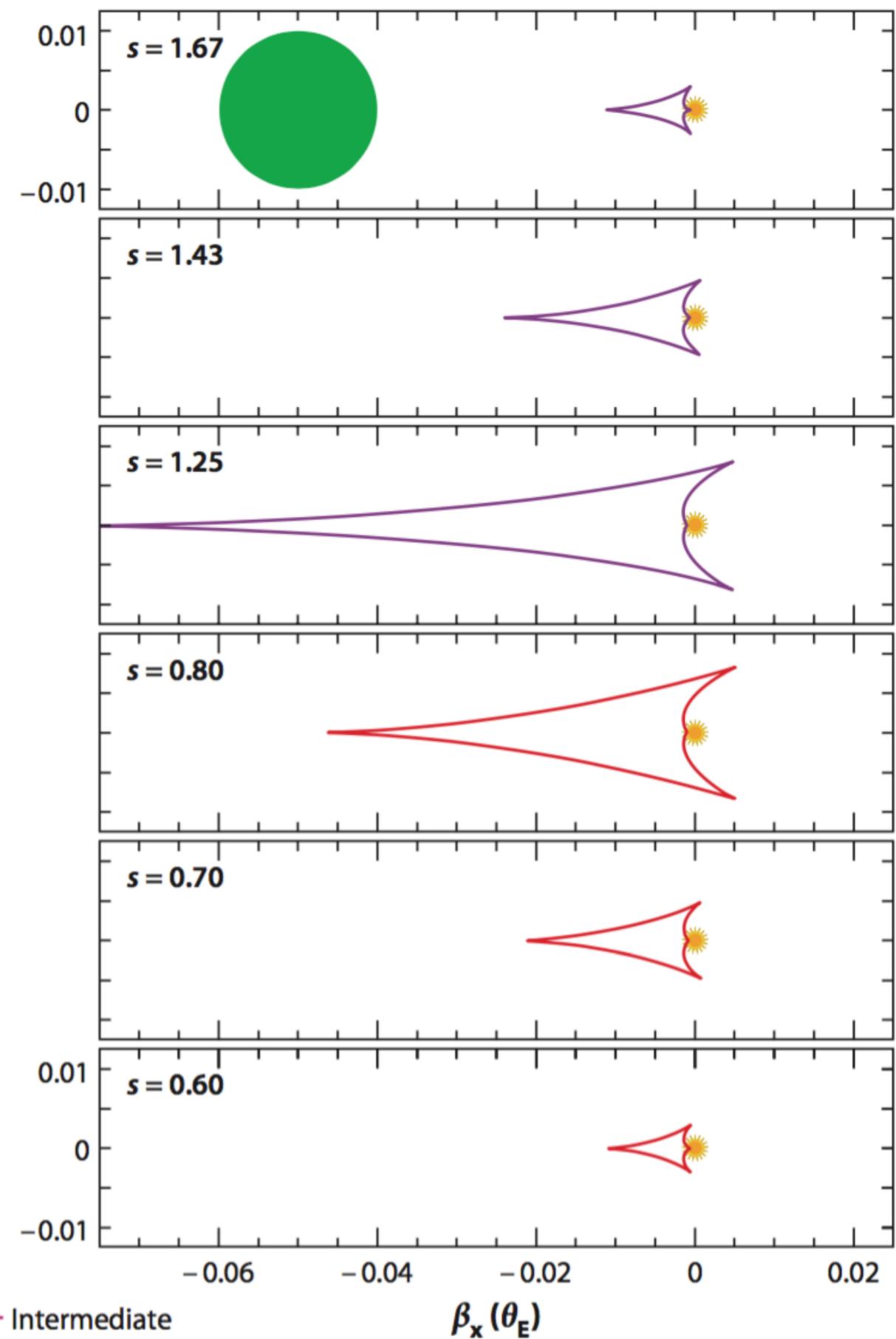
---

- Let us consider the system consisting of an host star and a planet orbiting around it.
- This is an example of **binary** lens
- The host star is of course much heavier than the planet!
  - example: for a Jupiter-like planet  $q=0.001$  (solar mass star)
  - example: for a Earth-like planet  $q=0.000003$

# WHAT KIND OF SIGNAL?

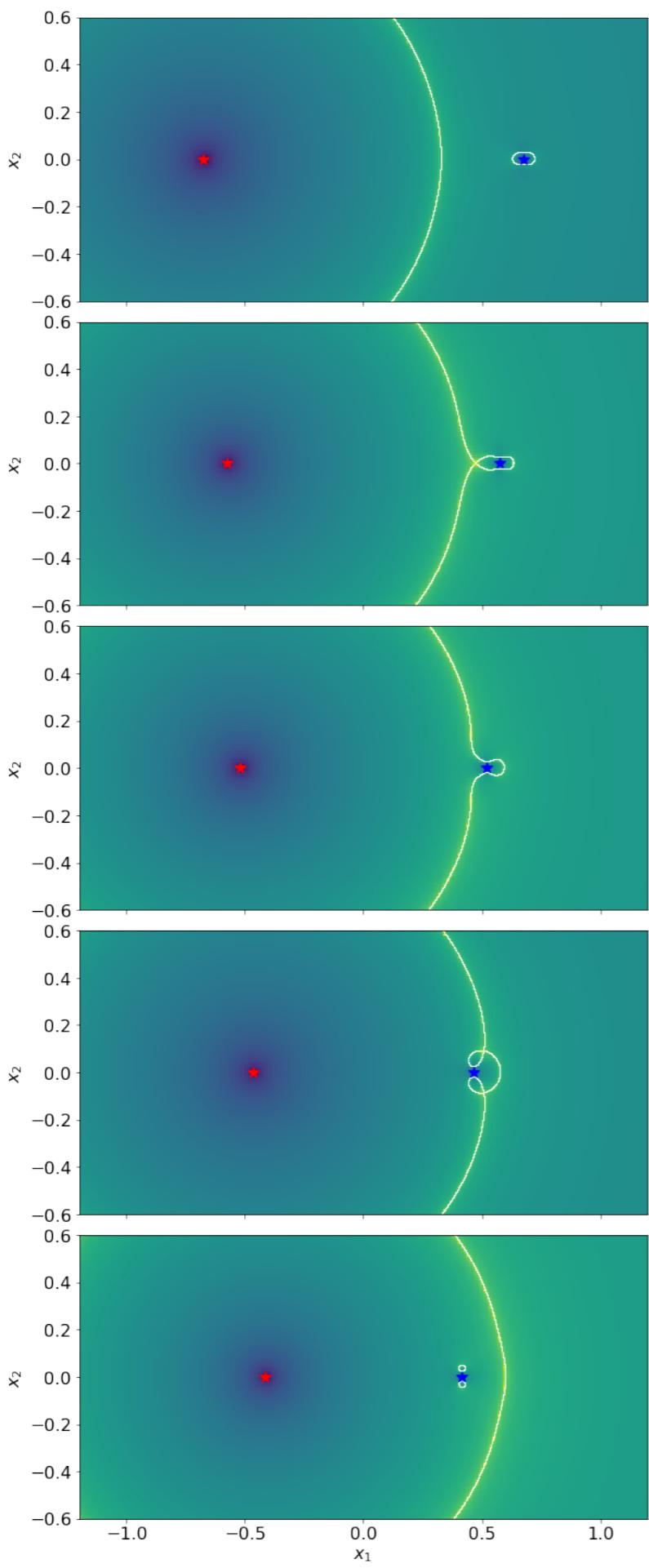
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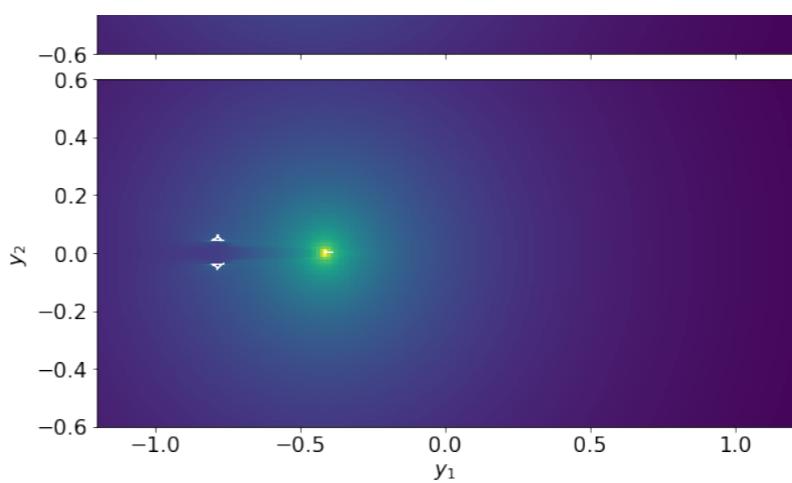
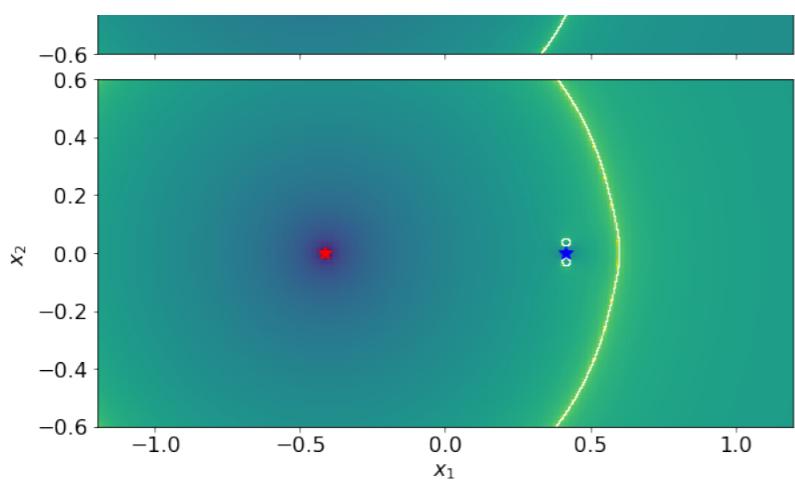
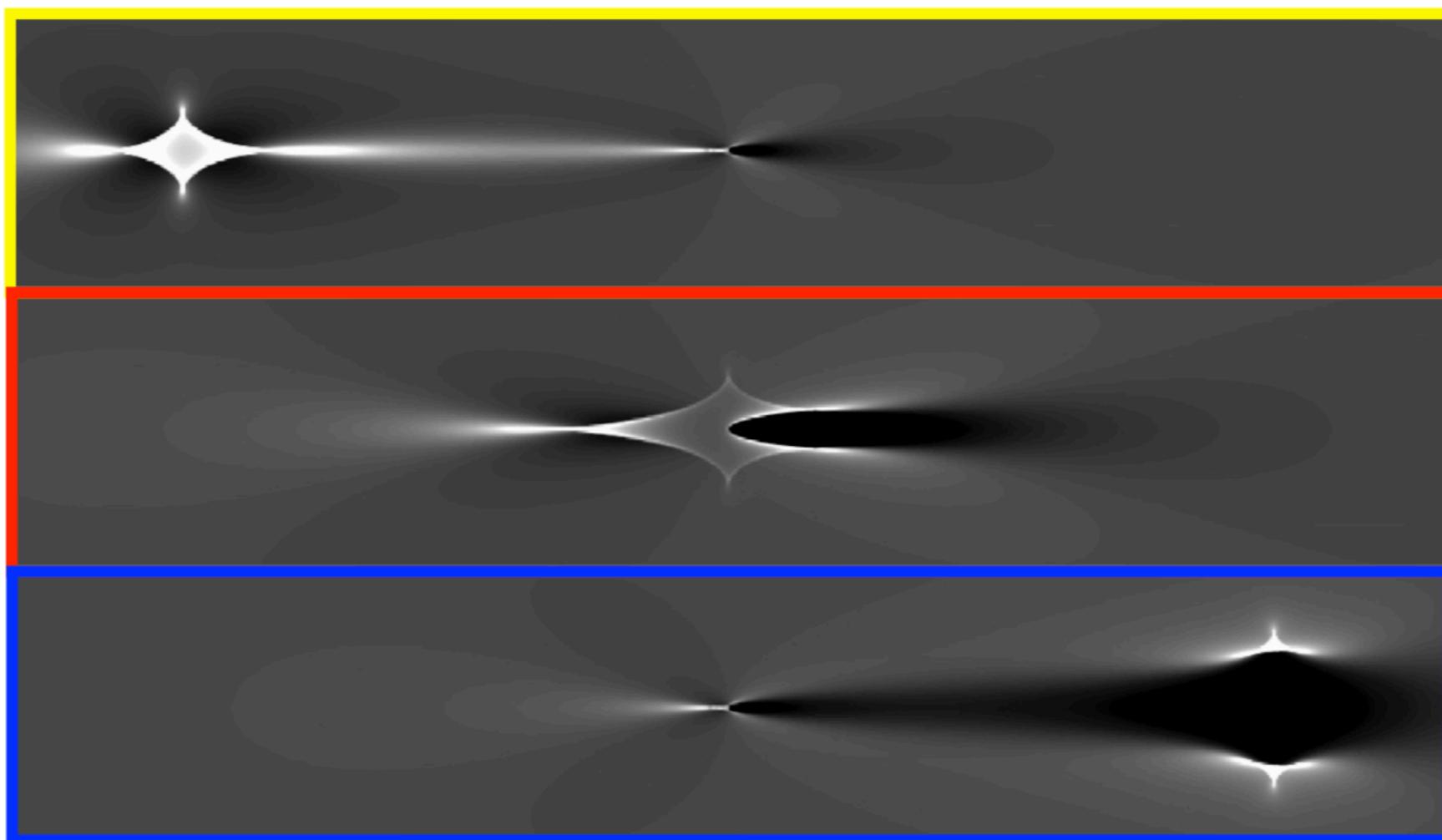
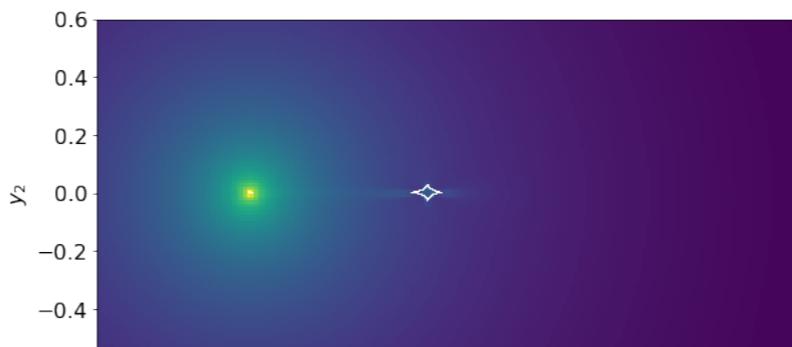
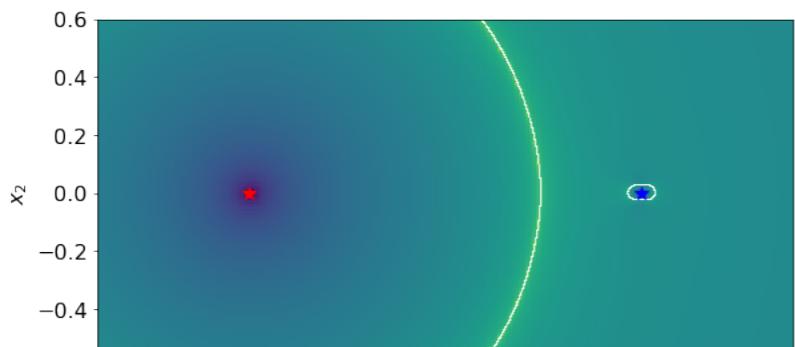
- The light curve is that of the star...
- The planet produces only a small perturbation to the magnification pattern, localized in a small region around the caustics
- Must cross one of these perturbed regions in order for the planet to be detected.
- The shape of the perturbation is determined by the caustic configuration...

