GRAVITATIONAL LENSING

LECTURE 9

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CONTENTS

TIME DELAY SURFACE

$$t(\vec{\theta}) = t_{geom} + t_{grav} \propto \left(\frac{1}{2}(\vec{\theta} - \vec{\beta})^2 - \hat{\Psi} \right)$$

$$\vec{\nabla} t(\vec{\theta}) \propto \left(\vec{\theta} - \vec{\beta} - \vec{\nabla}\hat{\Psi} \right)$$

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Lens equation!

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$$T_{ij} = \frac{\partial^2 t(\vec{\theta})}{\partial\theta_i \partial\theta_j} \propto (\delta_{ij} - \Psi_{ij})$$

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$$T_{ij} = \frac{\partial^2 t(\vec{\theta})}{\partial\theta_i \partial\theta_j} \propto (\delta_{ij} - \Psi_{ij})$$ ***This is the Jacobian!***

TYPES OF IMAGES

- minima (eigenvalues of A are both positive, hence detA>0 and Tr A>0; positive magnification)
- saddle (eigenvalues have opposite signs, thus detA<0; negative magnification)
- maxima (eigenvalues are both negative, hence detA>0 and Tr A<0; positive magnification)
- Let see some examples…

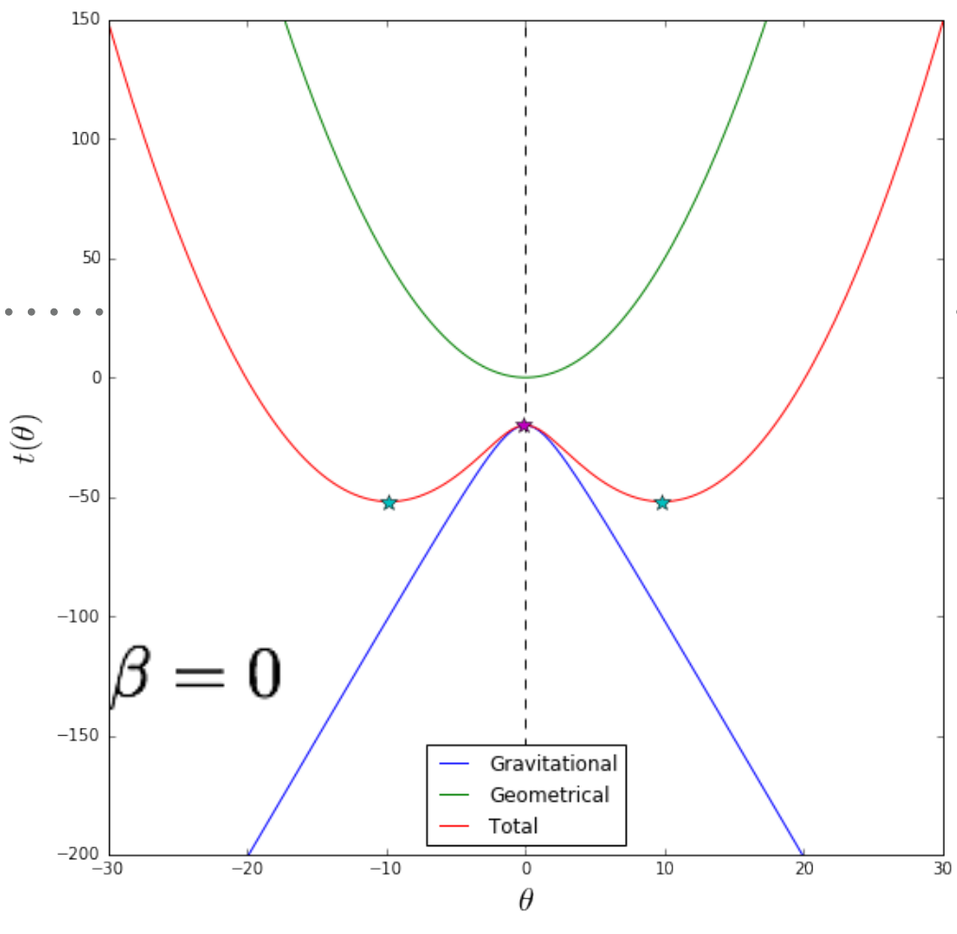
EXAMPLE OF TIME DELAY SURFACE

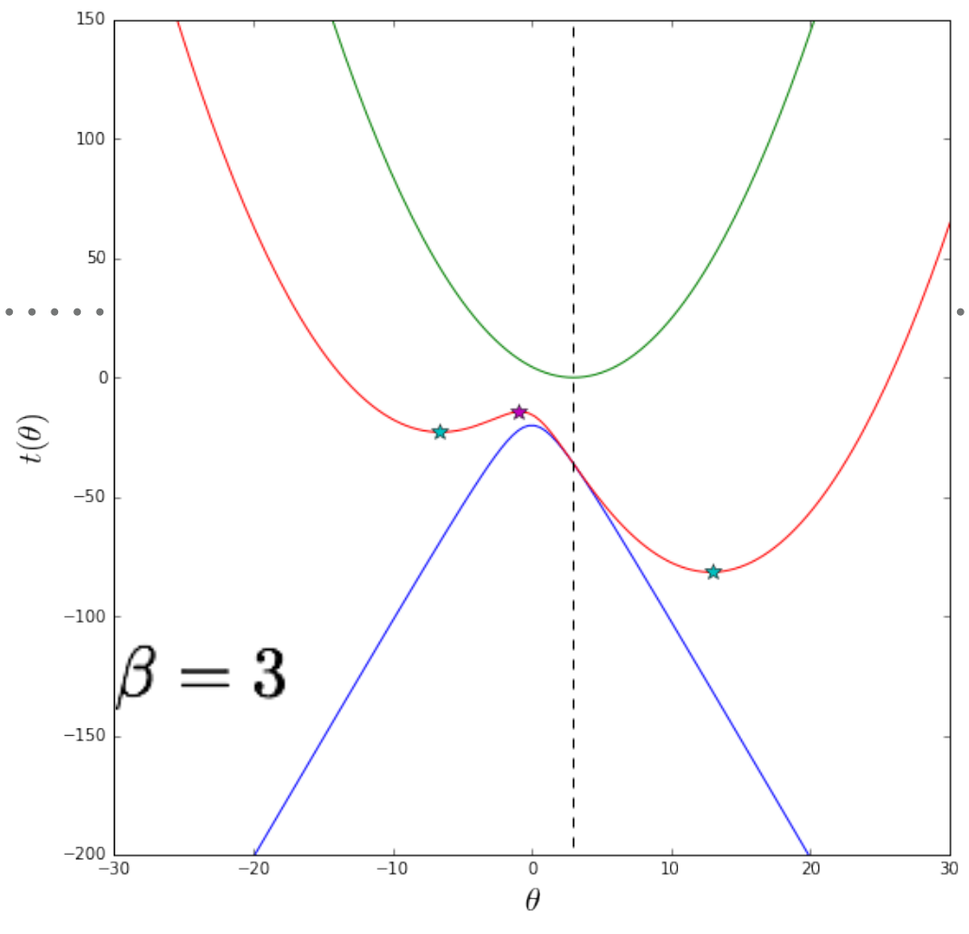
Toy potential:

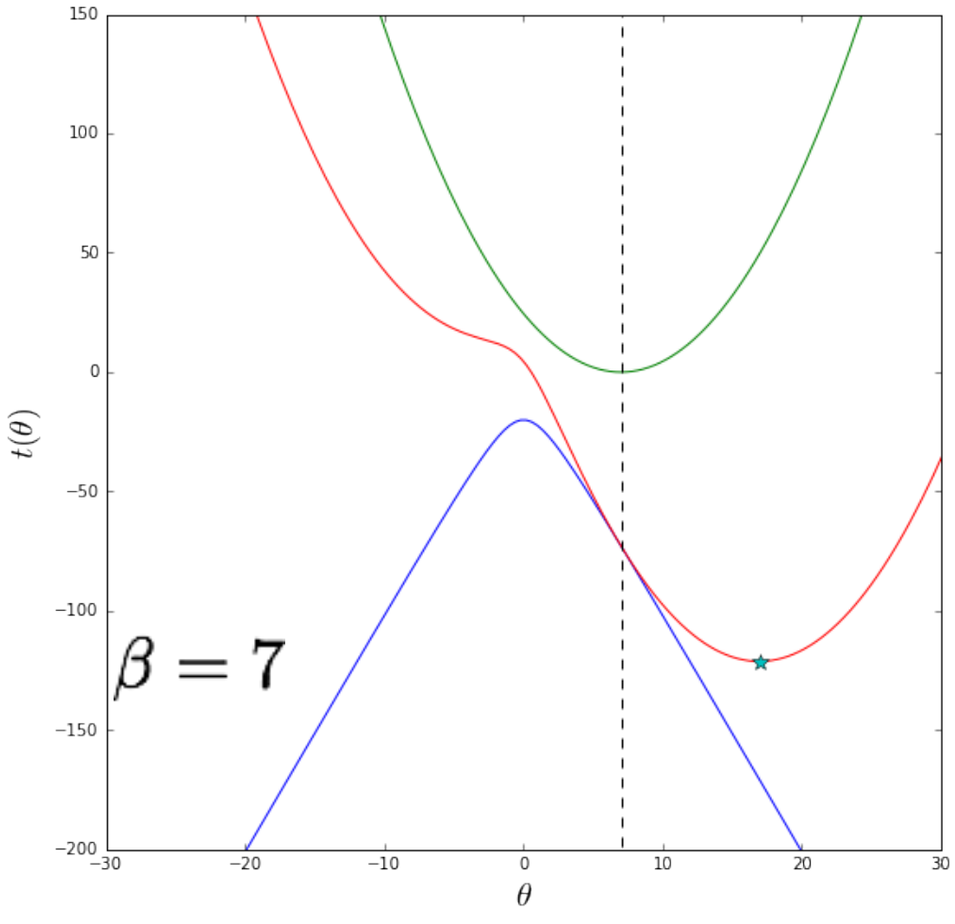
$$\psi(\theta) \propto \frac{1}{\sqrt{\theta^2+\theta_c^2}}$$

