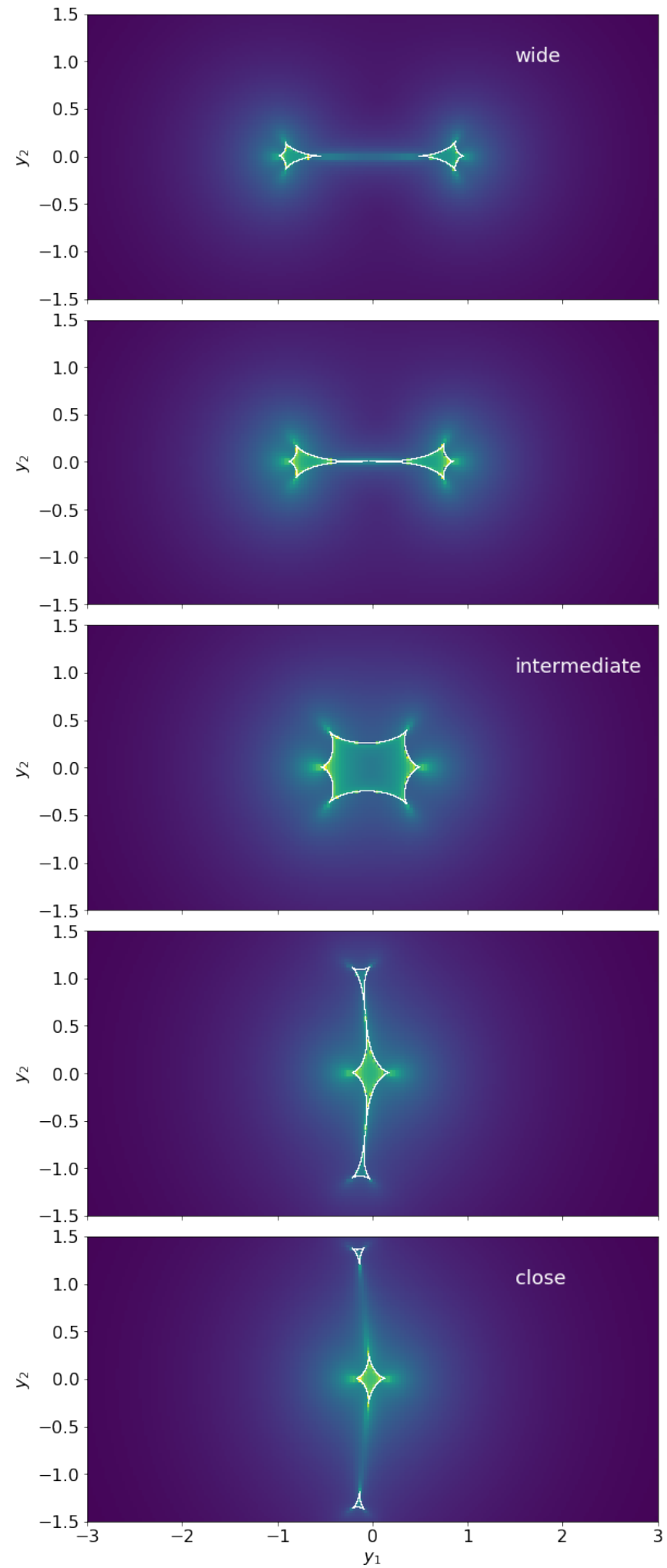
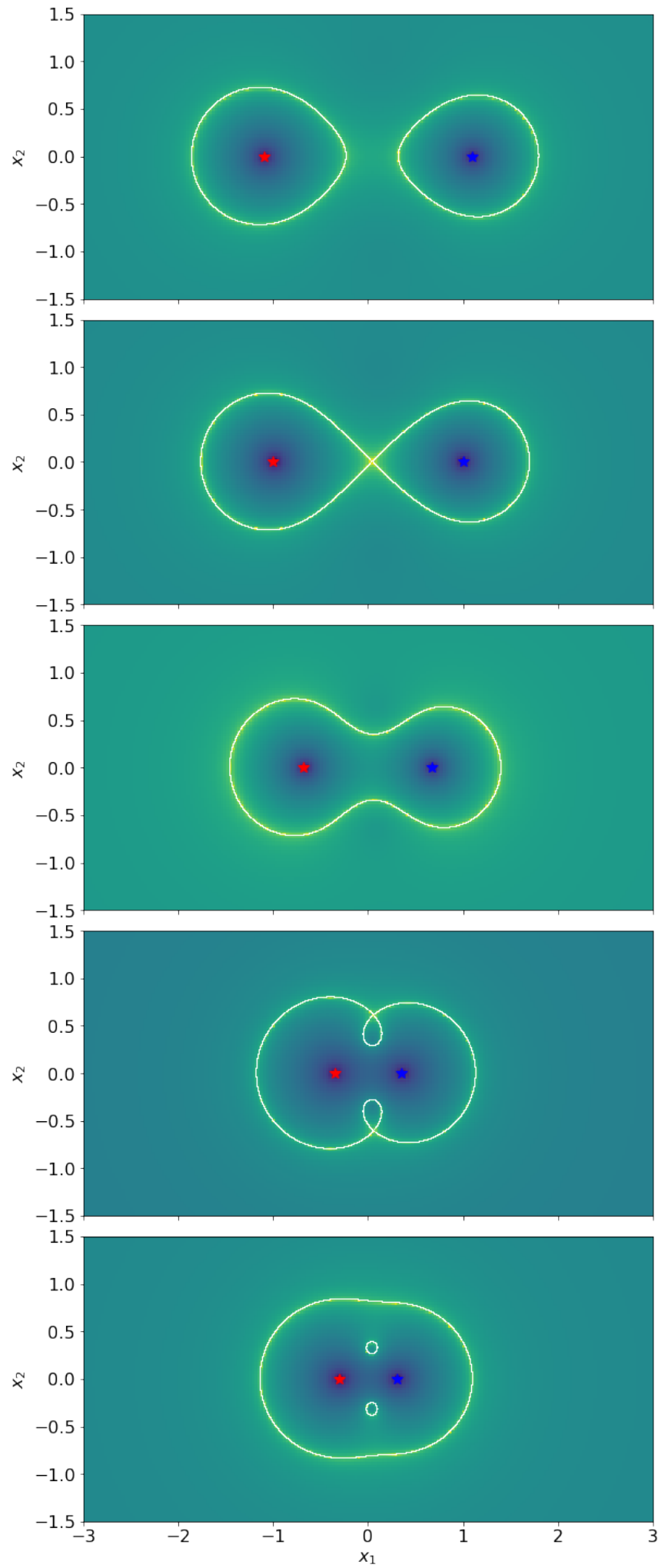


# GRAVITATIONAL LENSING

## 16 – BINARY LENSES: PLANETARY MICROLENSING

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*Massimo Meneghetti*  
*AA 2018-2019*



# PLANETARY MICROLENSING

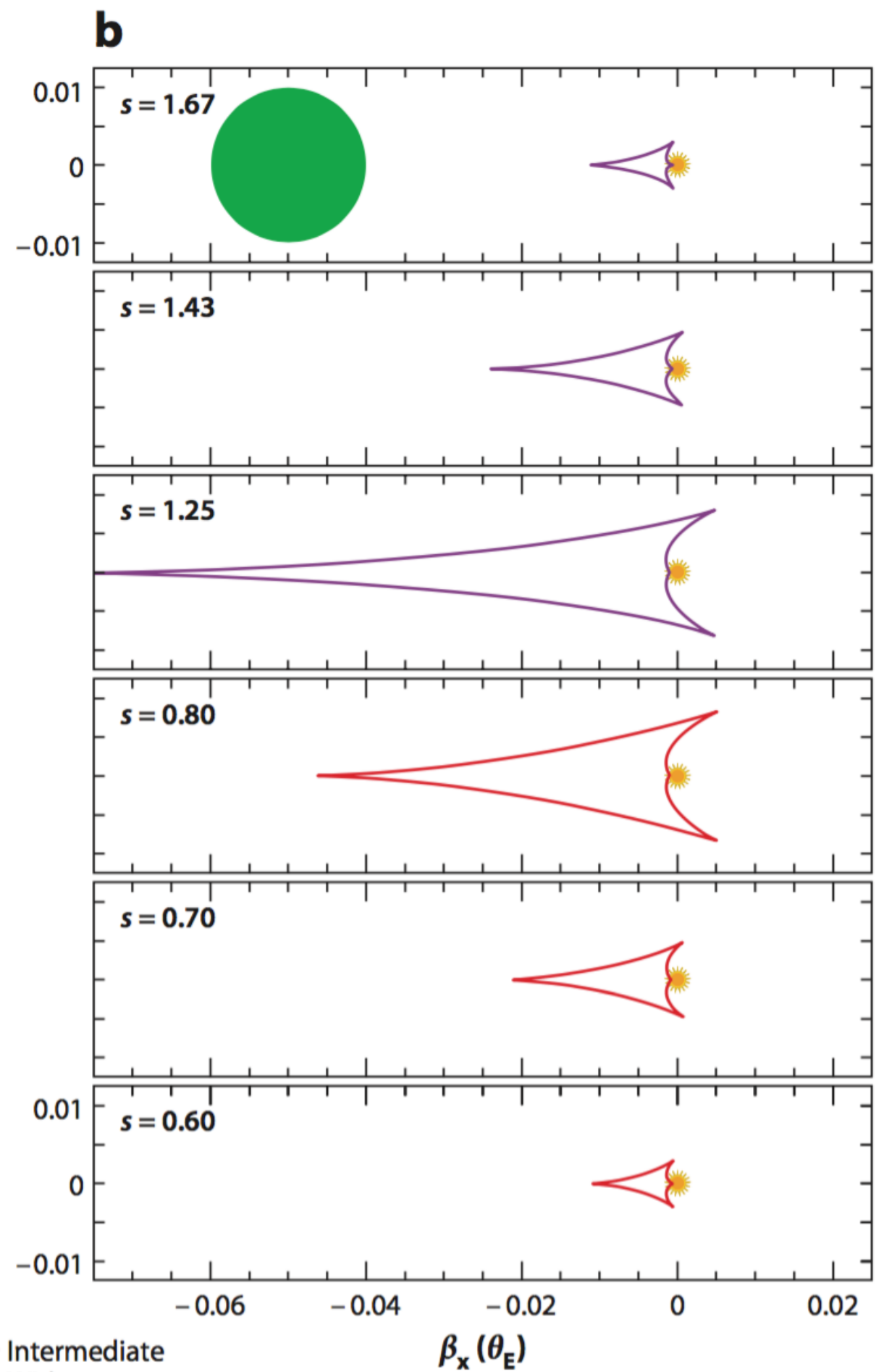
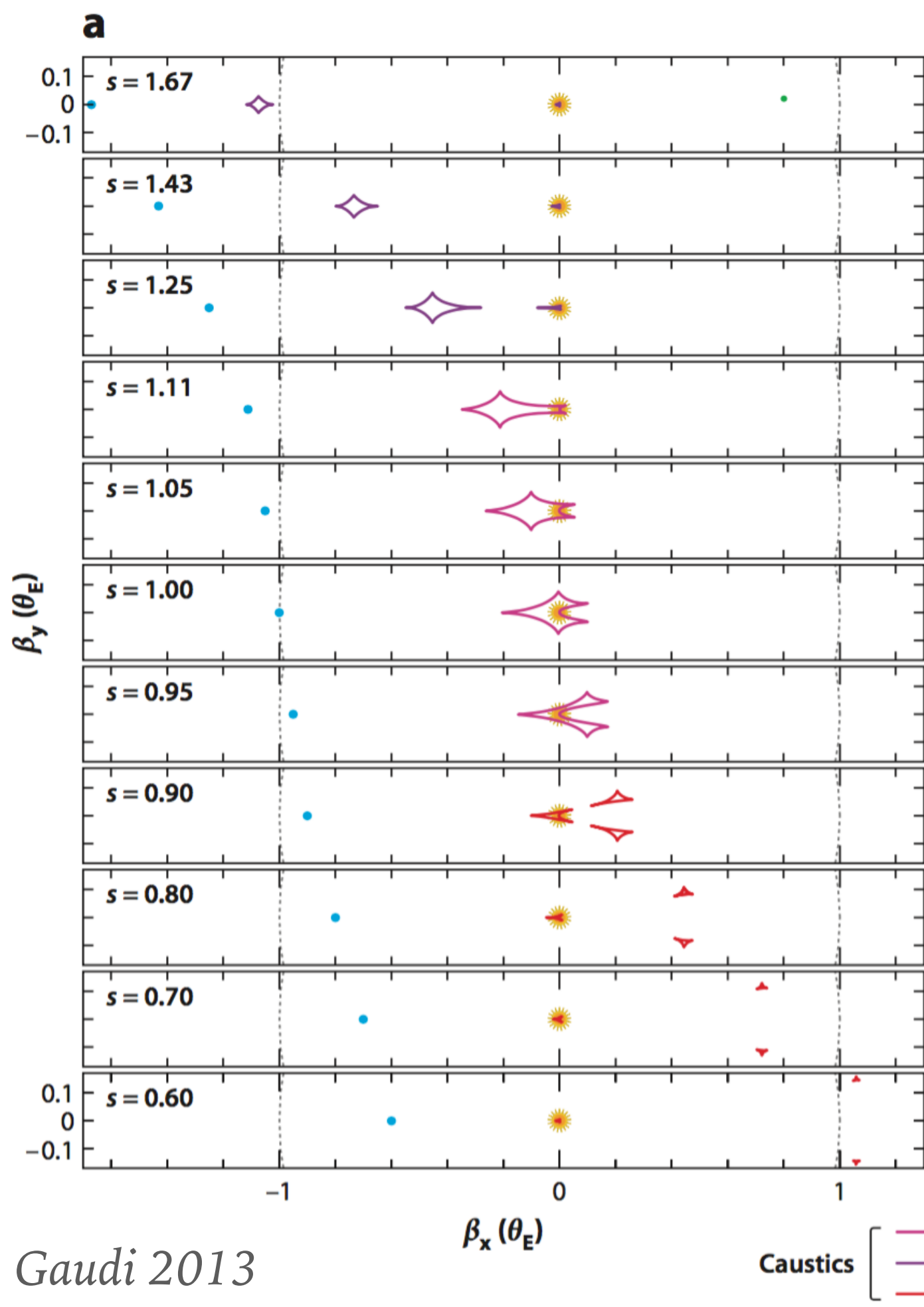
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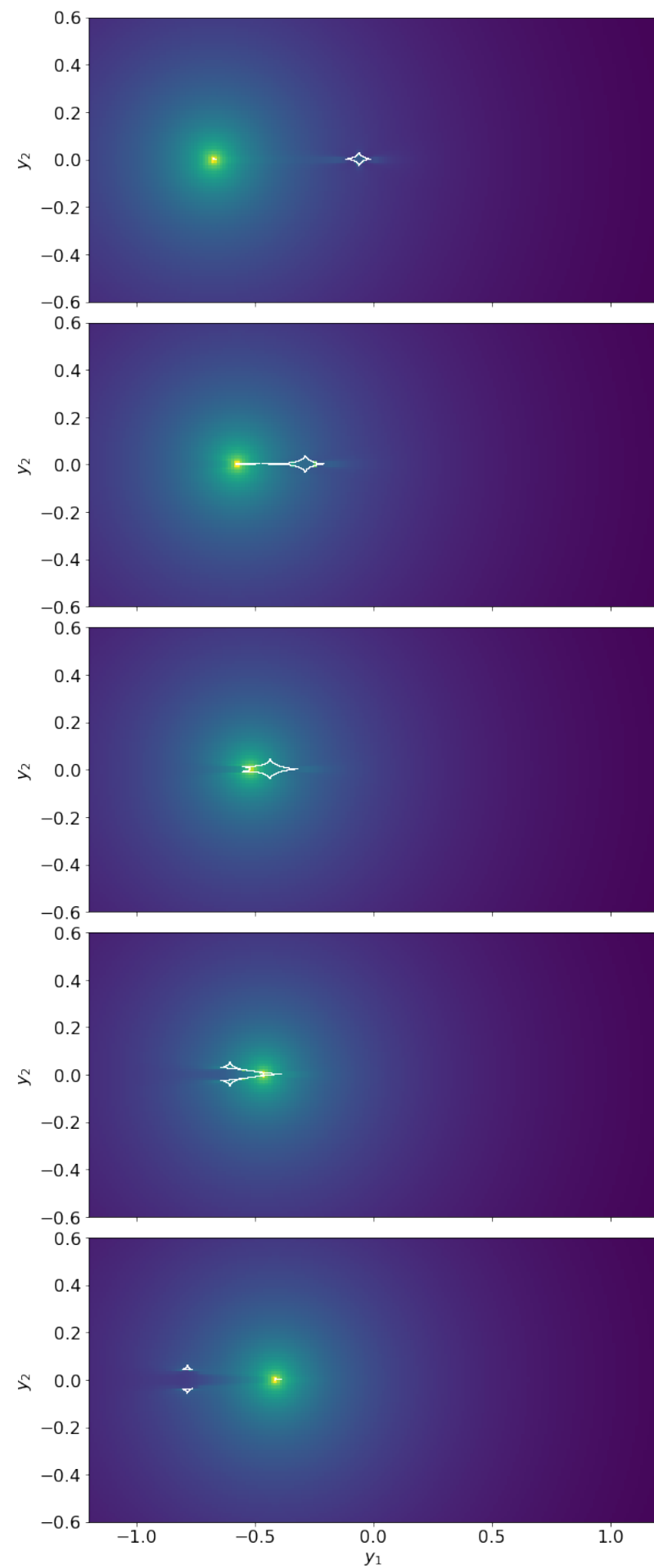
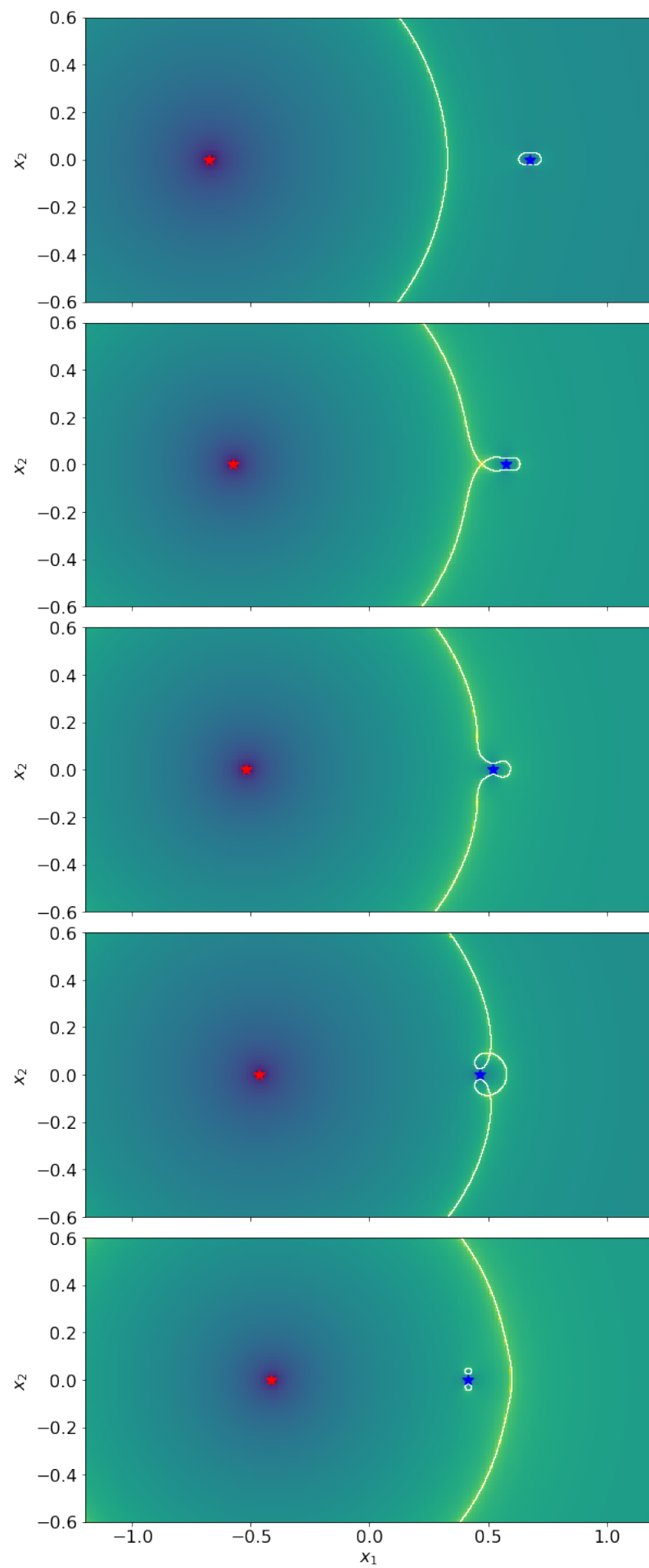
- Let us consider the system consisting of an host star and a planet orbiting around it.
- This is an example of **binary** lens
- The host star is of course much heavier than the planet!
  - example: for a Jupiter-like planet  $q=0.001$  (solar mass star)
  - example: for a Earth-like planet  $q=0.000003$

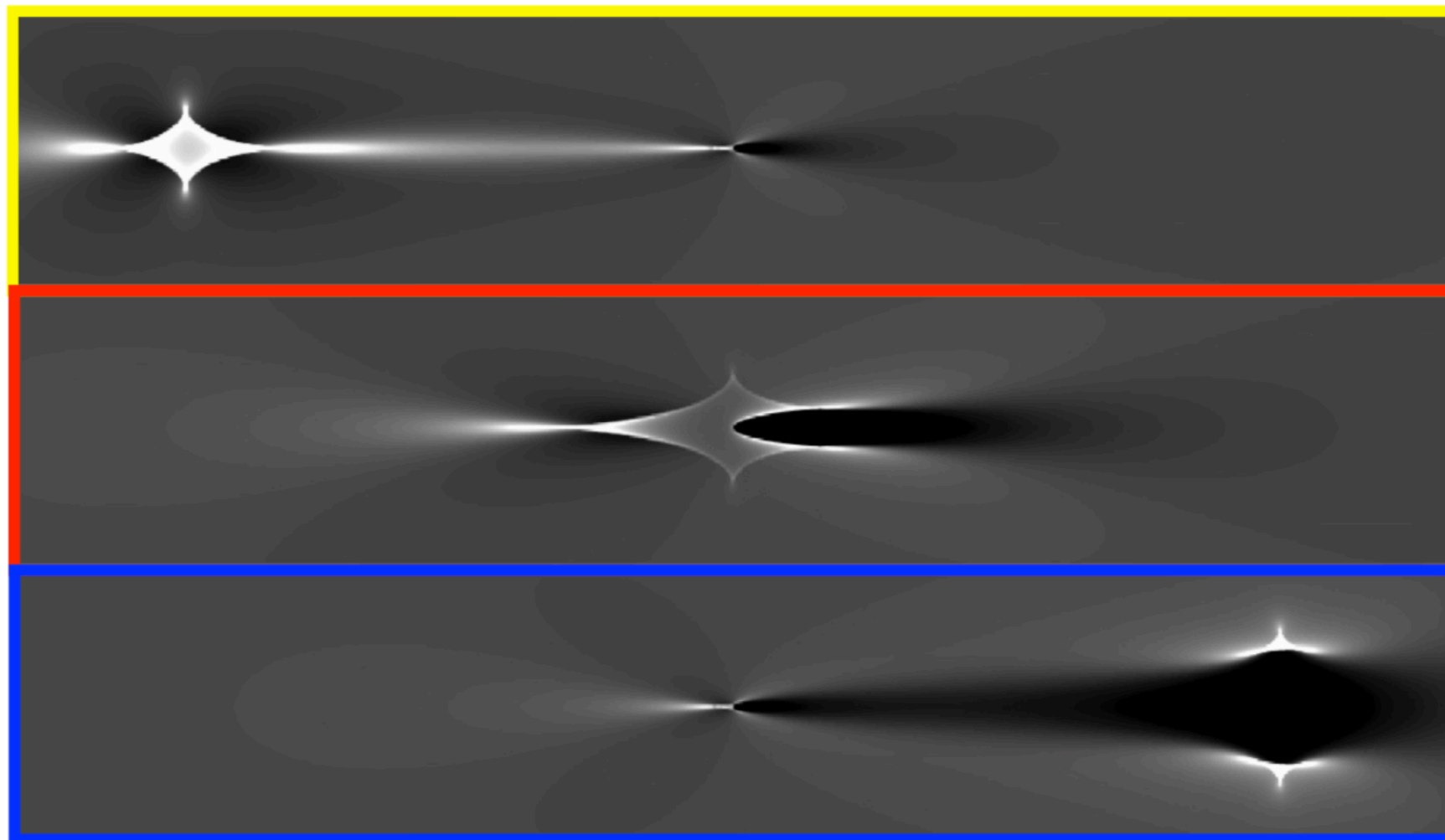
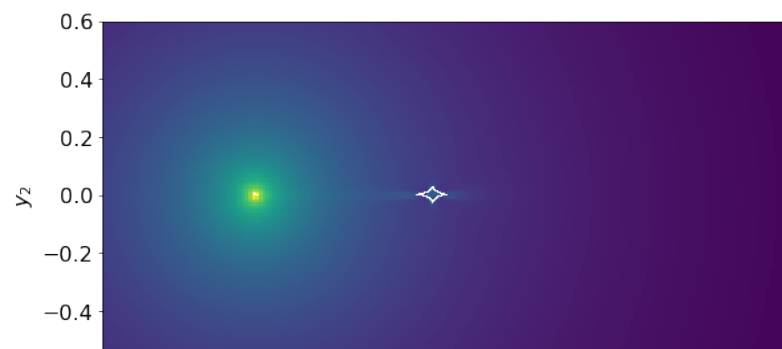
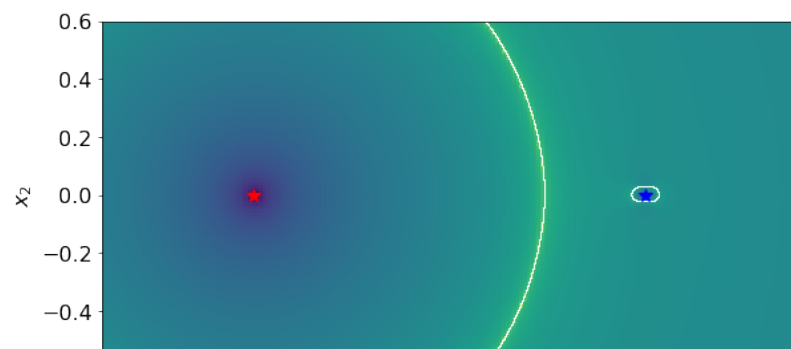
# WHAT KIND OF SIGNAL?