**a****b**

Caustics

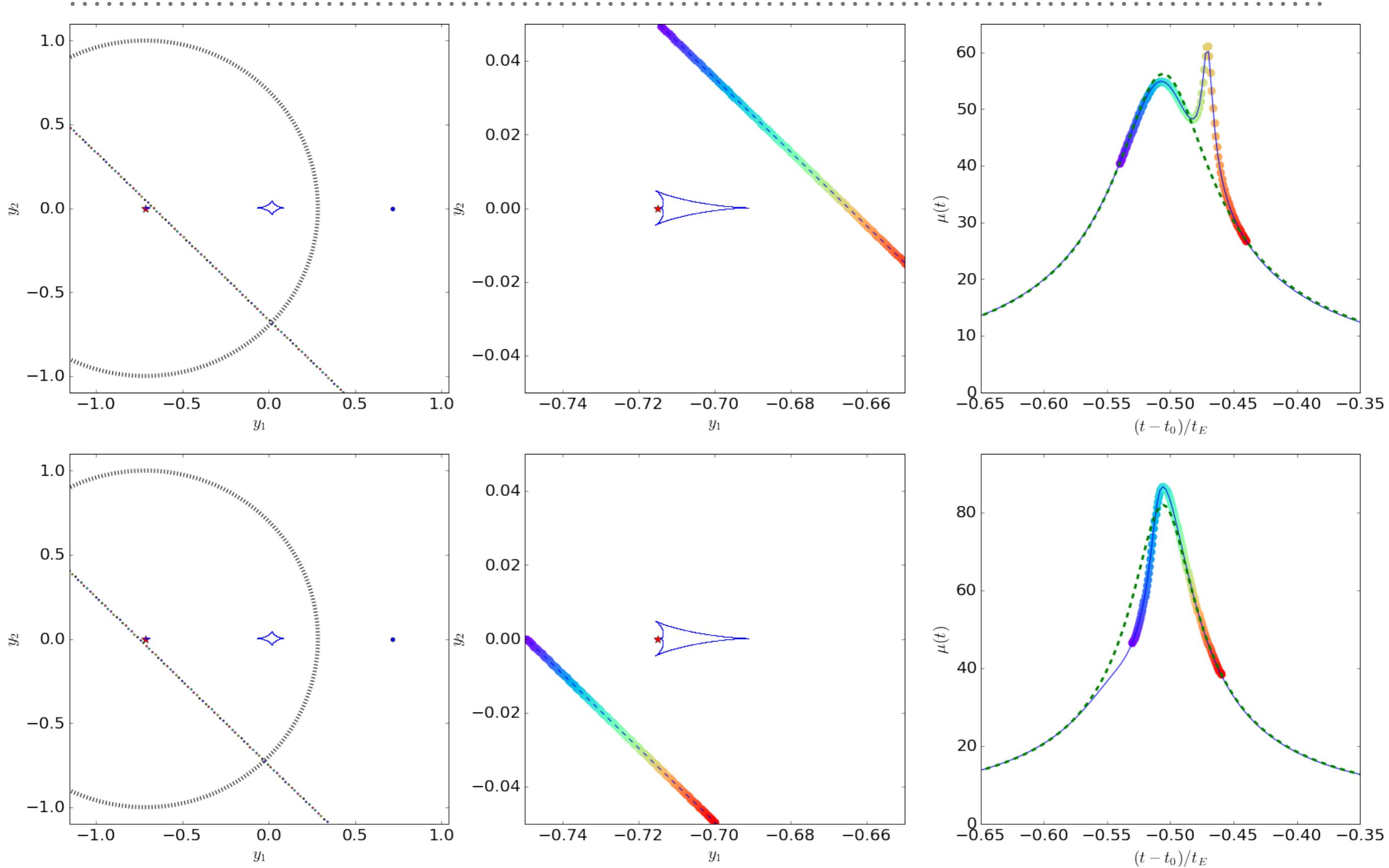
- Intermediate
- Wide
- Close



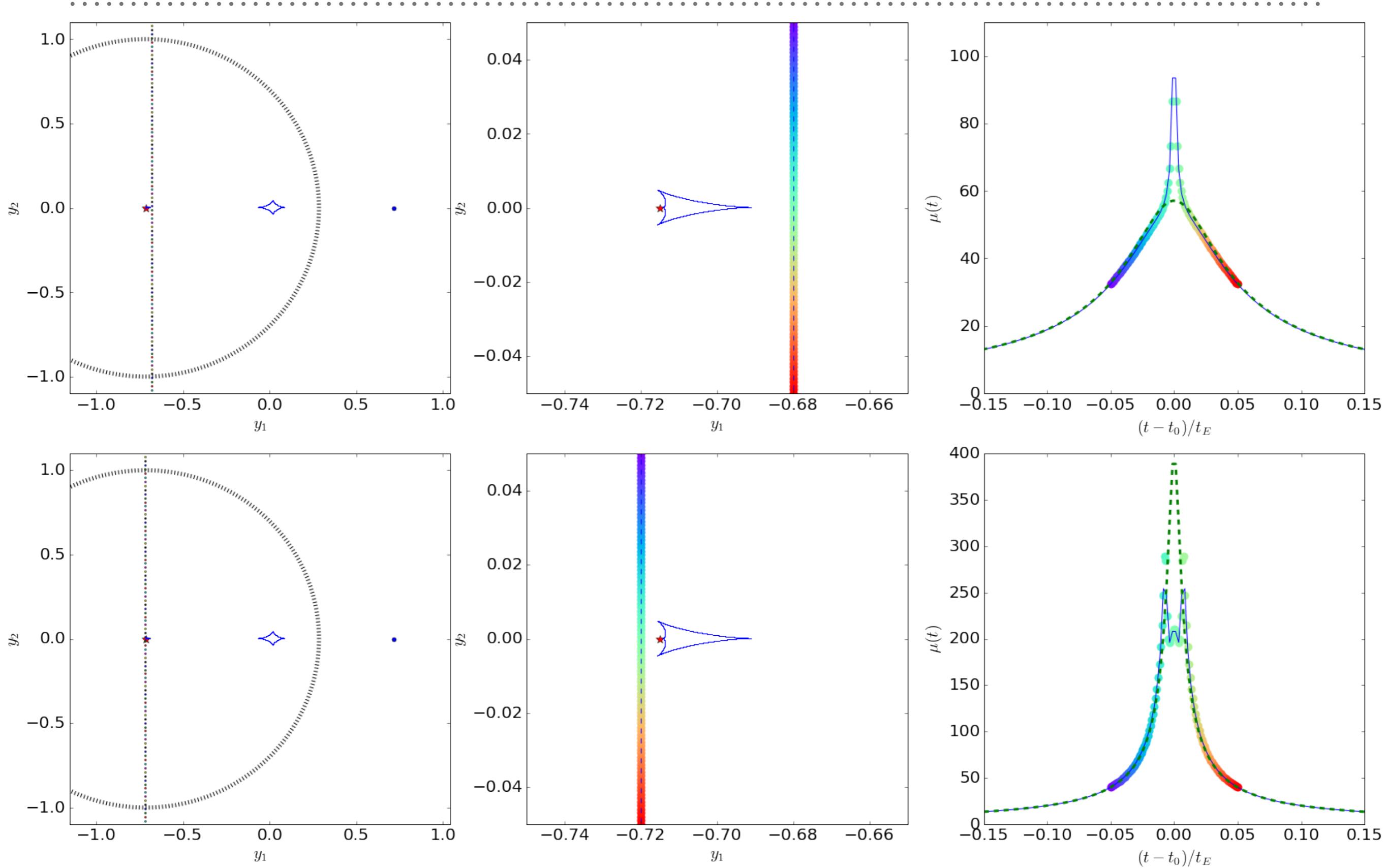


Wide  
Intermediate/  
Resonant  
Close

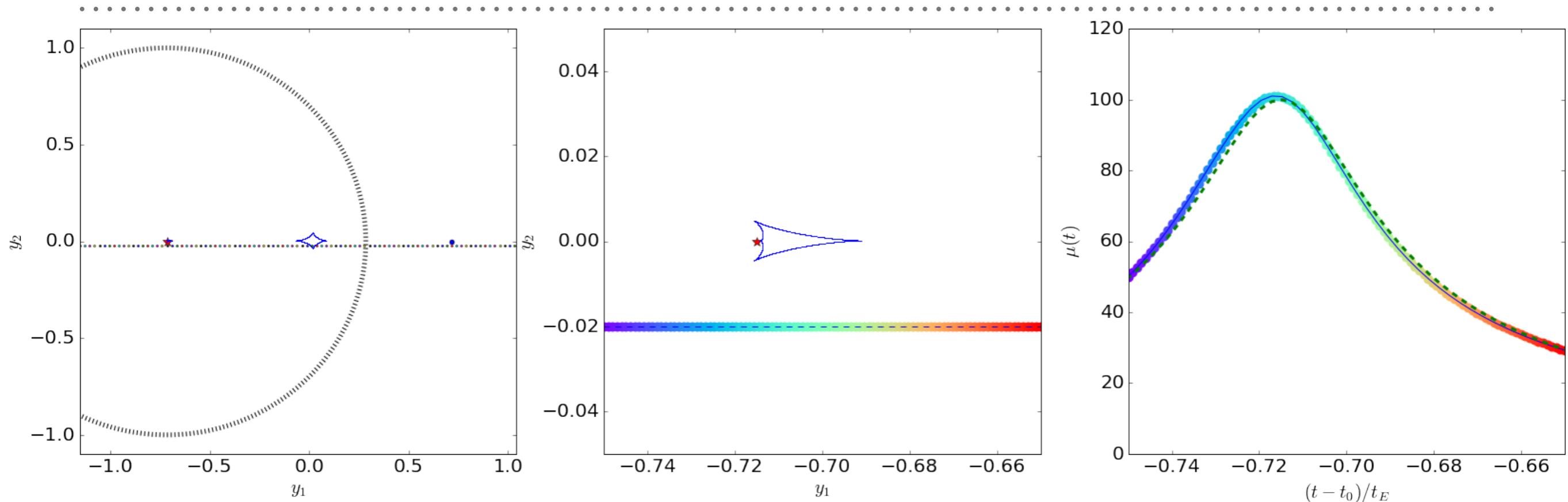
# CENTRAL CAUSTIC PERTURBATIONS



# CENTRAL CAUSTIC PERTURBATIONS



# CENTRAL CAUSTIC PERTURBATIONS



# PLANET DETECTION THROUGH CENTRAL CUSP PERTURBATIONS

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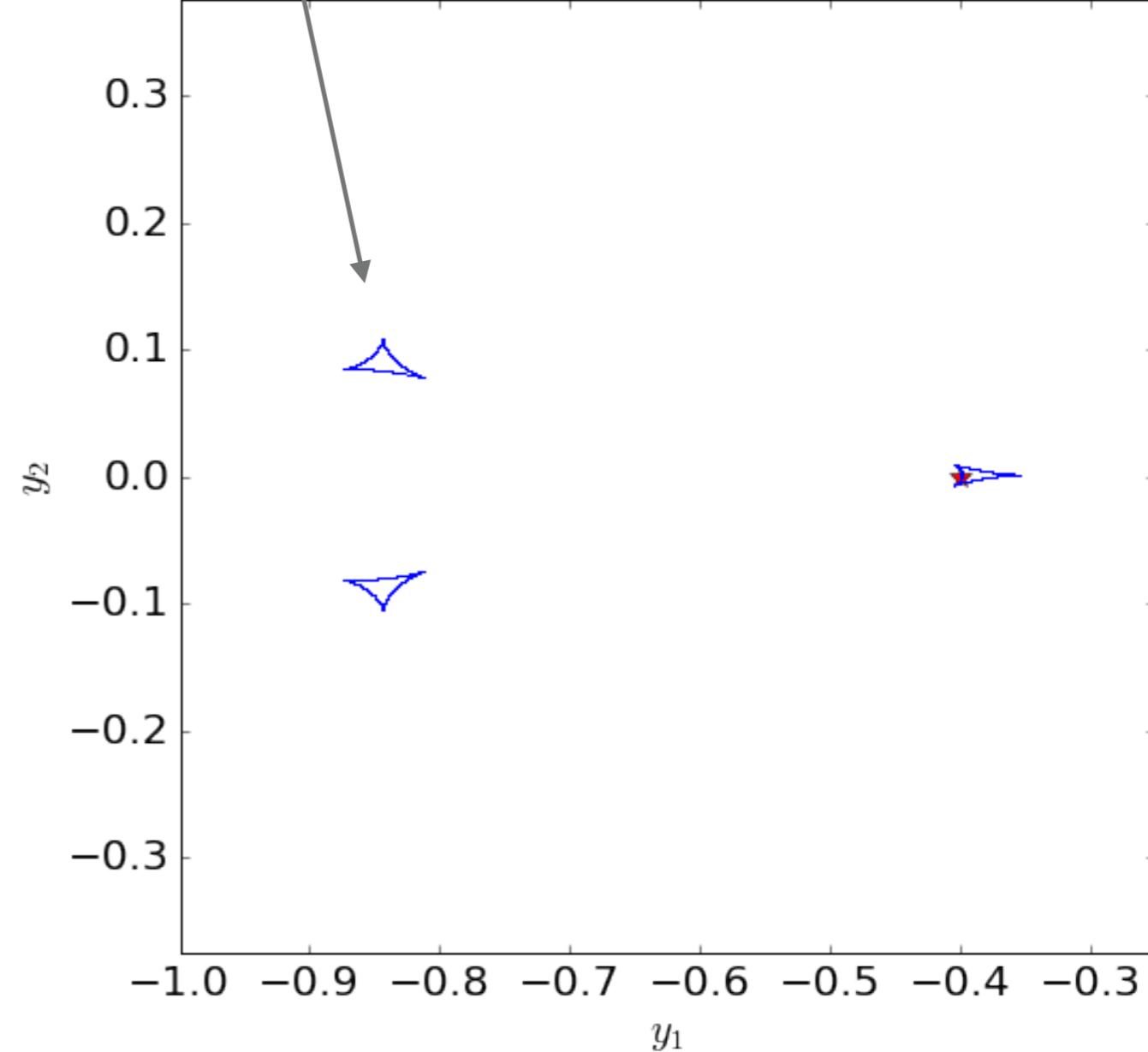
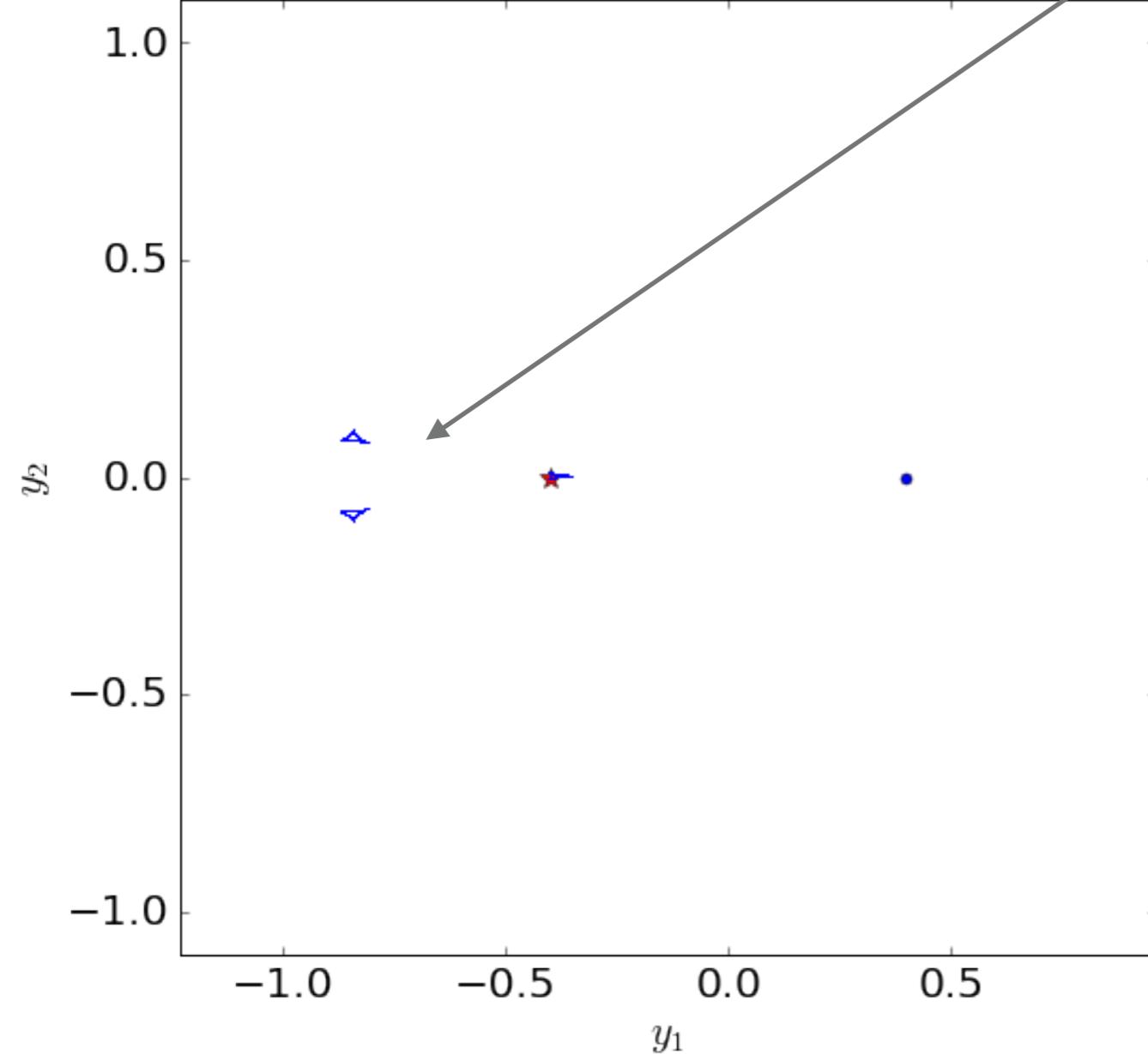
- Only possible in the case of high magnification events (sources passing very close to the host stars)
- For this reason, they are rare events
- Advantages:
  - near the peak of the event
  - can sometimes be predicted in advance
  - high magnification makes possible to follow-up the events using small telescopes
  - more accurate photometry (and easier separation of source and lens)
- Disadvantages:
  - degeneracy wide-close topologies

# PLANETARY CAUSTICS IN CLOSE TOPOLOGIES

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*planetary caustics*

*Han 2006*



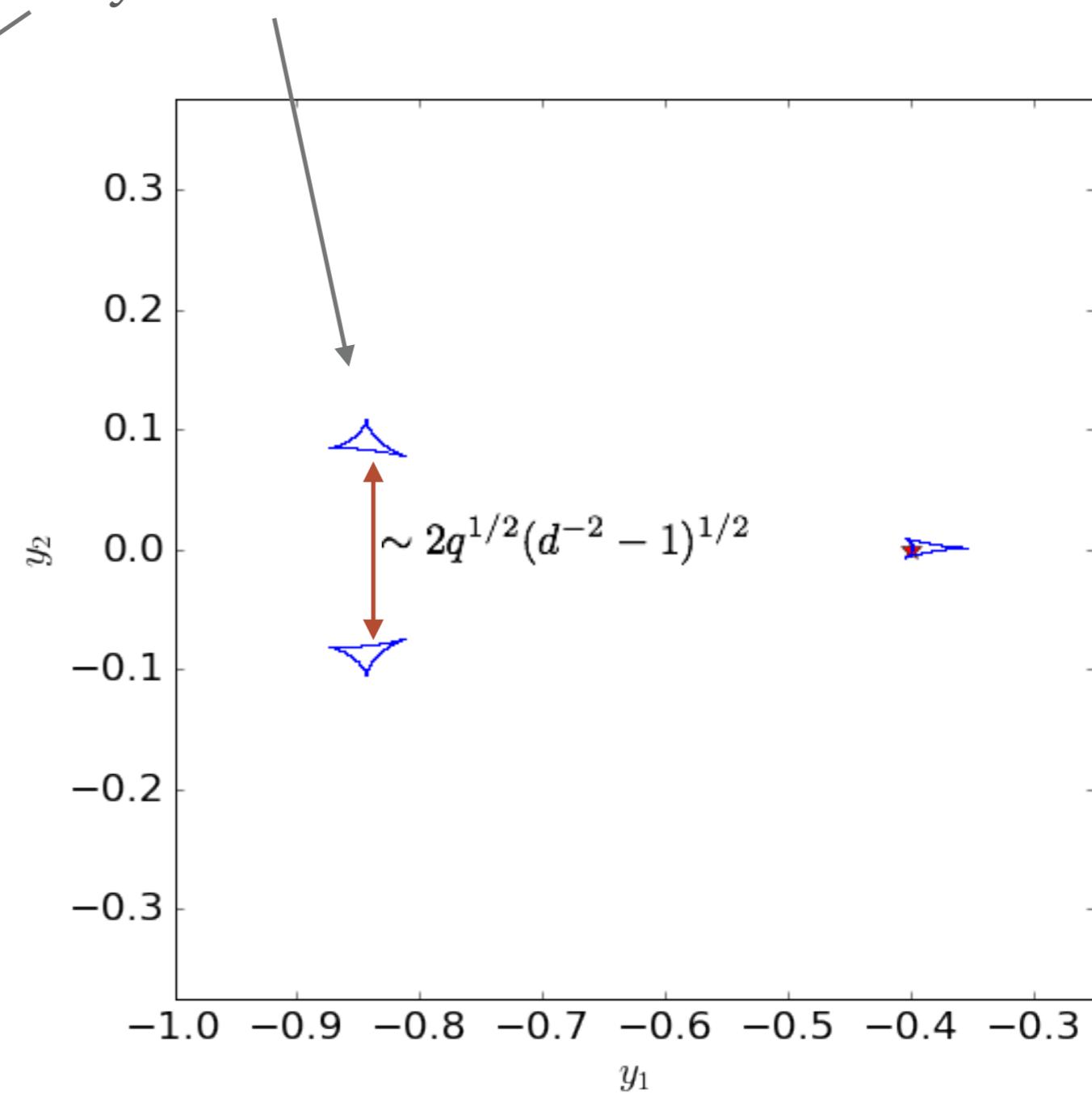
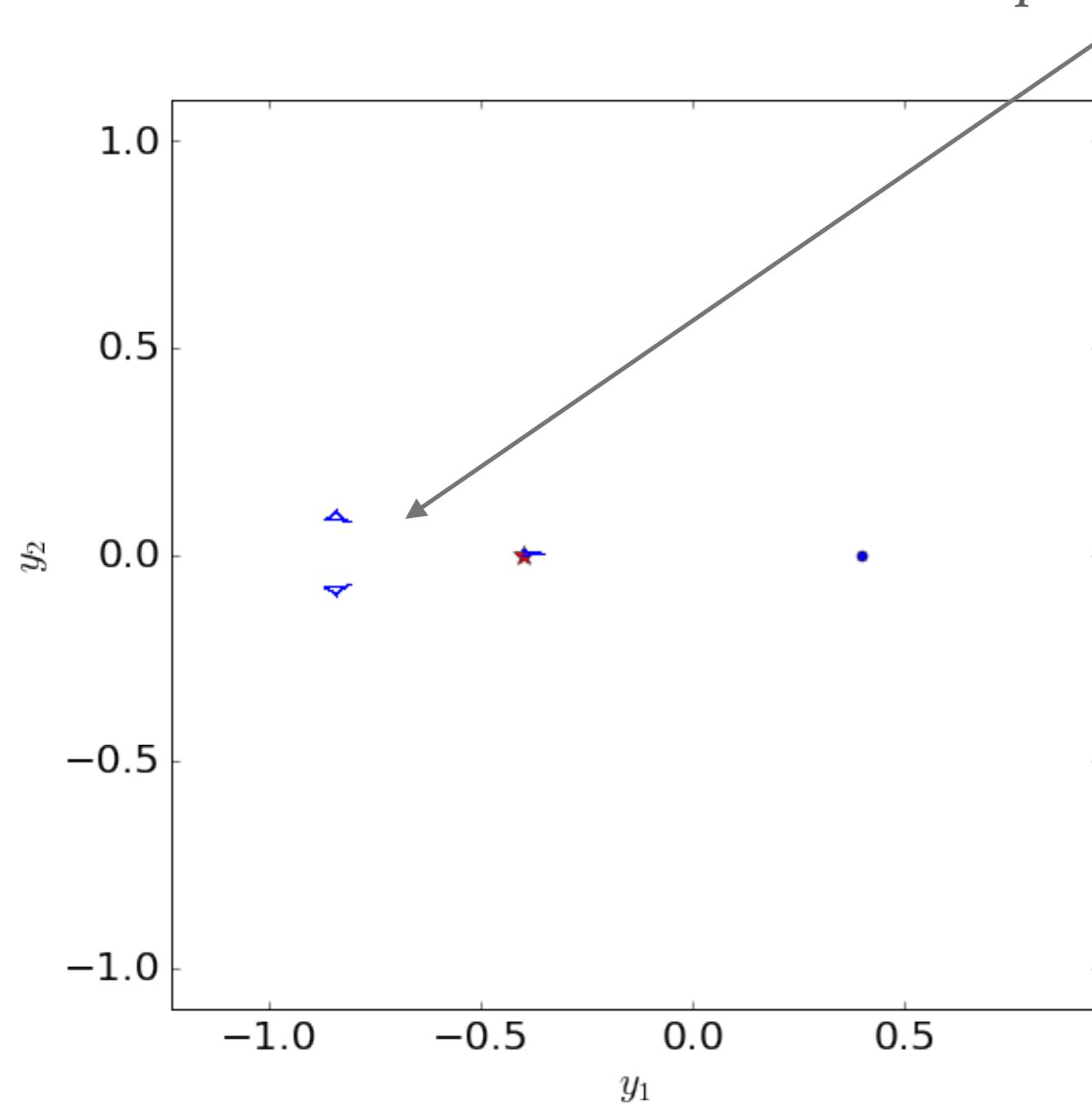
*Recommended reading: Han, C., 2006, ApJ, 638, 1080*