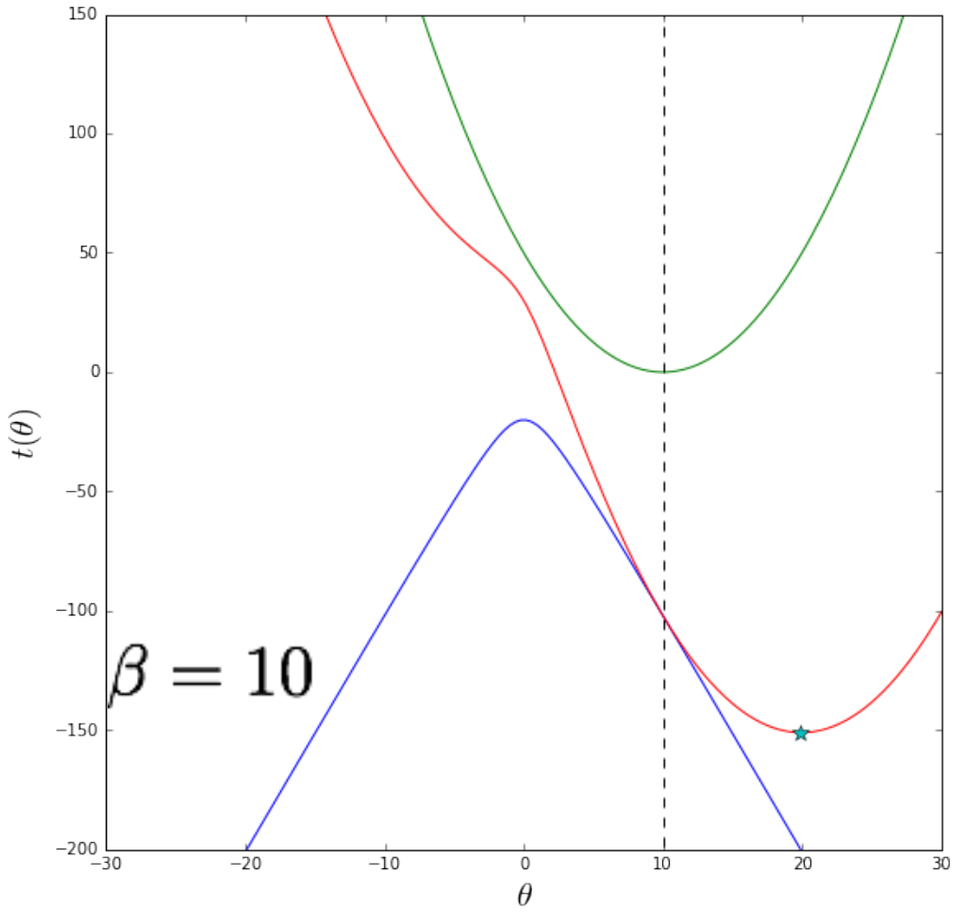
Assuming axial-symmetry, we can discuss the time-delay function instead of the time delay surface.