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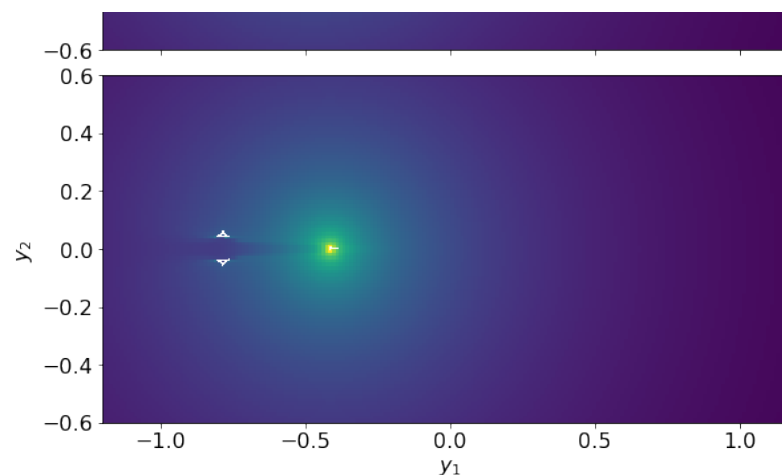
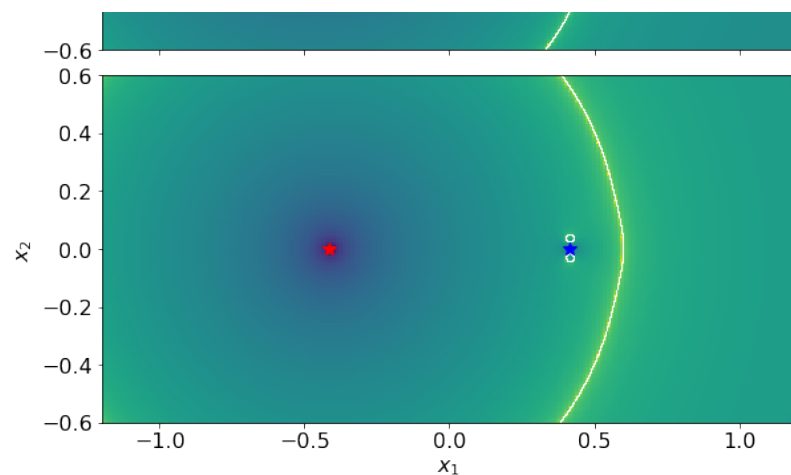
- The light curve is that of the star...
- The planet produces only a small perturbation to the magnification pattern, localized in a small region around the caustics
- Must cross one of these perturbed regions in order for the planet to be detected.
- The shape of the perturbation is determined by the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



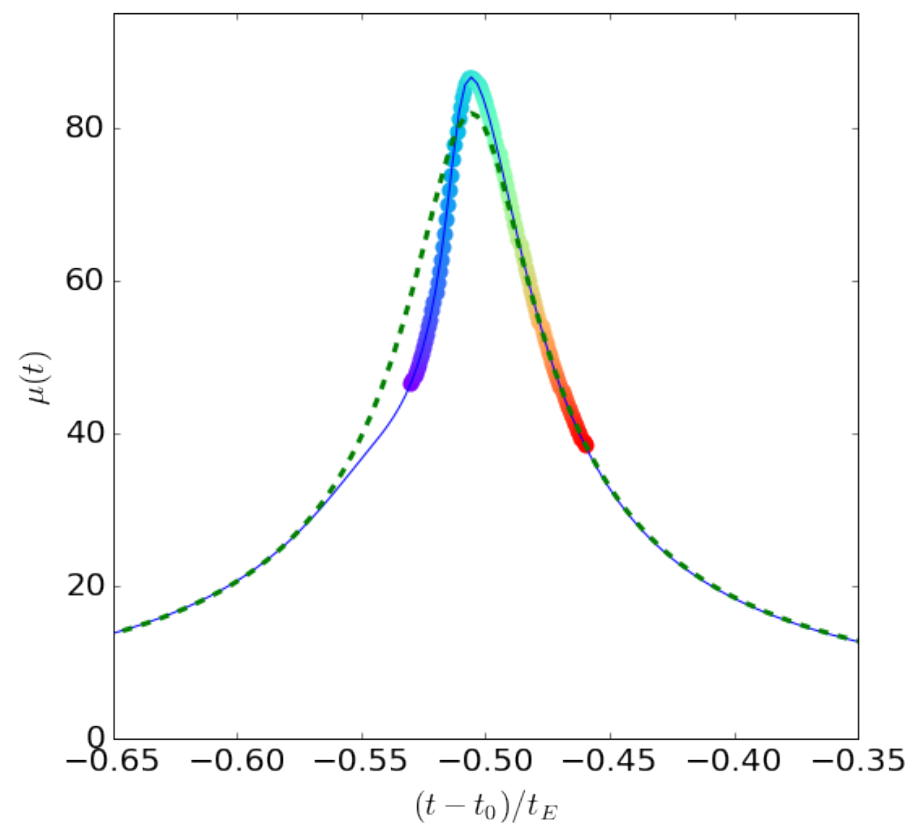
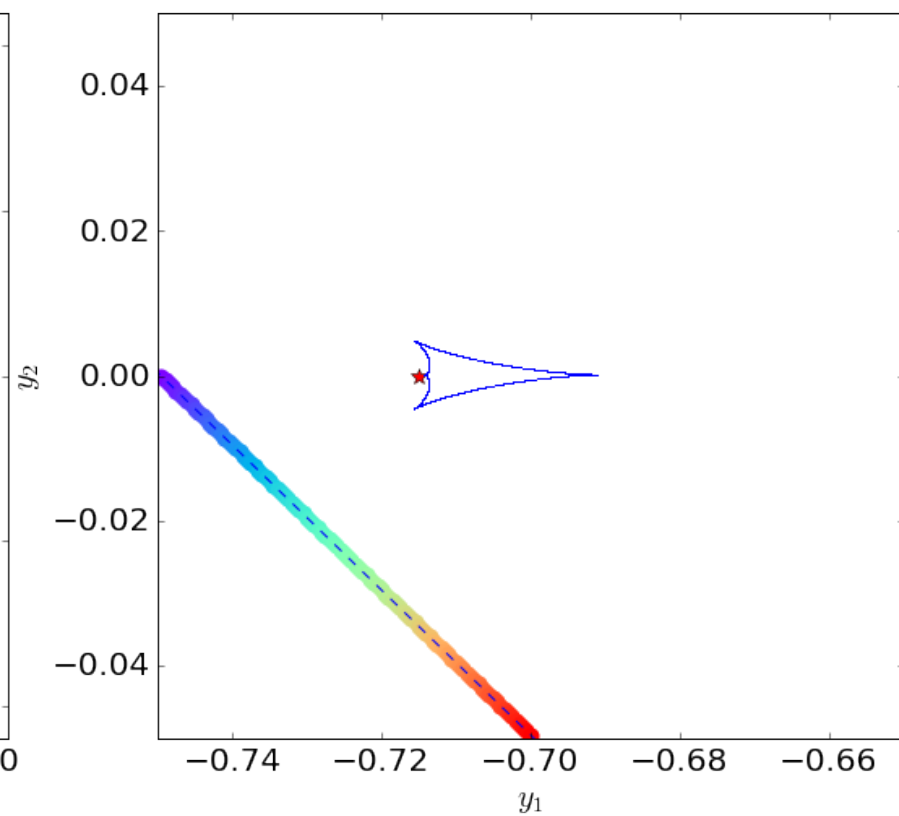
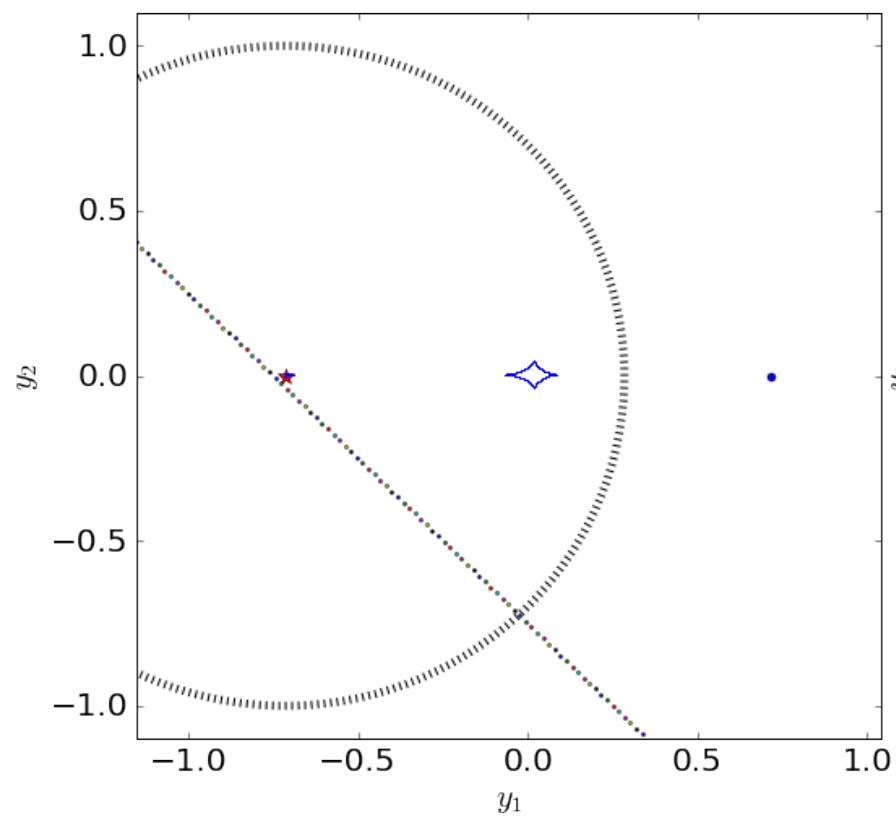
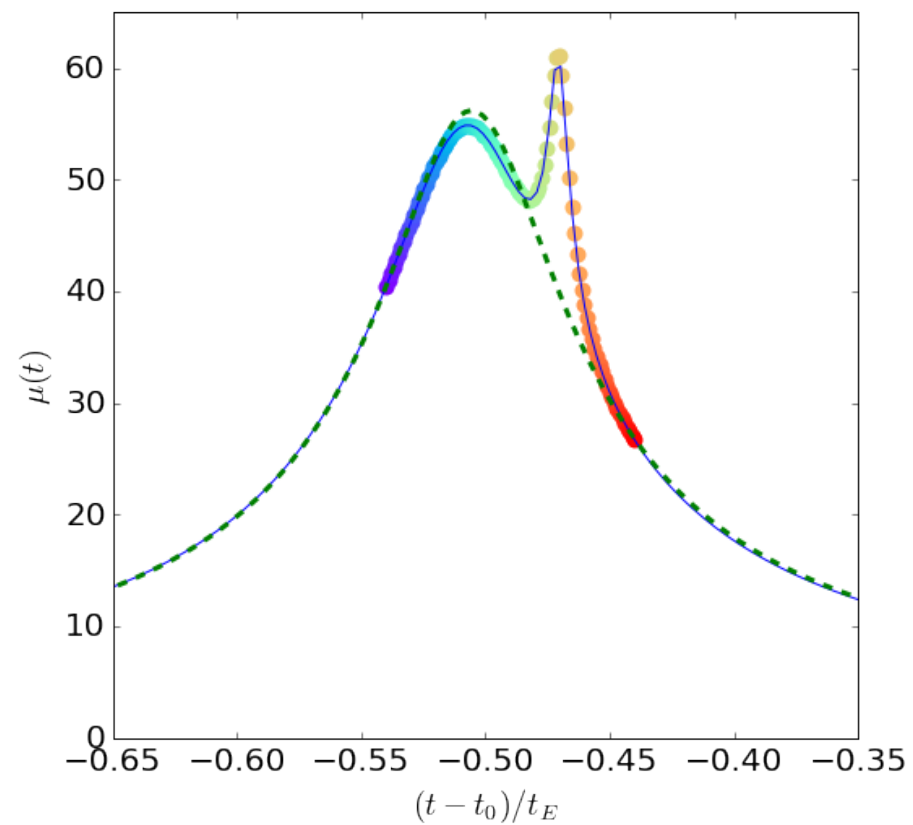
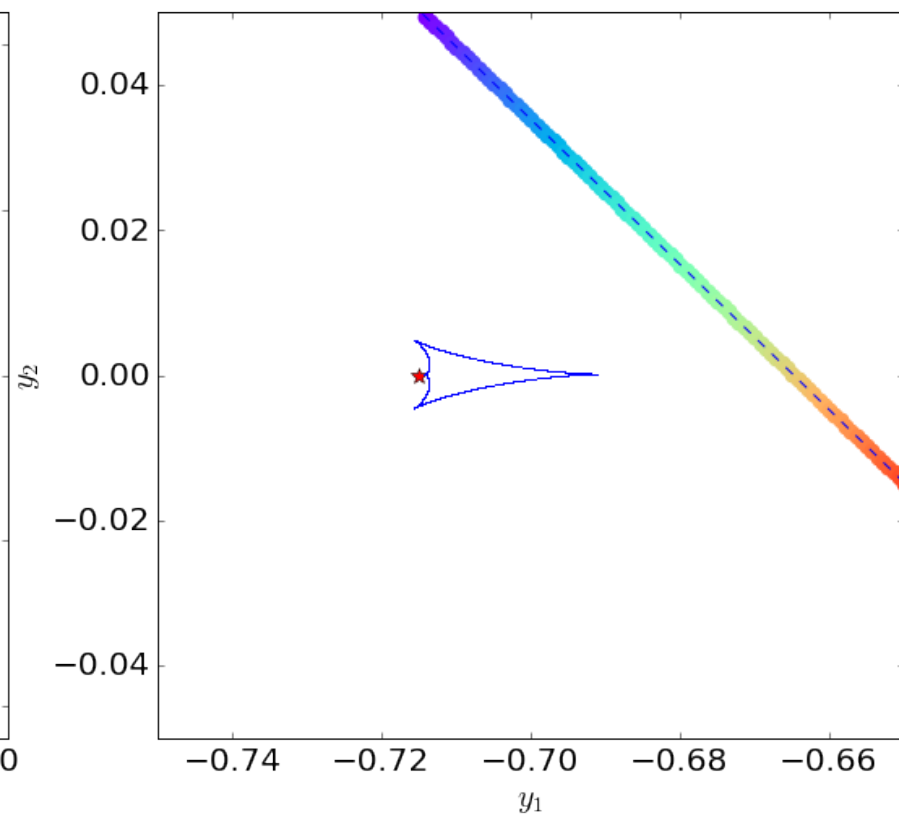
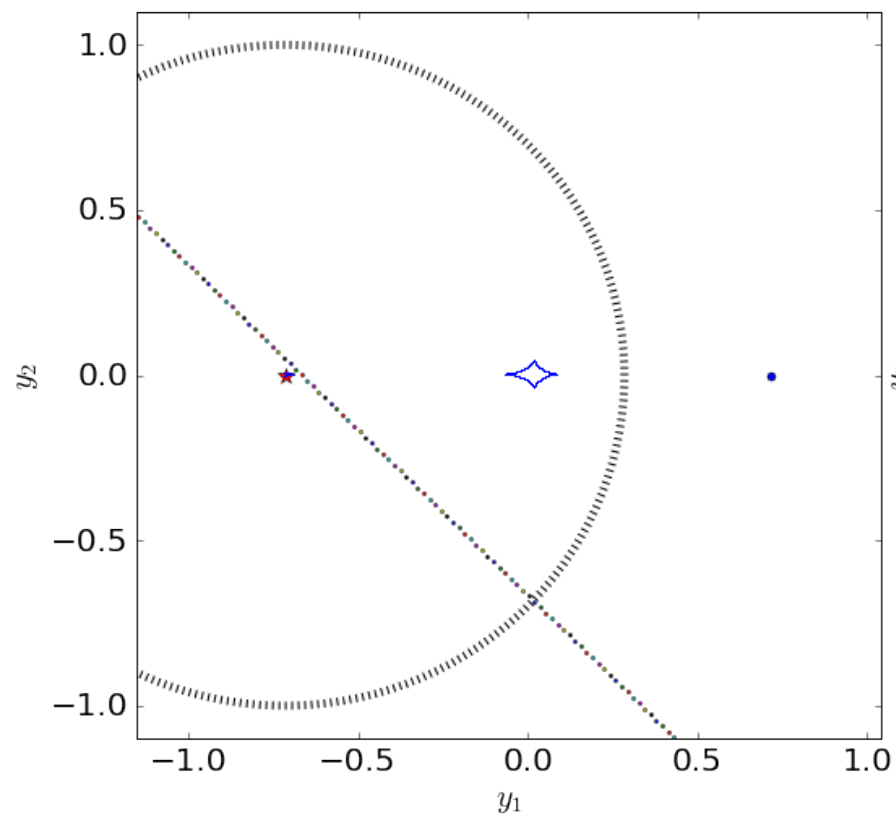




Wide  
Intermediate/  
Resonant  
Close

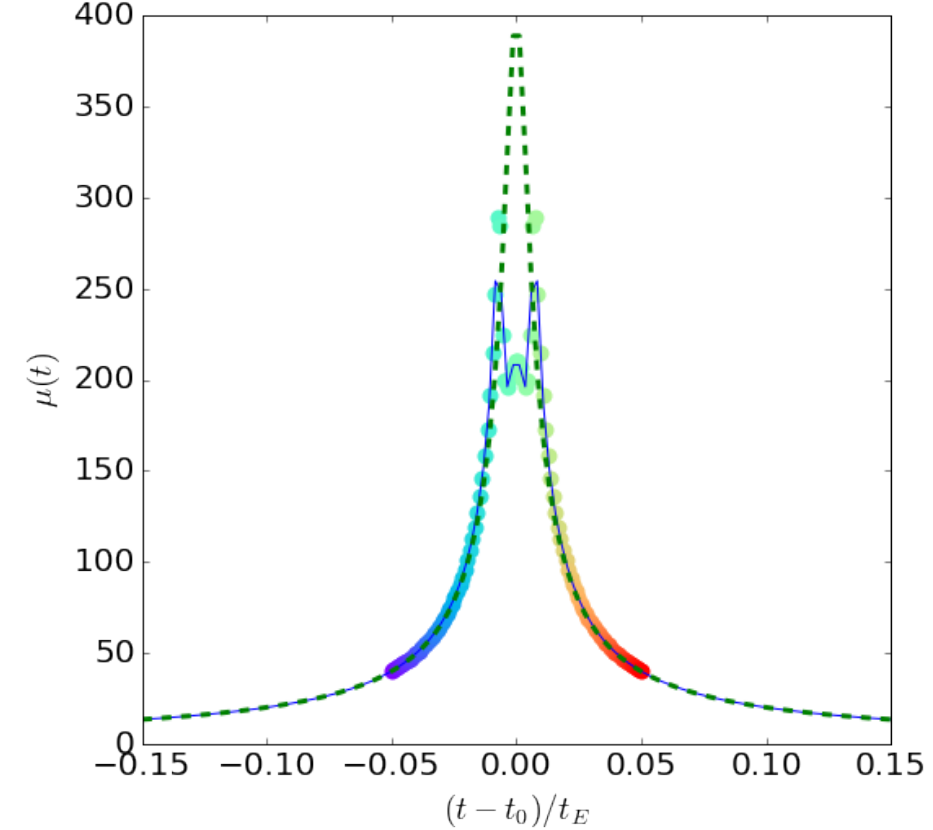
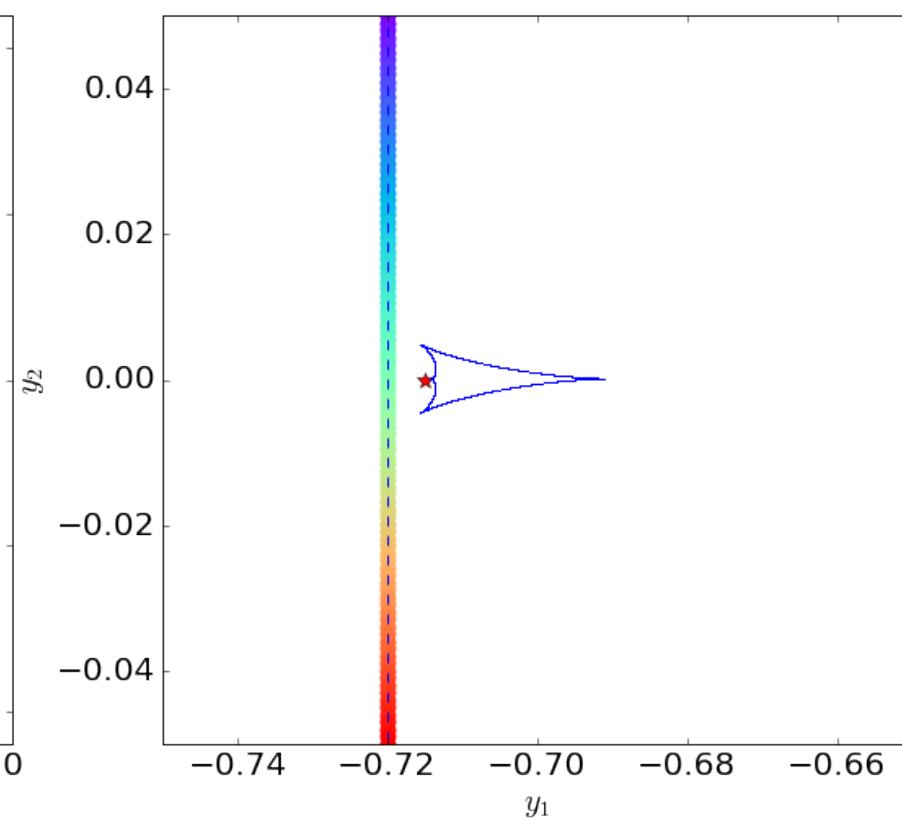
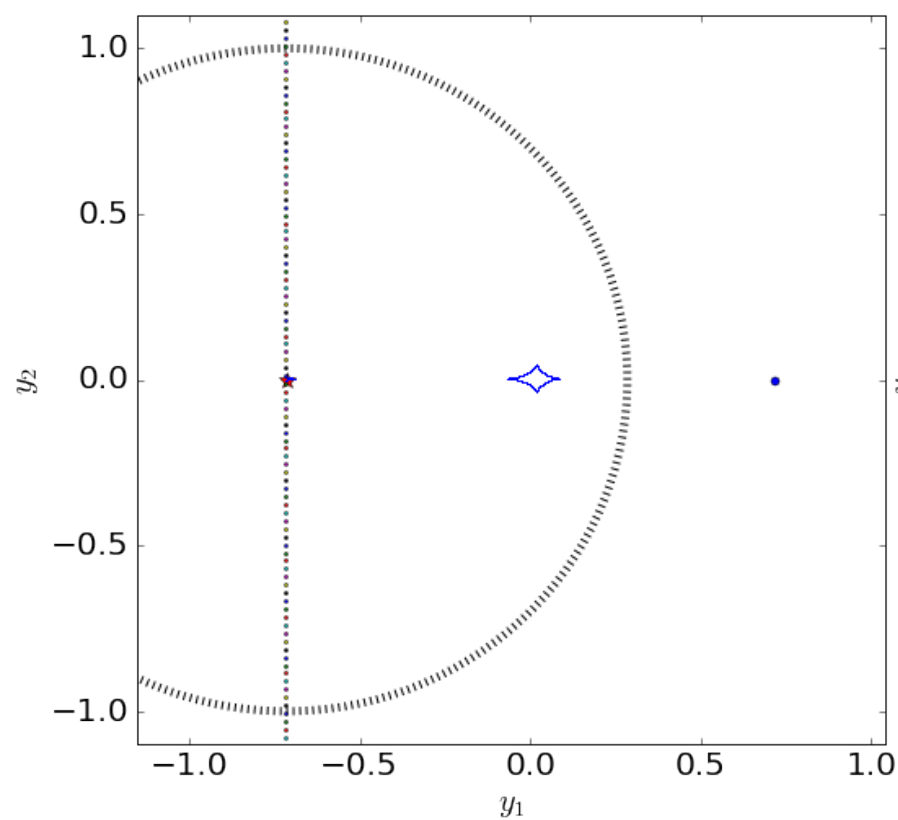
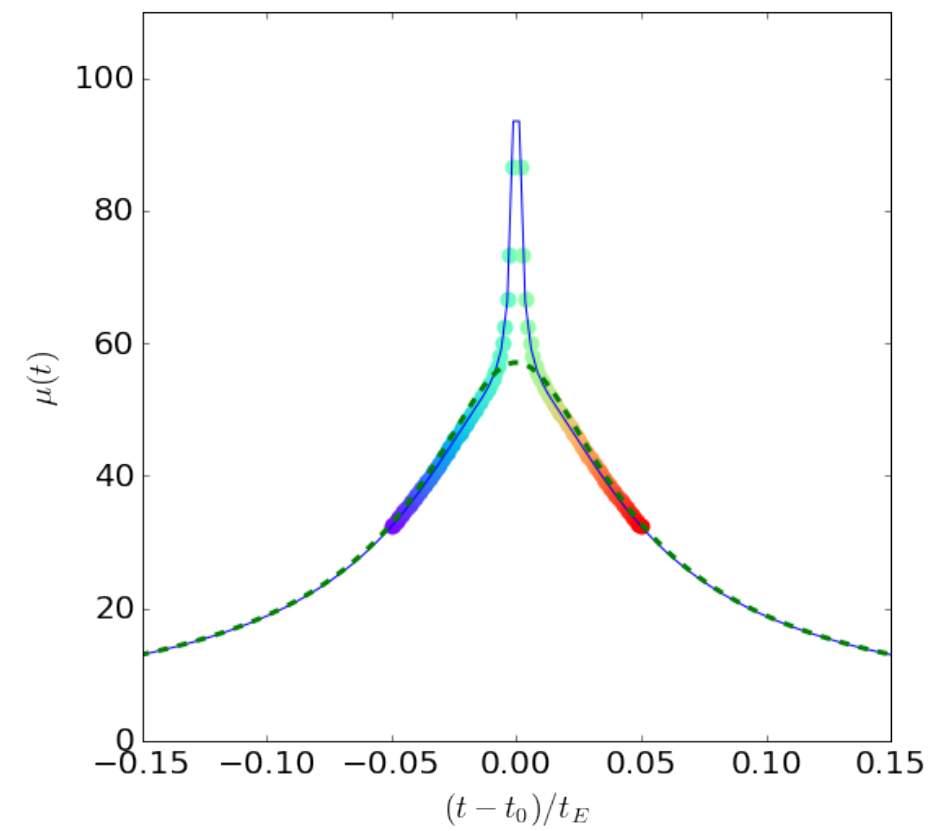
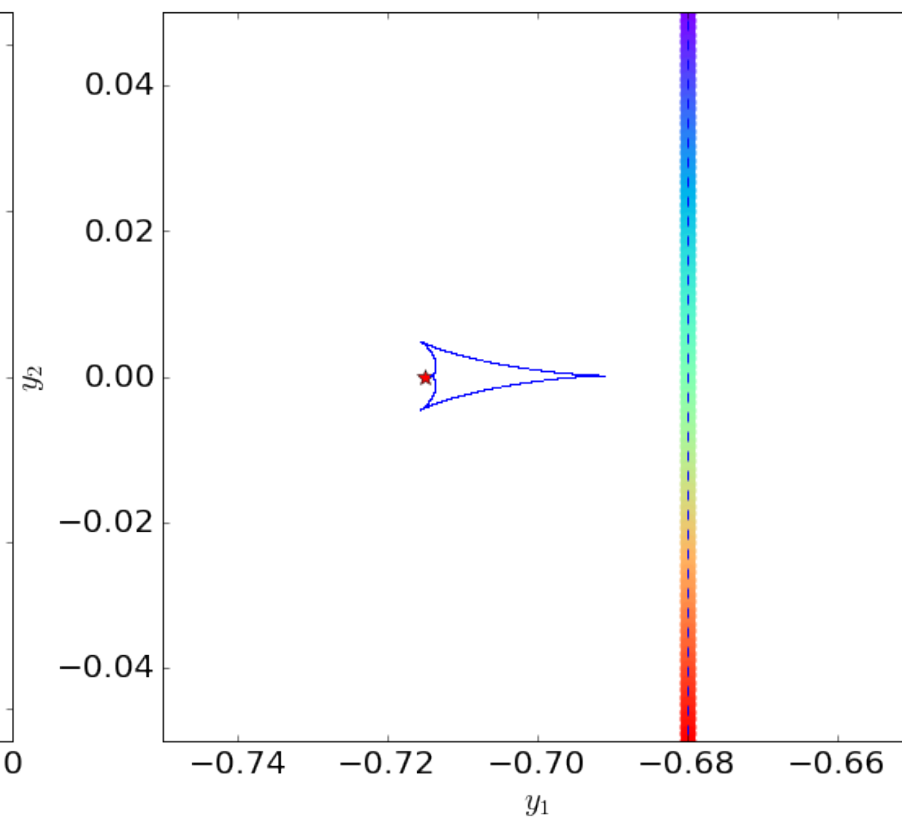
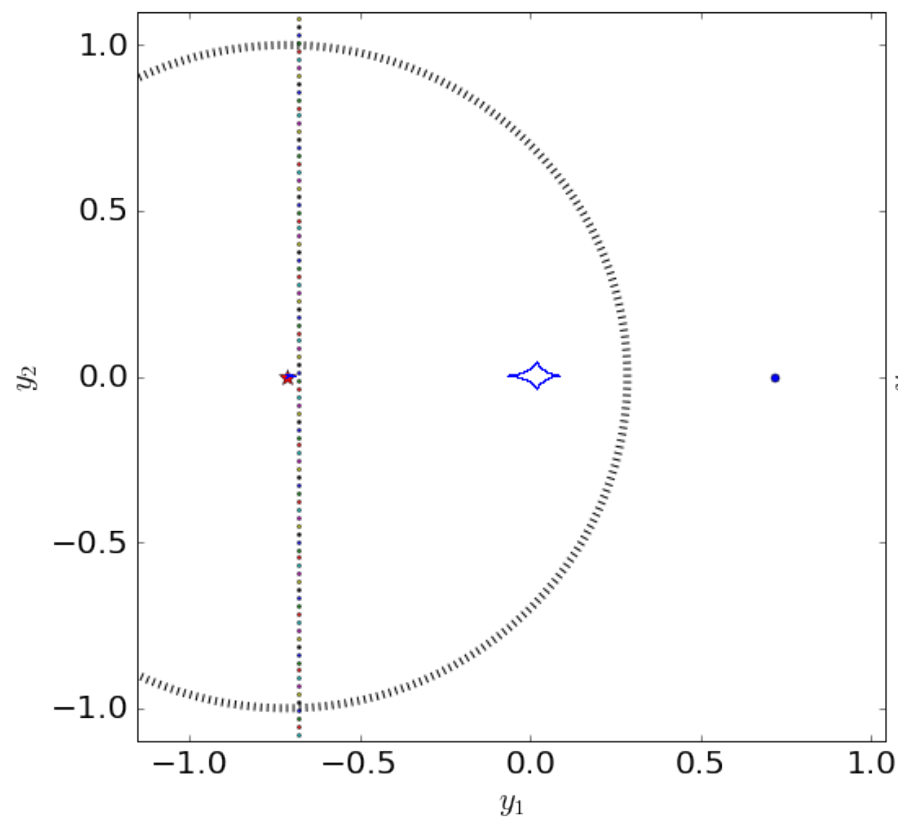