# PLANETARY CAUSTICS IN CLOSE TOPOLOGIES

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*planetary caustics*

*Han 2006*



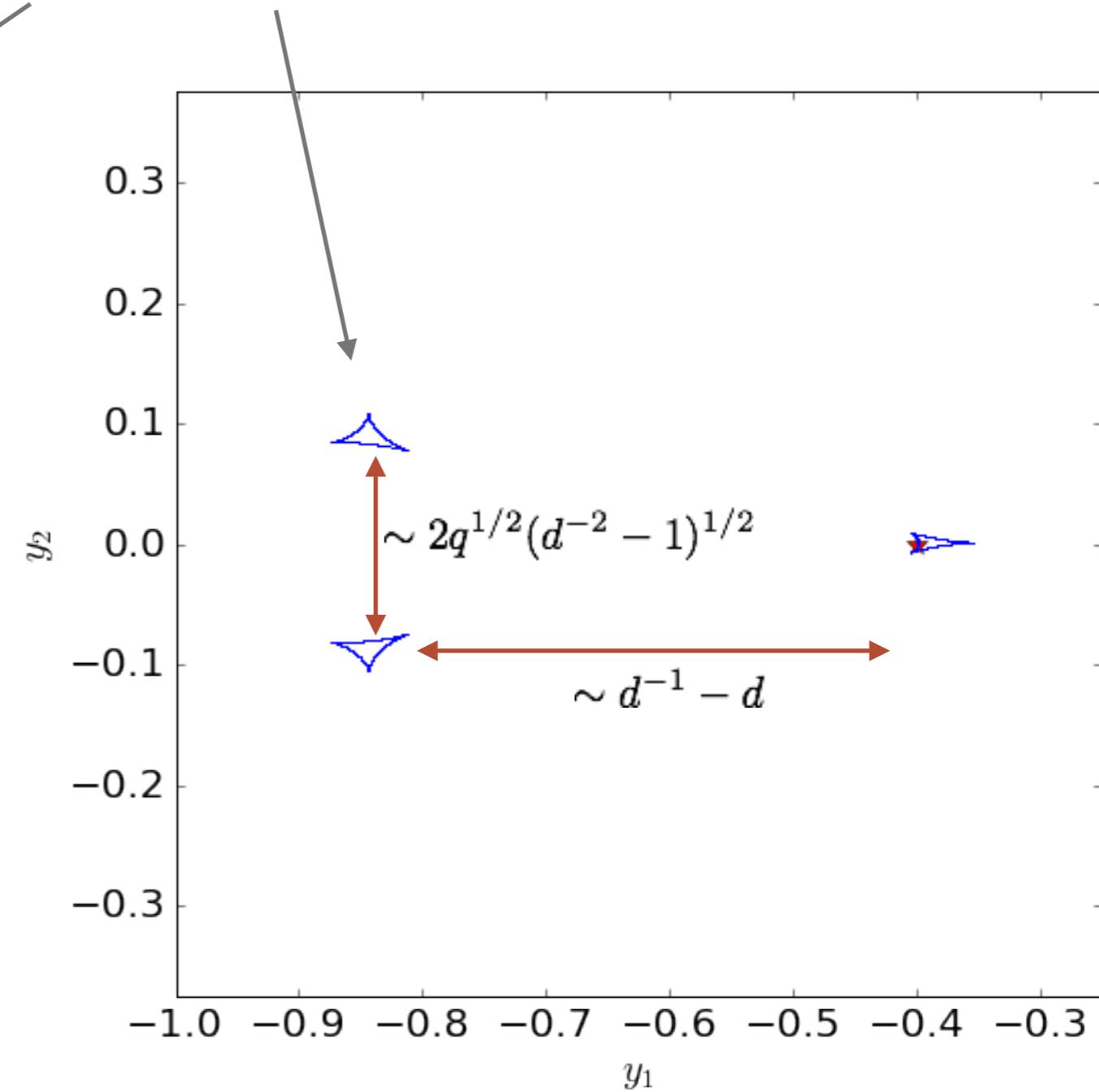
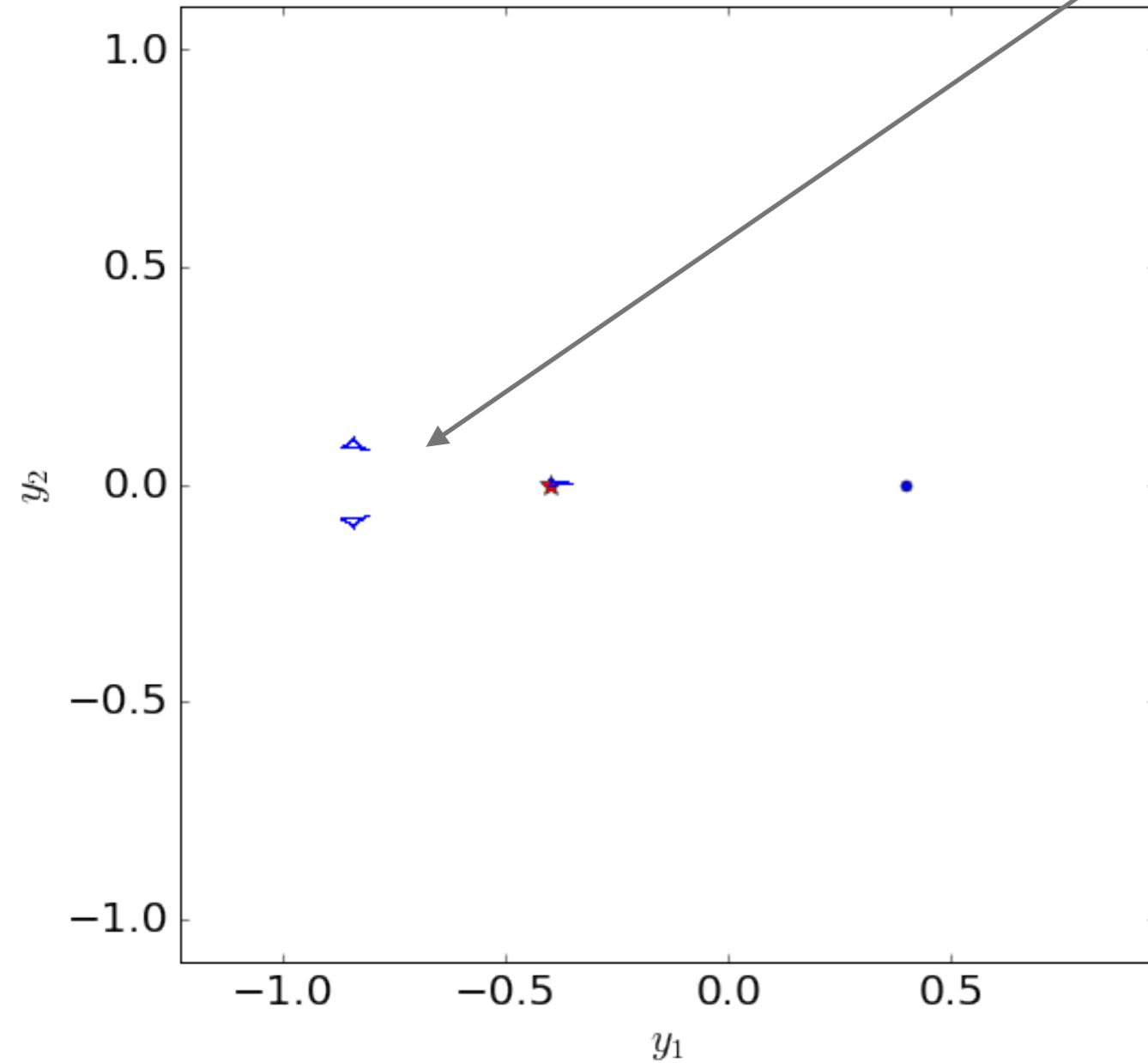
*Recommended reading: Han, C., 2006, ApJ, 638, 1080*

# PLANETARY CAUSTICS IN CLOSE TOPOLOGIES

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*planetary caustics*

*Han 2006*



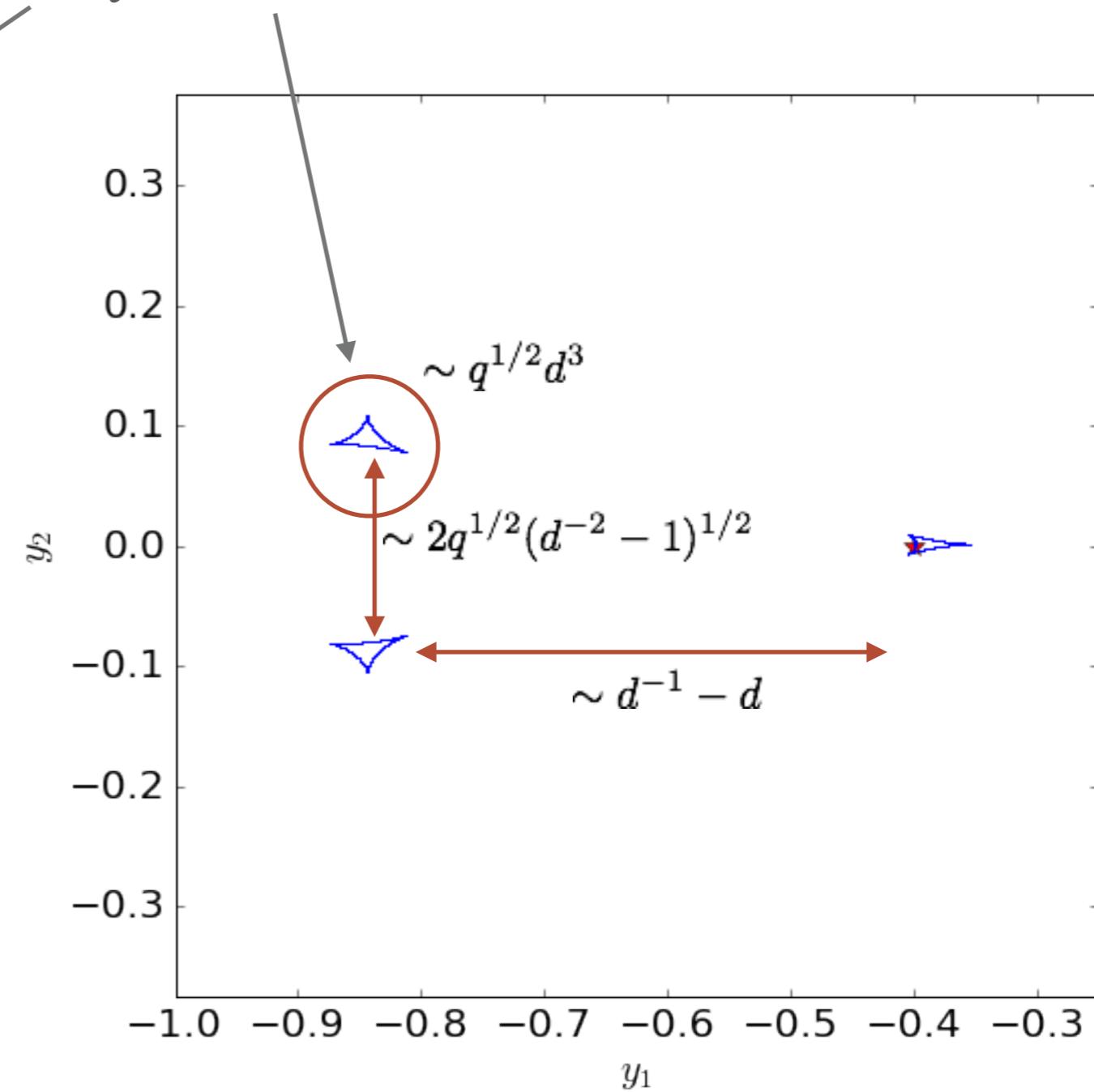
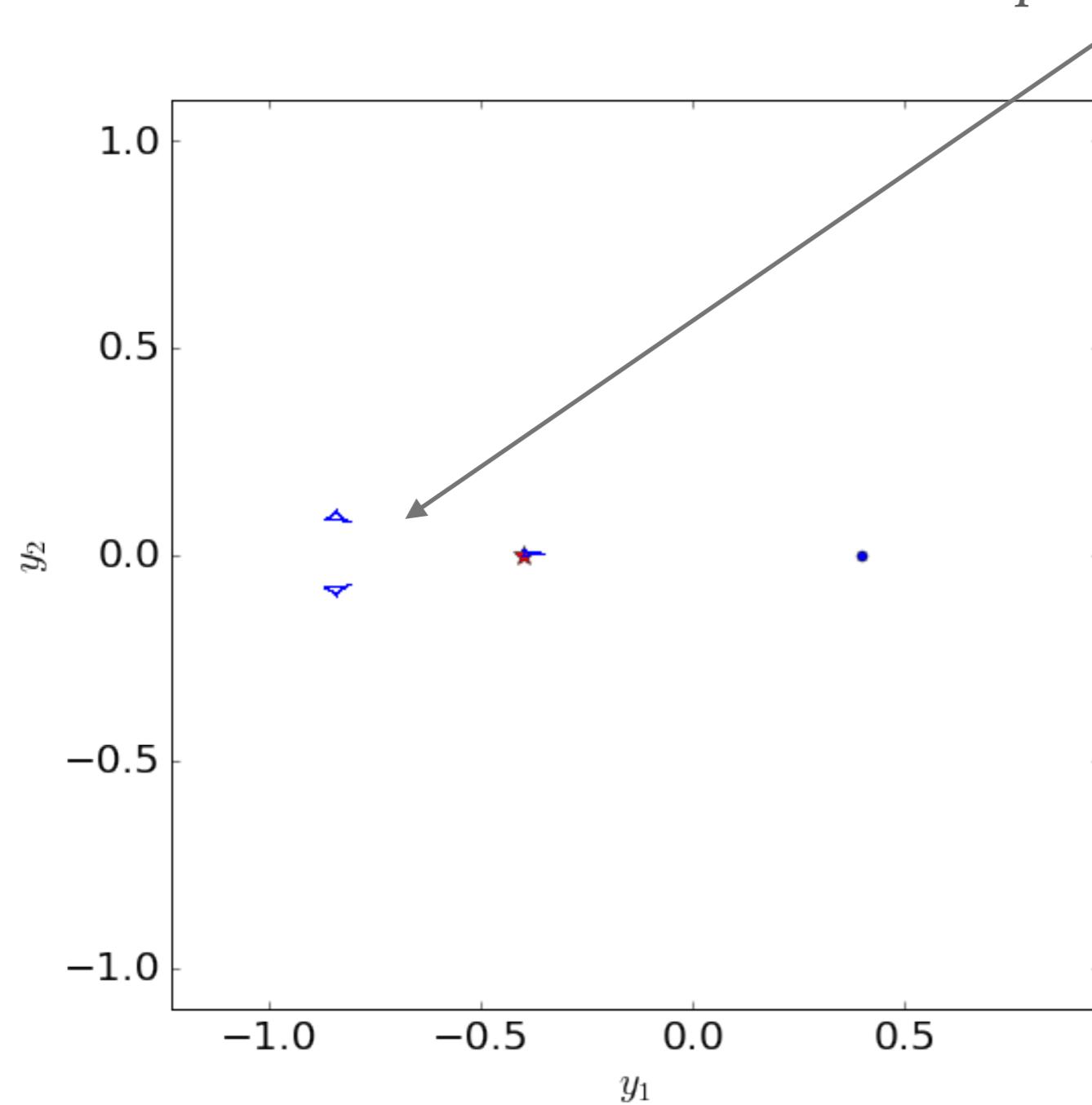
*Recommended reading: Han, C., 2006, ApJ, 638, 1080*

# PLANETARY CAUSTICS IN CLOSE TOPOLOGIES

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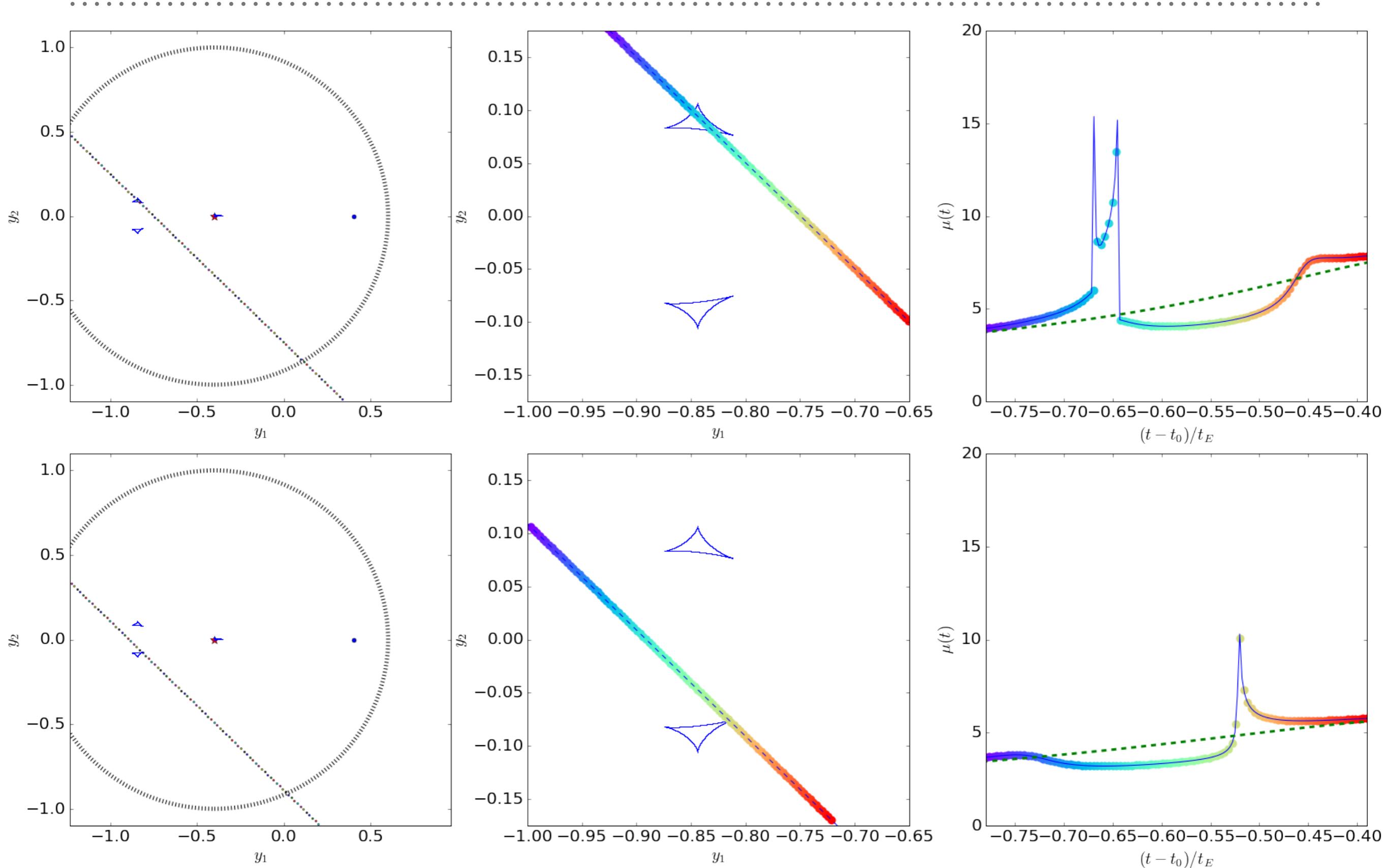
*planetary caustics*