$$t(\theta) \propto \left[\frac{1}{2}(\theta-\beta)^2 - \psi(\theta)\right]$$


$\beta = 0$
Gravitational
Geometrical
Total
$t(\theta)$
θ


$\beta = 3$
$t(\theta)$
θ

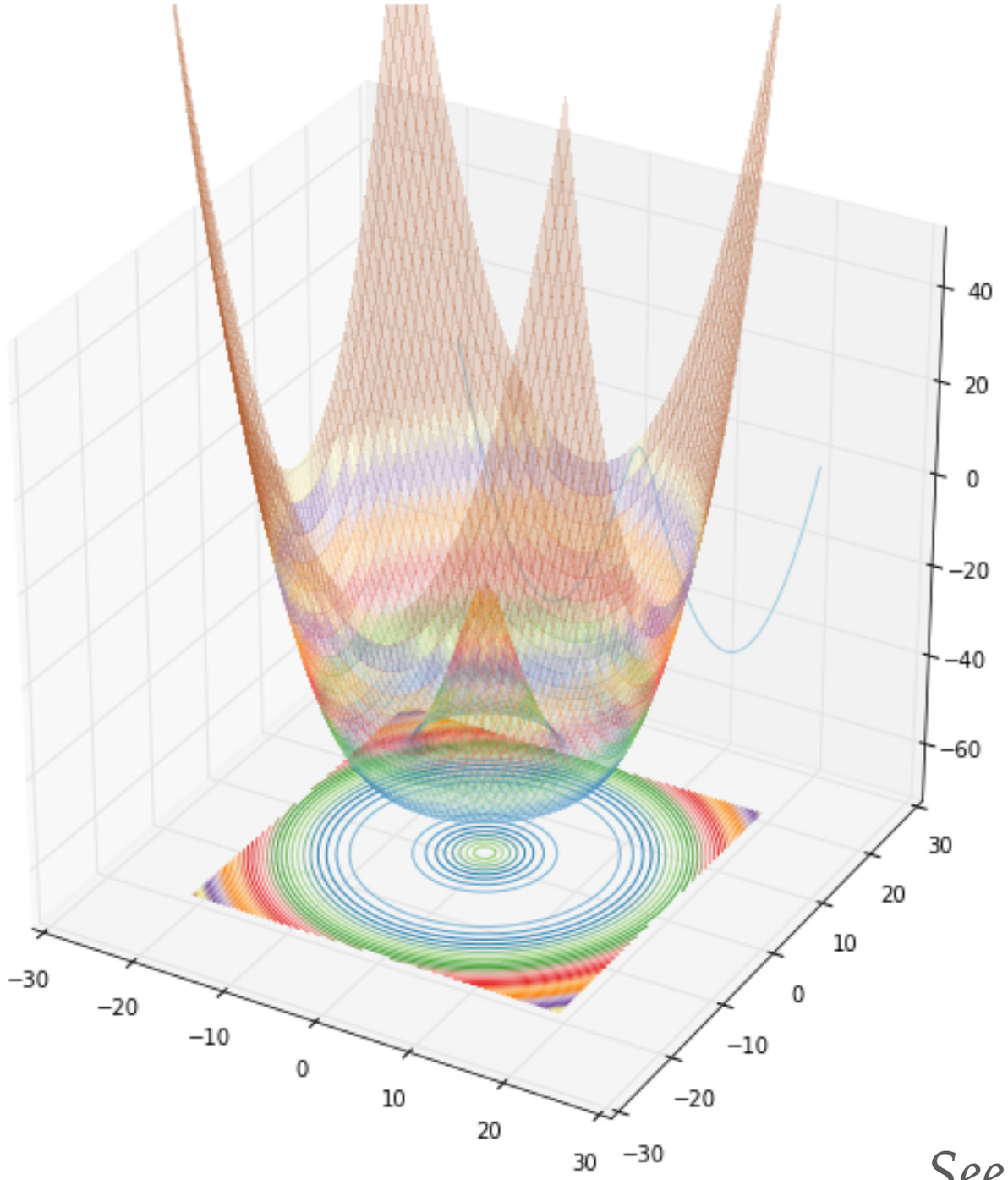

$\beta = 7$
$t(\theta)$
θ


$\beta = 10$
$t(\theta)$
θ

SOME INTERESTING PROPERTIES

- image multiplicity depends on the relative position of lens and source
- couples of images disappear after approaching each other
- the time-delay function is flat when this happens!
- det A=0 means infinite magnification: the images disappear on the critical lines!
- this happens every time a source crosses a caustic!

THE TIME DELAY SURFACE OF AN AXIALLY SYMMETRIC LENS



See the jupyter notebook!