# CENTRAL CAUSTIC PERTURBATIONS

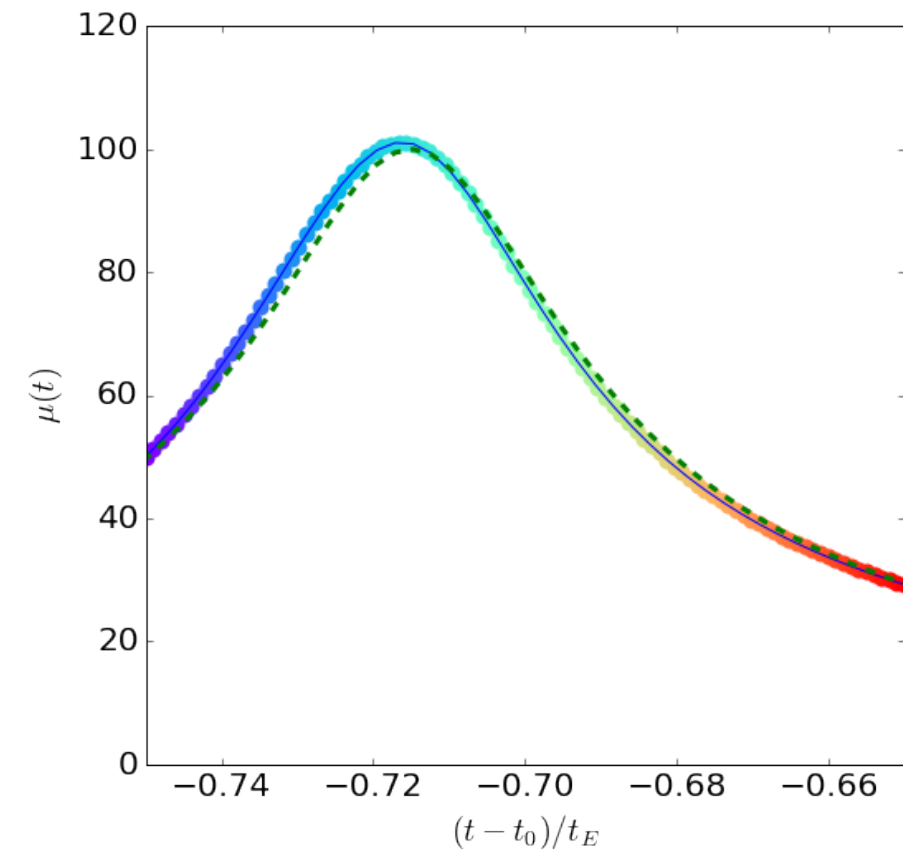
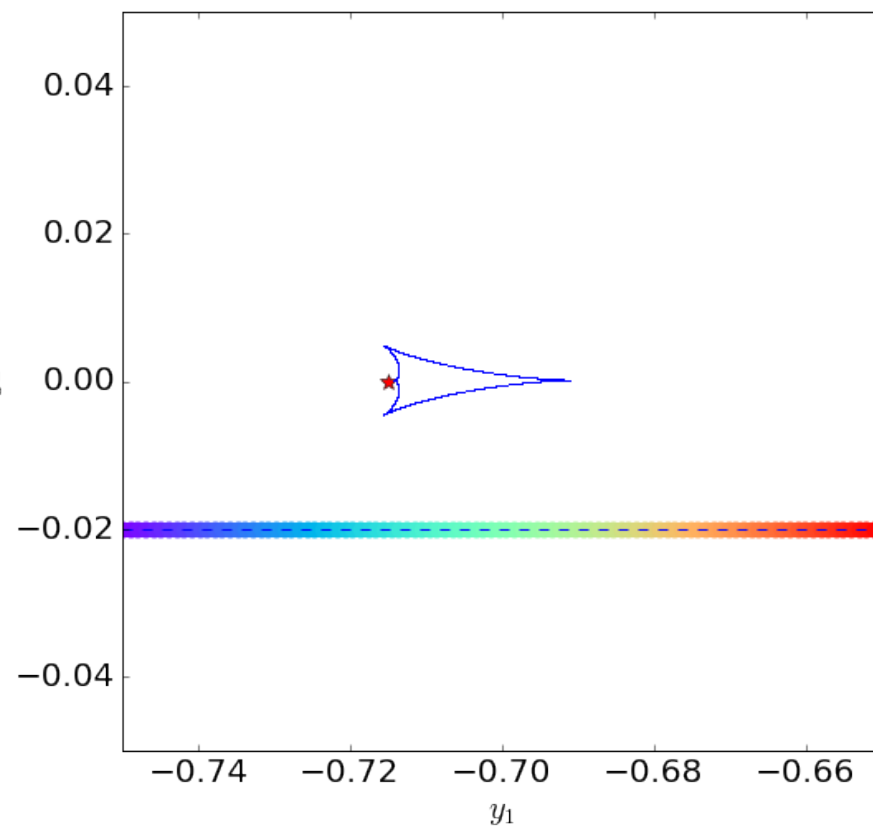
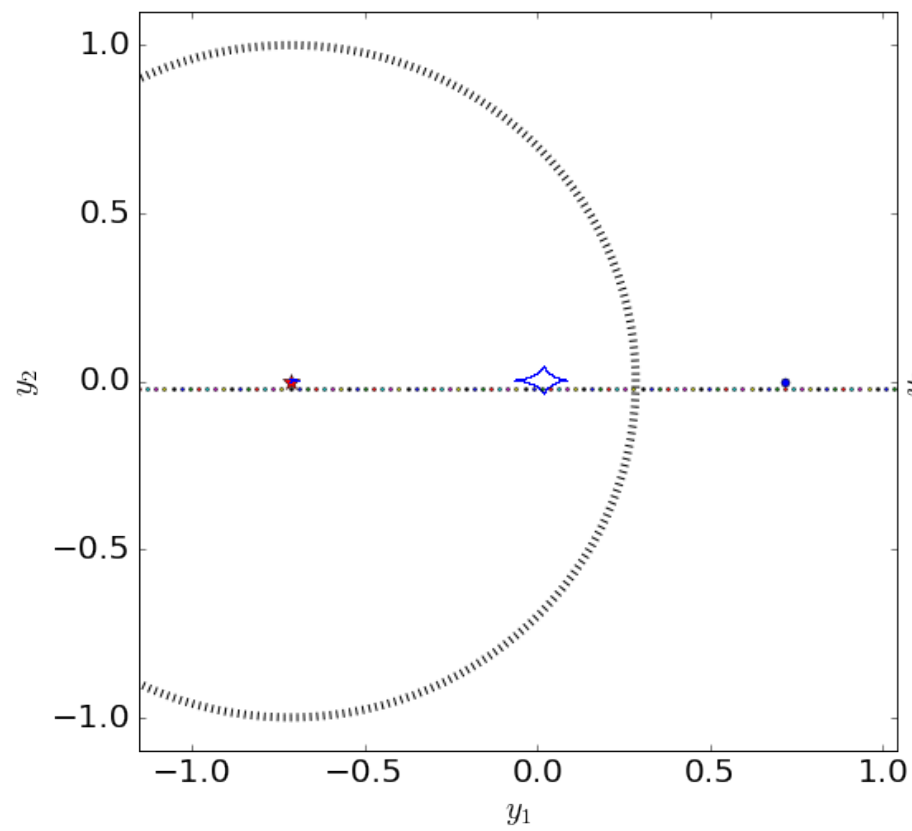




# CENTRAL CAUSTIC PERTURBATIONS



# CENTRAL CAUSTIC PERTURBATIONS



# PLANET DETECTION THROUGH CENTRAL CUSP PERTURBATIONS

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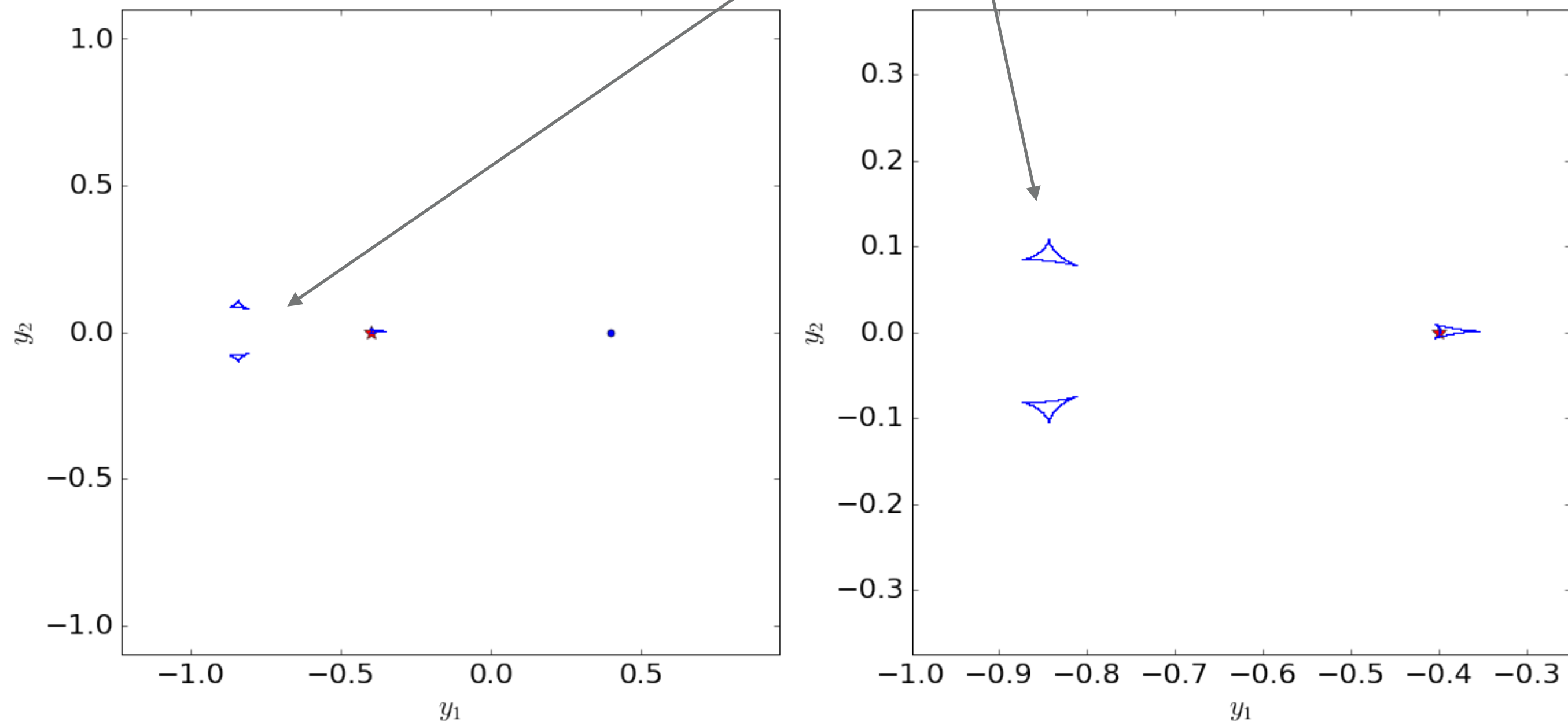
- Only possible in the case of high magnification events (sources passing very close to the host stars)
- For this reason, they are rare events
- Advantages:
  - near the peak of the event
  - can sometimes be predicted in advance
  - high magnification makes possible to follow-up the events using small 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*