*Han 2006*

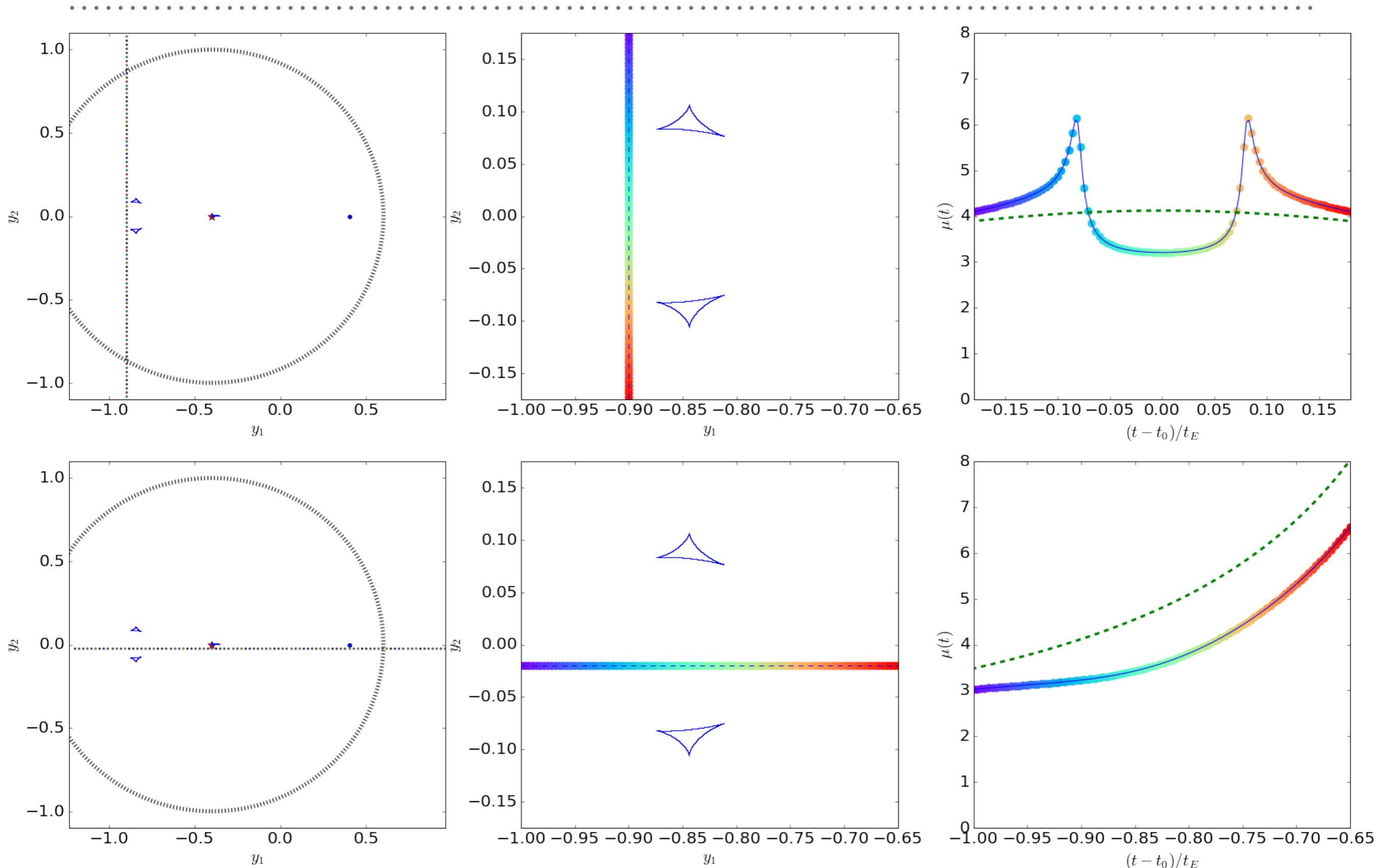


*Recommended reading: Han, C., 2006, ApJ, 638, 1080*

# PLANETARY CAUSTICS PERTURBATIONS IN CLOSE TOPOLOGIES

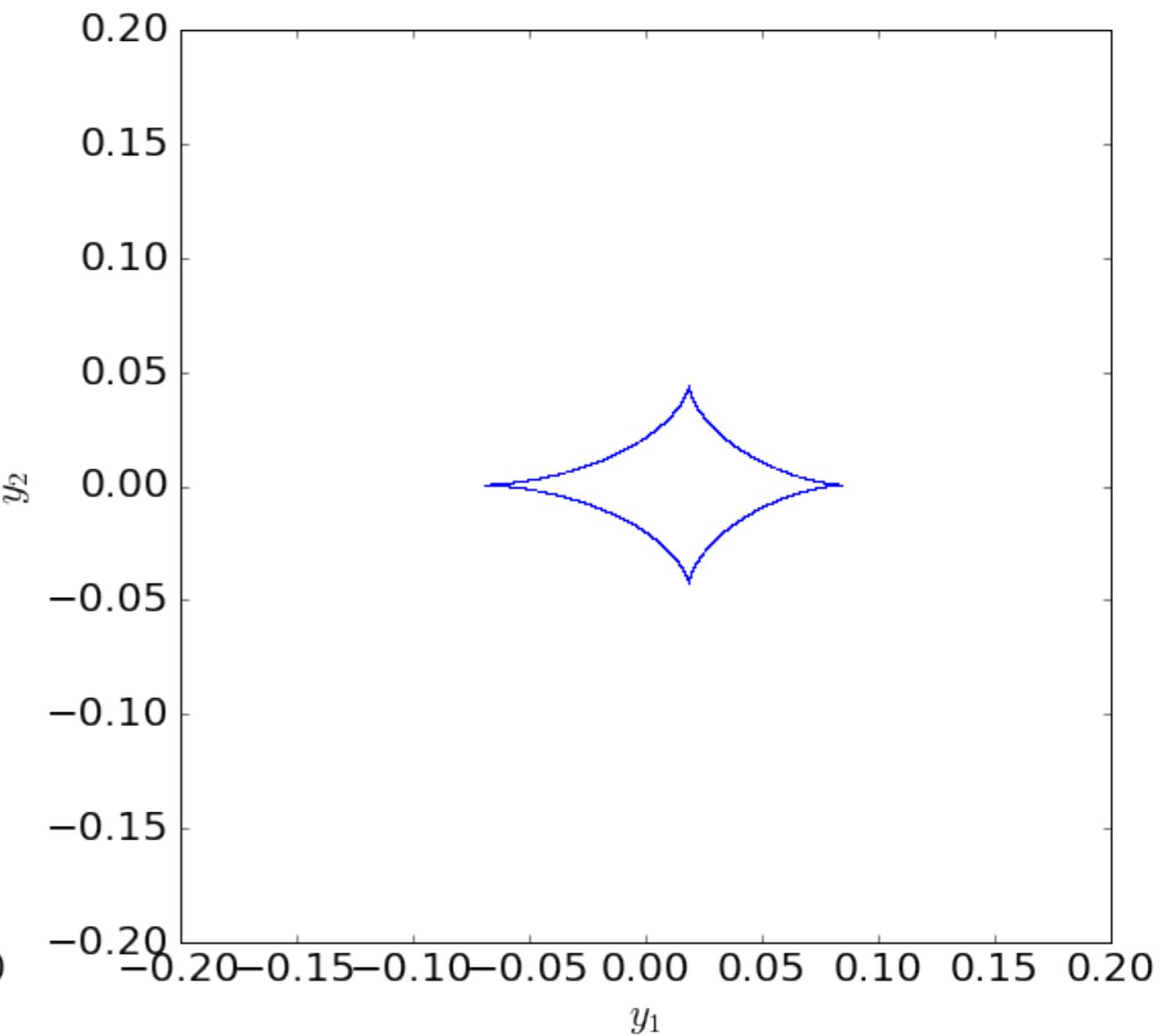
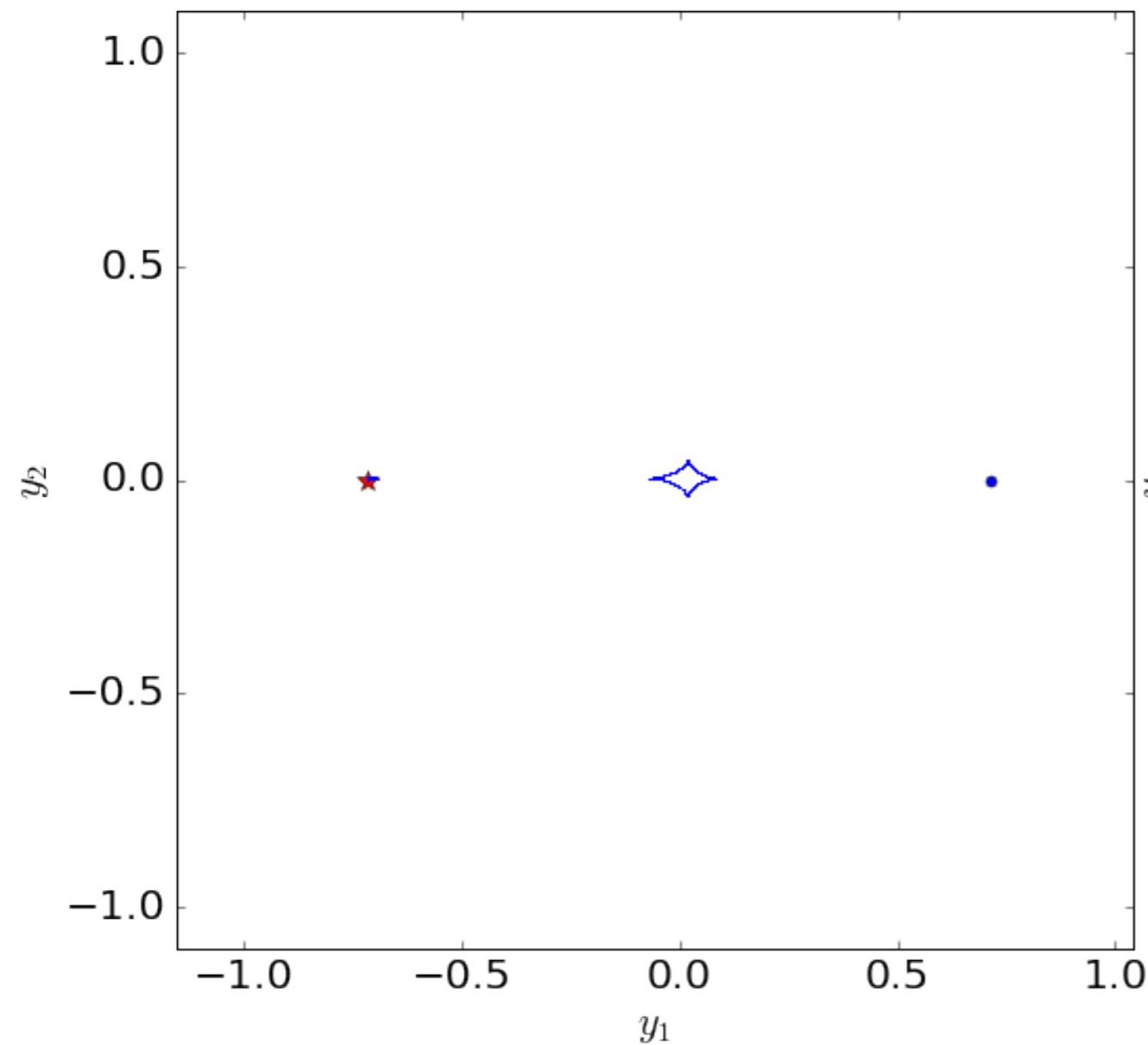


# PLANETARY CAUSTICS PERTURBATIONS IN CLOSE TOPOLOGIES



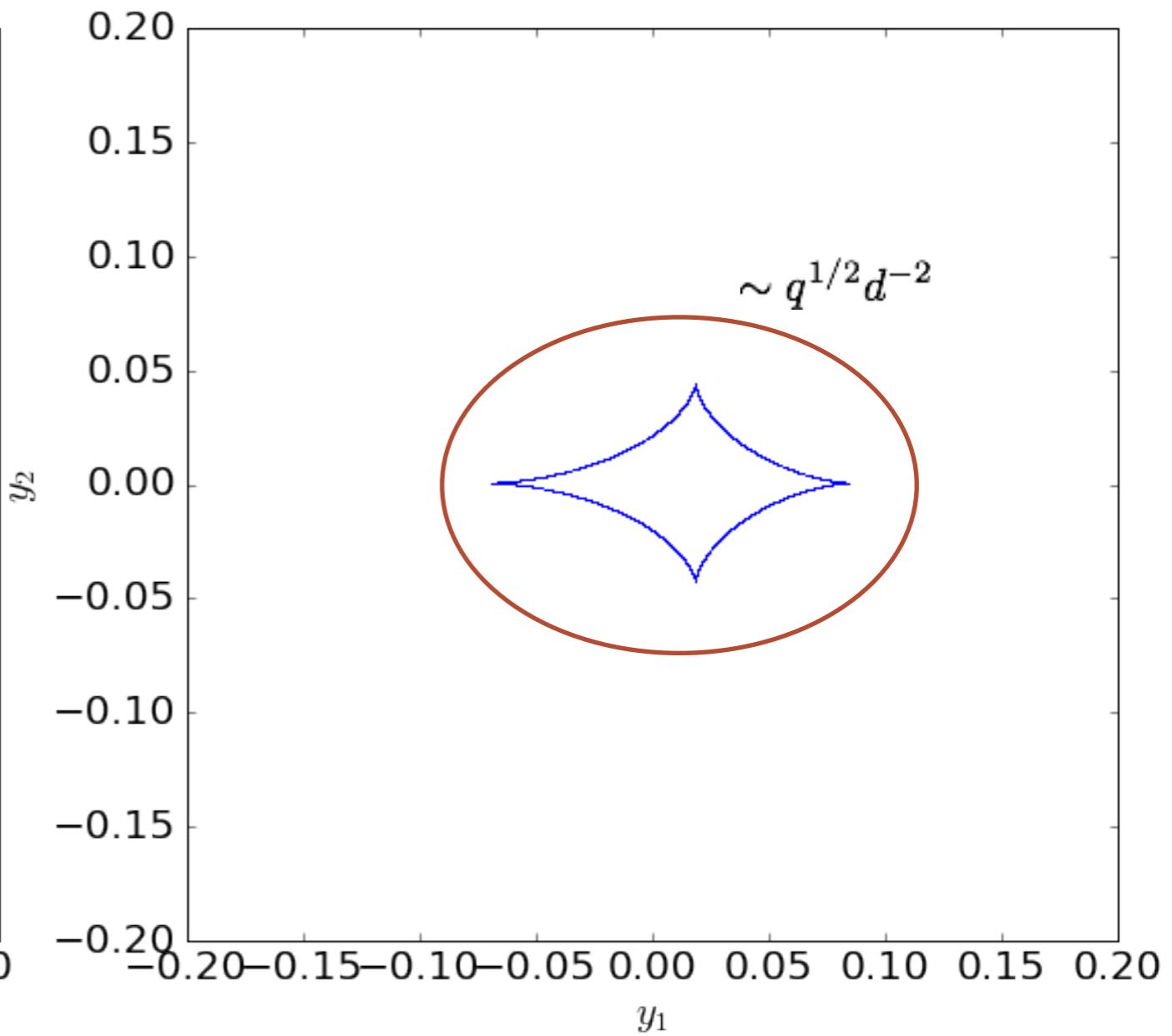
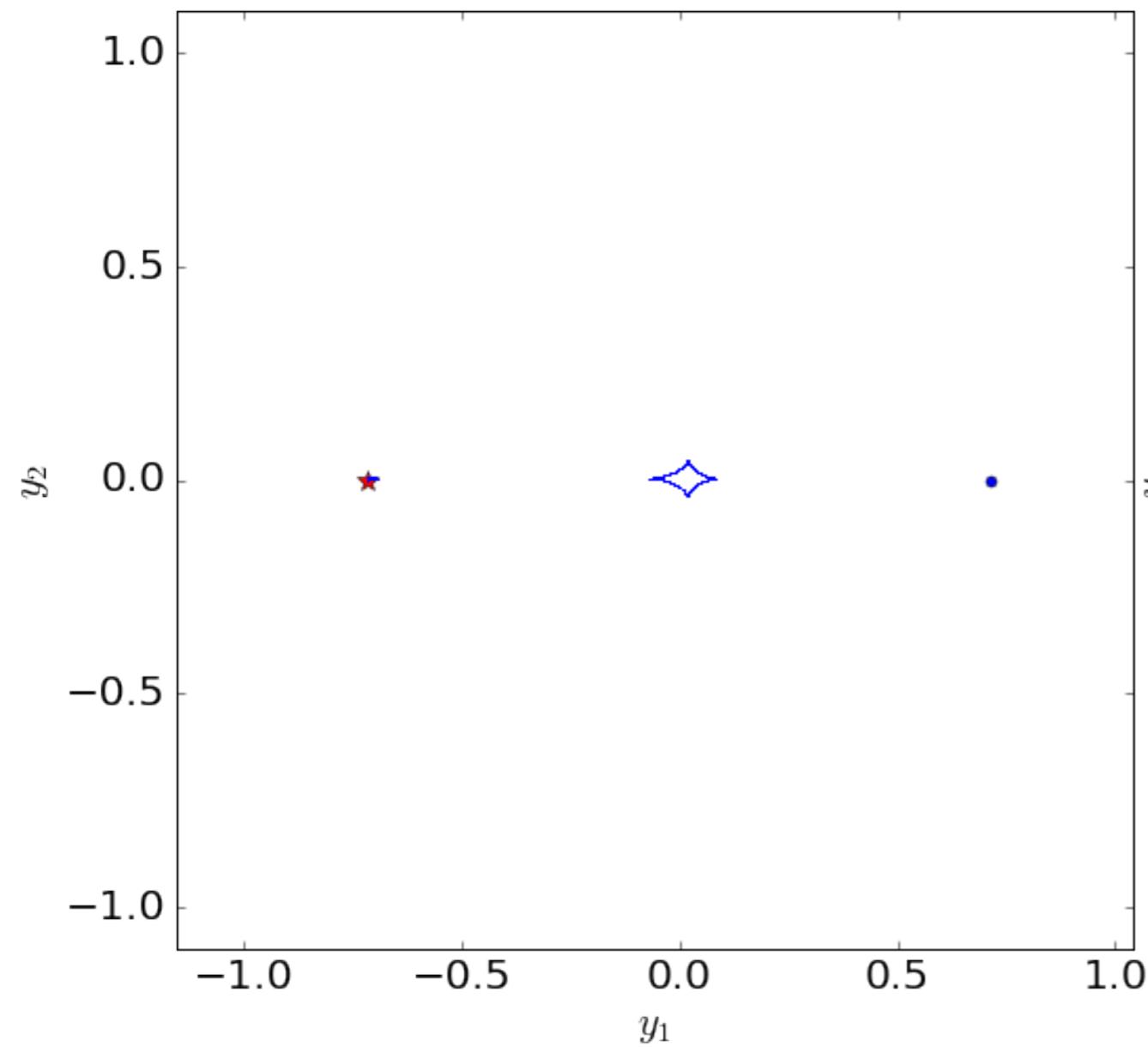
# PLANETARY CAUSTICS IN WIDE TOPOLOGIES