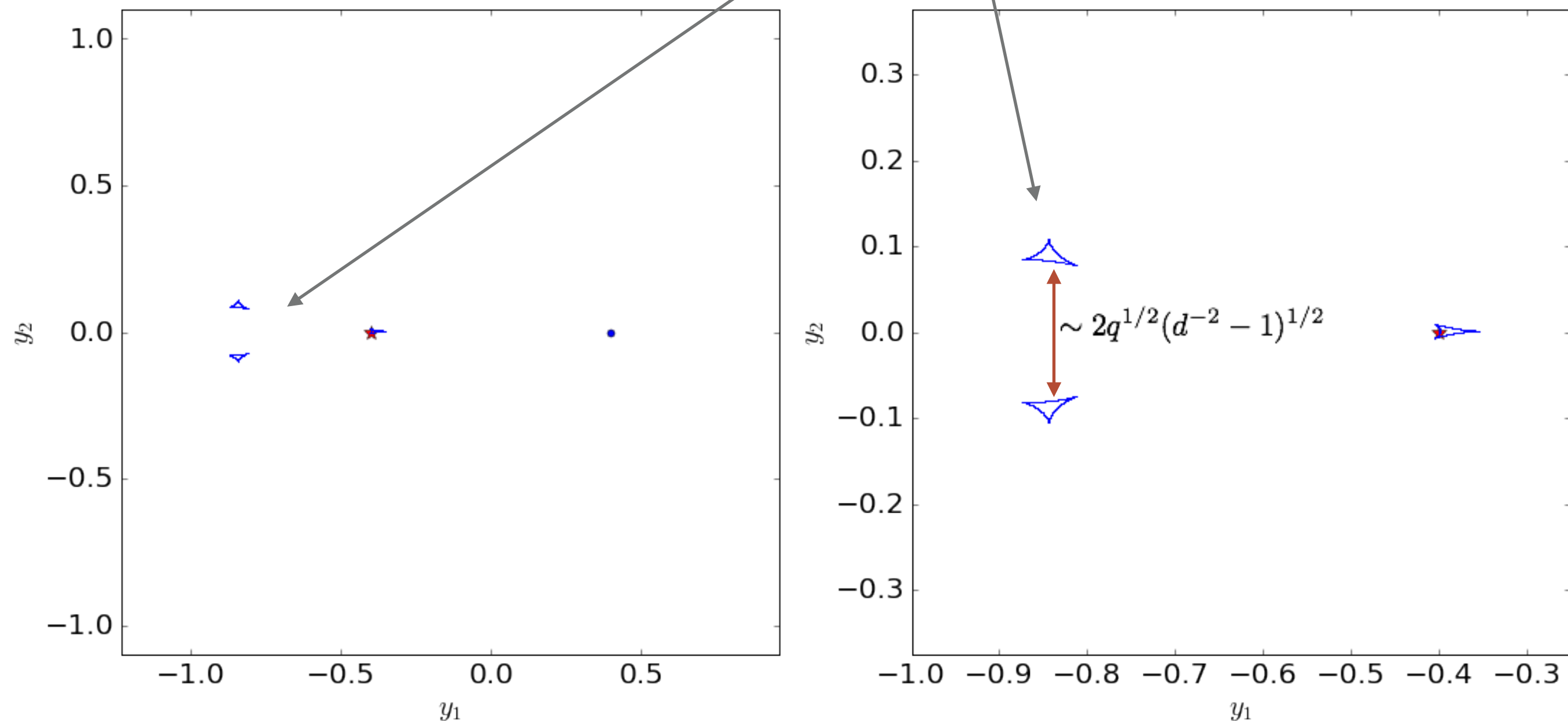


*Recommended reading: Han, C., 2006, ApJ, 638, 1080*

# PLANETARY CAUSTICS IN CLOSE TOPOLOGIES

*planetary caustics*

*Han 2006*

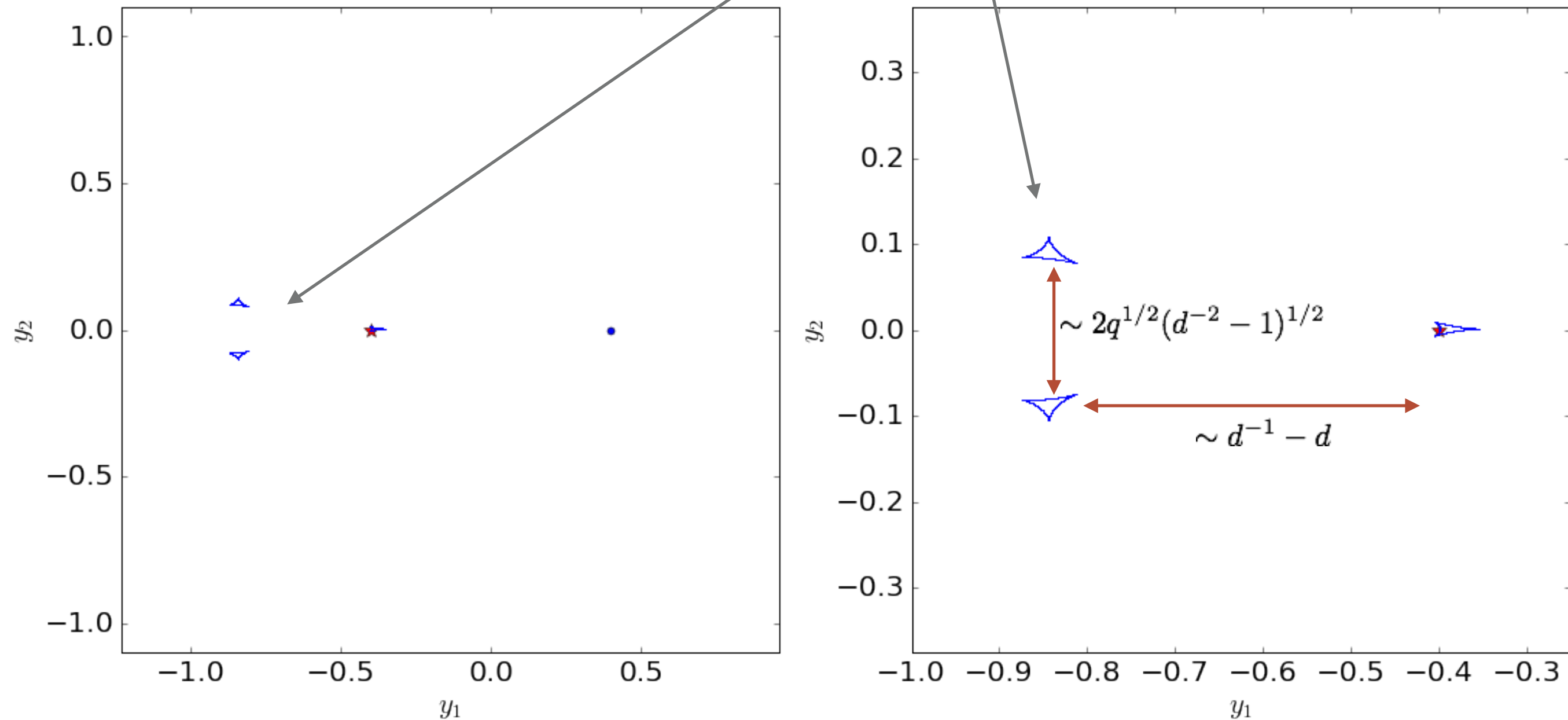


*Recommended reading: Han, C., 2006, ApJ, 638, 1080*

# PLANETARY CAUSTICS IN CLOSE TOPOLOGIES

*planetary caustics*

*Han 2006*

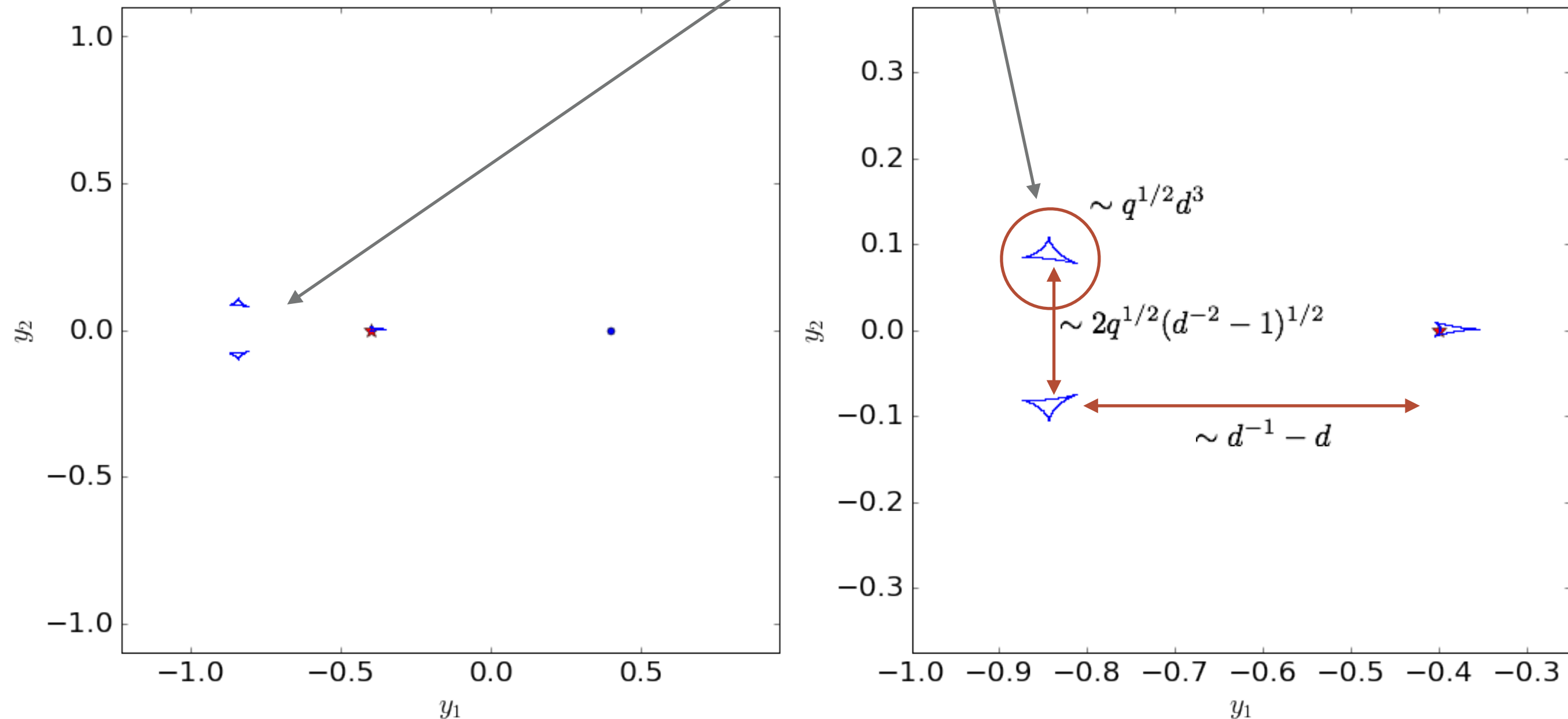


*Recommended reading: Han, C., 2006, ApJ, 638, 1080*

# PLANETARY CAUSTICS IN CLOSE TOPOLOGIES

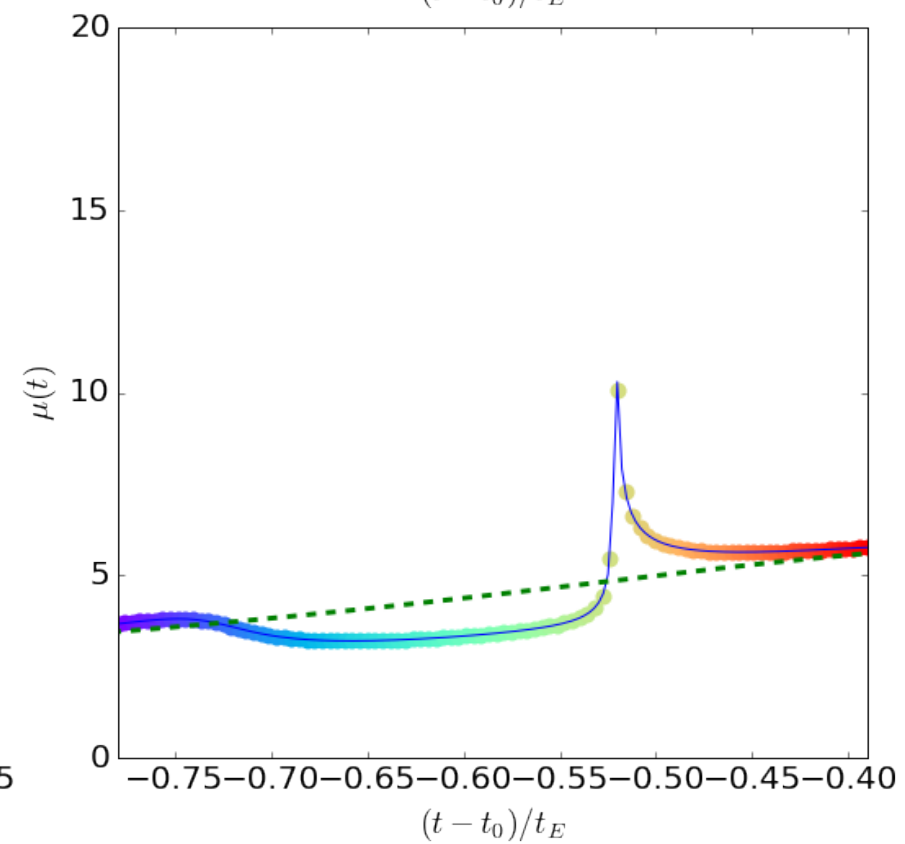
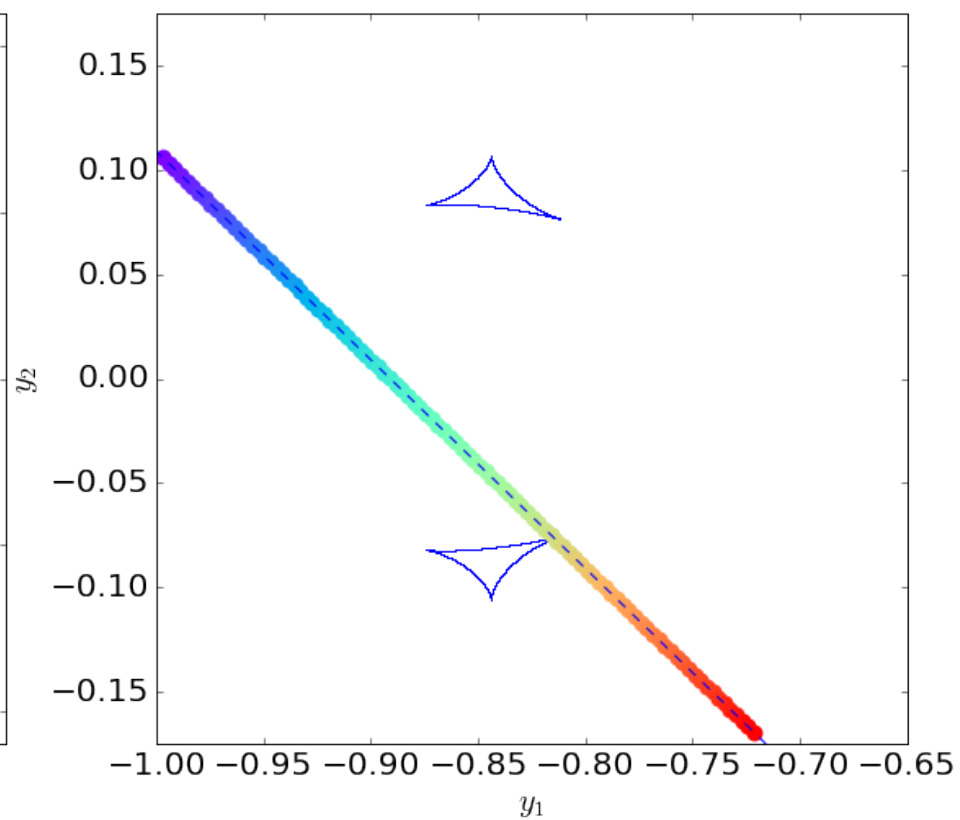
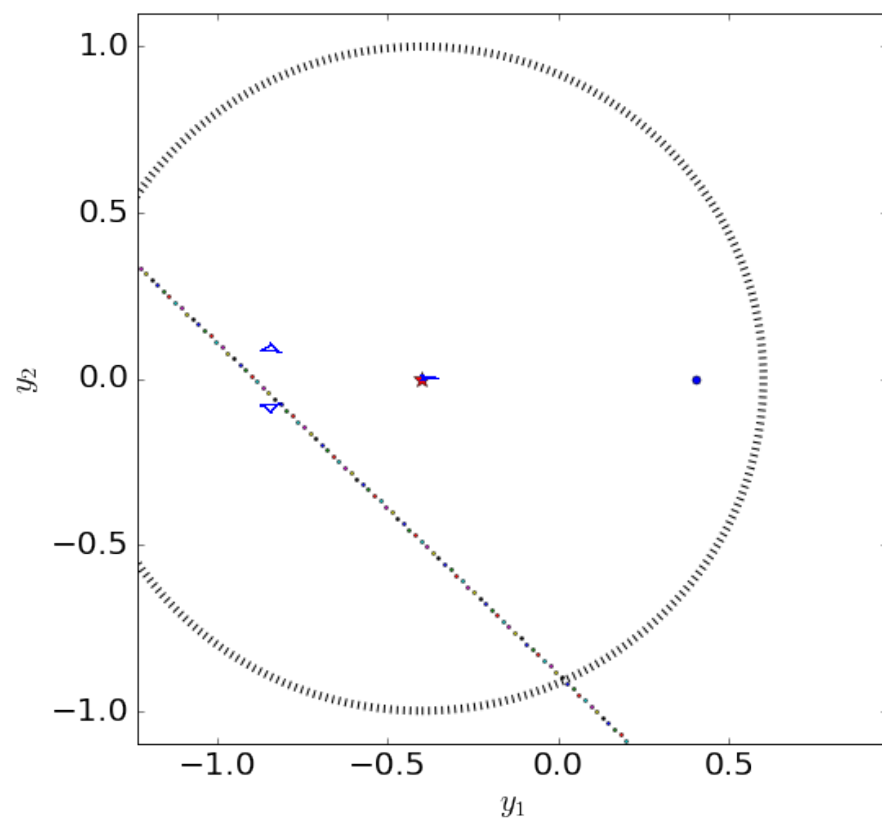
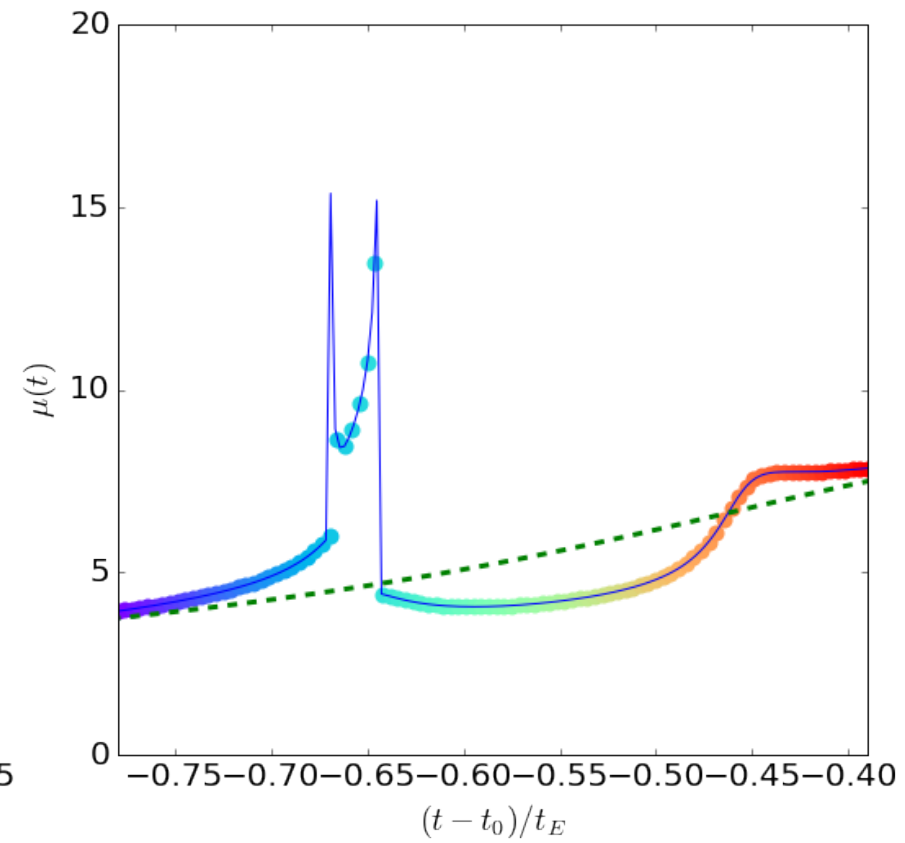
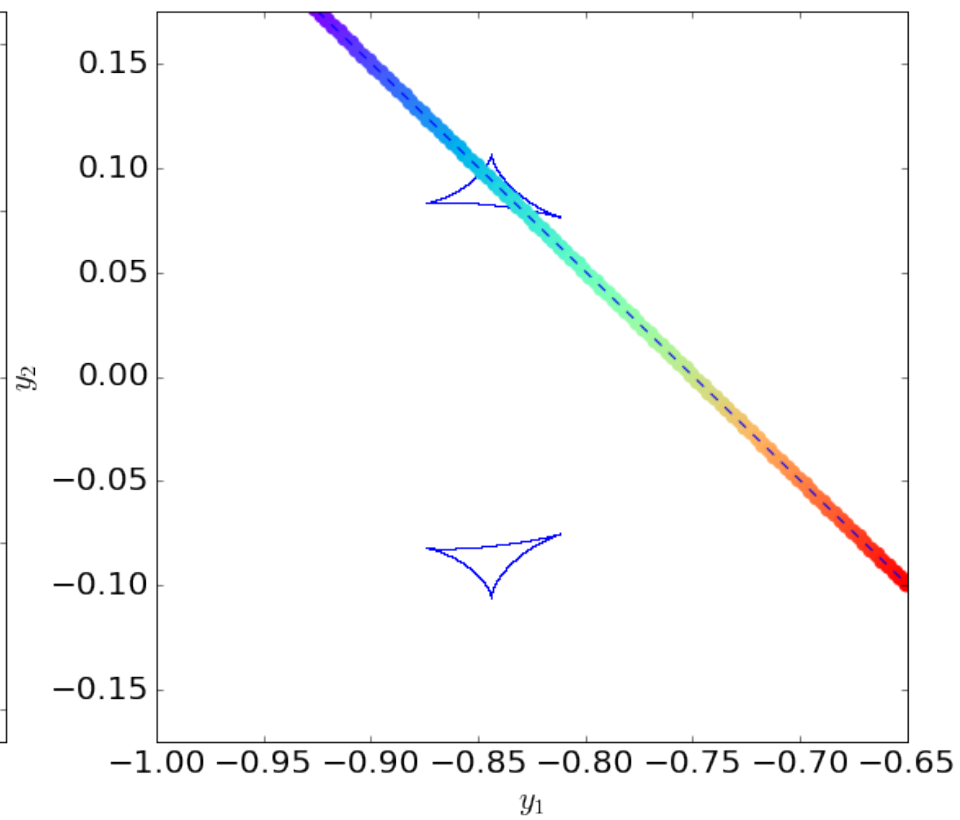
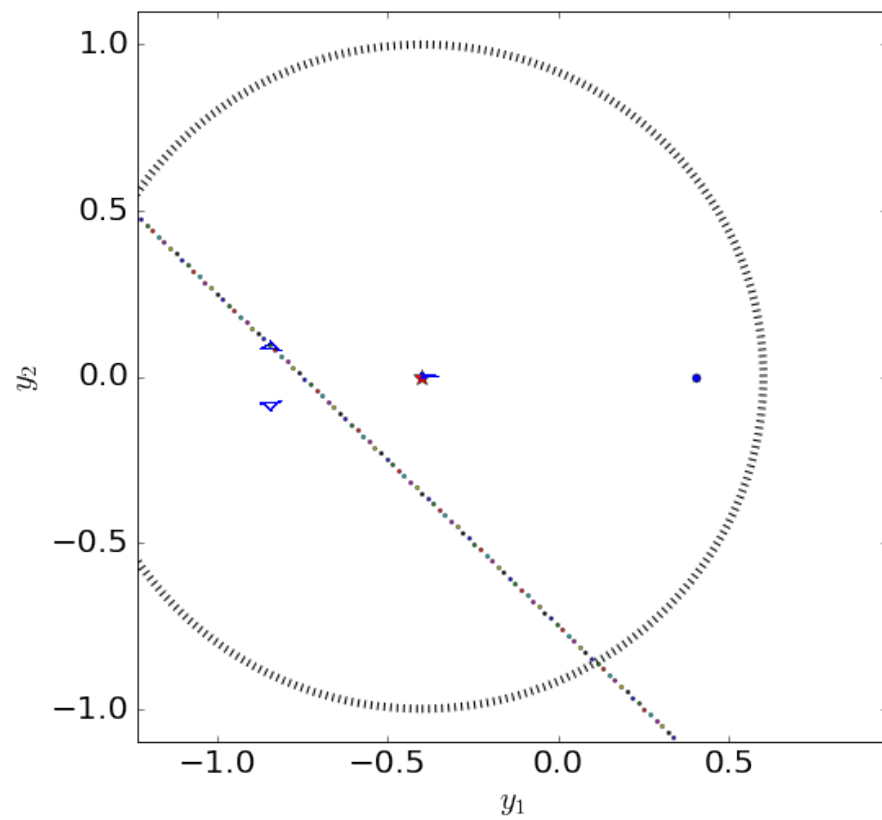
*planetary caustics*

*Han 2006*



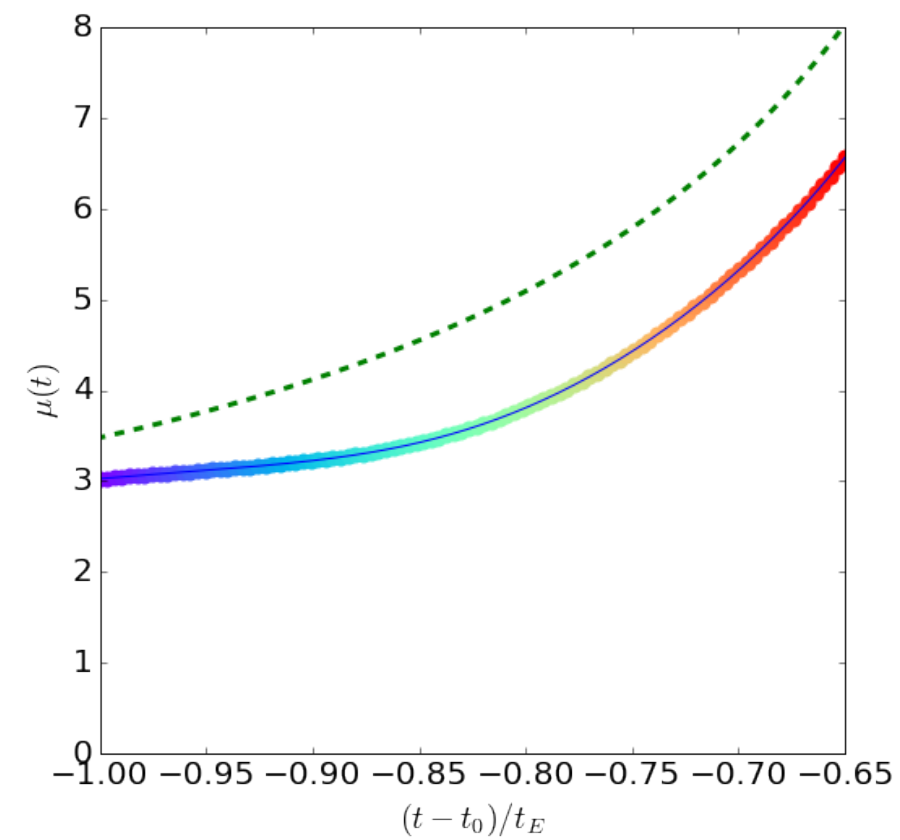
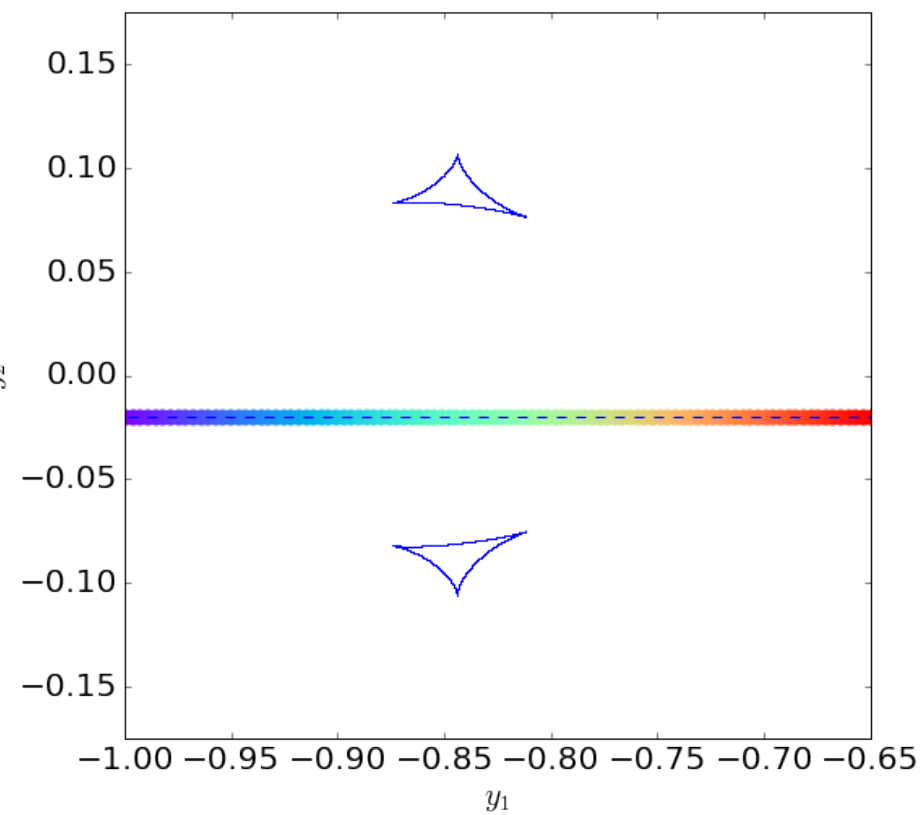
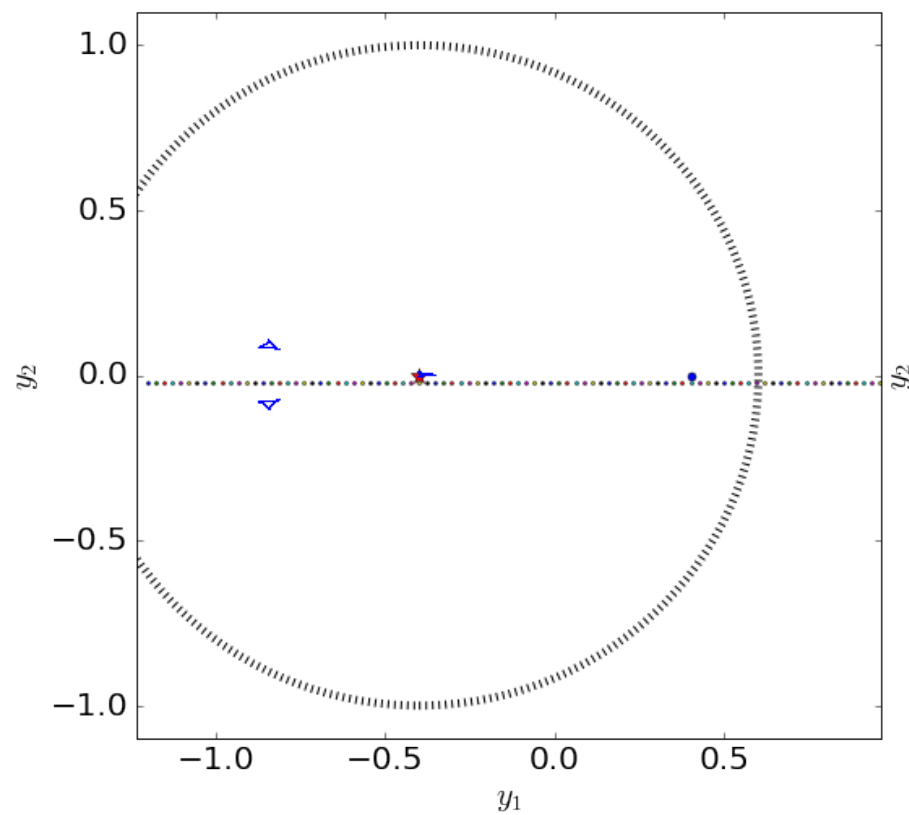
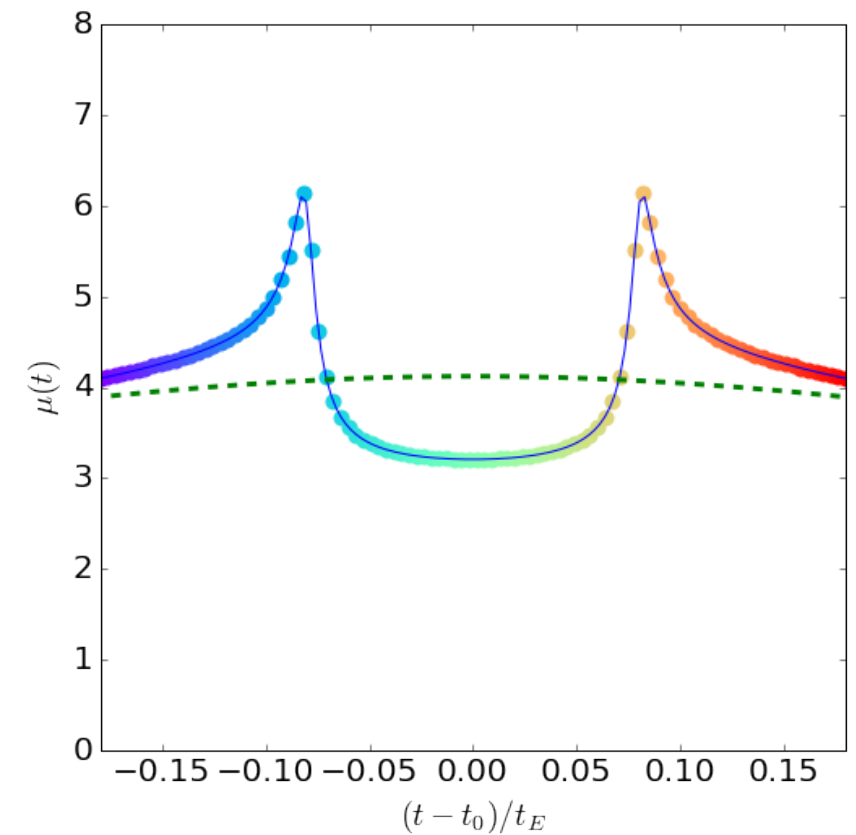
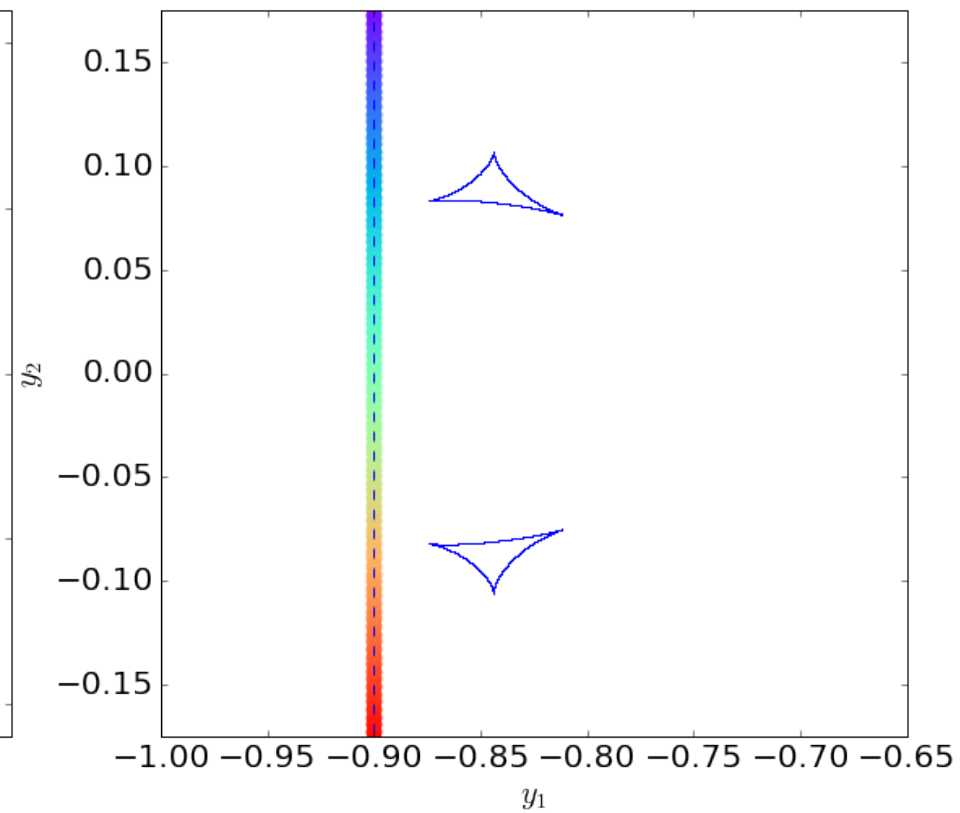
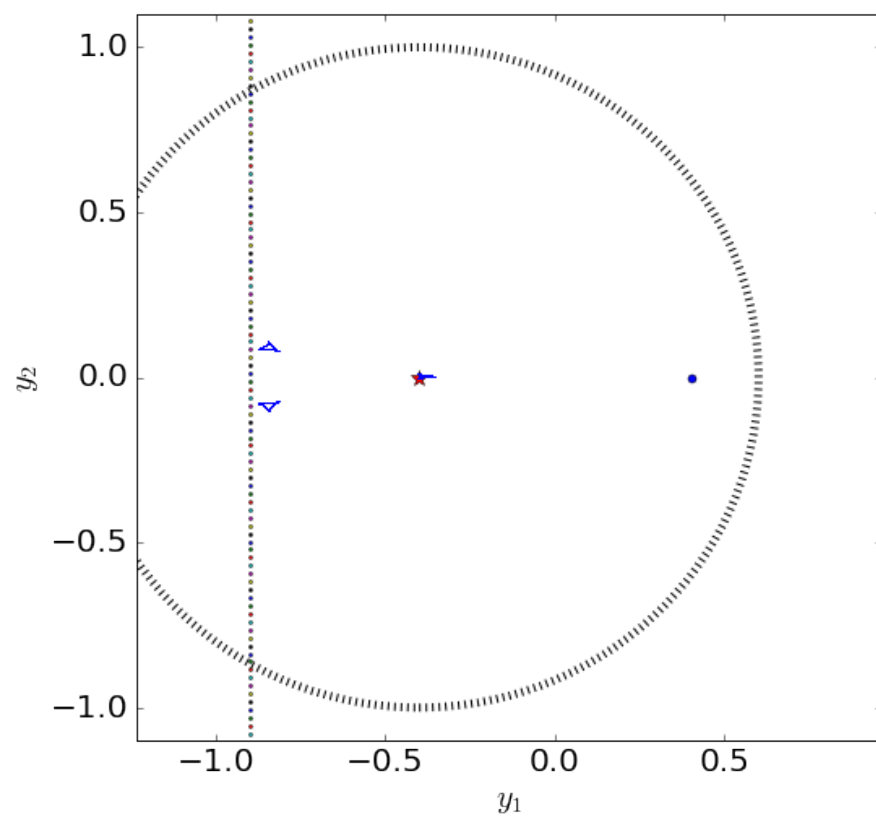
*Recommended reading: Han, C., 2006, ApJ, 638, 1080*

# PLANETARY CAUSTICS PERTURBATIONS IN CLOSE TOPOLOGIES



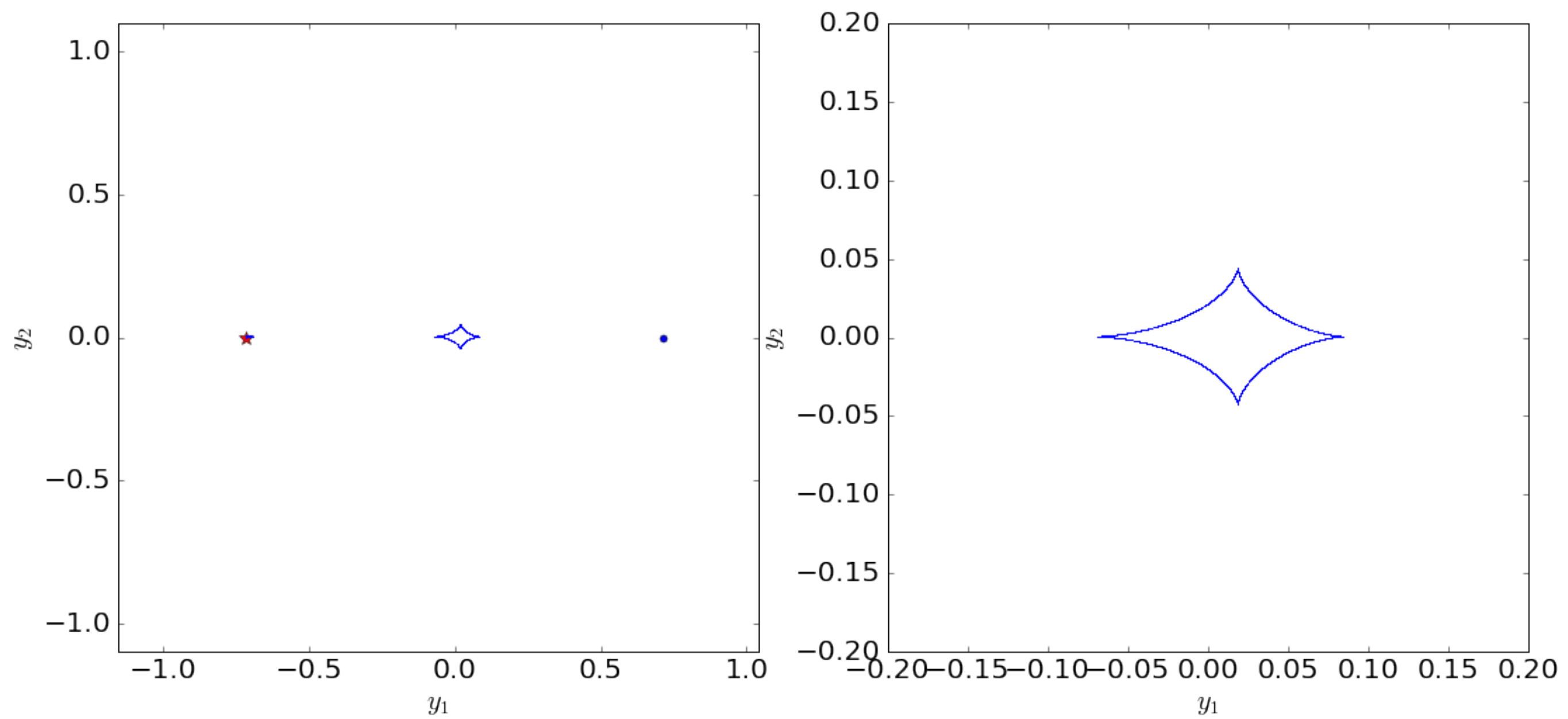


# PLANETARY CAUSTICS PERTURBATIONS IN CLOSE TOPOLOGIES



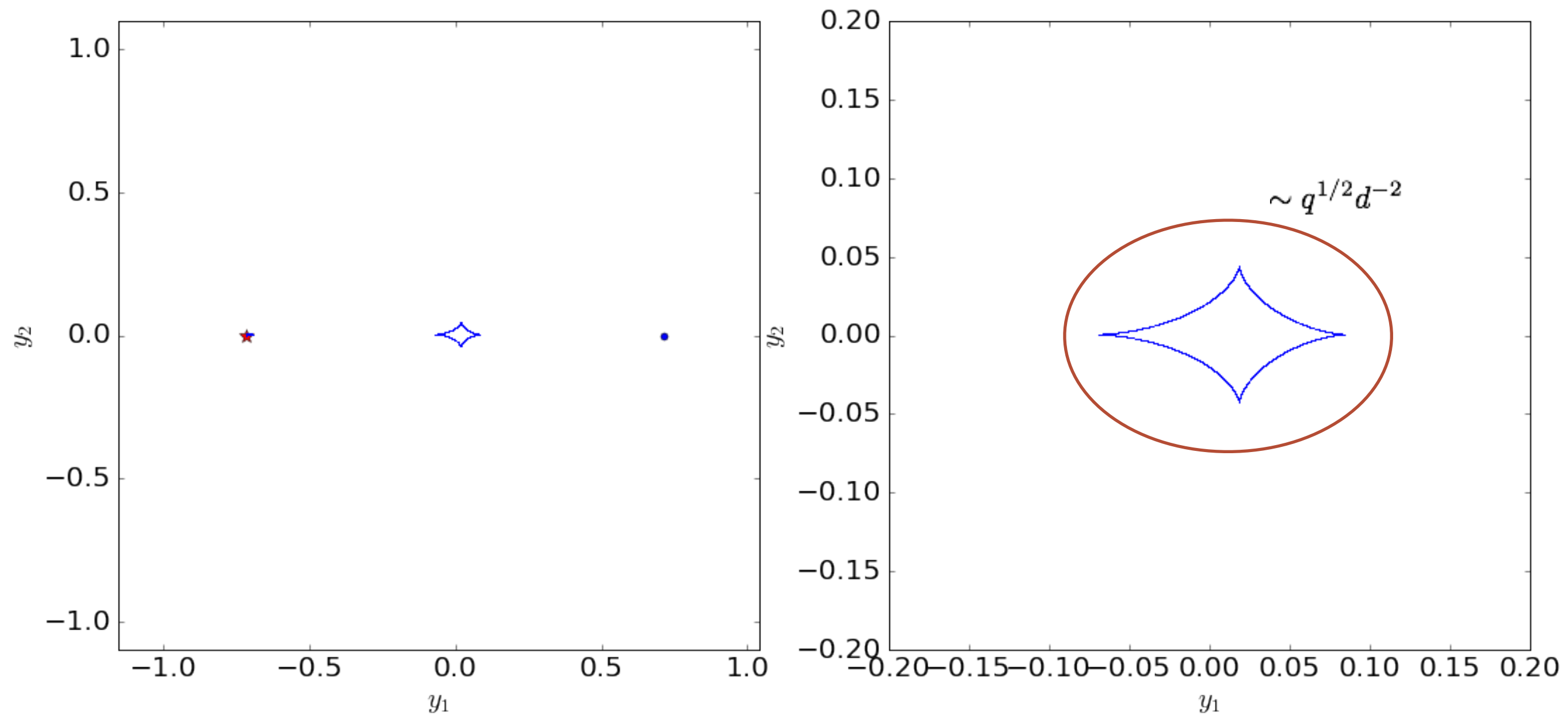
# PLANETARY CAUSTICS IN WIDE TOPOLOGIES

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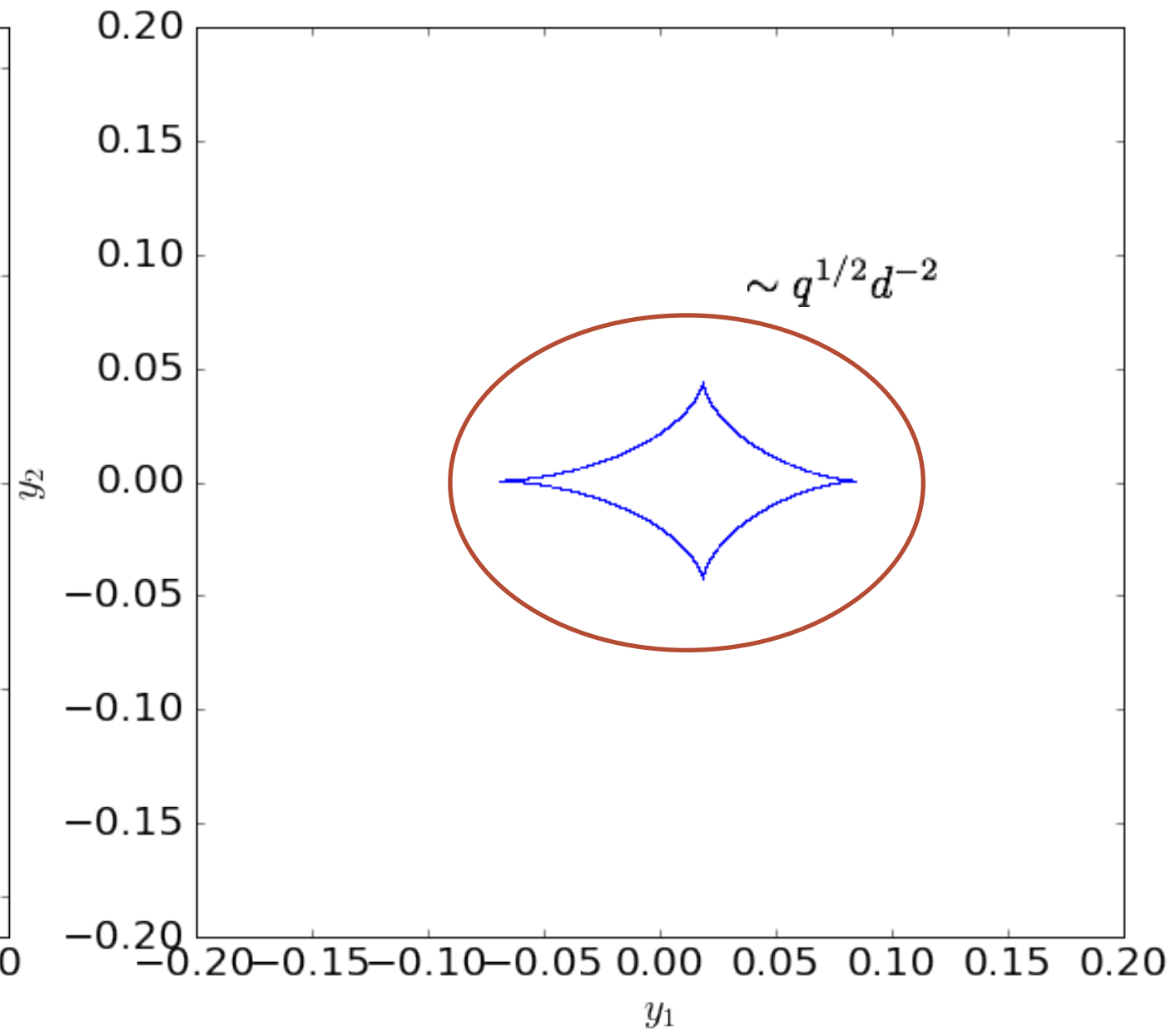
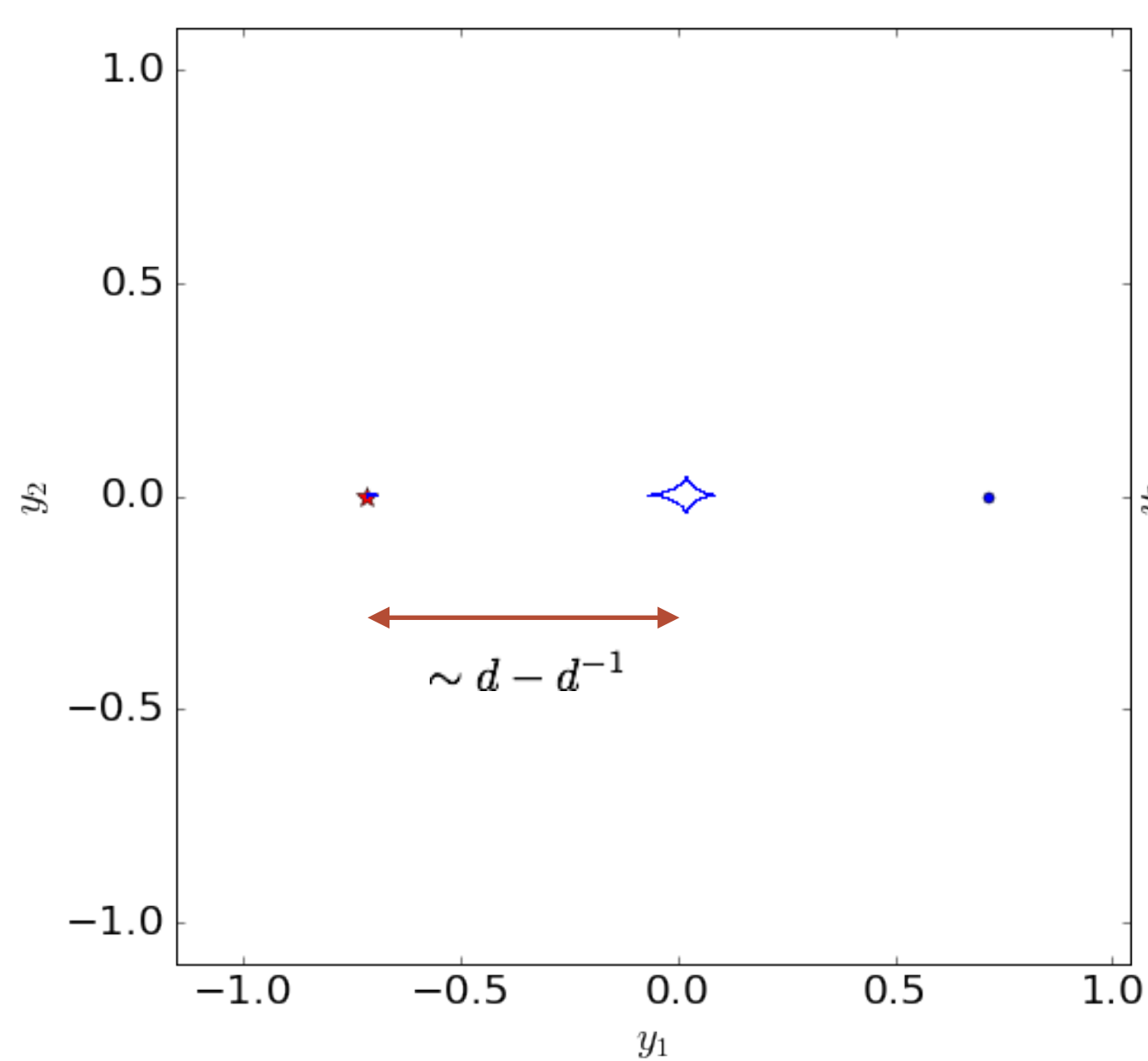
# PLANETARY CAUSTICS IN WIDE TOPOLOGIES

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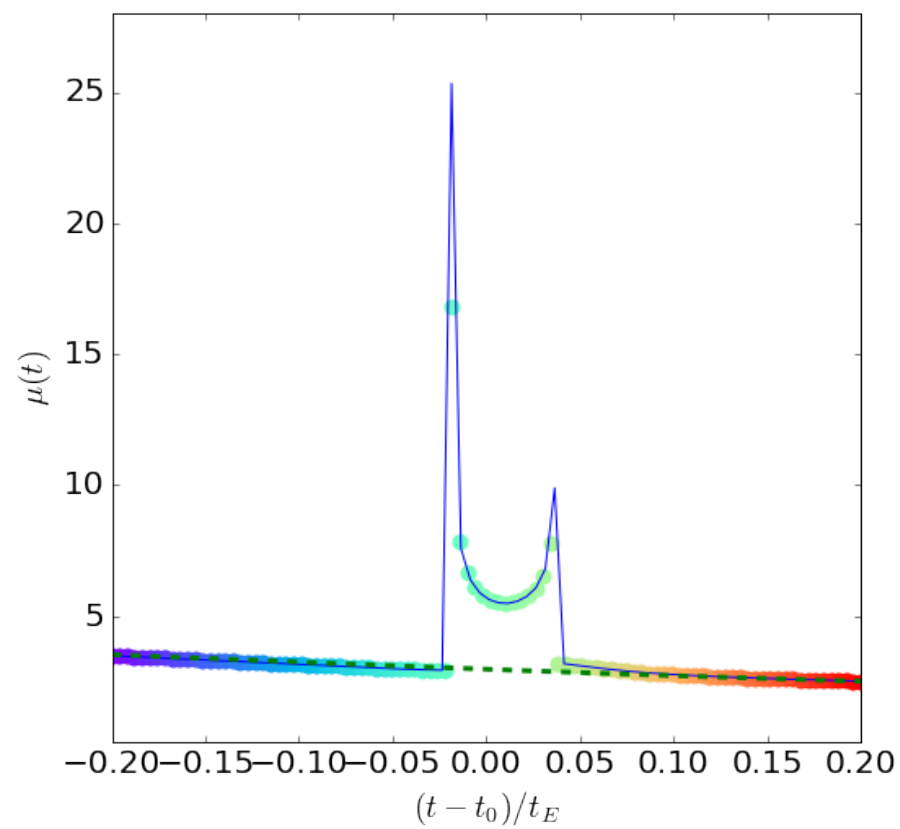
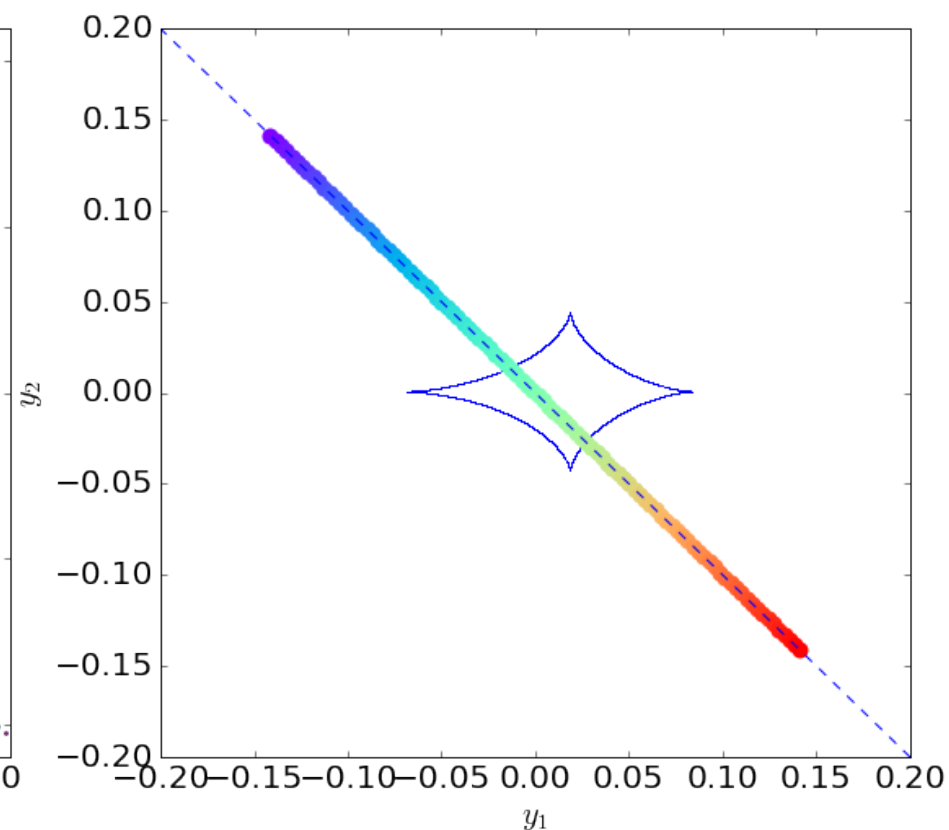
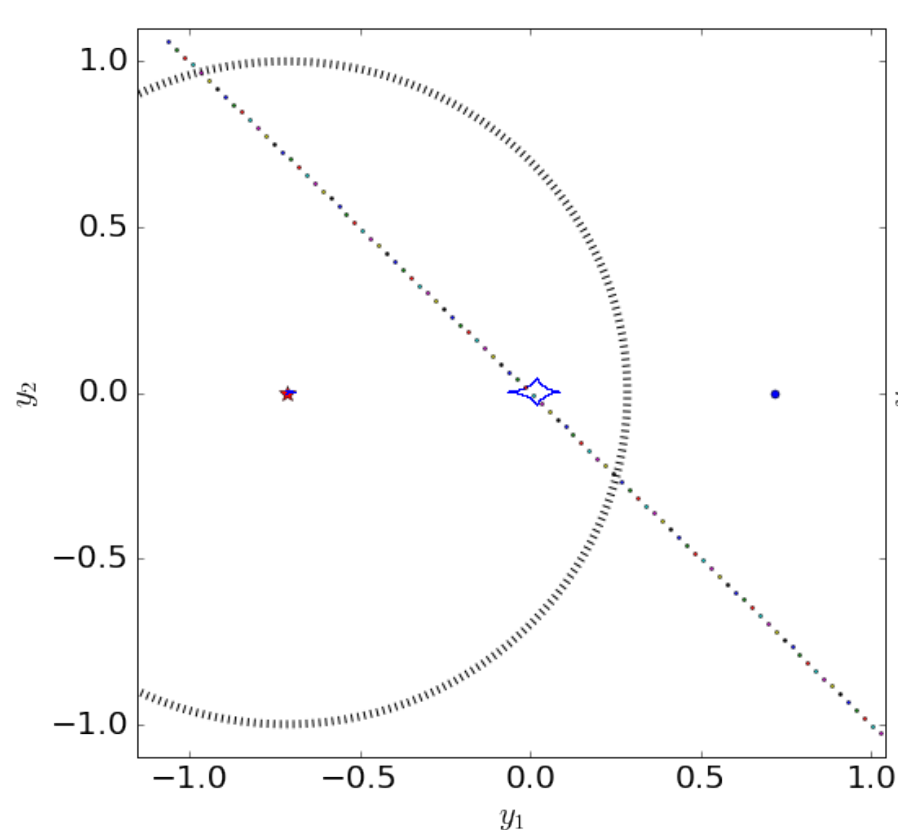
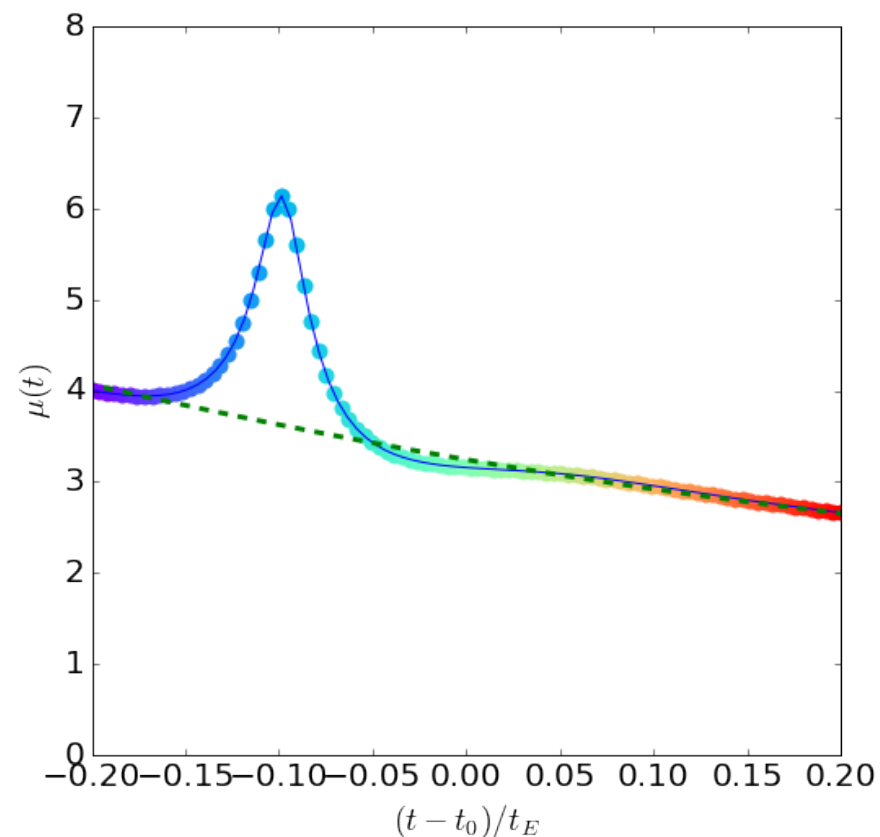
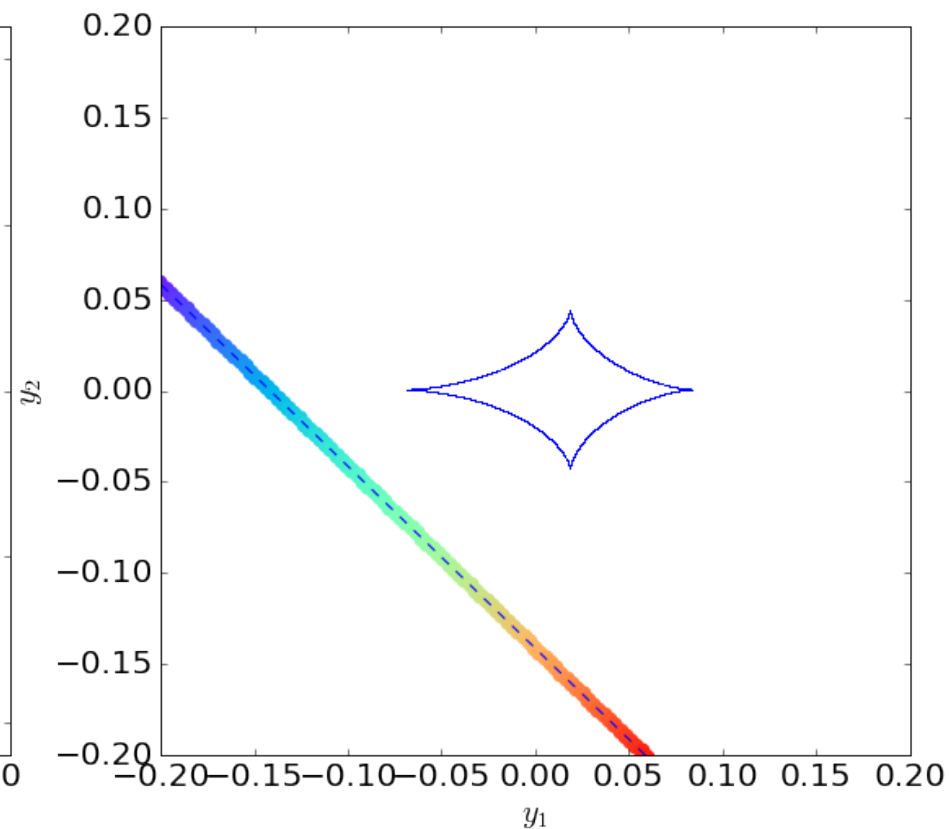
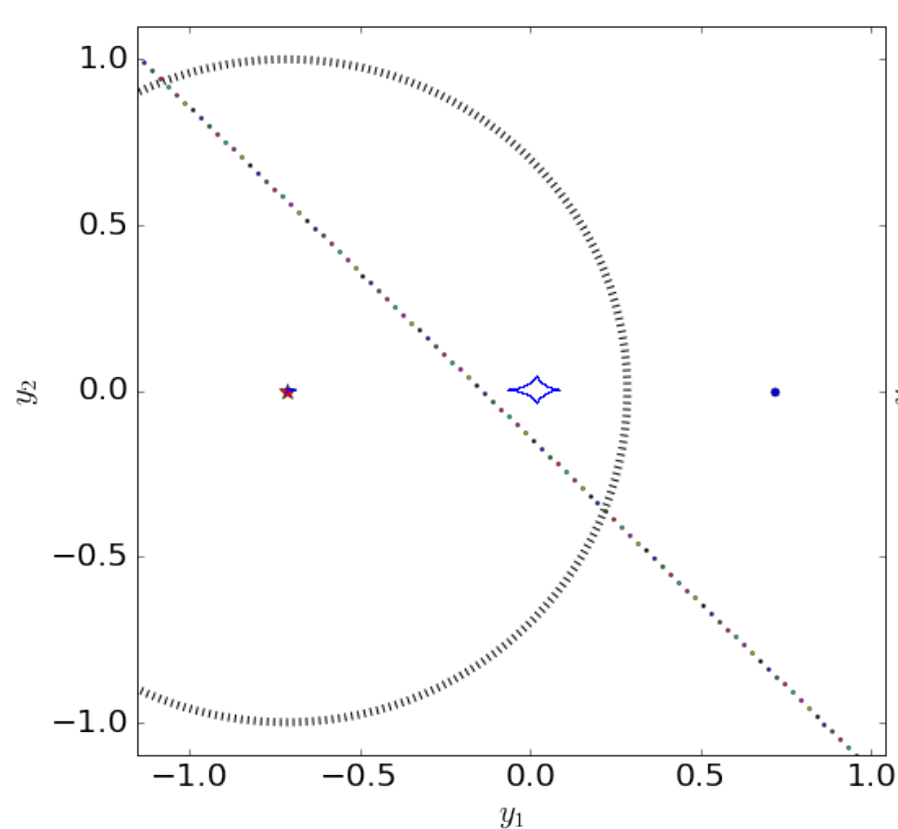