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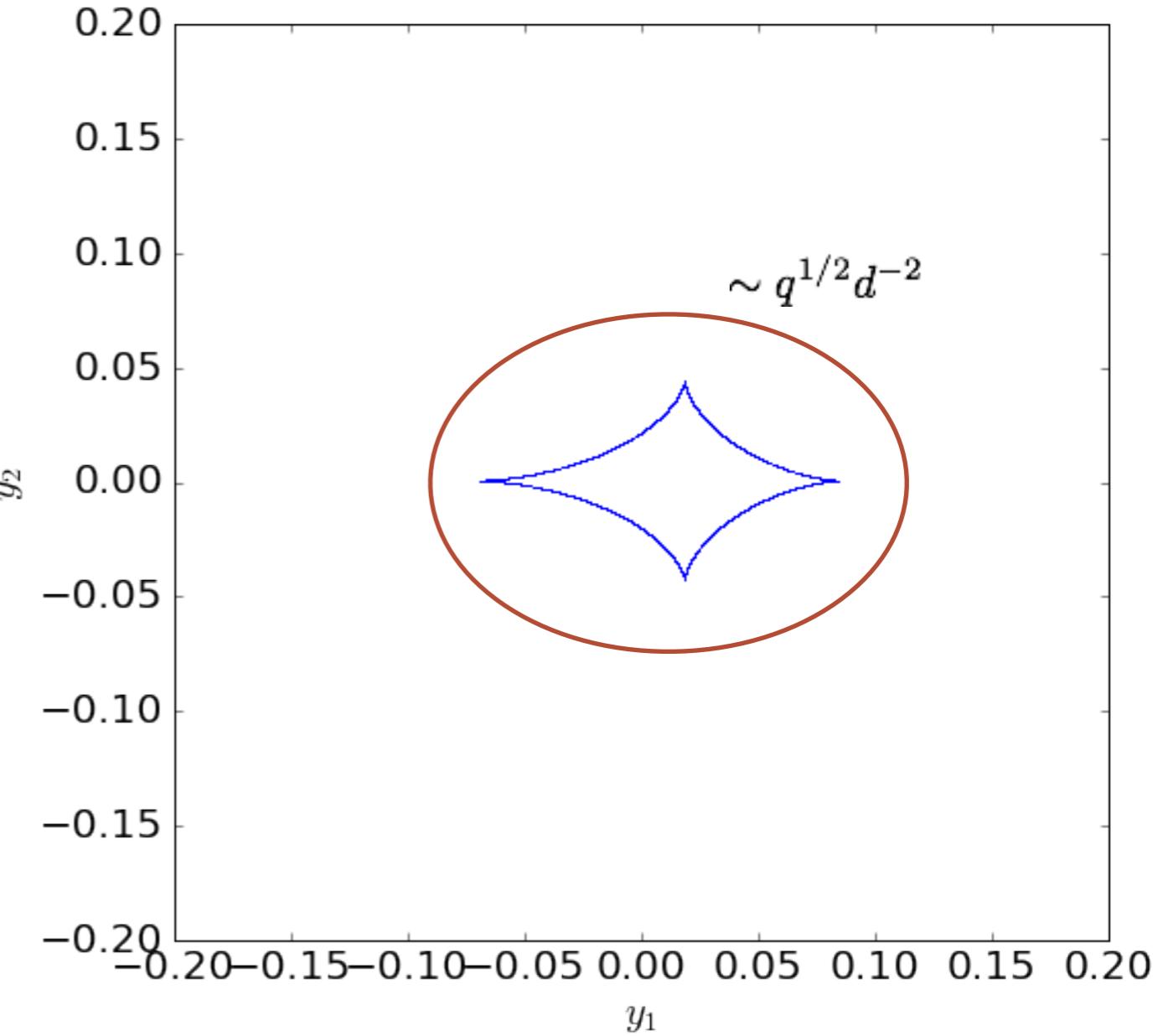
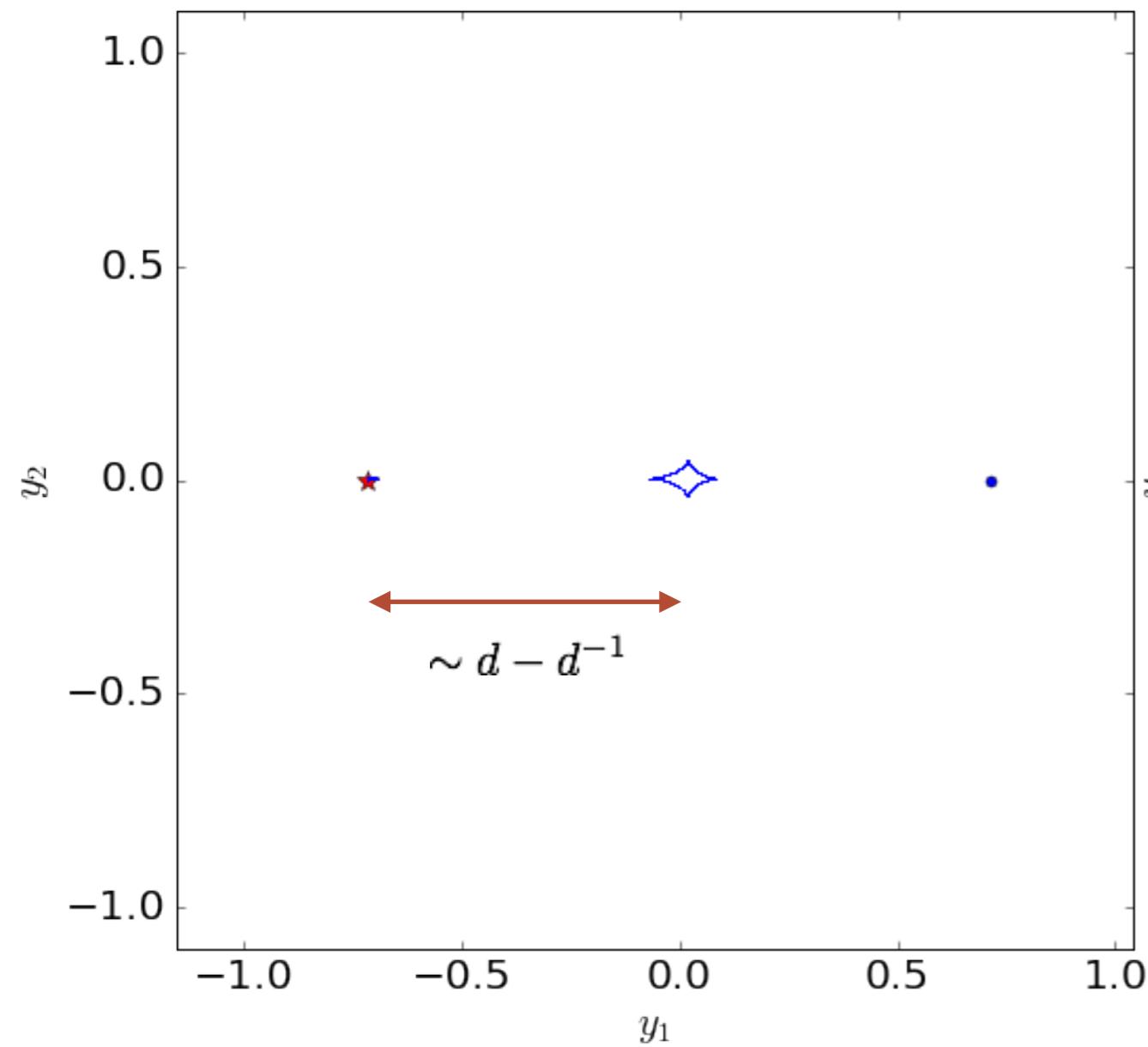
# PLANETARY CAUSTICS IN WIDE TOPOLOGIES

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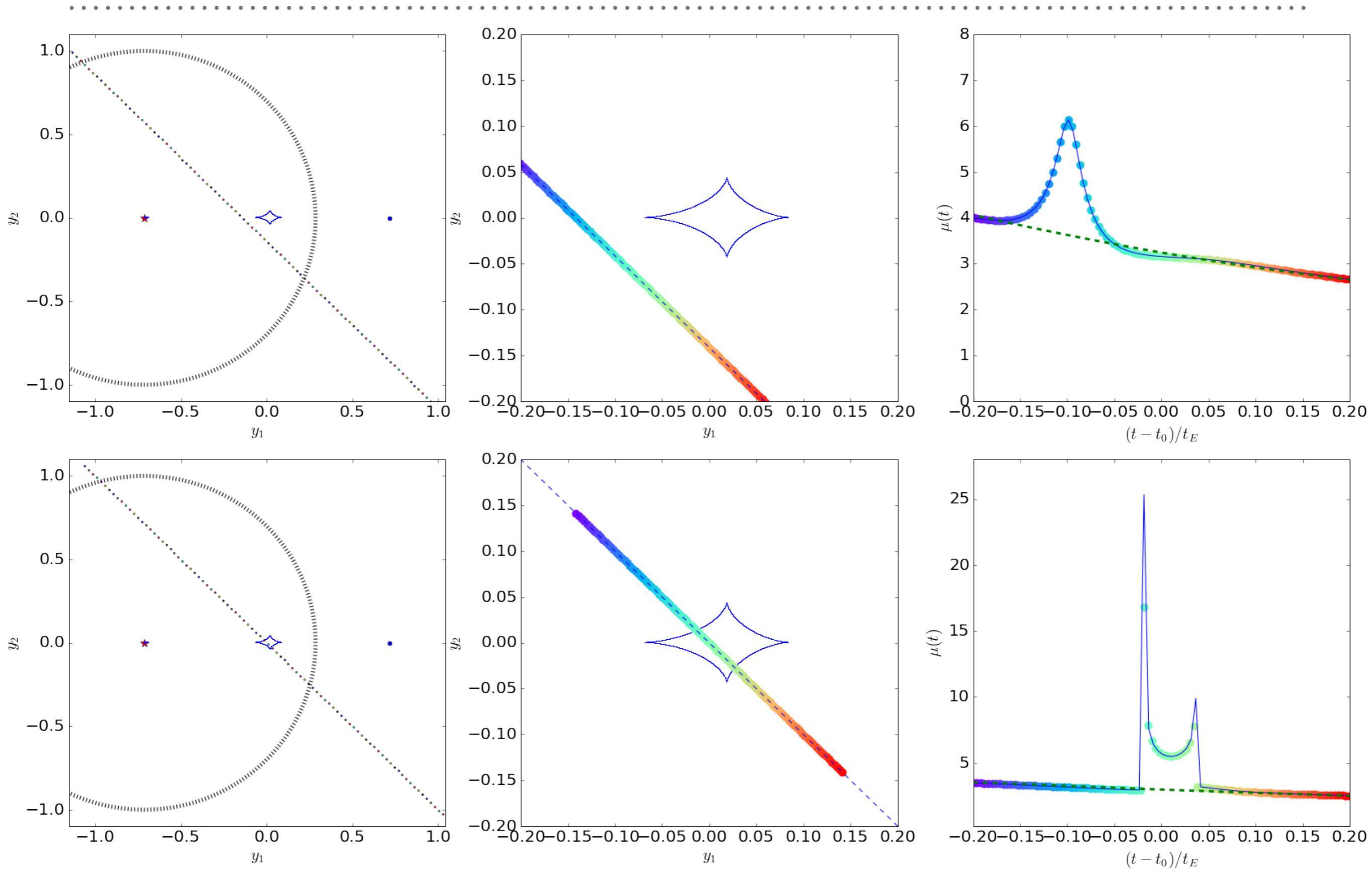


# PLANETARY CAUSTICS IN WIDE TOPOLOGIES

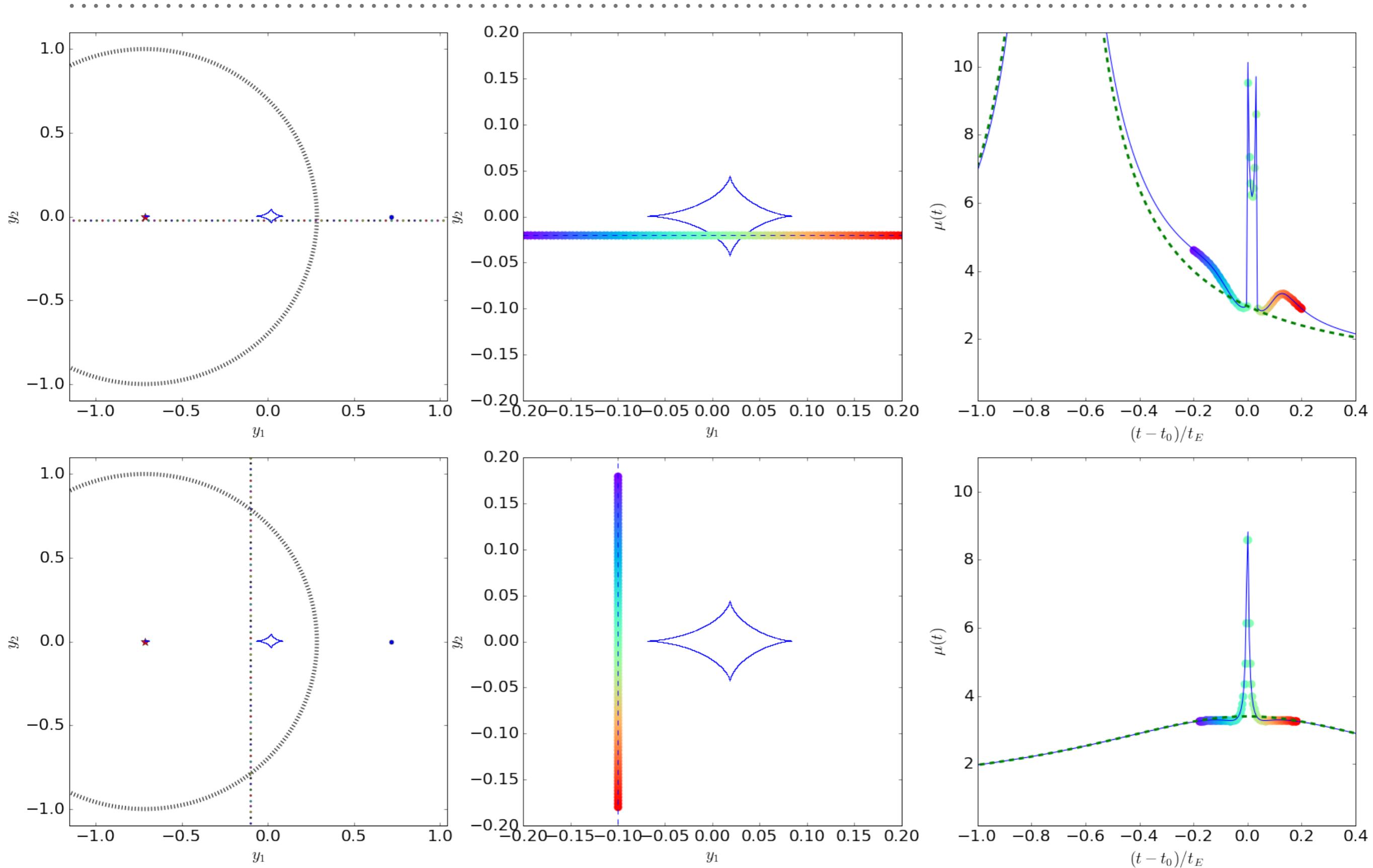
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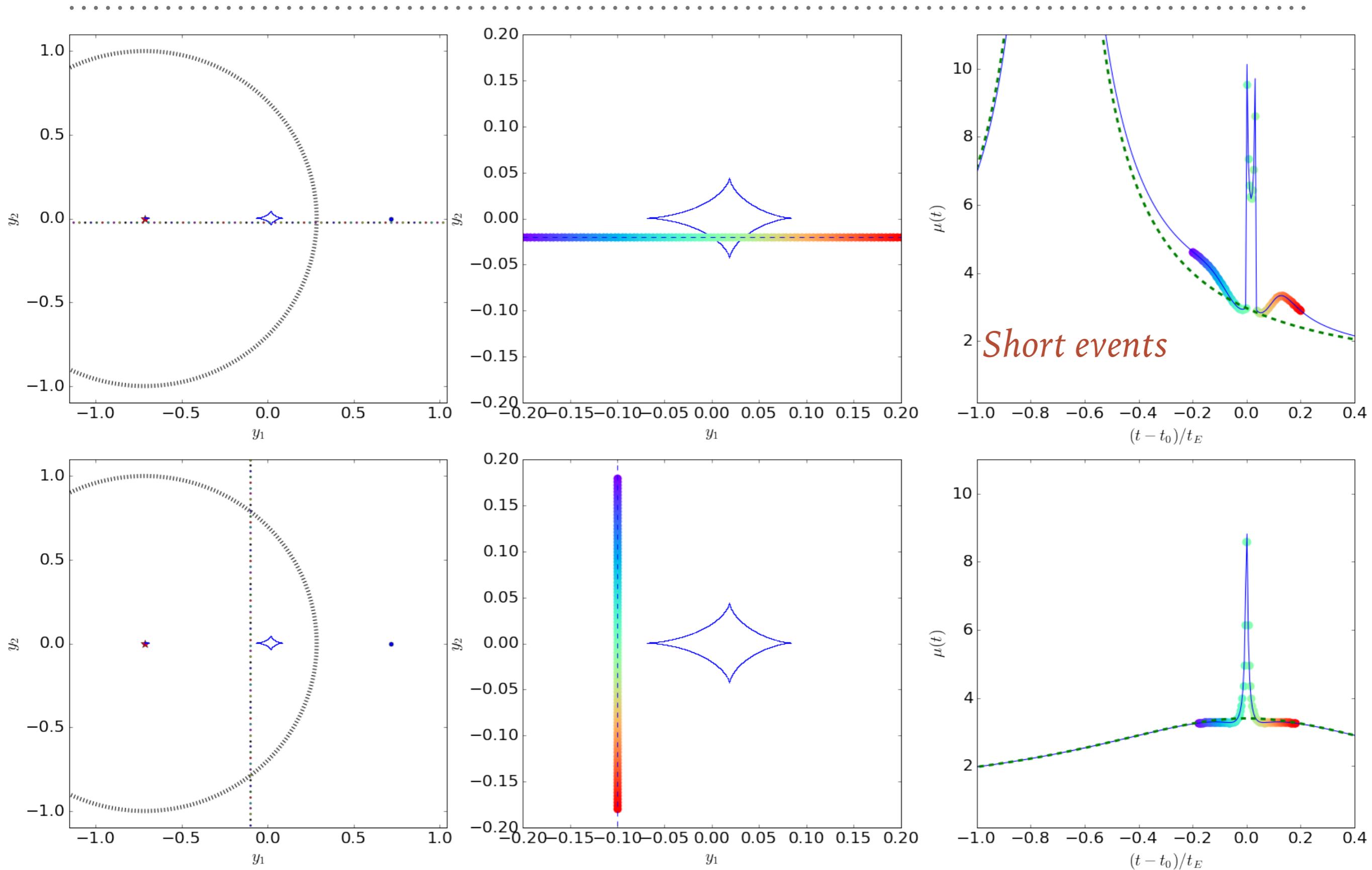
# PLANETARY CAUSTICS PERTURBATIONS IN WIDE TOPOLOGIES