# PLANETARY CAUSTICS IN WIDE TOPOLOGIES

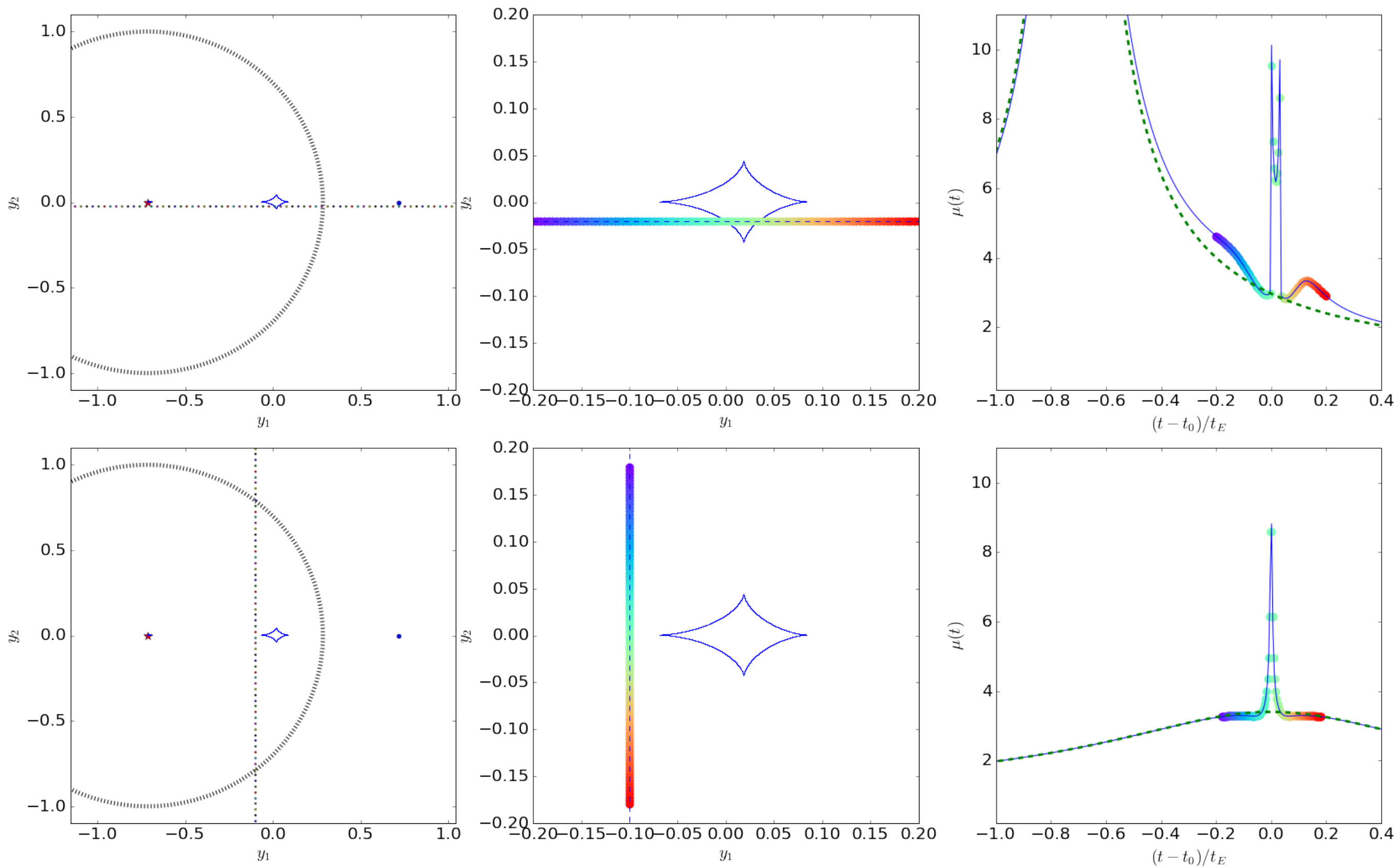
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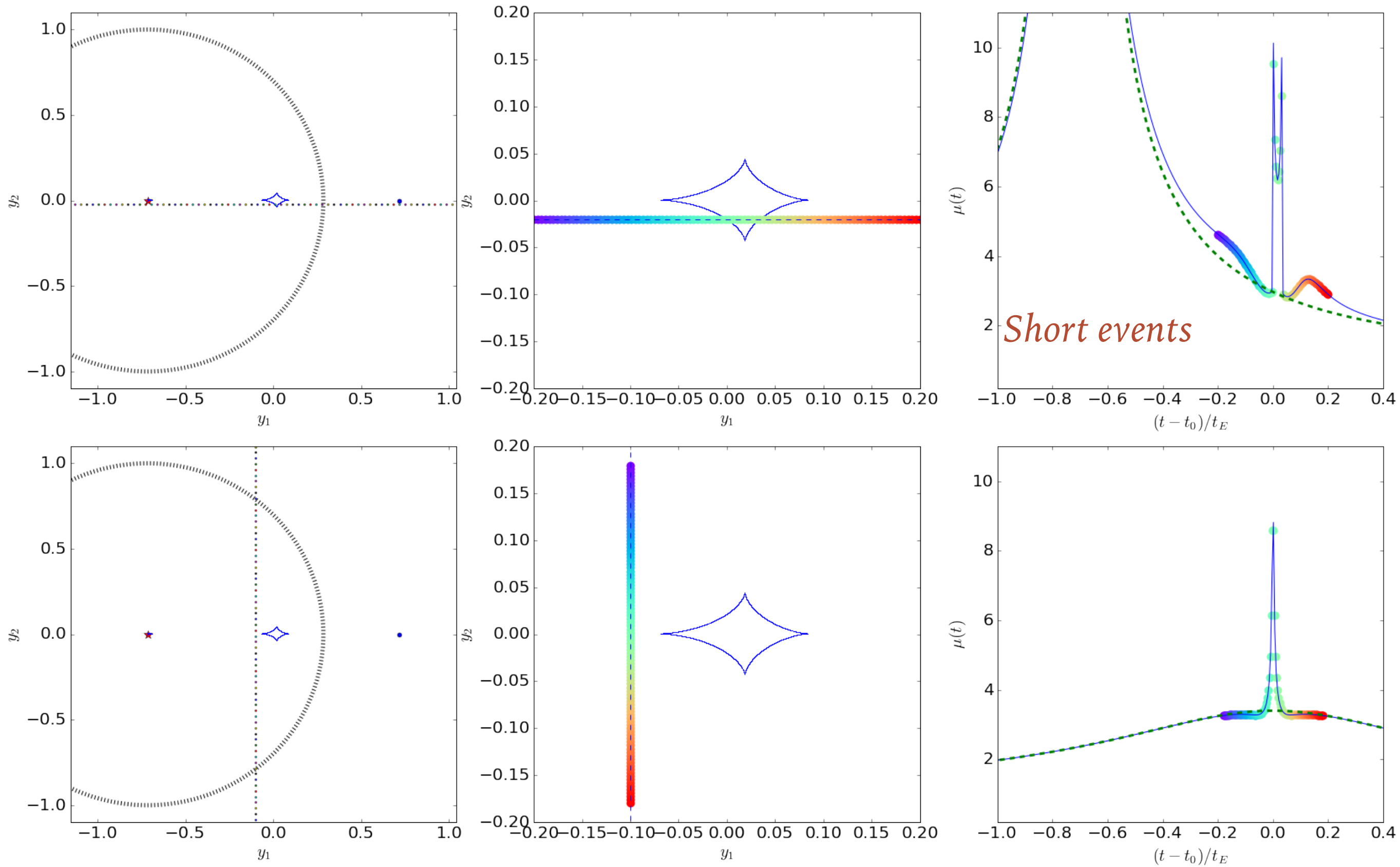
# PLANETARY CAUSTICS PERTURBATIONS IN WIDE TOPOLOGIES



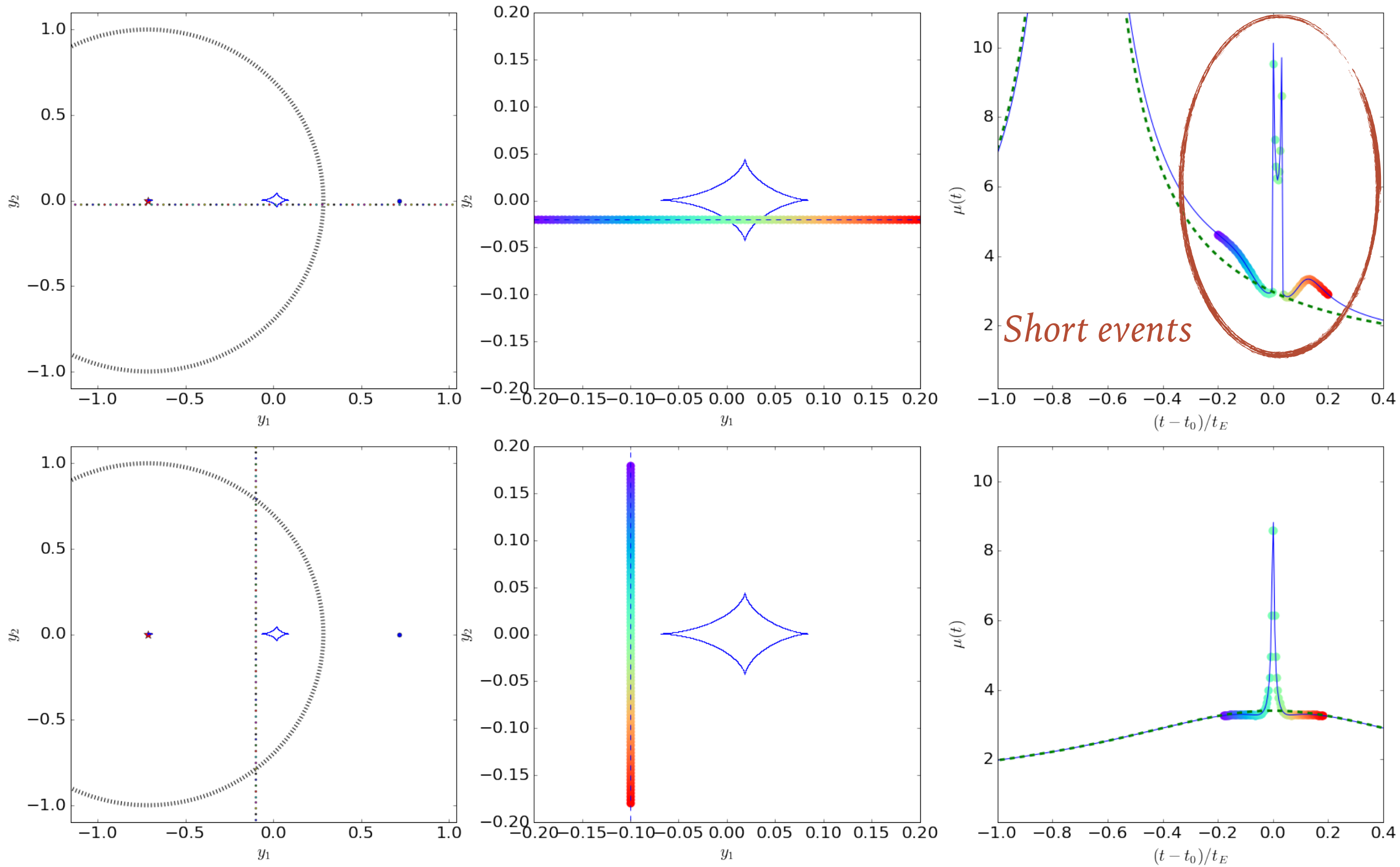
# PLANETARY CAUSTICS PERTURBATIONS IN WIDE TOPOLOGIES



# PLANETARY CAUSTICS PERTURBATIONS IN WIDE TOPOLOGIES



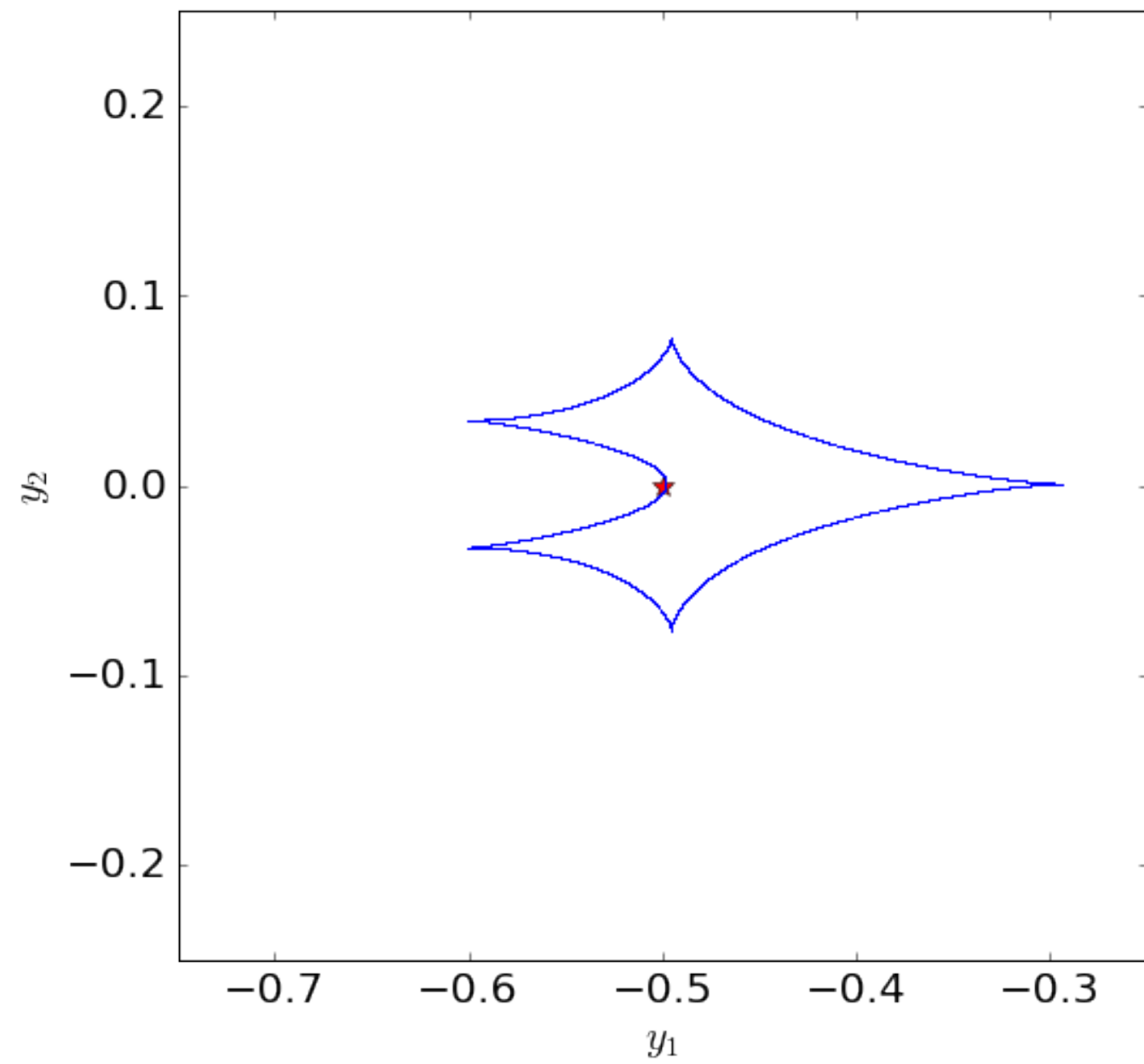
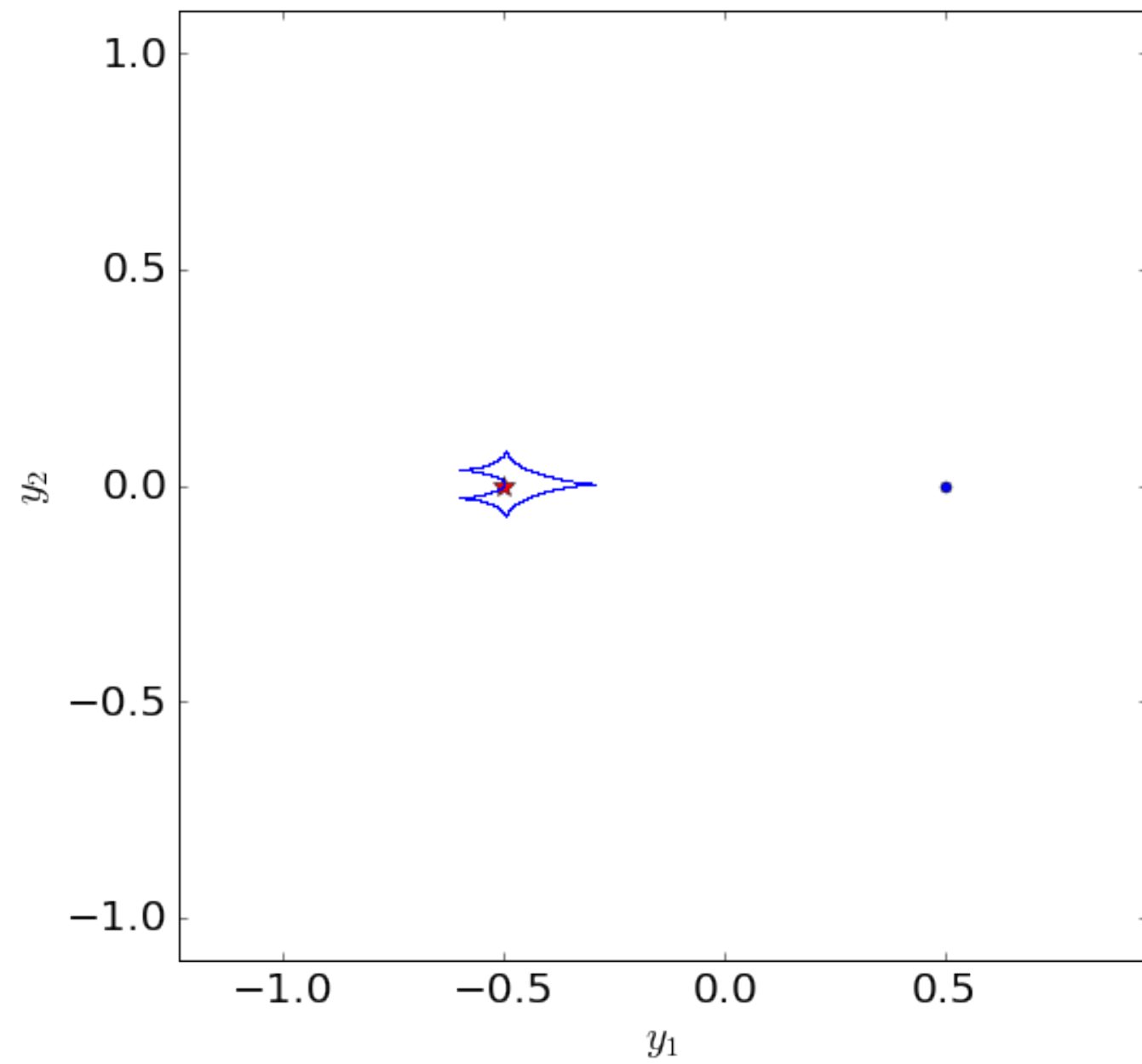
# PLANETARY CAUSTICS PERTURBATIONS IN WIDE TOPOLOGIES





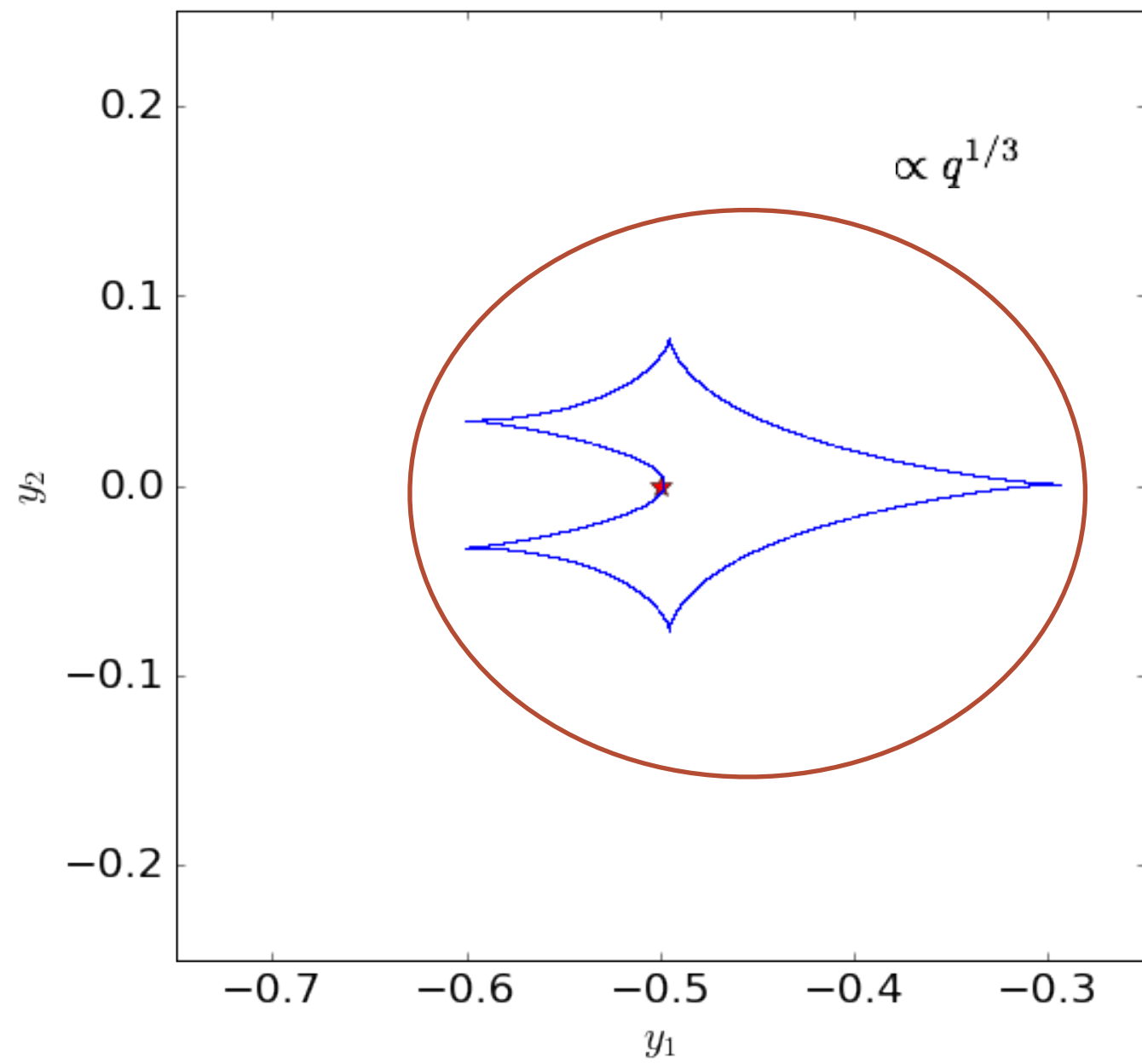
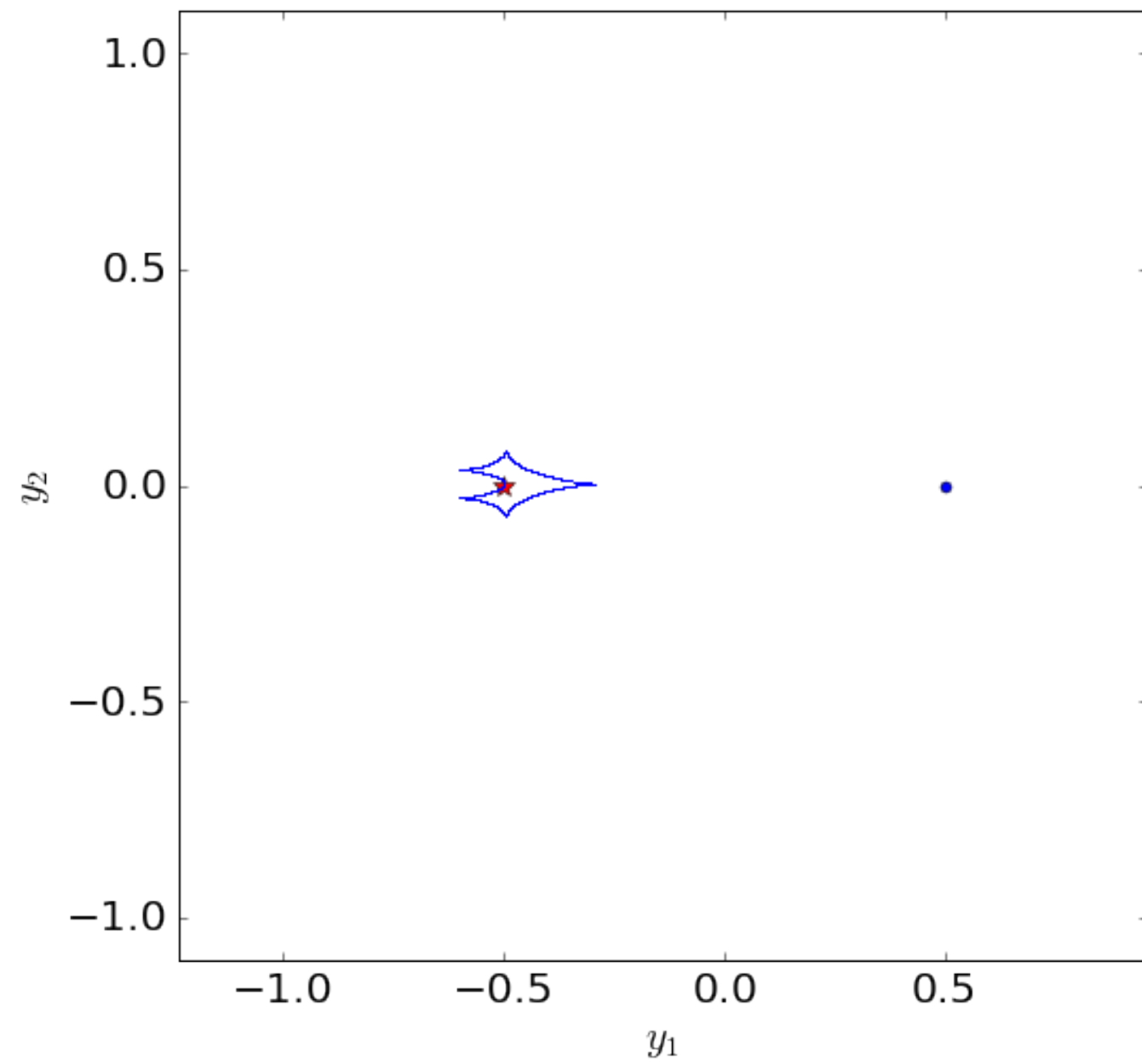
# PLANETARY CAUSTICS IN INTERMEDIATE TOPOLOGIES

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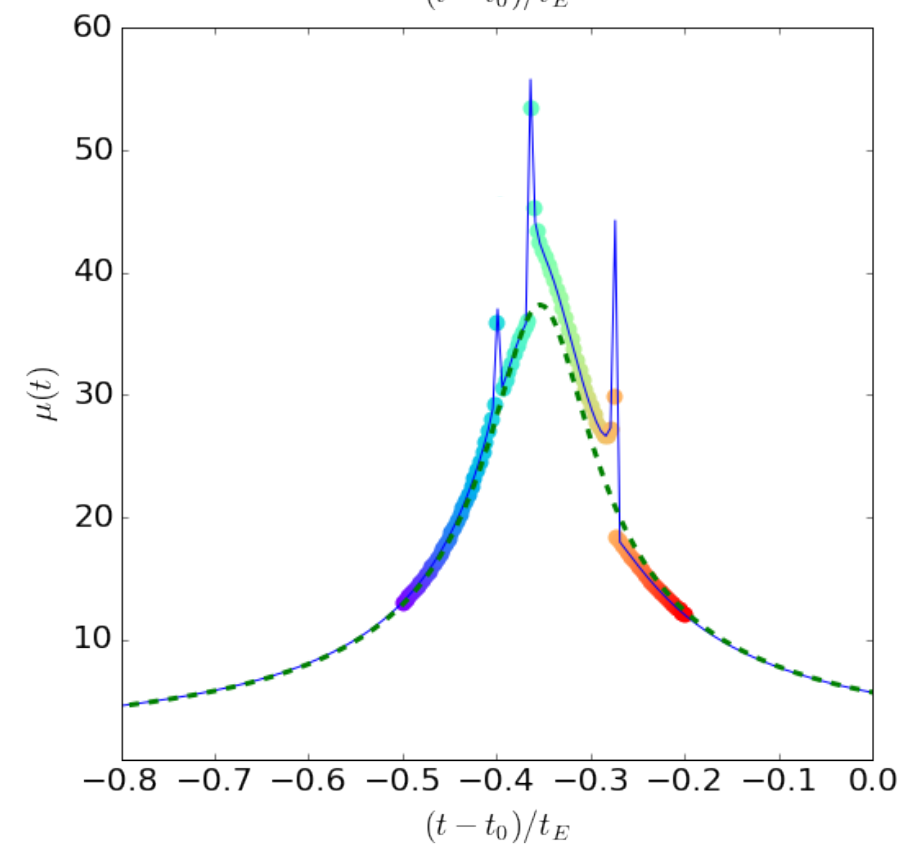
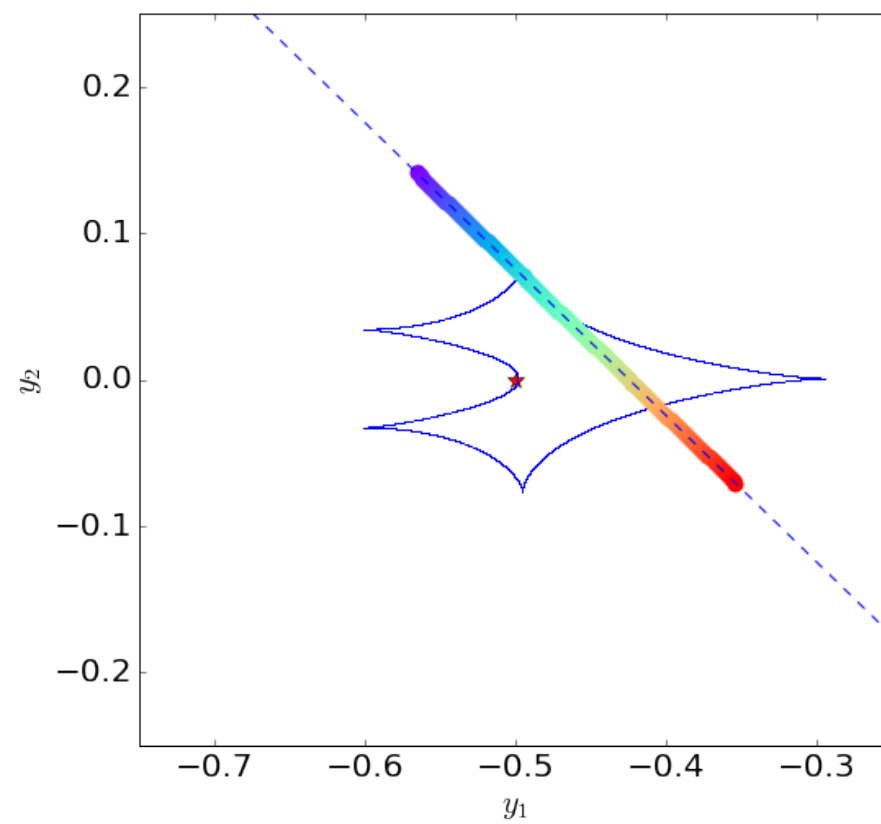
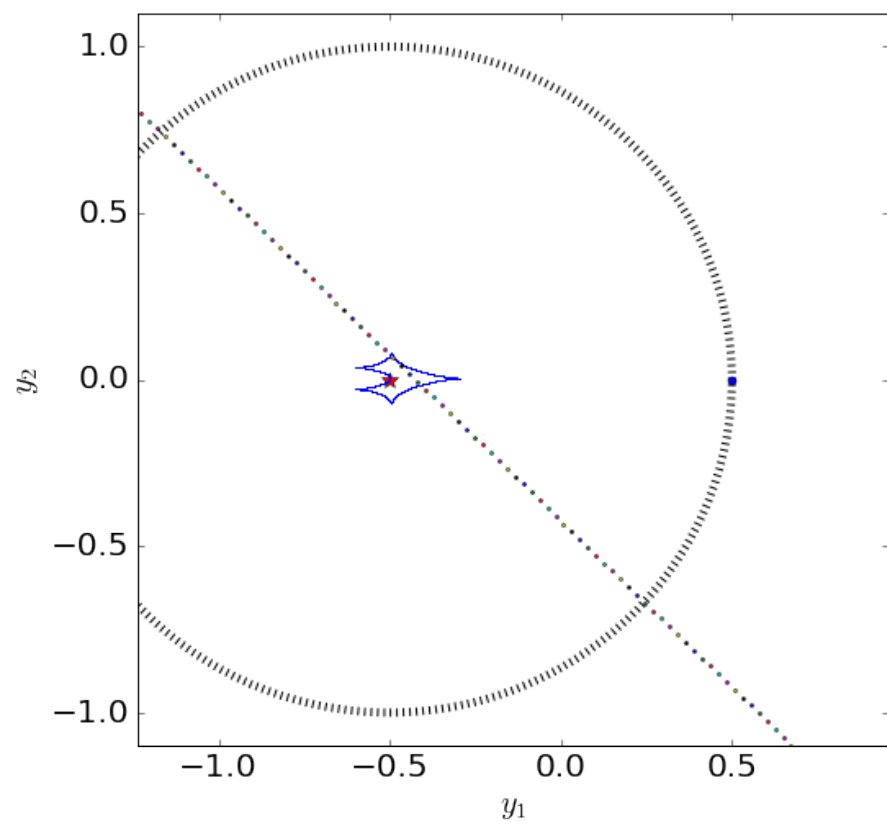
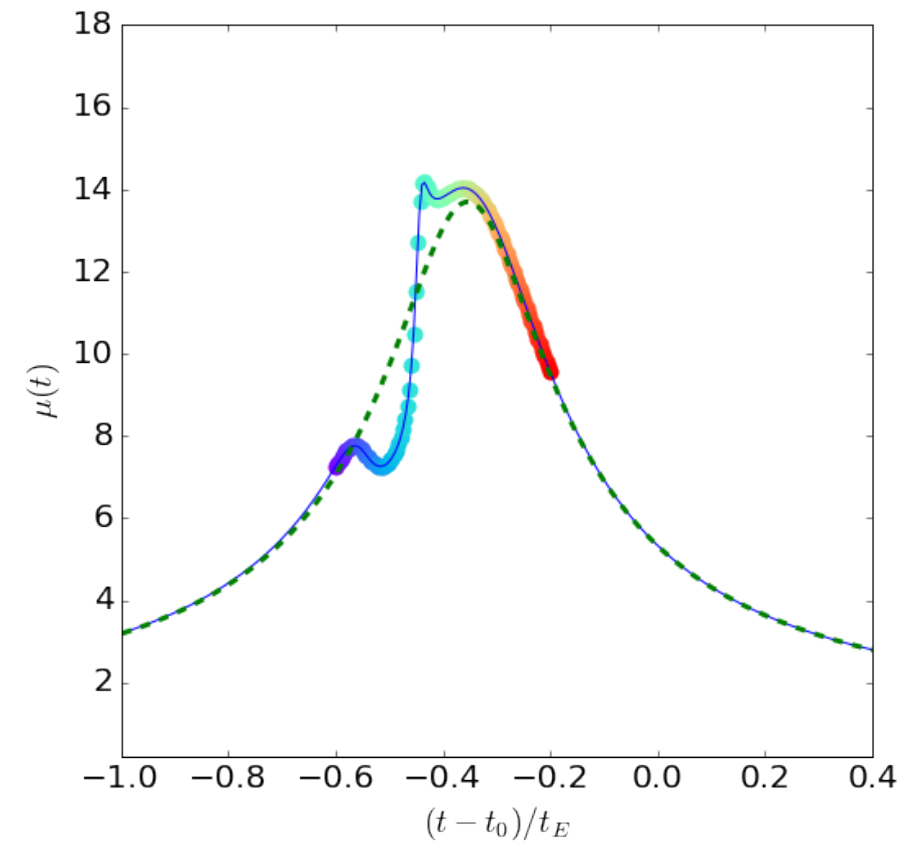
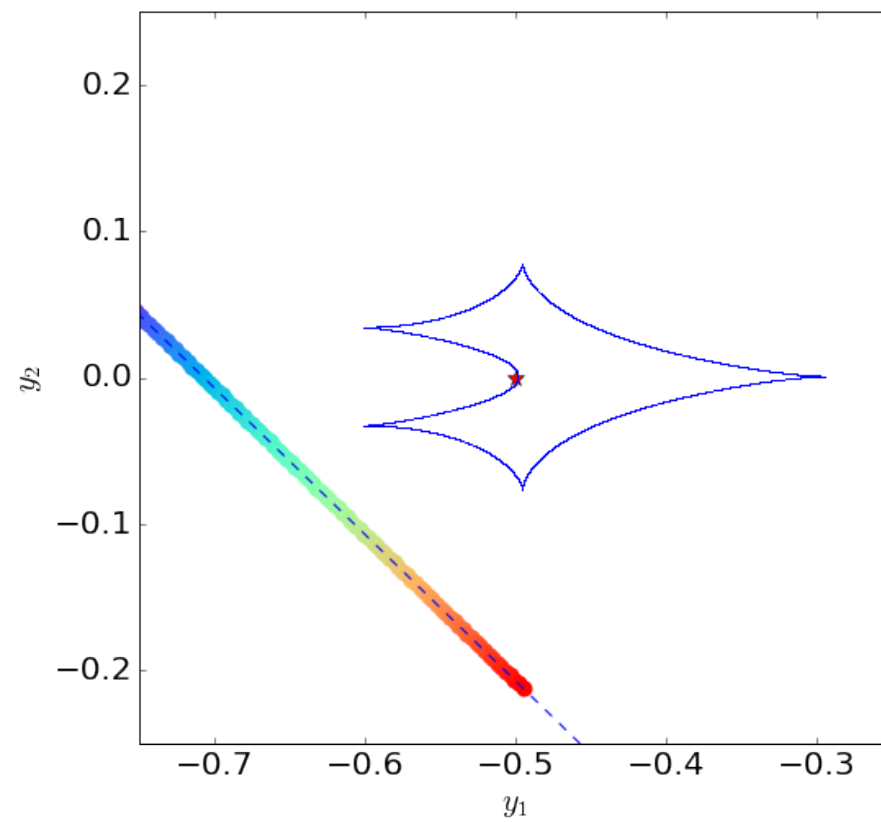
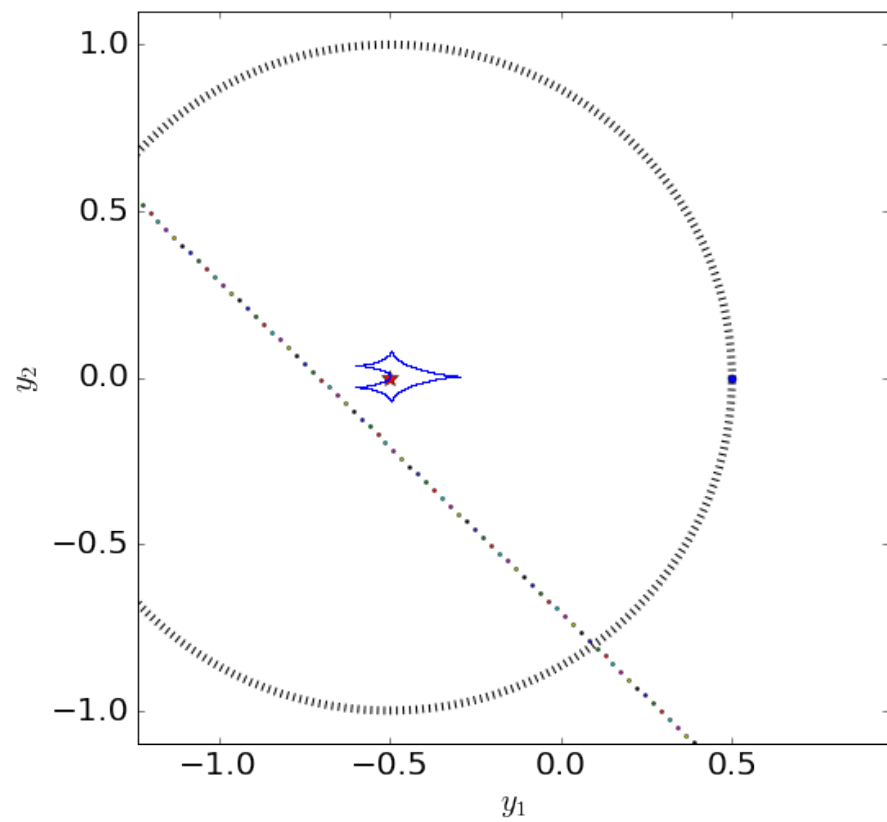


# PLANETARY CAUSTICS IN INTERMEDIATE TOPOLOGIES

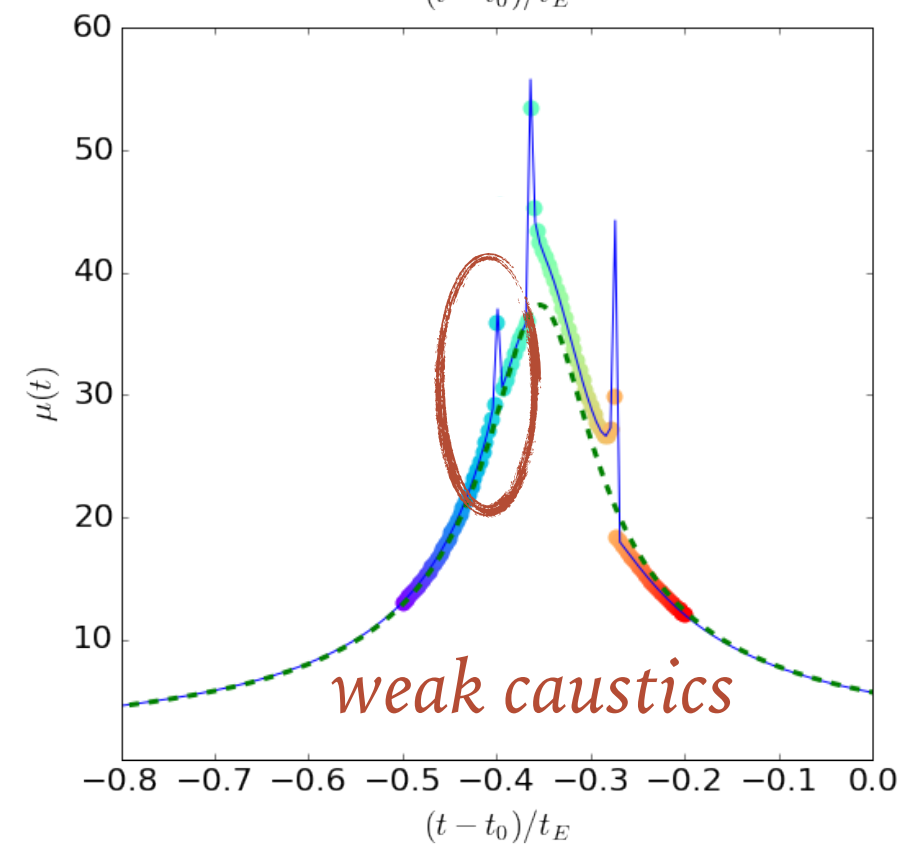
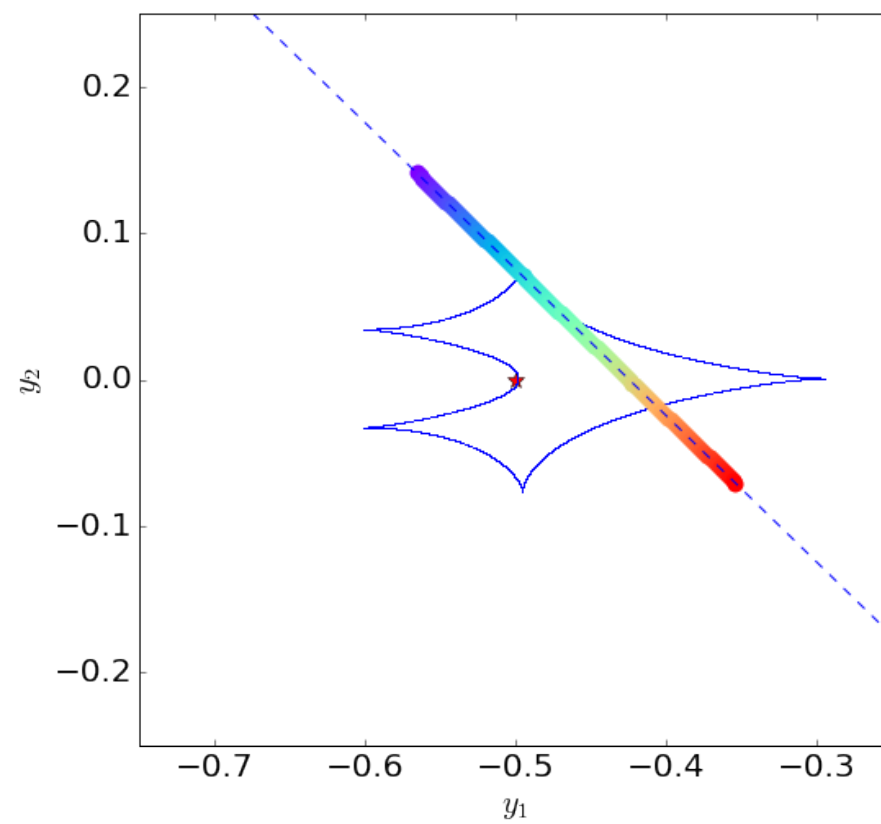
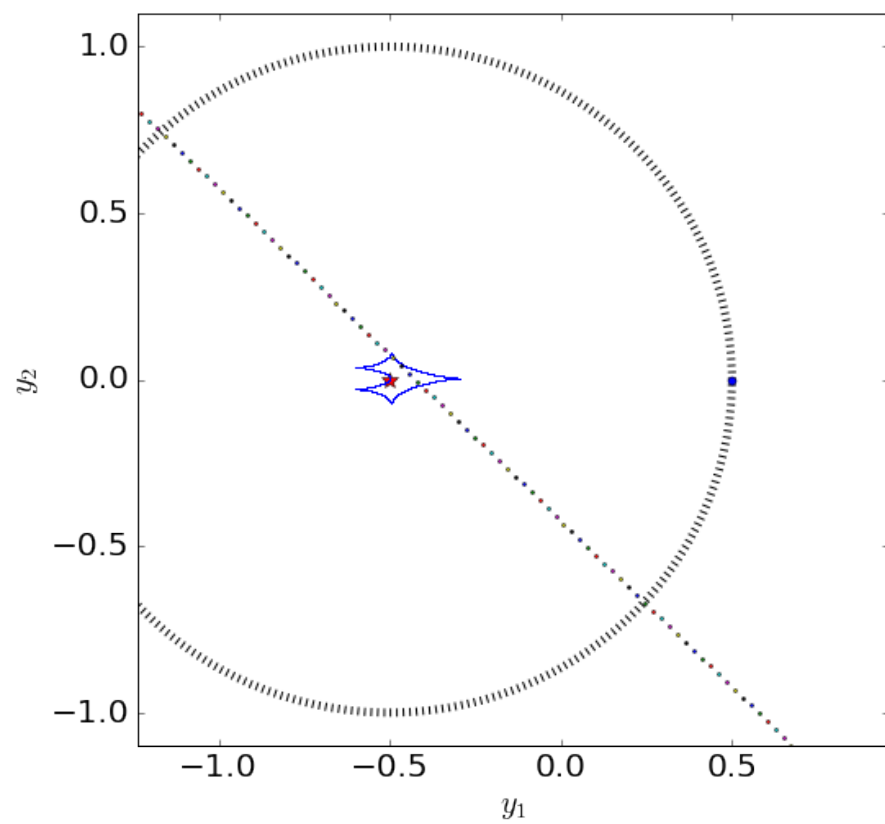
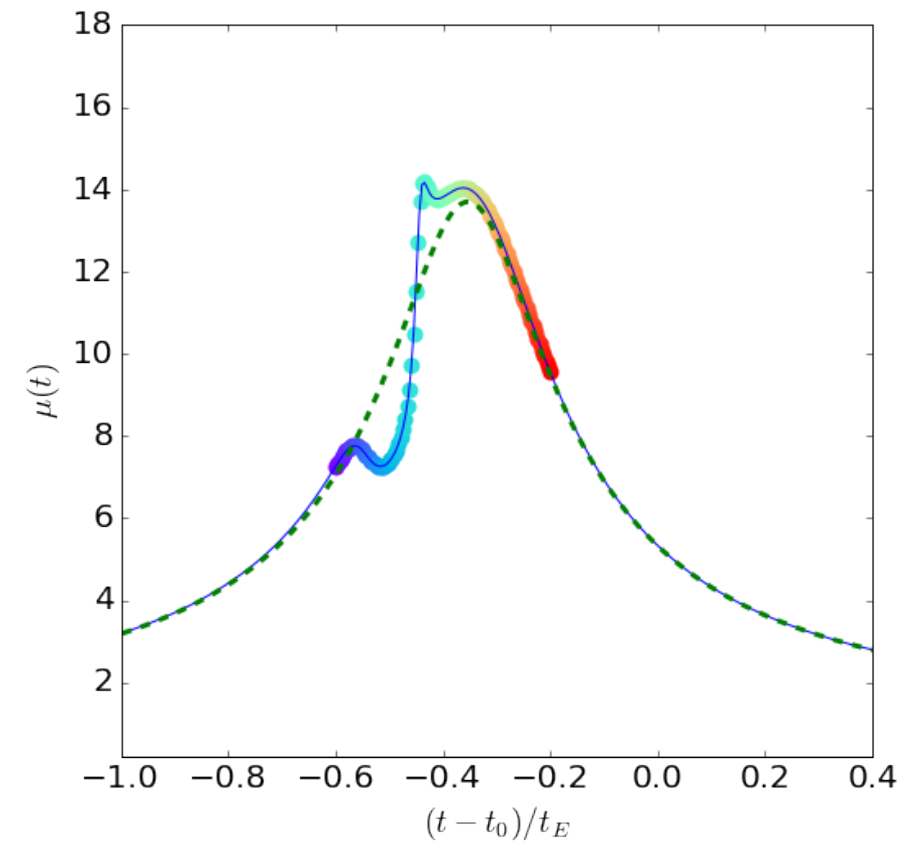
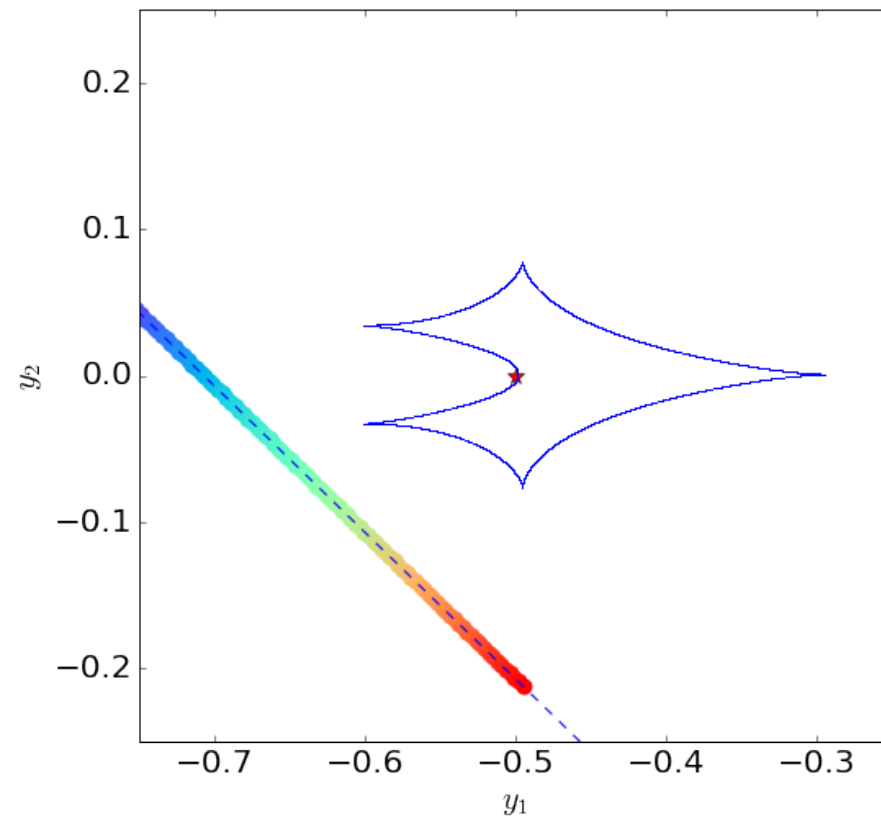
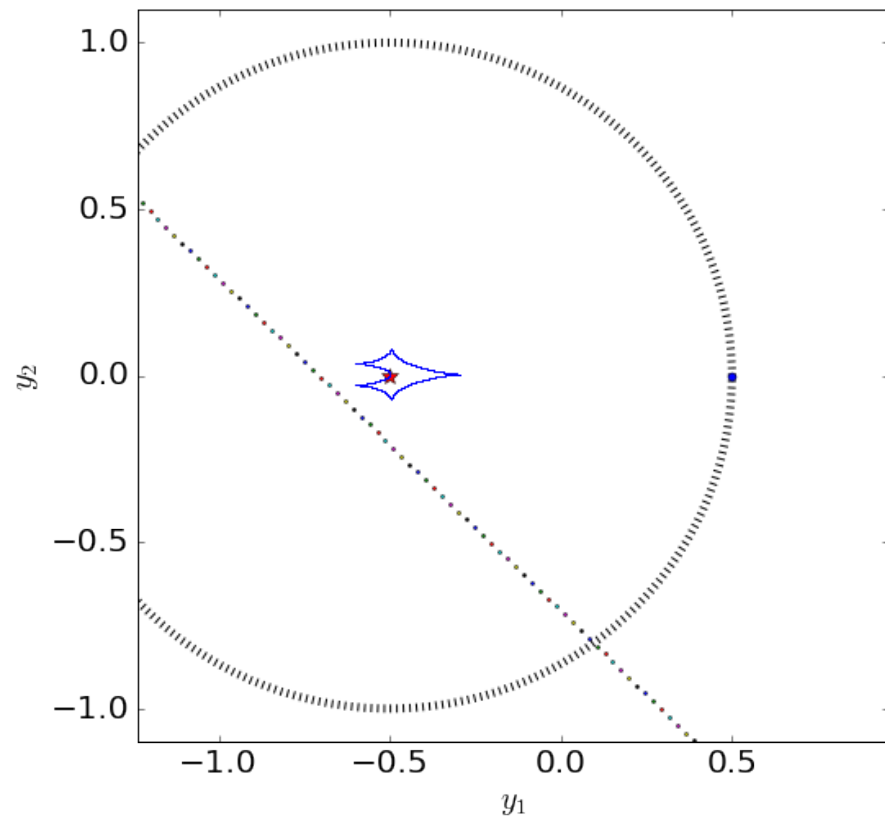
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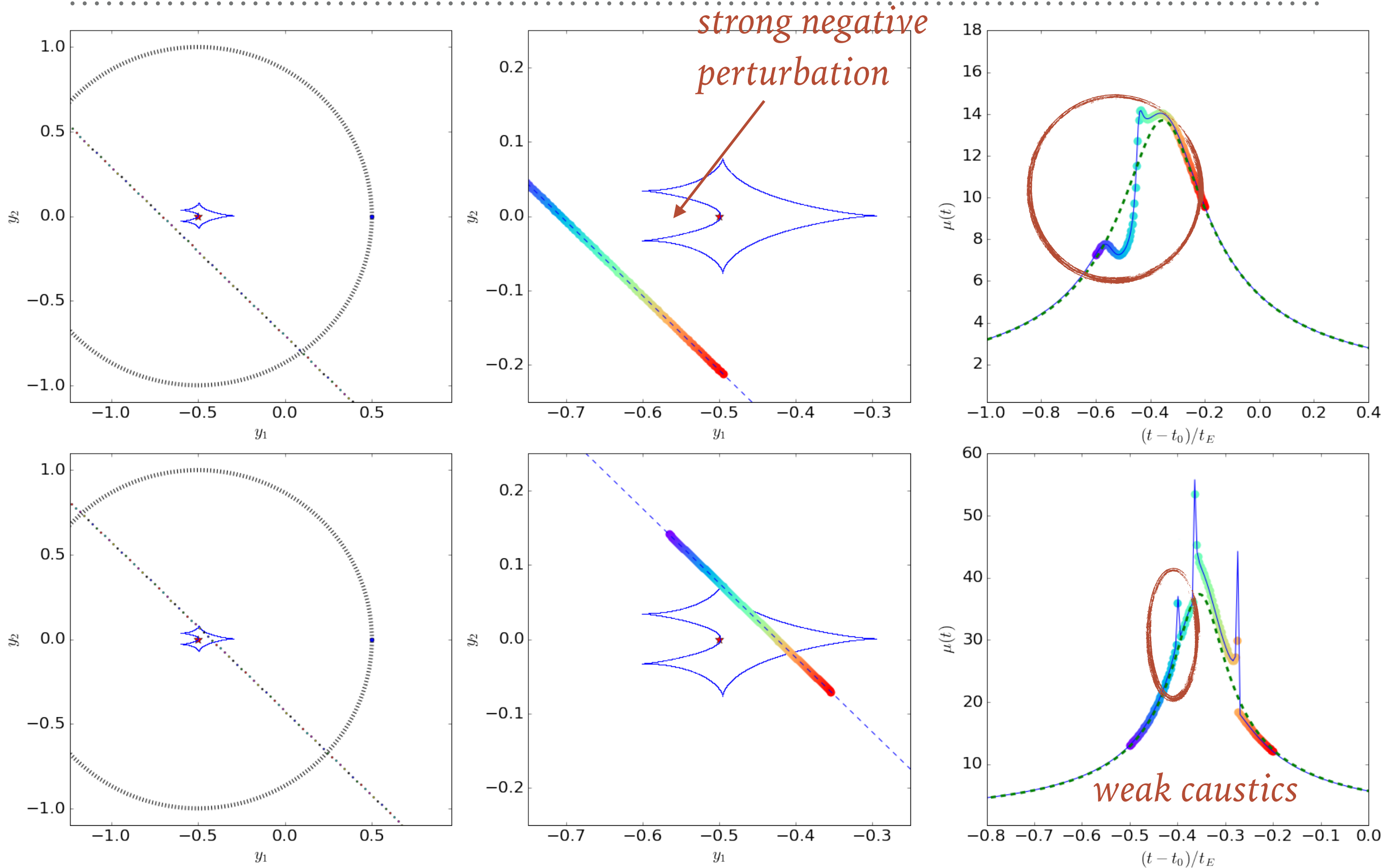
# PLANETARY CAUSTICS PERTURBATIONS IN INTERMEDIATE TOPOLOGIES