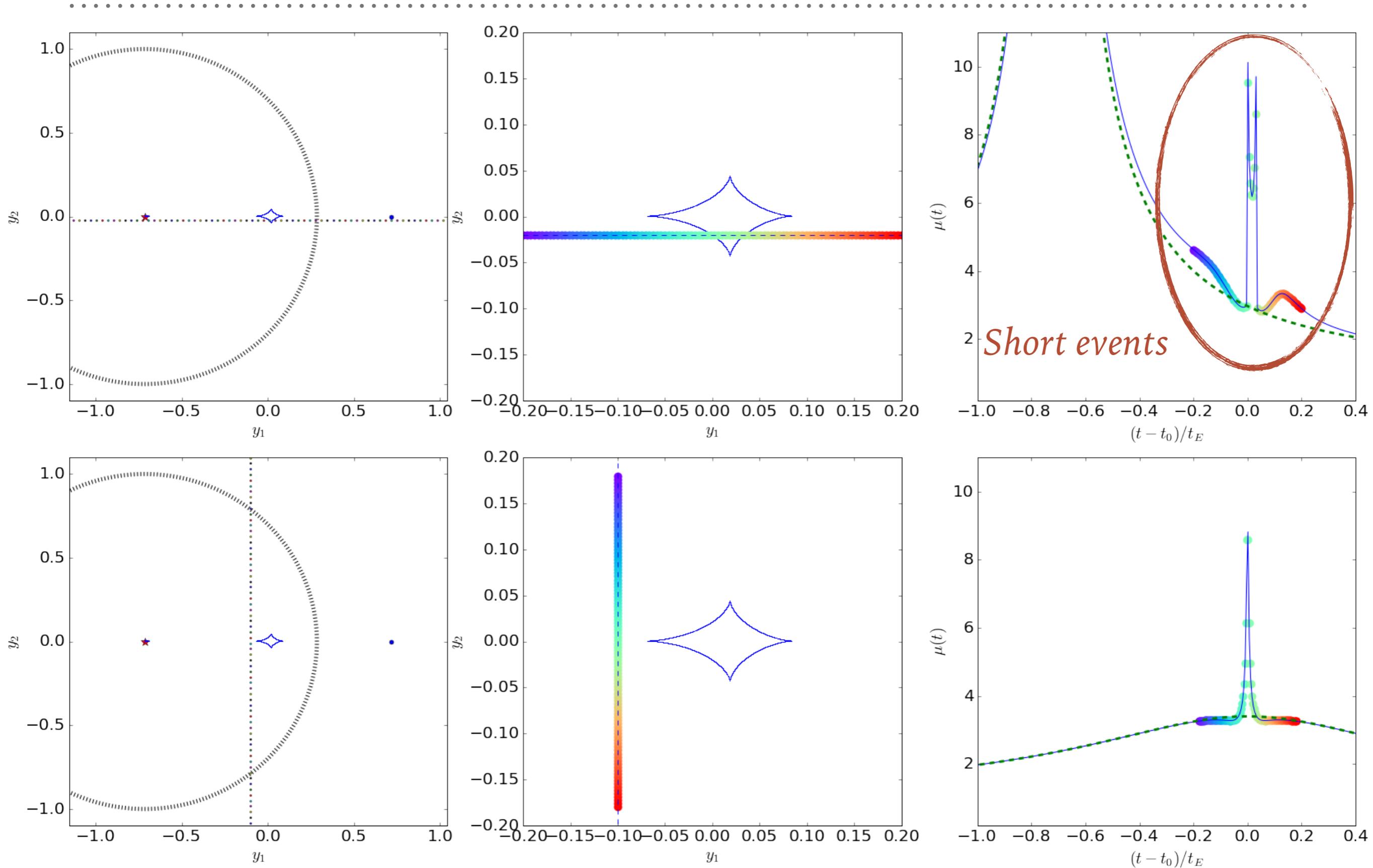
# PLANETARY CAUSTICS PERTURBATIONS IN WIDE TOPOLOGIES



# PLANETARY CAUSTICS PERTURBATIONS IN WIDE TOPOLOGIES

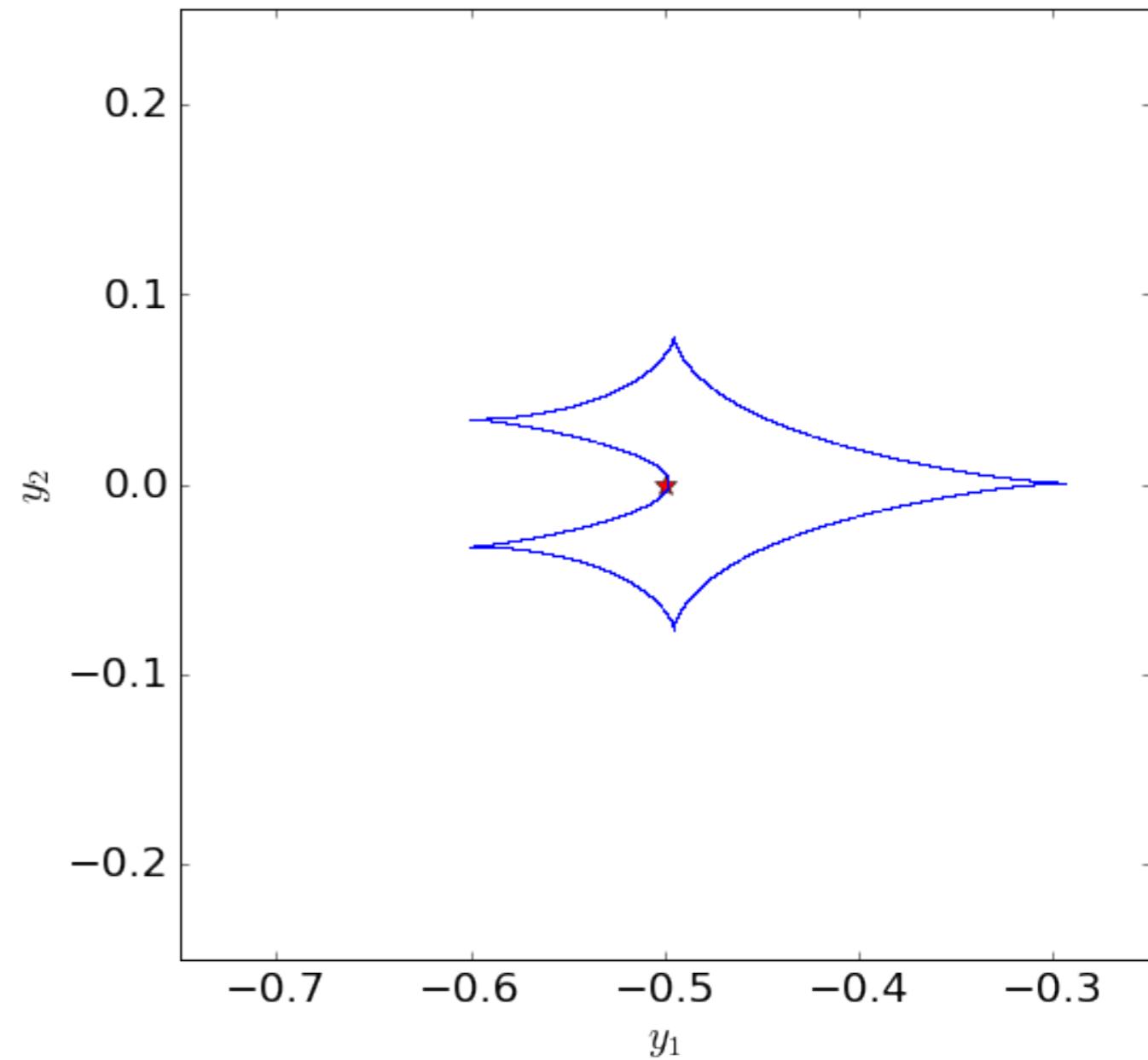
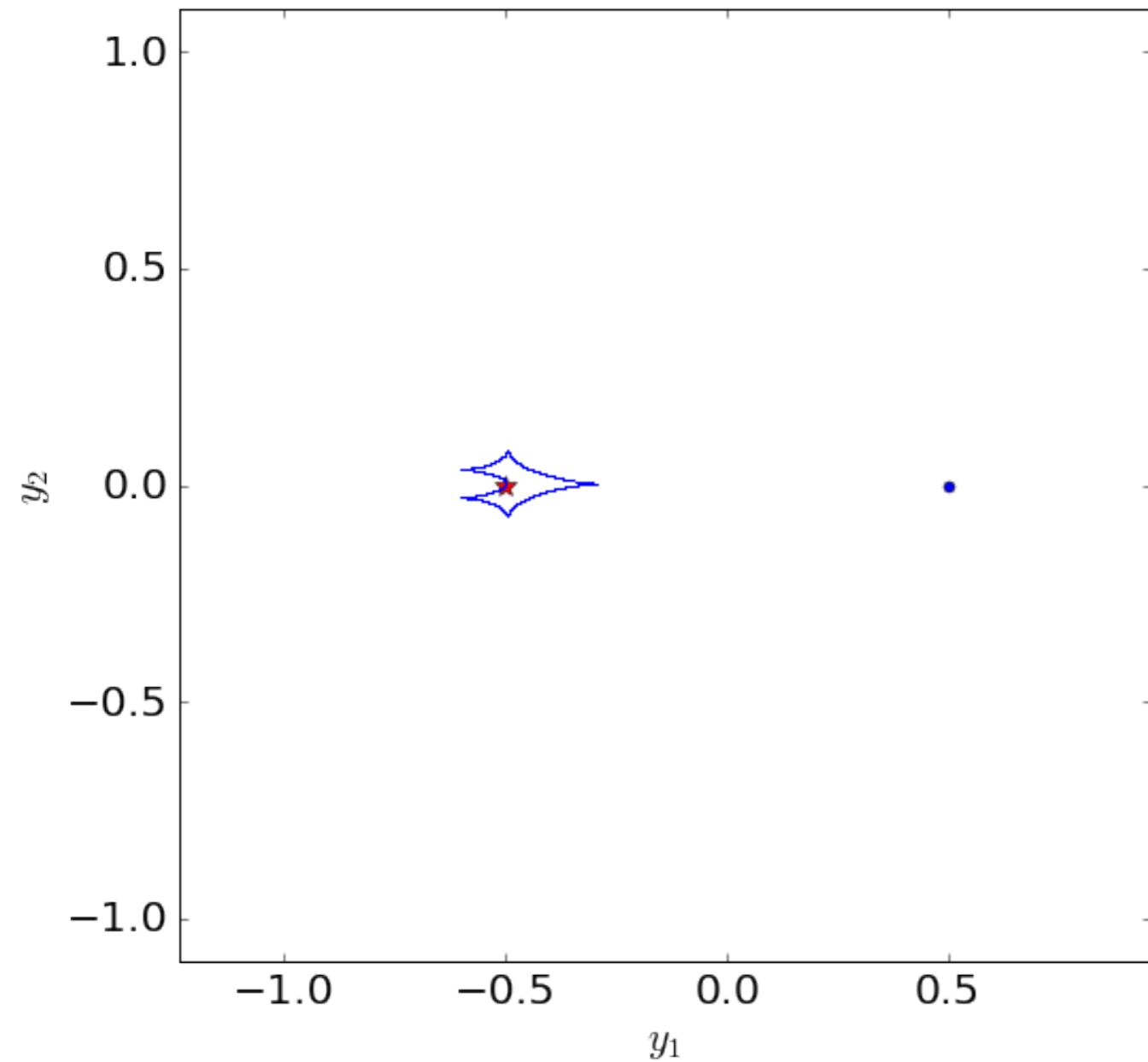


# PLANETARY CAUSTICS PERTURBATIONS IN WIDE TOPOLOGIES



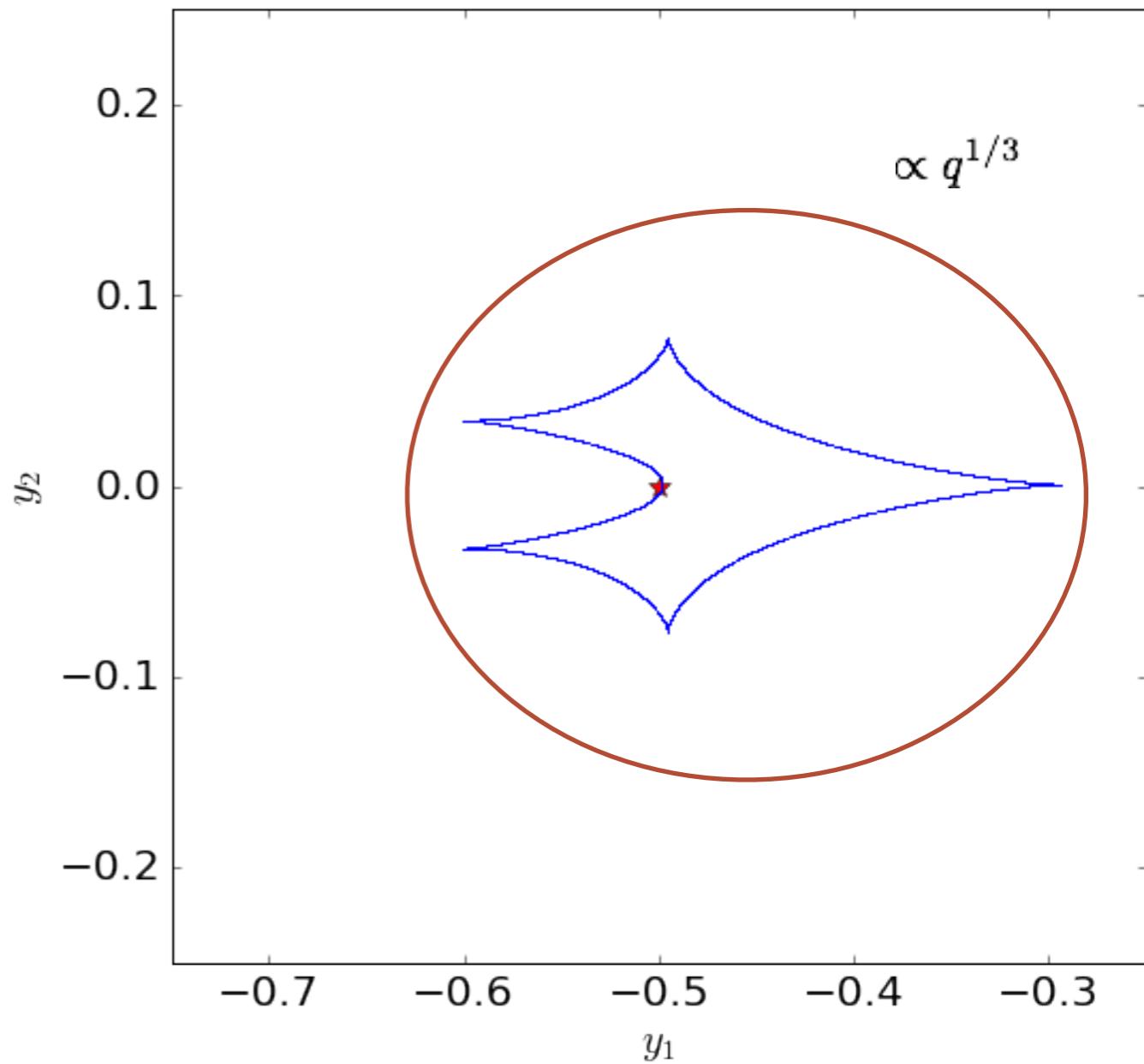
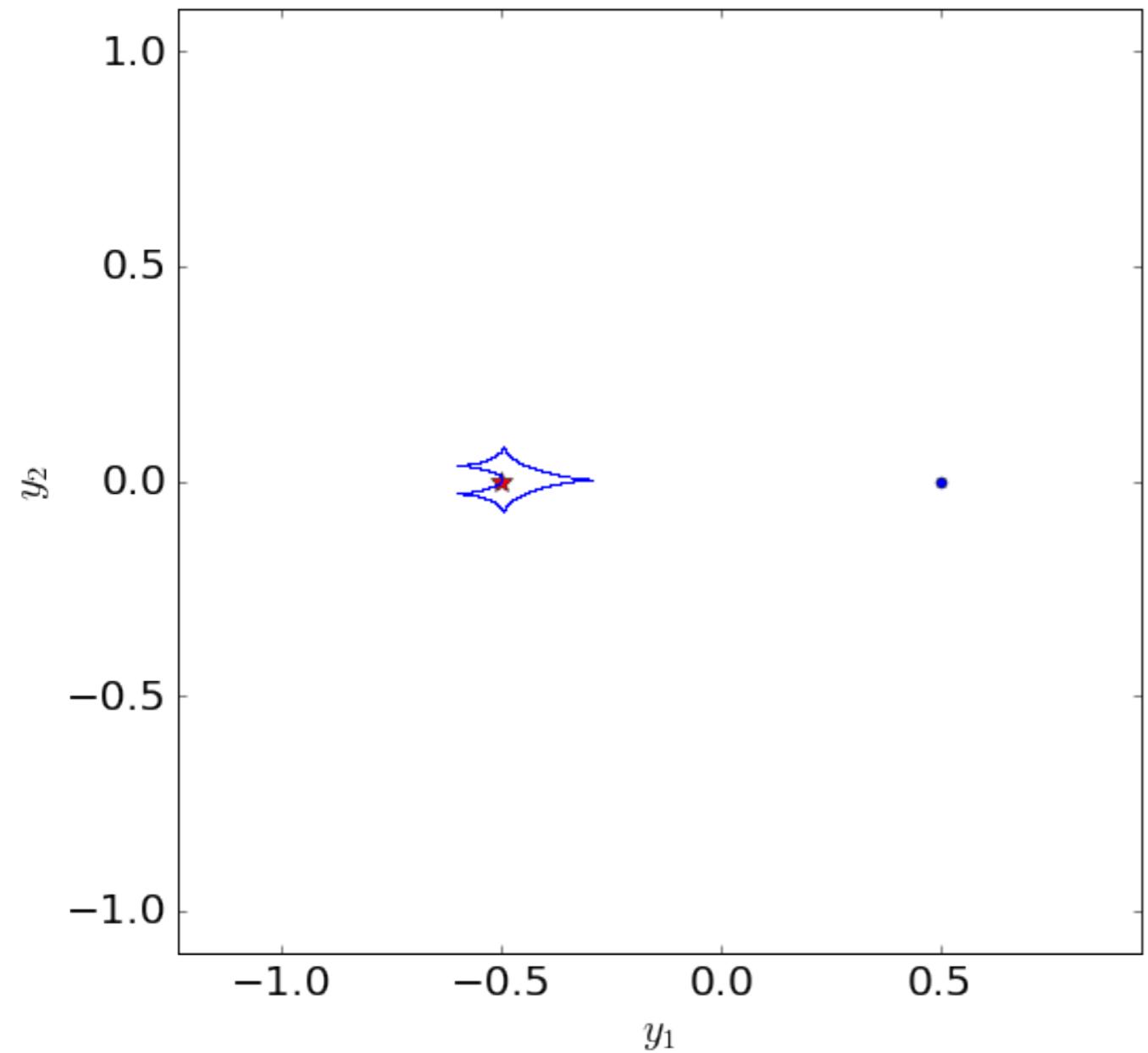
# PLANETARY CAUSTICS IN INTERMEDIATE TOPOLOGIES

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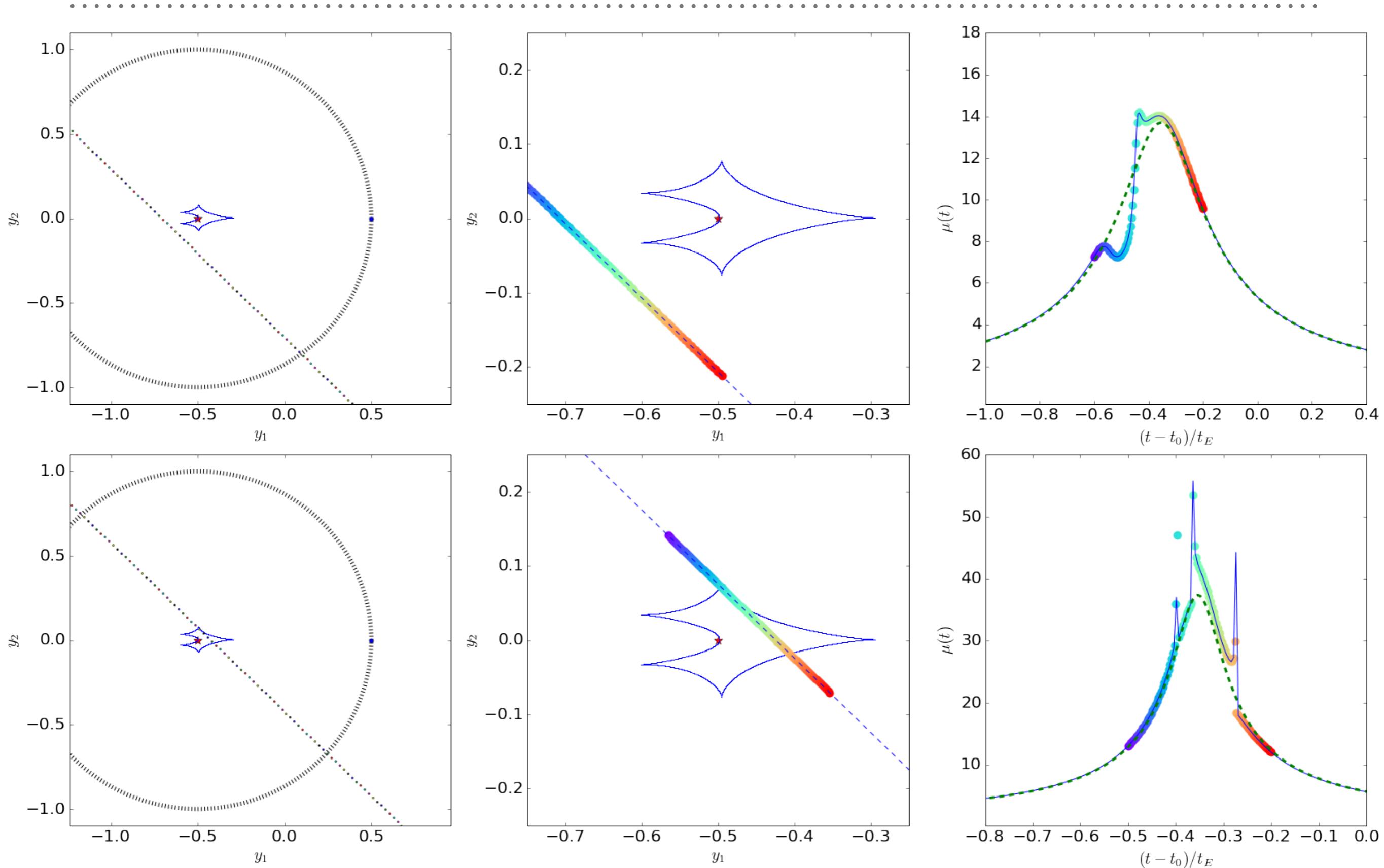