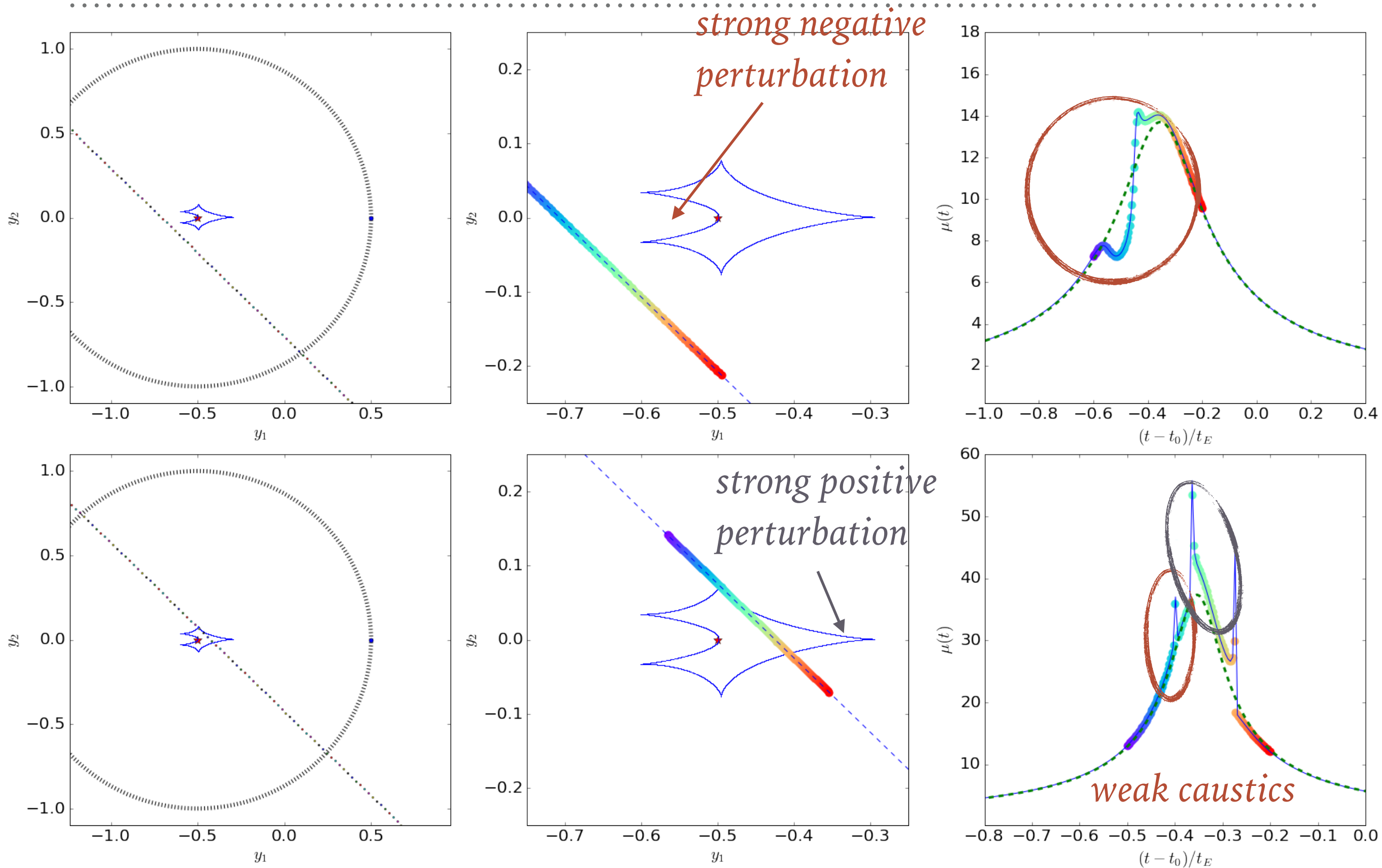
# PLANETARY CAUSTICS PERTURBATIONS IN INTERMEDIATE TOPOLOGIES



# PLANETARY CAUSTICS PERTURBATIONS IN INTERMEDIATE TOPOLOGIES



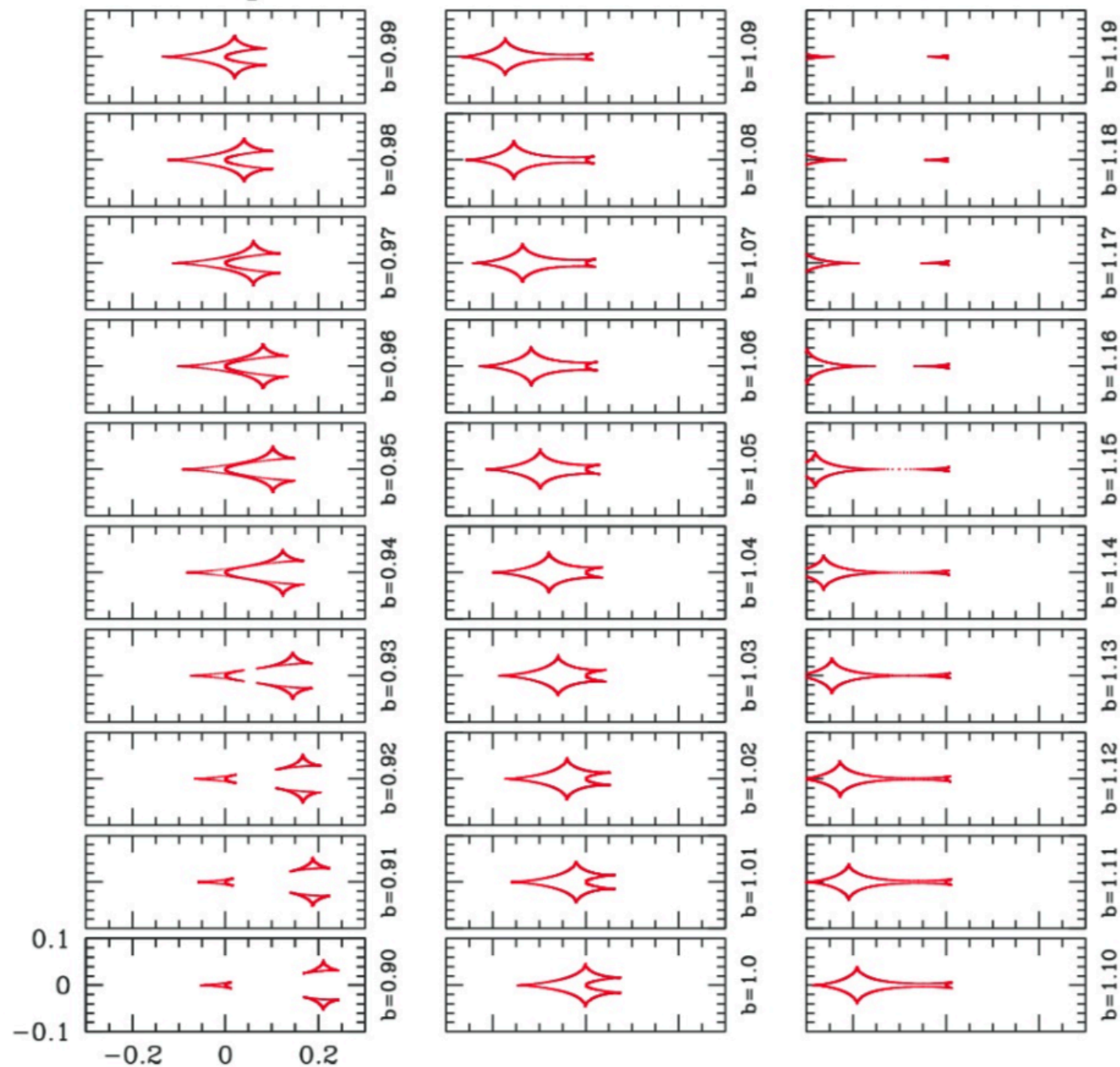
# PLANETARY CAUSTICS PERTURBATIONS IN INTERMEDIATE TOPOLOGIES



# SHAPE OF THE RESONANT CAUSTIC VS D

---

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

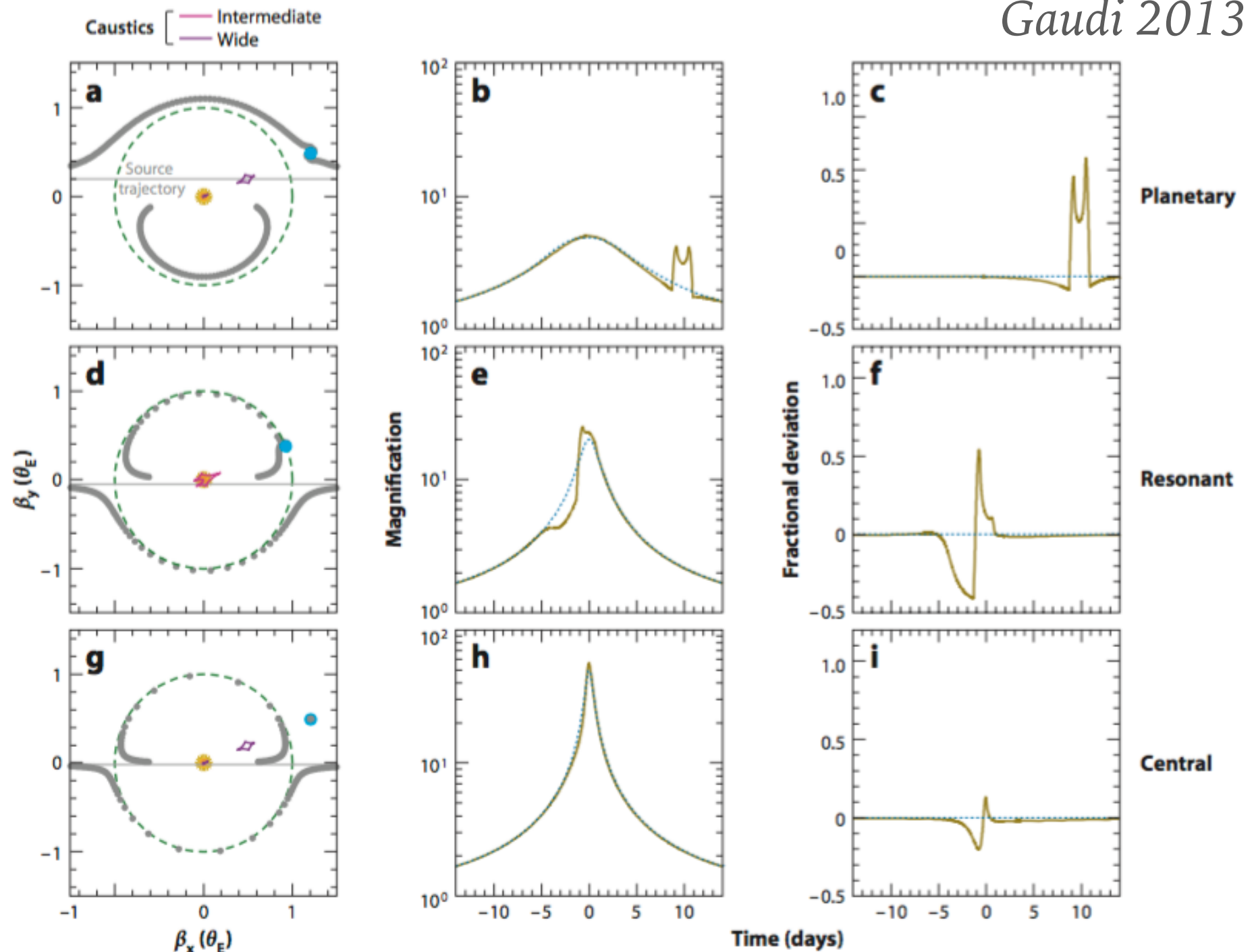




# A COMPLEMENTARY VIEW

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

*Gaudi 2013*

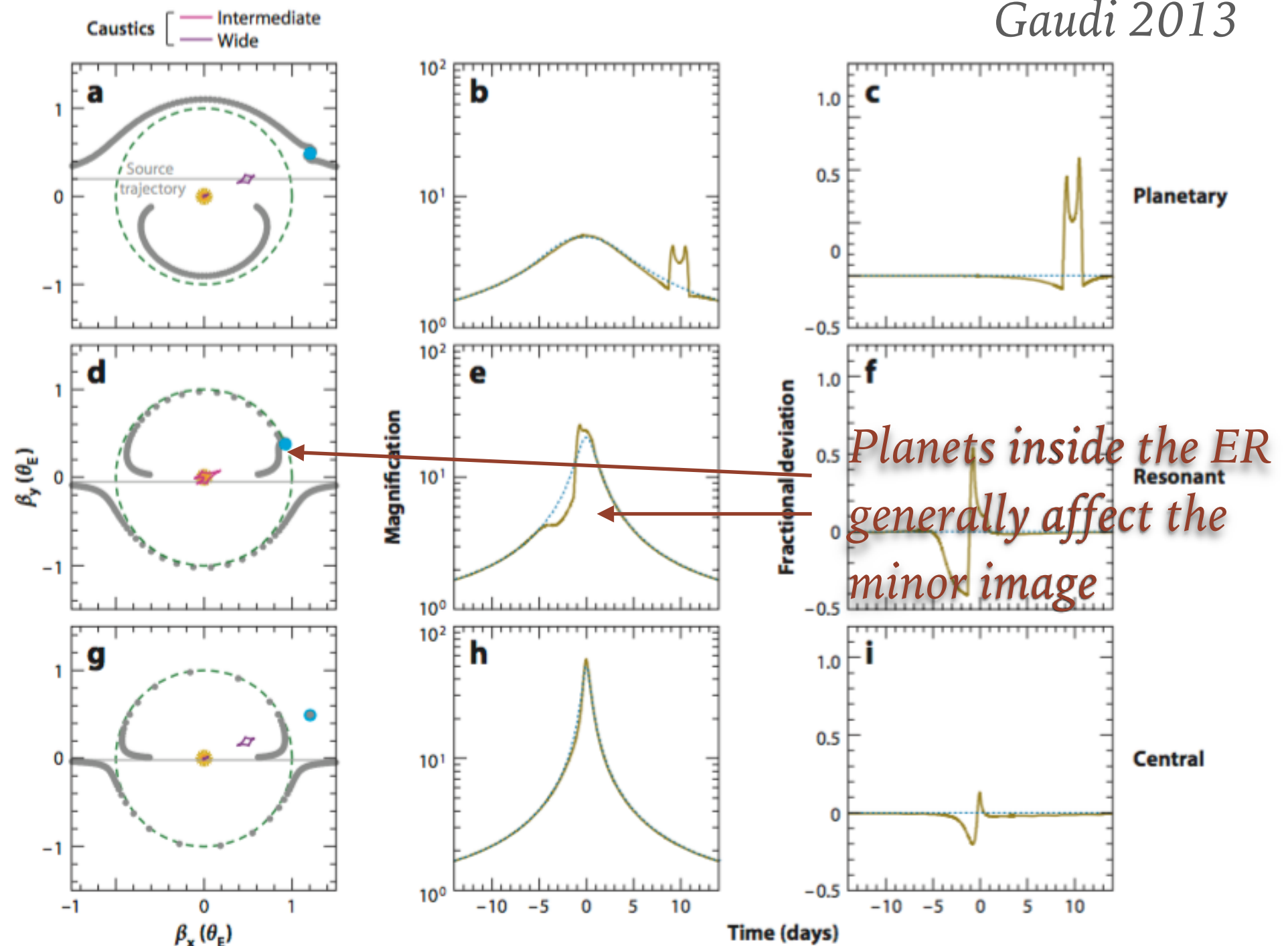




# A COMPLEMENTARY VIEW

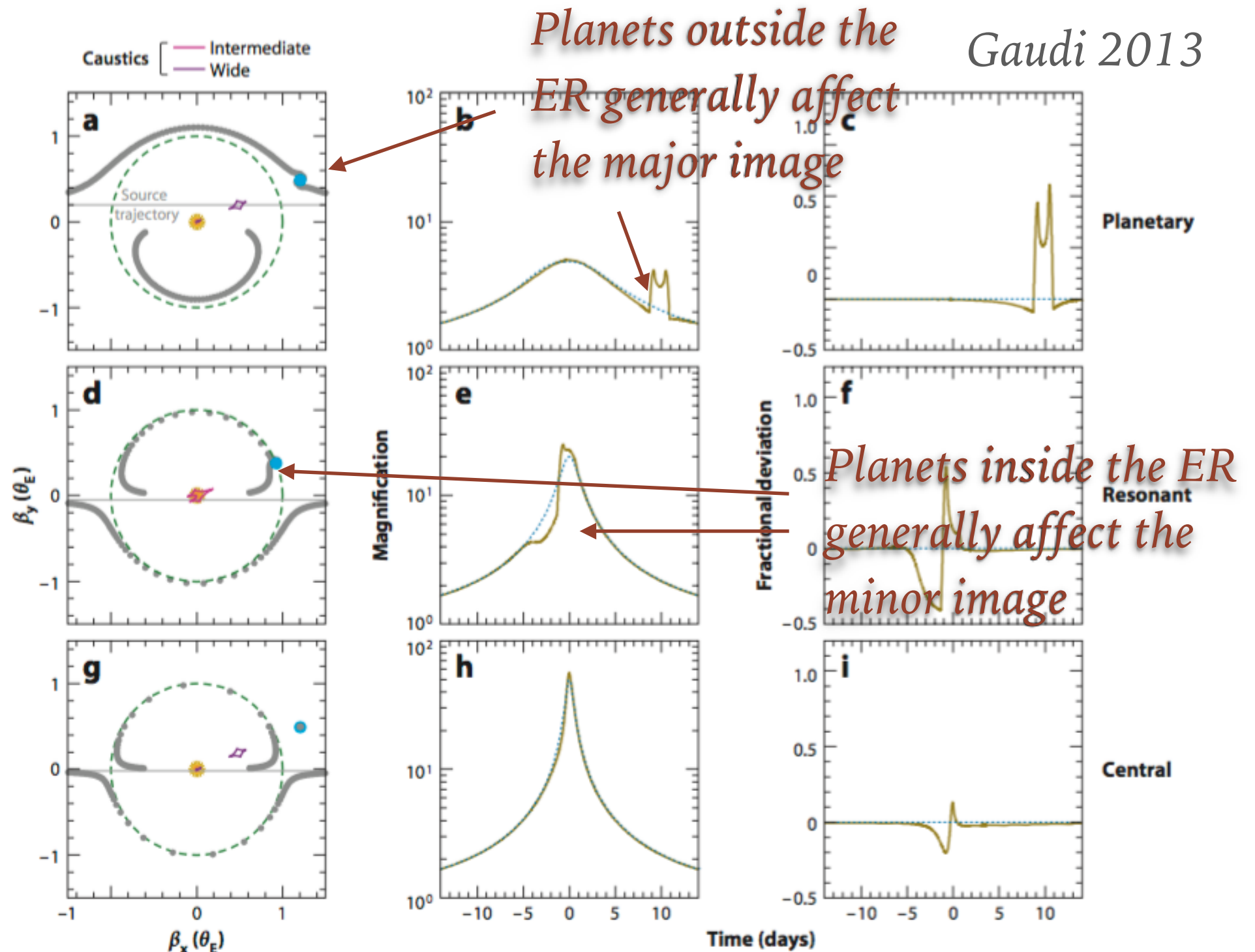
Gaudi 2013

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



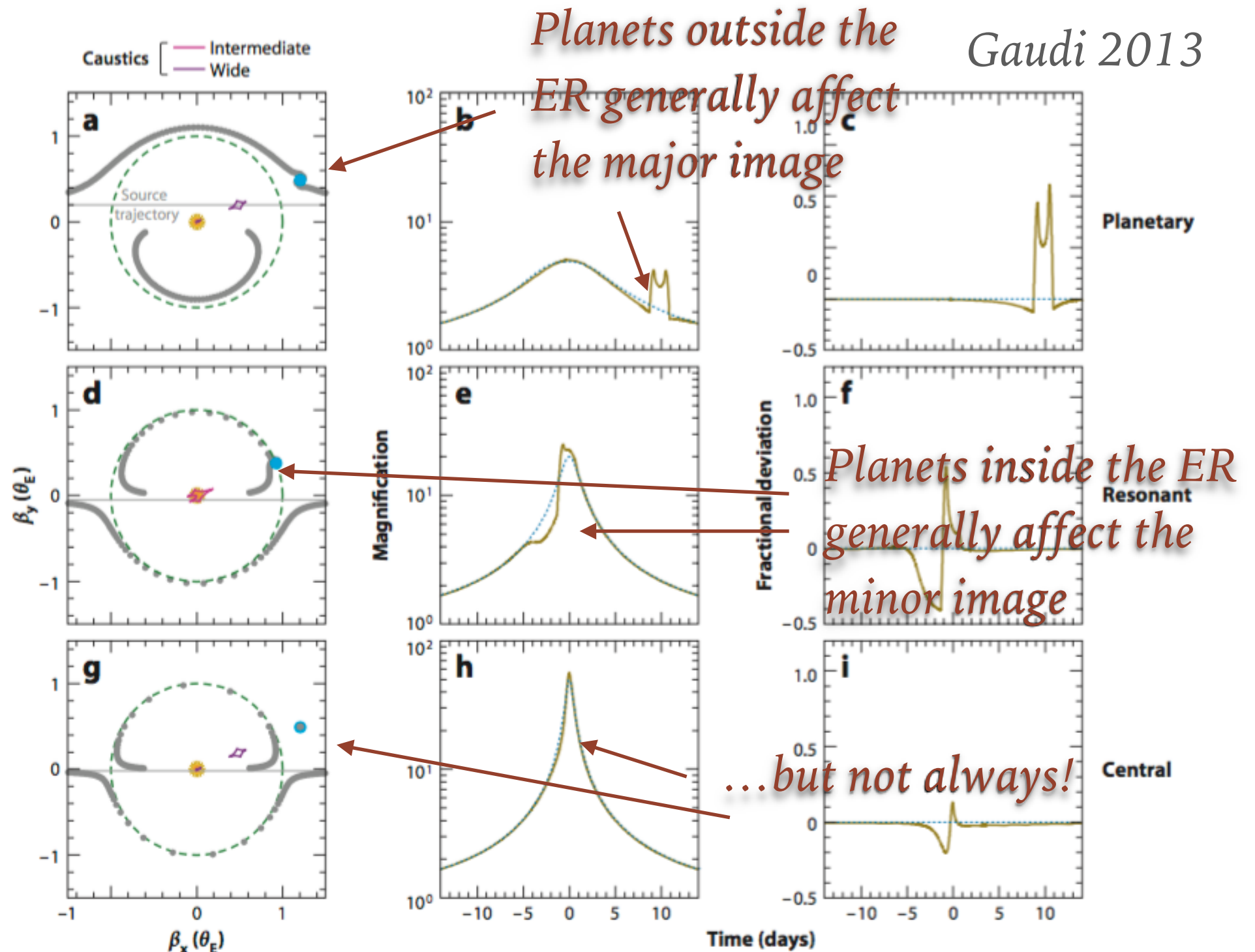
# A COMPLEMENTARY VIEW

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



# 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)*

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