# PLANETARY CAUSTICS IN INTERMEDIATE TOPOLOGIES

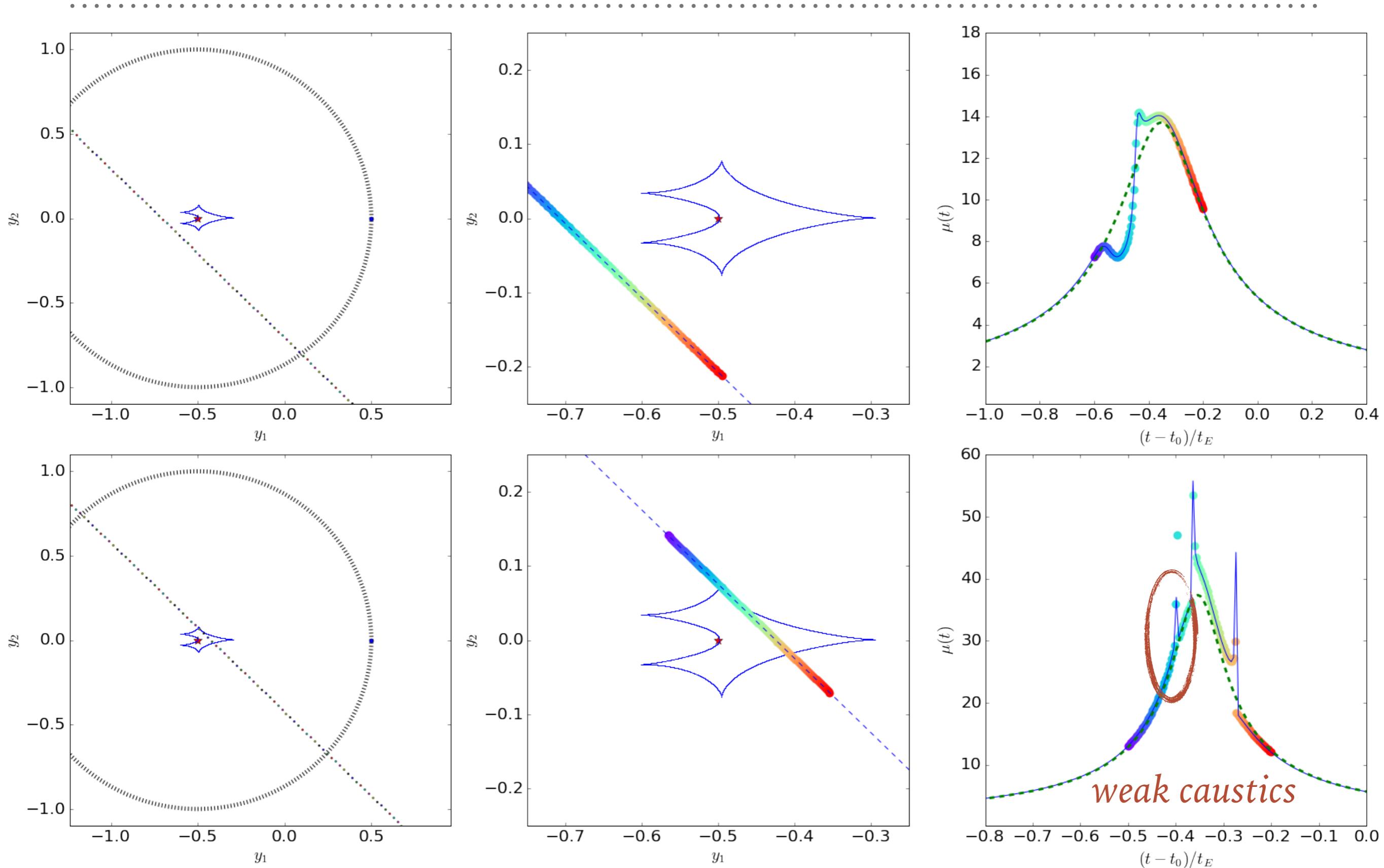
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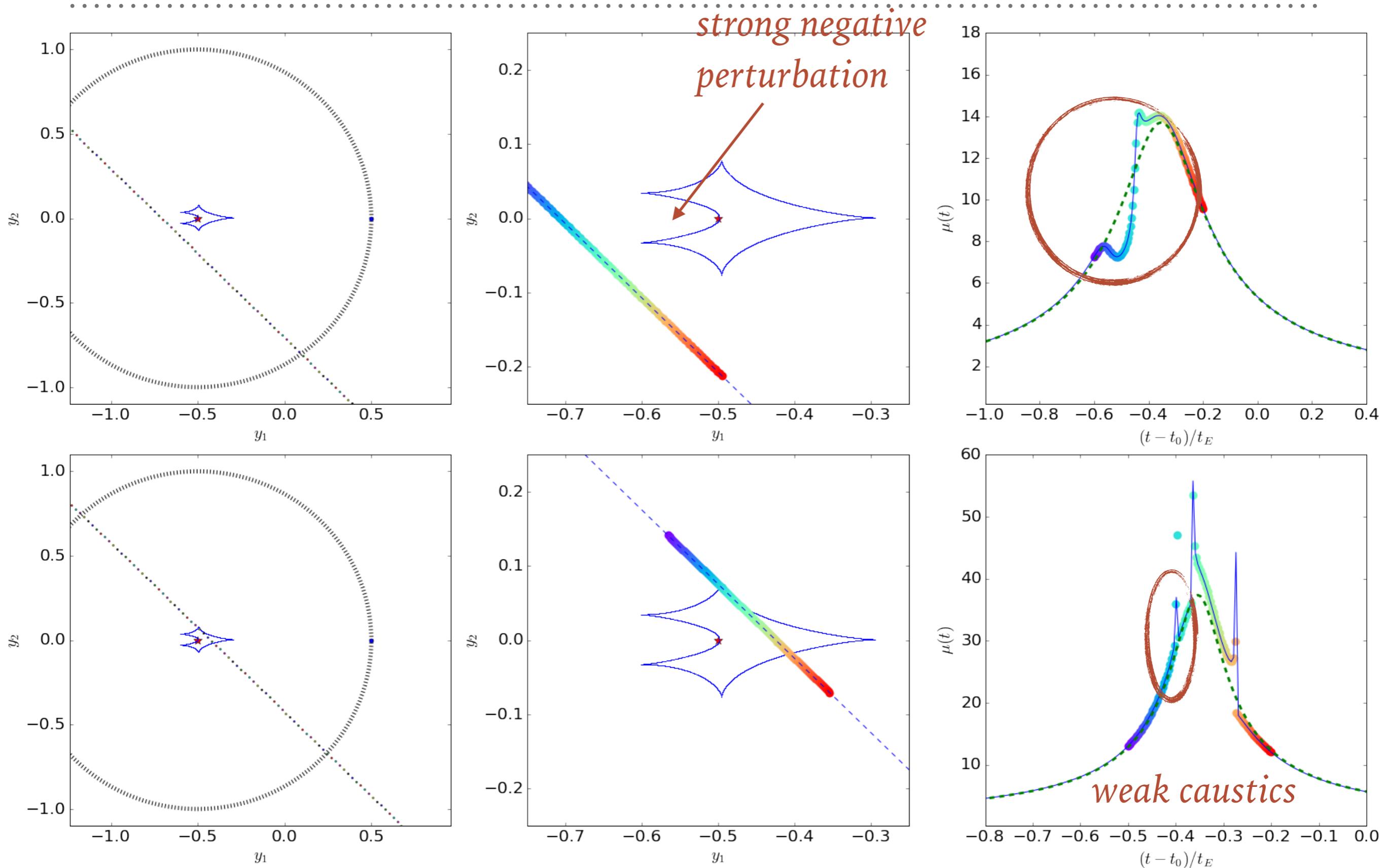
# PLANETARY CAUSTICS PERTURBATIONS IN INTERMEDIATE TOPOLOGIES



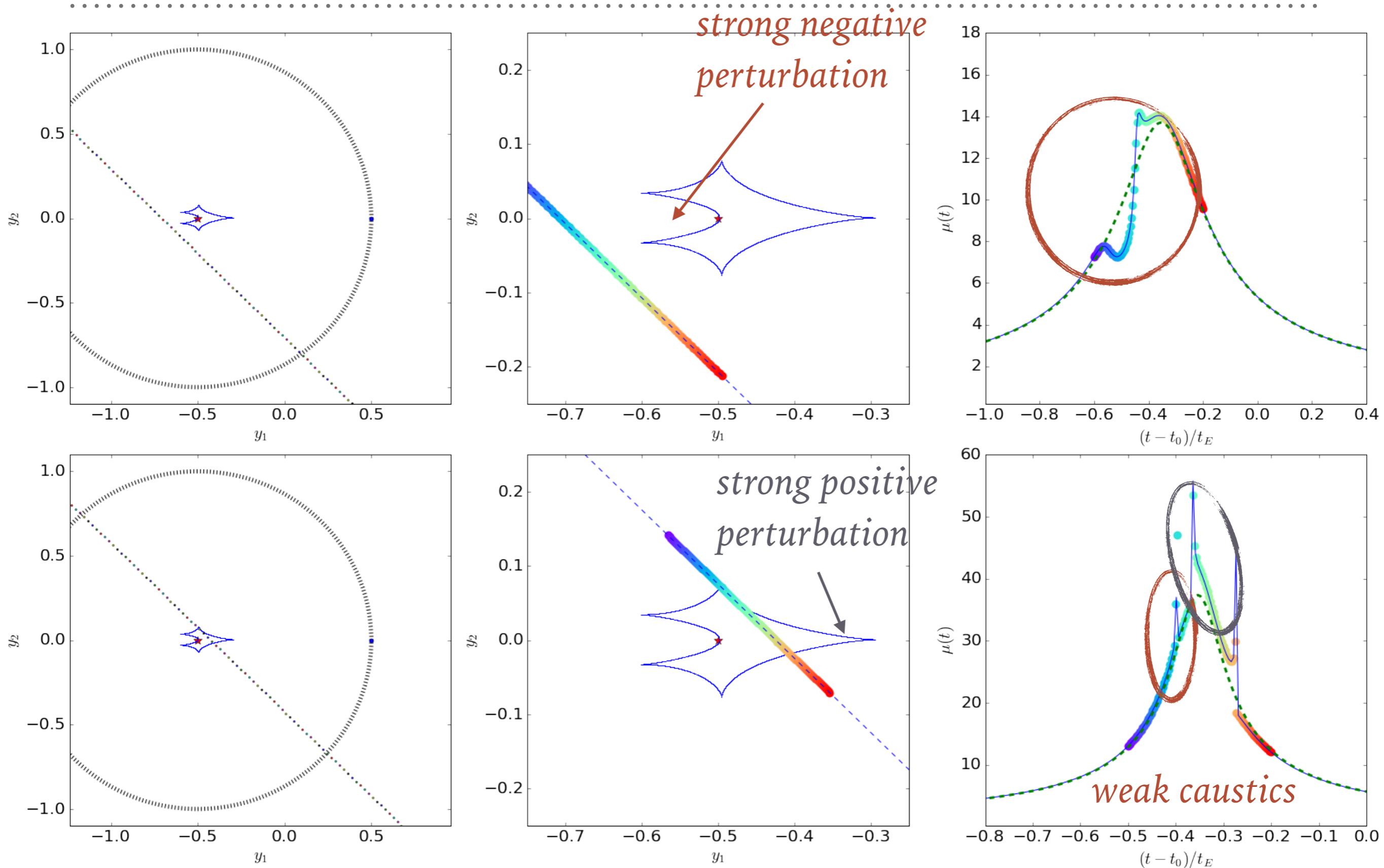
# PLANETARY CAUSTICS PERTURBATIONS IN INTERMEDIATE TOPOLOGIES



# PLANETARY CAUSTICS PERTURBATIONS IN INTERMEDIATE TOPOLOGIES



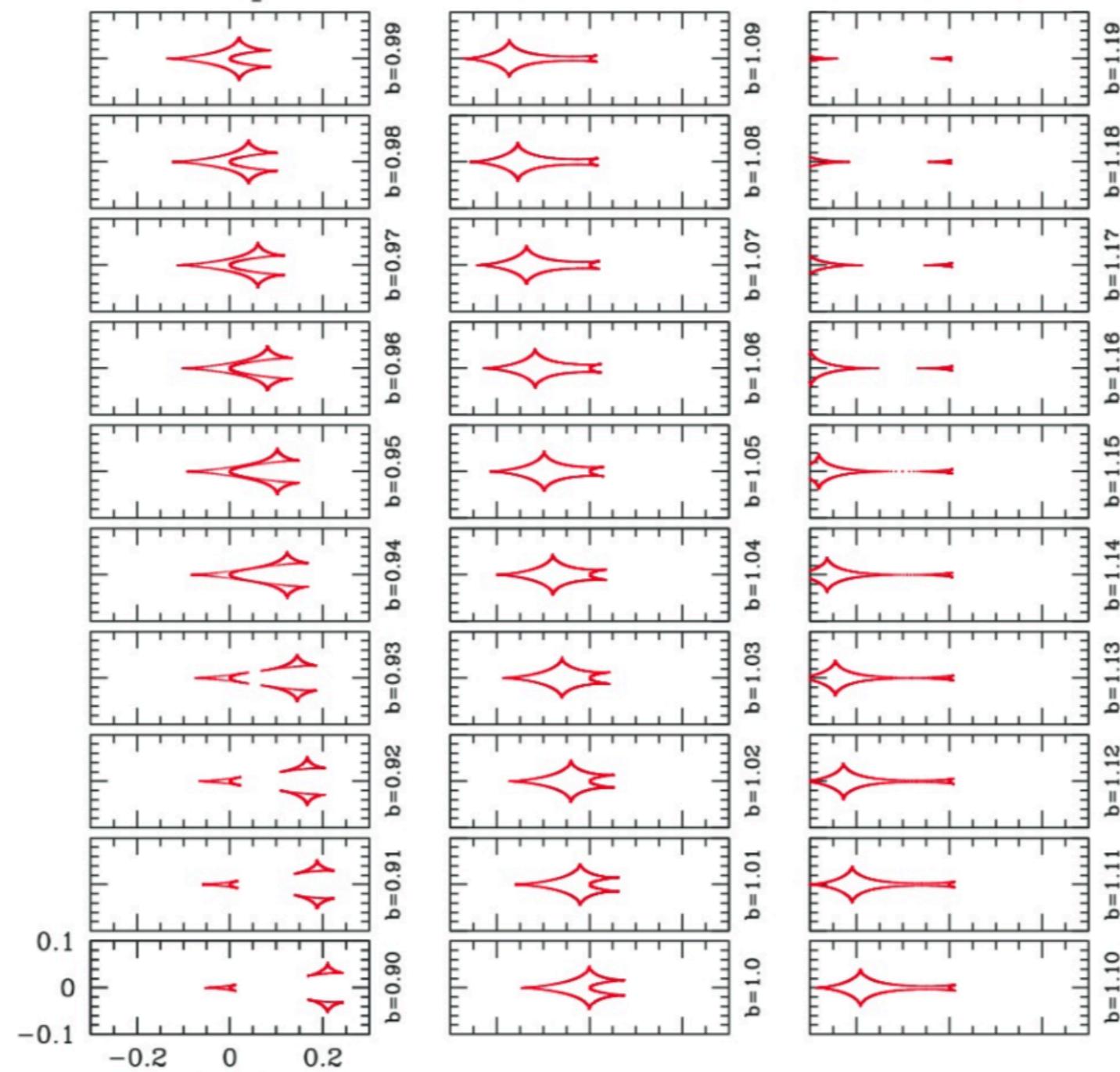
# PLANETARY CAUSTICS PERTURBATIONS IN INTERMEDIATE TOPOLOGIES



# SHAPE OF THE RESONANT CAUSTIC VS D

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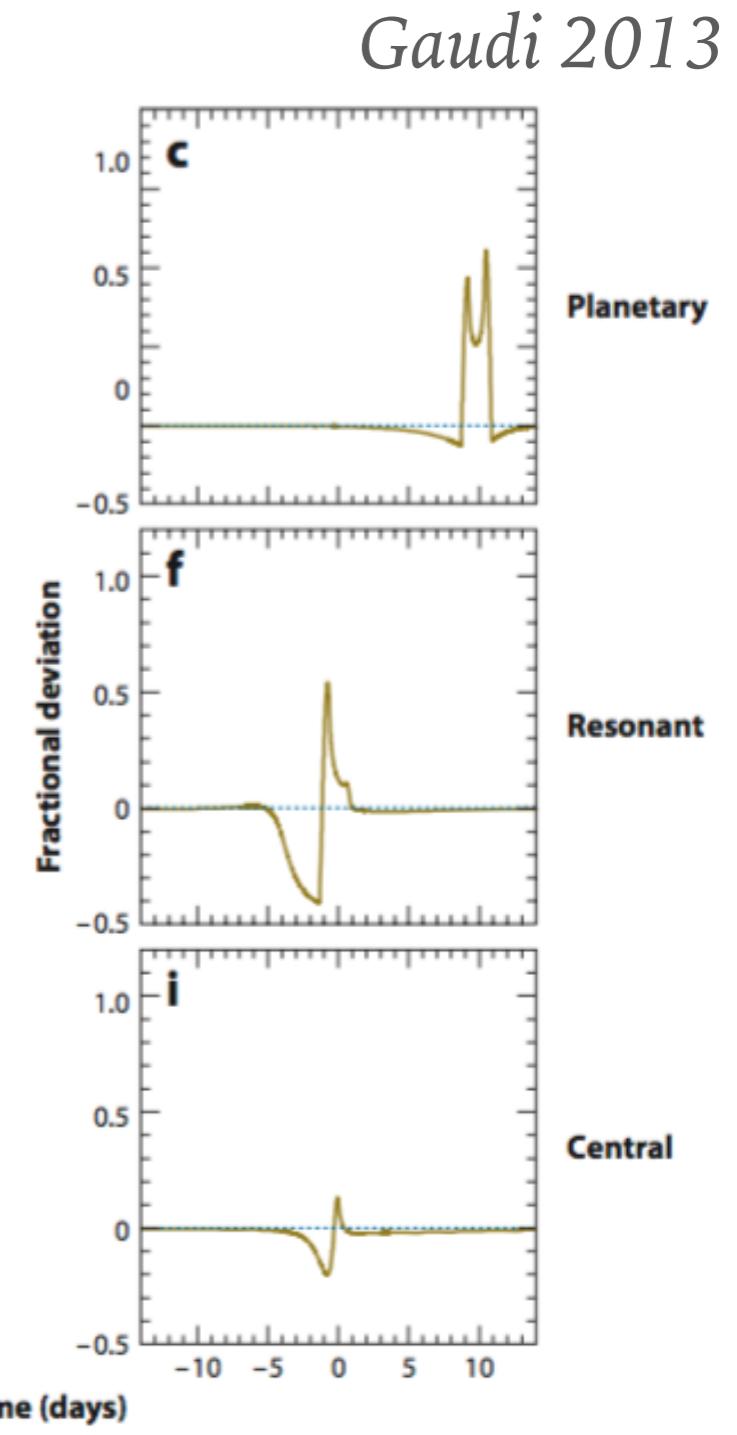
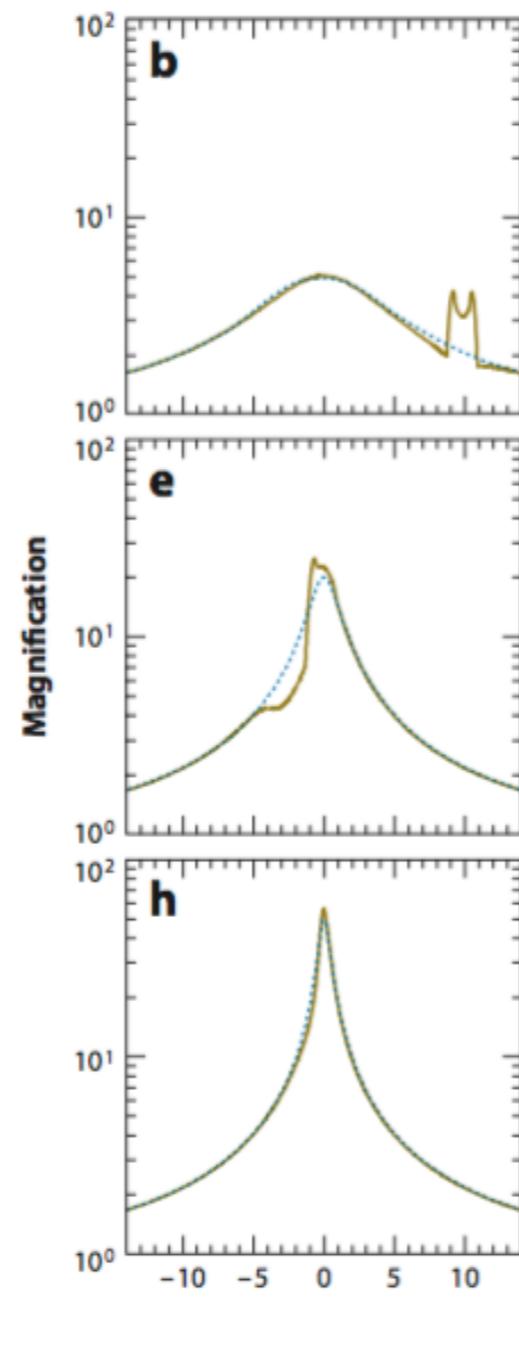
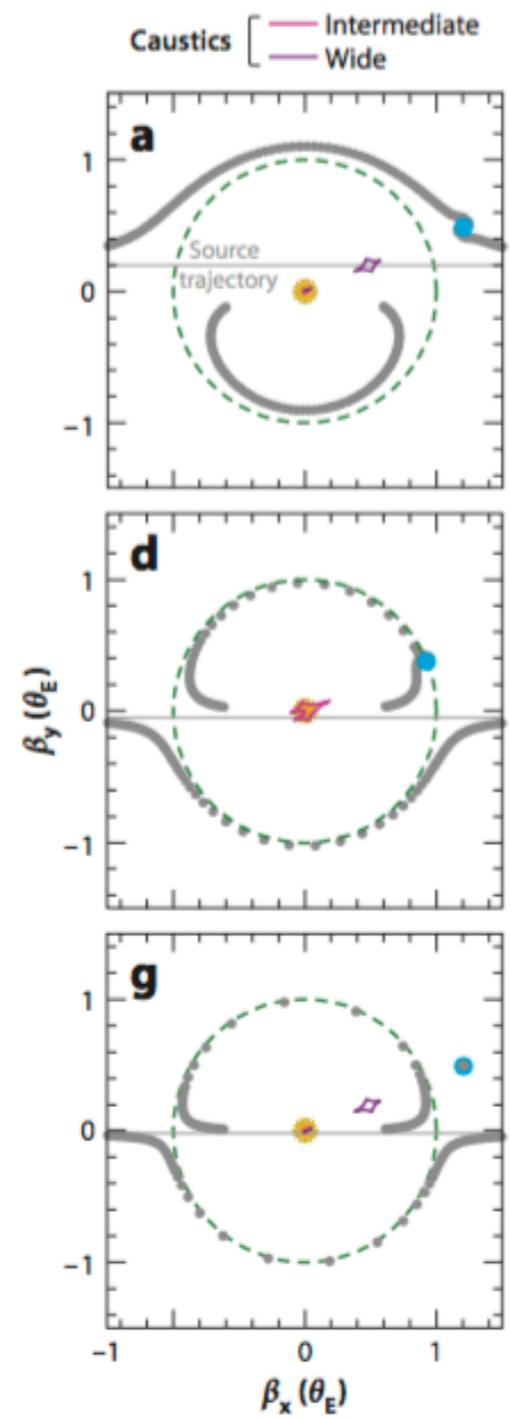
$q = 0.001, s = 0.90 - 1.19, \Delta s = 0.29$



# A COMPLEMENTARY VIEW

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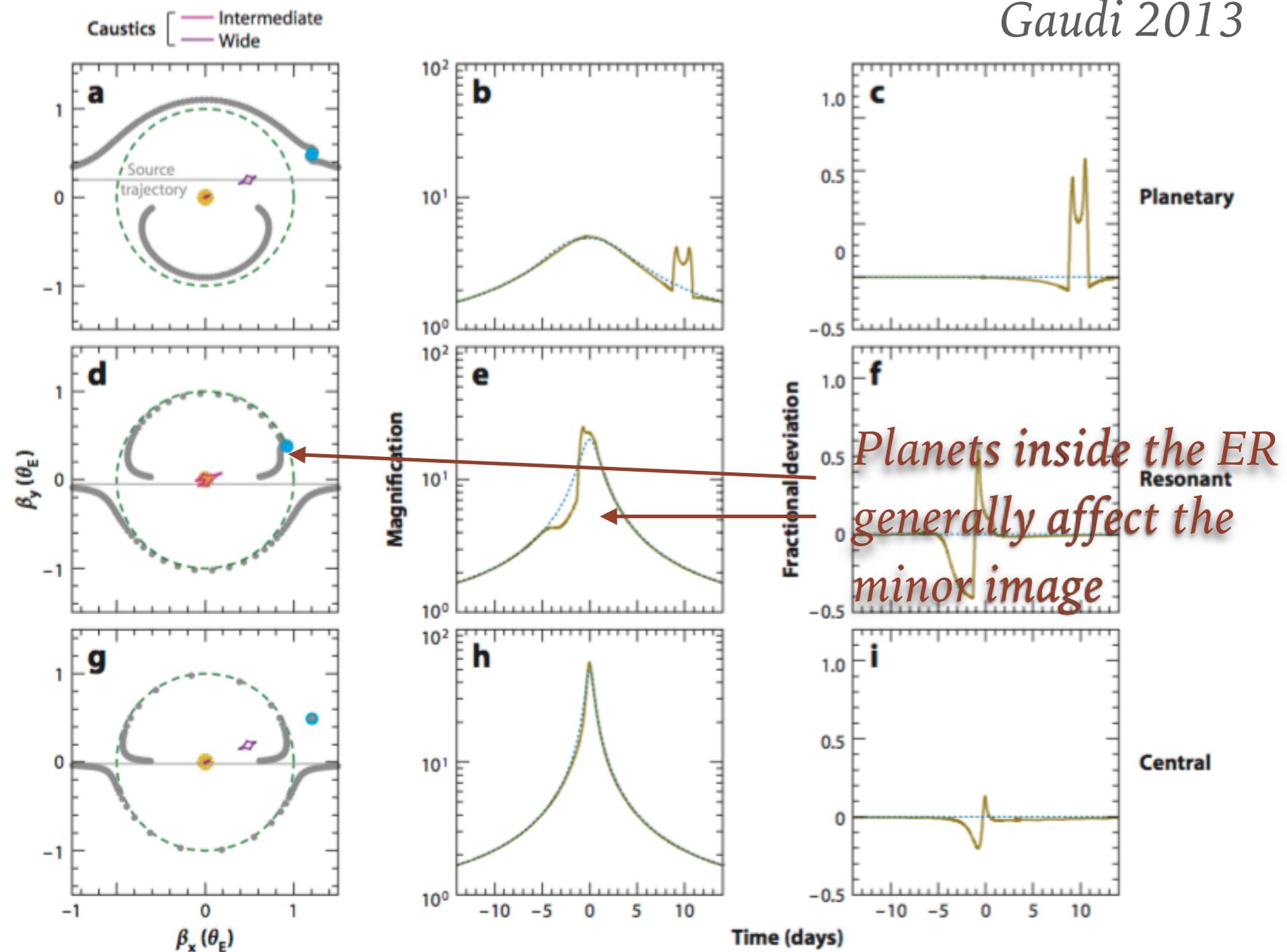
The planet can be detected when it perturbs one of the two images of the source!



Gaudi 2013

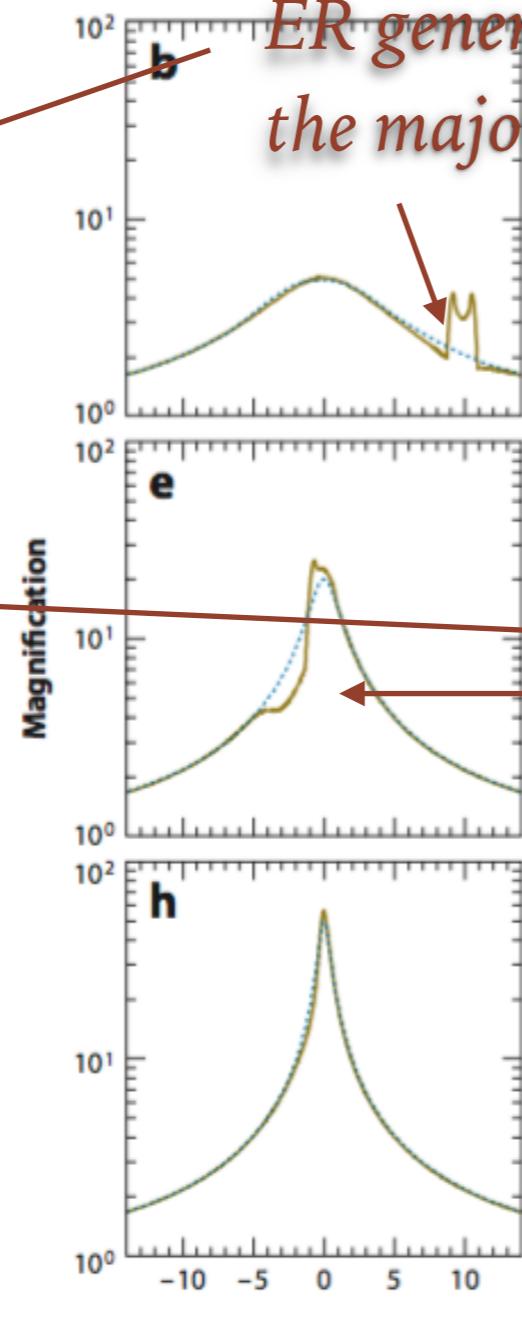
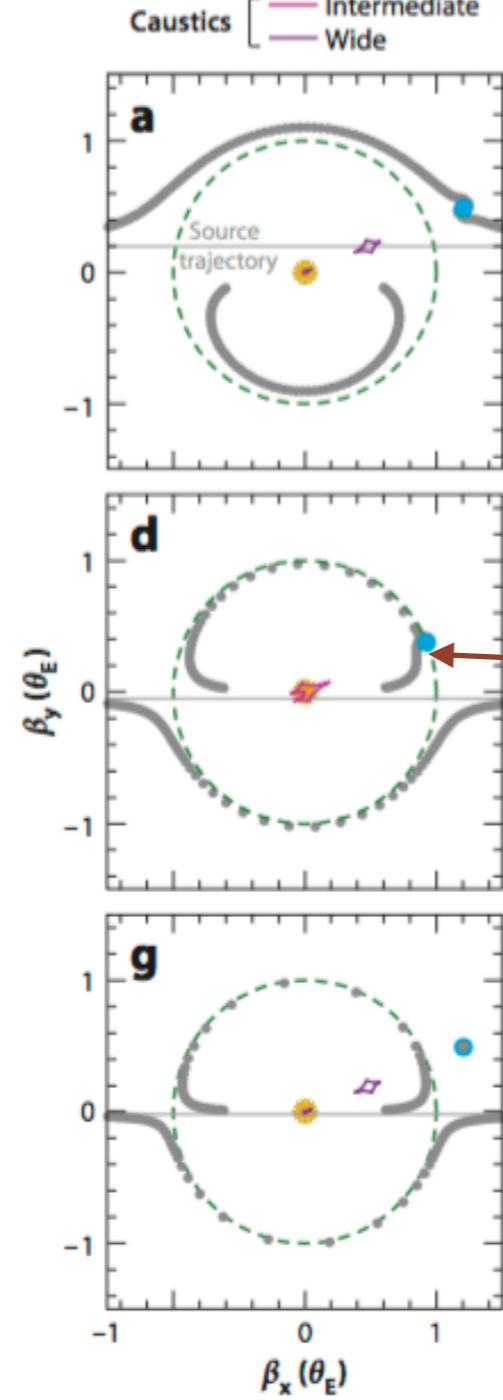
# A COMPLEMENTARY VIEW

The planet can be detected when it perturbs one of the two images of the source!

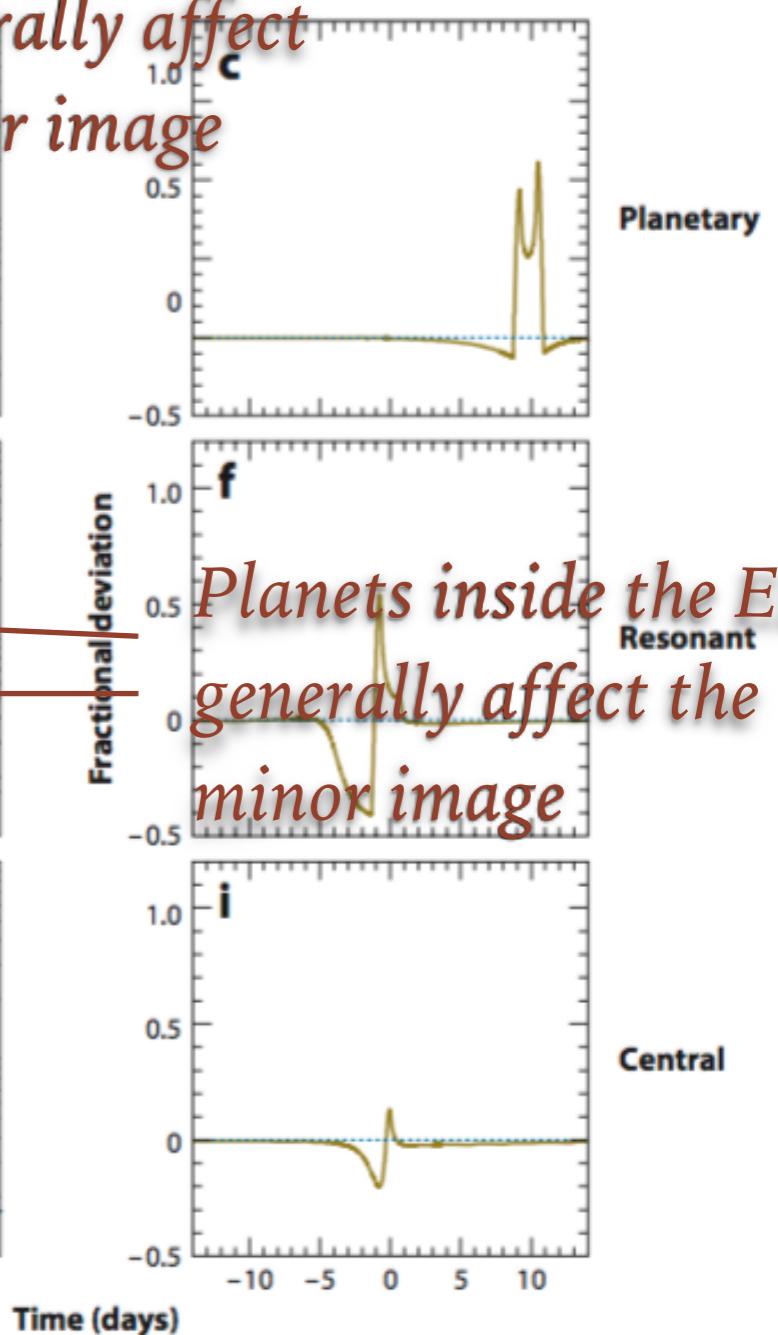


# A COMPLEMENTARY VIEW

The planet can be detected when it perturbs one of the two images of the source!



Planets outside the ER generally affect the major image

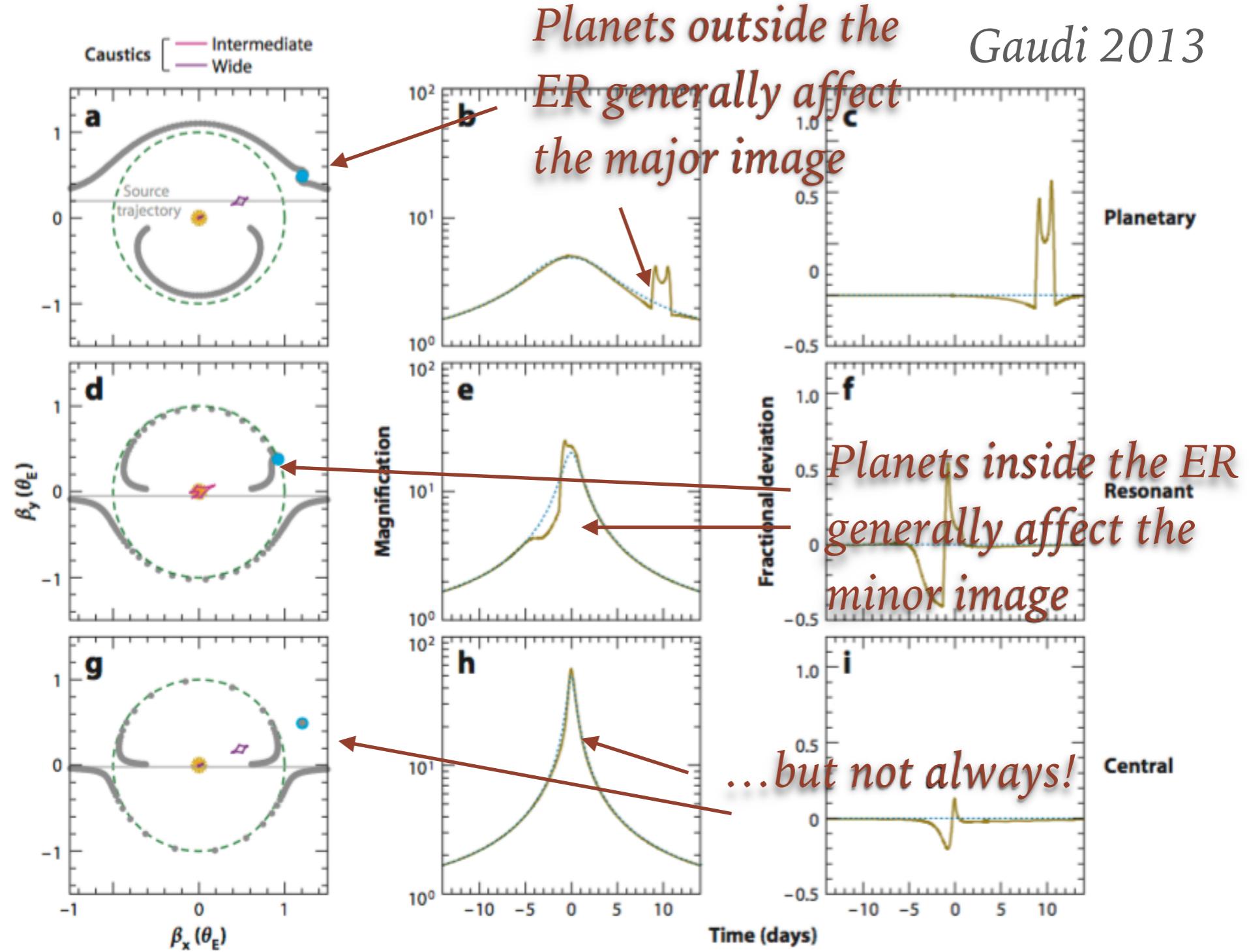


Gaudi 2013

Planets inside the ER generally affect the minor image

# A COMPLEMENTARY VIEW

The planet can be detected when it perturbs one of the two images of the source!



# INTERPRETING THE LIGHT CURVES

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*If we notice a planetary caustic perturbation, it means that the planet is located at the position of one of the images:*

$$x_{\pm} = d$$

*Consequently the caustic which is being crossed has a position which can be derived from the lens equation (which is satisfied by the images)*

$$y_c = |d - d^{-1}|$$